Model Based Engineering: MBSE Session

The Convergence Of And The Emerging Necessity Of Both Model-Based Engineering And Model-Based Systems Engineering

April 27, 2021

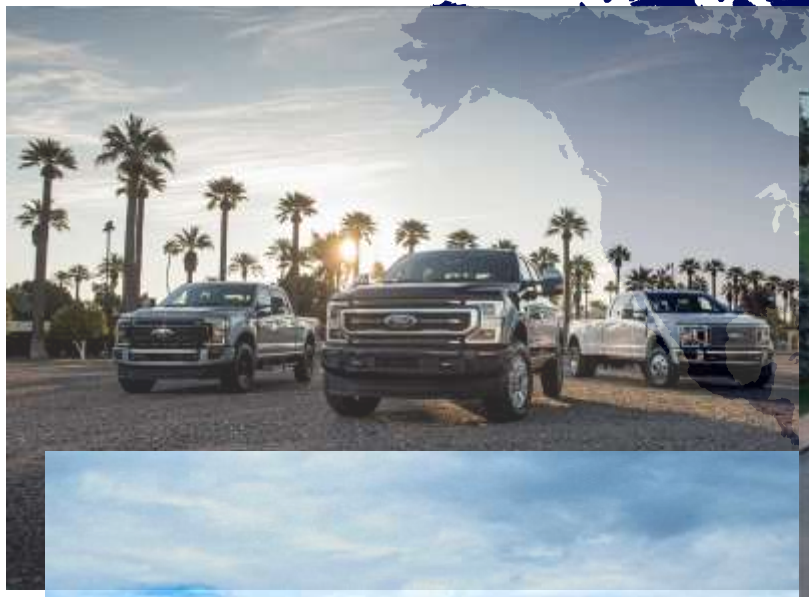
J. Robert Wirthlin, PhD

Systems Engineering Senior Technical Leader

Dr. Robert Wirthlin - Biography

- 27-year career in Systems Engineering (DoD, Academia, GM, Ford)
- Ford Senior Technical Leader for Systems Engineering and Global Corporate Systems Engineering POV Owner
  - Methods and Process
  - SE Training – Curriculum and Instruction
  - External Liaison and Benchmarking
  - MBSE Descriptive modeling
- Member of INCOSE, AIAA, SAE
- BS, US Air Force Academy; MS & PhD, MIT
- Certified Systems Engineering Professional

Worldwide Presence & Broad Product Portfolio



North America South America Europe China International Markets Group

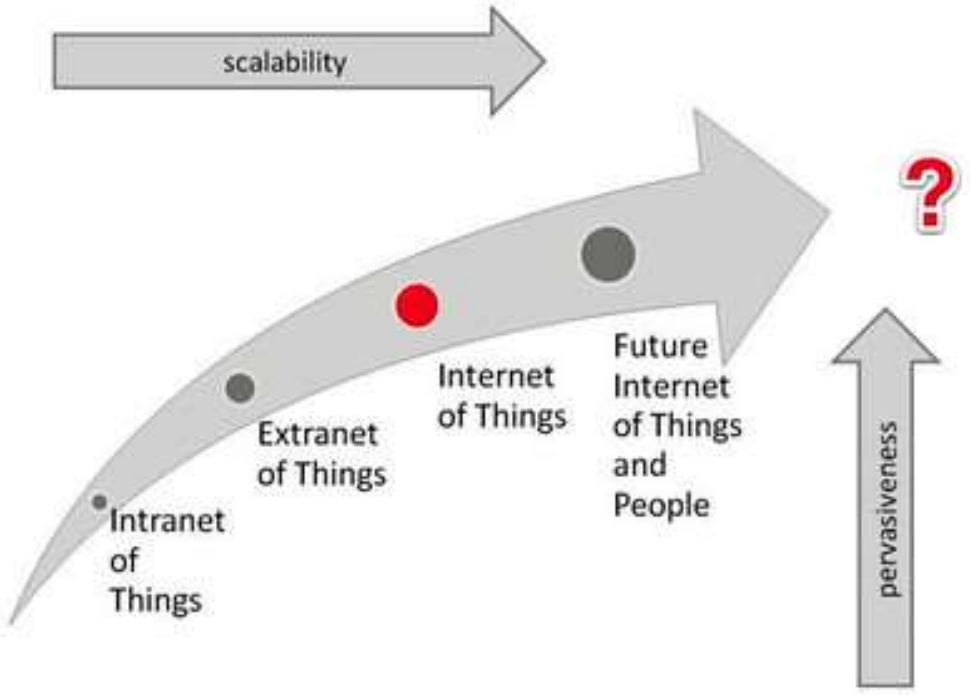
Market And Product Pressures

- Time-to-market is essential in today's business climate

- Consumers expect innovative products with new and exciting features

- Quality and Safety are non-negotiable
  - » Warranty and Recall expenses are expensive

Information Is Increasing - Explosion Of Connected Content



- Connectivity
- "Instant-on" / Persistence
- Cloud-based computing

2.5 quintillion bytes of data created every day (2019)
(a *quintillion* is a 1 followed by 18 zeros...)
https://iorgforum.org/case-study/some-amazing-statistics-about-online-data-creation-and-growth-rates/

The Product Development Environment Is Being Squeezed – Faster, Better, Cheaper Demanded

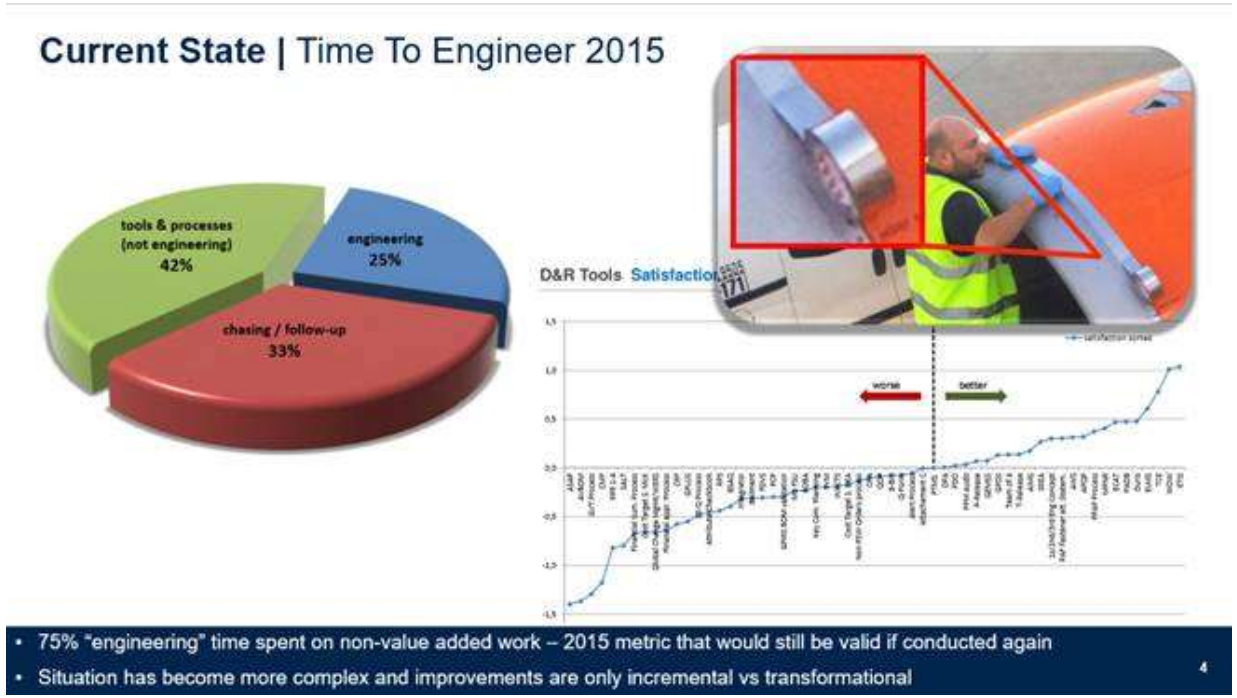
- Time-to-market pressures increasing
- What is the objective?
  - Decrease mistakes? / Increase quality?
- Reduce Cost?

- Continuous Improvement “Buzz”
  - “More” Process – yet “simplified”
  - “Easier” Tools – yet “robust” for more complex and complicated products
  - Additional Key Skills & Attributes needed – Engineer’s training demands increase

Do More With Less – OR – Faster, Better, Cheaper: Pick Two Of The Three

Where Are Engineers Spending Their Time?

- Many claims are out there - 50%-80% of engineer's time is non-value add; some are based on data others are conjecture
- One data-based claim: engineers spend up to 75% of their time NOT doing engineering
  - 42%: tools & process
  - 33%: Chasing / follow-up
    - » With more information being created every day, the more difficult it will be to find what is needed
    - » Lack of information at the right place and time to the right people in order to make the right decisions



Reduce The Time To Find Information, Spend More Time Engineering

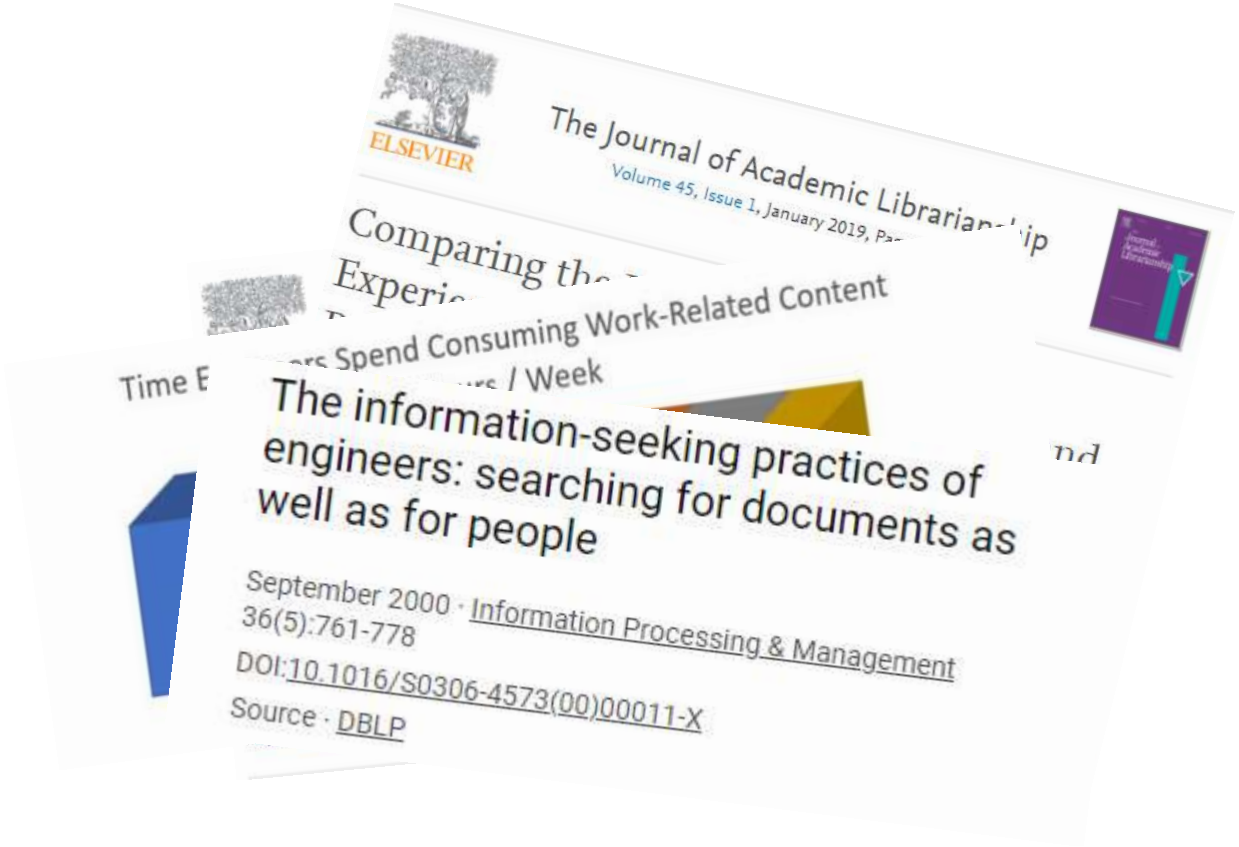
Where Design Engineers Spend/Waste Their Time (1993)

"The survey indicated that engineers spend about 13 % of their time in information gathering, 30% problem solving and thinking, 21% documenting their work, 8% planning their work, 8% negotiating requirements, 18% supporting and consulting and 2% doing other thing such as downtime, administrative functions and expediting."

"The frustrations they encounter are many, and they rank their activities from highest to lowest level of frustration as follows: 1-Information Gathering, 2-Documentation, 3-Planning, 4-Negotiation, 5-Support and Consulting, 6-Problem Solving & Thinking, and 7-any other activities."

R. A. Crabtree, N. K. Baid, M. S. Fox, Department of Industrial Engineering University of Toronto, Ontario, Canada

Small Sample – Engineers, Work Habits, Information Consumption



This Will Continue To Be A Strong And Fruitful Area Of Research.

The Information-seeking Practices Of Engineers: Searching For Documents As Well As For People

- **"…engineers search for documents to find people, search for people to get documents, and interact socially to get information…**
- This ... interplay between document and people sources can be explained by the nature of the design task. Many possible solutions are normally available … and in choosing one over the others the designer must take into account a complex set of issues involving both the product as such and its context…**design documentation seems to be biased toward technical aspects of the chosen solution, while information about the context of the design process is typically not available**.
- We propose … a model involving two dimensions–stakeholder domains and **levels of abstraction**–and hypothesize that **design documentation is strongly biased toward technical descriptions of the resulting product** ... This leaves it **largely undocumented how the various goals and constraints involved in the design were transformed into a product** and thus makes it necessary to get into contact with a person who was involved in the project to subsequently understand and learn from the design process … **one important factor in engineers' choice of written versus oral information sources seems to be that while concrete product information can be found in documents, context information must be obtained from people."**

Hertzum, Morten & Pejtersen, Annelise. (2000). The information-seeking practices of engineers: searching for documents as well as for people. Information Processing & Management. 36. 761-778. 10.1016/S0306-4573(00)00011-X.

Where Design Engineers Spend/Waste Their Time (cont).

In order to solve these problems, some fundamental research issues have to be addressed.

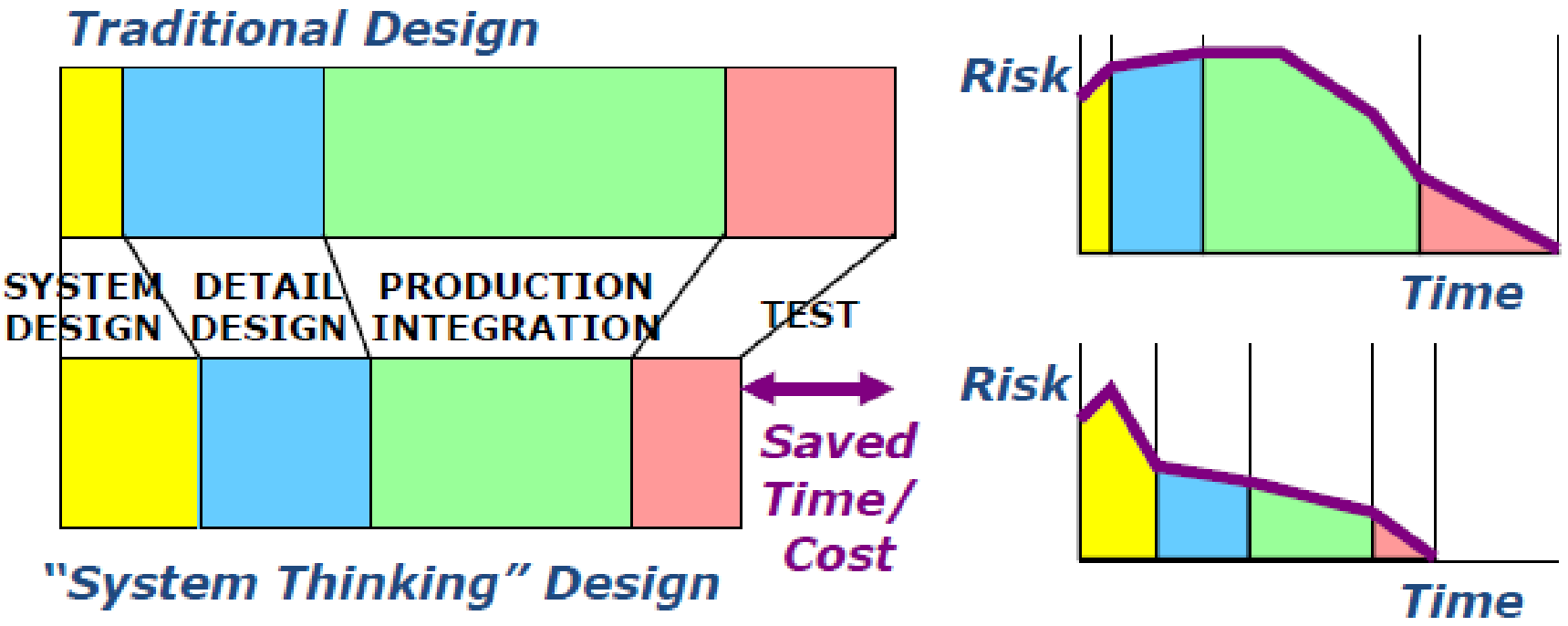
- First…**capturing design rationale is a particularly difficult task.**
- Second, access to information is impeded by …the **lack of integration among the various programs and systems** that the organizations use.
- Third, **capturing and distributing expertise** is possible … but the cost of acquisition and its continued maintenance is still too great to be of much use…
- Fourth, **decision interdependence requires a method of modelling and managing the inter-dependencies**.
- Fifth, activity management technologies abound, e.g., project management systems, but **the engineering of usable system that adds value to the process still remains beyond our grasp.**
- And sixth, **access to people and systems remains a problem**, but is being reduced with current communication technologies …

R. A. Crabtree, N. K. Baid, M. S. Fox, Department of Industrial Engineering University of Toronto, Ontario, Canada

"Solutions Will Arise When We Realize That They Have To Be System Solutions, Where The System Is Redesigned As An Integration Of People, Procedures And Technologies."

Heuristic Claims Of Systems Engineering

- Save time *and* cost

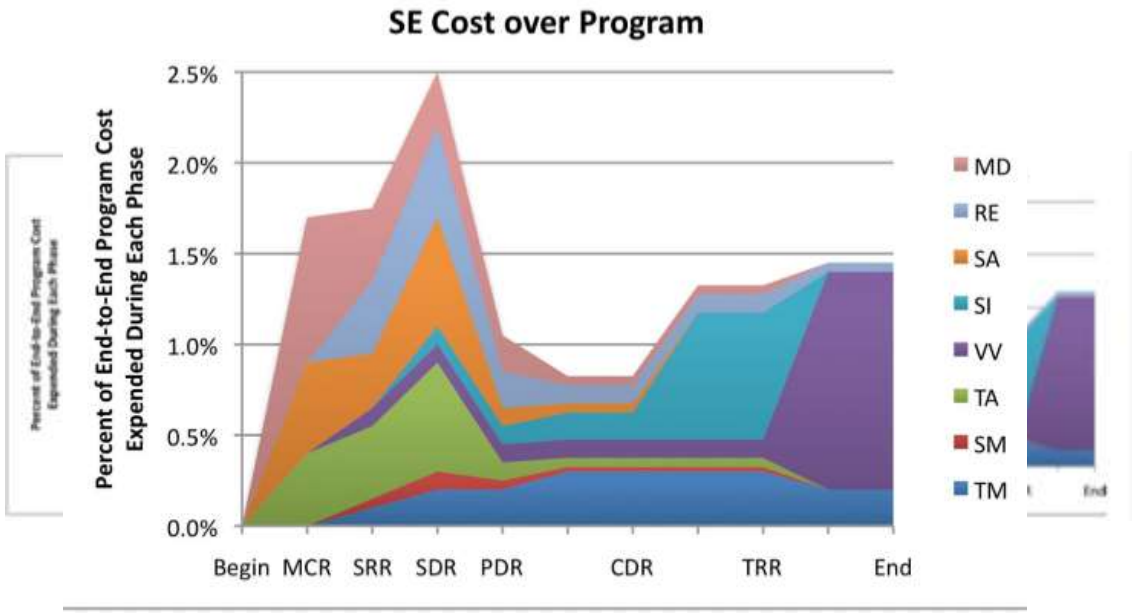


Honour, EC, Systems Engineering Return on Investment, PhD Thesis, Univ South Australia 2013

But How?

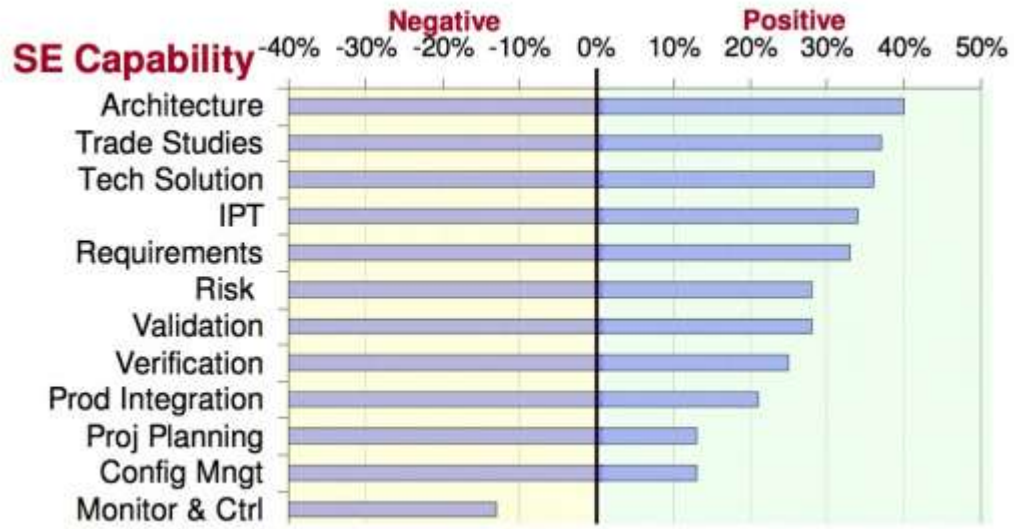
A Closer Look At SE Activity

- SE Activity Breakout By Success



Honour, EC, Systems Engineering Return on Investment, PhD Thesis, Univ South Australia 2013

- SE Capabilities Correlate With Performance / Success



Elm, A Survey of Systems Engineering Effectiveness, NDIA, CMU/SEI 2007

Key Mix Of Early SE Activities; Functional Analysis, Architecting, Technical Analysis Have The Greatest Correlation With Success

This Is An Engineer. He And Most Other Engineers Don't Love…

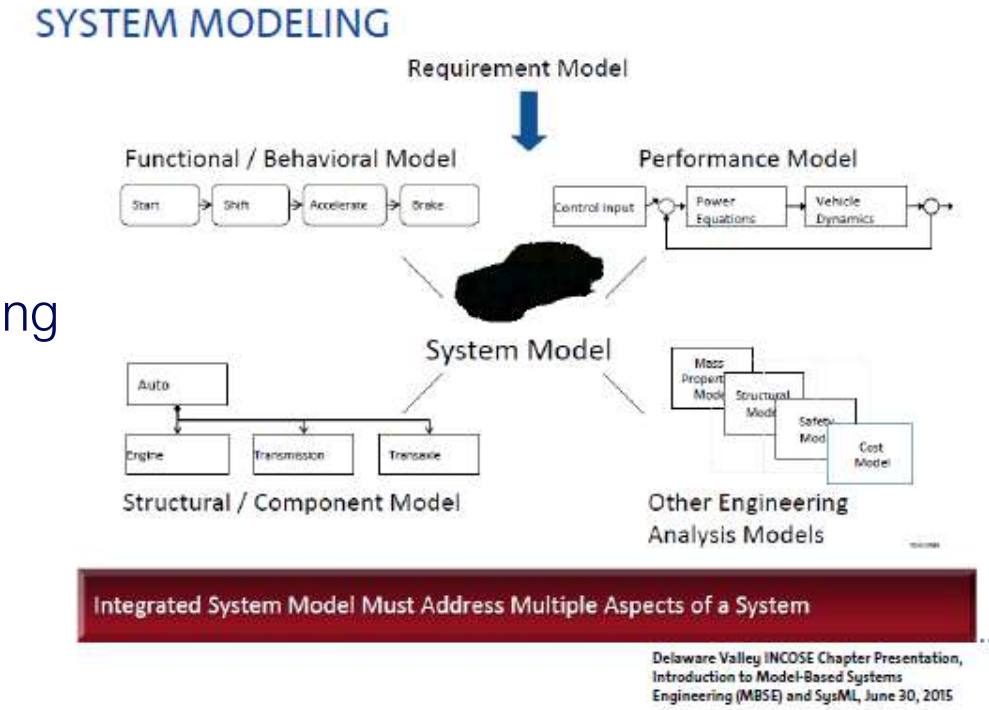
- Writing/Managing Requirements
- Updating FMEAs and P-Diagrams in right formats, to check the box
- Mining / manipulating data to update status reports
- Maintaining traceability
- (Re)Formatting documents

Can A Systems Engineering Based Modeling Approach Address These And Other Non-"Loved", Seemingly Non-Value-Added Activities?

Model-based Systems Engineering – Coming Of Age?

The core of MBSE methodology is a System Model representing the decomposition structure of the engineered system (functional, logical, physical) and the relationships between engineering information and entities

- Requirement elicitation, allocation and traceability
- Enables Functional modeling – including operational, functional, and logical analysis
- Enables Physical modeling – based on mathematical modeling of systems and numerical analysis
- Interoperability of models – with heterogeneous simulation techniques
- Preliminary description of verification and validation of the systems
- Frames strategic issues between design and production



Adapted from: Systems Engineering and its Application to Industrial Product Development

One PLM Vendor Said, "There Are Three Foundational Concepts Which Are Inseparable: Parameterized Requirements, Systems Architectures, And Pervasive Simulations Everywhere."

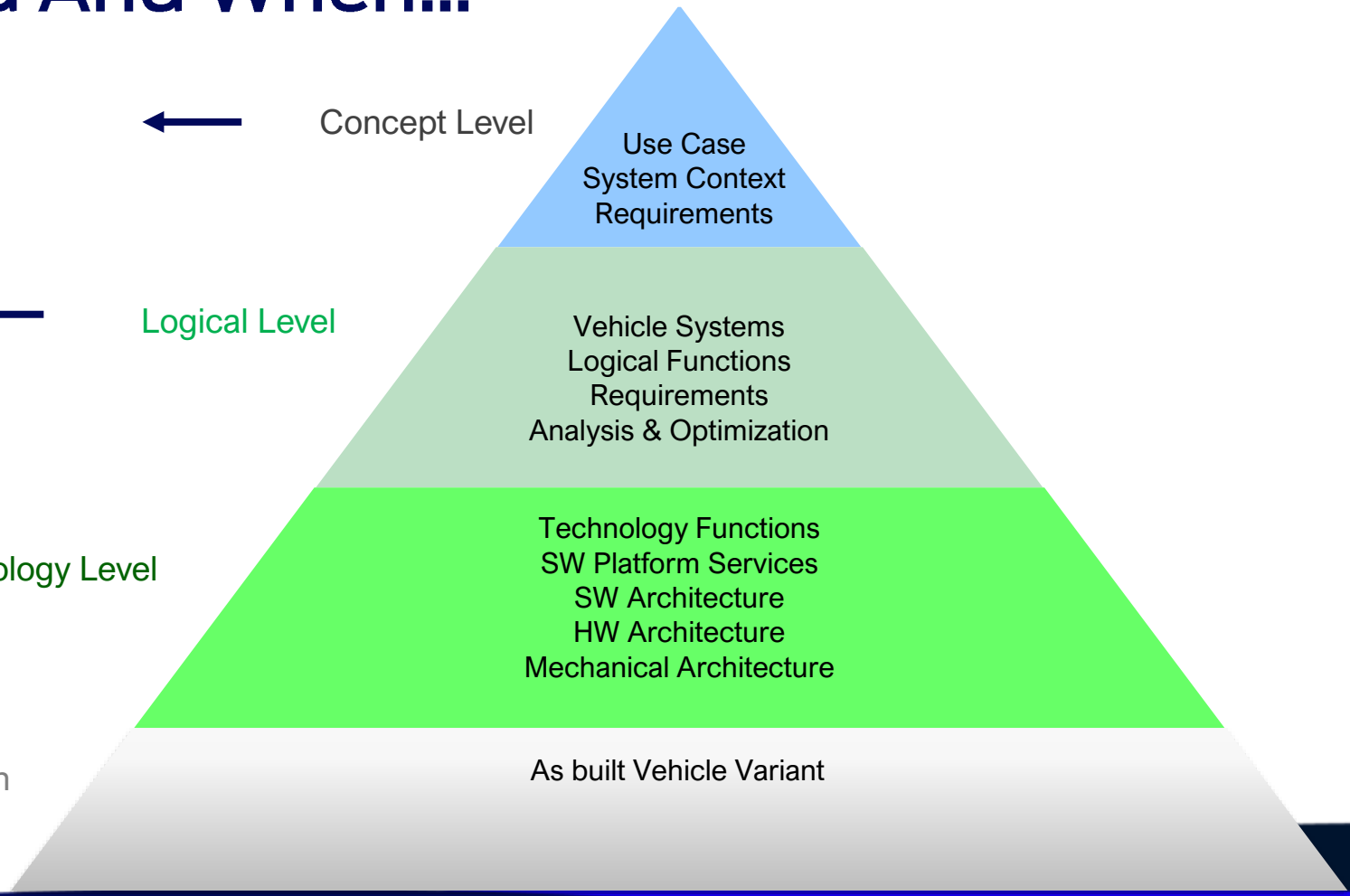
Architecture Abstraction Levels – What Kind Of **Questions Are Answered And When…**

What problem is being solved ← Concept Level

How is problem solved agnostic of technical choices ← Logical Level

How is problem solved specific to technical choices ← Technology Level

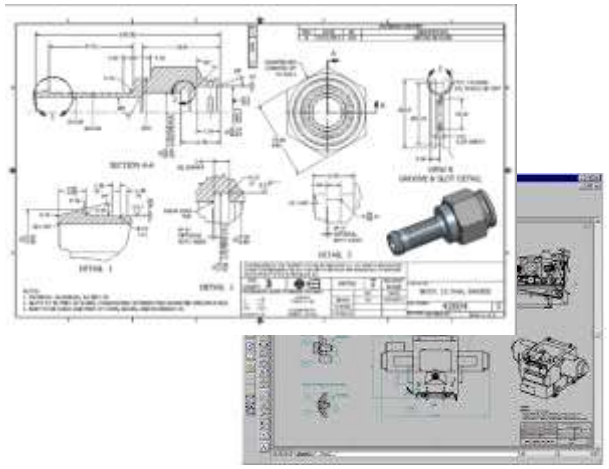
What is the Built artifact ← Implementation Level



Architecture: The fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution. (ISO/IEC/IEEE 42010:2011)

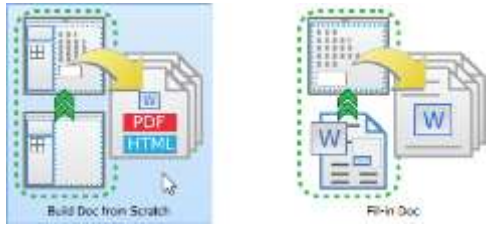
Documents to Models - Another Paradigm Shift Underway

Drafting to CAD

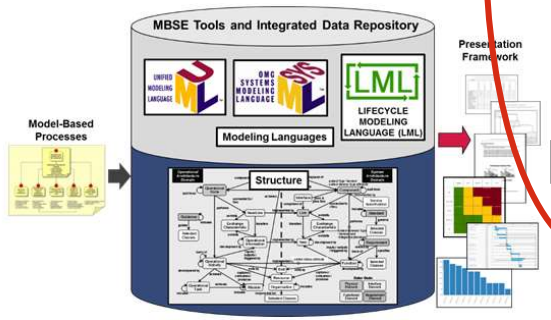


Math-based analytical models
Incl. CAE/Simulation

Requirements to models

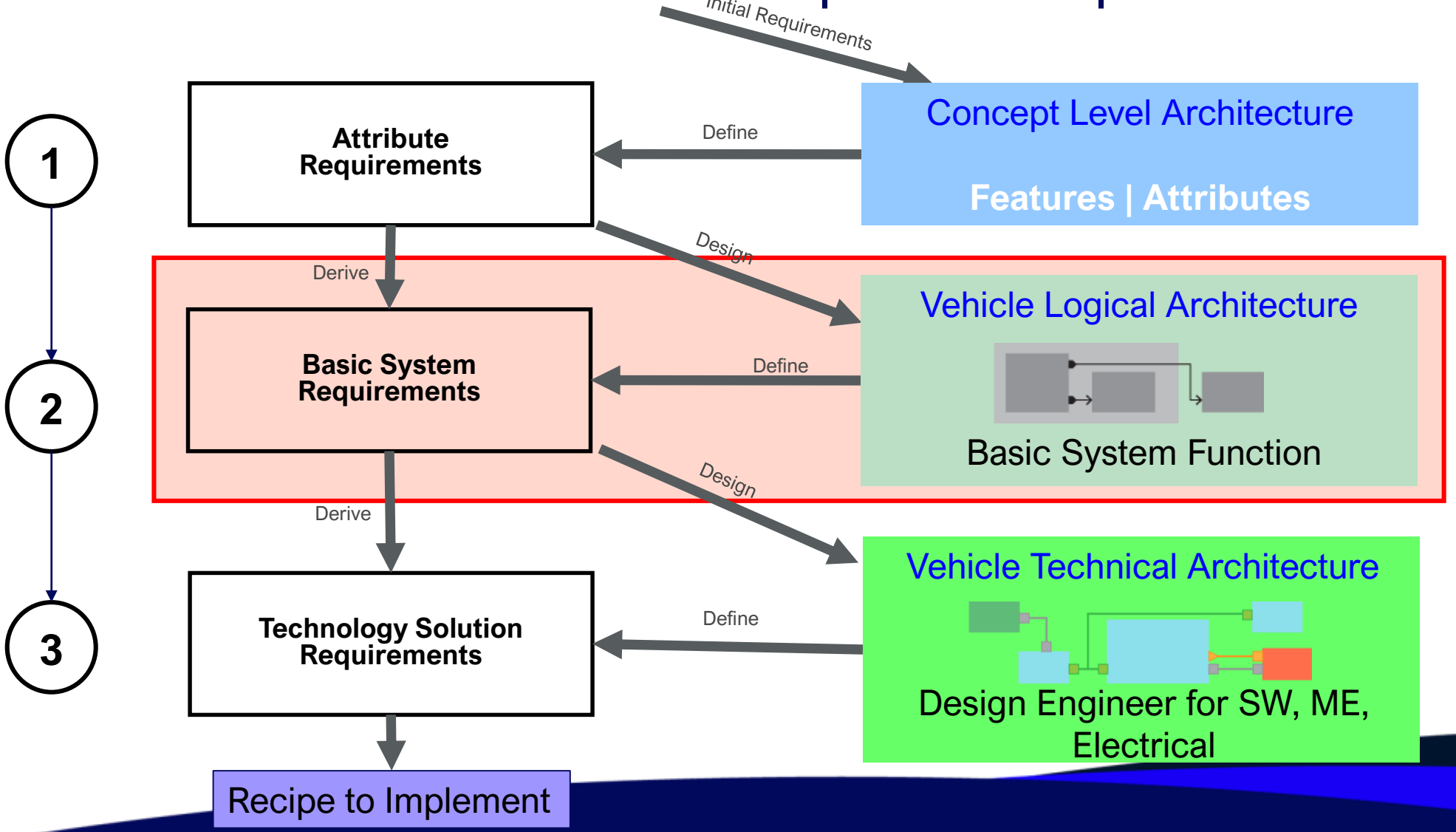


Machine-readable



Descriptive analytical models
Linked Data
Visualization methods
Informs math-based models

Architectural Path To A Recipe For Implementation



Describing *Basic Function* As Part Of An *Architecture* Important For Efficiency

What is Needed – “The Ford Requirement”

A de-centralized communication framework that allows a connected data flow and integrated view of the asset’s data throughout its lifecycle across traditionally siloed functional perspectives.

Data interoperability that is configuration aware, allows variation and change to be managed regardless of partitioning and contexts of data across multiple architecture approaches, e.g. web-apps to client-server

Addresses shortcomings of current data import-export, warehousing/aggregation, point-to-point integration approaches

Analysis and Simulation Tools that utilize authoritative sources of data, versatile enough to span architectural abstraction layers, agnostic to operating systems, and utilize linked-data and configuration aware frameworks

A Digital Thread Is Needed

Digital threads seek to *create homogeneity* **and simple** *universal access to data*. **They follow a single** *set of related data as it weaves in and out of business processes and functions* **to create continuity and accessibility.**

Most commonly, a digital thread of a product follows the lifecycle from design inception through engineering and product lifecycle management, to manufacturing instructions, supply chain management, and through to service histories and customer events. This thread enables enterprises to *anticipate and effectively communicate bi-directionally up and down stream of where the product is in its lifecycle*, **ensuring all participants utilize the most current data and can react quickly to changes or new insights.**

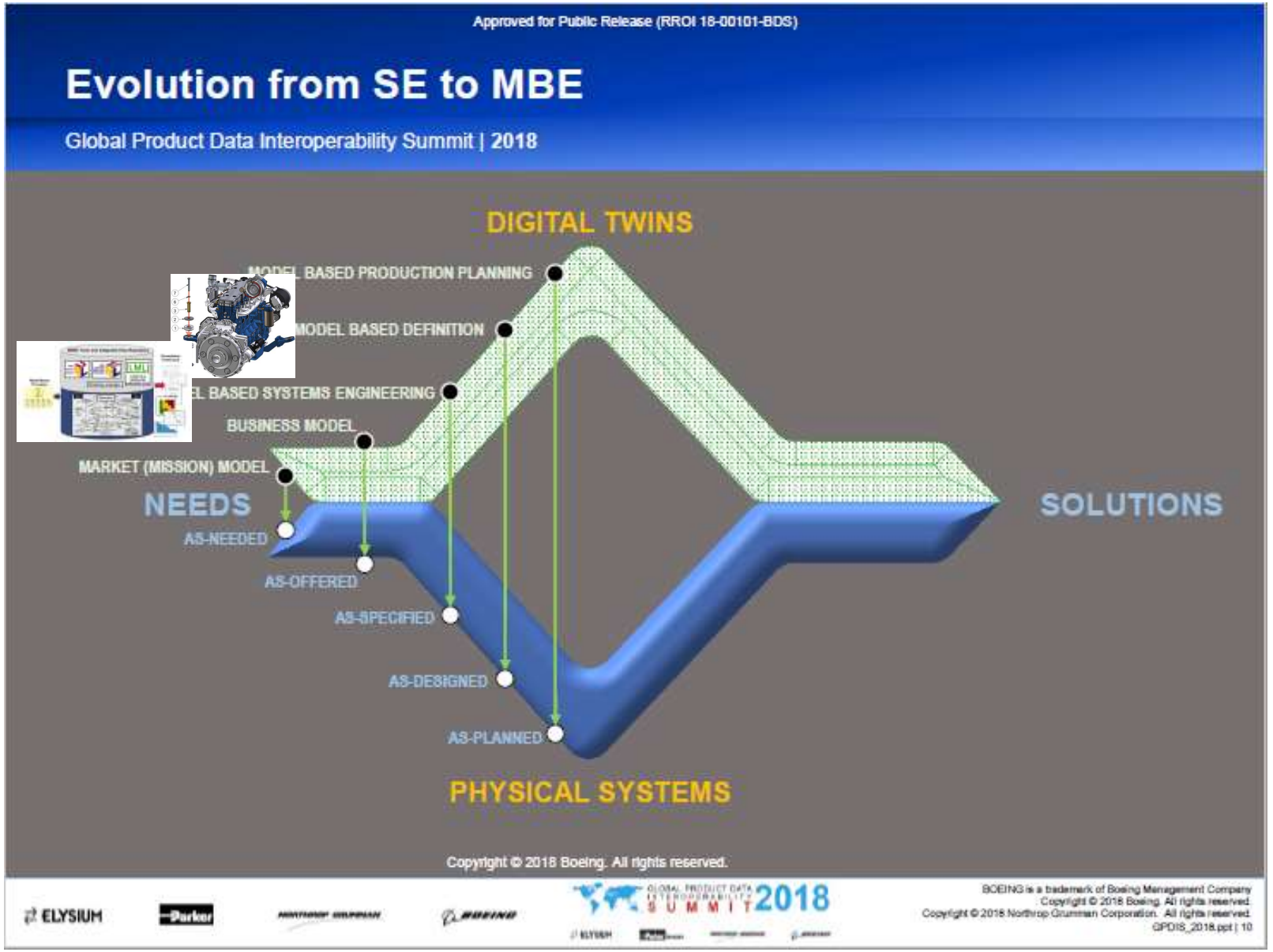
https://www.ptc.com/en/product-lifecycle-report/what-is-a-digital-thread

The digital thread is a critical component in the emergence of Industry 4.0.

https://nxrev.com/2018/05/digital-thread/

With A Digital **Thread In Place…**

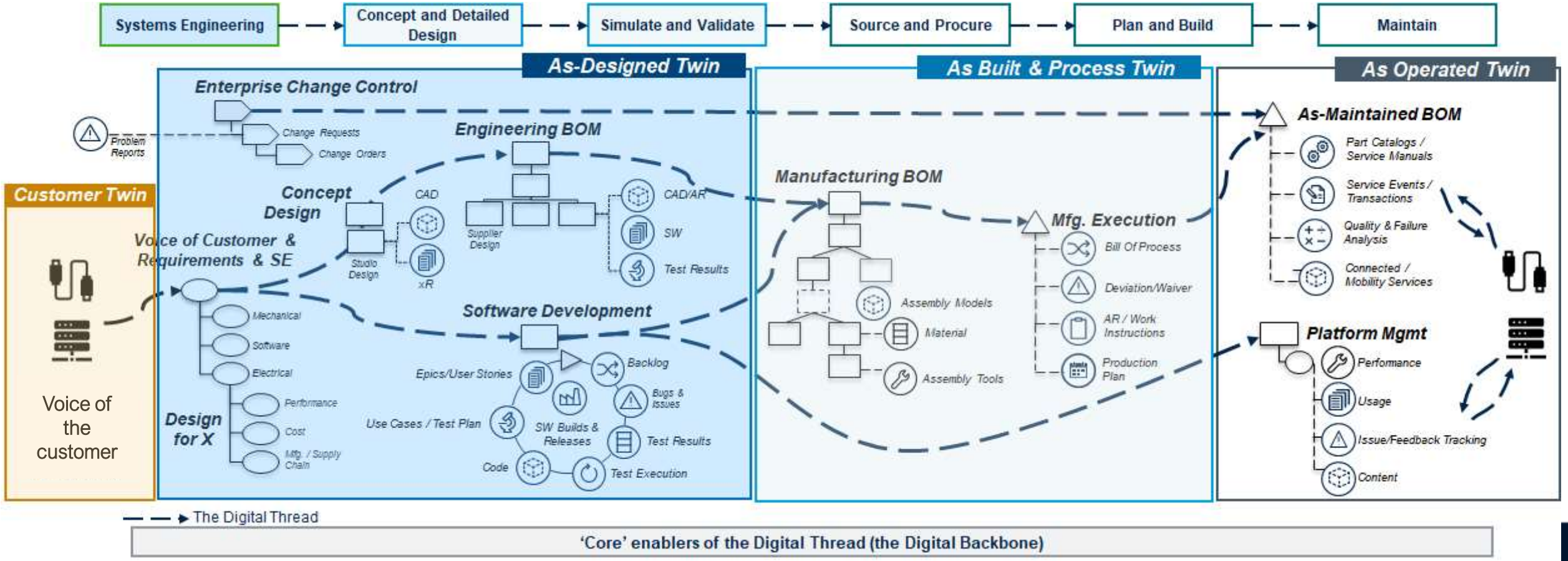
…Model Based System Engineering (MBSE) And Model Based Engineering (MBE) Are Not Rivals But Codependent For Accelerating Success And Minimizing Duplication.



Seal, Daniel. The System Engineering "V" – Is It Still Relevant In The Digital Age? GPDIS 2018

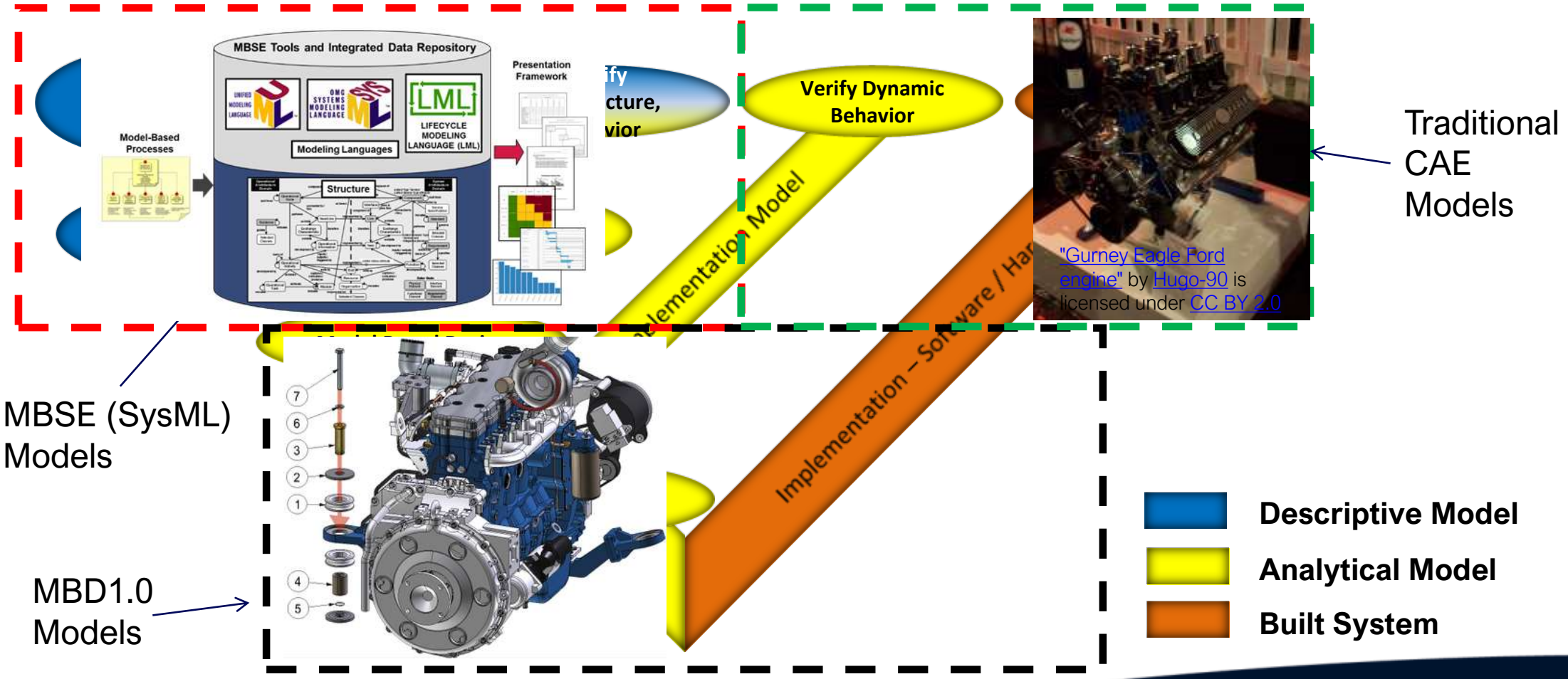
Digital Thread

"Digital Thread" comprised of digital twins that connect features to hardware and software throughout the lifecycle



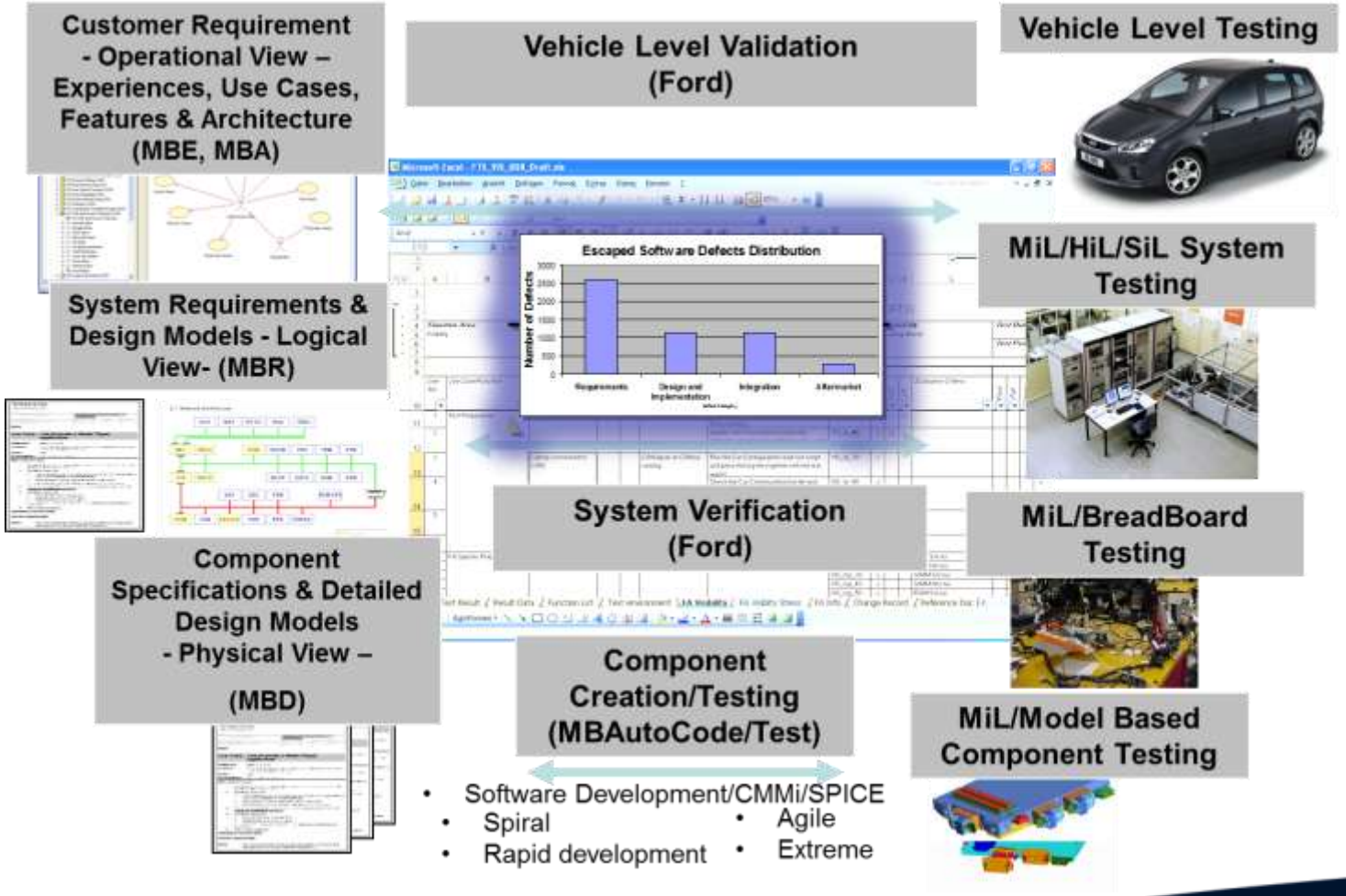
A Digital thread backbone will allow data interoperability to unlock benefits across the company (inclusive of manufacturing, purchasing, mobility, service, etc.)

Modeling Convergence Across Product Development



Different Model Based Approaches Are Required Depending On The Systems Engineering Task At Hand.

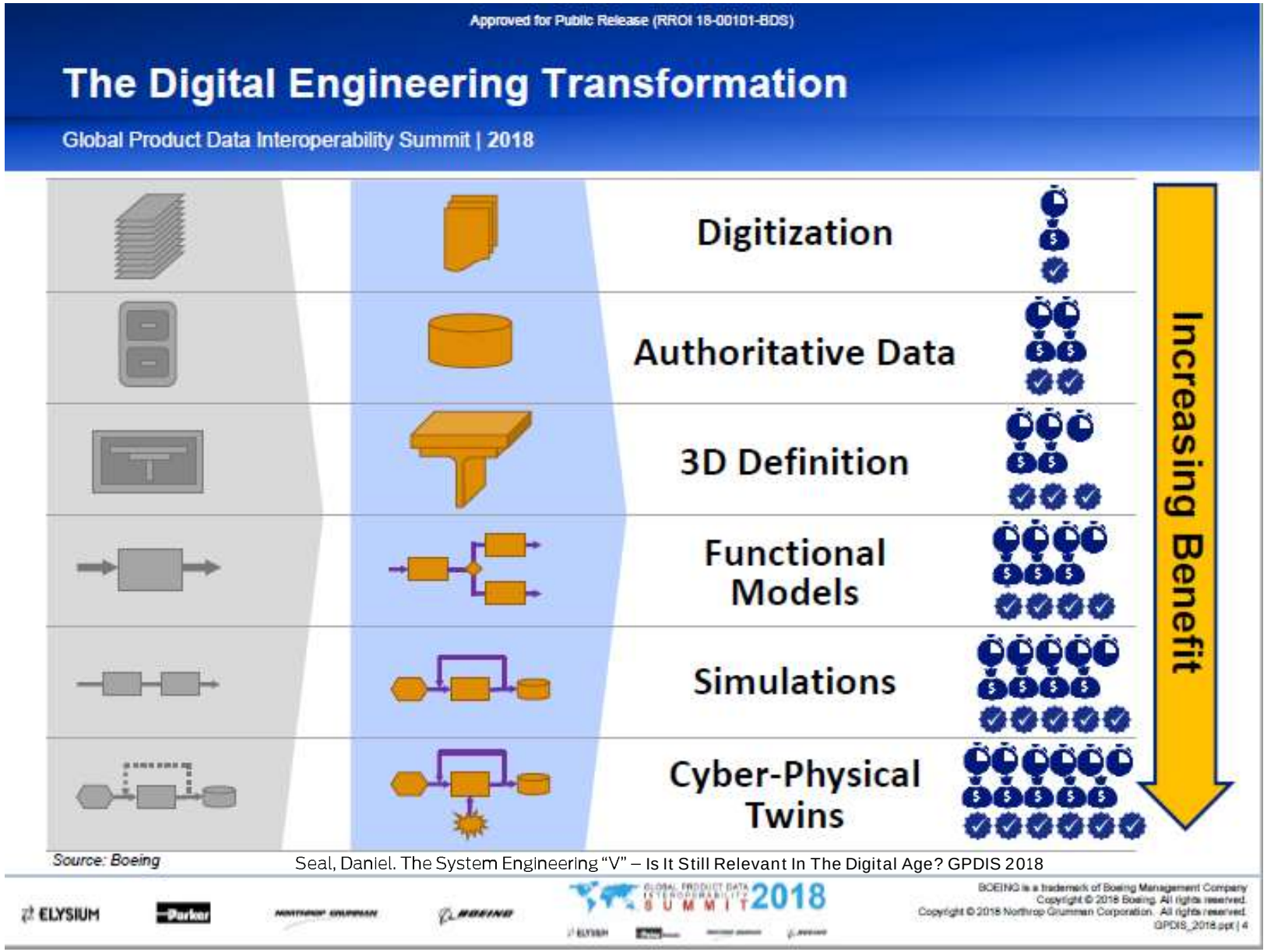
Engineering: Model-Based



The Concept Of Model-Based Engineering Represents A Compilation Of Multiple Model Based Capabilities: Architecture, Requirements, Design, Coding, Calibration, Testing And Simulation.

The Future Is Now: 21st Century Engineering

Payoff In Terms Of Saving Time, Money, And Greatest Fidelity Engineering Analysis & Simulation



Recap Of The Problem

In order to solve engineer's time allocation problems, some fundamental research issues have to be addressed.

- First, **capturing design rationale is a particularly difficult task.**
- Second, access to information is impeded by …the **lack of integration among the various programs and systems** that the organizations use.
- Third, **capturing and distributing expertise** is possible … but the cost of acquisition and its continued maintenance is still too great to be of much use…
- Fourth, **decision interdependence requires a method of modelling and managing the inter-dependencies**.
- Fifth, activity management technologies abound, e.g., project management systems, but **the engineering of usable system that adds value to the process still remains beyond our grasp.**
- And sixth, **access to people and systems remains a problem**, but is being reduced with current communication technologies …

R. A. Crabtree, N. K. Baid, M. S. Fox, Department of Industrial Engineering University of Toronto, Ontario, Canada

Convergence of MBSE And MBE – It Isn't A Magic Button. But With Effort, The Payoff Is REAL And In The Form Of Time Needed To Do Engineering.

Thank You

Questions?