The Growing Importance of Models for Defense Acquisition

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John Colombi
Professor and Program Chair, Systems Engineering
john.colombi@afit.edu, 937-255-53636 x3347
Air Force Institute of Technology (AFIT)

- **Graduate School of Engineering and Management**
  - Department of Systems Engineering & Management

- **Systems Engineering Certificate – AFMC/EN sponsored**
  - 4 Graduate courses (4 quarters part-time online)

- **Systems Engineering Masters**
  - Thesis or non-thesis (capstone) options, Online, Resident or Mixed
  - Tracks (Human, Space, Cyber, Autonomy, SE Tools, Energy, Nuclear)

- **Systems Engineering Doctoral Program**

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Overwhelming demand for MBSE and SysML professional continuing education (PCE), often program-tailored, with tool demo/support
Historic Observations

Integrated Definition (IDEF) models/ SADT, 1970-80s

C4ISR Architecture Framework 1996
Unified Modeling Language (UML) 1996
Simulation Based Acquisition (SBA) late 1998
Mature simulation models throughout the acquisition lifecycle

DoD Architecture Framework 2003, 2009
52 Views (Models) to support DoD core processes - Acquisition
Interoperability, PBBES, Portfolio Mgmt, Capability Engineering, Systems Engineering

Comp Research and Eng Acq Tools and Environments (CREATE) 2011
High Performance Computing (HPC) and Modeling support

Digital Engineering Strategy 2016
Observation

Continued and growing DoD emphasis on the use of models to understand, design and manage complex systems

- Time for success
  - Widespread adoption of SysML
  - Improved tools with analytical tool integrations
  - Prime contractors evolving to model-based engineering
  - Senior Leadership commitment
  - Acquisition policies need model support (OSA, Agile/Rapid, OTB, …)
Digital Transformation

Document-driven

SOO, SOW, RFP
Specifications
Reviews
SRD/TRD
ICD/CDD/CPD
System Studies
CDRL/DID
Reports
Plans

Integrated, Authoritative, Shared
System Model

Any information missing or not easily represented
Model-Based Systems Engineering

“The formalized application of modeling to support system requirements, design, analysis, verification, and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases.”

Need: Use of modern system modeling to improve acquisition, engineering and engineering management activities.
DoD Systems Engineering

Requirements Management
Interface Management
Risk Management
Configuration Management
Technical Data Management
Technical Planning
Technical Assessment
Decision Analysis

Implementation
Integration
Verification
Validation
Transition

Stakeholder Requirements Definition
Requirements Analysis
Architecture Design

Defense Acquisition University
Three pillars of MBSE

Implementing MBSE effectively requires...

Language

Method

Tool

Delligatti, SysML Distilled
4 Types of SysML Elements

## MBSE Methods

<table>
<thead>
<tr>
<th>Name</th>
<th>Focus</th>
<th>Author</th>
<th>Year</th>
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<tbody>
<tr>
<td>Functional Architecture for Systems (FAS)</td>
<td>Use-case driven approach (fits within and derives from SYSMOD)</td>
<td>Weilkiens</td>
<td>2010</td>
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<tr>
<td>Harmony-SE</td>
<td>General systems development with real-time and embedded software focus</td>
<td>Telelogic / IBM</td>
<td>2006</td>
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<tr>
<td>Magic Grid</td>
<td>“Zachman-like” architectural framework approach to systems modeling &amp; architecting</td>
<td>NoMagic with V19</td>
<td>2016</td>
</tr>
<tr>
<td>Object Process Methodology (OPM)</td>
<td>“Conceptual modeling language and methodology for…designing systems”</td>
<td>Dori</td>
<td>1995</td>
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<tr>
<td>Object-Oriented Systems Engineering Method (OOSEM)</td>
<td>Top-down, scenario-driven approach applying object-oriented analysis and design to MBSE</td>
<td>INCOSE</td>
<td>1998</td>
</tr>
<tr>
<td>Rational Unified Process SE</td>
<td>Development of large-scale systems which includes an architectural model</td>
<td>Rational / IBM</td>
<td>2001</td>
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<tr>
<td>State Analysis</td>
<td>Model- &amp; state-focused description of the momentary, evolving condition of the system</td>
<td>JPL</td>
<td>~2010</td>
</tr>
<tr>
<td>Systems Modeling Toolbox (SYSMOD)</td>
<td>“A discovered set of well-known methods and practices&quot; for systems modeling</td>
<td>Weilkiens</td>
<td>2006</td>
</tr>
<tr>
<td>ViTech MBSE</td>
<td>Concurrent requirements &amp; behavior analysis, architecture synthesis, and V&amp;V</td>
<td>ViTech</td>
<td>~2010</td>
</tr>
</tbody>
</table>

Select methods listed in alphabetical order.
Insights of Models

Engineering has always used models
... a useful “representations of something”

MBSE System Model contains

Descriptive Elements | Analytical Elements

Descriptive: SysML Elements / relationships, source docs
Analytical: Quantitative or Qualitative use of Descriptive
System Model

- Technical baseline(s)
- Requirements and relationships
- Behavior definitions
- Internal and external interfaces
- Form/Structure
- Actual Cost/Estimated Cost
- Design viewpoints, rationale, assumptions
- Relevant system interactions
- Parametric descriptions
- Analysis definitions, results
- Plans (To-be depictions)
- Explicit Relationships – trace, derive, satisfy, allocate, refine, depends
- Test equipment, behaviors/use cases
- Simulation
- Source Documents
- Reference Architecture
- Component Libraries
- Style Guide

System model should represent an integrated, authoritative set of technical data that is useful for lifecycle management

Tech Review SysML support

**Preliminary Design Review (PDR)**
- Assessment of the maturity of the design
- Requirements – system, subsystem, component, configuration items,…
- Allocated baseline
- Work Breakdown structure (WBS)
- Key Performance Parameters (KPPs), Key System Attributes (KSAs), Technical Performance Measurements (TPMs) and other metrics
- TEMP (plan)

**System Requirements Review (SRR)**
- System requirements, system performance specification
- KPP, KSA, TPMs, and other metrics
- Conceptual designs
- Initial Capacities Document (ICD) – capabilities and capability traceability
- Risk Assessment
- TEMP (plan)

**Descriptive Elements**
- Structure
- Behavior
- Requirements
- Relations

**Analytical Elements**
- Plans
- Assessment
- Evaluation
- Strategy
- Schedule
Tech Review SysML support

**System Functional Review (SFR)**
- Functional baseline satisfies the end-user requirements and capability needs
- Functional baseline satisfies performance requirements
- Performance requirements traced to (draft) CDD requirements
- Functional Configuration Audits (FCA)

**System Verification Review/ Func Conf Audit (SVR/FCA)**
- Actual system performance meets the requirements
- Baseline requirements meet the needs / warfighter capabilities
- Configuration items (CIs) verification

**Production Readiness Review (PRR)**
- Determination if the design is ready for production
- Assessment of contractor production planning vs cost, schedule, performance
- Evaluation of LRIP and Full-Rate Production (FRP) readiness
- Physical Configuration Audit (PCA) plan
- Integrated Master Schedule (IMS)/ Integrated Master Plan (IMP)

**Descriptive Elements**
- Structure
- Behavior
- Requirements
- Relationships

**Analytical Elements**
- Plans
- Assessment
- Evaluation
- Strategy
- Schedule
- Determinations
1. Reliability, quality, and manufacturing program plans
2. Contractor policies and procedures
3. Durability and damage tolerance control plans
4. Work instructions
5. Process specifications
6. Production/assembly progress reports
7. Quality records
8. Defect/failure data
9. Failure modes, effects, and criticality analysis (FMECA) documentation
10. Tech data package
11. As-built list to include part numbers/serial numbers for all critical safety items/components
12. List of deviations/waivers and unincorporated design changes
13. List of approved class I engineering change proposals (ECPs)
14. Proposed DD Form 250, Material Inspection and Receiving Report
15. Configuration management plans/process description documents
16. Diminishing Manufacturing Sources Plan
17. Obsolete Parts Plan
18. Test reports
19. Test plans
20. FAA Airworthiness Directives / Advisory Circulars
21. Manufacturer-issued service bulletins
22. Civil aviation authority certification plan
23. Civil aviation authority certification basis
24. Civil aviation authority certification report

Document/ Data Management, Assessment, Design/ Process Evaluation
Example Program Office Expectations

1. Standardize program documentation
2. Centralized tech data repository (SysML model)
   - Examine engineering data rapidly
3. Improves cyber risk management
4. Promote training system HW & SW commonality
   - Reduce logistics cost
5. Change-Point time savings
6. Common models and language
7. Change management
8. Environmental paper savings

From Kickoff for MBSE short courses, May 2019
System Model Insights/ Opportunities

- **Technical Baseline Insight**
  - Lost configuration control. Lot of as-is/ as-built modeling
  - Insights for Tech Evaluations/ ECPs. But must avoid “over-modeling”
  - Component Libraries (reuse, commonality)

- **Reference Architectures**
  - An authoritative source of information about a specific subject area that guides and constrains instantiations of multiple architectures and solutions”
  - Examples: Autonomy Design #22508, UAS Prototyping #22502

- **Optimal Set-based Design, Requirements Analysis**
  - Optimal Multi-domain Design, HPC massive parallel search/sim, Multiple Objective Decision Analysis, Stochastics
MBSE Vision… Closer Reality

Adapted from Tom Wheeler, MITRE, WPAFB MBSE Workshop, 2016.