Models & Simulations Development Best Practices

Katherine L. Morse, PhD

13th Annual NDIA Systems Engineering Conference

27 October 2010

APL
The Johns Hopkins University
APPLIED PHYSICS LABORATORY

Presentation Outline

- **Background**
- **Study Objectives and Major Technical Activities**
- **Literature Search**
- **Systems Engineering Framework**
- **Example – Develop Conceptual Model**
- **Example – Perform Product Validation**
- **Current Status**

Background

- The AMSWG included the following action in the Acquisition M&S Master Plan (AMSMP) published in April 2006:
  - ACTION 3-2. Define and foster sound practices for efficient development and evolution of credible M&S tools, incorporating user-defined requirements in a systems engineering approach with appropriate verification and validation.
- This study is funded by Office of the Director, Defense Research & Engineering - Systems Engineering/Systems Analysis

AMSMP Rationale

- **Although the importance and use of modeling and simulation tools (models, simulations, and utilities) is expanding across the DoD, relatively few persons have a good grasp of the process and principles that should be followed when developing such tools.**
  - **The DoD has identified the Federation Development and Execution Process (FEDEP - IEEE 1516.3) as a recommended practice for distributed simulation federations using the HLA, but no equivalent best practice exists for the development of individual modeling and simulation tools.**
- **Whether conducting such a development or overseeing a contractor's efforts to do so, DoD acquisition professionals need to understand best practices for developing modeling and simulation tools.**

Study Objectives and Major Technical Activities

- **Study Objectives**
  - **Identify effective practices for the efficient development and evolution of credible models and simulations**
- **Major Technical Activities**
  - **Conduct a literature search and survey of M&S tool developers to identify sound practices for M&S development**
  - **Develop an overarching systems engineering framework for describing the activities and tasks necessary for effective M&S development**
  - **Develop a plan for populating the SE framework with the appropriate process elements (activities and tasks), and for capturing best practices specific to chosen domain areas**
  - **Review the draft framework with organizations and individuals that can help ensure its correctness and appropriateness**
  - **Refine the core process document descriptions per the above reviews**

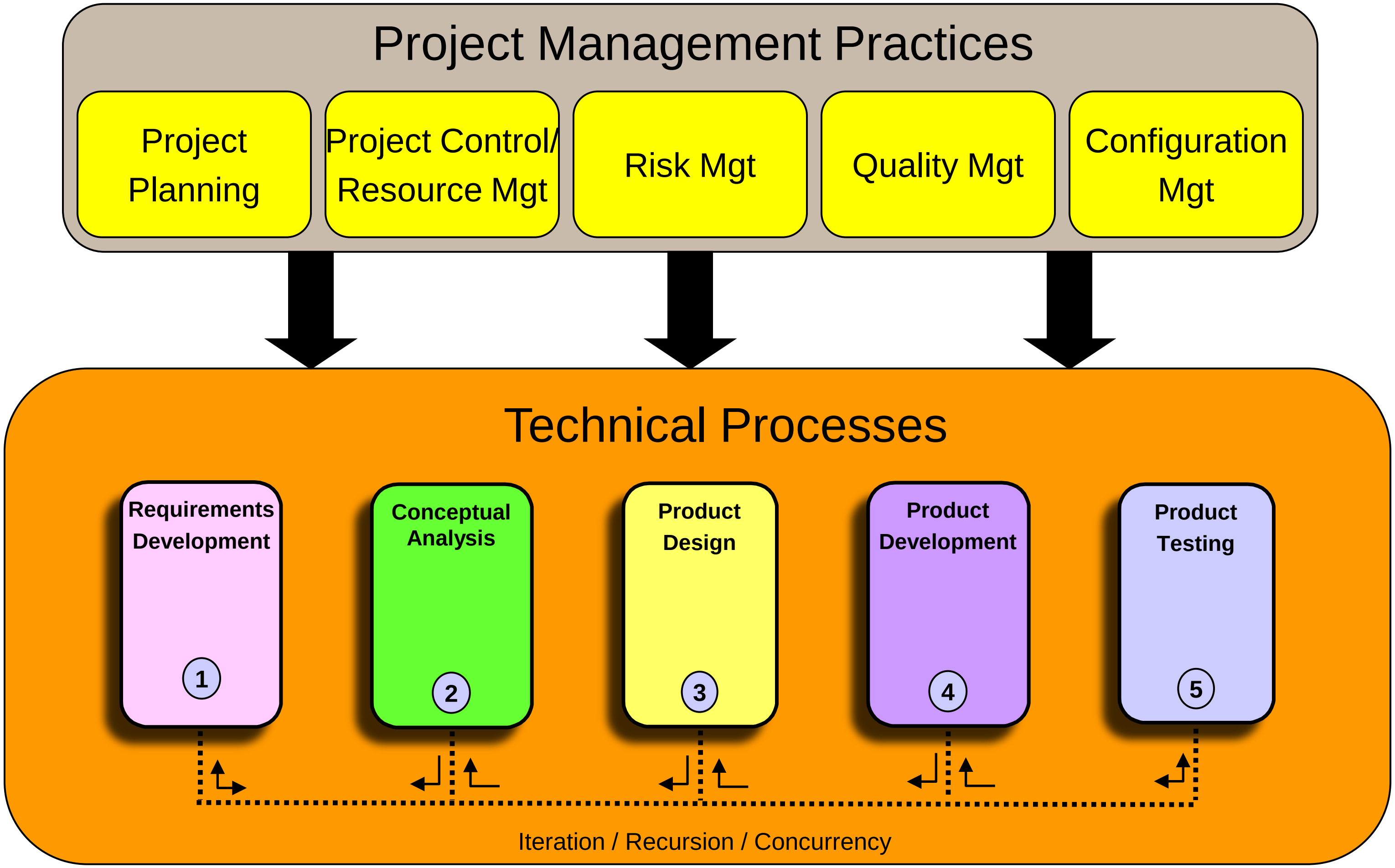
Literature Search

- Assembled bibliography of (mostly) journal and book sources
- Searched NDIA, Simulation Interoperability Workshop (SIW) and Interservice/Industry Training, Simulation & Education Conference (I/ITSEC) papers from the last 5 years
- Literature search and survey together resulted in approximately 116 practices for consideration
  - After removing practices that overlapped with the SE Framework itself, removing practices that weren’t M&S specific, and merging similar practices, the team arrived at 50 best practices.

Systems Engineering (SE) Framework Inputs

- International Council on Systems Engineering (INCOSE) Handbook (v3.1)
- Electronic Industries Alliance (EIA) Processes for Engineering a System (EIA-632)
- Institute for Electrical and Electronics Engineers (IEEE) Standard for Application and Management of the Systems Engineering Process (IEEE-1220)
- International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) Systems engineering - System life cycle processes (ISO/IEC-15288)
- Military Standard - System Engineering Management (MIL-STD-499C)
- IEEE Federation Development and Execution Process (FEDEP) (IEEE 1516.3-2003)/Distributed Simulation Engineering and Execution Process (DSEEP) (IEEE P1730)
- Capability Maturity Model Integration (CMMI)

SE Process Overview



SE Framework Outline

- **Phase 1:** ***Requirements Development***
  - Activity 1: *Develop Stakeholder Requirements*
  - Activity 2: *Develop Product Requirements*
  - Activity 3: *Validate Requirements*
- **Phase 2:** ***Conceptual Analysis***
  - Activity 1: *Develop Conceptual Model*
  - Activity 2: *Validate Conceptual Model*
- **Phase 3:** ***Product Design***
  - Activity 1: *Perform Functional Analysis*
  - Activity 2: *Synthesize Design*
  - Activity 3: *Verify Design*
- **Phase 4:** ***Product Development***
  - Activity 1: *Establish Software Development Environment*
  - Activity 2: *Implement Product Design*
- **Phase 5:** ***Product Testing***
  - Activity 1: *Perform Product Verification*
  - Activity 2: *Perform Product Validation*
- ***Project Management Practices***
  - *Project Planning*
  - *Project Control/Resource Management*
  - *Risk Management*
  - *Quality Management*
  - *Configuration Management*

Phase 1: Requirements Development

- **Establish intent for model use.**
- **Use focus groups in simulation creation.**
- **Specify data content.**
- **Use survey methods to elicit Subject Matter Experts' (SMEs') knowledge.**

Phase 2: Conceptual Analysis

- Establish model focus by carefully choosing model behavioral aspects and data.
- Use a formal language for linking requirements to a conceptual model.
- Use a standard process for creating a conceptual model.
- Select computer scientists with domain expertise to be on the conceptual modeling team.
- Augment logical data models with semantics.
- Create a data dictionary.
- Include full simulation specification and context in a conceptual model for a simulation system.
- Format the conceptual model using a standard notation accessible to all stakeholders.
- Combine conceptual modeling with knowledge acquisition/knowledge engineering.
- Document a rationale for realistic output measures.
- Use a standardized conceptual model to mitigate stakeholder subjectivity in simulation design.
- Involve the decision-maker in the model development process.

Phase 3: Product Design

- Maintain a distinction between models and simulations.
- Use archived models and model components from an authoritative source.
- Select input data items based on a complete problem context.
- Define uncertainty models.
- Use design patterns in M&S.
- Balance modeling needs with data considerations.
- Design data storage and retrieval architecture.
- Consider availability of data sources when designing simulation.
- Group and separate data from models with varying resolution.
- Distinguish unknowns from unknowables.
- Use intelligent analytical approaches to handle unavailable or unknowable data.
- Adopt commonly accepted icons, symbols, shapes, and colors used to represent simulation entities, where possible.
- Evaluate a model's pedigree before (re)using it as a component.
- Create both an analysis data model and a logging data model to facilitate capture and use of simulation output data.
- Use standards where applicable.
- Separate data I/O interface from model code.
- Use a standardized logical data model and format for I/O data.
- Select output data items based on a complete view of simulation usage.
- Design models as components with loose coupling.

Phase 4: Product Development

- Use scenario generation tools to promote consistency and efficiency.
- Choose the right architecting tool for static and dynamic aspects of the M&S application.
- Employ common random numbers in models.

Phase 5: Product Testing

- **Collect referent information.**
- **Decompose qualitative SME input into quantitative indicators.**
- **Validate models against each intended use.**

Project Management

- Conduct engineering integration reviews.
- Include user domain representatives and external developers in peer reviews.
- Use SMEs throughout the development life cycle.
- Use Systems Engineering analysis and documentation.
- Use a standardized method of "packaging" for developing model components.
- Document model abstraction decisions.
- Keep data current.
- Establish a configuration management system.
- Document models and simulation data with metadata.

2.1 Conceptual Analysis - Develop Conceptual Model

A conceptual model is developed to identify those relevant entities within the M&S domain of interest that should be represented in the product to satisfy validated requirements. The conceptual model identifies the attributes of each entity that should be represented, the behaviors/performance of each, and the static and dynamic relationships among the entities. Algorithms should be specified where feasible.

- **Establish model focus by carefully choosing model behavioral aspects and data.**
- ***Use a formal language for linking requirements to a conceptual model.***
- **Use a standard process for creating a conceptual model.**
- ***Select computer scientists with domain expertise to be on the conceptual modeling team.***
- **Augment logical data models with semantics.**
- **Create a data dictionary.**
- **Include full simulation specification and context in a conceptual model for a simulation system.**
- **Format the conceptual model using a standard notation accessible to all stakeholders.**
- **Combine conceptual modeling with knowledge acquisition/knowledge engineering.**

Develop Conceptual Model – Sample Best Practices

- **Use a formal language for linking requirements to a conceptual model**
  - **UML/SysML diagrams may be used for requirements analysis and conceptual modeling. Requirements and use case diagrams can be used to explore objectives. Activity, sequence, state machine, block definition, and parametric diagrams can model dynamic behavior traceable back to the requirements.**
- **Select computer scientists with domain expertise to be on the conceptual modeling team**
  - **Good conceptual modelers are computer scientists with domain expertise. If either skill is lacking, the conceptual modeler has difficulty building a model that bridges the gap between the real world and the computation space.**

5.2 Product Testing - Perform Product Validation

The purpose of this activity is to ensure that the M&S application, when exercised for its intended use, will meet all of the operational needs articulated in the original stakeholder requirements. This may involve capability demonstrations or other such customer reviews, or could involve a trial-use period, whereby users report any faults/errors detected during normal use, for which corrective actions are defined and taken. Stakeholder satisfaction is the overriding goal of this activity.

- ***Collect referent information.***
- ***Decompose qualitative SME input into quantitative indicators.***
- ***Validate models against each intended use.***

Perform Product Validation – Sample Best Practices

- **Collect referent information.**
  - **Identify and collect appropriate referent information for validation of M&S results (test and experimental data and observations, laws of physics and theory, results from other M&S, SMEs, etc.) with explicit quantification of uncertainties related to that information.**
- **Decompose qualitative SME input into quantitative indicators.**
  - **Qualitative concepts used by SMEs may be decomposed hierarchically in a recursive fashion until all sub-components (called indicators) are quantitative. These quantitative indicators (called leafs) can be combined with weights to measure conformance. This allows comparisons of qualitative concepts.**
- **Validate models against each intended use.**
  - **Models must be validated against each intended use. If a previously-validated model is applied to new questions or new uses, it must be reevaluated in the new context.**

Status

- The final report has been cleared for public release.
  - Send me an email if you would like a copy: katherine.morse@jhuapl.edu
- We're currently evaluating whether there's sufficient interest in the SISO Study Group to progress the report results to an open standard.

APL

Questions and Feedback