Data Integration is more than aligning formats!

GLOBAL PRODUCT DATA INTEROPERABILITY SUMMIT 2021

Virtual Sessions

From MBSE Working Group: March 2021

Adrian Murton – Airbus

Mark Williams – Boeing

The Digital Transformation Begins

Portable computing and shared models.

Numerical data formed the thread, and collaboration was a required activity.

Our Sponsors

LOTAR
LONG TERM ARCHIVING AND RETRIEVAL

PDES, Inc.
Connecting the Digital Enterprise
Model Based Manufacturing
Model Based Engineering
Model Based Sustainability
Product Data Exchange Specification

Two Team Leaders Manage a Single Team

Adrian Murton – Airbus
Mark Williams – Boeing

AIA AEROSPACE INDUSTRIES ASSOCIATION

ASD-STAN Standardization

NAFEMS

INCOSE International Council on Systems Engineering

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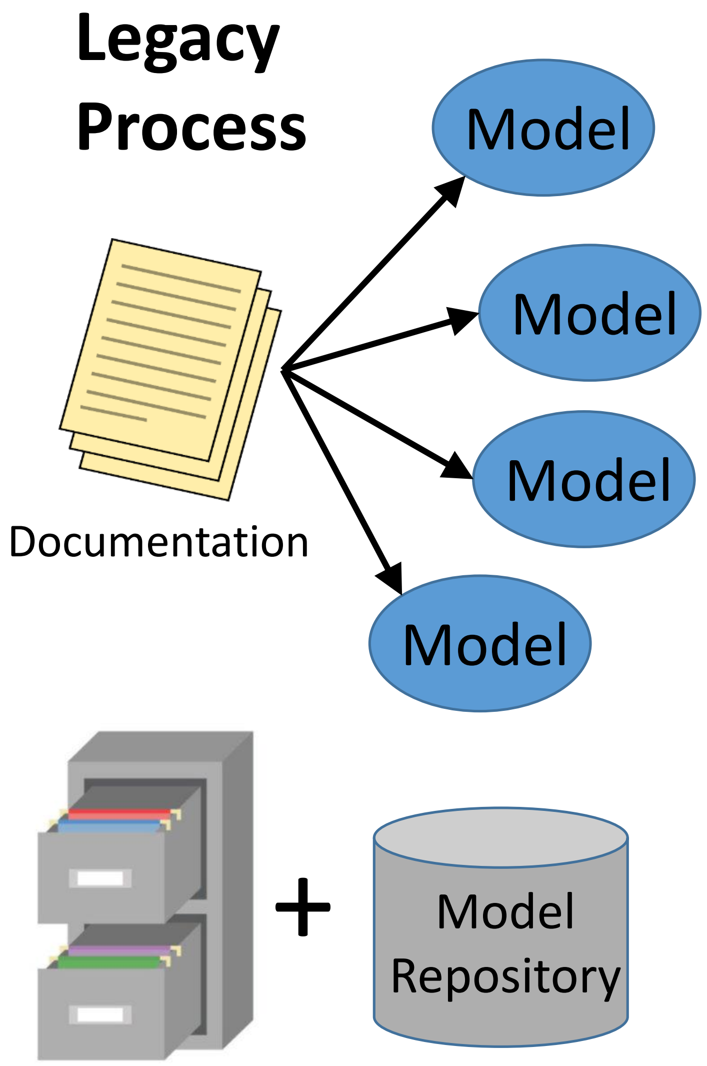
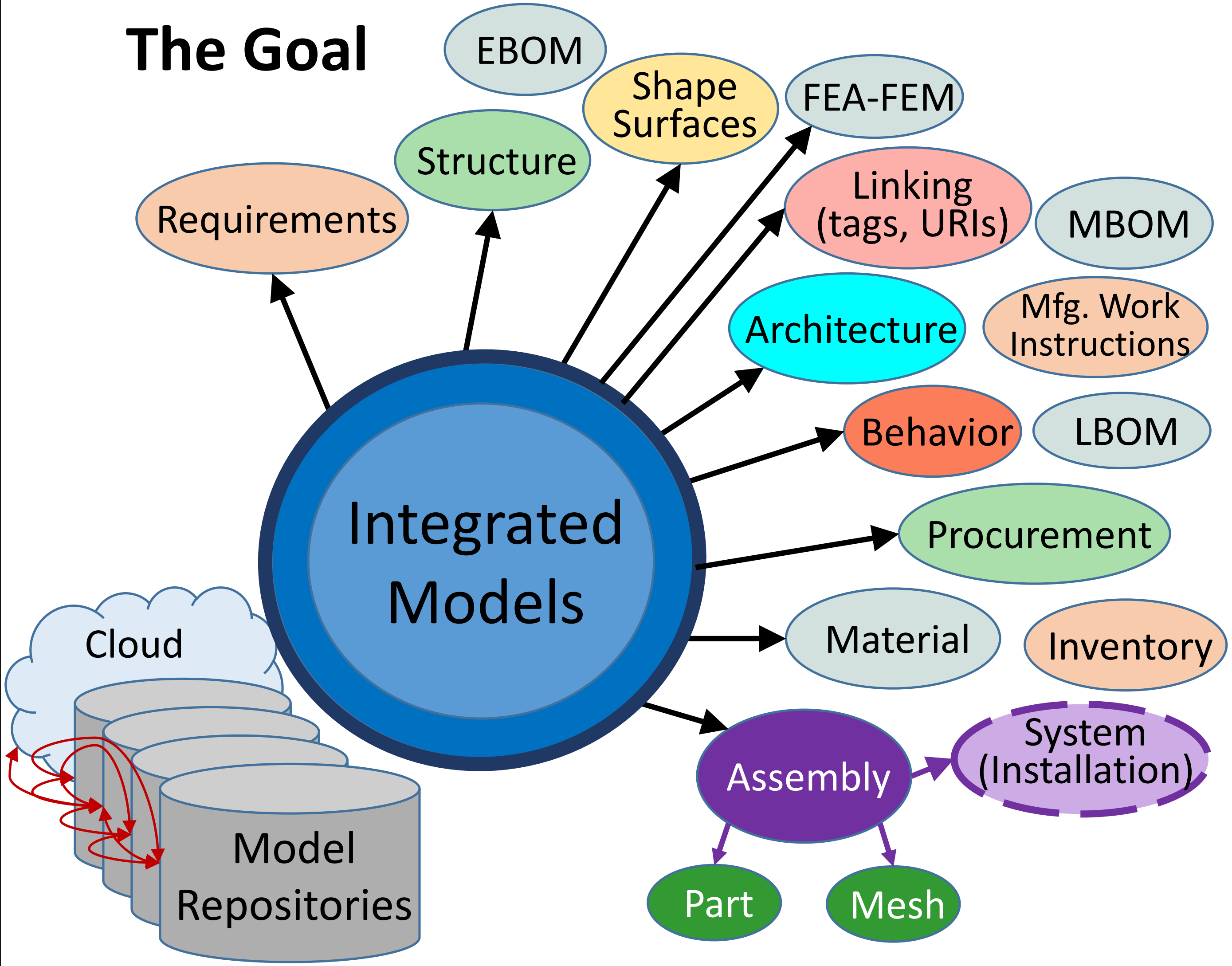
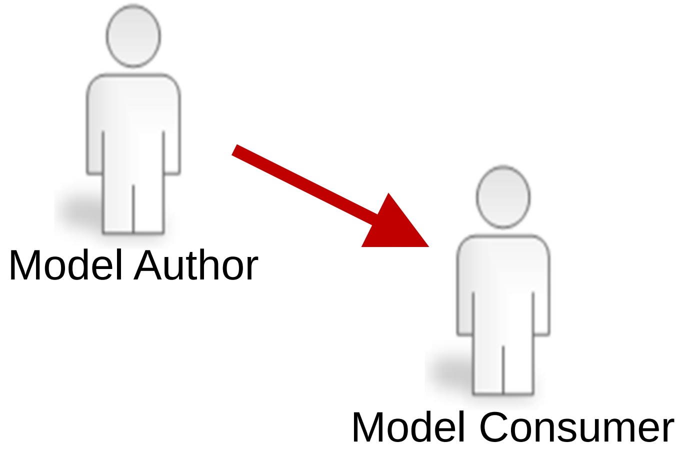
Digital Transformation – System Definition





The Data Transformation PROBLEM



WHAT data to exchange and integrate?

HOW to exchange and integrate our models?

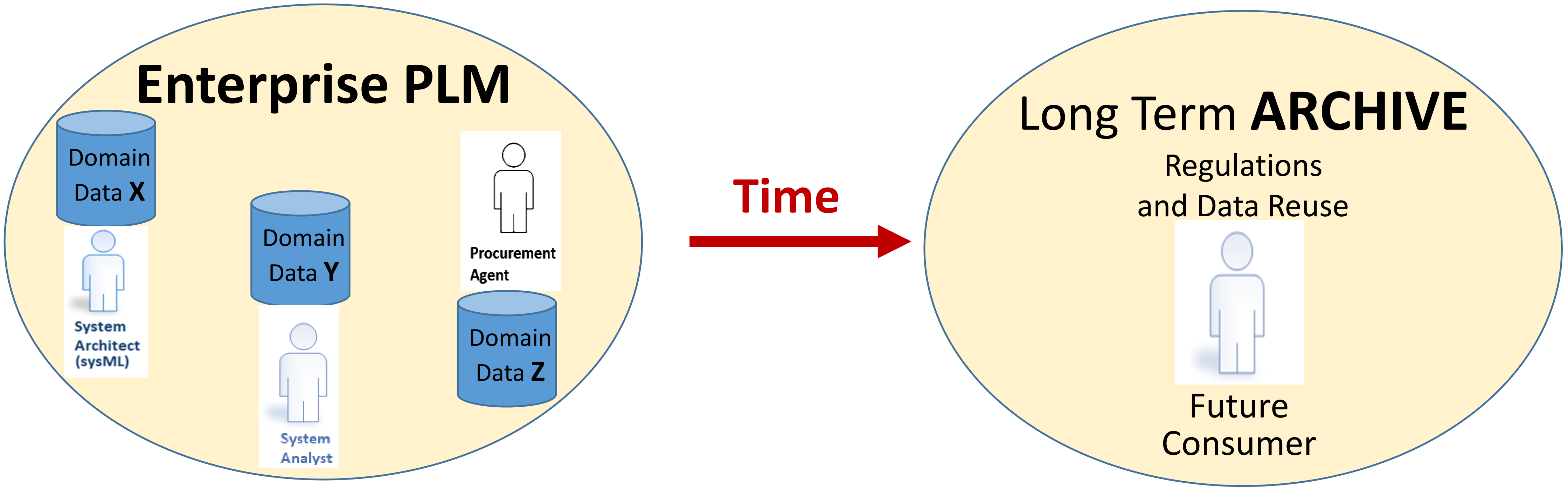
What is the description of each model?

Assumption: We share our models (internally and externally)

Consumers need to know the model's purpose, pedigree, provenance, fidelity, V&V criteria, etc.

Only the author can specify the model's purpose
(not the consumer or the tool)

Data Identification with PLM



ISSUES:

- Diversity of the models
- Terminology describing the models
- What and how to archive
- The lifecycle of the authoring and DB tools

Organizing Our Data

Why we must train our PLM Systems

What is the model's purpose?

- A model characterizes a system, and every model has its own unique description. Models may share attributes, but the pedigree, provenance, and intended results are generally exclusive.
- Our challenge is think beyond the management of files. We must understand the diversity of our models, what data each model contains, and how to define their relationships.
- Can we decompose the contents of every model and expose them to the PLM system (these systems do exist)? Or, do we utilize a model manifest that classifies the model's characteristics, its scope, standardizes the vocabulary, and manages the model's relationships?

Domain Specific Model Representations

Use Case: 1 D Behavior models

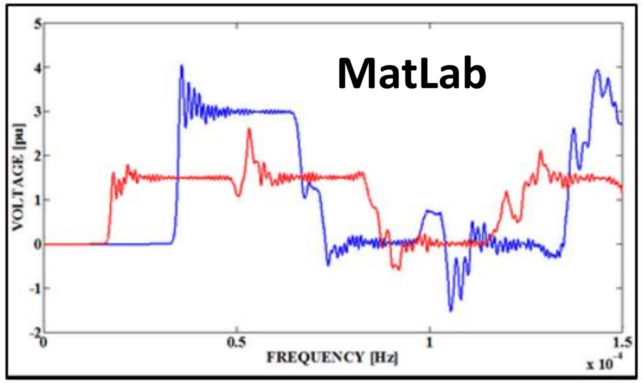
Consider the combination of multiple modeling domains:

Scenario: Mechanical parts used in a software controlled fluid system

- SysML for the logical architecture (define components-function)
- MatLab for electrical controls (dynamic time in Hz)
- Modelica for mechanical physics (duration sequence timing)
- Flomaster for fluid-thermal CFD (state changes)
- C/C++ for LSW/firmware (software control)

To merge and integrate the simulation results is not easy, yet the models share functional requirements and parameters.

How to Integrate our Models?



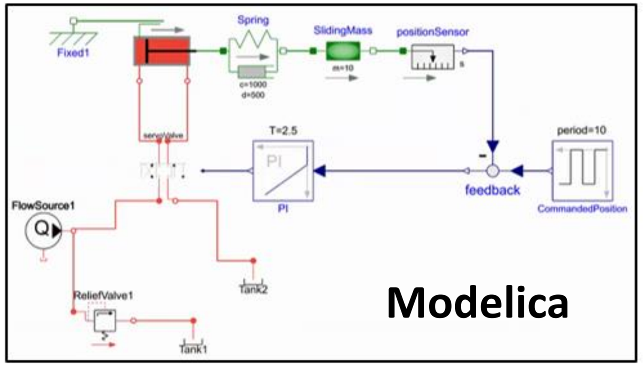
<u>Model Characteristics:</u>

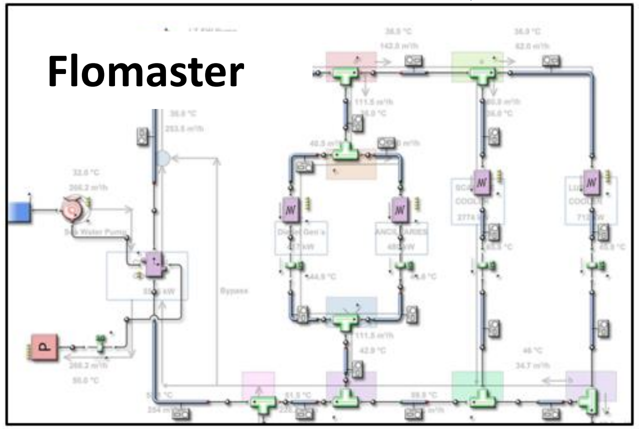
Specific Purpose

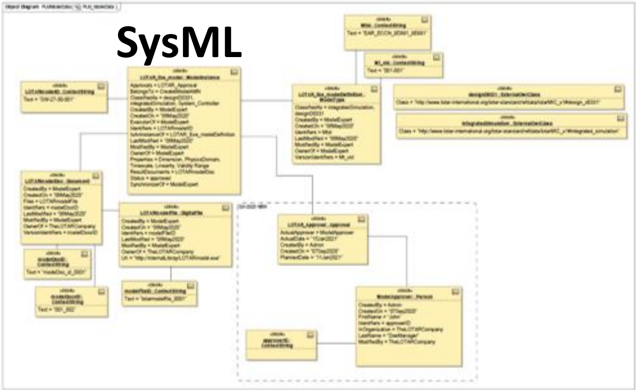
Unique Functions

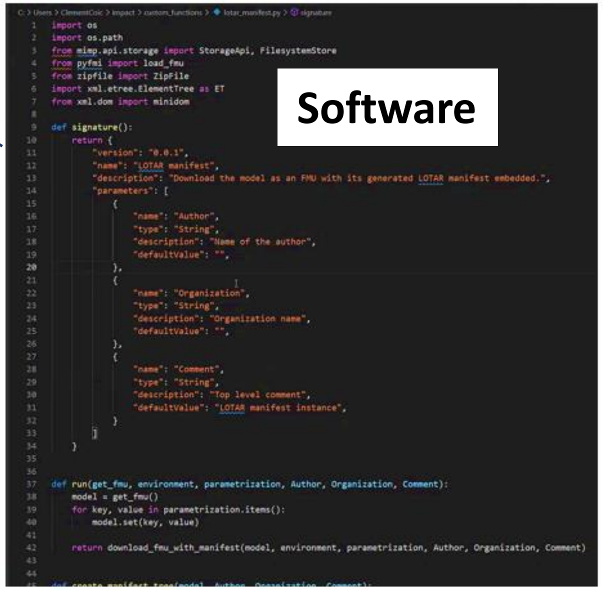
Shared Parameters

Simulation Interdependencies







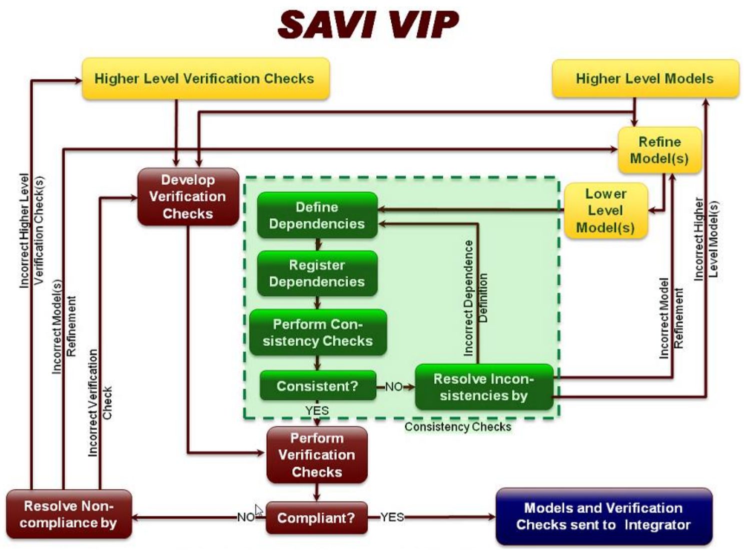


Integration Guidelines

SAVI Consistency Checks

Consistency is based on the model's purpose and dependencies

1. Data Value (numerical values)
2. Data Type (variables, units, range, tolerance)
3. Data Semantics (interpretation)
4. Data Metadata (restrictions, assumptions, source)
5. Model Property (patterns, components, interfaces)
6. Model Semantics (interpretation)
7. Model Metadata (restrictions, assumptions, source)
8. Model Behavior (time history response, invariant properties)



SAVI – The System Architecture Virtual Integration Program

SAVI Behavior Model Consistency Analysis, K. Woodham, M. Kerstetter, GPDIS 2016

What is Metadata?

Metadata - Data about the model

- Metadata is "information about other data“
- Formal classifications: descriptive, structural, administrative, reference, statistical, and legal
- Digital Metadata is key to data interoperability, exchange, integration, linking, traceability, reuse, translation, archiving, and synchronization
- The metadata baseline for digital storage-archiving is **OAIS** (ISO 14721)
- Metadata is a tool to manage data, models, repositories, and simulations

Metadata formats: Text, human-readable (xml), coded, graphical, binary forms

Categories and Types of Metadata

Metadata – Technical, Business, Process

- Descriptive: Context, Content, Purpose, Dependencies, Hierarchy
- Structural: Model-type, Standards, Format, Tools, Compilers
- Administrative: Authorization, Approvals, Policies, Audits, Reproduction
- Reference: Identifiers, Usage, Pedigree, Provenance, Quality, Integrity
- Statistical: Fixity, Validity, Verification, Versions, Edition
- Legal: Access Rights, Controls, Export, Restrictions, Duration

OECD - International Organization for Economic Co-operation and Development
NISO - National Information Standards Organization

Metadata Vocabulary Examples

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Numerical Behavior Models (terminology choices)

Physics Domains

- Classical mechanics (subdomains?)
- Thermodynamics and statistical mechanics
- Electromagnetics and photonics
- Relativistic mechanics
- Quantum mechanics, atomic physics, molecular physics
- Optics
- Condensed matter physics
- High-energy particle physics and nuclear physics

(No domain for networks, software, or control systems)

Timescale

- A measure of the relative or absolute duration
- Defined as real numbers (**R**), or a discrete time scale (hZ - hertz)
- Light years, H:M:S, calendar (units, precision)
- Differential calculus (rate of change)
- Finite difference, (boundary conditions, sequential)
- Quantum calculus, (no limits, infinite, finite differences)

Classifications Prototype

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Many concepts of time!

Sample Vocabulary

1. **Define system:** (S1000D standard)

EXAMPLE:

system (S1000D)	2910 (primary hydraulic system)
purpose_rationale	acausal
level_domain	behavioral_noncompressible
fidelity_method	static_conceptual

CLASSIFICATIONS
system
purpose_rationale
abstraction_level
domain
fidelity
method

2. **Establish purpose_rationale:**
   a. architectural (operational)
   b. establish boundary conditions
   c. experimental (system)
   d. acausal
   e. user_defined

3. **abstraction_level**
   a. architectural (operational)
   b. functional
   c. behavioral
   d. capability (performance range)
   e. affordability (best value)
   f. availability
   g. life-cycle
   h. integration
   i. specification *(link)*
   j. user_defined

4. **domain**
   a. mechanical
   b. signal network
   c. noncompressible fluids
   d. compressible fluids
   e. thermal
   f. control
   g. environmental
   h. vibration/acoustics
   i. optics
   j. user_defined

5. **model fidelity**
   a. ideal
   b. static or quasi-static
   c. dynamic
   d. fault detection
   e. user_defined

6. **method**
   a. Deterministic (time is exact)
   b. Empirical Validation (calculate sizing, tolerance or variation)
   c. Emulation (contribution-influence-impact from external system)
   d. Epistemic Uncertainty (subjective estimate)
   e. Conceptual-Experimental (DOE, uncertainty, predictive)
   f. Probabilistic (non-deterministic time variables)
   g. Regression Baseline (representative, or repetitive test results)
   h. Sensitivity (estimates variation)
   i. Simulation-Computational (based on high degree of certainty)
   j. Stochastic (influenced by random variable)
   k. optimization (exploring the maximum of a function)
   l. user_defined

OAIS Fundamentals: CI and PDI

Preserving Digital Product Data

Metadata Standards for management and preservation: ISO 14721 (OAIS) , and EN/NAS9300-011

Content Information (CI): managed by the archive / repository

Preservation Description Information (PDI): managed by the model

- **Provenance:** integrity includes where it came from. Includes a **record of its origin** and chain of custody.
- **Reference:** requires multiple identifiers, includes system and usage identifiers, enables Content Information to be **uniquely identified** over the passage of time.
- **Fixity:** If an object is not fixed, the content is subject to change or withdrawal without notice, compromising its integrity. Fixity information **prevents change**.
- **Context:** Context describes how the Content Information **relates to other information** outside the Information Package. Why the model was produced, its dependencies, constraints, and hierarchy.
- **Access Rights:** Security, privacy, data markings and control of use

OAIS - Open Archival Information System, EN – European Norm, NAS – National Aerospace Standards

Reference Info: Model Identification

- Index ID (example: part number)
  - Each element would have its own ID
  - Each element would identify its parent and children IDs
  - Each level in the hierarchy would also have an ID

Probability for unique identification is a function of the quantity of repository objects, and the quantity-quality of ID attributes

- Design Role (functional role)
  - Defines replaceable features, requirements, or parts
  - A stable ID that has a representative taxonomy
- Textual name*(s)* *[Definition + Usage (instance) + Occurrence (multi-instance)]*
- Model description/purpose *[systemID, abstraction level, domain phrase, fidelity, method]*
- UID, UUID (model and/or DB index ID) (tool assigned, not neutral)
- URI schema (model link locator: URL + URN)
- Configuration, Version, Edition identifiers

Metadata Use Cases (Business Needs)

- Model Integration, Traceability and Synchronization
- Model Identification and basis for SEARCH
- Computer Sensible Operational (executable) Characteristics
- Data Archiving and Reuse (knowledge recovery and the decision process)
- Reduce “data islands” and “Data OBSOLESCENCE”
- Facilitate Design Collaboration and data links
- A formal path to verify design information
- Capture of data pedigree and provenance (model integrity)
- Customizable descriptions based on model/data type/purpose
- Standard attributes and vocabulary for common model types
- A capability supporting legacy and modern data (old and new data)

Metadata Standards

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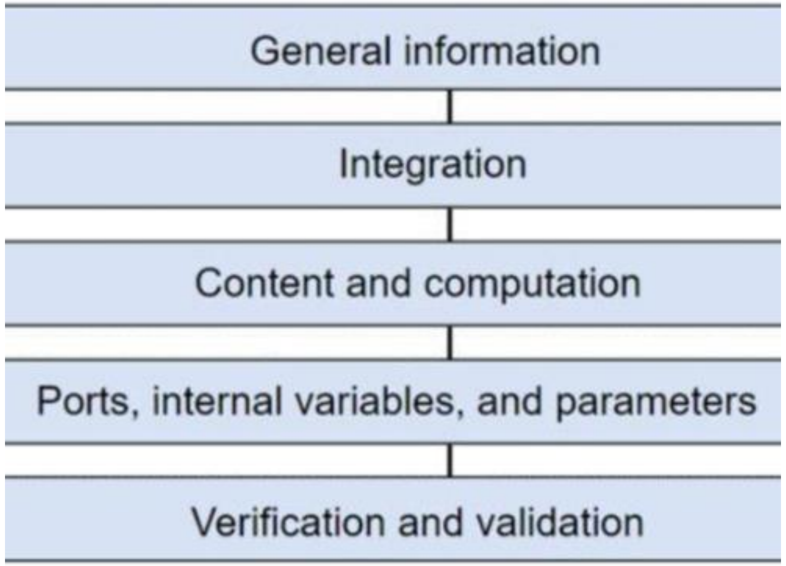
- SystemX Model Identity Card (MIC)
- INCOSE's Model Characterization Pattern (MCP)
- ASSESS Initiative – UMC4ES, Unified Model Characteristics for Engineering Simulation
- ASME Y14.47, Model Organization Practices
- OMG PPMN, Pedigree and Provenance Model and Notation
- W3C PROV standard [PROVenance]
- OAIS - Metadata Framework (ISO 14721 Sec 4.2)
- PDF XMP - Extensible Metadata Platform, ISO 16684-1:2012 (schemas of metadata properties)
- PREMIS metadata schema for internal preservation metadata
- ISO/TS 23081, Metadata for records
- MODDALS methodology, developing an ontology for terminology
- MoSSEC: ISO 10303-243, Modeling and Simulation in a Collaborative Systems Engineering Context

SystemX MIC

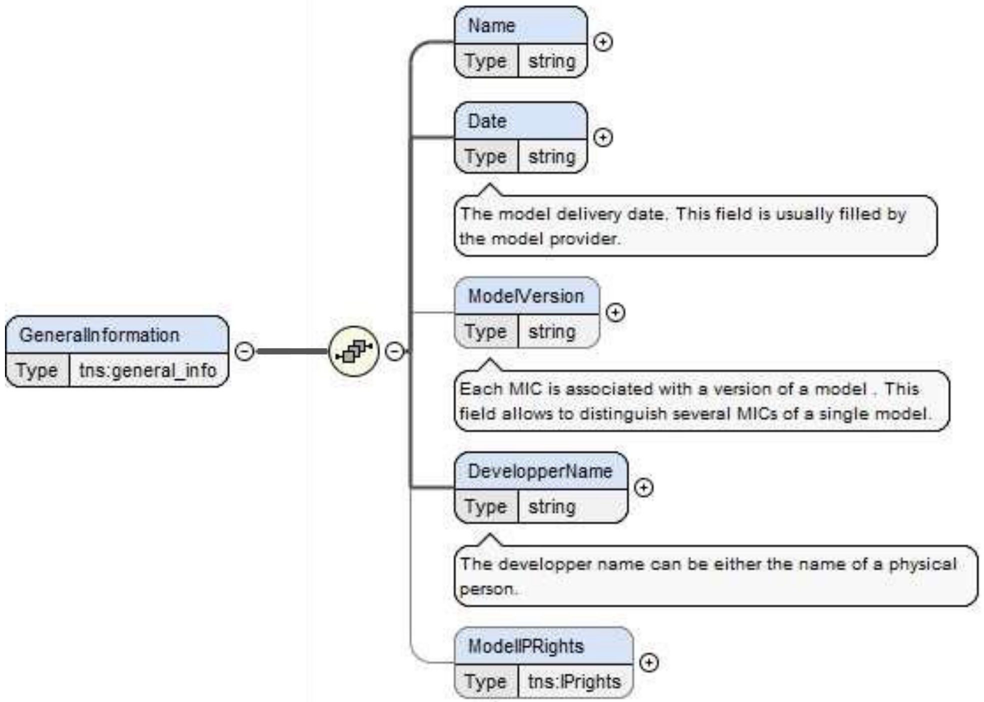
The Model Identity Card

- Originally the Identity Model Form (IMF), decomposes numerical models into 3 layers
  - product (object model),
  - Process (model activity)
  - Model organization (its dynamic environment)
- Includes interfaces and vocabulary guidelines
- Promoted by the automotive domain



Limitations:

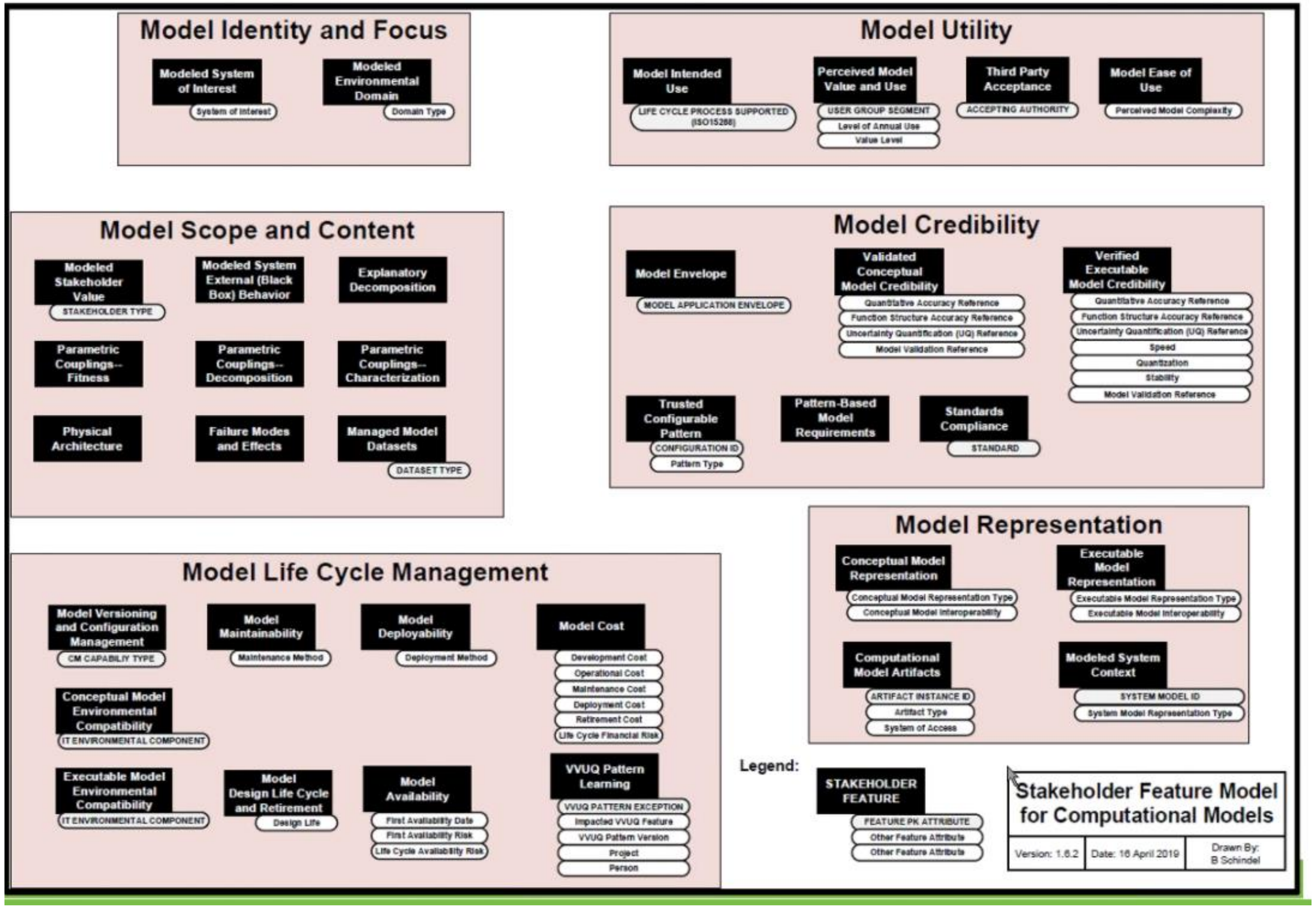
- Not generic, numerical model focus
- Suited for components vs systems
- Limited Process control
- Relies on attached document



Model Characterization Pattern (MCP)

INCOSE MBSE Patterns Working Group

- A framework of information that describes virtual models
- A utility that captures a characterization of the different model types - acts like a “model wrapper”
- A mature method to manage a large collection of diverse models



Limitations:

- Not a data standard
- Obscure implementation Infrastructure
- Needs PLM system automation

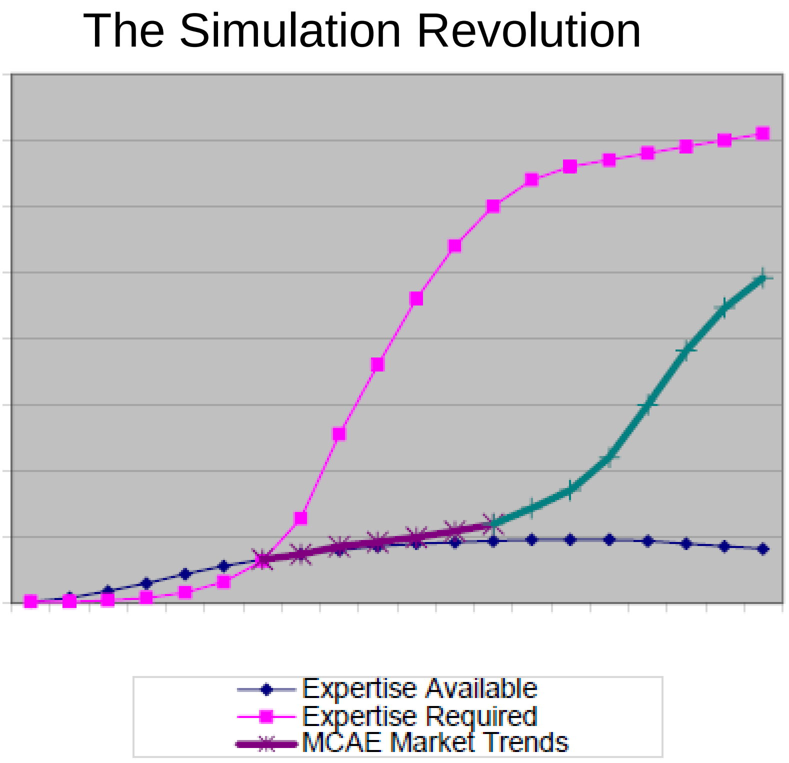
ASSESS Initiative – UMC4ES

Unified Model Characteristics for Engineering Simulation

- Addresses the diversity of models, their purpose, assumptions, and vocabulary
- A classification system that represents the model's features, characteristics and their definition
- Merge the work of the MIC, MCP, MoSSEC, and AP209

Limitations:

- Industry Guidelines, not a data standard
- Under development (clean slate)
- Specific to Simulation modelling domain



Element Name [Note (1)]	Required/ Optional [Note (2)]		Description [Note (4)]
NEXT_ASSY	Optional	String	PIN of next higher assembly using this product.
NOMENCLATURE	Required	String	Nomenclature description of product.
ORIGINAL_DESIGN_ACTIVITY	Required	String	Name of original design activity for the data set. Required per ASME Y14.100.
PART_NUMBER	Required	String	PIN for product defined in data set. Required per ASME Y14.100.
MODEL_PRECISION	Required	Integer	Value that indicates numeric accuracy (number of significant digits) of model required in production of part in order for it to fulfill the design intent (ASME Y14.41).

Table 6-3 Metadata Elements

Element Name [Note (1)]	Required/ Optional [Note (2)]	Data Type [Note (3)]	Description [Note (4)]	Data Category [Note (5)]
***_DATE	Optional	ISO 8601 extended form date/time	Date that data set was reviewed and/or approved by a function and/or role. "***" is a wild card.	2
***_NAME	Optional	String	Name of person for function and/or role that reviewed and/or approved the data set. "***" is a wild card.	3
***_NAME_CERTIFICATE	Optional	Digital certificate per X.509PKI	Digital certificate for function and/or role that reviewed and/or approved the data set. "***" is a wild card.	1
ALT_MATERIAL	Optional	String	Definition for alternative materials that are defined for the product. See also *MATERIAL*.	2
ALT_PART_NUMBER_*	Optional	String	PIN of an equal part for product defined in data set. When more than one alternate PIN is supplied, append "_*" to the attribute name where number(s) or letter(s) code is substituted for "*."	2
CAGE_CODE	Optional	String	Company CAGE Code assigned by DoD Defense Logistics Agency (DLA).	2
CODE_ANN_ATTR_STATE	Optional	String	Code that represents the annotati[illegible]d attribute state.	2
CODE_EXPORT	Optional	String	Code for EAR from U.S. Dept. of Co[illegible]TAR from U.S. Dept. of State, or AEA Regulations from U.S. Dept. of Energy.	1
CODE_GEOMETRY_STATE	Optional	String	Code that represe[illegible]	2
CODE_MATURITY_STATE	Optional	String	Code that re[illegible]state.	2
CONTRACT_NUMBER	Optional	String	Contr[illegible] prod[illegible]nd/or design.	3
COPYRIGHT_YEAR_*	Optional	ISO 8601 extended form date/time	[illegible]ore than one copyright year is supplied, append "_*" to attribute name [illegible]er(s) code is substituted for "*."	1
CREATE_DATE	Required	ISO 8601 exte[illegible]	[illegible] initially created.	2
CREATE_NAME	Optional	[illegible]	[illegible]me of author who created the data set.	2
CREATE_NAME_CERTIFICATE	Optional	[illegible]rtificate p[illegible]	Digital certificate for author who created the data set.	1
CURRENT_DESIGN_ACTIVITY	Optional	[illegible]	Name of organization with the current design activity.	3
DATA_SET_IDENTIFIER	Required	String	In accordance with ASME Y14.41-2012, para. 4.1.1.	2
DATA_SET_RELEASE_CERTIFICATE	Optional	Digital certificate per X.509PKI	Digital certificate for release (approval) of the data set. Include when data set is for released data.	1
DATA_SET_RELEASE_DATE	Required	ISO 8601 extended form date/time	Initial release (or approval) date for data set. Include when data set is for released data.	2
DATA_SET_RELEASE_NAME	Required	String	Name of person who approved release (approval) of data set. Include when data set is for released data.	2
DIST_CODE_DOD	Optional	String	The U.S. DoD distribution statement code letter of the product in accordance with DoD Instruction 5230.24.	2
GEOMETRIC_SCALE	Required	String	Scale of the model (e.g., 1:1, 1:2).	2
MASS	Optional	Real	Mass of product defined in data set.	2
MASS_UNITS	Optional	String	Units of the mass identified in the model. Include when *MASS* is supplied.	2
MATERIAL	Optional	String	Definition for primary material of the product. Include when material is specified for the product.	2
MODEL_UNITS	Required	String	System of units of measure (SI or U.S. Customary) of the model.	2

4 pages

- Uses metadata elements to define the product when exchanging/sharing data
- Divides data into Categories applicable to multiple domains
- A formal data standard that includes both **Required** and **Optional** elements

<u>Limitations:</u>

- Generally based on design documents vs digital/virtual models
- Required attributes align best to CAD models and what is generally included in MBOM

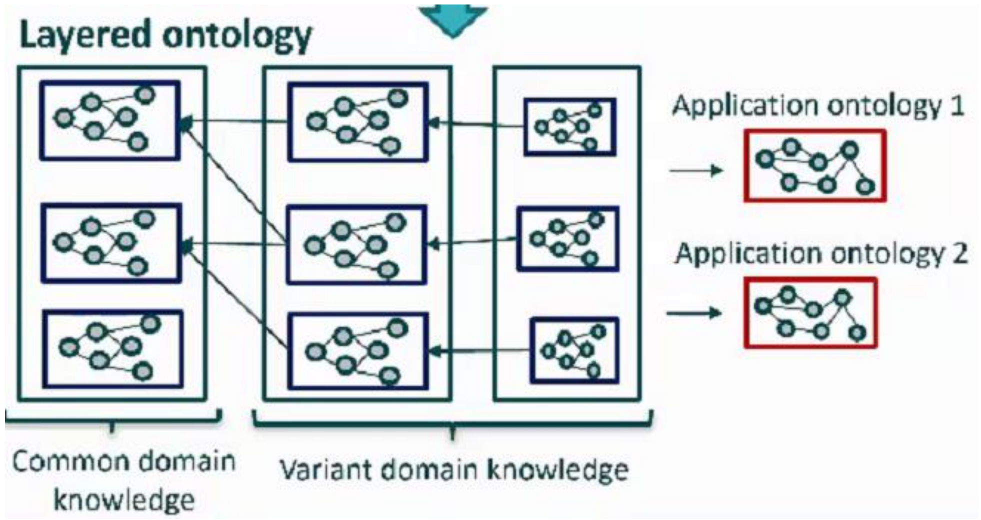
MODDALS methodology

Apply an Ontology to the metadata vocabularies

- Layered Ontology: common, variant and independent vocabulary domains
- Relationship with the Semantic Web project
- Creates domain knowledge hierarchies
- Semantic ontologies can be shared and reused across multiple applications

<u>Limitations:</u>

- Requires semantic converters and tools to access the ontology data
- Implementation infrastructure is best suited to PLM system and tools that support OWL converters

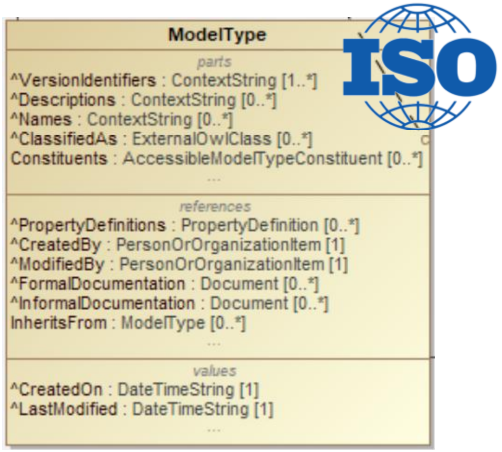


RDF in xml format

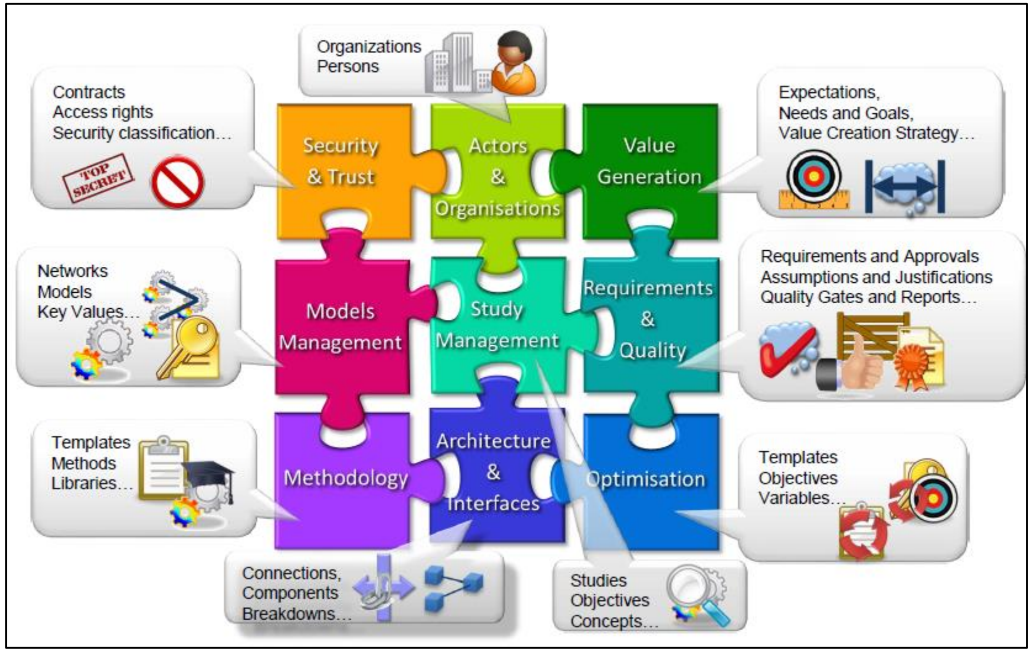
MoSSEC: ISO 10303-243, AP243

Modeling and Simulation in a Collaborative Systems Engineering Context

- A new cross-domain standard that captures the model context. Enables a collaboration framework across distributed datasets.
- Manages links and model traceability based on consumer – subscriber business needs
- Informs: **who, what, when ,where, why, and how**



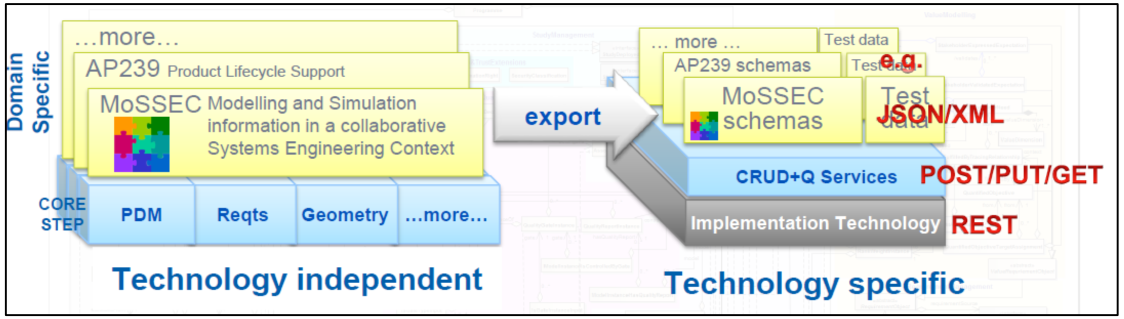
Business Object Model



Limitations:

- Relies on the Tool Vendor's implementation
- Max benefits if data exposed to PLM System
- Tools will need metadata viewer-editor

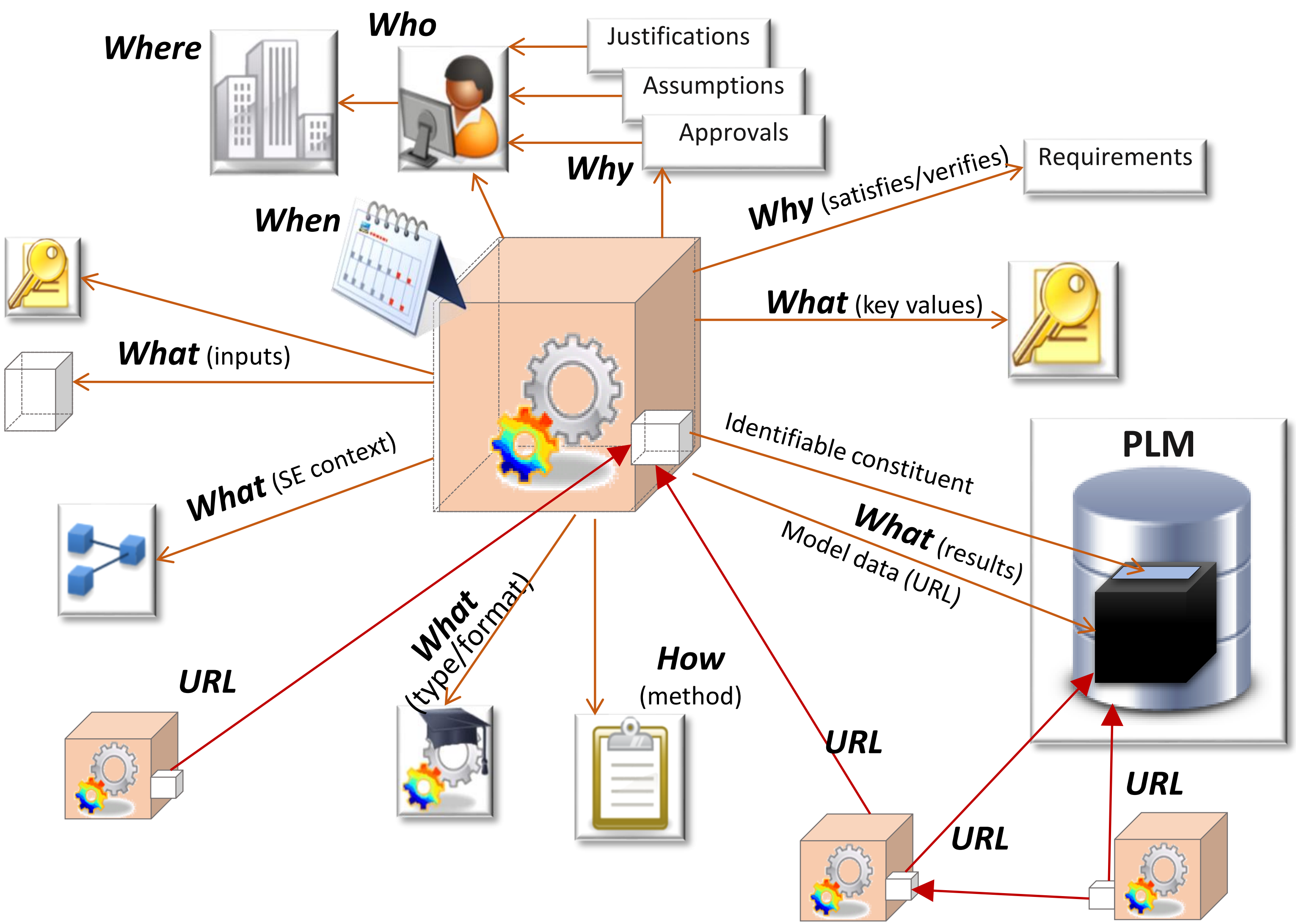
Implementation technology: Restful services



MoSSEC - "Model Instance" context

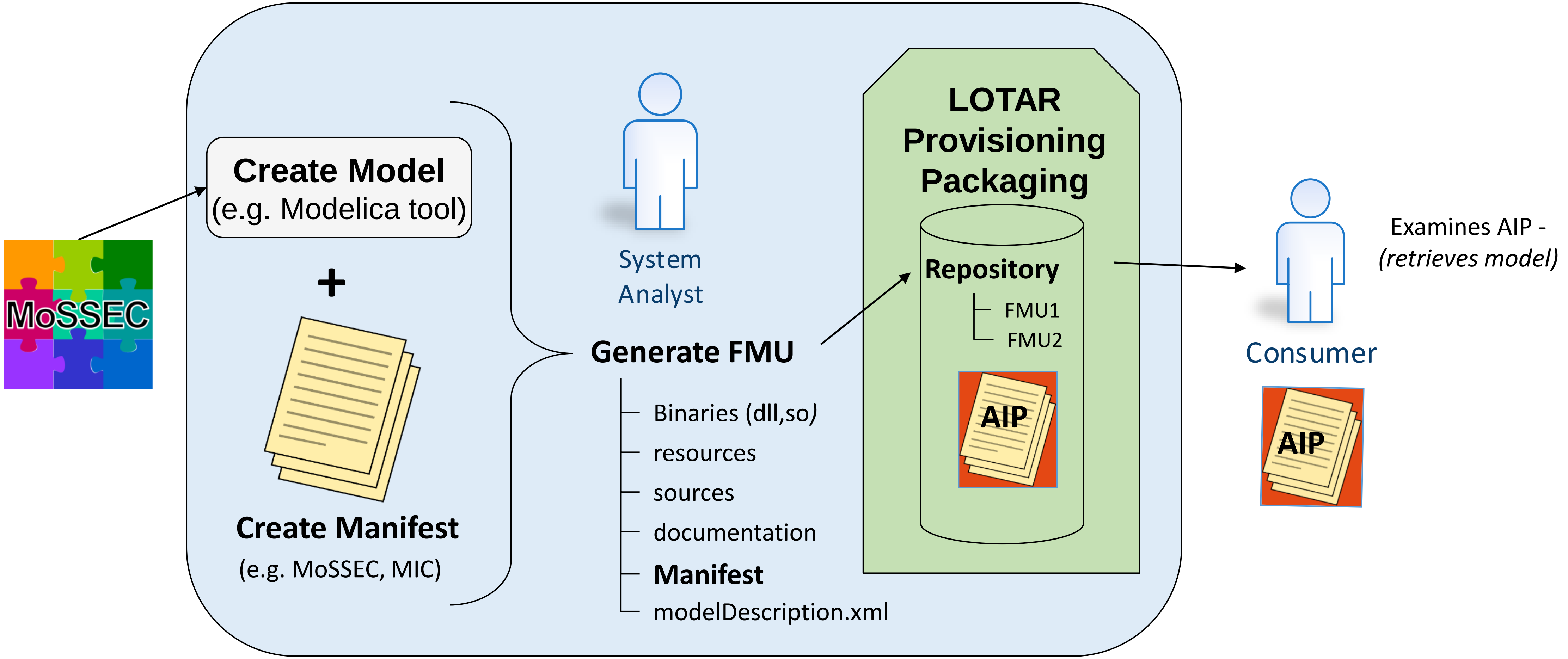
Modeling and Simulation in a Collaborative Systems Engineering Context

- Comprehensive View
- Exclusive for Models
- Application Standard
- Model Connectivity
- Data Identification
- Data Exchange
- Data Preservation



NAS9300-520 Process

Archiving, Exchanging or Retrieving a Simulation Model (FMU or SSP)



AIP – Archive Information Package

Use MoSSEC to Integrate Models

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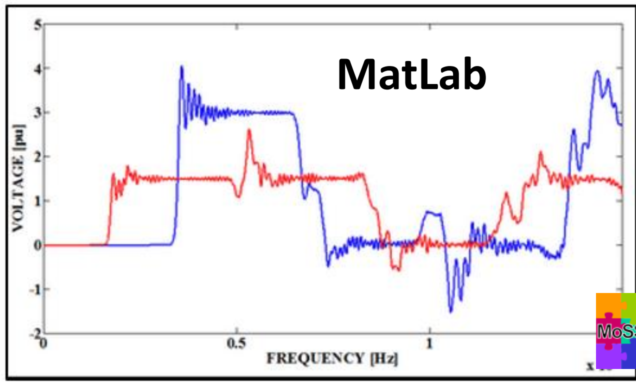

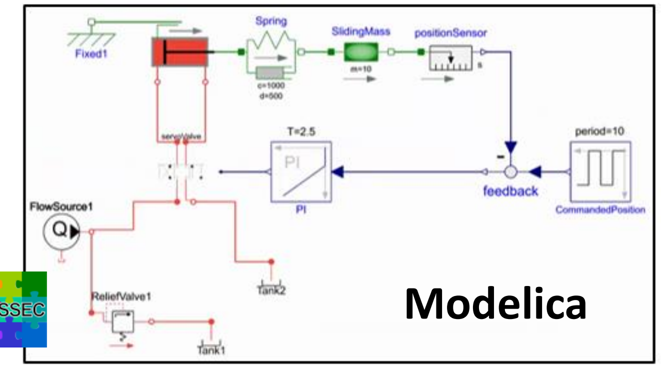

<u>Model Characteristics:</u>

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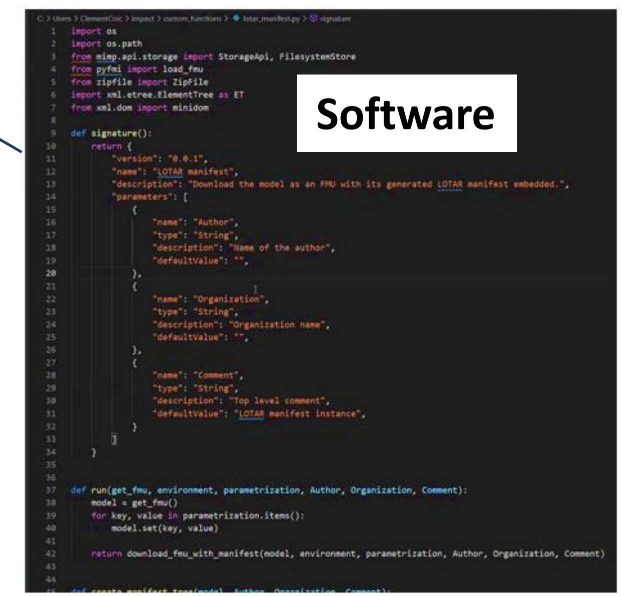
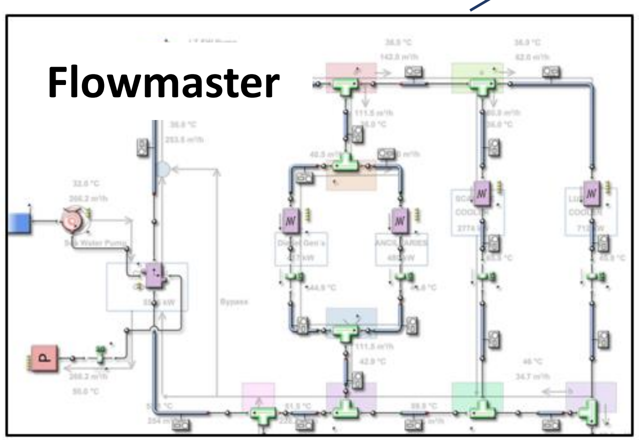
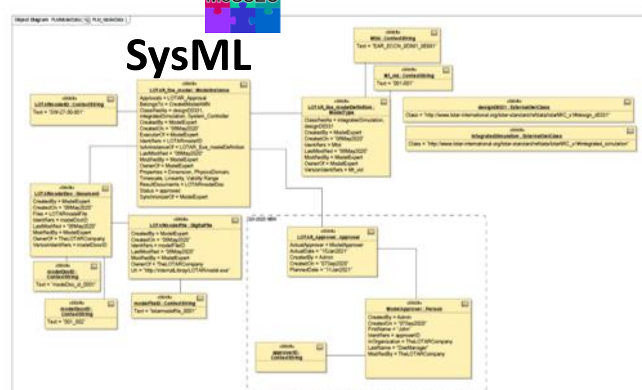
Unique Functions

Shared Parameters

Simulation Interdependencies



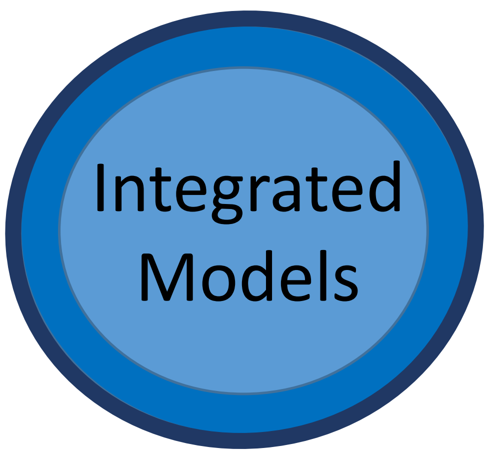




Integration is more than Format

Metadata Empowers the Digital Thread

- As a community, we can accelerate the transition to MBE
- First, we can measure the value of our data
- Second, we can emphasize model identification and integration
- Consider generating metadata that is more than text
- Ask your Solution Provider to share their MoSSEC Strategy!



Questions?

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ASD-STAN Standardization

PDES, Inc.
Connecting the Digital Enterprise
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INCOSE
International Council on Systems Engineering