34th Annual INCOSE international symposium

hybrid event

Dublin, Ireland
July 2 - 6, 2024

An overview of Boeing's reenvisioned approach to verification and validation

V&V in Boeing's 2nd Century

Introduction

James Craig

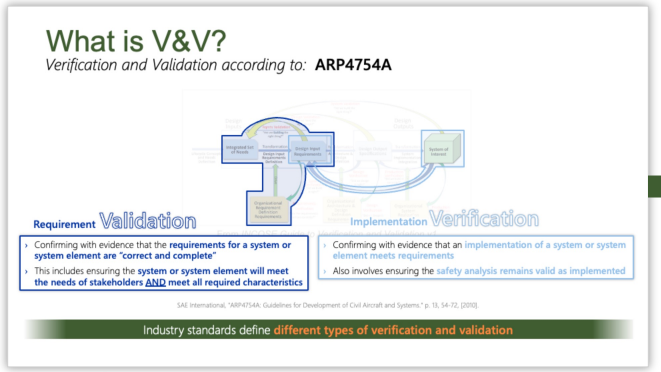
Boeing Digital &
Systems Engineering

James is a systems engineer with 16 years of experience working in the aerospace industry. He currently serves as the owner of Boeing's *Verification and Validation (V&V) Capability*. In this role, he manages Boeing's portfolio of V&V-related technology investments, helps with relevant process improvement efforts, and provides V&V consultation across Boeing's commercial and defense programs.

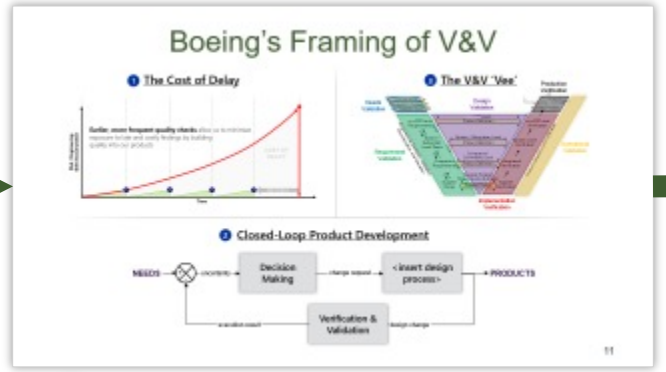
Prior to this, he worked as a guidance, navigation, and controls engineer performing safety and certification related analyses and tests at various stages of product development lifecycle. His switch to focusing on V&V occurred after leading an effort to build a large scale test automation system around a set of test assets. Through this work, he realized that, with the right framework, you can build a closed-loop control system around your product development process.

His career passion centers around making it easy for engineers to learn "sooner, faster, cheaper, and with as much clarity between cause and effect as possible".

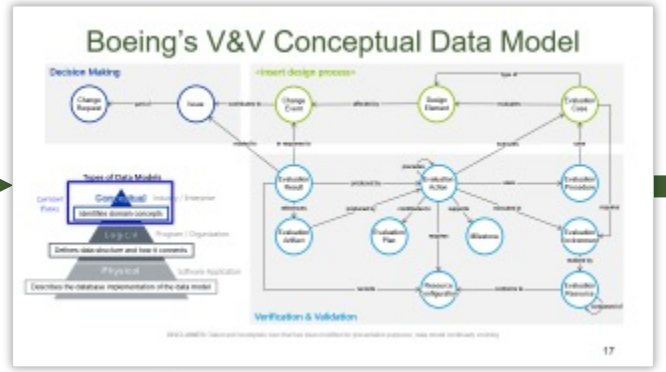
Introduction



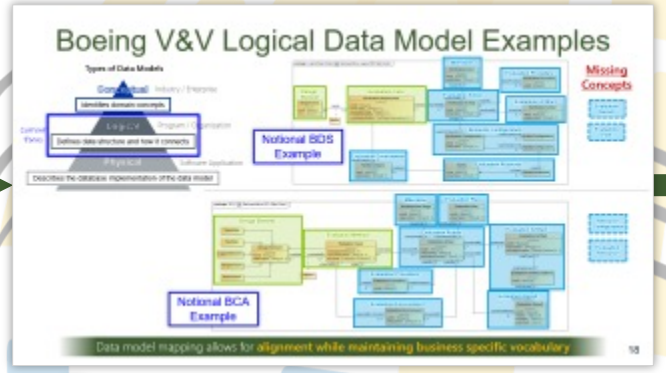
1 What does the industry guidance Boeing follows say about V&V



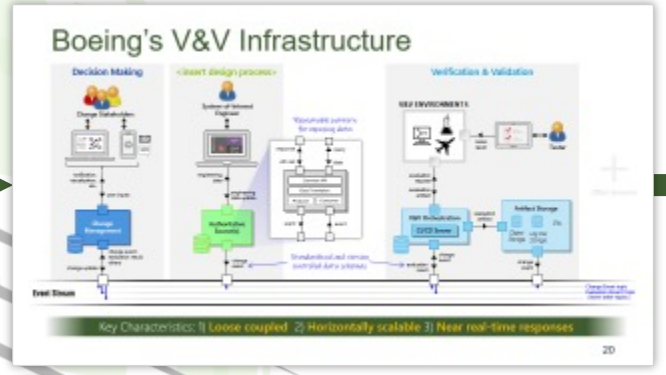
2 How Boeing is framing V&V with industry guidance and its future vision in mind



3 The core concepts in Boeing's framing of V&V



4 Representative Boeing implementations and how they map to core concepts

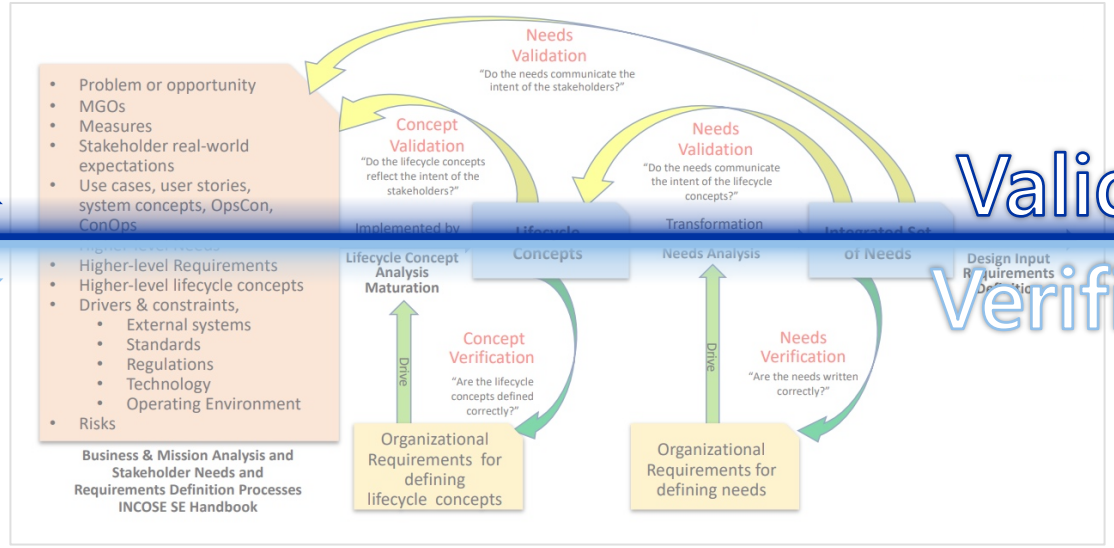


5 A conceptual architecture of the infrastructure Boeing is using to realize its vision

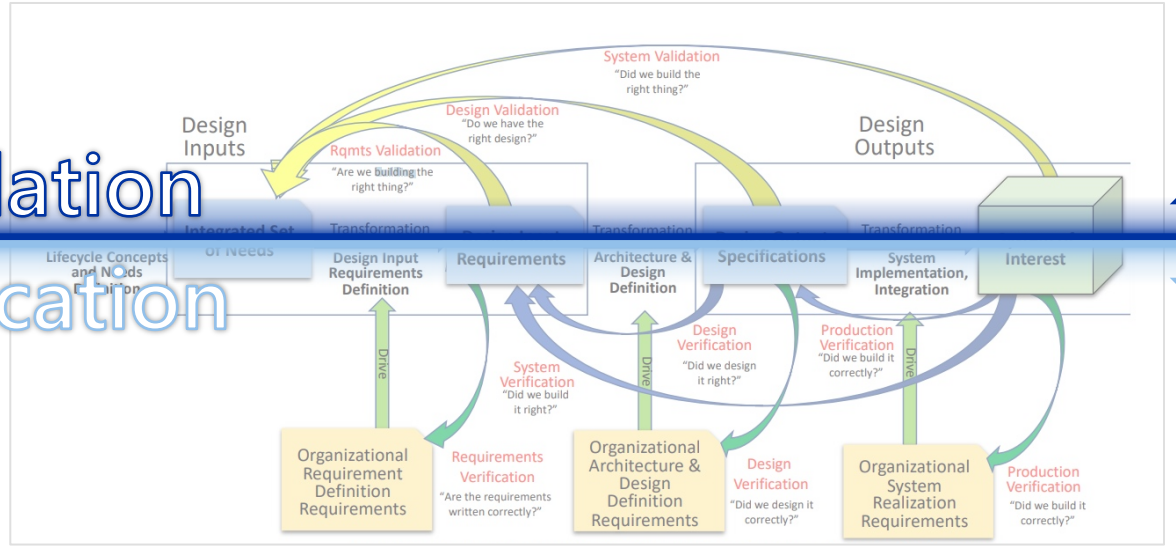
6 The motivation behind sharing and an invitation to collaborate

What is V&V?

Verification and Validation according to: **INCOSE Guides**



Katz, T., Orr, K., & Wheatcraft, L. (2022). **Guide to Needs and Requirements** (Document No. INCOSE-TP-2021-003-01, Version 1.0, pp. 41). INCOSE.

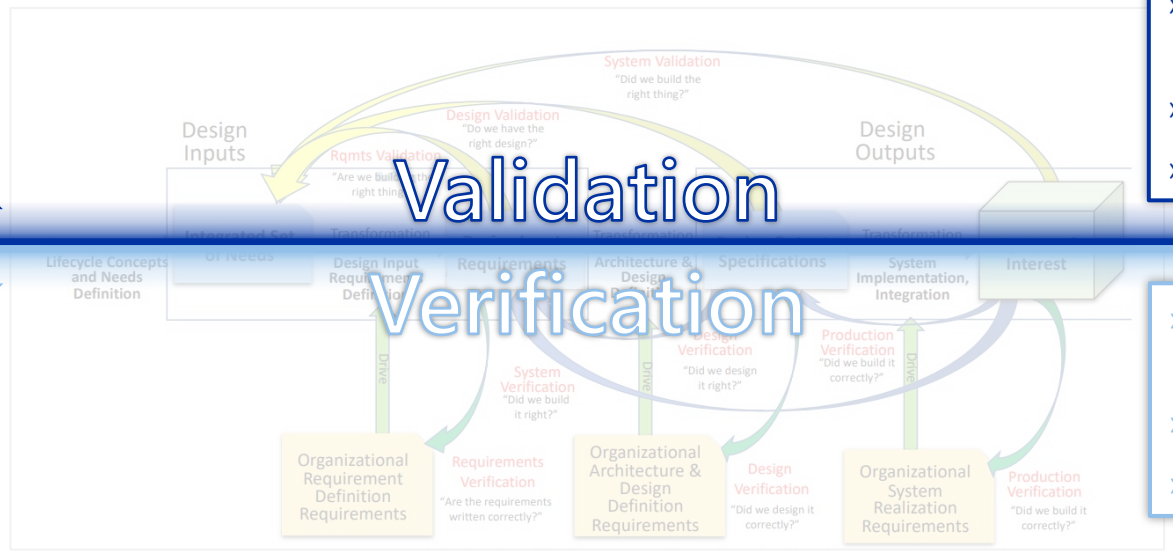


Wolfgang, R., Katz, T., & Wheatcraft, L. (2022). **Guide to Verification and Validation** (Document No. INCOSE-TP-2021-004-01, Version 1.0, pp. 21). INCOSE.

Different **types of verification and validation** occur throughout the product development lifecycle

What is V&V?

Verification and Validation according to: **ISO/IEC/IEEE 15288-2023**



From *INCOSE Guide to Verification and Validation v1*

See sections **3.54** *and* **6.4.11**

- Confirming with evidence that a **system, system element, or artifact achieves its intended use**
- About **building confidence that validation criteria can be met**
- Validation is something **confirmed by stakeholder**

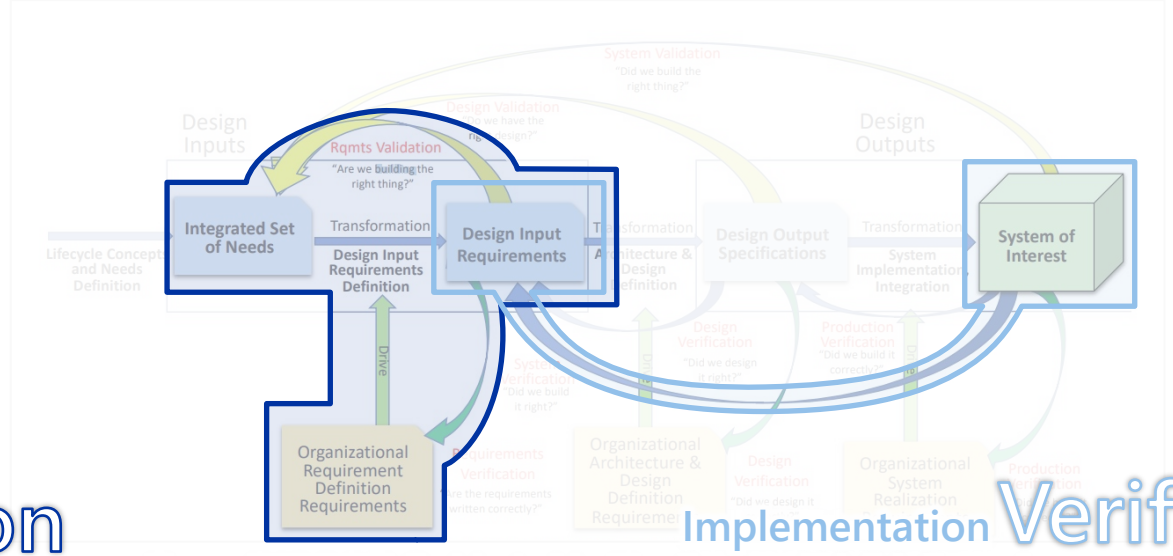
- Confirming with evidence that a **system, system element, or artefact meet specified requirements**
- About **comparing against required characteristics**
- Verification is something **confirmed based on standards or rules**

See sections **3.55** *and* **6.4.9**

"ISO/IEC/IEEE International Standard - Systems and software engineering--System life cycle processes," in *ISO/IEC/IEEE 15288:2023(E)* , pp. 9, 83-85, 88-91, 16 May 2023, doi: 10.1109/IEEESTD.2023.10123367.

What is V&V?

Verification and Validation according to: **ARP4754A**



From *INCOSE Guide to Verification and Validation v1*

Requirement Validation

- Confirming with evidence that the **requirements for a system or system element are "correct and complete"**
- This includes ensuring the **system or system element will meet the needs of stakeholders AND meet all required characteristics**

Implementation Verification

- Confirming with evidence that an **implementation of a system or system element meets requirements**
- Also involves ensuring the **safety analysis remains valid as implemented**

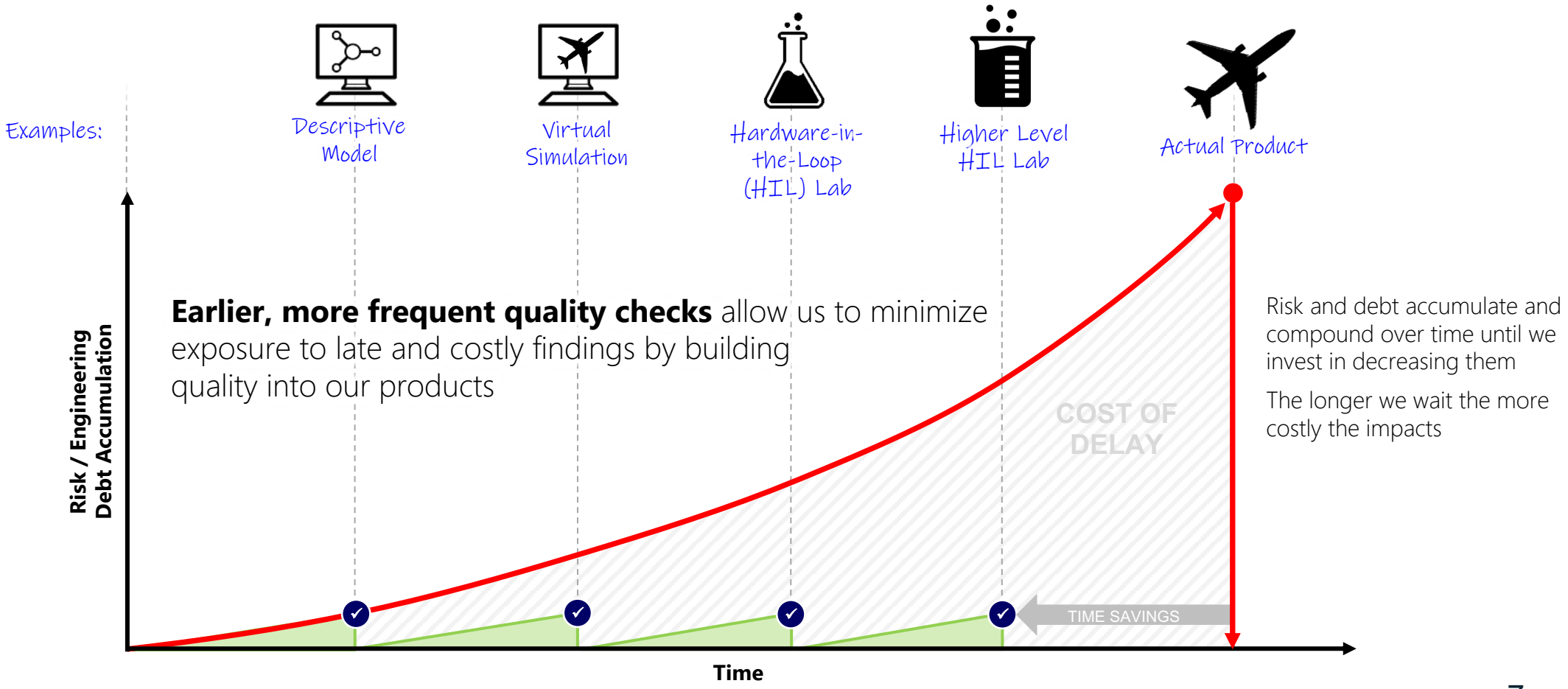
SAE International, "ARP4754A: Guidelines for Development of Civil Aircraft and Systems." p. 13, 54-72, [2010].

Industry standards define **different types of verification and validation**

Boeing's Framing of V&V

Common themes across industry guidance:

Iterative checking of engineering quality throughout the development lifecycle



Boeing's Framing of V&V

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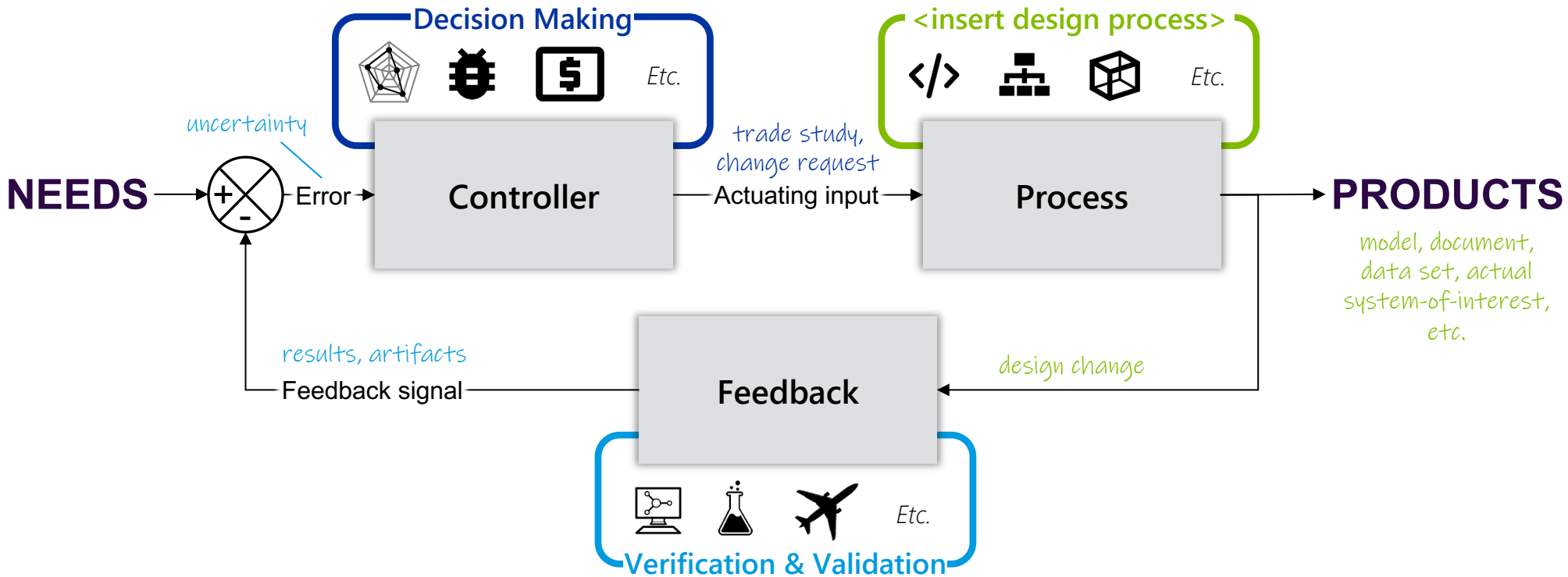
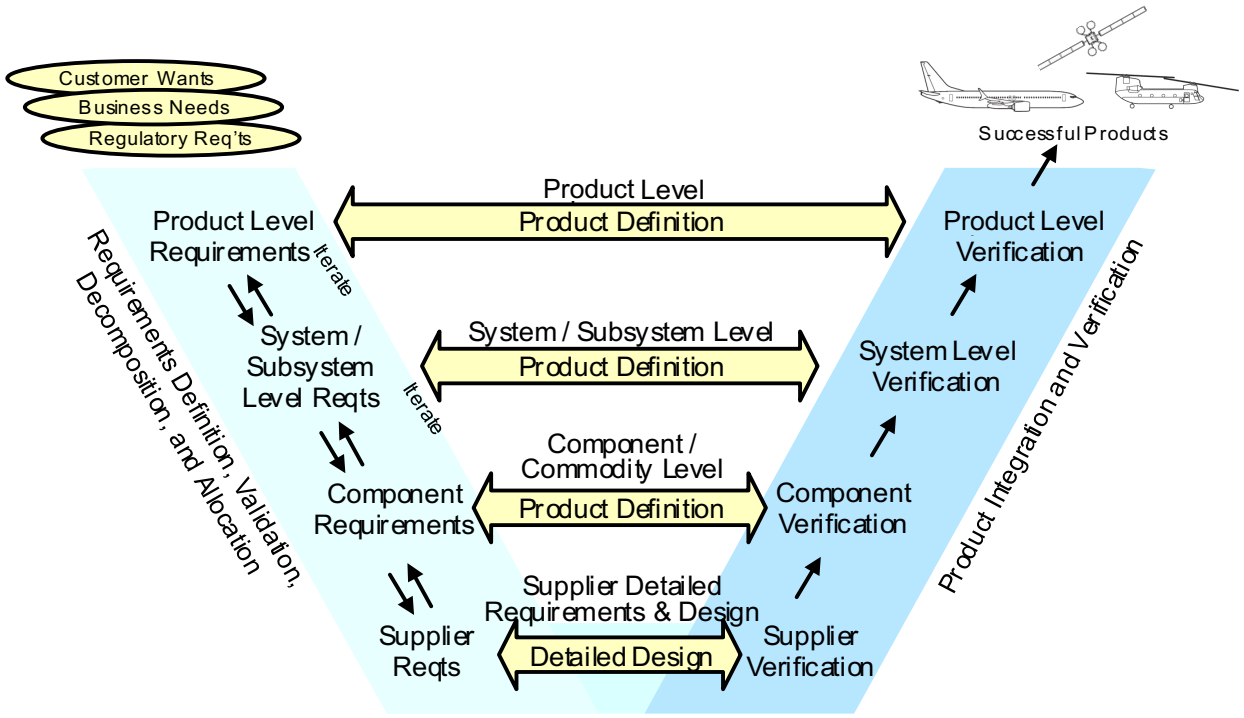


Boeing's Framing of V&V

Common themes across industry guidance:

Categorization of criteria sets with **<noun> verification** or **validation**



Requirement Validation

Implementation Verification

These need to match ARP4754A definitions used in Boeing Commercial Airplanes

Operational Validation

Design Validation

Needs Validation

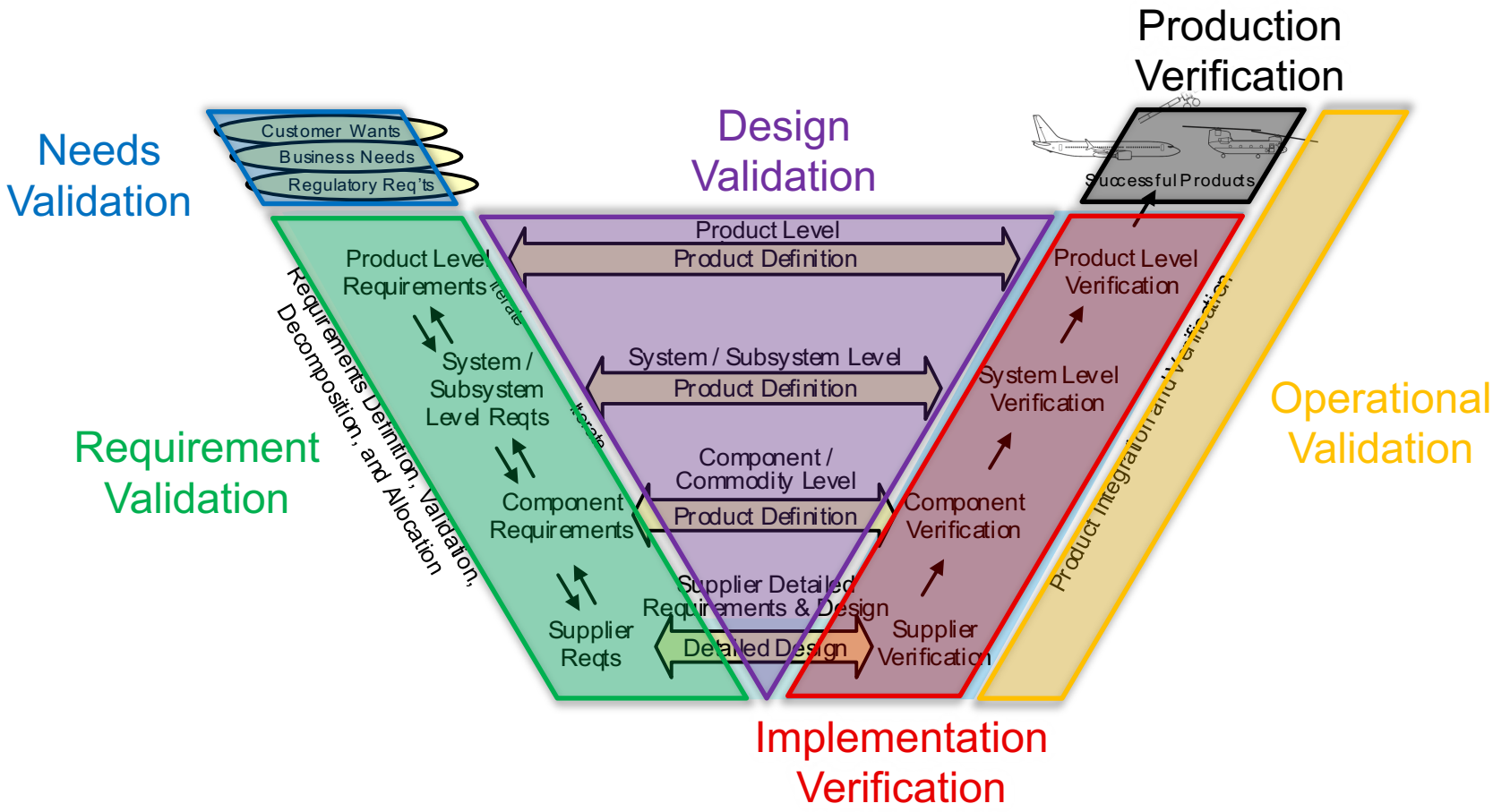
⋮

Boeing has more freedom here, but should strive for a common pattern

Boeing's Framing of V&V

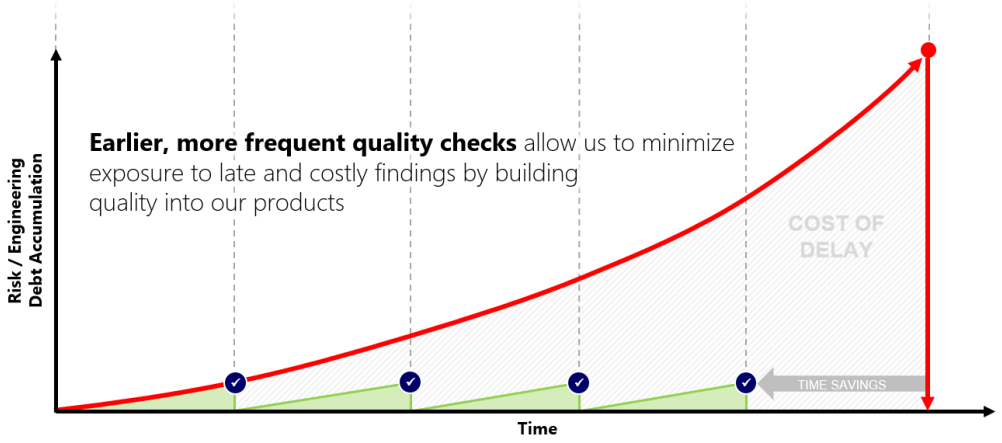
Common themes across industry guidance:

Categorization of criteria sets with **<noun> verification** or **validation**

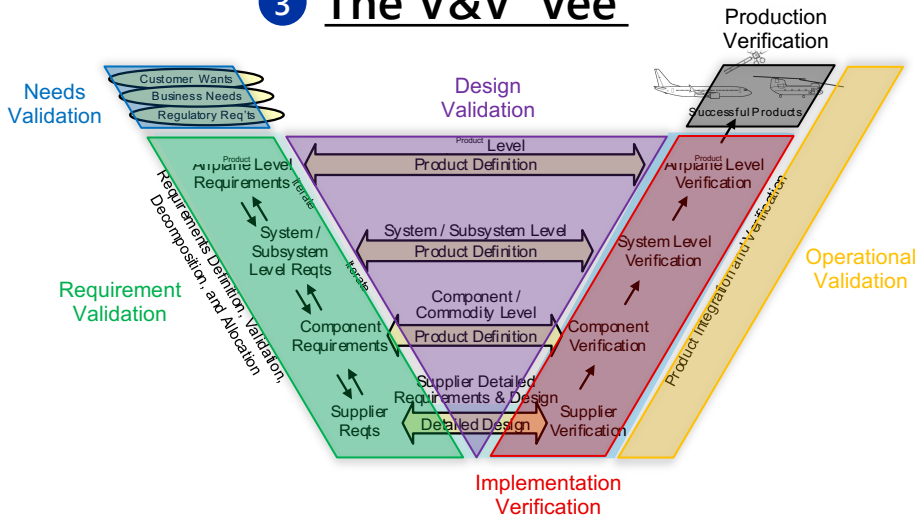


Boeing's Framing of V&V

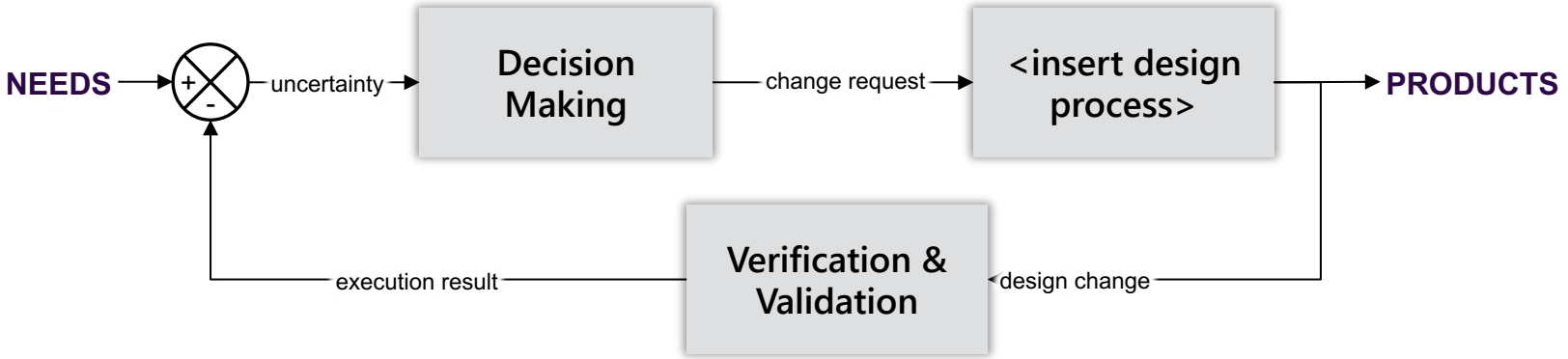
1 The Cost of Delay



3 The V&V 'Vee'

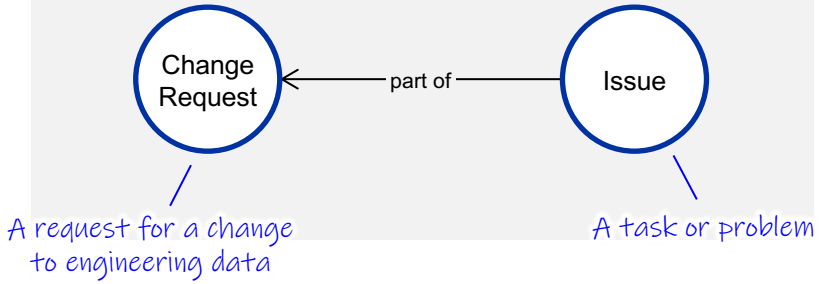


2 Closed-Loop Product Development

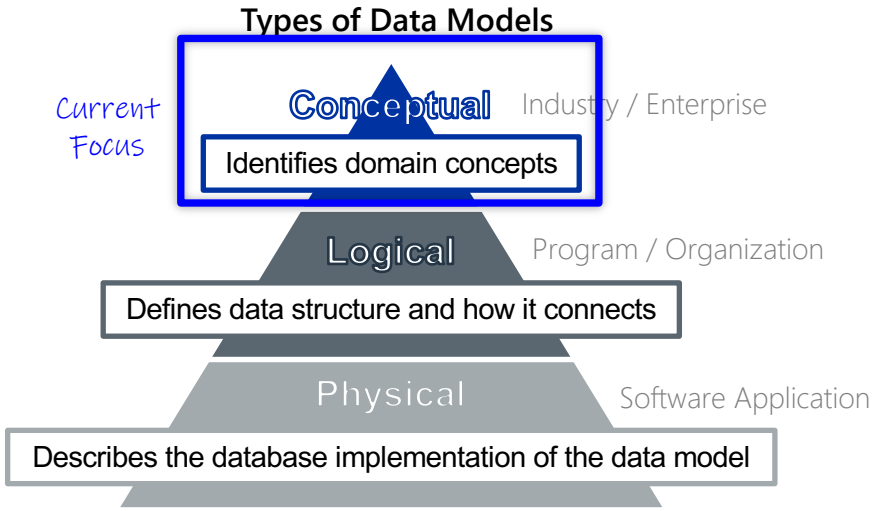


Boeing's V&V Conceptual Data Model

Decision Making



<insert design process>

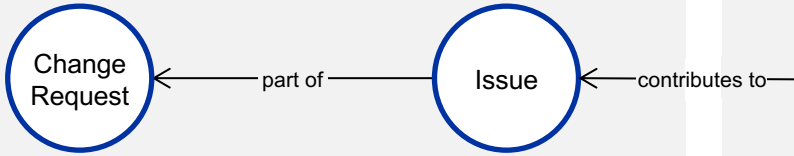


Verification & Validation

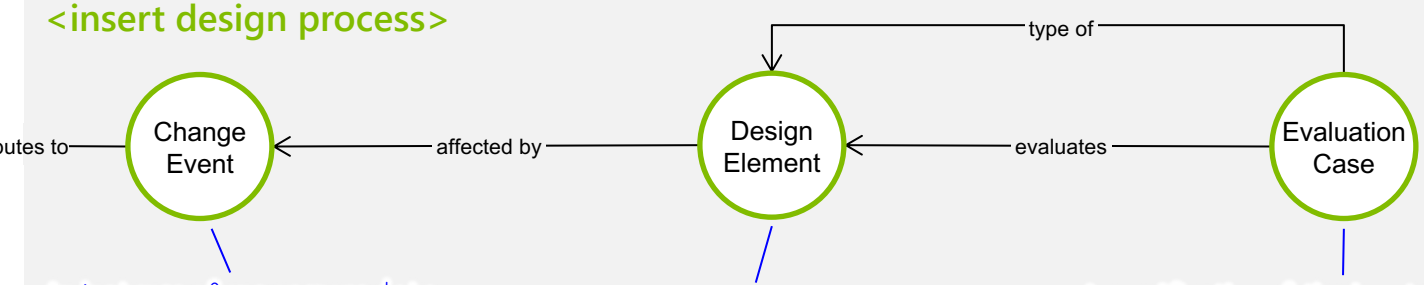
DISCLAIMER: Dated and incomplete view that has been modified for presentation purposes; data model continually evolving

Boeing's V&V Conceptual Data Model

Decision Making



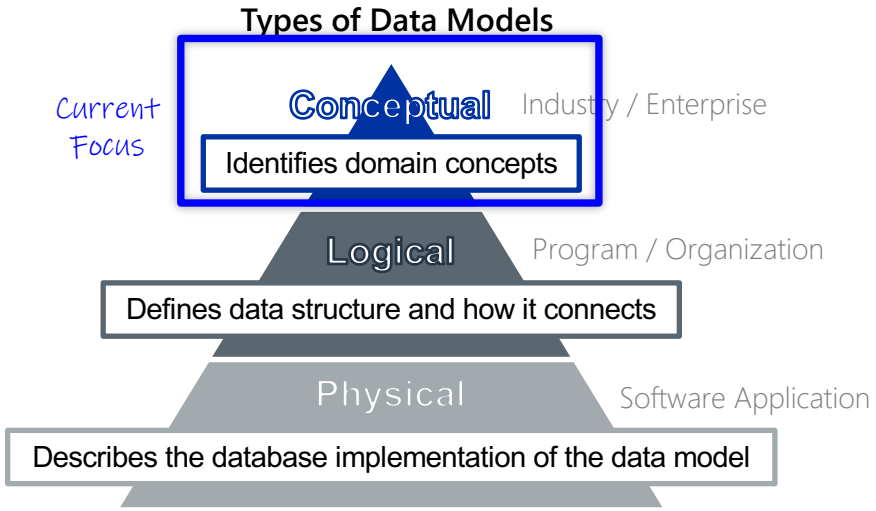
<insert design process>



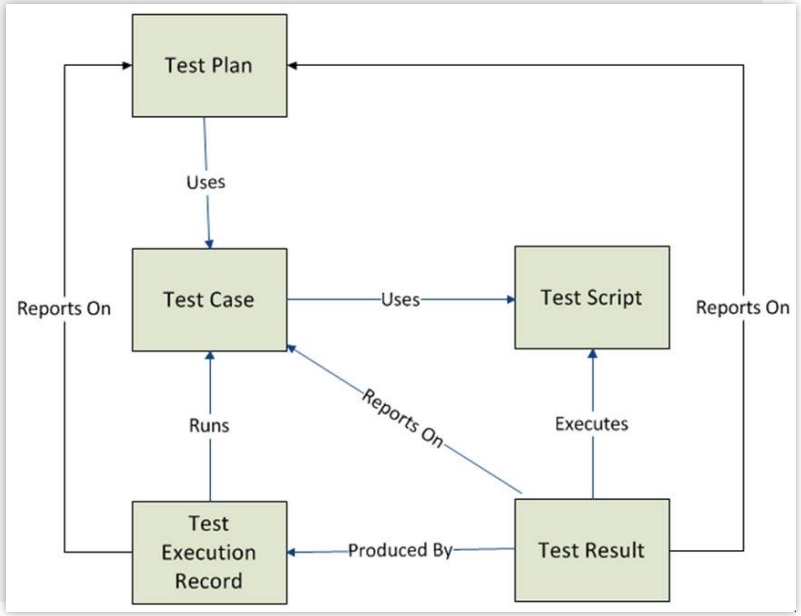
An instance of one or more data elements being added, modified, or deleted from an authoritative source

A uniquely identifiable element of a product's design

A specification of the inputs, execution conditions, success criteria, and procedural steps associated with evaluating a design element



Verification & Validation



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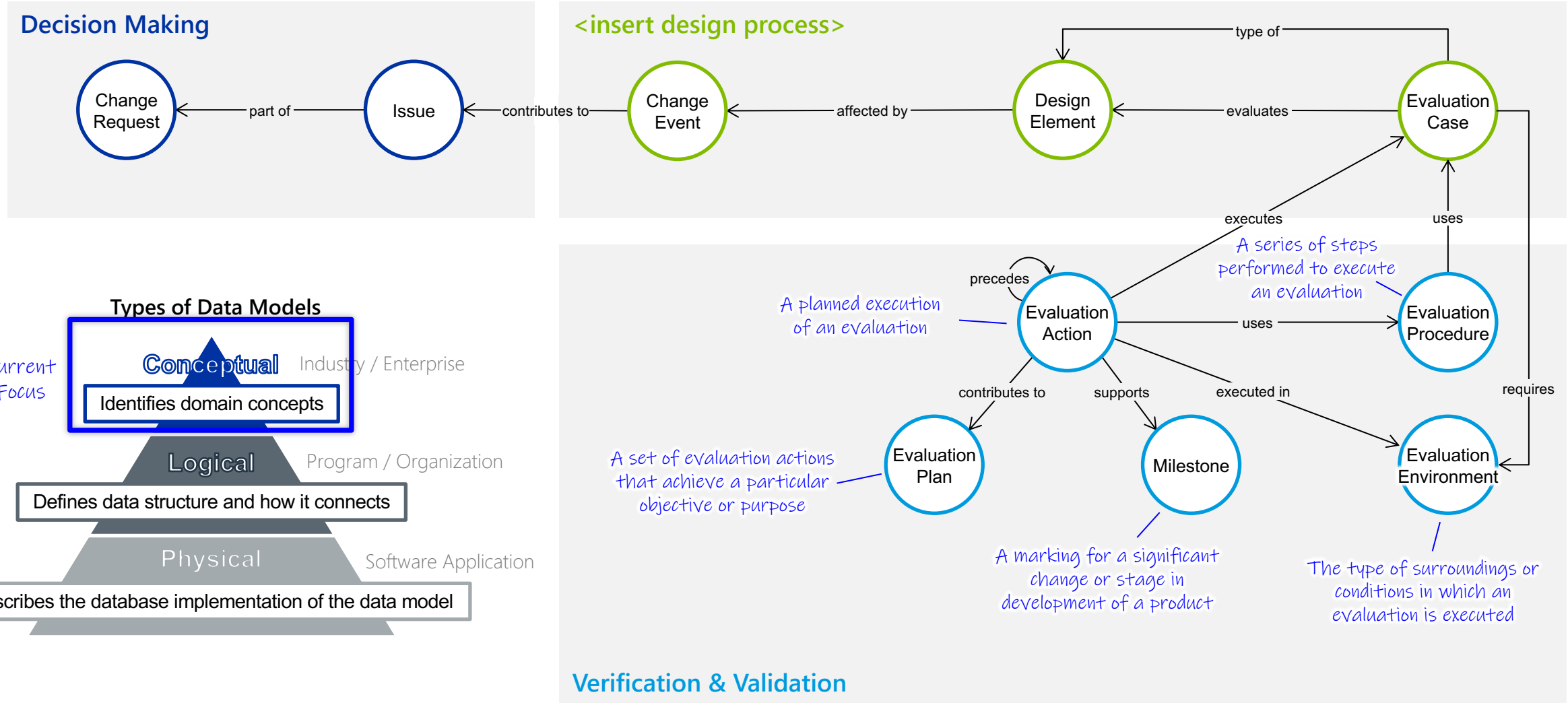
From OSLC Quality Management Vocabulary

Boeing's V&V Conceptual Data Model



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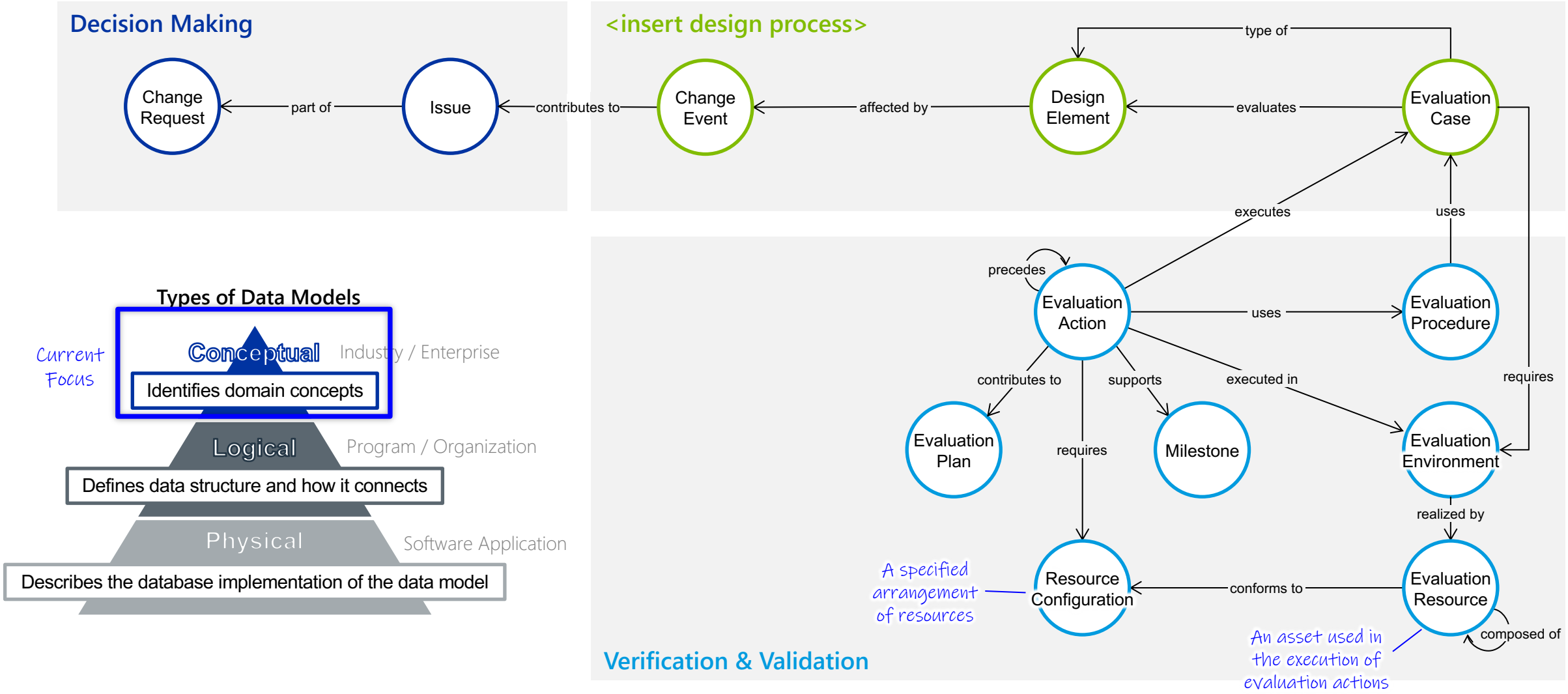

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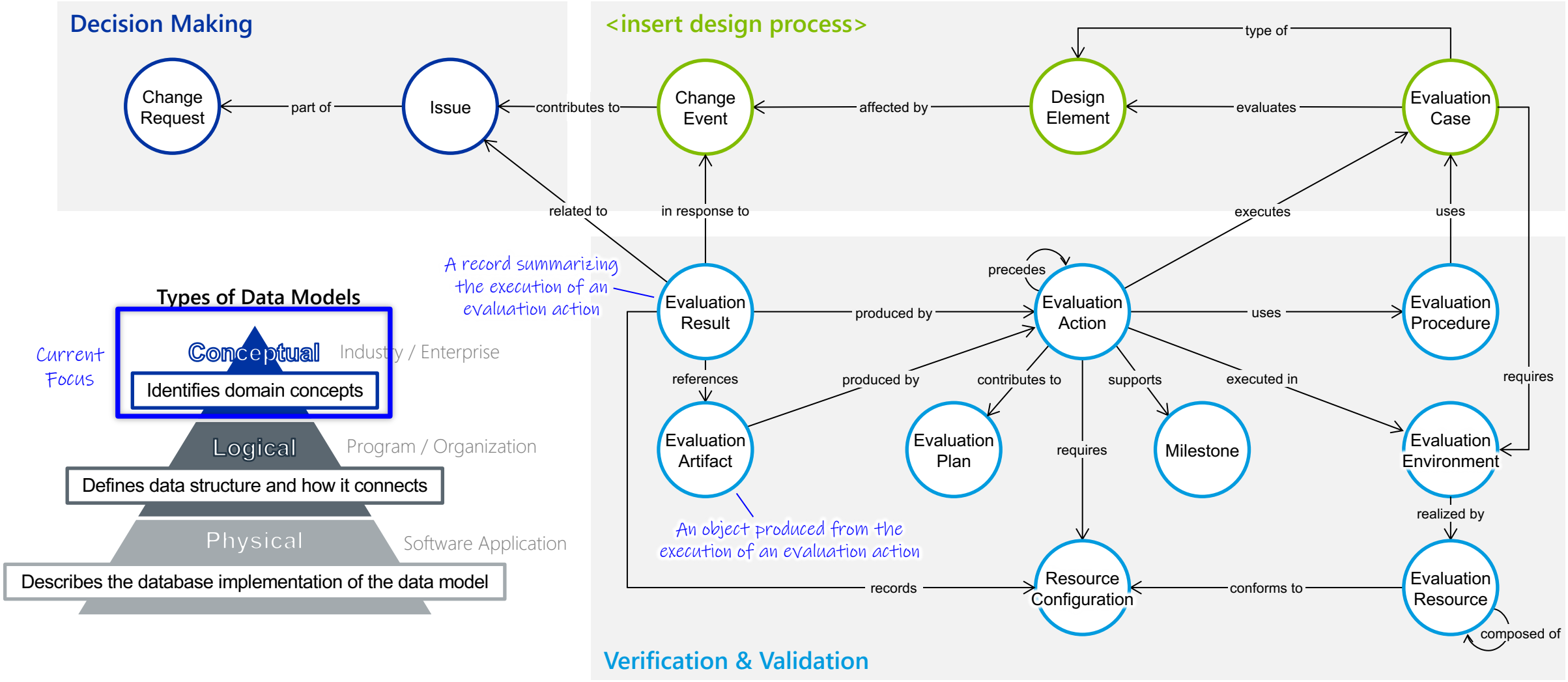

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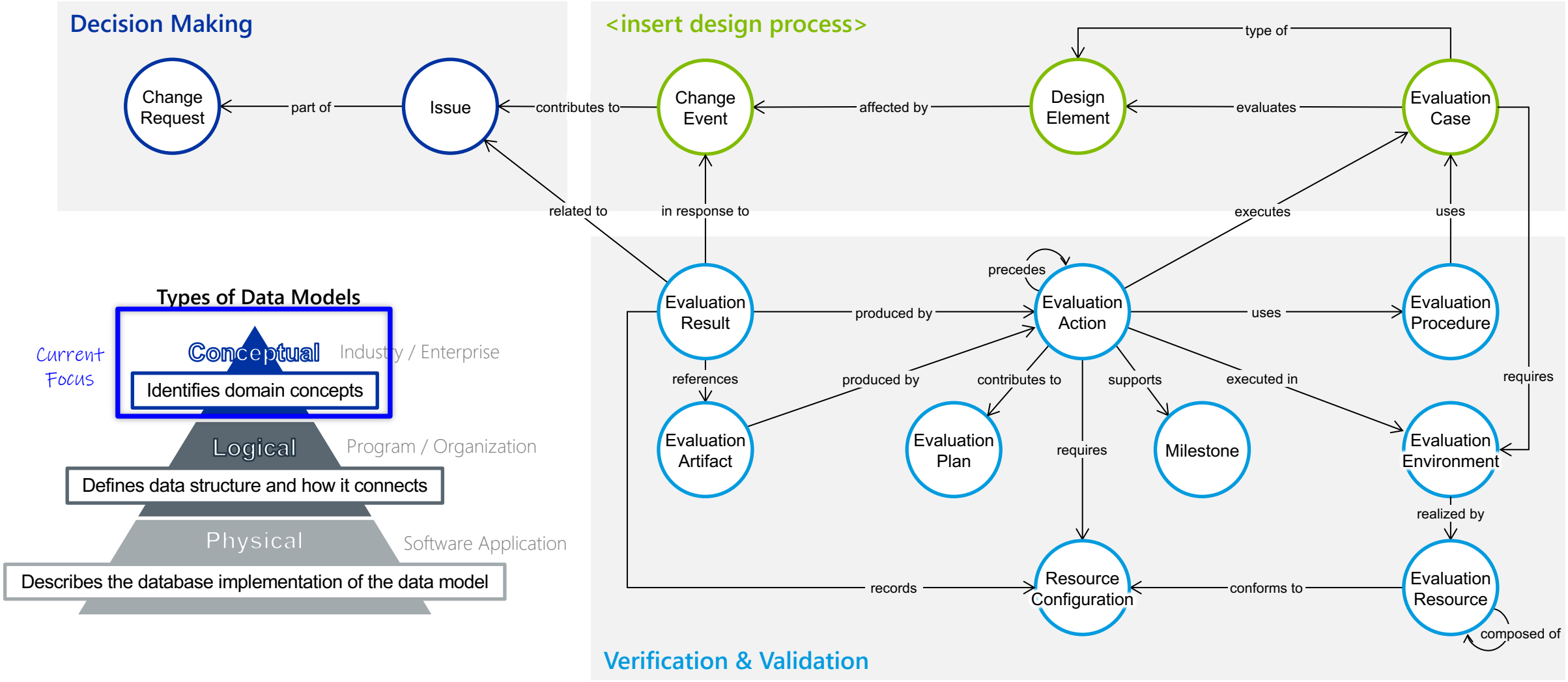
Activity instead of action?

Boeing's V&V Conceptual Data Model



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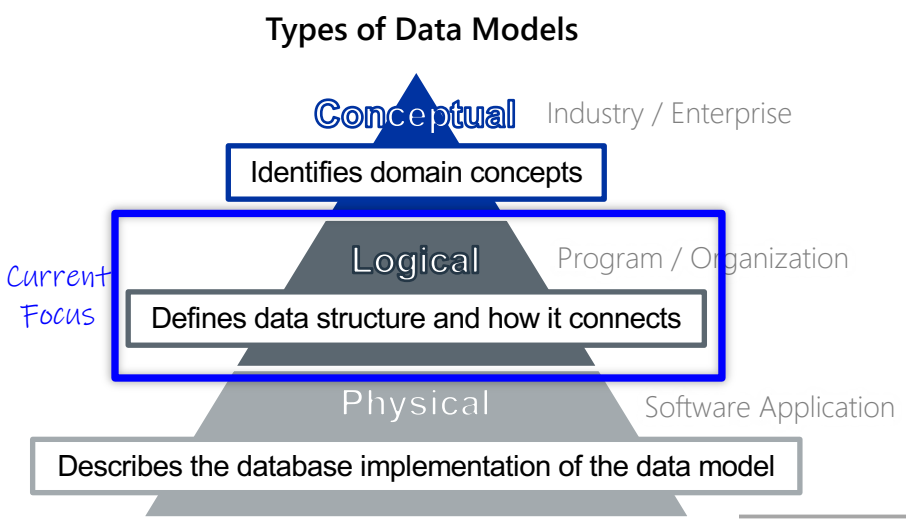
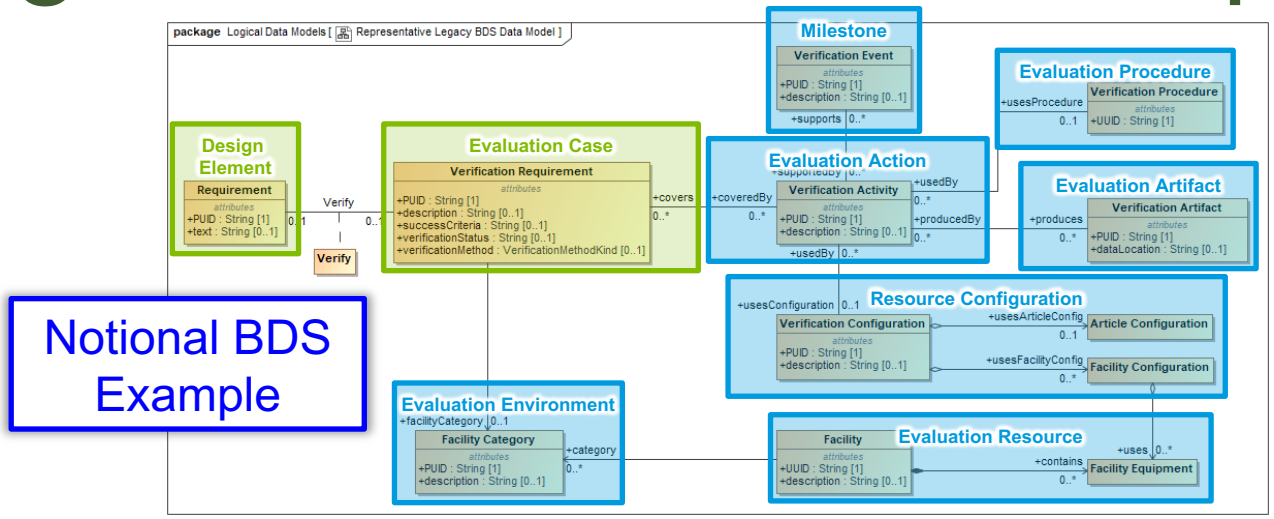
Boeing V&V Logical Data Model Examples

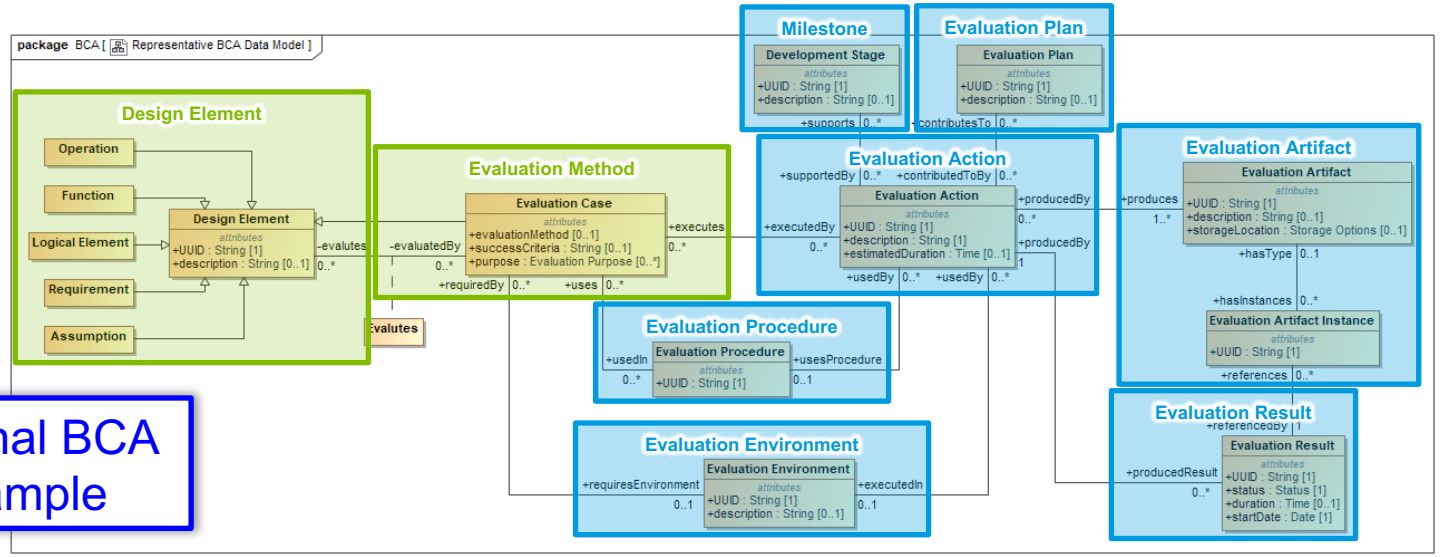




Notional BDS Example

Missing Concepts

- Evaluation Result
- Evaluation Plan



Notional BCA Example

- Resource Configuration
- Evaluation Resource

Data model mapping allows for **alignment while maintaining business specific vocabulary**

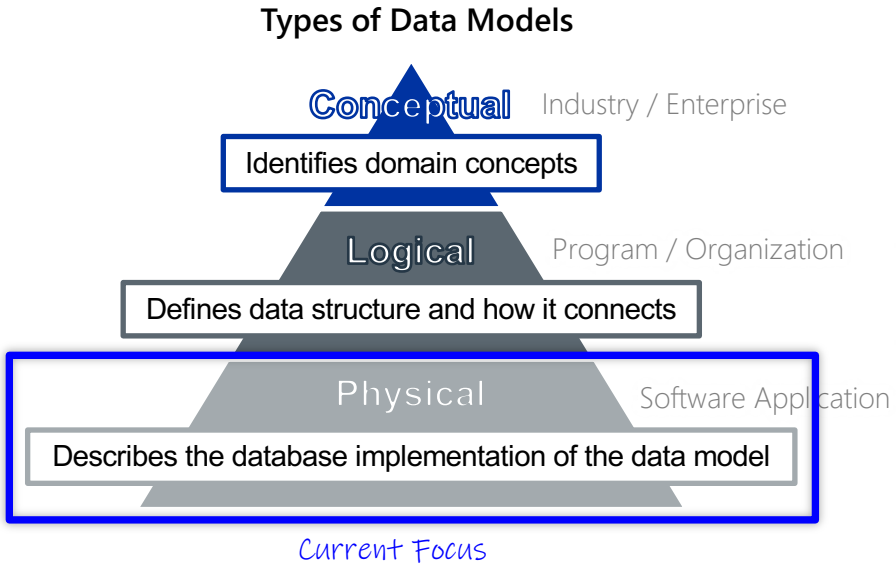
Boeing's V&V Infrastructure

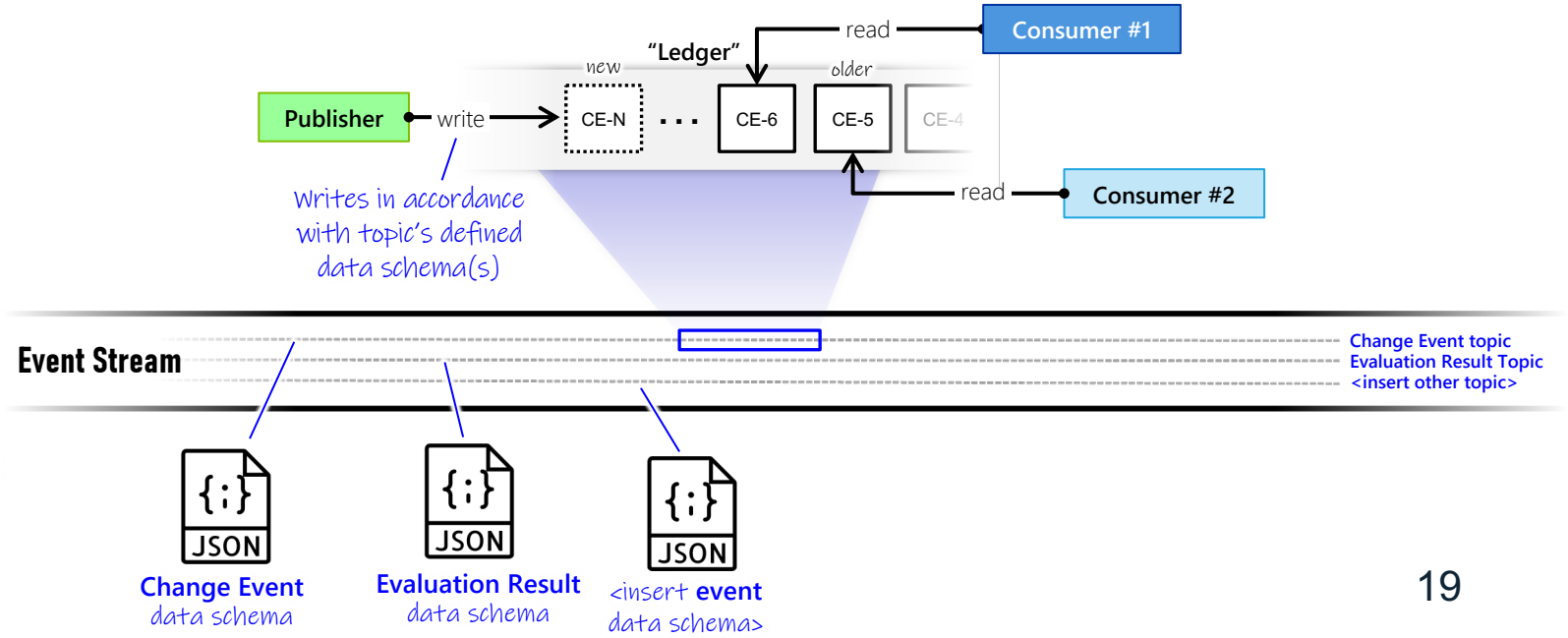
Key Characteristics: 1) **Loose coupled** 2) **Horizontally scalable** 3) **Near real-time responses**

STREAMING PLATFORMS

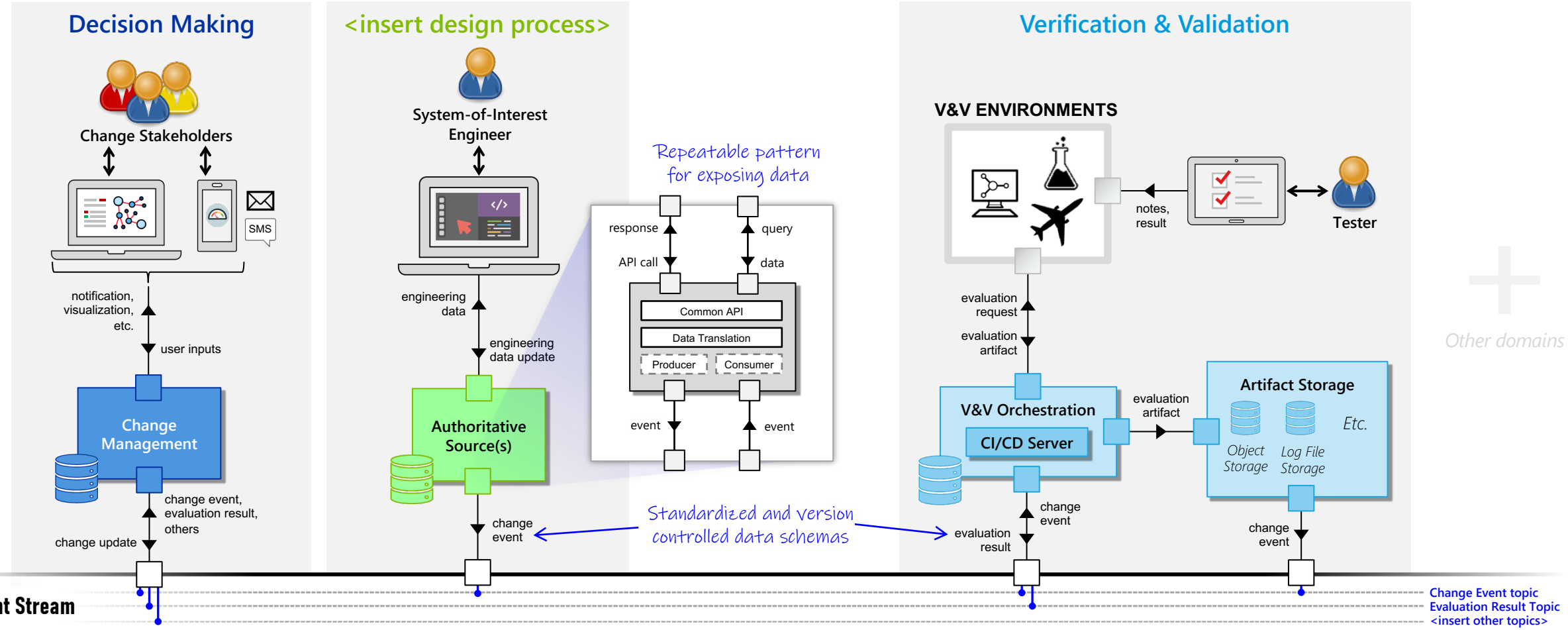
"Smart ends, dumb pipes"

- Decentralization of control of logic, orchestration, and transformation to services
- Allows applications and services to adapt and change at their own pace
- Enables automation and orchestration to respond in near real-time



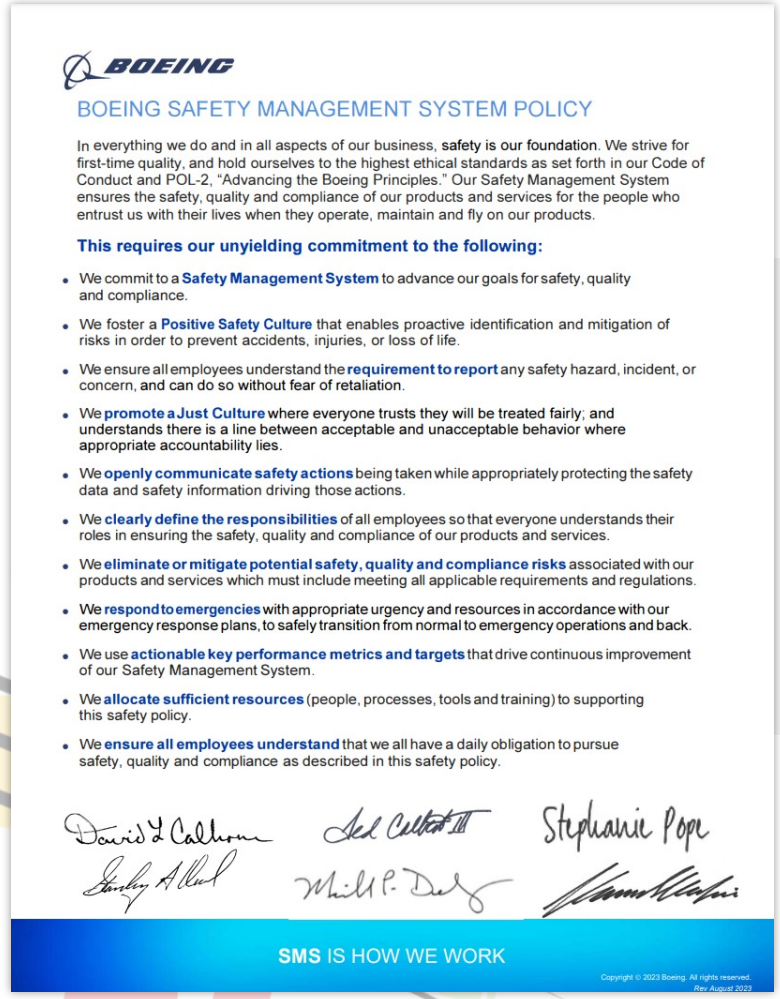


Boeing's V&V Infrastructure



Key Characteristics: 1) **Loose coupled** 2) **Horizontally scalable** 3) **Near real-time responses**

Why are we sharing?



BOEING

BOEING SAFETY MANAGEMENT SYSTEM POLICY

In everything we do and in all aspects of our business, **safety is our foundation**. We strive for first-time quality, and hold ourselves to the highest ethical standards as set forth in our Code of Conduct and POL-2, "Advancing the Boeing Principles." Our Safety Management System ensures the safety, quality and compliance of our products and services for the people who entrust us with their lives when they operate, maintain and fly on our products.

This requires our unyielding commitment to the following:

- We commit to a **Safety Management System** to advance our goals for safety, quality and compliance.
- We foster a **Positive Safety Culture** that enables proactive identification and mitigation of risks in order to prevent accidents, injuries, or loss of life.
- We ensure all employees understand the **requirement to report** any safety hazard, incident, or concern, and can do so without fear of retaliation.
- We **promote a Just Culture** where everyone trusts they will be treated fairly; and understands there is a line between acceptable and unacceptable behavior where appropriate accountability lies.
- We **openly communicate safety actions** being taken while appropriately protecting the safety data and safety information driving those actions.
- We **clearly define the responsibilities** of all employees so that everyone understands their roles in ensuring the safety, quality and compliance of our products and services.
- We **eliminate or mitigate potential safety, quality and compliance risks** associated with our products and services which must include meeting all applicable requirements and regulations.
- We **respond to emergencies** with appropriate urgency and resources in accordance with our emergency response plans, to safely transition from normal to emergency operations and back.
- We use **actionable key performance metrics and targets** that drive continuous improvement of our Safety Management System.
- We **allocate sufficient resources** (people, processes, tools and training) to supporting this safety policy.
- We **ensure all employees understand** that we all have a daily obligation to pursue safety, quality and compliance as described in this safety policy.

SMS IS HOW WE WORK

Rev August 2023

https://www.boeing.com/principles/safety.page

"Each of Westrum's organization types, because of its communication patterns, represents a different…buildup of latent pathogens in the human envelope. **Effective communication is vital** for identifying and removing these latent pathogens"

– Handbook of Aviation Human Factors

Westrum, Ron; Adamski, Anthony J. (2010). "Organizational factors associated with safety and mission success in aviation environments". Handbook of Aviation Human Factors. Lawrence Erlbaum Associates. p. 5-18

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References

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[OSLC-QM-2.1-Part1]
OSLC Quality Management Version 2.1. Part 1: Specification. Edited by Jim Amsden, Andrii Berezovskyi, and Gray Bachelor. 27 August 2020. OASIS Project Specification 01. https://docs.oasis-open-projects.org/oslc-op/qm/v2.1/ps01/quality-management-spec.html. Latest stage: https://docs.oasis-open-projects.org/oslc-op/qm/v2.1/quality-management-spec.html.

Westrum, Ron; Adamski, Anthony J. (2010). "Organizational factors associated with safety and mission success in aviation environments". Handbook of Aviation Human Factors. Lawrence Erlbaum Associates. p. 5-18

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