



32nd Annual **INCOSE**
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Charles Krueger, PhD
CEO, BigLever

From Systems Engineering to System Family Engineering



Nobody Builds Just One

- Product lines are ubiquitous
- Virtually all systems engineering is performed in the context of a product line – a family of similar systems with variations in features and functions



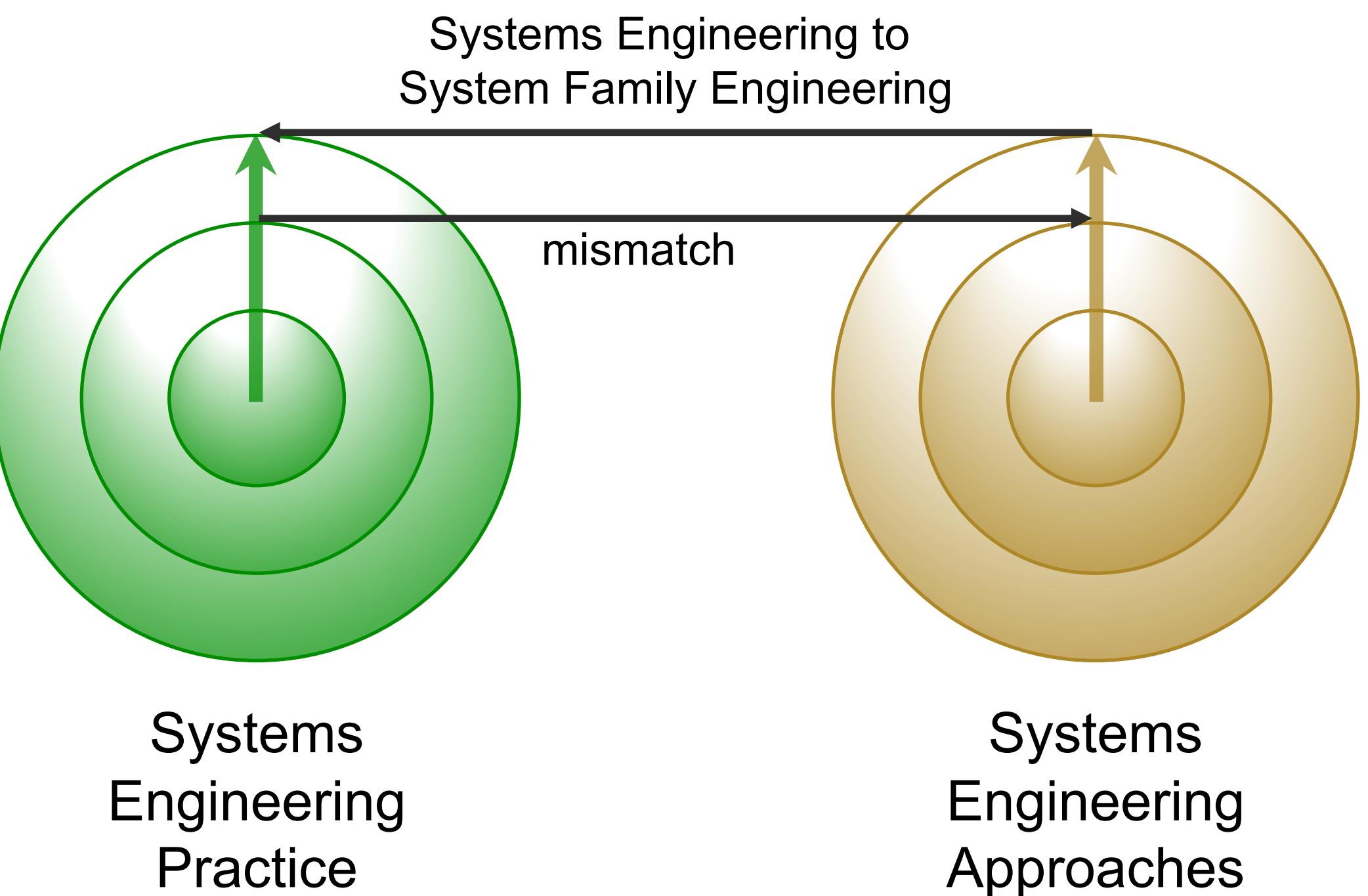
But wait, what about...

- Nuclear power plants
 - I hope it's not their first and only
- James Webb space telescope
 - It's a composition from many proven subsystem families
- Product lines with just a few members are not like automotive with tens of thousands of members
 - A product line with two members is a perfectly valid system family



From Systems Engineering to System Family Engineering

- However, conventional systems engineering practice focuses on a singular *system of interest* rather than holistically on the system family
- This mismatch introduces significant engineering risks
- Resolving this mismatch requires us to elevate the *system family* to be the *system of interest*





ISO/IEC 26580

- On April 20, 2021, it became official:
 - ISO/IEC 26580, “Methods and Tools for the Feature-based Approach to Software and Systems Product Line Engineering”, was published as an international standard
 - <https://www.iso.org/standard/43139.html>
- For system family engineering:
 - this powerful engineering approach, created to deliver unprecedented effort avoidance and quality, can now be readily and unambiguously applied,
 - leveraging 26580 as the authoritative definition from the international engineering community,
 - enabling precision digital system family engineering

The screenshot shows the ISO website with the following details:

- Header:** ISO logo, navigation menu with links to Standards, About us, News, Taking part, Store, and a search bar.
- Breadcrumb:** ICS > 35 > 35.080
- Title:** ISO/IEC 26580:2021
- Section:** Software and systems engineering – Methods and tools for the feature-based approach to software and systems product line engineering
- Abstract:** This document is a specialization of the more general reference model for software and systems product line engineering and management described in ISO/IEC 26550. The specialization defined herein addresses a class of methods and tools referred to as feature-based software and systems product line engineering, or feature-based PLE, which has emerged as a proven and repeatable product line engineering and management (PLE) practice supported by commercial tool providers.
- Document Details:** This document:
 - provides the terms and definitions specific to feature-based PLE;
 - defines how feature-based PLE is a specialization within the general ISO/IEC 26550 reference model for product line engineering and management;
 - defines a reference model for the overall structure and processes of feature-based PLE and describes how the elements of the reference model fit together;
 - defines interrelationships and methods for applying the elements and tools of the product line reference model;
 - defines required and supporting tool capabilities.
- Buy This Standard:** CHF 178, with options to select FORMAT (PDF + EPUB) and LANGUAGE (English).
- Text at bottom:** In this document, products of feature-based PLE include digital work products that support the engineering of a system. Some of the artefacts are actually part of the delivered products, while other artefacts can be non-deliverable, such as physical or digital design models.



Product Line Engineering (PLE) Defined

ISO 26580 Methods and Tools for Feature-based PLE

Product Line:

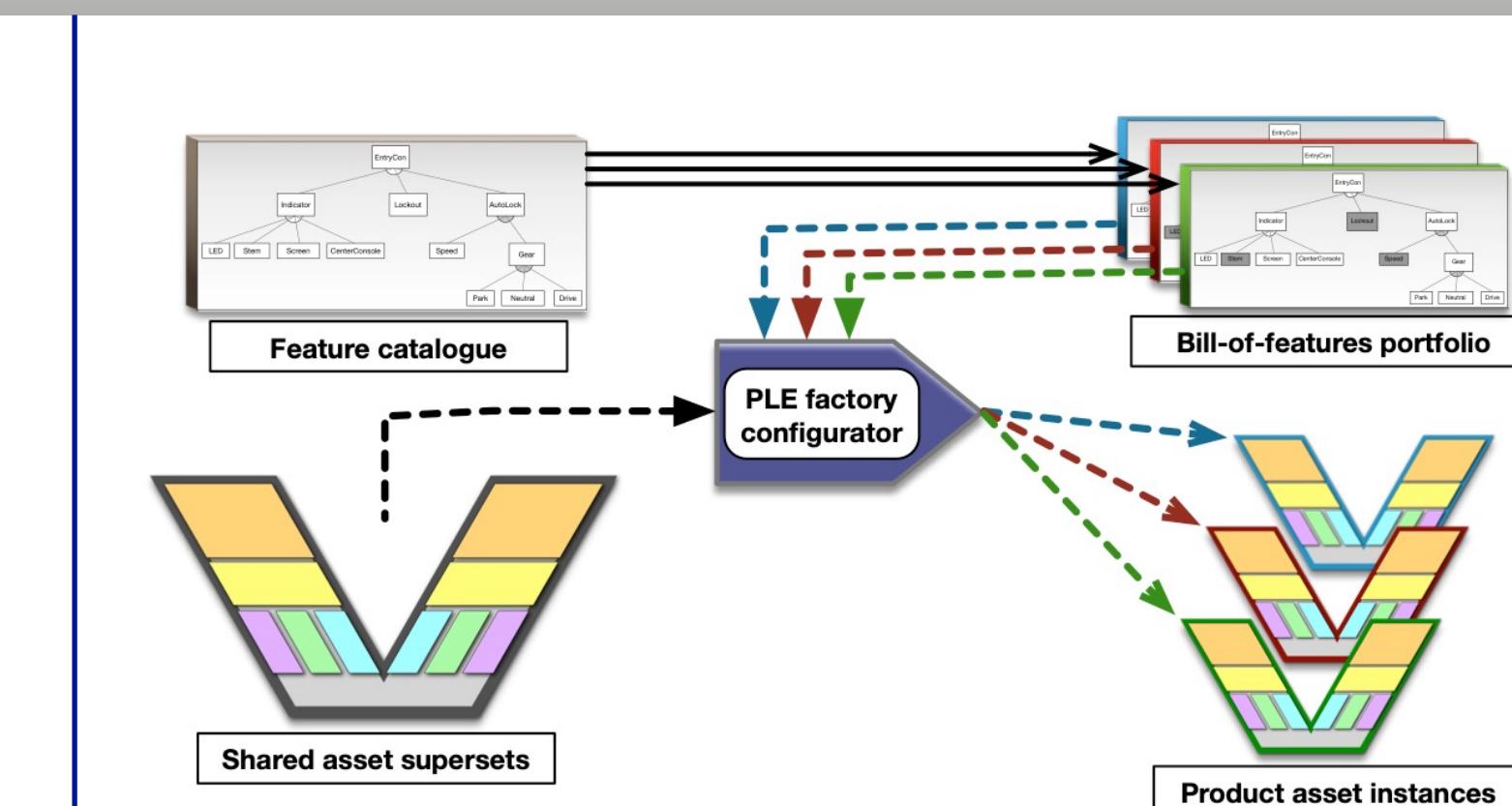
A family of similar products or systems with variations in features.

“Product Line” and “System Family” are interchangeable



International
Organization for
Standardization

Product Line Engineering:
the engineering of a product line using
shared engineering assets,
a managed catalog of features, and
an automated means of production...



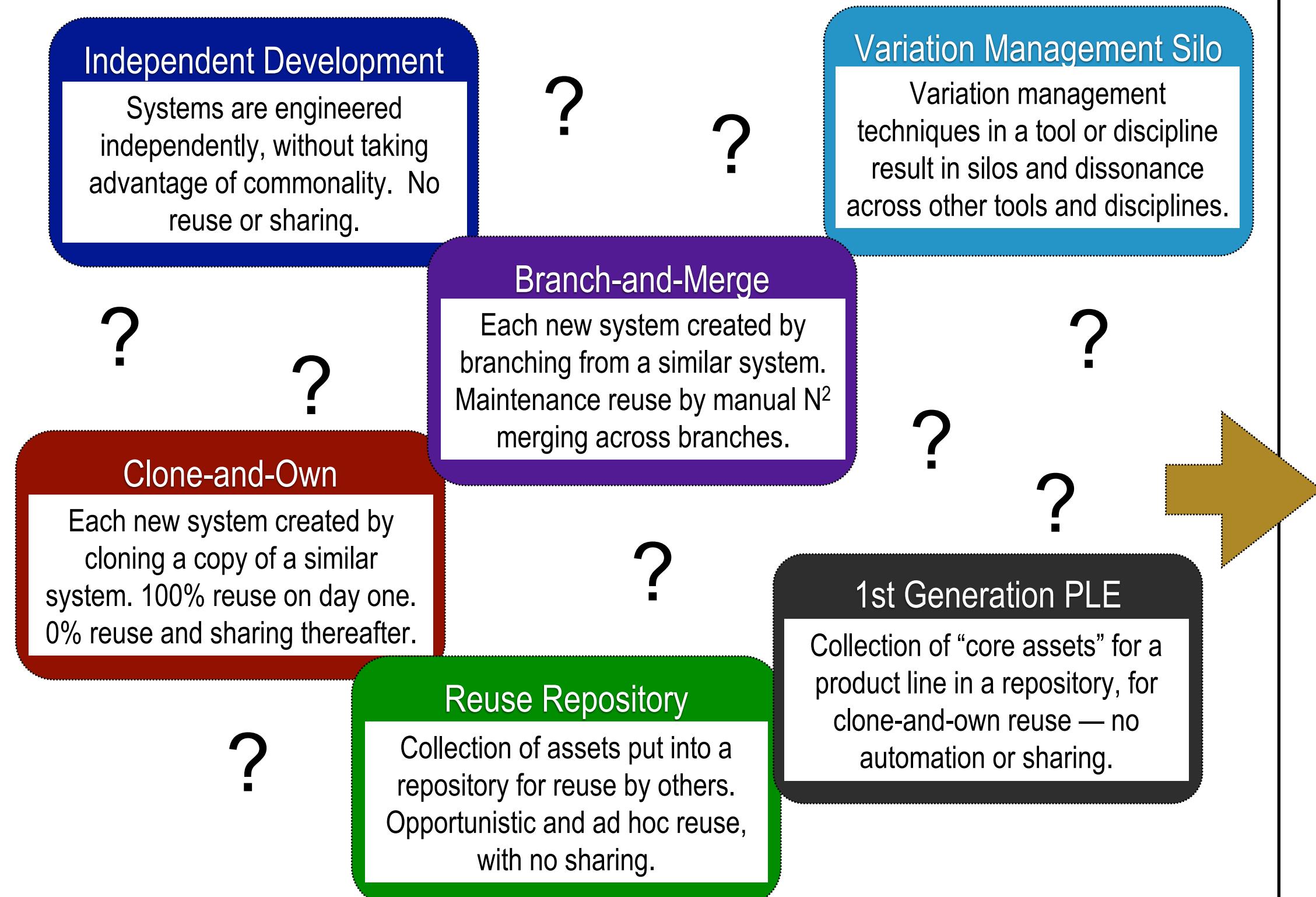
- taking advantage of the **commonality** shared across the family
- efficiently and systematically managing the **variation** among the products or systems



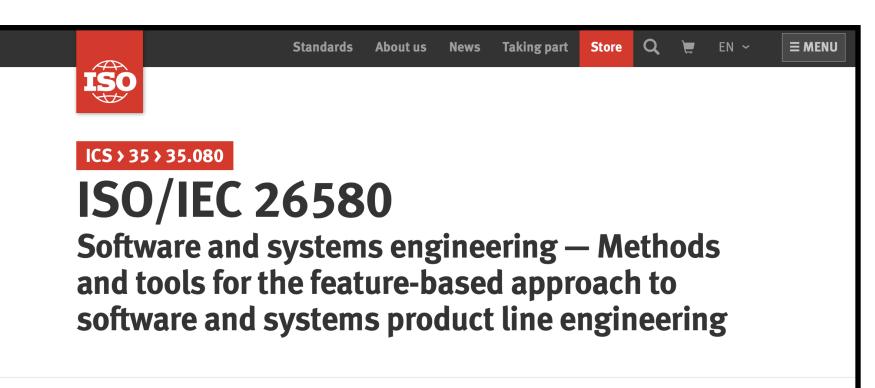
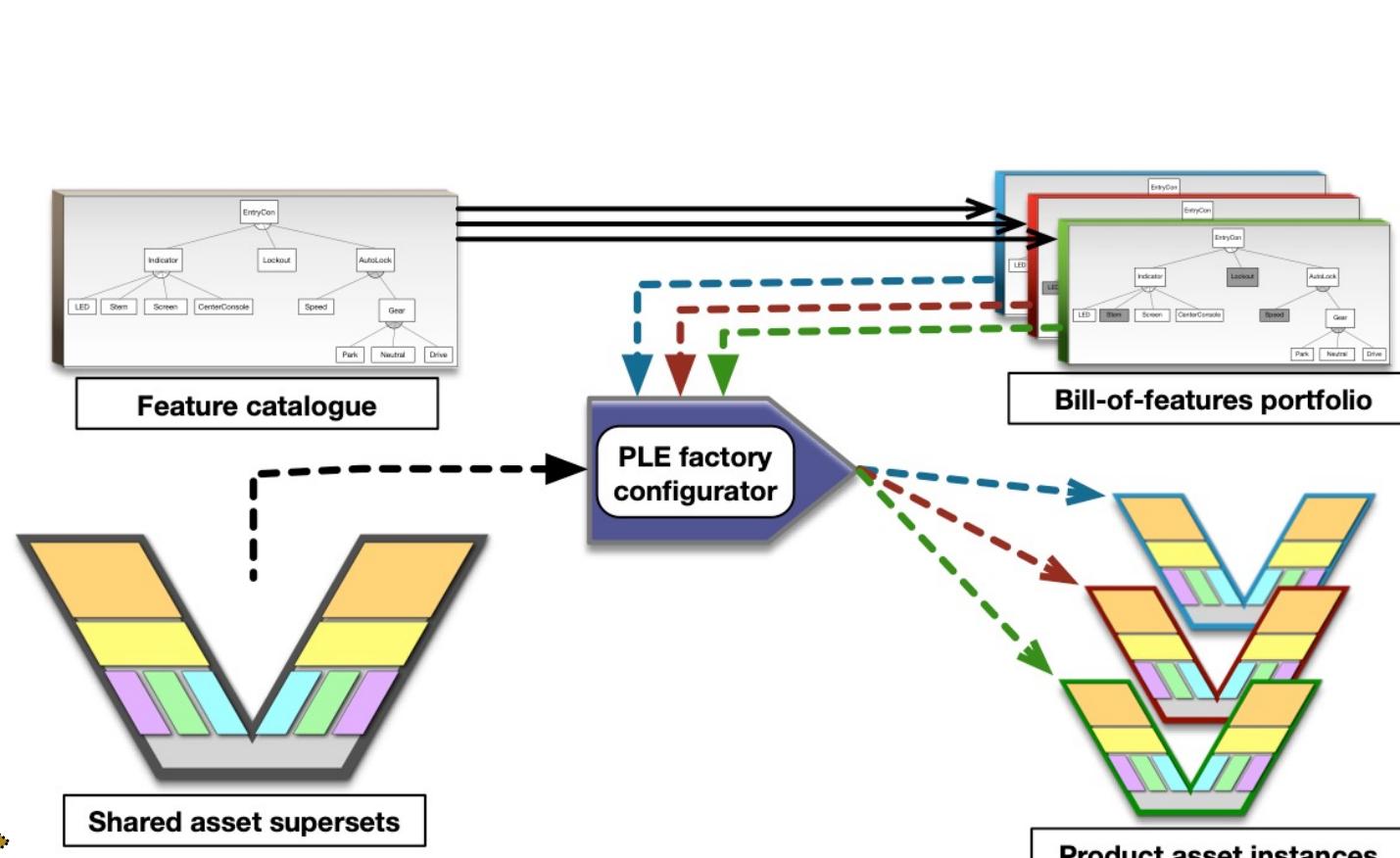
Feature-based PLE is a Paradigm Shift away from Early Generation Complexity

“The top driver of operational complexity in complex engineering organizations, as identified by surveys of hundreds of business leaders, is the number of product and system configurations engineered, manufactured, deployed, and sustained.”

Michelle Boucher,
VP of Research for Engineering Practices,
Tech-Clarity



Complex Early Generation
Product Line Approaches

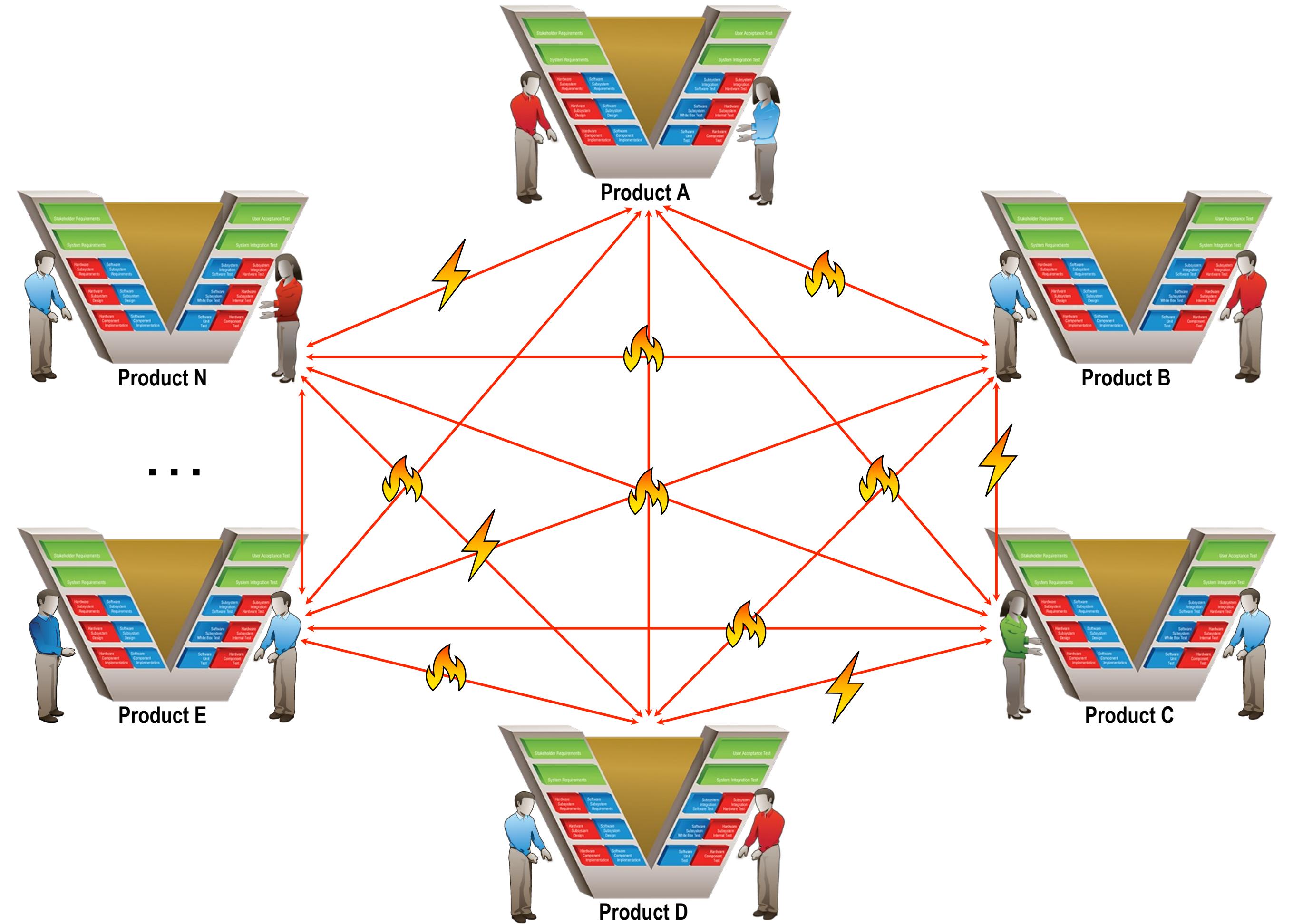


Feature-based
Product Line Engineering



Early Generation Single-System Engineering

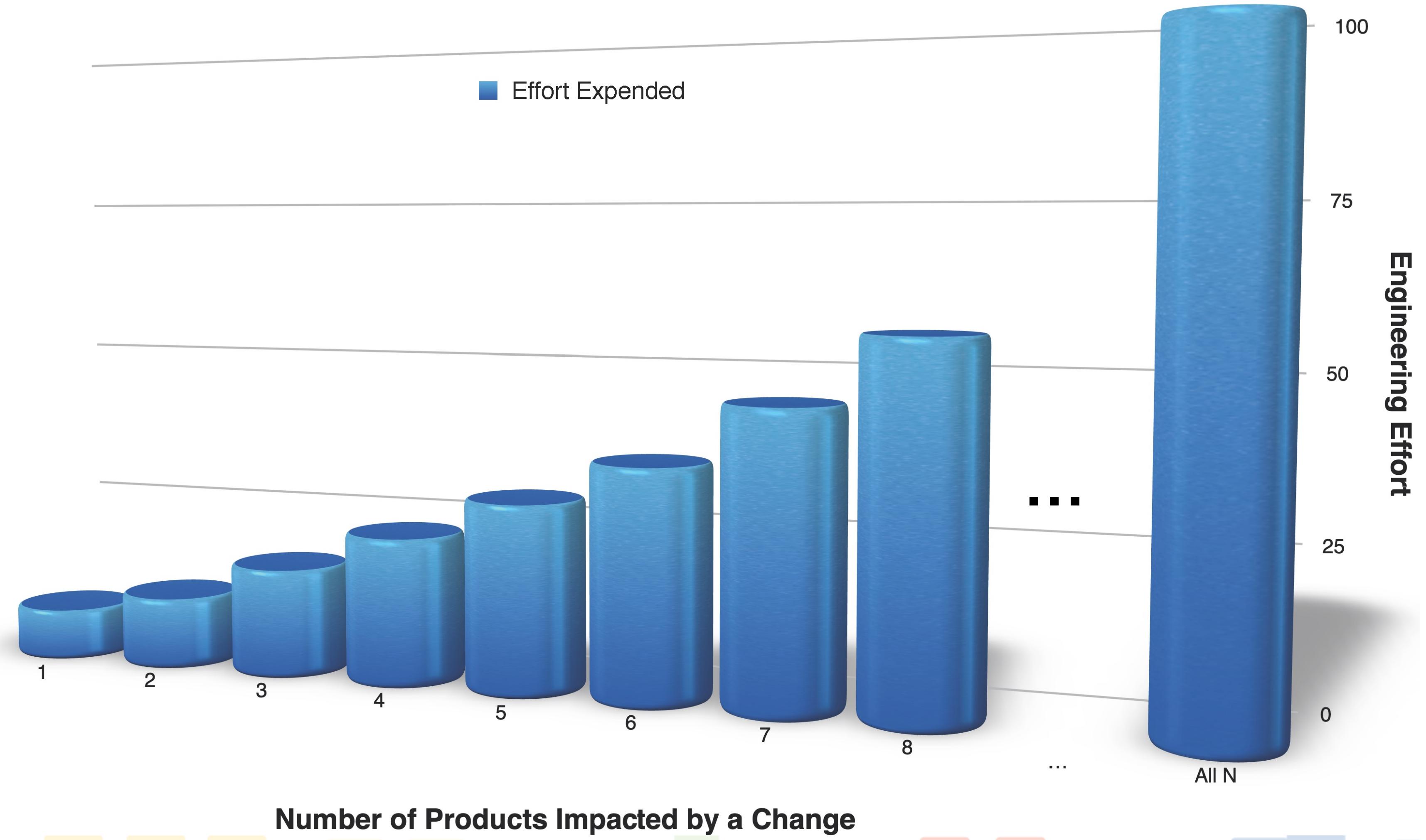
- Duplication, branch-and-merge, clone-and-own, self-inflicted N^2 complexity, ...
- Informality introduces significant risks in the form of defects, errors, and omissions
- Leads to delays, budget overruns, recalls, system failures, and opportunity losses





Single-System Engineering Effort

- Dominated by low-value, mundane, replicative work
- Deprives teams of time and energy better spent on high-value innovative work that advances business objectives





Feature-based Product Line Engineering

ISO 26580 Methods and Tools for Feature-based PLE

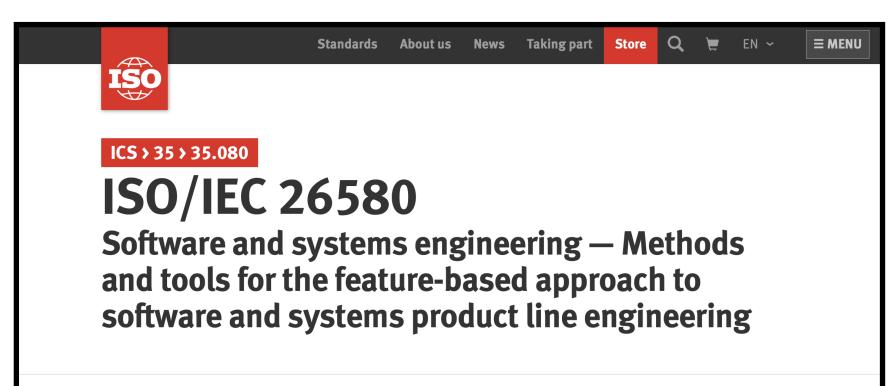
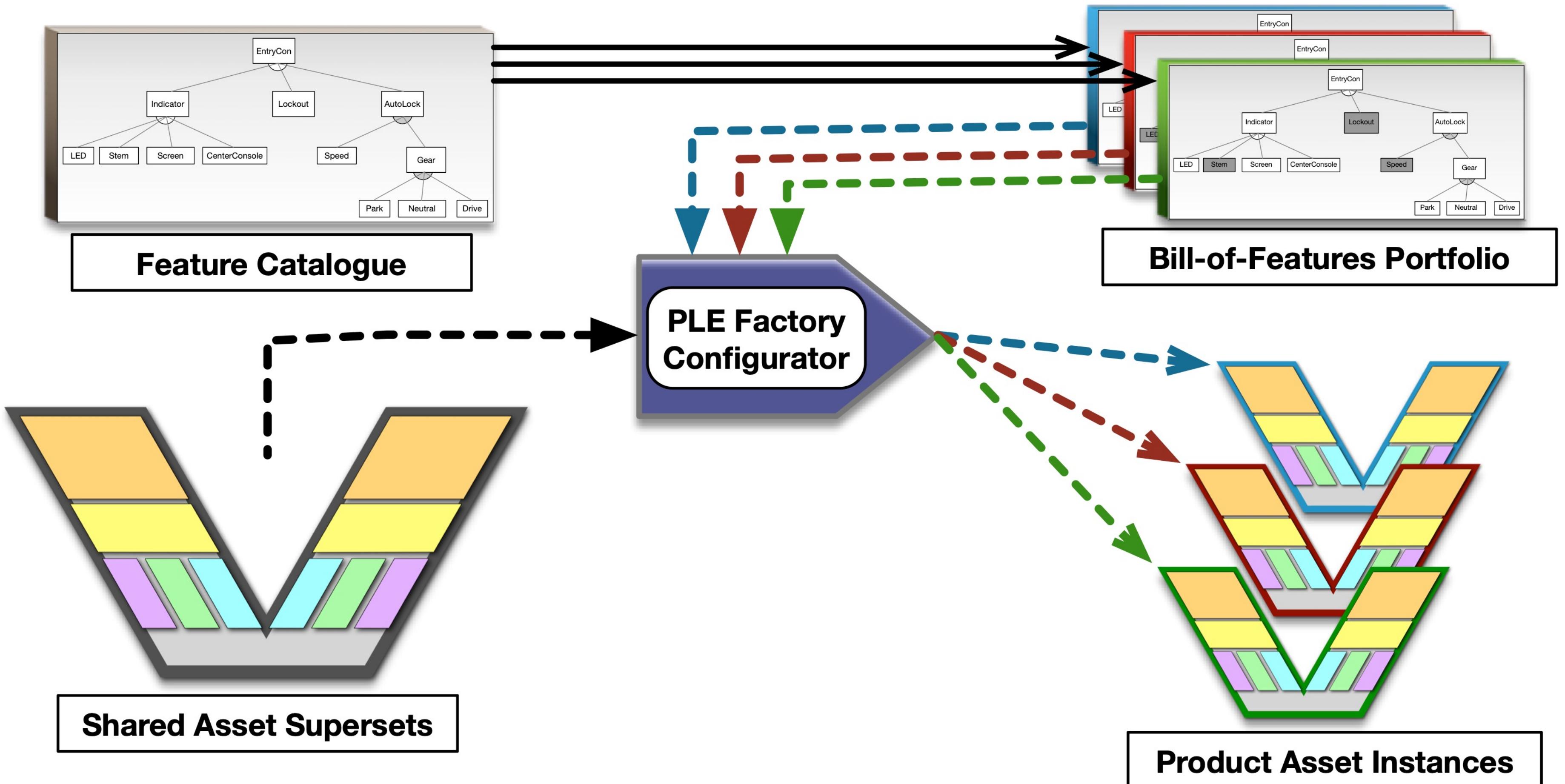
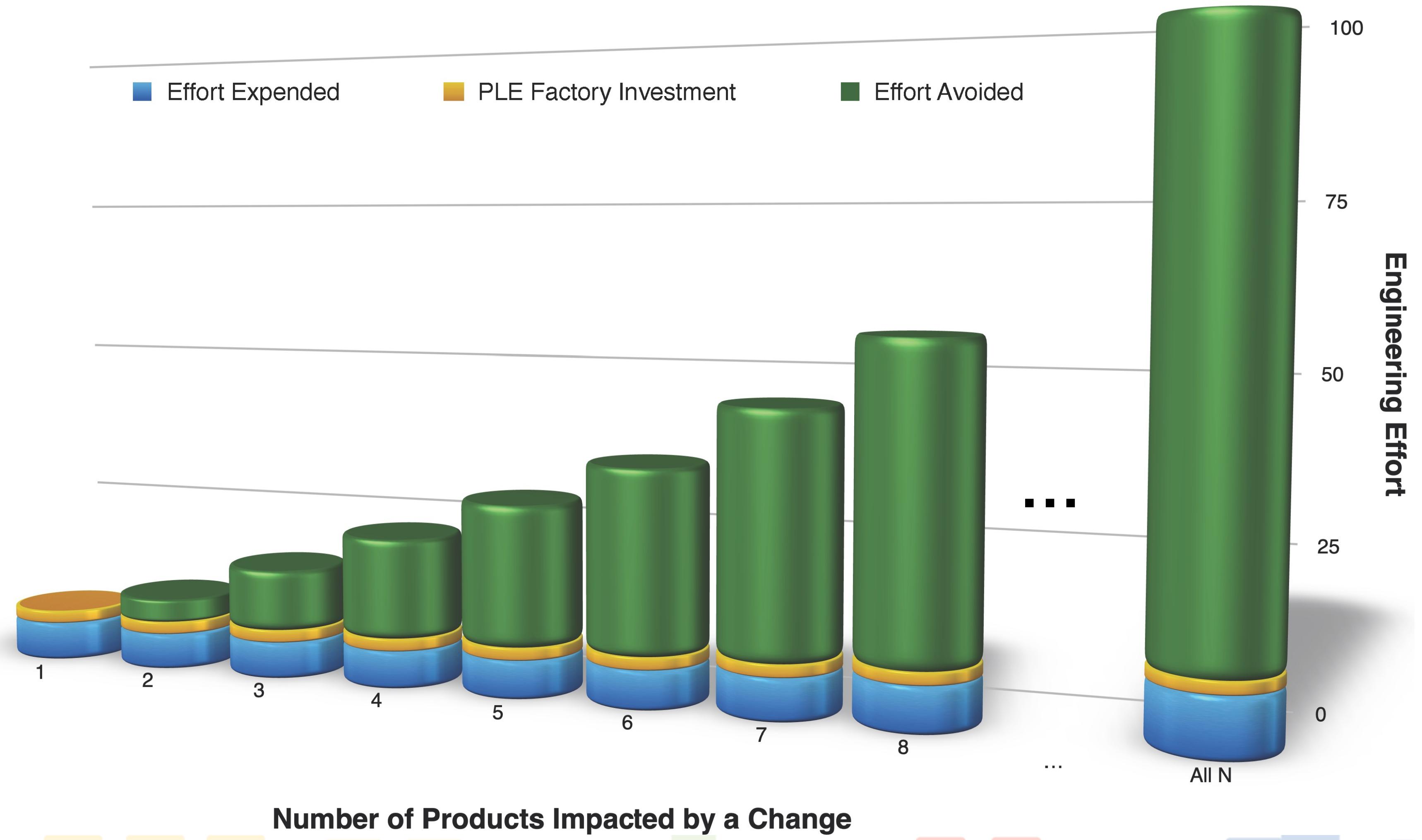


Figure from ISO/IEC 26580
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<https://www.iso.org/standard/43139.html>



Feature-based PLE Effort Avoidance

- What if your engineers could do their normal day's work before lunch?
- What would you have them do in the afternoon?



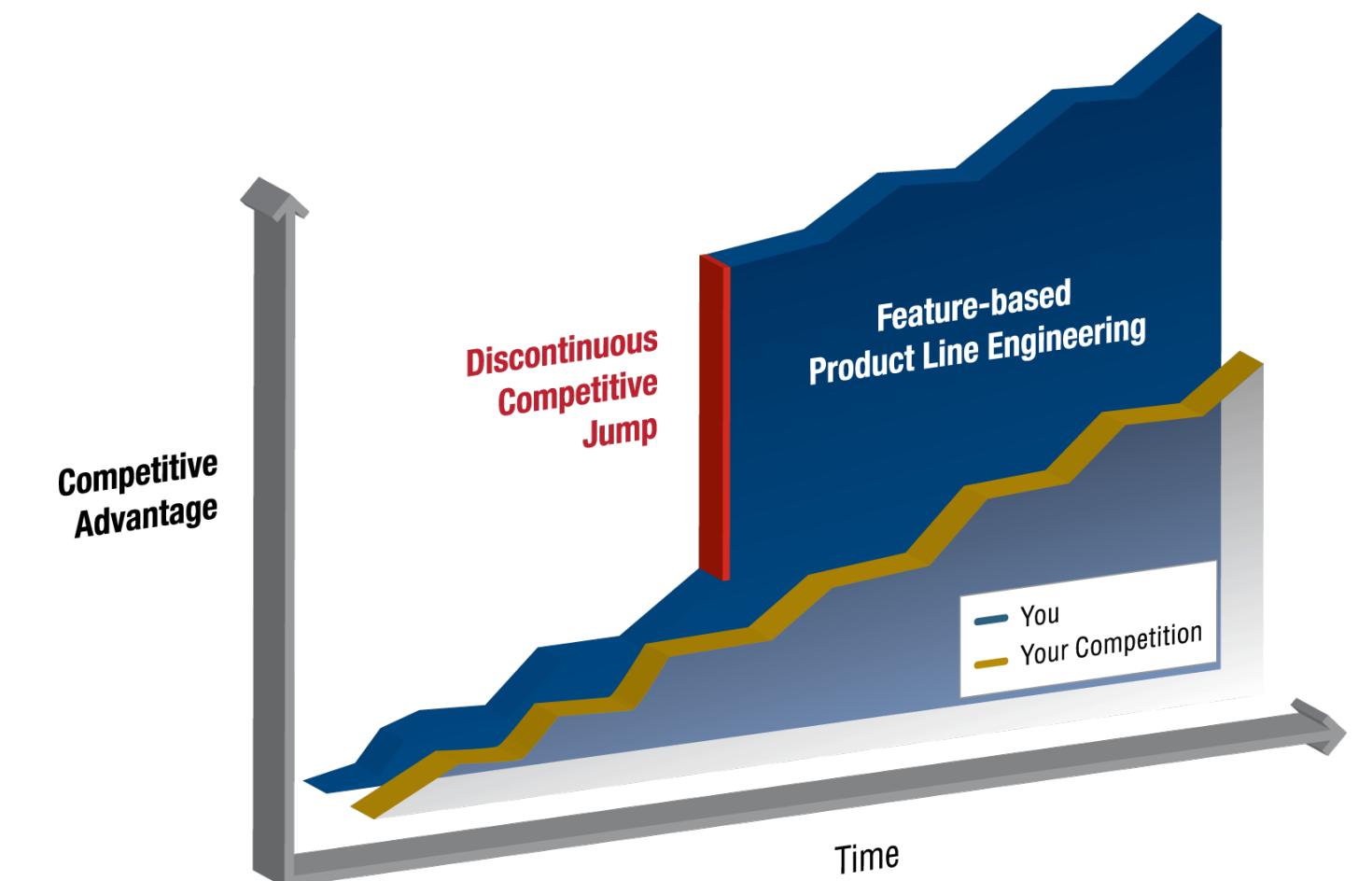


Benefit Hierarchy of Feature-based PLE

Competitive Advantage

Strategic Business Benefits

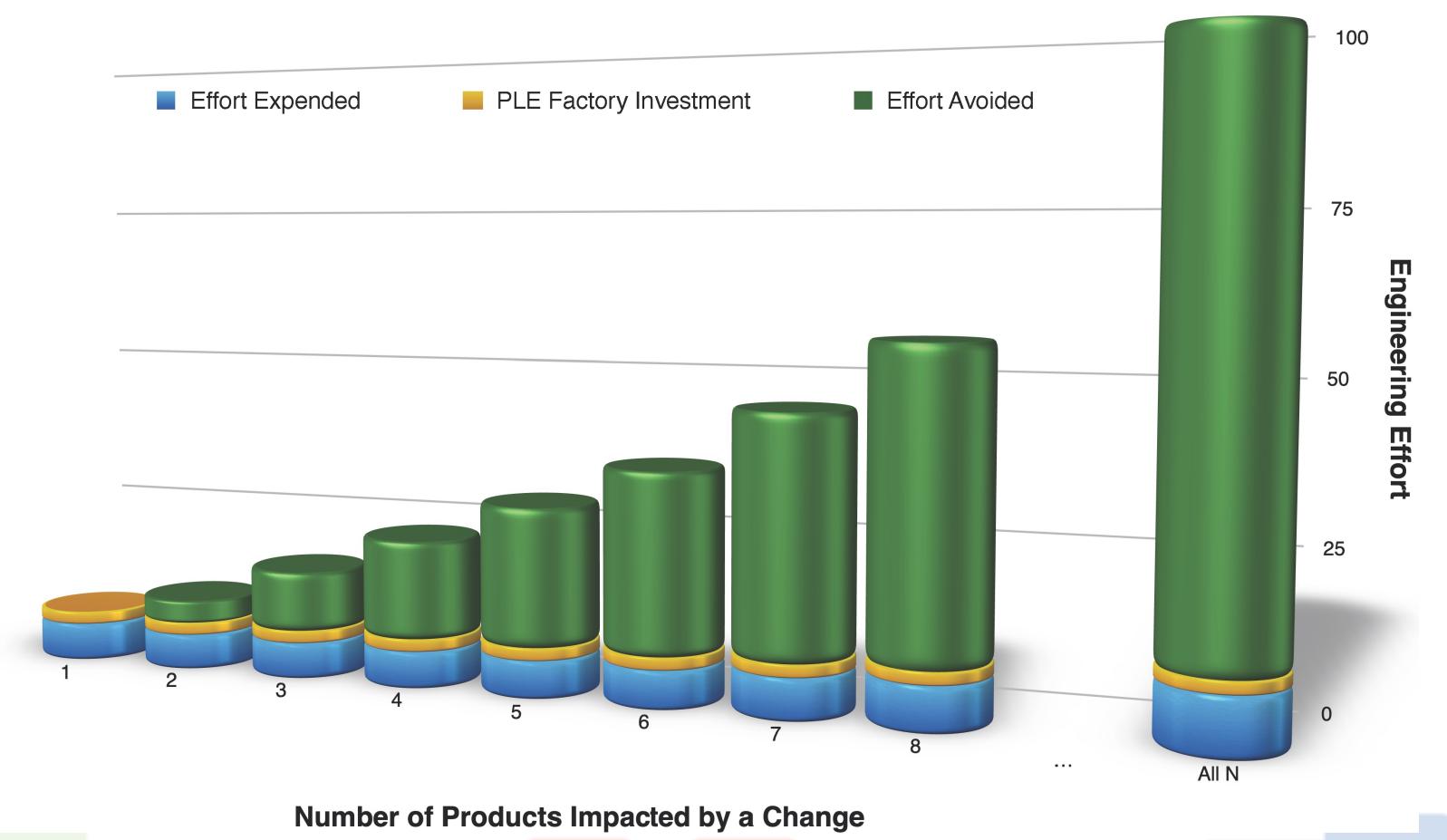
- More competitive pricing, more wins, higher sales
- Beat competitors to market with new innovations
- Higher quality, better reviews, better perception, fewer recalls, happier customers
- Higher engineering effectivity mitigates staff retention and hiring challenges



Strategic Engineering Benefits

- Higher productivity, shift from low value to high value effort
- Higher quality, lower defect density
- Faster time to market for new features and new products
- Greater scalability of the product line

Root-cause Engineering Effort Avoidance





AEGIS Weapon System for US and International Navies

High cost of old approach threatened loss of entire contract

Live Training Transformation: US Army, Air Force, Marines. Plus enterprise initiative.

Innovative low-cost solution essential to win and retain major contracts

One of the largest and most complex product lines, comprising millions of instances per year

Significant challenges to provide suppliers with a family of complex specs for electronic controller unit families

Rapidly growing and evolving portfolio of the world's most advanced missile systems

Traditional methods of creating and testing prototypes are too slow, imprecise, expensive to meet mission demands

Helicopter engines for all configurations of the new US Army Future Vertical Lift (FVL) program

Demand to maximize sharing and reuse to prevent multiplicative costs for flight certification

Feature-based PLE Results with BigLever

Turned an at-risk program into an enthusiastic long-term relationship by eliminating low-value redundant effort

Grew a \$2B+ business from scratch with the US DoD. Delivering 3x more capability within budget, to the delight of the customer

Digital transformation to a digital supply chain by applying PLE to MBSE

Using Feature-based PLE to proliferate best candidate simulations to find optimal solution within a trade space

Using a single Feature-based PLE Factory with a single collection of shared engineering assets for the full engineering lifecycle



“Change is good. You go first.”

- Proven technology, methodology, and successful practice exists today
- Where is everybody?
- Broader awareness and adoption are lagging significantly
- Organizational Change impediments
 - technology is easy, people are hard
 - too busy to save time, can't afford to save money





Lowering the risk of organizational change by elevating System Family Engineering to a standard practice in the industry

ISO/IEC 26580
Software and systems engineering – Methods and tools for the feature-based approach to software and systems product line engineering

GENERAL INFORMATION

Status: Under development | Publication date: 2021-04 | Edition: 1 | Technical Committee: ISO/IEC JTC 1/SC 7 Software and systems engineering | ICS: 35.080 Software

SUSTAINABLE DEVELOPMENT GOALS
This standard contributes to the following Sustainable Development Goal:

OMG SysML v2
The next-generation Systems Modeling Language

Responses to RFP
Due: 4 November 2019

Feature-based Systems and Software Product Line Engineering: A Primer

Feature-based Product Line Engineering lets you build your product line portfolio as a single production system rather than a multitude of individual products.

SEBoK GUIDE TO THE SYSTEMS ENGINEERING BODY OF KNOWLEDGE

Main page | Read | View source | View history | PDF Export | Search SEBoK

Guide to the Systems Engineering Body of Knowledge (SEBoK)

The SEBoK provides a compendium of the key knowledge sources and references for users. It is a living product, accepting community input continuously, with regular releases. Systems engineering is an interdisciplinary approach and means to enable the full life cycle of a system. It is a process of problem discovery and formulation, solution definition and realization, and operation and sustainment. It is also a means to manage multiple interventions in commercial or public environments or to the management of multiple interventions in commercial or public environments. The SEBoK is a valuable resource for anyone involved in systems engineering, providing an overview of systems engineering, place it in historical context, and provide a guide to the key knowledge sources and references for users.

Welcome to SEBoK v. 2.2

On behalf of the BKCASE Editorial Board, the BKCASE Governing Board, and sponsors, we are pleased to present the SEBoK v. 2.2. This version was released on 15 May 2020 and reflects the continuing development of the SEBoK.

What's new in v. 2.2?

For a summary of the changes made for v. 2.2 see the [Letter from the Editor](#). See the [Release History](#) for a full description of the current and all previous SEBoK versions.

About the SEBoK

Systems engineering has its roots in the fundamentals, principles, and models of engineering sciences, and associated management and engineering sciences. It is applied throughout systems engineering processes within a managed life cycle working with a number of engineering, and specialist disciplines. While traditionally applied to product development systems. As systems engineering is a collaborative approach, working with other engineering competencies and structures at individual, team, and organizational levels.

Starting from this basic view of the scope of knowledge relevant to SE, the SEBoK is organized into five parts:

- Part 1: Introduction (Overview of the role of SE and of the SEBoK)
- Part 2: SE Foundations (Systems Knowledge and how it relates to SE)
- Part 3: SE and Management (Standard Life Cycle Process and Practice)
- Part 4: Enabling SE (Creating enabling teams and enterprises to enable good SE)
- Part 5: Social/Systems Science Knowledge (People & Competency Knowledge, Education & Training Knowledge)

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2015 ANNIVERSARY

SYSTEMS ENGINEERING HANDBOOK
A GUIDE FOR SYSTEM LIFE CYCLE PROCESSES AND ACTIVITIES

WILEY

FOURTH EDITION

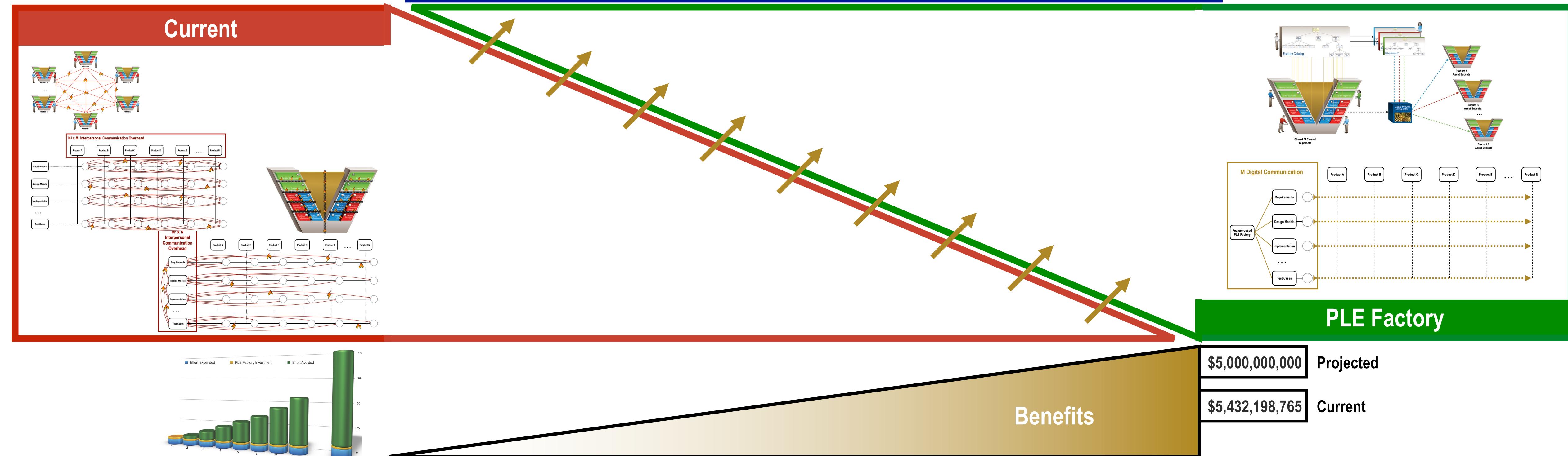
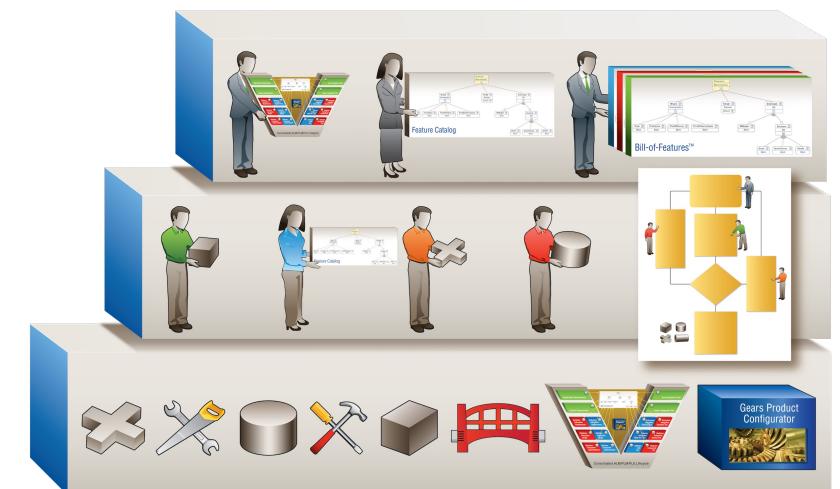
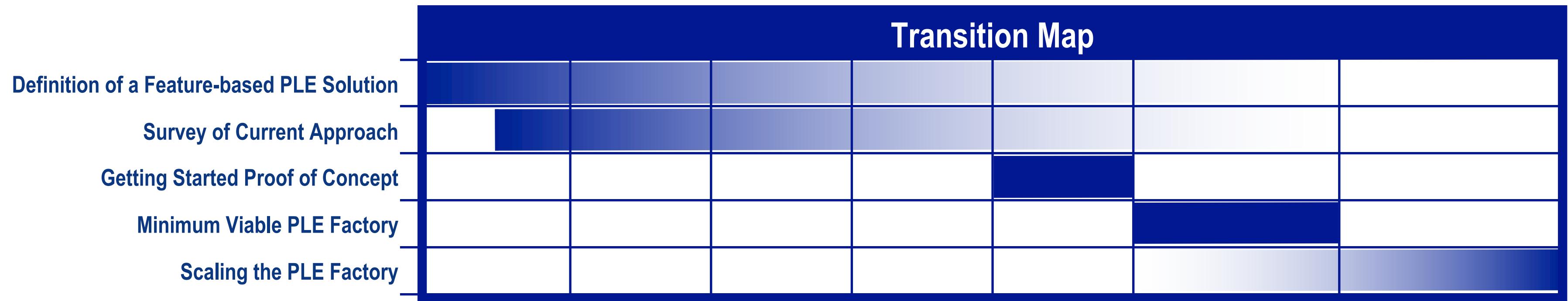
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SYSTEMS ENGINEERING VISION 2035
ENGINEERING SOLUTIONS FOR A BETTER WORLD

INCOSE Vision35



Architect Studio for Systems Engineering to System Family Engineering





Summary

- Nobody builds just one
- The systems engineering community must elevate our thinking from Systems Engineering to System Family Engineering
- The release of ISO/IEC 26580 is good news
 - Can be readily and unambiguously applied to create a full lifecycle digital fabric for system family engineering
- The better news is that Feature-based PLE does not need a break-in period
 - It's been here all along with proven and validated successes, and continues to be ready to serve



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www.incose.org/symp2022

Learn more:

- [ISO/IEC 26580:2021](#). Software and systems engineering — Methods and tools for the feature-based approach to software and systems product line engineering
- [INCOSE Product Line Engineering Primer](#)
- [biglever.com](#)
- ckrueger@biglever.com