PLM Road Map™ & PDT North America 2024
Value Drivers for Digitalization of the Product Lifecycle
Insights for the PLM Professional—Why the investment, what are the returns, and how are they achieved?
May 8 & 9

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MBSE Collaboration with SysML 2.0: A Pre-Release Investigation

Chris Watkins, AD PAG MBSE Project Leader

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- 25yrs Experience / 13yrs Gulfstream
- Associate Fellow, American Institute of Aeronautics and Astronautics
- BS Electrical Engineering
  Kettering University
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  Missouri University of Science and Technology
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  Caltech
- Private Pilot

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Aerospace & Defense PLM Action Group
Founded in February 2014

Mission

- An association of aerospace & defense companies within CIMdata's globally recognized PLM Community Program, which functions as a PLM advocacy group to:
  - Set the direction for the aerospace & defense industry on PLM-related topics that matter to members
  - Promote common industry PLM processes and practices
  - Define requirements for common interest PLM-related capabilities
  - Communicate with a unified voice to PLM solution providers
  - Sponsor collaborative PLM research on member-prioritized industry and technology topics
- Website: www.ad-pag.com

Members

AIRBUS

BOEING

GE Aerospace

Gulfstream
A GENERAL DYNAMICS COMPANY

PRATT & WHITNEY
DEPENDABLE ENGINES

Rolls-Royce

SAFRAN

SPIRIT AEROSYSTEMS

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MBSE Project Presentation Agenda

ADPAG Project Focus: MBSE Collaboration

Phase 5 Objective: Collaboration with SysML 2.0

Phase 5 Current Findings

Phase 5 Next Steps

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ADPAG Project Focus
MBSE Collaboration

- SE/MBSE Workflow is Inherently Complex and Collaborative
- OEMs & Suppliers Are Invested in Different MBSE Tool Chains
- MBSE Tool Collaboration Lacking (Standards, Openness)
- ADPAG Investigating MBSE Collaboration Since 2018
- Business Case: DARPA, NIST, and AVSI estimate the model interoperability opportunity cost to exceed > $1billion per product across the Lifecycle

* NIST GCR 04-867 Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry, https://www.nist.gov/news-events/news/2020/02/inadequate-modeling-data-costs-billions-us-manufacturers

PROBLEM STATEMENT:
Currently there are no common methods and standards for exchanging digital model-based requirements and architecture deliverables for the design, procurement, and acceptance of aerospace systems equipment across the industry.

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ADPAG MBSE Collaboration Journey

- Phase 1 (2018): Project Definition and Organization
- Phase 2 (2019): Recommended/Ranked Potential Digital Exchange Solutions
- Phase 3 (2020): Direct Data Exchange Use Cases
- Phase 4 (2022): Indirect Data Exchange Use Cases
- Phase 5 (2023): SysML 2.0 Pre-Release Evaluation

* Phase Kick-off Year

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Phase 5 Objective: Collaboration with SysML 2

Evaluate SysML v2.0 and Provide Feedback to Tool Vendors

Focus Areas

- SysML 2.0 Syntax/Notation
- SysML 2.0 Application Programming Interface (API)

Activities

- SysML 2.0 Vendor Engagement
- Pre-Release Tool Evaluations
- Benefits and Gap Identification
- External Considerations

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Phase 5: Current Findings

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Syntax/Notation Purpose

Abstract Syntax: Metamodel
- Authoritative data source
- API read/write

Concrete Syntax: Textual Notation
- Can be used as authoritative data source for lite models
- Lacks UUID – poor change management
- API read/write

Concrete Syntax: Graphical Notation
- Not used as authoritative data source
- Lacks UUID – poor change management
- View of authoritative model for human understanding

Model Interchange Format
- Not used as authoritative data source
- Archived Copy: Share unsynchronized data
- Unreliable: not sure how or where data was produced (doesn't self-document its origin)

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SysML 2.0 Use Cases
1 of 3

- Use Cases Assume Abstract Syntax is Authoritative Source
- Simplification: One model repository shown in use cases, multiple repositories likely in real projects

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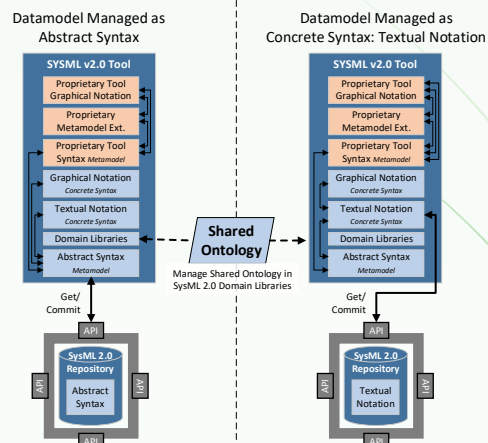
SysML 2.0 Use Cases — 2 of 3 — Boeing Collaboration Levels / Airbus Collaboration Schemes

Unidirectional Exchange: Project Interchange File, Shared Model Repository(s). Bidirectional Exchange: Project Interchange File.

SysML 2.0 Use Cases — 3 of 3 — Boeing Collaboration Levels / Airbus Collaboration Schemes

Collaboration: Shared Model Repository(s), Referenced Model Repository(s). Platform Co-Simulation: Shared Model Repository(s), Referenced Model Repository(s).

Tool Implementation Options

WORK LOCALLY (GIT LIKE)

- **Repo is Managed by User**
- User GETS model from repo, which creates local copy
- User COMMITS model to repo, after making changes

WORK REMOTELY

- **Repo is Transparent to User**
- User opens model, which is stored in repo
- Tool manages GET/COMMIT behind the scenes
  - User edits model in local computer memory
  - Tool decides when to COMMIT changes to repo

*ADPAG PLANS TO IDENTIFY PREFERRED TOOL IMPLEMENTATION
AND COMMUNICATE TO TOOL VENDORS*

Datamodel Managed as Abstract Syntax

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Tool Implementation Options

BROWSER BASED TOOL

- **No Install for Users**
- Access from any computer that can access tool server
- IT:
  - Requires server(s) that can handle load for many users
  - Tool version management outside direct control of users

APP INSTALLED ON USER COMPUTER

- **Direct Version Control and Potential Performance Improvement**
- IT:
  - Requires tool installation on user computer
  - Users have direct control of tool versions

*ADPAG PLANS TO IDENTIFY PREFERRED TOOL IMPLEMENTATION
AND COMMUNICATE TO TOOL VENDORS*

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SysML 2.0 Tool Evaluations

	Graphical Notation	Textual Notation	Containment Tree	Import / Export (XML)	Standard Import / Export (.kerml)	Standard Import / Export (.SysML)
SysML v2 - Eclipse Pilot Implementation (release 2022-09)	Only Visualization	Yes	No edition from Containment Tree	No (Import / Export)	No (Import / Export)	Yes (Export)
SysON (v2024.1.0)	Yes, but limited to structural viewpoint (No behavior)	No	Edition without assistant (Need to create each relationships) ⇒ Expert Oriented	Yes (Import / Export) but not compatible with CATIA MCSE	No (Import / Export)	No (Import / Export)
CATIA Magic Cyber Systems Engineer - 2024x (R1 - Alpha 1.2) (CAMEO)	Unable to share due to Non-Disclosure Agreement					

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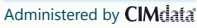
Known SysML 2.0 Vendors

ANSYS	IncQuery	**Obeo (SysON)**
Dassault Systèmes Magic Cyber Systems Engineer (Cameo)	Intercax (Syndeia)	PTC (Windchill Modeler)
IBM (Rational Rhapsody)	Maplesoft/MapleSim	Qualtech Systems, Inc (QSI)
Siemens	Mathworks *	Sparx (Enterprise Architect)
Imandra	Mgnit Inc.	Tom Sawyer Software
OMG (Pilot Implementation Eclipse / Jupyter)		

Evaluated Purple Tools

* AD PAG engaged MathWorks, a new entrant to SysML. We surveyed each other on SysML 2.0.
MathWorks has announced Plan to Release SysML 2.0 Tool in 2025

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General Findings

Initial Release of SysML 2.0 is Lacking/Incomplete

- Adoption likely to increase in future SysML 2.x releases

Adoption & Transition

- All-new projects will likely adopt SysML 2.x (rare to not start with past models)
- Big Barrier to Adoption: Tool vendors need to support effective SysML 1.x to 2.0 translation functions with confidence of no data loss

Tool Vendors are Building SysML 2.0 Tools NOW

- Open source + commercial pre-releases available now
- Flood of vendors with plans for production releases in 2024 + 2025
- New entrants in SysML tools

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Encouraging Findings

Collaboration Greatly Enhanced by Abstract Data Model + APIs

- Open, standardized API interface to data model repositories enables tool integration
- Common metamodel & shared ontology in domain libraries enables collaboration

SysML 2.0 Drove Reset in Vendor Market

- Fostered vendor excitement
- New SysML tool entrants
- Raised hope in tool collaboration / lost interest in bespoke tool integrations

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Biggest Gaps

Lack Graphical Layout in Abstract Syntax & Textual Notation

- Layout important to understanding
- Must rely on tool auto-layout capabilities
- Significant discussion at 2024 INCOSE International Workshop (IW)

Poor Universally Unique ID (UUID) Support

- Textual & graphical notations don't support UUIDs
- Abstract metamodel DOES define UUID as element property
- Global uniqueness needs further investigation: SysML 2.0 states high probability of uniqueness, but not guaranteed uniqueness

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Other Gaps

Ambiguity Between Textual and Graphical Notations

- Inconsistent model translation by different tools

Semantics Defined for Model Execution, but not for Static Model Constructs

Lack Mapping of SysML 2.0 Queries to External Queries, ex. SQL, openCypher

Physics Model Interaction Not Addressed

OMG Didn't Focus on Interoperability (yet)

- SysML 2.0 query mapping to external queries
- Data Governance explicitly excluded from SysML 2.0. Tool implementation specific, driving compatibility issues.
- Interoperability Working Group being established in OMG now (late)

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SysML 2.0 API Investigation Kicked Off

- **INVESTIGATING** Aerospace Use Cases for SysML 2.0 APIs
- **EVALUATING** an Experimental SysML 2.0 API Prototype
    - Freeware prototypes (limited in functionality)
    - Map the use cases to API feature support
    - Evaluating API capabilities
    - Determine if APIs are sufficiently defined for A&D industry
    - Plan to evaluate APIs in commercial tools when available

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Phase 5 Next Steps

- In-Tool Evaluations of SysML 2.0 Syntax/Notation
    - Dassault CATIA Magic Cyber Systems Engineer (Cameo)
    - IBM Rhapsody   *Pre-Releases*
    - Mathworks System Composer
- In-Tool Evaluations of SysML 2.0 APIs
- Interoperability Test: Exchange Model Between Tools
    - Abstract Syntax, Textual Notation, Project Interchange File
- Priorities for SysML 2.0 Subpart Conformance
- Compare SysML 1.x Graphical Notation to SysML 2.0
- Migration from SysML 1.x to 2.0 Benefits & Challenges
- Additional Considerations External to SysML 2.0
- Publish Phase 5 Report Q1 2025

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