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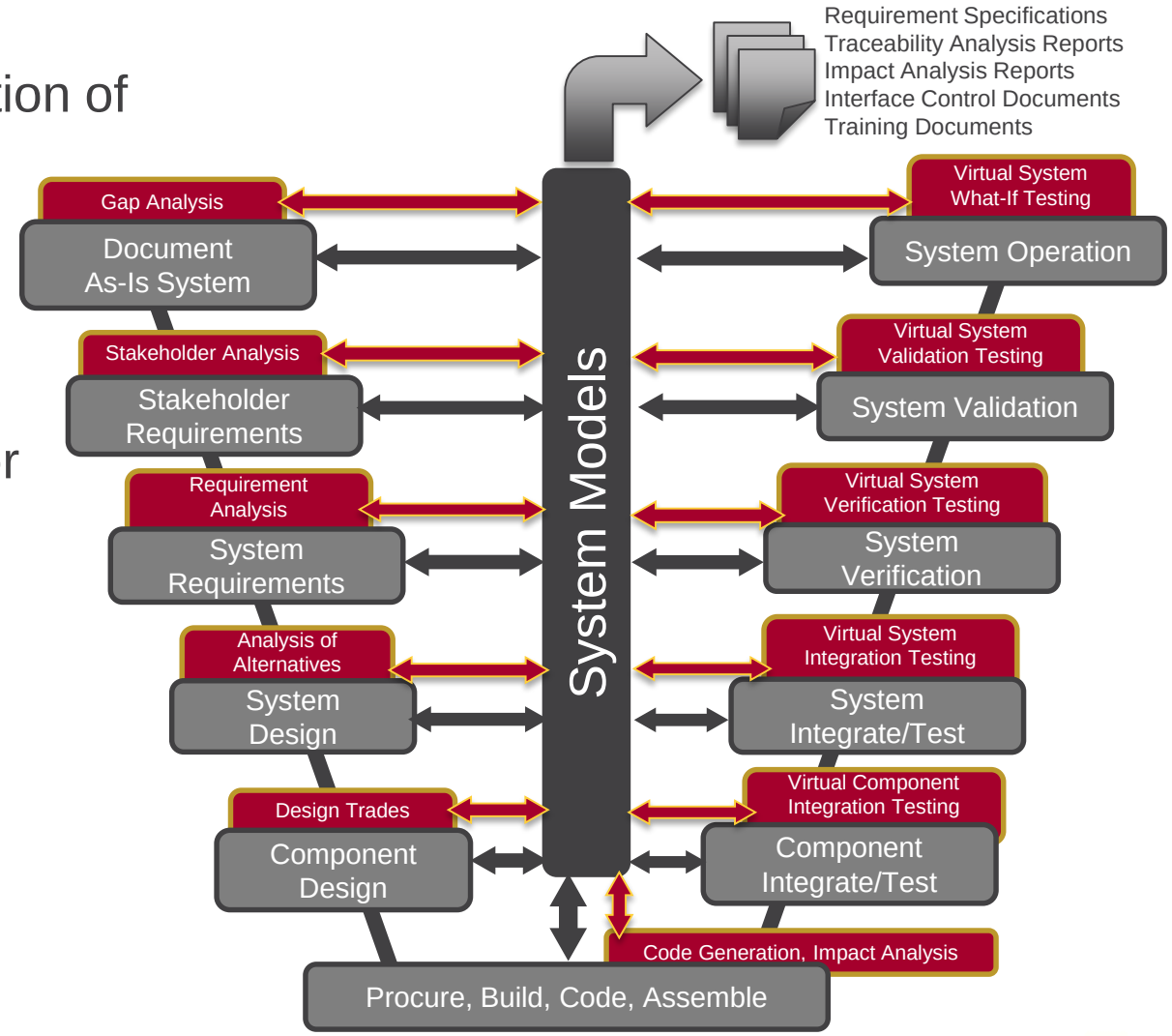
Recommended Best Practices based on MBSE Pilot Projects

Why MBSE?

- Increasing system **complexity**
  - More **escapes** with greater impacts → program delays, cancellations
  - Many **legacy** systems and interfaces → constrains system evolution
  - **Spiral and agile** development → multiple requirement/design baselines
- Increasing information **stovepipes**
  - Organizational, structural, temporal, projects, etc.
  - Knowledge lost between lifecycle phases
- Ambiguous representation results in **inconsistent mental models**
  - Lack of a “common systems engineering picture”
  - Misinterpretation is common
- Documents and stovepiped models are **brittle** artifacts
  - Difficult to keep synchronized and consistent
  - Difficult to capture complex and numerous interrelationships
  - Difficult to find disconnects

MBSE Improves Upon SE

- System models are **central** to the execution of SE processes
  - Traceability analysis
  - Impact analysis
  - Gap analysis
  - Virtual I&T
  - "Single source of truth"
- System models provide the foundation for improved **knowledge capture** and **information sharing**…
  - … among technical disciplines
  - … between organizations
  - … spanning life cycle phases
- System models improve the **speed and quality of SE execution**
  - Reduced human error
  - Reduced data inconsistency
  - Reduced miscommunication



Benefits of MBSE

- Improved **collective** understanding of system capabilities, requirements, composition, functionality, behavior, interdependencies, and resilience
- Better **organization** of technical information across system life cycle phases
- Less-ambiguous **communication** across contractual, organizational interfaces
- Improved **efficiency** in evaluating architectural options
- Better **traceability** and more efficient transition from early concept studies and capability-based assessments through all subsequent life cycle activities
- Ability to perform rapid, **comprehensive** impact assessment crossing architectural layers and organizational stovepipes
- Strengthened ability to architect enterprise-wide and cross-enterprise solutions by **integrating knowledge and insight** across the enterprise's portfolio

The MBSE System

- MBSE implementation includes many interdependent pieces
  - Descriptive system modeling
    - Modeling tools, languages, methodology, processes, etc.
  - Analytical modeling and simulation
  - Databases and other data stores
  - Product lifecycle management
  - etc.
- These pieces should not be developed in isolation, but rather should be architected into a coherent MBSE System to serve the needs of its stakeholders
  - Its users, contributors, and beneficiaries

MBSE Experience and Lessons Learned

- This presentation describes some of the key lessons learned and resulting recommended best practices

- These lessons have emerged from several MBSE pilot projects executed over the past several years
  - Spanning a broad range of Government enterprises and programs
  - Some internally funded efforts
  - All involved teams of multiple modelers
  - All used SysML or UPDM to build models of existing and/or proposed systems
  - All had different objectives with regard to demonstrating MBSE value and/or informing program decisions

- Some of these lessons were also reinforced by independent assessment of MBSE and enterprise architecture modeling efforts performed by other organizations

Lessons Learned

Organized into four categories:

1. Understanding the Problem Space
2. System Modeling Practices
3. Tools, Infrastructure, and Training
4. Organizational and Human Engineering Challenges

Define Model Purposes Early

- Defining a model's purposes early is critical to ensuring the model will be built to address those needs
- Whenever purposes were not defined very clearly, models were built that were not very useful
- Take the time to define key use cases for the models
  - NOT the same as use cases for the system being modeled
  - Focus on major model stakeholder decisions to be informed
  - Identify questions that need to be answered to inform those decisions
  - Plan the modeling effort to construct the elements, attributes, relationships, and views needed to answer those questions

Seek the “Killer Apps”

- Identify the “killer apps” that motivate stakeholders to make the leap from skeptic to advocate
- Getting buy-in from critical stakeholders may be difficult until you can address the “big rocks” that keep them up at night
- Elicit from stakeholders their key concerns
- Don’t be afraid to “fight the last war”

Exploit “Network Effects”

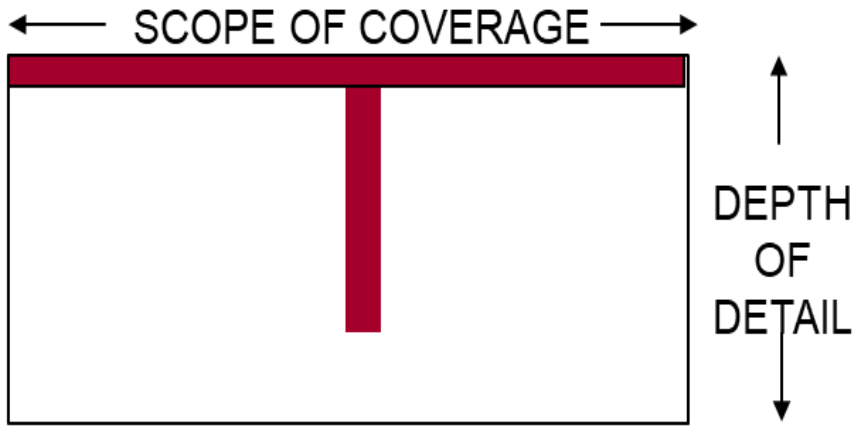
- MBSE improves the design process by facilitating improved concurrency across the range of SE technical processes and life cycle phases
- The more a model is used, and the more data it contains and integrates from multiple sources, the more valuable it becomes and its value can continue to grow
- The value of the models is magnified by integrating data from many sources into a coherent body of knowledge
  - Integrate isolated local knowledge into coherent global knowledge
- Early engagement with downstream users of the model can improve support for pilot efforts

Replace the “Vicious Circle” with the “Virtuous Circle”

- Foster positive feedback between usefulness of descriptive models and the maintenance of these models as the authoritative source of truth
  - Make the models more useful to more people
    - The value of the models is fundamentally driven by the interactions between people that take place virtually within the model space
    - Establish co-dependency on sharing of information
  - Make the model easier to maintain
    - Exploit automation and integration with existing datasets
    - Make as much of the models as possible maintainable by engineers who do not need to be modeling SMEs

Model the “T” to explore both breadth and depth

- Decisions made early in the model’s architecture can severely impact the models’ usefulness, scalability, or maintainability later
- Explore both breadth and depth of the model concurrently
  - Burn down risk of poor model architecture before it becomes too painful to fix
  - Modeling issues driven by breadth are generally different than those driven by depth
- Focus early efforts on “just enough breadth” and “just enough depth” to make the right model architecture decisions
  - Filing in the gaps can be done later to train new modelers



Build in flexibility to adapt to future needs

- Balance near-term demonstration goals with building in flexibility to adapt the model to future needs
- Quick model architecture decisions may be needed to make near term progress, but can also make it difficult to address future use cases
  - Beware of accumulating too much “technical debt” in the models that will have to be paid back through time-consuming refactoring
- Add layers of abstraction to facilitate future applications
  - But don’t worry too much about building a permanent foundation
- Design for reuse and federation to exploit MBSE’s biggest benefits

Focus on the underlying data, not just diagrams

- Common danger is to think of static graphical diagrams as requirements
- The majority of the value of a model comes from the dynamic creation of views spanning multiple perspectives to answer specific questions
  - Elicit from model stakeholders the views that they want to see to answer their questions
- Linkages between model elements that span multiple stakeholder perspectives are often the most valuable
- Avoid large static diagrams
  - They are rarely useful at answering questions

Tool selection should be driven by needs

- Tools should be selected to accomplish the needs for the modeling effort
  - Choosing tools first can severely constrain what can be accomplished
- Combine a top-down, needs-driven process with a bottom-up process based on understanding of available modeling tools to iteratively drive to a compatible set of needs and solutions
- Establish testbed capabilities to obtain hands-on experience in using multiple tools to better understand their strengths and limitations
- Tools are evolving quickly, so tool comparisons are perishable

Tools, Infrastructure, and Training
Pilot programs can use available tools for early exploratory work

- Pilot efforts can use available tools, but stakeholders should have realistic expectations about the results
- The principal product of the pilot is not the models that are built
- Rather, the principal product is the insight learned through the learning process of architecting, building, and using the models
- Ideally, pilots should also help to inform real decisions, to build support and confidence in the value of MBSE
- Preferably, more than one modeling tool should be used to provide insight into the capabilities of different tools

Organizational and Human Engineering Challenges

Provide expected SE products to accelerate adoption

- MBSE should be implemented incrementally
- Focus initially on the construction of familiar SE products from the model to provide confidence that MBSE can be adopted conservatively
- The process of using prototype models will inform stakeholders on how to think more objectively about their needs and understand how MBSE methods can provide a more effective approach to address their needs
- An agile development approach for developing the models and the MBSE System has been found to be very effective

Resolving disconnects is a key benefit of MBSE

- Capturing the “as-is” system serves as a useful point of departure for a modeling pilot effort
- Resolving disconnects in the pre-MBSE body of knowledge is often one of the most time-consuming aspects of pilots
  - Don’t be surprised when the baseline isn’t well understood
  - Found often that existing documentation is confusing or contradictory
  - This is an inherent risk of existing document-focused SE practices
  - MBSE didn’t cause the problem
  - MBSE simply exposed the latent problem
- SME support to resolve disconnects can add significant uncertainty for project scheduling
  - What is the “truth?”

Beware the “sunk cost fallacy”

- Stakeholders will often strongly resist spending time to “refactor” models if it detracts from more visible efforts
  - Shoring up the foundation is less appealing than adding more stories
  - They often prefer to incrementally add to an inadequately architected model and resist allowing time and resources to re-architect the model to address newly discovered needs
- Recognize that refactoring the model may be needed as the situation evolves
  - Evolution of modeling language and tools
  - Evolution of understanding of how to best use the languages and tools
  - Evolution of understanding of the problem space

Organizational and Human Engineering Challenges
Measure success in the problem space, not the solution space

- Quantitative measurement of progress is very challenging
- Clearly identify and prioritize the uses for the model in the form of explicit questions that the model must answer
  - Ability to answer these questions is the best measure of progress
  - Focus not just on quantity of answered questions, but on quality of those answers in comprehensiveness, fidelity, and/or speed
- Metrics in the solution space will generally be “gamed” to the detriment of real progress
  - Avoid incentivizing work that may not contribute to stakeholder value

Conclusions

- MBSE can offer significant benefits to Government organizations responsible for managing their increasingly complex enterprises
- However, implementing MBSE is not a straightforward task, and there are many pitfalls along the way
- An incremental approach built on solid system architecting principles, focusing on supporting major stakeholder decisions, and informed by best practices and lessons learned from previous efforts offers the best chances of success

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