Modeling Languages: What makes a good language and why?

Ronald E. Giachetti, PhD
Professor and Chair
Department of Systems Engineering
Naval Postgraduate School
regiache@nps.edu

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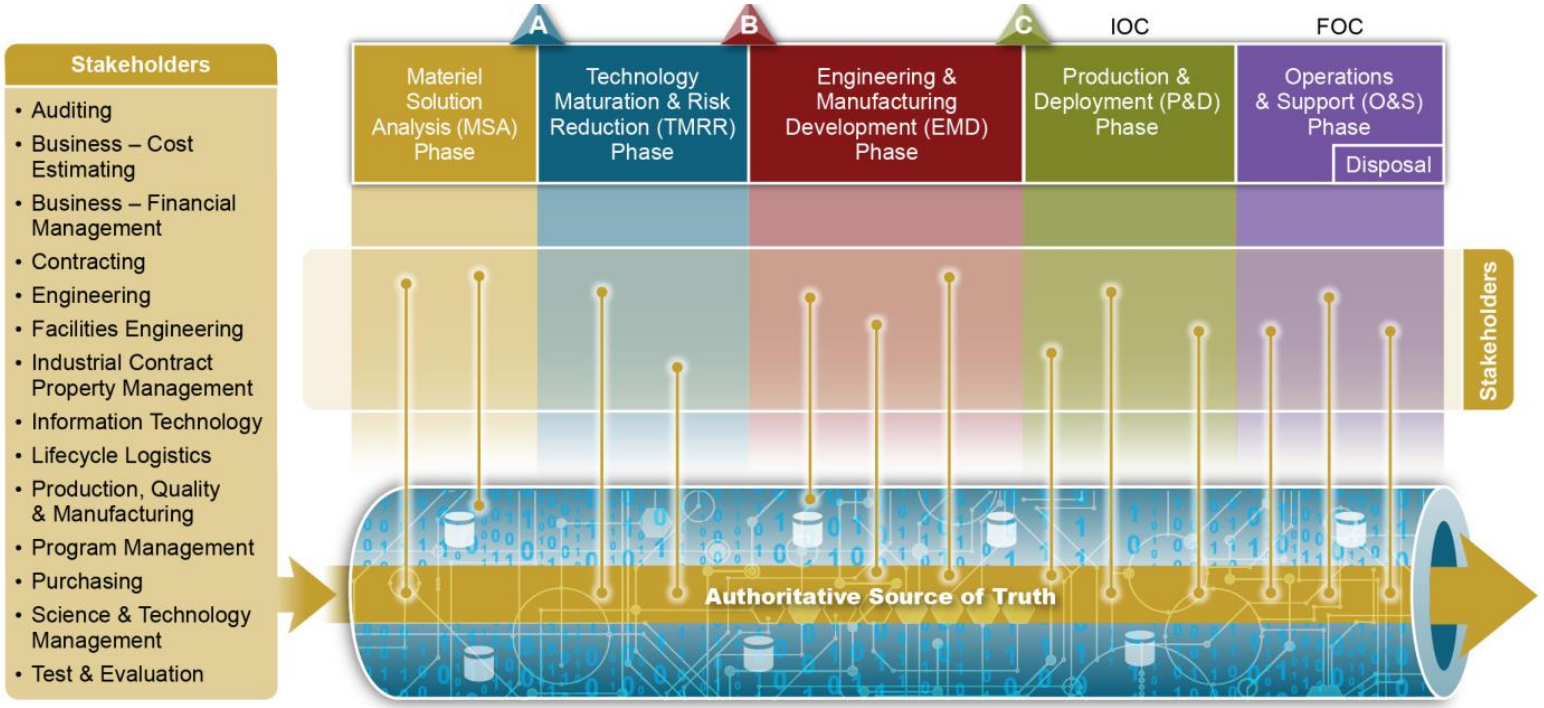
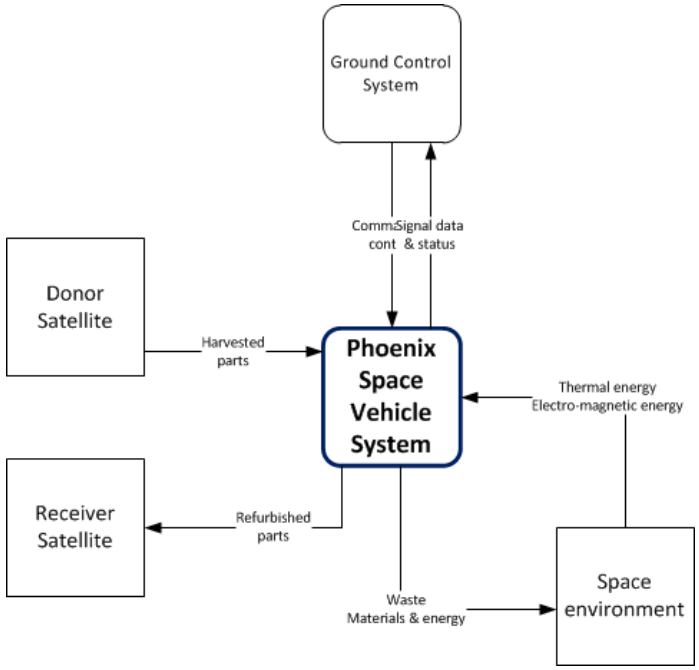
Digital Engineering

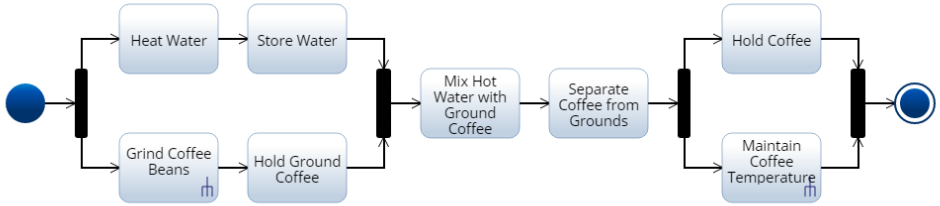
US Department of Defense has a digital engineering strategy to use models for all phases of system development



Many who have never interacted with models, now will

Transforming to MBSE



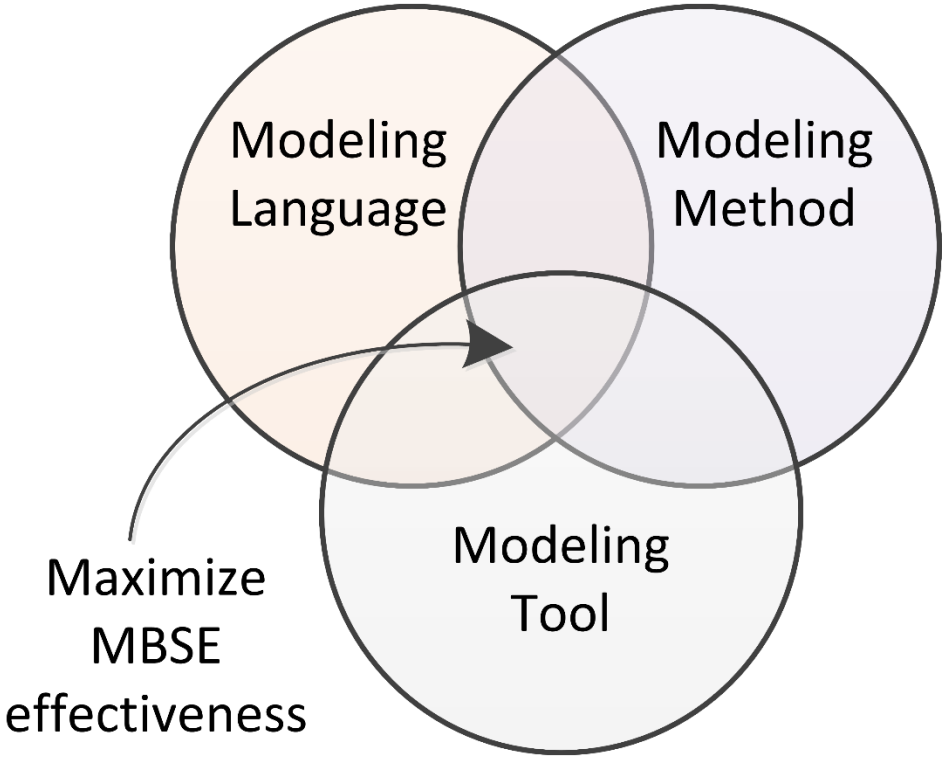


Models

A conceptual model describes relevant concepts of a system of interest (SoI) to facilitate understanding of the problem domain and the SoI

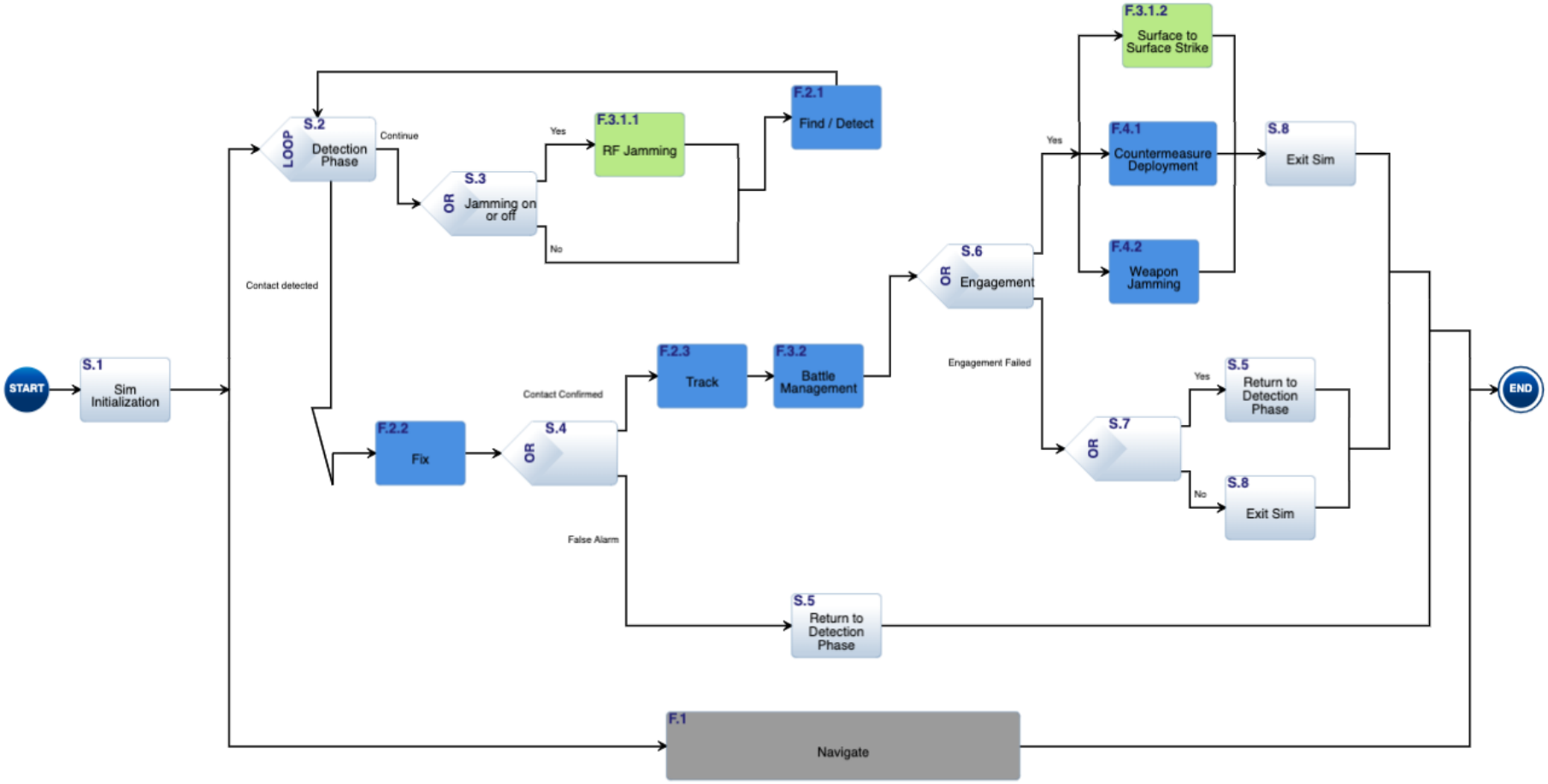
Examples:

- SysML requirements diagram
- DoDAF capability views
- Functional hierarchy
- SysML behavior diagram



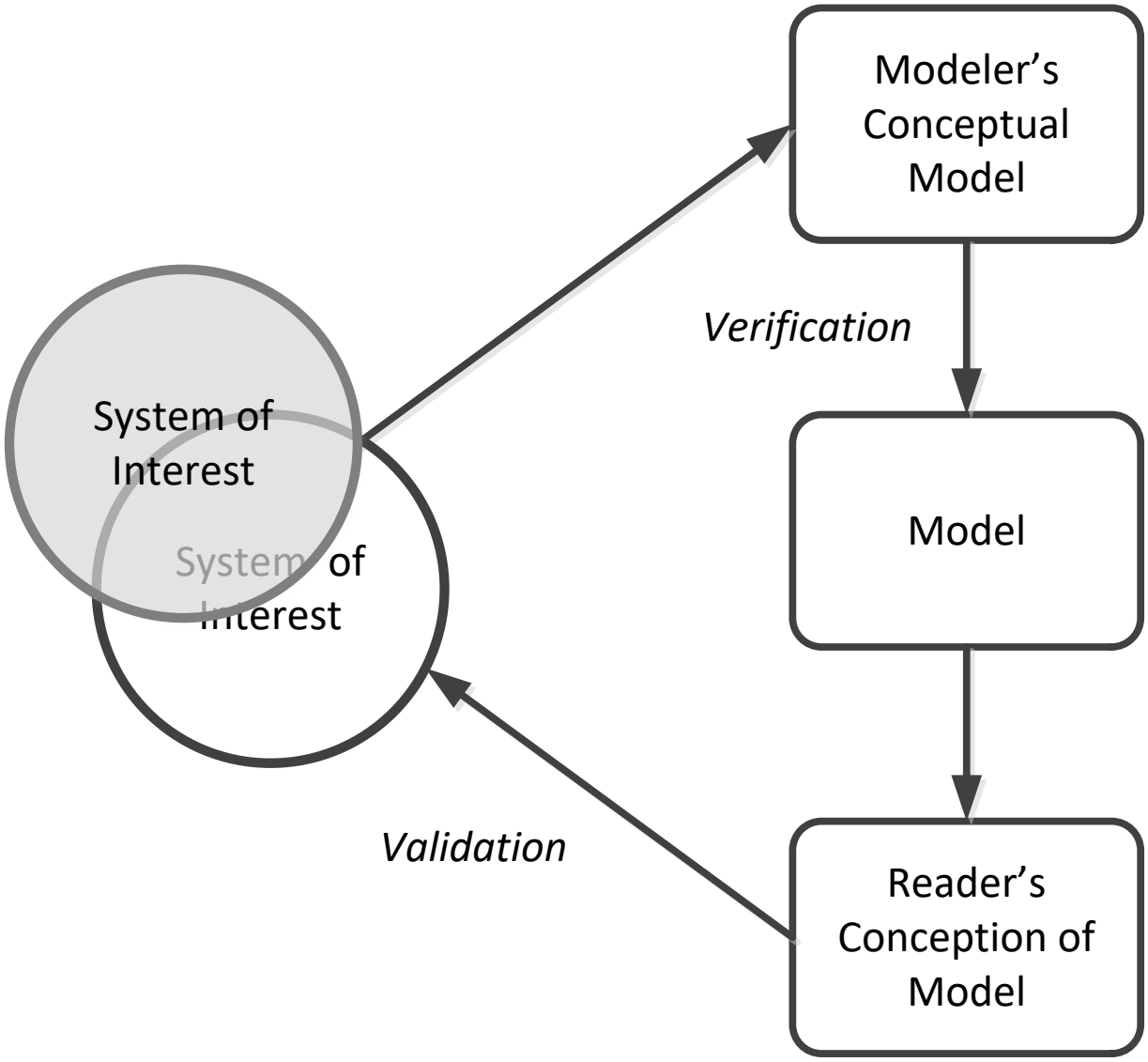
graphic derived from Warren Vanneman lecture on MBSE Demystied, 2018.

Is this a good model?



What is “good”?

Quality of Model Interpretation



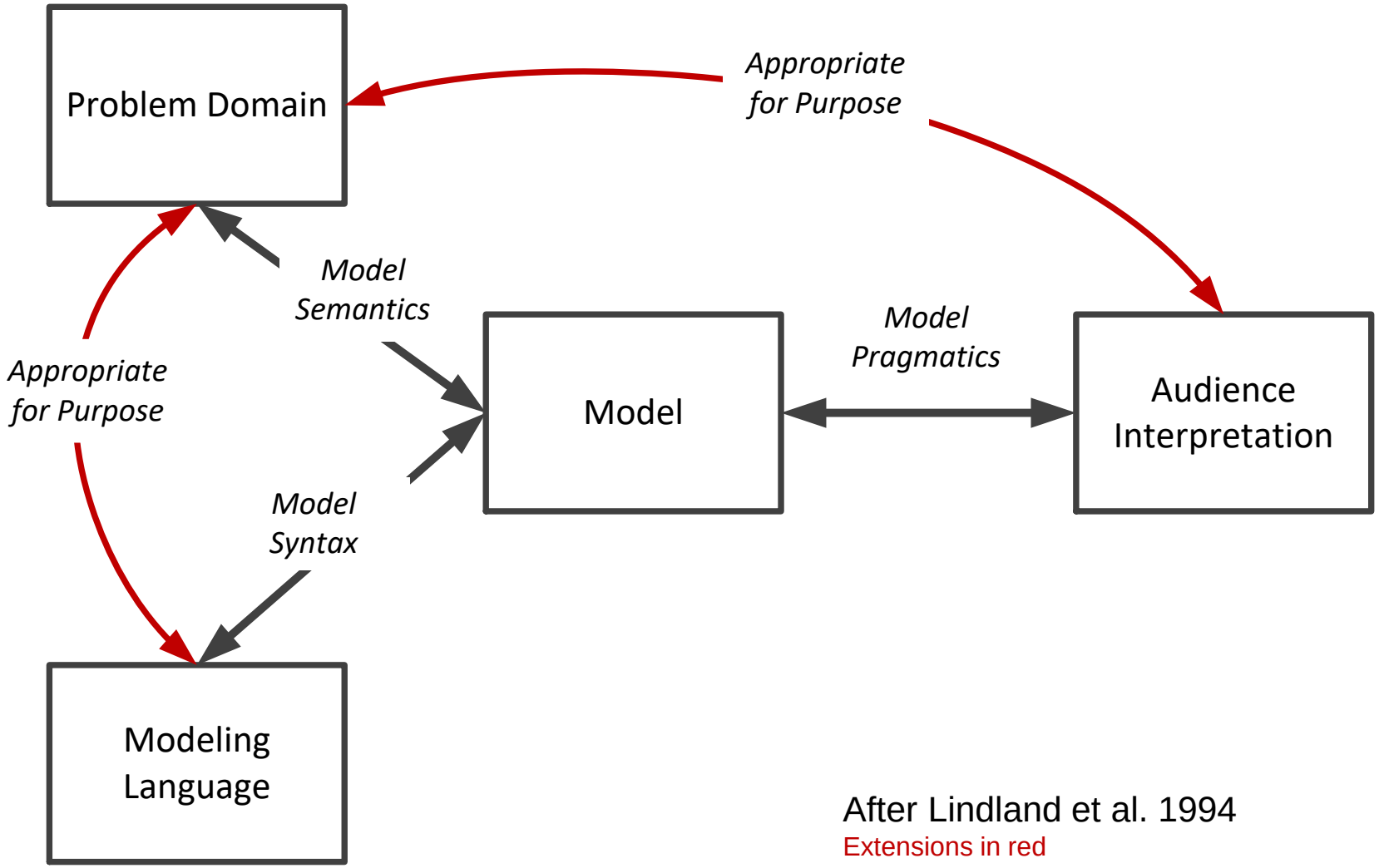
What makes a good modeling language?

Instead of evaluating models, we evaluate the modeling language used to create the models

Evaluation guided by two theories:

- Semiotics: Syntactic, semantic, and pragmatic quality metrics
- Linguistic relativity theory: How language affects thinking

Quality Metrics Model



After Lindland et al. 1994

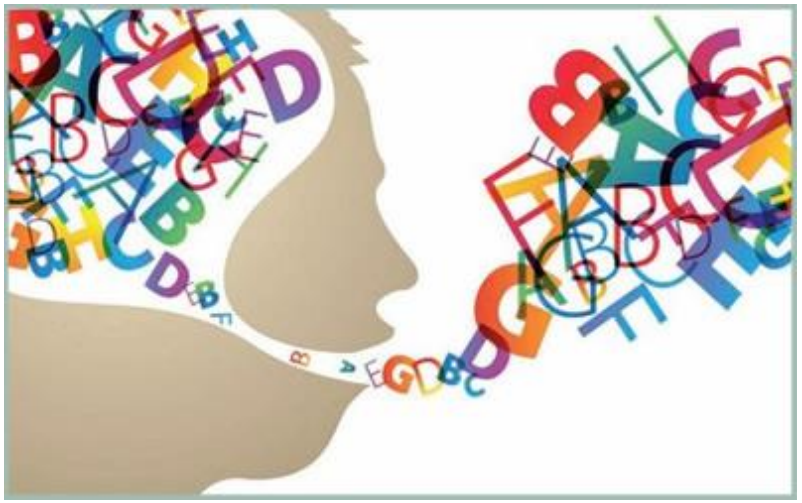
Extensions in red

Linguistic Relativity Theory

Empirical evidence supports a form of linguistic relativity theory claiming our language influences how we think about time, space, and other concepts

Linguisitic Relativity Theory

Linguistic Relativity, associated with Sapir and Whorf, says language limits and influences thought



German – *die Brücke*

Beautiful, elegant, fragile, pretty, slender

Spanish – *el Puente*

Big, dangerous, strong, sturdy, towering

Source: Boroditsky, L., Schmidt, L., Phillips, W. (2003). Sex, Syntax, and Semantics. In Language in mind: Advances in the study of language and cognition, ed. D. Gentner and S. Goldin-Meadow, pp. 61- 80. Cambridge University Press.

Model Relativity Theory

We build models using a modeling language, and it seems reasonable the modeling language would influence how we think about the system

Model Relativity Theory has not been investigated, but similar ideas exist:

Bucciarelli and Ferguson both make a strong case that engineers think nonverbally – effect of graphic models?

Dori (2016) developed the object-process method for modeling systems based on assumption humans must process both images and text.

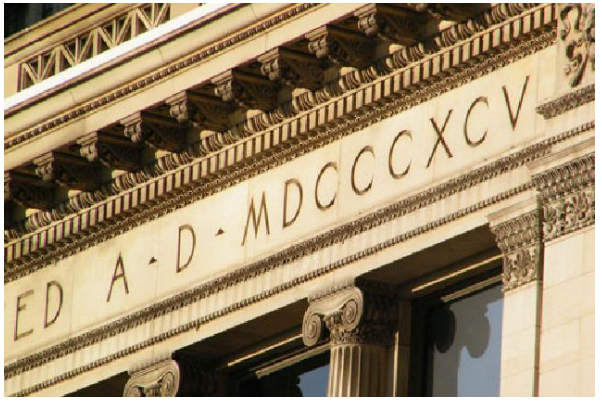
Bucciarelli, L.L. Between thought and object in engineering design, *Design studies* 23.3 (2002): 219-231.

Ferguson, E.S. *Engineering and the Minds Eye*, MIT press, 1994.

Modeling Language and Thought

Do this division:

MMMCMXLVII / CCXLIV



The representation language (model) constrains how you think and reason

Roman numerals were cumbersome to do calculations – Romans did not develop algebra, it was the Arabs with place holders and zero

Research Approach

- Lexical Analysis of Modeling Languages

- Experiments using Human Subjects

Text vice Model Requirements

"The study suggests that systems engineers and stakeholders can comprehend complex system requirements better under an MBSE setting."

1.0 SCOPE

1.1 Scope. This specification prescribes the performance requirements for the Tactical Sling. The Tactical Sling allows the Warfighter's weapon to remain in a ready position while conducting non-weapon firing-related tasks.

1.2 Requirement levels. This specification lists two values for certain performance parameters. The threshold (T) is the minimum acceptable level. The objective (O) is the desired level at which performance of the Tactical Sling results in an operationally significant increase in capabilities. When only one requirement is stated, it is the threshold requirement.

2.0 APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3 of this specification. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3 of this specification, whether or not they are listed.

2.2 Government Document. The following specifications and standards form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitations or contract.

ARMY FIELD MANUAL

FM 3-22 Rifle marksmanship M16A1, M16A2/3, M16A4, and M4 Carbine

(Copies of this Field Manual are available from the General Davis J. Reimer Training and Doctrine Digital Library at www.adtdl.army.mil/cgi-bin/atdl.dll/fm/2-33/fm2-33.htm).

3.0 REQUIREMENT

3.4 Operating Requirements.

3.4.1 High Ready Position upon Release. The Tactical Sling shall keep the weapon in the high ready position (as defined in FM 3-22, Chapter 7) when the weapon is released.

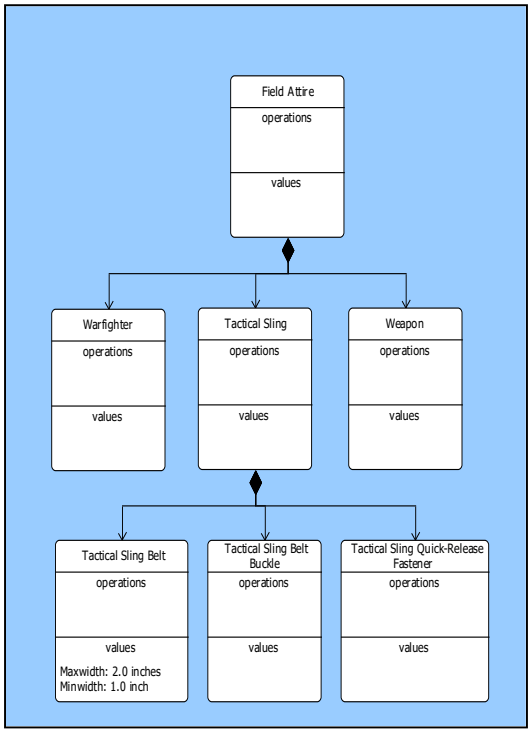
3.4.2 Low Ready Position upon Release. The Tactical Sling shall keep the weapon in the low ready position (as defined in FM 3-22, Chapter 7) when the weapon is released.

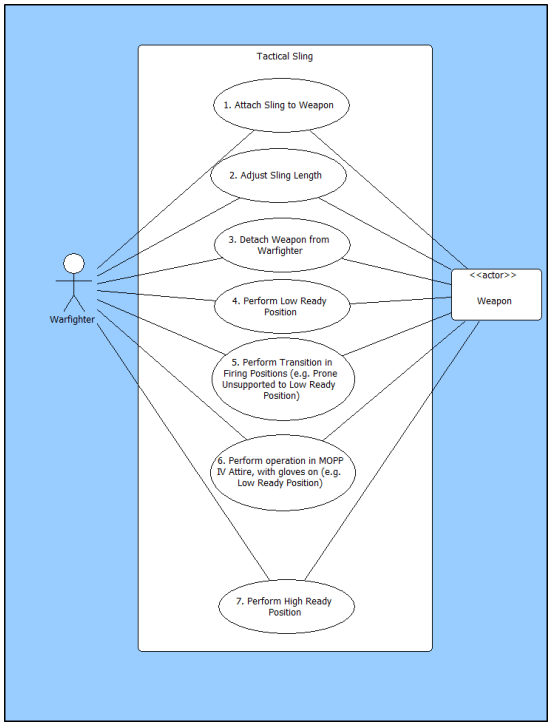
3.4.3 Adjustment Ability. The Tactical Sling shall enable the Warfighter to adjust the sling length and secure it with the belt buckle, and assume all fighting positions stated below (as defined in FM 3-22, chapters 4 and 7).

- Individual Foxhole Supported Firing Position
- Basic Prone Unsupported Firing Position
- Alternative Prone Unsupported Firing Position
- Kneeling Supported Firing Position
- Kneeling Unsupported Firing Position
- Standing Firing Position
- Modified Supported Firing Position

3.4.4 Transitioning between Fighting Positions. The Tactical Sling shall not interfere with the Warfighter's transition actions from one fighting position to another.

2



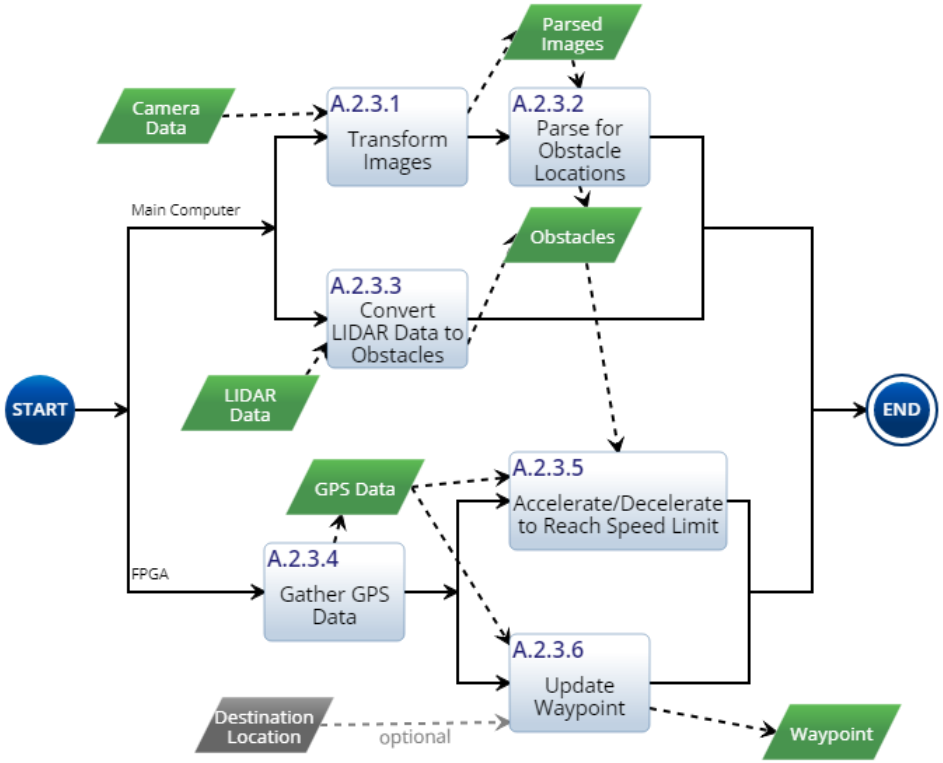


Chia, Yong J. *Comparison Of Requirements Understanding In Model Based Systems Engineering Versus Traditional Methods*. Naval Postgraduate School Monterey United States, 2018.

Further Experiments on Model Relativity

A system function can either transform inputs into outputs or change the state of the system.

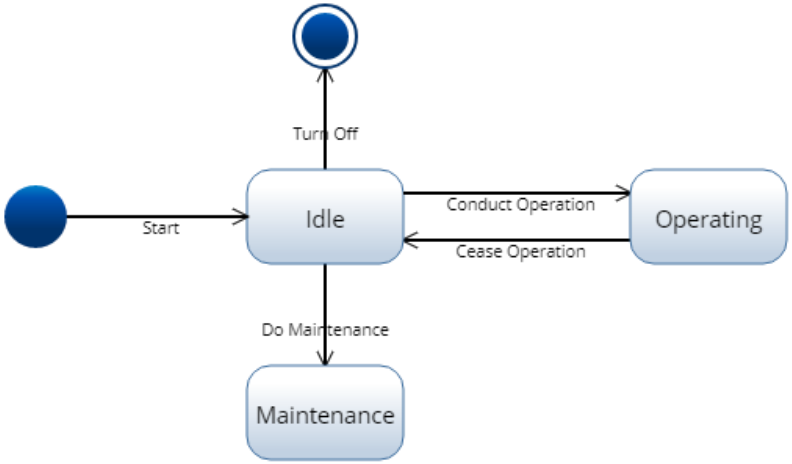
Many modeling languages emphasize the transformation of inputs into outputs and do not support state transitions



Activity Model emphasizing transformation and process flow

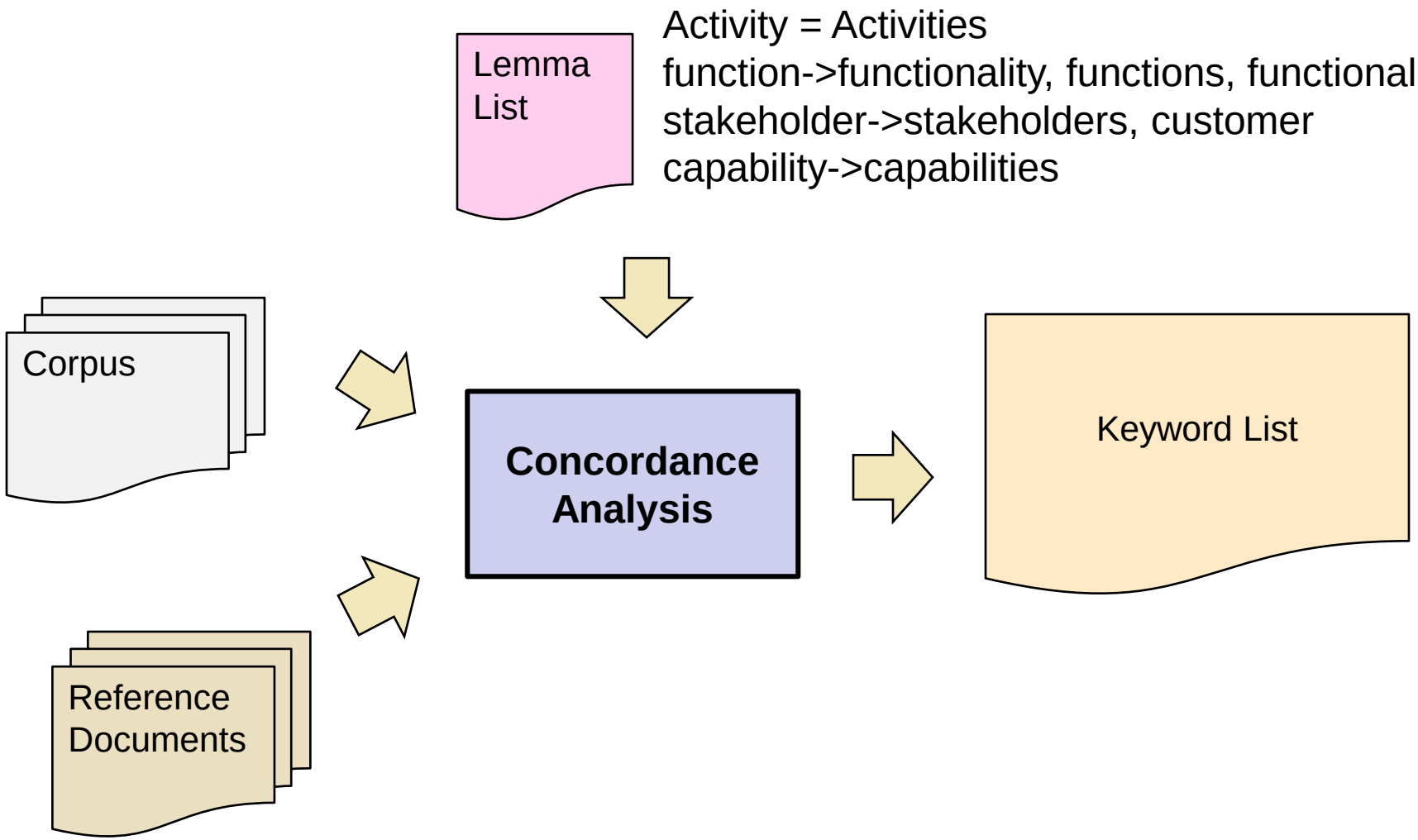
State-Intensive System

What about state-intensive systems? Does a process-oriented view effect how engineers think about the system?



experiments to determine whether the models effect how people think about the system, how it effects their efficiency and understanding

Lexical Analysis Research Method



Correspondence with DM2

Rank	Keyword	DM2 Term	Summary Analysis
1	System	Performer	A subtype of performer. A mismatch in the aggregation level.
2	requirement	-	Not included
7	risk	-	Not included
8	Function	Activity	
11	Stakeholder	-	Not included. The DM2 Data Dictionary has a term Actor that was considered as a candidate term in DM2 but not included. A stakeholder cannot be a Performer because a Performer performs an activity and provides a capability, which stakeholders do not do.
14	Interface	Port	A Port is a sub-type of Performer. Definition of Port does not correspond well to common SE usage of Interface.
29	Capability	Capability	

Research Findings To Date

- A lexical analysis comparing the DoDAF Meta-Model (DM2) to Systems Engineering guides and manuals
  - Findings: Some mis-matches, non-standard vocabulary, unique to DoDAF (e.g., “performer”)
- Investigated quality metrics for modeling languages
- Experiments on model relativity theory

Summary

- MBSE involves many conceptual models that cannot be verified and validated using the same means as for physics-based and/or simulation models
- NPS is pursuing research on the quality of modeling languages using experimental approaches based on linguistic relativity theory and semiotics
- It is important for the Systems Engineering community to consider the quality of the languages we adopt and use because it impacts the effectiveness and efficiency of the systems engineering activities as well as acquisition process

Support for Model Relativity Theory

Ludwig Wittgenstein a philosopher wrote
Tractatus Logico-Philosophicus

"Our ordinary language has no means for describing a particular shade of a color. Thus it is incapable of producing a picture of this color."

"The limits of my language means the limits of my world"

Popular Culture and Linguistic Relativity

THE WALL STREET JOURNAL.

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ADVENTURE & TRAVEL
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FÊTE ACCOMPLI
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For Better Relationships, Know Your Deal Breakers

WORK & FAMILY

The Best Language for Math

Confusing English Number Words Are Linked to Weaker Skills

Turkish students at a school in Istanbul. The Turkish language expresses some math concepts more clearly than English does.

By SUE SHELLENBARGER
Updated Sept. 15, 2014 3:44 p.m. ET

376 COMMENTS

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3. Giachetti, Ronald E. "Evaluation of the DoDAF Meta-model's Support of Systems Engineering." *Procedia Computer Science* 61 (2015): 254-260.
4. Giachetti, Ronald E. "Making the case for quality metrics for conceptual models in systems engineering." *2017 12th System of Systems Engineering Conference (SoSE)*. IEEE, 2017.
5. Chia, Yong J. Comparison Of Requirements Understanding In Model Based Systems Engineering Versus Traditional Methods. Naval Postgraduate School Monterey United States, 2018.