



2022
Annual **INCOSE**
international workshop
HYBRID EVENT
Torrance, CA, USA
Jan 29 - Feb 1, 2022

MBSE Workshop
January 30, 2022

Digital Engineering/PLM Market Update

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www.incose.org/IW2022



- 40+ years of experience in the definition, development and implementation of simulation-driven engineering solutions
- Range of senior positions with PLM/CAE software & services providers (SDRC, UGS/Siemens PLM, Comet Solutions)
 - Product Development Consulting Services
 - Software Product Management and Product Development
 - I-deas CAE & Test Business General Manager
 - Corporate Marketing, Business Development and Strategy/Mergers & Acquisitions
- Joined CIMdata in 2013 to help lead up the Simulation & Analysis Practice, Focus expanded to SDSD in 2015 to include S&A integration with SE (MBSE)
- Active participant in INCOSE, NAFEMS/INCOSE SMS WG, NAFEMS SDM WG, Aerospace & Defense Action Group, GPDIS, ASSESS Initiative Working Groups
- B.S in Mechanical Engineering and Masters in Business from Univ of Cincinnati

Our Mission...

Strategic management consulting for competitive advantage in global markets

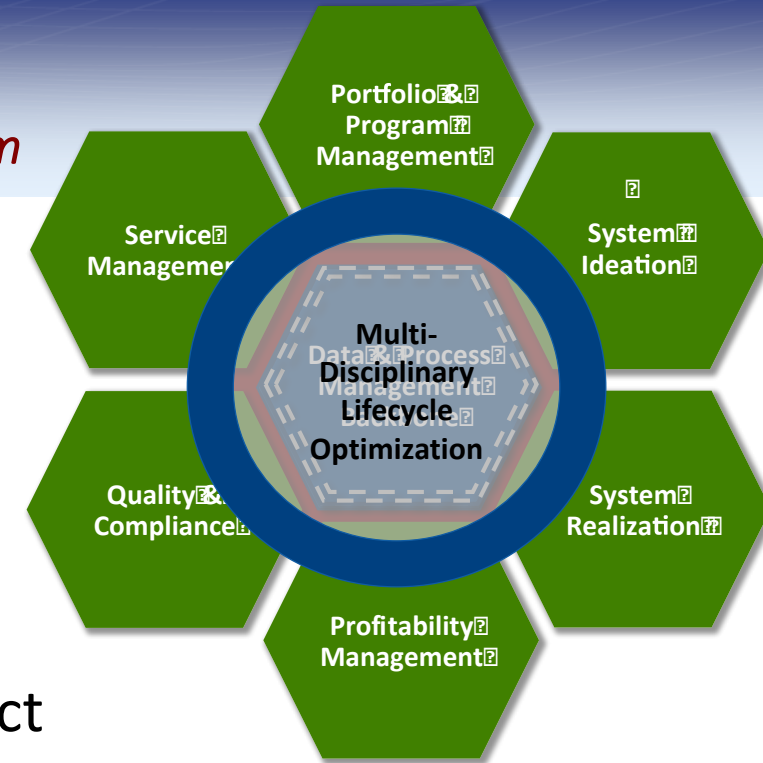
CIMdata is the leading independent global strategic management consulting and research authority focused exclusively on PLM and the digital transformation it enables.

We are dedicated to maximizing our clients' ability to design, deliver, and support innovative products and services through the application of PLM.

PLM – CIMdata's Definition

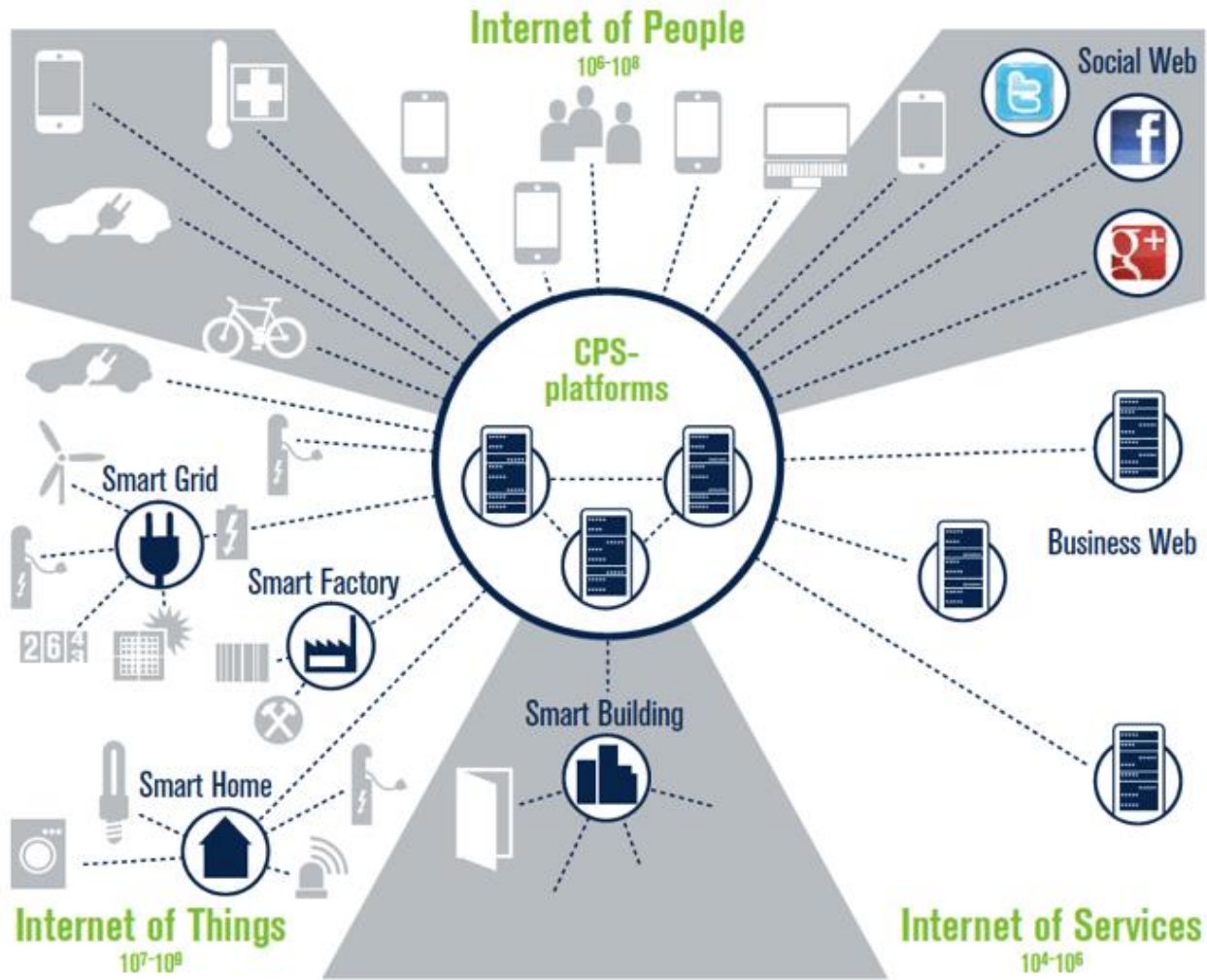
Digital transformation of the lifecycle—enabled by a product innovation platform

- Strategic business approach
 - **NOT** just technologies
 - Consistent set of business solutions
- Collaborative creation, use, management & dissemination of product related *intellectual assets*
 - All product/plant definition information – the virtual product
 - AEC, MCAD, EDA, ALM, SE, requirements, simulations, analytics, portfolio, formulas...
 - All product/plant process definitions – the virtual processes
 - Processes that plan, design, produce, operate, support, decommission, recycle...
- An innovation platform that supports the extended enterprise
- Spans the full lifecycle, from idea/concept through life



The Industrie 4.0 Vision

4th Industrial Revolution focused on creating smart products, procedures, and processes



In a “smart, networked world”, the Internet of Things and Services will make its presence felt in...five key areas identified for action in 2009: climate/energy, mobility, health, security and communication.

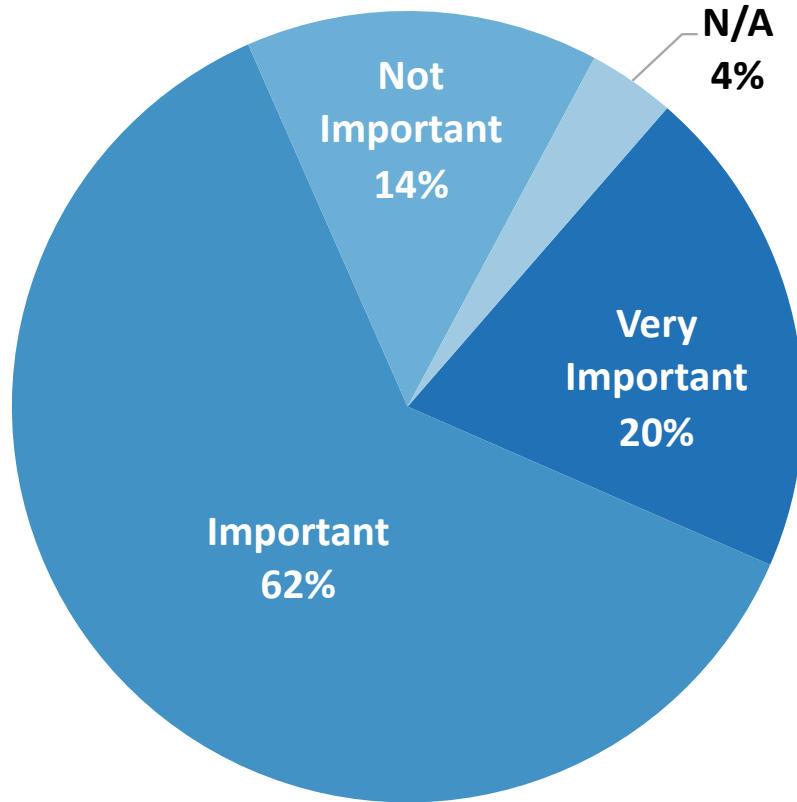
In the manufacturing environment, vertical networking, end-to-end engineering and horizontal integration across the entire value network of increasingly smart products and systems is set to usher in the fourth stage of industrialisation – “Industrie 4.0”.

Recommendations for implementing the strategic initiative INDUSTRIE 4.0, Final report of the Industrie 4.0 Working Group

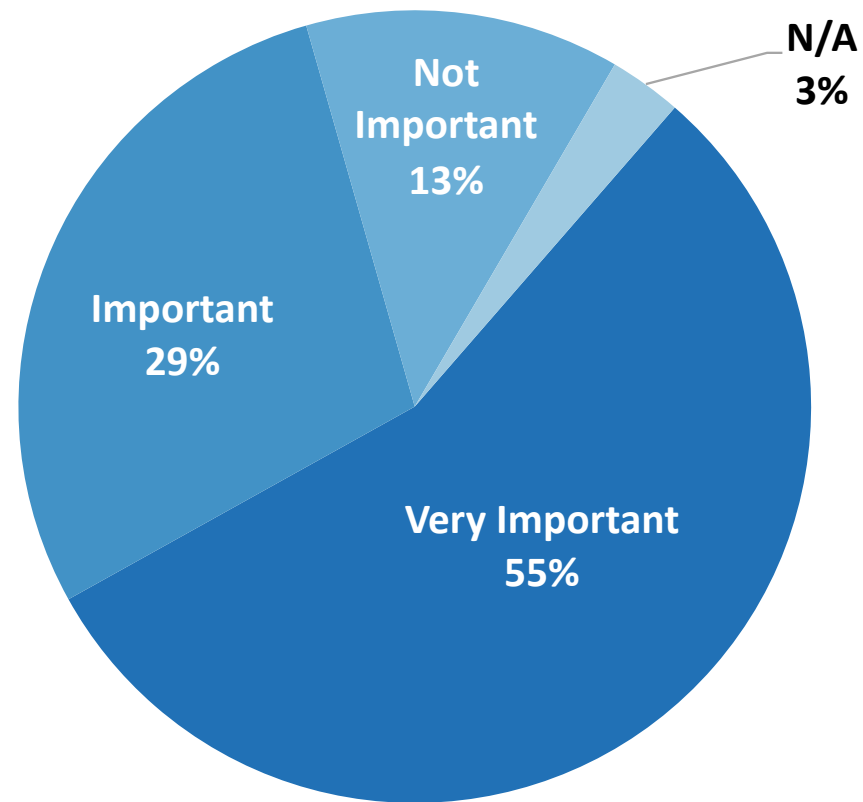
Importance of IoT to Company strategy

Gaining in importance over the next five years

Today

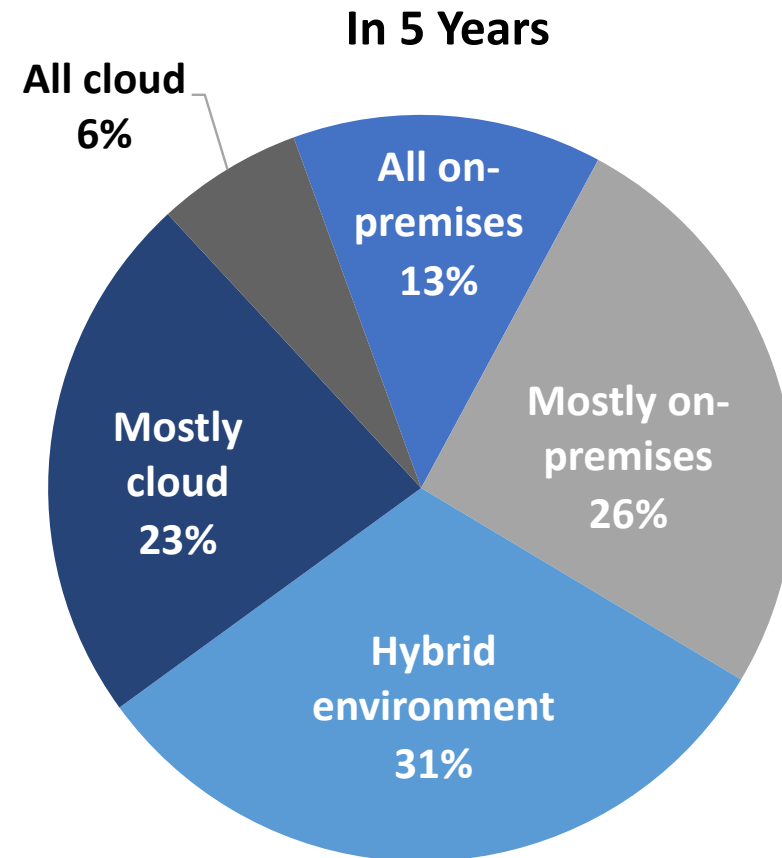
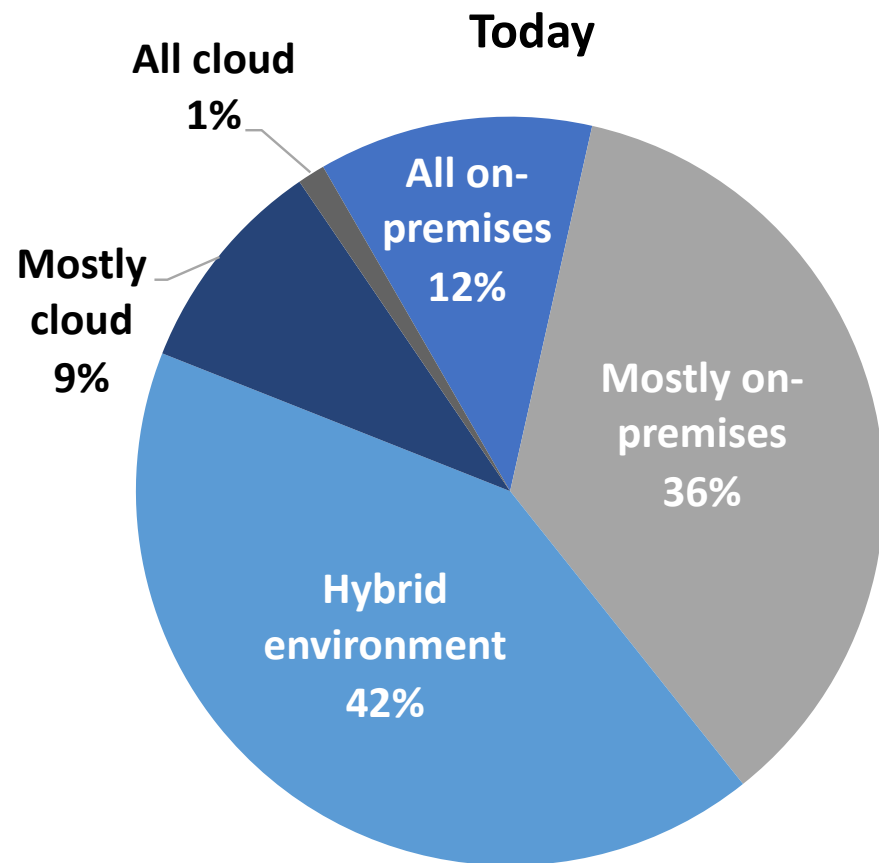


In 5 Years



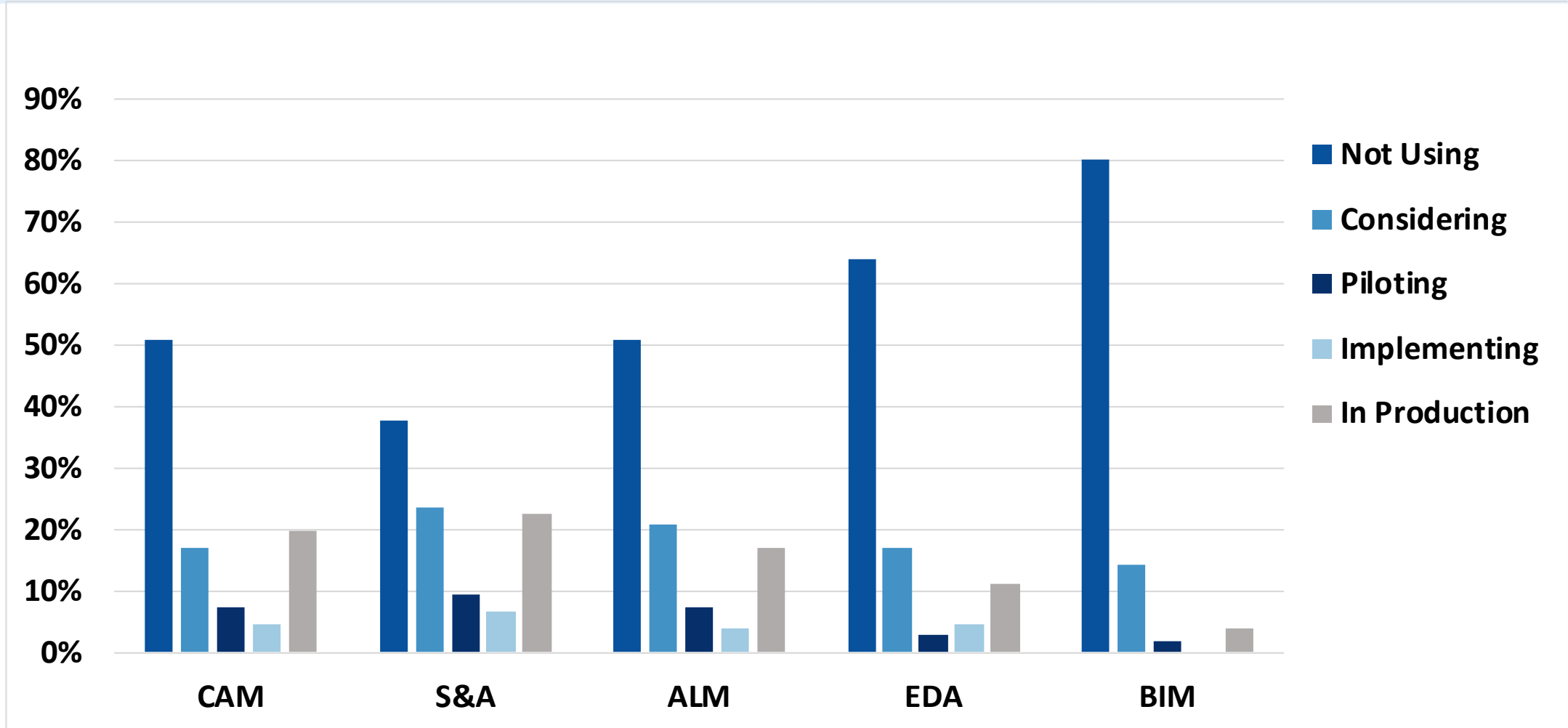
Data Analytics and Simulation in the Cloud

Some cloud use today, growing over the next five years



Adopting Cloud-based Solutions beyond PDM

Please indicate your company's progress toward adoption of each solution category listed below.



Digitalization is Driving Major Trends in Market

Investment in Simulation-Driven Systems Development

- Product Innovation Platforms



Cross-domain systems level design and simulation increasingly relevant throughout the product lifecycle to enable innovation, quality and profitability (Mechanical, Electronics, Software, Biological, etc.)

- Modeling & Simulation Platforms



Open Platforms with 'best of breed' multi-physics S&A solutions based on data interoperability standards are critical for delivering simulation value across the product lifecycle

- Model-Based Systems Engineering



Connecting VOC/requirements with systems level design, modeling and simulation and V&V across the major engineering domains

- Digital Thread & Digital Twins



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

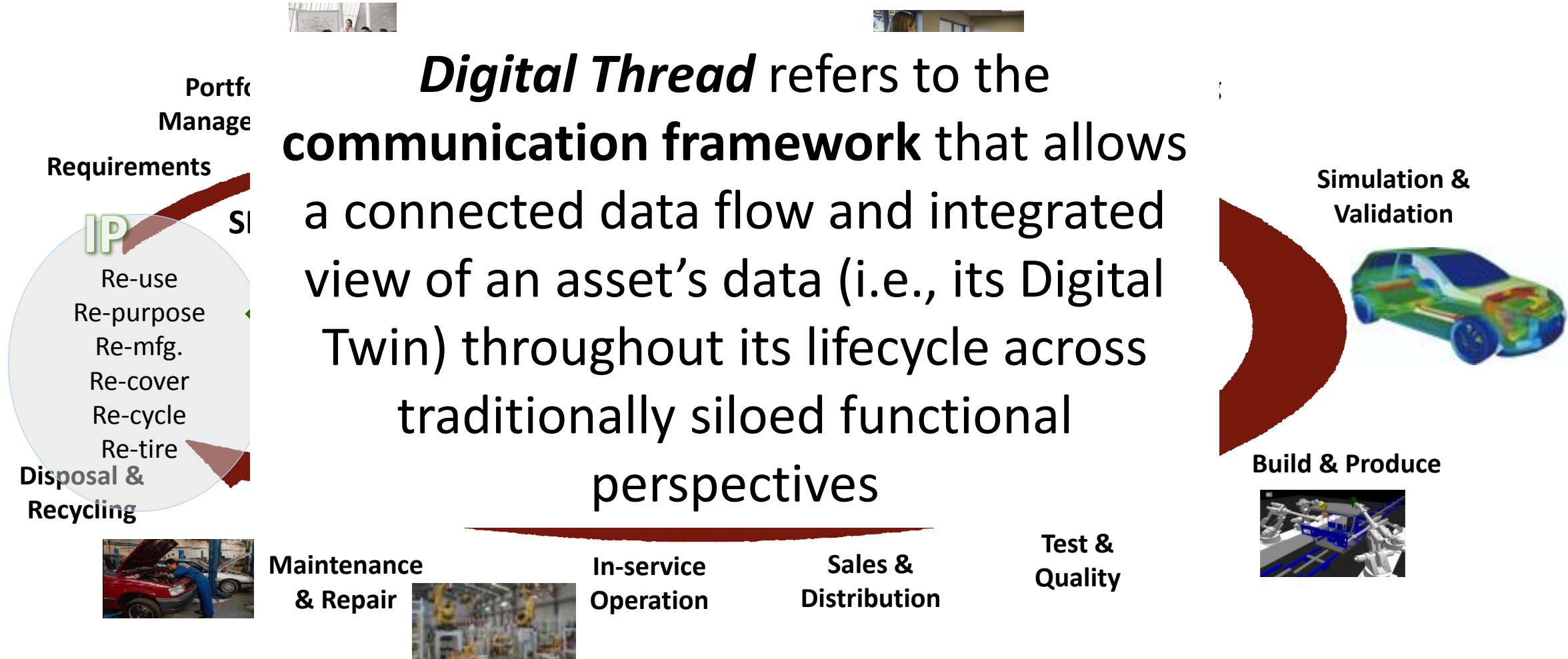
- Democratization of Simulation



Technological advances enabling simulation, analysis and optimization use by more engineers earlier and throughout the product lifecycle

The Digital Thread & MBE enables Industry 4.0

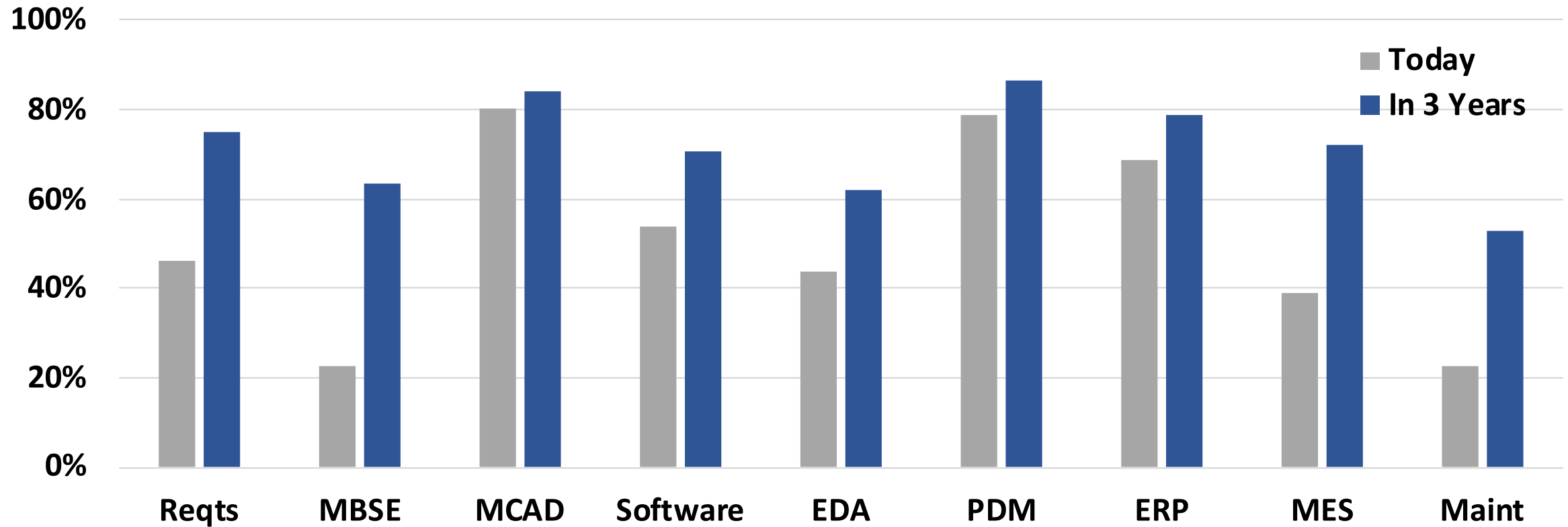
Integration across many applications, each often focused on a part of the lifecycle – not an exhaustive list!



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

Breadth of the Digital Thread

What types of software offerings are contributing to your digital thread today? In three years?



Everyone is Talking Digital Twins

Started in discrete, now everywhere, but those twins are “fraternal” – same phrase, very different meanings

aveva.com

CREATING A RELIABLE DIGITAL TWIN

The importance of intelligent data management and digital continuity

INDUSTRY INSIGHT
February 2018

AVEVA

aspentech | Technology That Loves Complexity

Industries Solutions Products Resources About AspenTech

Press Release

Aspen Technology and Hexagon Announce New Collaboration to Accelerate Digital Transformation in Process Industries

June 12, 2019

BEDFORD, MA – Aspen Technology, a leader in process optimization, design, construction, collaboration and conceptual, basic process design (PPM), to enable

cadence | Products Solutions Services Support Community Company

Breakfast Bytes Blogs

Paul McLellan 26 Jul 2019

Digital Twins at the Paris Air Show

The idea of a digital twin should be easy for anyone in aerospace to understand. After all, pilots learn to fly planes on simulators.

Trimble

Why BIM Needs Digital Twins

FARO | Home Key Technology Digital Twin ARENA2036 Factory Auto

Digital Twin

The digital twin is an essential component of smart factories.

SYSTEMS & DESIGN | OPINION

Digital Twins For Hardware/Software Co-Development

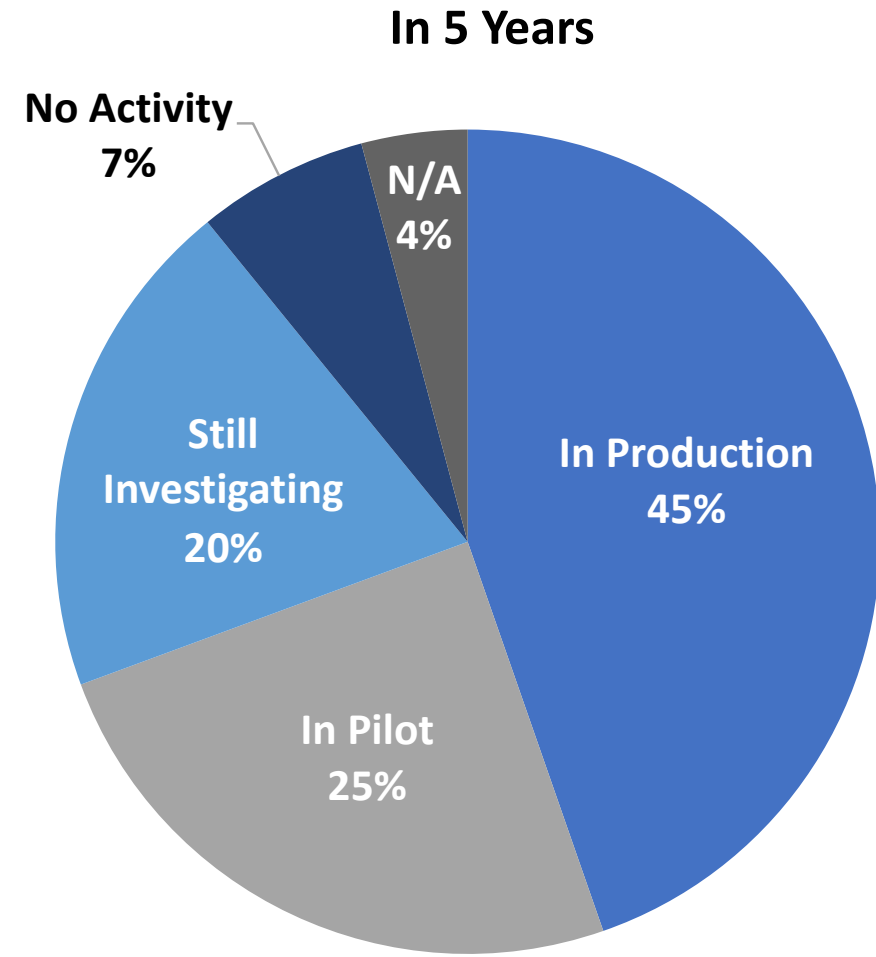
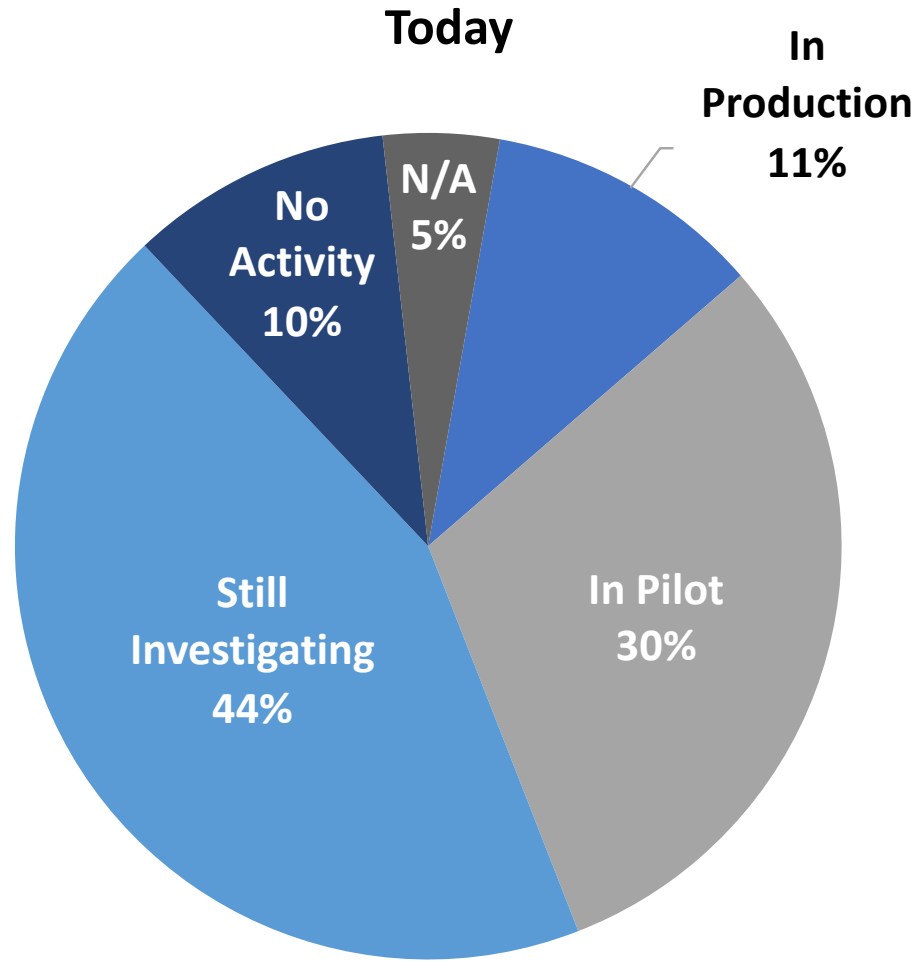
5 Shares

Properly defining what digital twins are is an important part of determining their usefulness.

MARCH 28TH, 2019 - BY: FRANK SCHIRRMEISTER

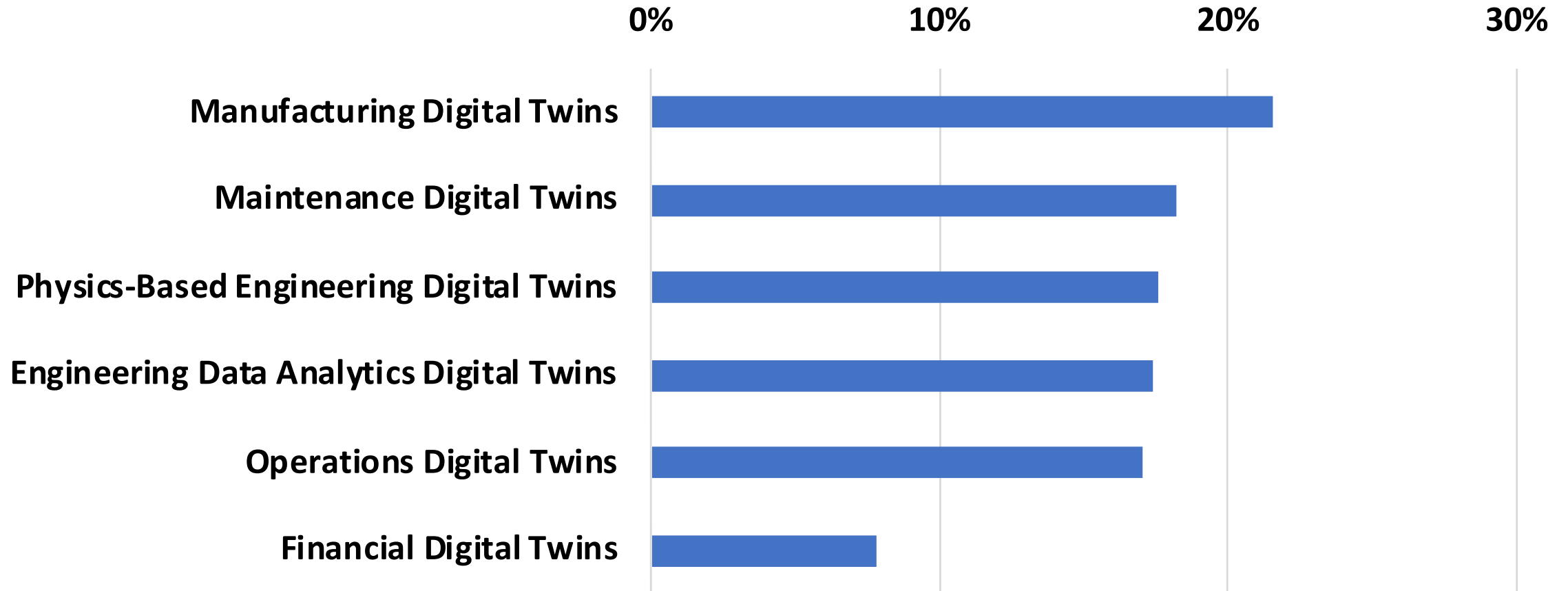
Status of Digital Twin Journey

41% in production/pilot today, up to 70% in five years



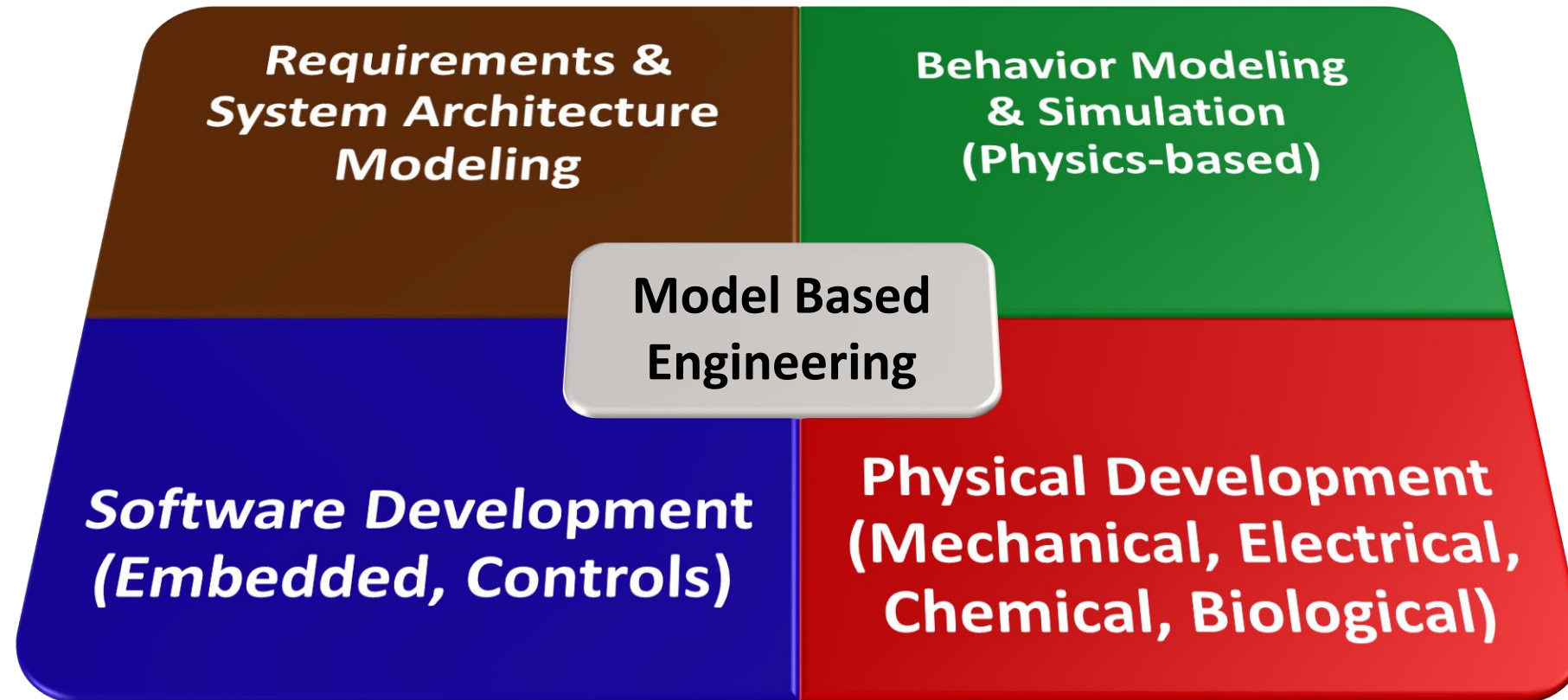
Many Types of Digital Twins Planned

Where the respondents will be in five years, spanning the lifecycle



Model-Based Engineering- Converging Domains

Disciplines are approaching digital design & development from different perspectives



*All areas are supported by a number of overlapping solutions;
PLM platforms are consolidating and integrating across domains*

Significant Mergers & Acquisition (M&A) Activity

Have well surpassed pre-pandemic levels

- In 2021, over 175 acquisitions tracked; More than 2020 and 2019
- Partnership/M&A activity continues in the MBSE/S&A domains
 - ANSYS acquires AGI and Phoenix Integration
 - Altair acquires World Programming
 - Accenture acquiring MBSE implementation services expertise globally
 - Siemens partnering with SAP for PLM(SaaS) and OBEO for Capell
 - Cadence acquires 2 companies in CFD area; More to come in MBSE/S&A?

2020 Market Results

Results by segment (US\$ Millions) mostly positive

Segment	2020 Revenues	YoY Growth
cPDM Comprehensive Technology Providers	\$6,949.2	4.4%
cPDM-Focused Applications	\$2,665.8	3.9%
Digital Manufacturing	\$833.0	-6.0%
SI/Reseller/VAR	\$7,906.6	-3.4%
Tools		
MCAD-Multi Discipline	\$3,841.3	-2.2%
MCAD-Design Focused	\$3,541.3	0.7%
Non-Bundled CAM	\$1,455.9	-7.6%
Simulation & Analysis	\$7,477.2	4.2%
Other Tools (e.g., System Eng, ALM)	\$1,796.2	7.6%
EDA	\$11,467.3	11.6%
AEC	\$5,539.0	9.1%
Total	\$53,472.9	3.81%

Market Forecasts

For 2021 (US\$ Millions) and 5-year compound annual growth rate (CAGR)

Segment	2021 Estimate	YoY Growth	5 Year CAGR
cPDm Comprehensive Technology Providers	\$7,419.22	6.8%	7.5%
cPDm-Focused Applications	\$2,829.79	6.2%	7.1%
Digital Manufacturing	\$877.16	5.3%	6.8%
SI/Reseller/VAR	\$8,317.78	5.2%	6.3%
Tools			
MCAD-Multi Discipline	\$3,889.27	1.3%	2.8%
MCAD-Design Focused	\$3,877.68	9.5%	9.7%
Non-Bundled CAM	\$1,521.47	4.5%	5.8%
Simulation & Analysis	\$8,082.88	8.1%	10.0%
Other Tools (e.g., System Eng, ALM)	\$1,936.35	7.8%	7.9%
EDA	\$12,384.68	8.0%	8.4%
AEC	\$6,325.56	14.2%	14.7%
Total	\$57,461.78	7.5%	8.5%

Q1-Q3 2021 Performance of Public Companies

Based on the quarterly results presented this year, reporting years vary

Company	Original 2021 Guidance(M)	YoY Growth*	Final Guidance	Est YoY Growth*
Altair	\$502 - \$510	7.7%	\$515 - \$518	9.9%
Ansys	\$1,770.5 - \$1,855.5	7.8%	\$1,860.3 - \$1900.3	11.8%
AspenTech*	\$704 - \$754	2.0%	\$705 - \$729	18.5%
Autodesk	\$4,265 - \$4,345	14%	\$4,360 - \$4,375	15%
Cadence	\$2,860 - \$2,920	7.7%	\$2,960 - \$2,980	10.7%
Dassault Systemes	€4,715 - €4,765	6.5%	€4,800 - €4,825	8.1%
PTC	\$1,690 - \$1,730	11.6%	\$1,733 - \$1,763	14.2%
Synopsys	\$4,000 - \$4,050	9.2%	\$4,190 - \$4,220	14.1%
Nemetschek	"High Single Digits"	---	12 - 14%	13%↑
Trimble	\$3,299.7 - \$3,399.7	6.7%	\$3,590 - \$3,640	14.8%
Hexagon	€4,600 - €5,100	13.0%	€4,600- €5,100	13%

*Growth estimated from midpoint

↑Through 9 months

Is there an MBSE market? How big is it? Growth?

Depends on how one defines the "MBSE domain"

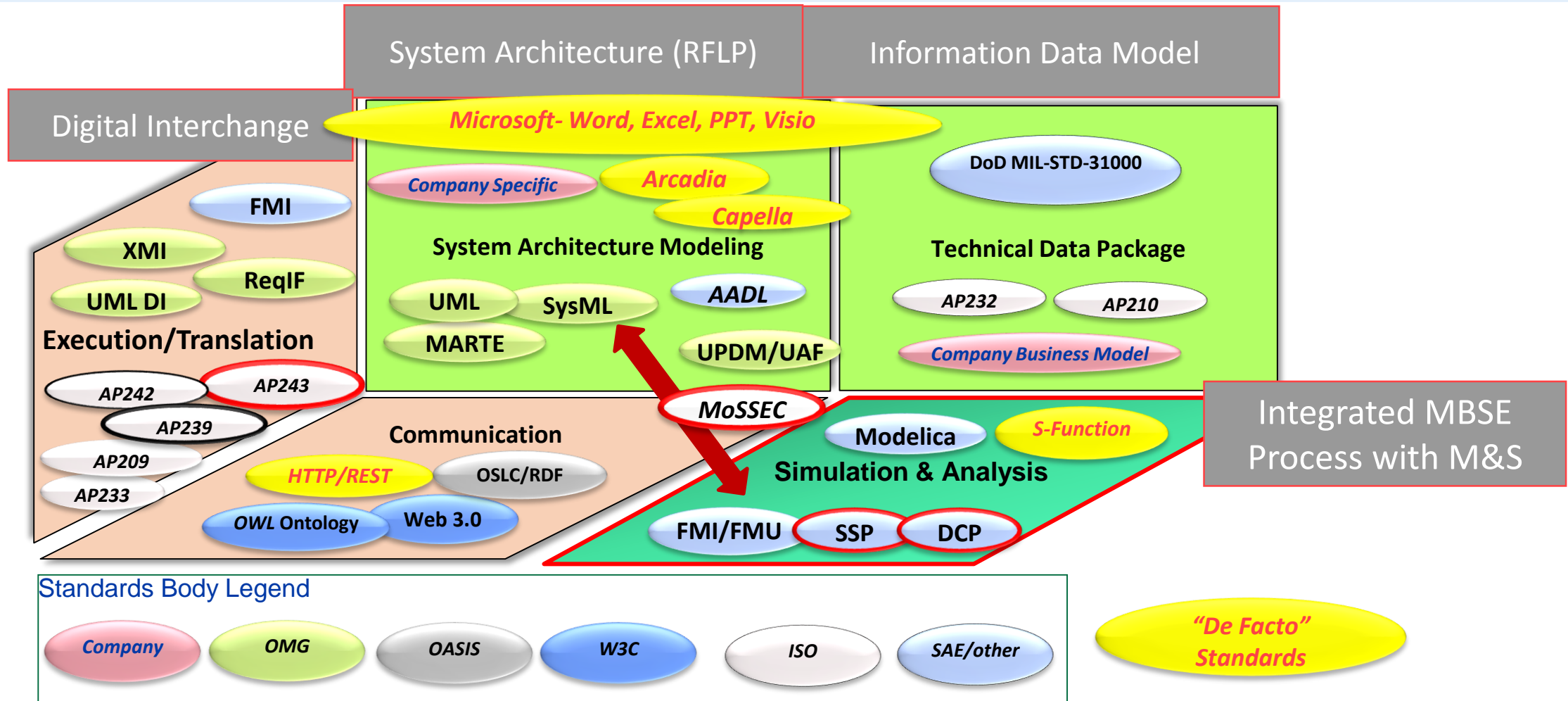
INCOSE defines MBSE as end-to-end lifecycle *process*, cutting across domains

Key capabilities commonly included in MBSE process definition today

- QFD, Requirements authoring and requirements management
- System Architecture Design and Development
 - Mechanical, Electrical/Electronics, Software, Networks, Biological, Chemical
- Excel-based trade studies, DoE, Six Sigma, FMEA, etc.
- V&V leveraging physics-based simulation & optimization tools
- Interoperability solutions for linking of M&S and SPDM tools with SE tools

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

Connecting the MBSE Digital Thread


Significant collaboration efforts underway to integrate data and processes

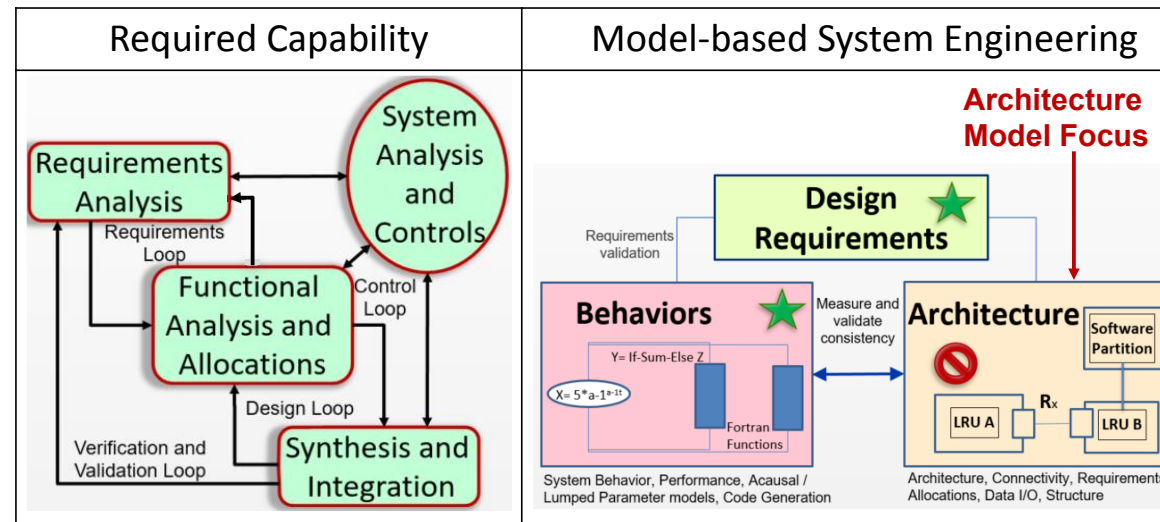
- Vendor neutral solutions addressing the need for interoperability of MBSE models and data across the PLM domains and major solution providers

MBSE Data Interoperability Specification

Background Information: Traditional System Engineering versus MBSE Methods

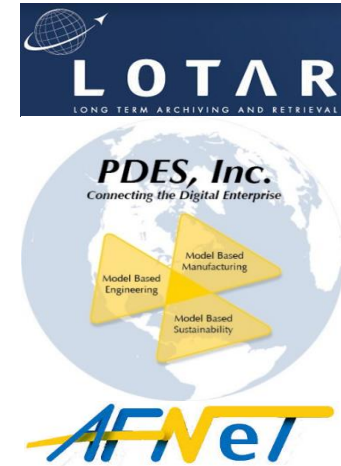
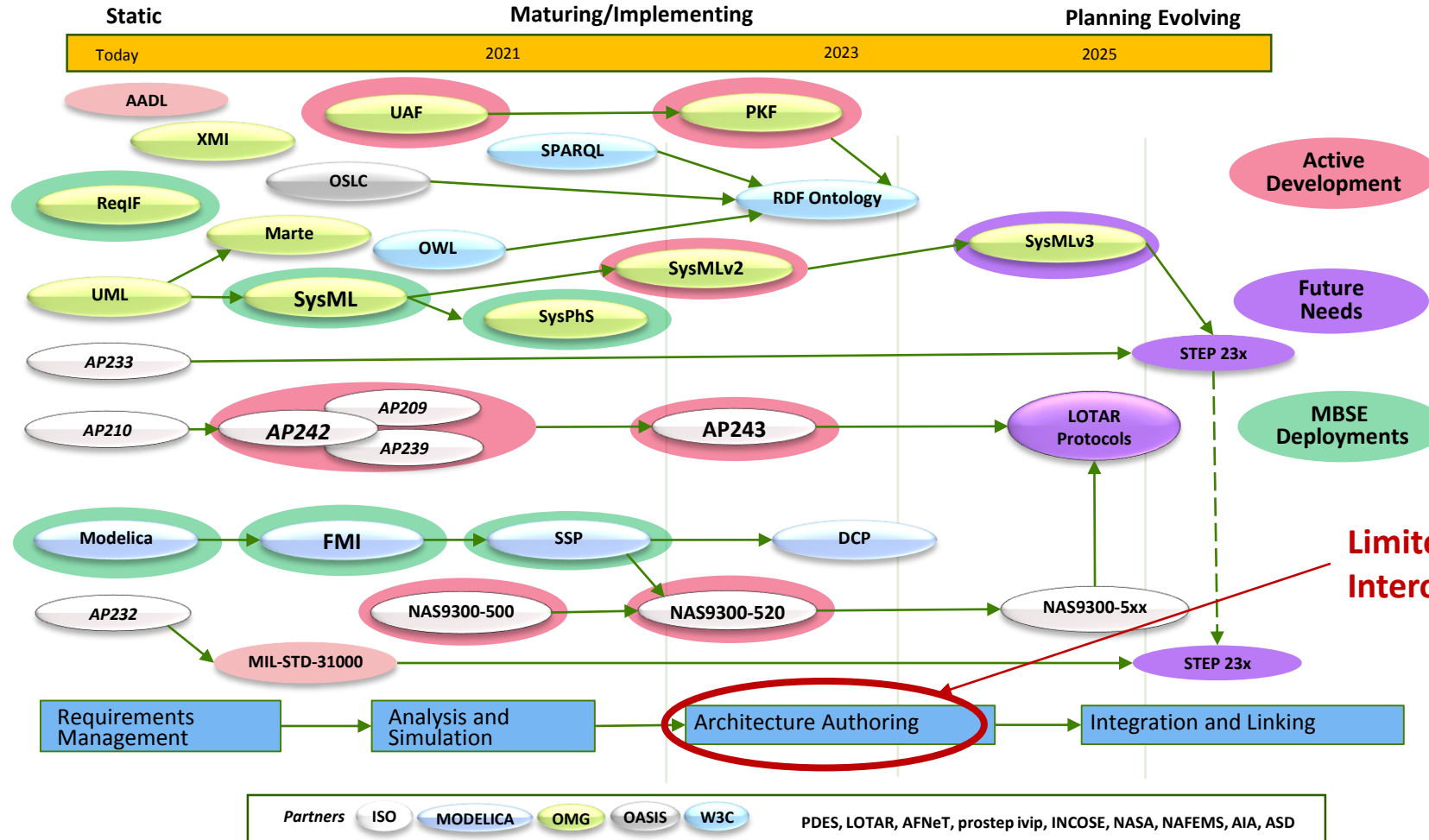
See white papers at
<https://www.cimdata.com/en/aerospace-and-defense/publications/mbse>

Effective Exchange options for 2 out of 3 common MBSE model types 



MBSE Data Interoperability Specification

MBSE Standards Roadmap



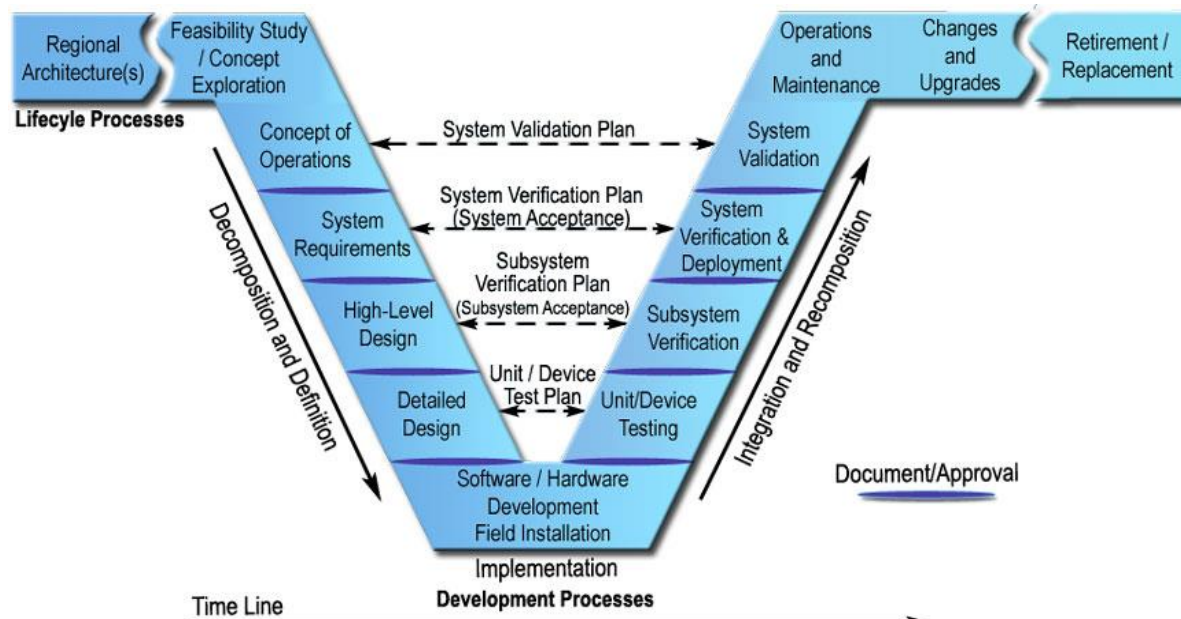
from PDES-LOTAR MBSE Conference, May 8th, 2019. Revised Dec 11th, 2019

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

Moving Toward a Model-Based Future

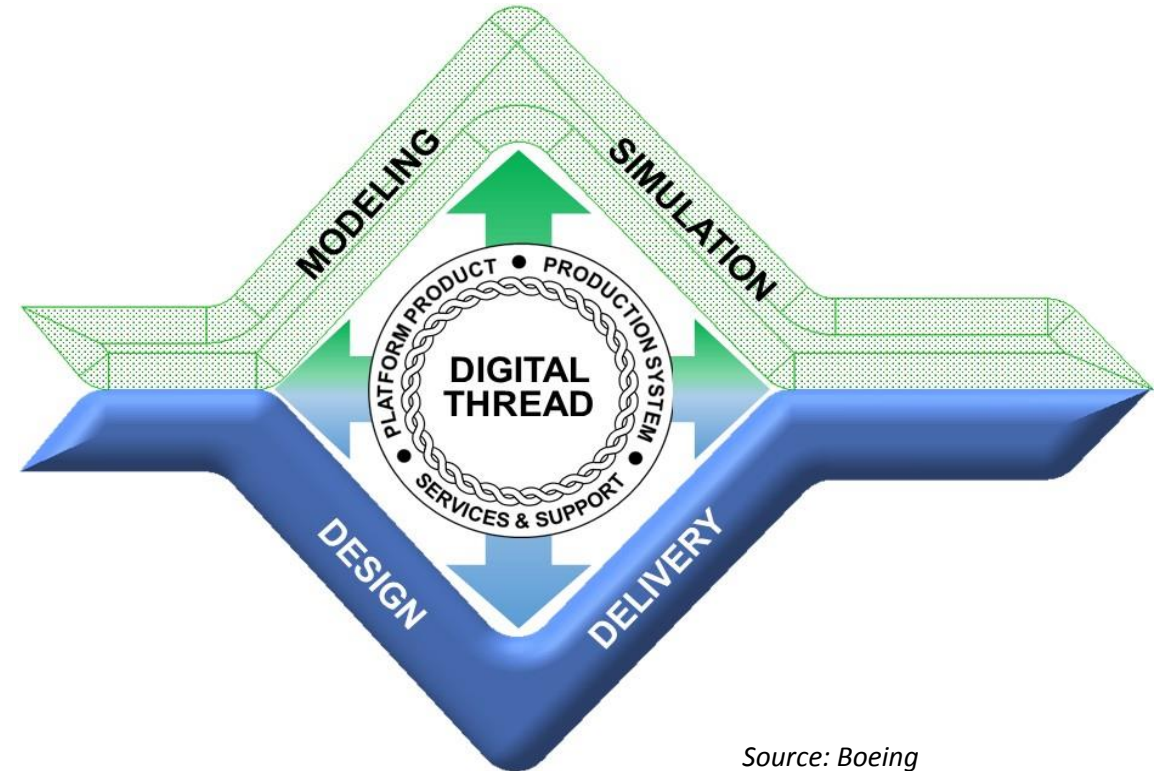
Transitioning to a digital thread of systems of systems

Systems Engineering 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

Concluding Remarks

The MBSE market and applications will continue to expand and evolve

- The development & management of smart, connected products is changing what PLM is, key role for MBSE and how it is enabled throughout the lifecycle
- Innovation and quality is the WHY; Model-Based Engineering is the HOW
- Most companies are still spending on traditional areas of PDM and S&A; But we need to get past these foundational elements into new areas like MBSE
- The growing application areas of system design/simulation, enabled by AI/ML, graph databases, digital twins, AR/VR and emerging data standards, hold great promise when deployed effectively across the engineering lifecycle domains
- Enterprise MBx processes, culture and people skills are critical to success

“The only thing we have to fear is fear itself...”

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