34th Annual **INCOSE** international symposium

hybrid event

Dublin, Ireland
July 2 - 6, 2024

Making the Digital Thread Work

Digital Data Packages
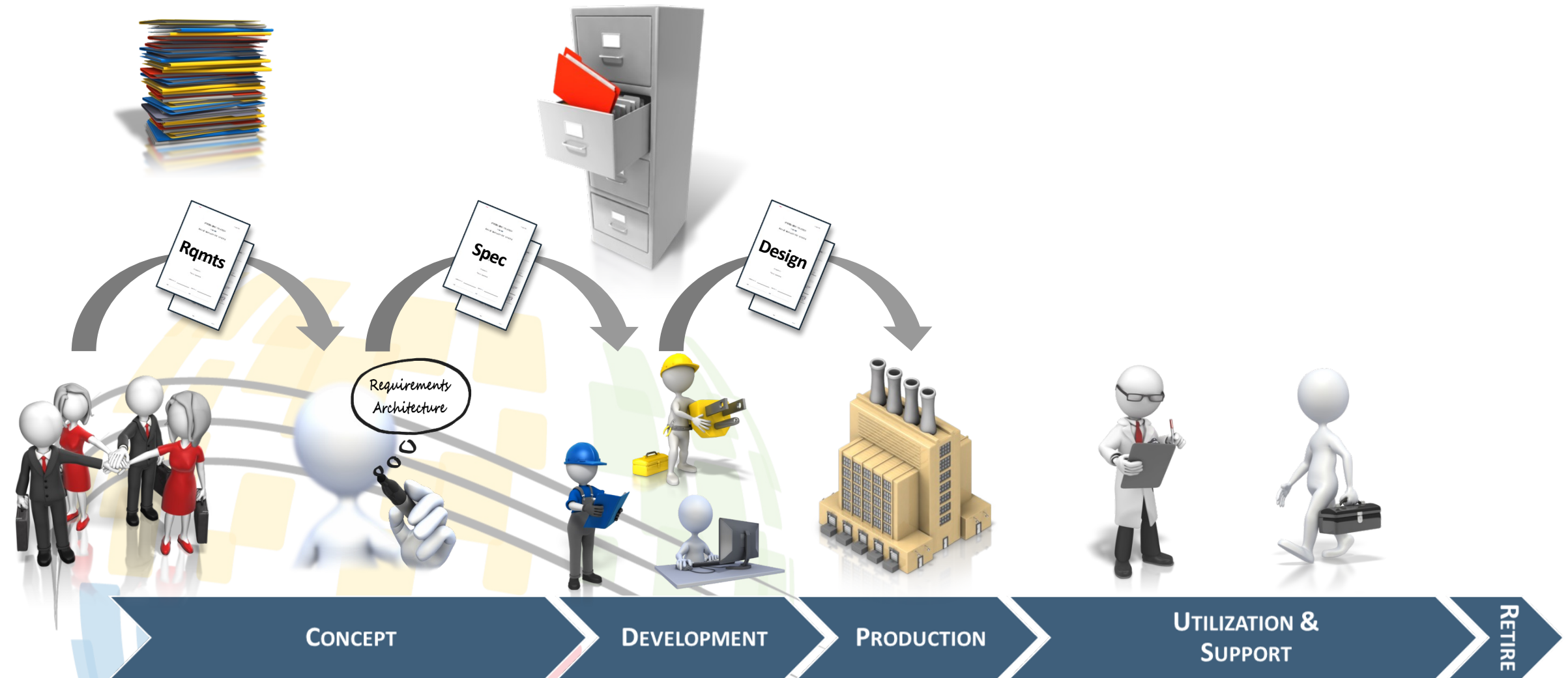
Looking Back
Classical Engineering in a Complicated World

CONCEPT → DEVELOPMENT → PRODUCTION → UTILIZATION & SUPPORT → RETIRE

Embracing Technology to Digitize Engineering

Requirements

MBSE

ECAD

MCAD

ALM

PLM

Rqmts

Requirements Architecture

CONCEPT

DEVELOPMENT

PRODUCTION

UTILIZATION & SUPPORT

RETIRE
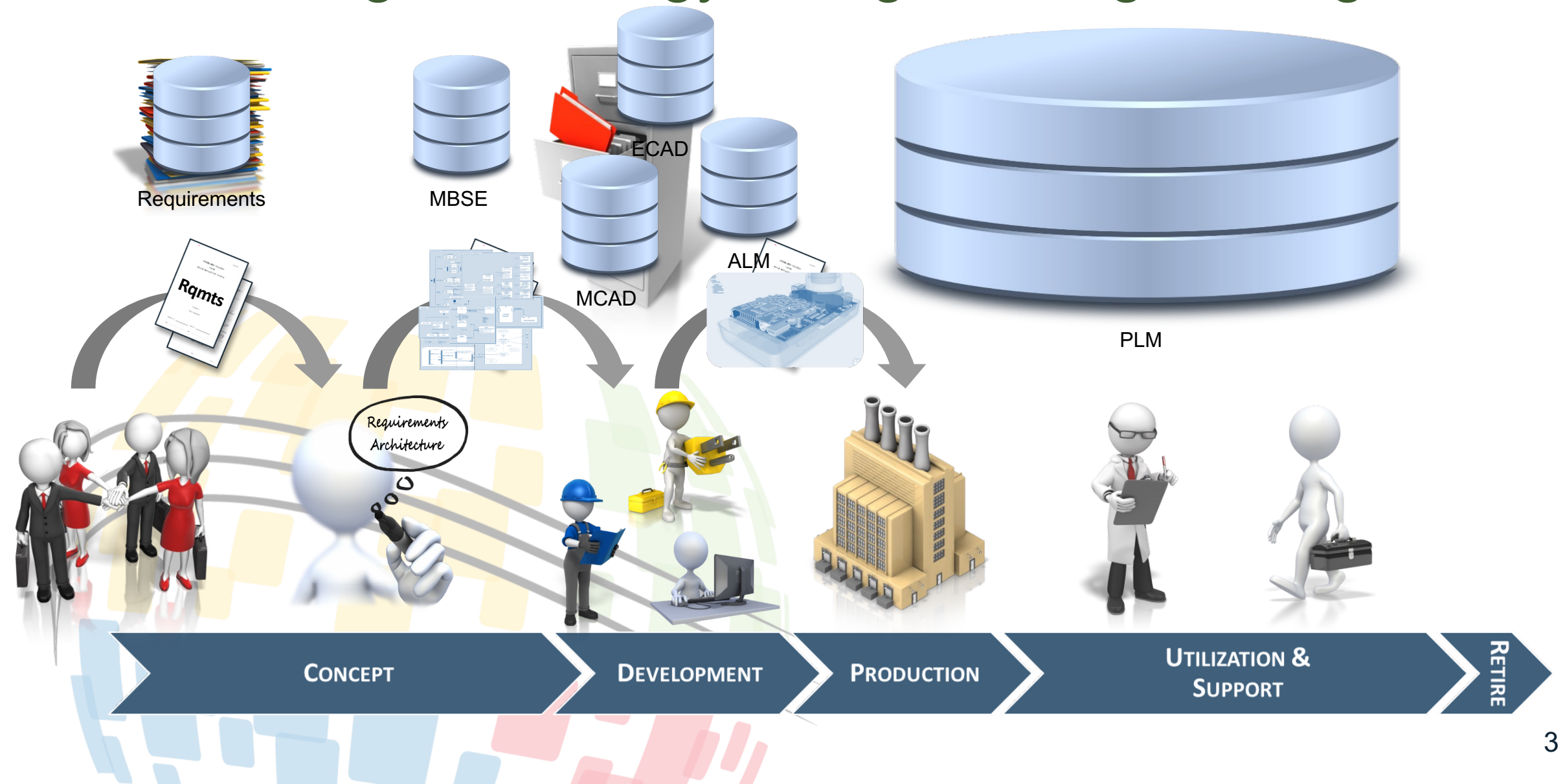
Appreciating the Cost of Miscommunication
The Perils of Silos and Stopping at Digitization

Data Integrity

Number of Translations / Handovers	1	2	3	4	5	6
95%	95%	90%	86%	81%	77%	74%
90%	90%	81%	73%	66%	59%	53%
85%	85%	72%	61%	52%	44%	38%
80%	80%	64%	51%	41%	33%	26%

Legend: 95% | 90% | 85% | 80%
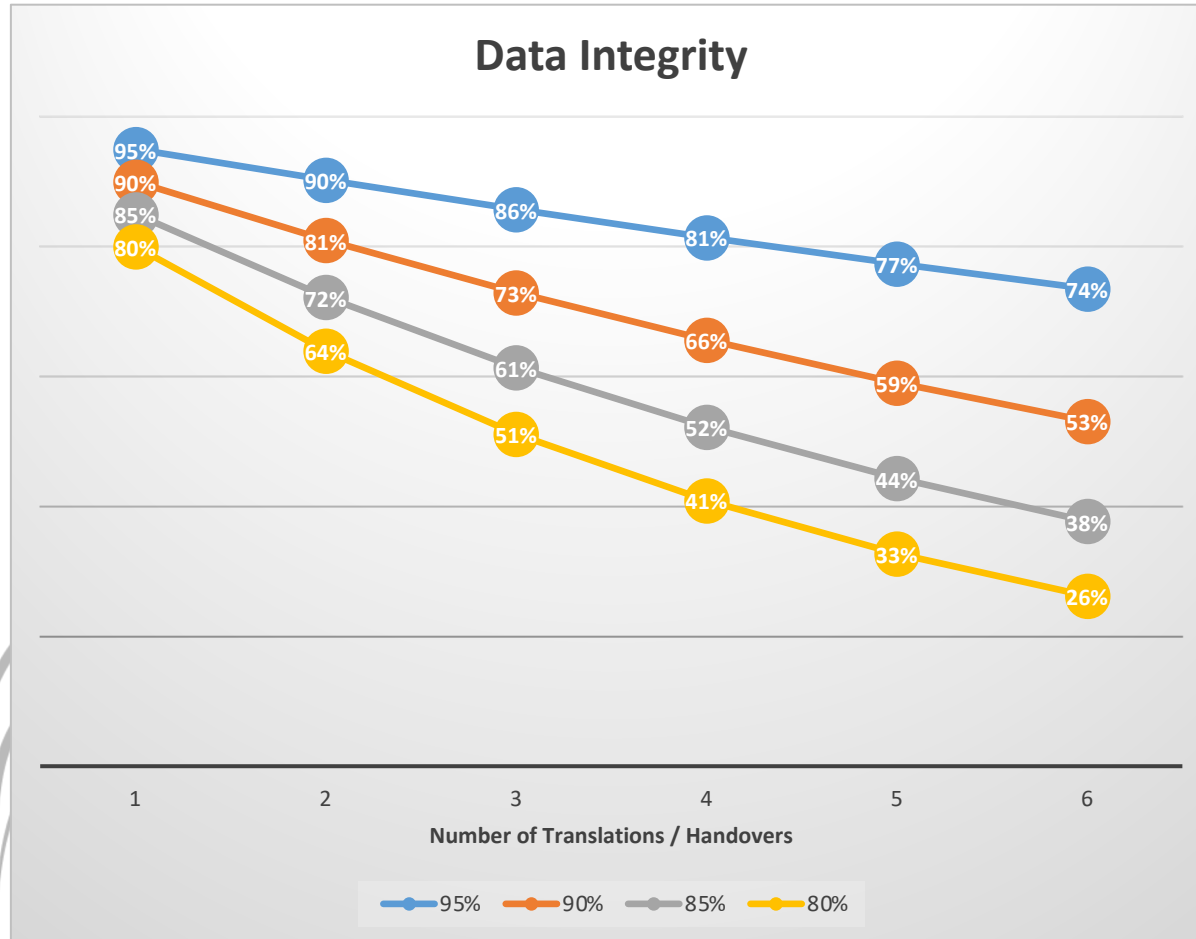
Credit Henrik Balslev, Systems Engineering A/S

Any organization that designs a system (defined broadly) will produce a design whose structure is a copy of the organization's communication structure
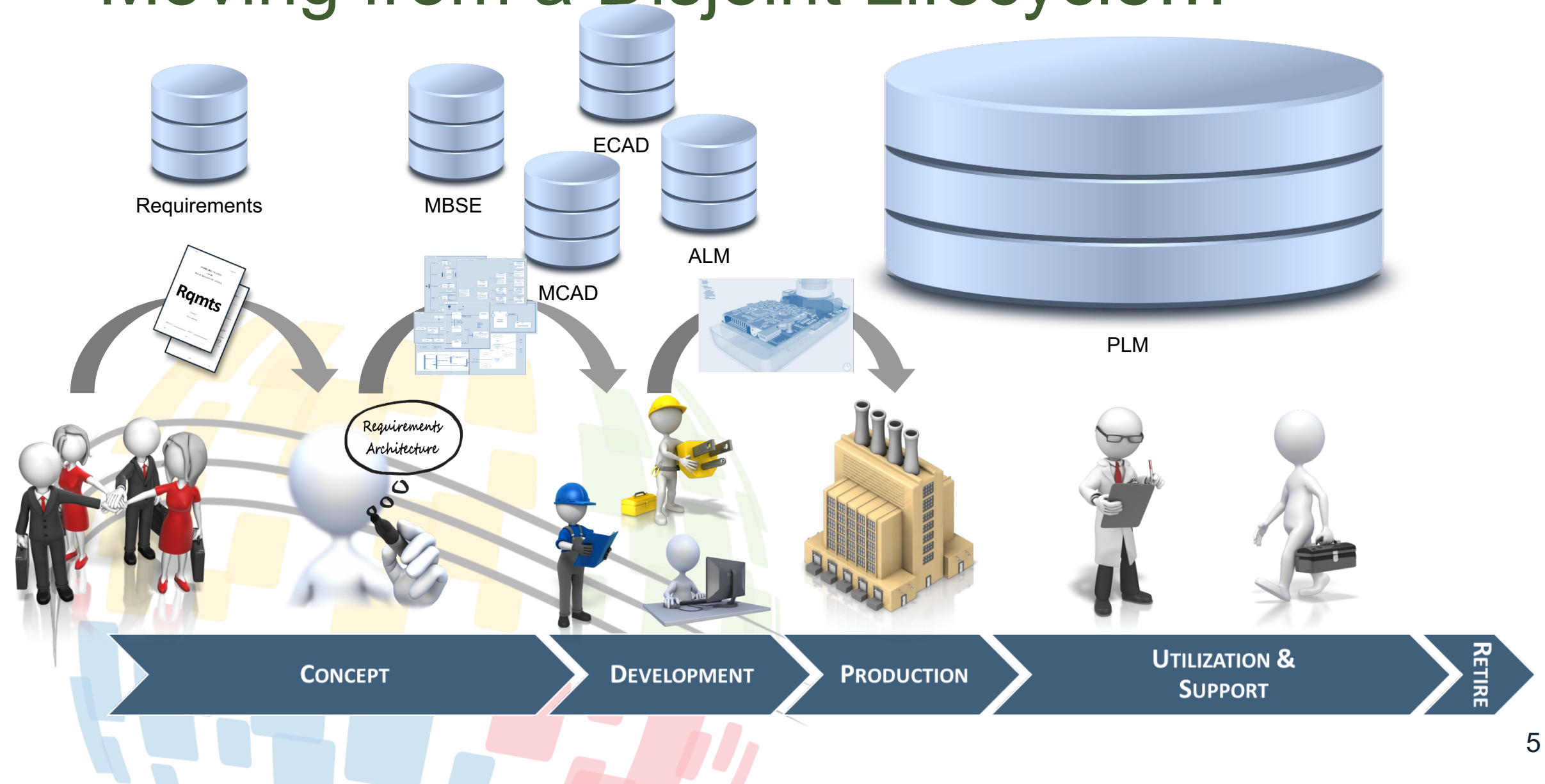
Conway's Law, 1967

Flaws in the communication structure of an enterprise will manifest as defects in the system under development
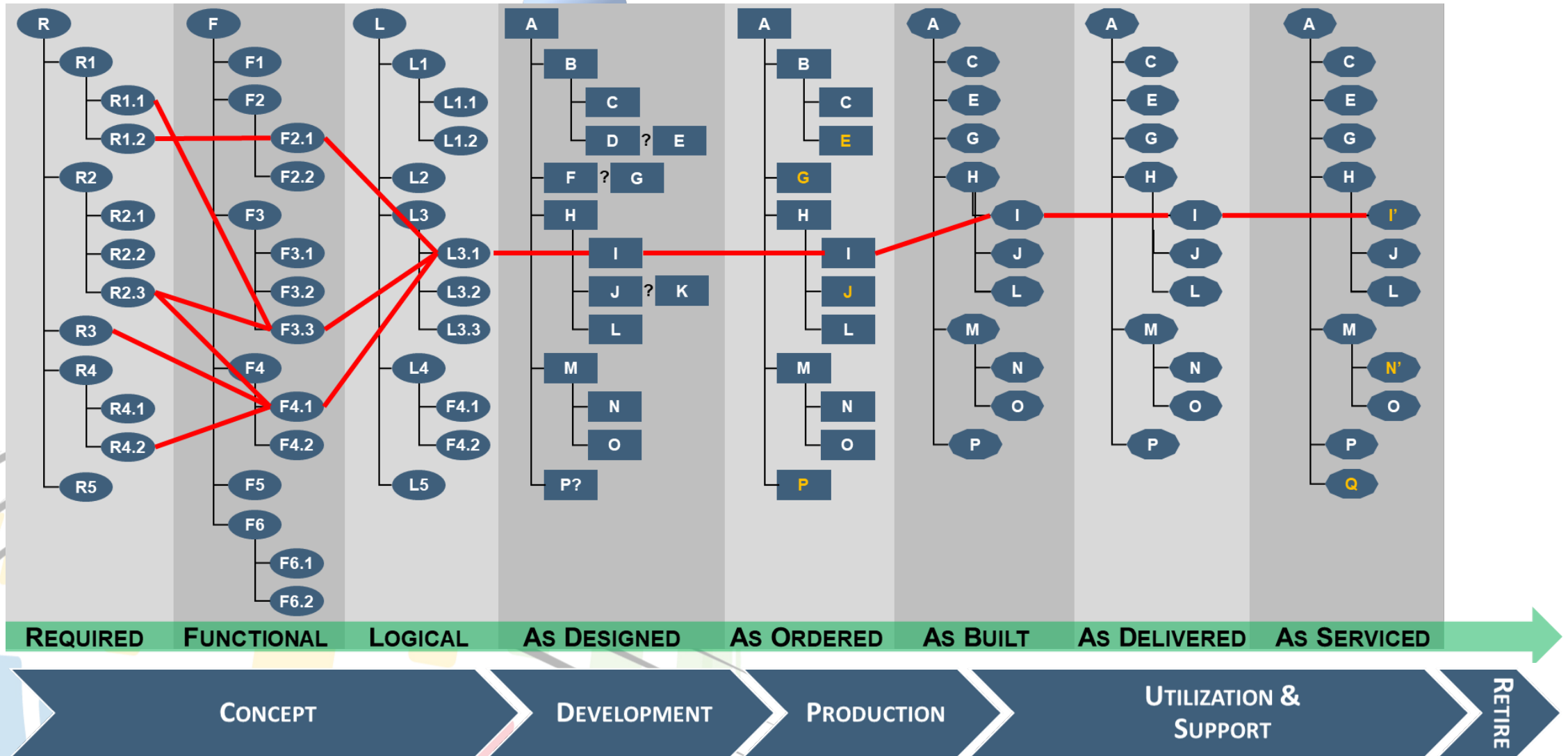
Long's Corollary, 2020

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Moving from a Disjoint Lifecycle…

Requirements

MBSE

ECAD

MCAD

ALM

PLM

Rqmts

Requirements Architecture

CONCEPT

DEVELOPMENT

PRODUCTION
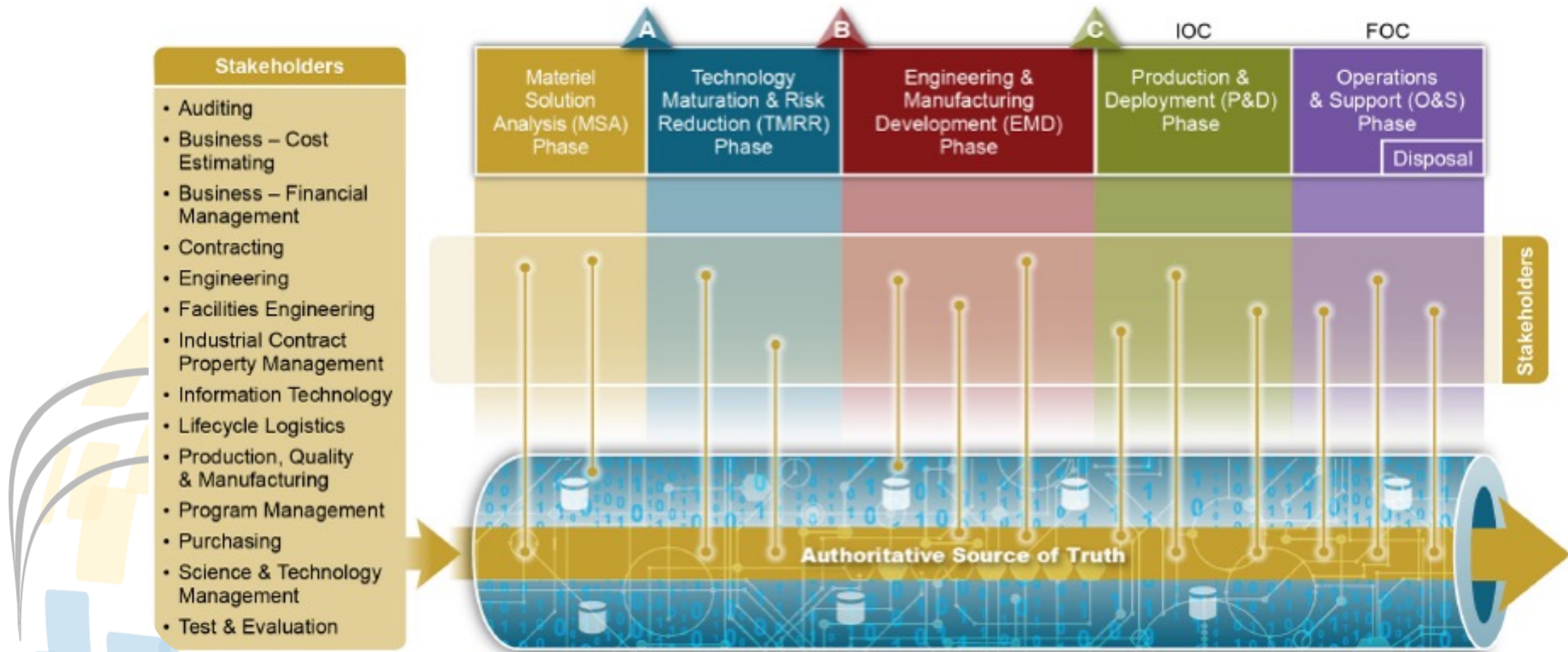
UTILIZATION & SUPPORT

RETIRE

5

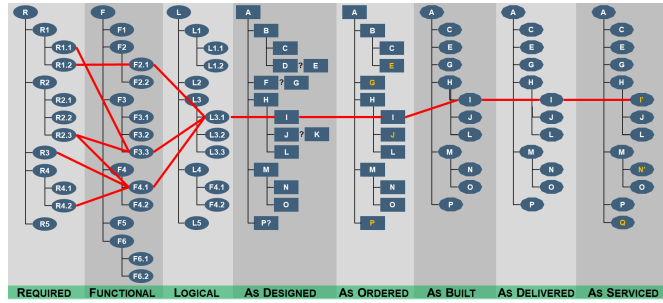# to Maintaining an Unbroken Thread of Traceability

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Advancing to Digital Engineering
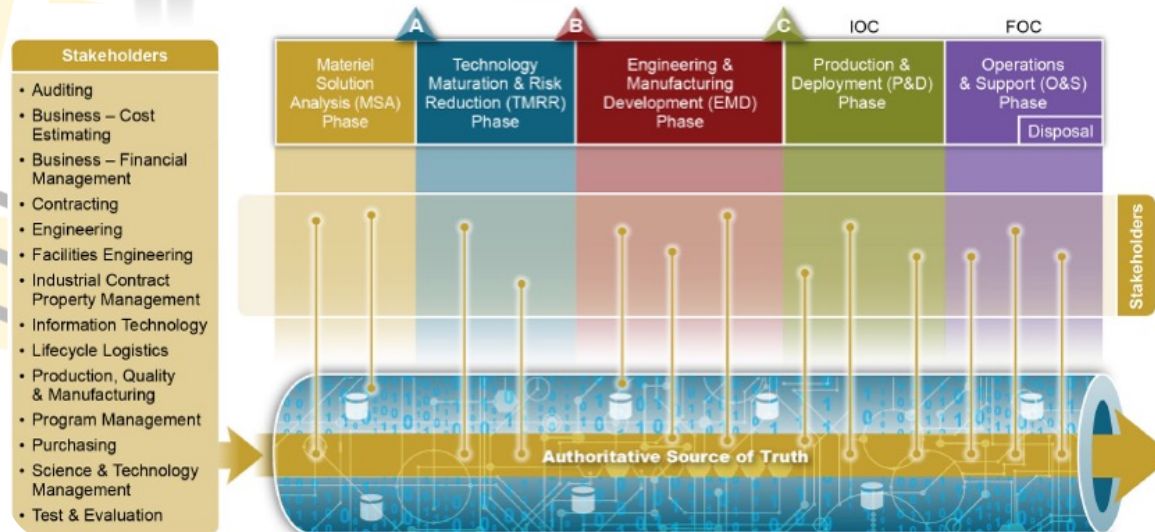## *Digitalization and Building on a Foundation of Authoritative Data*

But What about the Engineers and Engineering?

REQUIRED FUNCTIONAL LOGICAL As Designed As Ordered As Built As Delivered As Serviced

Requirements
Architecture

Photo credit: Adam Schweigert.
Creative Commons 2.0.

Stakeholders

- Auditing
- Business – Cost Estimating
- Business – Financial Management
- Contracting
- Engineering
- Facilities Engineering
- Industrial Contract Property Management
- Information Technology
- Lifecycle Logistics
- Production, Quality & Manufacturing
- Program Management
- Purchasing
- Science & Technology Management
- Test & Evaluation

A	B	C	IOC	FOC
Materiel Solution Analysis (MSA) Phase	Technology Maturation & Risk Reduction (TMRR) Phase	Engineering & Manufacturing Development (EMD) Phase	Production & Deployment (P&D) Phase	Operations & Support (O&S) Phase
				Disposal

Stakeholders

Authoritative Source of Truth

Credit US Department of Defense Digital Engineering Strategy, June 2018

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But What about the Engineers and Engineering?

REQUIRED   FUNCTIONAL   LOGICAL   AS DESIGNED   AS ORDERED   AS BUILT   AS DELIVERED   AS SERVICED
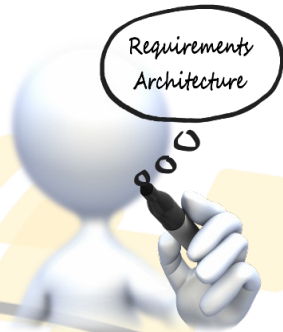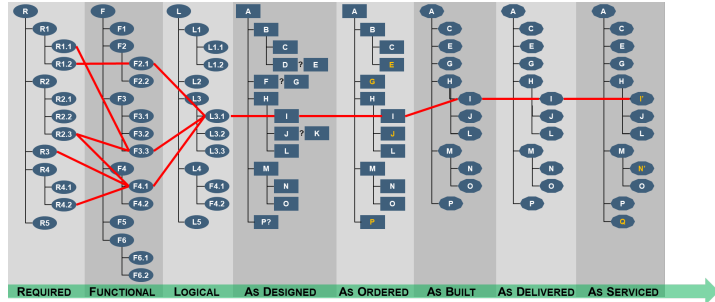
Requirements
Architecture

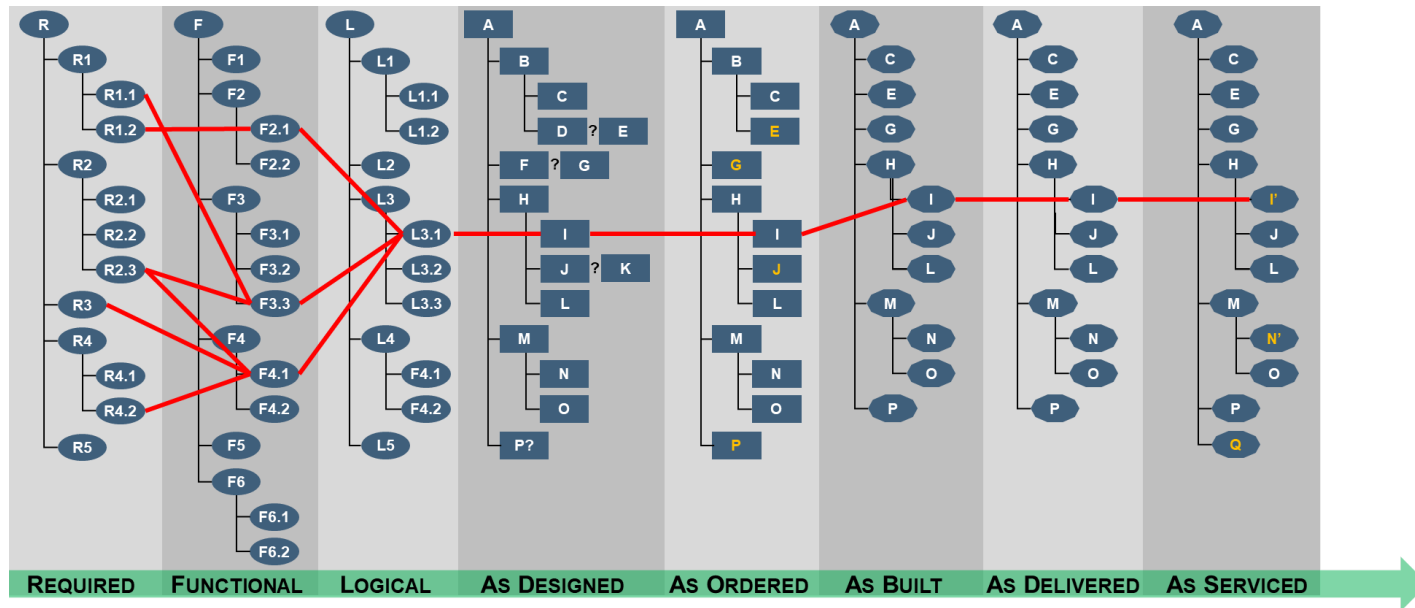Photo credit: Adam Schweigert.
Creative Commons 2.0.

Everything should be made as simple as possible, but not simpler

Albert Einstein

Provide only the information required to make a decision, but no more
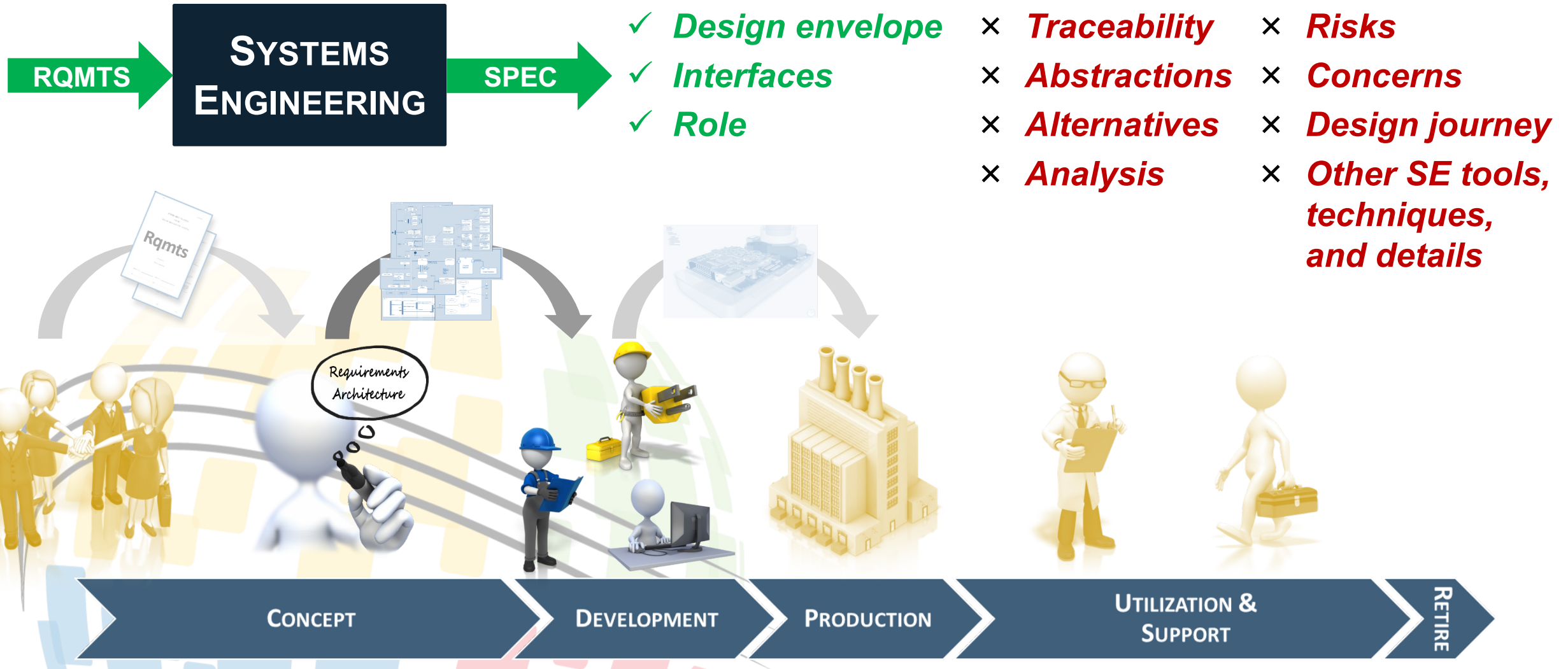
Einstein applied to the Digital Knot

Complementing the Digital Thread and Authoritative Data with Digital Data Packages

Returning to Engineers, Engineering, and Workflow
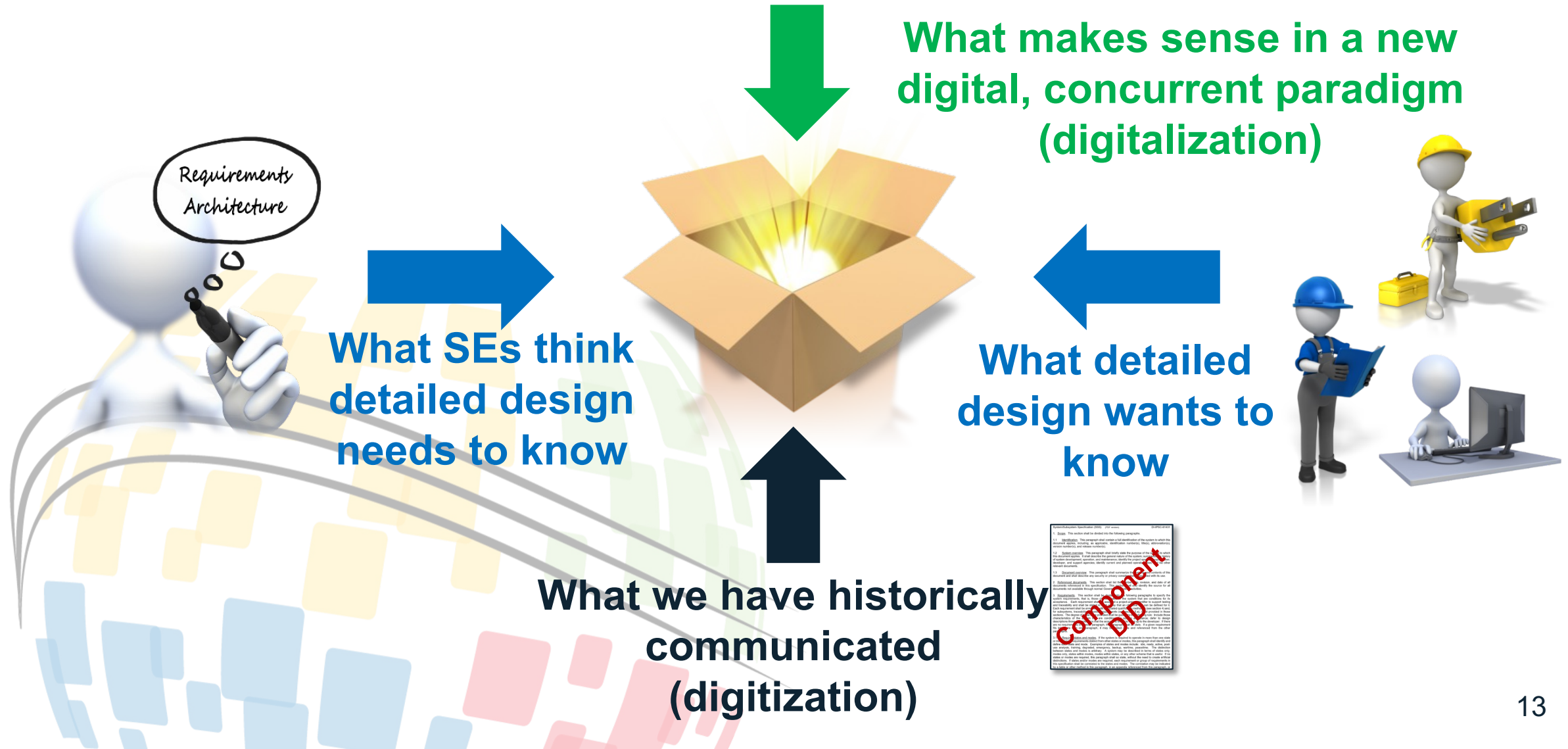## *Keeping the Black Box Opaque*

RQMTS → **SYSTEMS ENGINEERING** → SPEC

- ✓ **Design envelope**
- ✓ **Interfaces**
- ✓ **Role**

- ✗ **Traceability**
- ✗ **Abstractions**
- ✗ **Alternatives**
- ✗ **Analysis**

- ✗ **Risks**
- ✗ **Concerns**
- ✗ **Design journey**
- ✗ **Other SE tools, techniques, and details**

Requirements Architecture

CONCEPT → DEVELOPMENT → PRODUCTION → UTILIZATION & SUPPORT → RETIRE

Establishing Key Concepts before Defining an Exemplar Digital Data Package

- "Specification" is a **relative concept** just like "system"

- It's all about requirements, and **architecture is requirements**

- Truth resides at the **lowest level of decomposition**

- Traceability and provenance is **irrelevant in the moment**

- Context, rationale, and additional information is **helpful when needed**

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Defining Digital Data Packages
A Pattern to Embrace Systematic and Systemic, Past and Future

What makes sense in a new digital, concurrent paradigm (digitalization)

Requirements Architecture

What SEs think detailed design needs to know

What detailed design wants to know

What we have historically communicated (digitization)

Component DID

Defining an Exemplar Digital Data Package
Connecting Systems Architecture and Detailed Design
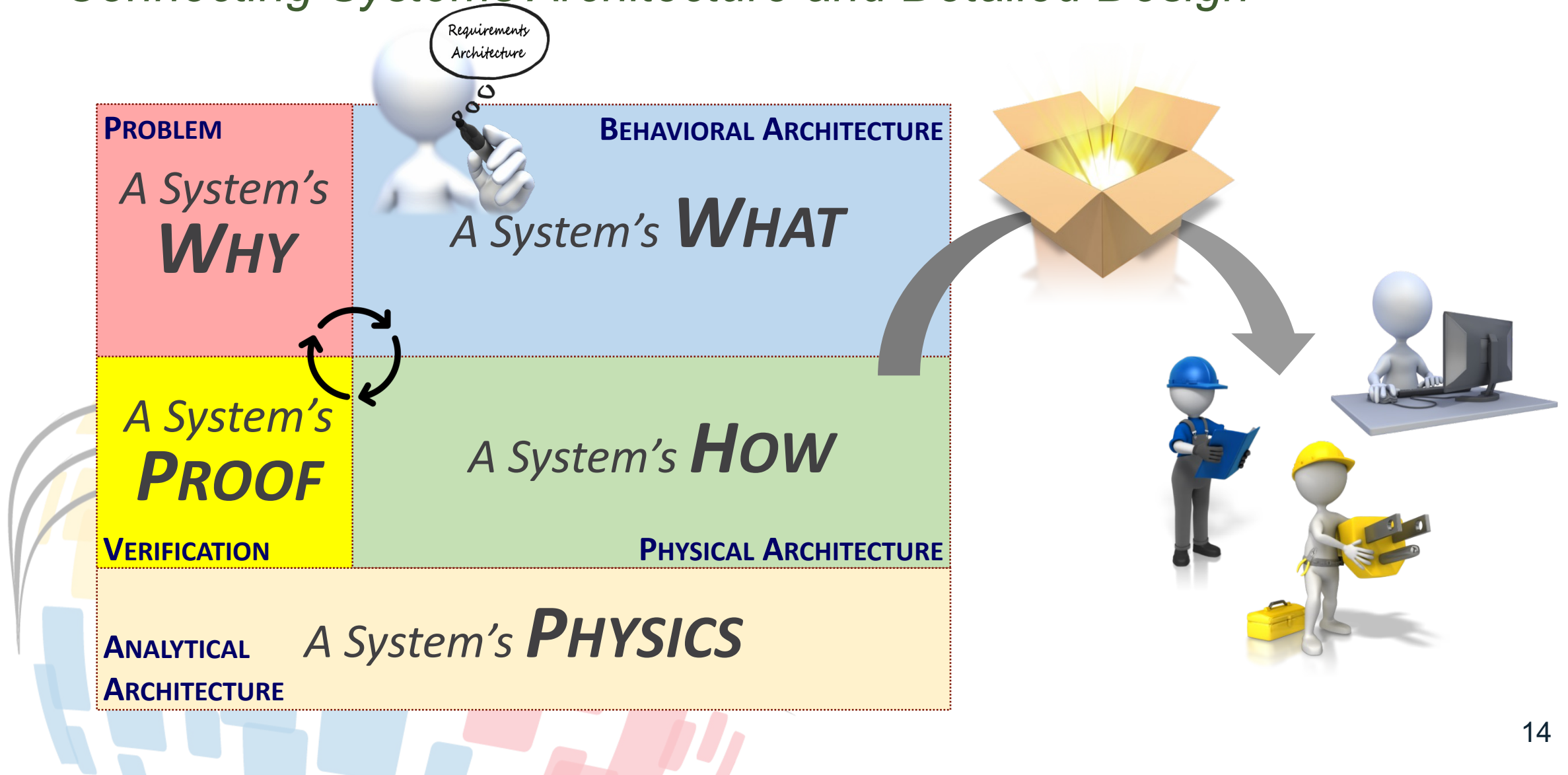
Beginning with the Design Envelope and Interfaces
Center Detailed Design Package Definition around the Parts Tree

Implementation architecture communicates effectively across the architecture-detailed design gap, but it is more than a bill of materials (composition and connection)

- ✓ Targeted Component and its decomposition
- ✓ Interfaces (Links) and their decomposition
- ✓ Connection surfaces (Ports) and their decomposition
- ✓ Design-dependent parameters for included content ("numerics" of the architecture)
- ✓ Composition diagram for the Component
- ✓ Connectivity diagram for the Component
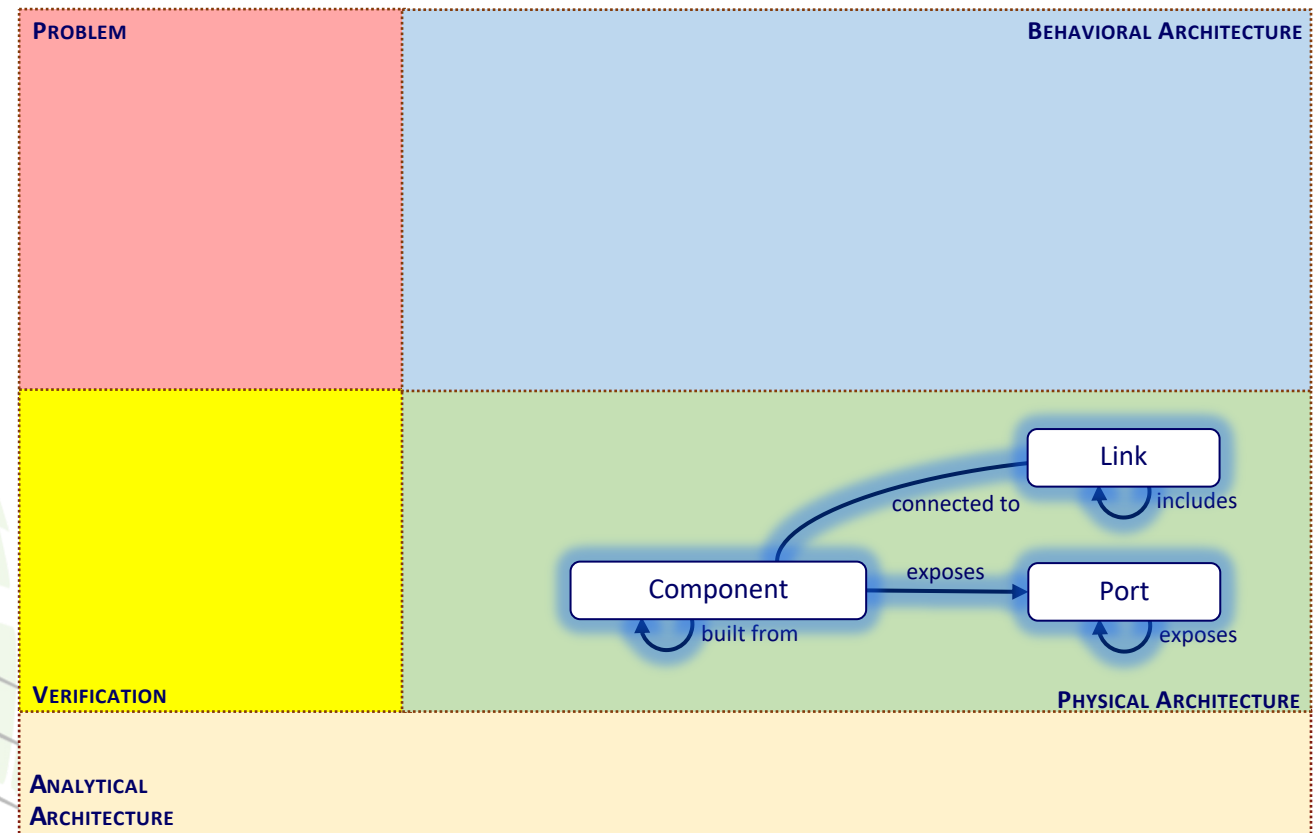
Addressing All Aspects of Architecture

Not all Architecture is Implementation; Not all Requirements are "Requirements"

Allocated architecture defines the required states, behavior, and exchanges addressed by the implementation architecture (requirements by different names)

- ✓ Exhibited States
- ✓ Performed Functions
- ✓ Transferred Items
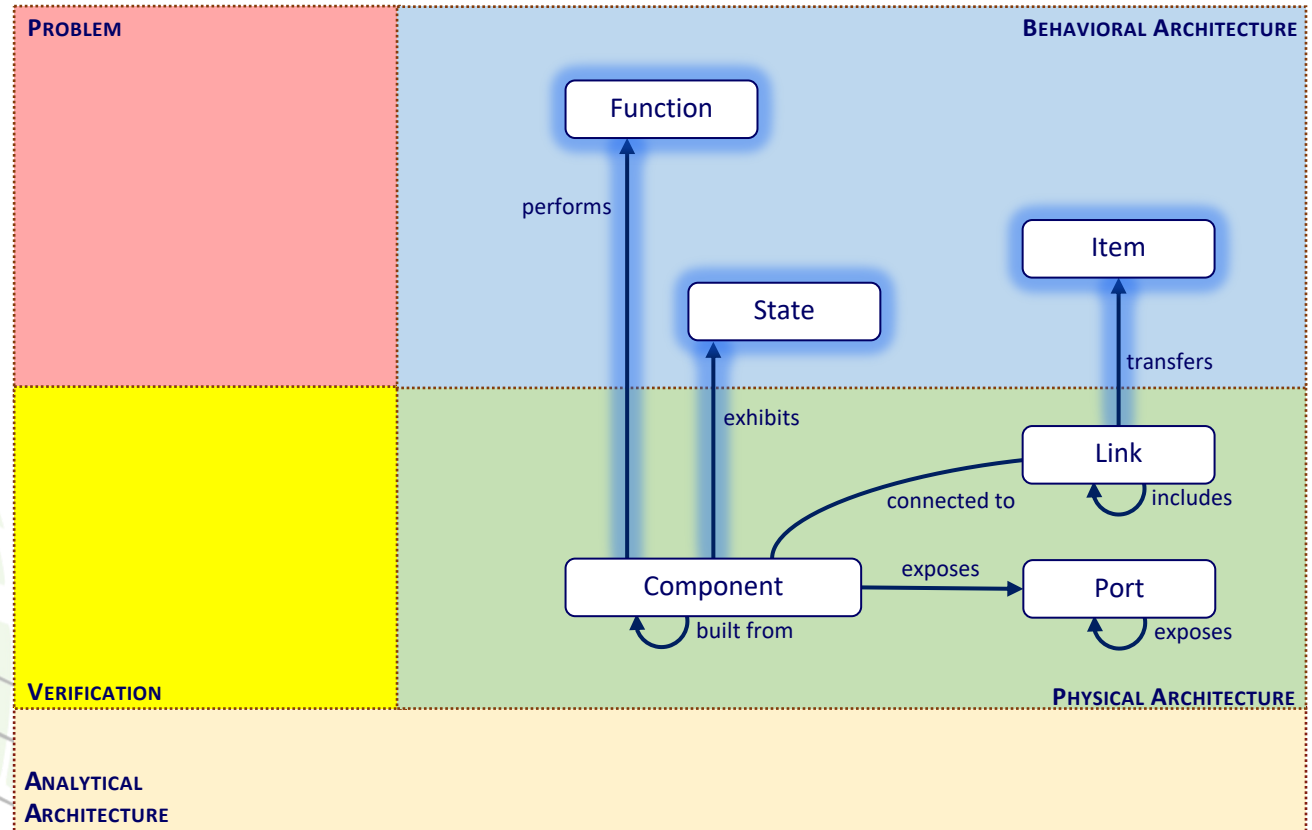
Completing the Allocated Architecture
Detail All Specified State and Behavior

Full specification of state and behavior represent additional requirements for detailed design

- ✓ State decomposition, associated Transitions, and Events
- ✓ Function decomposition and associated Items
- ✓ Item decomposition
- ✓ Design dependent parameters for included States, Functions, and Items
- ✓ State transition diagrams for all included States
- ✓ Behavior diagrams (e.g., activity diagrams) for all included Functions

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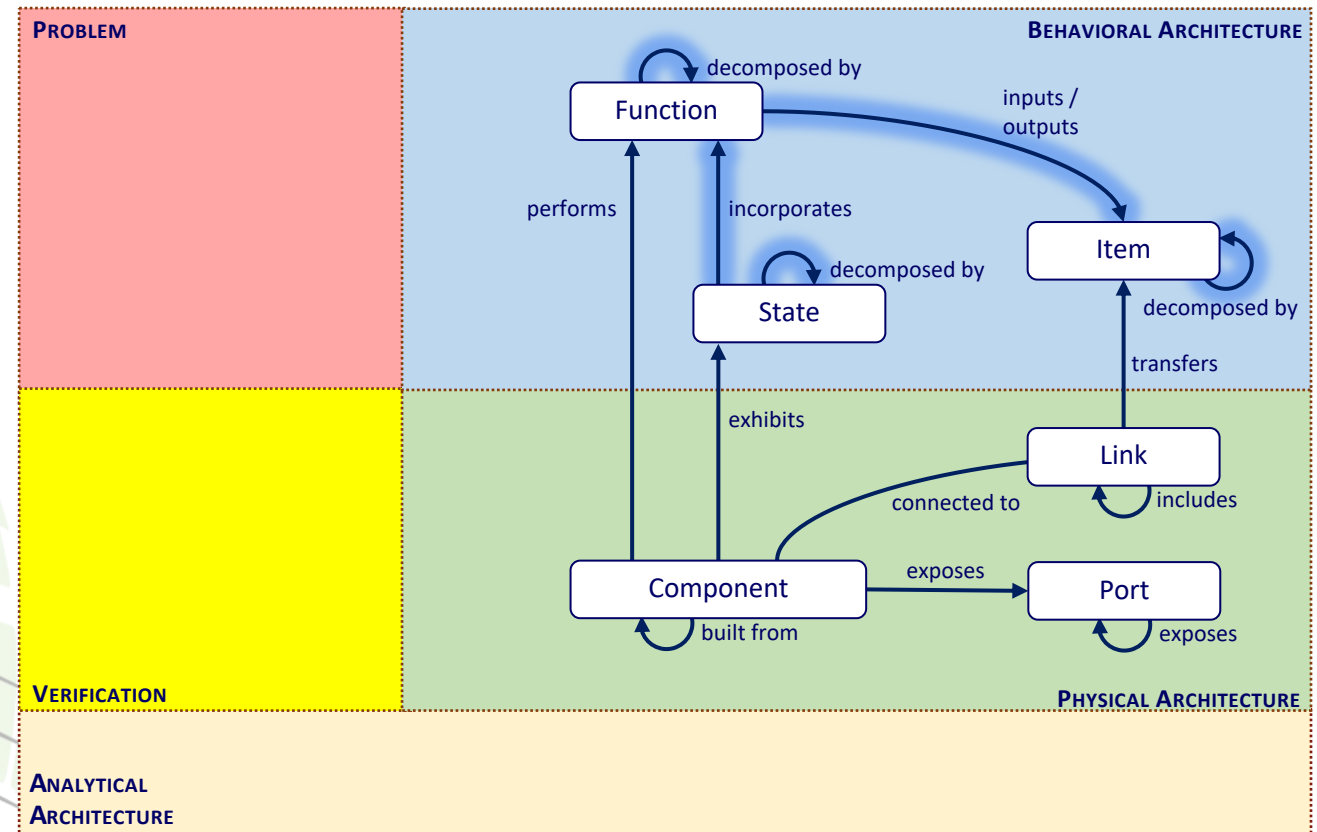
Exposing All Requirements and Verification Requirements
Address Why and Proof for the Complete Architecture

Requirements express the why behind implementation and further constrain the design envelope while verification requirements reflect black box assessments at this level

- ✓ All Requirements which specify included Components, Ports, and Links
- ✓ All Verification Requirements which verify the included Components, Ports, and Links
- ✓ All Requirements which are the basis of or specify included States, Functions, and Items
- ✓ All Verification Requirements which verify included States, Functions, and Items
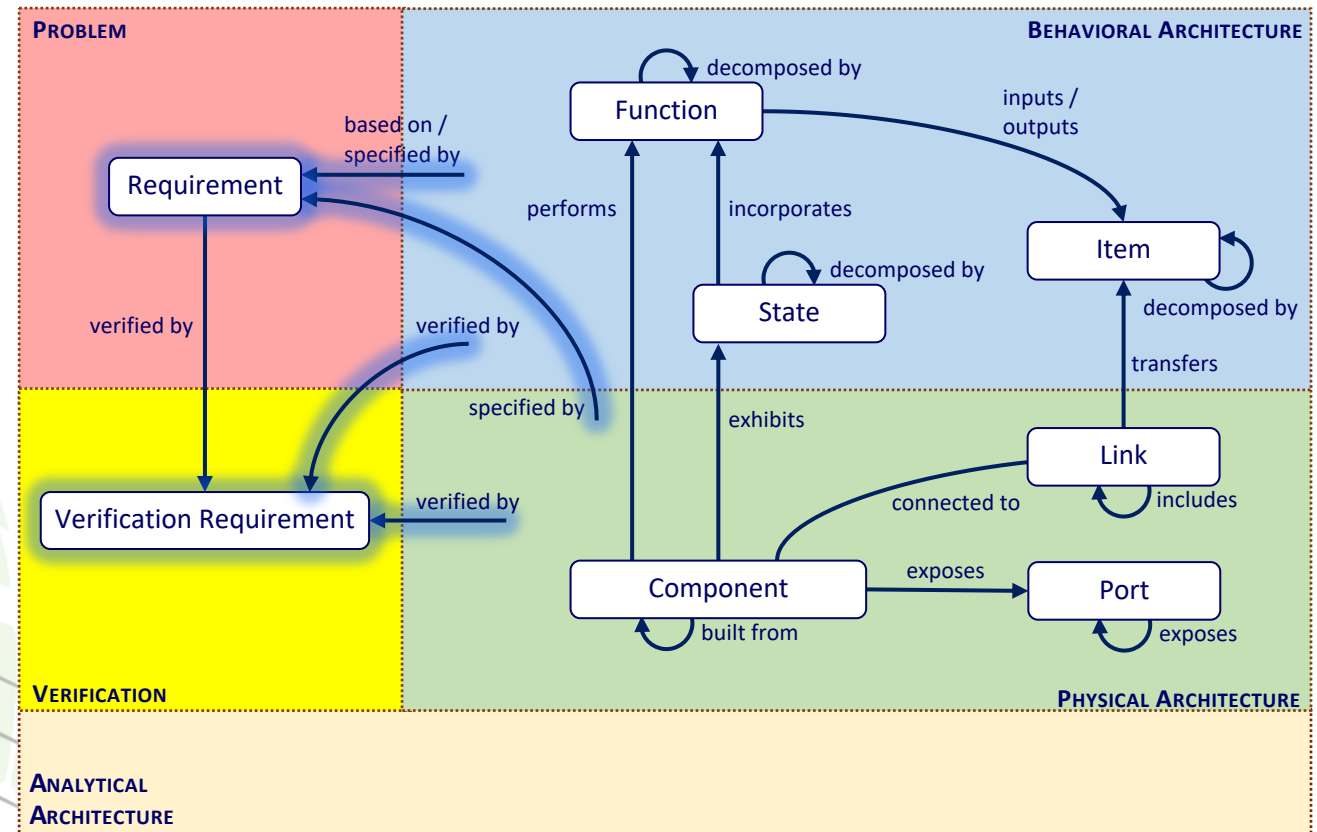
Recognizing the Greater Content not Required

Provide only the information required to make a decision, but no more
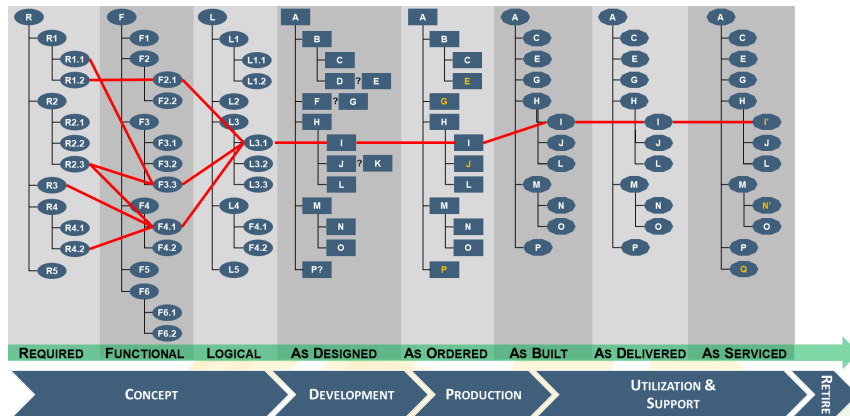*Einstein applied to the Digital Knot*

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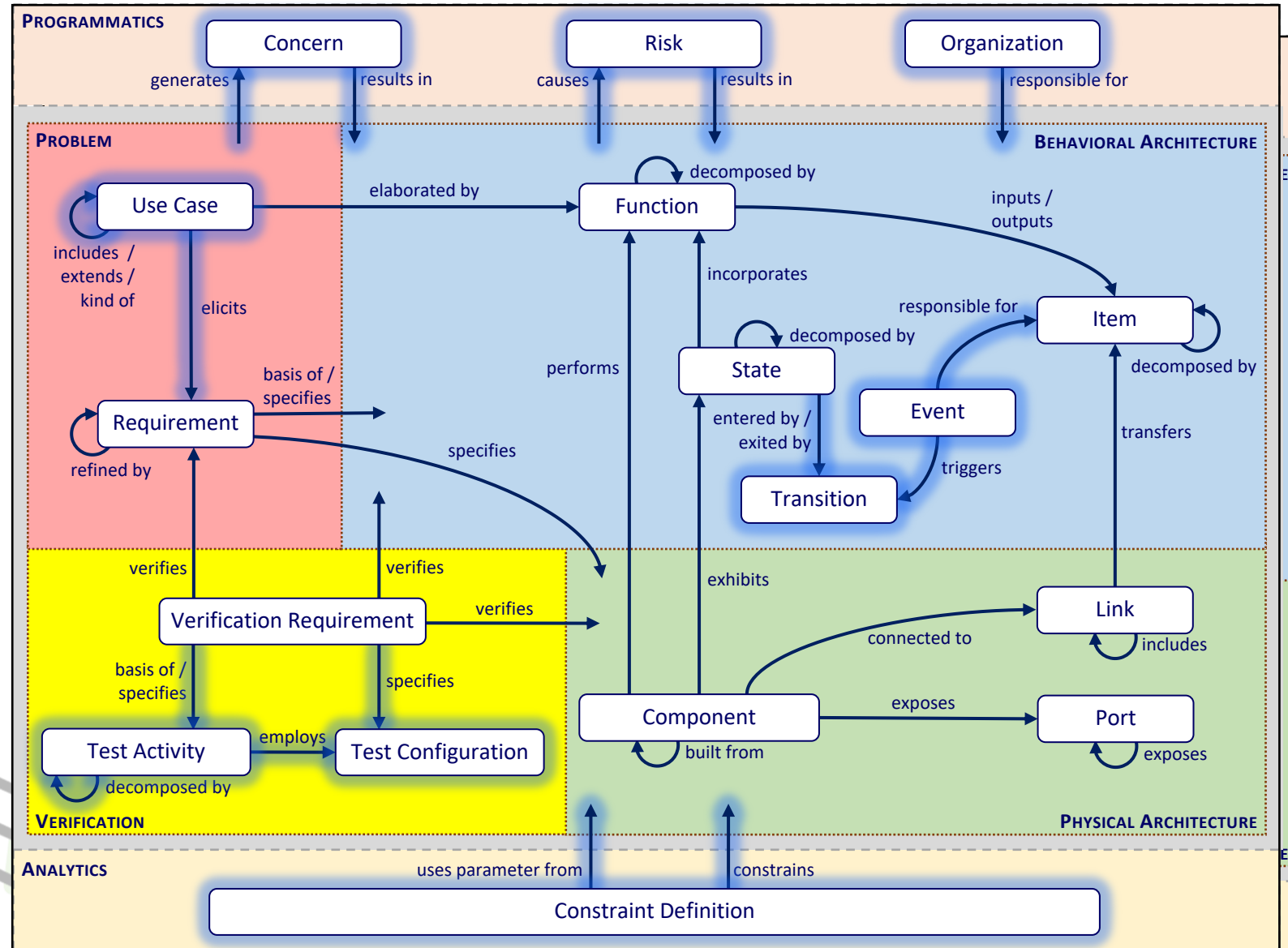
Completing the Digital Picture

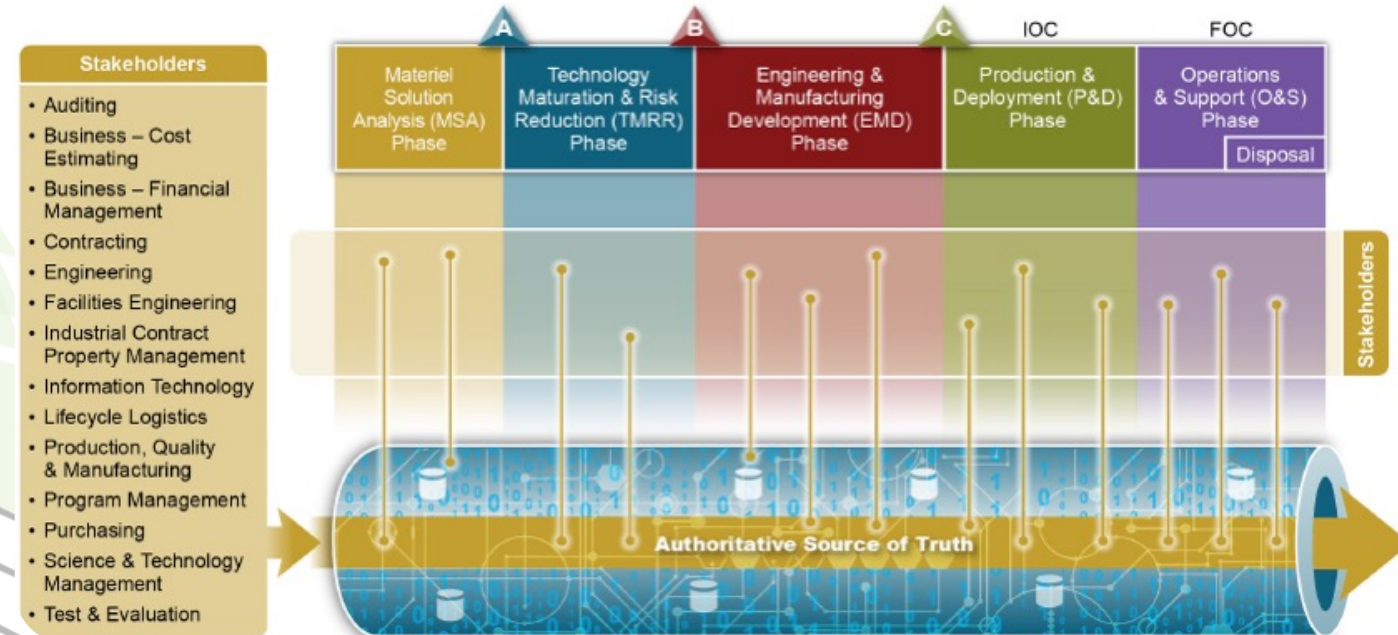# Appreciating the Accelerating Growth in Information throughout the System Lifecycle

Adapted from Aras Corporation, 2018

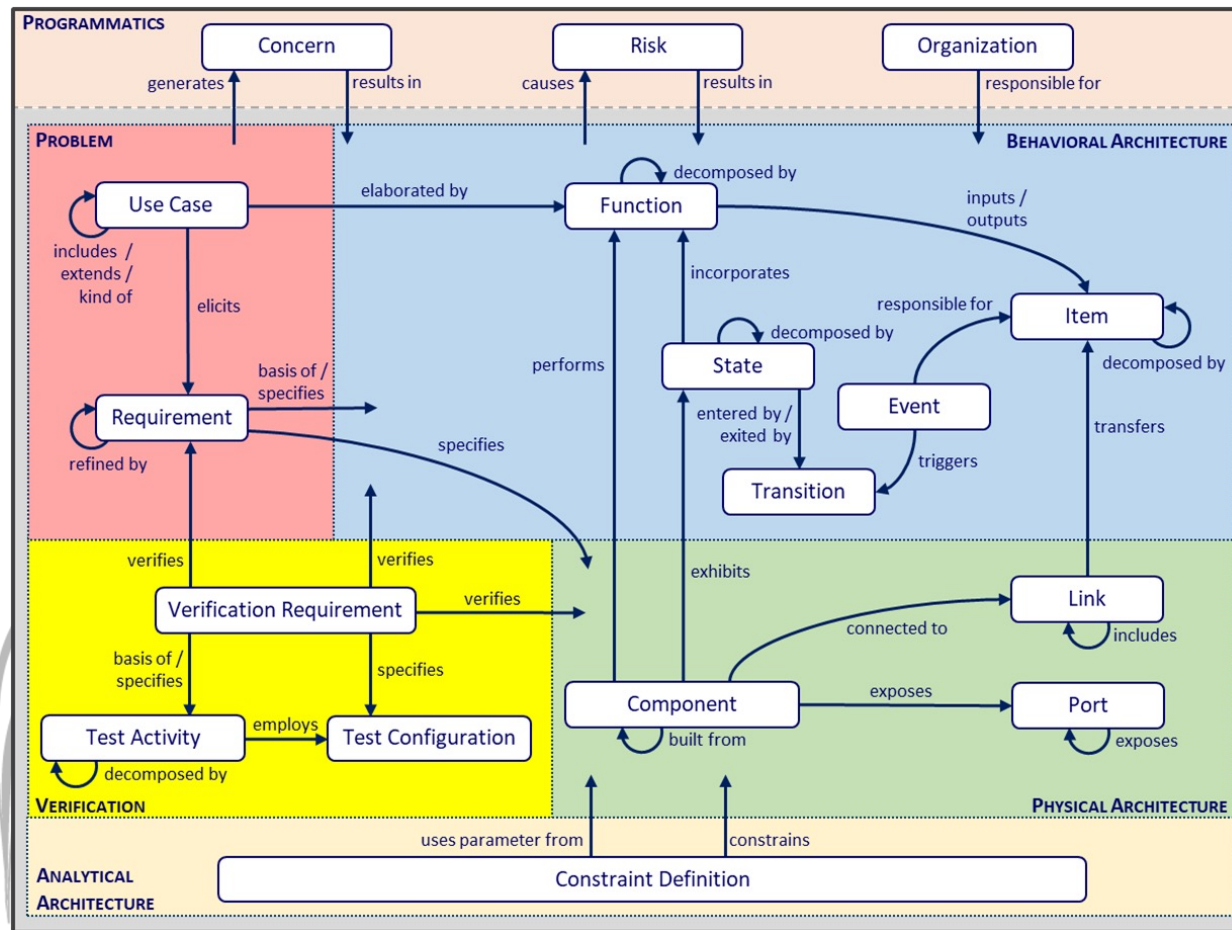Credit: Adam Schweigert. Creative Commons 2.0

Credit: Sumit Awinash, Creative Commons 4.0

Credit: US Department of Defense Digital Engineering Strategy, June 2018

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Identifying Critical Enablers for a Solution

- A **semantically meaningful** common information infrastructure or metamodel
  - "A common systems language translatable across the **engineering team**"
- "**Lines** matter as much as boxes" (Dave Walden)
- **Standardized but extensible** queries
  - Tailored to workflow and consumer (human or machine)
  - Informed, but not constrained, by existing DIDs
- Linkages providing **additional data on demand**
  - Traceability and authoritative data are still required

Engineering Doesn't Require <u>All Data</u> at All Times
Right Data, Right Abstraction, Right Place, Right Time, Right Presentation
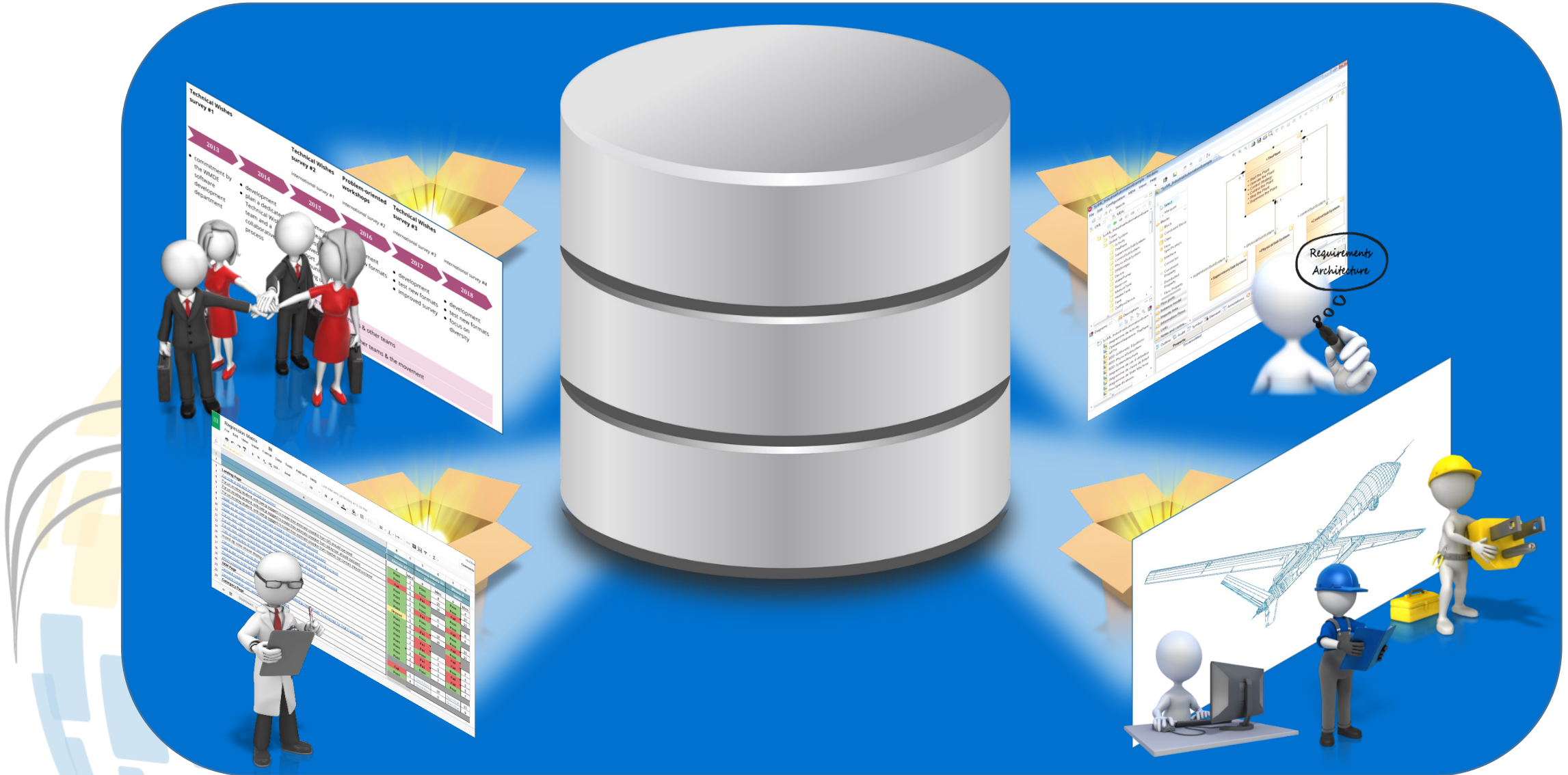
Questions and Discussion

David Long, ESEP
President, Blue Holon

Director for Strategic Integration
Past President (2014/2015)
Fellow

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