MBSE Modeling Standards Committee Overview and Rapid Prototype Modeling

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Overview of the Model-Based Systems Engineering (MBSE) Modeling Standards Committee of the Space Systems Modular Open Systems Approach (MOSA) Interface Standards Alliance

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Model-Based Systems Engineering (MBSE) Modeling Standards Committee Background

MBSE Modeling Standards Committee Background

- MBSE is being increasingly used by both government and industry in the space domain to improve the efficiency and effectiveness of systems engineering practice
- The benefits MBSE can provide are magnified by reuse, e.g., by exchanging and federating descriptive to share and reuse the information and knowledge the models contain
- Achieving the benefits of model sharing, reuse, and federation also requires effort to foster and improve model interoperability
- Establishment of consensus standards is preferable to the point-to-point negotiation between individual model producers and consumers
- Model interoperability is a challenging, multidimensional problem, so it is important to prioritize some small subsets of the total problem space to achieve incremental progress

MBSE Modeling Standards Committee Objectives

- This Committee will develop standards for the creation, configuration management, curation, and sustainment of the models that serve as the authoritative sources of truth for MBSE and DE
- These standards are intended to improve the quality, value, usability, and interoperability of these models between government and industry organizations
- The Committee will develop a modular set of modeling standards via an incremental and iterative standards development process
- These individual modeling standards would each focus on a subset of the total scope of descriptive modeling
- The Committee will apply and continuously improve an agile development methodology for standards, and report on lessons learned from this process of adaptation

MBSE Modeling Standards Committee Strategy

- Develop consensus standards quickly to address the speed of need
  - Small team provides focus not possible with a very large standards group
  - Collaborate with other standards bodies where appropriate
- Adopt standards to begin applying them in real-world situations
  - Quickly discover issues and gaps so they can be addressed
- Broad adoption is key to the value of interoperability standards
  - Public release of MBSE Modeling Standards Committee standards facilitates broader adoption
  - Broader adoption adds credibility and weight through network effects
  - Larger user base strengthens evolution of the standards by providing more and better feedback
  - Larger user base incentivizes tool vendors to support the standards
- Goal is to improve interoperability and effectiveness of MBSE in the U.S. space industrial base
  - Applying MOSA concepts to models to advance model sharing and federation
  - Lifting all boats is a desirable side effect

MBSE Modeling Standards Committee General Principles

- Facilitate federation of descriptive models into digital model ecosystems
  - MBSE is an essential foundation of DE implementation
- Emphasize government-industry integration
  - Focus on model exchanges between government and industry to motivate collaboration by both sides
- Align with modeling dependencies and the acquisition lifecycle
  - Prioritize modeling standards that are beneficial to pave the way for later work
- Align with external standards work
  - Leverage existing external standards activities where possible
  - Posture the community to accelerate standards for SysML v2 models
- Plan for evolution
  - Expect to evolve these standards over multiple iterations

MBSE Modeling Standards Committee General Principles

- Avoid being overly prescriptive
  - Don’t prescribe process—we are not trying to achieve process interoperability
  - Focus on the models themselves—we are trying to achieve interoperability of the models

- Achieve an appropriate balance between tool independence and tool dependence
  - Strict adherence to tool independence can severely constrain interoperability or utility of models
    - The “least common denominator” can significantly constrain usability and utility
  - If members sharing models are all using the same tools, they could take advantage of significantly value-added capabilities of those tools, providing better model interoperability, usability, and value
    - If other tools are not being used, the risk of tool dependence may be minimal
  - Distinguish between tool-independent and tool-dependent requirement statements for standards
  - SysML v2 may facilitate democratization of MBSE tool market, improving the viability of a tool-independent approach relative to its viability for SysML v1
    - Strive for greater tool-independence for SysML v2 standards

MBSE Modeling Standards Committee General Principles

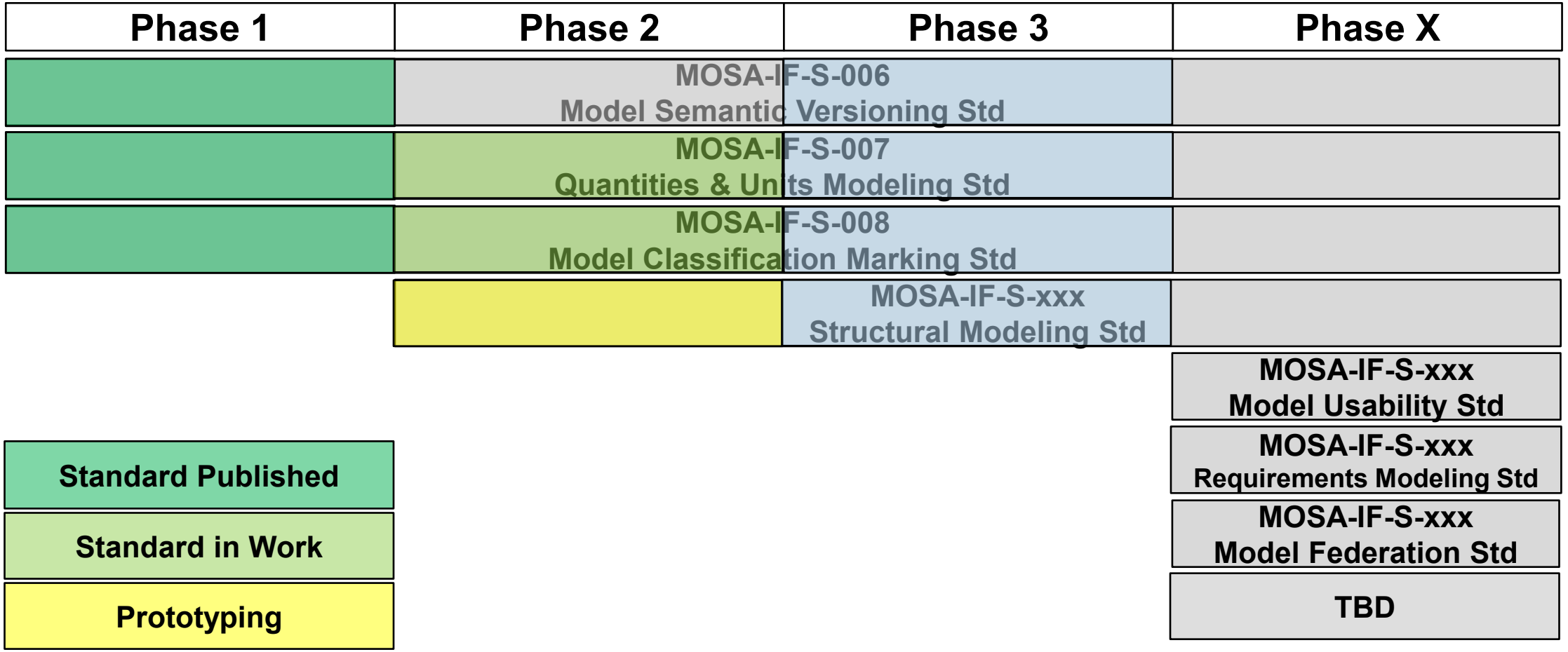
- Model-based standards
  - Standards should be constructed to have models be the authoritative source of truth, from which documents may be generated if a static document is required for contractual or usability purposes
  - Need to develop modeling standards for authoring models representing standards
  - Standard model libraries and requirements should go together in the same model

- Incremental and iterative development of modular standards
  - The scope of a particular standard area is partitioned into modules that are as independent as possible
  - Enable incremental progress to develop a standard
    - Produce intermediate products that can be used immediately by programs that cannot wait until the entire scope is complete, which may take a few years
  - Iteration may be necessary to account for lessons learned and to ensure the entire scope of standard is consistent and compatible
    - Proper partitioning of the total scope into modules will minimize the risk of need for iteration but cannot eliminate the risk

Comparison of OMG and MOSA Alliance Standards Practices

	Object Management Group (OMG)	MOSA Alliance
Membership	Very broad in industries, domains, and countries	Very focused on US space industry and government
Scope	Primarily software, modeling, and data standards	Fewer restrictions on scope; hardware, software, or modeling standards can be pursued
Process rigor	Very high—heavily process-driven with many levels of voting required for standards adoption	Low—agile development approach with lightweight processes
Timeline	Request for Comments (RFC) process can take several months to a year after the standard has been created; Request for Proposal (RFP) process can take multiple years	Very fast, roughly 6 month iterations
Voting policy	All votes are majority-rule	All votes must be unanimous
Veto rights	No member has veto rights	USG Stakeholders have veto rights
Membership cost	Membership cost is high ($13k/yr for Government, $22k to $75k/yr for contractors	Membership cost is low (free for Government, max $5k for contractors
Participation cost	Participation cost is high, especially to submit; typically requires participation in the OMG Quarterly Meetings to be effective ($20k/yr travel per person)	Participation cost is low for industry members, no travel
Reach	Widely adopted and heavily marketed; diversity of participation strengthens brand and reach	Lack of marketing and small consensus community limits adoption reach
Quality of standards	Broader consensus and participation strengthens the quality of the standards produced	Smaller team, faster tempo, and reduced rigor constrains the strength of the standard

MBSE Modeling Standards Committee Roadmap



MBSE Modeling Standards Committee Portfolio of Standards

MOSA-IF-S-006 Model Semantic Versioning Standard Overview

- Scope
  - Defines requirements for versioning and version numbering of descriptive models used in MBSE
  - Defines requirements for semantic versioning of models
    - Defines criteria for incrementing version numbers to communicate the severity of model updates
    - Similar to the prevailing de facto semantic versioning standard used in open source software community

- Problems Addressed
  - Prioritizing and planning for the update of a model federation with a new model version
    - Were there breaking changes that may impact model queries, plugins, report templates, etc.?
    - Were there updates that may change the answers of existing queries?
    - Were substantive changes made or just editorial ones?

- Phase 1 Content (Jul 2025 – Mar 2026)
  - General requirements for versioning of models
  - Requirements for semantic versioning of models
    - Criteria for incrementing major, minor, and patch version numbers of a model
  - Requirements on defining a public model interface and defaults when not specifically defined
  - Requirements on release notes

- Future Content
  - Generalize to be inclusive of SysML v2 models
  - Higher granularity in distinguishing between major & minor changes
  - Include other kinds of models, e.g., analytical, design
  - Guidance for model users for when/how to transition
  - Address SysML v2 implementation

MOSA-IF-S-007 Quantities and Units Modeling Standard Overview

- Scope
  - Defines requirements for modeling of quantities and units in SysML models for all value properties representing physical properties
  - Constrains the use of the model implementation of the ISO-80000 standard to avoid inconsistencies
  - Defines a standard library of SysML QuantityKinds and Units that extends the ISO-80000 standard library

- Problems Addressed
  - Inconsistent use of explicit identification of quantities and units in SysML models, resulting in misinterpretation of numerical values in the model
  - Incompatible use of QuantityKinds and Units in the ISO-80000 standard that are compatible in the real world
  - Incompatible bespoke libraries of QuantityKinds and Units that modeling teams must create due to the lack of a standard library they can leverage

- Phase 1 Content (Jul 2025 – Mar 2026)
  - Requirements for explicitly identifying QuantityKinds and Units of value properties
  - Requirements on using standard quantities and units libraries and on creating new QuantityKinds and Units
  - Standard model library of QuantityKinds and Units
    - Includes Priority 1 items only
    - mdzip and xmi formats

- Future Content
  - Evolve the standard library of QuantityKinds and Units
    - Address Priority 2+ items
    - Address new discovered items
    - Unit conversions per National Institute of Standards and Technology (NIST) HB44
  - Address SysML v2 implementation
    - Including SysML v1 to v2 transition and transformation

MOSA-IF-S-008 Model Classification Markings Standard Overview

- Scope
  - Defines requirements for marking of models in MBSE for security classification and dissemination control
  - Emphasis is on DoDM 5200 (and CUI) compliance, at least in intent
    - Identify gaps for marking descriptive models
  - Address other applications of model markings as needed
    - Proprietary, Export Control/International Traffic in Arms Regulations (ITAR), etc.

- Problems Addressed
  - Inconsistent application of portion and banner markings in descriptive models
  - Inconsistent interpretation of portion markings in descriptive models
  - Gaps between security classification guidance and compliance with that guidance in descriptive models

- Phase 1 Content (Jul 2025 – Mar 2026)
  - General requirements for marking models
    - Which models should be marked and how should unmarked models be interpreted?
  - Requirements for marking of model names
  - Requirements for the use of Cameo Data Classification & Marking Plugin in a homogeneous Cameo ecosystem
  - Requirements for banner markings of views

- Future Content
  - Requirements on marking of model elements, relationships, attributes, metadata, etc.
  - Standard interpretation of portion markings applied to different components of a model
  - Address SysML v2 implementation
    - Including SysML v1 to v2 transition and transformation
    - Influence SysML v2 standard if needed to address gaps in ability to portion mark models

MOSA-IF-S-0xx System Structure Modeling Standard Overview

- Scope
  - Defines requirements and guidelines for modeling system structural elements (e.g., blocks, parts, ports, etc.)
    - Government reference or developer architecture
    - Elements that would appear on a SysML Block Definition Diagram (BDD) or Internal Block Diagram (IBD)
      - Blocks/parts, ports, associations/connectors, interface blocks, item flows, etc.

- Problems Addressed
  - Large variation seen in modeling styles used by different agencies, programs, and companies
    - Substantial risk of misinterpretation
    - Poor model interoperability

- Phase 1 Content (Jul 2025 – Mar 2026)
  - None; MVP #1 planned for Phase 3

- Future Content
  - Assess current and emerging standard approaches
    - USG emerging internal standard (Model Composition Pattern) to be assessed
    - Other approaches to be assessed as well
  - Address SysML v2 implementation
    - Including SysML v1 to v2 transition and transformation
    - Influence SysML v2 standard if needed to address gaps in ability to portion mark models

MOSA-IF-S-0xx Model Federation Standard Overview

- Scope
  - Defines requirements and guidance for federating models
  - Defines requirements and guidance for managing model federations and managing federated models
  - Identifies use cases for model federation and defines distinct federation approaches
    - e.g., government-contractor, contractor-contractor, classified-unclassified,

- Problems Addressed
  - Large variation seen in modeling styles used by different agencies, programs, and companies
    - Substantial risk of misinterpretation
    - Poor model interoperability

- Phase 1 Content (Jul 2025 – Mar 2026)
  - None; MVP #1 planned for Phase 4 TBD

- Future Content
  - Assess current and emerging standard approaches
    - Top-down, bottom-up, Science Applications International Corporation (SAIC), Aerospace Pub/Sub, etc.
  - Address SysML v2 implementation
    - Including SysML v1 to v2 transition and transformation
    - Influence SysML v2 standard if needed to address gaps in ability to portion mark models

MOSA-IF-S-0xx Requirements Modeling Overview

- Scope
  - Defines requirements and guidance for modeling requirements and standardized interpretations
    - Different kinds of requirements, e.g., system, work, deliverable (DID), verification, test, etc.
    - Requirement attributes and metadata
    - Requirement relationships

- Problems Addressed
  - Large variation seen in modeling styles used by different agencies, programs, and companies for requirements, their attributes and relationships
    - Substantial risk of misinterpretation
    - Poor model interoperability
  - Loose semantics of SysML requirement relationships

- Phase 1 Content (Jul 2025 – Mar 2026)
  - None; MVP #1 planned for Phase 4 TBD

- Future Content
  - Assess current and emerging standard approaches
  - Address SysML v2 implementation
    - Including SysML v1 to v2 transition and transformation
    - Influence SysML v2 standard if needed to address gaps in ability to portion mark models

MOSA-IF-S-0xx Model Usability Standard Overview

- Scope
  - Defines requirements and guidance for improving the usability of descriptive models for MBSE
    - Model navigation
    - Model organization
    - Model ergonomics
    - Model view readability

- Problems Addressed
  - Large variation seen in modeling styles used by different agencies, programs, and companies
    - Results in interpretability and usability challenges for human and machine users
  - Model value is limited by ability of users to extract useful information from them
    - Improve usability to improve model value

- Phase 1 Content (Jul 2025 – Mar 2026)
  - None; MVP #1 planned for Phase 4 TBD

- Future Content
  - Assess current and emerging standard approaches
  - Address SysML v2 implementation
    - Including SysML v1 to v2 transition and transformation
    - Influence SysML v2 standard if needed to address gaps in ability to portion mark models

MBSE Modeling Standards Committee Standards Background and Considerations

MOSA-IF-S-006 Model Semantic Versioning Standard

Background

- Users must decide if/when they will transition to a new model version based on potential impact

- An update may…
  - Supersede previous information that was previously in the model
    - Previously obtained information from the model may be obsolete
    - Analyses may need to be re-performed
  - May break queries or other mechanisms used to extract information from the model
    - Rework may be needed to update those queries or other mechanisms
  - May break the model's connections to other models in the users' model federations
    - Rework may be needed to re-establish those connections

- Changes in model form may result in new interpretations of the modeling language notation
  - May drive rework or the need for retraining of model users

- A new major version number signals the presence of significant changes
  - Likely to drive the need for rework in one or more of these areas

MOSA-IF-S-006 Model Semantic Versioning Standard

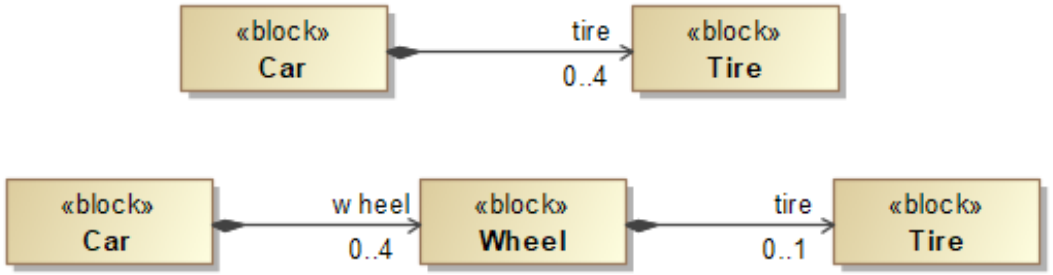
Content of the Standard

- Require models be versioned
- Require released models to be given semantic version numbers
- Standardize format for semantic version numbers
- Standardize criteria for incrementing semantic version numbers
  - Separate criteria for major, minor, and patch versions

MOSA-IF-S-006 Model Semantic Versioning Standard

Information Content Criteria for Incrementing the Major Version Number of a Model

- Deleting or changing information in the model
  - Impacts everyone who was using that information
- Adding information in existing categories
  - Impacts queries that were leveraging those categories
- Adding, changing, or deleting intermediaries
  - Breaks the graph structure that queries leverage
- Deleting or significantly updating existing model views
  - Impacts users who were relying on those views
- Establishing a formal baseline
  - Align with user expectations and more clearly identify incremental changes
- Increasing classification level or dissemination control of any model element or view
  - Impacts users who may no longer have access at the higher classification



MOSA-IF-S-006 Model Semantic Versioning Standard

Model Form Criteria for Incrementing the Major Version Number of a Model

- Changing or deleting existing stereotypes or tags
  - Impacts model queries expecting to see those
- Adding an existing stereotype (that already exists in the model) to a model element
  - Impacts queries that were leveraging those stereotypes
- Adding, updating, or deleting a model profile
  - Impacts queries and may drive cascading rework across model federation
- Changing or deleting model elements that serve as base classifiers of other model elements
  - Impacts queries with propagating impacts to all specializations
- Changing or deleting quantities or units used in the model
  - Impacts interpretation of numerical properties
- Changing the implementation of elements or relationships
  - Impacts queries and model federation

MOSA-IF-S-006 Model Semantic Versioning Standard

Criteria for Incrementing the Minor Version Number of a Model

- Adding information to the model
  - Where it does not satisfy the criteria for incrementing the major version number
  - Mostly, this will be completely new information
  - It wasn’t in the model before, so no one could have been using it

- Adding new model views
  - It wasn’t in the model before, so no one could have been using it

- Decreasing classification
  - Less constraining on access

MOSA-IF-S-006 Model Semantic Versioning Standard

Information Content Criteria for Incrementing the Patch Version Number of a Model

- Typographical corrections to information content in the model that doesn't impact its interpretation
  - Generally, limited to natural language content

- Cosmetic changes to existing model views
  - Moving boxes or lines around on the diagram should not change their formal meaning
  - Sometimes modelers attach semantics to these cosmetic details, which is problematic

- Addition, change, or deletion of model content clearly identified as non-essential
  - e.g., experimental sandboxes or temporary views
  - Content not intended for anyone else to use and is clearly marked accordingly

MOSA-IF-S-007 Quantities and Units Modeling Standard

Background and Implications

- System models containing properties with ambiguous quantities or units may be misinterpreted by human or machine model users

- If physical properties are not clearly defined with units, their true value may not be properly interpreted
  - Is a mass of "5" intended to be 5 kg, 5 g, or 5 lbm?

- Physical properties should also have clearly defined quantities, or they may also be misinterpreted
  - Does N-m represent torque or energy?

- System models, data sets, and software applications should all use consistent quantities and units
  - Or at least properly convert them when inconsistent units are unavoidable

Image Credit: NASA
https://science.nasa.gov/mission/mars-climate-orbiter/

Mars Climate Orbiter, a casualty of misinterpreted units (not just SI vs. USCS units!)

SI: “Système international d'unités” or “International System of Units”
USCS: “US Customary System”

MOSA-IF-S-007 Quantities and Units Modeling Standard

Quantities and Units in SysML Models

- Most SysML models do not consistently use the built-in capability of SysML to specify quantities and units of value properties
- The implementation of quantities and units in the SysML standard has changed several times from SysML 1.0 through 1.4 but has remained stable ever since
- ISO 80000 is the authoritative standard for the use of SI, defining standard quantities, units, and prefixes
- Cameo and other SysML tools typically implement the ISO 80000 standard since it is specified in the SysML specification
  - Still, its use is not widespread

MOSA-IF-S-007 Quantities and Units Modeling Standard

Content of the Standard

- Require SysML 1.4+ standard modeling approach for QUDV (Quantities, Units, Dimensions, & Values)
- Require consistent use of quantities and units for value properties representing physical properties
- Require consistent use of general QuantityKind and Unit to avoid incompatibilities
- Specify precedence order for using libraries of QuantityKind and Unit elements
- Provides a standard library of QuantityKind and Unit elements widely used in the community
  - Not limited to the space domain
- Does not require use of SI units or preclude use of USCS units!

MOSA-IF-S-008 Model Classification Markings Standard

Background

- Current guidance for security classification marking (e.g., DoDM 5200.01) and CUI marking (e.g., DoDI 5200.48) was written for documents and does not provide adequate clarity for descriptive models
- Other needs for dissemination control and/or data rights markings such as proprietary, Non-Disclosure Agreement (NDA)-controlled, Export Controlled, International Traffic in Arms Regulations (ITAR)-controlled, etc. information are not addressed for descriptive models either
- Models are similar to documents in being a manifestation of information content
- However, they are very different from documents in many ways
  - There is generally no clear “face of the document” where some of these markings must appear
  - There is often no place to put the equivalent of “banner markings” other than on some diagrams and tables
  - Model elements can be reused in different contexts, but often cannot have different markings in those contexts to reflect their different classification in those contexts
  - Some model elements cannot be readily marked at all
  - No one marking method will work for all elements
  - What does marking an element even mean??

- Establishing a standard implementation of marking of models is a challenge
- Establishing guidance for when to mark elements and how to interpret those markings is a greater challenge

MOSA-IF-S-008 Model Classification Markings Standard

Content of the Initial Standard

- Requirements for marking of a model as a whole
- Requirements for use of the Dassault Systemes Cameo Data Markings and Classification Plugin
  - And for interpretation of some malformed markings it produces
- Requirements for banner marking of views

MOSA-IF-S-008 Model Classification Markings Standard

Content of the Second Iteration of the Standard

- Requirements for marking models with one or more Protection Declaration Notices
  - Classification Authority Block
  - CUI Designation Indicator
  - Similar required content for proprietary, export controlled, etc., information

- Requirements for marking models with Implied Marking Notices
  - Implied markings are markings to be assumed apply to each unmarked model element within a specific scope
  - Overriding those implied markings with explicit markings

- Requirements for marking elements meeting certain criteria
  - Name is classified
  - Content is classified
  - Nested content (e.g., contained items in a package) is classified

MOSA-IF-S-008 Model Classification Markings Standard

Work in Progress, for Second Iteration and Beyond

- Requirements for marking specific kinds of SysML v1 model elements
  - Prefix portion marking in name
  - Suffix portion marking in name
  - Stereotype and/or tags
  - Annotations
  - Data Marking & Classification Plugin
  - Not only the implementation but also the interpretation of these markings
  - Also, define when it is necessary to explicitly mark an item

- Requirements for marking specific kinds of SysML v2 model elements