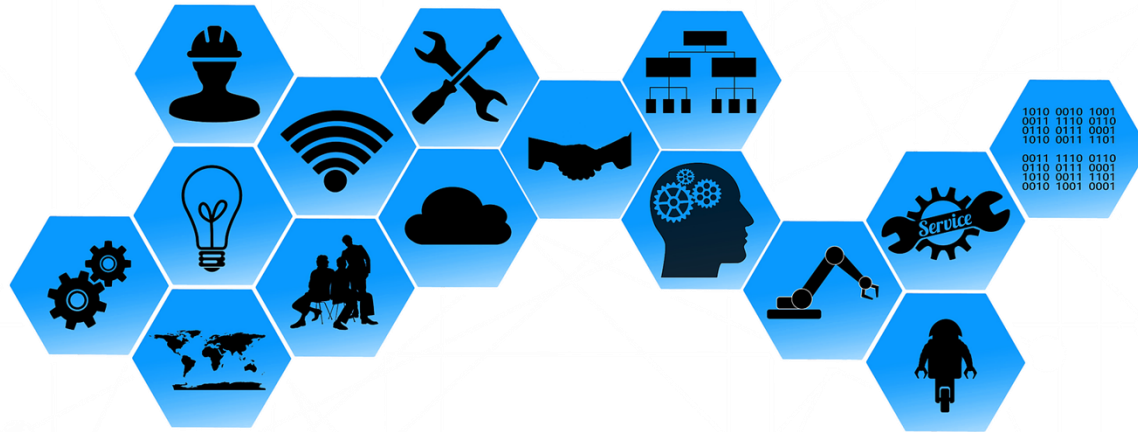2023
Annual **INCOSE**
international workshop

HYBRID EVENT

Torrance, CA, USA
January 28 - 31, 2023

Configuration Management Of Variants Across The Digital Thread

"When integrating artifacts across the life cycle in the digital thread, do we need Configuration Records?"

Characteristics Of Our Context

- 5+ product types
- 50+ architectures
- 500+ technical models
- 5000+ SKUs

Agenda

- Configuration Management 101
  - Artifacts produced across the system life cycle
  - Traceability between transformations occurring across the life cycle
  - Configurations vs digital thread - definitions

- System Meta Model - MBSE vs PLM domain challenges

- Trace links, OSLC

- Configuration Management And Digital Thread Needs/Jobs
  - Defining System Configurations
  - Analyzing completeness and correctness

- Feature based approach to generating configuration items and configurations

- Conclusion, Call-to-action

Configuration Management 101
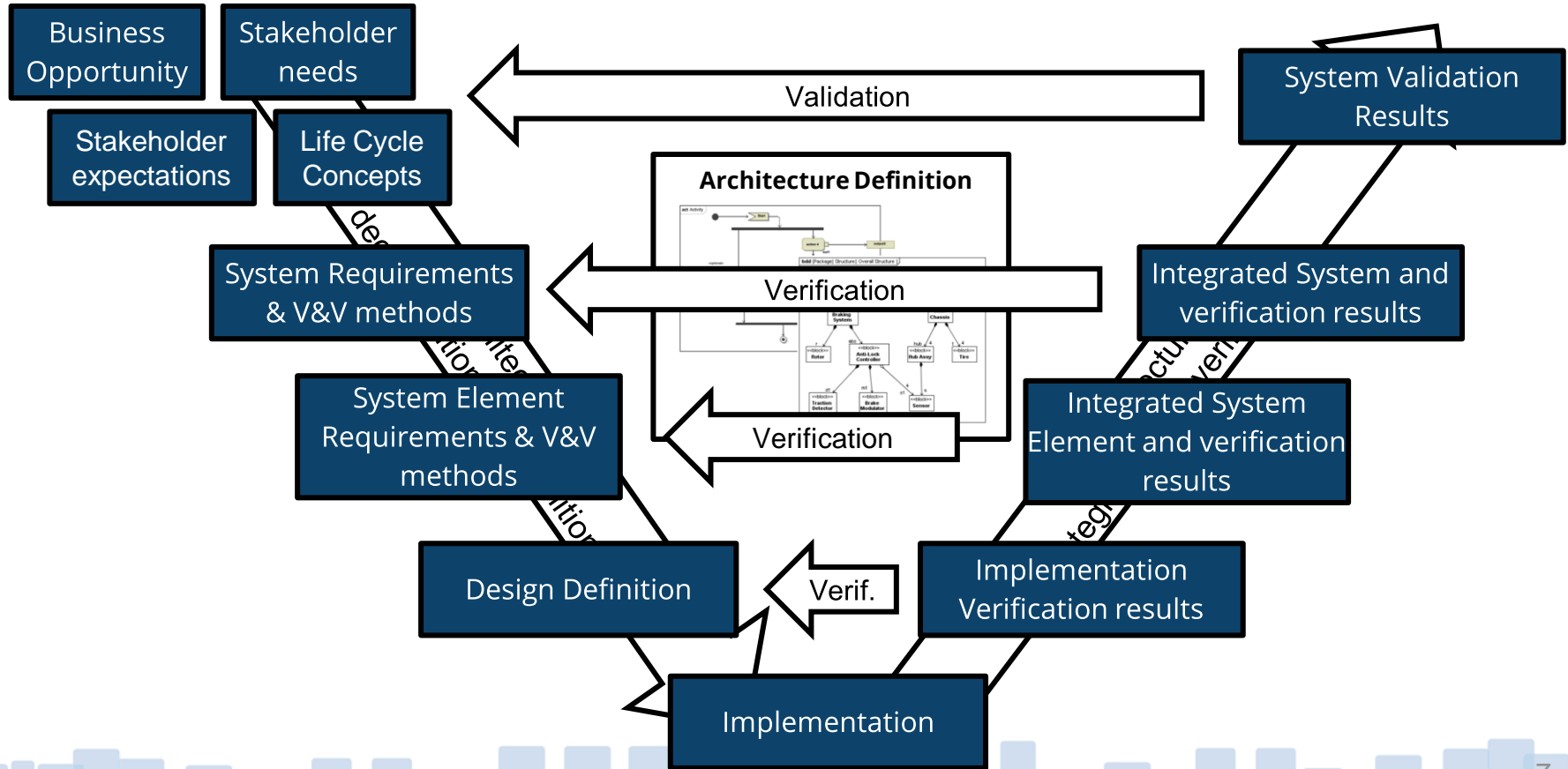
Definition

5.5.1.1 Purpose   As stated in ISO/IEC/IEEE 15288,

[6.3.5.1] The purpose of the Configuration Management process is to manage and control system elements and configurations over the life cycle. CM also manages consistency between a product and its associated configuration definition.

Configuration Items
(In Work, Baselines) → **Configuration Management** → Configuration Record (In work)

Configuration Record (Baseline)

A configuration record consist of configuration items

Potential Configuration Items Across The Life Cycle

Business Opportunity

Stakeholder needs

Stakeholder expectations

Life Cycle Concepts

System Validation Results

Validation

Architecture Definition

System Requirements & V&V methods

Verification

Integrated System and verification results

System Element Requirements & V&V methods

Verification

Integrated System Element and verification results

Design Definition

Verif.

Implementation Verification results

Implementation

Configuration Items vs System Stages

CONCEPT	DEVELOPMENT	PRODUCTION	TRANS-PORTATION	OPERATIONAL PERIOD				RETIREMENT
				SALES	INSTALL-ATION	UTILIZATION	SUPP-ORT	

- Life Cycle Concepts
- Needs
- Requirements
- Architecture
- V&V methods
- System verification
- Simulation models

- Design Definitions
- System Verification
- Manufacturing BOMs
- Whitebox test
- Simulation models

- Manufacturing BOMs updates
- Product SN

- Re-manufacturing

- Usage statistics
- SW update

- Service history

- Retirement record

Configuration Records Of Configuration Items
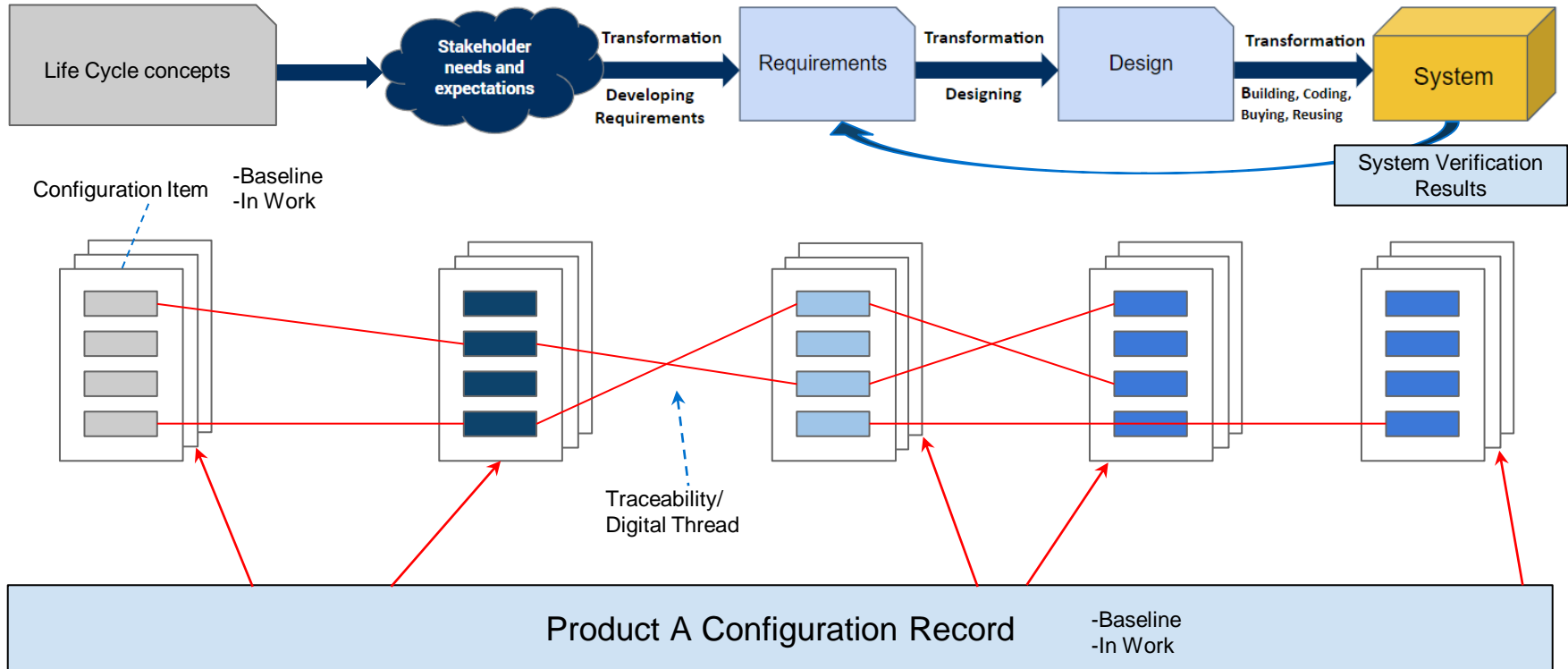
How We Define Product Configuration Records

"A **configuration item** contains artifacts that describes the system"

"A product **configuration record** contains configuration items that applies to the system"

"The **digital thread** is the connections between artifacts"

The Integrated Data Set (2017)

"..... a common, integrated dataset to represent the SE work products and underlying data and information generated throughout the system life cycle."
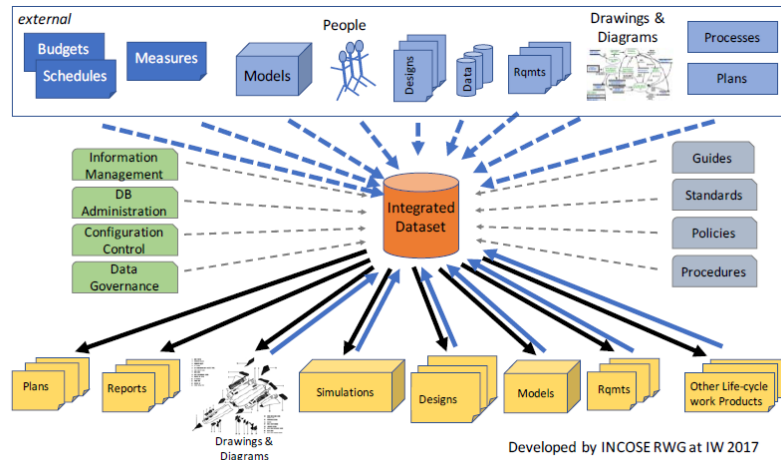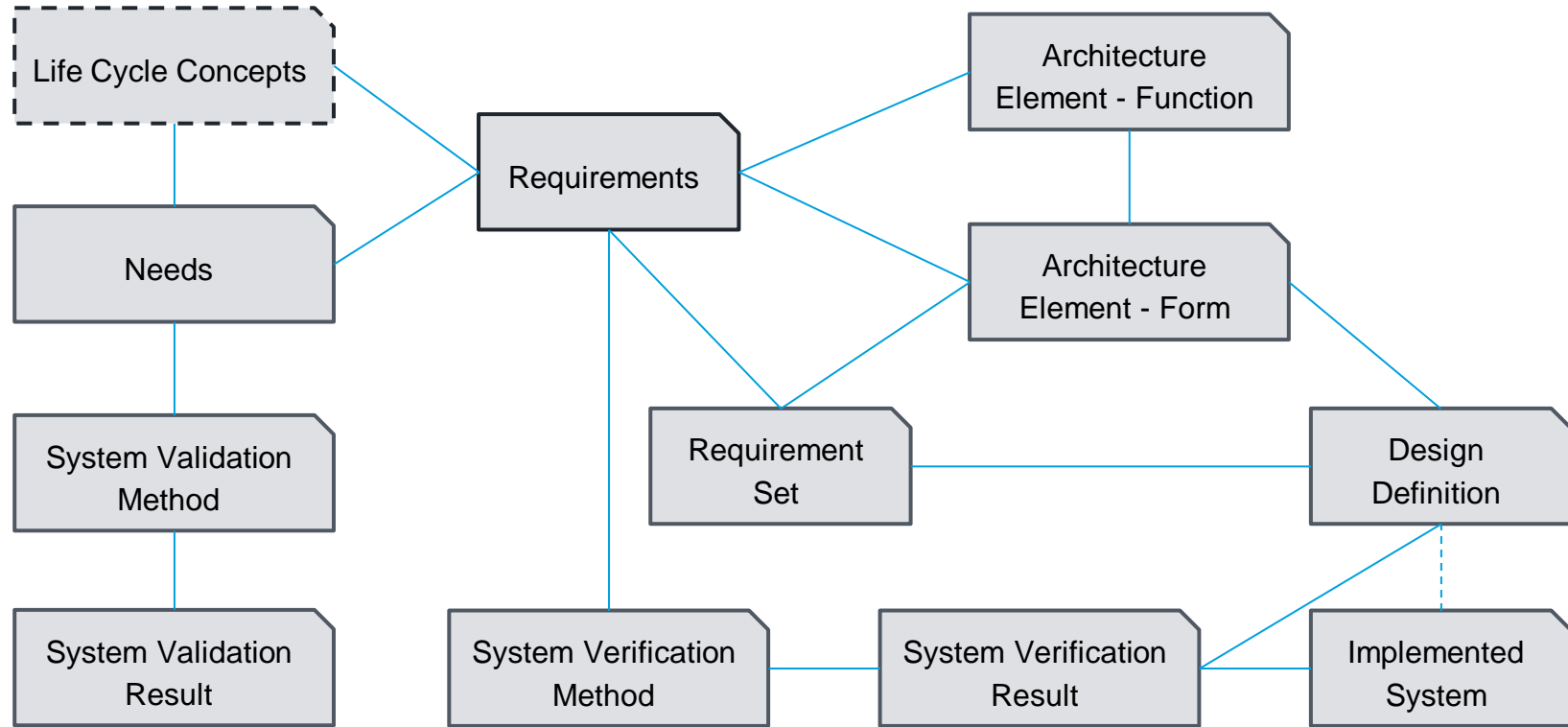

Figure 1: Integrated Data as the foundation for SE

"The ontology includes the formal naming and definition of a set of terms, entities, data types, and properties as well as defining the **relationships** between these terms, entities, data types…"
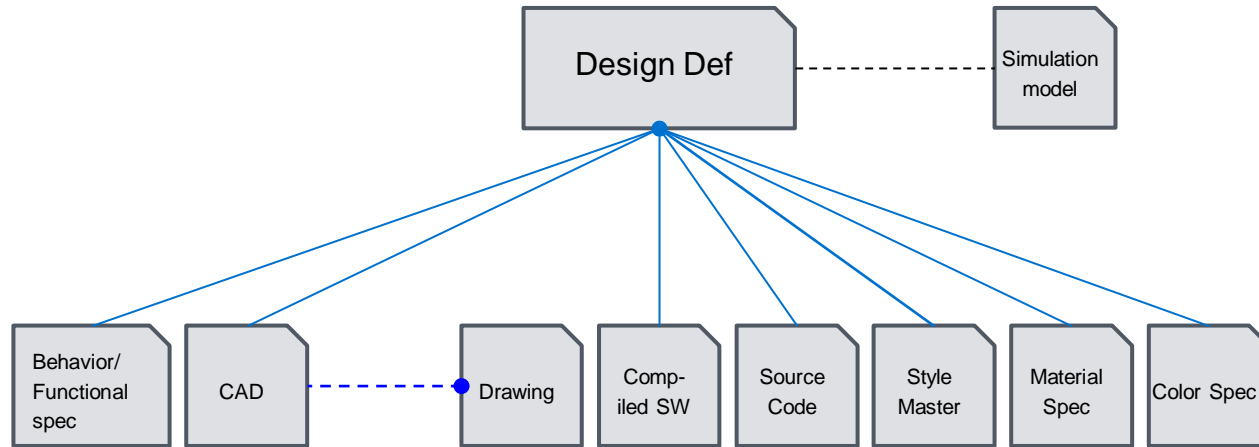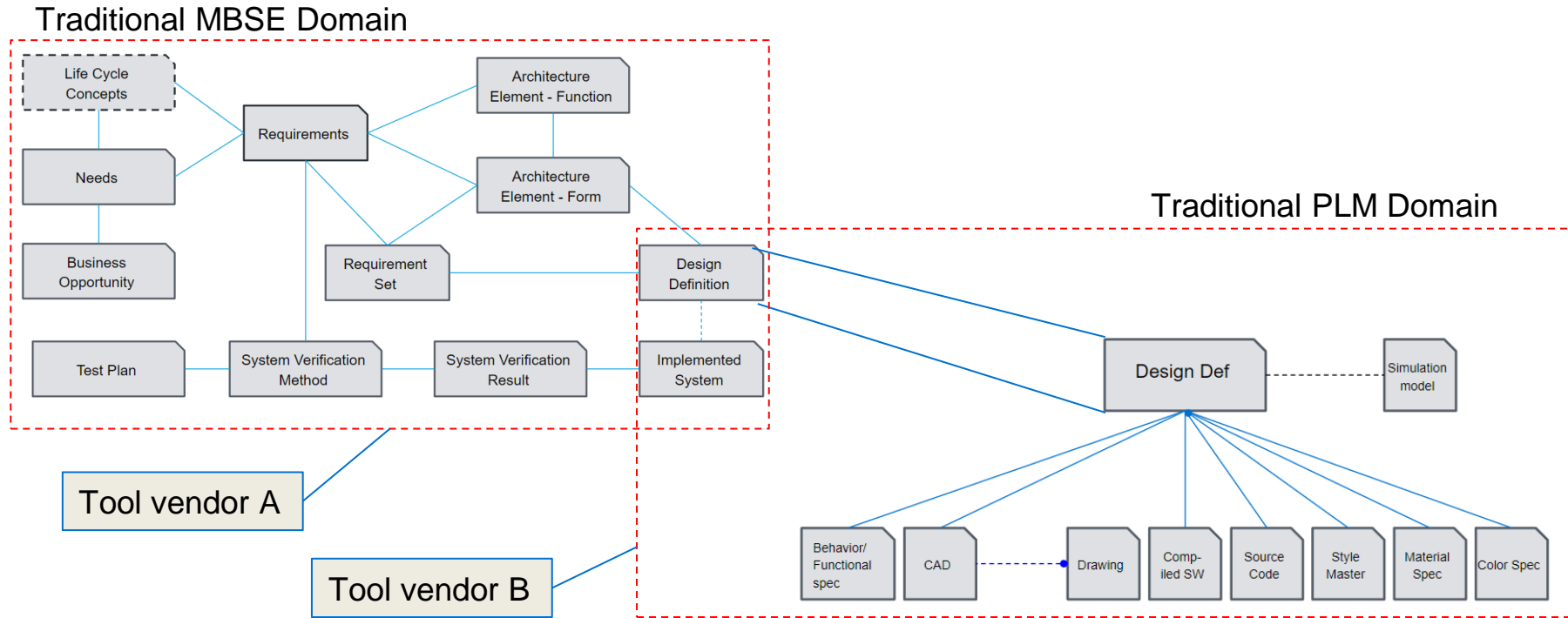
MBSE and PLM domains

System Meta Model

System Meta Model MBSE Centric

System Meta Model PLM Centric

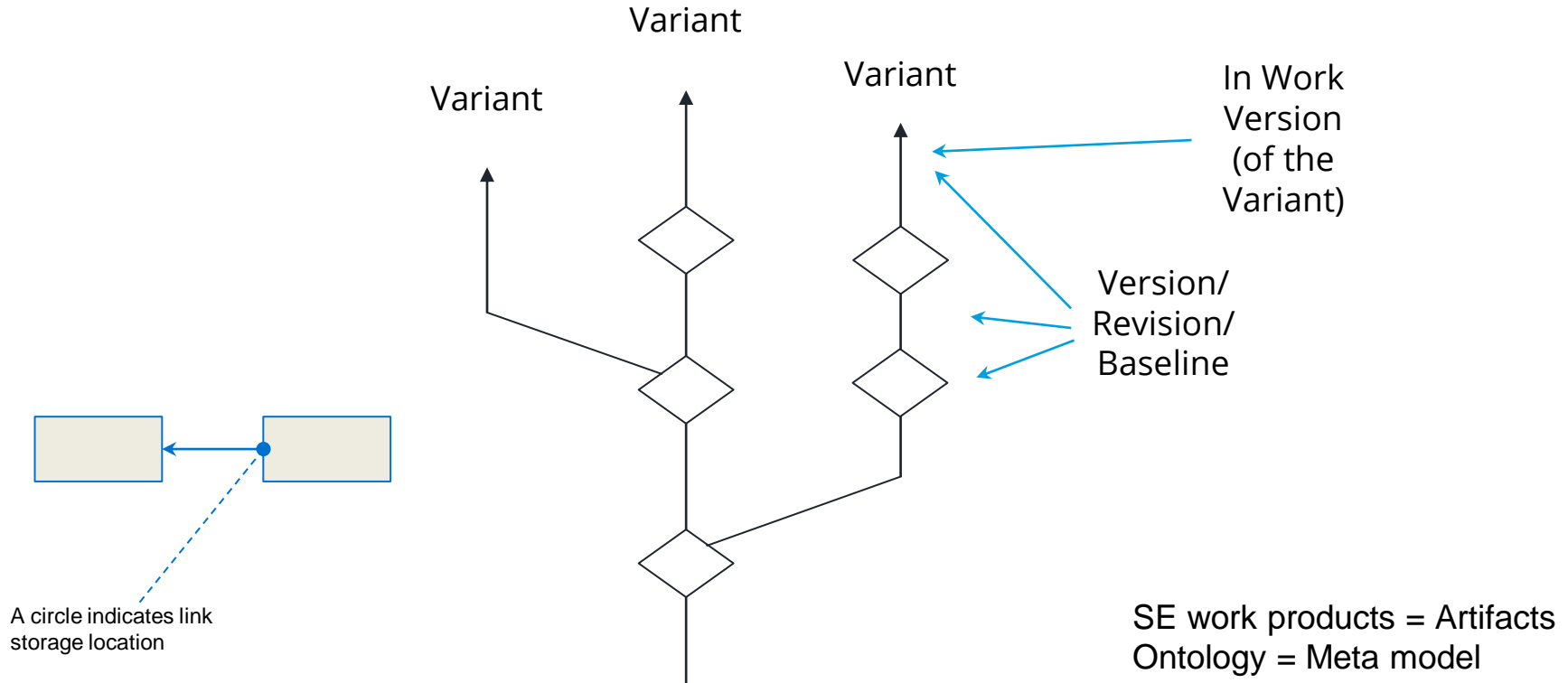# The Intersection Between PLM and MBSE Domains

Trace Links

Terms

Variant

Variant

Variant

In Work Version (of the Variant)

Version/ Revision/ Baseline

A circle indicates link storage location

SE work products = Artifacts
Ontology = Meta model

Different Approaches To Linking

Requirement ← **One way** link ← Design Definition

Requirement ← **Reverse lookup** link ← Design Definition rev1 / Design Definition rev2

Context

Variant vs Revision specific link

Requirement A Var3 ← Var3 Link
Requirement A Var2 ← Var2 link
Requirement A Var1 ← Var1 Rev 4 link

Verification Method

Many revisions

Different Approaches To Linking

Dynamic link   **OSLC**

Requirement A Var3

Requirement A Var2

Requirement A Var1

Many revisions

Verification Method

Dynamic link to
Requirement A

Context/
Configuration

Link Validity

Is the relationship still valid for a new revision?

Requirement Var 1 Rev 2 — Var1 Link — ❓ Valid

Requirement Var 1 Rev 1 — Var1 link — ✔️ Valid

Design Definition Rev 1
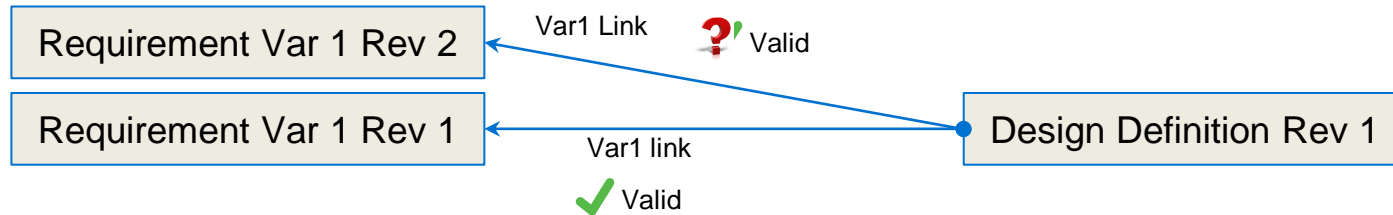
Management of Link Validity at an individual link level significantly adds to the complexity of managing trace relationships - Is it worth it? Is there a better way?

Many tools lack the capability to flag only relevant changes

Configuration Management And Digital Thread Needs

What Are The Jobs To Be Done?
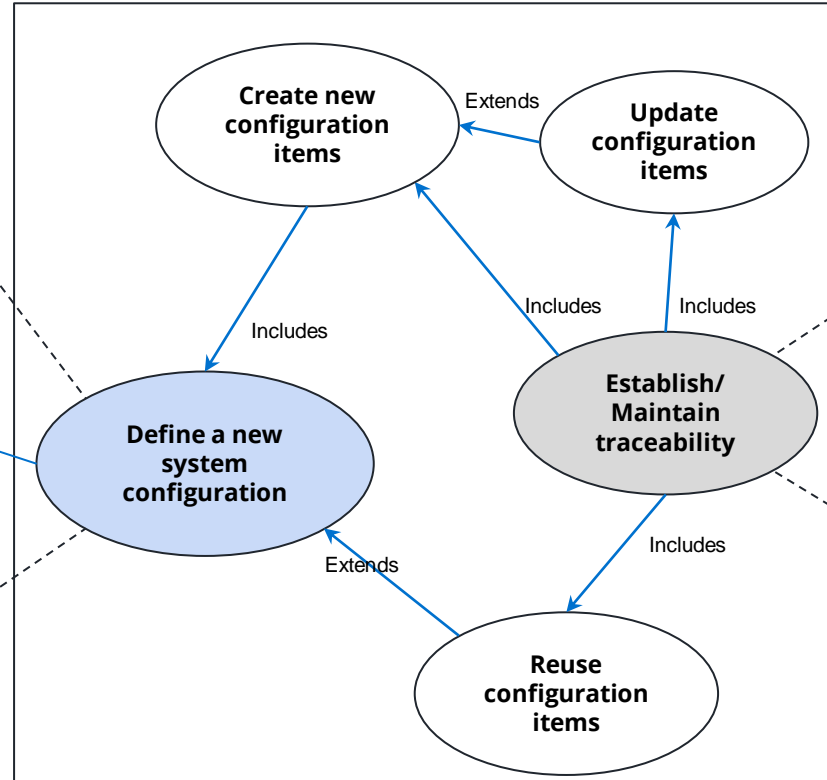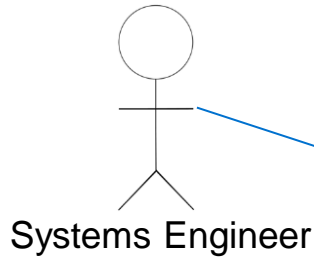
Why would I need Configuration Records?

Three main jobs:

1. Define a new system configuration
2. Find the complete set of artifacts describing a specific system configuration
3. Analyze correctness and completeness of the system definition

Use Cases

As a systems engineer I want to **define a set of artifacts from across the life cycle that describes a system configuration** so that my project team has an up to date easily accessible single source of truth of the system definition
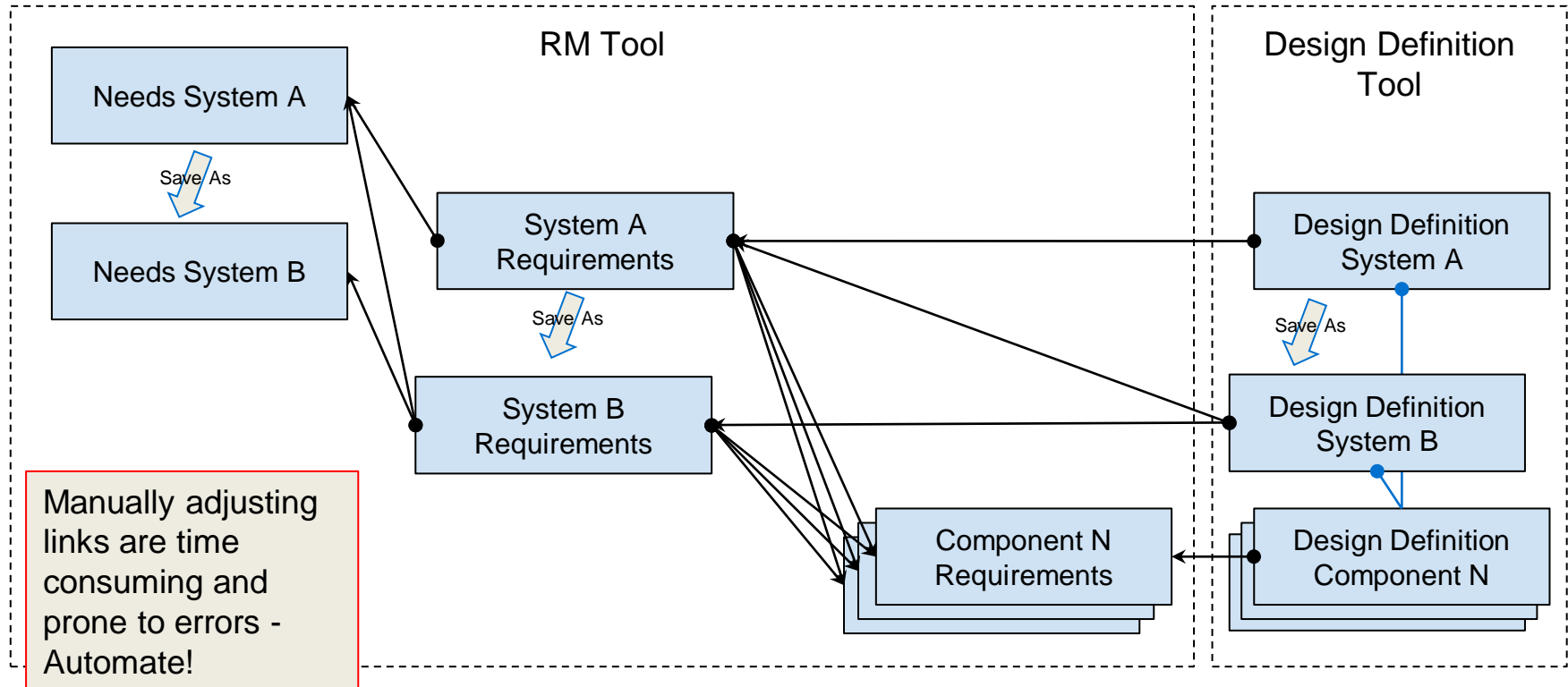
Create new configuration items

Extends

Update configuration items

As an engineer I want to **minimize the time it takes to maintain trace links** when creating new versions of artifacts

Includes

Systems Engineer

Define a new system configuration

Establish/ Maintain traceability

As an engineer I want to **maximize the correctness of the trace links**

Includes

Includes

Includes

Extends

Reuse configuration items

As an engineer I want to **minimize the time** it takes to create **new variants of a system configuration**
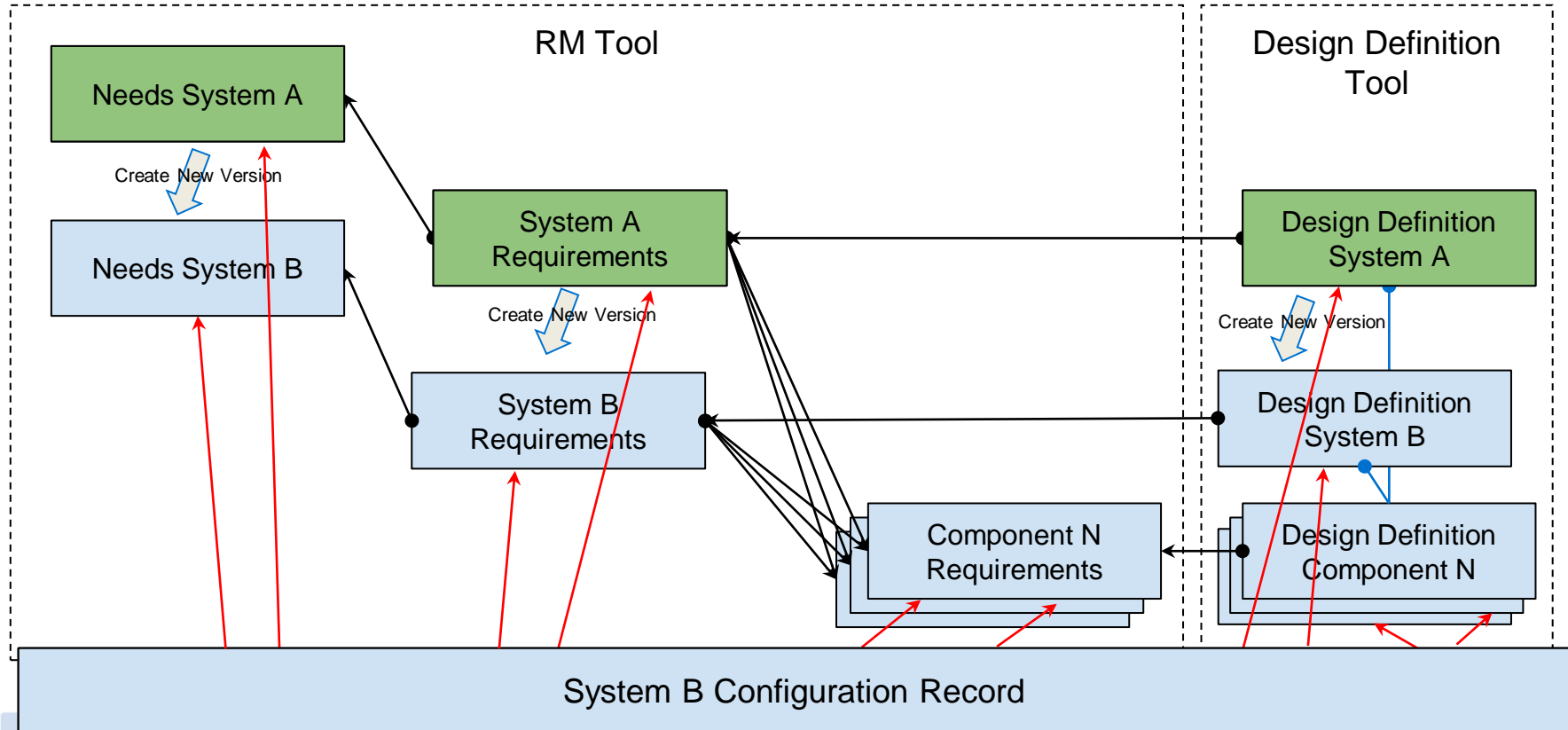
Use Case: Create new configuration + items

Use Case: Create new configuration + items

Use Case: Reuse Of Configuration Items
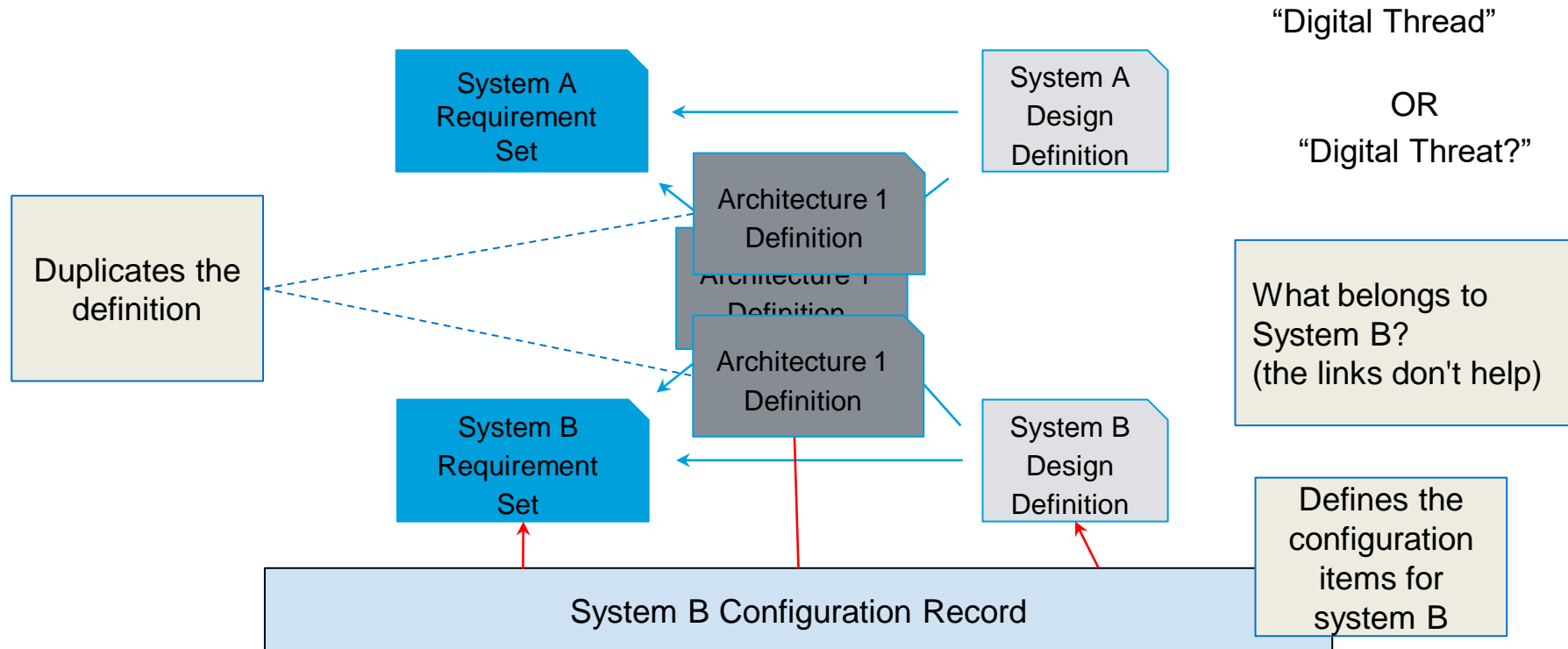
"Digital Thread"

OR
"Digital Threat?"

System A Requirement Set

System A Design Definition

Architecture 1 Definition

Architecture 1 Definition

Architecture 1 Definition

Duplicates the definition

What belongs to System B?
(the links don't help)

System B Requirement Set

System B Design Definition

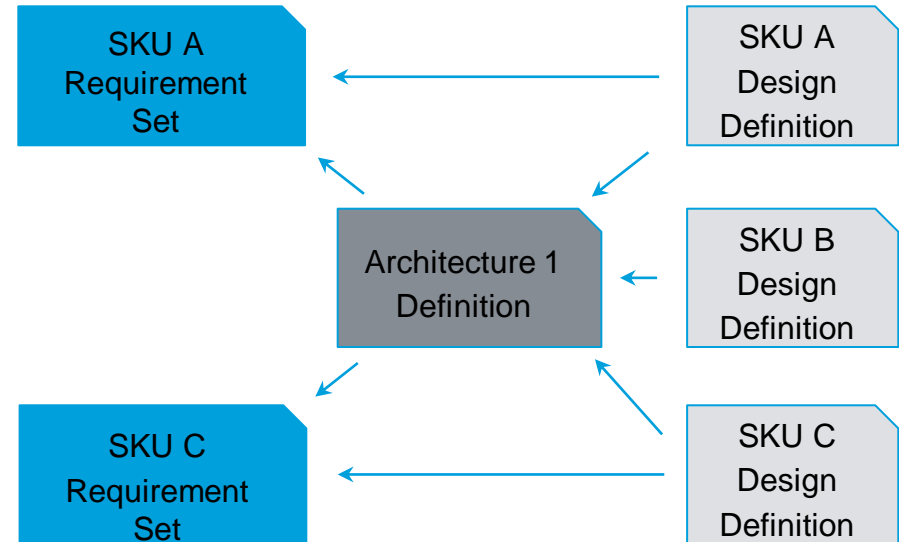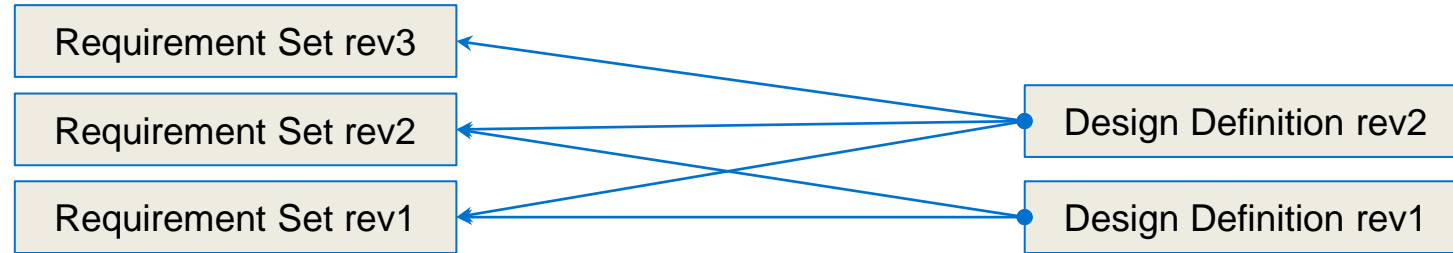Defines the configuration items for system B

System B Configuration Record

Use Case: Updating configuration items

As an engineer I want to **minimize the time it takes to maintain trace links** when creating new revisions of artifacts

Use Case: Updating configuration items

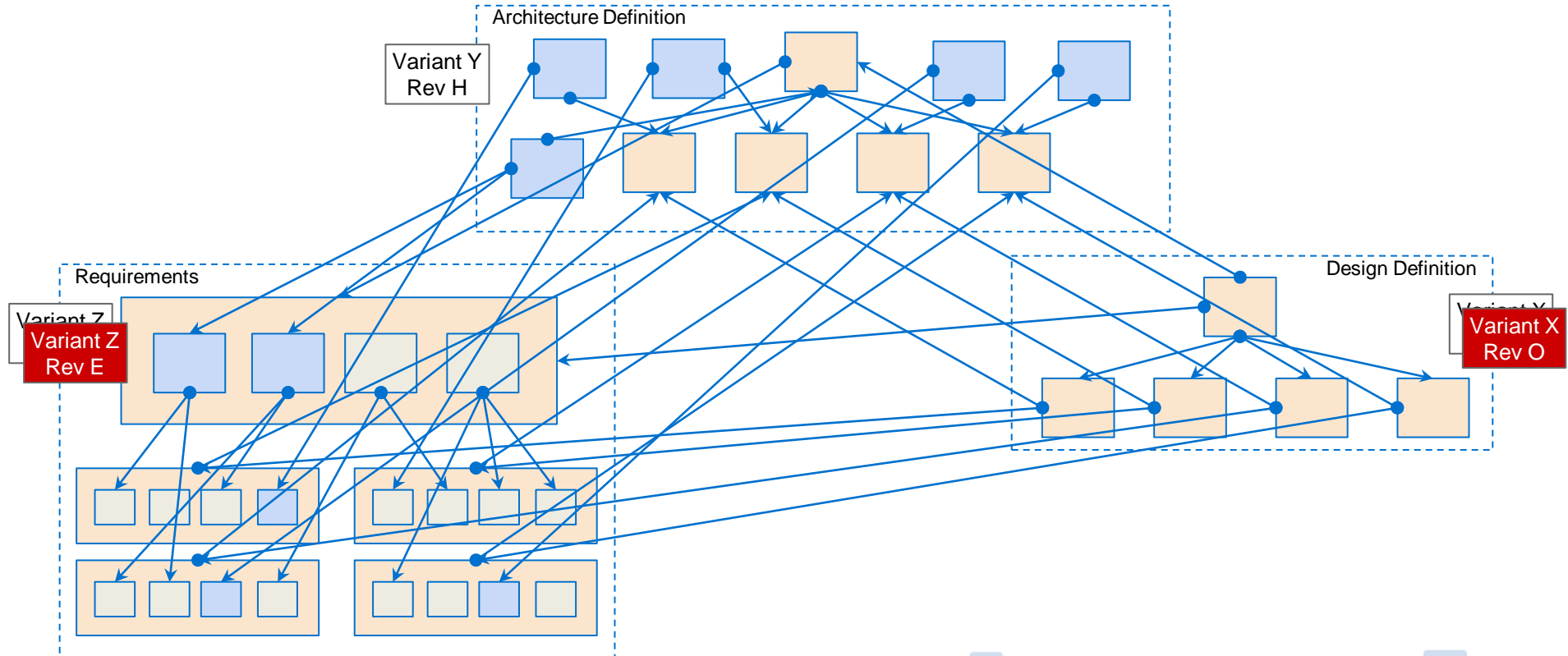|	
Requirement Set rev3	
Requirement Set rev2	Design Definition rev2
Requirement Set rev1	Design Definition rev1

Not a problem for relationships between two artifacts but at scale (100-1000 links per configuration x many configurations) it get complex, time consuming to manage and links risks to be left outdated eroding the trust in the links

Use Case: Updating configuration items

Use Case: Updating configuration items

Variant Y
Rev H

Architecture Definition

Requirements

Variant Z
Variant Z
Rev E

A configuration record offers a quick way to confirm validity between revisions of artifacts

Design Definition

Variant X
Variant X
Rev O

System N
Rev U

Configuration Record

Requirements
Variant Z
Variant Z
Rev E

Architecture Definition
Variant Y
Rev H

Design Definition
Variant X
Rev O

Use Case: Analyze Correctness/Completeness

As a Quality manager I want **to analyse the correctness and completeness of the system definition** through artifacts like needs, requirements, test methods, test results, architecture elements, design definitions and their relationships so that I can get an indication of risk level

As a Quality manager **I want** to **minimize the effort it takes to analyze correctness and completeness** of artifacts and their relationships so that I do **not waste time or skip the analysis**

Analyze correctness and completeness of the system definition

Systems Engineer/ Quality Manager

As a System Engineer I want **to analyse completeness** of my data set so that I reduce the risk of providing an incomplete and incorrect system definition

Use Case: Analyze Correctness/Completeness

As a System Engineer I want **to analyse correctness and completeness of my data set** so that I reduce the risk of providing an incomplete and incorrect system definition

Stakeholder Need

System Requirements

Function

Allocated To?

SOI
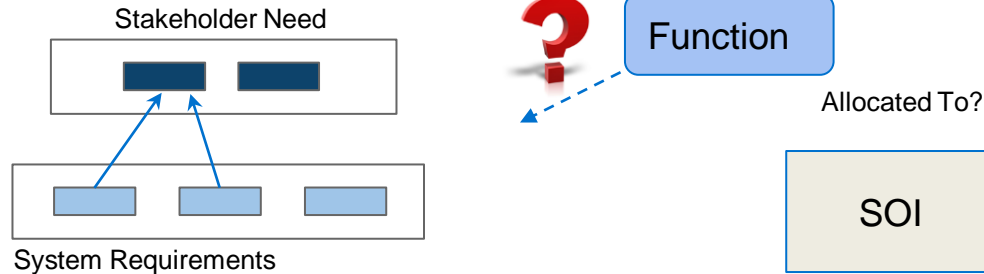
A configuration record **defines the artifacts applicable to the configuration**, <u>independent on established traceability</u>. This is instrumental for analyzing completeness

[RWG YouTube: IW2022 Digital Thread for Requirement Quality Assessment](#)

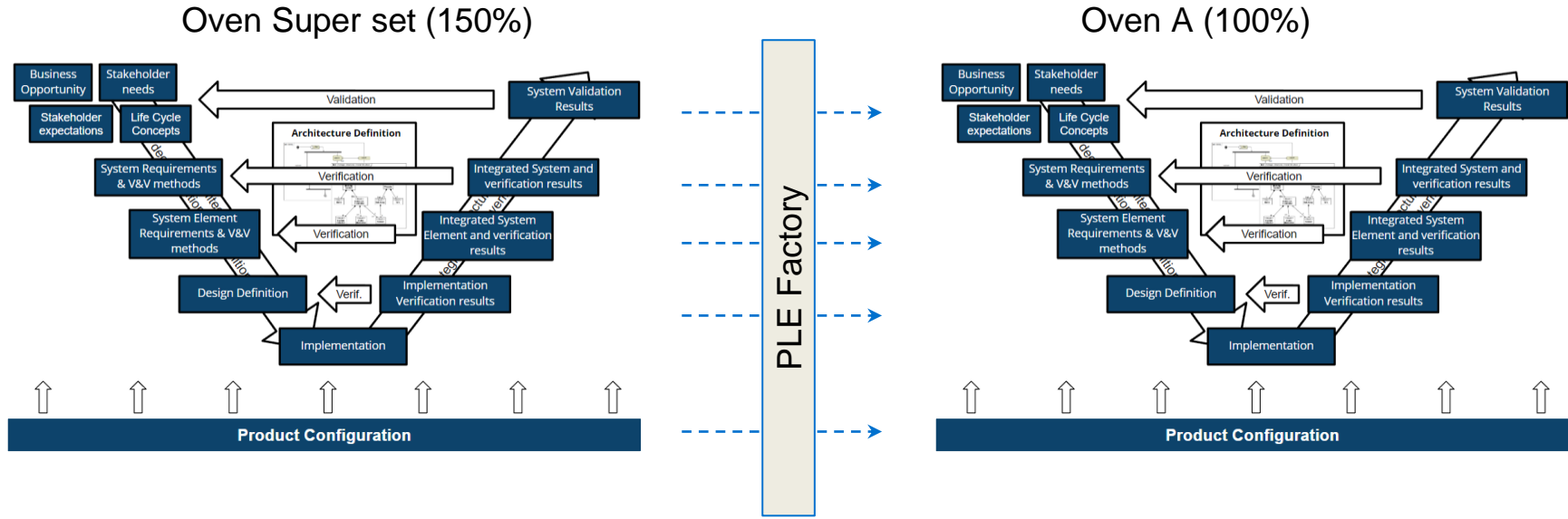# Feature Based Configuration Management

ISO/IEC 26580:2021
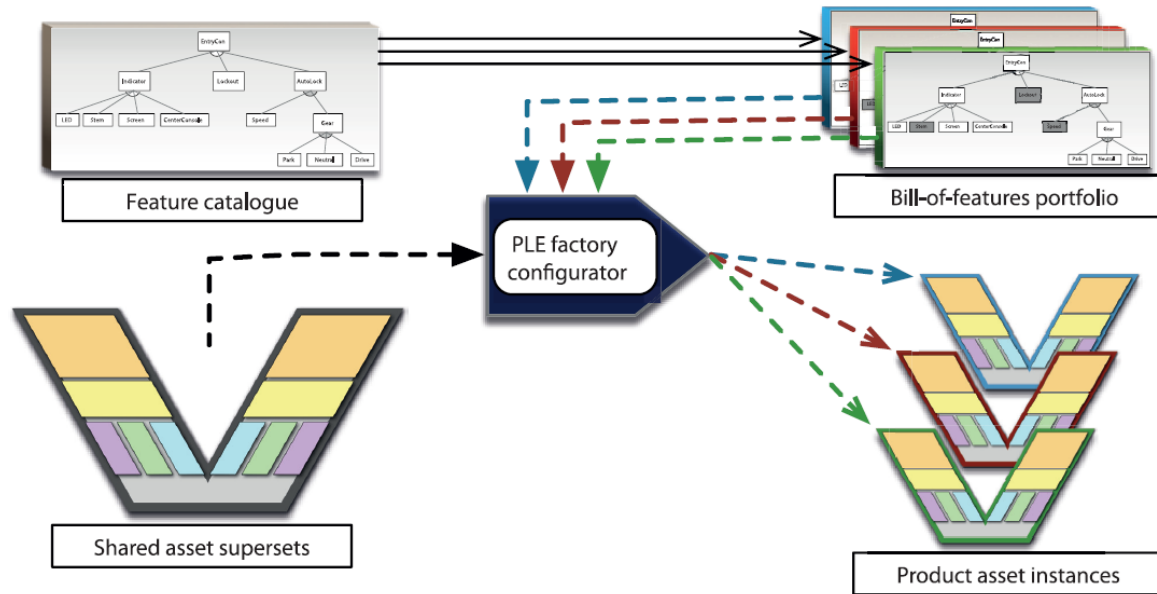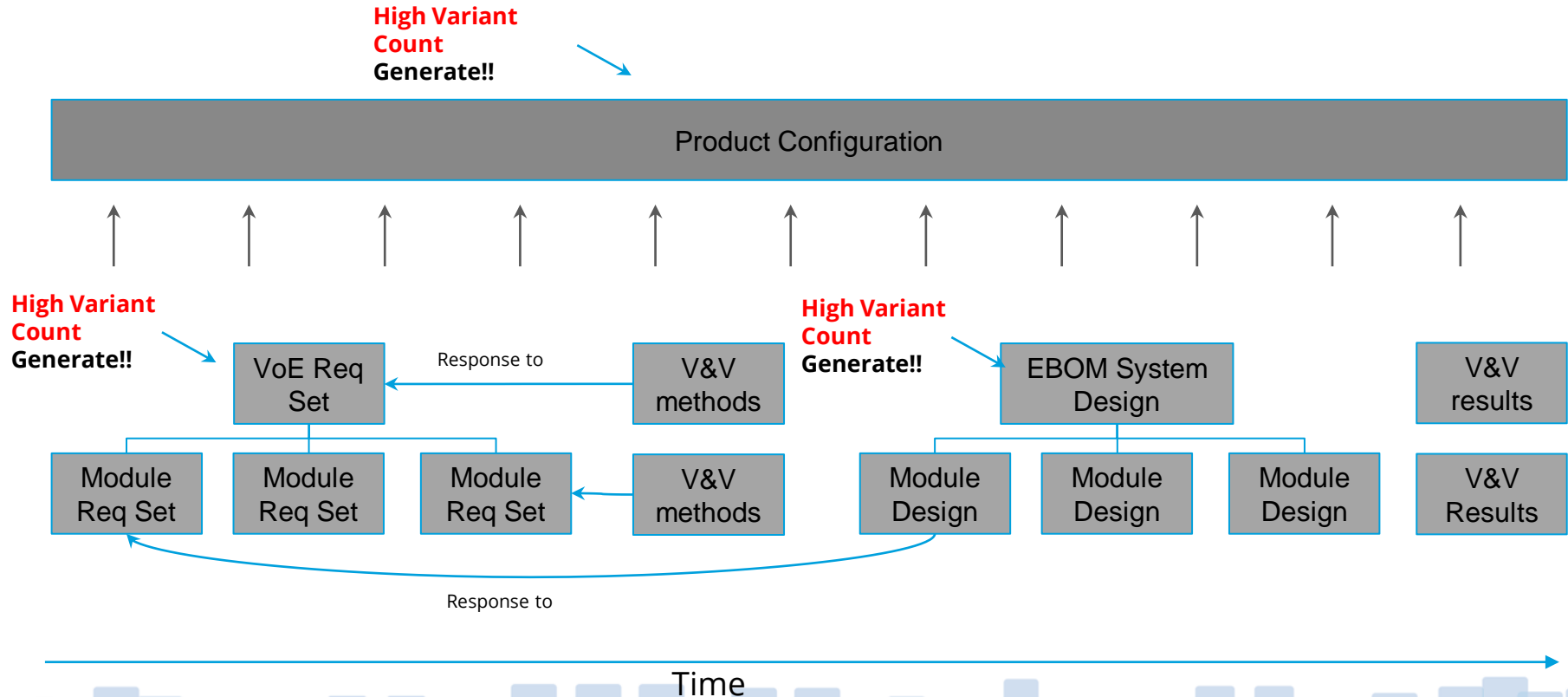

Figure 4 — Key elements of the feature-based PLE factory

Excerpt from ISO 26580

Deciding On Scope

Oven A
Bill of features

Oven Super set (150%)

Oven A (100%)

PLE Factory

Where to start?

High Variant Count
Generate!!

Product Configuration

High Variant Count
Generate!!

VoE Req Set

Response to

V&V methods

High Variant Count
Generate!!

EBOM System Design

V&V results

Module Req Set

Module Req Set

Module Req Set

V&V methods

Module Design

Module Design

Module Design

V&V Results

Response to

Time

Generating A Configuration Item

```
Desired                Generate bill        System A bill-
Feature                of features          of-features
Choices

System Feature Model                              Rev N of 100%
                                                  requirement set

                                                                        Read only
150% feature centric     Generate the       Update          Rev N+1 of 100%
requirement set          100% req set       current         requirement set
                         based on           version
                         choices
```
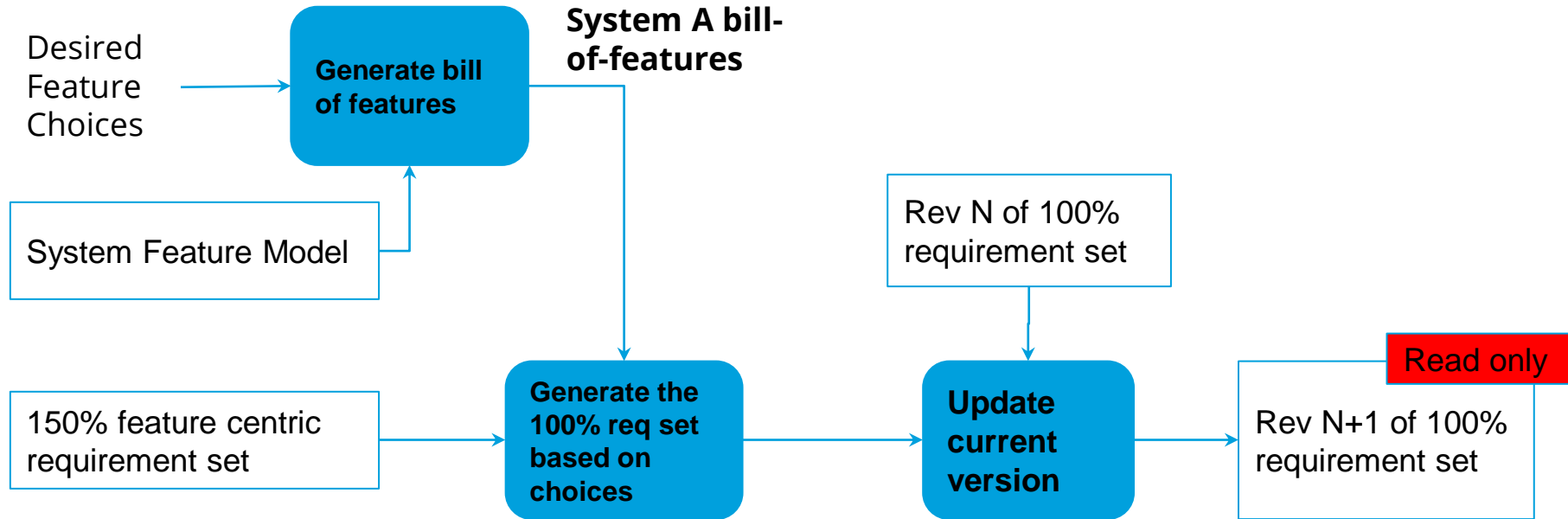
Summary

Configuration Records - Benefits

- Enables Configurations to be created even before a physical architecture exists

- Easier to automate analysis and reports in context of specific system configurations

- Can help automating the creation of new configurations

- Reduces the cost of maintaining trace links

- Reduce artifact complexity

- Compensates for errors in trace links

- A quick way to find information applicable to a configuration

Call-to-action For Tool Vendors

- Unified approach to configuration management between traditional MBSE and PLM tools

- Enable configuration records to be created that can hold configuration items from all life cycle stages

- Improve support for feature based generation of configuration items across multiple tools

- Unite on a standard for interoperability(OSLC), will reduce tool integration cost for customers

Use Cases

As a systems engineer I want to **define a set of artifacts from across the life cycle that describes a system configuration** so that my project team has an up to date easily accessible single source of truth of the system definition

Create new configuration items

Extends

Update configuration items

As an engineer I want to **minimize the time it takes to maintain trace links** when creating new versions of artifacts

Includes

Includes

Includes

Systems Engineer

Define a new system configuration

Establish/ Maintain traceability

As an engineer I want to **maximize the correctness of the trace links**

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Includes

Reuse configuration items

As an engineer I want to **minimize the time** it takes to create **new variants of a system configuration**

Use Cases

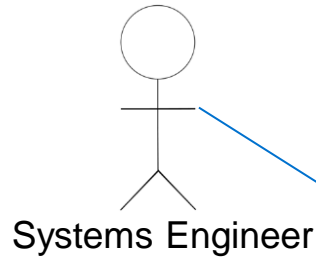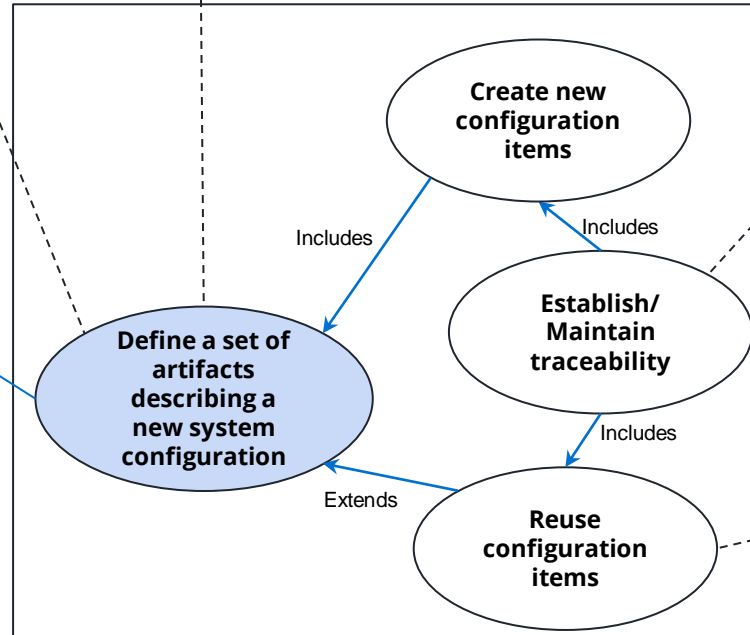As an engineer I want to **minimize the time** it takes to create **new variants of a system configuration**

As a systems engineer I want to **define a set of artifacts from across the life cycle that describes a system configuration** so that my project team has an up to date easily accessible single source of truth of the system definition

Systems Engineer

Create new configuration items

Includes

Includes

Define a set of artifacts describing a new system configuration

Establish/ Maintain traceability

Includes

Extends

**Reuse configuration items**

As an engineer I want to **minimize the time it takes to maintain trace links** when creating new versions of artifacts

As an engineer I want to **maximize the correctness of the trace links**

As a systems engineer I want to **reuse configuration items** when defining new variants of the system so that I do **not need to create unnecessary complexity**

Transformations Across The Life Cycle

Total set of needs and
life cycle concepts
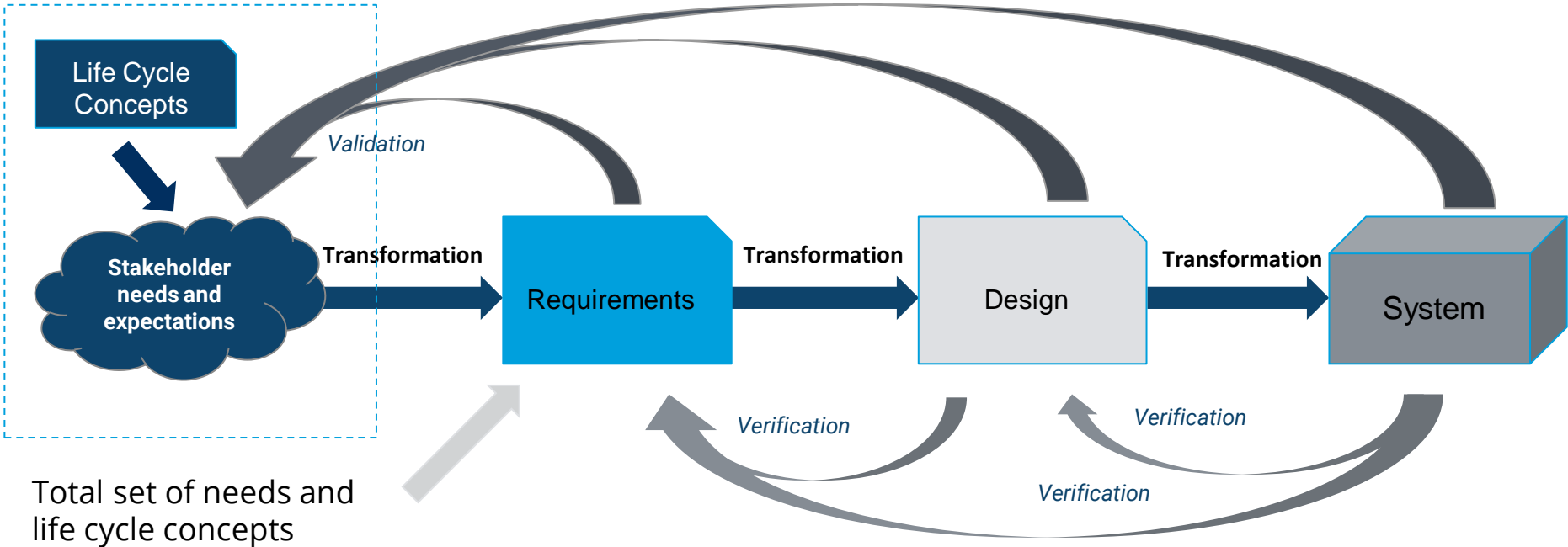
Replicated from INCOSE
Requirements Writing guide
2017 ed.

Considerations when Reusing System Element Configurations

Requirements vs Design definitions

Product

Display Module

Operational temp range 0-50C

Display Module Req Set
Refrigerator Variant

Operational temp range 0-55C

Display Module Req Set
Washer Variant

Operational temp range 0-75C

Display Module Req Set
Oven Variant

Design
Definition

$$

Operational temp range 0-80C

Design
Definition

$

Operational temp range 0-60C $

Requirements vs Design definitions

Dishwasher　　　　**Dishwasher Door**

Low Noise
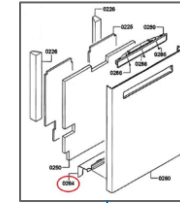
Noise damping - Low

Door Req Set - Low Noise Variant

Silent

Noise damping - Mid

Door Req Set - Silent Variant

Super Silent

Noise damping - High

Door Req Set - Super Silent Variant

Door Design Definition

$$

High absorbing damping material

Door Design Definition

$

Low absorbing damping material

Door Configuration Records