A LOOK AT THE STATE-OF-THE-ART OF THE DIGITAL SYSTEM MODEL: THE STATUS BEYOND THE HYPE

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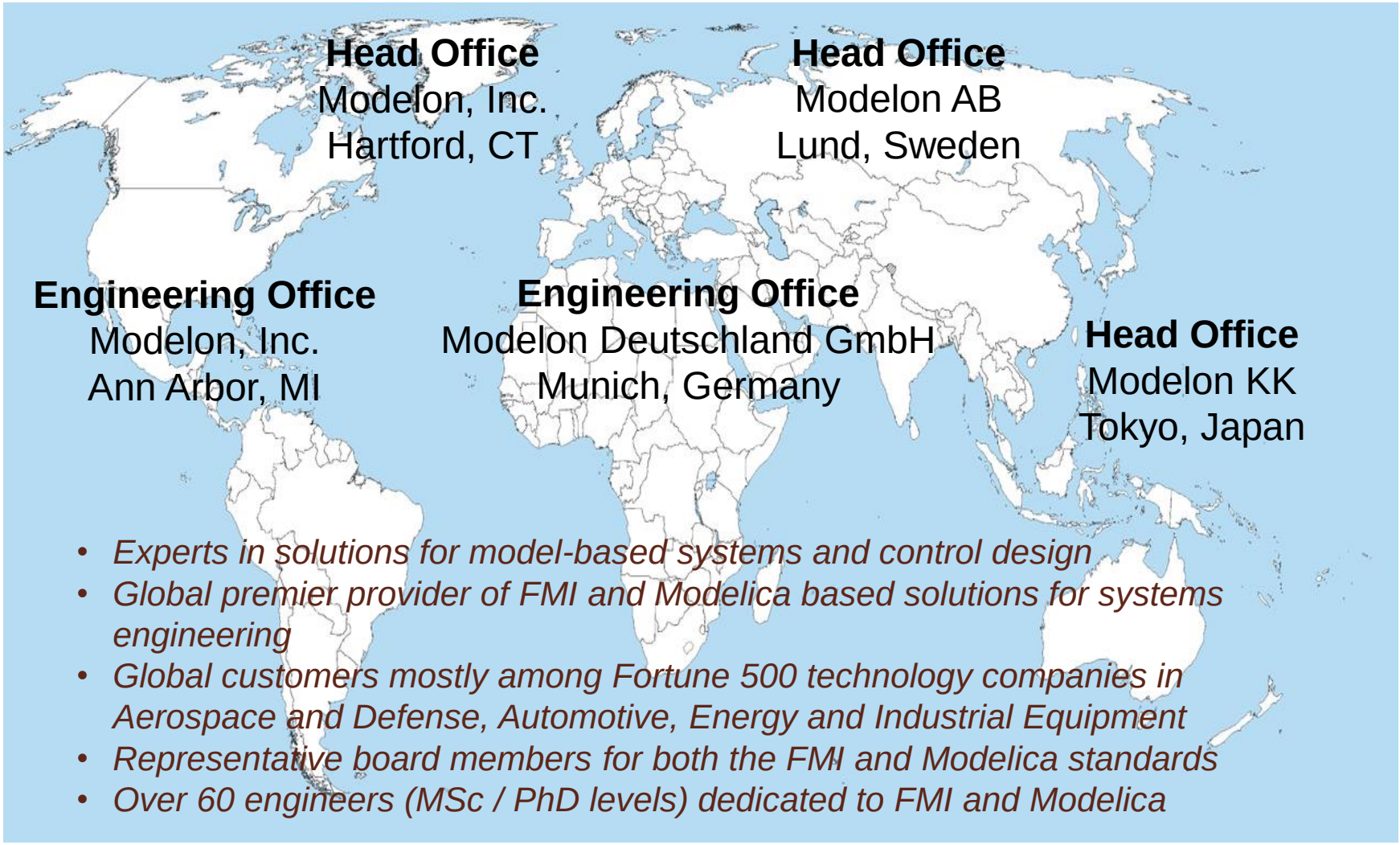
MODELON

Supporting International Standards for Systems Engineering



- *Experts in solutions for model-based systems and control design*
- *Global premier provider of FMI and Modelica based solutions for systems engineering*
- *Global customers mostly among Fortune 500 technology companies in Aerospace and Defense, Automotive, Energy and Industrial Equipment*
- *Representative board members for both the FMI and Modelica standards*
- *Over 60 engineers (MSc / PhD levels) dedicated to FMI and Modelica*

CIMDATA

STRATEGIC CONSULTING FOR COMPETITIVE ADVANTAGE IN GLOBAL MARKETS

CIMdata is the leading independent global strategic management consulting and research authority focused exclusively on the PLM market.

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

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OVERVIEW

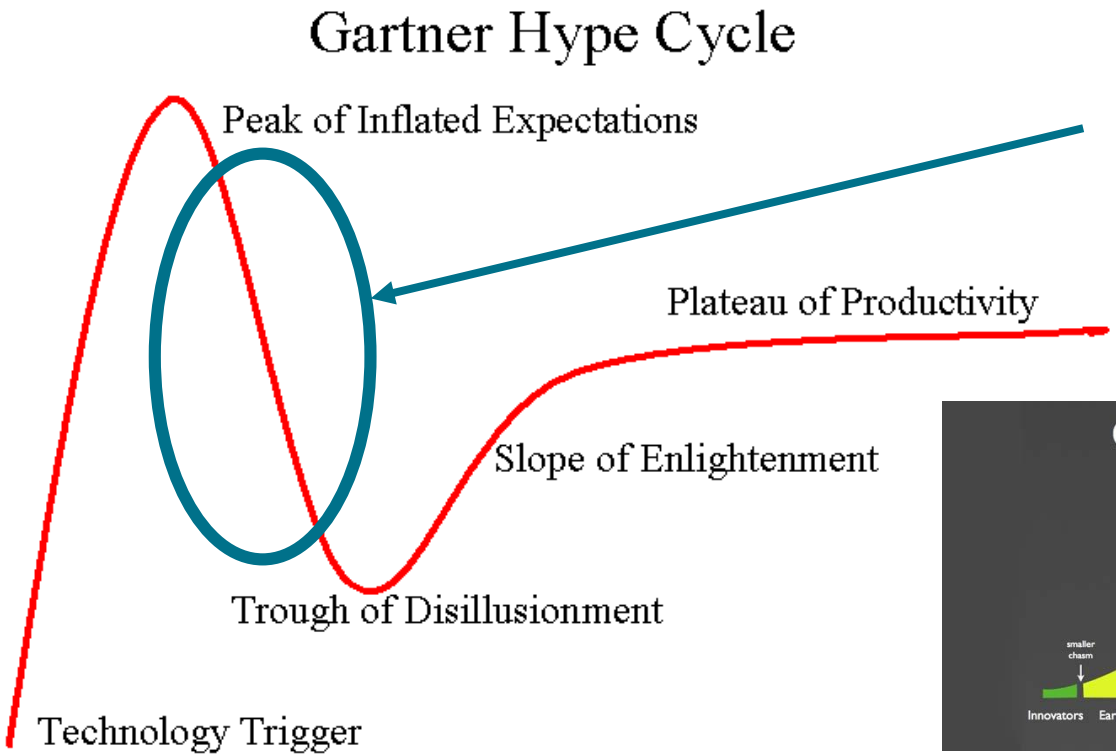
- Who We Are
- Why Hype?
- System Modeling
- Interoperability Standards
- Data and Process Management Tools
- Summary

WHY HYPE?

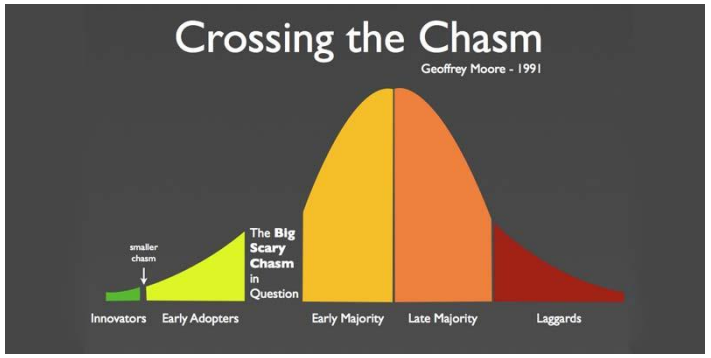
- Have you lately watched the presentation of any CEO of a big PLM Vendor?
- Have you ever used their software where interoperability in a complex context is important?
- Any disconnect?




THE HYPE CYCLE



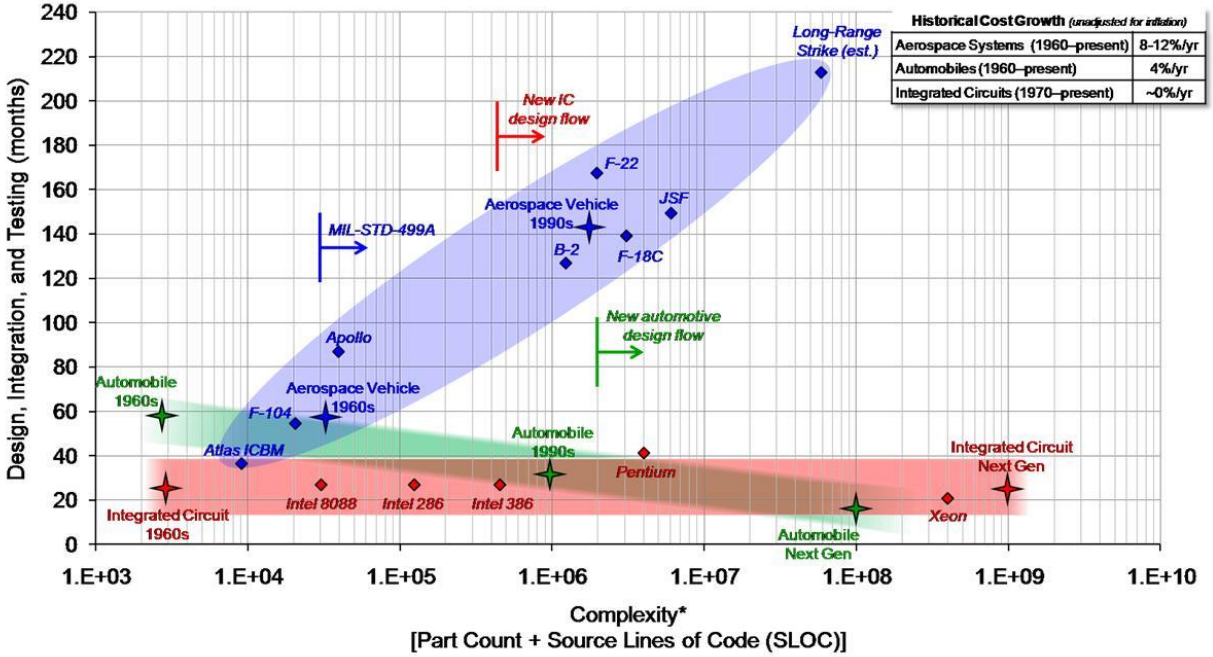
Some important technologies may be on the way down right now



Where are different standards and technologies relevant for the Digital System Model?

THE COMPLEXITY ISSUE

Source: DARPA AVM pres.

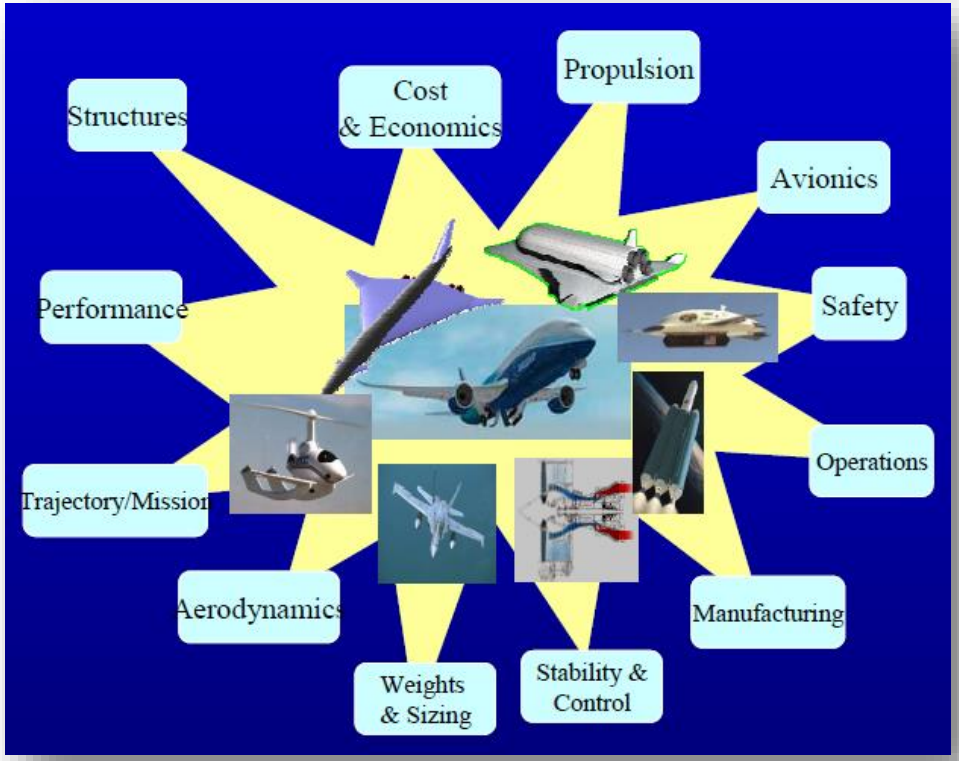


- System complexity increases while
- Required time to market decreases (most industries)
- Without disruptive changes, an impossible equation to solve.
- The main culprit: (embedded) software complexity

MODEL-BASED SYSTEMS ENGINEERING (MBSE)

MODELS, NOT DOCUMENTS, AS THE PRIMARY MEANS OF INFORMATION EXCHANGE

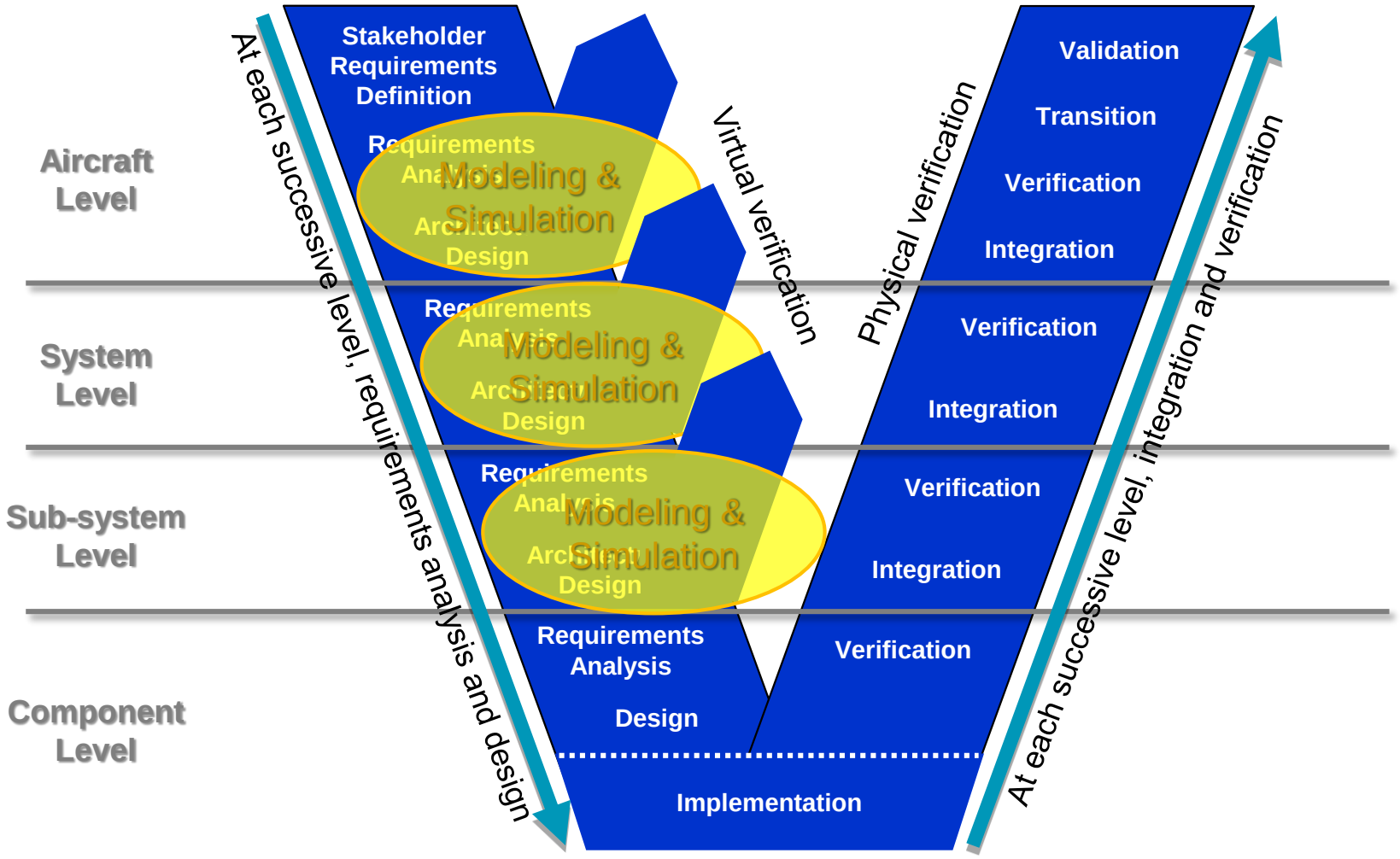
Modeling the structure, behavior and performance (including response to errors and malfunctions) of system elements individually and in integrated combinations to simulate, analyze and optimize functional allocation within the system architecture and to verify the resultant design functionality, performance, safety, failure propagation, testability and maintainability properties.



Source: Dimitri Mavris, Georgia Tech
http://www.asdl.gatech.edu/

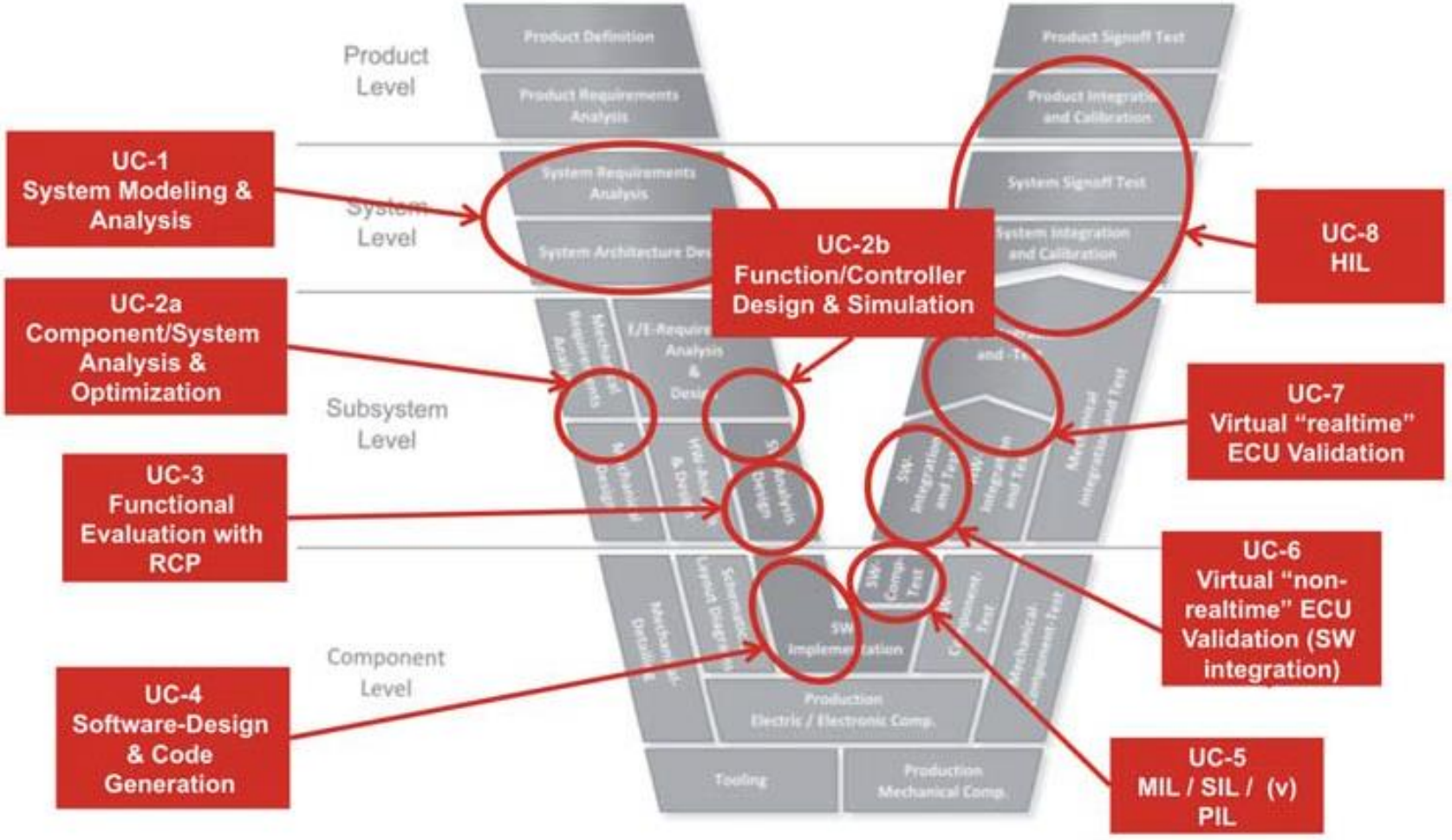
MBSE – MODELING & SIMULATION IN THE V-MODEL

APPLIED AT EACH LEVEL FOR DESIGN OPTIMIZATION AND VIRTUAL VERIFICATION



MBSE – MATURITY IN THE V-MODEL

VARIES SIGNIFICANTLY BY DOMAIN, WITH LITTLE THAT IS CROSS-DOMAIN



Modification of the V-model in *Smart Systems Engineering, Behavior Model Exchange Version 1.0*, ProSTEP iViP Recommendation, May 2014

MODELING DURING DEVELOPMENT

- Requirements and Functional Modeling
- Performance: System to Subsystem to Component
- Domains: Mechanical, Thermal, Fluid, Electrical, Control, Software
- Technologies: FEM, CFD, Optimization, CAD & Design
- PLM, including PDM, ALM, SDPM
- Physical testing, supported by simulation (computational DOE makes sure that maximum information is obtained from tests)

TRAINING SIMULATORS

- Very important aspect to protect and optimally use expensive assets: aircraft, tanks, ships
- Often standard part of delivery of asset
- Very often supporting HLA/DIS for multi-aircraft scenarios
- Mostly completely proprietary/ limited when added functionality is needed
- Standards not necessarily complete (no on-the-wire protocol for HLA)

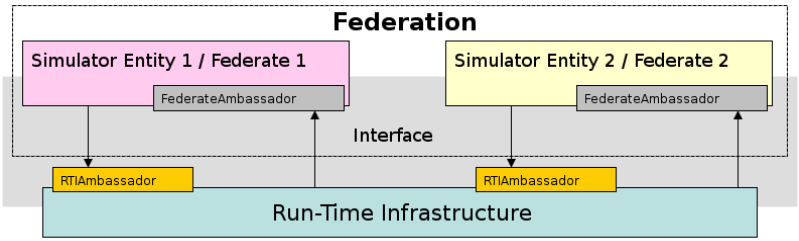
MODELING FOR CHANGES AFTER DEPLOYMENT

- Rapidly evolving software tools a challenge for long-lived assets: systems delivered in the 90's not "old" by hardware standards, but very old in terms of design tool use.
  - Standards, and open source tools seen as best guard against "bit-rot"
  - Combined with Virtualization of hardware & OS
- Performance & design models usually not part of deliverables to customer
- System level design simulation are not made persistent in PLM
- No versioning, no reuse of IP, no access for end user
- But: essential for efficient upgrades to weapons systems etc.
- If system updates use model-based design, new models are built

EXISTING STANDARDS: HLA/DIS/DDS

- DIS: Distributed Interactive Simulation (IEEE, since 80's)
- HLA: High-Level Architecture (IEEE, since 90's)
- DDS: Data Distribution Service (OMG standard, more generic 00's)

- HLA/DIS both developed for military simulation applications, DDS more generic
- HLA usually only works if all participants use RTI library from same vendor



Both HLA and DIS supported by most commercial aircraft simulators for distributed simulation with multiple aircraft

EXISTING STANDARDS: STEP / ISO 10303

- ISO 10303 (STEP) is a standard for the computer-interpretable representation and exchange of product manufacturing information
- **Mature**: started1984, 1st release 1994, second major release 2002, last major update end 2014 for industry-specific application protocols.
- **Broad**: Geometry to Systems Engineering
- **Incomplete**: Does not cover performance or simulation of any kind
- **Evolving**: STEP is broad and complex, existing AP's are superseded by new ones as experience grows
- **Example**: AP209 deals with interoperability for FEA analysis data and similar, by far not as mature/used as CAD geometry

EMERGING STANDARDS: OSLC

- OSLC- Open Services for Lifecycle Collaboration
  - Data interoperability between enterprise systems, based on web-standards- linked data & RESTful web services
- Need: Current PLM software has no interoperability with PLM software by other vendors
- Started in 2008
- Many specifications of different levels of readiness/maturity. Some are W3C recommendations, many are in draft status
- Today: Attempting to bridge ALM—PLM worlds, which come from different histories and fulfill different requirements.

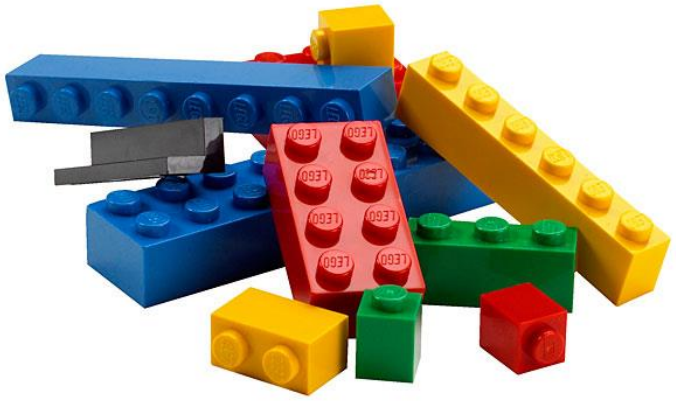
Complex systems/products will continue to be built by a wide array of PLM platforms/tools throughout the supply chain

EXISTING STANDARDS: MODELICA

NEW M&S TECHNOLOGIES AND DATA STANDARDS RAPIDLY EMERGING TO ENABLE MBSE

Modelica: A special purpose programming language for modeling cyber-physical systems. Modelica is:

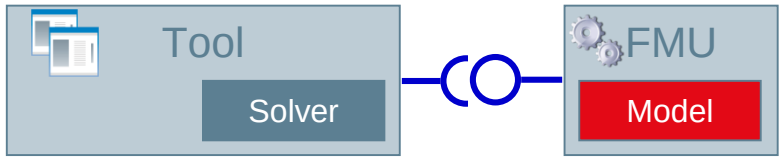
- A vendor-neutral standard
- Multi-domain
- Object oriented
- Equation based (acausal)
- Covers multiple formalisms
- With a consistent graphical and textual system representation



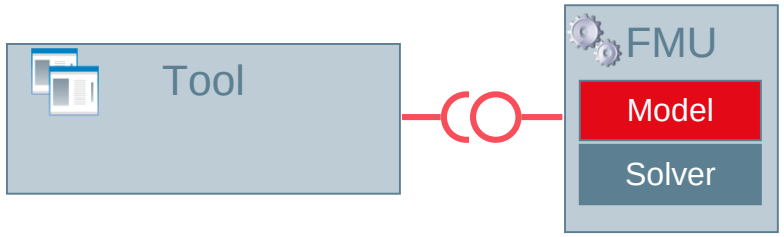
Modelica is like LEGO for Physical Systems Modeling

FMI: EXCHANGE OF EXECUTABLE MODELS

- The Functional Mock-up Interface (**FMI**) is a **tool independent standard** for
  - **Model Exchange (ME)**



  - **Co-Simulation (CS)**



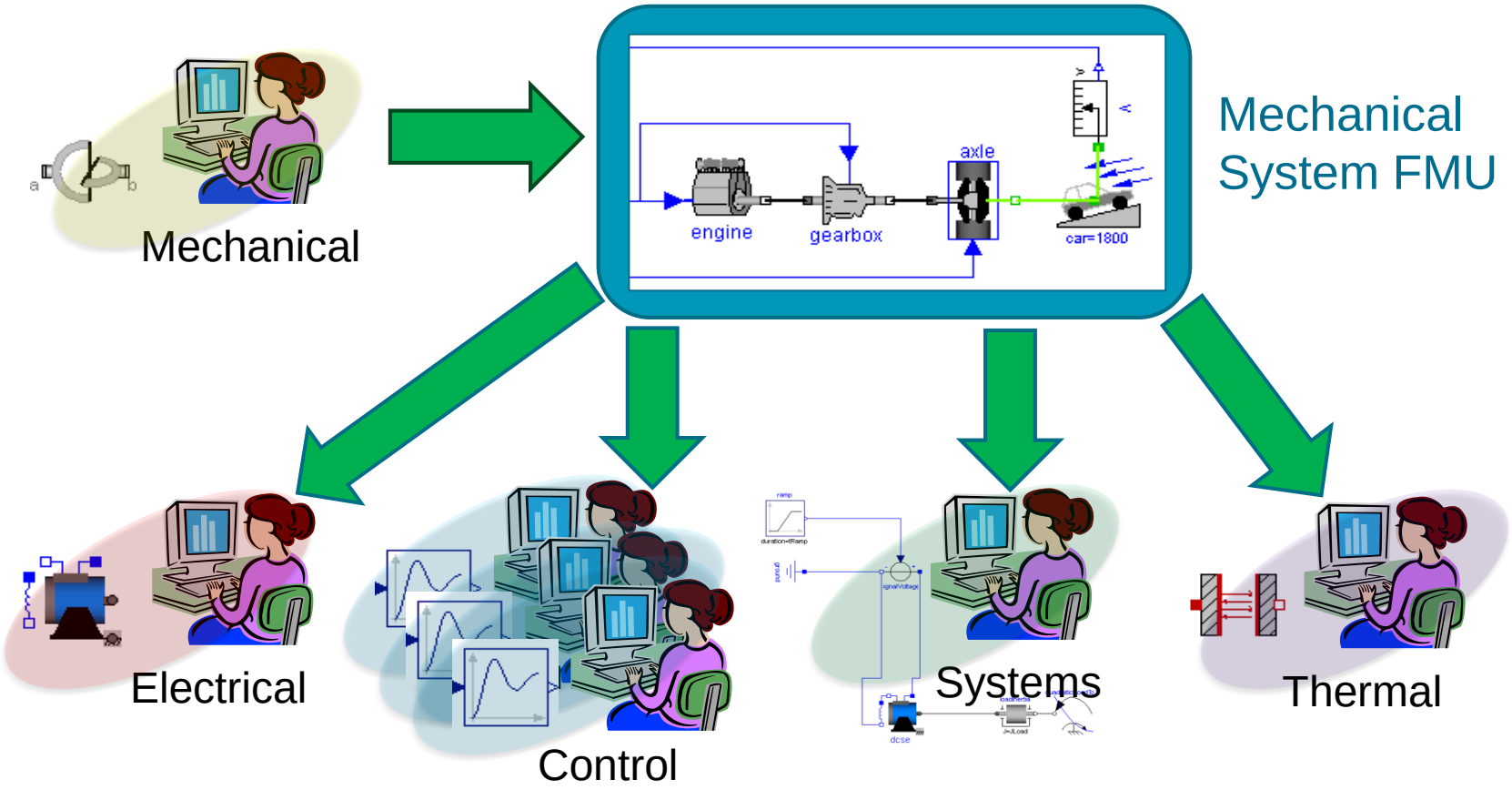
- The FMI defines an interface to be implemented by an executable called Functional Mock-up Unit (**FMU**)

FMU=Model w/ Standard Interface

Models "plug in" through a common interface definition

FMI: MODEL DEPLOYMENT

- FMU deployed (native tool) to support multiple applications



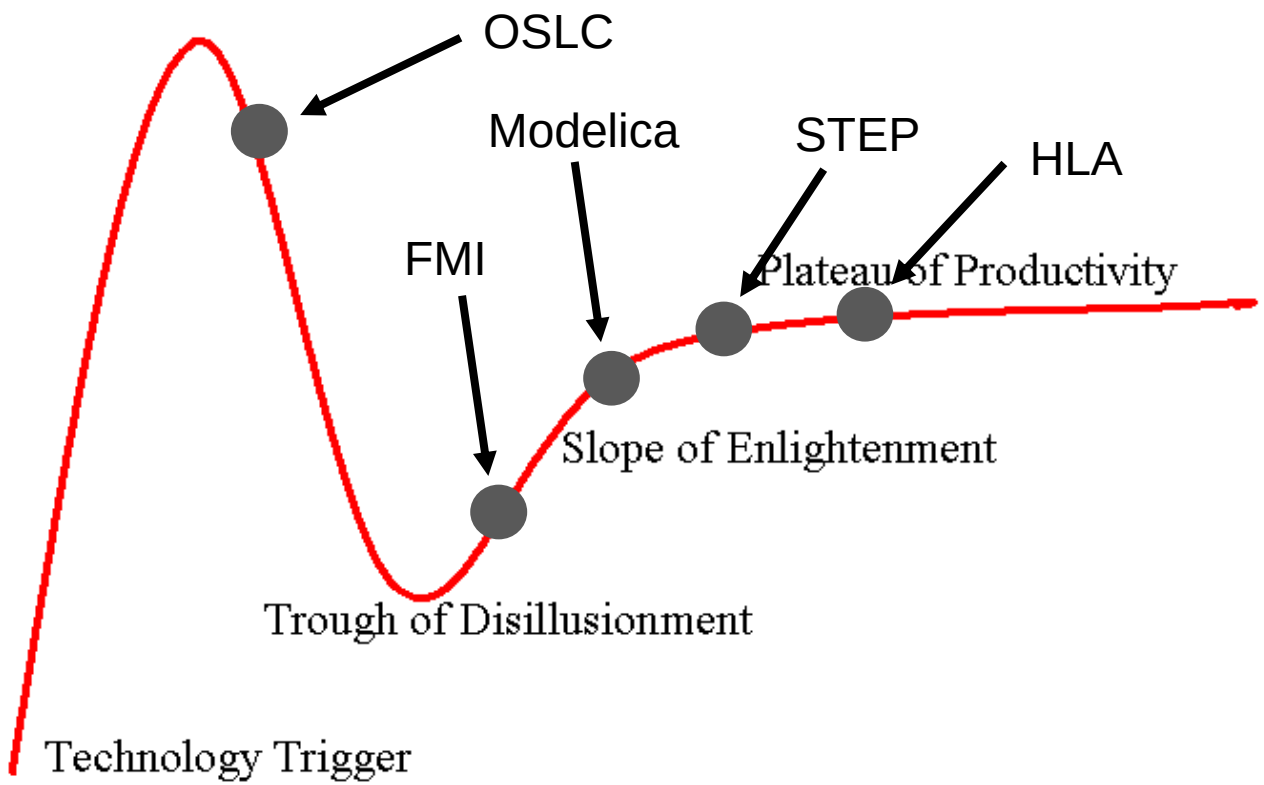
FMI: A BUSINESS MODEL INNOVATION

- FMI-compliant tools often allow liberally licensed export of models for distribution in the organisation and to partners
- Exported FMUs most often don't require a license from the model authoring tool
- Deployment from few simulation specialists to designers, domain specialists, control engineers
  - One FMU used by many engineers

    (control design)
  - One FMU run on many cores

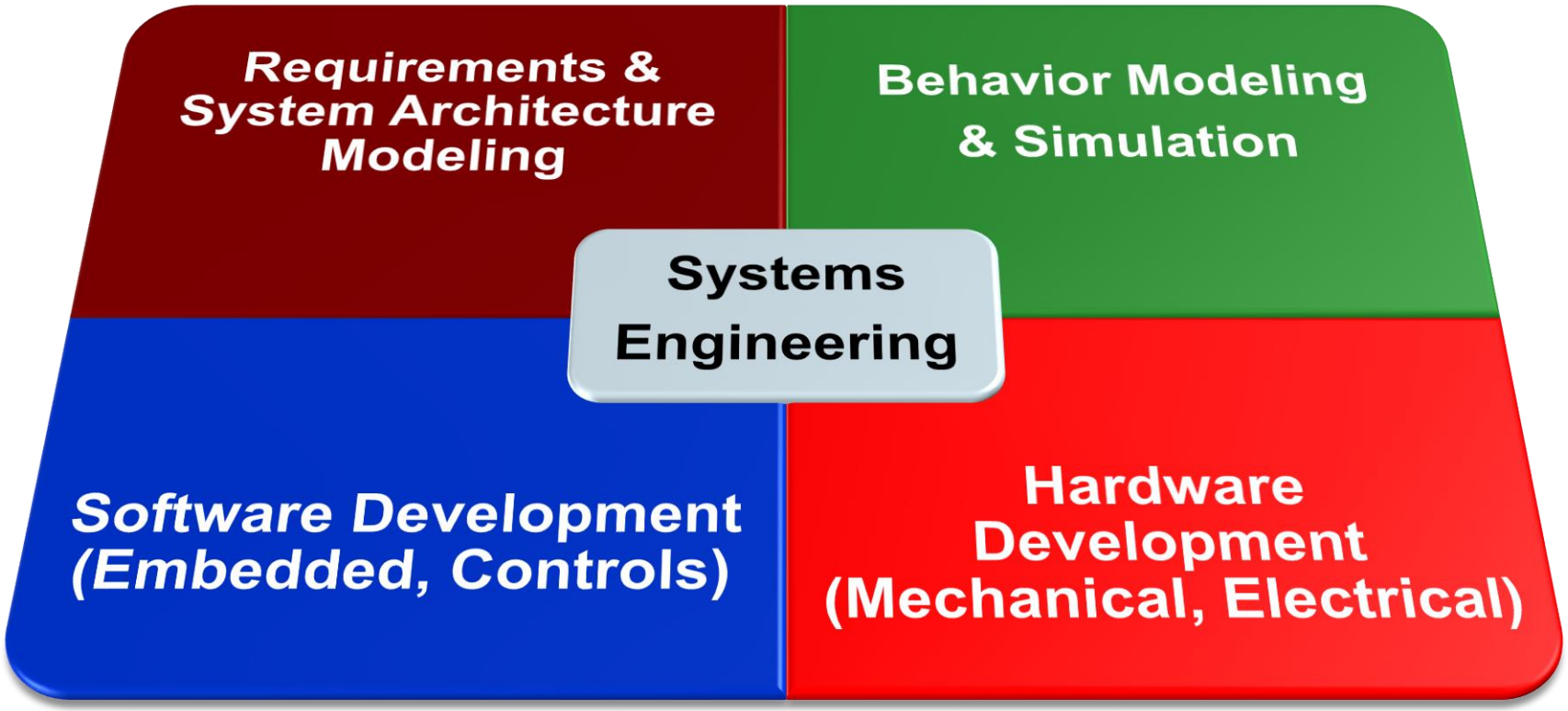
    (robust design)

THE HYPE CURVE REVISITED



MBSE – WHAT IS THE BUSINESS CHALLENGE?

DISCIPLINES ARE APPROACHING PRODUCT DESIGN FROM DIFFERENT PERSPECTIVES



All areas are supported by a number of overlapping solutions

MBSE – DATA AND PROCESS MANAGEMENT TOOLS

SORTING OUT THE ALPHABET SOUP – DEFINITIONS HELP, BUT . . .

PLM – "Product Lifecycle Management" is a strategic business approach that applies a consistent set of business solutions in support of the collaborative creation, management, dissemination, and use of product definition information across the extended enterprise, and spanning from product concept to end of life—integrating people, processes, business systems, and information.

PDM – "Product Data Management" solutions to capture, manage, disseminate, visualize and collaborate on product related intellectual (digital/virtual) information, including related processes.

Note: *Some vendors are attempting to redefine **PLM** as **PDM** and market other offerings as "beyond PLM".*

ALM – "Application Lifecycle Management" is the product lifecycle management (governance, development, and maintenance) of application software.

SDPM – "Simulation Data and Process Management" integrates and manages simulation and analysis data and processes across the product development processes.

MBSE – MAIN GAPS

***PDM, ALM** OPERATE IN DIFFERENT DOMAINS AND ARE NOT INTEGRATED*

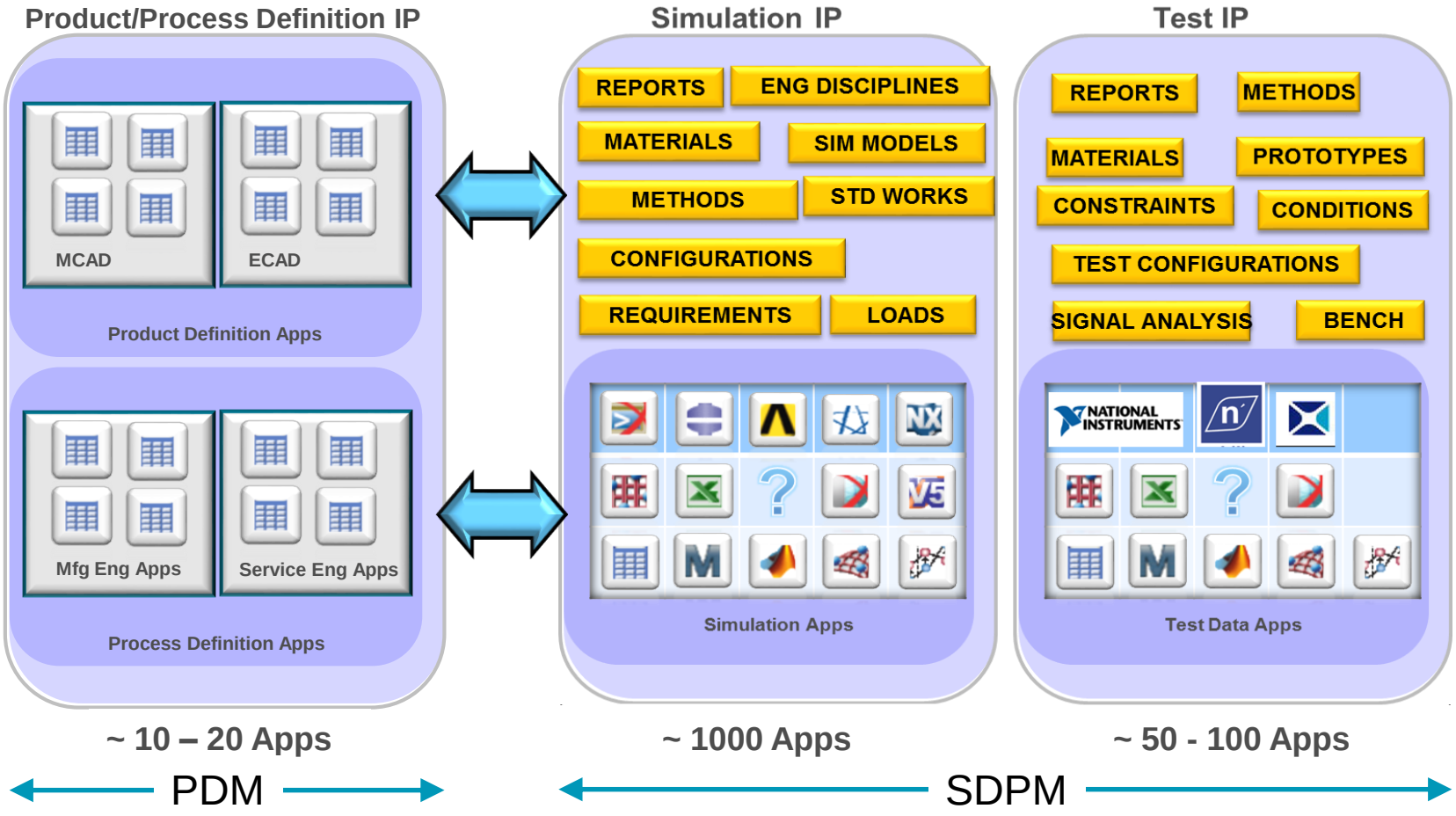
- Many different domain specific simulation tools live on isolated islands (e.g. thermal radiation & thermal signatures) not centrally managed, or connected to complete system
- Today, most simulation IP is not linked to and maintained with PDM/ALM data bases: the IP is lost for reuse!
- Embedded software and system simulation are not well integrated
- System level simulation data and processes not managed on same level as geometry and manufacturing data

Simulation Data and Process Management (SPDM) tools have emerged to fill these gaps

SDPM – VIRTUAL & PHYSICAL TEST DATA MANAGEMENT

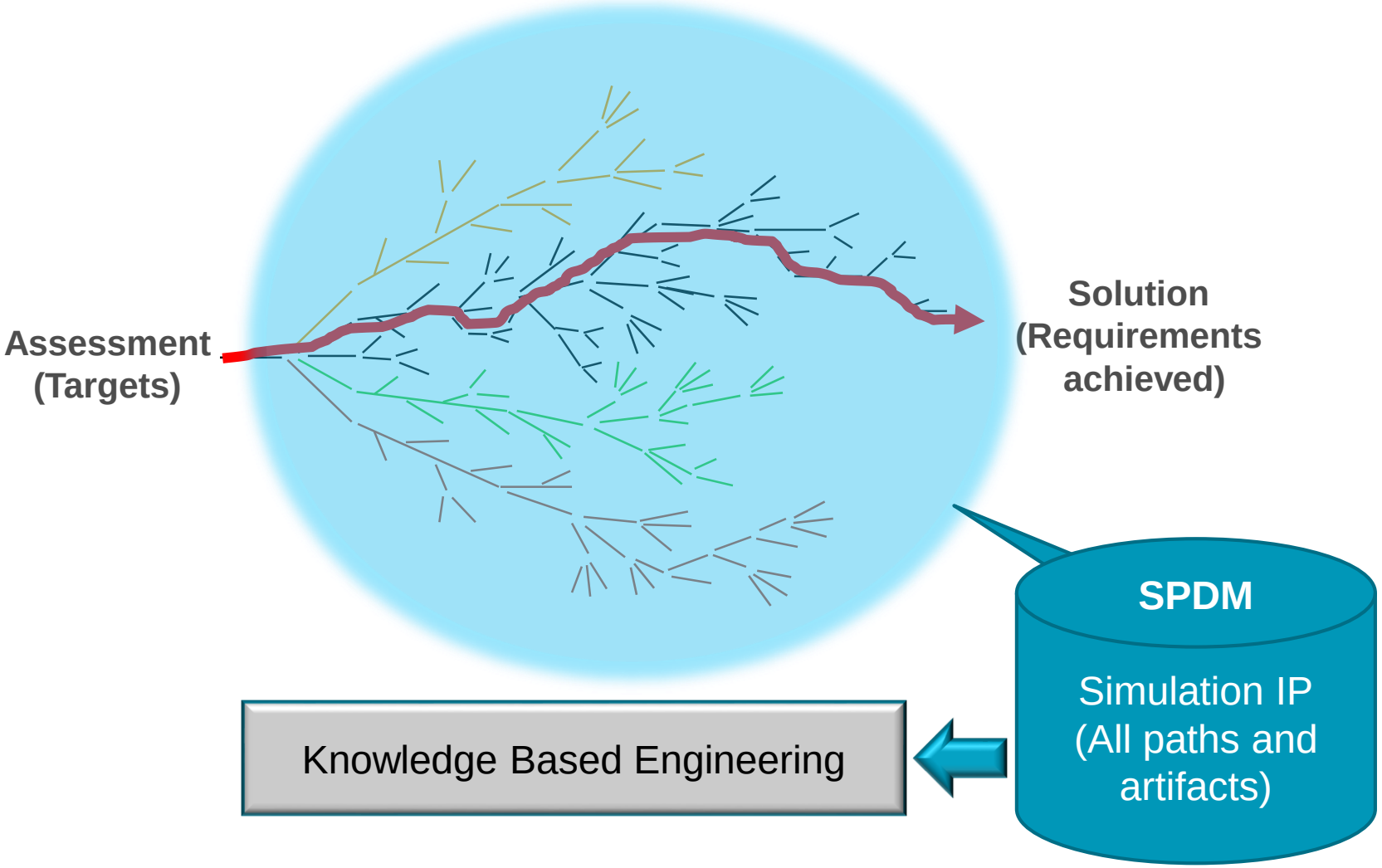
NEW M&S DATA STANDARDS AND TECHNOLOGIES ARE RAPIDLY EMERGING

Due to the sheer volume of simulation and test tools, standards and technologies such as FMI/FMU, OSLC, STEP AP2xx are the only viable approach to interoperability



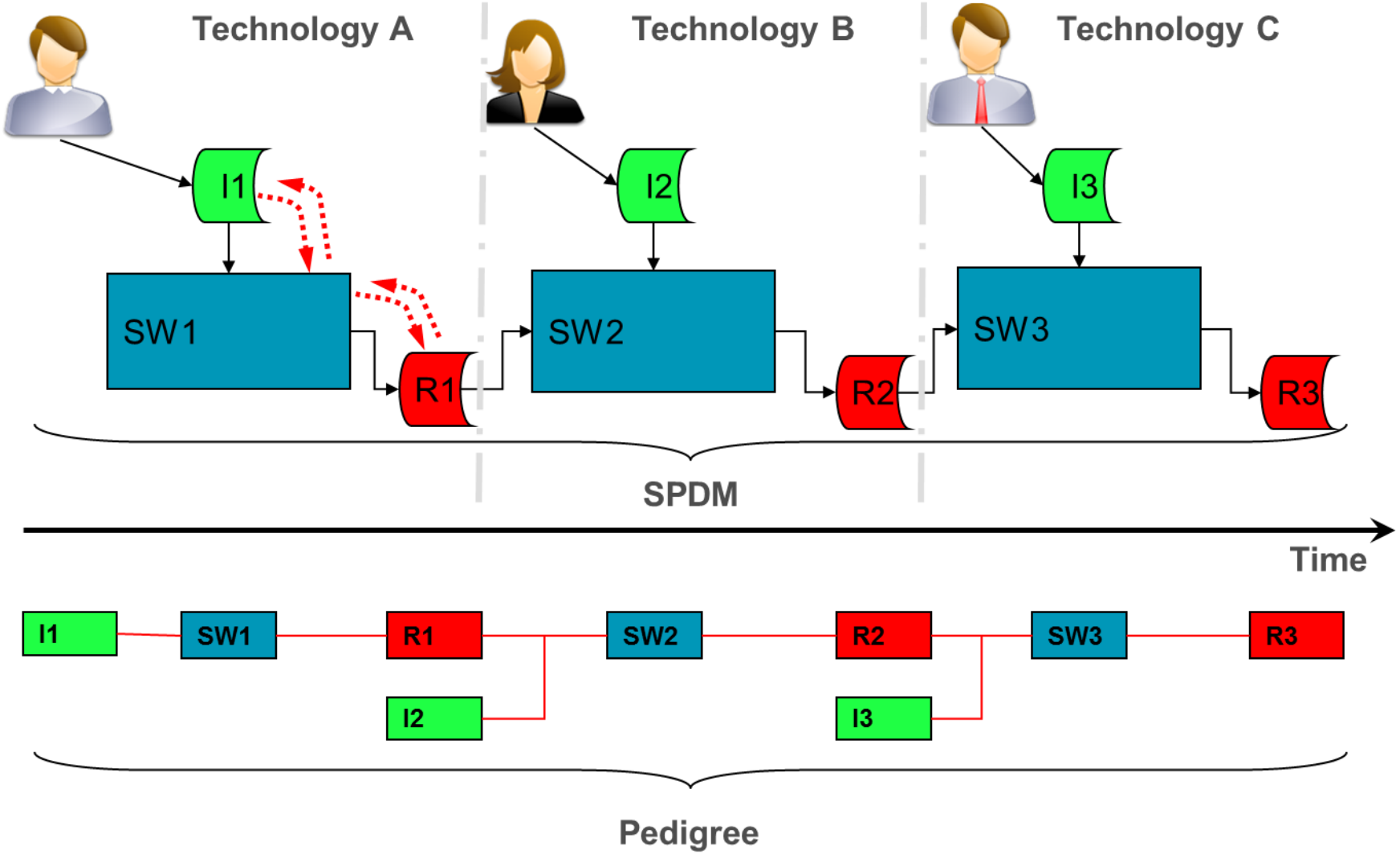
SPDM – MODELING & SIMULATION IP MANAGEMENT

ALL TRADE STUDY ALTERNATIVES RETAINED FOR REUSE



SPDM – VIRTUAL & PHYSICAL TEST PROCESS MANAGEMENT

PROCESS WORKFLOW AND OR AUTOMATION WITH TRACEABILITY OF ARTIFACTS



SUMMARY

- Enforce standards!
- Sins of the 1st and 2nd kind
  - 1st kind: The data is in an open format, accessible, but no API
  - 2nd kind; Proprietary data and no API
- All the data, access through different software with looser coupling is much better than partial data that is fully integrated
- PDM, ALM and SPDM will retain their individual strengths while expanding and competing at the edges – none will be subsumed by the others
- Industrial users must promote standards and vendor cooperation to achieve a comprehensive interoperable MBSE technology platform