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CIMdata: Emerging Standards for MBSE

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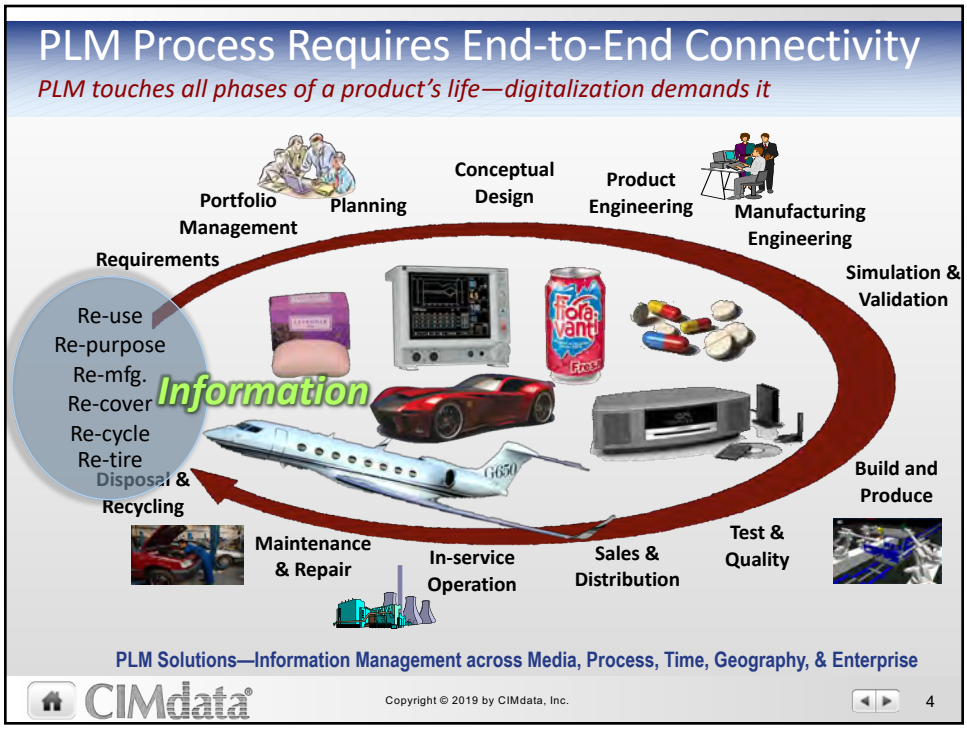
CIMdata: Emerging Standards for MBSE



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

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Digitalization: Transforming Enterprises

Digitalization requires rethinking the business, product, and data

- Radical advances in digitalization are underway all around us in both our personal social and professional lives
- Digitalization itself as been defined in many ways, but the most succinct is the business strategy best geared to extract real-world value from digital data (e.g., Airbnb, Amazon, etc.)
- The Internet of Things (IoT) with its billions of connected devices is and will play a major role
  - A source of "big data" and enabling closed loop lifecycle management
  - Making the digital thread and digital twin more achievable

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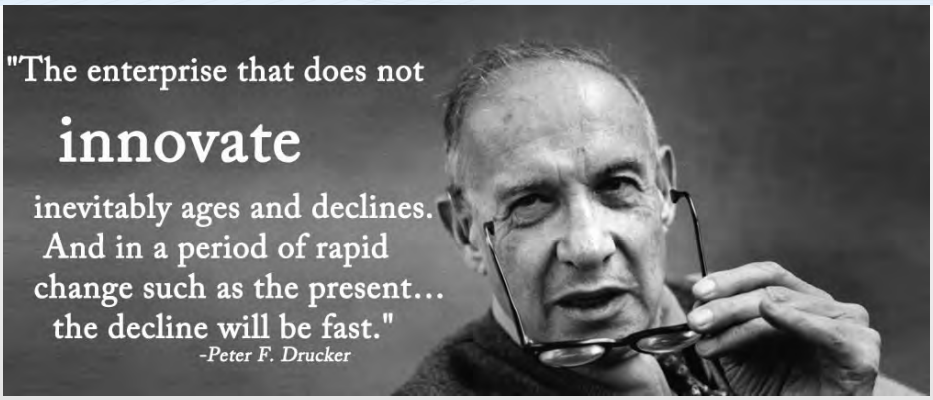
"Digitalization" accelerates change & innovation



"Digitalization is the main reason just over half of the companies in the Fortune 500 have disappeared from the list since 2000."

Pierre Nanterme, CEO Accenture, World Economic Forum

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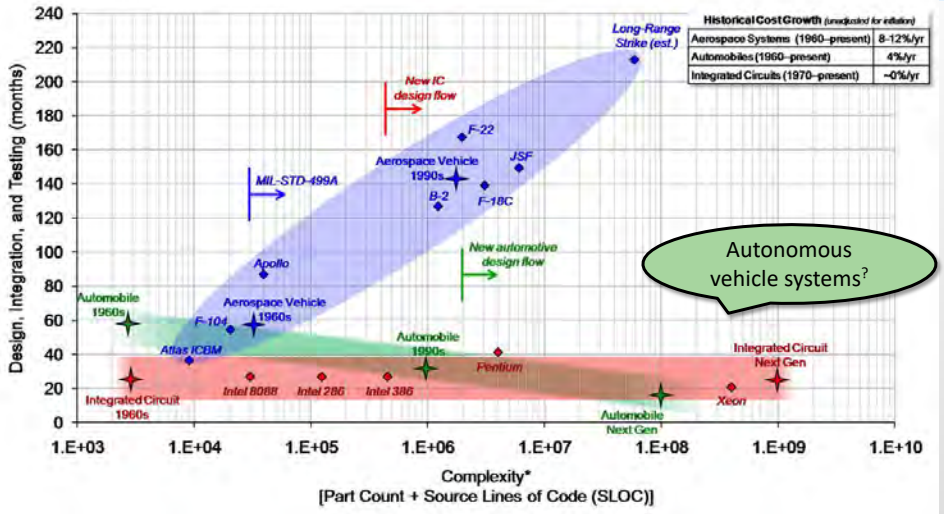
The Complexity Issue cuts across all Industries



Source: DARPA AVM project presentation.

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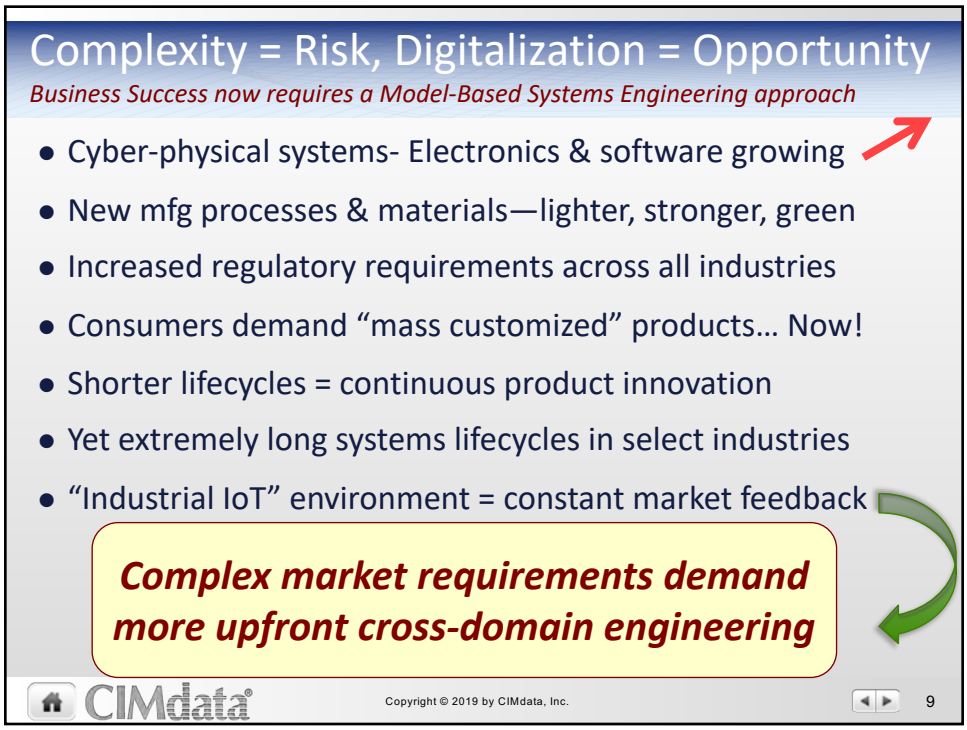

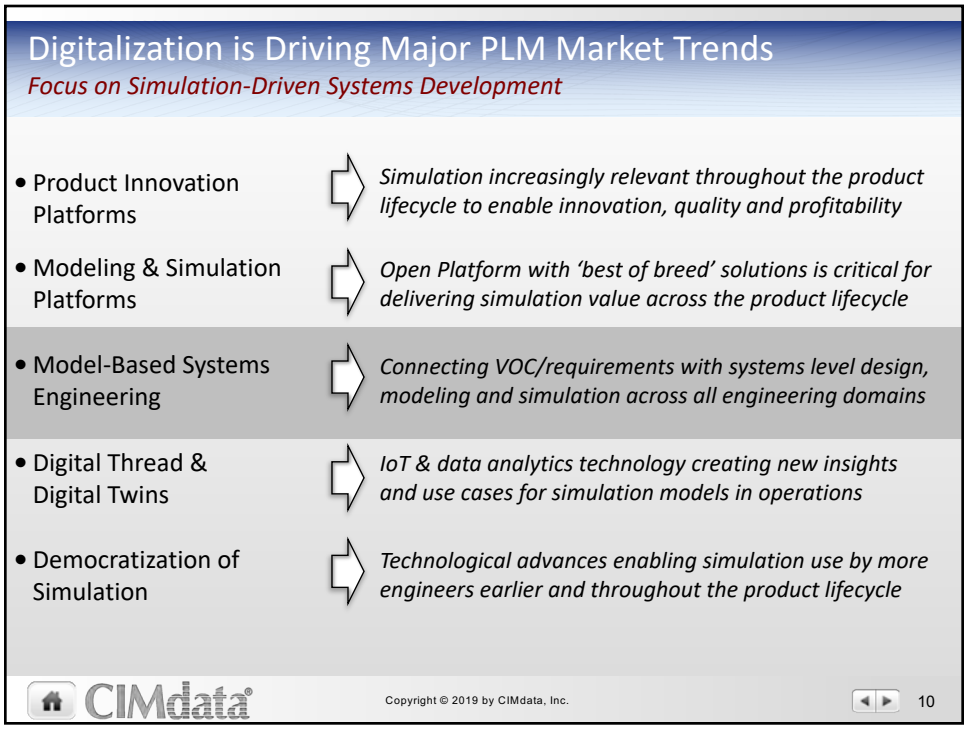

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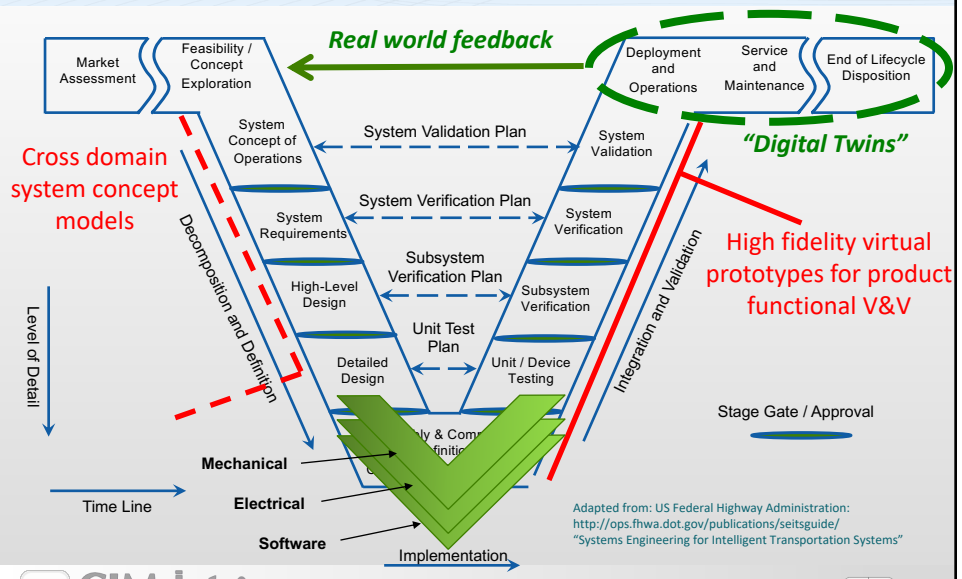
Model-Based Enables Systems Engineering

Digital collaboration enables high-value information continuity across lifecycle processes

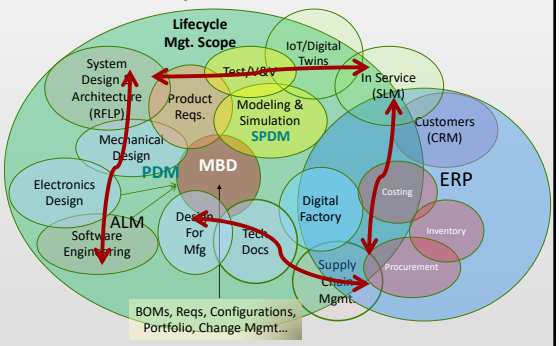


Digital Thread

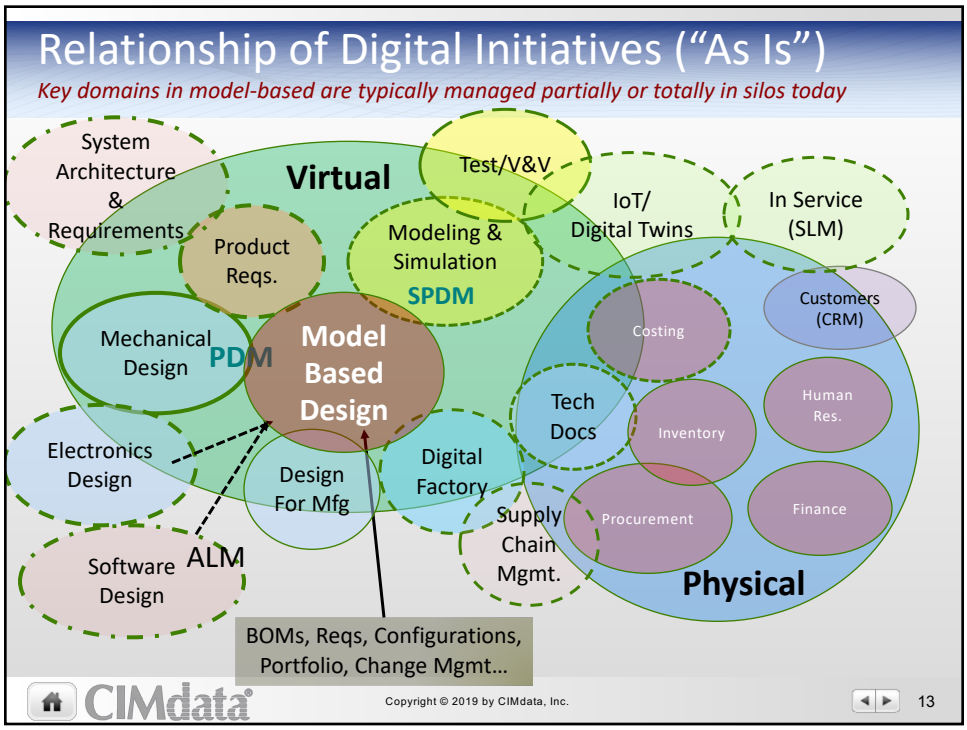
CIMdata's preferred definition

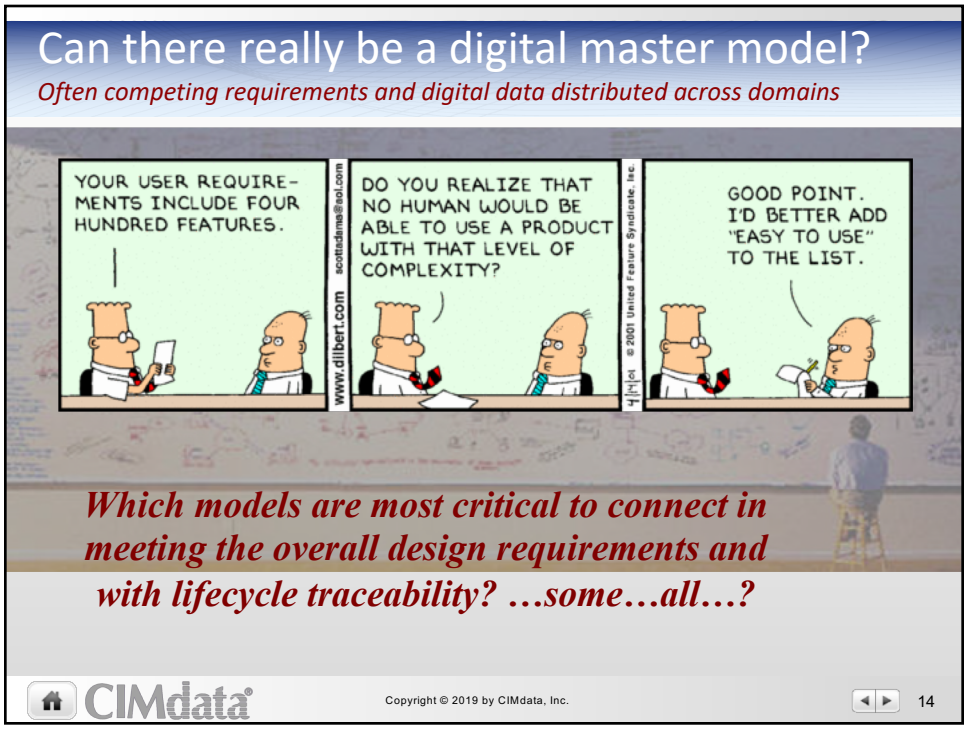
- ***Digital Thread*** refers to the communication framework that allows a **connected data flow and an integrated view** of a physical asset's digital data (i.e., its Digital Twin) throughout its lifecycle cutting across traditionally siloed functions

Digital thread is enabled and supported by a robust end-to-end and connected systems model and related MBx processes



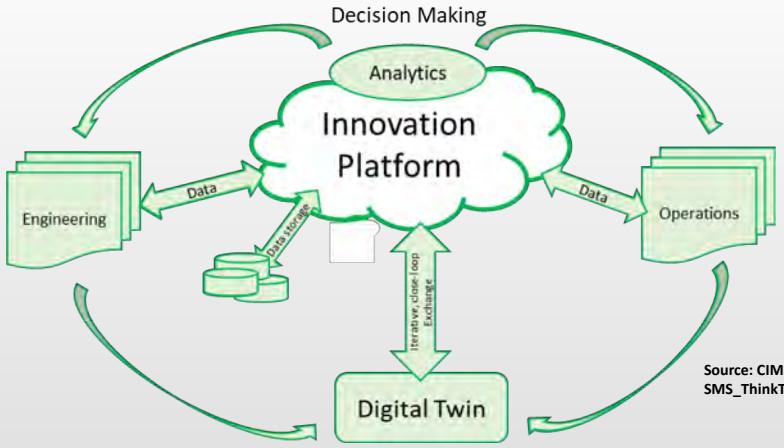
Extracted from: https://www.dodmantech.com/ManTechPrograms/Files/AirForce/Cleared_DT_for_Website.pdf
Also see: http://www.manufacturing-operations-management.com/manufacturing/2016/04/what-is-the-digital-thread-and-digital-twin-definition.html





The Emergence of the Digital Platform

Platformization: The next evolution of PLM, required to support digitalization

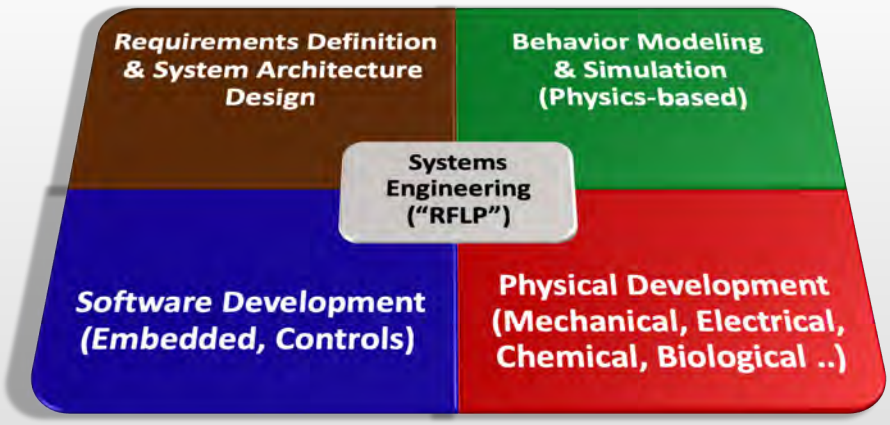


Source: CIMdata & SMS_ThinkTank™

Typically, there are several platforms involved to realize all the benefits of having a Digital Twin available. The underlying Product Innovation Platform needs to be able to bring the threads of all those platforms together to ensure that data and information is consistent and not duplicated.

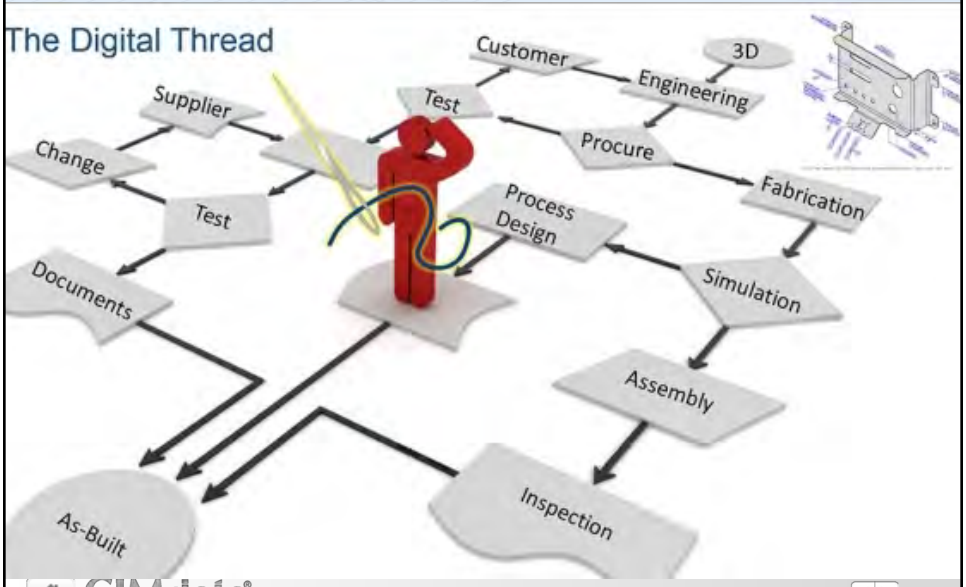
Platforms are consolidating across domains

Major players acquiring MBSE, M&S, ALM, EDA & IoT technologies



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

"Sewing the Digital Thread" - How? Where?



Why we need MBx Interoperability Standards

- Deal with Complexity of Systems Design Information
  - Across heterogenous software tools and data architectures
- A Methodology for Data Exchange & Collaboration to Support Design Reuse of Product Data and Models
  - Connect information silos in engineering and manufacturing domains
  - Digital thread across the entire product lifecycle
  - Digital thread for the extended virtual enterprise including suppliers
  - Maintain information over time- Long Term Archiving & Retrieval (LOTAR)
- ➢ *Deliver Business Impact & ROI = $$*
  - *Reduce Product Total Lifecycle Costs*
  - *Control/Improve Product and Process Quality*
  - *Enable Product and Process Innovation for Competitive Advantage*

Many Groups Involved with Many Standards

Consortiums, Bodies, and Specifications

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Remember early cell phone "standard" connectors?

- Lack of standards is bad but..
- Too many "standards" are equally a problem for practical implementation and widespread adoption by industry & solution providers

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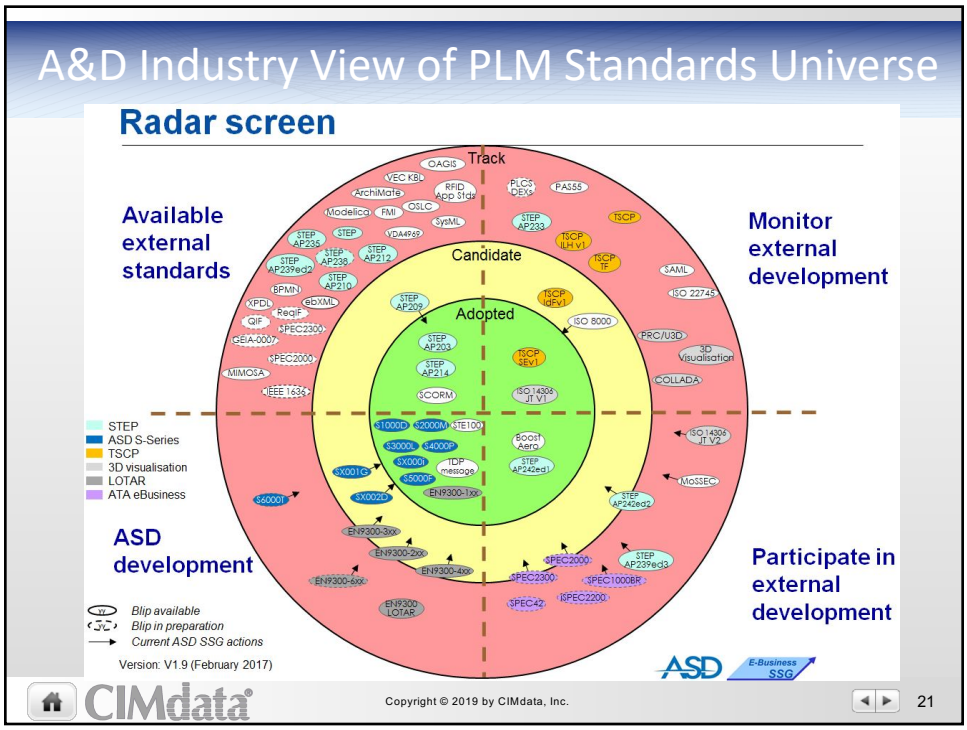

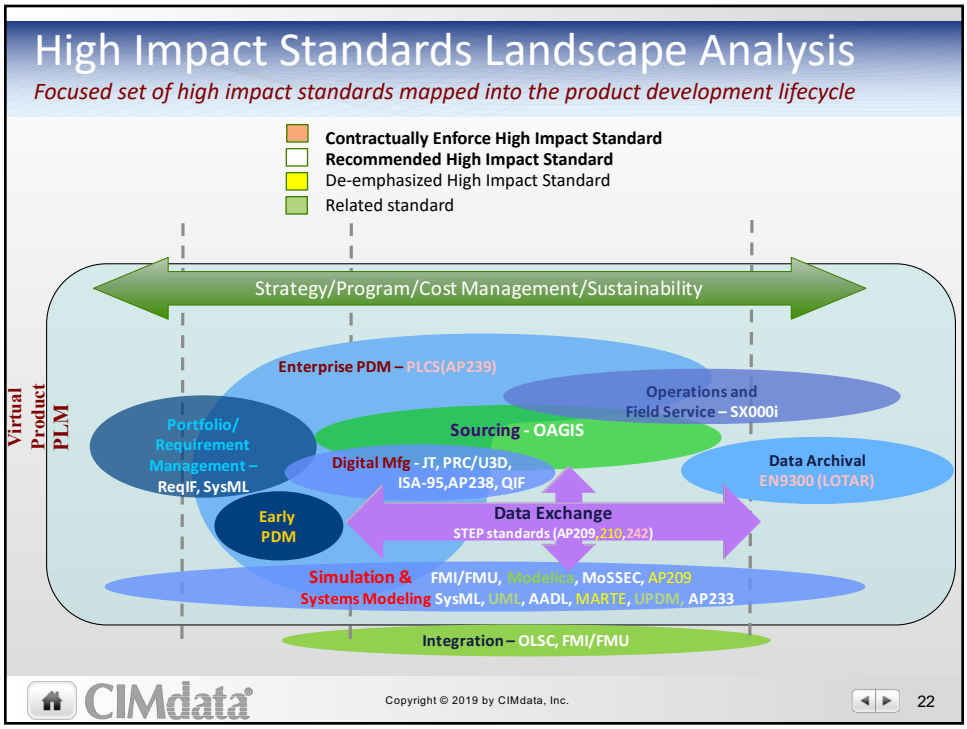

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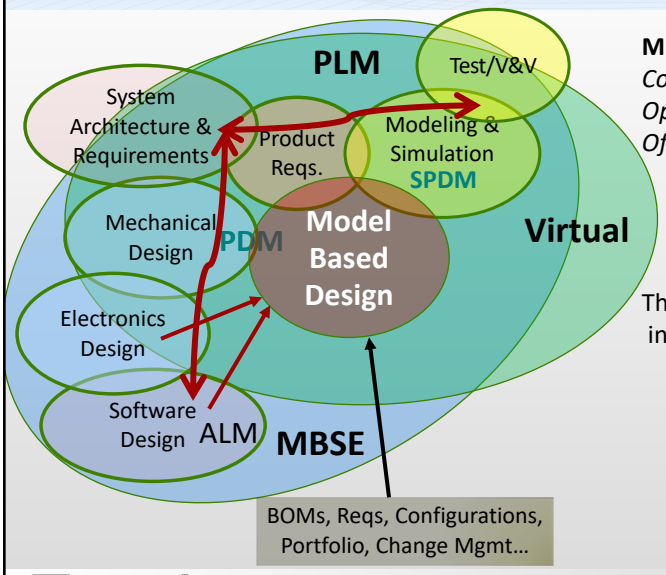
Sewing the MBSE Digital Thread ("To Be")

Conceptual Systems Engineering across domains; connections to PLM/M&S for V&V



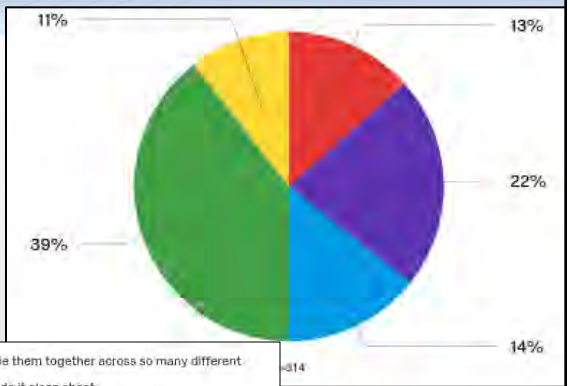
MBSE Use Case:
Conceptual Design, Optimization and Validation Of Cyber-Physical Systems

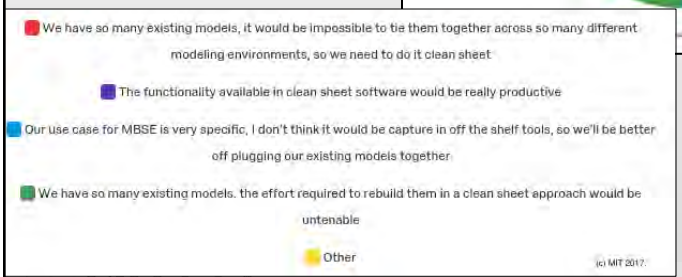
The thread needs to connect information across domains:

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

Challenge: Tool Integration, Data Interoperability

- If you pursued MBSE, would you start with a clean sheet in specific MBSE software, or would you write custom software to tie your existing models together? Why?
- *Majority indicated need to tie together existing models in some manner*





MIT MBSE On-line Course Survey of 300+ Engineers

Bruce Cameron, TSP MBSE LinkedIn blog post May 17, 2017

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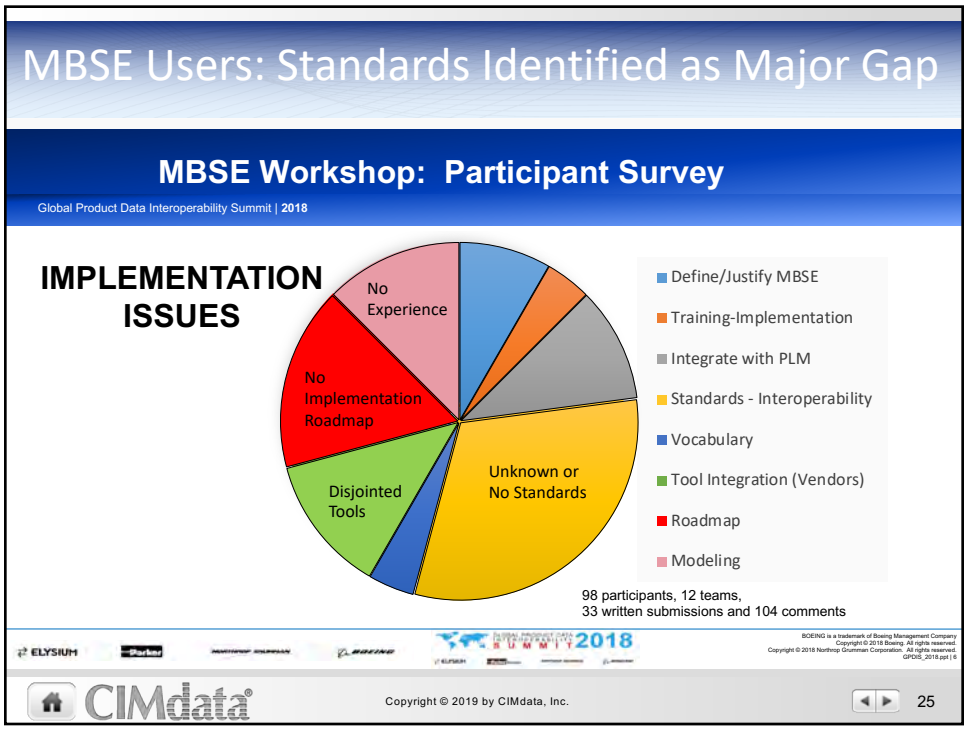

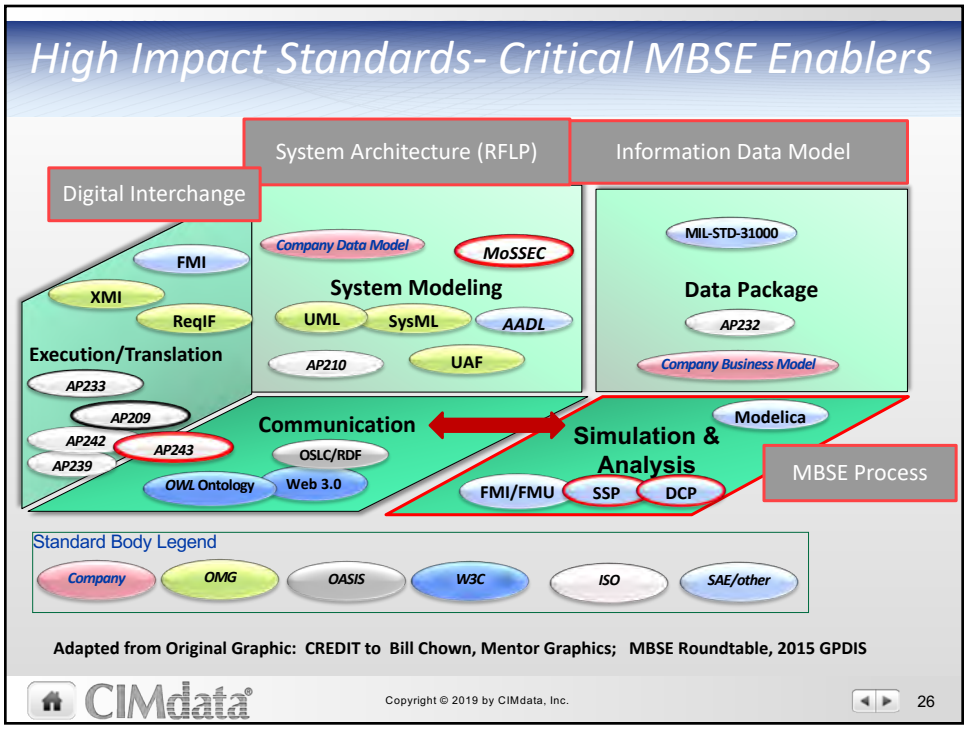

Cross-Domain Model Interoperability & Digital Data Linking

Evolving Industry Standards will be critical for "sewing the Digital Thread"

- MBSE systems modeling languages (UML/SysML, Papyrus, Capella, etc.) and architecture frameworks (UPDM/UAF, Systematica, Arcadia, etc.)
- ISO/STEP AP 233/239/242 & 209– Consolidated data model backbone
- Web collaboration standards such as XML/XMI, URLs, RDF and OSLC for data linking across authoring tools and data management platforms
  - Open Services for Lifecycle Collaboration (https://open-services.net/)
- ReqIF- Requirements Interface Format based on XML
- Modelica® & FMI/FMU – Functional Mockup Interface/Mockup Unit
  - New standard in process- System Structure and Parametrization (SSP)
  - New standard in process- Distributed Co-simulation Protocol (DCP)
- MoSSEC – Modeling & Simulation information in a collaborative Systems Engineering Context (AP243) See http://www.mossec.org/

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Formal Standards and "de facto" Standards ("As Is")

Are we moving fast enough to provide real business impact to the industry?

- Some of the most widely used data formats today for digital data interoperability have become "de facto" standards for engineering data exchange and collaboration just because so many engineers use them
  - Microsoft "engineering tool suite" (.xls., .doc., .pptx, .vsd, mpp)
  - Systems simulation- Matlab/Simulink S-Functions, Modelica .mo
  - Structural analysis- Nastran .bdf, ADAMS .mnf, ABAQUS .odb, ANSYS .agdb, etc.
- Others evolved into formal collaboration standards- 3DPDF, JT, OSLC
- On the the other hand, a number of formal standards are not widely used by industry today despite relative maturity of the standards
  - Unfortunately, some are in the MBSE domain- ISO STEP AP233 (SE focus)
- Some standards have been in process for well over a decade and are still evolving towards maturity/widespread adoption (e.g., AP209, SysML)
- Some standards moved quickly to adoption- Modelica and FMI/FMU

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Modelica Assn: Functional Mockup Interface (FMI)

Problems / Needs

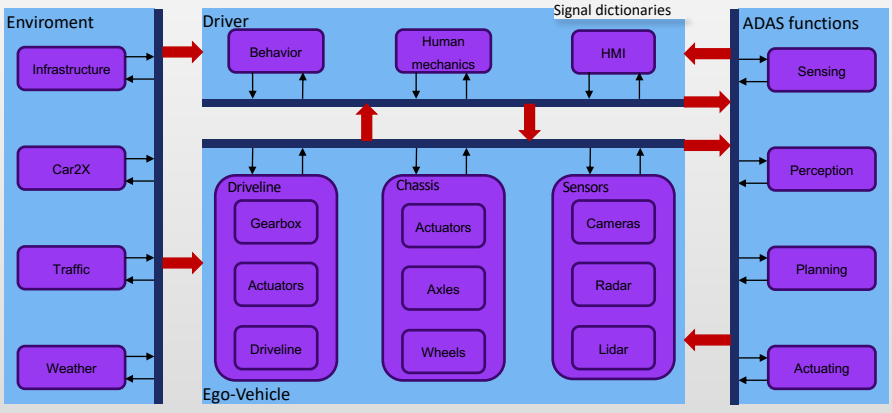
- Component development by supplier
- Integration by OEM
- **Many different simulation tools**

- Tool independent standard to support both model exchange and co-simulation of dynamic models https://fmi-standard.org/
- Original development part of EU-funded MODELISAR project led by Daimler
- First version FMI 1.0 published in 2010; FMI 2.0 released July 2014 with additional functionality
- Active development, testing and support from Modelica® Association project
- Standard currently widely adopted and supported by over 100 tools
- FMI's business model helps drive industry adoption

System Structure and Parameterization: SSP

One level "above" an FMU- Public release expected during Q1, 2019

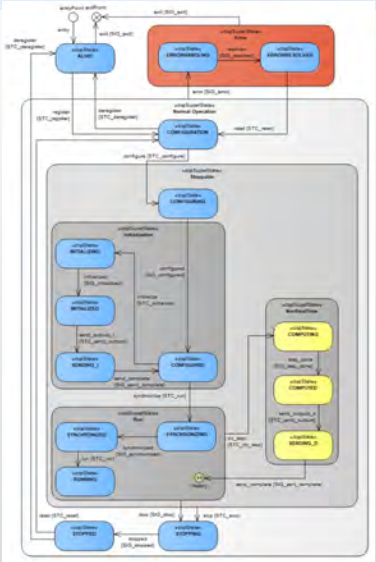
Purpose of SSP: Standardize interconnected system of components and controls, including parameterization and variants handling



Usage of SSP in defining Simulation Architecture for ADAS

Distributed Co-simulation Protocol: DCP

- What is it?
  - Standardization of data exchange protocol for distributed co-simulation, real-time and non real-time, also connecting real hardware testbeds with virtual parts
- Who is involved?
  - Developed by automotive OEM, and suppliers, test hardware vendors and simulation software vendors
- Continuation of EU research project ACOSAR
- Public review of draft standard started in Q4 2018



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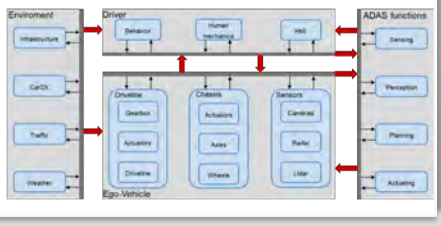
Modelica Assn: Coordinated Set of Standards

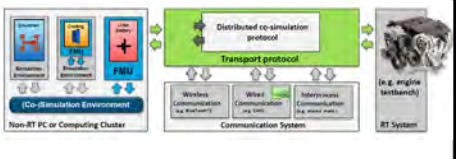
Modelica:
Build the model

FMI: Interface
and deploy models

SSP: model-based collaboration
across the extended enterprise



Distributed Co-simulation Protocol: Let models
talk to one another and hardware



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Formal Standards and "de facto" Standards ("As Is")

Are we moving fast enough to provide real business impact to the industry?

Observations based on ~40 years working in the PLM technology industry

- *Standards need to address a real business issue for a sufficiently large yet targeted segment of industrial end users (detailed use cases!)*
- *Software solution providers will invest in supporting standards when industry really adopts and uses them…. and especially if industry requires contractual compliance in order for solution providers to continue to sell their commercial software*
- *Industrial users will lose interest in standards that take too long to be developed and officially released by the standards organizations*
- *Standards that don't get quickly adopted & widely used will die a slow painful death and become useless, even if/when they ultimately mature*

MoSSEC: Emerging Standard to Enable MBSE

Combining Modelling and Simulation Data with Collaboration Data:

Who, What, Where, When, How & Why

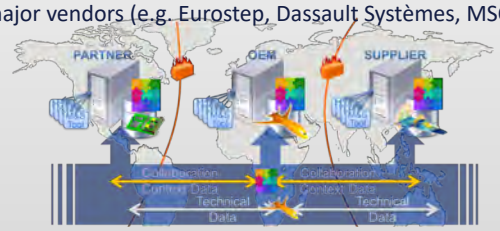
Modelling and Simulation data
- Managed by PLM/SPDM tools
- Exchanged with technical standards

Together this supports a lifecycle model-based enterprise

PDT Europe
October, 2017

MoSSEC: Work-in-Progress ISO/STEP Standard

- ISO Committee Draft approved June 2018 (ISO/AWI 22071, **AP243**)
  - International Standard release planned by late 2019/early 2020
- ***The Who, What ,Where, When, How, Why***: Shares systems engineering context of modelling and simulation data between internal teams/domains and extended enterprise
  - Builds on AP239/AP242 standards and leverages new STEP extended architecture
  - Leverages modern W3C/REST/OSLC type web services for global collaboration
- Supported by industrial partners (e.g. Airbus, Rockwell Collins, Boeing, BAE Systems)
- Supported by major vendors (e.g. Eurostep, Dassault Systèmes, MSC Software, Siemens)



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Sewing the MBSE Digital Thread ("To Be")

Significant collaboration efforts underway to integrate data and processes

In addition to the standards organizations, there are a number of industry initiatives underway to help enable MBSE data interoperability and design collaboration within enterprises as well as across the OEM/supply chain

- Global Product Data Interoperability Summit (GPDIS)- SE/MBSE track since 2014
- NIST Model Based Enterprise Summit- Annual event since 2016
- MBSE for PDES & LOTAR for MBSE- PDES and INCOSE collaboration
- INCOSE Tool Integration and Lifecycle Management (TIMLM) Working Group
- Digital Engineering Information Exchange (DEIX) Working Group
- protstep ivip- Smart SE project focused on M&S integration with SE for V&V
- ASSESS- Analysis, Simulation, and Systems Engineering Software Strategies
- Joint NAFEMS/INCOSE Systems Modeling & Simulation Working Group (SMSWG)
- CIMdata Aerospace & Defense PLM Action Group

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Sewing the MBSE Digital Thread ("To Be")

Significant collaboration efforts underway to integrate data and processes

Reference sites for some of the major MBSE-related industry initiatives:

- https://gpdisonline.com/2018-presentations/
- www.nist.gov/news-events/events/2018/04/model-based-enterprise-summit
- http://wiki.omg.org/MBSE/doku.php?id=mbse:smswg
- http://www.omgwiki.org/MBSE/doku.php?id=mbse:incose_mbse_iw_2019
- https://www.incose.org/incose-member-resources/working-groups/transformational/digital-engineering-information-exchange
- https://www.prostep.org/en/projects/smart-systems-engineering/
- https://www.acq.osd.mil/se/initiatives/init_de.html
- https://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:modelmgt:iw2017:pdes_lotar_slides_iw2017.pdf
- https://www.cimdata.com/en/aerospace-and-defense#

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SMSWG Standards Ecosystem Focus Area

An SMSWG sub-team has been established to provide a focal point for identifying and promoting formal standards (and "de facto" standards) that enable systems modeling and simulation via improved ***model/data interoperability and cross-domain engineering collaboration*** within the context of achieving MBSE/MBE (i.e., the lifecycle Digital Thread)

- Don Tolle of CIMdata is acting as project leader/coordinator of this MBSE Standards Ecosystem sub-team (d.tolle@cimdata.com)

- The role of this sub-team is to provide a more formal linkage to the various standards bodies (e.g., OMG, Modelica, OASIS, PDES/STEP, etc.) and industry/government working groups and associations involved with standards (e.g., INCOSE, NAFEMS, NDIA, NIST, ESA, ASD, CIMdata, prostep ivip, ASSESS, etc.)

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SMSWG Standards Ecosystem Focus Area

The 4 major focus areas identified to date are outlined below and each focus area will be led by one or more industry subject matter experts (SME)

1) Modelica Association standards (Modelica, FMI/FMU, SSP, DCP, etc.)
   SME- Hubertus Tummescheit (Modelon)
2) PDES/STEP AP standards related to systems modeling and simulation including linkage with LOTAR and MoSSEC (pending AP standard)
   SMEs- Mark Williams (Boeing), Adrain Murton (Airbus)
3) Web standards (OASIS/OSLC, RDF, XML/XMI, UML DI, others TBD)
   SME- Axel Reichwein (Koneksys)
4) OMG standards- Requirements and Systems Architecture (RFLP) (ReqIF, SysML v2, UAF, others TBD)
   SME- Roger Burkhart (John Deere)

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How to learn more about the SMSWG Community

Complete the request form on the NAFEMS SMSWG website.

Indicate if your organization is a member of NAFEMS and/or you are a member of INCOSE.

Once signed up, you will receive announcements for upcoming meetings and also have access to the SMSWG Collaborative Community.

The INCOSE MBSE Initiative also maintains an SMSWG wiki page, with publicly available meeting materials.

An INCOSE Working Group page for SMSWG is in progress.

INCOSE NAFEMS

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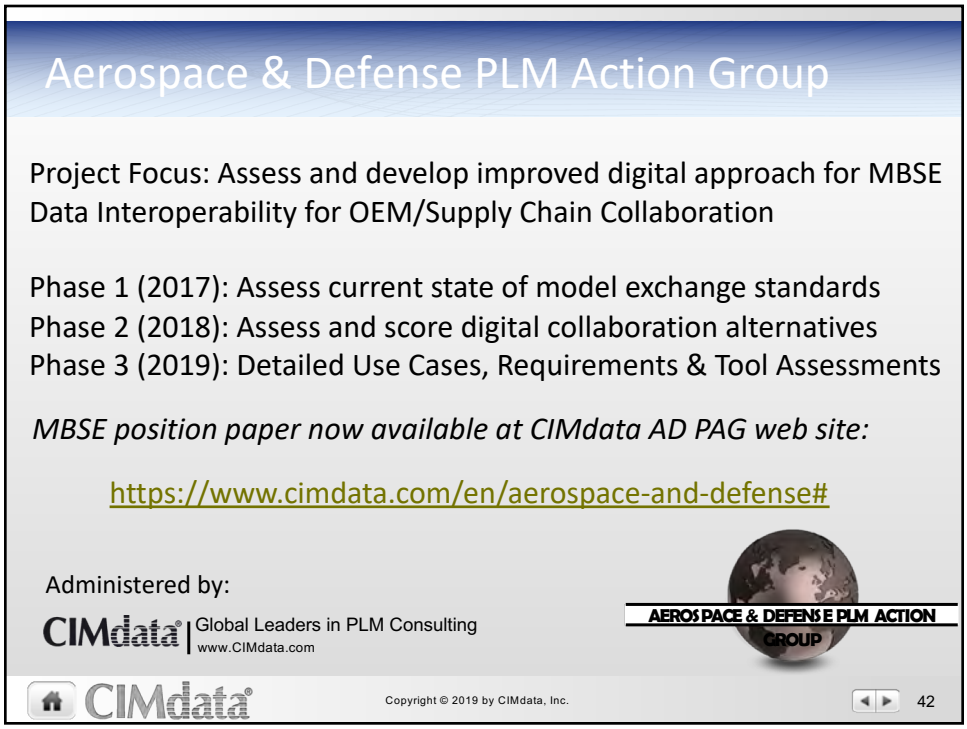

Sewing the MBSE Digital Thread ("To Be")

Commercial software solutions emerging to integrate 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 models and data capturing systems requirements and systems architecture design:

- InterCAX- Syndeia suite http://intercax.com/products/syndeia/
- Sodius- SE Collab https://www.sodius.com/en/products/secollab
- Ingrano Solutions- ModelBus http://ingrano-solutions.com/tool-integration
- MID AG- smartfacts platform https://www.smartfacts.com/
- Koneksys- Focus on OSLC/web collaboration standards www.koneksys.com
- Others: Know Gravity, HCL, dSpace

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

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Sewing the MBSE Digital Thread ("To Be")

Significant collaboration efforts underway to integrate data and processes

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

- Maplesoft- MapleMBSE https://www.maplesoft.com/products/maplembse/
- Phoenix Integration- ModelCenter MBSEPak https://www.phoenix-int.com/product/mbsepak/
- Modelon - https://www.modelon.com/#
- InterCAX- http://intercax.com/products/syndeia/
- Open CAE & OpenMBEE- Open source frameworks developed by NASA/JPL http://www.openmbee.org/

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

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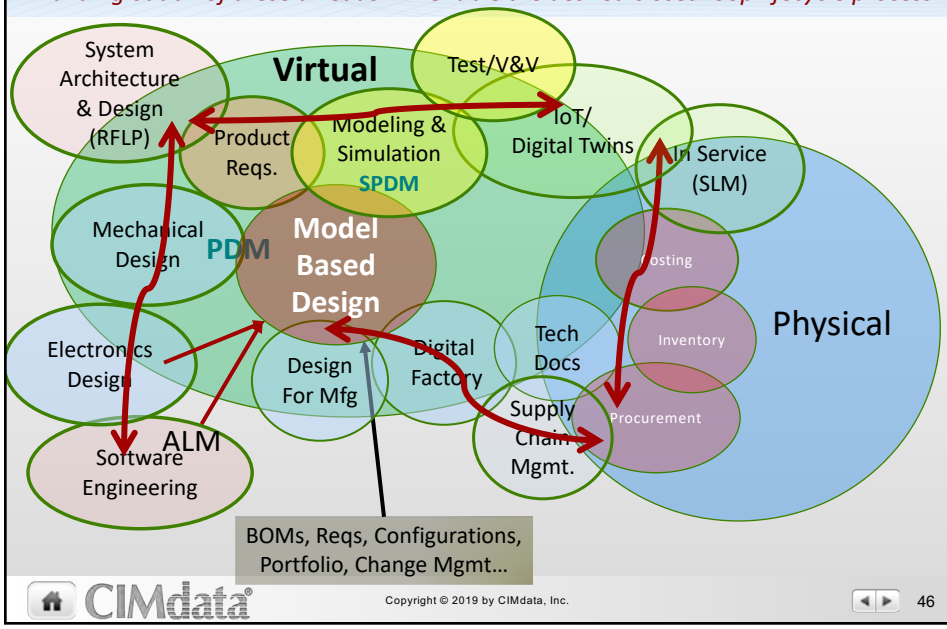
Final Thoughts

Digitalization, MBSE, PLM and Digital Thread: Where to next?

Connecting the Lifecycle Digital Thread

Building out all of these threads will enable the desired closed loop lifecycle process



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Enabling the Digital Thread Vision for MBSE

What is needed to address the industry's business needs?

MBSE implementation will ultimately require a blend of:

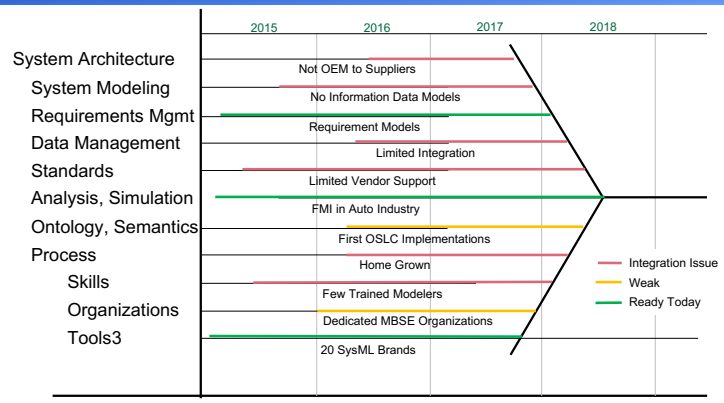
1) ***Process change*** leveraging MBSE best practices of early adoption leaders across all industry segments[1]
2) ***Common ontology, semantics & languages*** for systems architecture design
3) ***Innovation platforms & software tools*** for PLM/MBSE/IoT integration
4) ***Model & Data management*** across the enterprise domain silos
5) ***Robust standards*** for PLM/MBSE data interoperability

[1] Frank Popielas, Edward A. Ladzinski – SMS_ThinkTank: "Systems Engineering – Challenges for Management"; CAASE18, June 5-7, 2018; Cleveland, OH

Progress Being Made in Several MBSE Areas

MBSE Workshop: Industry Roadmap

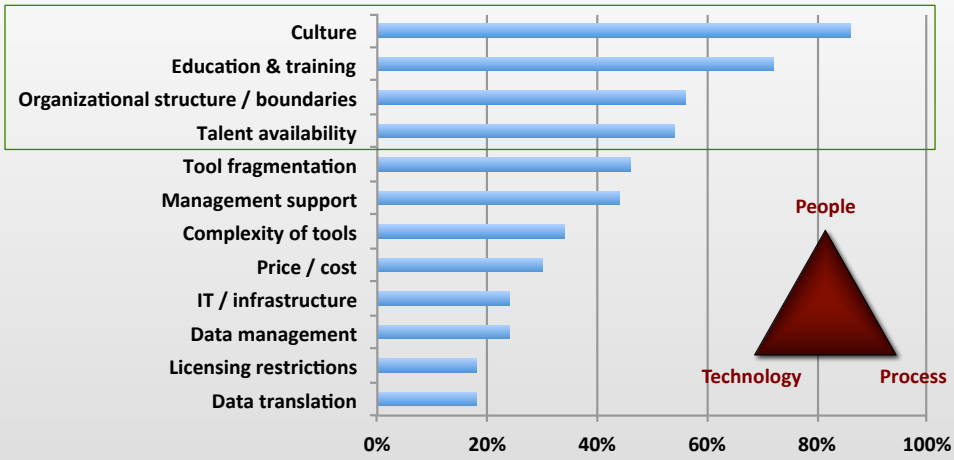
Global Product Data Interoperability Summit | **2018**



Barriers to Industry Implementation

What users cited as problems to overcome in adopting & using MBE/MBSE

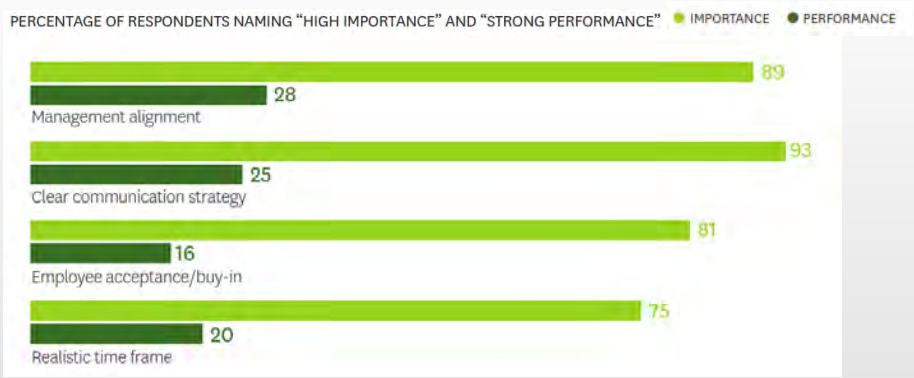
- It is about people & process as well—not just technology



Source: CIMdata MBSE web survey conducted with ANSYS & INCOSE (2015)

Moving towards Change Success

The Change Performance Gap

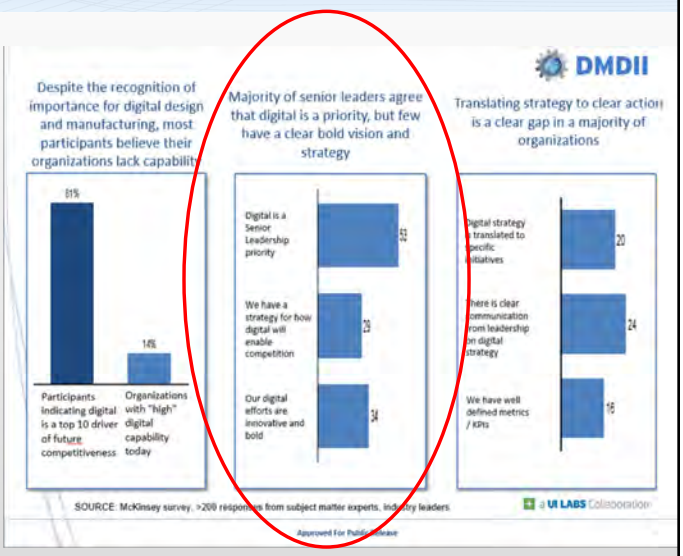


How important is each of the following to the success of a change initiative, and how well does the organization perform on each of these same factors when implementing the change initiative

2018 GPDIS MBSE Workshop– Dr. Harris Keynote

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



Summary - Key Factors for Business Success

Driving a Model-Based Enterprise Digitalization Strategy to Realization

- Needs to be developed and supported in the context of an enterprise application architecture platform and data model
- *Implemented and promoted based on specific MBE business use case success and measurable ROI* *Crawl…Walk…Run!*
  - Define and pilot well-defined MBx processes in specific business focus areas—Must account for cultural change and the people buy-in/training required
- Maturity models and governance are essential to success
- Need to have "integrated, yet open" solutions of software and services based on industry standards and best practices
- Industry & DoD need to support new contractual concepts *AND* accept electronic project deliverables/signoffs/TDPs

Enabling the Digital Thread Vision for MBSE

Industry initiatives underway to address known gaps and challenges

MBSE standards bodies as well as industry research and best practices collaborations are actively underway. They need active industry support!

GET INVOLVED!

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Emerging Standards for MBSE

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

NAFEMS

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