2021 Annual INCOSE international workshop
Virtual Event
January 29 - 31, 2021

Where is your Roadmap for implementing MBSE Data Standards?

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Tools Integration & Model Lifecycle Management (TIMLM WG)

January 28th, 2021

Presentation Abstract

MBSE data standards are being developed by a wide range of consortia and continue to evolve. What are the functions and capabilities of the different standards? What standards are released and available for use today? What are the roles of the different standard bodies and who is involved? How does each company develop a strategy and roadmap?

Lots of MBSE data standards: but need forums/industry/consortia to create/validate standards, and recommend enhancements.

Your participation is needed!

(implementer Forums, industry groups, standard bodies)

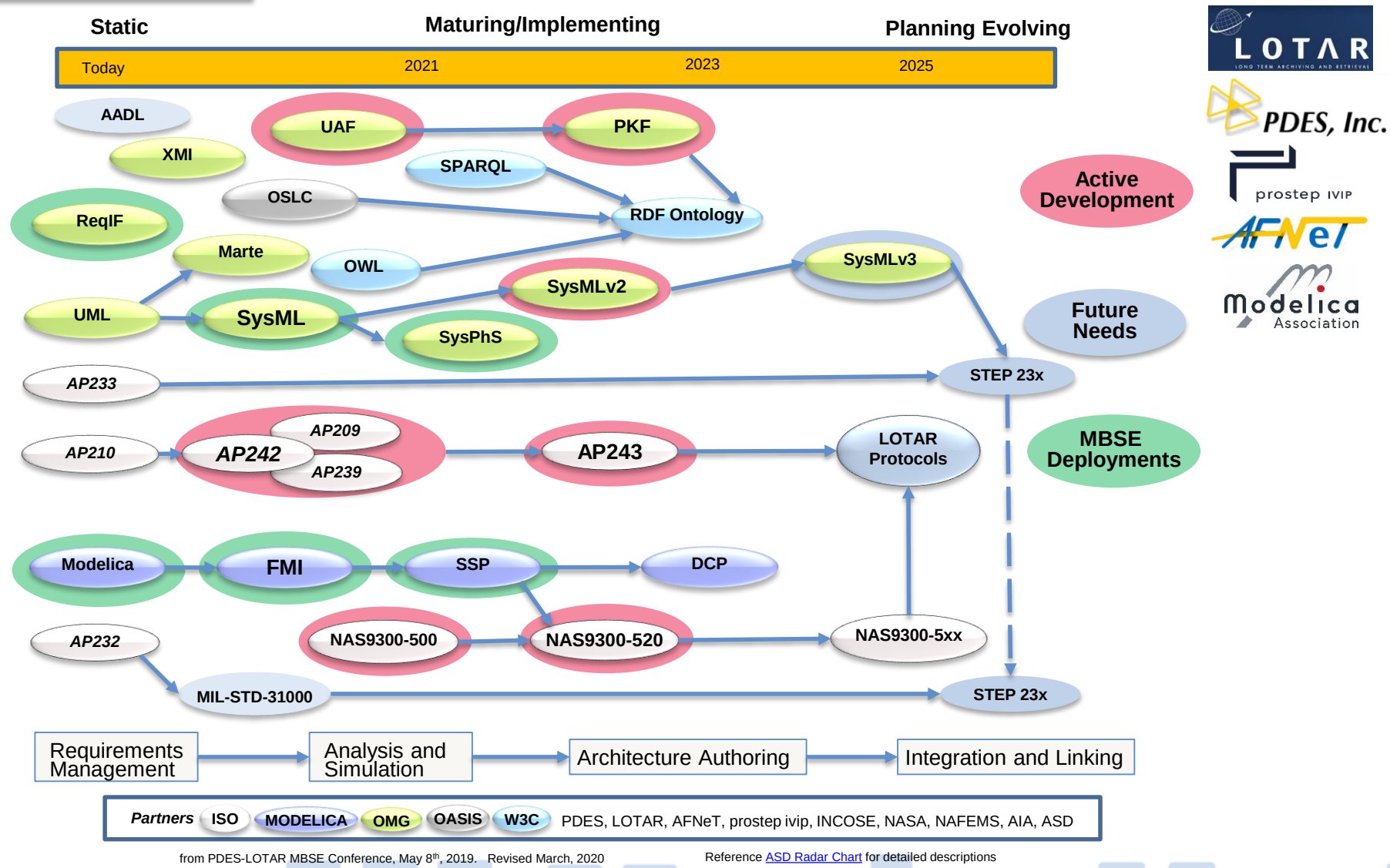
Why MBSE Data Standards?

- OEM – Supplier Design Development
- Collaboration opportunities
- MBE digital thread and model interactions
- Data preservation and reuse
- Prerequisite for standard process and procedures

Four categories of Standards?

- **Data and Interoperability Standards**: *includes modeling, exchange or language standards*
- **Process standards**: *specifications for methods, outcomes, compliance, lifecycle*
- **Procedural standards**: *for data measurement, testing and qualification*
- **Part/Product (Design) Standards**: *dimensional, material, operation, performance, protocols/specifications*

MBSE Data Interoperability Specifications



from PDES-LOTAR MBSE Conference, May 8th, 2019. Revised March, 2020

Reference ASD Radar Chart for detailed descriptions

Standards Bodies and Consortia

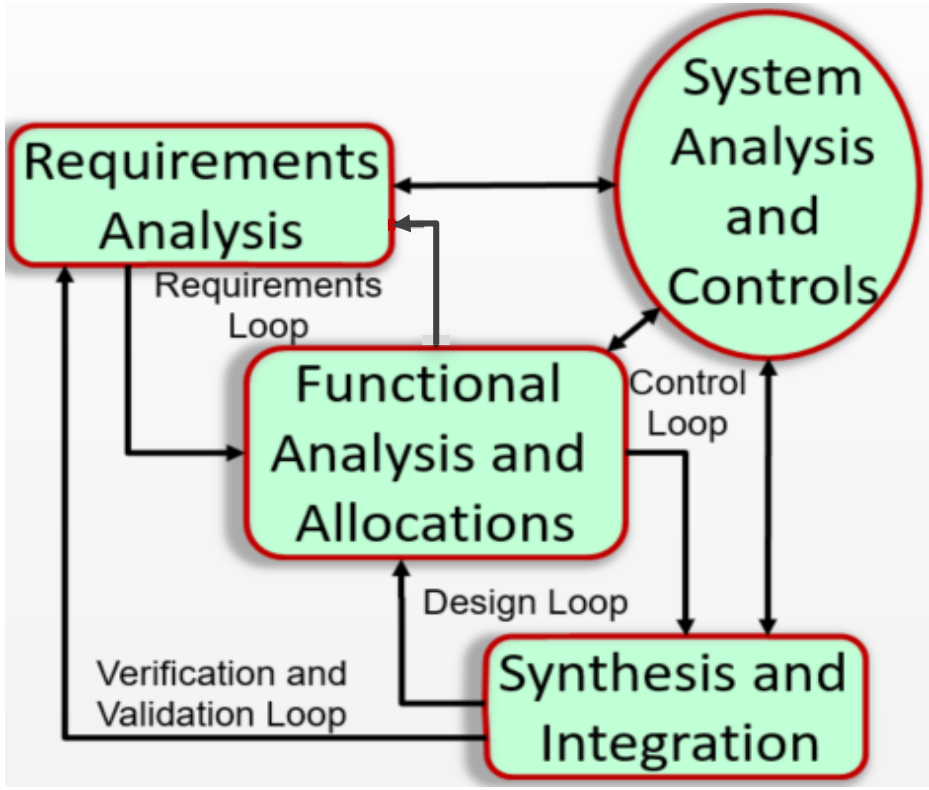
MBSE Standards Development

- PDES, MBSE WG (STEP, MoSSEC, INCOSE MoU)
- LOTAR, MBSE WG (data preservation and reuse)
- Modelica Association (MBD, language, FMI, SSP)
- NAFEMS (consortium, Systems Modeling & Simulation)
- AFNeT (consortium, digital transformation/stds)
- prostep ivip (consortium, industry best practices)
- AVSI (Academia, virtual integration, PBR/PMM)
- Others: W3C, OMG, OASIS, OAIS, INCOSE,

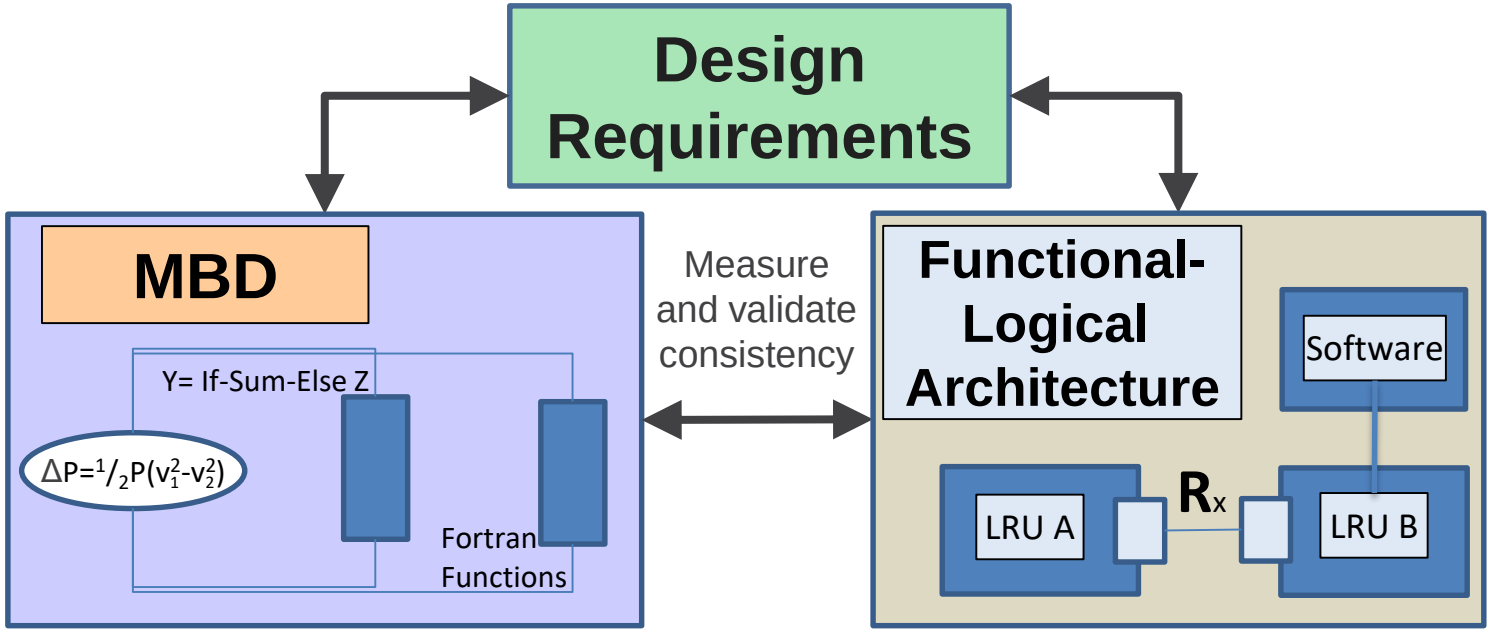
Industry and Governance

ISO, NASA, ASD, AIA, A&D PLM Action Group, GPDIS

MBSE Capabilities: Data Types



MIL-STD-499

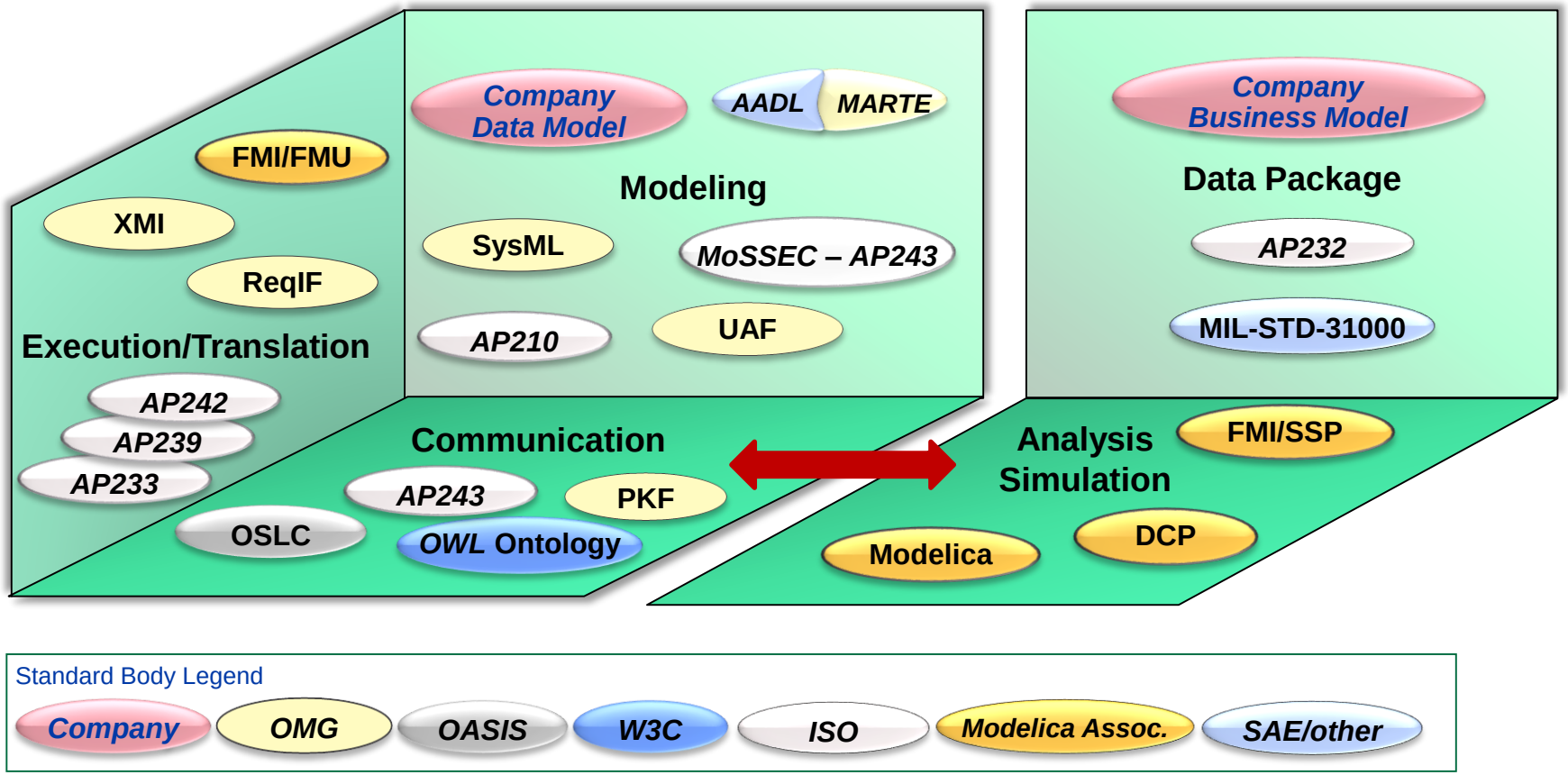


System Behavior, Performance, Controls, Code Generation, Acausal - Lumped Parameter models

System Architecture, Connectivity, Data I/O, Requirements Allocations, System Structure

MODELS

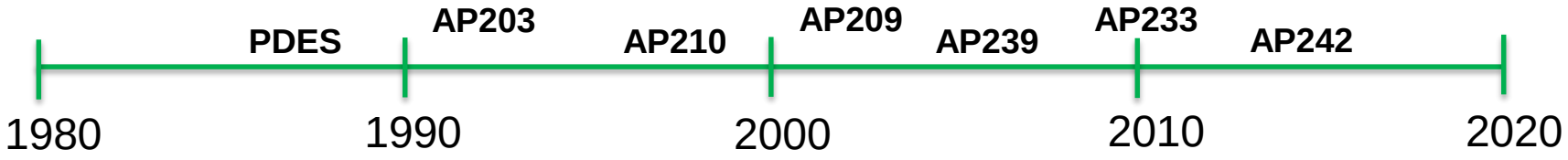
MBSE Data Standard Categories



CREDIT: Bill Chown, Mentor Graphics; MBSE Roundtable, 2015 GPDIS

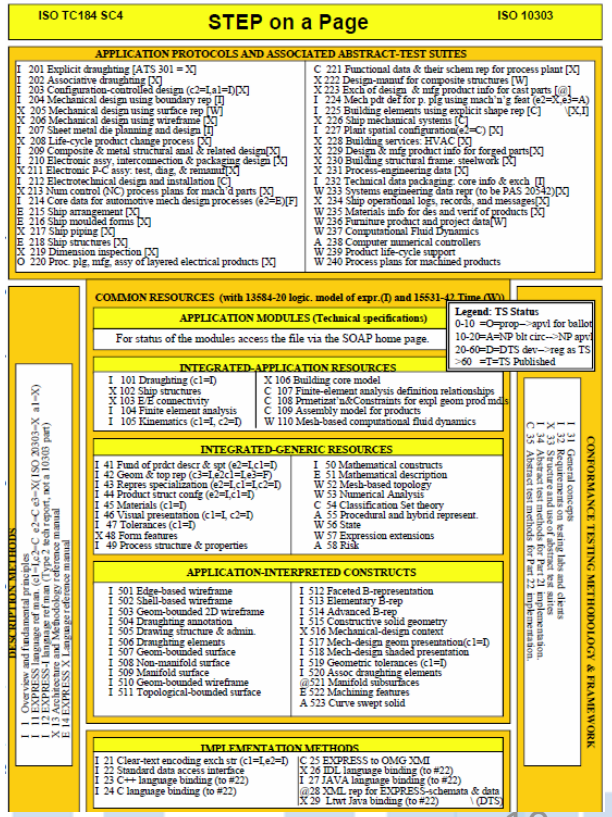
PDES, Inc.

PDES, Inc. is an international consortium joining industry, government and academia.



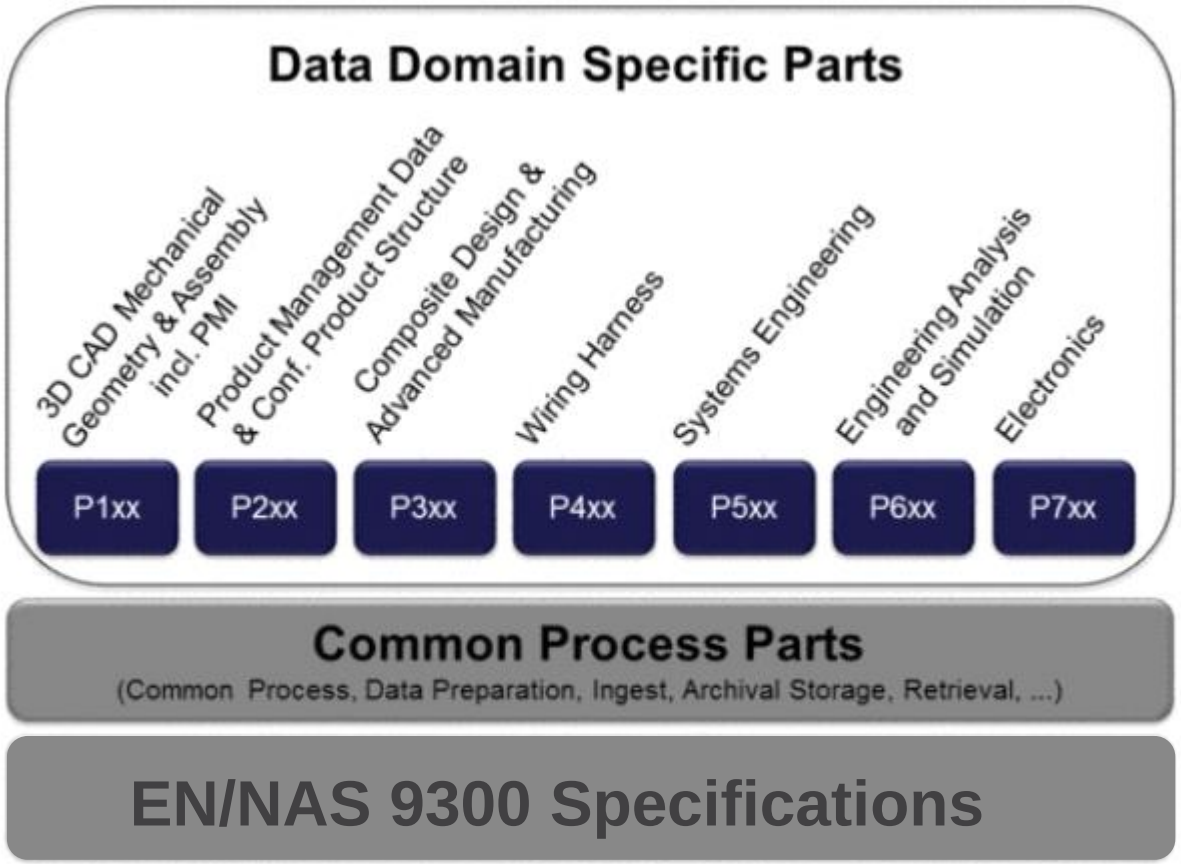
Formed in 1988 to standardized data exchange and accelerate the development and implementation of standards.

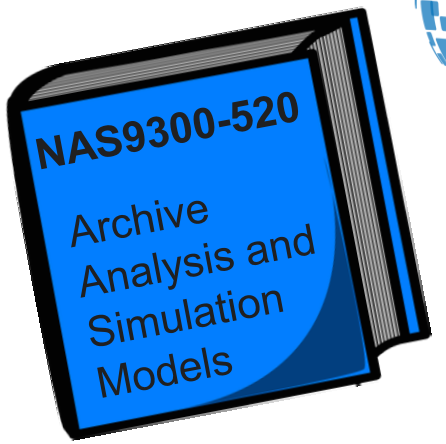
PDES = Product Data Exchange Specification
(Product Data Exchange using STEP)

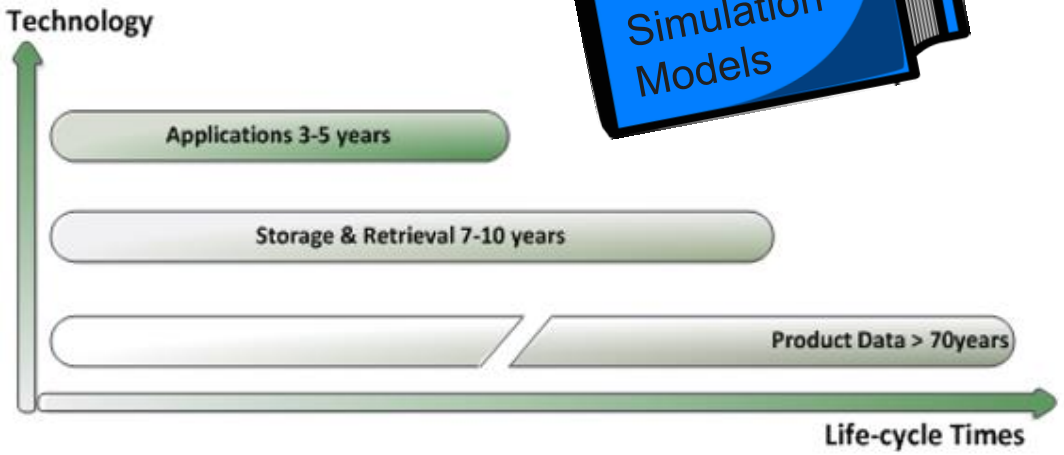


LOTAR Parts Structure

LOTAR International is supported by the AIA and PDES Inc. in the US, ASD-STAN and ProSTEP iViP in Europe







LOTAR is Enabled by Standards

- Data preservation, Reuse, Accident Investigations, Maintenance, Regulations, Obsolescence, Safety
- Assume Application versions 3yr; storage/access 10yrs; translate to stable formats for 50yr product cycles.

Modelica Standards: FMI, SSP, DCP

FMI: Functional Mock-up Interface

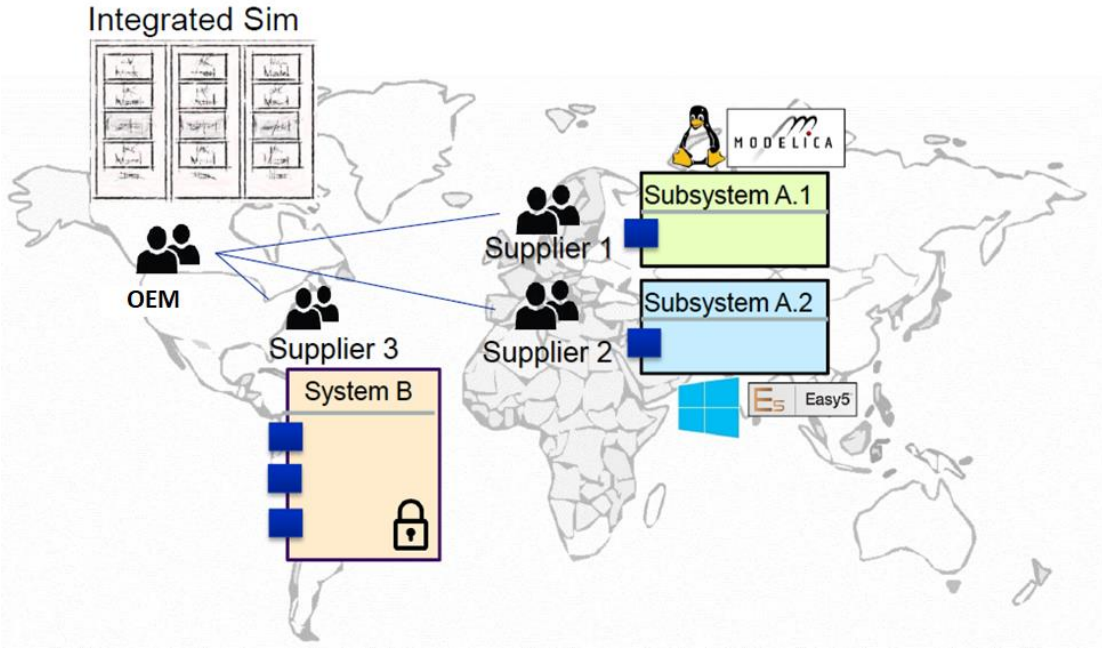
- ✓ **Supplier – OEM Model Exchange**
- ✓ **Early requirements validation**

SSP: System Structure and Parameterization

- ✓ **Supplier – OEM Simulation Exchange**
- ✓ **Traceability with Architecture definition**

DCP: Distributed Co-simulation Protocol

- ✓ **High fidelity, real time co-simulation**



fmi Functional Mock-Up Interface

End users have identified Improvement Areas

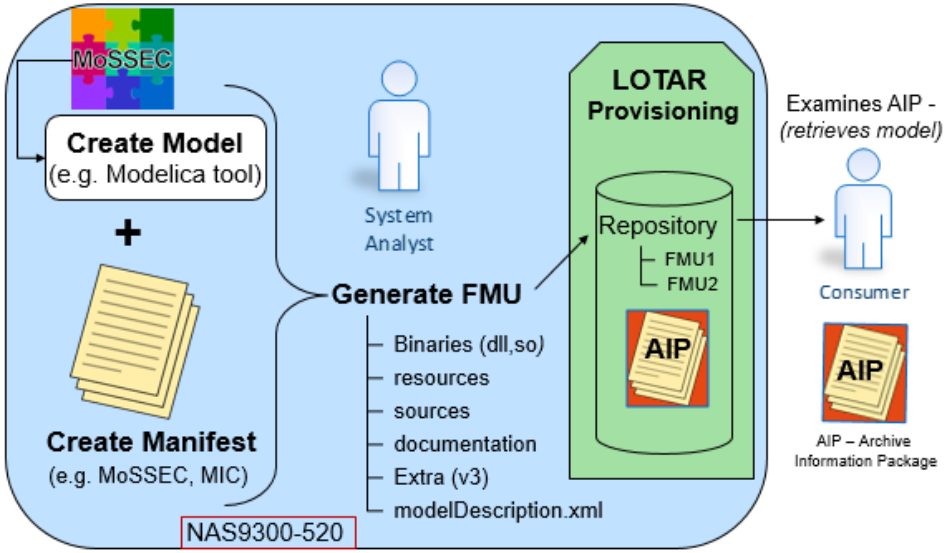
Juan Carlos Mendo,
Boeing Research & Technology - Europe

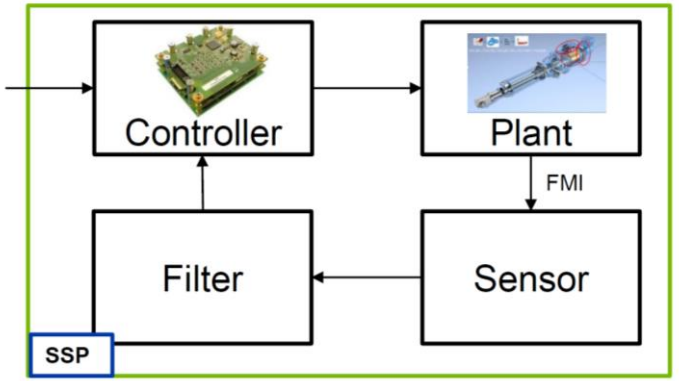
Industry Use Case: Reuse of FMI and SSP models

Industry collaborative prototype. LOTAR-PDES Activity.

Goals are:

- ✓ **Define the process to archive and retrieve behavioral/ executable models (particularly the MBSE use case).**
- ✓ **Define the process to archive and retrieve simulations**
- ✓ **Identify changes to the FMI and SSP Standards for Modelica.org**
- ✓ **Align and bring together AP243 and the concept of the Model Identity Card (MIC)**
- ✓ **Deliver a LOTAR prototype that can be reused for other MBSE model types**

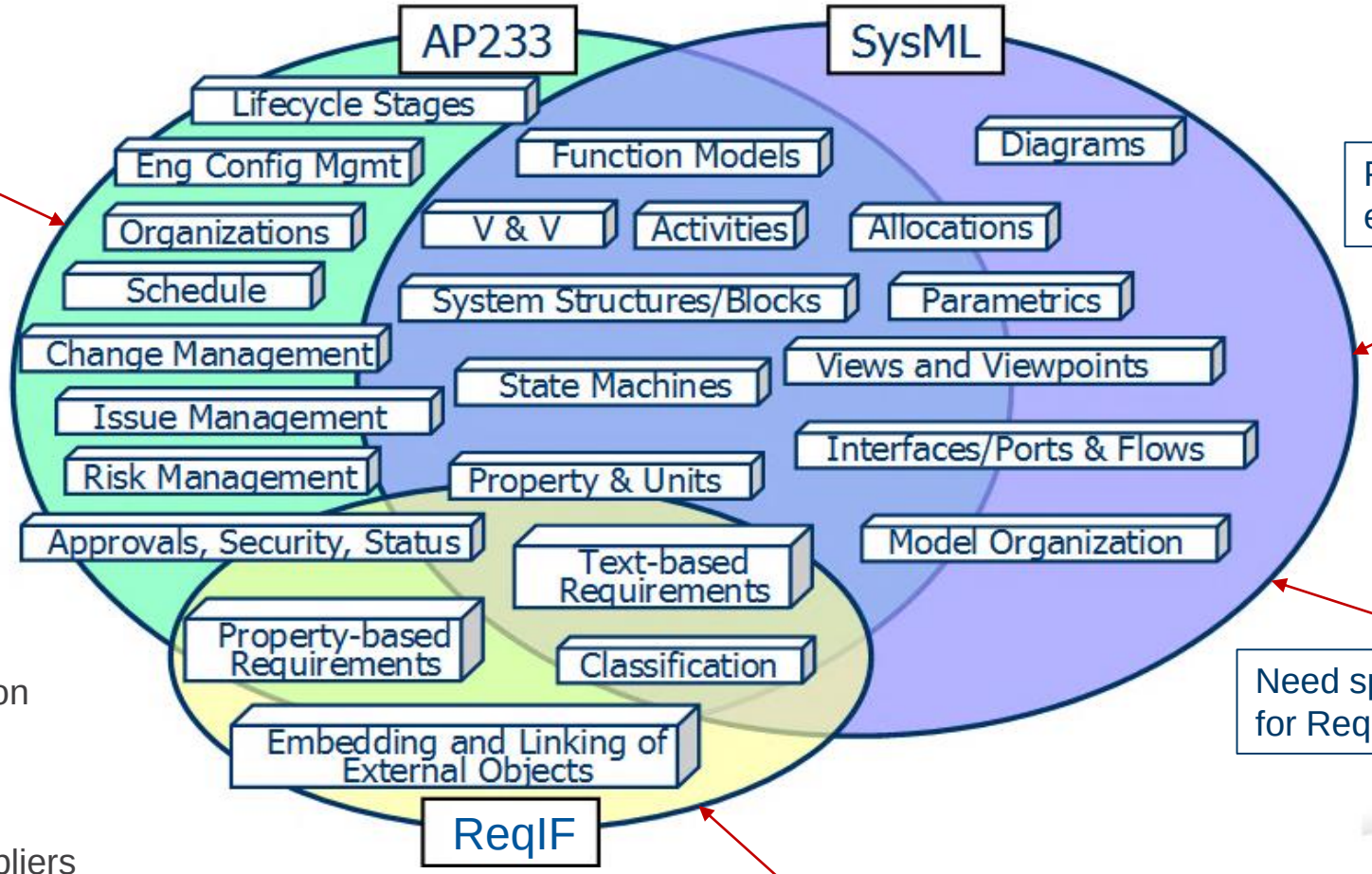




Closed loop Actuation Industry use case

Juan Carlos Mendo,
Boeing Research & Technology

The Need for Harmonization



Exchange standard not implemented in the tools

Product Structure is not exposed in PLM systems

Need specification support for Requirements traceability

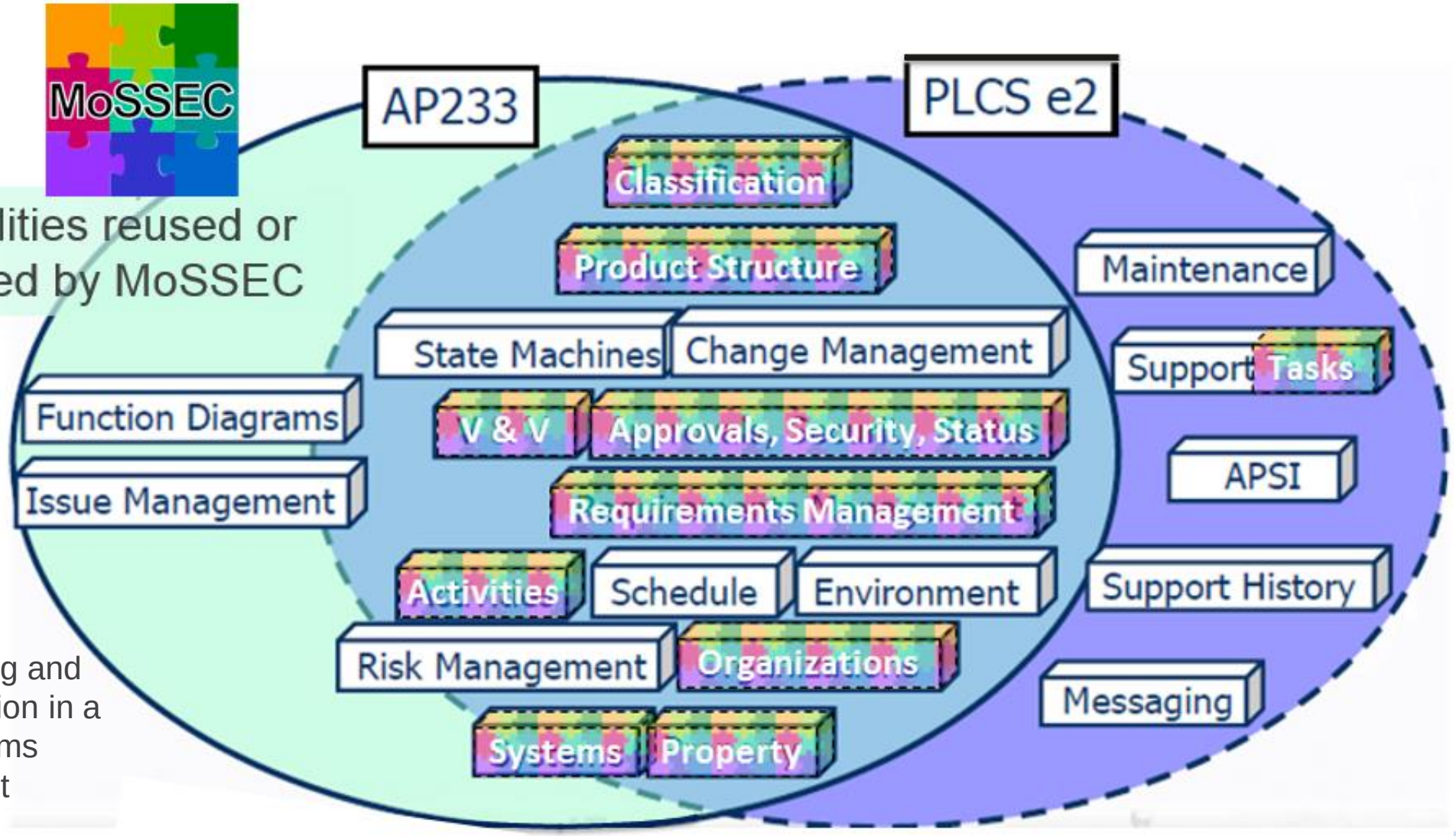
Limited support for Requirements development and traceability strategies

Process Support

- Requirements Allocation
- Design Authoring
- Analysis Verification
- Data / Info Context
- Data Exchange – Suppliers
- Enables Digital Thread

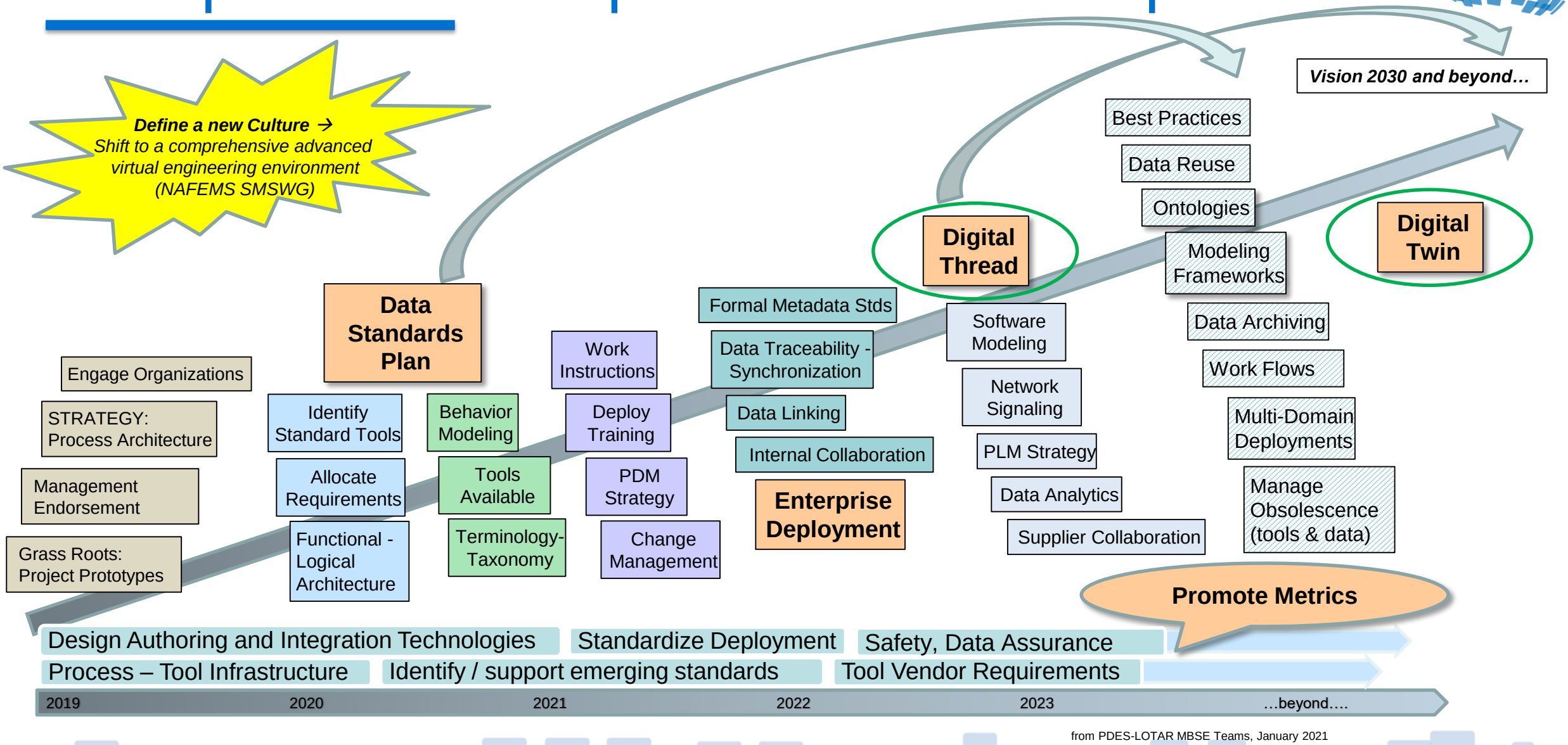
Source: Eurostep

AP233 + AP239 + AP243



MoSSEC = Modeling and Simulation Information in a Collaborative Systems Engineering Context

Sample MBSE Capabilities Roadmap



from PDES-LOTAR MBSE Teams, January 2021

Collaboration Strategies

1. Share data/models without expectation of receiving model revisions
2. Share data/models using a drop-box technology with the expectation to make changes and iterate the sharing process. Must manage multiple versions.
3. Use a secured common repository, or interactive environment, where data/models from all parties are shared and executable. The shared models represent the latest version. Add additional controls to support model modifications, and sister repositories for comparative trade studies.

Test your knowledge of MBSE standards and the related consortia

MBSE QUIZ

1. What are the MBx's and MBxx's (Model-Based acronyms) and how do they relate?
    a) Marketing terms developed by the PLM Solution Providers
    b) Ecosystems developed within a digital framework
    c) New academic sciences that are driven by the data standards consortia

2. Define the acronyms "STEP" and "AP" used in a data standard's descriptive name
    a) Standard Transactions to Exchange Parts, and Advanced Protocols
    b) Standard for the Exchange of Product model data, and Application Protocols
    c) Standards to support Enterprise Processes, and Application Processes

3. STEP technology developed in the 1980s, used EXPRESS as a modeling language. The "STEP Extended Architecture" is a significant evolution of this initial framework, and the first STEP protocols (AP) implementing this architecture are planned in 2021 (AP243 MoSSEC and AP239 ed3 PLCS). **Which modeling language is used in the STEP Extended Architecture?**
    a) JAVA and JSON
    b) ExpressLite using Python libraries
    c) SysML and STEPLib

4. Define the SysML acronym
    a) Systems Modeling Language
    b) Systems Modeling Linguistics
    c) System Model Layout

5. Identify the first major STEP AP specification sponsored-endorsed by INCOSE, depicting a Systems Engineering model.
    a) SysML
    b) AP239
    c) AP233
    d) AP232

6. The European consortium that developed the STEP Systems Engineering Application Protocol?
    a) CORDIS_CRESCENDO
    b) ARTEMIS-CESAR
    c) ESPRIT_SEDRES

7. Identify one of the many sources or references for the STEP SE AP?
    a) IEEE 1220
    b) ANSI\EIA-632A
    c) ISO 15288
    d) ISO-15289
    e) All of the above

8. What is the ISO standard defining the Systems and software engineering design Architectures?
    a) ISO/IEEE 42010
    b) ISO/IEEE 42020
    c) ISO/IEEE 42030

9. What is one of the alternative descriptive names for AP239?
   a) STEP Application Protocol for Uniform Shapes
   b) Exchange of Product and Support Information
   c) PLCS, or “Product Lifecycle Support”
   d) a and c
   e) b and c

10. Name at least three of the Data Standard consortia (or standard bodies) supporting MBSE.

11. Define the SOSA data standard acronym, or the specification’s governing body.
   a) System Operations Standards Organization
   b) Sensor Open System Architecture Standard
   c) Air Force Life Cycle Management Center (AFLCMC)
   d) The Open Group
   e) a and d
   f) b and c
   g) b and d

12. Define the MoSSEC acronym
   a) Models of Sub-Systems for Engineering Collaborations
   b) Models of System Simulations, Extensions and Controls
   c) Models of System Simulations for Engineering Collaboration
   d) Modelling and Simulation Information in a Collaborative Systems Engineering Context

13. What types of models are created using the AADL or MARTE language stds?
    a) The functional analysis of decomposed stakeholder requirements
    b) Functional Architectures of Portable Requirements
    c) Signal allocations to electrical transport elements
    d) Embedded and Loadable Software Architectures and Analysis

14. What Data Standard consortium created SSP and DCP?
    a) the Digital Modeling Association
    b) the Modelica Association
    c) the Mathematical Academics Association
    d) a and c

15. Identify popular language alternatives to SysML
    a) ARCADIA, EXPRESS, and OPM
    b) AADL, Architecture-Animate, and UML
    c) ARCADIA, LML, OPM
    d) b and c

16. What is SISO, or the acronym definition?
    a) Simulation Interoperability Standards Organization, supporting mathematical behaviors and simulations
    b) Systems Interoperability Standards Organization, supporting networks and signal protocols

17. Identify the set of standards managed by **The Open Group**
    a) TOGAF, UNIX, X Windows, FACE, and Archimate
    b) MOSA, AdvSys, Linux, EMACS
    c) HLA, UAF, MOF, OSLC

18. What is the international standard for exchanging requirements information?
    a) ReqIF, the Requirements Interchange Format
    b) Reqtify, the Requirement Text Interchange Format
    c) REQ, the Requirements Exchange

19. Define the acronym LOTAR
    a) Linear Oblique Theorems using Average Reciprocals
    b) LOng Term Archiving and Retrieval
    c) Laplace Object Transforms to Absolute Rules

20. What is identification prefix for the set of technical standards developed by LOTAR?
    a) European Norm and National Aerospace Standards identified as EN/NAS 9300
    b) European Norm and NASA standards EN/NAS 5300
    c) National Aerospace Standards and NASA standards, NAS/NASA 4300

Short ANSWERS

1. b
2. b
3. c
4. a
5. c
6. c
7. e (any answer is correct)
8. a (any answer is correct)
9. b, c, or e
10. LOTAR, PDES, Modelica Assoc., W3C, OMG, OASIS, OAIS, ISO, NASA, ASD-Stan *(all good answers)*
11. b, d, or g
12. d
13. d (but a, b, and c are supported)
14. b
15. d (but any answer is technically correct)
16. a
17. a
18. a
19. b
20. a

Extended descriptive answers and resources

MBSE QUIZ - ANSWERS

1. MBX and MBXX are Model-based ecosystems developed within a digital framework, that enable a Digital Thread and potentially a Digital Twin. Welcome to the MBx acronym war.
   EXAMPLES: **MBE, MBD, 3DMBD, MBSE, mBSE, MBEE, MBPP, MBM, MBO, MBT, MBS**.
   The Model-Based Enterprise, Model-based Engineering, Model-based Engineering Environment, Model-based Design, Model-based Development, Model-based Definition, Model-based Systems Engineering, Model-based, Model Based Production Planning, Model-based Manufacturing, Model-based Operations, Model-based Test, Model-based sustainment

2. Standard for the Exchange of Product model data (**STEP**), and STEP Application Protocols (**AP**s), are part of the ISO 10303 family of standards, Industrial Automation Systems - Product Data Representation and Exchange. Example STEP AP242.

3. **SysML**: In the STEP Extended Architecture, SysML is used for all layers: Activity models, Data planning models, Domain Models, Core Models, Application Reference Models (ARM), Parametric Diagrams which are used to map data between layers. Example: the MoSSEC Domain Model is modeled in SysML, ISO 10303-243, or STEP AP243

4. the SysML acronym, **Systems Modeling Language**, is a domain specific modeling language standard and an profile extension to a subset of the Unified Modeling Language (UML).

5. ISO 10303-233, Systems Engineering Data Representation, also known as **STEP AP233**. It has many similarities to the SysML specification (graphic)

6. The SEDRES Project, **Systems engineering data representation and exchange standardization** (1996-1999) developed AP233. SEDRES was an originally initiated/sponsored by ESPRIT, the **European** Strategic Programme on Research in Information Technology and funded by CORDIS, Community Research and Development Information Service of Europe. INCOSE and NIST were major sponsors providing technical oversight.

7. A few of Systems Engineering process standards that contributed to AP233: **IEEE 1220**, SYSTEM ENGINEERING PROCESS (SEP); **ANSI\EIA-632A**, Processes for Engineering a System; the ISO 15288 , Systems and software engineering — System life cycle processes; **ISO 15289**, Systems and software engineering — Content of life-cycle information items as documentation

8. International Standard ISO/IEC/IEEE 42010. First defined as ISO/IEC DIS 25961, the standard evolved into IEEE 1471:2000 and became ISO/IEC 42010 in 2007 (updated in 2011). Today it has been augmented by ISO/IEEE 42020, Software, systems and Enterprise - Architecture processes (published in 2019), and ISO/IEEE 42030 Software, Systems and Enterprise - Architecture evaluation framework. There are four cases of conformance that must be satisfied to comply with the 42010 standard:
    a) architecture description (AD)
    b) architecture viewpoint
    c) architecture framework
    d) architecture description language (ADL)

9. STEP Application Protocol, **AP239** (ISO 10303-239), is also known as the "Exchange of Product and Support Information", or PLCS, "Product Lifecycle Support"

10. MBSE data standard governing bodies and development consortia include ISO, ASD-STAN, AIA, PDES, LOTAR, OMG, prostep ivip, AFNeT, Modelica Assoc., SISO, The Open Group, ASME, OASIS, and more …..

11. SOSA = Sensor Open System Architecture Standard originated at the Air Force Life Cycle Management Center (AFLCMC) and is now managed by The Open Group. Originally defined for aerospace, it has become an important standard for the autonomous car industry.

12. Also known as AP243, or ISO 10303-243, **MoSSECC** is defined as Modelling and Simulation Information in a Collaborative Systems Engineering Context. Version 1 is scheduled for release in 2021.

13. The standards **AADL** (Architecture Analysis & Design Language) and **MARTE** (Modeling and Analysis of Real Time and Embedded systems) are Architecture modeling languages (e.g. functions, scheduling, timing, analysis, portability, allocations) that specialize in the development of embedded and loadable software. They are often used together (MARTE UML profile feeding an AADL model in OSATE2).

14. SSP (System Structure Parameterization) and **DCP** (Distributed Co-Simulation Protocol) were both developed by the Modelica Association. The SSP standard enables the interconnection of FMUs, and DCP is an underlying set of network functions that are defined as slaves to an FMU. FMUs (functional mock-up units) are created using the FMI (Functional Mockup Interface) specification.

15. **SysML** (the System Modeling Language) is an Architecture Description Language (**ADL**), as defined by ISO 42010. Popular language alternatives to SysML include **ARCADIA** (ARCHITECTURE ANALYSIS & DESIGN INTEGRATED APPROACH), **OPM** (Object Process Methodology), **Archimate** (Architecture-Animate), **LML** (Lifecycle Modeling Language).
SysML is comprised of modeling constructs with a limited ontology, while the DoDAF MetaModel 2.0 (DM2) is a visualization infrastructure and only has an ontology. The **ARCADIA** method adds a predefined architecture framework to the constructs of SysML. **OPM** includes a constrained ontology and is used to produce conceptual models. **Archimate** builds a 3 by 3 matrix of organizational domain layers that is used to described an Enterprise Architecture. It lacks a system ontology. **LML** simplifies both constructs and ontology to form a complete, easy to use modeling language.

16. **SISO**, the Simulation Interoperability Standards Organization, is a data standards consortium with a focus on mathematical behaviors and simulations. Important SISO Standards Committees include: IEEE Std 1278TM - Distributed Interactive Simulations (DIS), and IEEE Std 1516TM - High Level Architecture for Models & Simulations (HLA).

17. The Open Group consortium is a world wide organization that manages a wide range of data and format standards including TOGAF, UNIX, X Windows, FACE, and Archimate (Architecture-Animate).

18. **ReqIF**, the Requirements Interchange Format: Defined in an XML format, it was developed in the automotive industry, and formalized by prostep iVIP until it was handed over to OMG in 2010. Version 1.2 is currently being evaluated for improvements by the prostep ivip consortium

19. **LOTAR**, LOng Term Archiving and Retrieval is the focus of the LOTAR International, an industry specific consortium (aerospace) that produces standards applicable to multiple industries. The focus is the preservation and reuse of data and models. The LOTAR guidelines are defined by the OAIS standard, ISO 14721.

20. LOTAR creates standards that are identified as **EN/NAS 9300**. EN is European Norm standards and NAS is National Aerospace Standards. They are approved by the organizations supporting ASD-Stan (Aerospace & Defense Standardization), and AIA (Aerospace Industry Association).

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