

MBSE meets PLM: Trends, Challenges and Opportunities

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GLOBAL PRODUCT DATA
INTEROPERABILITY
S U M M I T
2019



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CIMdata Simulation-Driven Systems Development Consulting Practice



- Mission:
 - Enable industry's adoption of Model-Based Engineering (MBE) processes and tools focused on the ever-expanding intersection of emerging model-based systems engineering (MBSE) methods and technologies with Modeling, Simulation & Analysis
- Focus:
 - Management consulting services to industrial organizations and PLM/MBSE solution providers in the effective implementation of model-based technologies and integrated design and development processes
 - Research and thought leadership publications on market trends, technology gaps, industry standards and best practices to enable MBE/MBSE
- Experience: 40+ years in PLM/CAE/Test software and services industry
- Education: BSME, MBA

Digitalization: Transforming Enterprises

Digitalization requires rethinking the business, products/services, organizations, solutions, and data



PLM: Well Beyond PDM – Isn't MBSE the real glue?

Product data touches all phases of a product's life—the end-to-end connectivity required demands it

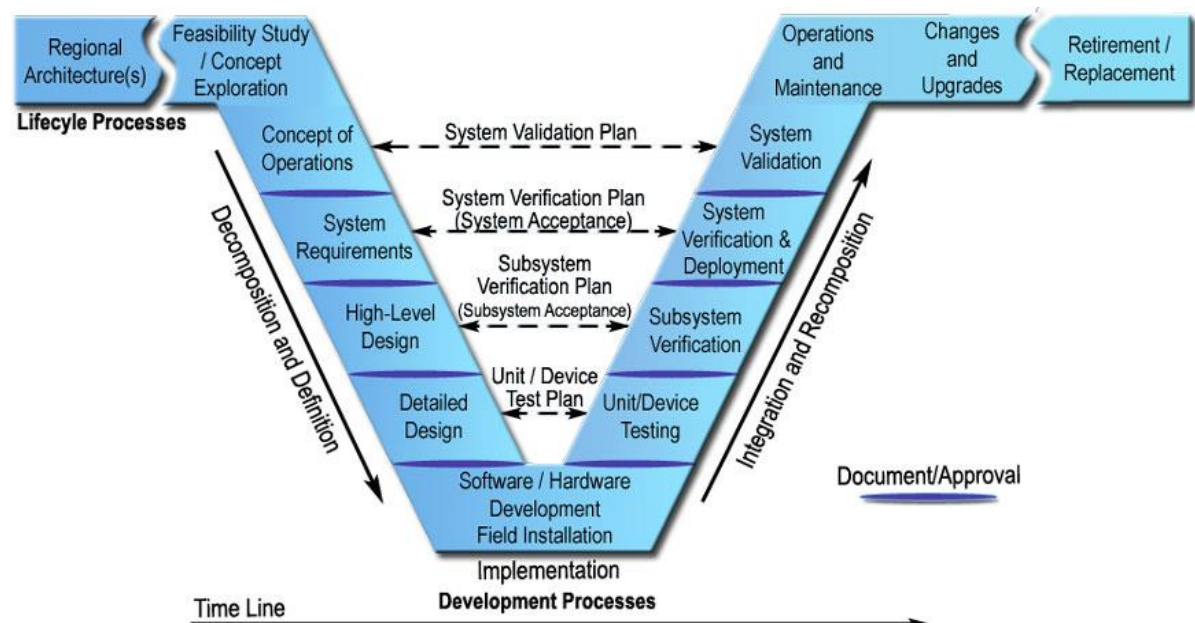


PLM Solutions—Information Management across Media, Process, Time, Geography & Enterprise

Moving Toward a Model-Based Future

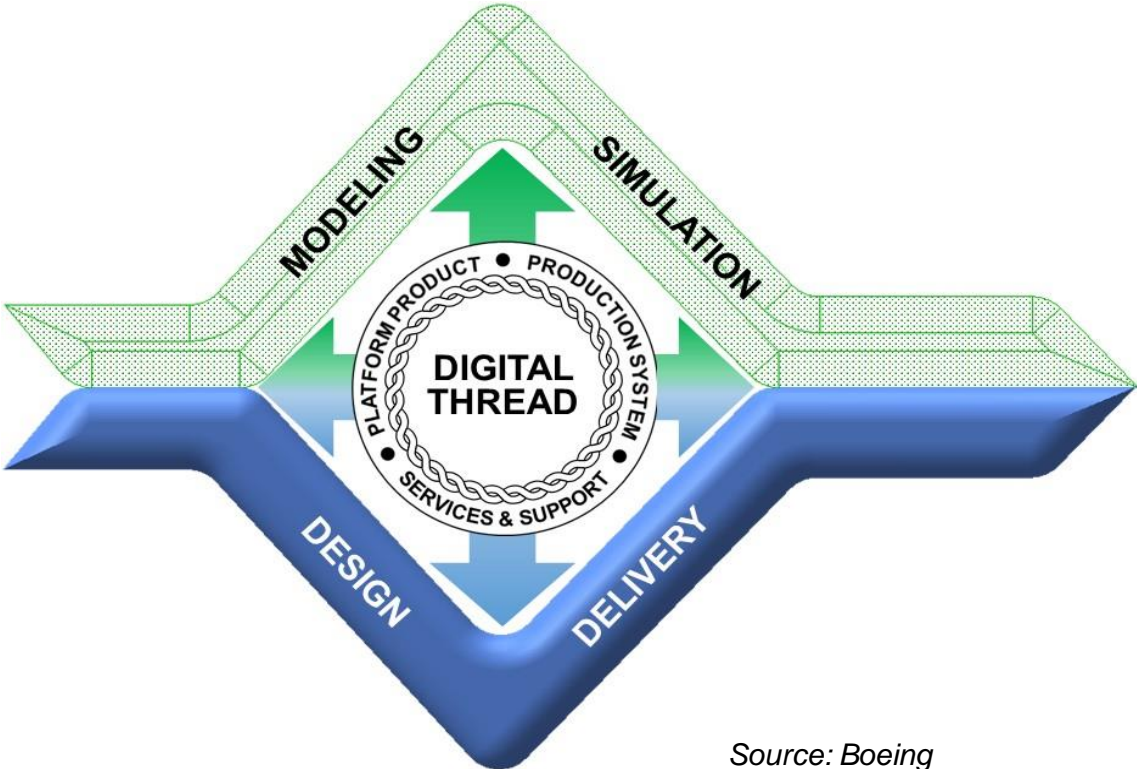
Transitioning to a digital thread of systems of systems

SE Vee



SOURCE: US Department of Transportation Federal Highway Administration
<https://ops.fhwa.dot.gov/publications/seitsguide/section3.htm>

MBE Diamond

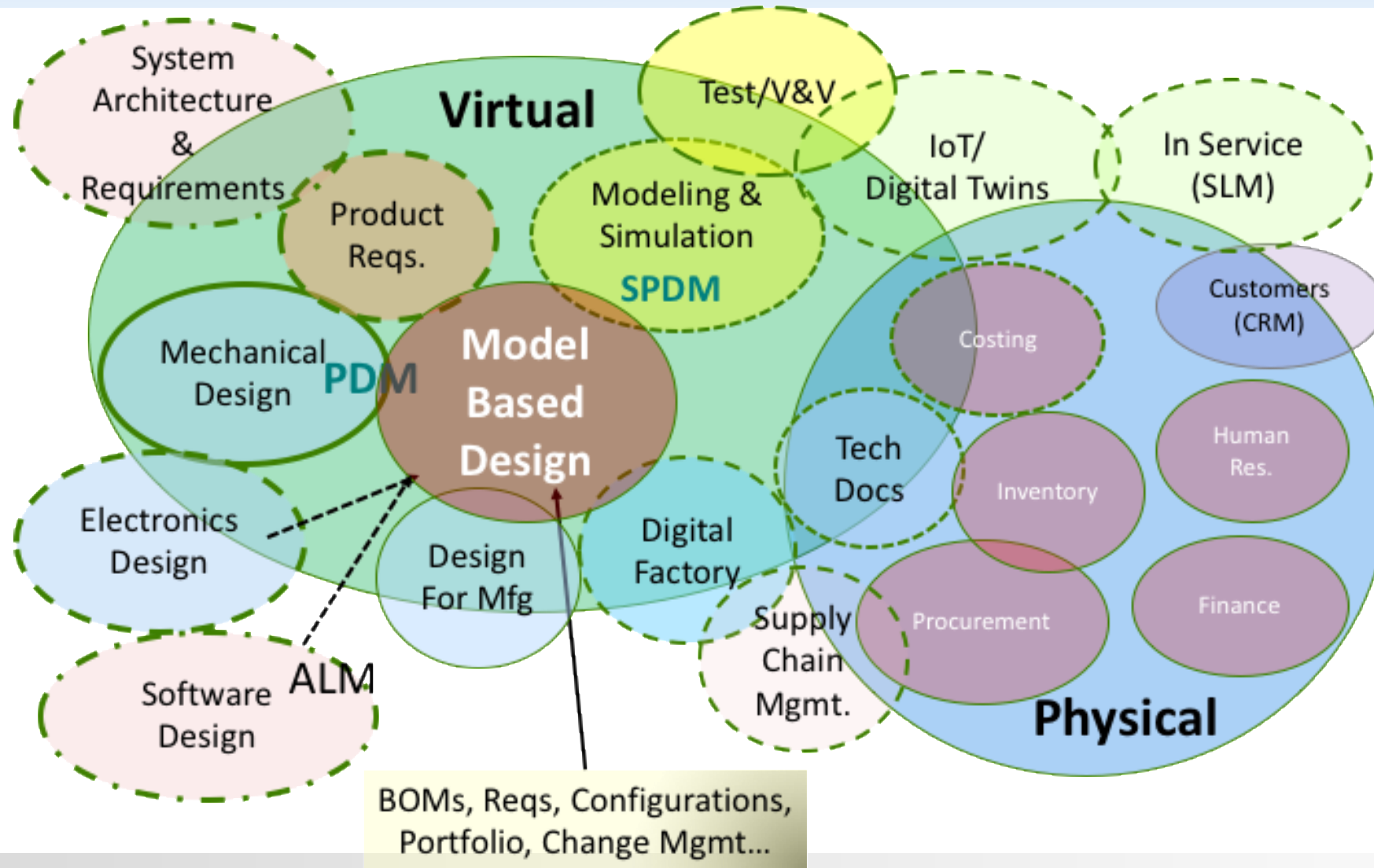


Source: Boeing
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Transitioning from a document-focused mindset to a data-based model mindset that leverages information flow across the lifecycle

Relationship of Digital Eng. Initiatives (“As Is”)

Key domains in model-based are typically managed partially or totally in silos today



Digitalization is Driving Major PLM Market Trends

Focus on Model-Based and Simulation-Driven Systems Development

- Product Innovation Platforms



Simulation increasingly relevant throughout the product lifecycle to enable innovation, quality and profitability

- Modeling & Simulation Platforms



Open Platform with 'best of breed' solutions is critical for delivering simulation value across the product lifecycle

- Model-Based Systems Engineering



Connecting VOC/requirements with systems level design, modeling and simulation across all engineering domains

- Digital Thread & Digital Twins



IoT & data analytics technology creating new insights and use cases for simulation models in operations

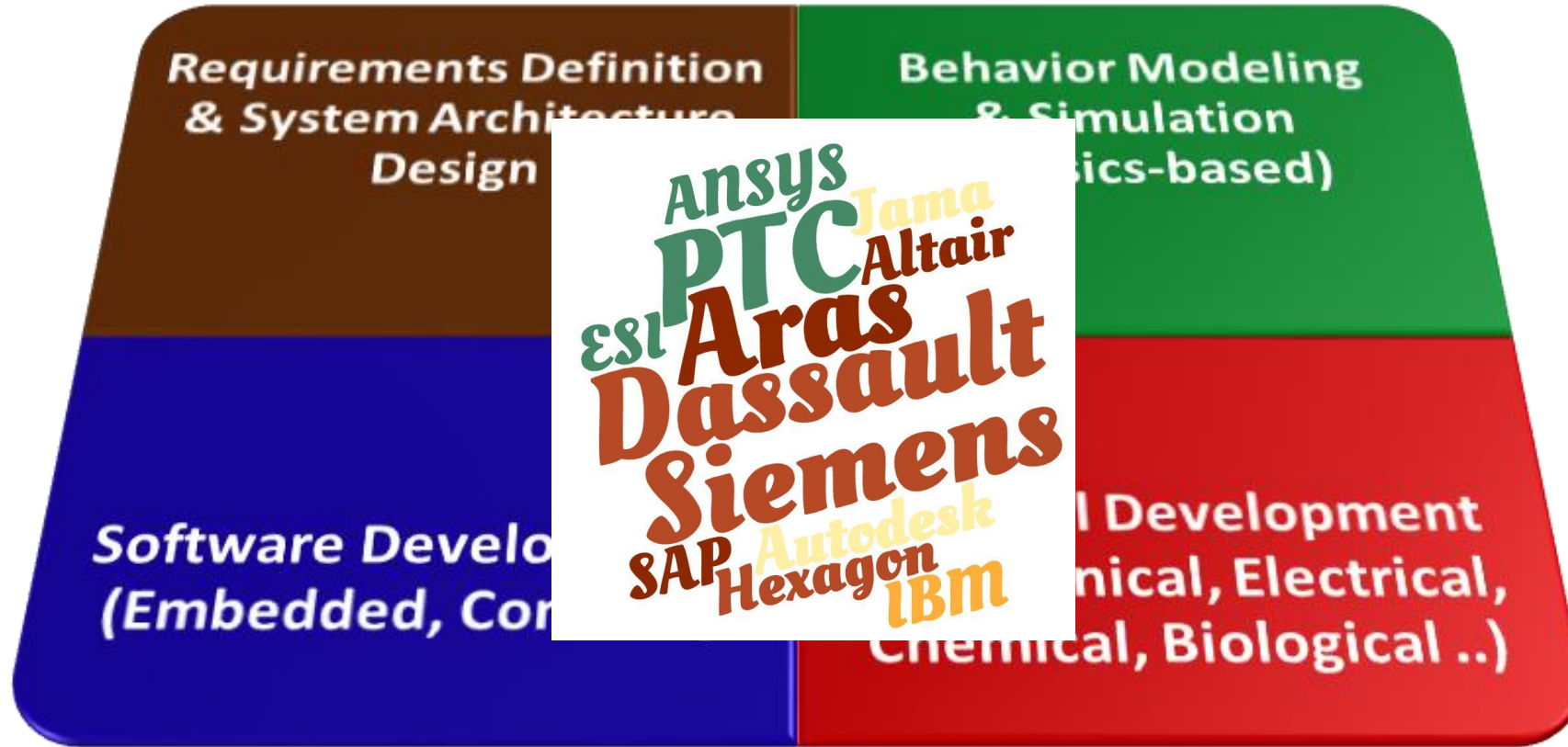
- Democratization of Simulation



Technological advances enabling modeling and simulation use by more engineers earlier and throughout the product lifecycle

Platforms Consolidating Across Domains

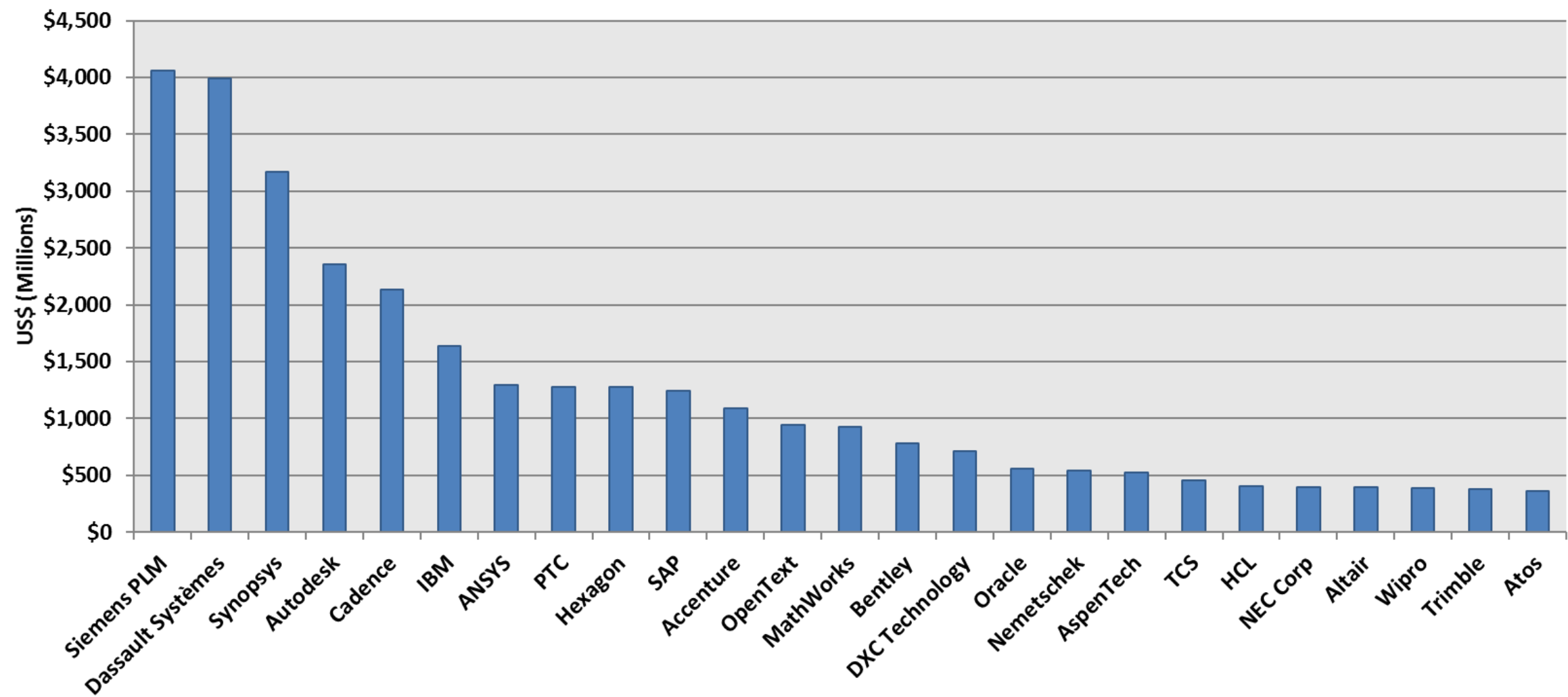
Market leading solution suppliers acquiring MBSE, M&S, ALM, EDA & IoT technologies



But still too way many tools in use for any single solution supplier to cover all the required disciplines

2018 Overall PLM Revenue Leaders

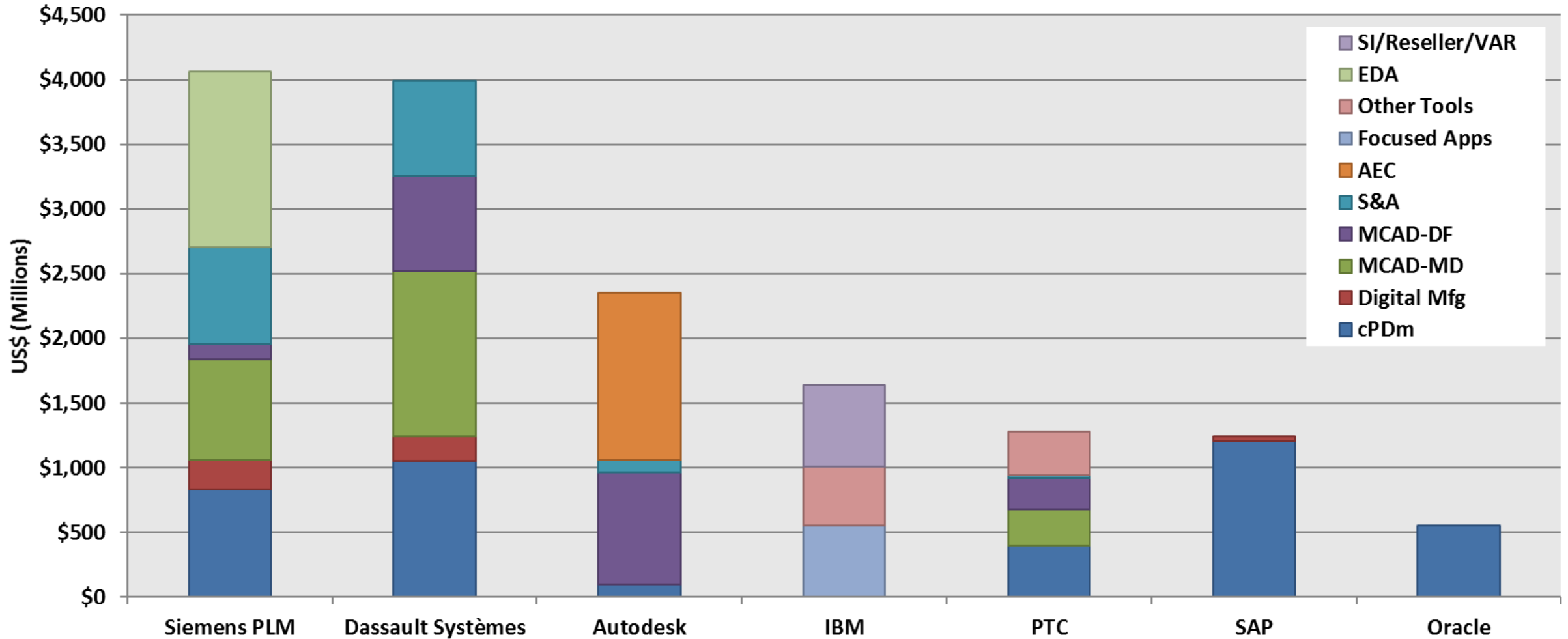
Many diverse companies generate PLM revenue



Revenues presented are CIMdata estimates

2018 PLM Leaders Revenue (Software & Services)

Leaders' direct revenues – led by providers of MCAD tools



Revenues presented are CIMdata estimates

2018 PLM Market Results (Software & Services)

Results by segment (US\$ Millions)

Segment		2018 Revenues	YoY Growth
cPDM Comprehensive Technology Providers		\$6,205.3	8.4%
cPDM-Focused Applications		\$2,403.9	7.9%
Digital Manufacturing		\$816.2	6.4%
SI/Reseller/VAR		\$7,640.2	8.9%
Tools			
MCAD-Multi Discipline		\$3,901.2	4.6%
MCAD-Design Focused		\$3,235.8	14.2%
Non-Bundled CAM		\$1,498.2	9.5%
MBSE lives here today	Simulation & Analysis	\$6,441.7	12.7%
	Other Tools (e.g., ALM, SE)	\$1,501.3	9.2%
	EDA	\$9,884.0	5.6%
AEC		\$4,270.3	19.1%
Total		\$47,798.1	9.4%

PLM Market Forecasts (Software & Services)

For 2019 (US\$ Millions) and 5-year compound annual growth rate (CAGR)

	Segment	2019 Estimate	YoY Growth	5 Year CAGR
	cPDM Comprehensive Technology Providers	\$6,635.63	6.9%	7.1%
	cPDM-Focused Applications	\$2,579.38	7.3%	7.5%
	Digital Manufacturing	\$889.63	9.0%	9.1%
	SI/Reseller/VAR	\$8,155.90	6.8%	6.8%
	Tools			
	MCAD-Multi Discipline	\$4,113.82	5.5%	5.6%
	MCAD-Design Focused	\$3,627.36	12.1%	10.5%
	Non-Bundled CAM	\$1,605.29	7.1%	7.2%
MBSE lives here today	Simulation & Analysis	\$7,188.95	11.6%	11.1%
	Other Tools (e.g., ALM, SE)	\$1,622.87	8.1%	8.3%
	EDA	\$10,674.70	8.0%	8.1%
	AEC	\$4,962.13	16.2%	13.2%
	Total	\$52,055.65	8.9%	8.6%

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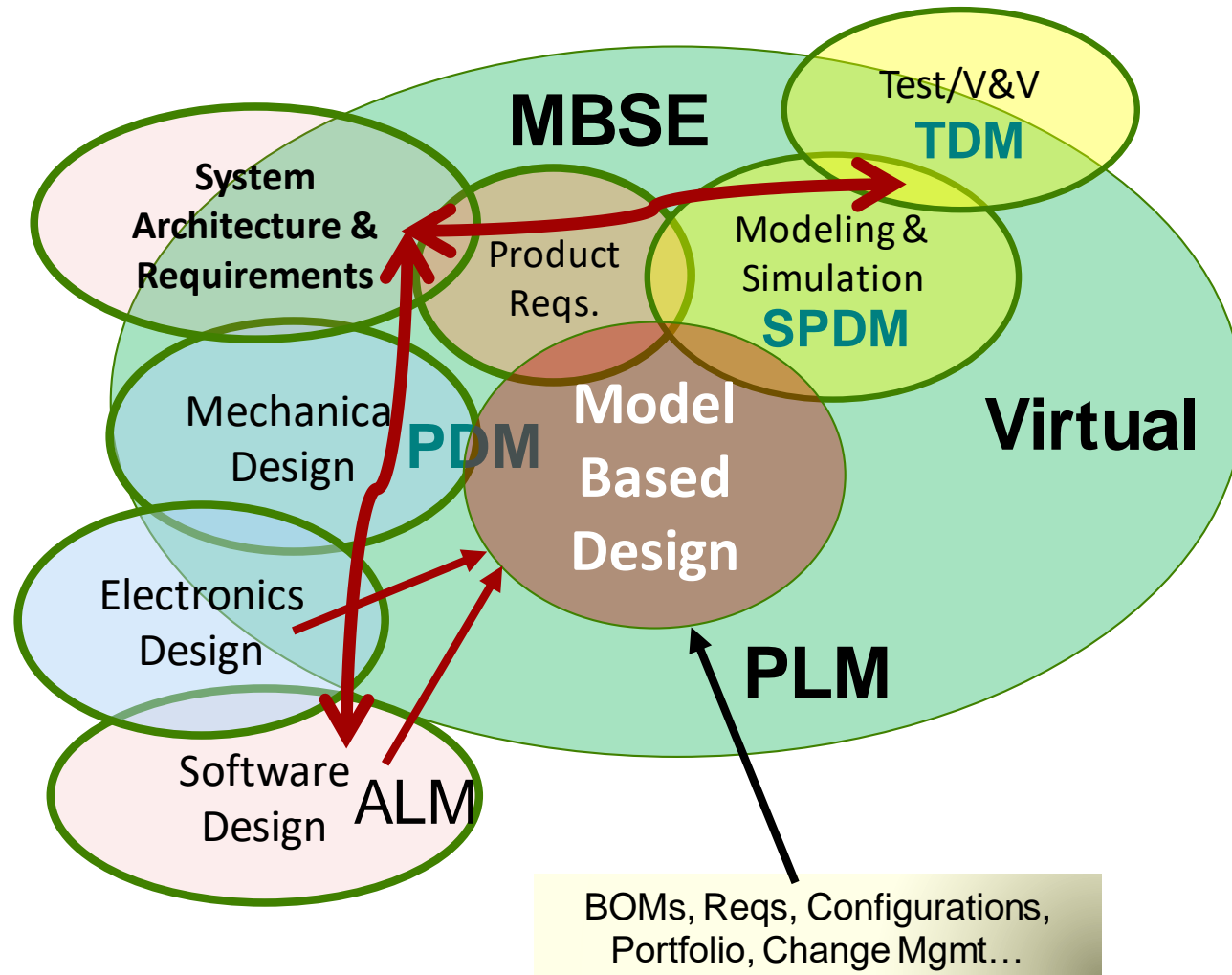
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Starting the MBSE Digital Thread (“The Challenge”)

Conceptual systems engineering across domains with connections to PLM/M&S for trade studies and V&V



MBSE – Primary Use Case today:
*Conceptual Design,
Optimization and Validation
Of Cyber-Physical Systems*

The digital thread needs to connect information across domains:

- * Systems Arch. & Requirements
- * Software/ALM
- * EDA/ECAD/EBOM
- * MDA/MCAD/PDM
- * M&S/CAE/SPDM
- * Test/V&V/TDM

MBSE Trends: Addressing the Challenges

How is the PLM solutions market responding?

- Product Innovation Platforms- Link MBSE with ALM + PLM + S&A + EDA + IoT
- MBSE Data Exchange & Interoperability Standards
- Integration of underused M&S and SPDM tools with SE tools
- Leverage of emergent technologies for “augmented intelligence” and “democratization” of an MBSE approach

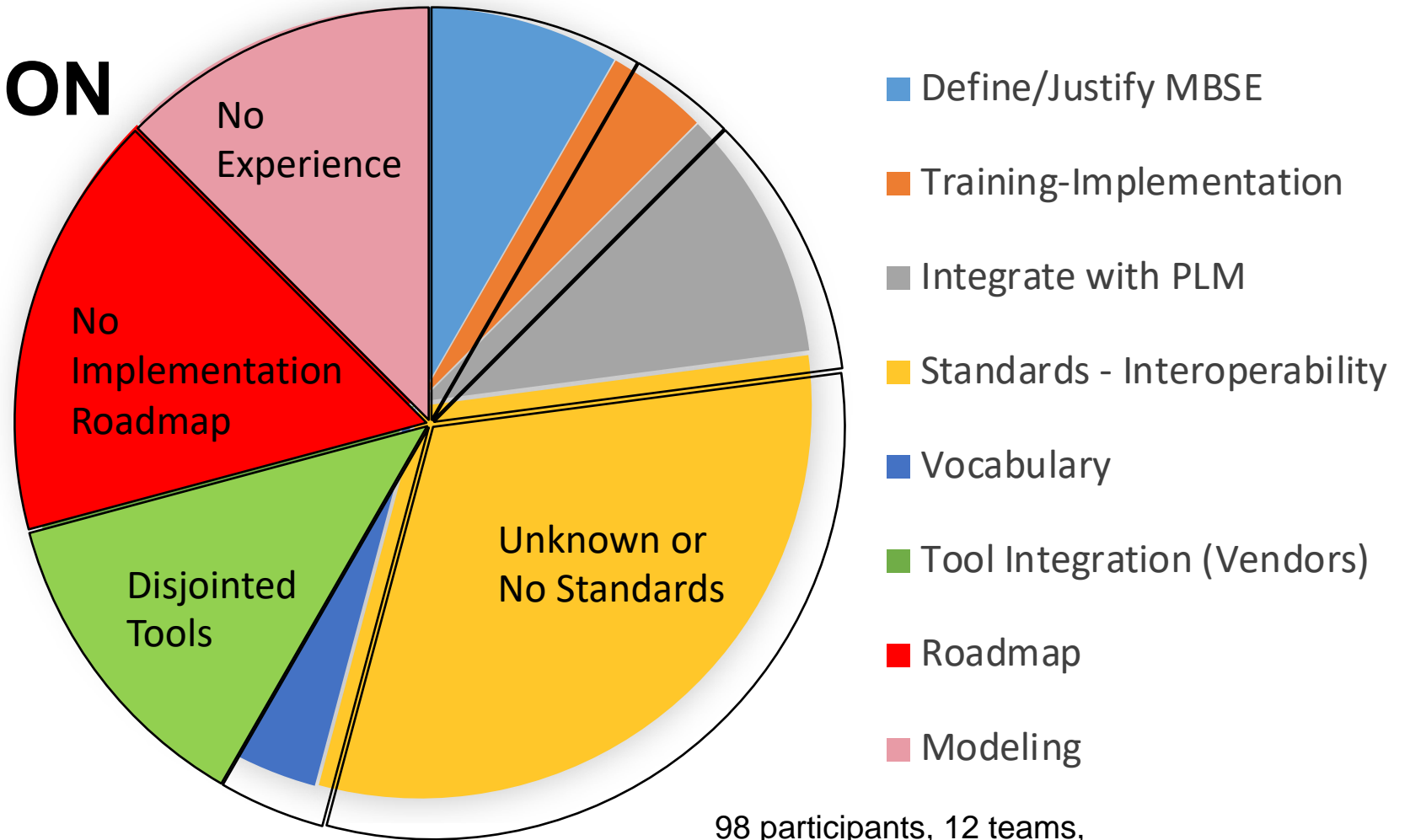
MBSE Users: Standards Identified as Major Gap

Survey from MBSE workshop at 2018 Global Product Data Interoperability Summit

IMPLEMENTATION ISSUES

~60% Technology and Interoperability Issues

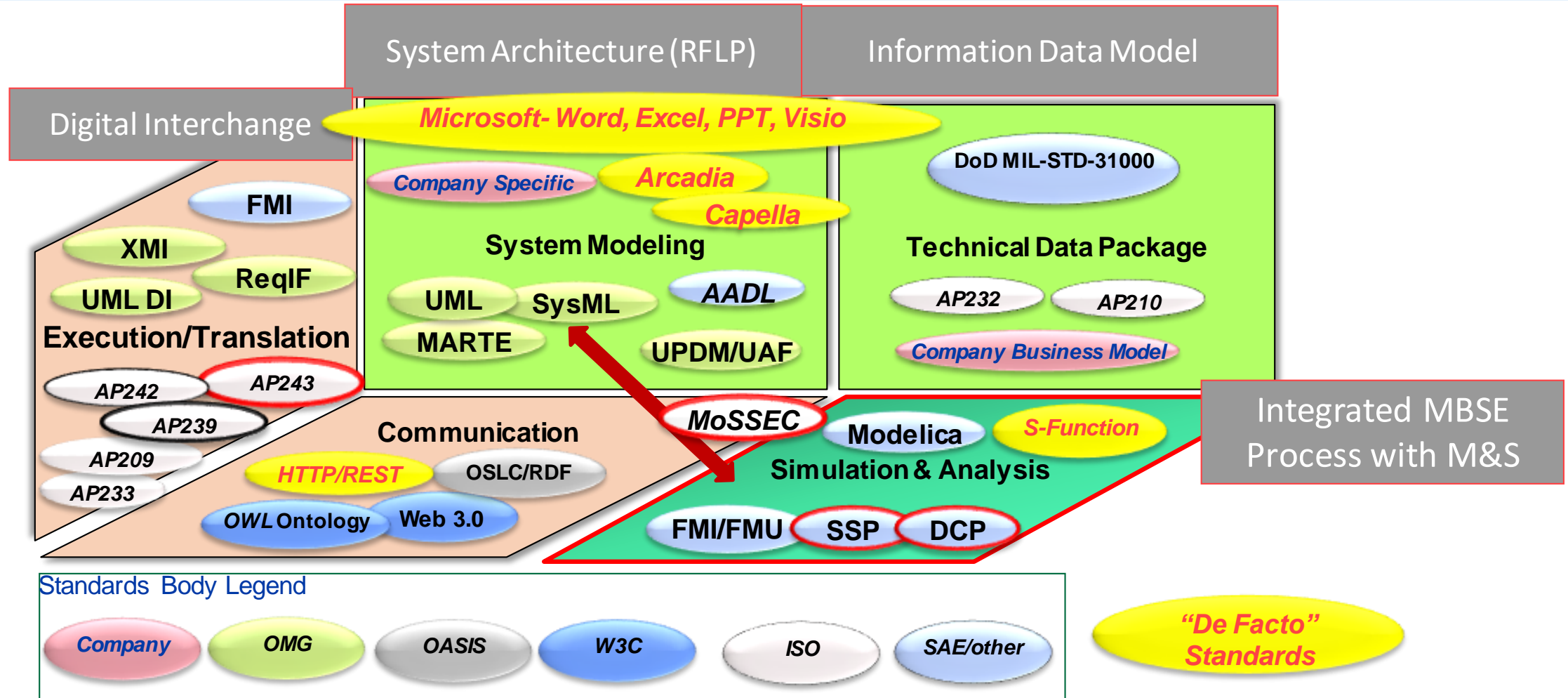
~40% related to Strategy Org/People and Process



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

High Impact “Standards” – MBSE Process Enablers

Combination of formal international standards and industry “de facto” standards will enable MBSE



Adapted from Original Graphic: CREDIT to Bill Chown, Mentor Graphics; MBSE Roundtable, 2015 GPDIS

MBSE Standards & Tools- Not currently up to the challenge

PLM/MBSE vendors & users not moving fast enough to provide real business impact to the industry

- The major software suppliers (Aras, DS, IBM, PTC and Siemens) have recognized the need to integrate SE with ALM and PLM systems and are providing various levels of “RFLP” capabilities
- But PLM/PDM software platforms only loosely integrated with MBSE data authoring tools today and APIs based on data exchange standards are either non-existent or lacking robustness to allow cross-discipline and cross-platform data exchange and multi-party collaboration
- Current SysML authoring tools are not capable of supporting bi-directional model/data exchange and collaboration across multiple MBSE tools
 - SysML model exchanges not practical today (published studies- A&D PAG, Kaiserslautern)
 - Diagrams/graph data not supported in XMI data exchange standard
 - Major SysML tool vendors not supporting UML DI standard for diagram exchange
 - Unfortunately, SysML v2.0 not expected to significantly address this situation
- OSLC is being used today to enable commercial integrations between some enterprise platforms

OSLC Positioning and Value Proposition

OSLC as an API standard complements perfectly other data standardization efforts such as AP 239/AP242, MoSSEC (STEP AP 243) and SysML v2

- These data standards only standardize the data schema for a domain, and do not specify how to expose the data through a REST API. This is covered by OSLC. Without an API standard, you need to rely on file-based exchange.

OSLC is the only engineering standard building on top of REST APIs (the de facto API standard) which is critical to make data easily accessible and easily connectable. Most digital transformation initiatives rely on APIs and not on file-based exchange.

OSLC is compatible with Semantic Web standards and provides the “standard API” component in semantic integration initiatives

OSLC is the only engineering standard being applied across the major engineering disciplines: ALM, PLM, MBSE, and IoT and to enable cross-disciplinary traceability

OSLC Adoption Status

By COTS vendors mostly in ALM domain:
IBM Jazz/CLM, Mentor Graphics, Sodus

Contact Software now using OSLC to connect
data from different disciplines (ERP, PLM, reqs)

Over 50 OSLC APIs developed for different
types of applications

By universities and consultants for MBSE,
simulation: <https://github.com/ld4mbse>
and <https://github.com/oslc>

General Motors MBSE efforts and vision
<https://koneksys.com/blog/presentation-of-oslc-at-purdue-plm-meeting-2018/>

Linking **PLM Parts** with **ALM requirements**

Linking **PLM Engineering Change Requests (ECR)**
with **ALM work items**

Integration from Sodus between

PTC Windchill and **IBM ALM**:

<https://www.sodus.com/en/products/oslc-connect-for-windchill>

Integration from Siemens between

Siemens Teamcenter and **Polarion**

https://docs.plm.automation.siemens.com/data_services/resources/polarion/17.3/help/common/en_US/graphics/fileLibrary/17_3_pdfs/Teamcenter_Polarion_Integration_Installation.pdf

Opportunities: Connecting the MBSE Digital Thread

Commercial software solutions emerging to integrate MBSE data and processes

Similar to the emergence of third-party software solutions for “vendor neutral” 3D MCAD interoperability in the 1990s, there are a number of companies outside of the major PLM/MBSE solution providers that are emerging to address the need for interoperability of MBSE data and models containing systems requirements and systems architecture design:

- InterCAX- Syndeia suite <http://intercax.com/products/syndeia/>
- Sodius/Willert- SE Collab <https://www.sodius.com/en/products/secollab>
- Artal- Capella to SysML Bridge <http://capella.artal-group.com/experimental-features/>
- OBEO- Team for Capella <https://www.obeo.fr/en/team-for-capella>
- Koneksys- Services focus based on OSLC and Web 3.0 collaboration standards www.koneksys.com
- Talisen Technologies- Web-based MBx collaboration environment <https://www.talisentech.com/>

Note: Not intended to be a comprehensive list of providers nor a CIMdata endorsement or ranking

Opportunities: Connecting the MBSE Digital Thread

Significant collaboration efforts underway to integrate SE data and processes with M&S tools and data

In addition to M&S integration efforts underway at the major PLM/CAE companies such as ANSYS, Altair, DS/SIMULIA, MathWorks, and Siemens PLM, “vendor neutral” commercial software solutions are also emerging to address the need for integration of MBSE requirements and systems architecture models with physics-based modeling & simulation capabilities for concept trade studies, design optimization and V&V

- Modelon- Suite of tools based on Modelica and FMI standards <https://www.modelon.com/#>
- Maplesoft- MapleMBSE <https://www.maplesoft.com/products/maplembse/>
- Phoenix Integration- ModelCenter MBSEpak <https://www.phoenix-int.com/product/mbsepak/>
- InterCAX- Syndeia suite <http://intercax.com/products/syndeia/>
- Open CAE & OpenMBEE- Open source frameworks developed by NASA/JPL <http://www.openmbee.org/>

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Opportunities: Addressing MBSE User Challenges

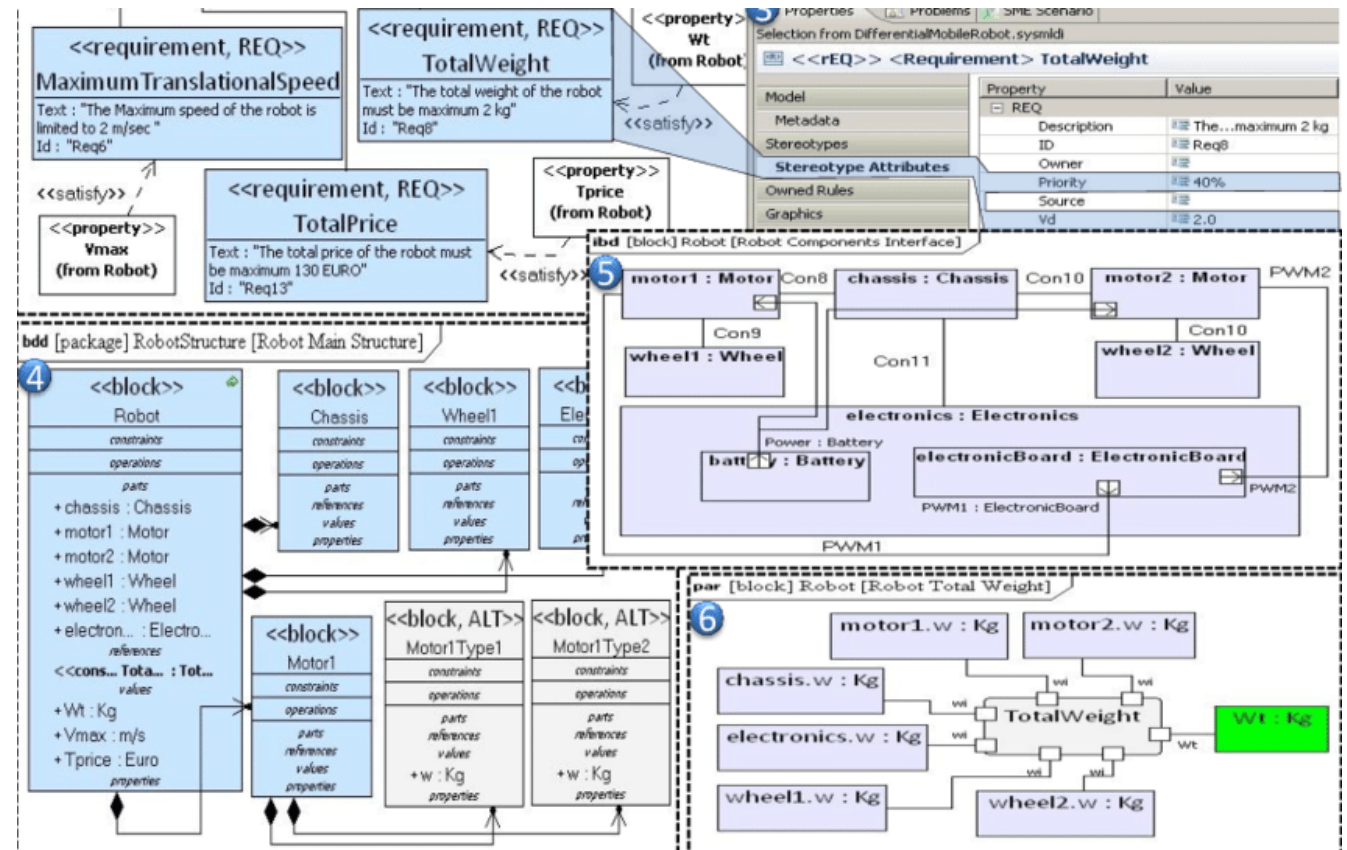
Many opportunities for AI technology insertion into MBSE processes & tools

Address systems model complexity: Leveraging emergent technologies for “augmented intelligence” and “democratization” of an MBSE approach

- SysML tools not easy to learn or to use by non-experts
- Size and complexity of models quickly becomes overwhelming

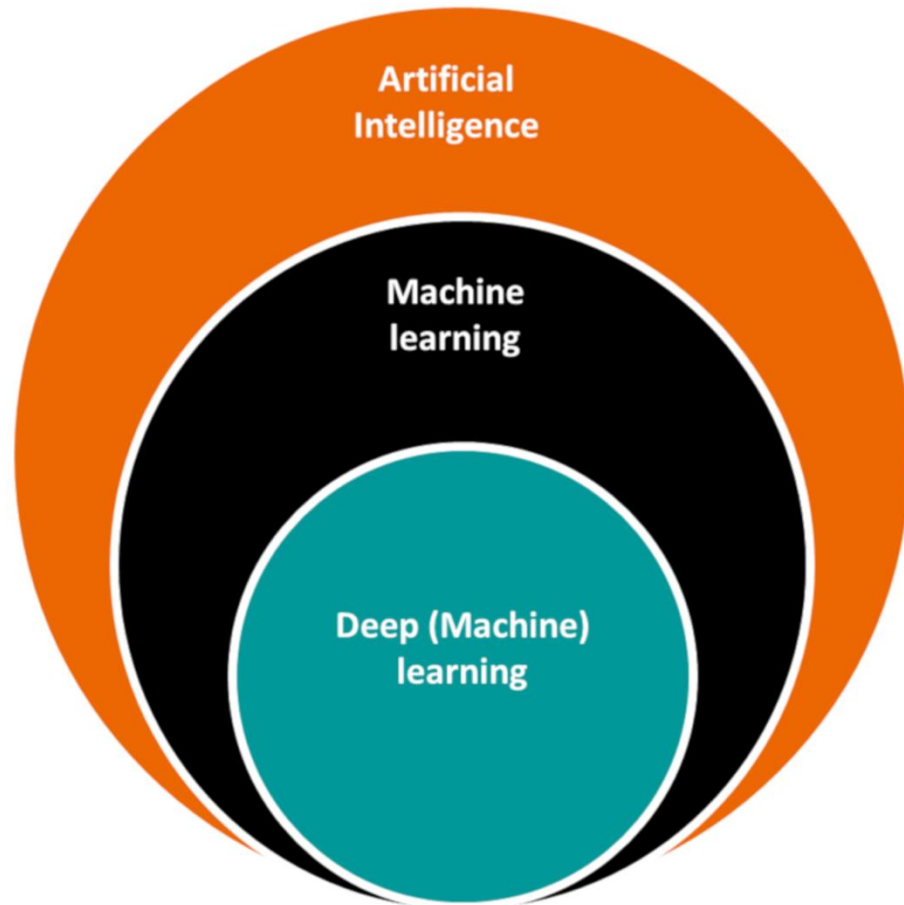
SysML diagrams created to describe a relatively simple two-wheeled differential drive robotic system

Source: Dr. Gerhard Weiss, Maastricht University



Opportunities: Addressing MBSE User Challenges

Efforts already underway to leverage AI/machine learning/deep learning with PLM, M&S, and MBSE processes



Source: Siemens Healthineers

MBSE application areas to augment human decision making and “democratize” usage:

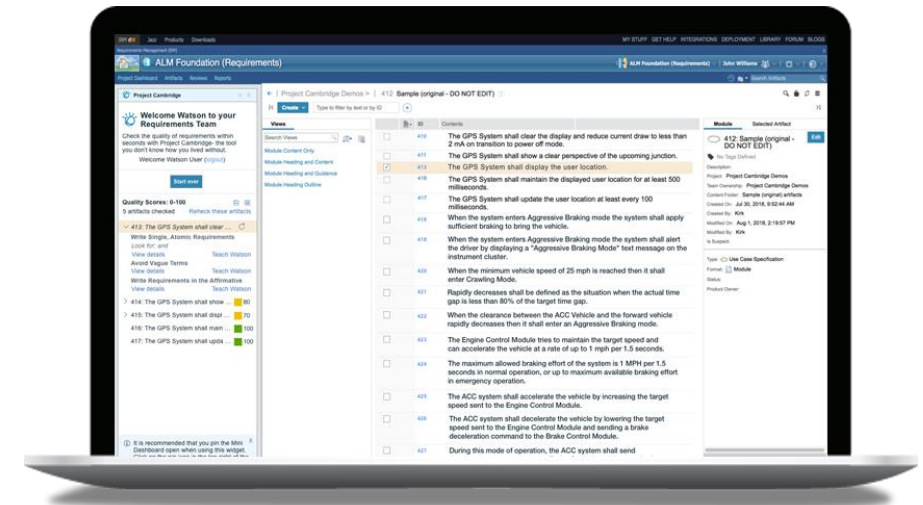
- Interactive task specific User Interaction (UI)
- Understand requirements interdependencies across domains (software, hardware) and between logical, functional and physical aspects
- Automated and guided exploration of the feasible systems design space based on the SysML model diagrams & parameters using Multi-Disciplinary Analysis and Optimization (MDAO)
- Automated and guided Uncertainty Quantification (UQ) for system level risk analysis
- VR/AR to “visually experience” the system design

Opportunities: Addressing MBSE User Challenges

Efforts already underway to leverage AI/deep learning/machine learning with PLM, M&S and MBSE processes

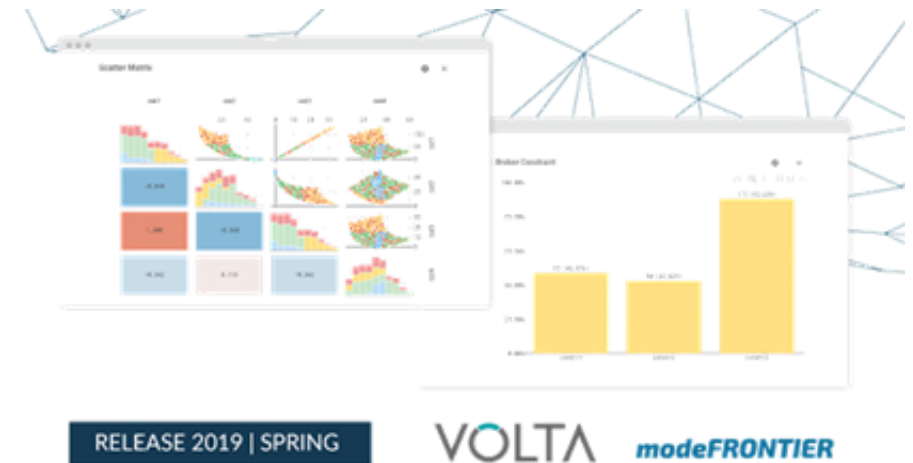
IBM Requirements Quality Assistant (RQA) - Powered by IBM Watson, Requirements Quality Assistant (RQA) applies the power of AI to engineering. RQA assesses the quality of requirements in DOORS Next Generation and provides guidance on how to improve them.

Image courtesy of IBM



ESTECO Volta™ platform linked with ModeFrontier™ now brings machine learning to simulation process automation and offers new AI algorithms for machine learning, new template charts for process pre-configuration, and an updated user interface.

Image courtesy of ESTECO



Final Thoughts

Digitalization, MBSE & PLM: Where to next?

Innovation
Digital Twin
IoT/Industry 4.0
Interoperability
Model-Based
PLM
Digital
Thread
Systems Engineering
Transformation
ROI
Collaboration



Final Thoughts

Digitalization, MBSE & PLM: Where to next?

- MBx vision & strategy needs to be developed & supported in the context of a product innovation platform with a “systems oriented” enterprise data architecture
- MBSE must be implemented and promoted based on specific business application use cases with demonstrable success & measured ROI
 - Must define and pilot well-defined MBSE processes in specific business focus areas
- Enterprises must account for organizational change and people buy-in. Process change & people training will absolutely be required for success
 - MBSE maturity models and a well defined governance structure are essential
- PLM/MBSE solution providers need to provide “integrated, yet open” platforms of software and robust API services based on industry standards and best practices

Users must contractually demand model & data portability across engineering platforms!

MBSE meets PLM: Trends, Challenges and Opportunities

MBSE standards will be effective when and only if we all help define and actively use them!



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