



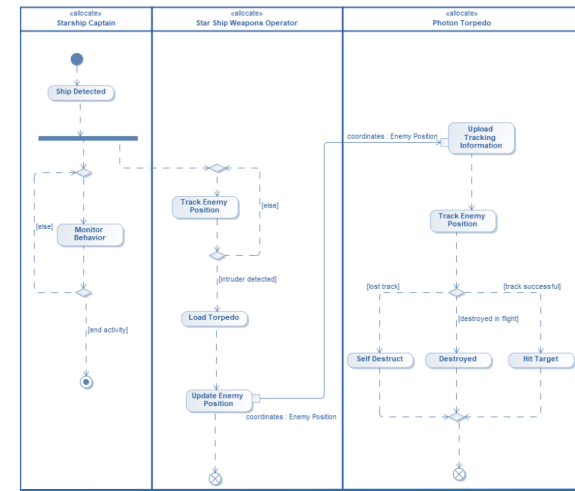
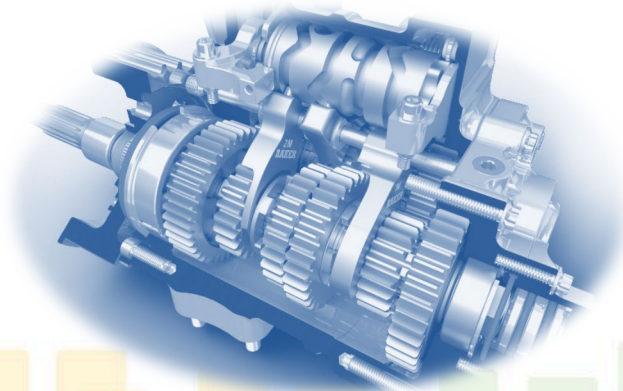
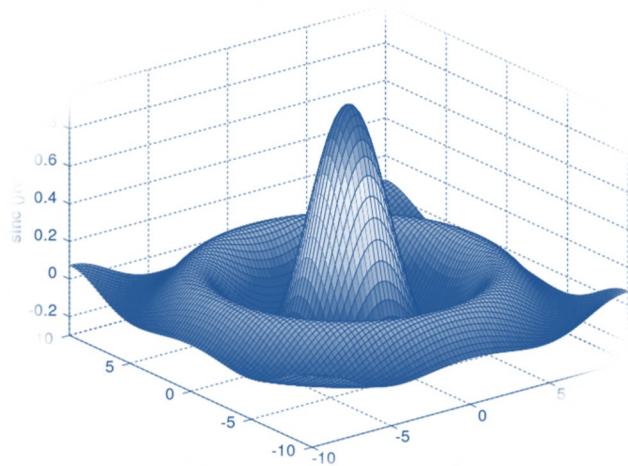
# Into the Great Digital Unknown

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The Evolving Landscape of MBSE and Digital Engineering

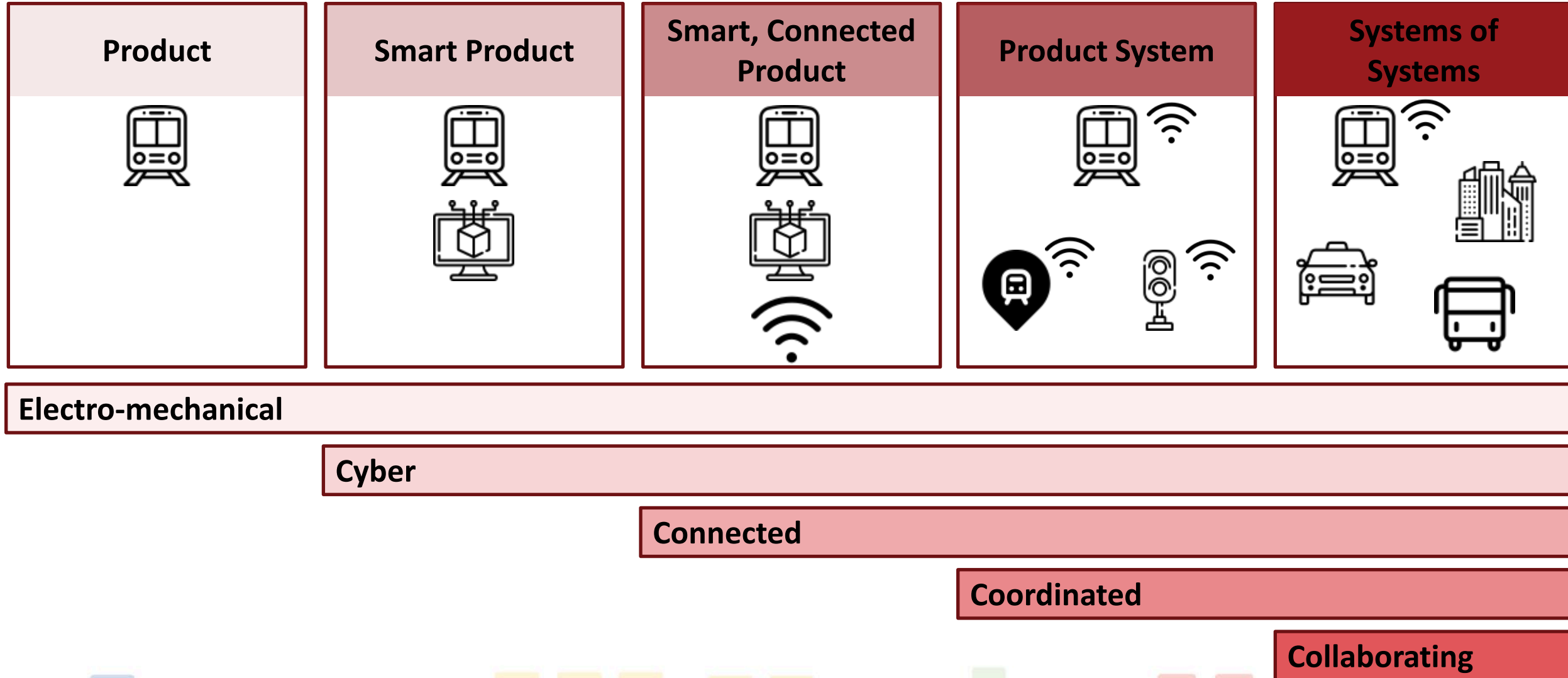


# What Do You Envision?



# Appreciating a Changing Context

## *From Static Products to Intelligent Systems of Systems*



# Exceeding the Capabilities of Traditional Engineering

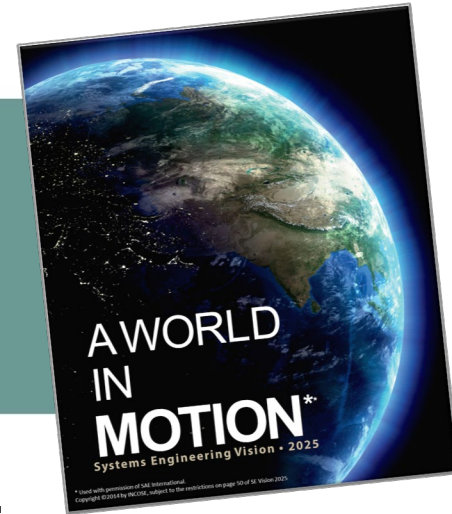
## *Common Challenges in Today's World*

1

Mission complexity is growing faster than our ability to manage it . . . increasing mission risk from inadequate specifications and incomplete verification.

4

Knowledge and investment are lost between projects . . . increasing cost and risk: dampening the potential for true product lines.



2

System design emerges from pieces, rather than from architecture . . . resulting in systems that are brittle, difficult to test, and complex and expensive to operate.

## An Explosion in Complexities and Expectations

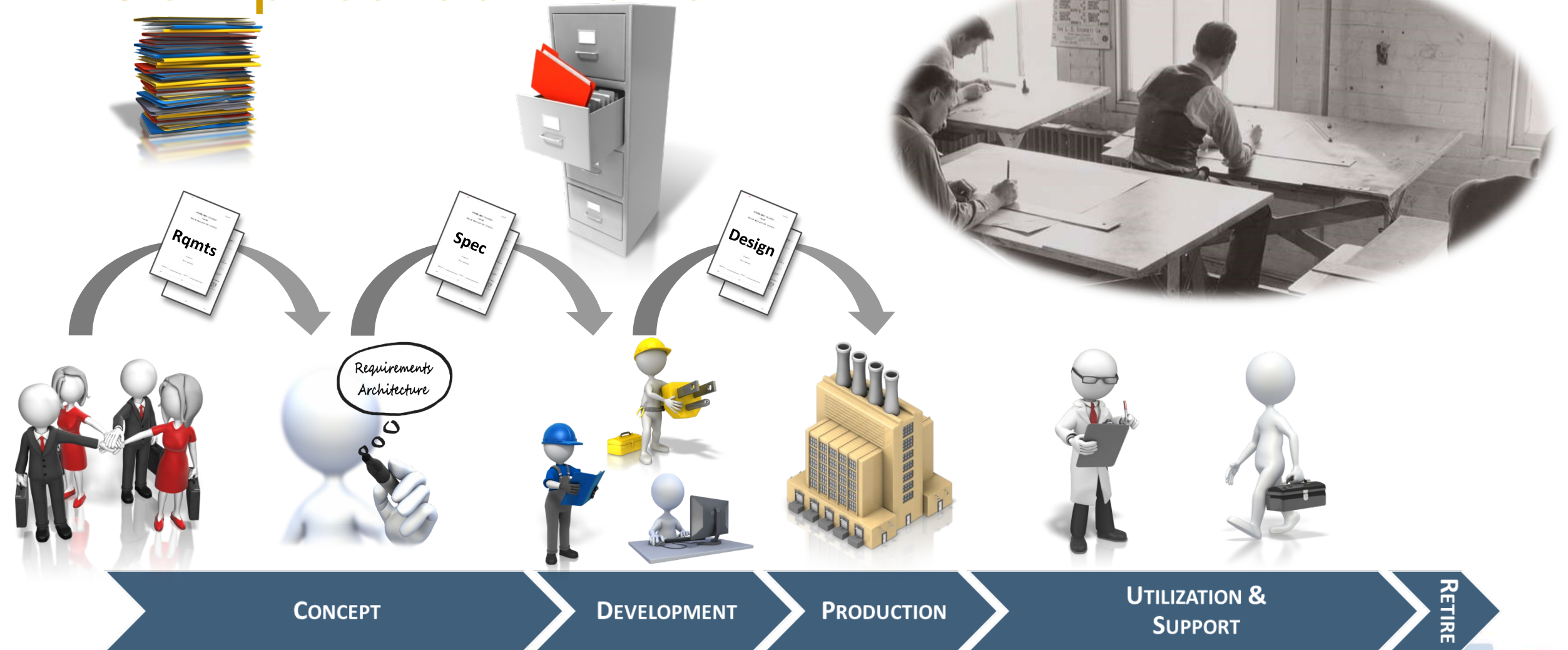
- ❖ System scale
- ❖ Mission complexity
- ❖ Technology complexity
- ❖ Project team complexity
- ❖ Dynamic complexity
- ❖ Build to order
- ❖ Cycle time

3

Knowledge and investment are lost at project life cycle phase boundaries . . . increasing development cost and risk of late discovery of design problems



# Performing Classical Engineering in a Complicated World

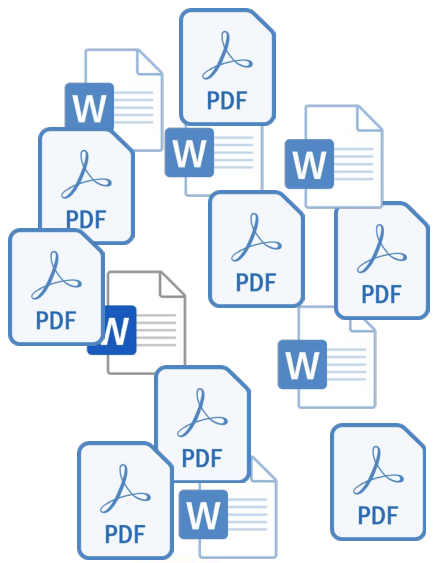
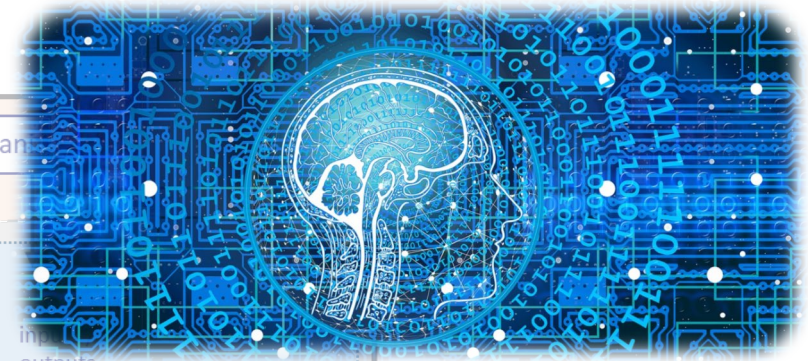
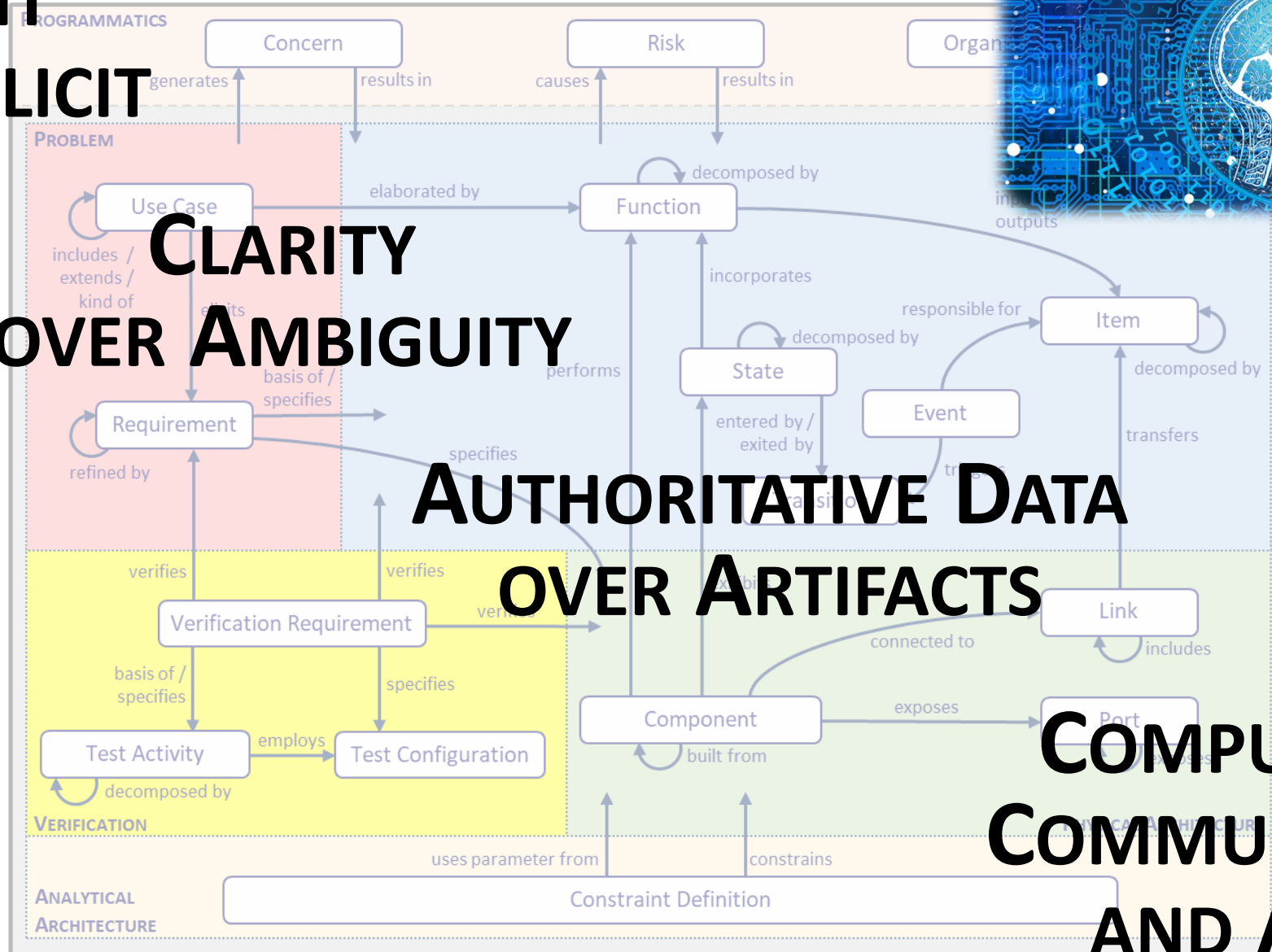


**EXPLICIT  
OVER IMPLICIT**

**CLARITY  
OVER AMBIGUITY**

**AUTHORITATIVE DATA  
OVER ARTIFACTS**

**COMPUTATION,  
COMMUNICATION,  
AND ACCESS**





# Addressing Increasing Complexity

## *Digitizing and Managing Information thru CAx and xLM*



# Responding to a Changing Context

## The MBSE Journey across the Years

### INCOSE SE Vision 2020

September 2007

Model-based systems engineering (MBSE) is the formalized application of model support system requirements, design analysis, verification and validation at the beginning in the conceptual design phase and continuing throughout development.



### A Practice in Transition: Transforming SE

- Value-driven practices
- Complex system understanding
- Leveraging technology for SE tools
- Collaborative engineering across all boundaries
- System design in a system of systems context
- Architecting systems to address multiple stakeholder viewpoints
- Architecting and design of resilient systems
- Cyber security – securing the system
- Leveraging information and analysis for effective decision making
- Virtual engineering – part of the digital revolution

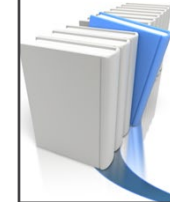


Source: SE Vision 2025.  
Copyright © 2014 by INCOSE.  
All rights reserved.

### INCOSE MBSE Workshop

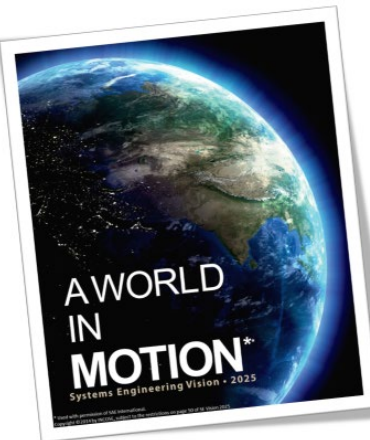
February 2010

Traditional



- Specifications
- Interface requirements
- System design
- Analysis & Trade-off
- Test plans

Future



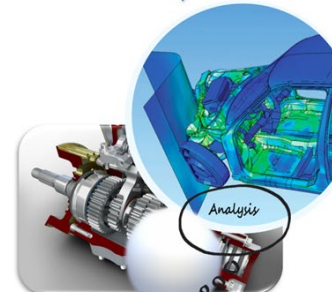
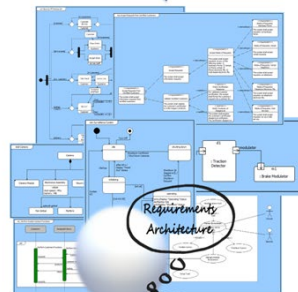
### Building for Tomorrow: Towards 21<sup>st</sup> Century Systems Engineering

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INCOSE President  
david.long@incose.org  
@thinkse

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### Leveraging MBSE as a Stepping Stone (but which do we choose?)



It looks like you are trying to write a requirements specification. Can I help?



It looks like you are trying to achieve .99999 reliability. Would you like me to help?



• 11



# Advancing SE for a Better Tomorrow

## INCOSE SE Vision 2035



### Practices

3. Systems engineering anticipates and effectively responds to an increasingly dynamic and uncertain environment.

4. Model-based systems engineering, integrated with simulation, multi-disciplinary analysis, and immersive visualization environments is standard practice.

5. Systems engineering provides the analytic framework to define, realize, and sustain increasingly complex systems.

6. Systems engineering has widely adopted reuse practices such as product-line engineering, patterns, and composable design practices.



### Tools and Environment

7. Systems engineering tools and environments enable seamless, trusted collaboration and interactions as part of the digital ecosystem.



SE Vision 2035. Copyright © 2021 by INCOSE.

### TOOLS AND ENVIRONMENT

- Part of digital ecosystem
- Seamless interactions and trusted collaboration
- Automated workflow
- Managed digital thread
- Enterprise reuse repository
- AI assist

\*first.sysml second.sysml

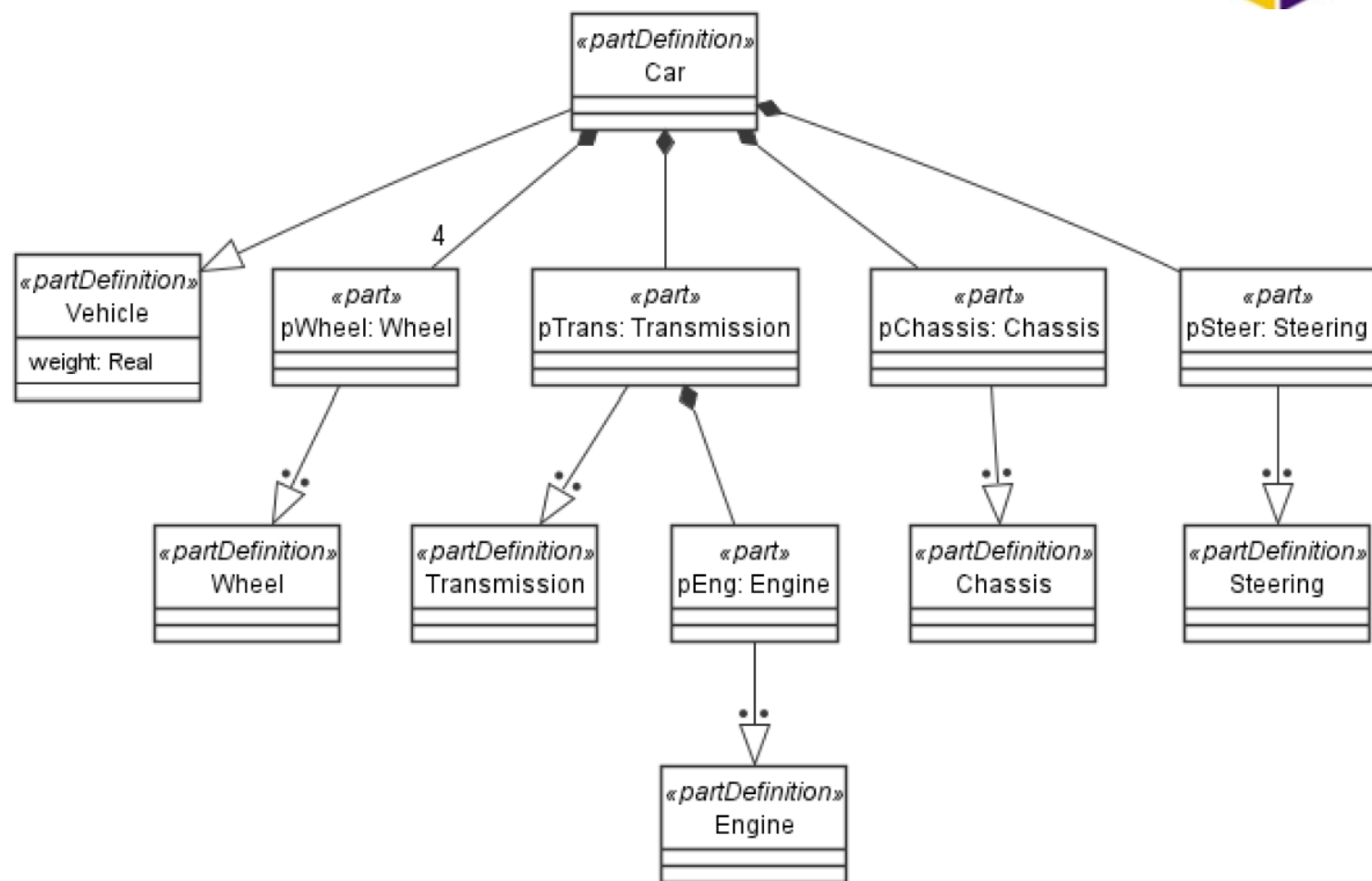
PlantUML

```

1 //definitions
2 package Definitions{
3
4     private import ScalarValues::*;
5
6     part def Vehicle{
7         attribute weight : Real;
8     }
9
10    part def Engine;
11    part def Transmission;
12    part def Wheel;
13    part def Steering;
14    part def Chassis;
15
16    part def Car specializes Vehicle{
17        part pWheel[4] : Wheel;
18        part pTrans : Transmission{
19            part pEng : Engine;
20        }
21        part pChassis : Chassis;
22        part pSteer : Steering;
23    }
24 }

```

## Definitions





# Defining the Purpose of Your Model

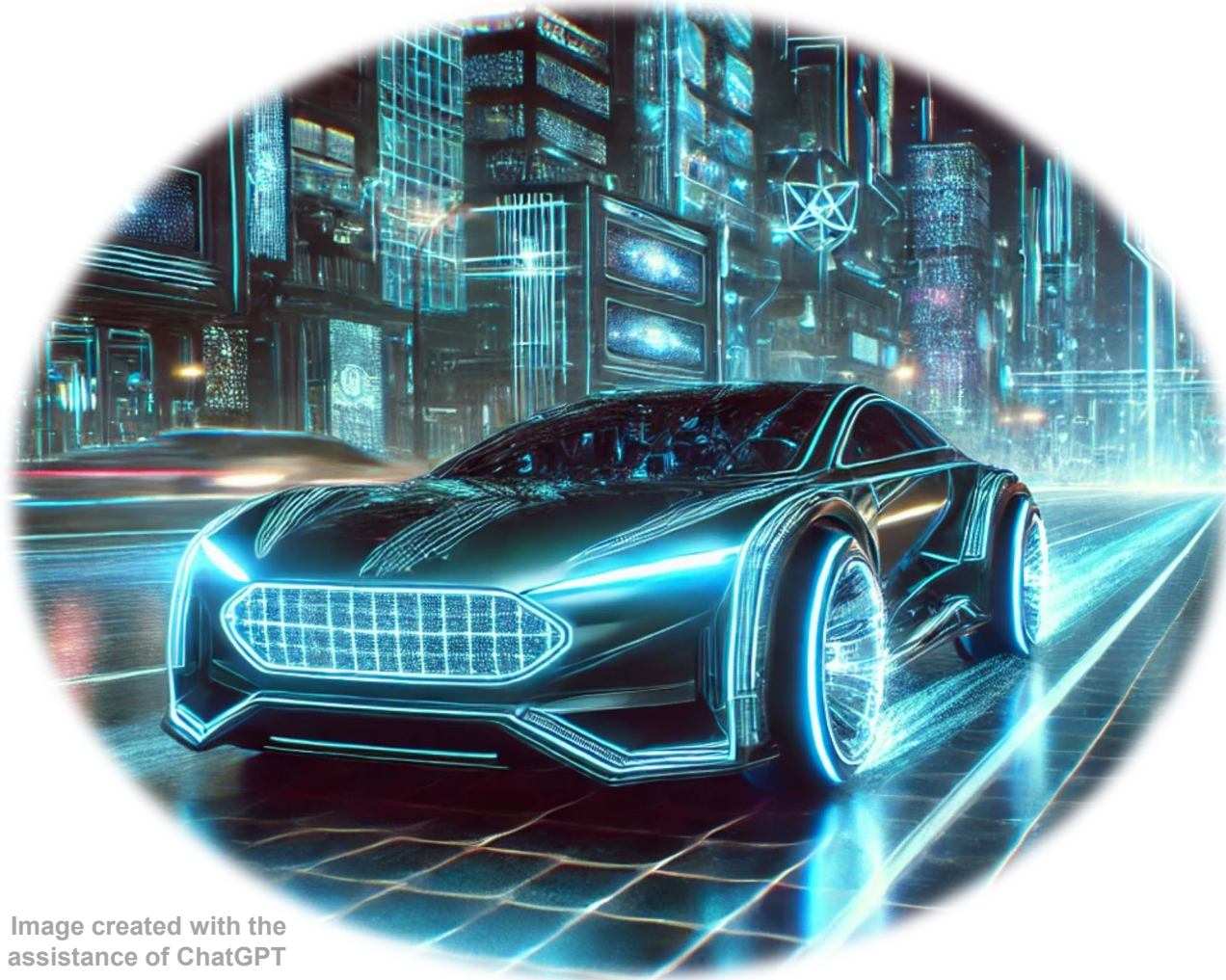
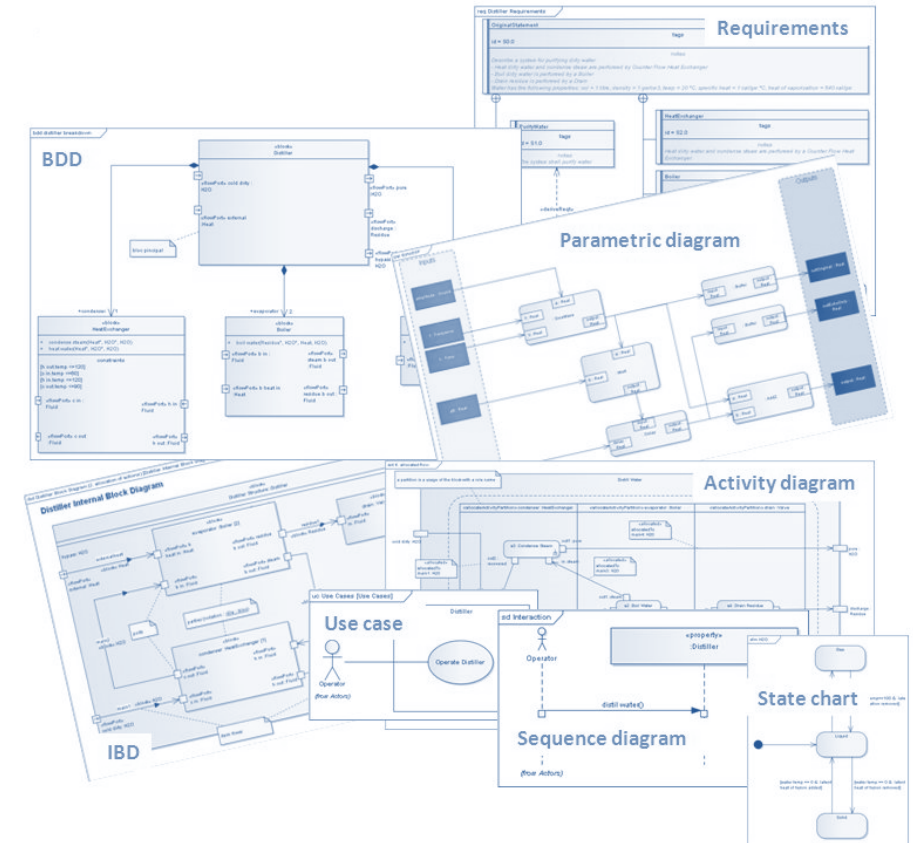
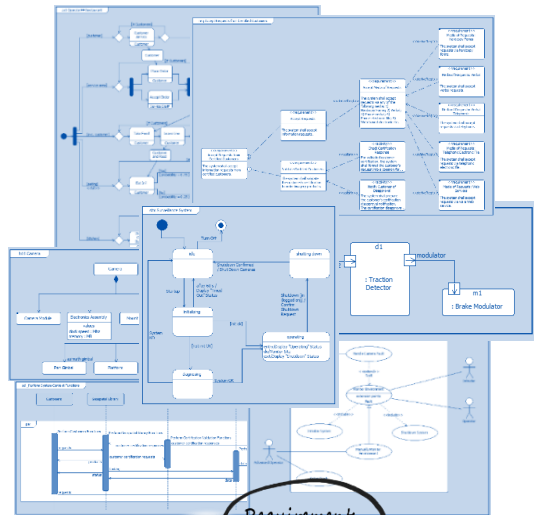


Image created with the assistance of ChatGPT



# Avoiding the Trap of Silos of Excellence

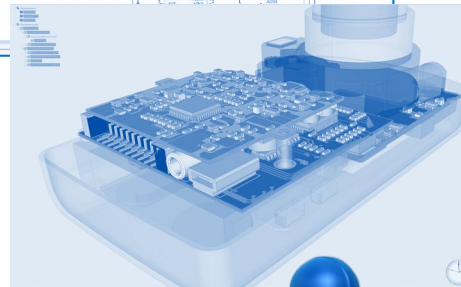
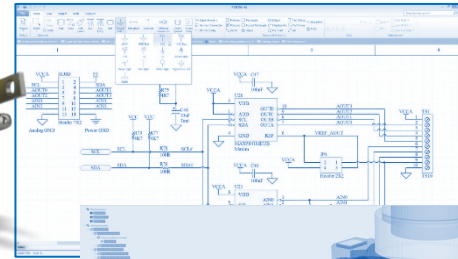
## *Disconnected Engineering in a Complex World*



MBSE



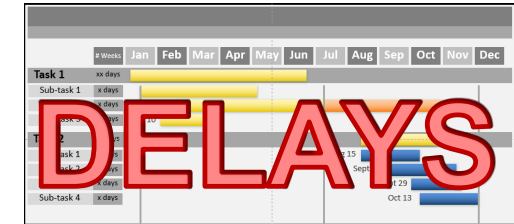
ECAD



ALM



MCAD



CONCEPT

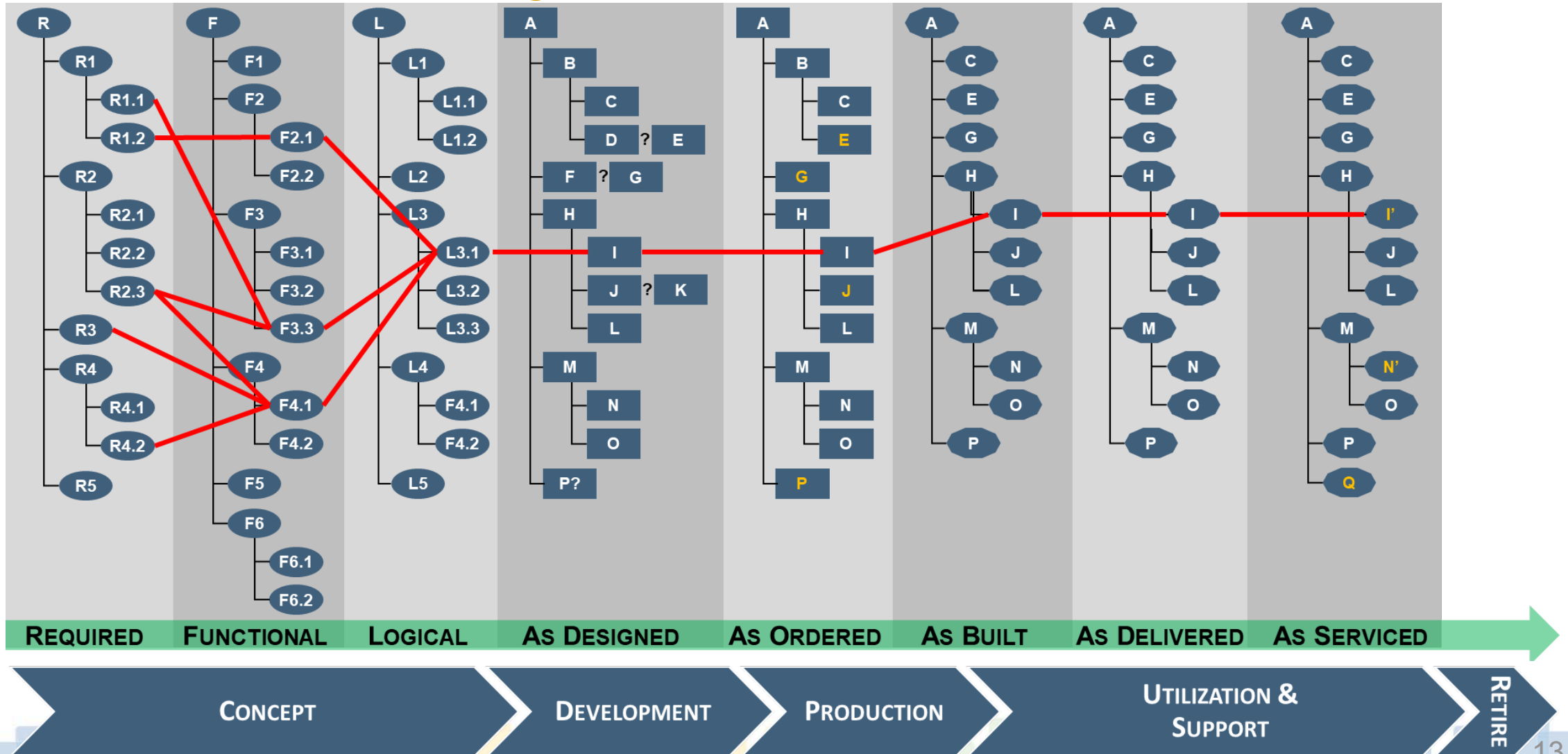
DEVELOPMENT

PRODUCTION



# Maintaining an Unbroken Thread of Traceability

## *The Power of the Digital Thread*



# Leveraging the Power of Digital

## *A “Smart” Digital Twin Connecting Design and Operation*



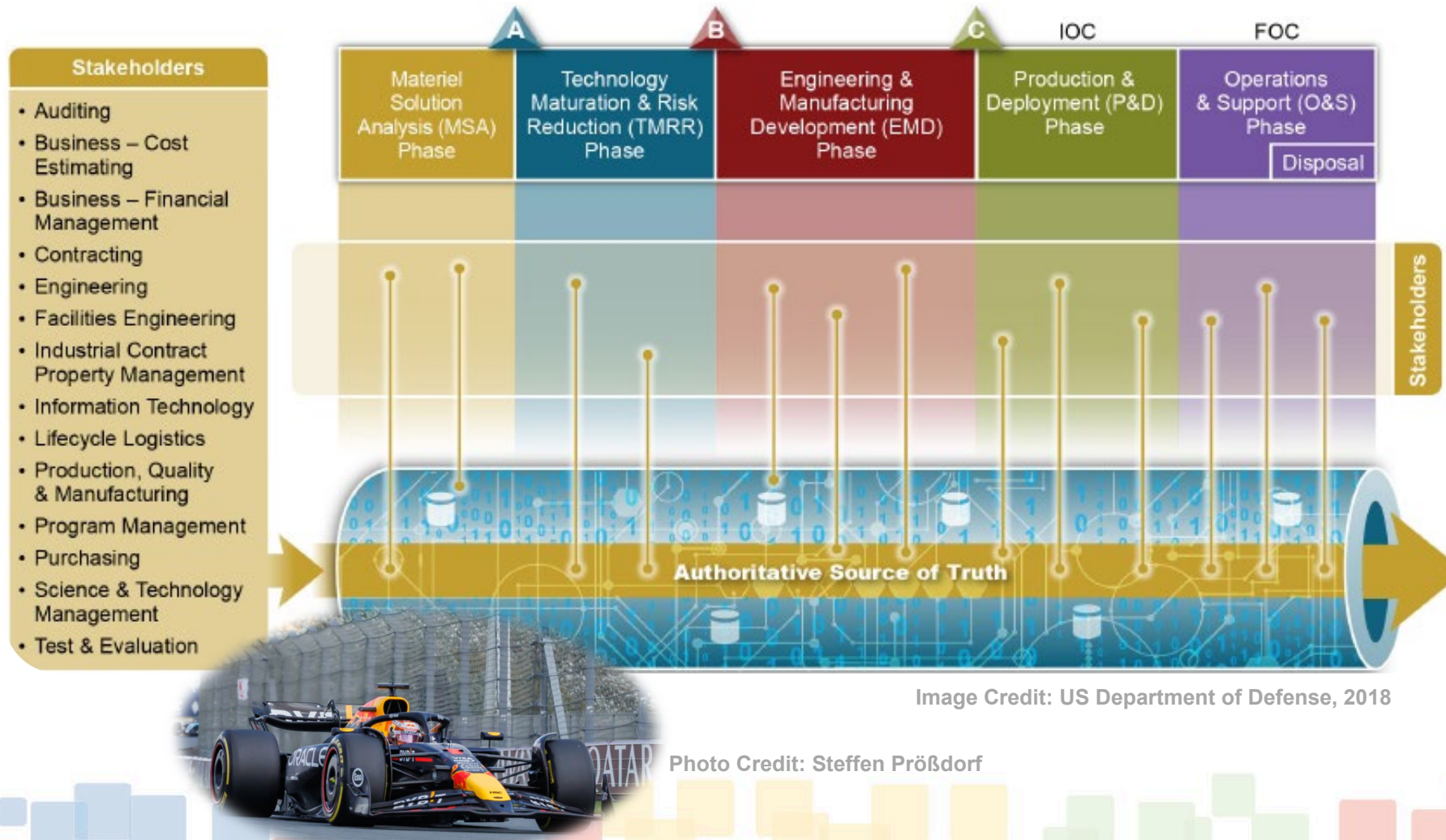
Credit: Sumit Awinash,  
Creative Commons 4.0

A digital twin is virtual representations of real-world entities and processes, synchronized at a specified frequency and fidelity

Digital Twin Consortium

# Connecting the Engineering Lifecycle

## *Engaging and Aligning beyond Engineering*



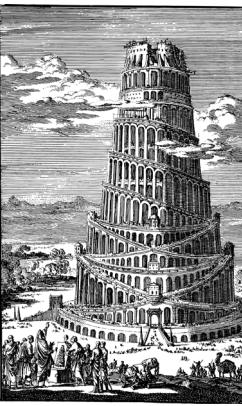
An integrated approach using authoritative data and models as a continuum across disciplines and across the lifecycle

US Department of Defense  
Digital Engineering Strategy



# Avoiding a Critical Trap

*Languages, Notations, and Concerns across the Lifecycle*



Requirements  
Architecture

FUNCTION

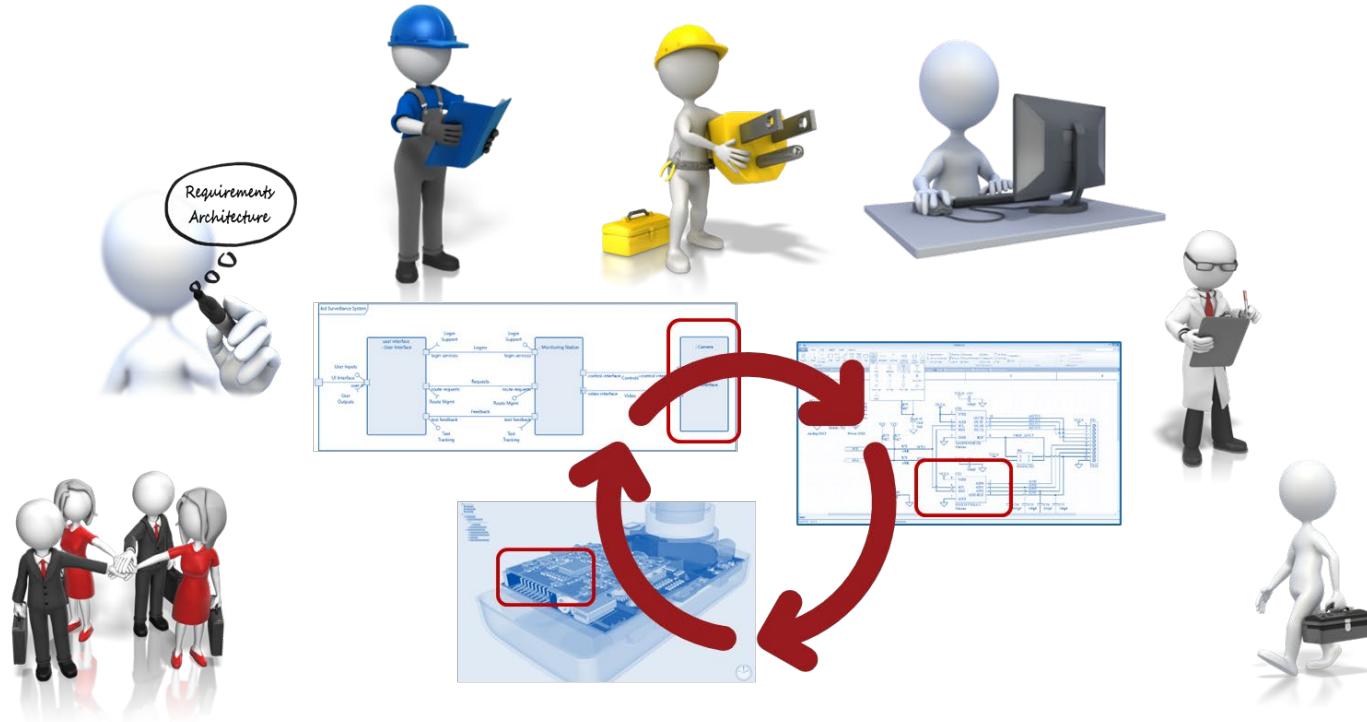
FUNCTION

FUNCTION

WHAT IS A  
FUNCTION?!?

# Recognizing a Different Type of Complexity

## *Embracing Transdisciplinary and Integrative*



### Seeing further together

- Diversity of perspectives and thought
- Inclusive, holistic, systemic mindset
- Across concerns
- Through life



# Relating the Key Concepts

## *The Foundations of DE and Our Digital Transformation*



**Digital Engineering** *a critical enabler for the modern engineering enterprise*



**MBSE**

*connective tissue of the  
Digital Engineering environment*



**Systems Engineering**

*technical connective tissue of  
the project team*



**Data**

*oxygen fueling 21<sup>st</sup> century  
engineering and operations*



## CONCEPT DEFINITION

Priya identifies her customers and key stakeholders. She forms Teams of Teams collaborative acquisition and shares dynamic dashboards.



**Lean Portfolio Management**

**Agile Product Delivery**

**Team and Technical Agility**

**Continuous Learning Culture**

Priya's team engaged the Company Government policy team and develops socially responsible and sustainability aligned User/Business and DevOps models of the mission outline.

## SYSTEMS DEFINITION

Priya leverages the essential digital threads created within the integration of enterprise-wide PLM, ALM, CAD, CAE tools and data lakes to perform virtual concept and architectural explorations.

An integrated and linked systems engineering framework, supporting agile processes is key to the successful incorporation of small and medium business into the project.

Early team forming leverages systems engineering development planning strategies that engage company workforce, the university student body, and the university faculty.

The team identifies critical SoS digital threads and AI/ML risk-based strategies for emergency response policy.

## SYSTEMS REALIZATION



Priya's Data Science and AI/ML team develops connected data methods to update, inhale, clean, and normalize both structured and unstructured data. These are provided as dynamically updated training data for the neural nets providing both AVF Emergency Response policy algorithms and to tune operational models.

The team engages in Epic-based Agile-systems engineering sprints and customer reviews to test hypothesis using over-the-air shadow-code updates on real-world naturalistic AVFs.

**INTEGRATED SE-MODSIM**

**TRUSTED SYSTEMS**

**SYSTEMS OF SYSTEMS**

## SYSTEMS PRODUCTION

Priya leverages the multi-layered AI/ML augmentations available connected "cloud" business intelligence and AI/ML-based engineering asset reuse.

The manufacturing team transfers the digital twin data from the PD cloud containers into a Manufacturing container. This is used to run pilot plant build cycles creating the ER communication hub and fleet transponders.

Priya's team leverages photo-realistic, gaming engine-supported, immersive modelling and simulation to viscerally engage stakeholders.

Priya reuses the enterprise flexible-reference architectures that have been developed with reliance, scalability, and extensibility in mind.

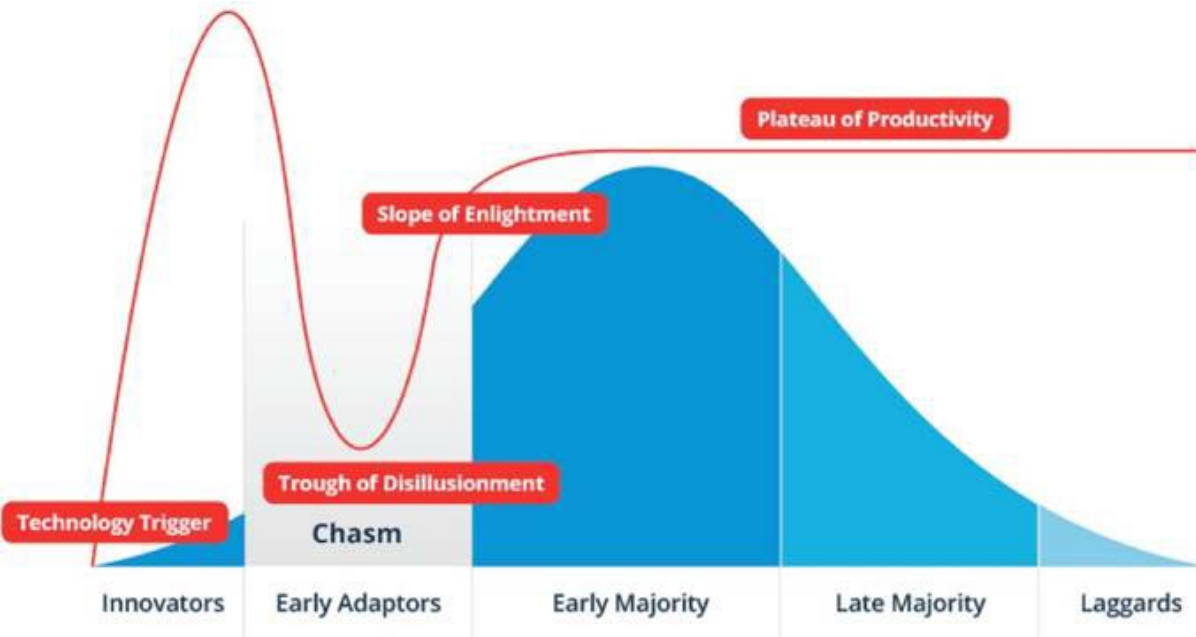
## SYSTEMS SUPPORT AND UTILIZATION

The service team uses the digital twin data to develop maintenance and update strategies that include multi-fleet software updates, prognostics, and OTA software updates.

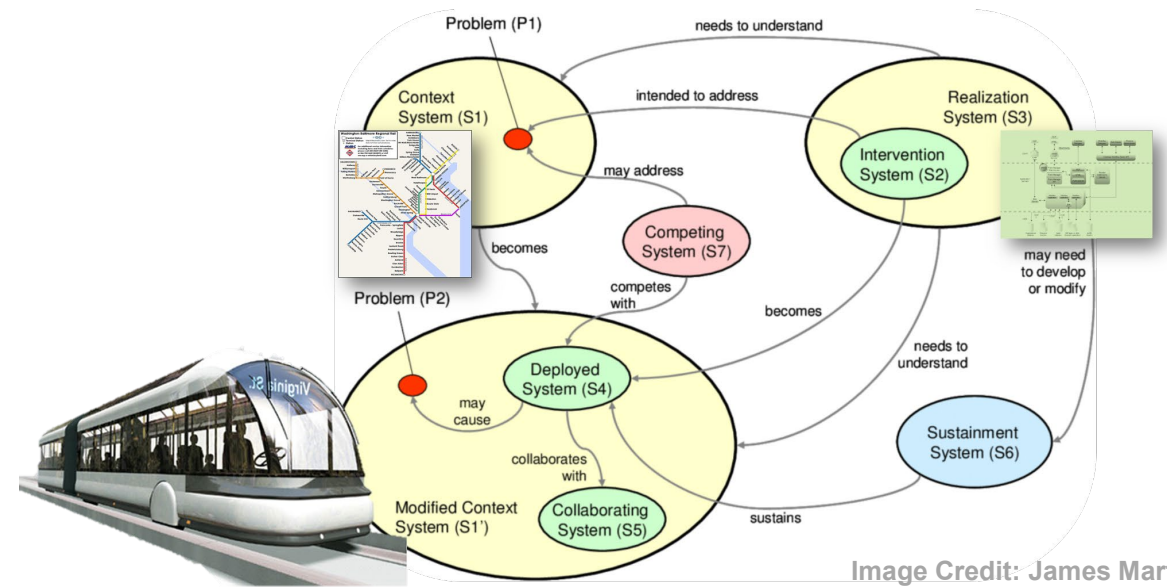
The ER deployment team leverages connected fleet data to track and analyze nominal and deployed ER behavior. They update AI/ML models and policy as required.

# Looking beyond Marketing Hype

## Assessing and Benchmarking Capability



	(1) Initial	(2) Managed	(3) Defined	(4) Qualitative	(5) Optimizing
Solution	Uncontrolled	Controlled Documents	Isolated models	Enterprise Integration	Continuous Engineering
<b>Product engineering</b>					
System Architecture Modeling <i>Product architecture definition</i>	PPT in docs	Disconnected Visio diagrams	Standalone SysML with simulations	Fine-grained integrated system architecture	Continuous integration via PLM-based architecture drives closed-loop MBDC
Planned Product Variability <i>PLE/Configuration/Variation</i>	None	Variation documents & spreadsheets	Disconnected variation rules	PLM Integrated variation rules	PLM variation definition drive architecture decisions
Reliability & System Safety Analysis <i>Technical Risk (RAMS)</i>	Risk documents & spreadsheets	Combined Risk Mgmt plans with manual RAMS artifacts (FMEA)	Disconnected RAMS tools output artifacts (FMECA)	RAMS analysis tools integrated with product architecture via PLM	Integrated RAMS, continuous risk assessment, alarms, dashboards..
<b>Cross domain services</b>					
System Definition & Design Integration <i>Logical modeling &amp; Interface mgmt</i>	ICD & logical description documents	Managed interfaces & logical hierarchy	SE artifacts linked to Logical models & Std. interface libraries	Integrated fine-grained logical arch with interfaces	Logical architecture carries across domains. Interfaces everywhere
<b>Integrated services</b>					
Feature Engineering <i>Feature/Functional Modeling</i>	Feature/Functional description docs	Functional hierarchy	Isolated functional behavior models	Integrated fine-grained functional modeling	Functional arch with allocations & traceability
Parameter/Target Mgmt <i>Characteristic/Targets/TPM</i>	Uncontrolled Excel/Docs	Controlled spreadsheets/Docs	Project-based Parameter/Target libraries	Enterprise PLM parameter/target mgmt & reuse	Integrated parameters, targets,... drive continuous compliance monitoring
Change management	Document-based change process	Isolated models included in change	Change impact analysis & suspension mgmt	Complete PLM configuration with models, parameters, history,...	Cross-project level reuse, starting point for next project history,...
<b>Content Management</b>					
Requirements Analysis <i>Requirements engineering &amp; mgmt</i>	Uncontrolled spreadsheets & docs	Managed requirements docs	Disconnected RM tools with exchange	Integrated requirements & traceability inside PLM	Continuous compliance thru connected, configured, cross-domain traceability & reuse
Behavior Model Management <i>System, performance, et al simulation</i>	Uncontrolled models on desktops	Version controlled models	SE artifacts linked into models	Integrated model & product configuration with simulation	Continuous, focused simulation & multi-domain simulation, dash boards
Verification Management & Governance <i>Product Test/V&amp;V</i>	Document-based test procedures	Managed test cases	SE artifacts linked to test	Devops-like V&V simulation	focused testing, model swap out
Physical Design Management <i>CAD, CAE,... control/mgmt</i>	Unmanaged CAX models	PDM controlled CAX	SE artifacts linked into CAD	Cross-domain fine-grained PLM integration	Continuous physical design verification (Digital Twin)



# Deploying MBSE and DE

A system is a system is a system



# Embracing Digitalization to Transform Engineering

## *More than Technology and Tooling*

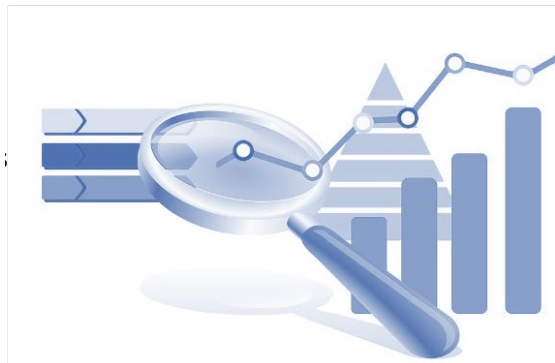
### Digitization

**Transitioning** existing documents and processes as they are into a digital environment (for example, generating all artifacts for a preliminary design review from models)



### Digitalization

**Transforming** existing approaches and artifacts to optimize for a connected digital environment (for example, shifting from milestone reviews to continuous customer and contractor reviews conducted in the DE environment).



### Digital Transformation

True transition from document-based acquisition to digital acquisition and engineering.



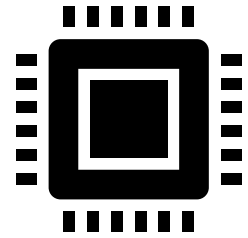
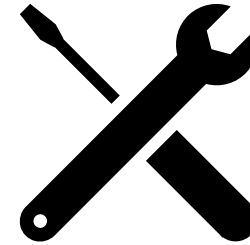
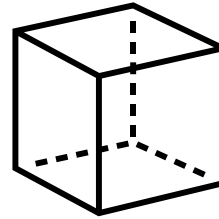
Hutchison et al. (2022)

# Appreciating the Full Scope

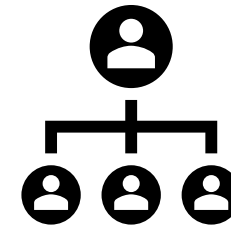
*Dependencies and Interactions thru Life*

TECHNICAL

1010  
1010



SOCIO



MANAGEMENT • CURATION • IP • ACCESS • SECURITY • EFFECTIVITY

# Identifying Traps

*Classic Errors on the Journey to Model-Based and Digital*

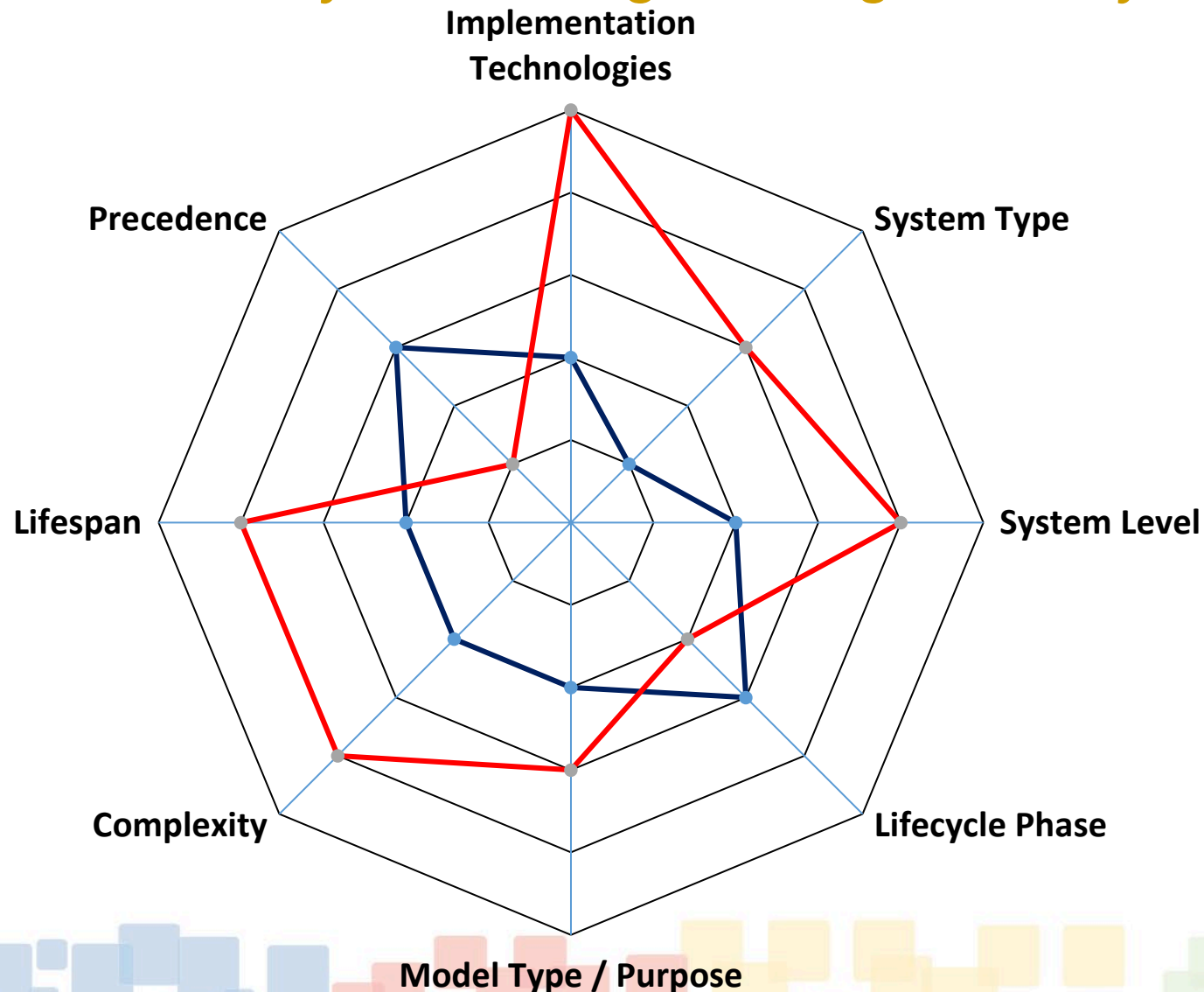
- Thinking it's a tool (or a technical) issue
- Implementing someone else's solution
- Ceding responsibility to a (tool) vendor
- Chasing standards
- Overlooking middle management
- Thinking sprint not marathon





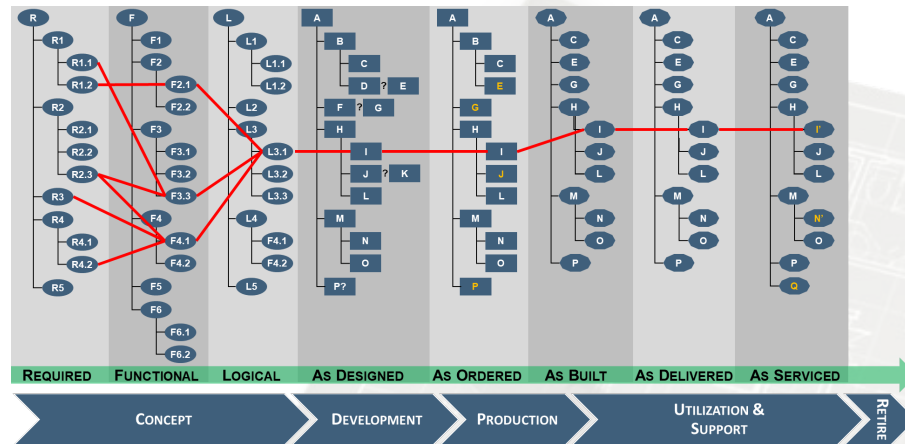
# Begin with Your End in Mind

## *Good Systems Engineering is Always Fit-for-Purpose*

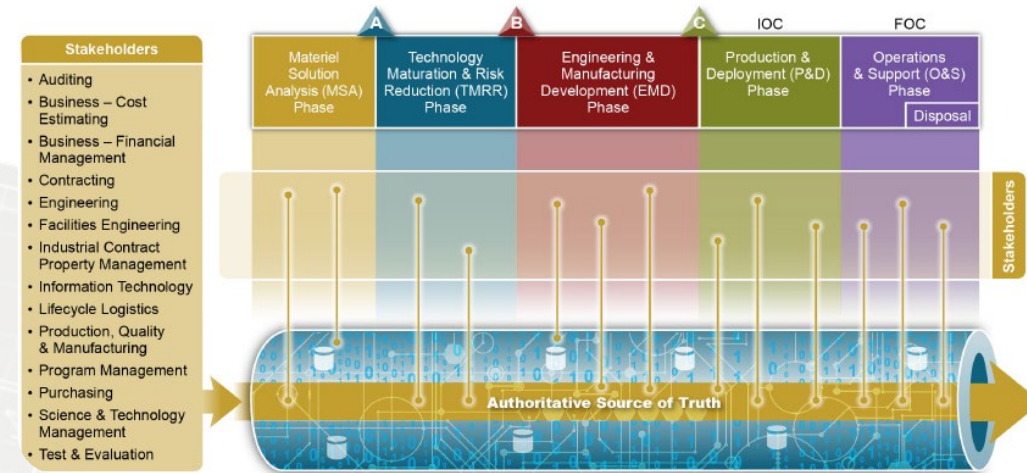


# Define Your Reach for Dx

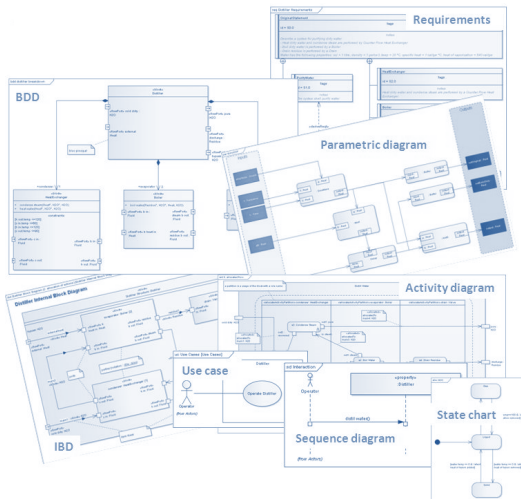
Where You Need to Be not Want to Be – SE, EoS, or Beyond?



Adapted from Aras Corporation, 2018



Credit: US Department of Defense, 2018

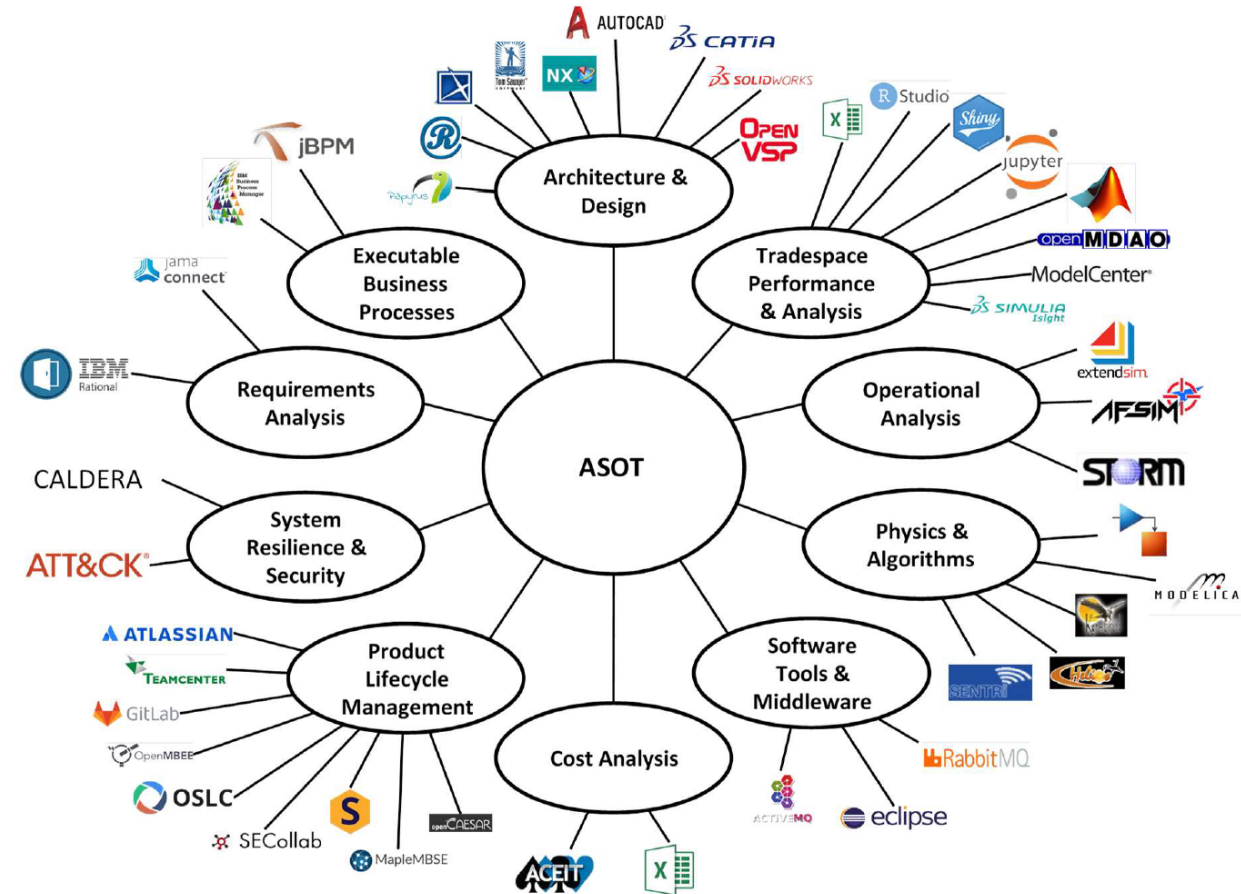
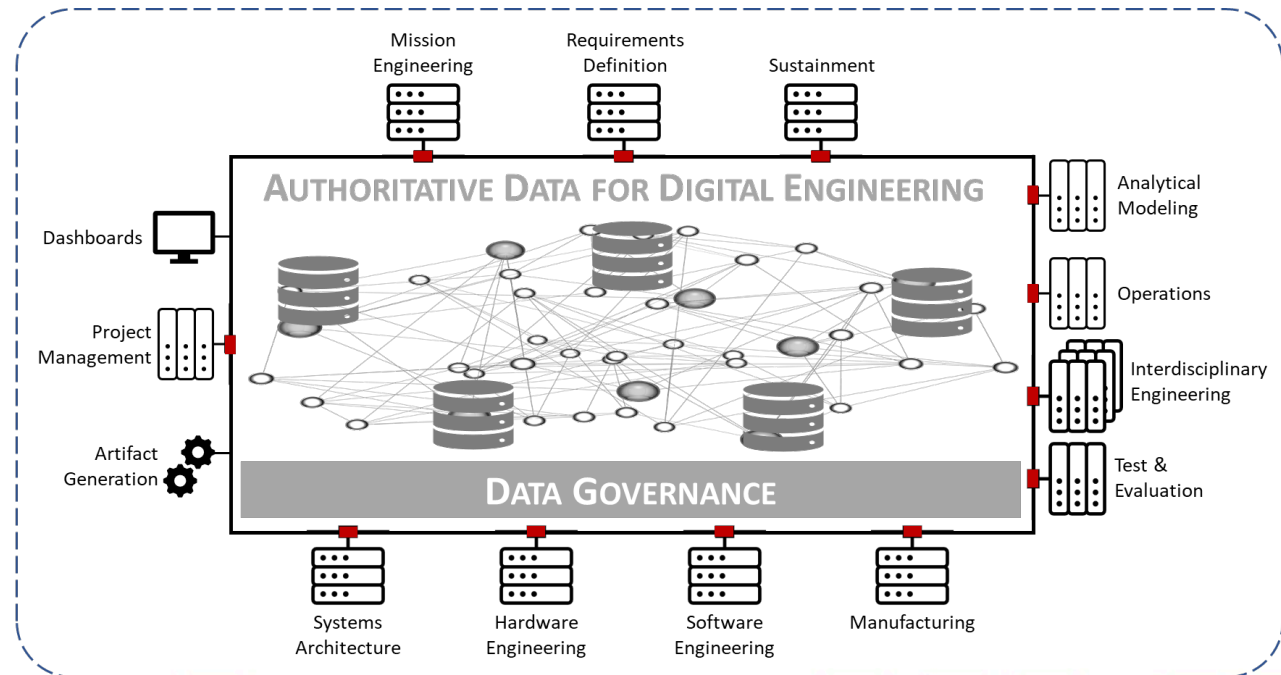
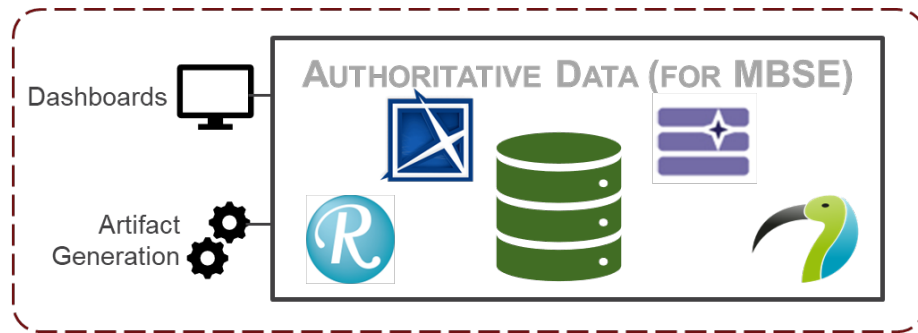


Credit: Sumit Awinash, Creative Commons 4.0



# Appreciate and Honor Your Scope

*Neither Benefit nor Difficulty Increase Linearly*



Credit: WRT-1051, Program Managers Guide to Digital and Agile Systems Engineering Process Transformation, August 2022



# Leverage the Thinking of George Box

*Both Caution and Guidance*



All models are wrong

All models are wrong  
but some are useful

The question is how wrong a  
model can be and still be useful

# Choosing to Create the Right Future

*Acting Individually and Collectively Selecting Progress Over Ruin*



- Knowledge OVER Artifact
- Principle OVER Notation
- Capability OVER Tool
- Communication OVER Analysis
- Connected OVER Siloed
- Outward OVER Inward
- (MB)SE+(D)E OVER MB(SE)+D(E)

***Prioritize your letters – E then S before D and M then lastly B***

# Continuing the Conversation



**David Long, ESEP**  
Director for Strategic Integration  
Past President (2014/2015)  
Fellow

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