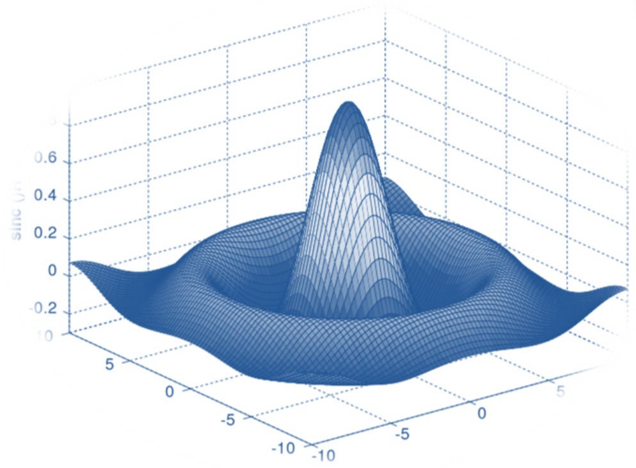
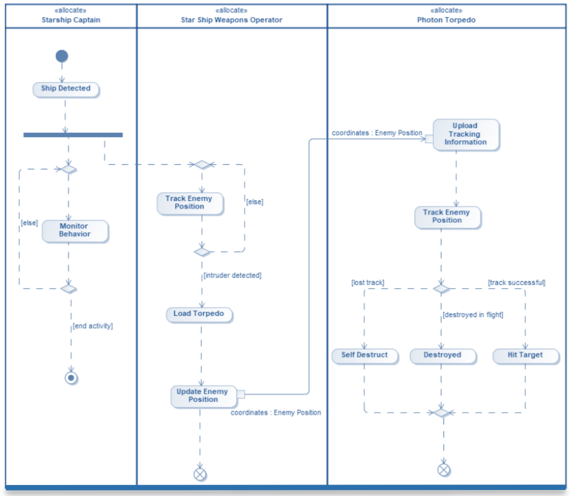
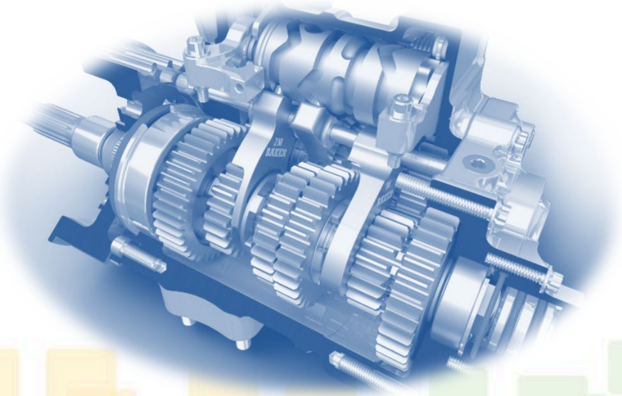
Into the Great Digital Unknown

The Evolving Landscape of MBSE and Digital Engineering

What Do You Envision?

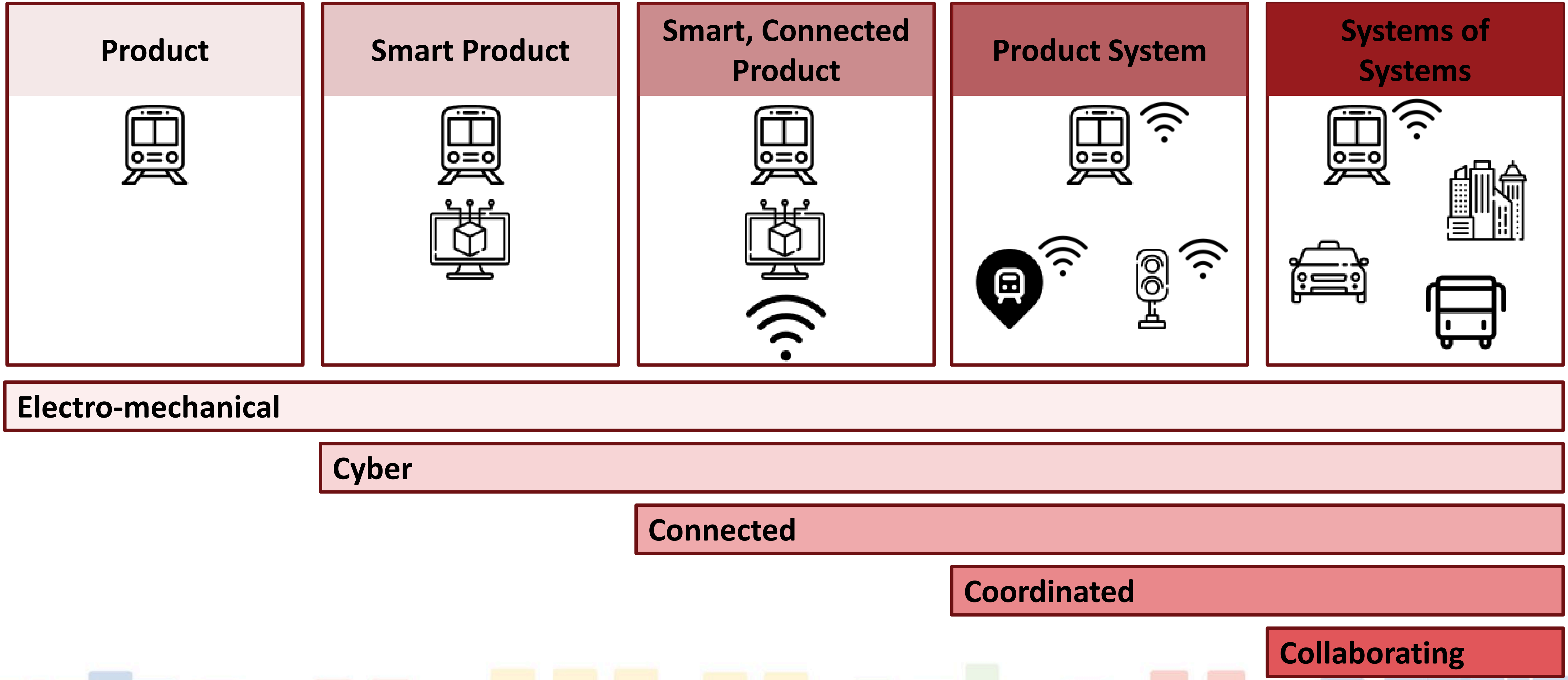






Appreciating a Changing Context

From Static Products to Intelligent Systems of Systems



Icons made by Freepik from www.flaticon.com
Adapted from Claas, November 2019

Exceeding the Capabilities of Traditional Engineering

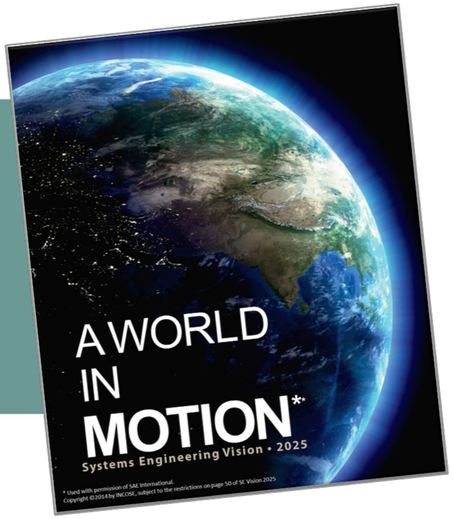
Common Challenges in Today's World

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

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.**

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

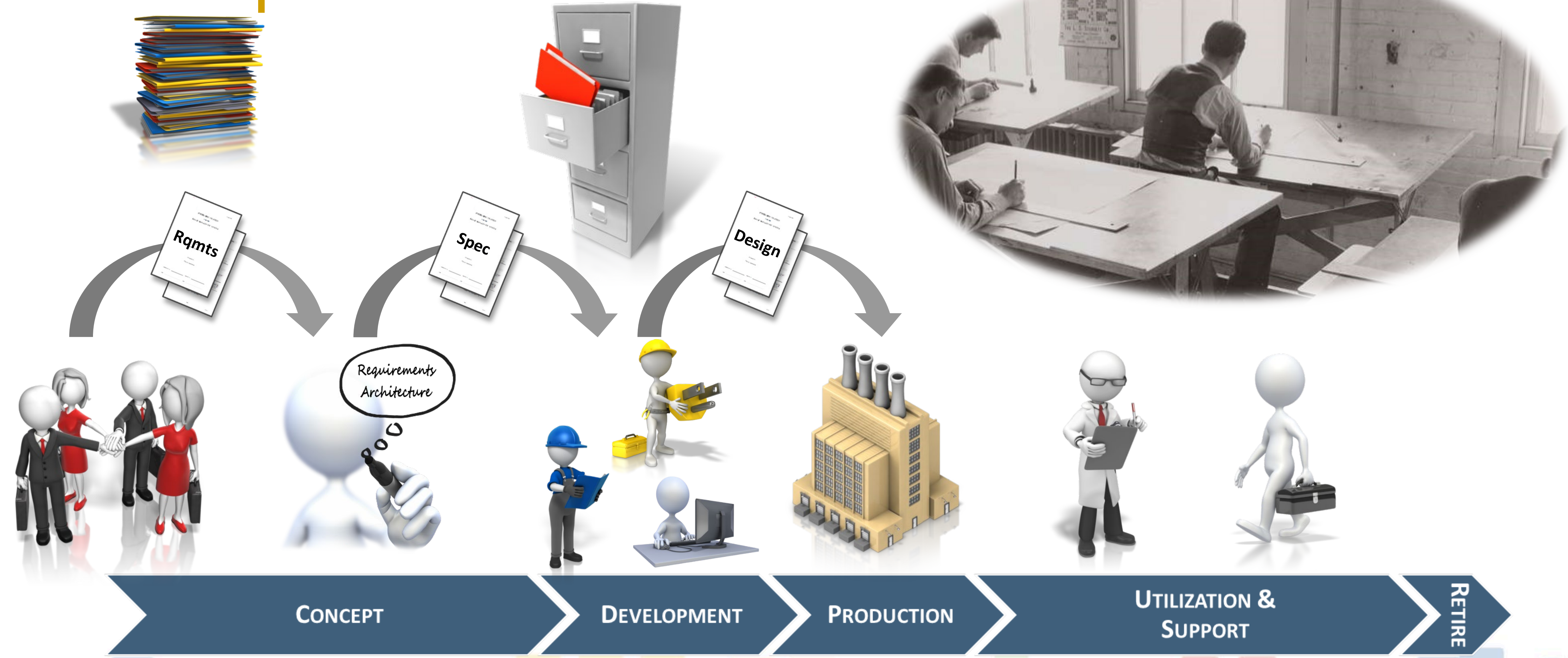
4 | **Knowledge and investment are lost between projects . . . increasing cost and risk: dampening the potential for true product lines.**



An Explosion in Complexities and Expectations

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

Performing Classical Engineering in a Complicated World

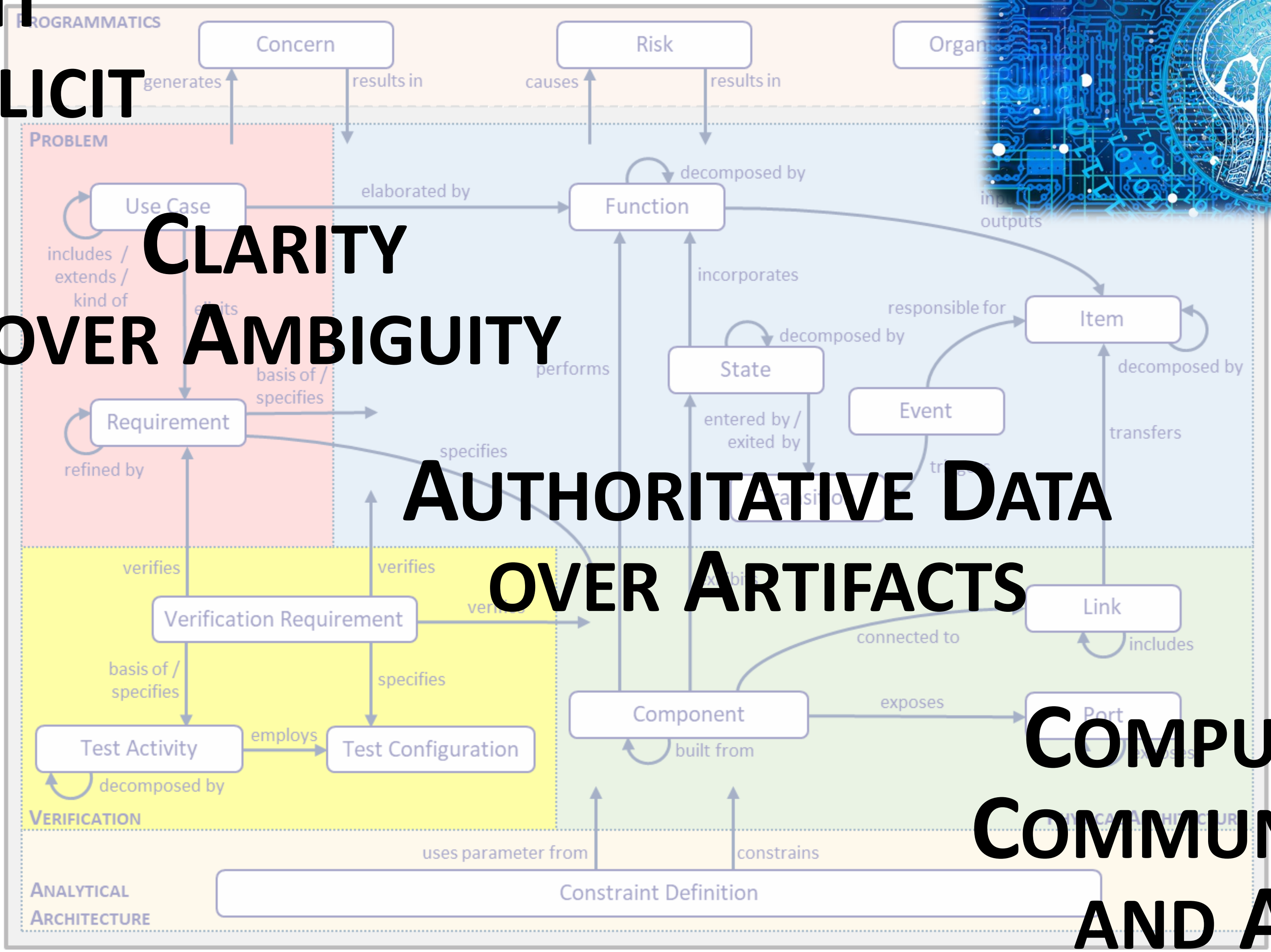


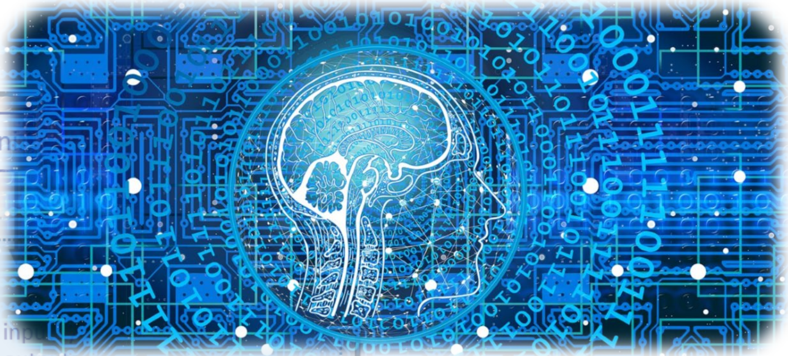
Explicit over Implicit

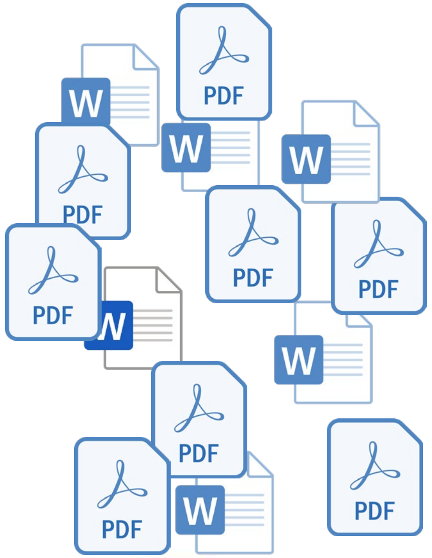
Clarity over Ambiguity

Authoritative Data over Artifacts

Computation, Communication, and Access





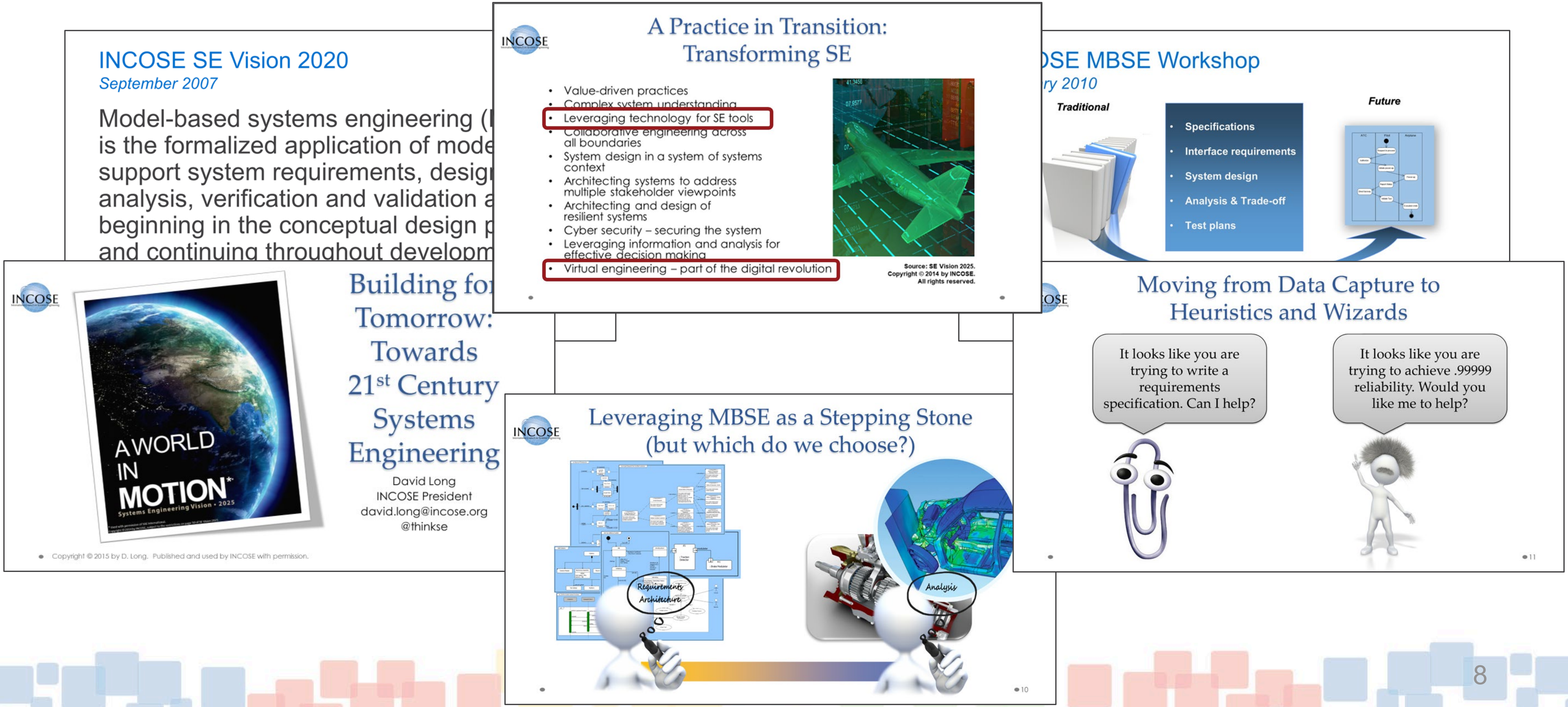


Addressing Increasing Complexity

Digitizing and Managing Information thru CAx and xLM

Responding to a Changing Context

The MBSE Journey across the Years



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.

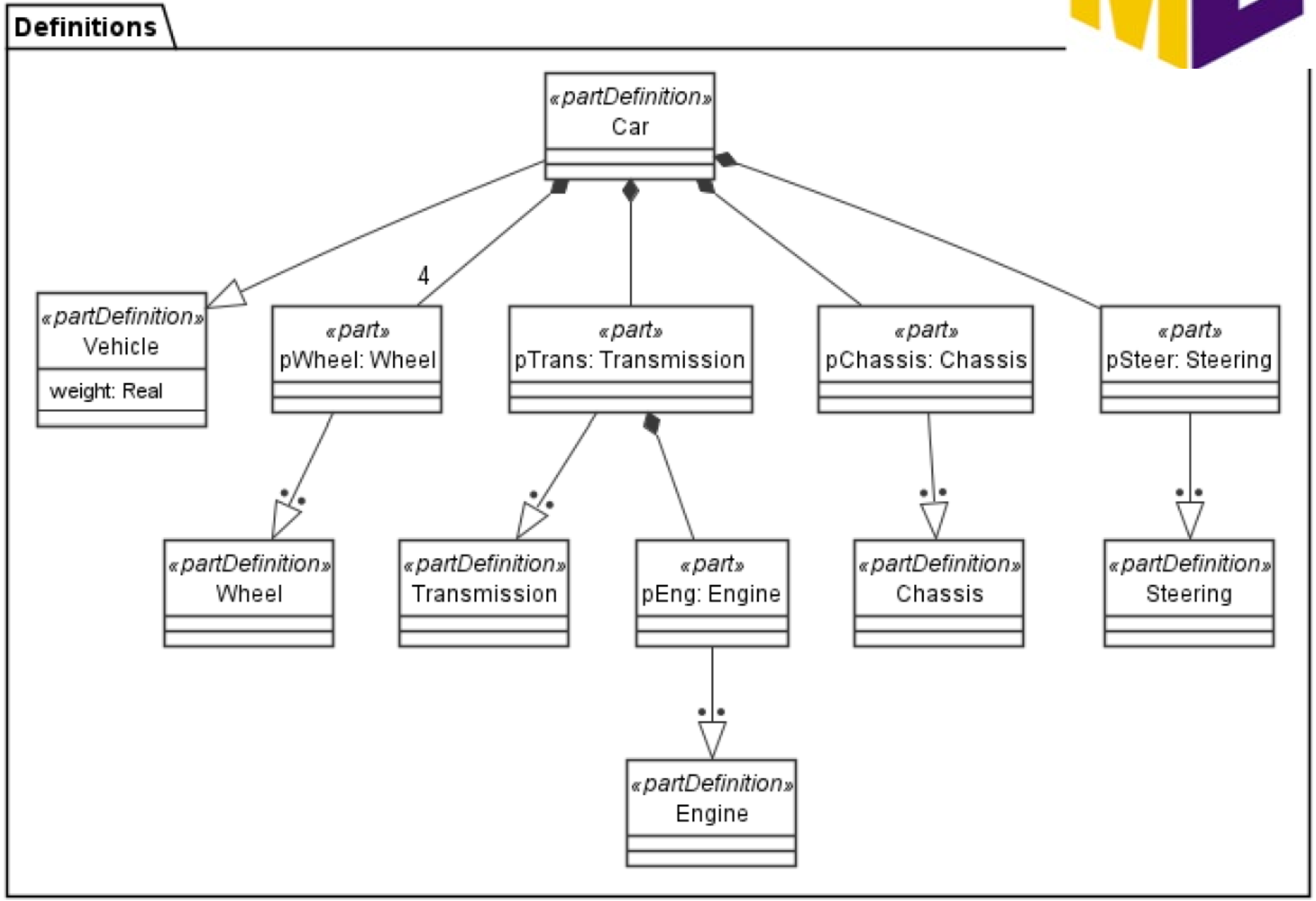
TOOLS AND ENVIRONMENT

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

*first.sysml second.sysml

```
//definitions
package Definitions{

    private import ScalarValues::*;

    part def Vehicle{
        attribute weight : Real;
    }

    part def Engine;
    part def Transmission;
    part def Wheel;
    part def Steering;
    part def Chassis;

    part def Car specializes Vehicle{
        part pWheel[4] : Wheel;
        part pTrans : Transmission{
            part pEng : Engine;
        }
        part pChassis : Chassis;
        part pSteer : Steering;
    }
}
```

PlantUML



Defining the Purpose of Your Model

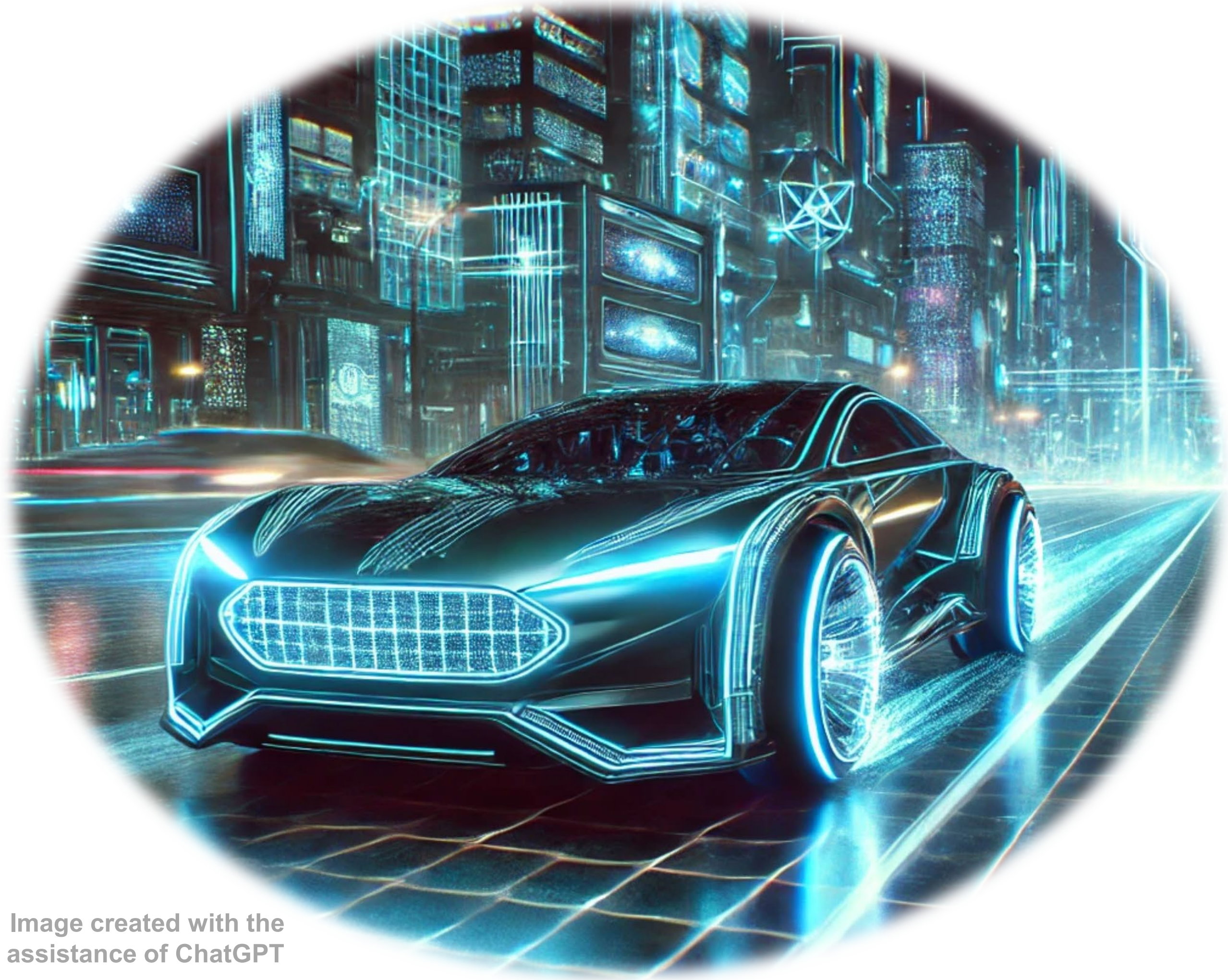
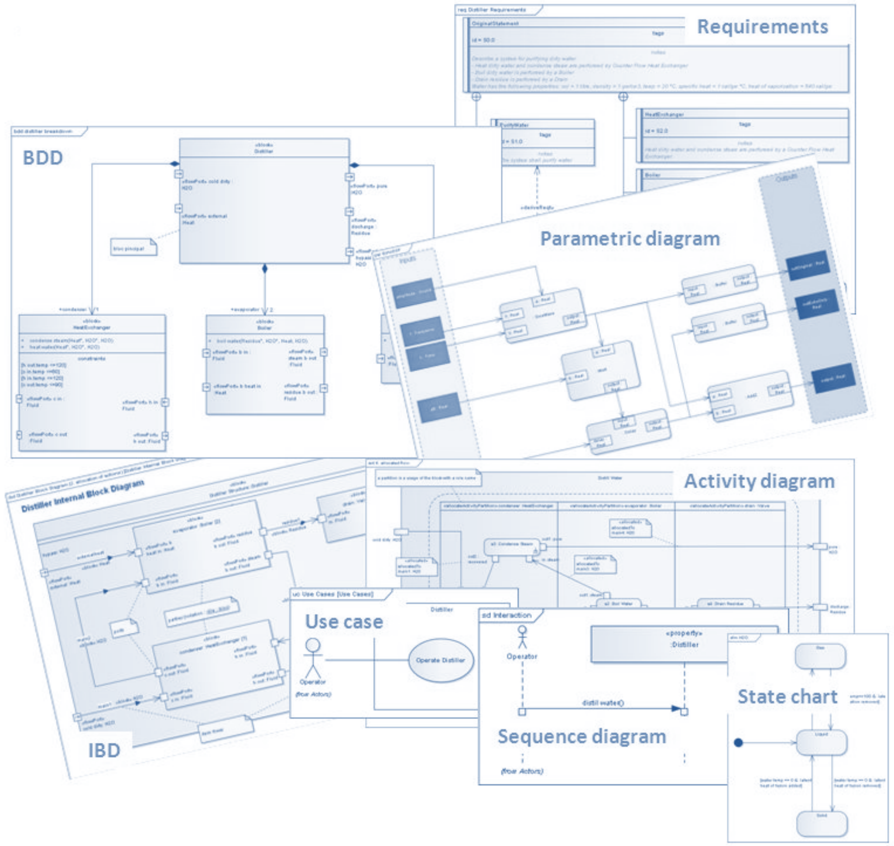
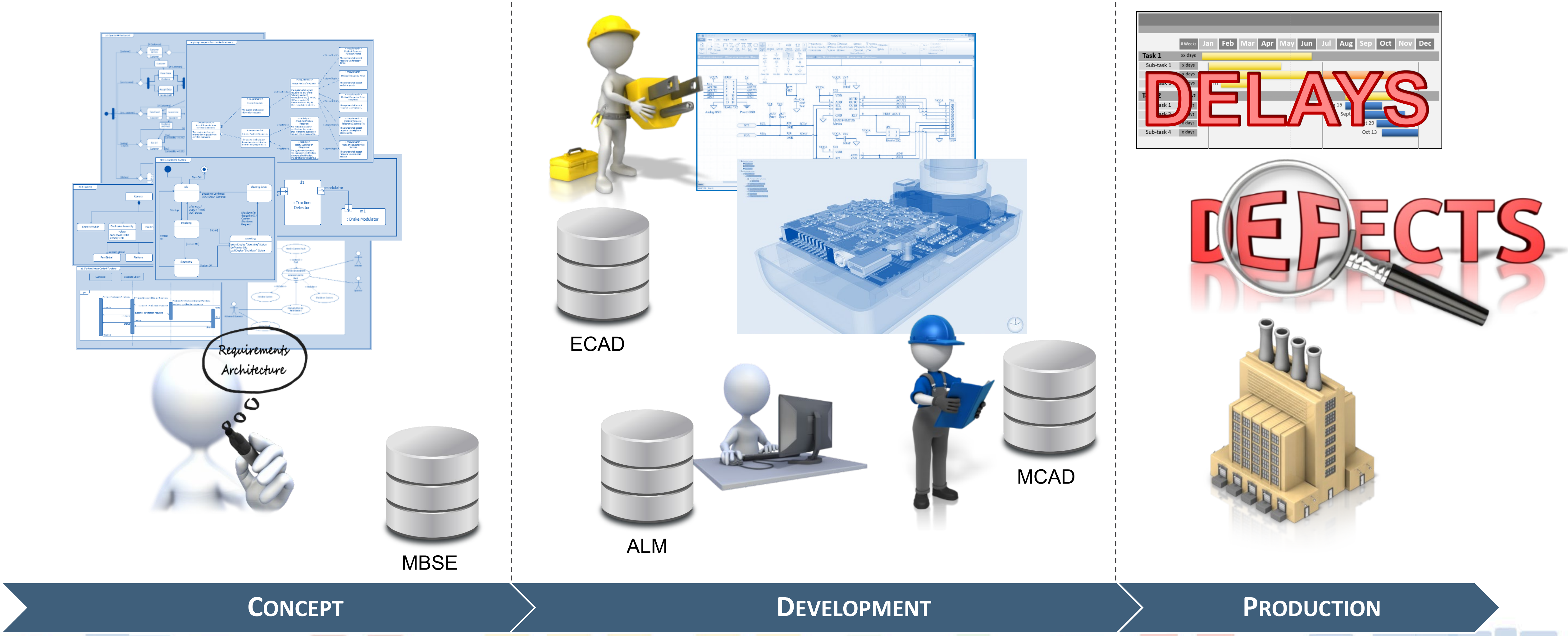


Image created with the assistance of ChatGPT



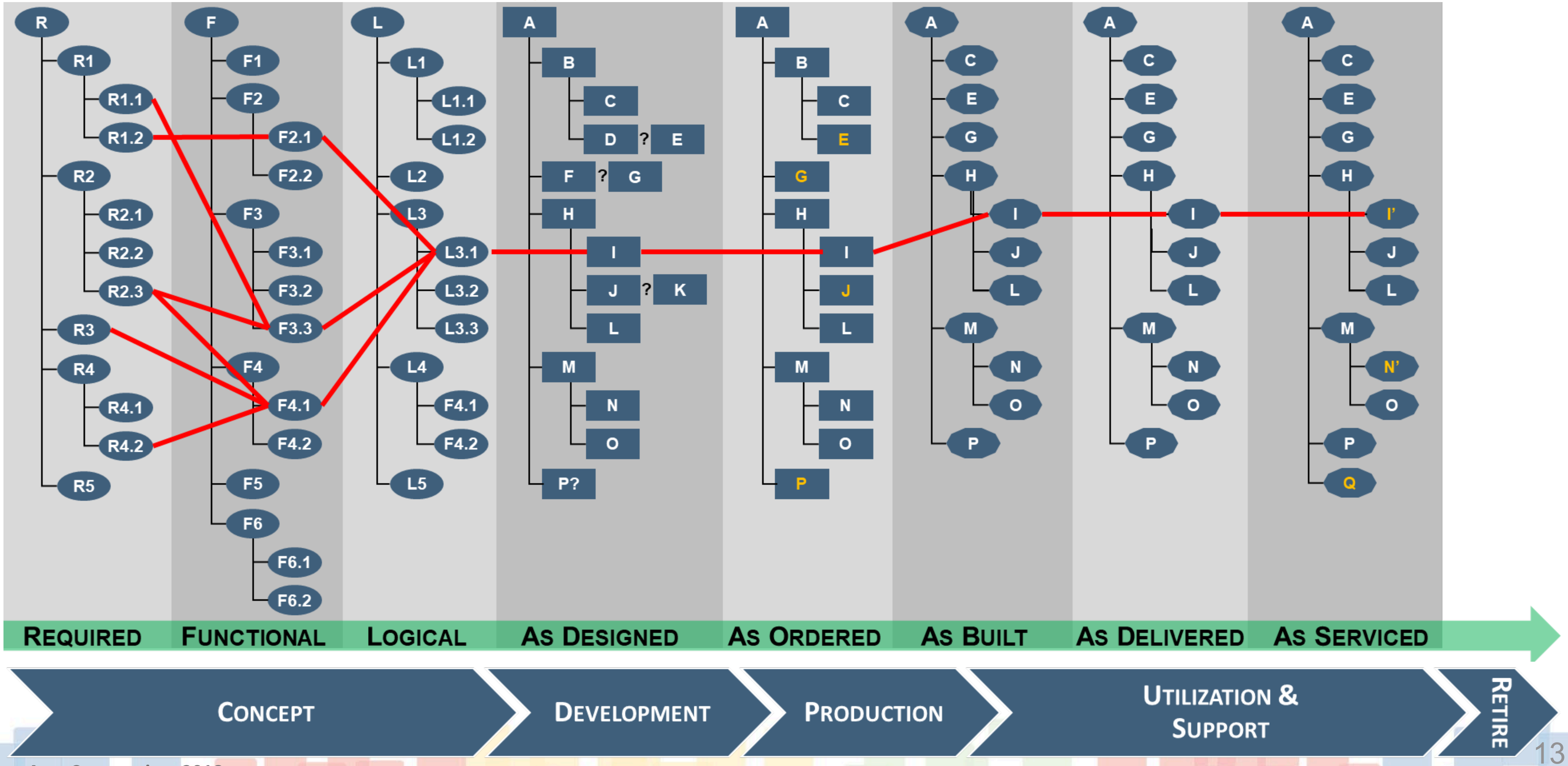
Avoiding the Trap of Silos of Excellence

Disconnected Engineering in a Complex World



Maintaining an Unbroken Thread of Traceability

The Power of the Digital Thread



Adapted from Aras Corporation, 2018.

Leveraging the Power of Digital

A "Smart" Digital Twin Connecting Design and Operation

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

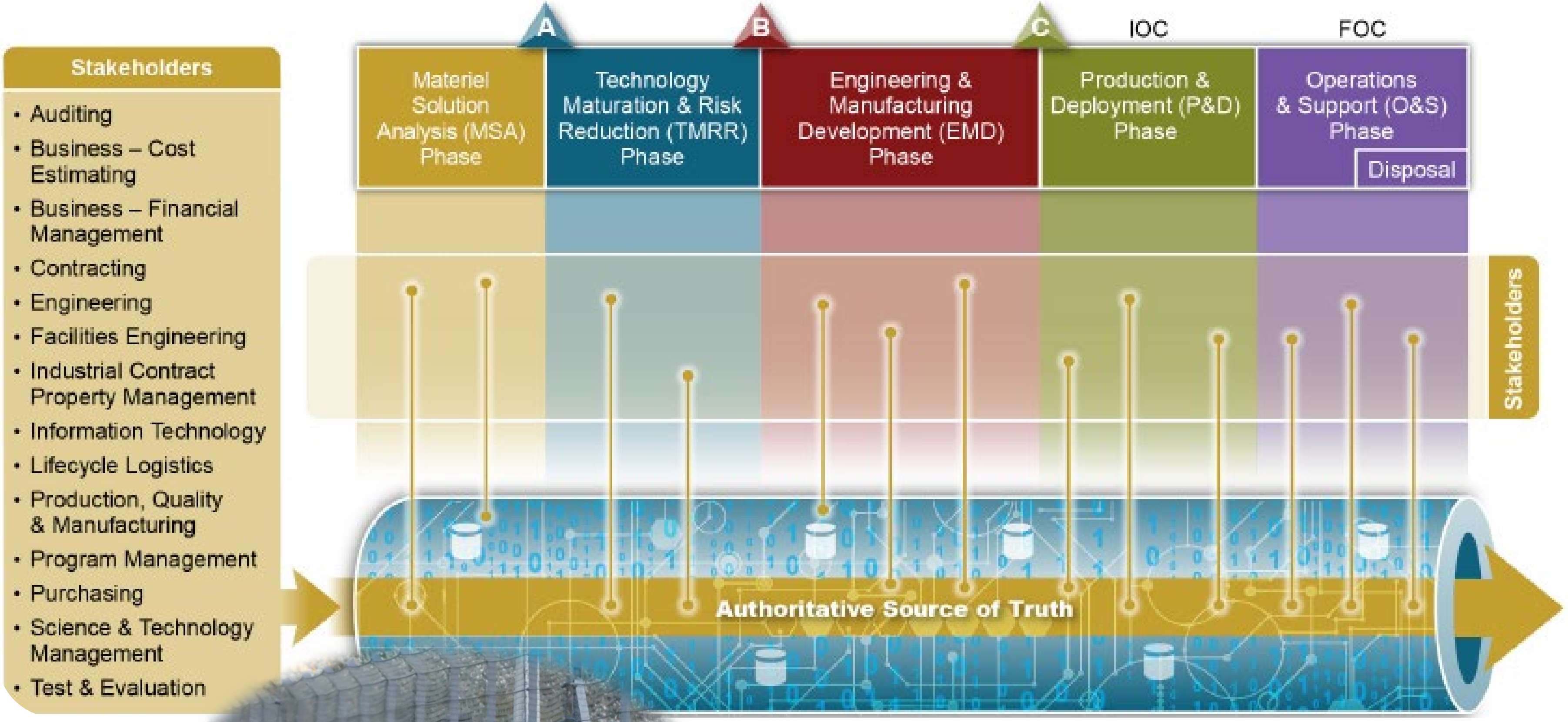


Image Credit: US Department of Defense, 2018

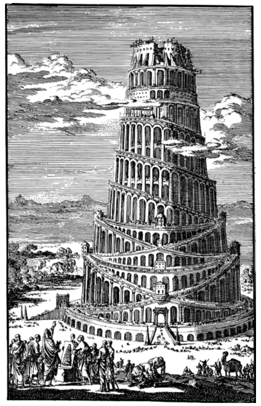
Photo Credit: Steffen Prößdorf

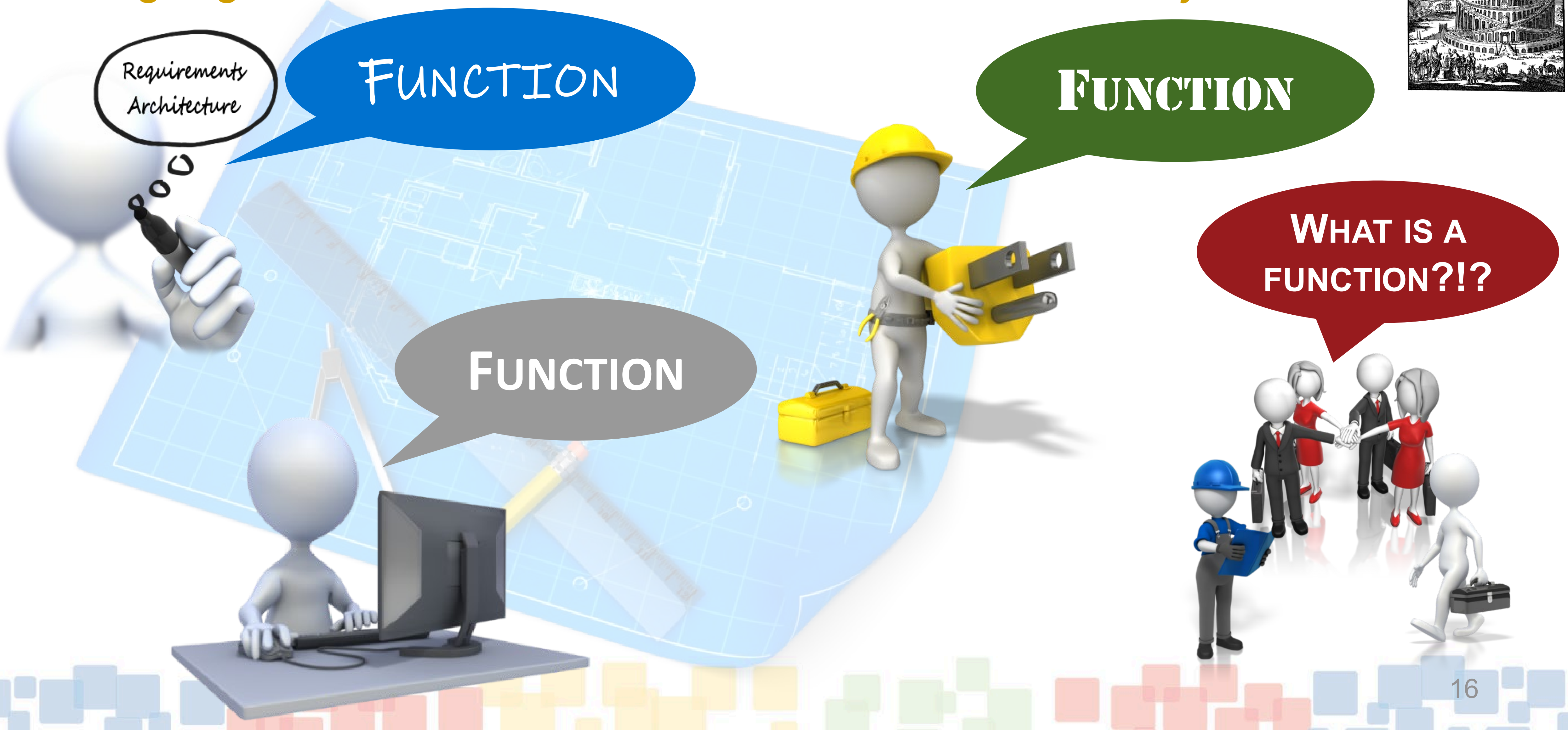
An integrated approach using authoritative data and models as a continuum across disciplines and across the lifecycle

US Department of Defense
Digital Engineering Strategy

Avoiding a Critical Trap

Languages, Notations, and Concerns across the Lifecycle





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

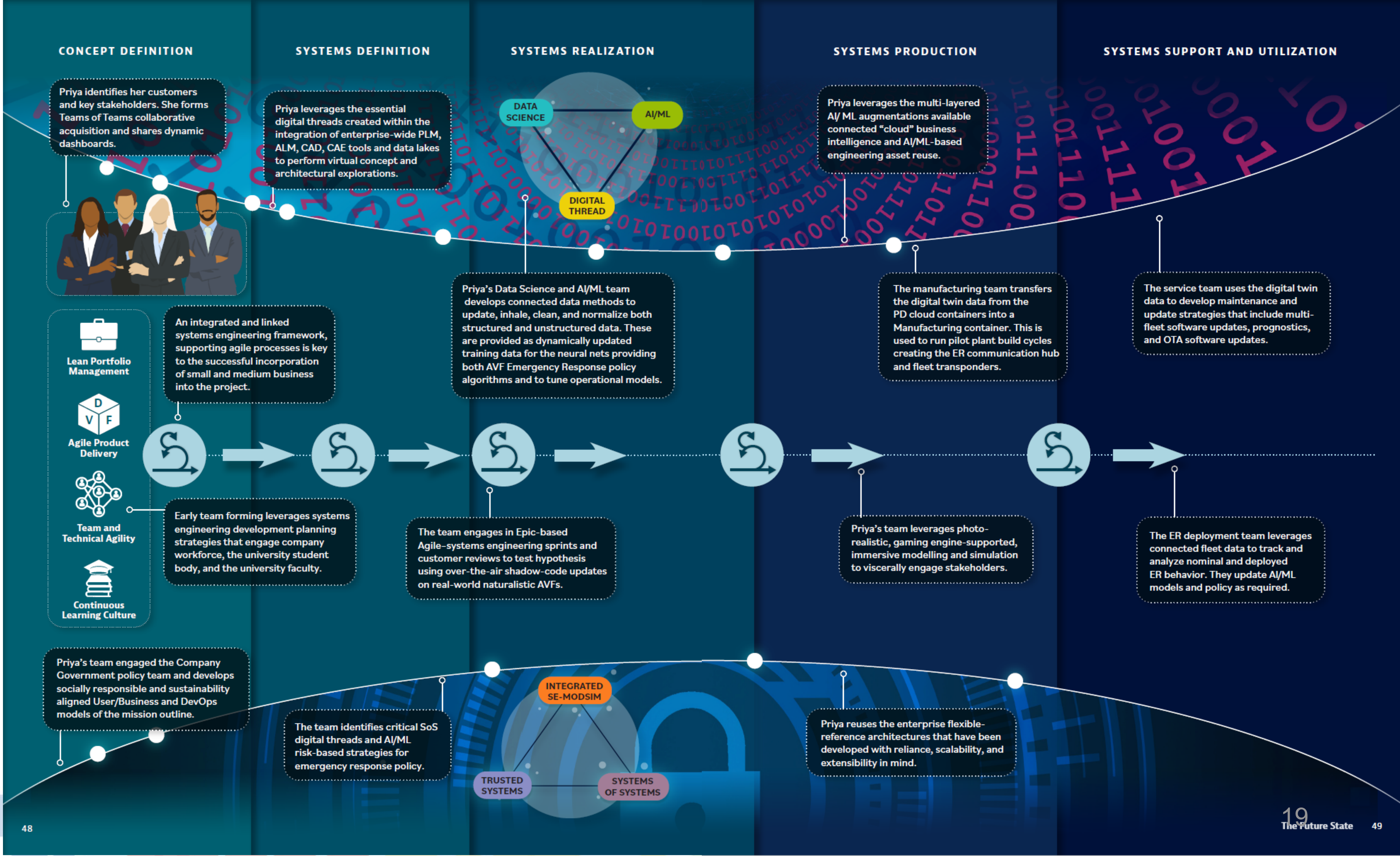
Systems Engineering

technical connective tissue of the project team

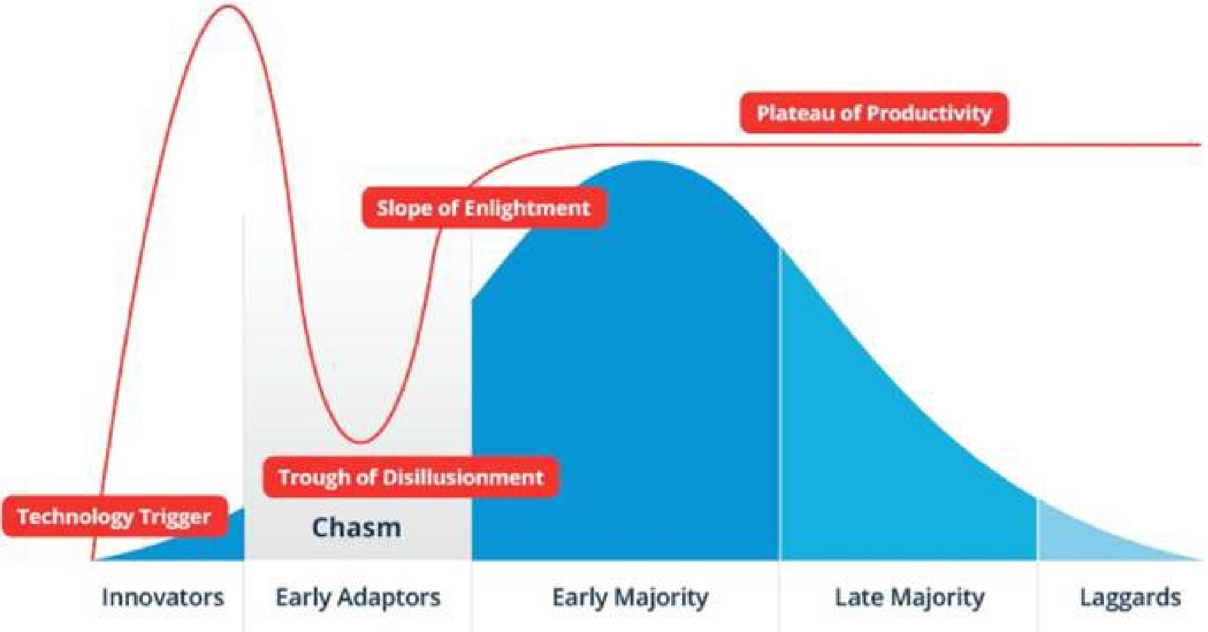
Data

oxygen fueling 21st century engineering and operations

A Day in the Life (SE Vision 2035)



Looking beyond Marketing Hype
Assessing and Benchmarking Capability



Solution	(1) Initial	(2) Managed	(3) Defined	(4) Qualitative	(5) Optimizing
Product engineering	**Uncontrolled**	**Controlled Documents**	**Isolated models**	**Enterprise Integration**	**Continous Engineering**
System Architecture Modeling *Product architecture definition*	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 *PLE/Configuration/Variation*	None	Variation documents & spreadsheets	Disconnected variation rules	PLM Integrated variation rules	PLM variation definition drive architecture decisions
Reliability & System Safety Analysis *Technical Risk (RAMS)*	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, continous risk assessment, alarms, dashboards..
Cross domain services					
System Definition & Design Integration *Logical modeling & Interface mgmt*	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
Integrated services					
Feature Engineering *Feature/Functional Modeling*	Feature/Functional description docs	Functional hierarchy	Isolated functional behavior models	Integrated fine-grained functional modeling	Functional arch with allocations & traceability
Parameter/Target Mgmt *Characteristic/Targets/TPM*	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 & suspicion mgmt	Complete PLM configuration with models, parameters, history,...	Cross-project level reuse, starting point for next project
Content Management					
Requirements Analysis *Requirements engineering & mgmt*	Uncontrolled spreadsheets & docs	Managed requirements docs	Disconnected RM tools with exchange	Integrated requirements & traceability inside PLM	Continouous compliance thru connected, configured, cross-domain traceability & reuse
Behavior Model Management System, performance, et al simulation	Uncontrolled models on desktops	Version controlled models	SE artifacts linked into models	Integrated model & product configuration with simulation	Continuous, focused simulation & multi-domain ..., dash boards
Verification Management & Governance *Product Test/V&V*	Document-based test procedures	Managed test cases	SE artifacts linked to test	Devops-like V&... simulation	... focused testing, ...s, model swap out
Physcial Design Management *CAD, CAE,.. control/mgmt*	Unmanaged CAx models	PDM controlled CAx	SE artifacts linked into CAD	Cross-domain fine-grained PLM integration	Continuous physical design verification (Digital Twin)

You are here

Best Auto (best case)

Best Aero (best case)

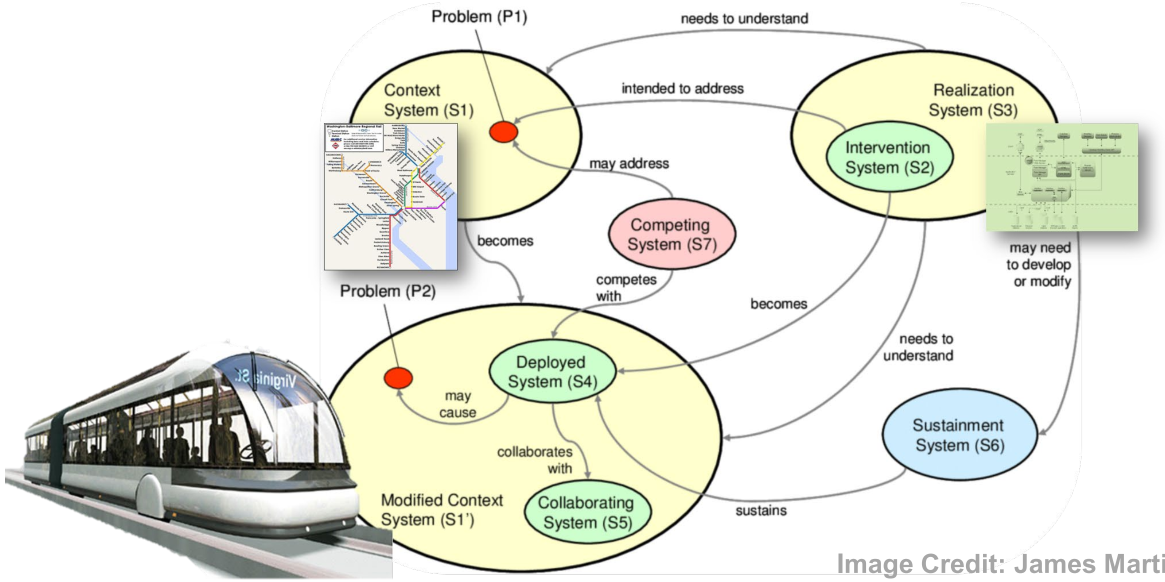


Image Credit: James Martin, Seven Samurai Framework

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).

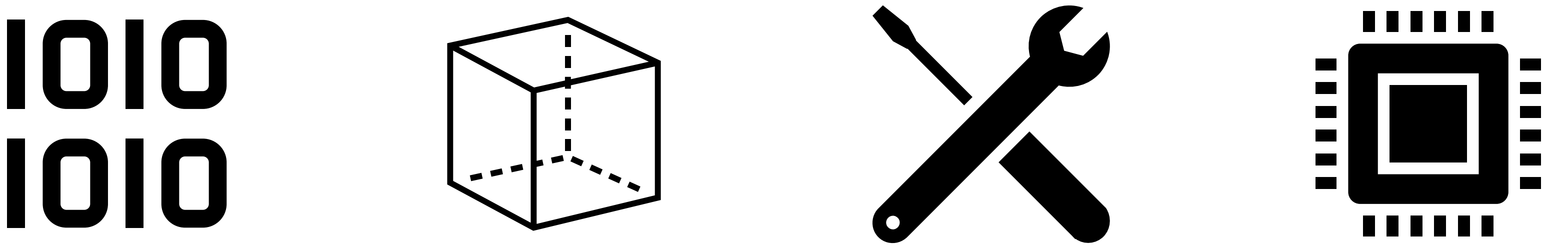
Digital Transformation
True transition from document-based acquisition to digital acquisition and engineering.

Hutchison et al. (2022)

Appreciating the Full Scope

Dependencies and Interactions thru Life

TECHNICAL



SOCIO

MANAGEMENT • CURATION • IP • ACCESS • SECURITY • EFFECTIVITY

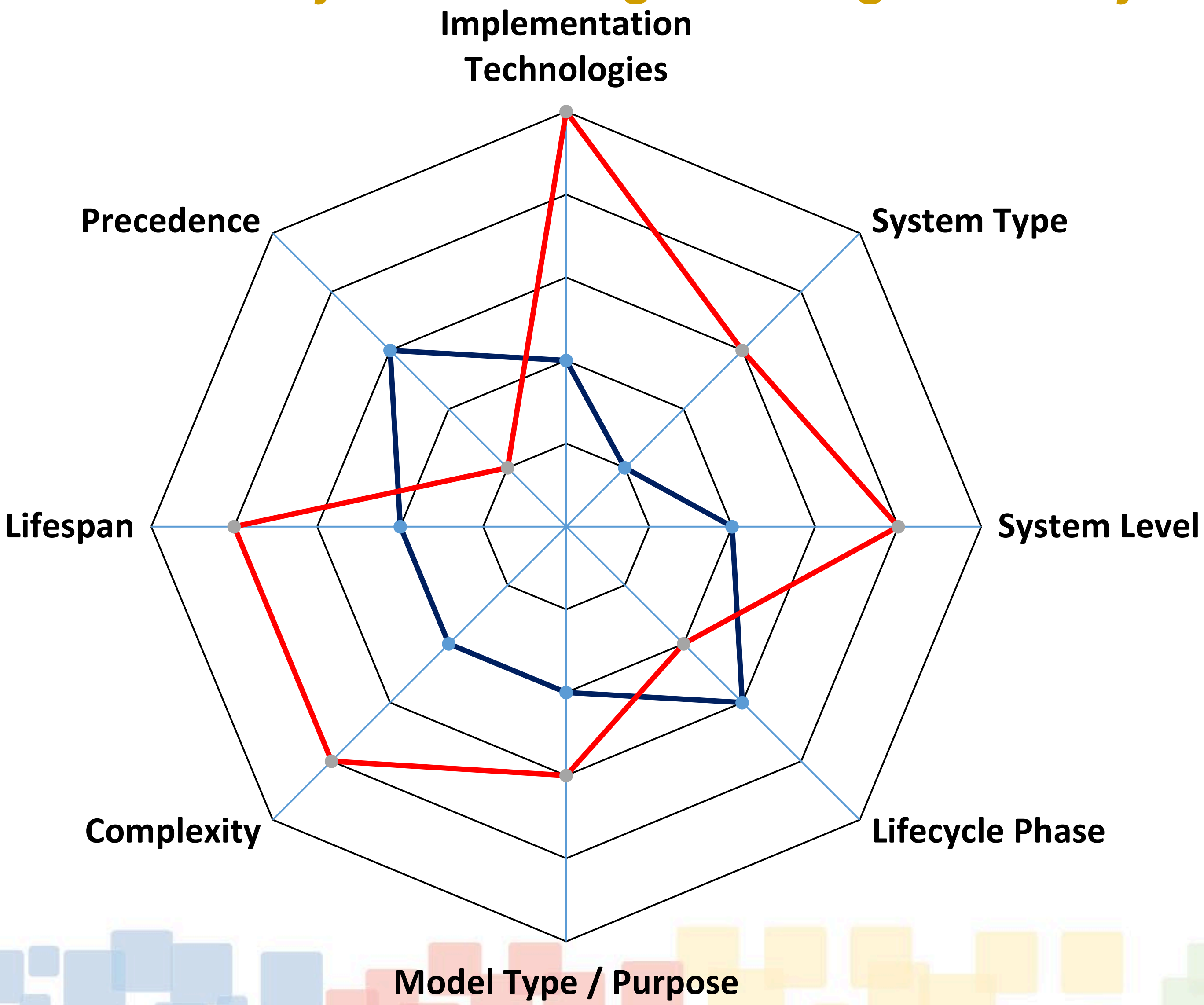
Identifying Traps

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

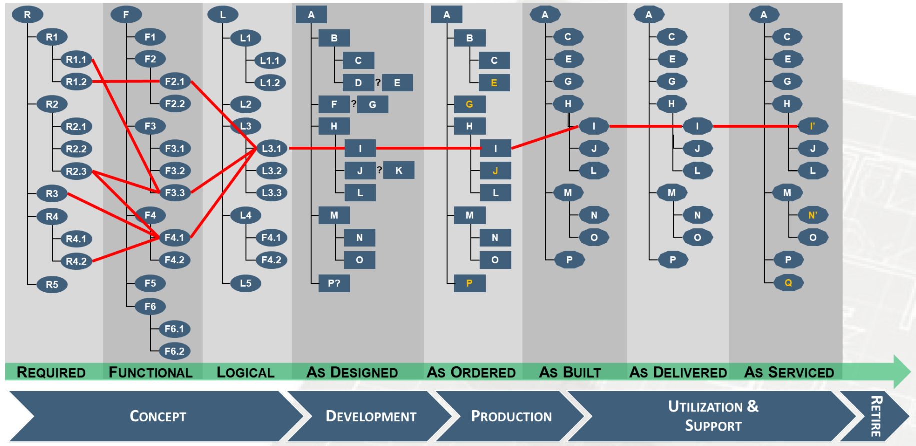
Begin with Your End in Mind

Good Systems Engineering is Always Fit-for-Purpose

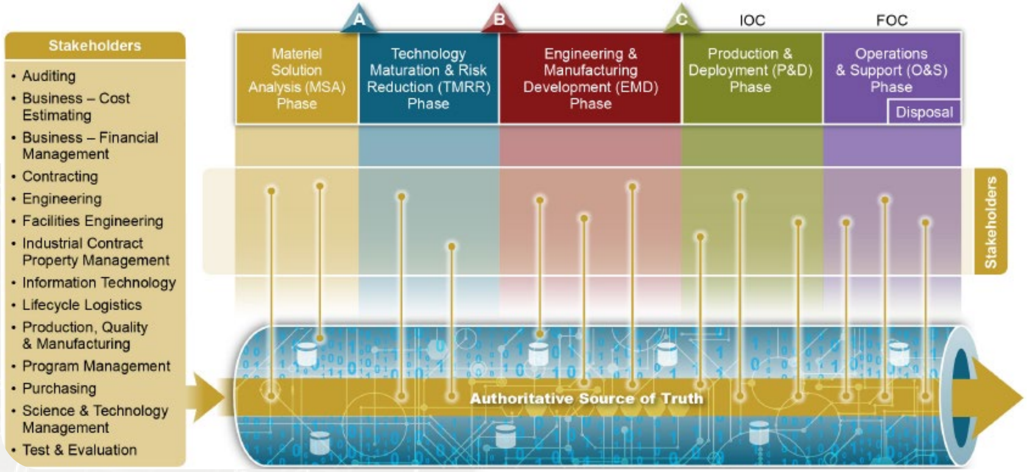


Define Your Reach for Dx

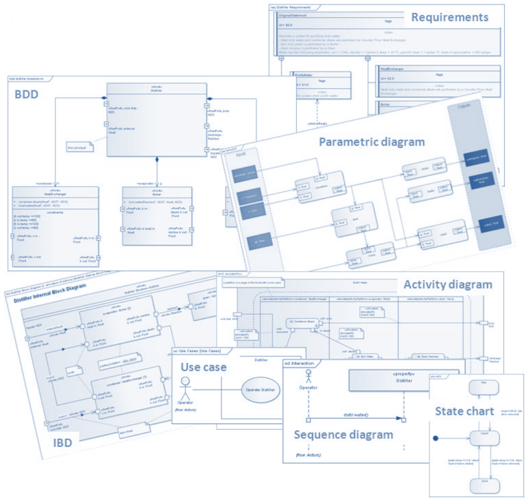
Where You Need to Be not Want to Be – SE, EoS, or Beyond?



Adapted from Aras Corporation, 2018



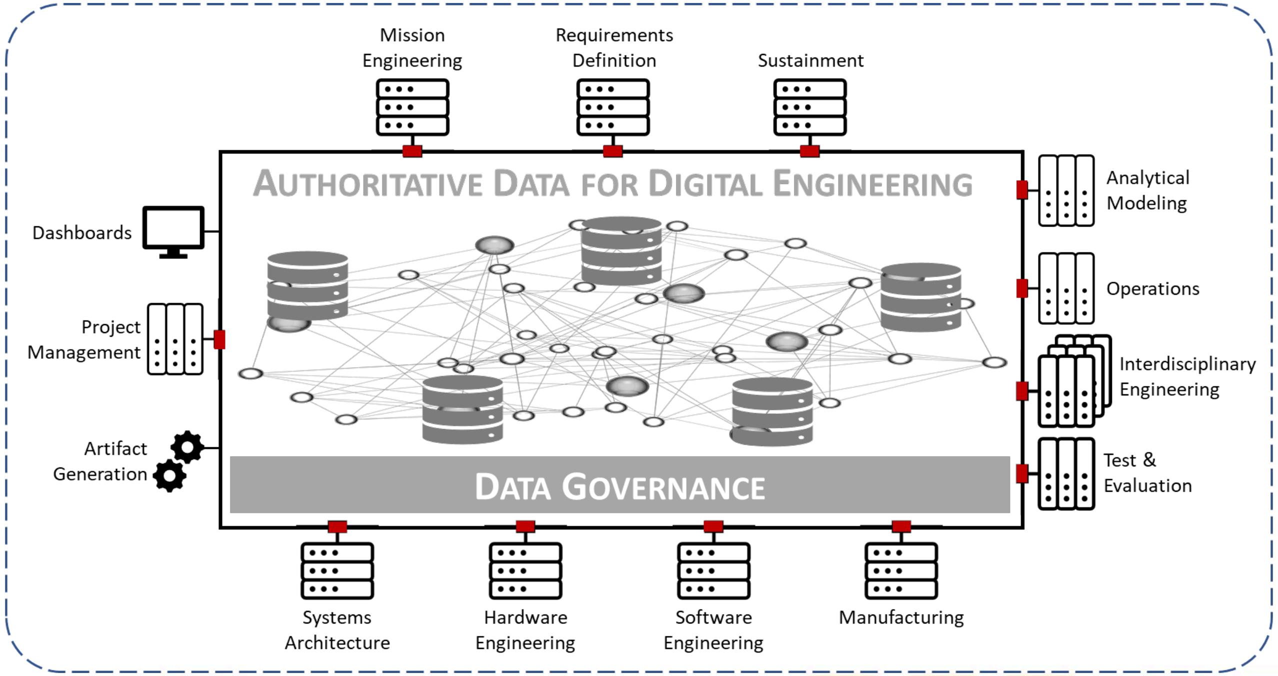
Credit: US Department of Defense, 2018

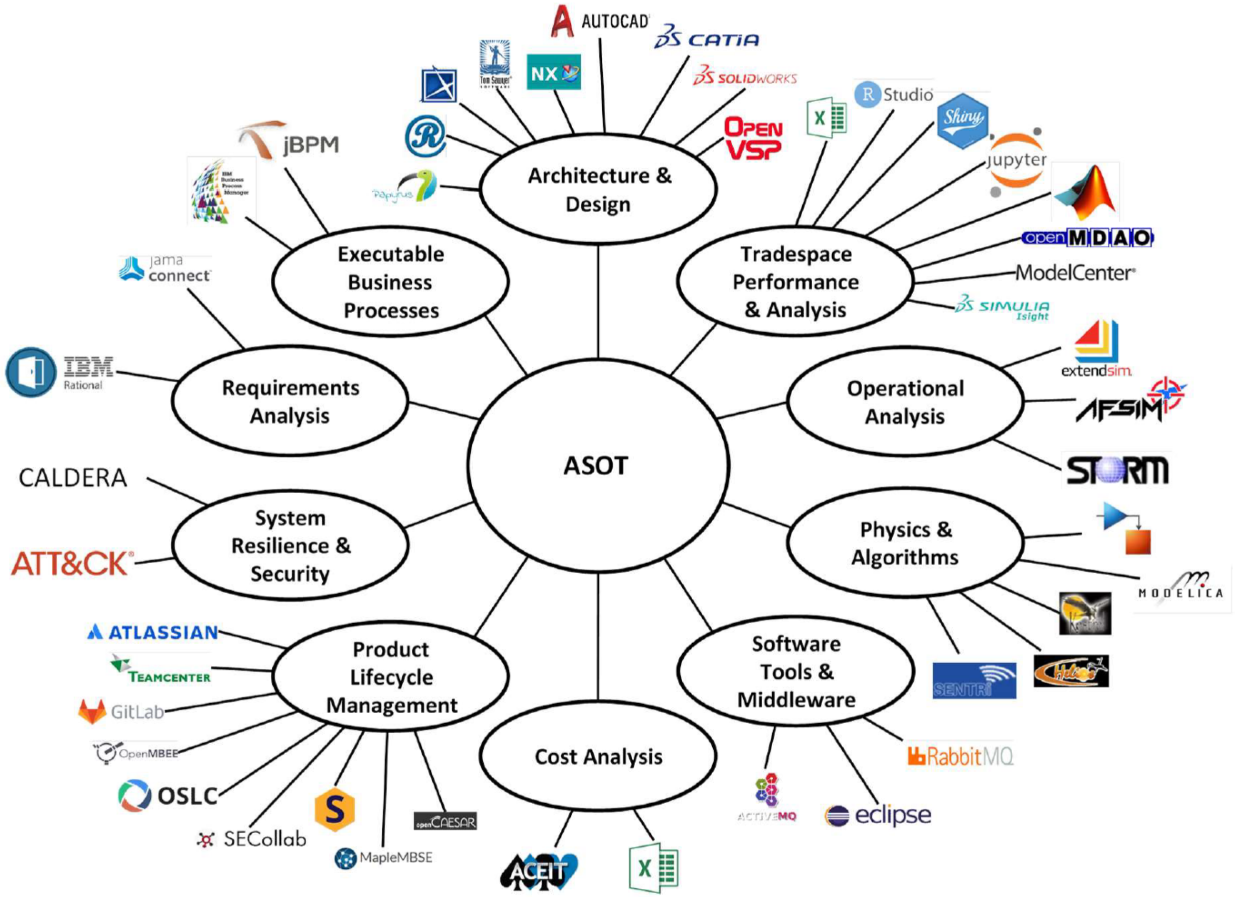


Credit: Sumit Awinash, Creative Commons 4.0

Appreciate and Honor Your Scope

Neither Benefit nor Difficulty Increase Linearly

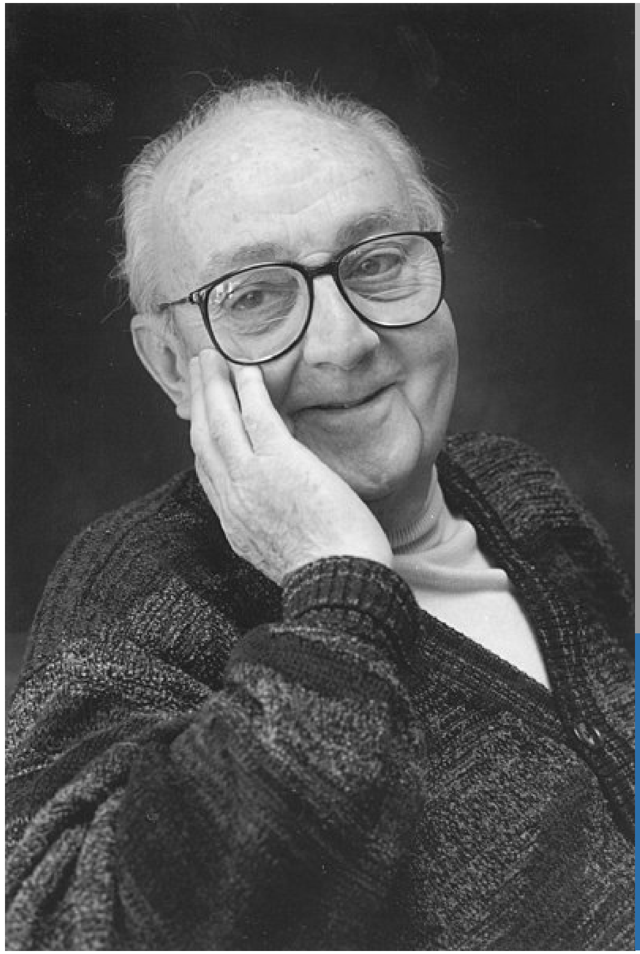




Credit: WRT-1051, Program Managers Guide to Digital and Agile Systems Engineering Process Transformation, August 2022

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

703.304.4425
david.long@incose.net