



**2021**  
Annual **INCOSE**  
international workshop  
**Virtual Event**  
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# *A Roadmap for MBSE Data Standards*

Mark Williams  
Boeing

AFFILIATIONS:  
PDES MBSE WG  
LOTAR MBSE WG  
NAFEMS SMS WG  
INCOSE TIMLM WG  
A&D PLM MBSE WG

# Why MBSE Data Standards?



- Data integration, preservation and reuse
- OEM – Supplier Design Development
- Collaboration opportunities
- MBE digital thread (traceability, exchange, integration, and synchronization)
- Foundation for standard process and procedures



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



**Your participation is needed!**

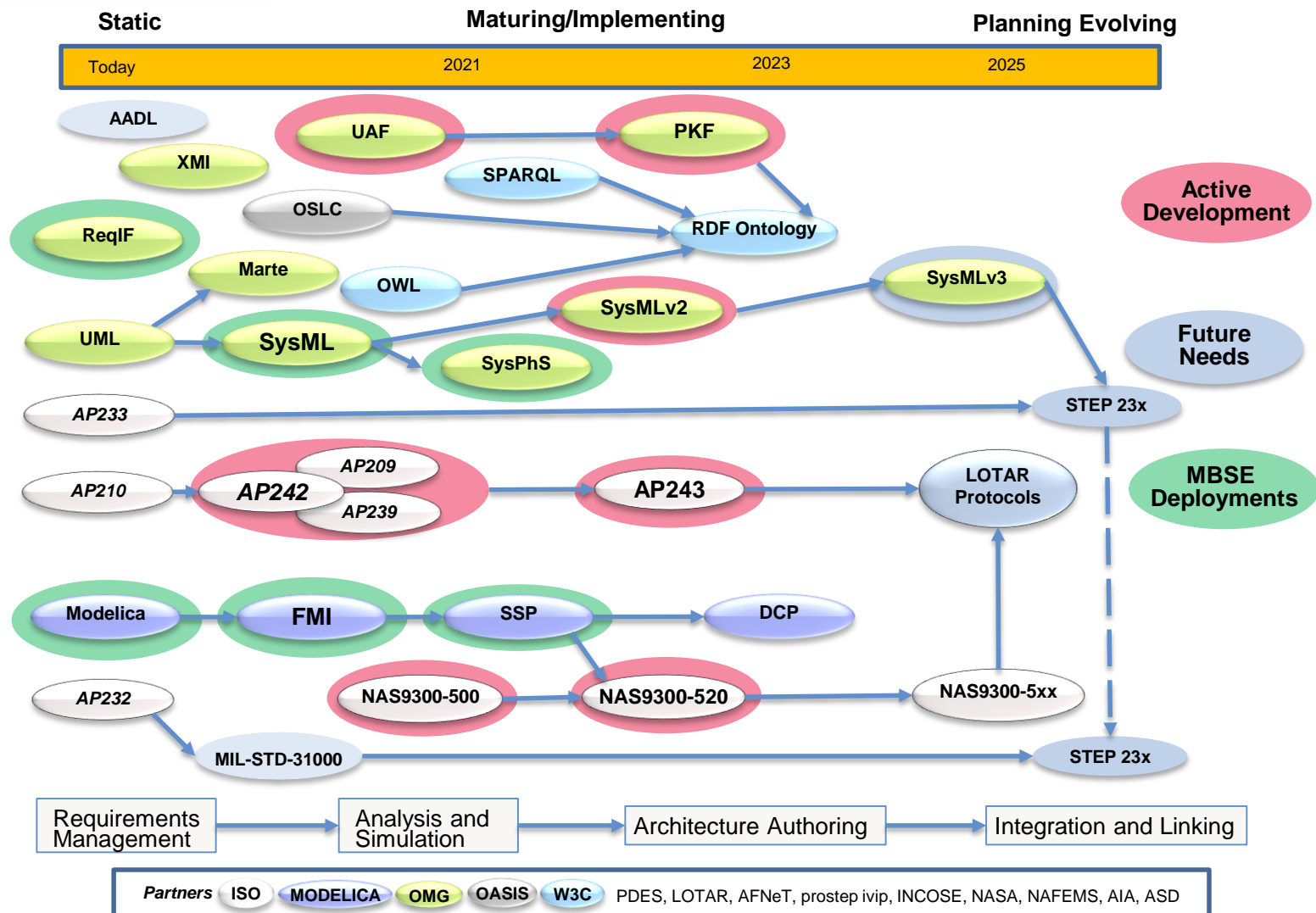
(implementer Forums, industry groups, standard bodies)

# 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 8<sup>th</sup>, 2019. Revised March, 2020

Reference [ASD Radar Chart](#) for detailed descriptions

# Standards Bodies and Consortia



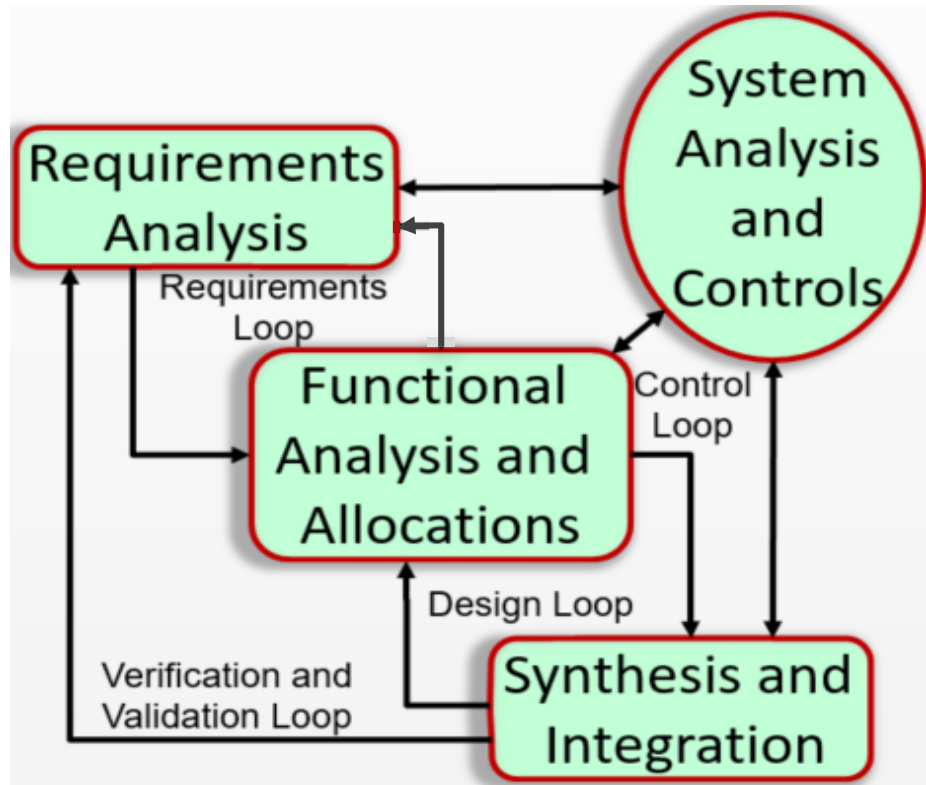
## MBSE Standards Development

- 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)
- SISO (consortium, modeling and simulation interoperability)
- AFNeT (consortium, digital transformation/stds)
- prostep ivip (consortium, industry best practices)
- AVSI (Academia, virtual integration, PBR/PMM)
- Others: W3C, OMG, OASIS, OAIS, INCOSE, Open Group

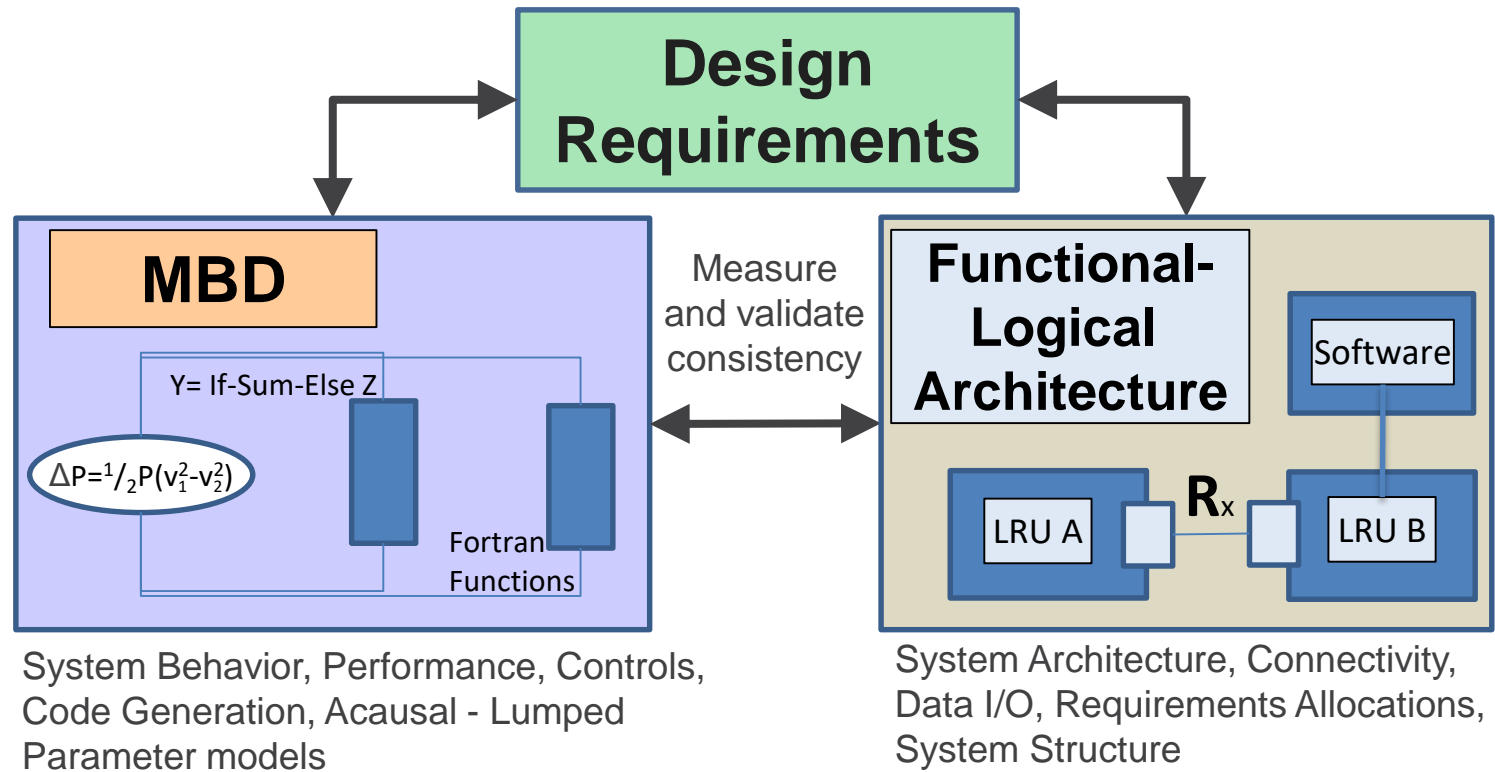
## Industry and Governance

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

# MBSE Capabilities: Data Types

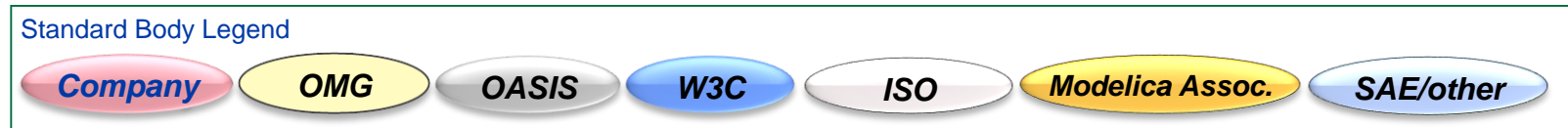
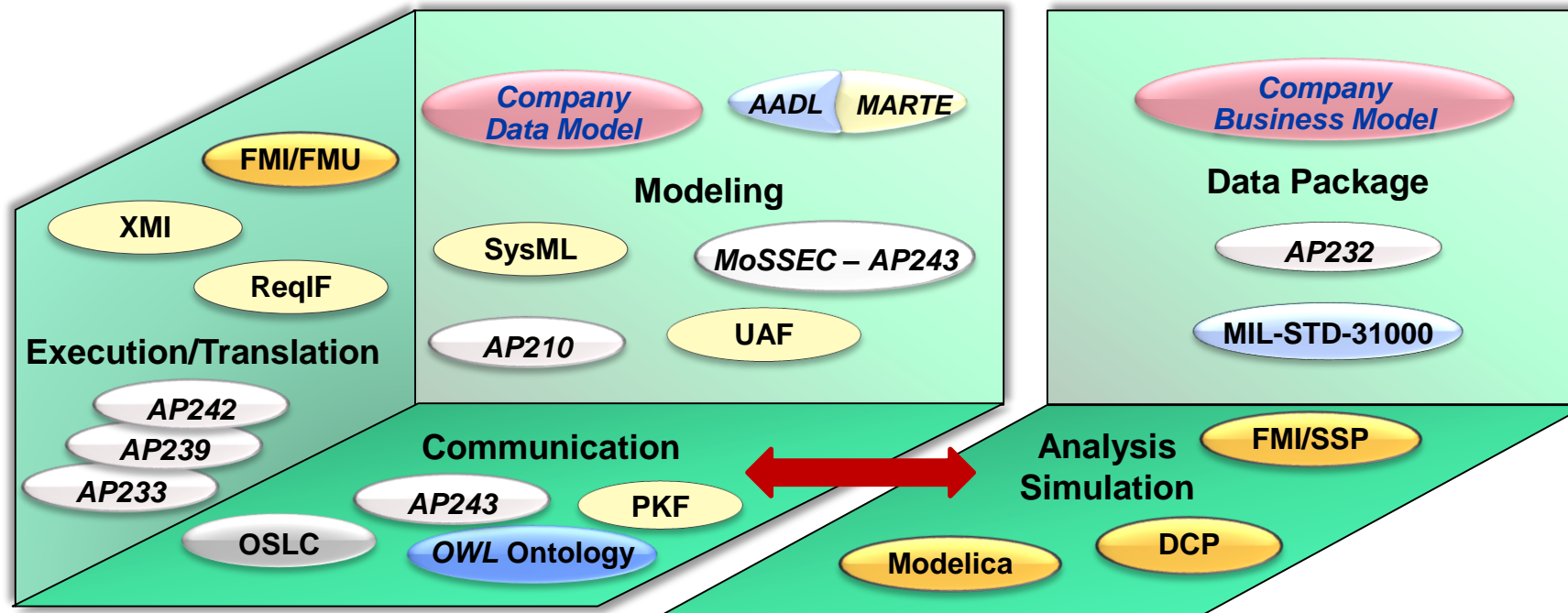


MIL-STD-499



MODELS

# MBSE Data Standard Categories



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



# Systems Behavior Model

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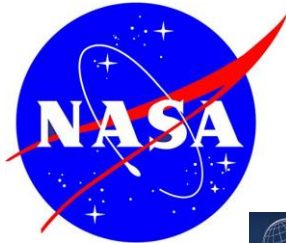
The quantitative assessment of functional systems that represent the environment, System/Structural Plant architectures, and/or regulated Control Loop activities. They are defined as lumped parameter models representing physics based behaviors and control logic. They are constructed using complex mathematical equations, specifications or executable code, containing differential, algebraic and discrete equations.

# Model Based Design

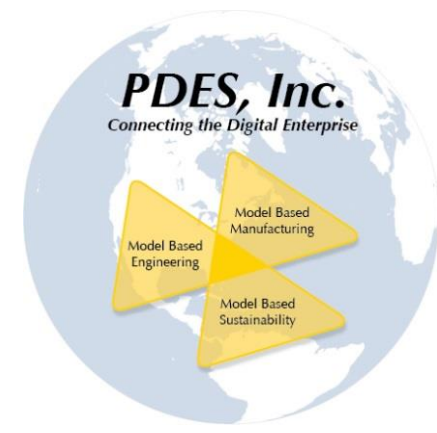


## MBD Standards Development

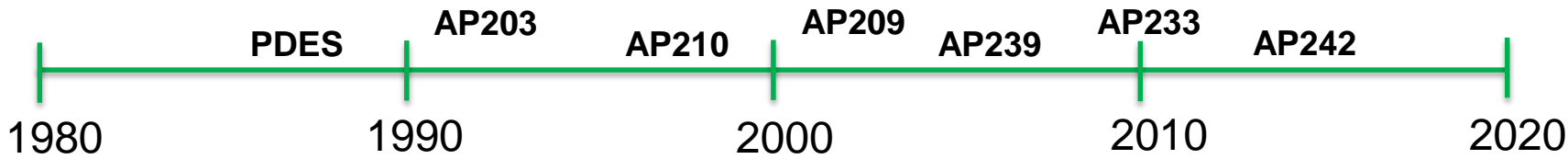
- [PDES](#) : Product Data Exchange Specification  
AP209 (FEM), AP243 (MoSSEC) 
- [LOTAR](#) : LOnG Term Archiving and Retrieval  
NAS9300-520, MoSSECC template
- [Modelica Association](#) : language, libraries, FMI, SSP, DCP
- [NAFEMS](#) : National Association of Finite Element Methods  
vocabulary, Engr Simulation Quality Standard
- [SISO](#) : Simulation Interoperability Standards Organization  
HLA for M&S, DIS (Dist SIM), DSEEP
- [NASA](#) : National Aeronautics and Space Administration  
NASA-STD-7009A, NASA-HDBK-7009A
- [The Open Group](#) : SOSA, Sensor Open Systems Architecture



# 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.

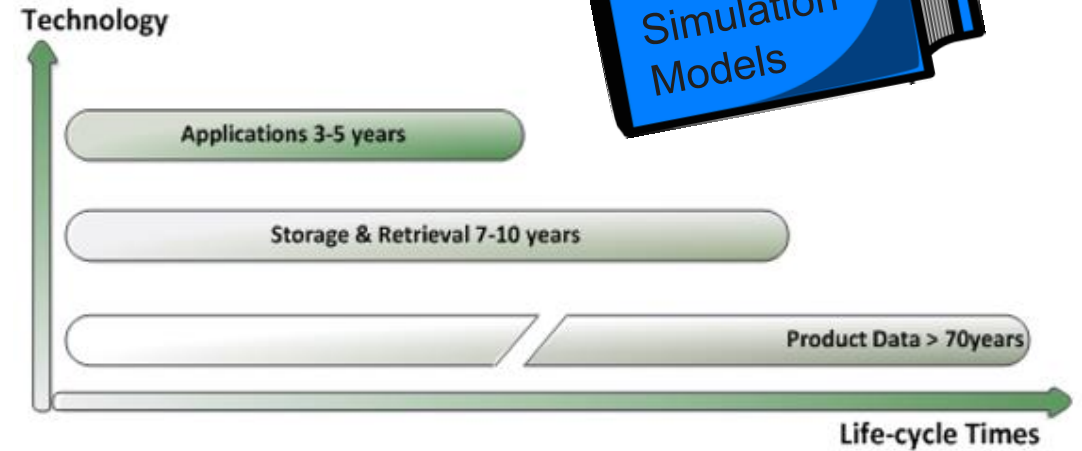
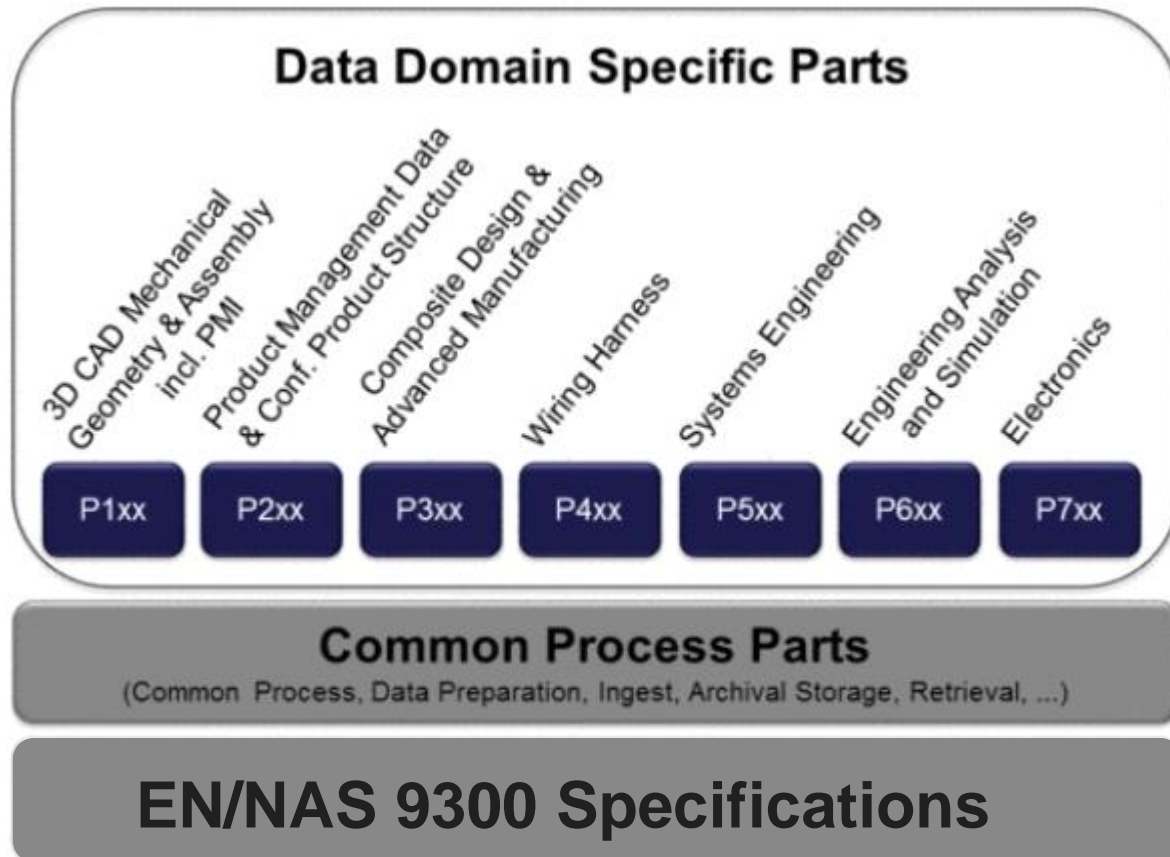
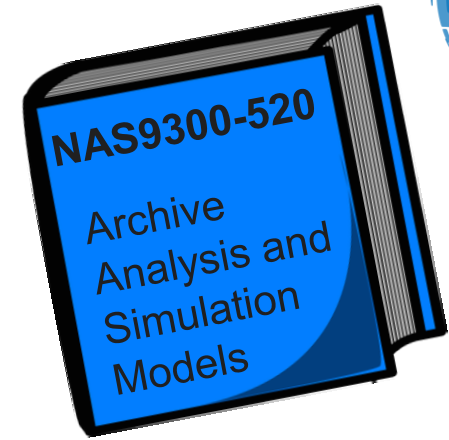
**PDES** = Product Data Exchange Specification  
(Product Data Exchange using STEP)

ISO TC184 SC4	STEP on a Page	ISO 10303
<b>APPLICATION PROTOCOLS AND ASSOCIATED ABSTRACT-TEST SUITES</b>		
<p>I 201 Explicit drafting [ATS 301=X]</p> <p>I 202 Associative drafting [X]</p> <p>I 203 Config-man controlled design (c=L,a=I) [X]</p> <p>I 204 Mechanical design using boundary rep [I]</p> <p>X 205 Mechanical design using surface rep [W]</p> <p>X 206 Mechanical design using wireframe [X]</p> <p>I 207 Sheet metal die planning and design [I]</p> <p>X 208 Life-cycle product change process [X]</p> <p>X 209 Composite &amp; metal structural anal &amp; related design [X]</p> <p>I 210 Electronic assy, interconnection &amp; packaging design [X]</p> <p>X 211 Electronic B/C assy test, diag &amp; simulatn [X]</p> <p>I 212 Electro-mechanical design and installation [C]</p> <p>X 213 Num control (NC) process plan for mach'd parts [X]</p> <p>I 214 Core data for automotive mech design processes (a=2,E) [F]</p> <p>I 215 Ship arrangement [X]</p> <p>I 216 Ship moulded form [X]</p> <p>I 217 Ship piping [X]</p> <p>I 218 Ship structures [X]</p> <p>O 219 Dimension inspection [X]</p> <p>O 220 Proc. pig. mfg. assy of layered electrical products [X]</p> <p>C 221 Functional data &amp; their schem rep for process plant [X]</p> <p>X 222 Design-manuf for composite structures [W]</p> <p>X 223 Exch of design &amp; mfg product info for cast parts [I]</p> <p>I 224 Mech pdt def for p. pig using mach'n g feat (e2=X,e3=A)</p> <p>I 225 Ship mechanical systems [X]</p> <p>I 227 Plant spatial configuration (e=C) [X]</p> <p>X 228 Building services: HVAC [X]</p> <p>X 229 Design &amp; mfg product info for forged parts [C]</p> <p>X 230 Building structural frame, steelwork [X]</p> <p>X 231 Process-engineering data [X]</p> <p>I 232 Technical data packaging: core info &amp; exch [I]</p> <p>W 233 Systems engineering data repr (to be PAS 2024) [X]</p> <p>X 234 Ship operational logs, records, and messages [X]</p> <p>W 235 Materials info for des and verif of products [X]</p> <p>W 236 Furniture product and project data [W]</p> <p>W 237 Computational Fluid Dynamics</p> <p>A 238 Computer numerical controllers</p> <p>W 239 Product life-cycle support</p> <p>W 240 Process plans for machined products</p>		
<b>COMMON RESOURCES (with 13584-20 logic model of expr (I) and 15531-42 Time (W))</b>		
<p><b>APPLICATION MODULES (Technical specification)</b></p> <p>For status of the modules access the file via the SOAP home page.</p> <p><b>Legend: TS Status:</b> 0-10 =O=prop--apvt for ballot 10-20=A=NP bit circ--NP apvt 20-60=D=DTS dev--reg as TS =90 =T=TS Published</p> <p><b>INTEGRATED-APPLICATION RESOURCES</b></p> <p>I 101 Drafting (c1=I)</p> <p>X 102 Ship structures</p> <p>X 103 E/E connectivity</p> <p>X 104 Finite element analysis</p> <p>I 105 Kinematics (c1=I, c2=I)</p> <p>X 106 Building core model</p> <p>C 107 Finite-element analysis definition relationships</p> <p>C 108 Parametric Constraints for expl geom prod mds</p> <p>C 109 Assembly model for products</p> <p>W 110 Mesh-based computational fluid dynamics</p> <p><b>INTEGRATED-GENERIC RESOURCES</b></p> <p>41 Fund of prod descr &amp; opt (e2=I, c1=I)</p> <p>43 Express specialization (e2=I, c1=I, c2=I)</p> <p>44 Product struct config (e2=I, c1=I)</p> <p>45 Materials (c1=I)</p> <p>46 Visual presentation (c1=I, c2=I)</p> <p>47 Tolerances (c1=I)</p> <p>48 Form features</p> <p>49 Process structure &amp; properties</p> <p>I 50 Mathematical constructs</p> <p>C 51 Mathematical description</p> <p>W 52 Mesh-based topology</p> <p>W 53 Numerical Analysis</p> <p>54 Classification Set theory</p> <p>A 55 Procedural and hybrid represent.</p> <p>W 56 State</p> <p>W 57 Expression extensions</p> <p>A 58 Risk</p> <p><b>APPLICATION-INTERPRETED CONSTRUCTS</b></p> <p>I 501 Edge-based wireframe</p> <p>I 512 Fractured B-representation</p> <p>I 502 Shell-based wireframe</p> <p>I 513 Elementary B-rep</p> <p>I 503 Geom-bounded 2D wireframe</p> <p>I 514 Advanced B-rep</p> <p>I 504 Drafting annotations</p> <p>I 515 Constructive solid geometry</p> <p>I 505 Drawing structure &amp; admin</p> <p>I 516 Mechanical-design context</p> <p>I 506 Drafting elements</p> <p>I 517 Mech-design geom presentation (c1=I)</p> <p>I 507 Geom-bounded surface</p> <p>I 518 Mech-design handed presentation</p> <p>I 508 Non-manifold surface</p> <p>I 519 Geometric tolerances (c1=I)</p> <p>I 509 Manifold surface</p> <p>I 520 Assoc drafting elements</p> <p>I 510 Geom-bounded wireframe</p> <p>E 521 Manifold sub-surfaces</p> <p>E 522 Machining features</p> <p>A 523 Curve swept solid</p> <p><b>IMPLEMENTATION METHODS</b></p> <p>I 21 Clear-text encoding each str (c1=I, e2=I)</p> <p>C 25 EXPRESS to OMG XML</p> <p>X 22 Standard data access interface</p> <p>X 26 IDL language binding (to #22)</p> <p>I 23 C++ language binding (to #22)</p> <p>I 27 JAVA language binding (to #22)</p> <p>I 28 XML rep for EXPRESS-schemata &amp; data</p> <p>X 24 C language binding (to #22)</p> <p>X 29 Ltrw java binding (to #22) (DTS)</p>		

# 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.

# Collaboration Strategies

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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.

# Modelica Standards: FMI, SSP, DCP



## FMI: Functional Mock-up Interface

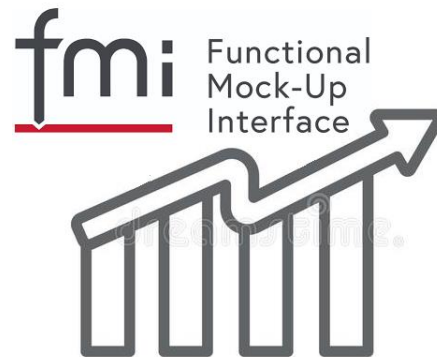
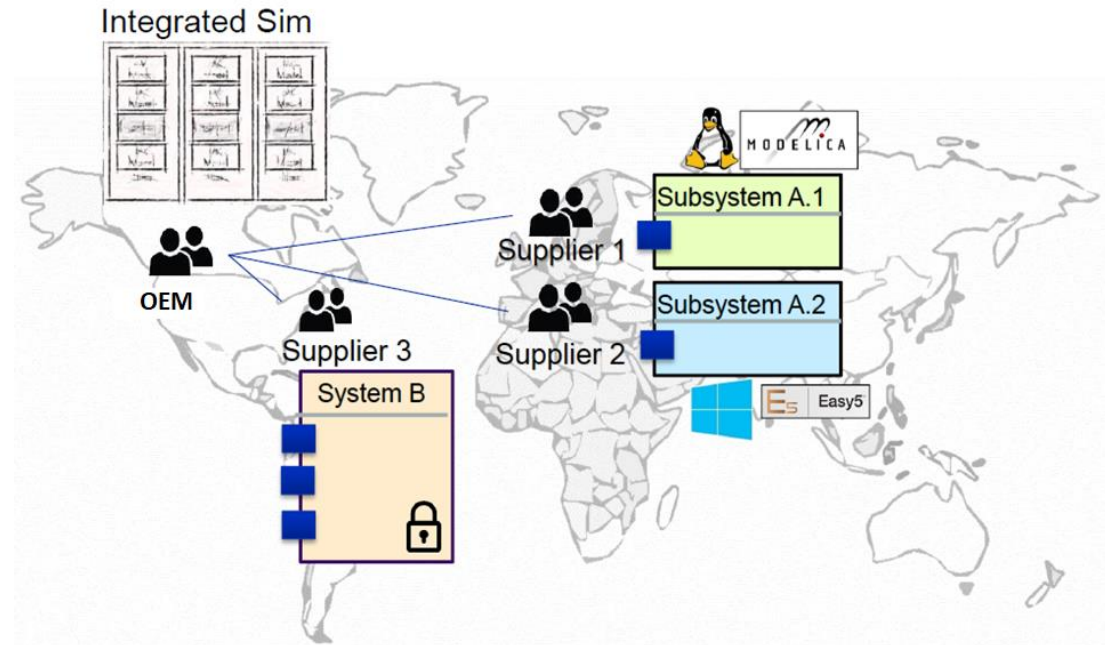
- ✓ Supplier – OEM Model Exchange
- ✓ Early requirements validation

## SSP: System Structure and Parameterization

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

## DCP: Distributed Co-simulation Protocol

- ✓ High fidelity, real time co-simulation



End users have identified Improvement Areas

Juan Carlos Mendo,  
Boeing Research & Technology - Europe

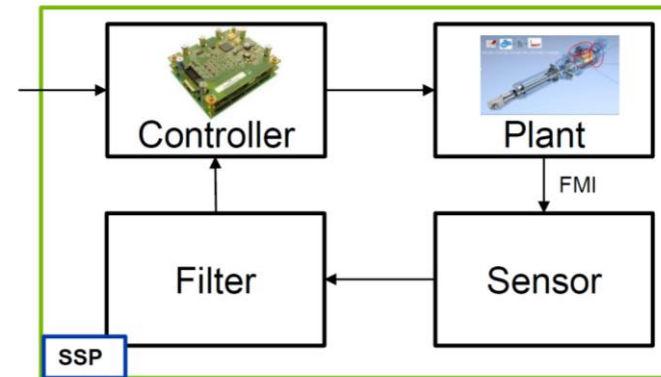
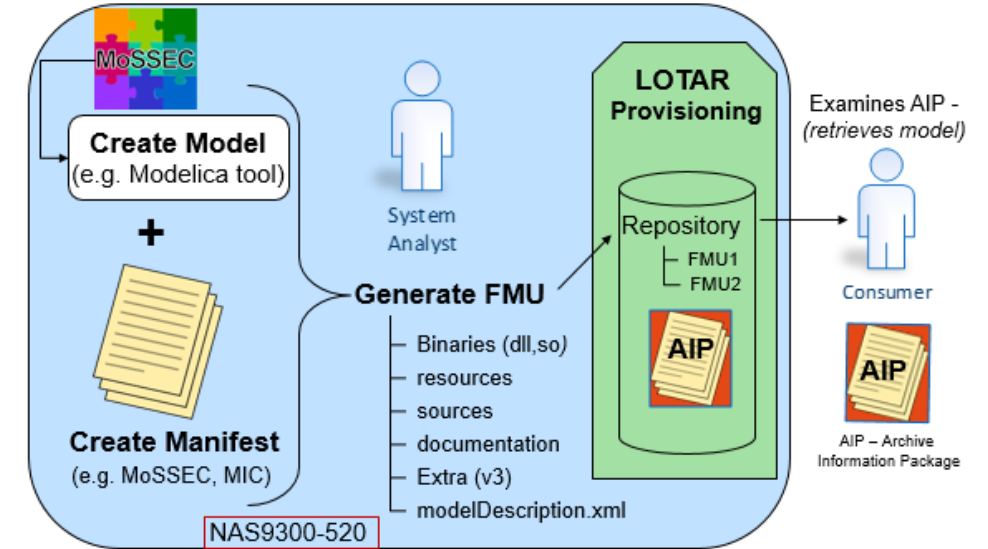
# Industry Use Case: Reuse of FMI and SSP models



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



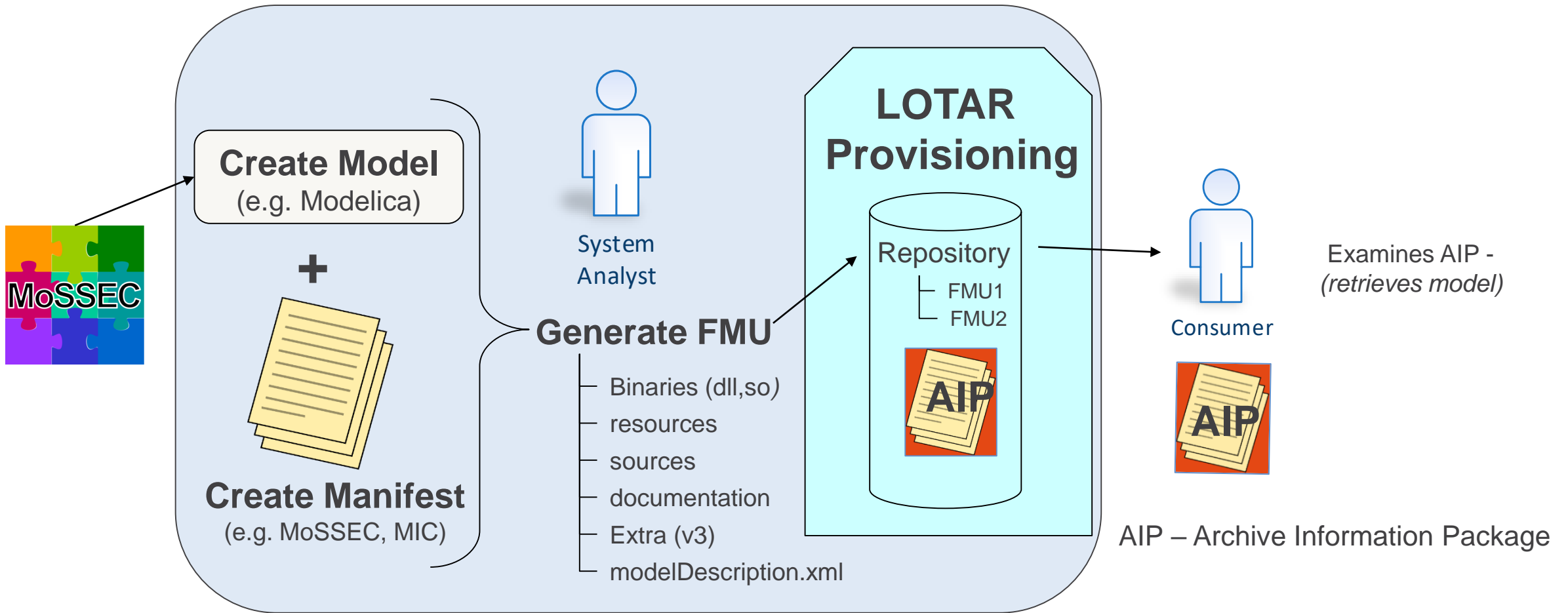
Juan Carlos Mendo,  
Boeing Research & Technology

*Closed loop Actuation Industry use case*

# NAS9300-520 Process

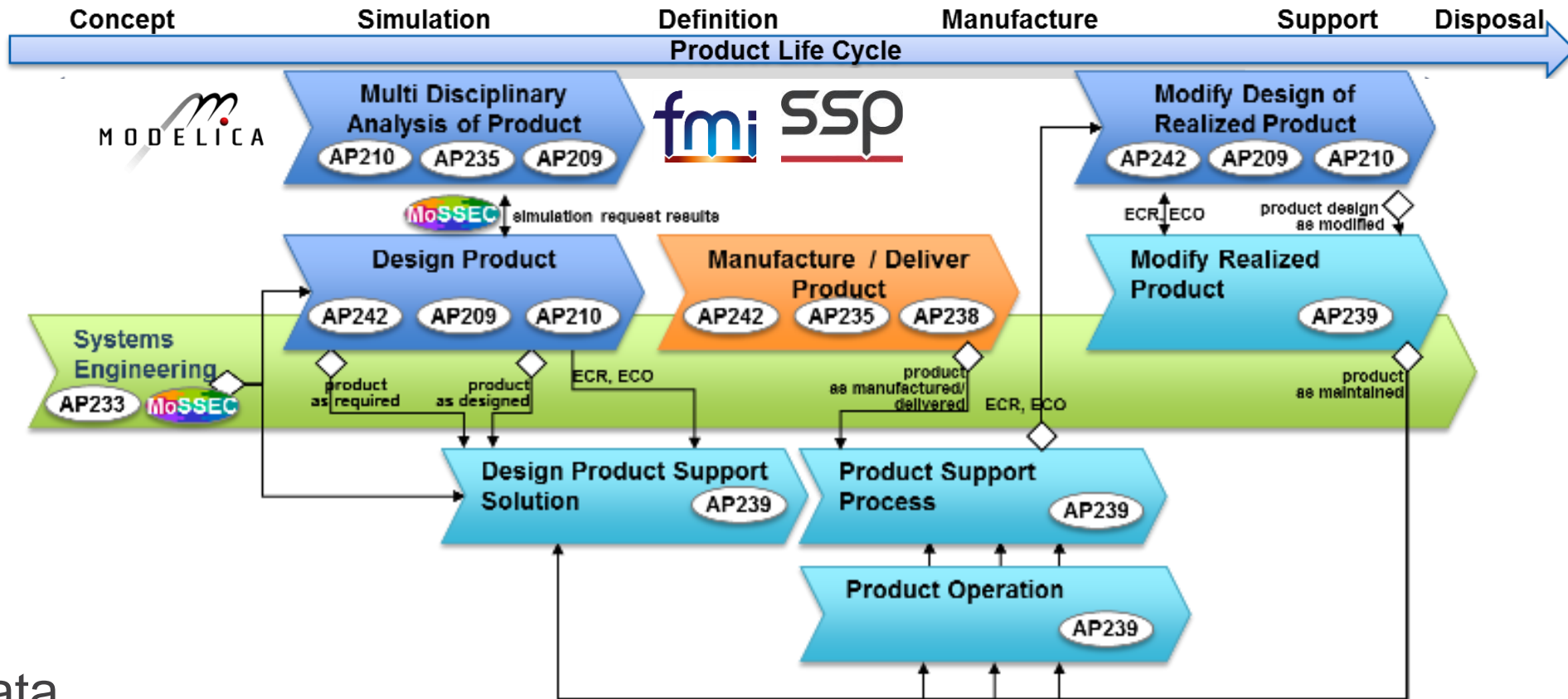


## Archiving a Simulation Model (FMU or SSP)



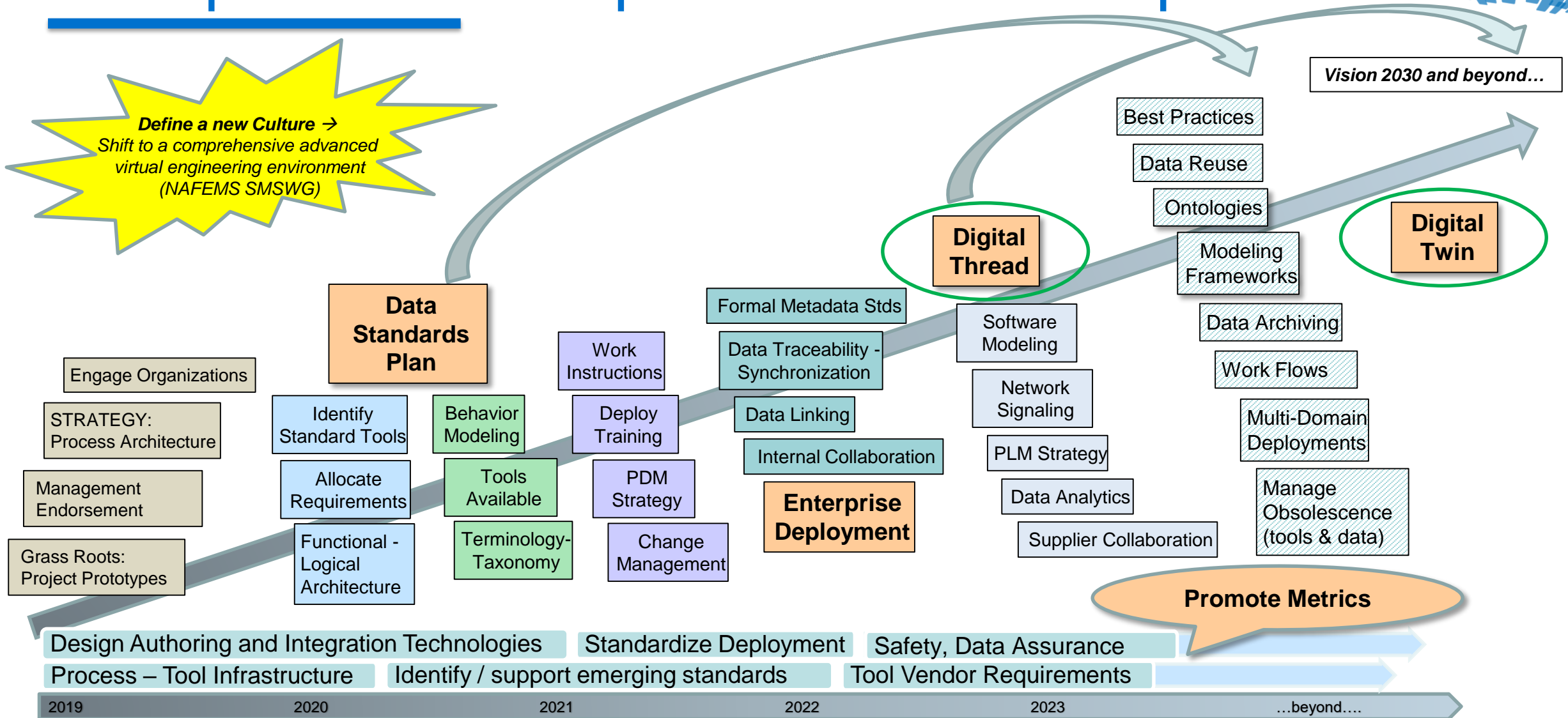


# The path to integrating data



Model metadata  
 Scope, Pedigree, Provenance  
 Who, What When Where, Why, How


# Sample MBSE Capabilities Roadmap



from PDES-LOTAR MBSE Teams, January 2021

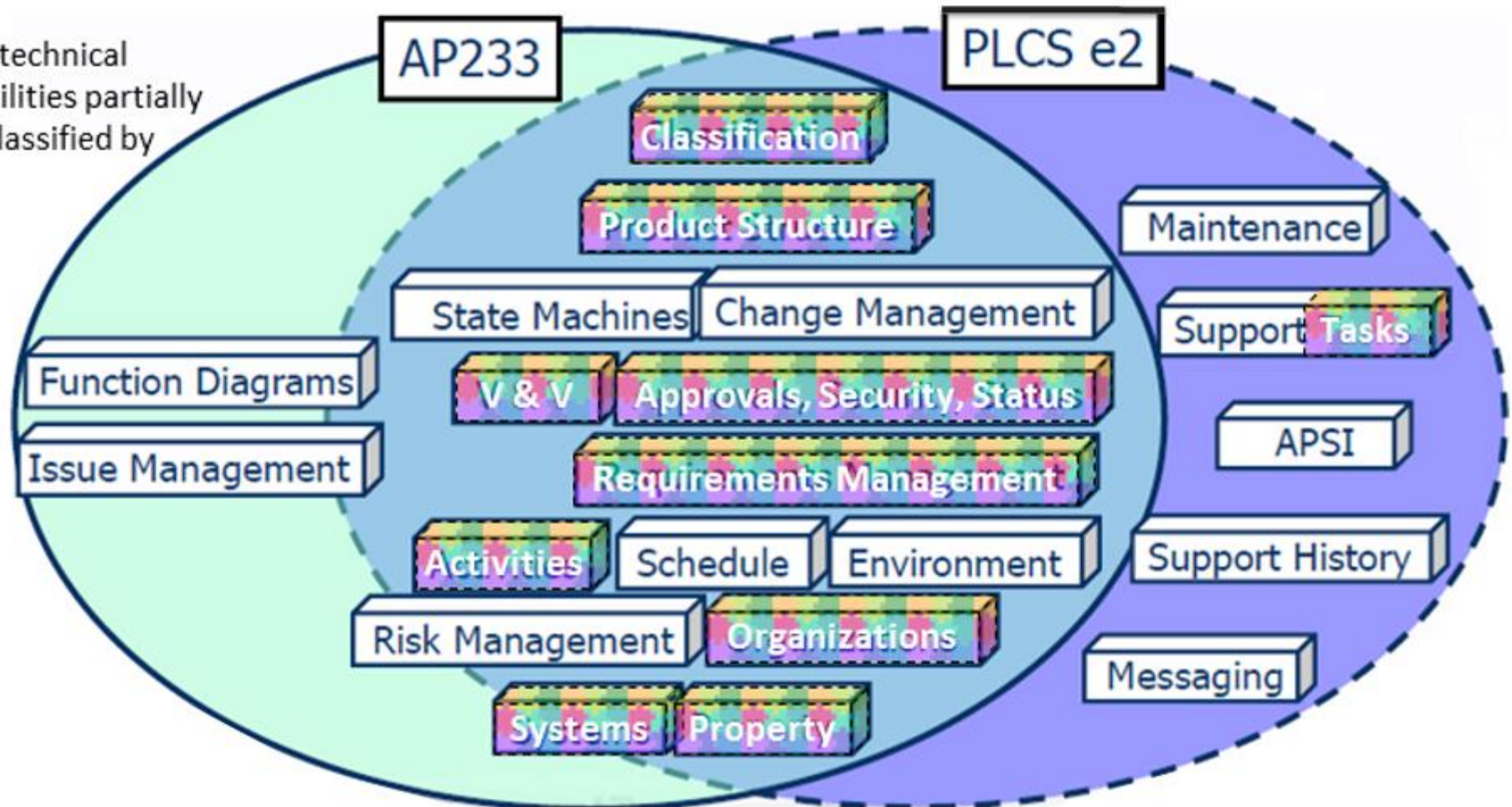
# AP233 + AP239 + AP243



 Core technical capabilities partially reused or classified by MoSSEC



Modeling and Simulation Information in a Collaborative Systems Engineering Context





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