Model-Based Systems Engineering (MBSE) – *An Introduction*

How We Explain MBSE without using the Traditional "V Model"

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SMS_ThinkTank™ LLC: Edward A. Ladzinski

Edward A. Ladzinski

- SMS_ThinkTank™: CEO, Co-Founder
- Began career as a Manufacturing Engineer, NC Programmer and Tool Designer with Burroughs Corp. (now Unisys Corp.).
- Joined IBM in the Kingston, NY laboratory as a Research & Development Engineer. During his 32 year career with IBM, Mr. Ladzinski worked in many different positions within engineering including systems research, systems product design/development and analysis/simulation.
- Immediately upon retirement Mr. Ladzinski joined Dassault Systems. While at Dassault Systemes he served as the Systems Engineering leader for the Americas. In 2014, he left Dassault Systemes and formed his own company dedicated solely to systems engineering.
- Serves on the NAFEMS Americas Steering Committee
- Co-founder of the Stochastics Working Group, Simulation Data Management working group and the joint INCOSE/NAFEMS Systems Modeling and Simulation working group.
- Award COE Fellow in 2013
- Chairman of the Analysis & Simulation and Systems Engineering tracks at COE
- Awarded the COE Fellow distinction in 2013.
- Winner of the best conference paper with presentations on Systems Engineering and Collaboration in both 2012 and 2016.
- Elected to the COE Board of Directors in 2016.
- Engineering graduate of RIT (Rochester Institute of Technology) and performed graduate work in Engineering and Business at RIT and UNCC (University of North Carolina Charlotte), respectively.

Introduction of Complexity
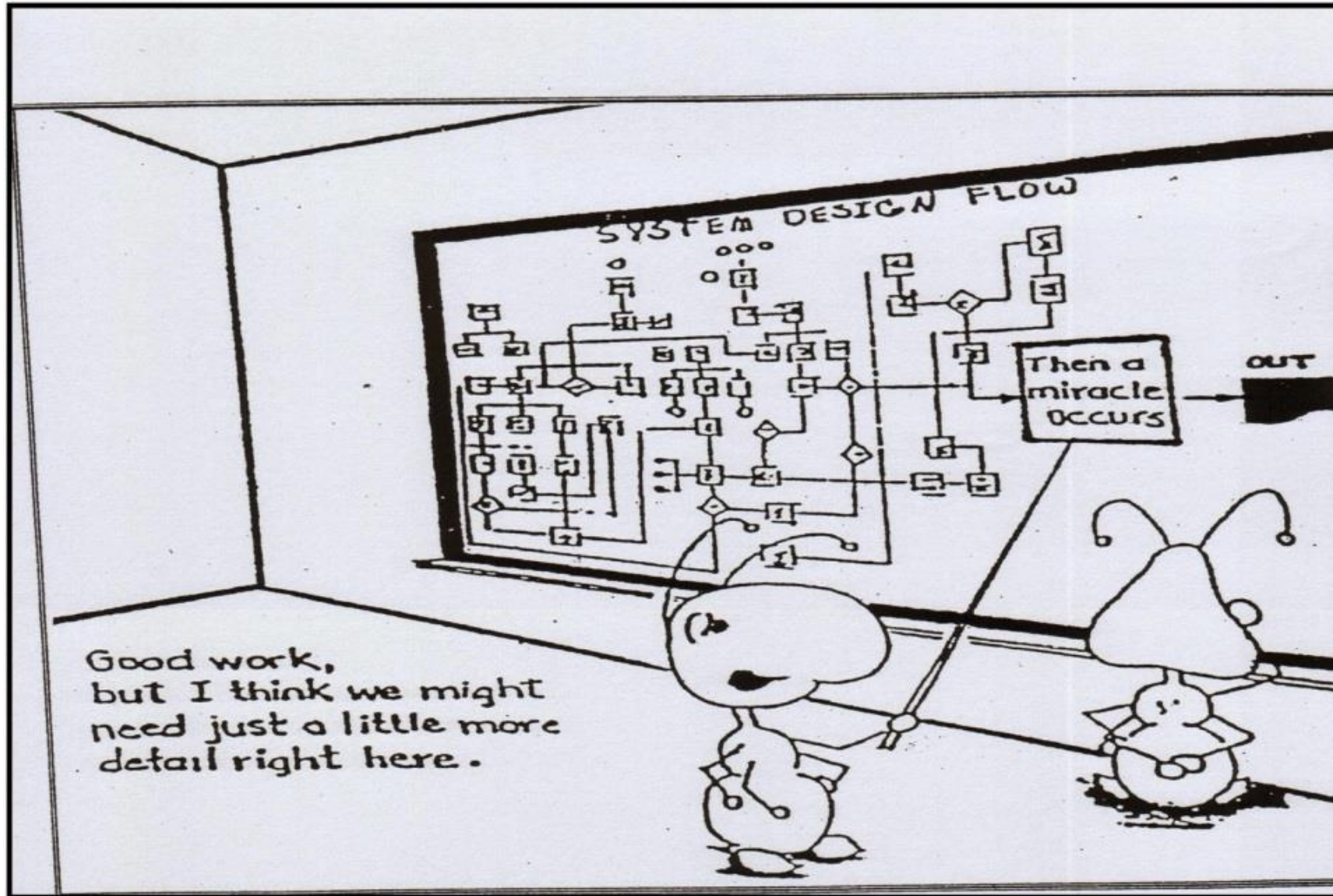
# Complexity = Risk, Digitalization = Opportunity
Business Success now requires a Systems and Model-Based Engineering approach

➢ Cyber-physical systems- Electronics & software growing

➢ New mfg processes & materials—lighter, stronger, green

➢ Increased regulatory requirements across all industries

➢ Consumers demand "mass customized" products... Now!

➢ Shorter lifecycles = continuous product innovation

➢ Yet extremely long systems lifecycles in select industries

➢ "Industrial IoT" environment = constant market feedback

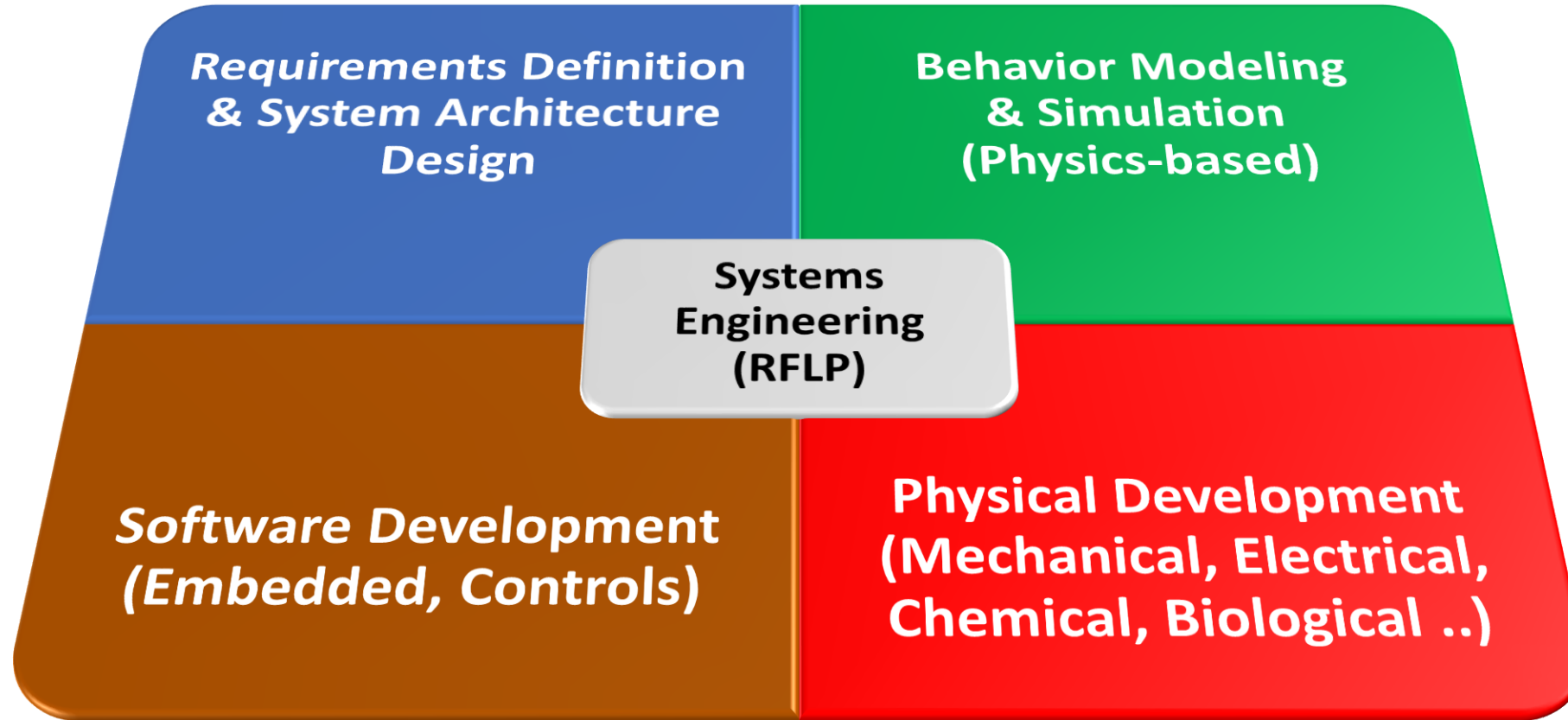*Complex market requirements demand more upfront cross-domain engineering*

Engineering Progression
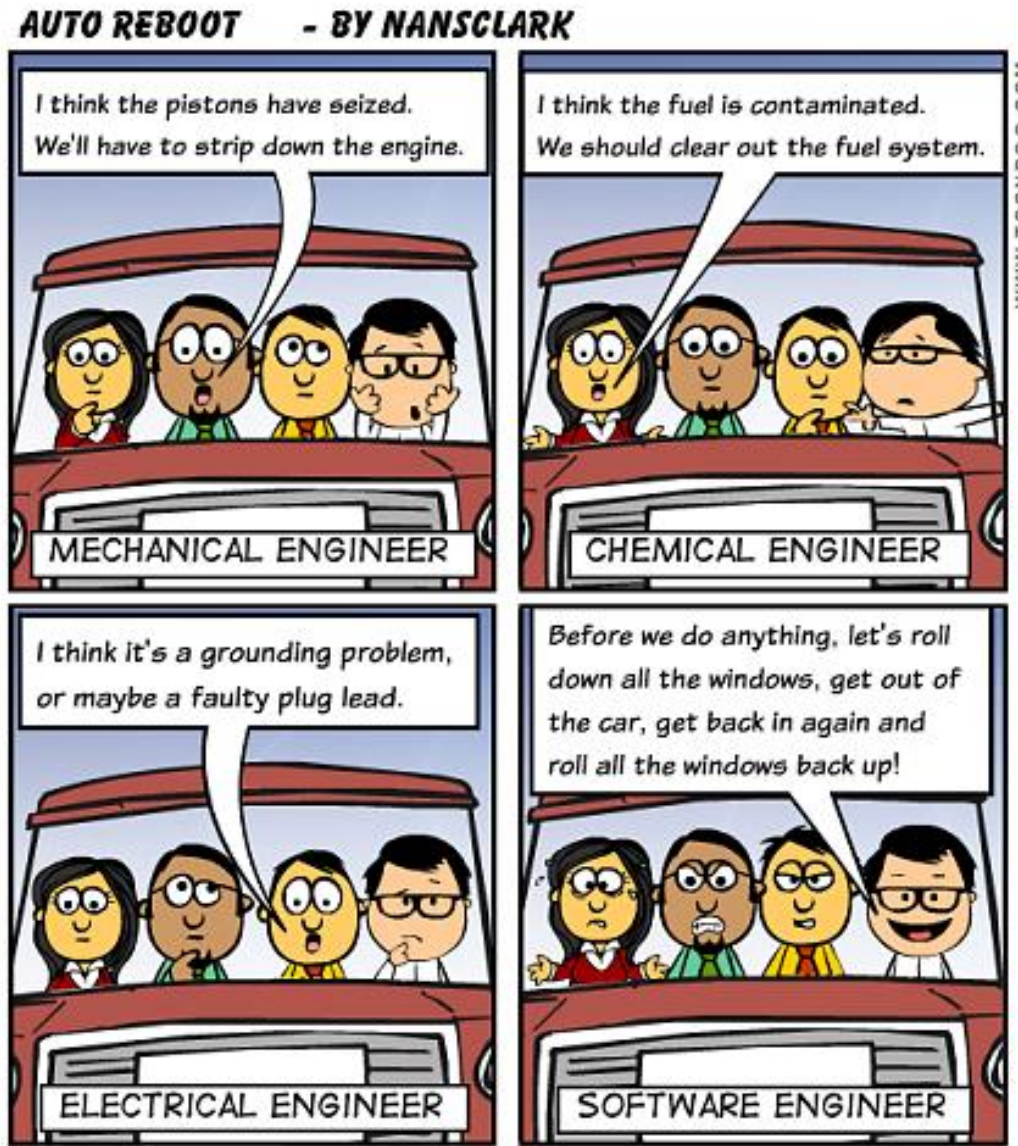
Model-Based – What are the Business Challenges?

Disciplines are approaching digital design & development from different perspectives

Requirements Definition & System Architecture Design

Behavior Modeling & Simulation (Physics-based)

Systems Engineering (RFLP)

Software Development (Embedded, Controls)

Physical Development (Mechanical, Electrical, Chemical, Biological ..)

All areas are supported by a number of overlapping solutions

* Source: CIMdata, 2017

"Sewing the Digital Thread"

The Digital Thread Defined (proposed)*

➢ The ***digital thread*** refers to the communication framework that allows a connected data flow and integrated view of the asset's data throughout its lifecycle across traditionally siloed functional perspectives. The digital thread concept raises the bar for delivering "the right information to the right place at the right time." *
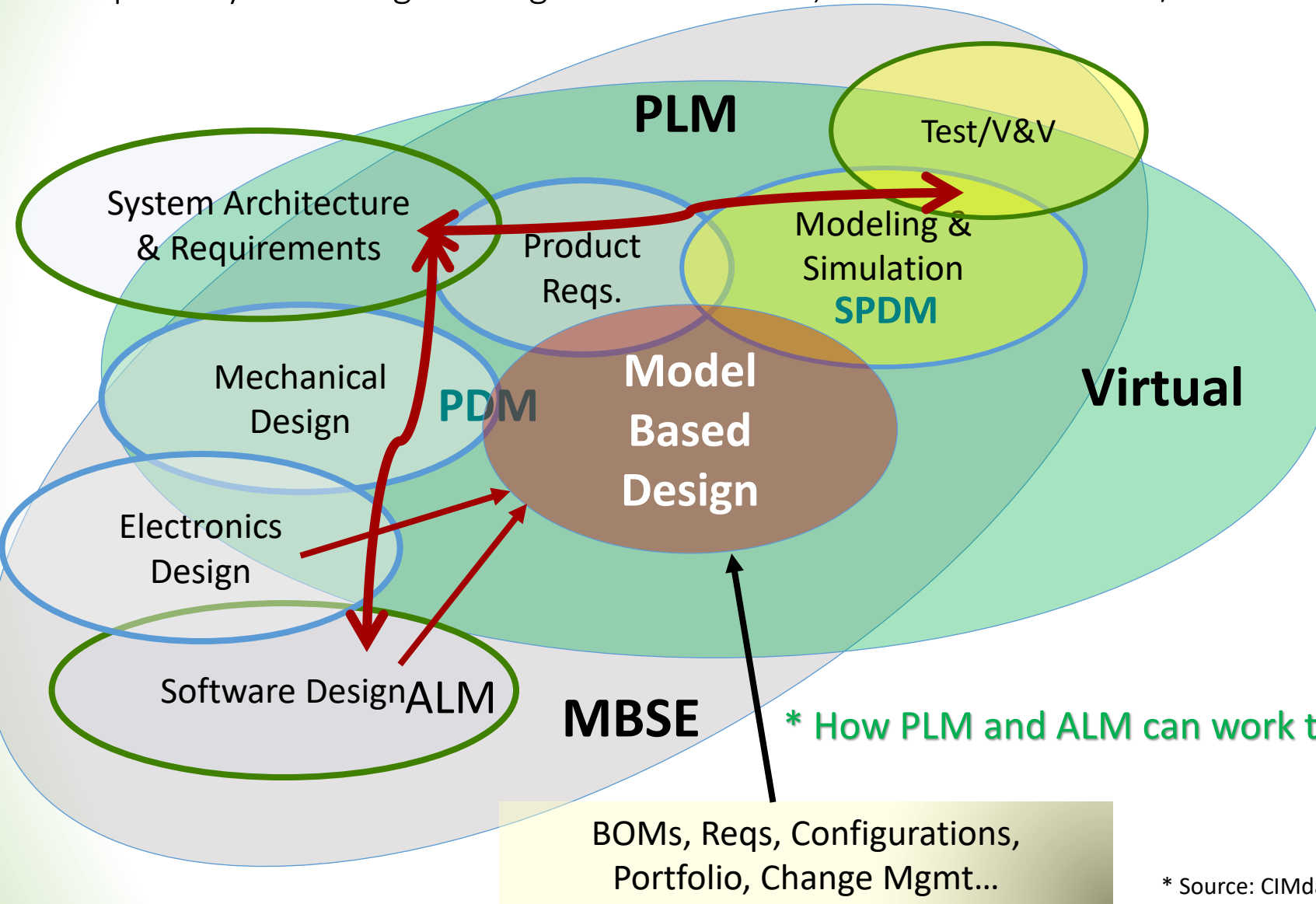
Digital Thread Concept: Main Goals *
Make *INFORMED DECISIONS* throughout acquisition
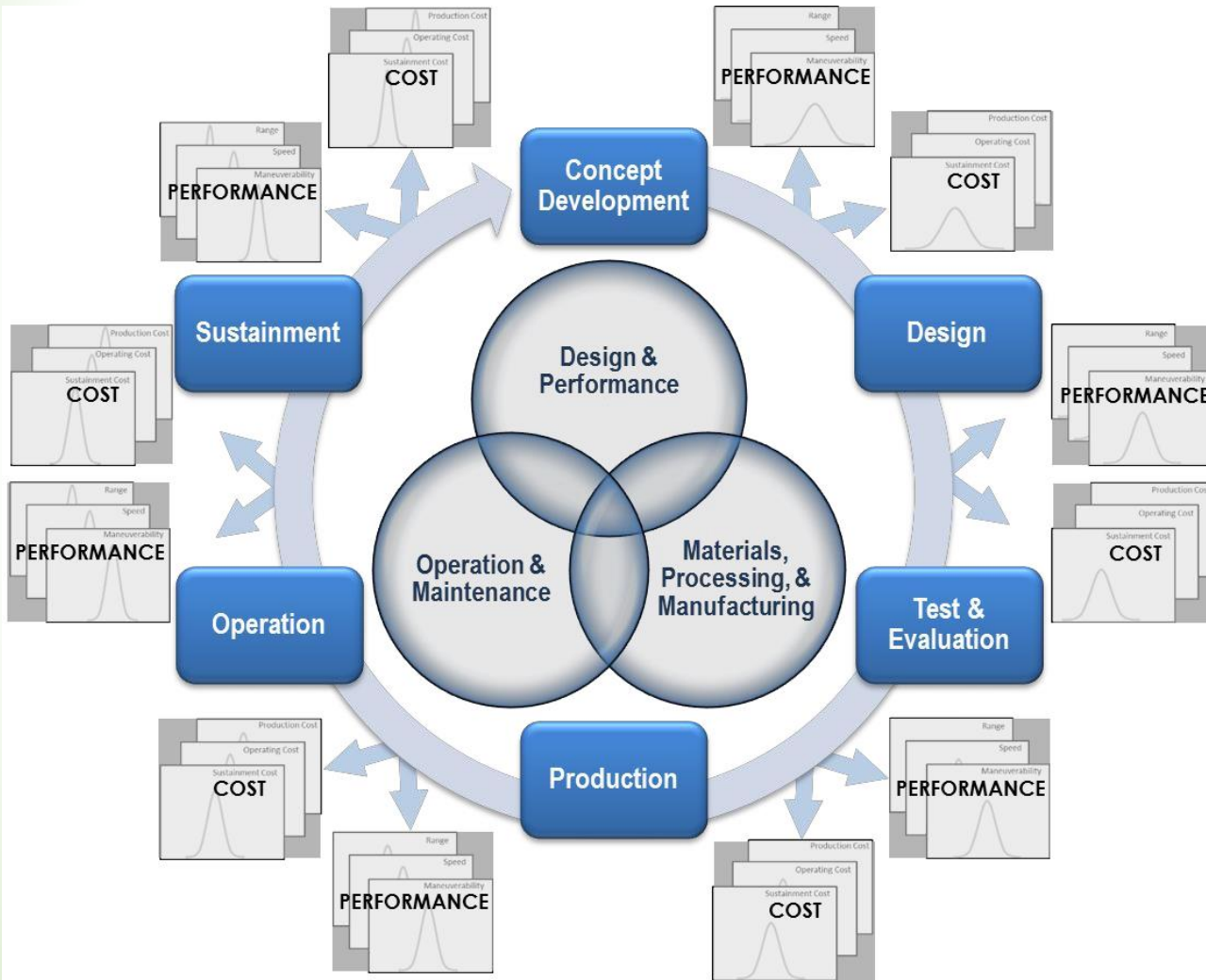
➢ Use ALL AVAILABLE INFORMATION in analyses

➢ Use PHYSICS to inform analyses

➢ Use PROBABILISTIC METHODS to quantify program risks

➢ CLOSE THE LOOP from the beginning to the end and back to the beginning of the acquisition lifecycle

* Source: "Digital Thread – USA Airforce Research Lab", AF/ST TR 13-01, 21 June 2013

Sewing the MBSE Digital Thread ("To Be")

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

PLM

Test/V&V

System Architecture & Requirements

Product Reqs.

Modeling & Simulation
SPDM

Mechanical Design

PDM

Model Based Design

Virtual

Electronics Design

Software Design ALM

MBSE

BOMs, Reqs, Configurations, Portfolio, Change Mgmt…

* How PLM and ALM can work together

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

* Source: CIMdata, 2017

MBSE Motivation

MBSE relies on a shared system model with remaining discipline-specific models providing their characteristic information in a mathematically rigorous format.

All disciplines "view" a consistent system model rather than through static documents. It may include structural, behavioral, physics and other simulation-based studies.
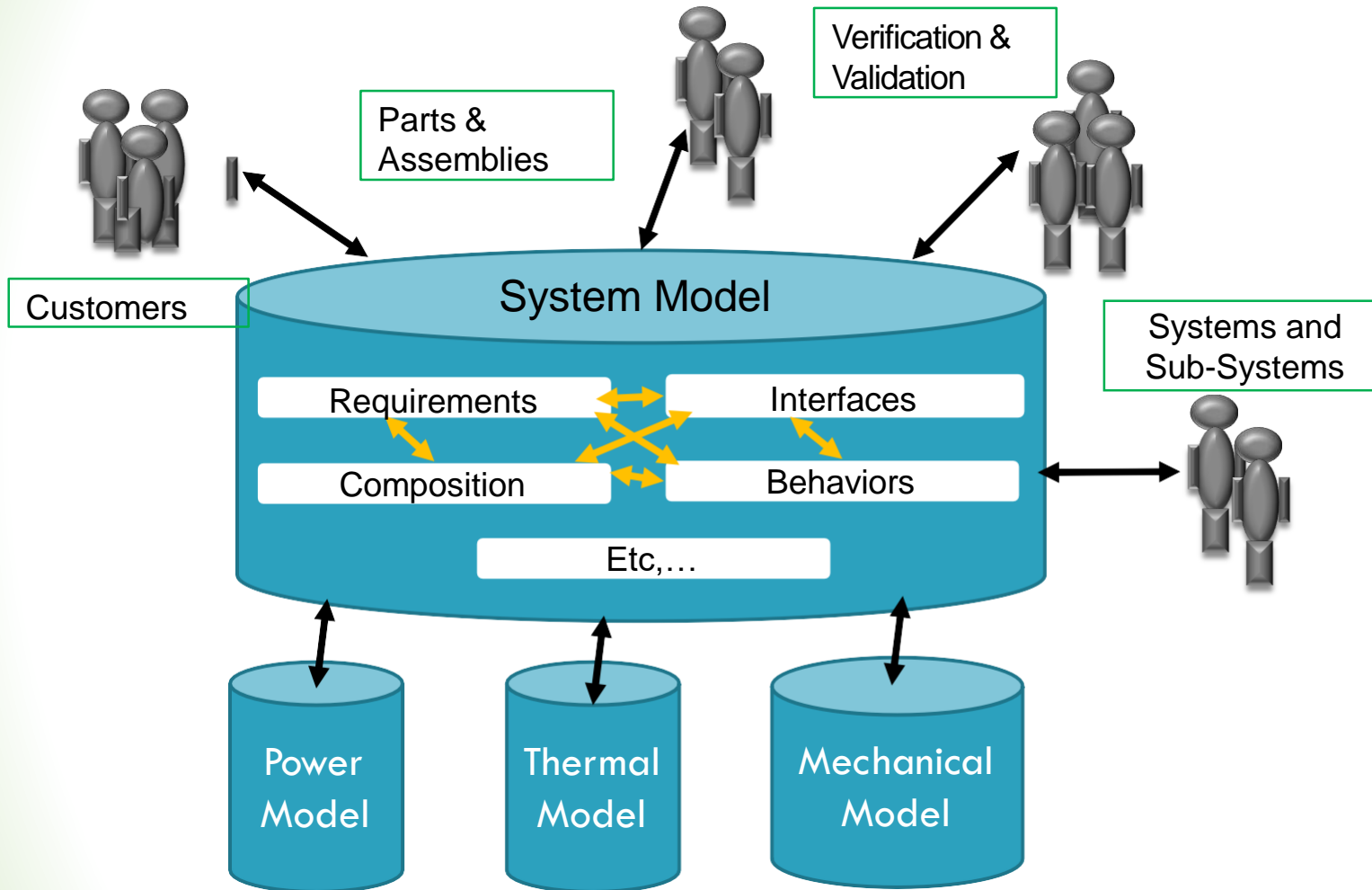
MBSE Terminology and Definitions*

➢ **Agree** on a Common Set of Definitions

➢ Members of the **Terms and Definitions Focus Team**, who are part of the **Systems Modeling & Simulation Working Group (SMSWG)** have compiled and created a common set of shared terms and definitions to serve the model-based systems engineering community

Traditional SE Practice
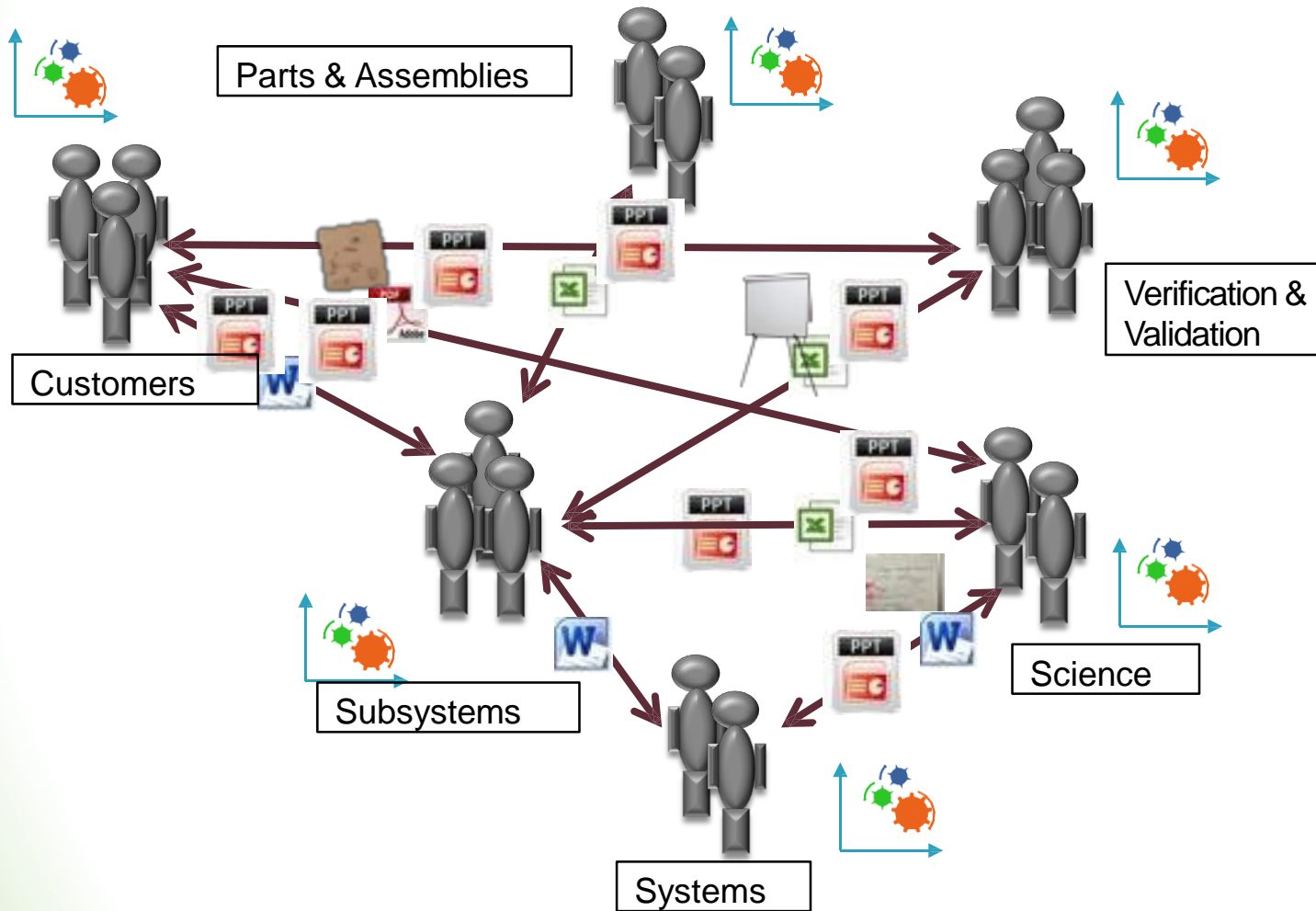
- ➤ **Stand alone** domain models/designs

- ➤ Institutional life cycle **documents**

- ➤ **Informal communications**
  - ➤ White boards
  - ➤ Design Team Meeting Presentations
  - ➤ Email
  - ➤ Chat
  - ➤ Napkin

Potential "To Be" MBSE Practice

Verification & Validation

Parts & Assemblies

Customers

System Model

Systems and Sub-Systems

| Requirements | Interfaces |
| Composition | Behaviors |

Etc,…

Power Model

Thermal Model

Mechanical Model

➢ **Integrated system model** with multiple views, connected to discipline models

➢ **Authoritative source** of information

➢ Information and exchanges accessible to **all members** of the project through the model information

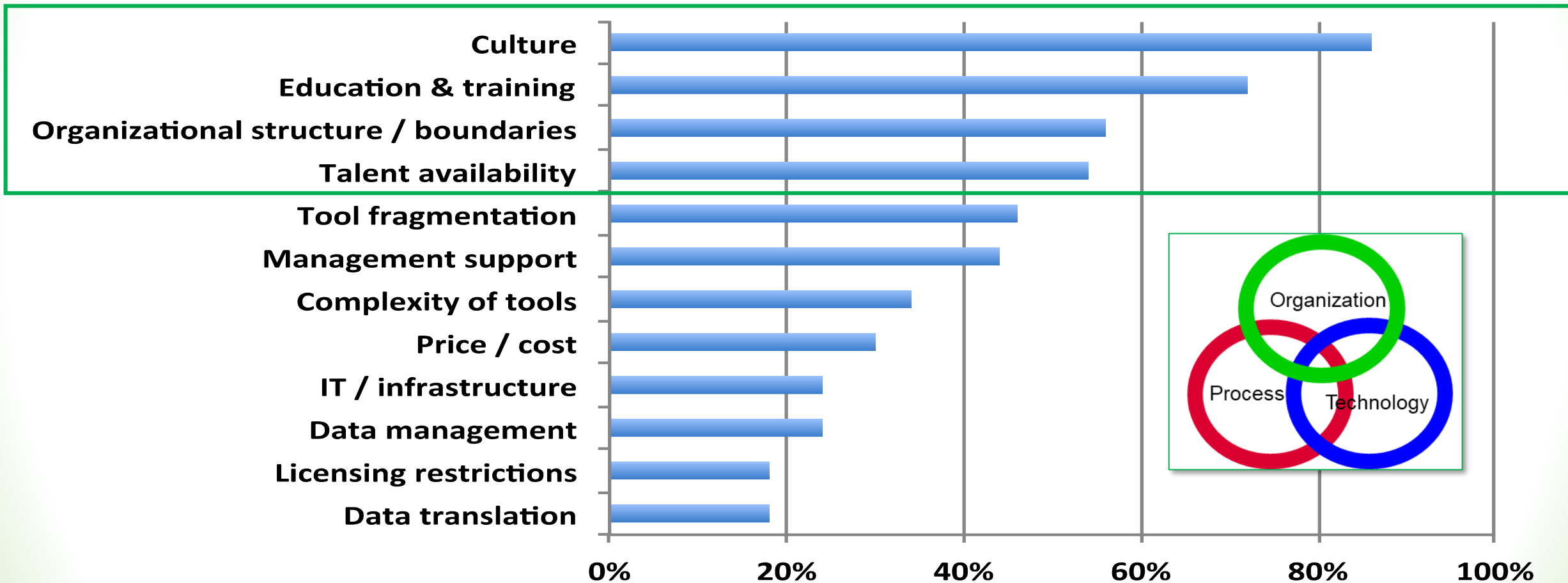# The Hype of MBSE* - *Where are you with MBSE?*
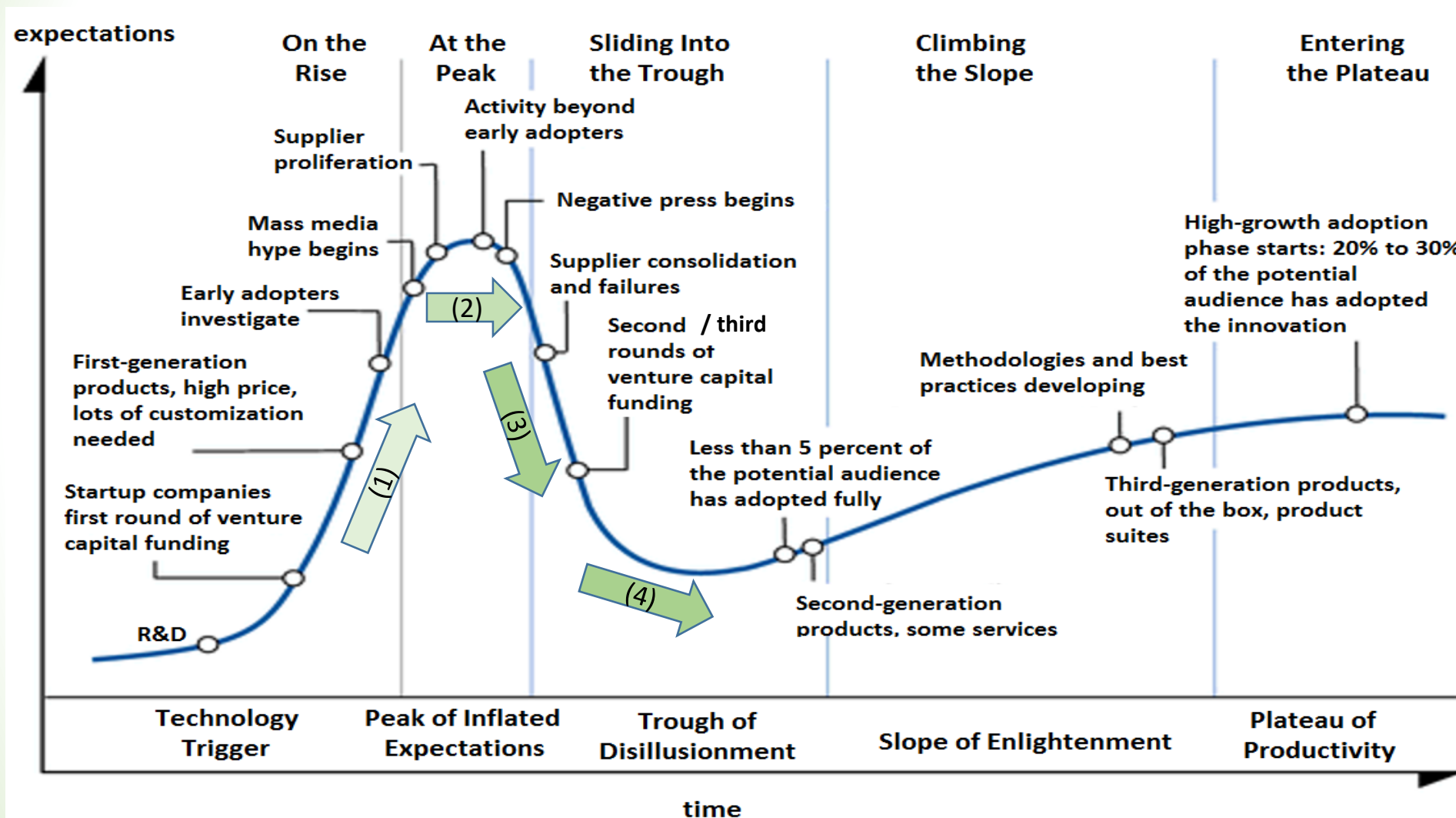
1. Late Adopters
2. Trying to sort things out
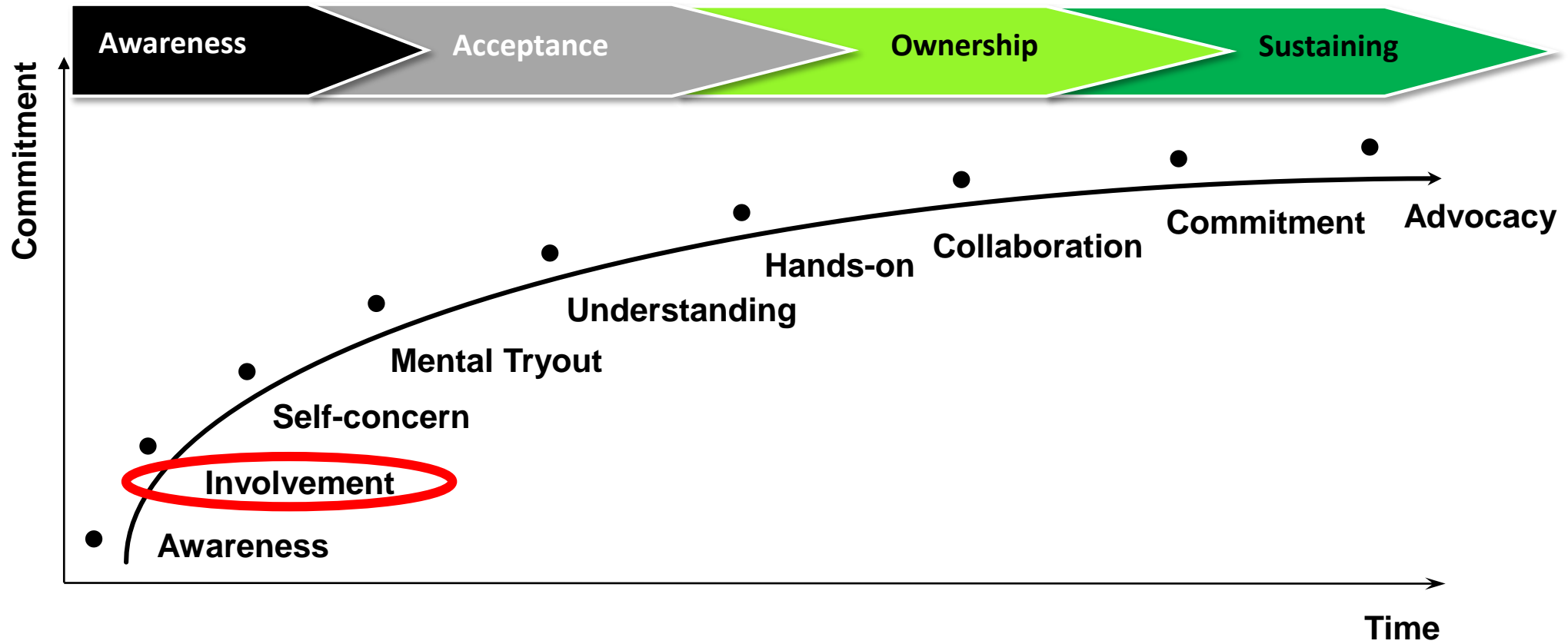3. Establishing roadmap
4. Leaders

Barriers to Industry Implementation

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

➢ It is about people & processes as well – not just technology

Cultural Change: Gain Acceptance to Advocate *

Awareness | Acceptance | Ownership | Sustaining

Commitment (y-axis) vs Time (x-axis)

- Awareness
- Involvement
- Self-concern
- Mental Tryout
- Understanding
- Hands-on
- Collaboration
- Commitment
- Advocacy

11/11/2019   17

Challenge: Tool Integration, Data Interoperability

➤ If you pursued MBSE today, 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*

11% 13%

22%

39%

14%

n=314

■ We have so many existing models, it would be impossible to tie them together across so many different modeling environments, so we need to do it clean sheet

■ The functionality available in clean sheet software would be really productive

■ Our use case for MBSE is very specific, I don't think it would be capture in off the shelf tools, so we'll be better off plugging our existing models together

■ We have so many existing models, the effort required to rebuild them in a clean sheet approach would be untenable

■ Other

(c) MIT 2017.

MIT MBSE On-line Course Survey of 300+ Engineers

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

Whose Driving Who?

Any customer can have a car painted any color that he wants, so long as it is black.
--Henry Ford
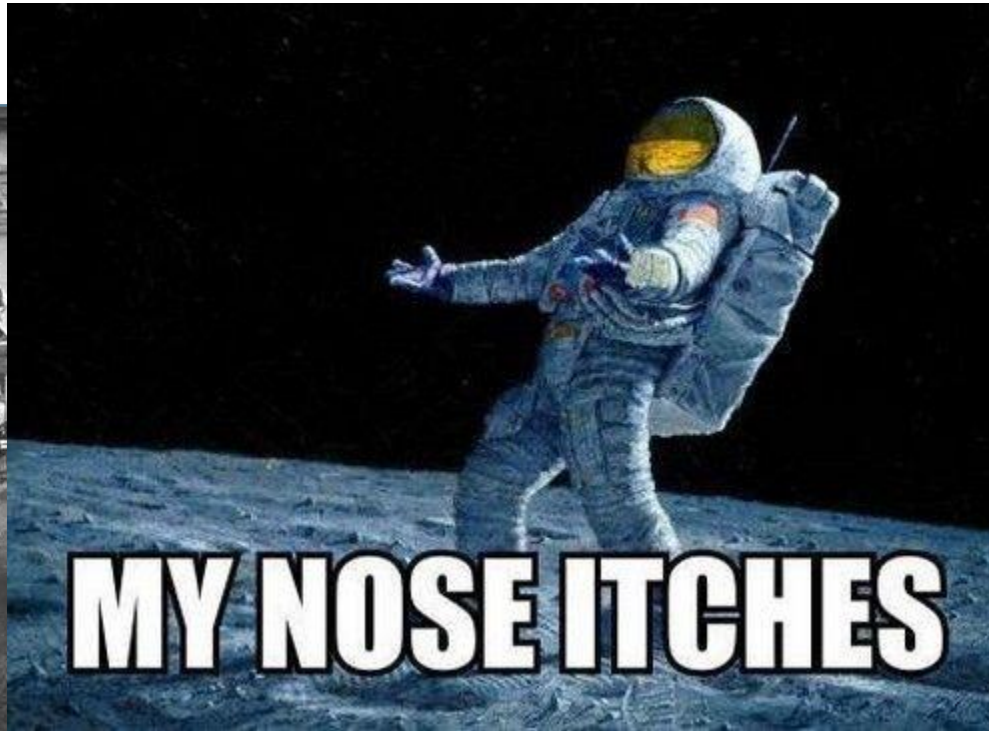
Whose done this before?
--Skeptical users

You need bigger and better tools.
--Said by many sales professionals

Enabling the Digital Thread Vision for MBSE
What is needed to address the industry's business needs?

MBSE solutions will ultimately require a blend of:
- ➢ *Process change* leveraging MBSE best practices across industry leaders
  - ➢ This element of success is vastly underrated and may be most important of all

- ➢ *Common ontology, semantics & languages* for systems architecture design
  - ➢ *AP 2xx Unified Architecture, UML/SysML, UPDM/UAF, AADL, OWL, ST4SE, others?*

- ➢ *Innovation platforms & software tools* for PLM/MBSE integration
  - ➢ Across engineering domains- mechanical, electrical, software, etc.
  - ➢ Across the product lifecycle- Requirements, System architecture design, detailed 3D design and validation, manufacturing, IoT/in-service operations
  - ➢ Across the global enterprise including OEM/Design Chain collaboration

- ➢ *Model management* across the engineering domain data silos
  - ➢ Key business metrics- Requirements Traceability, Change Management, Configuration Management, Long-term Archiving and Retrieval (LOTAR)

- ➢ *Robust standards* for PLM/MBSE data interoperability
  - ➢ XML/XMI, OSLC/RDF, ReqIF, FMI/FMU, FMI/SSP, MoSSEC (AP 234), etc.

In Parting...

➢ MBSE combines traditional SE methods and best practices with digital tools and modeling languages that support rigorous modeling techniques and integration of the various systems engineering disciplines (structural, electrical, mechanical, software, etc.) and associated stakeholders through:

> ➢ the availability of a **formal modeling languages** which can describe systems

> ➢ **engineering standards and tools** which enable **integration** of a system model with existing discipline models.

➢ Get **education**

➢ Each industry and company would be better served by determining what MBSE **means to them** rather that adhere to what vendors are **telling them to adopt**

➢ Identify management **sponsor(s)**

➢ Textual requirements will not be "riding into the sunset" anytime soon since they represent critical data for verification, regulatory, communication/collaboration with other government and non-government entities, etc.

➢ A central **governance organization** within each enterprise is necessary to maintain their sanity when embracing this complex and cultural development (not change)

➢ MBSE is a complex initiative. Don't expect an **overnight** adoption. MBSE demands taking incremental small steps for the proper development of best practices

➢ Seriously consider assessing your current "As-Is" and "To-Be" Systems Engineering **readiness** before embarking upon this journey

➢ Focus on **standards**, the tools will follow

➢ Be prepared to **lead** your solution providers based upon where you want to be

References

- **Model-based Systems Engineering MBSE 101,** Moderated by Elyse Fosse, Jet Propulsion Laboratory, California Institute of Technology: INCOSE IW January 30, 2016

- 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

INCOSE IW January 30th, 2016 *Fosse