Digital Engineering Metrics
SERC Tasks WRT-1001/1040

Sponsor: OUSD(R&E)

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12th Annual SERC Sponsor Research Review
HOSTED VIRTUALLY ON: November 18, 2020
www.sercuarc.org
SERC Research Program on DE Metrics

Baldrige Excellence Framework and Criteria for Performance Excellence
- Higher productivity
- Greater customer loyalty
- Increased market share
- Improved profitability
- Better employee relations

INCOSE Model-Based Capabilities Matrix and User’s Guide

Model-Based Systems Engineering Maturity Benchmark Survey
This survey is intended to assess the value and effectiveness of MBSE adoption for improving business outcomes. It is also intended to provide a common language and framework for organizations to assess and improve their MBSE adoption.

Metrics Framework:
Digital Engineering Value, Benefits, and Adoption

Metrics Implementation (follow-on)
Where is DE on the Gartner Hype Cycle?

Digital Transformation
- Tech Infrastructure
- Authoritative Source of Truth
- Models & Model Management
  - Capability maturity
  - Performance metrics
  - Digital Competencies
  - Culture of Innovation

What is the authoritative source of truth for Digital Engineering (DE) on the Gartner Hype Cycle?

We are here

How do we get here?
DoD Digital Engineering Strategy:

**Digital Engineering (DE) Vision:** Modernize how the Department designs, develops, delivers, operates, and sustains systems.

**DE Mission:** Securely and safely connect people, processes, data, and capabilities across an end-to-end digital enterprise.

<table>
<thead>
<tr>
<th>ENDS</th>
<th>MEANS</th>
<th>WAYS/INITIATIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Models are used to inform enterprise and program decision making</strong></td>
<td><strong>An enduring, authoritative source of truth is used over the lifecycle</strong></td>
<td><strong>Use technological innovation to improve engineering practices</strong></td>
</tr>
<tr>
<td><strong>Formalize the planning for models to support engineering activities and decision making across the lifecycle</strong></td>
<td><strong>Plan and develop the authoritative source of truth</strong></td>
<td><strong>Govern the authoritative source of truth</strong></td>
</tr>
<tr>
<td><strong>Formally develop, integrate, and curate models</strong></td>
<td><strong>Use the authoritative source of truth across the lifecycle</strong></td>
<td><strong>Make use of data to improve awareness, insights, and decision making</strong></td>
</tr>
<tr>
<td><strong>Use models to support engineering activities and decision making across the lifecycle</strong></td>
<td><strong>Infuse technological innovations to enable the end-to-end digital enterprise</strong></td>
<td><strong>Advance human-machine interactions</strong></td>
</tr>
<tr>
<td><strong>Infrastructure and environments support improved communication and collaboration</strong></td>
<td><strong>Develop, mature, and use digital engineering IT infrastructures</strong></td>
<td><strong>Secure IT infrastructure and protect intellectual property</strong></td>
</tr>
<tr>
<td><strong>Transform culture and workforce engineering across the lifecycle</strong></td>
<td><strong>Improve the digital engineering knowledge base</strong></td>
<td><strong>Build and prepare the workforce</strong></td>
</tr>
</tbody>
</table>

**WAYS / INITIATIVES ENDS**

- **Process, Methods, Tools, Technology, People**
- **Improve the digital engineering knowledge base**
- **Lead and support digital engineering transformation efforts**
- **Build and prepare the workforce**
Summary DE Success Measures Framework

---

**Quality:**
- Reduce Errors/Defects
- Improve System Quality
- Improve Traceability
- Reduce Cost

**Knowledge Transfer:**
- Better access to information
- Better communication/ info sharing
- Collaboration

**Velocity/Agility:**
- More Reuse
- Improve Consistency
- Increase Efficiency
- Support Integration
- Reduce Time

**User Experience:**
- Manage Complexity
- Improved System Understanding
- Automation

**Adoption:**
- Methods/Processes
- Roles/Skills
- Training/Tools
- Leadership support
- Change Mgmt Process
- Resources

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An enduring, authoritative source of truth is used over the lifecycle.

Use technological innovation to improve engineering practices.

Infrastructure and environments support improved communication and collaboration.

Transform culture and workforce engineering across the lifecycle.

Models are used to inform enterprise and program decision making.

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November 18, 2020
**Released January 2020 by INCOSE**

**Framework for assessing organizational maturity**

<table>
<thead>
<tr>
<th>Model-Based Capability Stages</th>
<th>Stage 0</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
<th>Stage 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tools &amp; IT Infrastructure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collaboration</td>
<td>E-mail, telecom.</td>
<td>System Model File Exchange.</td>
<td>Various organizations working on different parts of model. Full model integrated by a single organization.</td>
<td>Partial On-line, real-time collaboration amongst distributed teams.</td>
<td>On-line, real-time collaboration amongst distributed teams.</td>
</tr>
<tr>
<td>Disparate Database/Tool Interoperability</td>
<td>None</td>
<td>Tool-to-Tool, ad hoc interoperability</td>
<td>Partial Federated Database Management System (FDBMS)</td>
<td>Main tools interoperable. Supporting tools interact through file transfer.</td>
<td>Fully Federated w/ standard “plug-and-play” interfaces. Data is interchanged among tools.</td>
</tr>
<tr>
<td>Inter-Database/Tool Data Item Associations</td>
<td>Databases/tools are independent</td>
<td>Inter-Database/Tool Data Item associations defined</td>
<td>Inter-Database/Tool Data Item associations defined, captured, managed</td>
<td>Inter-Database/Tool Data Item associations among all data items defined, captured, managed and traceable</td>
<td>Inter-Database/Tool Data Item associations among all data items defined, captured, managed and traceable where changes in one data source alerts owners of other data sources of intended updates</td>
</tr>
<tr>
<td>User IF, Viewpoint/Views</td>
<td>N/A</td>
<td>Doc Gen</td>
<td>UI draws from Model app</td>
<td>UI supports Interrogation; multiple configs</td>
<td>UI supports Interrogation; multiple configs</td>
</tr>
<tr>
<td>Topics</td>
<td>Summary of Survey Questions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 1. MBSE Usage          | 1. MBSE strategy documented at enterprise level  
2. MBSE processes & tools integrated, inform enterprise staff  
3. Q: Primary value of cross-functional MBSE integration? |
| 2. Model Management    | 4. Taxonomy for modeling across organization  
5. Well-defined processes/tools for model management.  
6. Standard org guidance for model management/tools  
7. Q: Business value from consistent model management? |
| 3. Technical Management| 8. Modeling basis for enterprise org processes  
9. MBSE process support for technical reviews  
10. Q: Value of MBSE (or digital engrg) in technical reviews? |
| 4. Metrics             | 11. Modeling provides measurable improvement across projects  
12. Consistent metrics across programs/enterprise?  
13. Q: Most useful metrics? |
15. Defined processes/tools for data/model quality assurance |
| 6. Data Management     | 16. Org approach for data interface between tools  
17. Data managed independent of tools for portability  
18. Q: Data management roles/processes? |
| 7. Model Sharing and Reuse| 19. Teams establish, share, reuse org model libraries  
20. Org interface around models for stakeholder use  
21. Shared models used to consistently manage programs across lifecycle  
22. Q: org implementation for data/model discovery, reuse? |
| 8. Modeling Environments| 23. Modeling environment security  
24. Modeling environment protects IP  
25. Cross-discipline processes for tools, data interoperability  
26. Q: value from collaborating on models across disciplines |
| 9. Organizational Implementation| 27. Q: most challenging org obstacles for MBSE?  
28. Q: Best organizational enablers for MBSE?  
29. Q: Biggest changes our org needs for MBSE? |
| 10. Workforce          | 30. Organization defined critical roles to support MBSE  
31. Q: Top MBSE roles in your organization?  
32. Org staffing adequate to fill MBSE-related roles? |
| 11. MBSE Skills        | 33. Defined critical skills for MBSE  
34. Q: The most critical skills for MBSE? |
| 12. Demographics       | Organizational size, domain, MBSE experience |
Download Results:


Supporting Technical Report SERC-2020-SR-003
View the DE Metrics Summary Report (June 8, 2020)

March 19, 2020 – Benchmarking the Benefits and Current Maturity of Model-Based Systems Engineering across the Enterprise Results of the MBSE Maturity Survey / Part 1: Executive Summary
View the SERC-2020-SR-001 report on the results of the MBSE Maturity Survey

Overall Survey Scores indicate low maturity (Jan 2020)

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
<th>Category</th>
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</thead>
<tbody>
<tr>
<td>-78</td>
<td>8. Models are the basis for Technical Reviews</td>
<td>Technical Management</td>
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<tr>
<td>-52</td>
<td>9. MBSE is the basis for Technical Reviews</td>
<td>Technical Management</td>
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<tr>
<td>-99</td>
<td>11. Modeling provides measurable...</td>
<td>Metrics</td>
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<tr>
<td>-33</td>
<td>12. Have consistent metrics across enterprise</td>
<td>Metrics</td>
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<tr>
<td>-45</td>
<td>14. Consistent data/model V&amp;V processes</td>
<td>Model Quality</td>
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<tr>
<td>-48</td>
<td>15. Consistent data/model QA processes</td>
<td>Model Quality</td>
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<tr>
<td>-72</td>
<td>16. Processes to manage data interface...</td>
<td>Data Management</td>
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<tr>
<td>29</td>
<td>17. Data is portable across organizations &amp;...</td>
<td>Data Management</td>
</tr>
<tr>
<td>-49</td>
<td>19. Support model libraries for model reuse</td>
<td>Model Sharing &amp; Reuse</td>
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<tr>
<td>-75</td>
<td>20. Libraries support discoverable knowledge</td>
<td>Model Sharing &amp; Reuse</td>
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<tr>
<td>-107</td>
<td>23. Trust that environment is secure</td>
<td>Modeling Environment</td>
</tr>
<tr>
<td>-33</td>
<td>24. Trust that environment protects IP</td>
<td>Modeling Environment</td>
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<tr>
<td>-22</td>
<td>30. Have clearly defined roles supporting...</td>
<td>Workforce</td>
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<td>5</td>
<td>32. Have sufficient staffing for all roles</td>
<td>Workforce</td>
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<tr>
<td>183</td>
<td>21. Consistent use of shared models</td>
<td>Model Sharing &amp; Reuse</td>
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<tr>
<td>145</td>
<td>22. Consistent use of shared models with...</td>
<td>Model Sharing &amp; Reuse</td>
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<tr>
<td>8</td>
<td>25. Have processes for tool selection &amp;...</td>
<td>Model Sharing &amp; Reuse</td>
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<tr>
<td>5</td>
<td>33. Have defined critical skills supporting...</td>
<td>MBSE Skills</td>
</tr>
<tr>
<td>12</td>
<td>1. Mature use strategy</td>
<td>MBSE Usage</td>
</tr>
<tr>
<td>22</td>
<td>2. Mature process/tool strategies</td>
<td>MBSE Usage</td>
</tr>
<tr>
<td>54</td>
<td>4. Consistent lexicon &amp; taxonomy across...</td>
<td>MBSE Usage</td>
</tr>
<tr>
<td>64</td>
<td>5. Mature Model Management Processes</td>
<td>MBSE Usage</td>
</tr>
<tr>
<td>57</td>
<td>6. Standard Program &amp; Business Guidance...</td>
<td>MBSE Usage</td>
</tr>
</tbody>
</table>
Overall Survey Scores indicate management perceives greater progress than engineering
Overview of MBSE Literature Review

- A literature review was conducted to examine the benefits reported in the literature from using MBSE and whether claimed benefits are supported with evidence.
- Twenty journals and conferences known for publishing papers in the field of Systems Engineering were searched using keywords:
  - “Model-Based Systems Engineering” OR “Model Based Systems Engineering” OR “MBSE”
- Out of the 847 papers that mention MBSE in any way, 360 cited benefits of MBSE.
  - 1,233 unique statements about benefits were extracted from the 360 papers and aggregated into 48 benefit categories for analysis.

*Kaitlin Henderson (VT) PhD studies*
Literature Review Results

- Searched papers that mention a benefit of MBSE and what the source of that benefit was: measured gains, observed gains, perceived gains (no source for benefit), reference.
  - Total Papers that mention MBSE: 847
    - Papers that mention benefits: 360
      - Measured gains: 2
      - Observed gains: 27
      - Perceived gains: 236
      - Reference: 114
      - Misc.: 2

*Kaitlin Henderson (VT) PhD studies*
<table>
<thead>
<tr>
<th>Category</th>
<th>Perceived</th>
<th>Observed</th>
<th>Measured</th>
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<tr>
<td><strong>Quality</strong></td>
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</tr>
<tr>
<td>Reduce Errors/Defects</td>
<td>(16)</td>
<td>Reduce Errors/Defects (26)</td>
<td>Reduce Errors/Defects (2)</td>
</tr>
<tr>
<td>Improve Traceability</td>
<td>(61)</td>
<td>Improve Traceability (9)</td>
<td>Improve Traceability (1)</td>
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<tr>
<td>Improve System Quality</td>
<td>(21)</td>
<td>Improve System Quality (0)</td>
<td>Improve System Quality (1)</td>
</tr>
<tr>
<td>Reduce Risk</td>
<td>(22)</td>
<td>Reduce Risk (2)</td>
<td>Reduce Risk (1)</td>
</tr>
<tr>
<td>Increased Rigor</td>
<td>(0)</td>
<td>Increased Rigor (0)</td>
<td>Increased Rigor (1)</td>
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<td>Reduce Cost</td>
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<td>Reduce Cost (4)</td>
<td>Reduce Cost (0)</td>
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<td><strong>Velocity/Agility</strong></td>
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<tr>
<td>Consistency</td>
<td>(44)</td>
<td>Consistency (6)</td>
<td>Consistency (1)</td>
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<tr>
<td>Reuse</td>
<td>(37)</td>
<td>Reuse (5)</td>
<td>Reuse (1)</td>
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<tr>
<td>Efficiency</td>
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<td>Efficiency (2)</td>
<td>Efficiency (0)</td>
</tr>
<tr>
<td>Improve Standardization</td>
<td></td>
<td>Improve Standardization</td>
<td>Improve Standardization (0)</td>
</tr>
<tr>
<td>Collaboration/Info Sharing</td>
<td>(68)</td>
<td>Collaboration/Info Sharing (11)</td>
<td>Collaboration/Info Sharing (0)</td>
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<tr>
<td>Integration/V&amp;V</td>
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<td>Integration/V&amp;V (3)</td>
<td>Integration/V&amp;V (1)</td>
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<tr>
<td>Reduce Time</td>
<td>(24)</td>
<td>Reduce Time (8)</td>
<td>Reduce Time (1)</td>
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<tr>
<td><strong>User Experience</strong></td>
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<tr>
<td>Reduce SE Task Burden</td>
<td>(0)</td>
<td>Reduce SE Task Burden (0)</td>
<td>Reduce SE Task Burden (1)</td>
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<tr>
<td>Manage Complexity</td>
<td>(48)</td>
<td>Manage Complexity (2)</td>
<td>Manage Complexity (0)</td>
</tr>
<tr>
<td>Productivity</td>
<td>(14)</td>
<td>Productivity (0)</td>
<td>Productivity (0)</td>
</tr>
<tr>
<td>System Understanding</td>
<td>(24)</td>
<td>System Understanding (2)</td>
<td>System Understanding (0)</td>
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<tr>
<td><strong>Knowledge Transfer</strong></td>
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<tr>
<td>Information Access</td>
<td>(27)</td>
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<td>Information Access (2)</td>
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<td>Knowledge Capture/Sharing</td>
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<td>Architecture/Sys Understanding</td>
<td>(23)</td>
<td>Architecture/Sys Understanding (2)</td>
<td>Architecture/Sys Understanding (1)</td>
</tr>
</tbody>
</table>
Top Cited DE Benefits Areas from Literature and Survey Results

Key metrics:
- Increased traceability
- Reduced defects/errors
- Reduced time
- Improved consistency of processes & models
- Increased capacity for reuse
- Higher level of support for automation
- Better communication & information sharing
Survey Results linking Critical Skills to transformation

DE is no cure for poor systems engineering

DE requires new digital data and tool competencies

Question 34
The most critical skills for MBSE are:

Most Critical Digital Skills

Most Critical Tool Expertise

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Comparing Obstacles vs. Enablers vs. Changes

Key metrics:
- Availability & maturity of DE/MBSE methods & processes
- Training
- Willingness to use DE/MBSE tools
• The Baldrige Criteria for Performance Excellence (CPE) provide a comprehensive framework of organizational sub-systems

• Used for recognition (the national Baldrige Award), assessment & diagnosis of organizational and process maturity, and to guide large-scale transformation (e.g., to pay attention to all key sub-systems during transformation)

http://www.nist.gov/baldrige

For example:
• Leaders communicate clear reason for MBSE adoption
• MBSE aligned with overall organizational strategy
• Workforce have needed skills to support MBSE use
• Data management processes support MBSE
• Organizational culture aligned with MBSE use
• Clear metrics defined to track results and progress
• MBSE adoption aligned with what customers need
## Test application to NAVAIR Pilot

<table>
<thead>
<tr>
<th>REDUCE ERRORS/DEFECTS</th>
<th>INCREASED TRACABILITY</th>
<th>IMPROVE SYSTEM QUALITY</th>
<th>REDUCE RISK</th>
<th>REDUCE COST</th>
<th>IMPROVED CONSISTENCY</th>
<th>INCREASED EFFICIENCY</th>
<th>INCREASED EFFECTIVENESS</th>
<th>COMM/INFO SHARING</th>
<th>EARLY V&amp;V</th>
<th>REDUCE TIME</th>
<th>SUPPORT FOR AUTOMATION</th>
<th>REDUCE SE TASK BURDEN</th>
<th>MANAGE COMPLEXITY</th>
<th>INCREASED PRODUCTIVITY</th>
<th>IMP. SYSTEM UNDERSTANDING</th>
<th>BETTER ACCESS. OF INFO.</th>
<th>BETTER KNOWLEDGE CAPTURE</th>
<th>IMP. SYSTEM DESIGN</th>
<th>ALIGNMENT W/CUSTOMER</th>
<th>SUPPORT/COMMITMENT</th>
<th>DE/MBSE METHODS &amp; PROC.</th>
<th>DE/MBSE TOOLS</th>
<th>WORKFORCE DEVELOPMENT</th>
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<tbody>
<tr>
<td>9</td>
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<td>6</td>
</tr>
</tbody>
</table>
Obstacles, Enablers, Changes: linking leadership and metrics to transformation

**Leadership**
- Create Buy-in
- Shared knowledge/ Authoritative Source of Truth
- Guidebook Chapter on MBSE
- Communities of Practice/ Interest
- Innovation spaces & projects

**Messaging**
- Create better informed requirements
- Make better informed decisions
- Ability to assert completeness
- Do the same things faster
- Communicate better
- More work flexibility
- Reduce risk

**DE Initiatives**
- Leadership
- Must provide
- Must produce
- Must support investment in
- Must persist to

**Metrics**
- Increased traceability
- Improved consistency
- Reduce errors/ defects
- Reduce time
- Better Comm/Info sharing
- More work flexibility
- Reduce risk

**DE Initiatives**
- Leadership
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- Must produce
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- Improved consistency
- Reduce errors/ defects
- Reduce time
- Better Comm/Info sharing
- More work flexibility
- Reduce risk

**Transform Workforce and Culture**
- Identifying Enterprise Value Needed for
- Metric: People willing to use DE/MBSE tools
- Who will
- Must support investment in
- Must produce
- Must persist to

**Domain**
- Actors
- Structure
- Processes/Resources

**Legend**
## Example Metric Definitions

<table>
<thead>
<tr>
<th>Metric Area</th>
<th>Metrics Category</th>
<th>Inputs</th>
<th>Ex. Processes</th>
<th>Ex. Outputs</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td>Increased traceability</td>
<td>User needs and system requirements are in a modeling tool and linked to truth data &amp; models</td>
<td>MBSE: reqs., structure, use cases, traceability tools ASOT: all reqs. at each level are linked data</td>
<td>Decreasing number of requirements changes, improving requirement volatility trends</td>
<td>Fully digital traceability of requirements, design, test, and information; available from one source of truth</td>
</tr>
<tr>
<td>Quality</td>
<td>Reduce defects/errors</td>
<td>Data, models, requirements, design artifacts</td>
<td>Peer review and technical review in models, design automation, test automation</td>
<td>Defects/errors discovered and corrected earlier in development phases, less total defects/ errors, error-free deployments</td>
<td>Reduced total errors/defects in each program phase, reduce errors/defects that escape from one phase to the next, increased number of saves in each phase</td>
</tr>
</tbody>
</table>

**Example Metric Definitions**

**Metric Area:** Quality  
**Metrics Category:** Increased traceability, Reduce defects/errors

**Inputs:**  
- Increased traceability
  - User needs and system requirements are in a modeling tool and linked to truth data & models

**Ex. Processes:**  
- MBSE: reqs., structure, use cases, traceability tools
- ASOT: all reqs. at each level are linked data

**Ex. Outputs:**  
- Decreasing number of requirements changes, improving requirement volatility trends

**Outcomes:**  
- Fully digital traceability of requirements, design, test, and information; available from one source of truth
  - Reduced total errors/defects in each program phase, reduce errors/defects that escape from one phase to the next, increased number of saves in each phase
Using background literature and interviews, develop causal models for candidate metrics.

Select metrics to be measured based on causal relationships and sponsors’ recommendations.

Establish a measurement plan that combines quantitative and qualitative data, both from direct measurements and from personnel perceptions.

Characterize organizations and projects (1 or 2) where the measurements will be conducted.

Conduct sample measurement of benefits and analyze measurement results.
Questions?