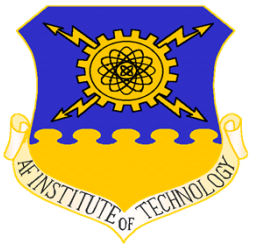
Air Force Institute of Technology



U.S. AIR FORCE

The Growing Importance of Models for Defense Acquisition

NDIA 22nd Systems and Mission Engineering Conference
21-24 Oct 2019

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**

2-hr MBSE Overview

4-hr MBSE Intro

3-4 day Model Developer/ Integrator

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

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

Document-driven

Digital Engineering

Integrated, Authoritative, Shared

System Model

Product Lifecycle Management (PLM)

Model-based SE

Any information missing or not easily represented

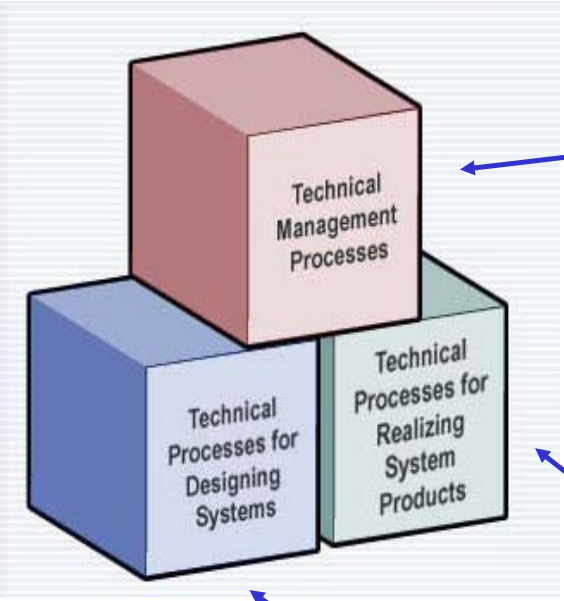
Model-Based Systems Engineering

"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."

INCOSE

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

DoD Systems Engineering



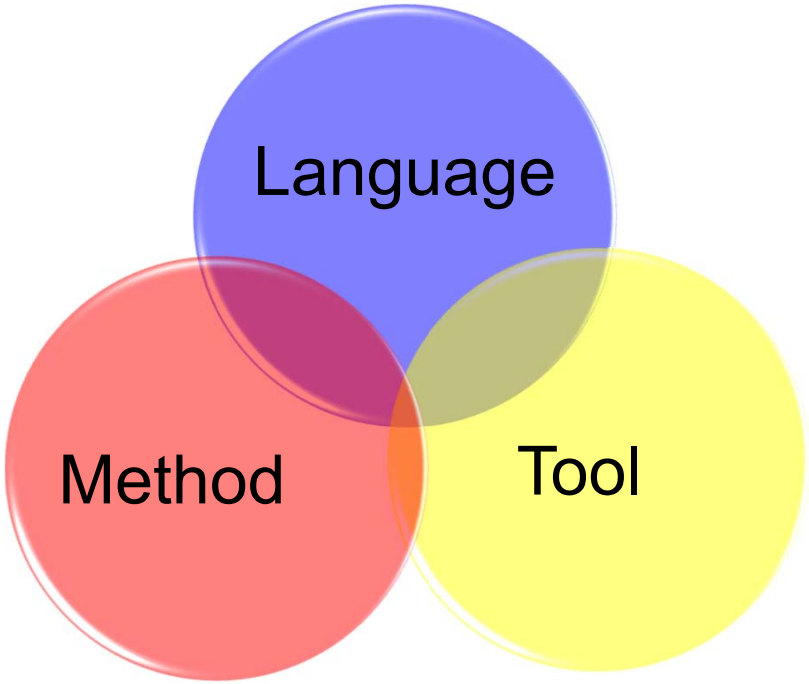
Requirements Management
Interface Management
Risk Management
Configuration Management
Technical Data Management
Technical Planning
Technical Assessment
Decision Analysis

Implementation
Integration
Verification
Validation
Transition

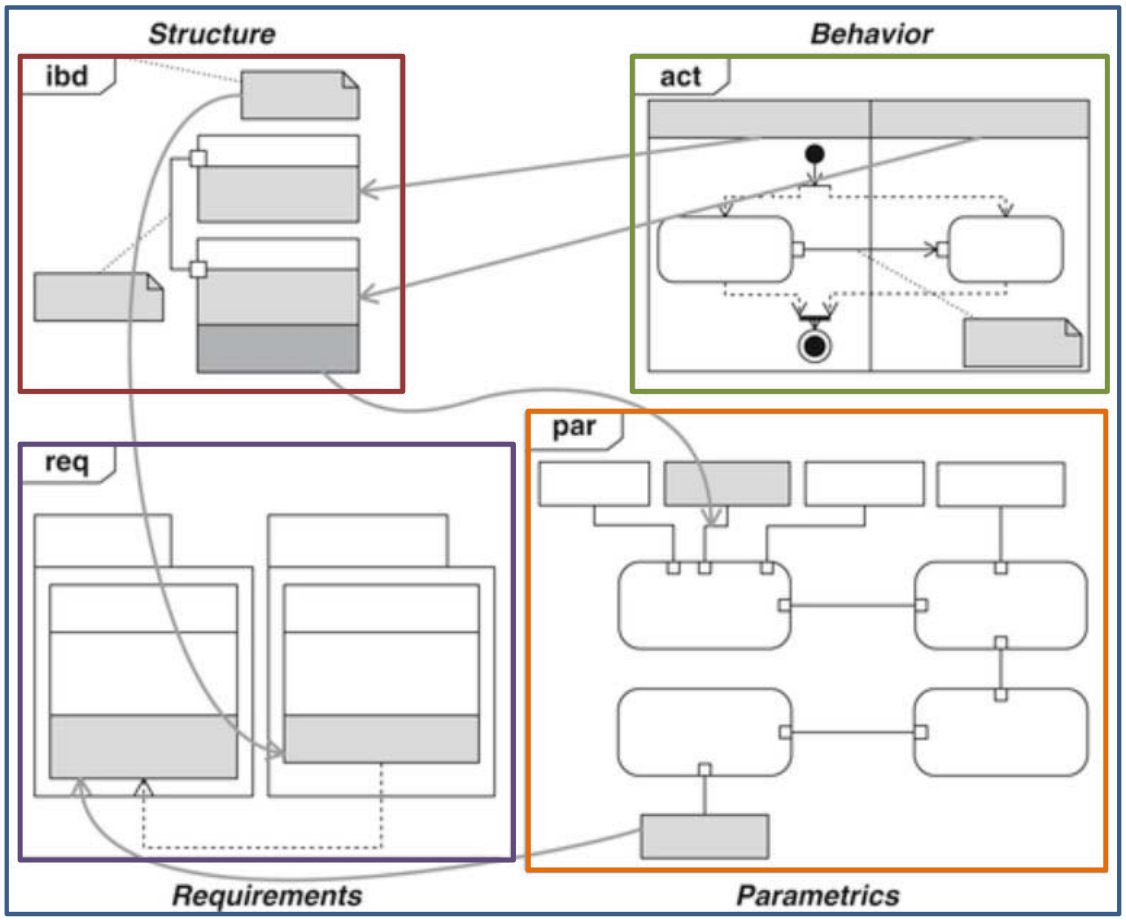
Stakeholder Requirements Definition
Requirements Analysis
Architecture Design

Three pillars of MBSE

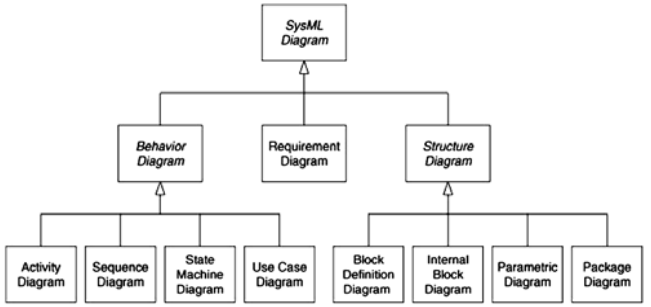
Implementing MBSE effectively requires…



4 Types of SysML Elements



Language



S. Friedenthal, A. Moore, and R. Steiner, A Practical Guide to SysML, 4th ed, Morgan Kauffman, 2012, Chap 2.

MBSE Methods

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

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

Extended from: DoD Digital Engineering Working Group, Systems Engineering Digital Engineering Fundamentals v1.0, March 2016

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

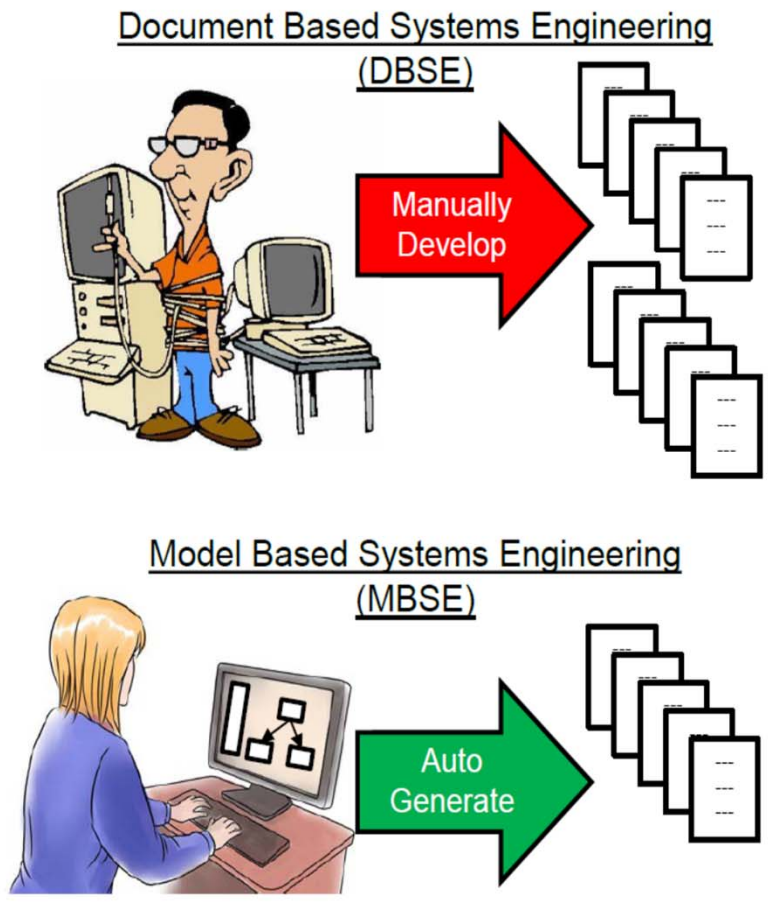
Tech Analysis - Air Worthiness Certification

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
25. System Safety Analysis 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



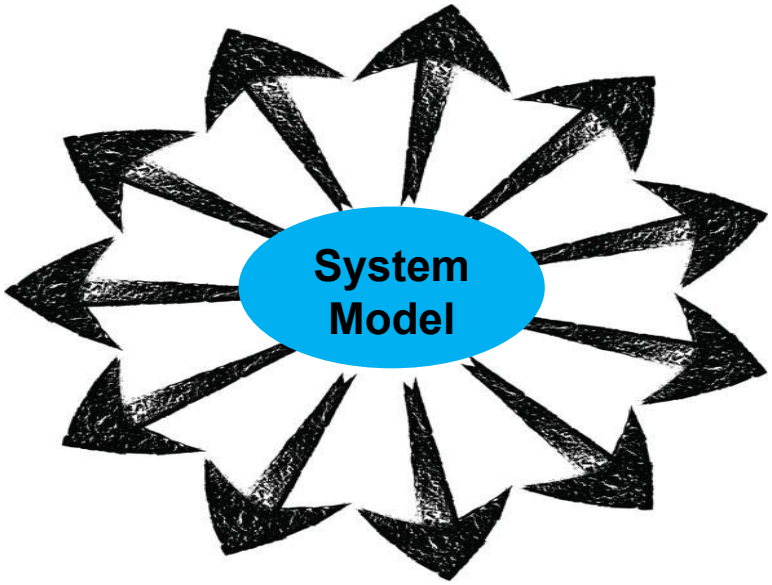
System Model Insights/ Opportunities

- **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



Operational Analysis

Cost and Effort Estimation

Requirements Management

Physics based Simulation & Algorithms

Contracts Section L/M

Performance & Value Analysis

Executable Business Process Improvement

Optimization Set-based design

Process Automation AI/ ML

Tech Reviews OSA/ MOSA

CDRLs/DIDs Generation (as needed)

Product Lifecycle Management

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