International Council on Systems Engineering
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Standards Gaps for Enabling Model Interoperability for MBSE in a Digital Engineering Context

Ryan Noguchi, The Aerospace Corporation

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Hello.

ryan.a.noguchi@aero.org
ryan.noguchi@incose.net

Ryan Noguchi

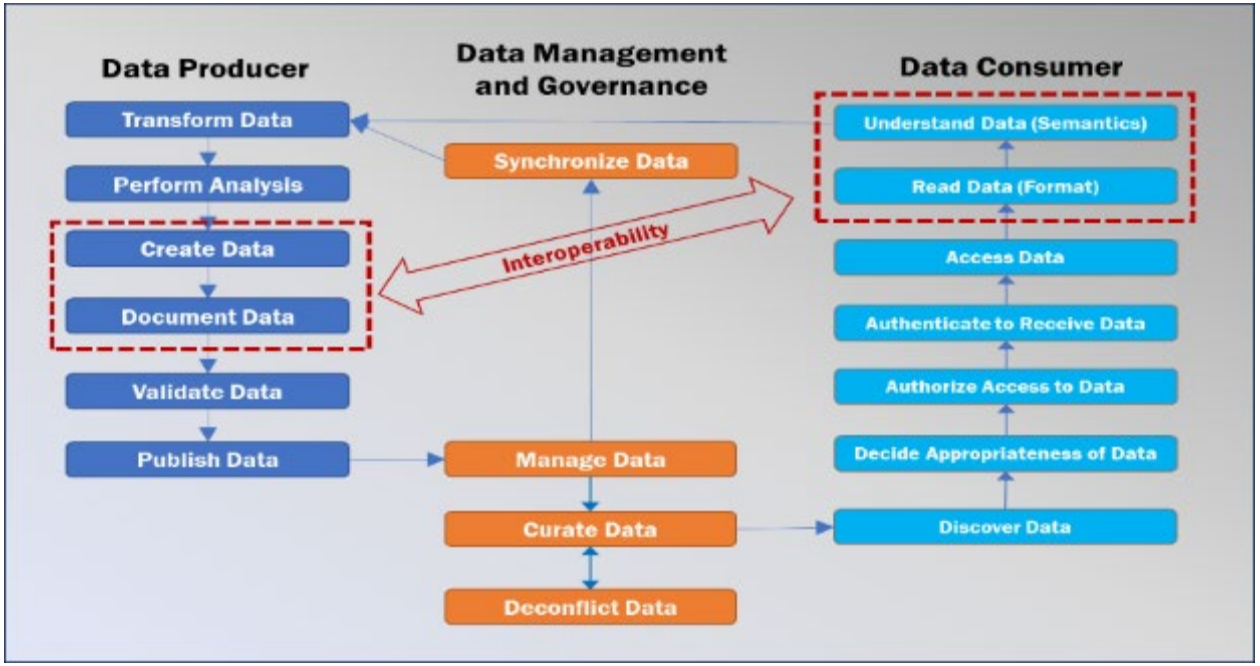
Principal Engineer, The Aerospace Corporation

- MBSE and system architecting practitioner and researcher
- Digital engineering and digital transformation strategist and implementation planner
- OCSMP SysML Model Builder Advanced
- Chair, INCOSE Object Oriented Systems Engineering Method (OOSEM) WG

Introduction

- Model-Based Systems Engineering (MBSE) is the modern practice of systems engineering (SE) in which descriptive models replace documents as the authoritative artifact capturing evolving SE knowledge
- Digital Engineering (DE) is the digital integration of information and work
- Descriptive models are often built to serve localized purposes but can provide greater value when they can be reused or federated
  - This enables the information and knowledge they contain to be more broadly and effectively used
- However, greater attention and effort is required to facilitate this reuse and federation
- This presentation will describe some of the key aspects of model interoperability and suggest next steps
  - A research agenda to advance the state of the art
  - A collaboration agenda to advance the development of standards and guidelines to improve the state of the practice

Interoperability in MBSE

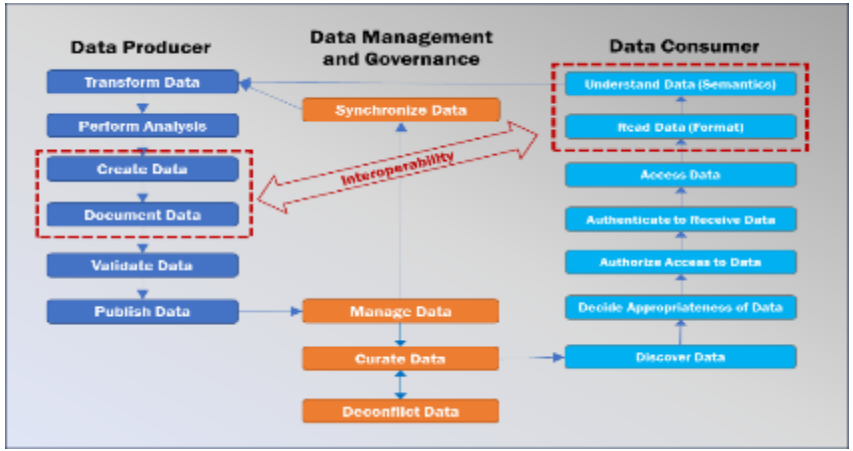


- This is a notional set of tasks that must be implemented to achieve successful reuse or federation of data or descriptive models
- Equivalent of a “kill chain” for models and data
- Each task represents a potential point of failure to achieve successful reuse or federation

This “kill chain” for model or data reuse or federation identifies risk areas to be mitigated

The “Kill Chain” for Model Interoperability

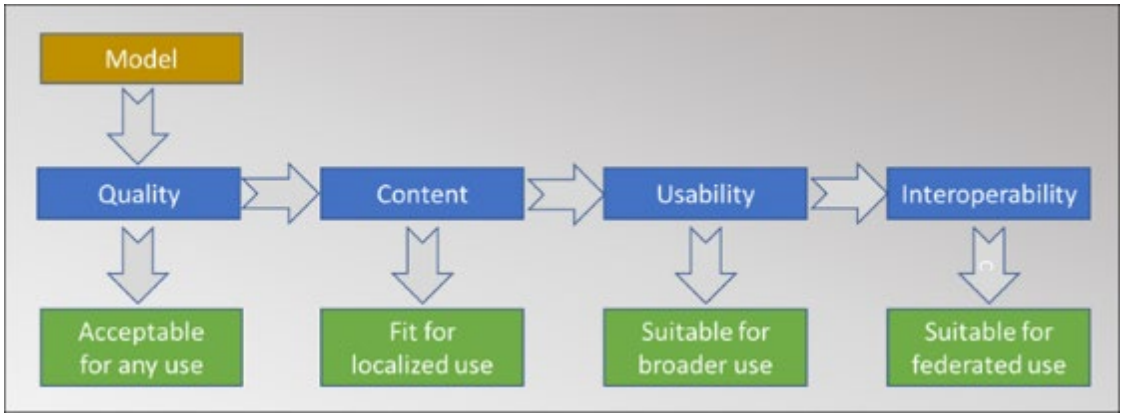
- The essential tasks for model interoperability are highlighted:
  1) *Creating* the data
  2) *Documenting* the data
  3) *Reading* the data from its repository
  4) *Understanding* or *interpreting* the data
- The general problem of data interoperability is simpler than for models
  - Due to the greater constraints on construction and federation of descriptive models
  - Particularly if model execution is intended
- Models may need substantial refactoring to achieve interoperability
  - Represents significant model *technical debt*



Models require greater attention to standards to facilitate interoperability

The Role of Standards in Model Interoperability

- Standards for descriptive models can serve four principal purposes, shown below in stages
- Each stage represents a conceptual filter for assessing fitness of a model for a new context
  - Quality: Fitness for any use
  - Content: Fitness for localized purposes
  - Usability: Suitability for wider use (by humans)
  - Interoperability: Suitable for federated use (by machines)



Achieving model reuse and federation requires convergence along these stages through the use of standards

Model Quality Characteristics

- The Quality stage provides a minimum standard of acceptability for models to be usable for any purpose
  - Independent of their functional capabilities or content
  - Essentially non-functional requirements on the models
- Software architecture model quality has been characterized by six quality goals:
  - 1) Correctness—both correctness of construction and of the assertions made in the model;
  - 2) Completeness—relative to its intended purposes;
  - 3) Consistency—representing a lack of contradictions within the model;
  - 4) Confinement—alignment with the model's intended purposes;
  - 5) Comprehensibility—understandability or readability; and,
  - 6) Changeability—facilitating evolution.

Mohagheghi, P., Dehlen, V., & Neple, T. (2009). Definitions and approaches to model quality in model-based software development—A review of literature. Information and Software Technology, v. 51.

- This presentation remaps these characteristics (and adds to them) to align with the four stages of modeling standards

The following slides will describe the characteristics and standards needs for each of these four stages

Model Quality Characteristics

- Correctness
  - Compliance with syntax rules and any pertinent conventions (e.g., style guide)
  - Static checks of model syntax to verify compliance with standards, custom rules, and guidelines
  - Dynamics checks are more difficult due to combinatorial explosion of input conditions and stimuli
- Completeness
  - Contains all pertinent components required of it for users' confidence in the model's provenance
  - Documented with sources
  - Documented with metadata to support model curation, cataloguing, and discovery
- Consistency
  - Does not contain any significant internal inconsistencies or contradictions
    - Both internally and with any authoritative external information sources with which it should not contradict

These model quality characteristics define a *Definition of Done* for agile model development

Model Quality Standards Needs

- Model semantic versioning
  - Standards for the meaning of model version numbers to establish expectations for model updates
- Model source documentation
  - Standards for documenting source material for which the model is not the authoritative source of truth
- Data protection markings
  - Standards for marking models for security classification and proprietary information
- Model metadata
  - Standards for metadata to facilitate curation, cataloguing, governance, and discovery of models
- Numbering and naming conventions
  - Standards for numbering and naming model elements
- Quantities and units conventions
  - Standards for defining quantities and units for numerical properties in models

These modeling standards would enable achievement of the first level of alignment: model quality

Model Content Characteristics

- Function
  - Models are abstractions of reality whose purpose is to answer stakeholders' questions
  - Failing to clearly identify the questions the models are intended to answer is one of the most frequently observed obstacles to successful MBSE adoption
  - These questions are essentially functional requirements for the models
- Confinement
  - Alignment of a model with its intended purpose
  - Appropriate perspectives and levels of abstraction
  - Omitting unnecessary content that impedes understanding and usability
- Traceability
  - Relationships of model elements with other model elements
  - Common understanding of the syntax and semantics of these relationships is key to proper interpretation of models

These model content characteristics define *Acceptance Criteria* for agile model development

Model Content Standards Needs

- Content to support SE processes and reviews
  - Standards for content required to satisfy entrance, acceptability, and exit criteria for SE reviews
  - Standard views that address those criteria
  - Standard methods for querying and reviewing model artifacts
- Content to support model-based acquisition
  - Standard concept of operations for exchange of digital artifacts during acquisition
  - Standard modeling templates for contract requirements, acquisition strategy, and proposal models
- Separation between enterprise and system-level models
  - Standard for determining when to use system modeling languages and when to use enterprise modeling languages
  - Standards for federating enterprise with system level models
- Layers of logical and physical abstraction
  - Standards for logical and physical layers of abstraction

These modeling standards would enable achievement of the second level of alignment: model content

Model Usability Characteristics

- Comprehensibility
  - Ability for users to properly interpret and understand the model
  - Ability for users to find the information they need within the model
- Portability
  - Ability for users to access the model
  - Ability for users to have everything they need to use the model
- Performance
  - Ability to open, view, query, and visualize the model within reasonable timeframes
  - Ability to generate views and reports

These model usability characteristics often require user evaluation in realistic environments to verify acceptability

Model Usability Standards Needs

- Model organization and navigation
  - Standards for model organization and aids for model navigation
  - Standards for partitioning models
- Model view and diagram layout
  - Standards for readability and usability of model views in general
  - Standards for visual design of graphical model diagrams for understandability
- Model collaboration
  - Standards for constructing models and views to facilitate use in web-based collaboration environments
  - Standards for capturing user feedback within models

These modeling standards would enable achievement of the third level of alignment: model usability

Model Interoperability Characteristics

- Compatibility
  - Content and ontology used must be compatible
  - The modeling constructs used to model that content also must be compatible
  - Reflect a shared understanding of concepts at the interfaces of the federation
  - Critical when a model needs to get the same information from multiple models
- Reusability
  - Avoid biases that constrain the model's content from being applicable in different contexts
  - Avoid introducing semantic ambiguity
    - Which can result in excessive growth of model technical debt
- Changeability
  - Proper partitioning of a large scope of model content into appropriate modules
    - Maximize cohesion while minimizing coupling
  - Conscious design of the interfaces between models to enable independent evolution

These model interoperability standards facilitate federation of models in a digital engineering ecosystem

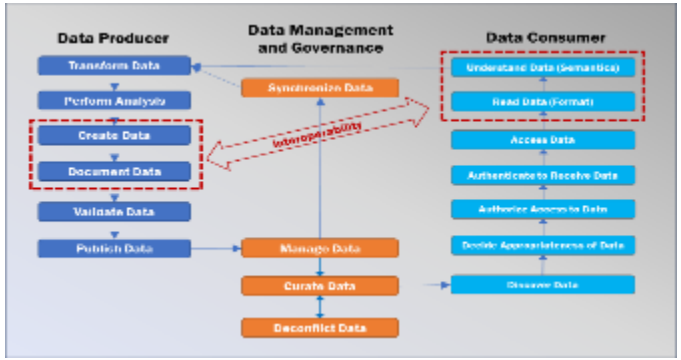
Model Interoperability Standards Needs

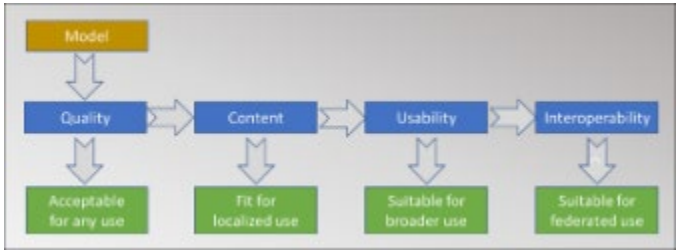
- Common ontologies for critical SE concepts
  - Standards for requirements, risk, reliability, etc. concepts and terms
- Consistent approaches for modeling common SE concepts
  - Standards for modeling system states, modes, phases, configurations, etc.
  - Standards for modeling requirements and their relationships and verifications
  - Standards for use of structured requirement templates and property-based requirements
- Modular Open Systems Approach (MOSA) for model interfaces
  - Standard modeling practices and model validation rules
  - Standard modeling constructs for commonly used system interfaces
    - e.g., communication protocols or waveforms, data standards, software or physical interfaces, etc.
- Consistent approaches for modeling common domains
  - Standards for modeling verification & validation (V&V) and test & evaluation (T&E) domains
  - Standards for modeling certification domains
    - e.g., safety, security, cybersecurity, nuclear surety, airworthiness, etc.

These modeling standards would enable achievement of the fourth level of alignment: model interoperability

Summary

- Descriptive models are the foundation of MBSE
  - They are built to serve localized purposes but provide greater value when reused or federated





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Let's collaborate to advance the state of the art and practice of MBSE

Ryan Noguchi
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