Model-Based Systems Engineering De-Mystified

Presented to
INCOSE New England Chapter Meeting
May 21st, 2019

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State of Systems Engineering

1950s Era TV

2019 Smart TV

Photo Credit: http://www.afternoonspecial.com

- Advances in technology have led to larger, more complex systems, which implies:
  - A need for a clear concise way to express the system design (clear, logically consistent semantics).
  - A need for larger, distributed teams.
  - A need to model emergent behavior.
  - A need for systems engineering tools to enable collaboration across the entire lifecycle.

Complexity has been identified by many as a critical problem facing system engineers.

MBSE Misperceptions

Contrary to popular belief:

- MBSE ≠ SysML
- MBSE ≠ UML
- MBSE ≠ LML

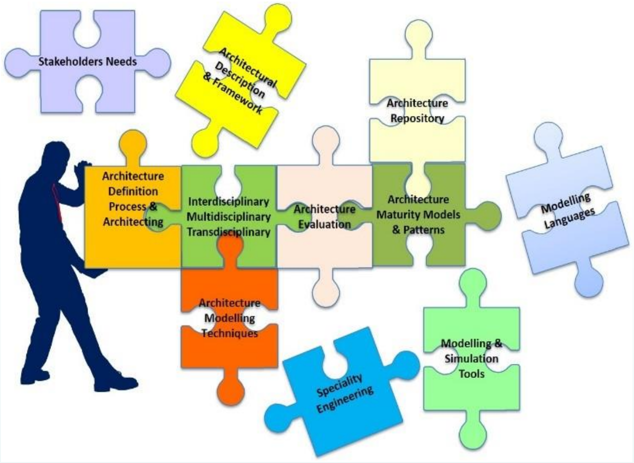
Modeling Languages

- MBSE ≠ DoDAF
- MBSE ≠ UAF

Presentation Framework

- MBSE ≠ MagicDraw
- MBSE ≠ Innoslate

Modeling Tools

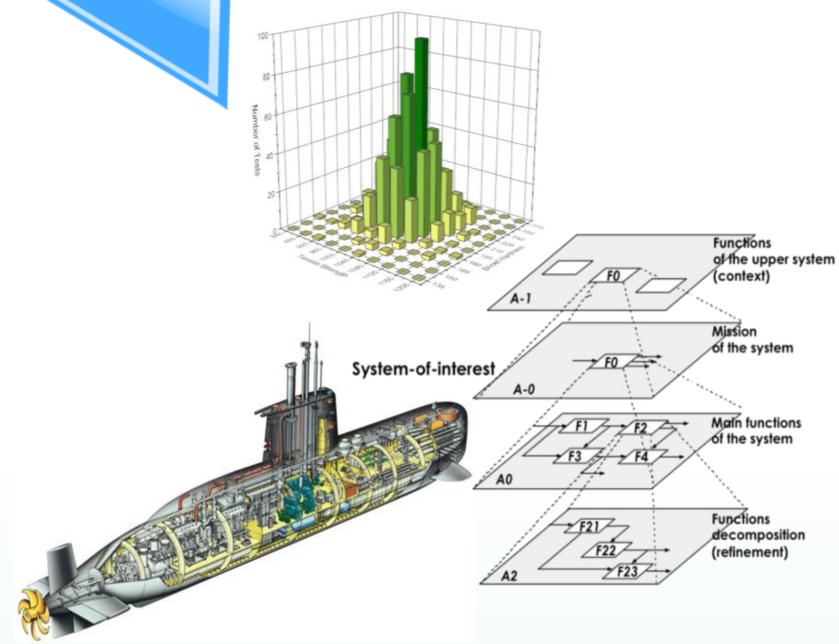


The goal of this presentation is to think about MBSE holistically, and independent of languages, frameworks, and tools.

MBSE: Document-based to Model-based

Traditional Systems Engineering

Model-Based Systems Engineering



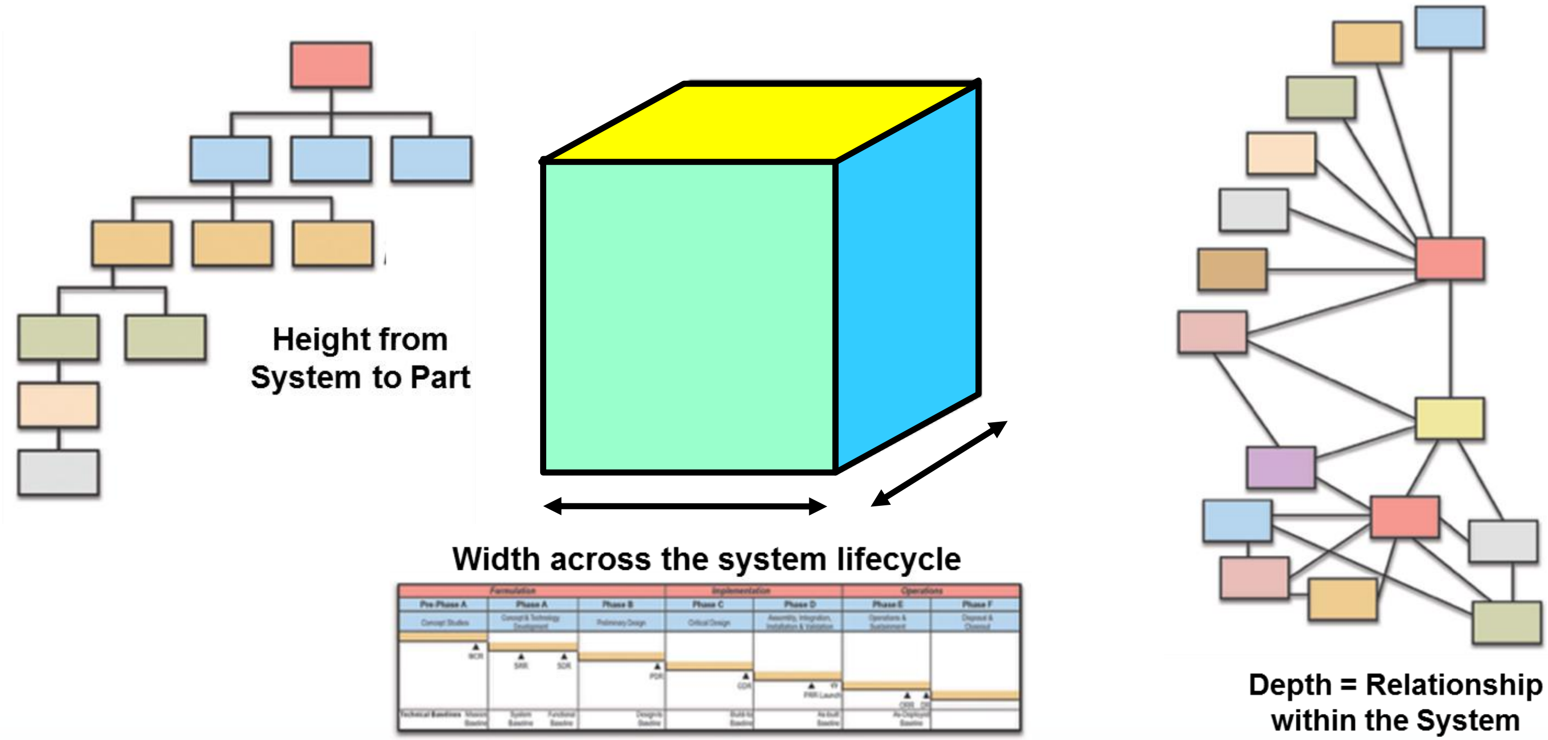
Model-Based Systems Engineering was envisioned to transform systems engineering from a document-based to model-based discipline.

INCOSE Definition of MBSE

INCOSE®

*"**Model-based systems engineering (MBSE)** is the formalized application of modeling to support system requirements, design, analysis, verification and validation, beginning in the conceptual design phase and continuing throughout development and later life cycle phases."* – INCOSE

Dimensions of a Systems Engineering Project



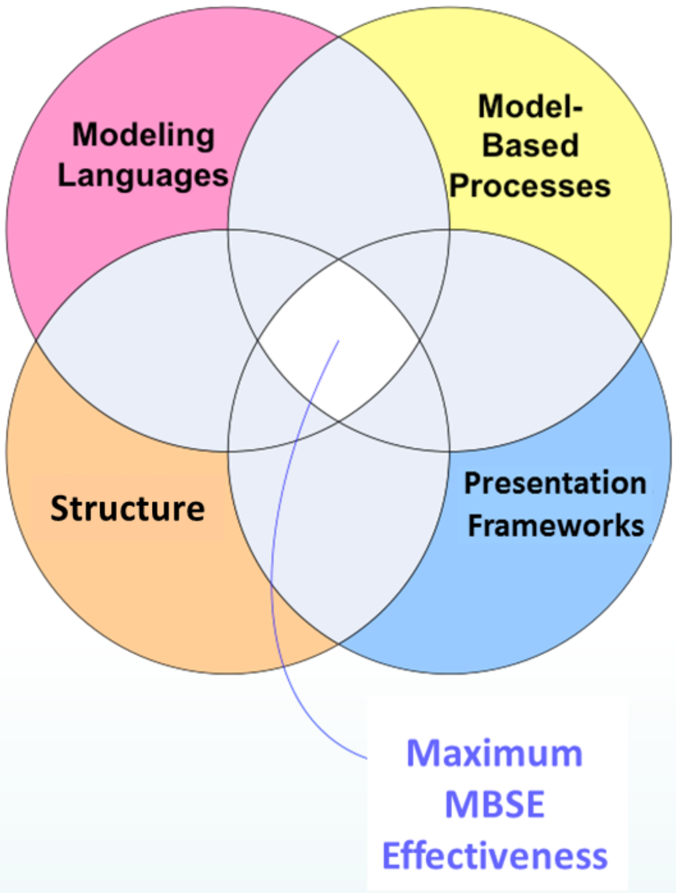
Height – Provides a decomposition from the highest system level down to components and parts

Width – Provides insight across the entire system lifecycle from concept through disposal.

Depth – Provides the complex relationships between systems, functions, requirements, etc

GRAPHIC SOURCE: W. Larson, D. Kirkpatrick, D. Verma, T. Dale, and J.J. Sellers, (2013) "Applied Space Systems Engineering" in Space Systems Engineering, McGraw Hill, Boston, MA.

Model-Based Systems Engineering

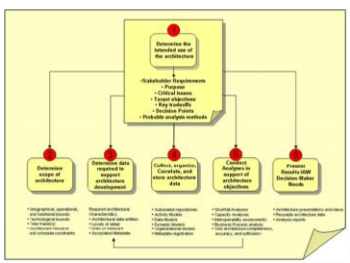


GRAPHIC DERIVED FROM: SySML Fourm, http://www. sysmlforum.com

Model-Based Systems Engineering (MBSE) is the formalized application of modeling (both static and dynamic) to support systems design and analysis, throughout all phases of the system lifecycle, through the collection of modeling languages, structure, model-based processes, and presentation frameworks used to support the discipline of systems engineering in a "model-based" or "model-driven" context.

MBSE Environment

Model-Based Processes



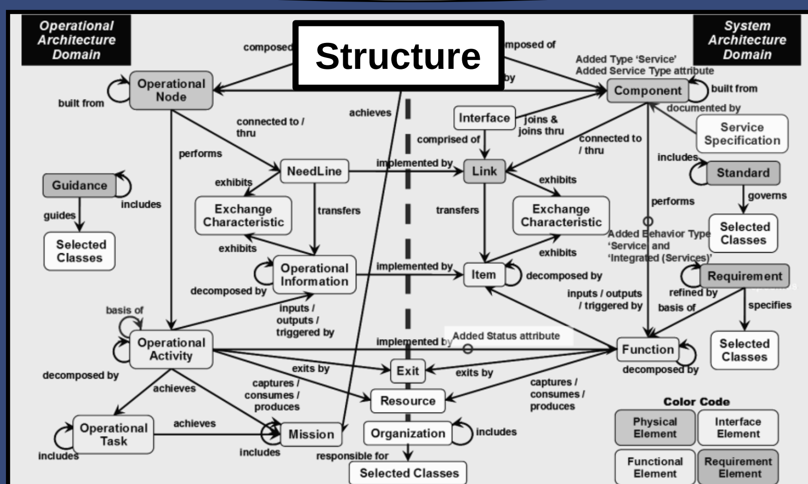
MBSE Tools and Integrated Data Repository

UNIFIED MODELING LANGUAGE

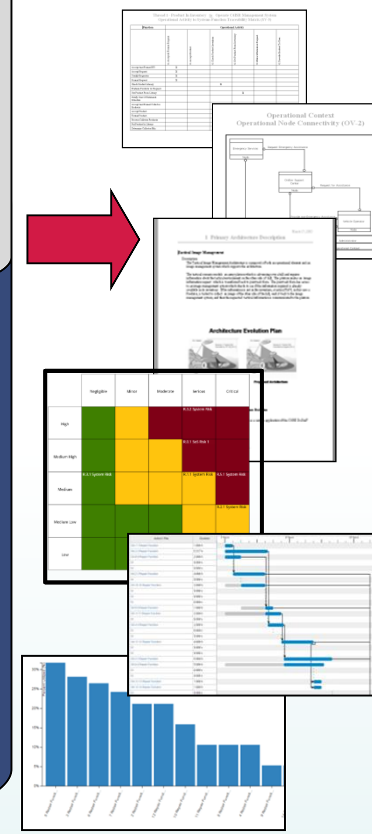
OMG SYSTEMS MODELING LANGUAGE

LIFECYCLE MODELING LANGUAGE (LML)

Modeling Languages

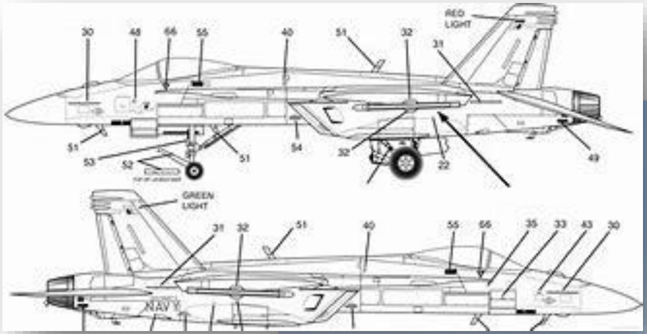


Presentation Framework

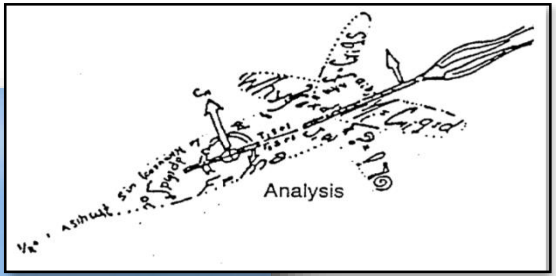


GRAPHICS FROM: Multiple Sources

Principle of Concordance



Systems Perspective



Analyst Perspective

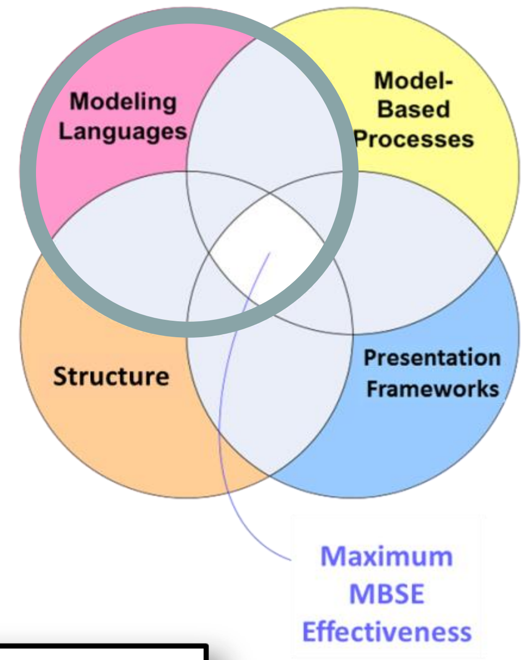
Operational Perspective

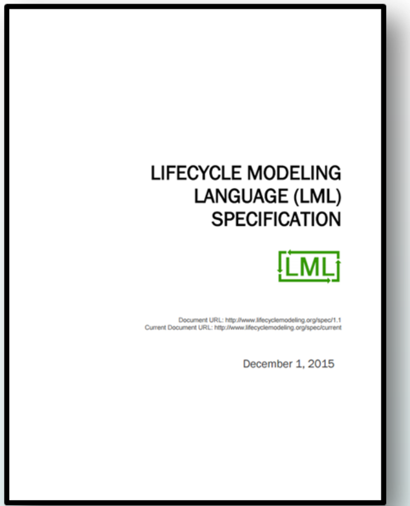
Weapons Systems Perspective

Concordance - the ability to represent a single entity such that data in one view, or level of abstraction, matches the data in another view, or level of abstraction, when talking about the exact same thing.

Modeling Languages

- **Modeling Languages –** Serves as the basis of tools, and enables the development of system models. Modeling languages are based on a visual representation (logical construct) and/or an ontology
  - An ontology (i.e. meta-model) is a collection of standardized, defined terms or concepts and the relationships among the terms and concepts.




LIFECYCLE MODELING LANGUAGE (LML) SPECIFICATION

LML

December 1, 2015

OMG SYSTEMS MODELING LANGUAGE

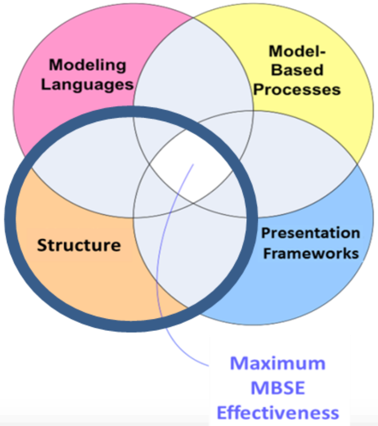
A Common Ontology

- A common ontology and data standards are required across the full spectrum of MBSE applications and tools.
- The ontology must be "simple" so that the system can be reduced to it's "atomic" elements.
- Each entity has one or more corresponding visual representation.
- Include a model structure to define system relationships to ensure concordance.
- A comprehensive ontology satisfies a broad set of data needs.

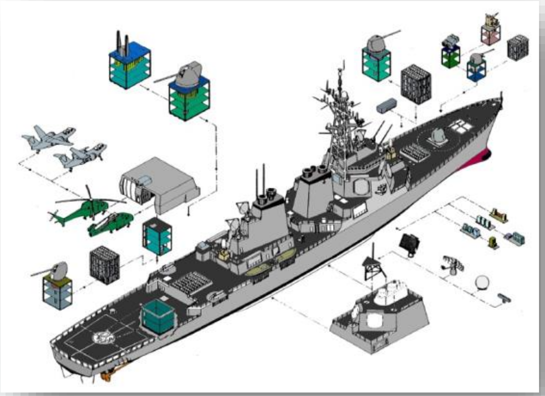
Entity	Visual Representation
Action	Action Diagram
Artifact	Photo, Diagram, etc.
Asset	Asset Diagram
Resource (Asset)	Asset Diagram
Port (Asset)	Asset Diagram
Characteristic	State Machine, Entity-Relationship, and Class Diagrams
Measure (Characteristic)	Hierarchy, Spider, and Radar Charts
Connection	Asset Diagram
Conduit (Connection)	Asset Diagram
Logical (Connection)	Entity-Relationship Diagram
Cost	Pie/Bar/Line Charts
Decision	
Input/Output	State Machine Diagram
Location	Map
Physical (Location)	Geographic Maps
Orbital (Location)	Orbital Charts
Virtual (Location)	Network Maps
Risk	Risk Matrix
Statement	Hierarchy and Spider Charts
Requirement (Statement)	Hierarchy and Spider Charts
Time	Gantt Chart, Timeline Diagram
Equation	*Equation*

Structure

- Structure defines the relationships between the system entities, establishes concordance within the model, and allows for the emergence of system behaviors and performance characterizations.



Systems consists not only of "building blocks."

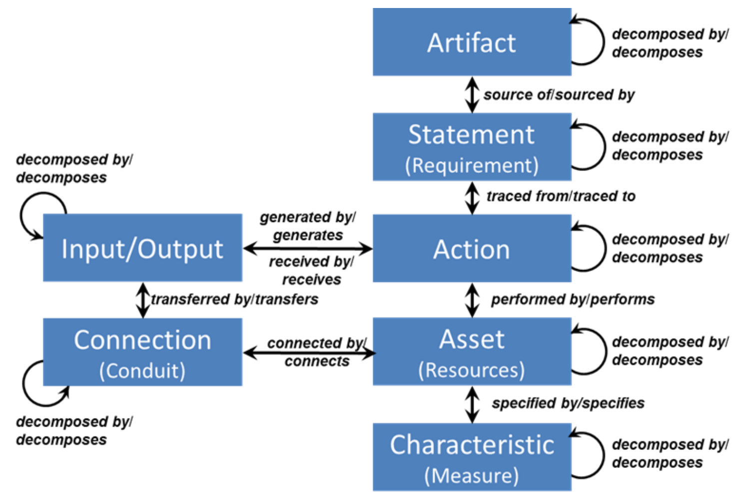


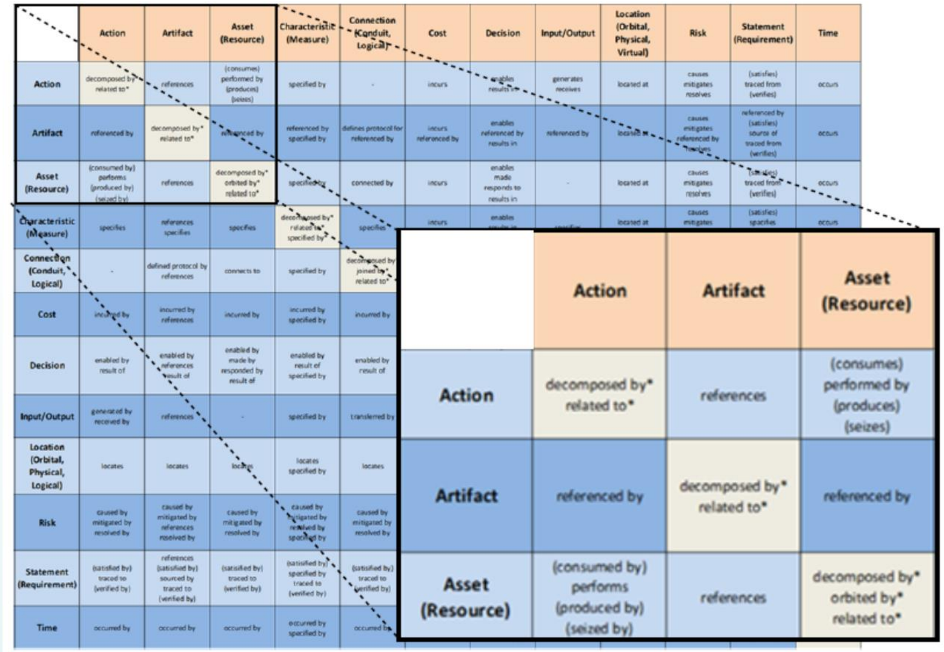
Systems consists of "building blocks" and the relationships between them that form a complete and functional system.

The relationships between the principal entities define structure, address complexity, and ensure system traceability across the model.

Structure Defines Relationships Among Entities

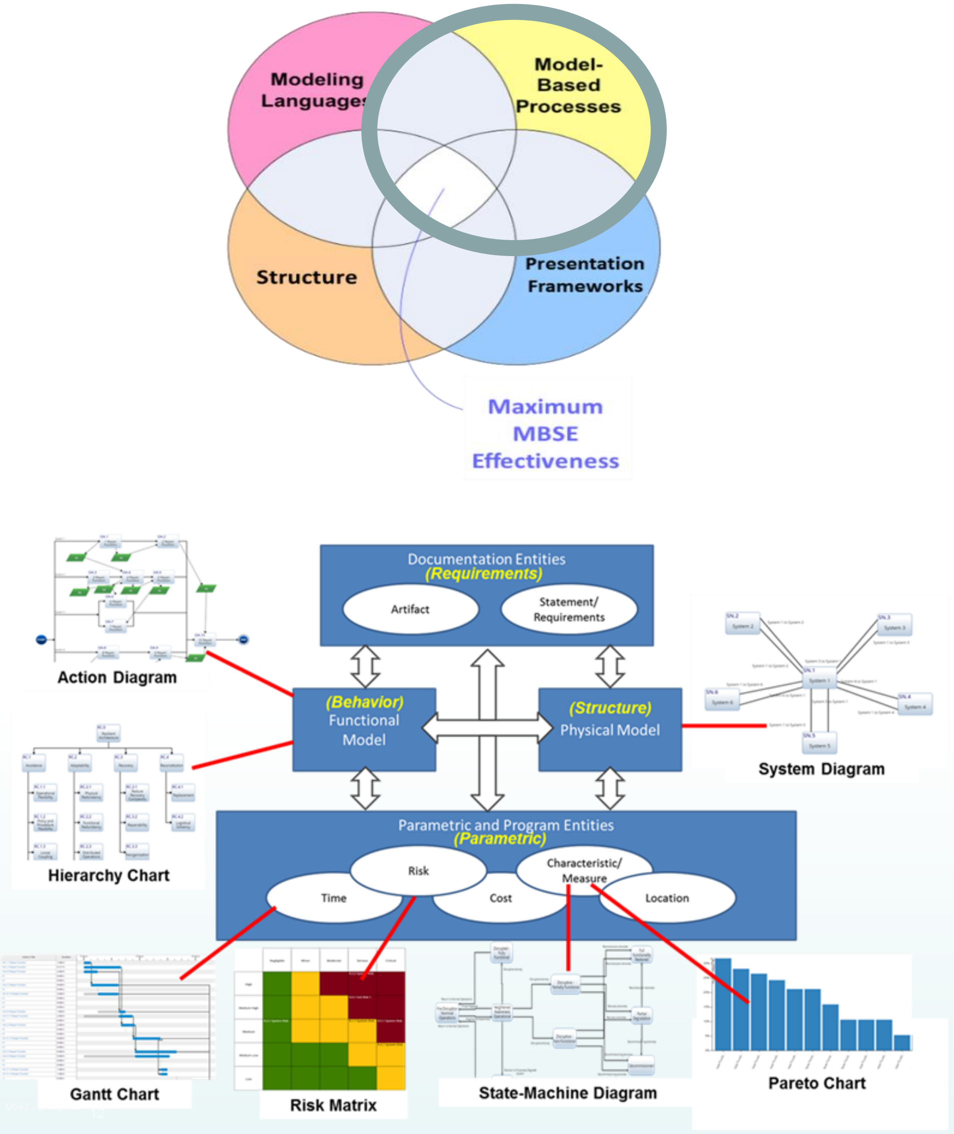
- Structure describes:
  - Elements, attributes, and relationships that can be made within the model.
  - How the elements are connected and interact with each other to achieve the system's purpose.
  - How the system is in relation to other systems that impact its behavior.
- Structure supports discovery and understandability of architecture datasets.
- Establishes concordance within the model.





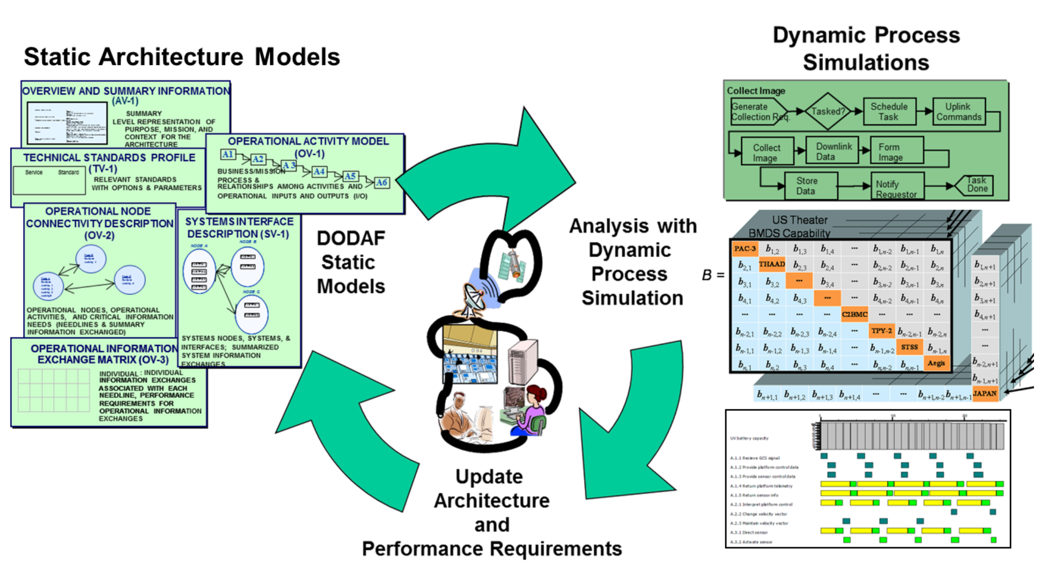
Modeling Processes

- Provides the analytical framework to conduct the analysis of the system virtually defined in the model. The model-based processes may be traditional systems engineering processes such as requirements management, risk management, or analytical methods such as discrete event simulation, and systems dynamics modeling.



Modeling Processes

- MBSE requires an increased emphasis on the model, specifically the objects and relationships it contains, rather than the "artifact" to encourage better model development, usage, and decision-making.

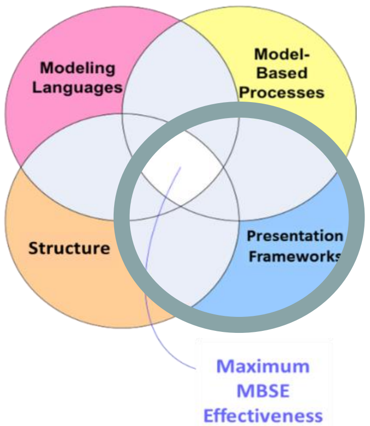


- MBSE processes include systems architecture, operations research, program management, and classical systems engineering methods and techniques.
- There is a strong need to ensure that the systems engineering and stakeholders understand the different model types and what information can be gleaned from them.

MBSE requires changes to engineering mindsets and processes, and to the expectations of the artifacts required during the systems engineering process.

Presentation Frameworks

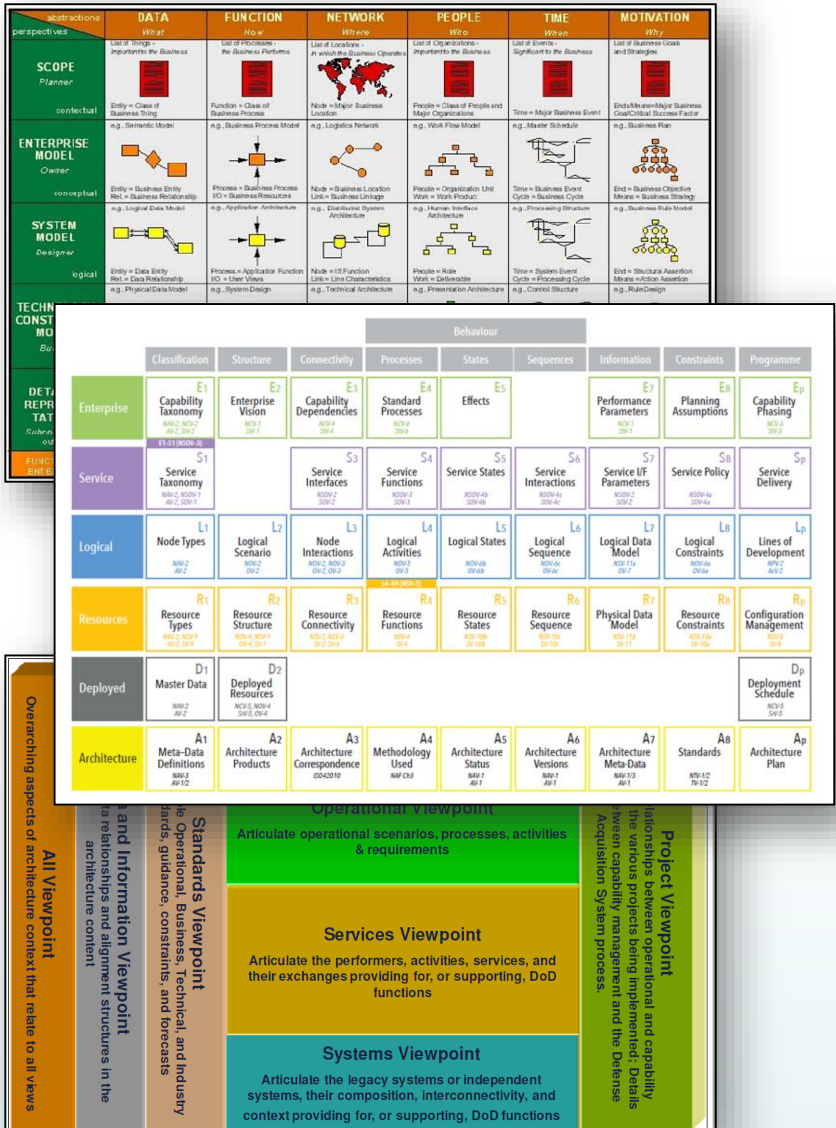
- **Presentation Frameworks** - Provides the framework for the logical constructs of the system data in visualization model that are appropriate for the given stakeholders. These visualization models take the form of traditional systems engineering models. These individual models are often grouped into frameworks that provide the standard views and descriptions of the models, and the standard data structure of architecture models.



Systems Engineering	Architecture	Program Management
Cost	(How Much)	Cost
Schedule	When	Schedule
Performance		
Form	Who	Organization
	What	Resource
	Where	Location
	Why	Goal, Objective & Decision
Function	How	Task
Metric (Fit)		Metric
Interface		
Risk		Risk
		Artifact

Presentation Frameworks

Source: *http://www.zifa.com/*

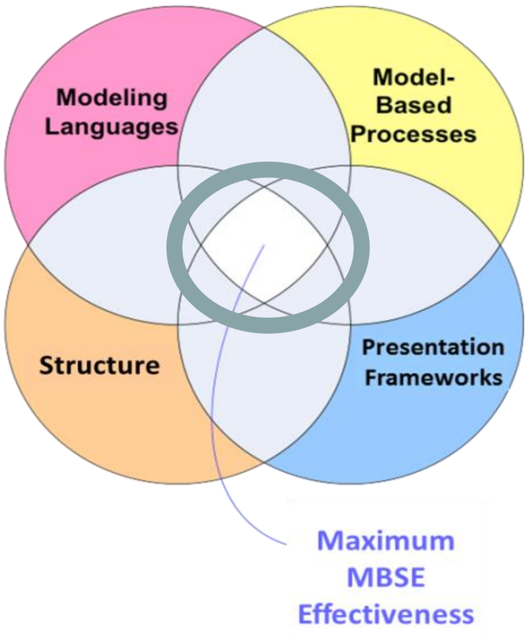


Source: DoD Architecture Framework Version 2.0 (2010).

- Systems engineers, enterprise architects and program managers have overlapping needs for information.
  - Popular modeling languages typically address only one aspect of the information needs.
- The framework provides the definitions, references, guidance and rules for structuring, classifying, and organizing architectures.
- Complexity in a model-based environment is significantly reduced by separating and characterizing systems issues into various data-driven viewpoints and views.
- Presentation frameworks should be extended to include data that is relevant across the system lifecycle.
  - (e.g. architectural data, requirements, risk, V&V data, programmatic data)

MBSE Tools

- **Model-Based Systems Engineering Tools** are general purpose software products that use modeling languages, and support the specification, design, analysis, validation and verification of [complex] system representations.



Innoslate®

Vitech
Insight through integration

IBM
Rational software

magicdraw
Architecture Made Simple

Capella

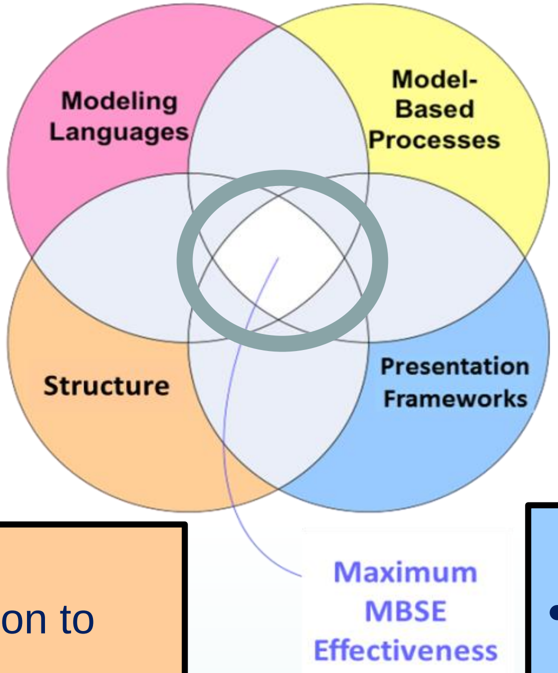
MBSE Tool Selection Considerations

Modeling Languages

- What is the technical knowledge of systems engineering and MBSE among the staff?
- What impact will the modeling language have on productivity?
- Does the organization have a preferred modeling language?

Model-Based Processes

- What are the engineering and analysis objectives for the model?
- Will the model-based processes be used represent the entire lifecycle, or just portions of it?
- What processes are needed for verification and validation of the model?



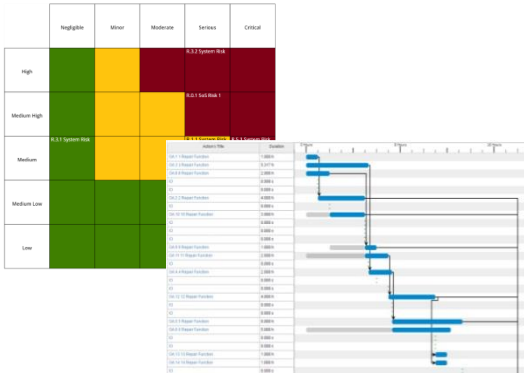
Structure

- How willing is the organization to migrate to a true MBSE environment where a virtual representation of the system replaces the traditional, document-based view of the system?
- Does a meta-model of existing data related to system entities exist?

Presentation Frameworks

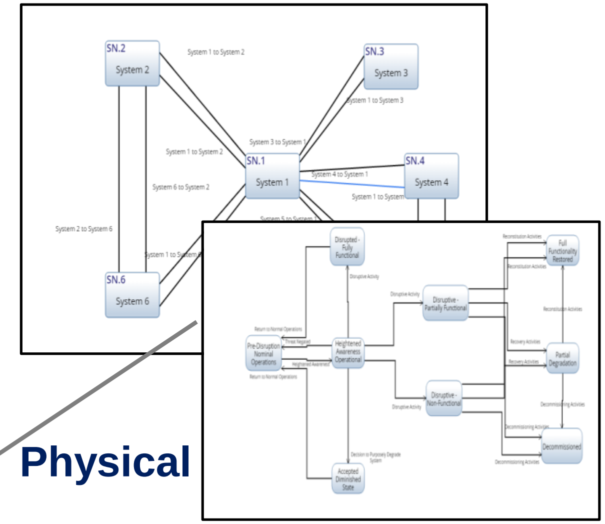
- What system perspectives (i.e. viewpoints) do the system stakeholders represent?
- What additional viewpoints, and views, are required to provide the stakeholders with the requisite information to make decisions?

MBSE… More than Systems Architecting



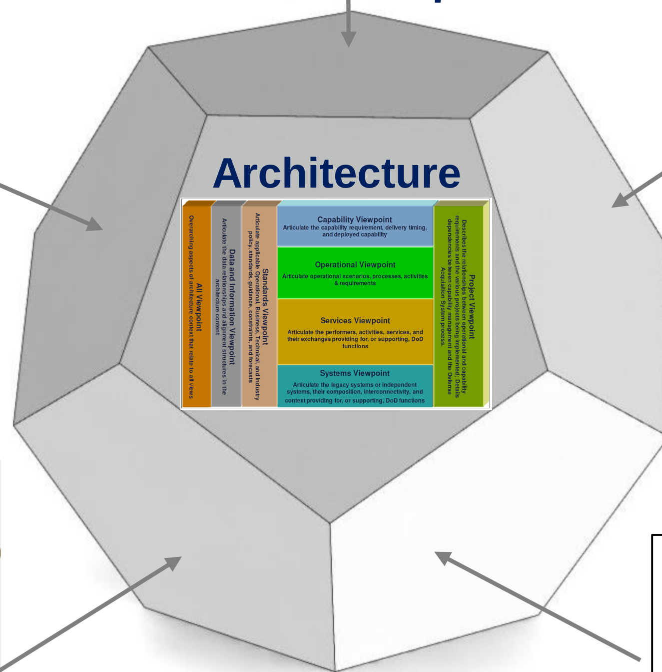
Programmatic

Requirements

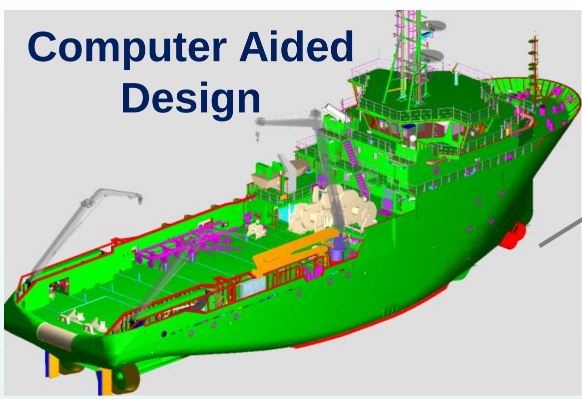


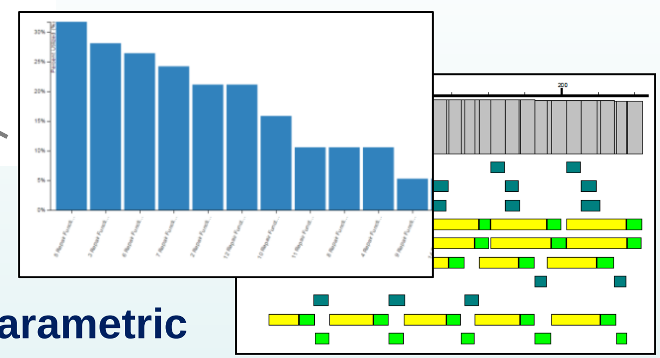
Physical

Architecture



Computer Aided Design

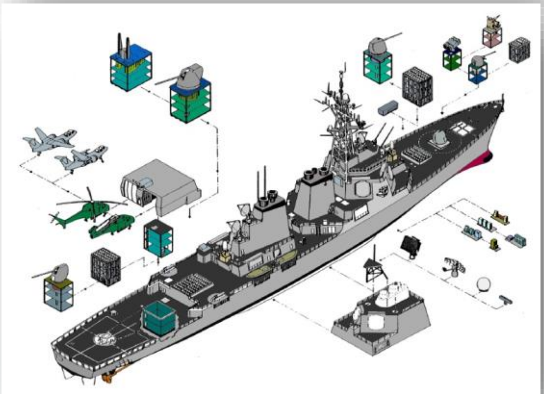




Parametric

MBSE Summary

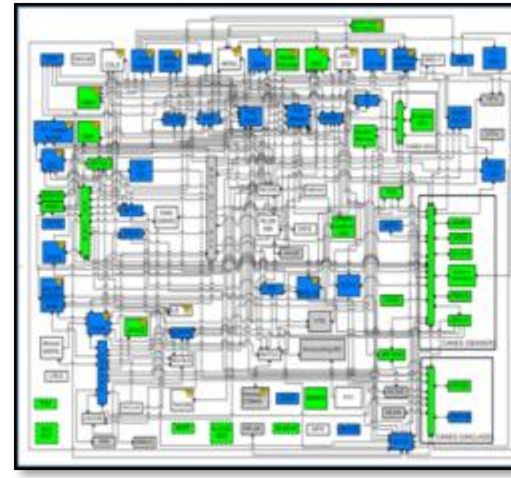
- A MBSE approach focuses on data at the entity level.
- Each entity has defined relationships, allowing it to represent the structural complexities within the system.
- Each entity has one or more corresponding visual representations that allow for comprehension and decision-making.
- The relationships between the principal entities define structure, address complexity, and ensure system traceability across the model.



Benefits of MBSE

Ensure focus on the vision

Ensure that the stakeholders needs are clearly understood, prioritized and addressed



Manage complexity

Support engineering decisions (cost, schedule and technical)

Manage change

Identify critical details that need special consideration/mitigation

Parting Thoughts

"I must sound a note of caution though with respect to [modeling], both technical and programmatic. They are a useful tool to support decision-making but they should always be continually updated as new information comes to hand and importantly, they should never completely supplant the wisdom of corporate knowledge held by the "grey beards" of an [organization]." - Senator David Fawcett – Parliament of Australia

- For MBSE to be truly successful, model-based processes must replace traditional Systems Engineering processes.
  - Requires a deliberate effort to transform the culture
- Lack of understanding, and definition, of a true MBSE environment will inhibit progress.
- A comprehensive ontology needs to be defined to ensure concordance and traceability through model entities that support all lifecycle activities.

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SYSTEMS ENGINEERING EST. 2002