



2019
Annual **INCOSE**
international workshop
Torrance, CA, USA
January 26 - 29, 2019

Mark Williams
The Boeing Company

MBSE Data Standards

Engaging the Industry

MBSE Presentation Agenda



- A&D PLM Action Group



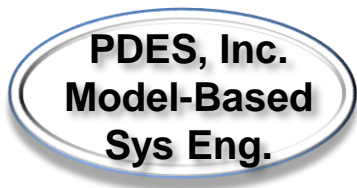
- MBSE for PDES



- LOTAR for MBSE



- GPDIS



- PDES – INCLOSE MoU



Contrast MBSE – Baseline Definitions

Define **MBSE**: Model-based Systems Engineering

The application of modeling to support system requirements, design, analysis, verification and validation throughout the development lifecycle.

Define **MBD**: Model-based Design

The mathematical representation of design functions, behavior, and software interactions.

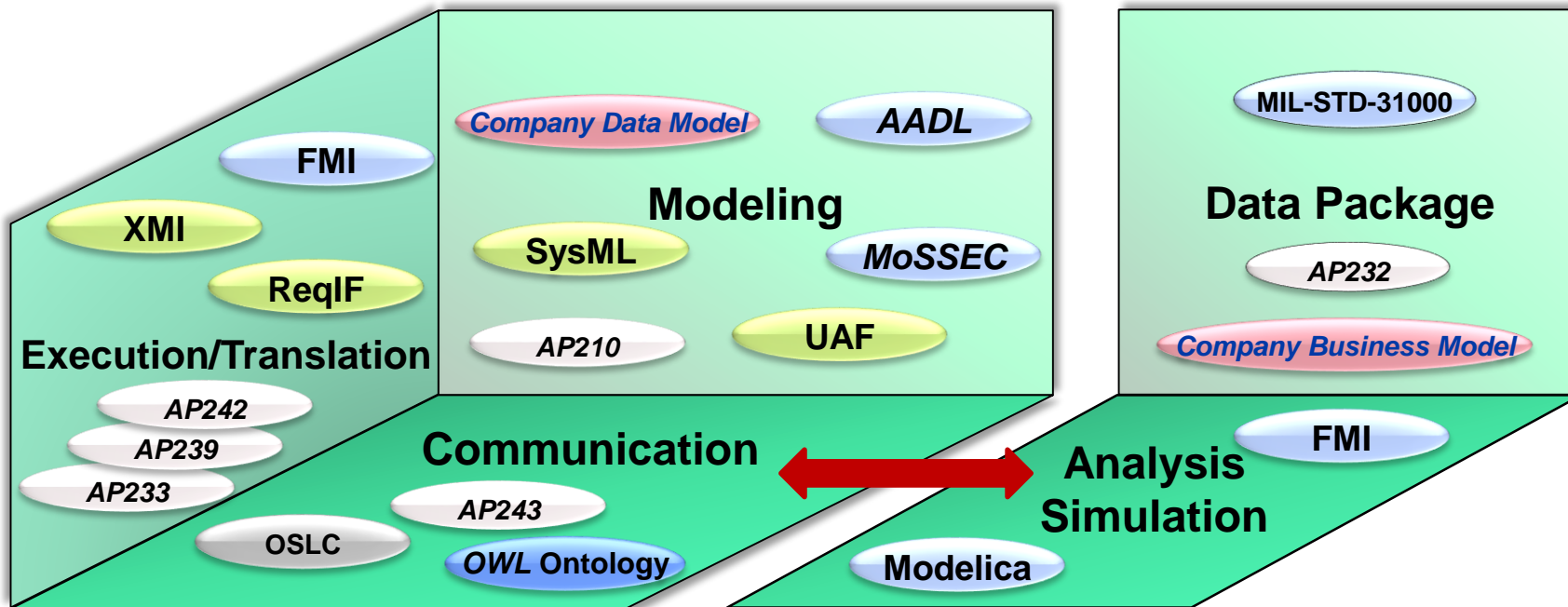
Define **3DMBD**: 3D Model-based definition

The use of 3D ECAD (digital geometry, 3D PMI and associated metadata) to define individual components, assemblies, and/or the complete product.

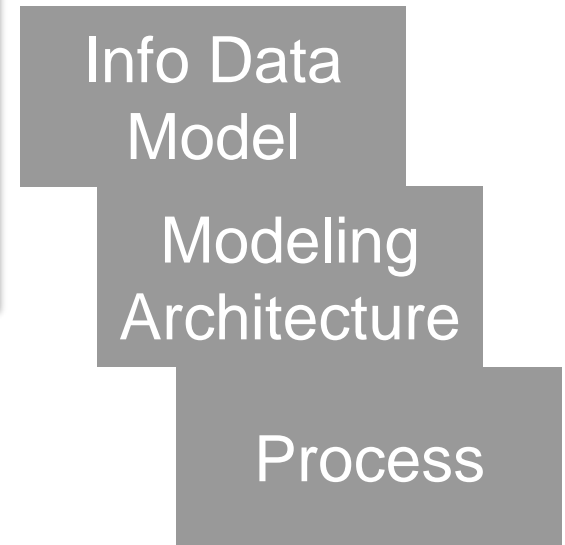
The System (MBSE) Model is the connective tissue between the domains..... John Sperling, ARAS Corp



MBSE Data Standards



Critical Enablers !

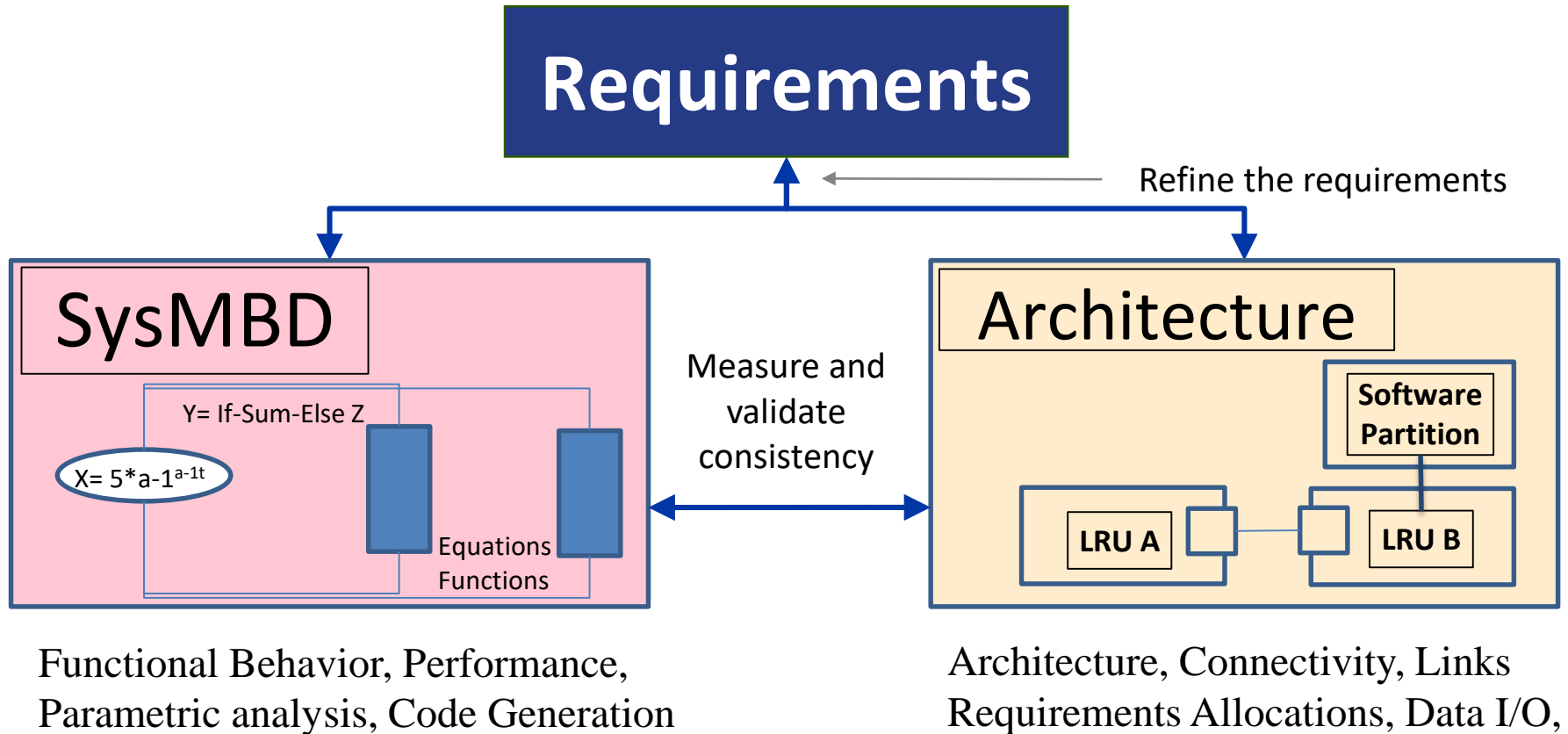


Standard Body Legend



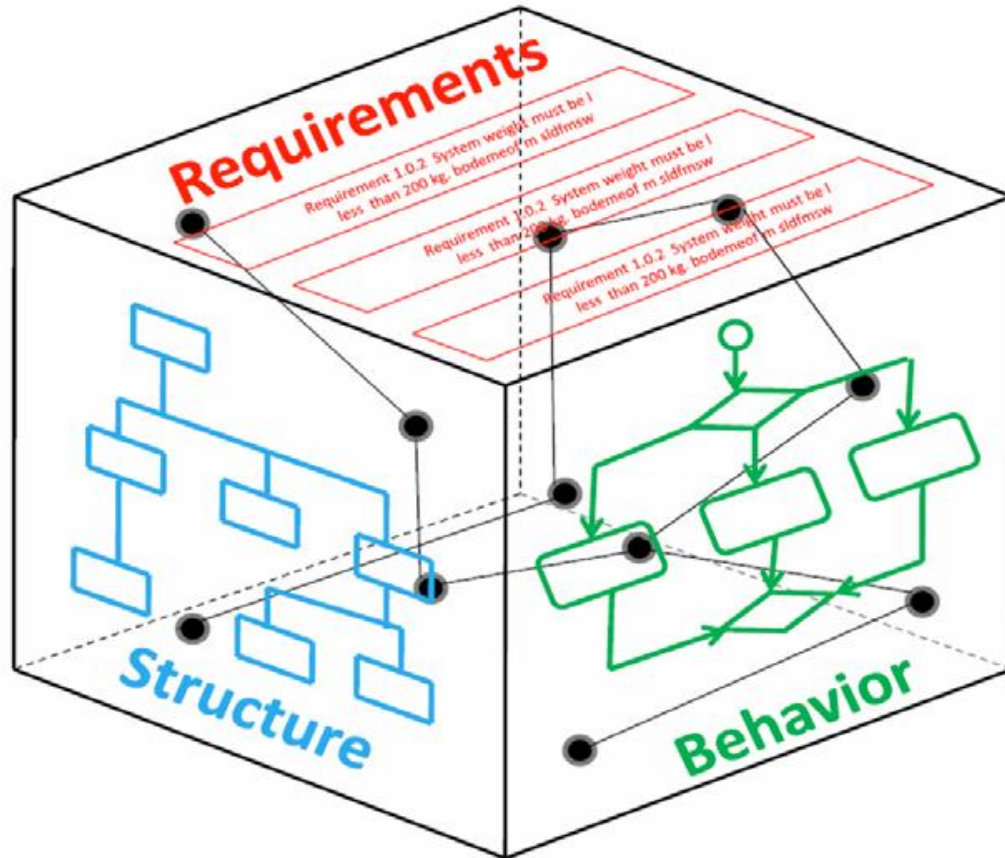
CREDIT: Bill Chown, Mentor Graphics; MBSE Roundtable, 2015 GPDIS

MBSE Digital Artifacts



The MBSE purpose is achieved if the models are consistent and can be used downstream **without recreation**

System Development view from AIA

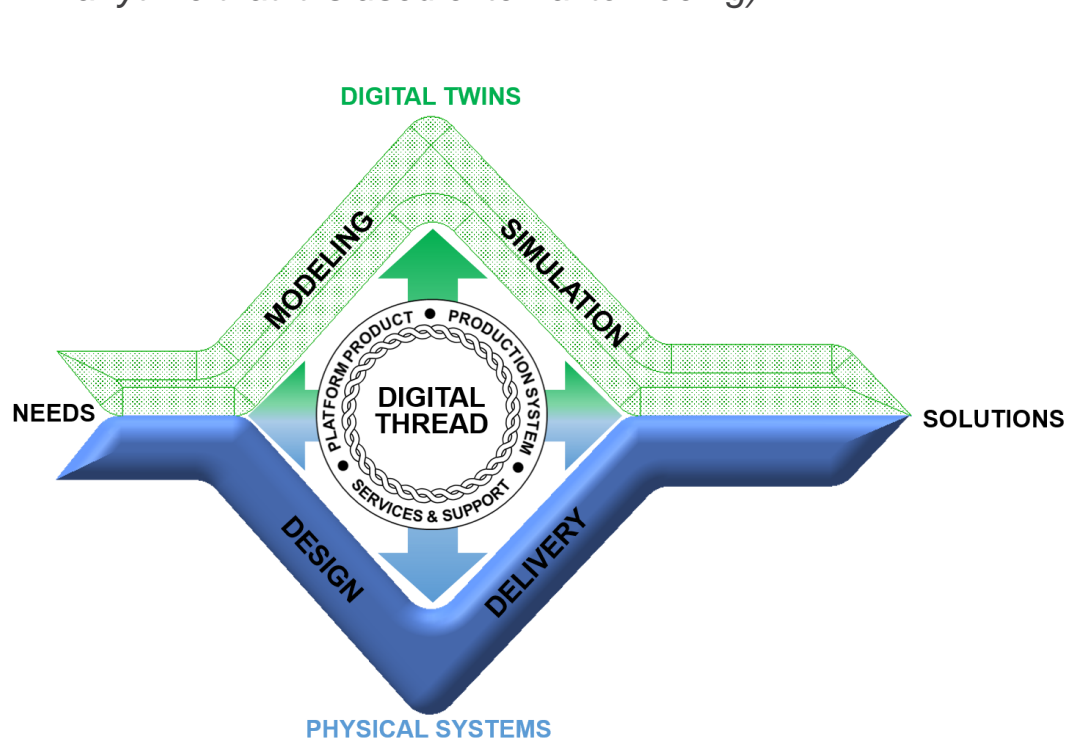


Critical MBE Themes that Enable a Collaborative Government-Industry Digital Engineering Process throughout the DOD Acquisitions Lifecycle,
Dr. Peter Pan, Northrop Grumman
[NIST MBE Summit presentation](#)

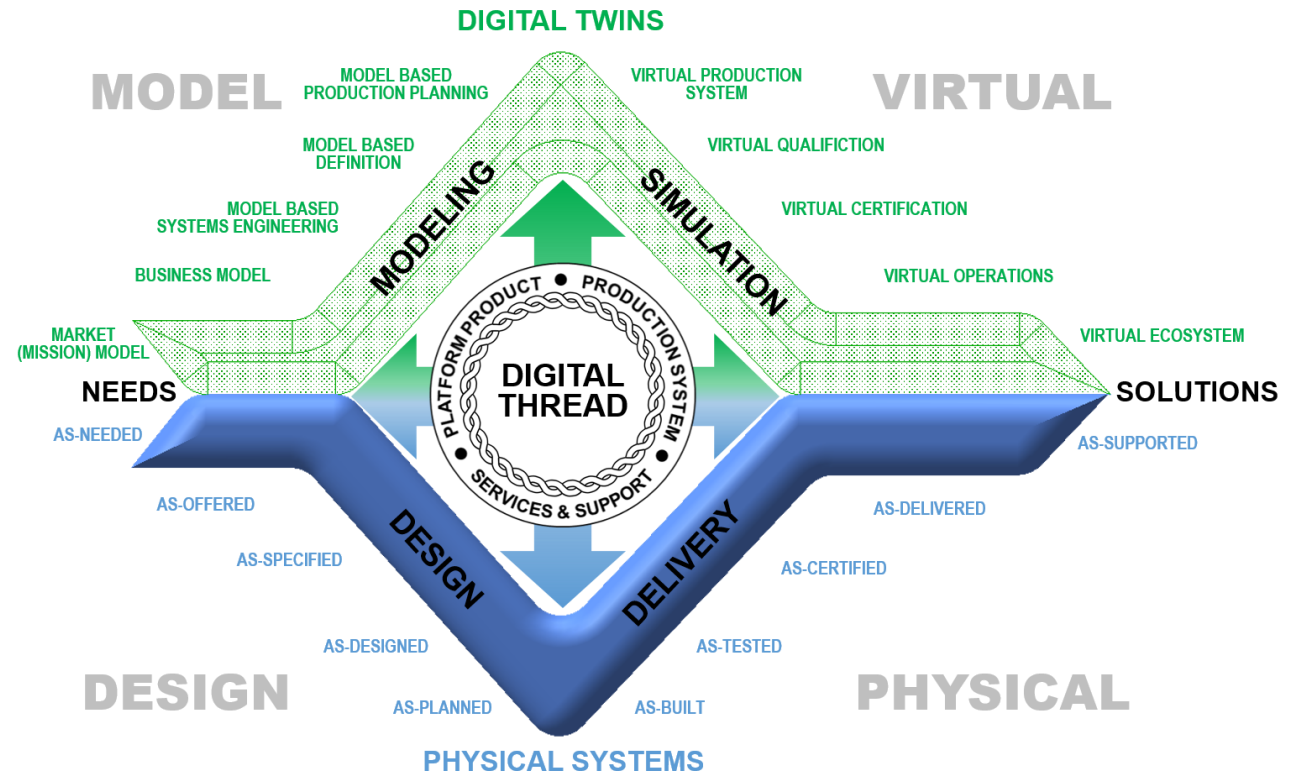


Evolution of the Engineering Vee

Compare AP233 with Dan Seal's [Diamond](#) presentation from GPDIS
(must include "Copyright © 2018 Boeing. All rights reserved" statement with the symbol anytime that it is used external to Boeing)



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Advocating for MBSE



- Home: Aerospace & Defense PLM Action Group
- Members
- Mission
- Publications
 - Direction Statements
 - Research Reports
 - Position Papers

[HOME](#) > HOME: AEROSPACE & DEFENSE PLM ACTION GROUP



Founded in 2014, the Aerospace & Defense PLM Action Group is an association of aerospace & defense companies within CIMdata's globally recognized PLM Community Program, which functions as a PLM advocacy group.

Our stated mission is to:

- › Set the direction for the aerospace & defense industry on PLM-related topics that matter to members
- › Promote common industry PLM processes and practices



MBSE Working Group

The MBSE Project is one of several focus areas

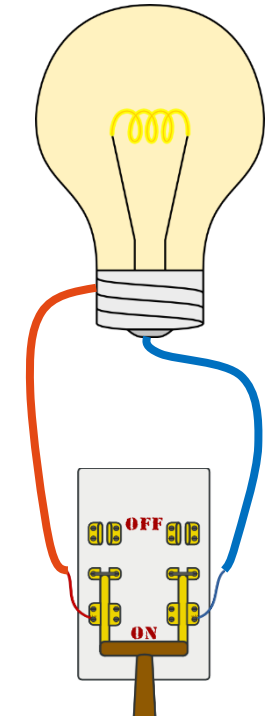
- Recognize that all Aerospace OEMs essentially use the same suppliers.
- Develop guidelines to exchange MBSE data between the OEMs and the Tier 1 Suppliers.
- Test our capabilities to exchange basic digital models
- Define gaps, develop Position Paper, explore near term opportunities.

[Aerospace & Defense PLM Action Group](http://www.incose.org/IW2019)



Summary for Phase 1 Testing

MBSE Data Exchange Trials		All participants prepared DEMSCD & Technical Data Package; All models and trial results data uploaded into AirCollab project folders				Red=Failure Grey=Partial Success Green=Success	Red=Failure Grey=Partial Success Green=Success
Round	OEM Role	OEM Modeling Tools Used	Data Export Standards Used	Supplier Role	Supplier Tools Used	Trial Outcome (System Model)	Trial Outcome (Requirements)
	Boeing	MagicDraw v18.1	UML 2.5 XMI	GE	IBM Rhapsody v8.2.1	Failure	Failure
	Boeing			Rolls-Royce	PTC Integrity v8.3.18 Enterprise Architect, DOORS v9.5	Failure	Partial Success
	Boeing			DOORS v9.6	ReqIF v1.1	Airbus	IBM Rhapsody v8.1.4
Round	OEM Role	OEM Modeling Tools Used	Data Export Standards Used	Supplier Role	Supplier Tools Used	Trial Outcome (System Model)	Trial Outcome (Requirements)
	Airbus	IBM Rhapsody v8.1.4 (Reqs Included in SysML model)	XMI	Rolls-Royce	PTC Integrity v8.3.18 DOORS v9.5	Failure	Failure
	Airbus			GE	IBM Rhapsody v8.2.1	Failure	Failure
	Airbus			Boeing	Rhapsody 8.1.5	Failure	Partial Success
	Rolls-Royce	PTC Integrity Modeler v8.3.18	XMI	Boeing	Rhapsody 8.1.5	Failure	Failure
	Rolls-Royce			GE	IBM Rhapsody v8.2.1 DOORS NG	Failure	Partial Success
	Rolls-Royce			DOORS v9.5	ReqIF v1.0	Rolls-Royce	PTC Integrity Modeler v8.3.18
	GE	IBM Rhapsody v8.2.1	UML 2.3 XMI	Boeing	Rhapsody 8.1.5	Failure	Failure
	GE	DOORS NG	ReqIF v1.2	Rolls-Royce	PTC Integrity v8.3.18 DOORS v9.5	Failure	Failure

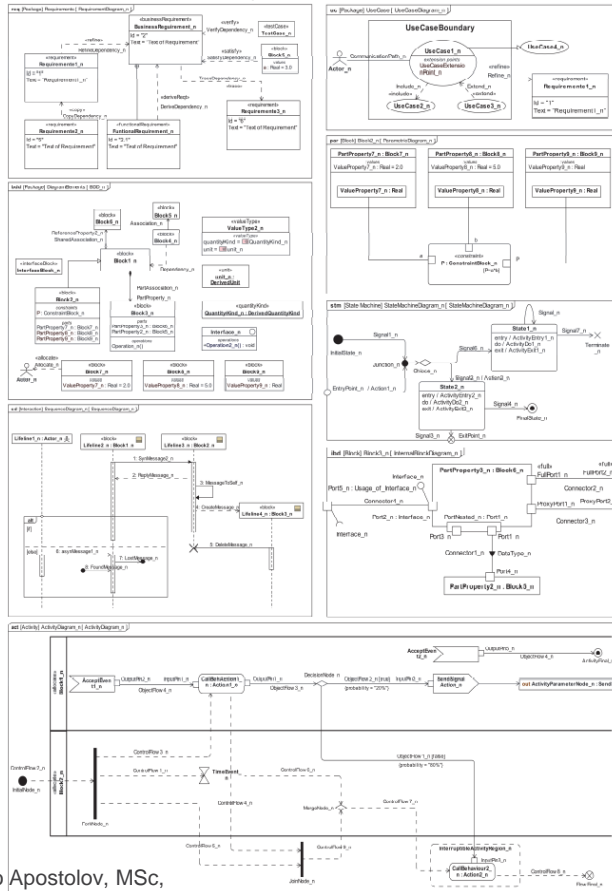


An Academic Analysis



Current Status of SysML Model Interchange between Common Modeling Tools via XMI – A Practical Study

Standard SysML Test Models



Hristo Apostolov, Damun Mollahassani Madjadabadi
University of Kaiserslautern,
Institute of Virtual Product Engineering (VPE),
EMEASEC 2018 / TdSE 2018

Used with permission : Hristo Apostolov, MSc,
[Institute for Virtual Product Engineering](#),
Technische Universität Kaiserslautern

Source tool > Target tool >	IBM RR				cluster total	NM CSM				cluster total
	IBM RR	NM CSM	PTC IM	SS EA		IBM RR	NM CSM	PTC IM	SS EA	
Structural Elements	72%	83%	0%	50%	51%	31%	100%	6%	88%	56%
Activities	100%	100%	82%	65%	87%	81%	100%	81%	81%	86%
Interactions	86%	100%	0%	100%	71%	86%	100%	0%	100%	71%
State Machines	100%	100%	25%	100%	81%	60%	80%	20%	60%	55%
Use Case	100%	100%	40%	100%	85%	100%	100%	40%	100%	85%
Requirements	100%	17%	0%	83%	50%	0%	100%	0%	17%	29%
	89%	86%	30%	72%		58%	98%	31%	78%	
Source tool > Target tool >	SS EA				cluster total	PTC IM				cluster total
Source tool > Target tool >	IBM RR	NM CSM	PTC IM	SS EA		IBM RR	NM CSM	PTC IM	SS EA	
Structural Elements	56%	31%	6%	100%	48%	19%	31%	44%	69%	41%
Activities	81%	100%	63%	100%	86%	82%	88%	88%	76%	84%
Interactions	86%	100%	0%	100%	71%	14%	14%	14%	14%	14%
State Machines	100%	100%	50%	100%	88%	100%	100%	75%	100%	94%
Use Case	100%	100%	40%	100%	85%	100%	80%	40%	100%	80%
Requirements	33%	0%	0%	100%	33%	0%	0%	17%	50%	17%
	72%	69%	28%	100%		49%	53%	53%	67%	



The Top Three Alternatives

for SysML Interoperability

1. Use a software adapter and/or service to facilitate data exchange
2. Require the use of a single brand of SysML-based authoring tools
3. Invest in the manual conversion of paper-based documents and/or hybrid



[MBSE Working Group](#)

[Aerospace & Defense PLM Action Group](#)

Recommendations



Short term:

Evaluate, validate, and employ the use of third-party MBSE interoperability software tools/adapters that supplement the basic capabilities present in the major SysML authoring tools, and/or the use of a translation service for more robust MBSE data exchange.

Interim:

We all must use an ISO 42010-compliant architecture description language (ADL) and deploy a common exchange service/methodology across the aerospace industry. The INCOSE's recommendation and the prevalent standard is SysML.

Long term:

- Endorse the SysML 2.0 RFP content, the non-mandatory features describing model interchange and formal semantics, and recommend the incorporation of UMLDI or equivalent into future SysML specifications.
- Encourage our tool Vendors to prioritize an industry wide exchange strategy and to implement new industry standards (e.g. SysML 2.0) when they become available.

Future Opportunities

- Define the requirements for a 3rd Party software adapter and translation service
- Understand our own requirements about what we want to exchange
- Define a set of priorities to be addressed by the standard bodies and industry consortiums
- Monitor the market for solutions in the space of data interoperability and 3rd party adapter software

[MBSE Working Group](#)

REQUEST the [Position Paper](#)



Press Release



To realistically reduce the cost of developing new products the Systems Engineering community must evolve from our document based paradigm and embrace MBE. The foundation of this evolution is MBSE. But the slow implementation of MBSE is an industry problem that relies on data standards, defining WHAT must be exchange, HOW to exchange, data interoperability and preservation. We also need Leadership and a robust source of Vendor products. Any alternatives must include not just the OEMs, but also the supply base.

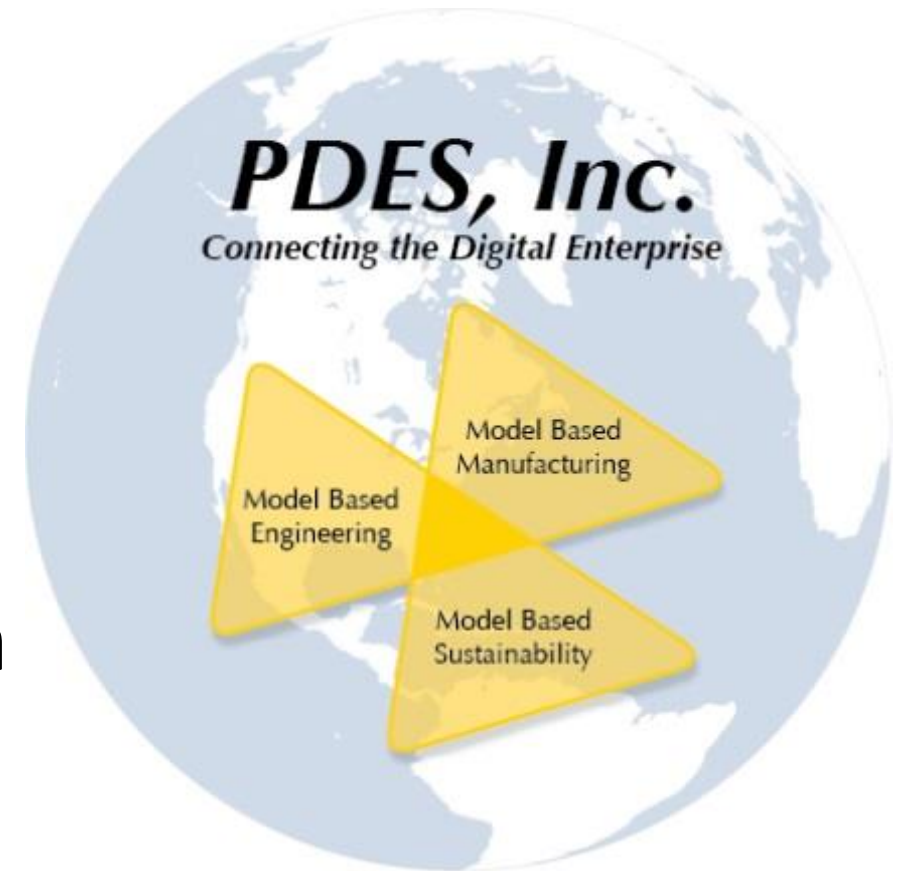
This presentation addresses some of those issues, and the communities engaged in identifying potential opportunities and solutions. Can you identify the role of PDES, LOTAR, and/or the industry consortiums aligned to implement change? Bring your questions and ideas to this two part session inspired by the need to empower INCOSE's thriving membership.



Why PDES ?

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 using STEP

- STEP is officially called ISO 10303
- ISO 10303 is the standard for the digital representation and exchange of product modeling information
- STEP standards are computer sensible

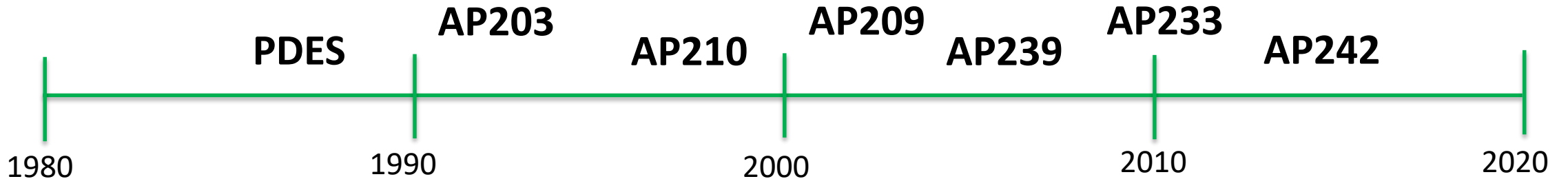
STEP = Standard for the Exchange of Project model data

Why Standards?

- Reduce Cost \$\$
- Control Part and Process Quality
- Support for Design Reuse
- Avenue for Data Exchange

ISO TC184 SC4		STEP on a Page		ISO 10303
APPLICATION PROTOCOLS AND ASSOCIATED ABSTRACT-TEST SUITES				
I 201 Explicit draughting [ATS 201 = X]	C 221 Functional data & their schem rep for process plant [X]	X 222 Design-manuf for composite structures [W]	X 223 Exch of design & mfg product info for cast part [U]	I 224 Mech part def for p. pfg using mach to g feat [C, X, A]
I 202 Associative draughting [X]	I 225 Building elements using explicit shape rep [C]	X 226 Ship mechanical systems [C]	I 227 Plant spatial configuration [C = C]	X 228 Building services: HVAC [C]
I 203 Configuration-controlled design (c2=1, a1=0) [X]	X 229 Design & mfg product info for forged parts [X]	X 230 Building structural frame: steelwork [X]	X 231 Process-engineering data [X]	I 232 Technical data packaging: core info & exch [I]
I 204 Mechanical design using boundary rep [I]	I 233 Systems engineering: data rep to be PAS 308:20 [X]	X 234 Ship operational logs, records, and messages [X]	W 235 Materials info for des and vnf of products [X]	W 236 Furnace product and prod [X]
X 205 Mechanical design using surface rep [W]	X 237 Computational Fluid Dynamics	A 238 Computer numerical controllers	W 239 Product life-cycle support	W 240 Process plans for machined products
X 206 Mechanical design using wireframe [X]				
I 207 Sheet metal die planning and design [I]				
X 208 Life-cycle product change process [X]				
I 209 Composite & metal structural anal & related design [X]				
I 210 Electronic assy interconnection & packaging design [X]				
I 211 Electronic P.C. assy test, diag, & reassembly [X]				
I 212 Electrochemical design and installation [C]				
X 213 Nura control (NC) process plans for mach'd parts [X]				
I 214 Core data for automotive mech design processes (e2=0) [F]				
I 215 Ship arrangement [X]				
I 216 Ship moulded forms [X]				
X 217 Ship piping [X]				
I 218 Ship structures [X]				
X 219 Distortion inspection [X]				
O 220 Proc. pig. mfg. assy of layered electrical products [X]				

COMMON RESOURCES (with 13584-20 logic model of expr. (I) and 15531-2 Time (W))	
APPLICATION MODULES (Technical specifications)	Legend: TS Status
For status of the modules access the file via the SOAP home page.	0-10 = Oprop - aprt for ballot
	10-20 = A=NP bit circ - NP aprt
	20-60 = D=TS des - reg as TS
	-60 = F=TS Published
INTEGRATED-APPLICATION RESOURCES	
I 101 Draughting (c1=0)	X 106 Building core model
X 102 Ship structures	C 107 Finite-element analysis: definition relationships
I 104 Finite element analysis	C 108 Assembly model for products
I 105 Kinematics (c1=0, c2=0)	W 110 Mesh-based computational fluid dynamics
INTEGRATED-GENERIC RESOURCES	
I 41 Fund of prod descr & org (e2=1, c1=0)	I 50 Mathematical constructs
42 Geom & top rep (c2=1, e2=c1, e3=F)	E 51 Mathematical description
43 Repres specialisation (e2=1, c1=c2=0)	W 52 Mesh-based topology
44 Product struct confg (e2=1, c1=0)	W 53 Numerical Analysis
45 Materials (c1=0)	C 54 Classification Set theory
46 Visual presentation (c1=1, c2=0)	A 55 Procedural and hybrid represent.
47 Tolerances (c1=0)	W 56 State
48 Form features	W 57 Expression extensions
49 Process structure & properties	A 58 Risk
APPLICATION-INTERPRETED CONSTRUCTS	
I 501 Edge-based wireframe	I 512 Faceted B-representation
I 502 Shell-based wireframe	I 513 Elementary B-rep
I 503 Geom-bounded 2D wireframe	I 514 Advanced B-rep
I 504 Draughting annotations	I 515 Constructive solid geometry
I 505 Deriving structure & admin.	X 516 Mechanical-design context
I 506 Draughting elements	I 517 Mech-design geom presentation (c1=0)
I 507 Geom-bounded surface	I 518 Mech-design hatched presentation
I 508 Non-manifold surface	I 519 Geometric tolerances (c1=0)
I 509 Manifold surface	I 520 Assoc draughting elements
I 510 Geom-bounded wireframe	I 521 Manifold sub-surfaces
I 511 Topological-bounded surface	E 522 Machining features
	A 523 Curve swept solid
IMPLEMENTATION METHODS	
I 21 Clear-text encoding exch str (c1=1, e2=0)	C 25 EXPRESS to OMD XMI
I 22 Standard data access interface	X 26 XML language binding (to #2)
I 23 C++ language binding (to #2)	I 27 XML language binding (to #2)
I 24 C language binding (to #2)	I 28 XML rep for EXPRESS-schemata & data
	X 29 XML language binding (to #2) (DTS)

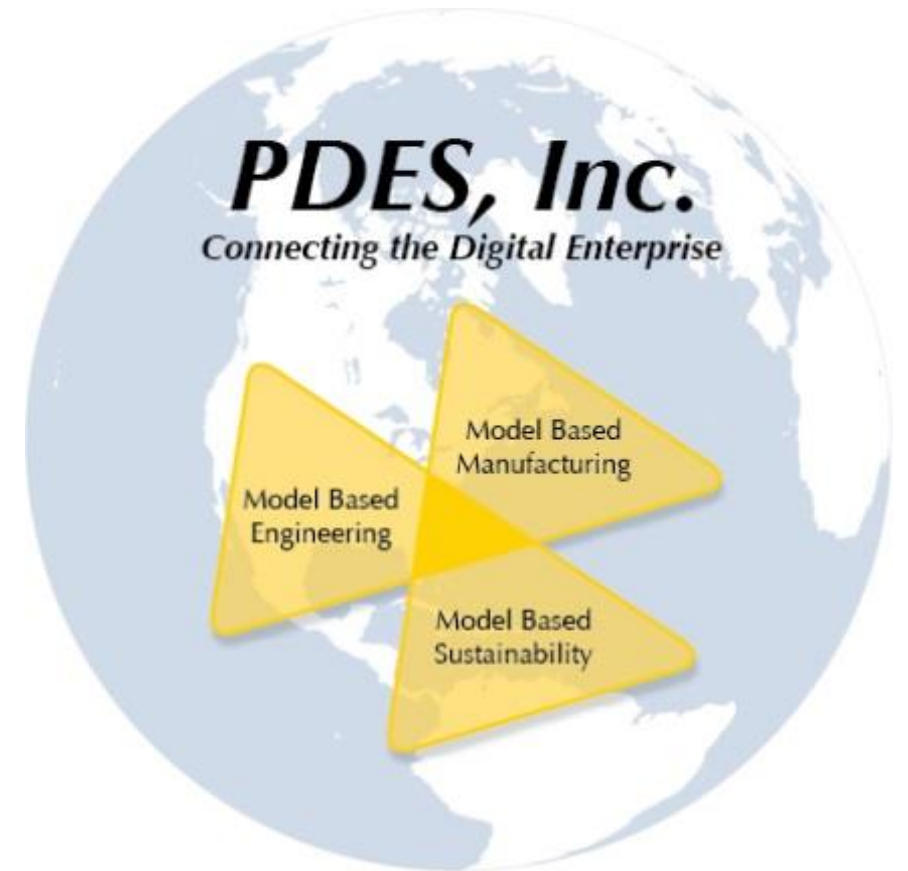


2008 – 2010, AP233 exchange of system engineering data

2014 Requirements Traceability

2017 Evaluate Industry Tools

2018 Organize applicable tools, define **HOW**



The Team's Current Focus:

Define **HOW** to assemble/bundle/couple/package the MBSE business objects (MBSE TDP) that need to be exchanged (architecture of the process), and **HOW** the exchange/sharing/access should occur.

the new TDP = the MBSE version of SE Handbook

MBSE for PDES – HOW Activities

1. Packaging - unpacking (containers, media, data types, etc.)
2. Define and maintain model relationships
3. Manifest of package contents and features
4. Marking and Security of package and contents
5. Reference a **WHAT** document for creation of TDP
6. How to manage the MBSE Diversity (mixed IP, obfuscated data/models, compiled code, software, CAD, documentation)

HOW to assemble/bundle/couple/ package the MBSE business objects that need to be exchanged (architecture of the process), and HOW the exchange/sharing/ access should occur.

Sample Document Taxonomy

Originally focused
on **Digital Artifacts**,
INCOSE's DEIX WG
(Digital Engineering
Information Exchange)
has the incentive to
fix this

Number & Name	inputs	outputs
0 Context		
1 External	6.1.2 Request for Supply (to Supplier) 6.1.3 Acquisition Agreement 6.1.5 Acquisition Payment 6.2.2 Supply Response 6.2.3 Supply Agreement 6.2.4 Supplied System 7.1.1 Life Cycle Model Management Plan 7.1.6 Life Cycle Model Management Report 7.2.1 Infrastructure Management Plan 7.2.4 Infrastructure Management Report 7.3.1 Portfolio Management Plan 7.3.6 Portfolio Management Report 7.4.1 Human Resource Management Plan 7.4.3 Human Resource Management Report 7.5.1 Quality Management Plan 7.5.4 Quality Management Report 7.5.5 Quality Management Evaluation Report 7.6.1 Knowledge Management Plan 7.6.3 Knowledge Management Report	1.1 ConOps 1.2 Source Documents 1.3 External Stakeholder Needs 1.4 Applicable Laws and Regulations 1.5 Acquisition Reply 1.6 Acquired System 1.7 Request for Supply (from Acquirer) 1.8 Supply Payment 1.9 Standards 1.10 Customer Satisfaction Inputs 1.11 Internal Stakeholder Needs 1.12 Organization Strategic Plan 1.13 Organization Portfolio Direction & Constraints
3 System Life Cycle Processes		
3.1 Controls and Enablers	1.4 Applicable Laws and Regulations 1.9 Standards 5.1.1 SEMP 5.2.5 Project Control Requests 6.1.3 Acquisition Agreement 6.2.3 Supply Agreement 7.1.2 Organizational Policies, Procedures, and Assets 7.2.2 Organization Infrastructure 7.2.3 Project Infrastructure	3.1 Controls 3.2 Enablers

Another Document Taxonomy of a TDP

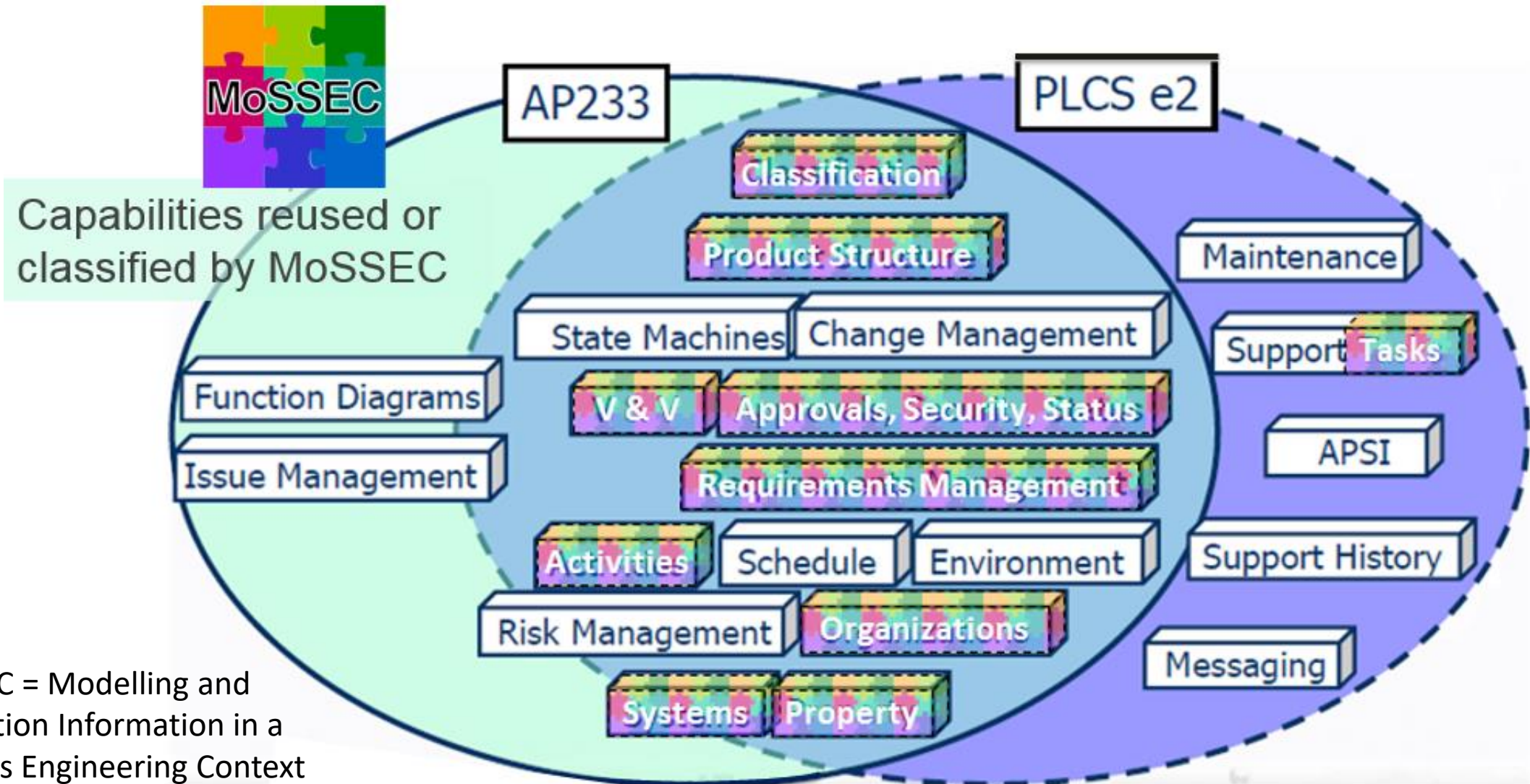
DoD CDRL DIDs

<p>1. Operational Context Info</p> <p>1.1 Study Guidance</p> <p>1.2 Mission/Study Plan</p> <p>1.3 Initial Threat Environment Assessment</p> <p>1.4 System Threat Assessment Report (STAR)</p> <p>1.5 Analysis of Alternatives (AOA)</p> <p>1.6 Concept of Operations/Operational Mode Summary/Mission Profile (CONOPS/OM/MP)</p> <p>1.7 Design Reference Mission Profile (DRMP)</p> <p>1.8 Operational Concept Description (OCD)</p> <p>1.9 Preferred Material Solution Set</p> <p>1.10 Preliminary Operational Concept Document</p> <p>2. Requirements</p> <p>2.1 Initial Capabilities Document (ICD)</p> <p>2.2 Joint Requirements</p> <p>2.3 Capabilities Development Document (CDD)</p> <p>2.4 Capabilities Production Document (CPD)</p> <p>2.5 Trace Matrix</p> <p>2.6 System Functional and Performance Requirement</p> <p>2.7 Performance Spec</p> <p>2.8 Software Requirements Specification (SRS)</p> <p>2.9 Component Spec</p> <p>2.10 Allocated Requirements</p> <p>2.11 Interface Requirements Specification (IRS)</p> <p>2.12 Interface Control Document</p> <p>2.13 Software Product Specification (SPS)</p> <p>2.14 System Requirement Specification, System Spec, System/Segment Specification, Systems/Systems Specifications (SS)</p> <p>2.15 Preliminary Software Requirements Specifications</p> <p>2.16 Preliminary Software Interface Requirements Specifications</p> <p>2.17 Draft Product Specification</p> <p>2.18 Type Specification, and referenced documentation</p> <p>3. Analysis</p> <p>3.1 Spectrum Supportability Risk Assessment (SSRA)</p> <p>3.2 Models & Test Cases (Simulations)</p> <p>3.3 Analysis/Trade Study Reports</p>	<p>3.4 TECHNOLOGY READINESS ASSESSMENT (TRA)</p> <p>3.5 Bandwidth Requirements Review</p> <p>3.6 Waveform Assessment Application</p> <p>4. Design Info</p> <p>4.1 Architecture</p> <p>4.2 Product Data Performance</p> <p>4.3 Design Description Documents (ALL)</p> <p>4.4 Drawings (e.g. CAD, schematics, etc.)</p> <p>4.5 Design (Engineering) Analysis (i.e. "DOQC" analysis, functional analysis, etc.)</p> <p>4.6 Design considerations</p> <p>4.7 Trade studies</p> <p>4.8 Conceptual Design Drawings/Models</p> <p>4.9 Developmental Design Drawings/Models and Associated Lists</p> <p>4.10 Product Drawings/Models and Associated Lists</p> <p>4.11 Functional Breakdown Descriptions</p> <p>4.12 Design Selection Decision Document</p> <p>4.13 Systems/Subsystem Design Description (SDD)</p> <p>4.14 Software Design Description (SDD)</p> <p>4.15 Interface Design Description (IDD)</p> <p>4.16 Database Design Description (DBDD)</p> <p>4.17 Results of Design Analysis</p> <p>4.18 Drawings Level 1 Data/DOB</p> <p>4.19 Drawings Level 1 or II Data/DOB</p> <p>4.20 Software Detailing Documents</p> <p>4.21 Hardware Interface Design Document</p> <p>4.22 Software Development Documentation</p> <p>4.23 Data Base Design Document</p> <p>5. Verification and Validation</p> <p>5.1 Development Test (DT)/Operational Test (OT) Results</p> <p>5.2 Software Test Plan (STP)</p> <p>5.3 Test Reports</p> <p>5.4 Operational Test Agency Report of Operational and Test Evaluation Results</p> <p>5.5 System Operational Verification Tests (SOVT)</p> <p>5.6 Software Test Description (STD)</p>	<p>5.7 Software Version Description (SVT)</p> <p>5.8 Test and Evaluation Master Plan (TEMP)</p> <p>5.9 Software Test Description</p> <p>5.10 Test Descriptions</p> <p>5.11 Test Procedures</p> <p>5.12 Informal Software Development Test Results</p> <p>5.13 Informal Hardware Development Test Results</p> <p>5.14 Test Plan</p> <p>5.15 Software test reports</p> <p>6. Technical Management Info</p> <p>6.1 Engineering/Product Structure</p> <p>6.2 Infrastructure Management</p> <p>6.3 Configuration Management Plan</p> <p>6.4 Product Unit Configuration Information</p> <p>6.5 Configuration Control</p> <p>6.6 Request for Change</p> <p>6.7 Request for Variance</p> <p>6.8 Configuration Control Board Decision</p> <p>6.9 Product Configuration Management Status Accounting Data</p> <p>6.10 Item Design Identification Implementation Plan (IDIP)</p> <p>7. Manufacturing Info</p> <p>7.1 INDUSTRIAL BASE CAPABILITIES CONSIDERATION (Part of Acquisition Strategy)</p> <p>7.2 Depot Maintenance Work Requirements (DMWR) and National Maintenance Work Requirements (NMWR)</p> <p>7.3 Depot Source of Repair/CORE Analysis/Determination</p> <p>7.4 Depot Performance</p> <p>7.5 Facilities Plan</p> <p>7.6 Planned Maintenance System Documentation</p> <p>7.7 Planned Maintenance System Performance</p> <p>7.8 Maintenance Concept</p> <p>7.9 Manufacturing Plan</p> <p>7.10 Proposed Critical Manufacturing Process Description</p> <p>7.11 Disassembling Manufacturing Sources and Material Shrinkage (DMSMS) Plan</p> <p>7.12 LOW-RATE INITIAL PRODUCTION (LRIP) QUANTITY</p>	<p>7.13 PRESERVATION AND STORAGE OF UNIQUE TOOLING PLAN</p> <p>7.14 Long Lead Production Requirements</p> <p>7.15 Mass Properties Report</p> <p>7.16 Manufacturing Instructions</p> <p>7.17 Commercial Drawings/Models and Associated Lists</p> <p>7.18 Special Inspection Equipment Drawings/Models and Associated Lists</p> <p>7.19 Drawing Model Number Assignment Report</p> <p>7.20 Special Tooling Drawing/Models and Associated Lists</p> <p>7.21 Preferred Parts Selection List/Approval Parts List</p> <p>7.22 Manufacturing Process Drawings</p> <p>8. Management Info</p> <p>8.1 Reliability, Availability, Maintainability (RAM) Plan & Reports</p> <p>8.2 Risk, Issues, & Opportunities</p> <p>8.3 Risk Management Plan/Assessment</p> <p>8.4 "Technology" Targeting Risk Assessment</p> <p>8.5 Quality Assurance Plan</p> <p>8.6 Program Management</p> <p>8.7 Integrated History/Management Plan</p> <p>8.8 Program Risk Assessment</p> <p>8.9 Technical Plans</p> <p>8.10 Acquisition Plan (AP)</p> <p>8.11 Acquisition Strategy</p> <p>8.12 CMM/SEI/CMR/ACT COMPLIANCE</p> <p>8.13 CONSIDERATION OF TECHNOLOGY ISSUES (Part of Acquisition Strategy)</p> <p>8.14 COOPERATIVE OPPORTUNITIES (Part of Acquisition Strategy)</p> <p>8.15 CYBERSECURITY STRATEGY</p> <p>8.16 Other Security Plan</p> <p>8.17 FREQUENCY ALLOCATION APPLICATION (DO Form 1494)</p> <p>8.18 INTELLECTUAL PROPERTY (IP) STRATEGY (Part of Acquisition Strategy)</p> <p>8.19 SMALL BUSINESS PROMOTION REQUEST (SBPR)/SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) PROGRAM TECHNOLOGIES</p> <p>8.20 Future Reporting/Corrective Action System (FRACAS)</p> <p>8.21 Corrosion Prevention Control Plan</p> <p>8.22 Human System Integration (HSI) Plan</p> <p>8.23 IRL Criteria</p> <p>8.24 Request for Proposal (RFP)</p> <p>8.25 Systems Engineering Plan (SEP)</p>
<p>8.26 Acquisition Program Baseline (APB)</p> <p>8.27 Contractual Documentation</p> <p>8.28 CONTRACT-TYPE DETERMINATION (Part of Acquisition Strategy)</p> <p>8.29 GENERAL EQUIPMENT VALUATION (Part of Acquisition Strategy)</p> <p>8.30 Systems Engineering Management Plan</p> <p>8.31 Software Plan</p> <p>8.32 Software Development Plan</p> <p>8.33 Work breakdown structure</p> <p>8.34 Schedule</p> <p>8.35 PESHE AND NEPA/E.O. 12114 COMPLIANCE SCHEDULE</p> <p>8.36 TERMINATION LIABILITY ESTIMATE (Part of Acquisition Strategy)</p> <p>8.37 Information Support Plan (ISP)</p> <p>8.38 Software development plan (SDP)</p> <p>8.39 Software Installation Plan (SIP)</p> <p>8.40 Software Transition Plan (STrP)</p> <p>8.41 Software Support/Sustainment Plan</p> <p>8.42 Data Management Plan</p> <p>8.43 Data Rights Strategy (DRS)/Intellectual Property Strategy</p> <p>8.44 Supportability Analysis Summaries (Maintenance Planning and Repair Analysis, Support and Test Equipment, Supply Support, MTR&E Facilities, PHS&T, and Post Production Support)</p> <p>8.45 Technical Data Rights Strategy (TDRS)</p> <p>8.46 Program Protection Plan (PPP)</p> <p>8.47 Life-Cycle Mission Data Plan</p> <p>8.48 Life-Cycle Sustainment Plan (LCSP)</p> <p>8.49 INDEPENDENT LOGISTICS ASSESSMENT (ILA)</p>	<p>9.6 Maintenance History, Supportability Cost Drivers</p> <p>9.7 Logistics Requirements Funding Summary (LRFS)</p> <p>9.8 INDEPENDENT COST ESTIMATE (ICE)</p> <p>9.9 Cost Analysis Requirements Description (CARD)</p> <p>9.10 Component Cost Estimate</p> <p>9.11 Fuel Handling Certification Memorandum</p> <p>10. Product Support Info</p> <p>10.1 Technical Data Package</p> <p>10.2 Lifecycle Sustainment Management</p> <p>10.3 TDP - Conceptual Design Drawings, Models</p> <p>10.4 TDP - Special Packaging Instructions</p> <p>10.5 TDP-Quality Assurance Provisions</p> <p>10.6 TDP - Developmental Design Drawings, Models, Lists</p> <p>10.7 TDP - Product Design Drawings/Models</p> <p>10.8 TDP - Commercial Drawings/Models</p> <p>10.9 TDP - Special Inspection Equipment (SIE) Drawings, Models, Lists</p> <p>10.10 Source Control Drawing Approval Requests</p> <p>10.11 TDP - Special Test Equipment (STE) Drawings, Models, Lists</p> <p>10.12 TDP - Software Documentation</p> <p>10.13 TDP - Specifications (Items)</p> <p>10.14 Software User Manual (SUM)</p> <p>10.15 Software Center Operator Manual (SCOM)</p> <p>10.16 Software Support/Operator Manual (SSOM)</p> <p>10.17 Computer Operations Manual (COM)</p> <p>10.18 Computer Programming Manual (CPM)</p> <p>10.19 Firmware Support Manual (FSM)</p> <p>10.20 TDP type and content per MIL-STD-21880C</p> <p>10.21 TDP type and content per MIL-STD-21880C</p> <p>10.22 TDP - Special Packaging Instructions</p> <p>10.23 Computer Resources - Integrated Support Document</p> <p>10.24 Software Programmer's Manual</p> <p>10.25 Firmware Support Manual</p> <p>10.26 Computer System Operator's Manual</p> <p>10.27 Software User's Manual</p> <p>10.28 Computer System Diagnostic Manual</p> <p>10.29 Tagged Tagging (TY) (MIL-STD-21880C)</p> <p>10.30 Government Industry Data Exchange Program (GIDEP) Notices</p>	<p>10.31 Supplier Notices of Obsolete Parts</p> <p>10.32 Disposal and Demilitarization Information</p> <p>10.33 Life Cycle Sustainment Plan</p> <p>10.34 Logistics Management Information</p> <p>10.35 Maintenance Planning Information/Technical Publications</p> <p>10.36 Maintenance Work Requirements (DMWR)</p> <p>10.37 Operator Manuals</p> <p>10.38 Maintenance Allocation Chart</p> <p>10.39 Maintenance Task Analysis</p> <p>10.40 Maintenance Task Analysis</p> <p>10.41 Support & Test Equipment Information</p> <p>10.42 Support & Test Equipment Information (Test Maintenance Diagnostic Equipment)</p> <p>10.43 Supply support Information</p> <p>10.44 CORE LOGISTICS DETERMINATION / CORE LOGISTICS AND SUSTAINING WORLDWIDE ESTIMATE</p> <p>10.45 Supply Support Management Plan</p> <p>10.46 Pre-issuing Technical Data (PTD)</p> <p>10.47 Manpower, Personnel & Training Information</p> <p>10.48 Manpower Authorization Requirement Criteria (MARC) Study</p> <p>10.49 Training Analysis</p> <p>10.50 Training Performance</p> <p>10.51 Training System Plan</p> <p>10.52 Training Materials</p> <p>10.53 Packaging, Handling, Storage, Transportation and Transportation (POST) Information</p> <p>10.54 Packaging, Handling</p> <p>10.55 Commercial/Unique Shelf Involvement Plan</p> <p>10.56 Storage</p> <p>10.57 Transportation</p> <p>10.58 Environmental, Safety & Occupational Health (ESOH) Information</p> <p>10.59 Environmental</p> <p>10.60 Safety / Occupational Health</p> <p>10.61 Material In-Service Information</p> <p>10.62 Field Feedback Information (Maintenance Incidents)</p> <p>10.63 Demand Data From Field Requirements</p> <p>10.64 Item Prognosis & Diagnostics Information</p>	

- 8.26 Acquisition Program Baseline (APB)
- 8.27 Contractual Documentation
- 8.28 CONTRACT-TYPE DETERMINATION (Part of Acquisition Strategy)
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- 8.46 Program Protection Plan (PPP)
- 8.47 Life-Cycle Mission Data Plan
- 8.48 Life-Cycle Sustainment Plan (LCSP)
- 8.49 INDEPENDENT LOGISTICS ASSESSMENT (ILA)

And the DoD has also asked for help

AP233 + AP239 + AP243



MoSSEC = Modelling and Simulation Information in a Systems Engineering Context

Strategic Issues

- The HOW strategy is dependent on a clear definition of **WHAT**
- The MBSE view of WHAT to exchange is not clearly defined
(missing from MIL-STD-31000 and AP232)
- The MBSE view of **WHAT** is not defined by INCOSE's SE Handbook
- The viewpoint of OMG's UAF is at a very high level, has limited adoption, and is defined without an ontology supporting exchange
- AP233 is out of date and missing some critical features

Technology Fallout

- The document taxonomy is not mapped to a model ontology
- Many industry segments have delayed their MBSE conversion
- The Vendor tools do not promote integration and data exchange
- The big PLM Vendors are late and only offer MBSE add-ons
- The transfer of requirements to CAD is still paper based
- Unlike Europe, major American industry players are not represented in many of the standard bodies and consortiums

Next Steps

- Initiate a draft conceptual model for “HOW” (start with roadmap)
- create a draft for missing MBSE TDP standards based on INCOSE’s SE Handbook product requirements (*from DEIX*)
 - Publish a position paper on the TDP gaps
 - Initiate update proposals for AP232 and/or MIL-STD-31000
- Define a model ontology based on the document taxonomy
- Define the AP233 gaps (age related)

How You can HELP?

- Promote the TIMLM initiatives and update the tools database
- Promote the DEIX initiative and help define the model-based deliverables
- Contribute to the plan phase that defines changes to the SE Handbook
- Follow the changes promoted by prostep ivip, the MoSSEC initiative, and Modelica Association
- Join work groups promoting the digital thread and digital twins
- Promote the INCOSE MoUs with PDES and NAFEMS

MBSE for PDES – Priority Use Cases



System Models

- Industry stds (SysML, AADL)
- Architecture Rep Definition (leaves)
- Architecture Views
- Architecture Context (tree)
- Data Exchange
- Requirements model development
- Other modeling languages
- Model management
- Model Integration
- Consistency verification
- Analytical/performance models
- Unified data model for design iterations
- Analysis, Simulation, test, logistics, training

Process Compatibility

- Artifacts, e.g. Views, products, deliverables
- Security and IP protection
- Recipe for lifecycle states
- Status, milestone, measurement for completeness, quality, and closure
- Task goals and Tool applicability
- Business data exchange type/timing/agreements
- Versioning, ConfigMgmt
- UAF – Unified Architecture Framework

Requirements Mgmt

Requirements

- V&V distinctions
- Product design specific
- Tool Exchange
- Lifecycle states
- Derivation and linking
- Hierarchy/history
- OEM-Supplier Iterations
- Combo Models and Docs

Meta Data

Meta Data

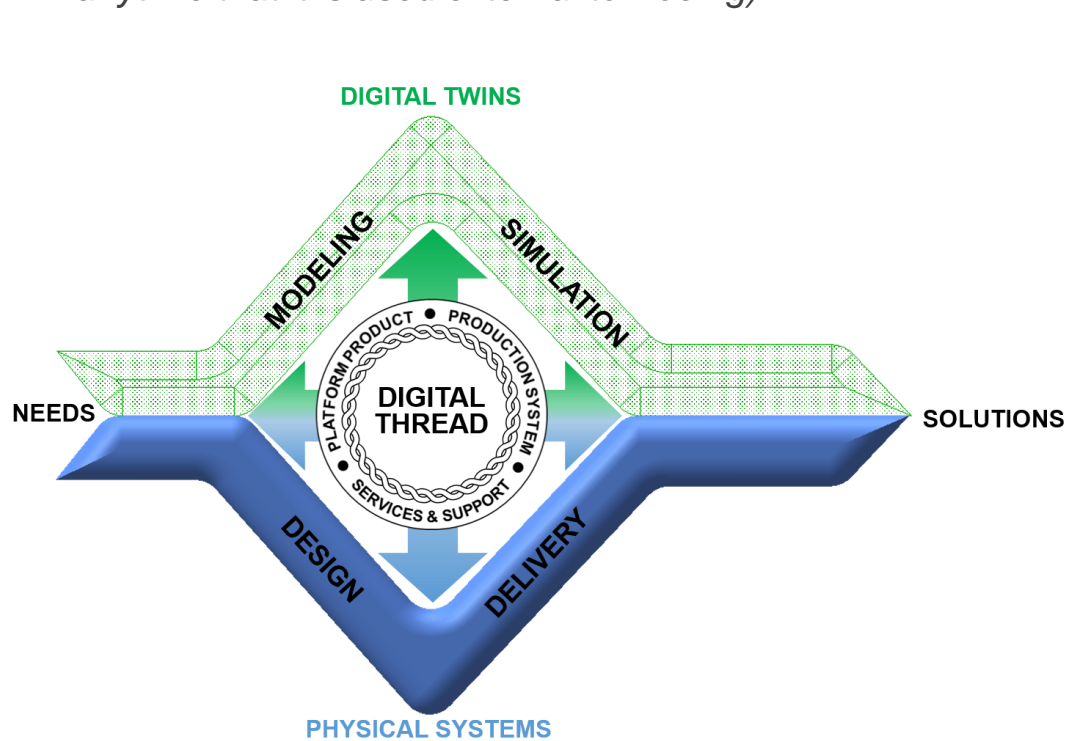
- Model application
- Model Identification/Activity/Mgmt
- Collaboration
- Terminology/taxonomy/ontologies
- Suitability for Exchange
- Who, What, When, Why, Where

Use Case defines transition to digital from document based process

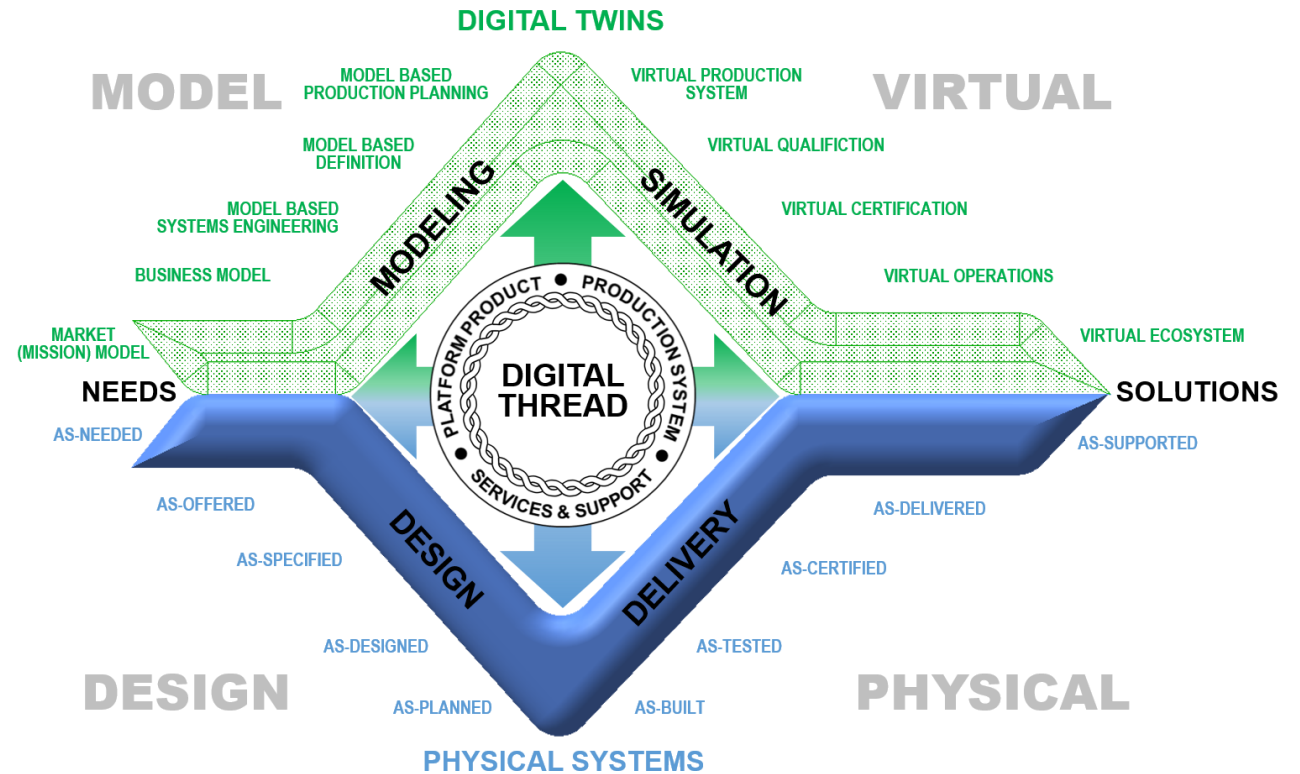


Evolution of the Engineering Vee

Compare AP233 with Dan Seal's [Diamond](#) presentation from GPDIS
(must include "Copyright © 2018 Boeing. All rights reserved" statement with the symbol
anytime that it is used external to Boeing)

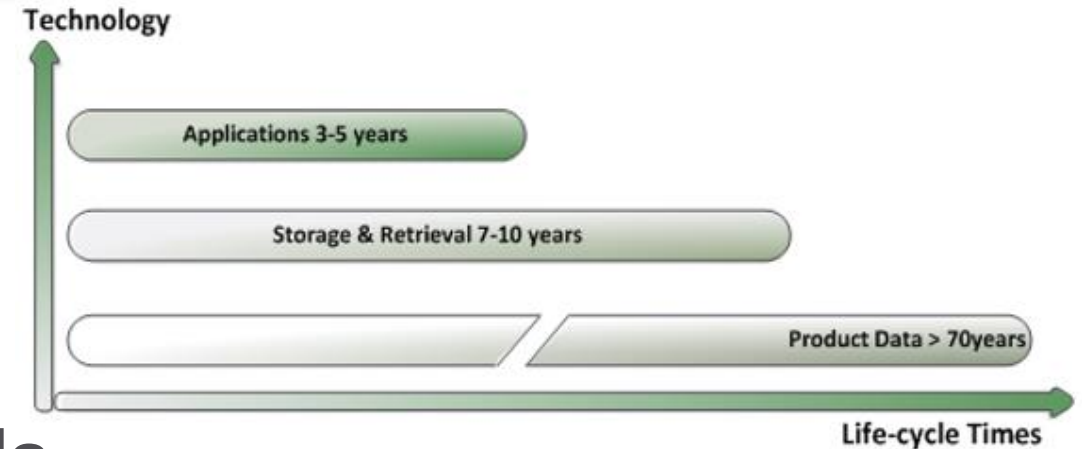


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Long Term Archiving and Retrieval



- LOTAR is Enabled by Standards
- MBSE Justification: Safety, Accident Investigations, Maintenance, Regulations, Obsolescence
- Assume Application versions 3yr; storage/access 10yrs; translate to stable formats for 50yr product cycles.

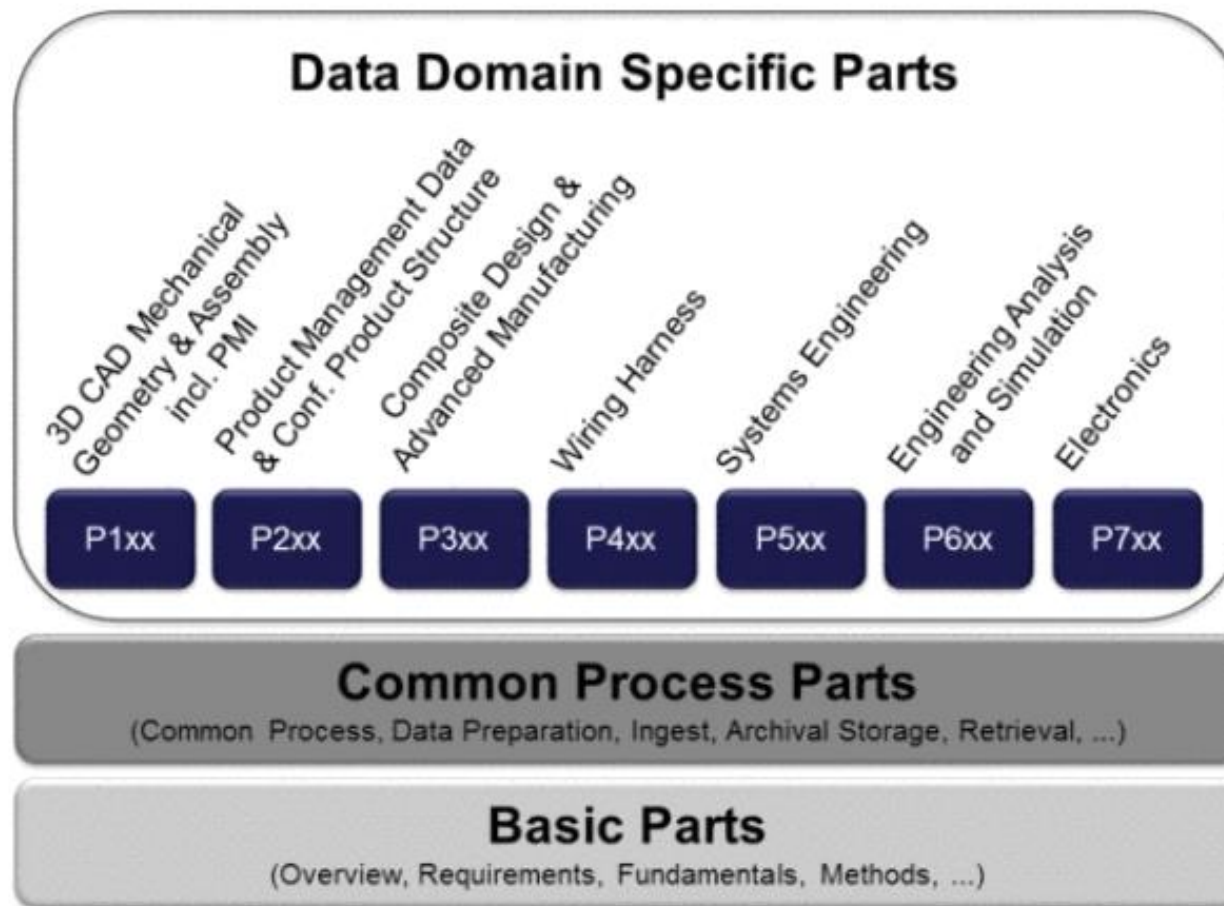
LOTAR Parts Structure

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

LOTAR began in late 90s; Europe and USA initiate merger in 2005; first pubs in 2012. In 2013 there was no plan for SE (MBSE).

<http://www.lotar-international.org>

EN/NAS 9300 Specifications



The structure of the family, organized in a series of parts, NAS 9300:

- **Part 500**: Fundamentals and Concepts for long term archiving and retrieval of Model-Based Systems Engineering information
- **Part 510**: Long term archiving and retrieval of Requirement management “text, graphics, table based” and “parameter based” information
- **Part 515**: Long term archiving and retrieval of Validation and Verification “text based” and “parameter based” information (expanding Part 515)
- **Part 520**: Long term archiving and retrieval of analytical models described by specification or executable code, containing differential, algebraic and discrete equations
- **Part 530**: Long term archiving and retrieval of models defined using architecture description languages (ADLs), ISO 42010, e.g. industry standards: AADL, SysML, UML etc.

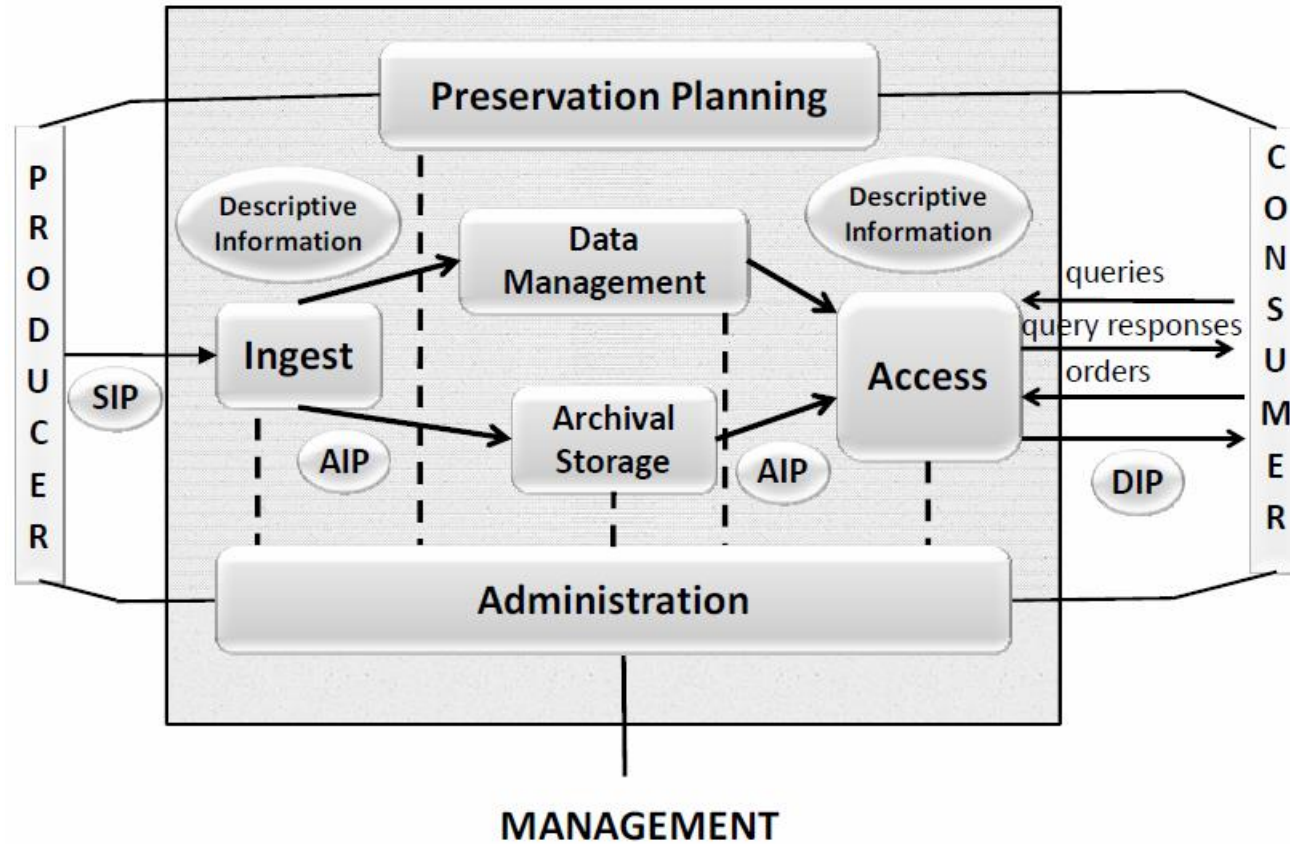
GOAL: Retrieval using a standard data representation and available tools

WHAT: Basis for Certification/Qualification, After-market Support Customer Services, Field and Accident Investigations, Part Obsolescence, Design Reuse, New Technology Development

DATA: Systems Architecture not captured on schematics, the LBOM, Requirements traceability, software function

HOW: Capture the Object model, relationships, and metadata

OASIS reference model - ISO 14721



<http://www.lotar-international.org>

- PDES - prostep ivip – AFNET
 - Process-Tool-Standards Consortia and Implementers Forums

- INCOSE:
 - a variety of working groups and activities for Systems Engineering

- NAFEMS:
 - Systems Modeling and Simulation Tech Group
(National Agency for Finite Element Methods and Standards.)

- Aerospace and Defense PLM Action Group:
 - MBSE Working Group

LOTAR for MBSE Opportunities

- Purpose: Design Reuse, obsolescence, accident investigations, after-market support



(ISO 10303-243)

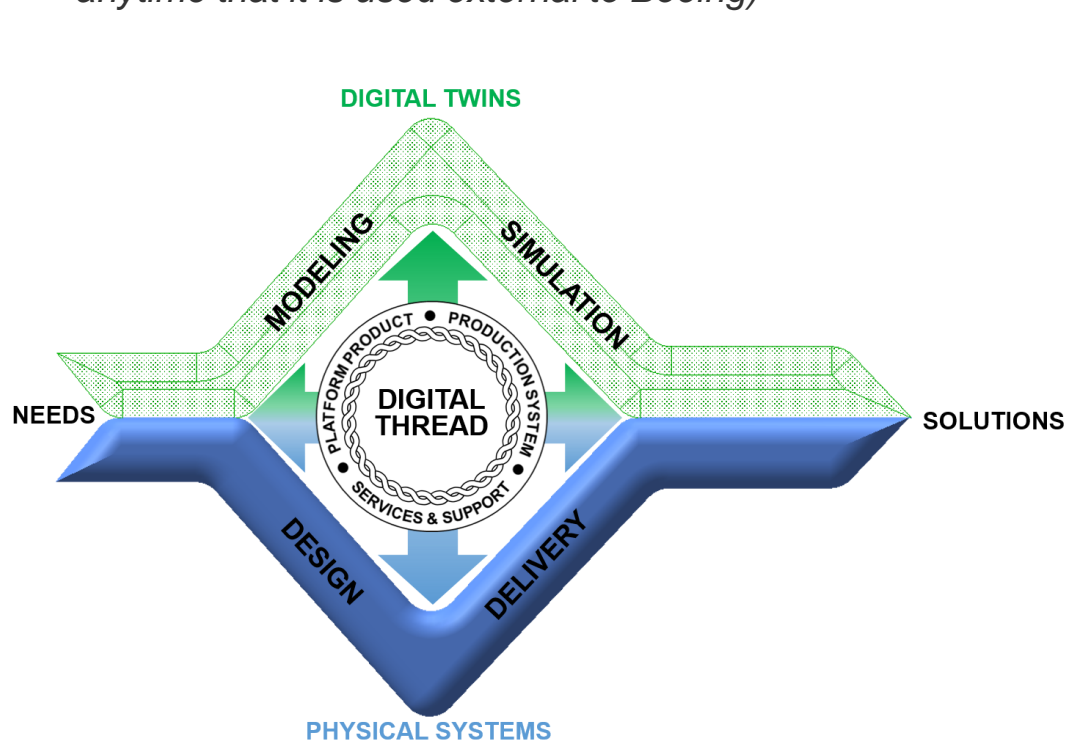
- For each part detail:
 - The business requirements and associated use cases,
 - The identification of the essential information to be preserved for long term,
 - The identification of the appropriate standard(s) (ISO or recognized internationally)
 - The description of the test and verification rules for quality control, as required

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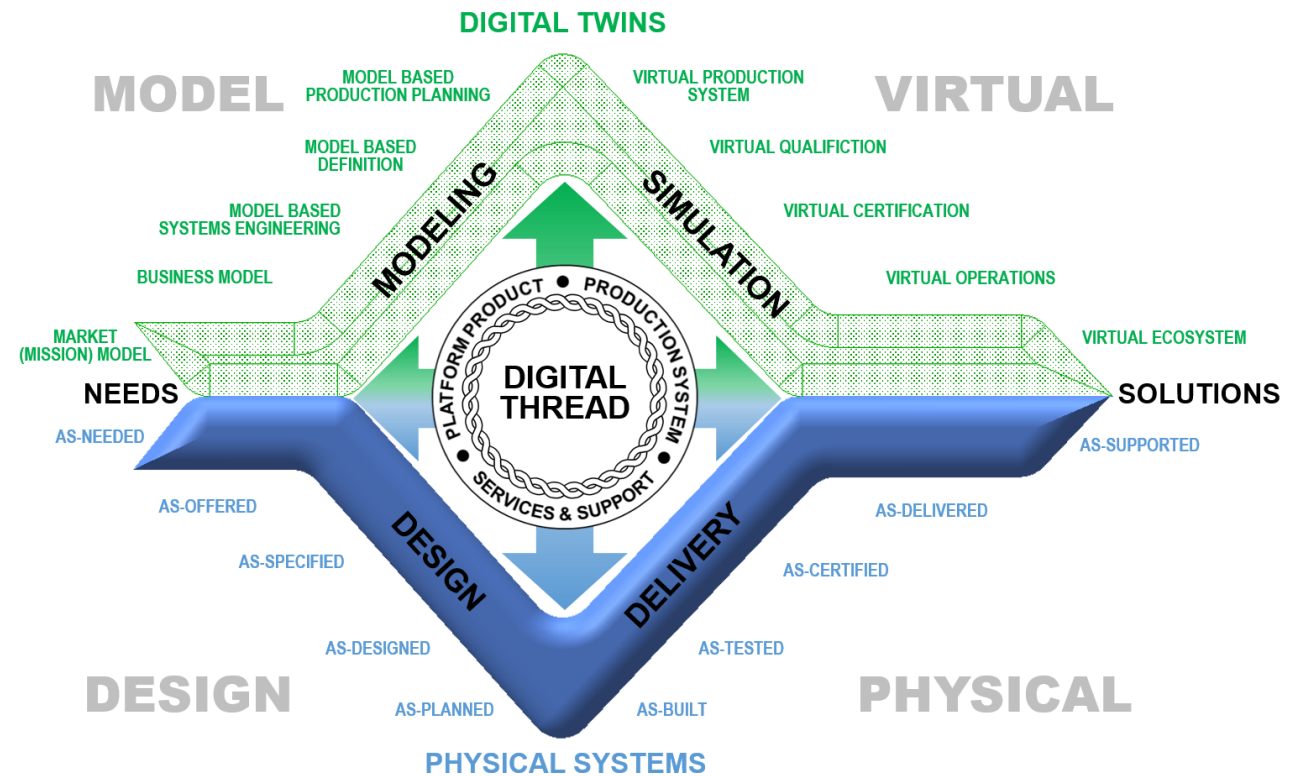
- ISO STEP AP233 Systems Engineering; AP242 Managed model-based 3D engineering; AP239 Product life cycle support
- ISO STEP AP243 Modeling and Simulation information in a Collaborative Systems Engineering Context (in-work, MoSSEC)
- FMI V2, Functional Mockup Interface
- Modelica Language Specification (for physics based equations and models)
- OMG, W3C, and OASIS standards (SysML V2, XMI, UML, OWL, OSLC)

Evolution of the Engineering Vee

Compare AP233 with Dan Seal's [Diamond](#) presentation from GPDIS
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2018 MBSE Workshop

Greg Pollari, Rockwell Collins
and
Mark Williams, Boeing Company

GLOBAL PRODUCT DATA INTEROPERABILITY SUMMIT 2018



ELYSIUM

Parker Aerospace

NORTHROP GRUMMAN

BOEING

ELYSIUM

Parker Aerospace

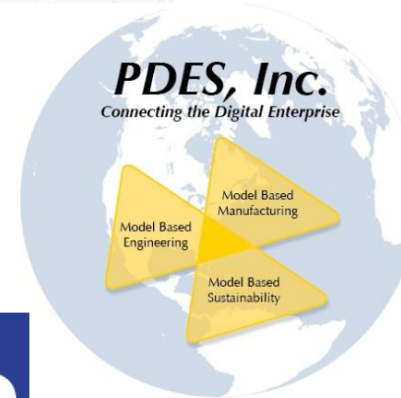
NORTHROP GRUMMAN

BOEING



GPDIS MBSE - The Landscape

Global Product Data Interoperability Summit | 2018



GPDIS Incentive – Affordability and COST Variables

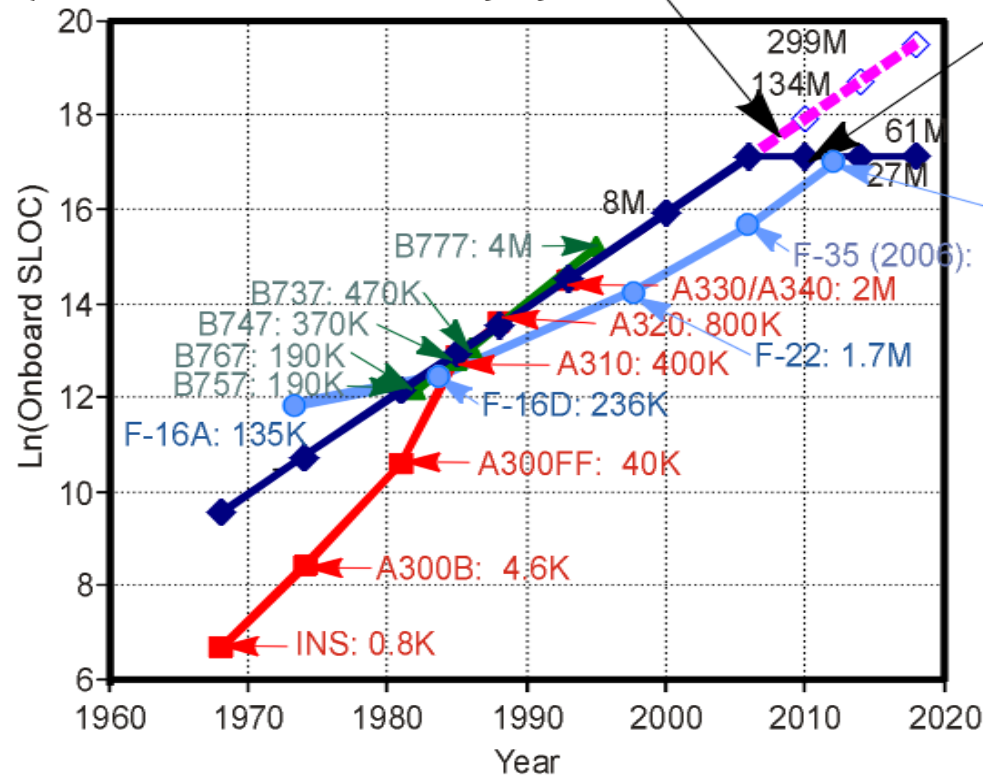
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Estimated Onboard SLOC Growth

Slope: 0.1778 Intercept: -338.5

(commercial airliners only)

Curve Implies SLOC doubles about every 4 years



This line fit is pegged at 27.5 M SLOC because the SLOC sizes for 2010 - 2020 are not affordable. The COCOMO II estimated costs to develop that much software is in excess of \$10B

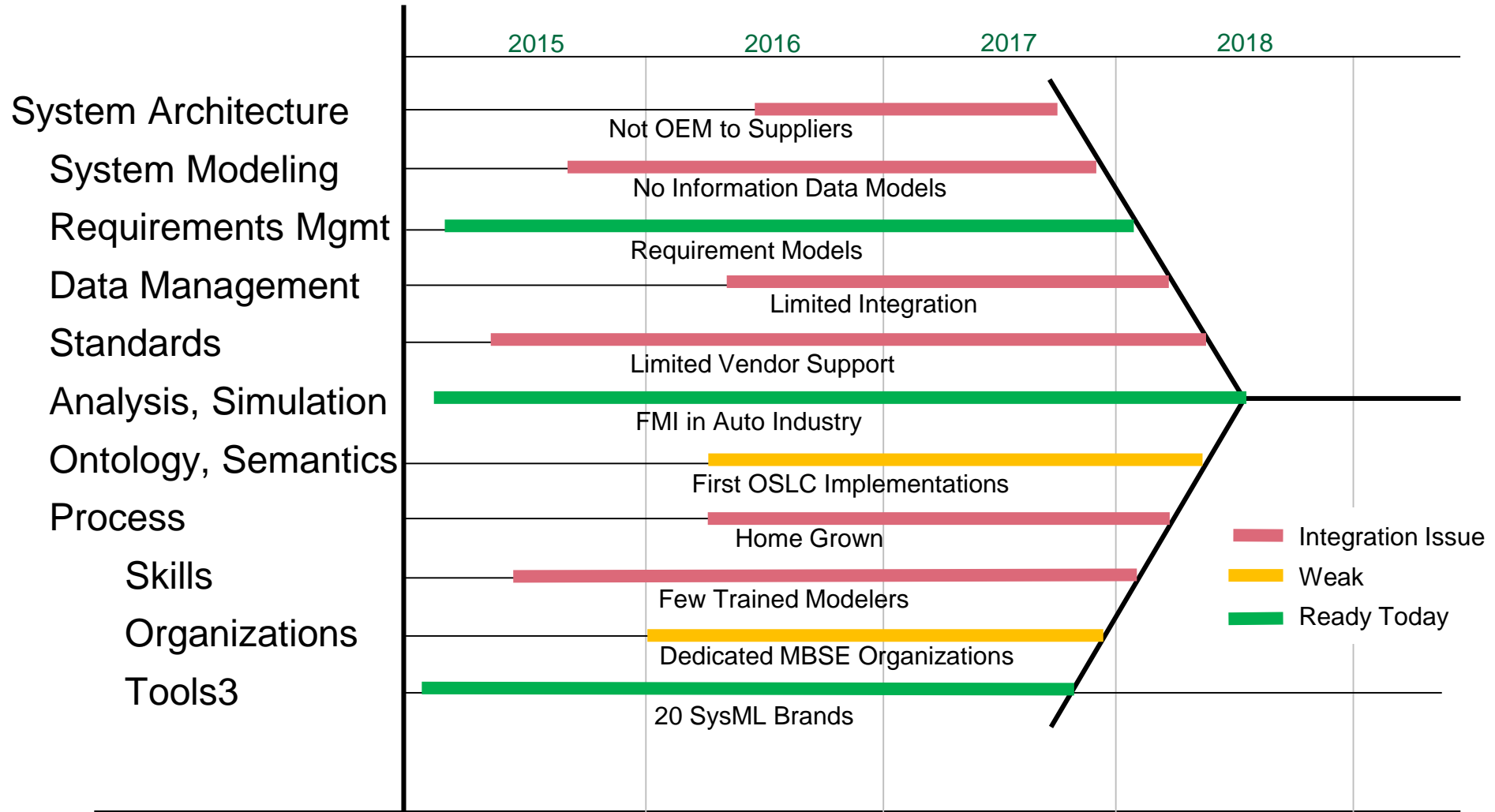
- ◆ Straight line curve fit
- ▲ Boeing aircraft
- Airbus aircraft
- USAF fighter aircraft
- Not affordable extrapolation

Airbus data source: J. P. Potocki De Montalk, "Computer Software in Civil Aircraft," Sixth Annual Conference on Software Assurance (Compass '91), Gaithersburg, MD, June 24-27, 1991
 Boeing data source: J. J. Chilenski, 2009
 USAF fighter data source: Hagen and Sorenson, "Delivering Military Software Affordably," Defense AT&L, March-April 2013

2014 GPDIS Presentation: Dr. David Redman, Director, Aerospace Vehicle Systems Institute (AVSI)

MBSE Workshop: Industry Roadmap

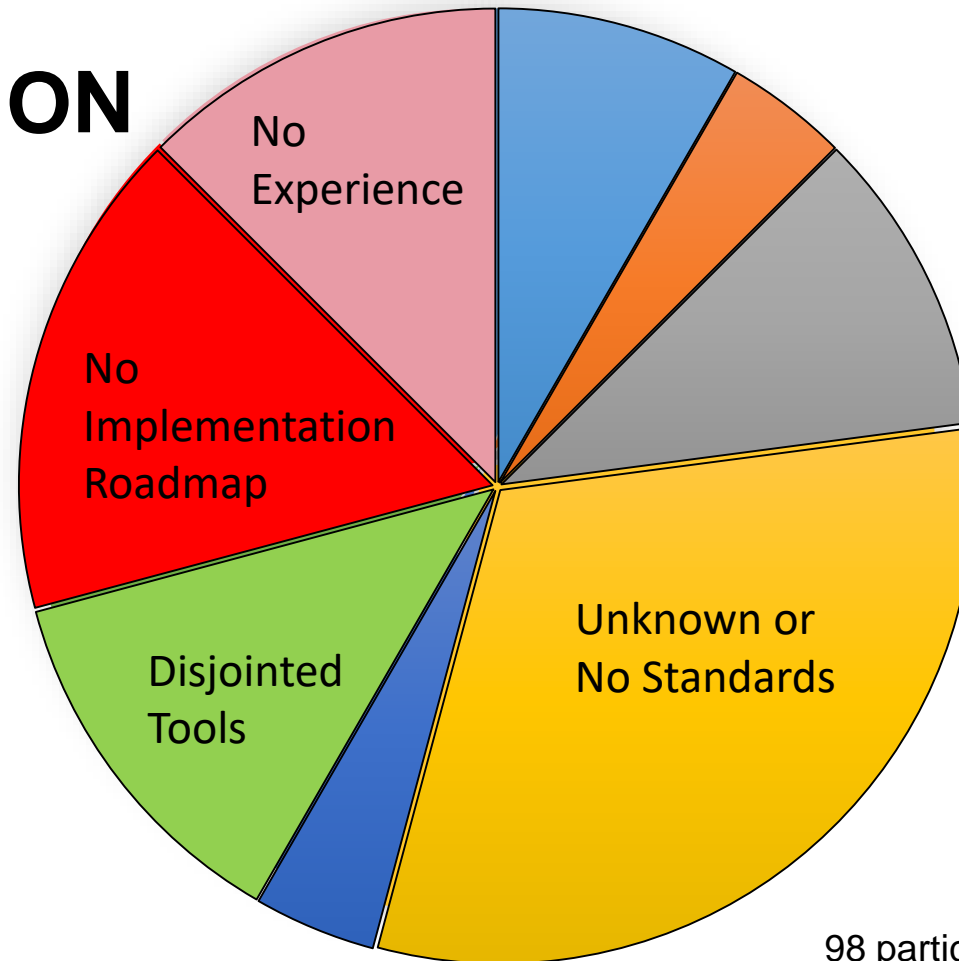
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MBSE Workshop: Participant Survey

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IMPLEMENTATION ISSUES



- Define/Justify MBSE
- Training-Implementation
- Integrate with PLM
- Standards - Interoperability
- Vocabulary
- Tool Integration (Vendors)
- Roadmap
- Modeling

98 participants, 12 teams,
33 written submissions and 104 comments

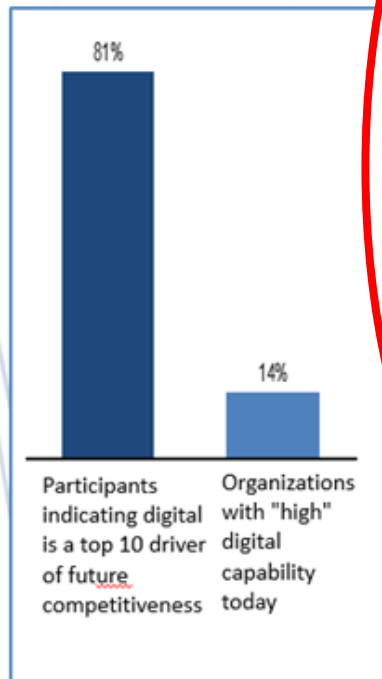
2018 MBSE Workshop – Greg Harris Keynote

Global Product Data Interoperability Summit | 2018

The implementation of digital capabilities in the product realization process, such as early consideration of manufacturability during the development of the science & technology and the design & acquisition phases, is essential to dealing with this complexity and succeeding in this 4th industrial revolution.

Gregory A. Harris, PH.D. –
Auburn University

Despite the recognition of importance for digital design and manufacturing, most participants believe their organizations lack capability



Majority of senior leaders agree that digital is a priority, but few have a clear bold vision and strategy



Translating strategy to clear action is a clear gap in a majority of organizations



SOURCE: McKinsey survey, >200 responses from subject matter experts, industry leaders

+ a UI LABS Collaboration

Approved For Public Release

6

Workshop History at GPDIS

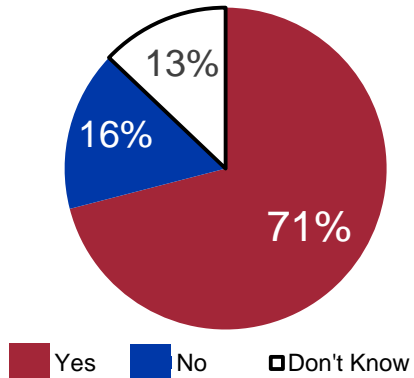
Global Product Data Interoperability Summit | 2018

- **The first Systems Engineering Track in 2014**
 - Solidified the impact on PLM
 - Contributions from Multiple Industries
- **2015 - The first Workshop**
 - Prioritized Industry Data Standards: SysML, OSLC, FMI, ReqIF
 - Focus on **OEM to Supplier Interoperability**
- **2016 Workshop produce a Roadmap outline**
 - Implementation issues - where/how to start
 - Future capabilities from the PLM Vendors
- **2017 Gaps in the Roadmap**
 - Interoperability Issues
 - The need for Leadership

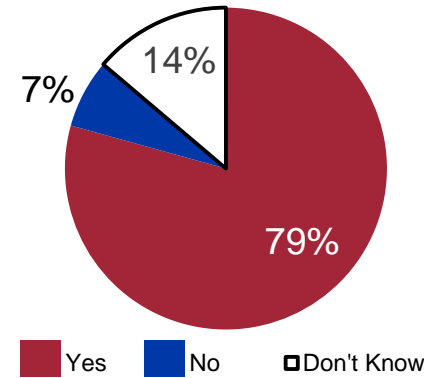
2018 MBSE Workshop Agenda at GPDIS

Global Product Data Interoperability Summit | 2018

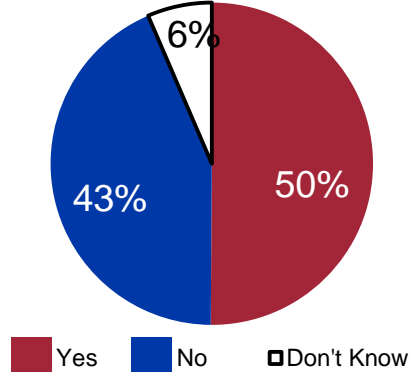
Do you have access to MBSE tools?



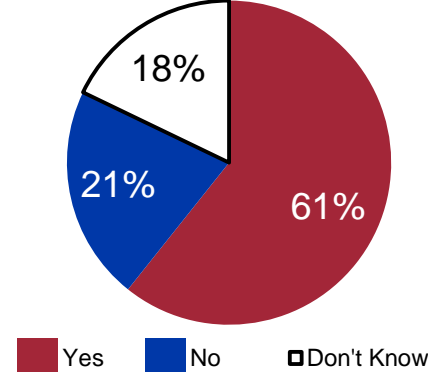
Company recognition of MBSE as contributor?



Do you have multiple ADL Tools?



Company has MBSE department



- Industry CIMdata
- Explore MoSSEC Build a Bicycle
- GPDIS Work Statement and Survey

Presentation	Participants
Airbus/Prostep iViP	63
Airbus	31
ANSYS	43
Aras	33
Boeing	43
Boeing	59
Boeing	42
Northrop Grumman	42
Northrop Grumman	73
Phoenix Integration	31
MBSE Workshop	70

MBSE Workshop - We need to make it work!

Global Product Data Interoperability Summit | 2018

Overwhelmed by implementation issues we lose sight of the technology's collaboration opportunities. Define NEXT STEPS:

Define process to integrate Data authored in multiple sources, places, formats, tools

Clarify the alternative avenues for managing IP and copyrights

Use standards to expand the views of diverse data

Overcome the Diversity in modeling methods, architecture frameworks

Educate the workforce, Management, Suppliers, Prod System

Define the Details: meta-data, data models, nomenclature, usability, product structure and configuration management

Every interoperability exercise is unique.



2019
Annual **INCOSE**
international workshop
Torrance, CA, USA
January 26 - 29, 2019

www.incose.org/IW2019

Presented to the TIMLM Working Group as part of IW2019.
Mark Williams, mark.Williams@boeing.com
Industry Data Standards for MBSE,
Engaging and Influencing the Industry