Effective SE Metrics Tailored to the Acquisition Life Cycle

Armament Research, Development & Engineering Center
Armament System Integration Center
Systems Engineering Division

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AGENDA

• ARDEC Background
• Measurement Approaches
  – Systems Engineering Plan
  – Level of Effort Assessment
• Tracking & Reporting
• Benefits
• Next Steps
ARDEC Background

Artillery & Mortar Systems

Advanced Fuze Technologies

R&D

Special Operations Weapons & Demolitions

DEMIL

Total Life Cycle

Advanced Explosives & Warhead Development

PROD

Smart Munitions

FIELD SUPPORT

Combat Vehicle Armaments & Fire Control

Logistics R&D

Non-Lethal Technologies

Future Small Arms

Providing over 90% of the Army’s lethality...
Planned versus Actual

Metric: SE Planning

- Purpose
  - Living Document for Planning
  - Drive Technical Execution

- Rolling Wave Concept

- Tailoring
  - Based on Acquisition Phase
  - Project Specific Technical Activities
    - Level of Risk Acceptance
  - Programmatic Factors to Consider
    - Resources
    - Complexity
    - Customer & Stakeholders Needs
    - Schedule
Metric: Level of Effort Assessment

- Based on Acquisition Phase
- Define Project SE status in Key Areas
  - Requirements
  - Functional Analysis & Allocation
  - Design Synthesis
  - Verification & Validation
  - System Analysis & Control
- Quantifies Remaining SE Work on Project
- Traced to OSD & ARDEC Guidance
  - Defense Acquisition Guide
  - Policies, Process, Procedures, Templates
- Validated with Other Factors to Consider
- Used to Develop SE Plans and Budgets
Other Factors to Consider

- Funding
- Customer
- Stakeholders & End User
- In-house Work Versus Outsourced
- ARDEC Priorities and Visibility
- Percent Complete
- Resources and IPT Members
- Technology Complexity & Domain
- Other Factors the Rater Wants SE to Consider
System Development and Demonstration Phase

Inputs:
- Sys Performance Spec
- Exit Criteria
- Validated Sys Support & Maintenance Objectives & Requirements
- APB • CDD • SEP
- ISP • TEMP

Outputs:
- Initial Prod Baseline
- Test Reports • TEMP
- Elements of Product Support
- Risk Assessment
- SEP • TRA • PESHE
- Inputs to:
  - CPD - STA - ISP
  - Cost/Manpower Est.

Elements of Product Support

- Risk Assessment
- SEP TRA
- PESHE

Inputs to:
- CPD - STA - ISP
- Cost/Manpower Est.

Outputs:
- System DT&E, LFT&E & OAs
- Verify System Functionality & Constraints Compliance to Specs
- Integrated DT&E, LFT&E & EOA verify Performance Compliance to Specs
- Individual CI Verification DT&E

Intermediate Phases:
- FCA
- SVR
- PRR

- Trades

Phases:
- SRR
- SFR
- PDR
- CDR
- TRR
- SVR

Overview:
- Interpret User Needs, Refine System Performance Specs & Environmental Constraints
- Develop System Functional Specs & System Verification Plan
- Evolve Functional Performance Specs into CI Functional (Design to) Specs and CI Verification Plan
- Evolve CI Functional Specs into Product (Build to) Documentation and Inspection Plan
- Fabricate, Assemble, Code to "Build-to" Documentation

Products That Radically Define Warfare, Enabling the American Warfighter to Dominate the Battlefield
### System Development & Demonstration: Pre-Milestone C

<table>
<thead>
<tr>
<th>SEL</th>
<th>Project Name</th>
<th>Type of Program (A-F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Key Areas</th>
<th>System Engineering Plan</th>
<th>Approved Updated Plan</th>
<th>N/A &amp; Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements</td>
<td>Drafted Updated Plan</td>
<td>Submitted Updated Plan</td>
<td>Manage system requirements; address and characterize risk associated with requirements; conduct SRR if necessary</td>
</tr>
<tr>
<td>Interpret User Needs</td>
<td>Do not have defined requirements</td>
<td>Develop requirements from lifecycle considerations; use prototypes for stakeholder buy-in</td>
<td></td>
</tr>
<tr>
<td>Refine System Performance Specs</td>
<td>Fundamental understand performance specs</td>
<td>Documented Performance Specs</td>
<td>Refined Performance Specs</td>
</tr>
<tr>
<td>System Engineering Plan</td>
<td>Developed Performance Specs</td>
<td>Defined performance specs</td>
<td></td>
</tr>
<tr>
<td>System Development &amp; Demonstration: Pre-Milestone C</td>
<td>Have not developed subsystems</td>
<td>Developed subsystem integration, verification and validation plan/process</td>
<td></td>
</tr>
<tr>
<td>Drafting Documentation</td>
<td>Have not allocated specs</td>
<td>Allocate system functional/performance requirements defined for CI</td>
<td></td>
</tr>
<tr>
<td>Fabricate, Assemble, Code to “Built-to” Documentation</td>
<td>Have not allocated specs</td>
<td>Create test plan for verification of CI for functionality/performance</td>
<td></td>
</tr>
<tr>
<td>Individual CI Verification DT&amp;E</td>
<td>Have not begun documentation for “building” components</td>
<td>Complete drawings; developed detailed design; completed CDR</td>
<td></td>
</tr>
<tr>
<td>Individual CI Verification DT&amp;E</td>
<td>Verify Performance Compliance to Specs</td>
<td>Conduct test and evaluation at subsystem level; Plan for TRR</td>
<td></td>
</tr>
<tr>
<td>System DT&amp;E, LFT&amp;E, OAs, Verify System Functionality &amp; Constraints</td>
<td>Have not worked to resolve interface/integration issues; do not monitor performance of integrated system</td>
<td>Resolve interface and integration issues; monitor and analyze risks for performance of integrated system</td>
<td></td>
</tr>
<tr>
<td>System DT&amp;E, LFT&amp;E, OAs, Verify System Functionality &amp; Constraints</td>
<td>Do not understand interface and interoperability issues; have not defined test environments/scenarios</td>
<td>Resolve interface/interoperability issues; confirm operational supportability and manufacturing process control; assess technical risk and mitigate</td>
<td></td>
</tr>
<tr>
<td>DM &amp; CM Tool(s) that meet the DM/CM Requirements</td>
<td>Identify DM &amp; CM Tool(s) that meet the DM/CM Requirements</td>
<td>Identified DM/CM Tool(s) that meet the DM/CM Requirements</td>
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</tr>
<tr>
<td>DM/CM Requirements</td>
<td>Identify DM &amp; CM Requirements</td>
<td>Maintain DM &amp; CM Requirements</td>
<td></td>
</tr>
</tbody>
</table>

**Products That Radically Define Warfare, Enabling the American Warfighter to Dominate the Battlefield**
## System Development & Demonstration

### Requirements Metrics

<table>
<thead>
<tr>
<th>Key Areas</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>N/A &amp; Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Requirements</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interpret User Needs</td>
<td>Do not have defined requirements</td>
<td>Develop requirements from lifecycle considerations; use prototypes for stakeholder buy-in</td>
<td>Manage system requirements; address and characterize risk associated with requirements; conduct SRR if necessary</td>
<td></td>
</tr>
<tr>
<td>Refine System Performance Specs</td>
<td>Requirements not yet decomposed; RM started</td>
<td>Utilized RM Tool</td>
<td>Requirements traced in database/tool</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fundamental understand performance specs</td>
<td>Documented Performance Specs</td>
<td>Refined Performance Specs</td>
<td></td>
</tr>
<tr>
<td>Key Areas</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>N/A &amp; Rationale</td>
</tr>
<tr>
<td>----------------------------</td>
<td>----------------------------------------</td>
<td>----------------------------------------</td>
<td>----------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Interpret User Needs</td>
<td>Do not have defined requirements</td>
<td>Develop requirements from lifecycle</td>
<td>Manage system requirements; address</td>
<td>Documented plan for system availability, supportability, logistics footprint,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>considerations; use prototypes for</td>
<td>and characterize risk associated with</td>
<td>developmental and operational test environments and scenarios, and disposal in SEP;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>stakeholder buy-in</td>
<td>requirements; conduct SRR if necessary</td>
<td>present prototype to stakeholders Sept 05</td>
</tr>
<tr>
<td>Requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refine System Performance</td>
<td>Requirements not yet decomposed; RM</td>
<td>Utilized RM Tool</td>
<td>Requirements traced in database/tool</td>
<td>System Requirements Linked to user Requirements in DOORS Database</td>
</tr>
<tr>
<td>Specs</td>
<td>started</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>Fundamental understand performance</td>
<td>Documented Performance Specs</td>
<td>Refined Performance Specs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>specs</td>
<td></td>
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</tbody>
</table>

**EXAMPLE**

**System Development & Demonstration**

**Requirements Metrics**

**Products That Radically Define Warfare, Enabling the American Warfighter to Dominate the Battlefield**
Calculations

- **LOE**: Translate Value to Percent out of 100

**Normalized Gaussian**

- Encloses 95% area under curve
- $\mu \pm 1\sigma = 68.27\%$
- $\mu \pm 2\sigma = 95.45\%$
- $\mu \pm 3\sigma = 99.73\%$

**Remaining Work**

100%
Traceability & Budgeting

• Traced to OSD & ARDEC Guidance
  – Defense Acquisition Guide “Vee” Models
  – Policies, Process, Procedures, Templates
  – Linked on the SE Website for Ease

• Used to Develop SE Plans and Budgets
# System Development & Demonstration: Pre-Milestone C

<table>
<thead>
<tr>
<th>Key Areas</th>
<th>Defense AT&amp;L &quot;V&quot; Model</th>
<th>DAG</th>
<th>ARDEC</th>
<th>INPUTS</th>
<th>OUTPUTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Engineering Plan</td>
<td>Approved SEP</td>
<td>102, 115</td>
<td>All SE Activities</td>
<td>SEP</td>
<td></td>
</tr>
<tr>
<td>Requirements</td>
<td>Interpret User Needs</td>
<td>4.3.3.3.1</td>
<td>304</td>
<td>System Spec</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Refine System Performance Specs</td>
<td>4.3.3.3.1</td>
<td>305-308</td>
<td>System ICD</td>
<td>RTM to Functional/Physical Architectures</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>System OCD</td>
<td>Environmental &amp; Design Constraints</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Prelim. Development Spec</td>
<td>MOE/MOP</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>802</td>
<td>Prelim CI ICD</td>
</tr>
<tr>
<td>Functional Analysis &amp; Allocation</td>
<td>Develop System Functional Specs &amp; System Verification Plan</td>
<td>4.3.3.3.2</td>
<td>403, 404, 406-409</td>
<td>System Constraints</td>
<td>RAS FMEA/FMECA ICD</td>
</tr>
<tr>
<td>Design Synthesis</td>
<td>Evolve Function Performance Specs &amp; CI Functional Specs &amp; CI Verification Plan</td>
<td>4.3.3.3.3</td>
<td>206, 503-506, 511</td>
<td>MOE/MOP</td>
<td></td>
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<tr>
<td></td>
<td>Evolve CI Functional Documentation &amp; Inspection Plan</td>
<td>602</td>
<td>601</td>
<td>System Constraints</td>
<td></td>
</tr>
<tr>
<td>Verification &amp; Validation</td>
<td>Fabricate, Assemble Documentation</td>
<td>4.3.3.3.5</td>
<td>509-510</td>
<td>IV&amp;V Plan Verification Procedures</td>
<td></td>
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<tr>
<td></td>
<td>Individual CI Verification DT&amp;E</td>
<td>4.3.3.8.1</td>
<td>803-913</td>
<td>Validation Procedures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Integrated DT&amp;E, LFT&amp;E, EOAs Verify Performance Compliance to Specs</td>
<td>4.3.3.8.2</td>
<td>403-404</td>
<td>Facility Request</td>
<td></td>
</tr>
<tr>
<td></td>
<td>System DT&amp;E, LFT&amp;E, Oas, Verify System Functionality &amp; Constraints Compliance to Specs</td>
<td>4.3.3.8.3</td>
<td>503-506</td>
<td>Staffing Request</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Combined DT&amp;E/OT&amp;E/LFT&amp;E Demonstrate System to Specified User Needs &amp; Environmental Constraints</td>
<td>4.3.3.8.4</td>
<td>509-510</td>
<td>Data Request</td>
<td></td>
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<tr>
<td></td>
<td>CM Tool(s) &amp; Architectures</td>
<td>111, 115</td>
<td>Team with NWA</td>
<td>WBS</td>
<td></td>
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<tr>
<td></td>
<td>CM Tool(s) &amp; Architectures</td>
<td>202, 205, 206</td>
<td>Milestones, Allotted Time, etc.</td>
<td>Project Schedule with Decision Points</td>
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<tr>
<td></td>
<td>Track major risks and execute risk strategy</td>
<td>405</td>
<td>ECP, CR, etc.</td>
<td>CM Plan</td>
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<tr>
<td></td>
<td></td>
<td>507-508</td>
<td>ICD</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>603</td>
<td>Risk Analysis Reports</td>
<td>Risk Assessment Report</td>
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<td></td>
<td></td>
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<td>Risk Mgmt Plan</td>
<td>Risk Status Report</td>
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</tr>
</tbody>
</table>

*Products That Radically Define Warfare, Enabling the American Warfighter to Dominate the Battlefield*
## Traceability Example

### System Development & Demonstration: Pre-Milestone C

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<tr>
<td>Interpret User Needs</td>
<td>4.3.3.1</td>
<td>304</td>
<td></td>
<td>System Spec</td>
<td>SRR</td>
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<tr>
<td>Refine System Performance Specs</td>
<td>4.3.3.2</td>
<td>305-308</td>
<td></td>
<td>System ICD</td>
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<td></td>
<td>System OCD</td>
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<td>310</td>
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<td>Prelim. Development Spec</td>
<td>MOE/MOP</td>
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<td></td>
<td></td>
<td>802</td>
<td></td>
<td>Prelim CI ICD</td>
<td></td>
</tr>
</tbody>
</table>
SE Resources Required

- Project SE WBS
  - Includes LOE Key Areas
  - Metrics to Obtain Actual Data
- Top Down Method
  - Step 1: Use Industry “Rules of Thumb” For Initial Estimate
  - Step 2: Refine Initial Estimates Using the LOE Assessment Tool

\[ \text{FY06 SE Resources ($)} = \text{Project FY06 Budget ($)} \times \text{Rule of Thumb (\%)} \times \text{LOE (\%)} \]
Metric Tracking & Reporting

- Tracked Major ARDEC Priority Project Database
  - Status and Performance of LOE Key Areas
  - Note Significant Events and Changes
  - Projects Evaluated Monthly During Reviews
- Reported at Senior Leadership and Other Management Reviews Quarterly
Priority Project Database Snapshot

Products That Radically Define Warfare, Enabling the American Warfighter to Dominate the Battlefield
SE Status & Performance Summary

IPT Membership
IPT Performance

Sys Engrng Perf
RM
W

Sys Engrng Plan

Simulation Support Plan

SE Status

Status Changed: Date:
# Reporting on Metrics

**SE Process STATUS - Project XYZ**

## Phase/TRL

<table>
<thead>
<tr>
<th>Process Area</th>
<th>Perf.</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Requirements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Functional Analysis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Design Synthesis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Verification &amp; Validation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>System Analysis &amp; Control</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SEL:** Name

**SEP Status:** (Not Started, Drafted, Submitted, Approved)

(MM/DD/YYYY)

**Baseline SE Level of Effort (BLOE):** XX%, (MM/DD/YYYY)

**Previous SE Level of Effort (PLOE):** XX%, (MM/DD/YYYY)

**Current SE Level of Effort (CLOE):** XX%, (MM/DD/YYYY)
Benefits

• Consistent Documentation and Tools for Evaluation
• Quantified and Comparable Results
• Collect Historical Data for Parametric Modeling
• Provides Senior Leadership Visibility to Technical Issues for ARDEC Projects
• Enforced Implementation Through Reporting
• Training the Workforce on SE
• Tailored to Provide Just Enough SE; Avoid “Process Paralysis” (too much SE)
• Allows Project Manager to Focus on Important Issues

BOTTOM LINE: Implementing Systems Engineering on Projects Brings Better Products to the Warfighter!
Next Steps

- Transition LOE from Pilot to Full Scale Implementation
- Estimate SE Resource for FY06 WBS
- Track Status and Performance at Major ARDEC Project Reviews and Management Reviews
- Gather and Incorporate Voice of the Customer Feedback
- Refine and Improve LOE Procedure and Training
Questions/Comments

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