A Few Words First

Courtesy – Please mute your phone (*6 toggle)

May 12-13, Tutorial by John Clark – INCOSE Handbook v4 & CSEP Prep

Fall Workshop Event – Produced by Enchantment Chapter and New Mexico Tech

- **Name: Socorro Systems Summit**
- **Date: Friday/Saturday, October 28-29**
- **Place: New Mexico Tech, Socorro, NM**
- **Keynote: INCOSE President-Elect Garry Roedler**
- **8 Collaborative workshops will explore issues of mutual interest**
- **Survey will ask for topics of interest to you and your organization**
- **See Q2 Newsletter page 1 and 7 for objectives and ConOps**

Chapter wins 2015 Platinum Award – new top category

First slide, not recorded, but retained in website presentation-pdf library.

And Now - Introductions

Enchantment Chapter Monthly Meeting

<u>11 May 2016 – 4:45-6:00 pm</u>:

Systems and Software Product Line Engineering – State of the Industry

Paul Clements, PhD, VP Customer Success, BigLever Software, pclements@biglever.com

Abstract: Product line engineering (PLE) is a way to engineer a portfolio of related products in an efficient manner, taking full advantage of the products' similarities while respecting and managing their differences. By "engineer," we mean all of the activities involved in planning, producing, delivering, deploying, sustaining, and retiring products. Born in the 1980s in the software field, but now having grown well beyond those early roots, PLE derives benefits from engineering the whole family rather than separately engineering each member. Numerous case studies show that exploiting the commonality throughout the products' total life cycles can return substantial improvements in time to market, cost, portfolio scalability, engineer productivity, and product quality; no other engineering paradigm shift has, to our knowledge, brought about results that rival these. This talk will explore how PLE is being used in industry today, and discuss how it has grown and evolved to meet the needs of such high-demand industries such as automotive, avionics, aerospace and defense, and more.

Download slides today-only from GlobalMeetSeven file library or anytime from the Library at www.incose.org/enchantment

NOTE: This meeting will be recorded

Product Line Engineering

Things to Think About

How can this be applied in your work environment?

What did you hear that will influence your thinking?

What is your take away from this presentation?

Speaker Bios

Paul Clements, PhD, VP Customer Success, BigLever Software

One of the founding fathers of the PLE field, Dr. Paul Clements brings to BigLever in-depth systems and software architecture and analysis expertise, applied research experience, and insight for helping commercial organizations define pragmatic solutions to complex engineering problems.

Clements assists BigLever customers in applying the latest PLE approaches, creating optimized deployment plans, and establishing successful ongoing PLE practices.

He was previously a senior member of the technical staff at The Carnegie Mellon Software Engineering Institute (SEI) where he gained recognition as co-creator of the book Software Product Lines: Practices and Patterns, the SEI's first product line case study, the SEI Framework for Product Line Practice, the SIMPLE modeling language for product line economics, and the International Software Product Line Conference.

Prior to SEI, he was a computer scientist with the U.S. Naval Research Lab. He received his PhD in computer science from The University of Texas at Austin.

Consolidate.

Simplify.

Leverage.

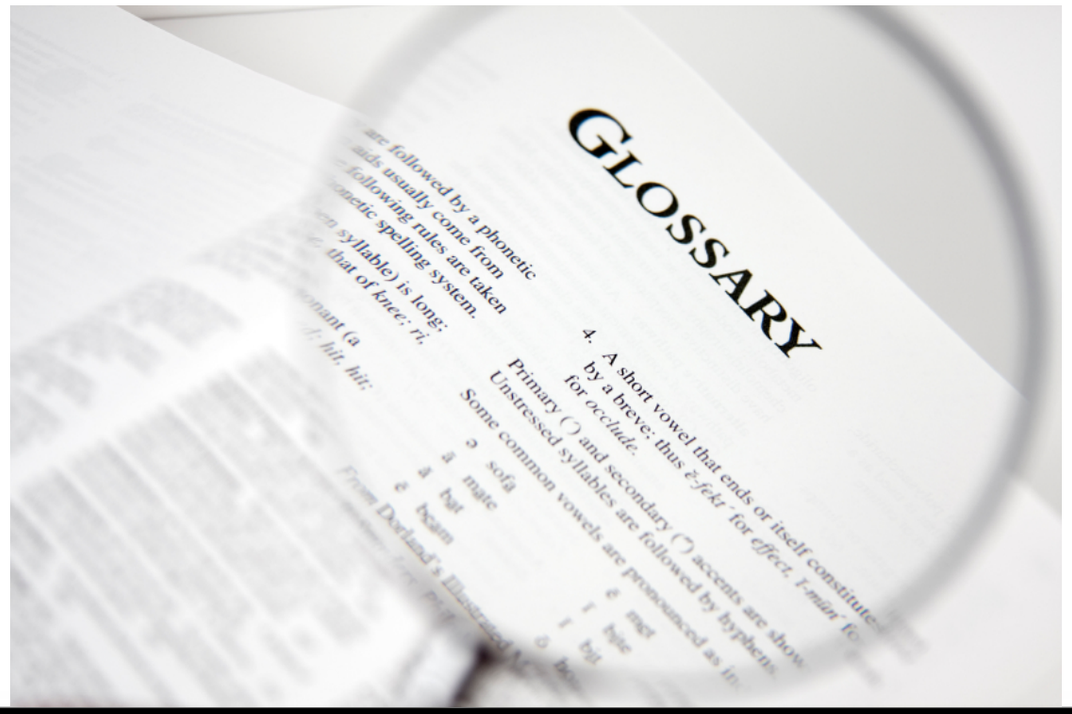
Systems and Software Product Line Engineering: The State of the Industry

Dr. Charles Krueger
President and CEO
BigLever Software, Inc.

Dr. Paul Clements
Vice President of Customer Success
BigLever Software, Inc.

Product Line Engineering (PLE) Defined

- A **Product Line** is a family of similar products with variations in features and functions
- **Product Line Engineering** is the engineering of a product line using a *shared set of engineering assets,* a *managed set of features,* and an *efficient means of production,*
  - taking advantage of the **commonality** shared across the family
  - efficiently and systematically managing the **variation** among the products



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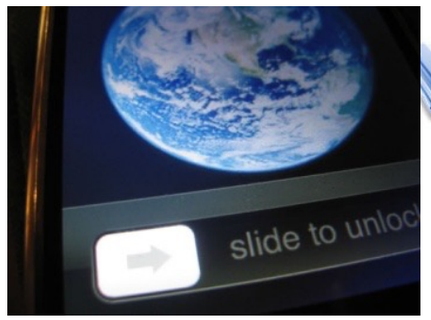
To be competitive, most product development organizations deliver a product line –
a portfolio of similar products or systems
with variations in features and functions

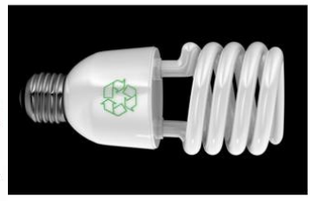








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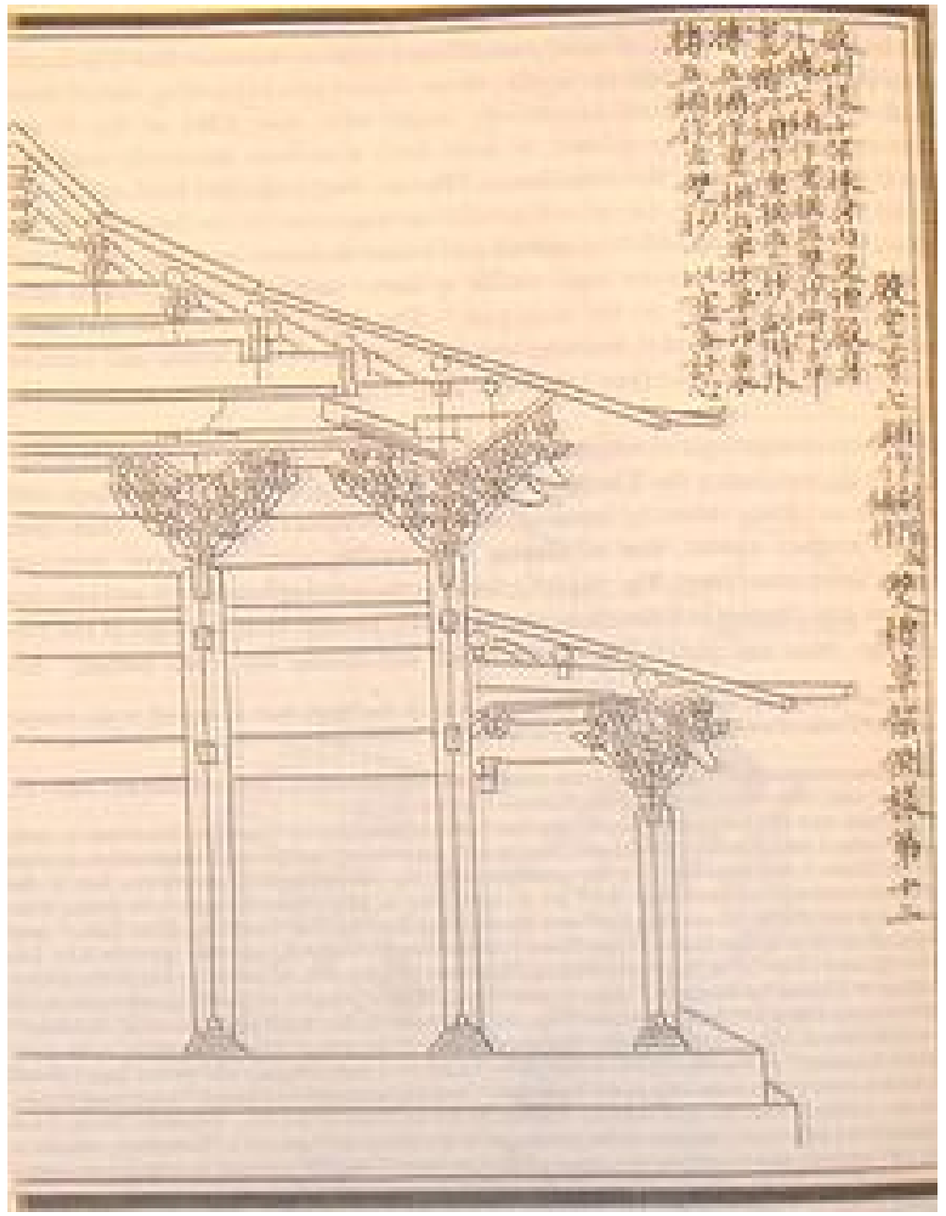
1103 AD: Ying tsao fa shih (營造法式)

- Written by Li Chieh, state architect of emperor Hui-tsung, published in 1103 AD
- Set of building codes for official buildings
  - Described layout, materials, and practices for designing and building
  - Listed standard parts and standard ways of connecting the parts
  - Parameterized variations of the parts
  - Allowed components based on the building's purpose
  - Gave options for various component choices
- Defined a “product line” of buildings



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1960s: IBM 360 and OS/360

- From the *Principles of Operation*:
  - *Models of System/360 differ in storage speed, storage width (the amount of data obtained in each storage access), register width, and capabilities for processing data concurrently with the operation of multiple input/output devices.*
  - *Several CPU's permit a wide choice in internal performance. Yet none of these differences affect the logical appearance of these models to the programmer.*
  - *An individual System/360 is obtained by selecting the system components most suited to the applications from a wide variety of alternatives in internal performance, functional ability, and input/output (I/O).*

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1970s-1990s

- Software reuse movement
  - Emphasized code repositories and opportunistic reuse, as opposed to planned reuse.
  - Primary contribution to PLE was to instill the notion that software systems might not (or should not) be built from scratch.

- Generative programming
  - Uses domain-specific languages to specify a product
  - Engineers work on shared assets (requirements, design, and so forth) that apply across the entire portfolio.

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1980s: Boeing 757 and 767

These two very different aircraft were designed together and have about 60% of their parts in common. Parts were designed to work on *both* aircraft.

www.boeing.com

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1990-2000s: First Generation Case Studies Emerge

Software Product Line Conferences

Sharing real-world software experience with the global community

SPLC

Current Conference | About | History | Hall of Fame | Contact

PRODUCT LINE HALL OF FAME

A hall of fame serves as a way to recognize distinguished members of a community in a field of endeavor. Those elected to membership in a hall of fame represent the highest achievement in their field, serving as models of what can be achieved and how.

Each Software Product Line Conference (SPLC) culminates with a session in which members of the audience nominate systems for induction into the Software Product Line Hall of Fame. Those nominations feed discussions about what constitutes excellence and success in product lines. The goal is to improve software product line practice by identifying the best examples in the field.

Nominations are voted on at the next SPLC by the majority of those present. For example, the Bosch Gasoline Systems: Engine Control Software Product Line and Philips Low-End Television Product Line were nominated at SPLC 2006. The Bosch Gasoline Systems: Engine Control Software Product Line was inducted at SPLC 2007.

Organizations in the Product Line Hall of Fame

- Boeing
- Bosch Group
- CelsiusTech Systems AB
- Cummins, Inc.
- Ericsson AXE
- FISCAN
- General Motors Powertrain (GMPT)
- Hewlett Packard
- HomeAway
- LSI Logic
- Lucent

News & Information

SPLC 2013 will be held in Tokyo, Japan, August 26-30, 2013.

Two new entries have been added to the Product Lines Hall of Fame.

SPLC ON LinkedIn | JOIN THE GROUP »

Software Engineering Institute | Carnegie Mellon University

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Software Product Lines

A software product line epitomizes strategic, planned reuse. More than a new technology, it is a new way of doing business. Organizations developing a portfolio of products as a software product line are experiencing order-of-magnitude improvements in cost, time to market, and productivity.

Overview | Getting Started | Research | Tools & Methods | Consulting | Case Studies | Our People

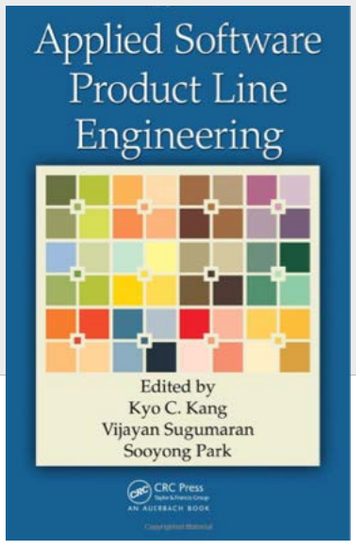
Catalog of Software Product Lines

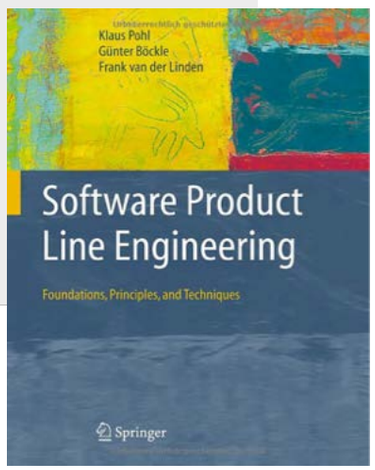
This pages lists examples of real software product lines. These examples, which cover diverse domains, show the kind of improvements your organization can achieve using a product line approach.

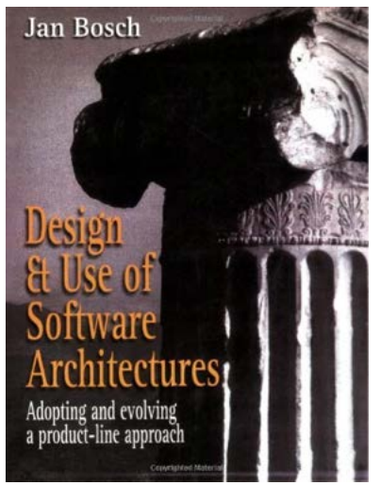
AKVAsmart ASA

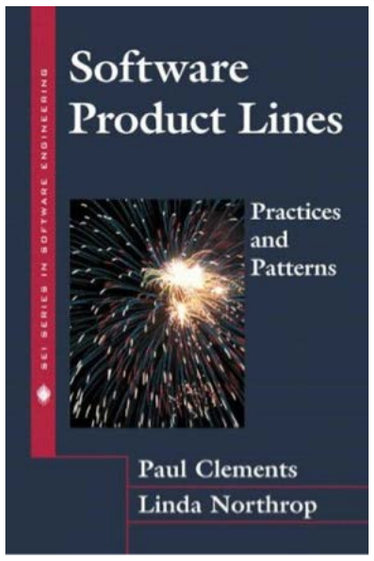
Description	Cited Improvements
Fish farm feed control and management software	• Reduction of code size by more than 70%. • Uniform look and feel. • Common technological platform and code

- Naval Undersea Warfare Center
- U.S. National Reconnaissance Office
- U.S. Army Technical Applications Program Office
- CelsiusTech
- Salion, Inc.
- Catalog of Software Product Lines









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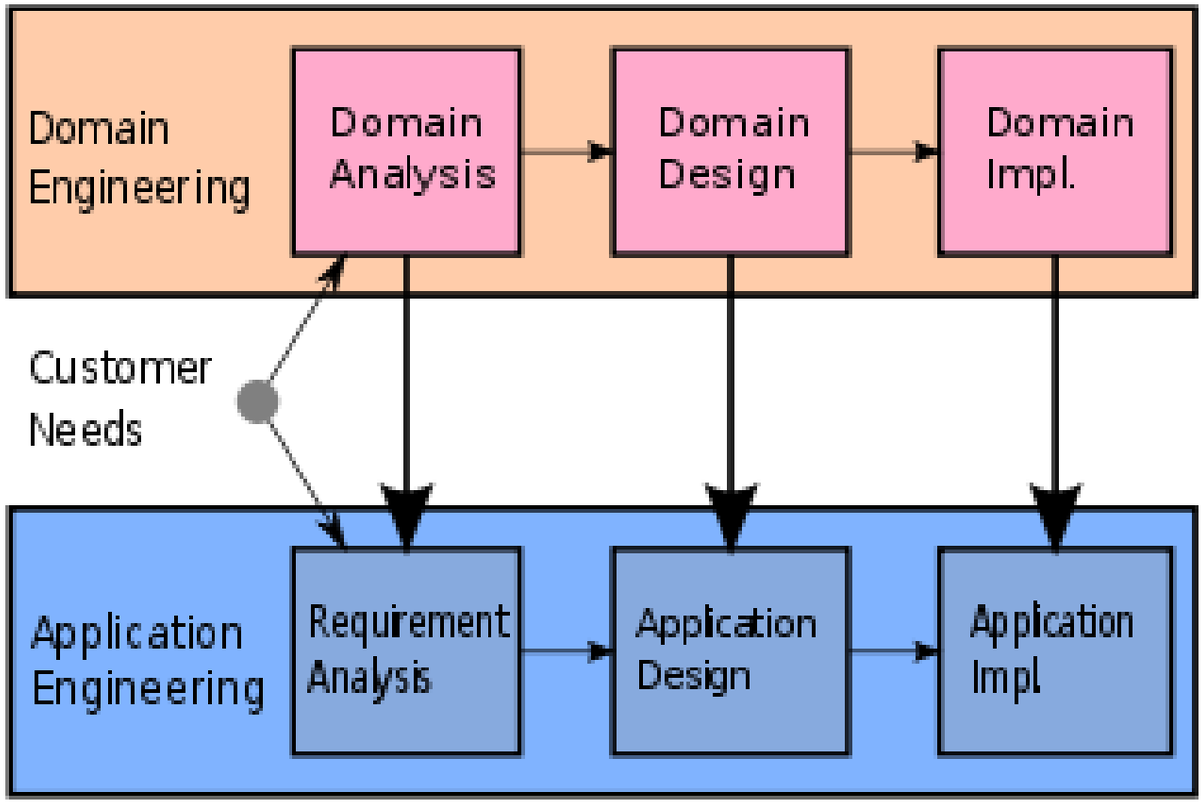
First Generation Approaches #1

- A strong dichotomy between *domain engineering* and *application engineering*
  - Or *core asset development* and *product development*.



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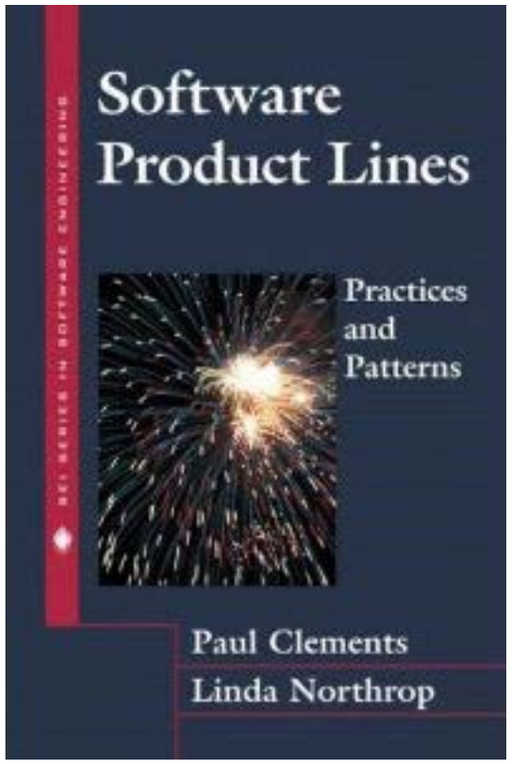
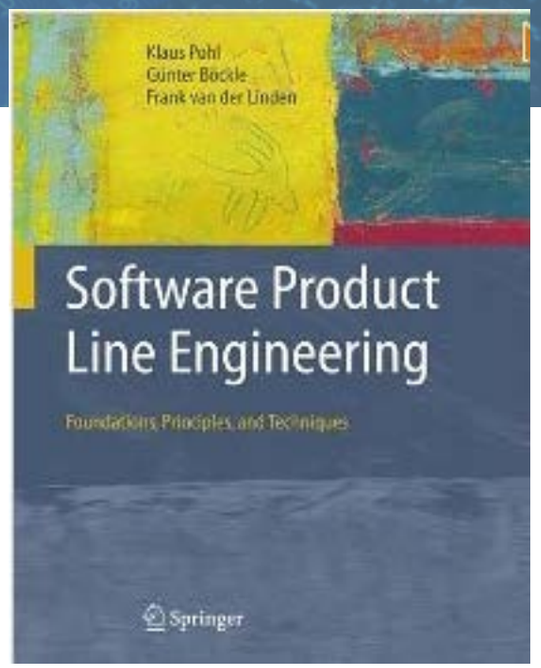
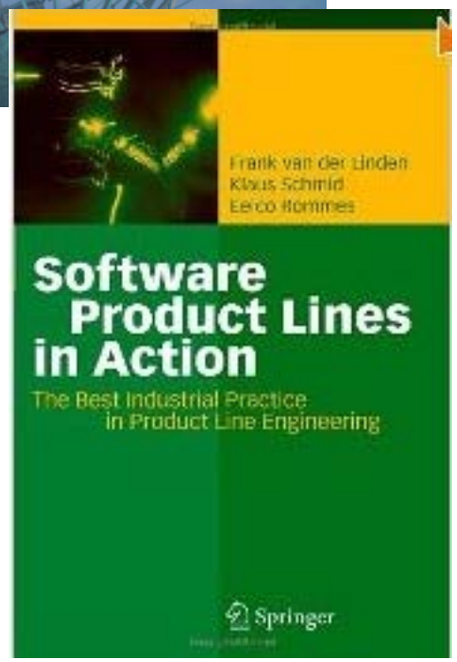
First Generation Approaches #2

- Explicit inclusion of non-software artifacts in the collection of core assets…
- …but an unmistakable emphasis on **software** as the principal kind of core asset.







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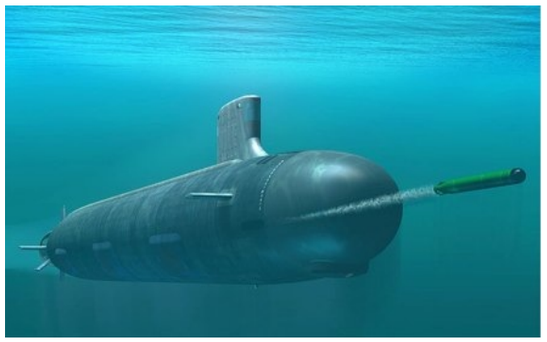
In DoD (and elsewhere), isolated First Generation PLE Successes

- A product line of satellite ground control systems for the National Reconnaissance Office
  - Clements, P.; Northrop, L. *Software Product Lines: Practices and Patterns*, Addison-Wesley, 2002.
- A product line of weapons test ranges at the Naval Undersea Warfare Center
  - Cohen, S., Dunn, E., Soule, A. , *Successful Product Line Development and Sustainment: A DoD Case Study*, CMU/SEI-2002-TN-018, September 2002.
- A product line of helicopter avionics systems for the Army's Technical Applications Program Office
  - Clements, P. and Bergey, J. The U.S. Army's Common Avionics Architecture System (CAAS) Product Line: A Case Study, Technical Report CMU/SEI-2005-TR-019, September 2005.
- A product line of submarine combat systems for the Navy's Submarine Warfare Federated Tactical System
  - Guertin, N., and Clements, P., "Comparing Acquisition Strategies: Open Architecture vs. Product Lines," *Proceedings of the 2010 Acquisition Research Symposium*, Monterey, May 2010.



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Problems with Early Approaches

- Emphasis on software is a serious limitation.
  - New generation approaches emphasize assets across the entire engineering life cycle.
- Automation was welcomed, but never embraced.
- No clear, prescriptive, repeatable methodology
  - Case studies tended to show ad hoc approaches.
  - Each success employed its own unique approach.

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Second Generation PLE

Second generation PLE strongly embraces the *factory* paradigm.

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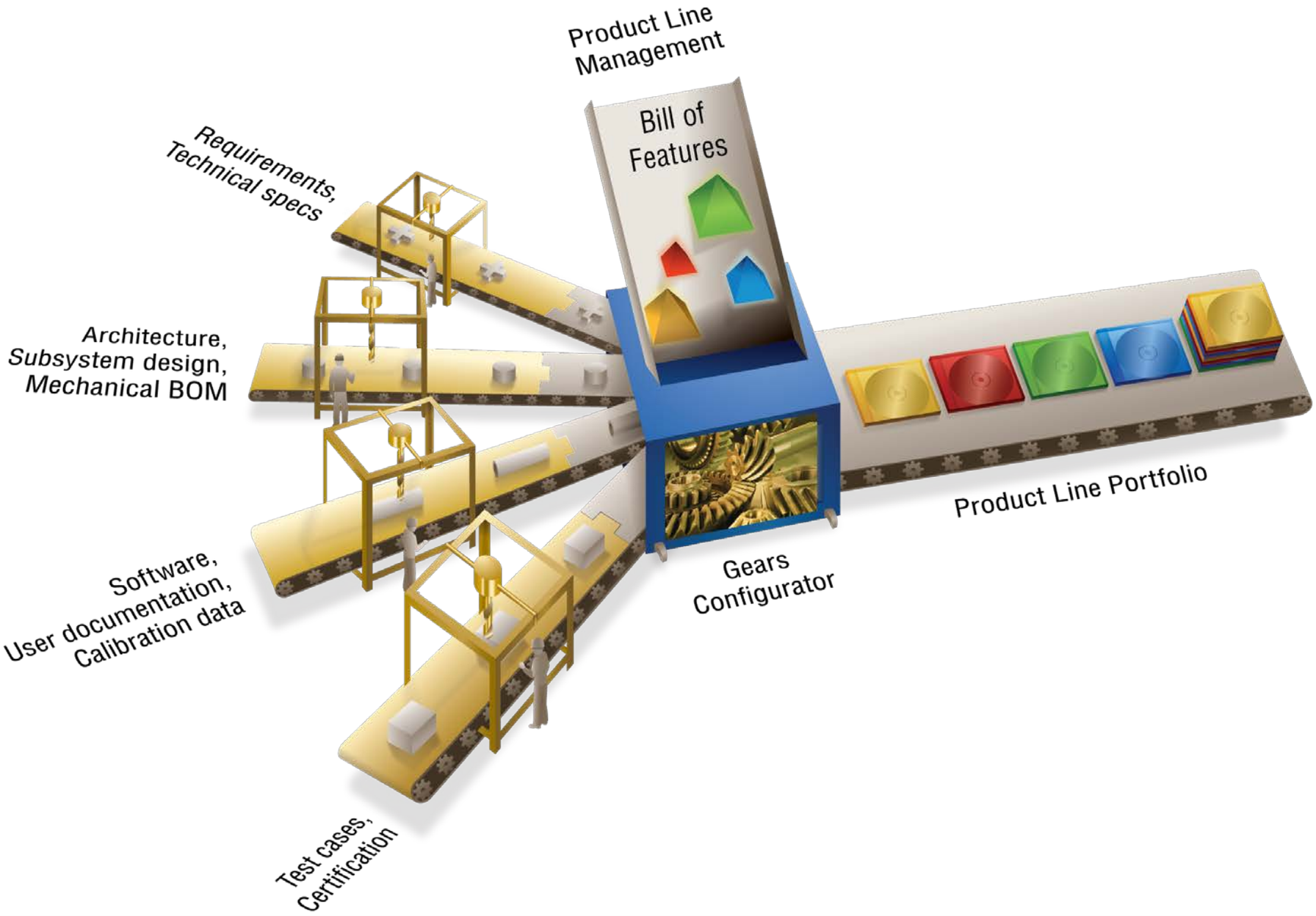
An Efficient Means of Production for Product Lines



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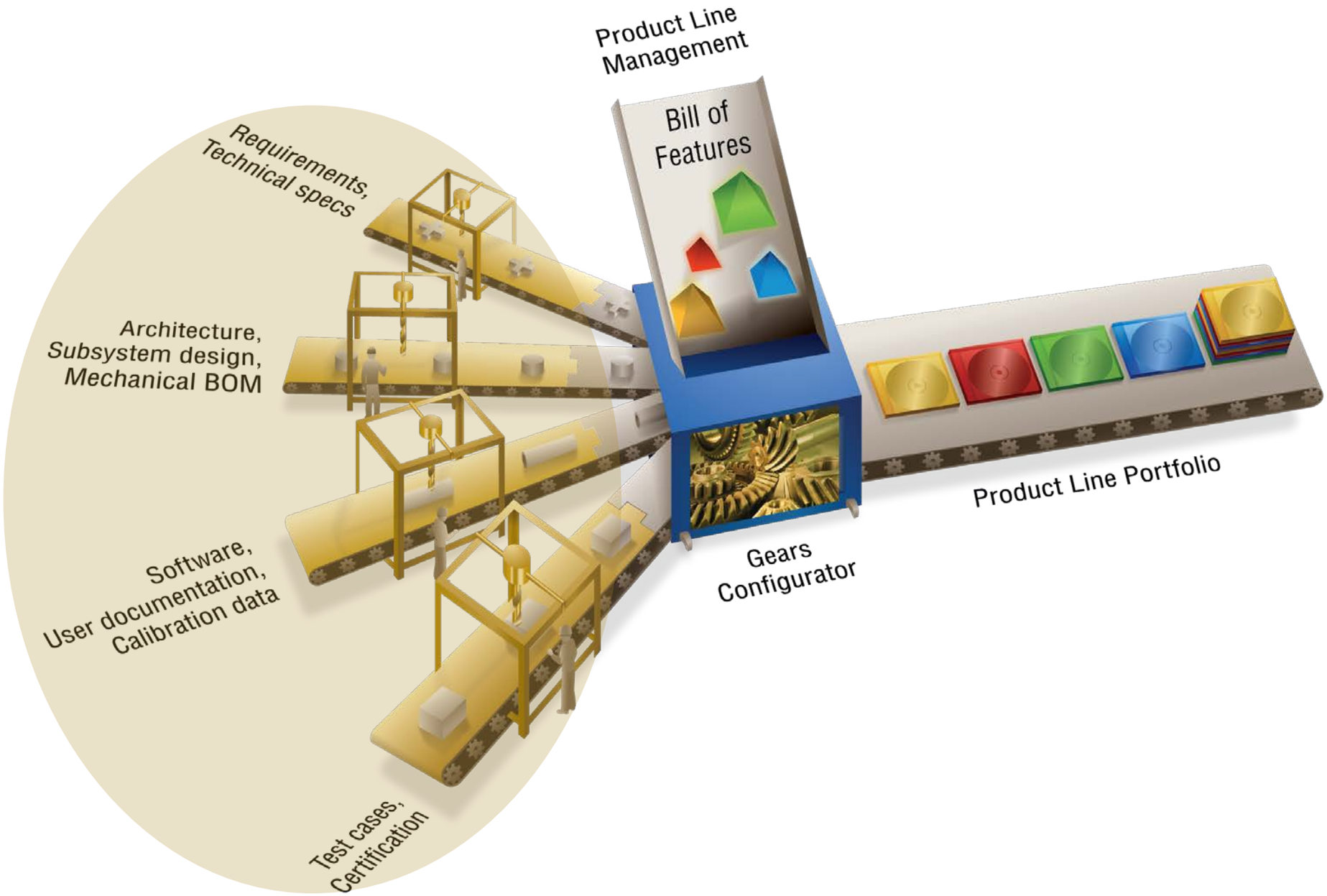
Shared assets **are like the factory's supply chain.**



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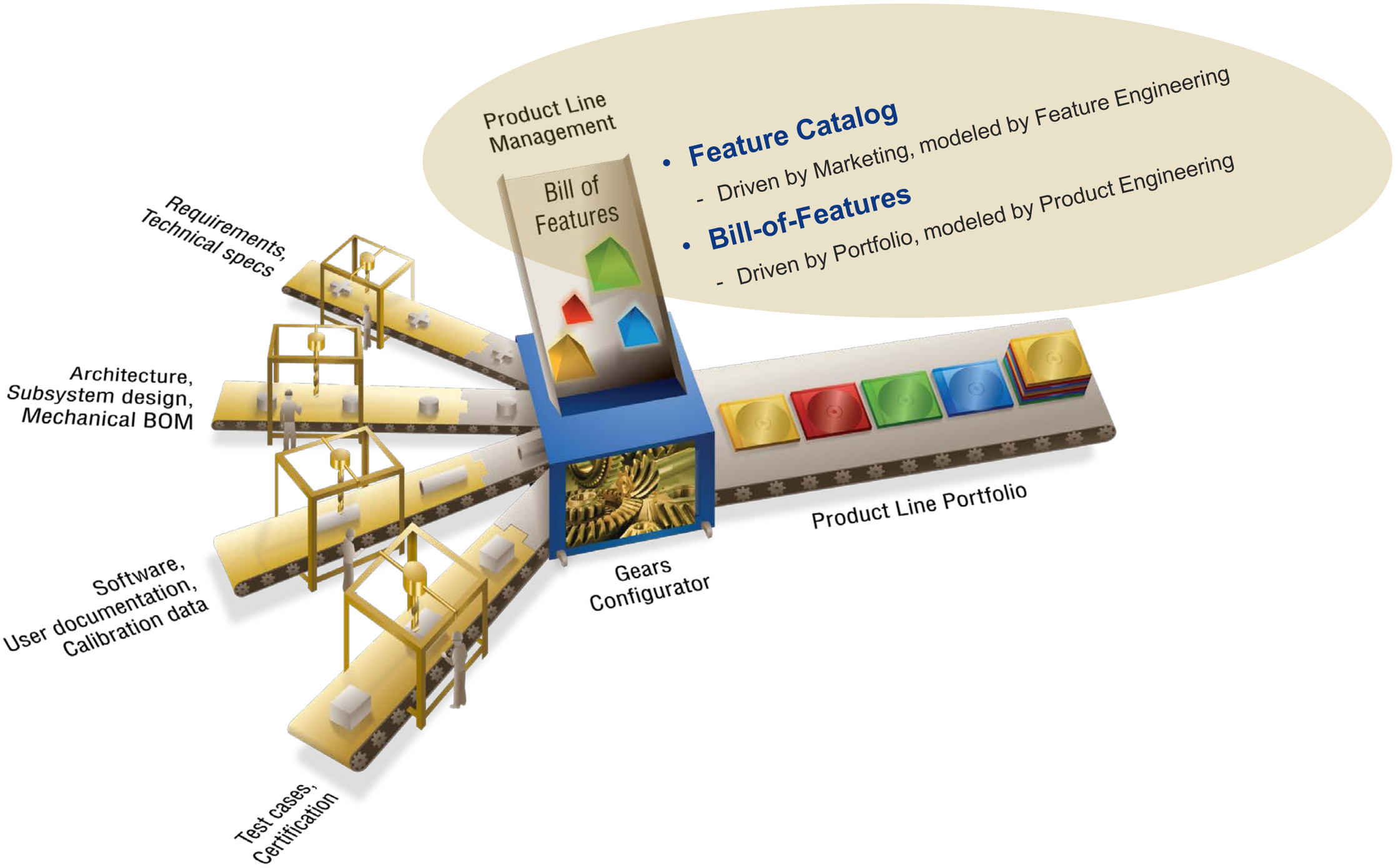
Features **describe capabilities that vary among products.**



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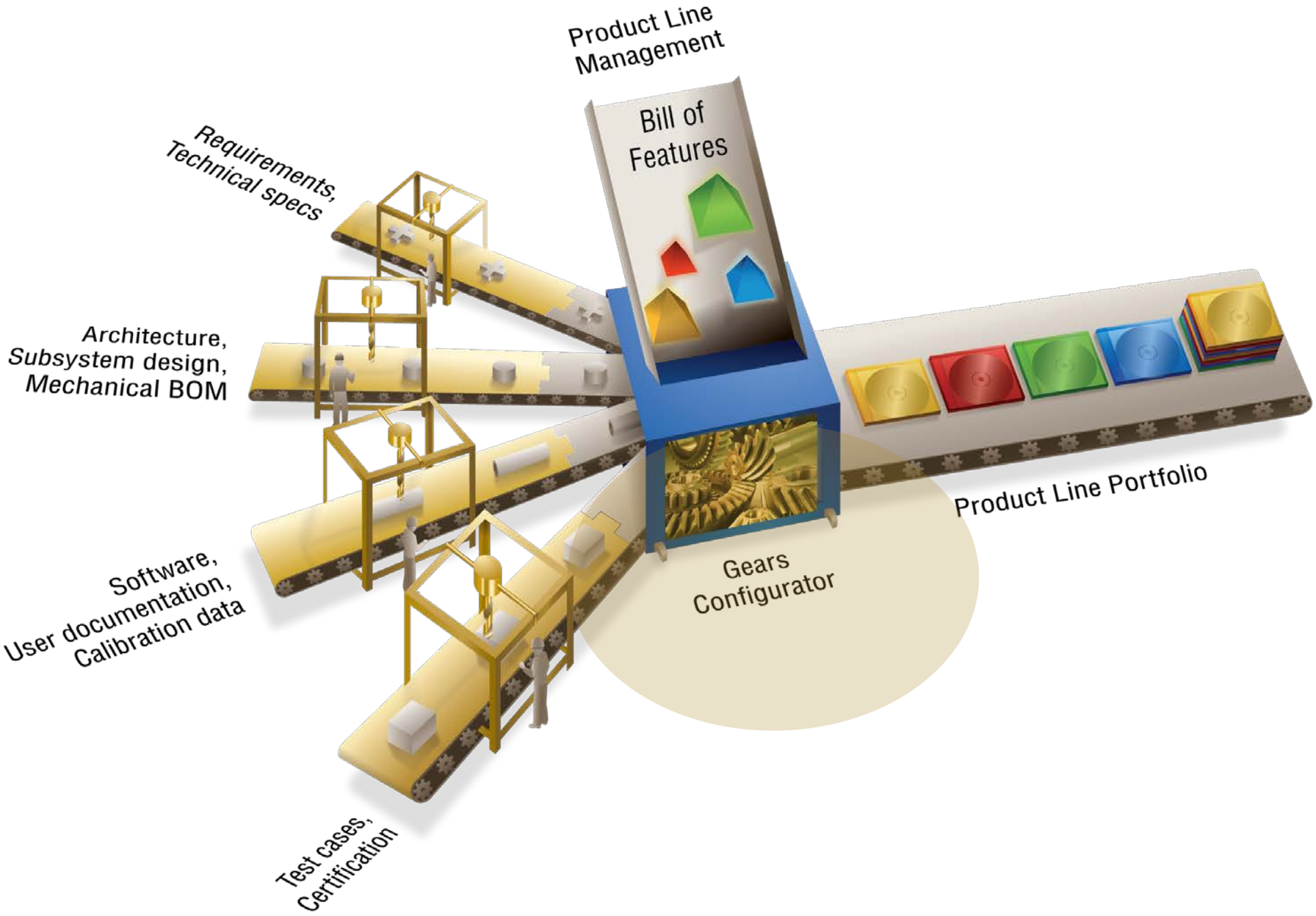
Assets **are configured according to the *feature profiles* of the products you want build.**



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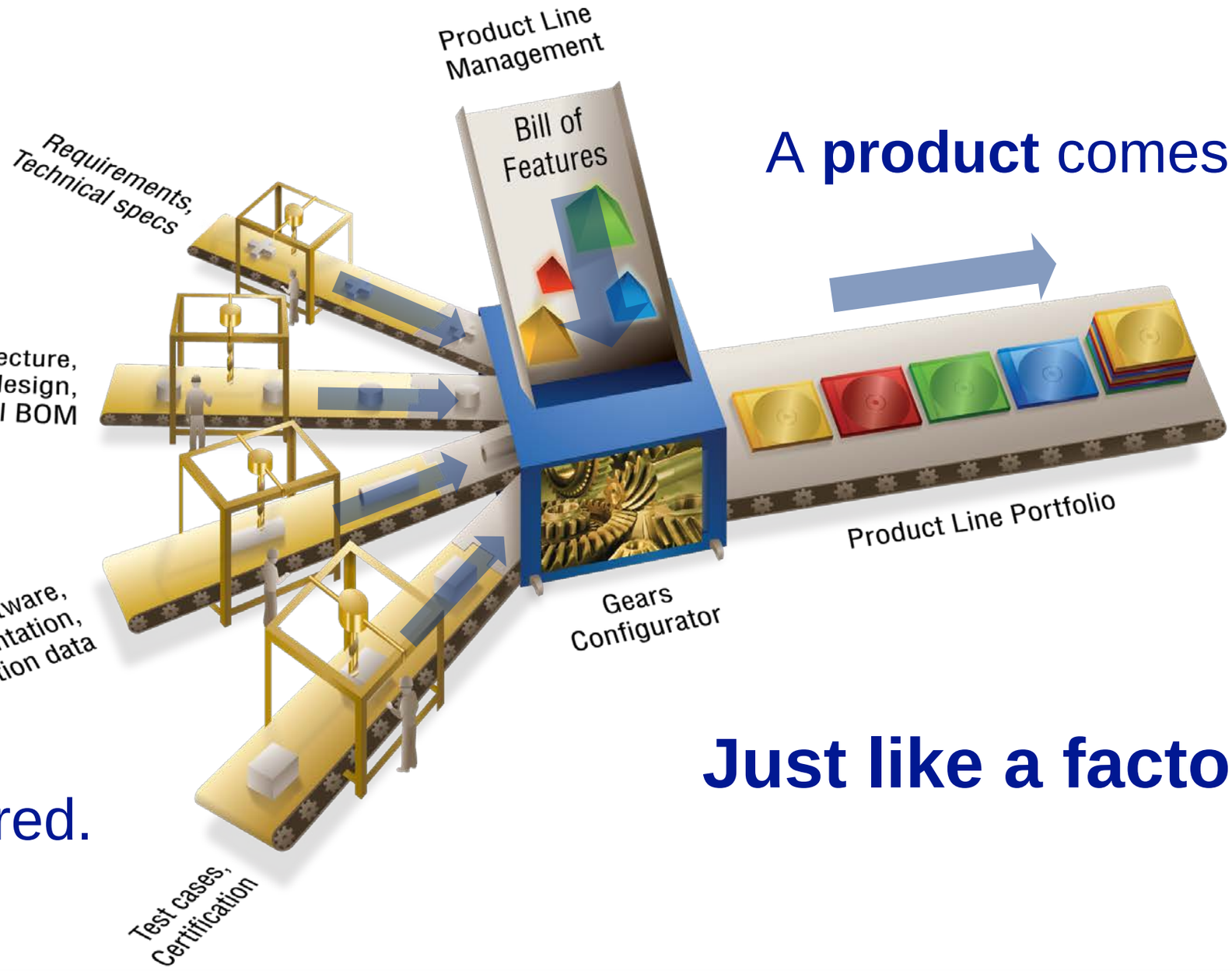
Features come in.



A **product** comes out.

Assets
are configured.

Just like a factory.

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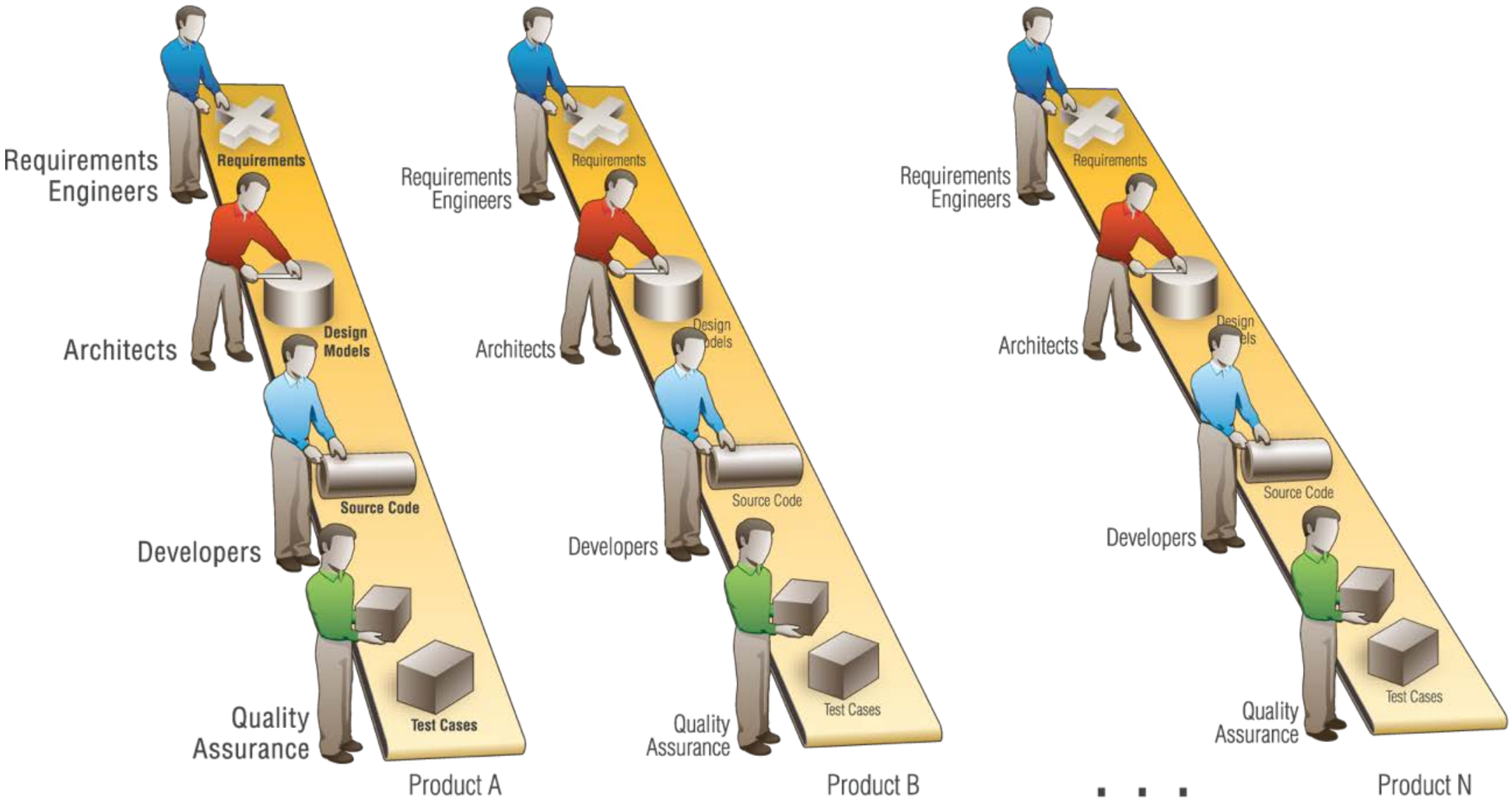
This is a move away from the traditional product-centric development silos.



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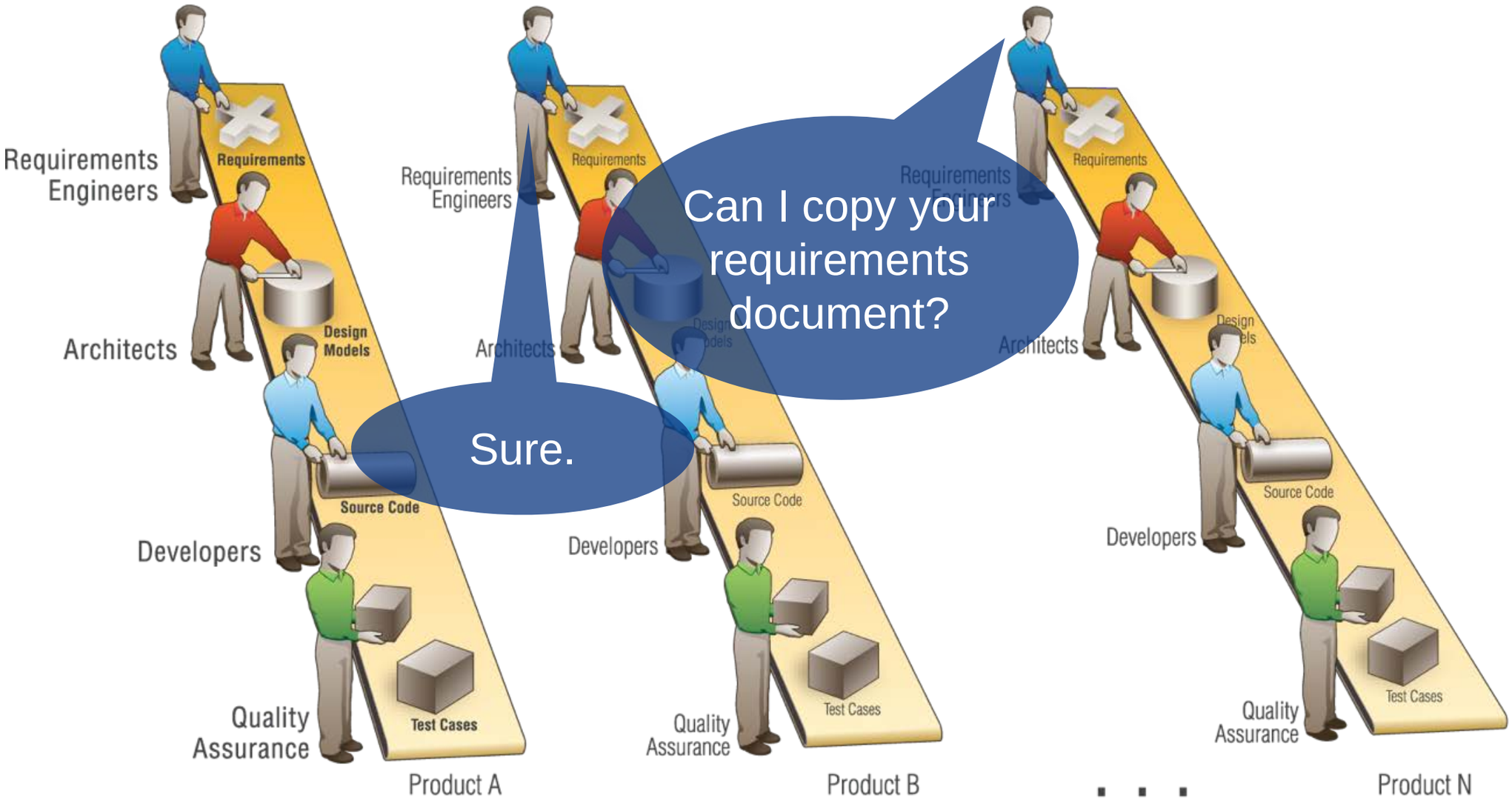
With traditional approaches there may be some reuse among products, but it's usually not systematic.



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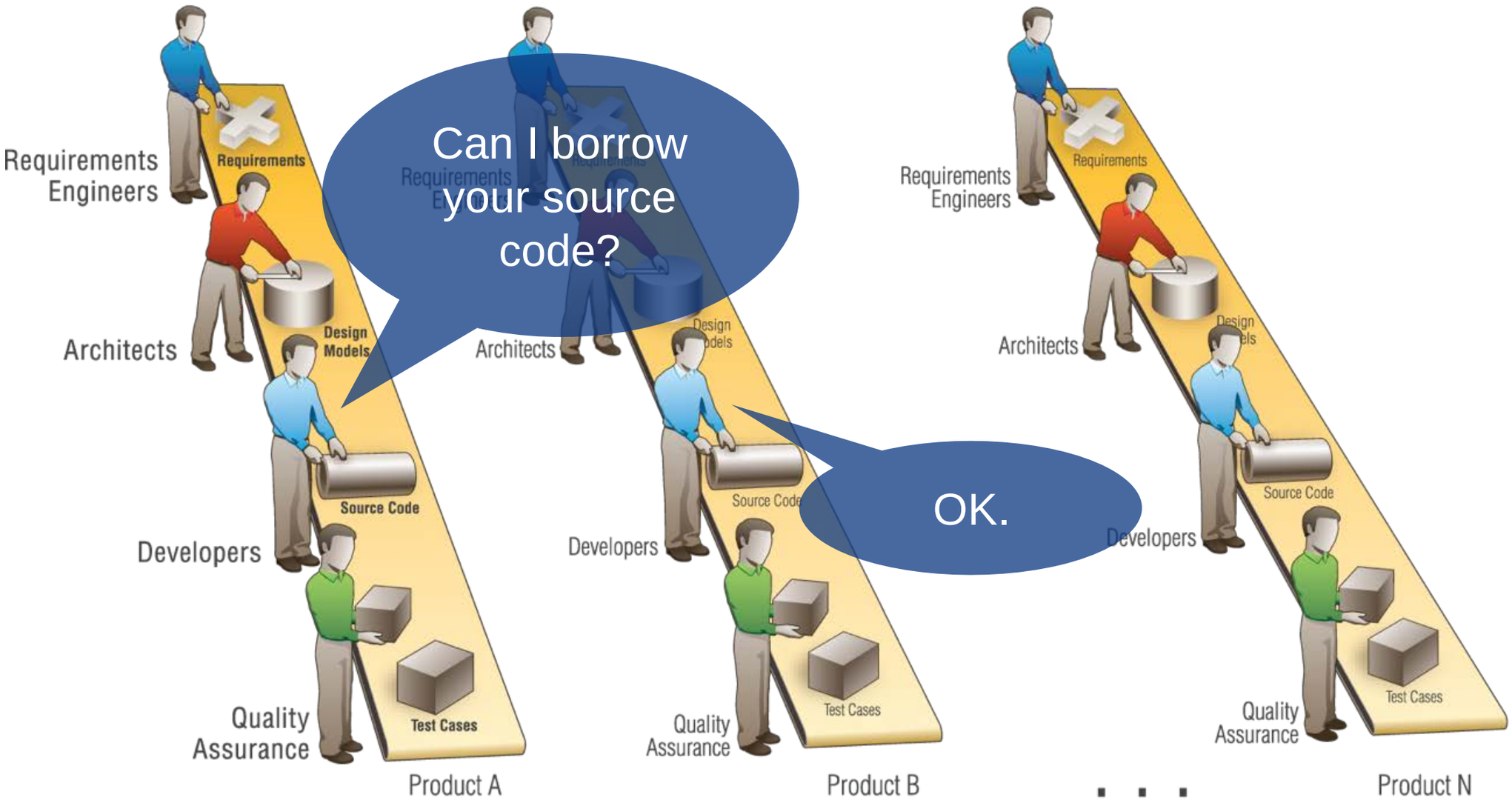

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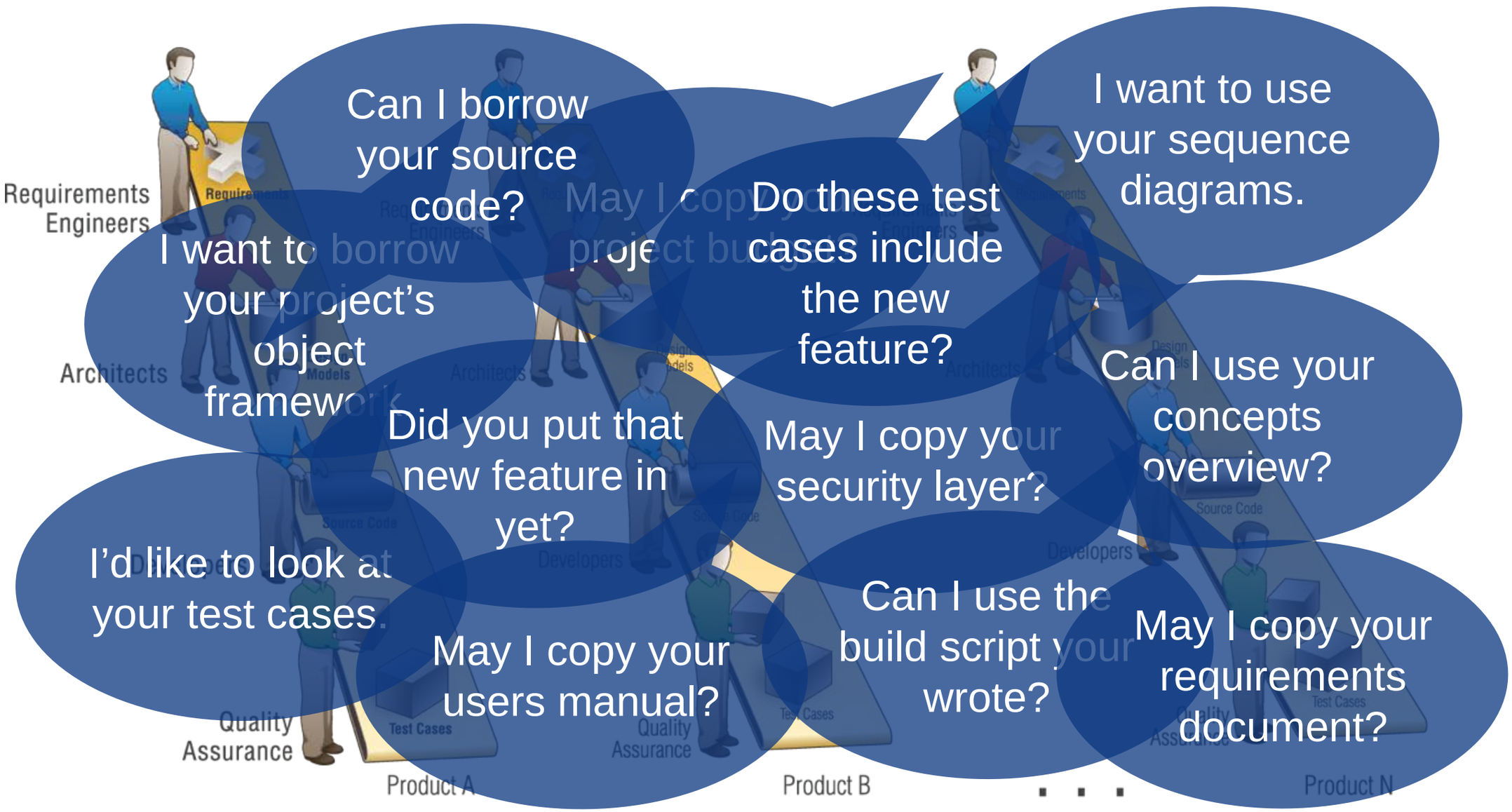
This doesn’t scale very well.



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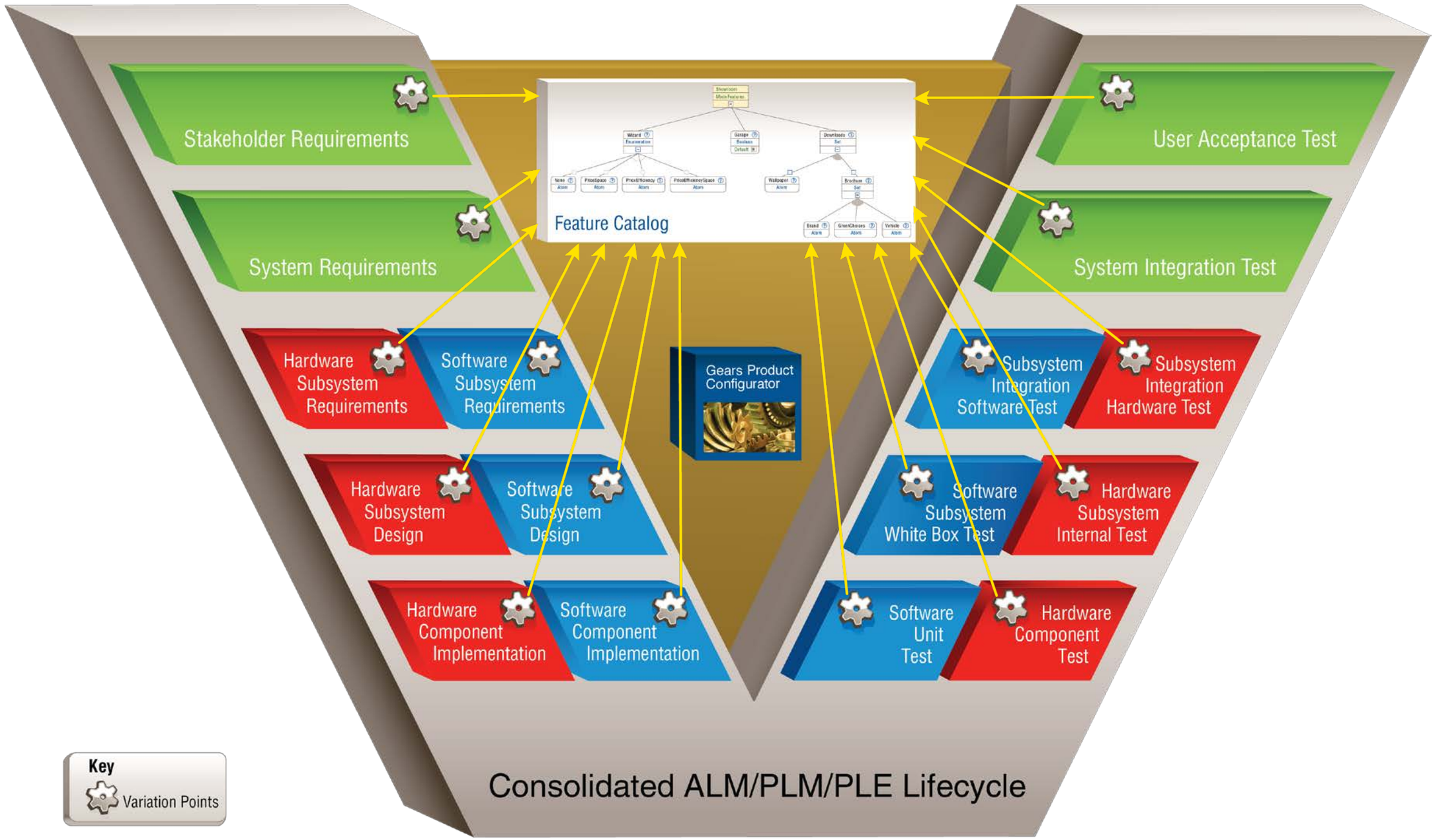
Feature catalog is the single source of feature truth across the entire engineering lifecycle



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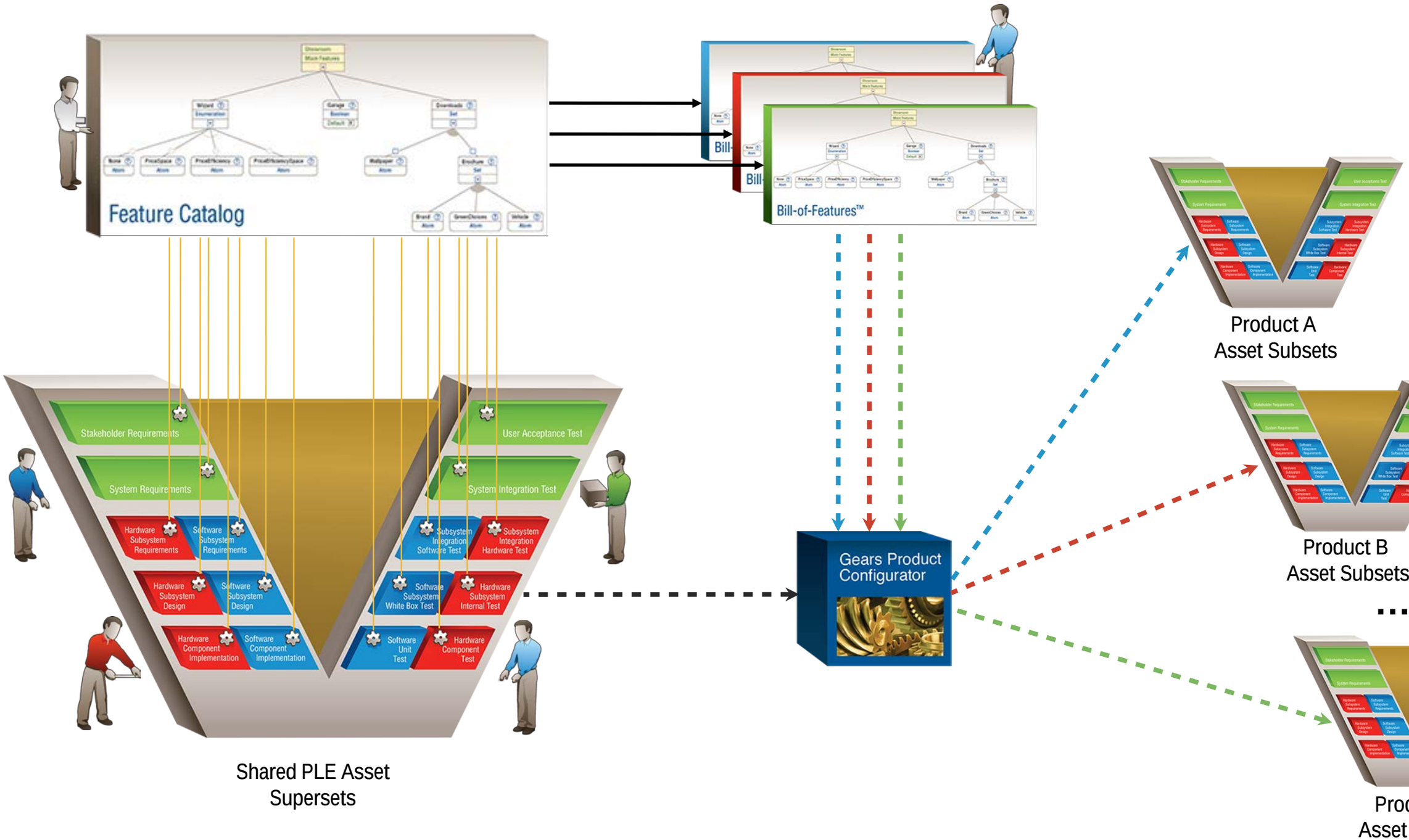
Multi-product Automated Production Line



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Second Generation Approaches

1. Features serve as the *lingua franca* to express product differences and exercise the variation points in all assets.
2. Industrial-strength easy-to-use automation is employed to maintain configurations and turn out products. “Application engineering” disappears.
3. Artifacts from all lifecycle phases are treated as first class citizens, not just the software.
4. A vastly simplified configuration management model: Manage the shared assets in the factory, not the products
5. Feature models with encapsulating constructs to facilitate modular and hierarchical product lines developed across organizational boundaries.

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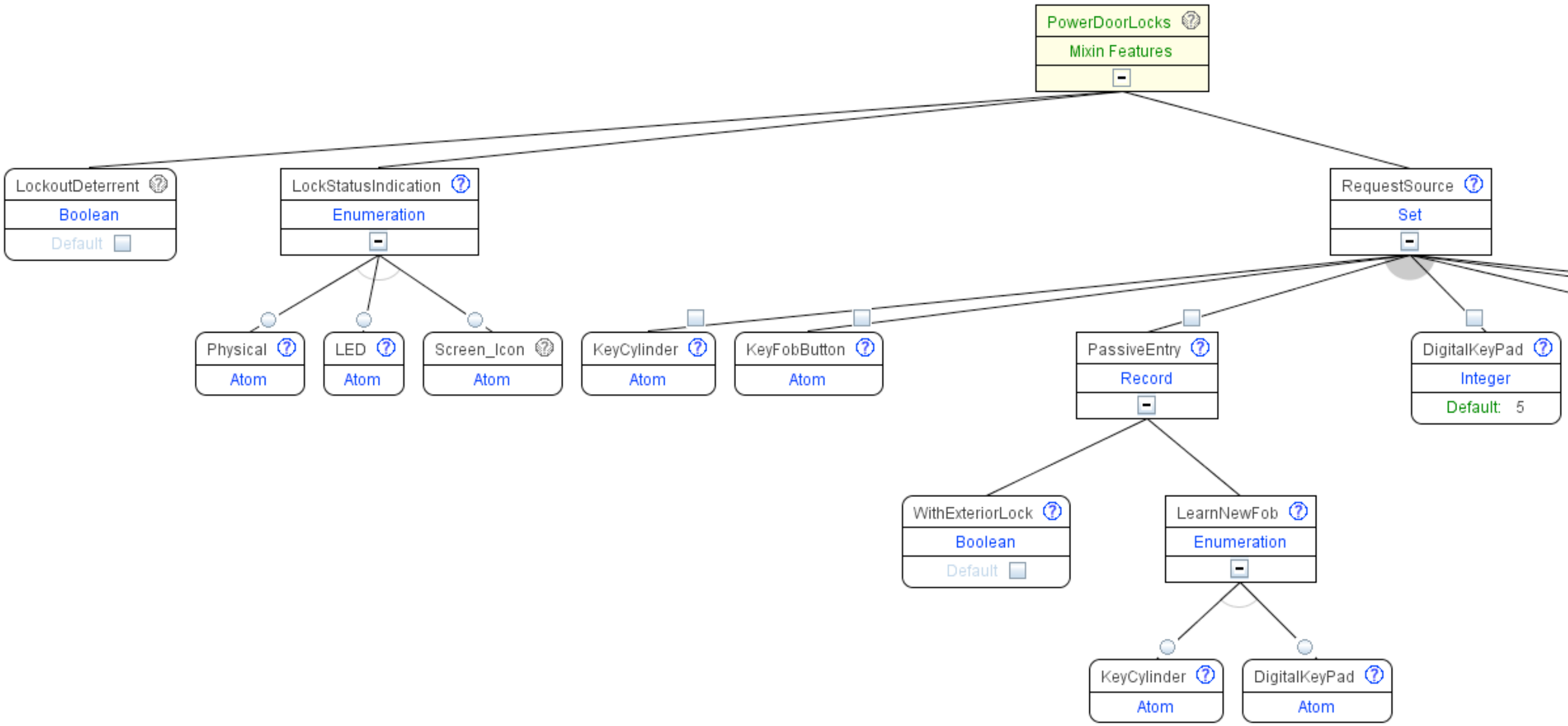
Feature model



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LOCKHEED MARTIN

Integrated weapons system for 100 ships

Entire family managed with a single set of requirements and a single set of source code.

Coast Guard produced new cutter spec in **2 weeks** compared to **3-4 months**

US Navy reports **$47M** cost avoidance per year

US Navy Aegis Cruisers & Destroyers

US Navy Littoral Combat Ships

US Coast Guard Nat'l Security Cutter

Aegis Ships for International Navies

Gregg, S., Scharadin, R., Clements, P. "The More You Do, the More You Save: The Superlinear Cost Avoidance Effect of Systems and Software Product Line Engineering," *Proc. SLC 201*5, Nashville.

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Live Training Transformation (LT2) training systems for US Army

General Dynamics teamed with BigLever to create the winning proposal for the US Army Live Training Transformation “Consolidated Product-line Management”.

US Army projects **$660M** cost avoidance over 10 years and 300 training range deployments.

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General Motors

Mega-scale Product Line Engineering

- Largest product line and one of the most complex systems and software product line engineering challenges in the world.
  - 3000 product line engineers
  - 300 hierarchical subsystems
  - Thousands of variant features
  - Millions of product instances
  - 15 concurrent temporal development streams
  - Dramatic increase in product line variation and subsystem interactions due to new propulsion systems, active safety, infotainment, and more
  - **Calibration generation alone projected to save $10M's to $100M's annually**

Wozniak, L., Clements, P. "How Automotive Engineering Is Taking Product Line Engineering to the Extreme," *Proc. SPLC 2015*, Nashville, 2015.

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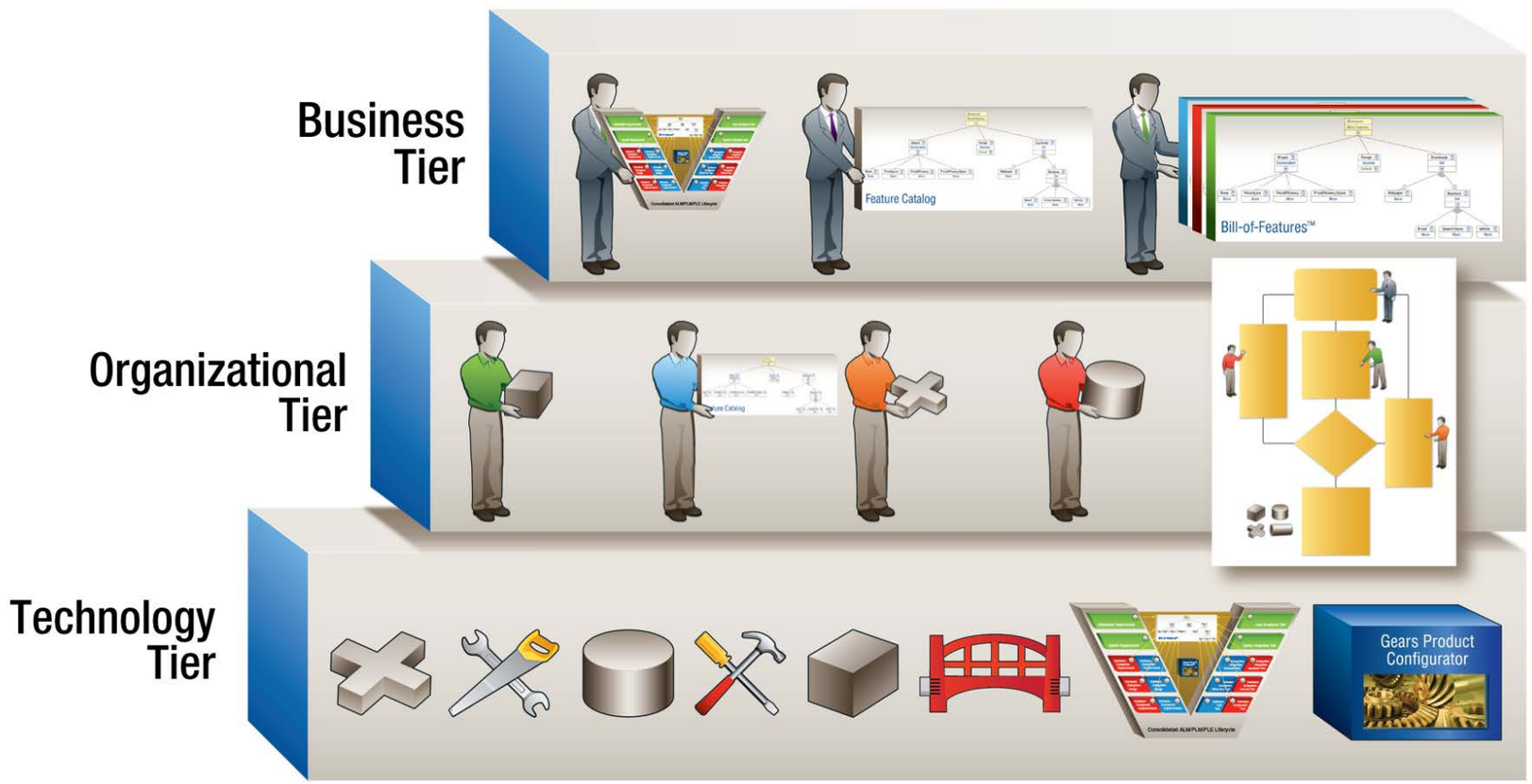
PLE and Organizational Change

- PLE is about more than technology.
- Successful PLE requires significant *Organizational Change*, much more so than other engineering disciplines.
  - Strong collaboration between business, management, and engineering leadership
  - Active commitment and participation of business and management leadership



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Successful PLE Adoption

- **Living business plan**, owned by **business leadership**
  - Communicates precise need, importance, urgency and vision for PLE
  - Makes clear what investment is needed and the payoff expected
- **Organizational operation**, executed by **management**
  - Establishes roles and responsibilities for PLE factory owners, feature owners, product content & portfolio managers, shared asset engineers, and more
- **Technology environment**, utilized by **engineering**
  - Establishes technological solutions to enable the products in a product line to be produced from shared engineering assets, evolving over time

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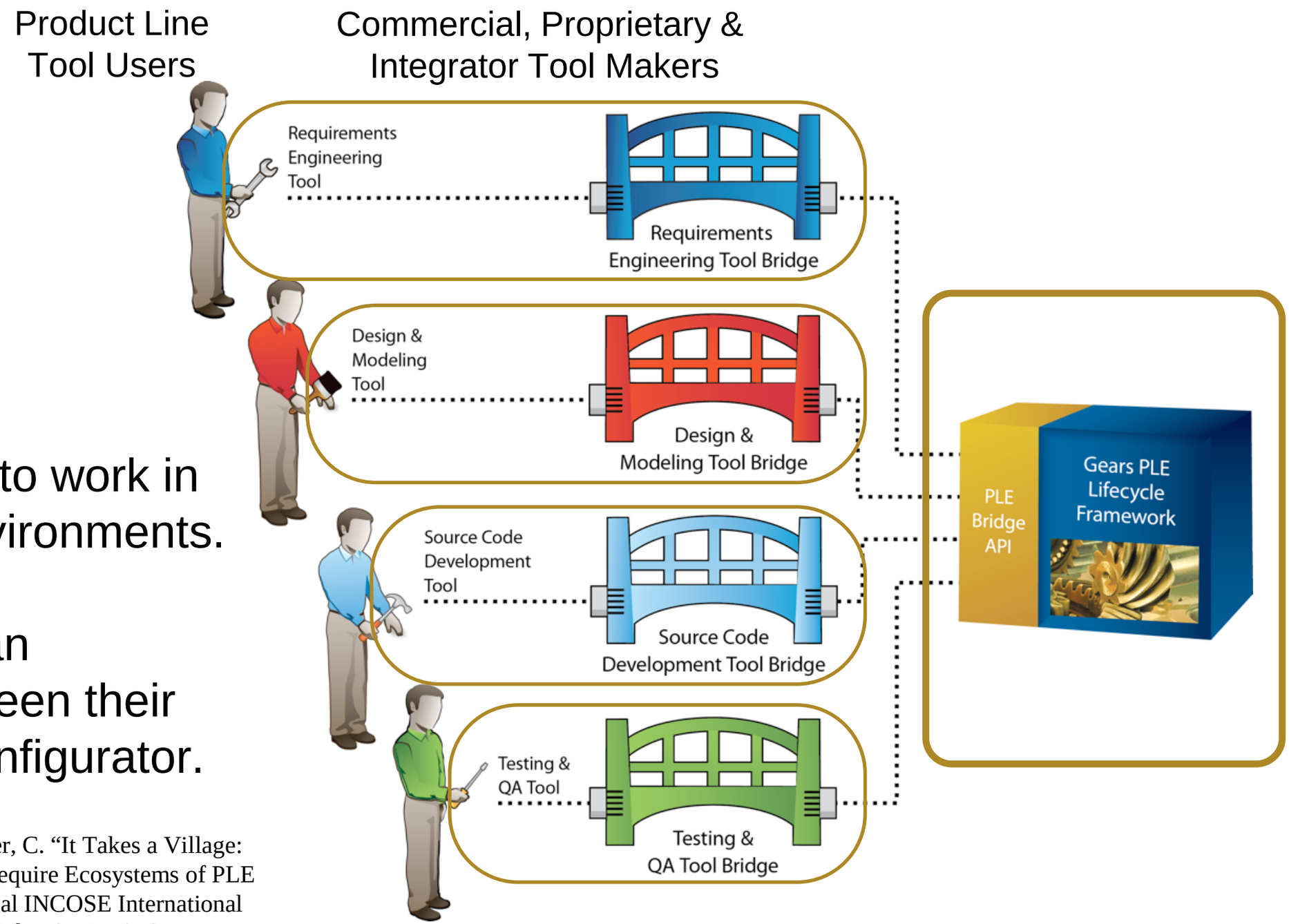
PLE and Systems Engineering: The PLE Ecosystem

Engineers want to work in their familiar environments.

There must be an integration between their tools and the configurator.



Bolander, B., Clements, P., Krueger, C. “It Takes a Village: Why PLE Technology Solutions Require Ecosystems of PLE Technology Providers,” 26th Annual INCOSE International Symposium (IS2016), Edinburgh, July 18-21, 2016.

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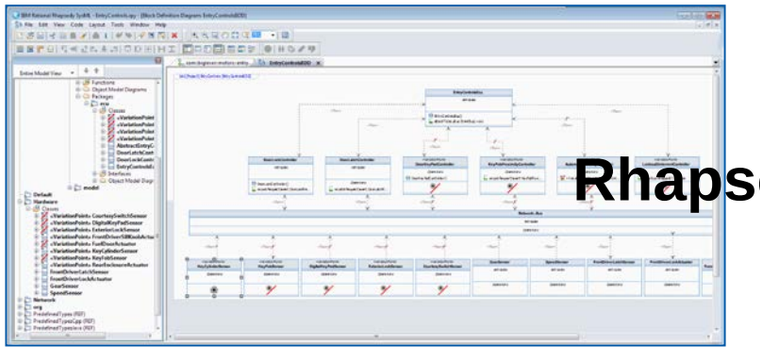
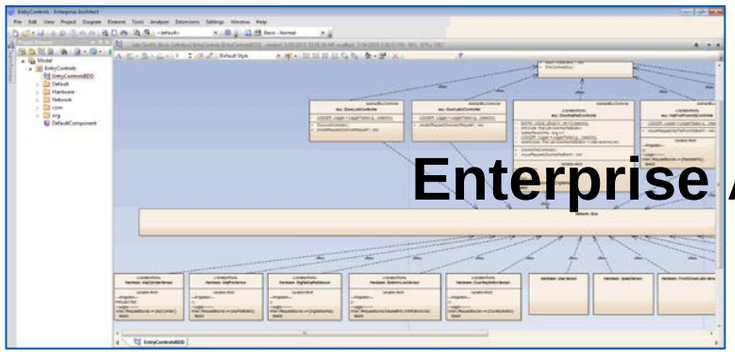
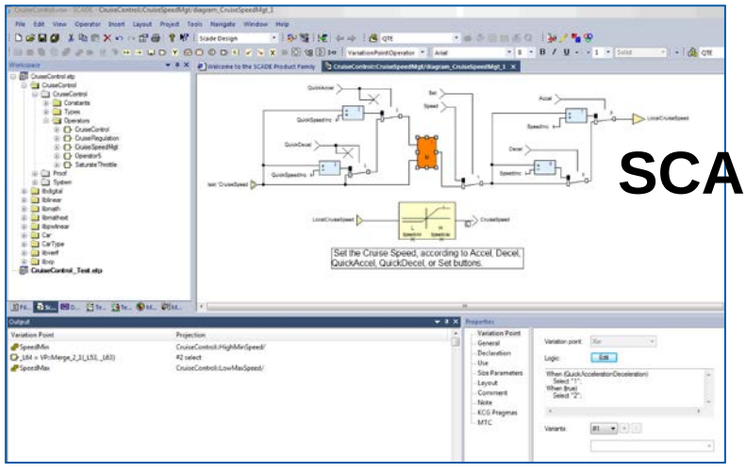
PLE and Model-Based Engineering



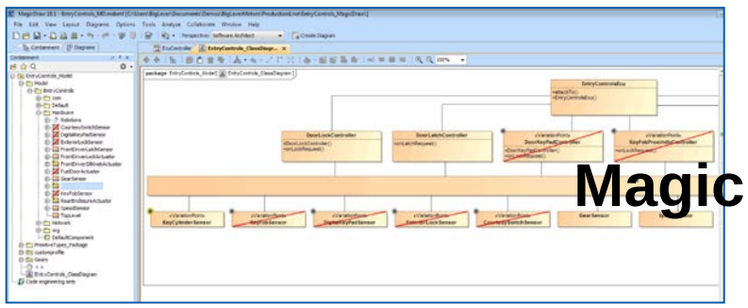
Rhapsody



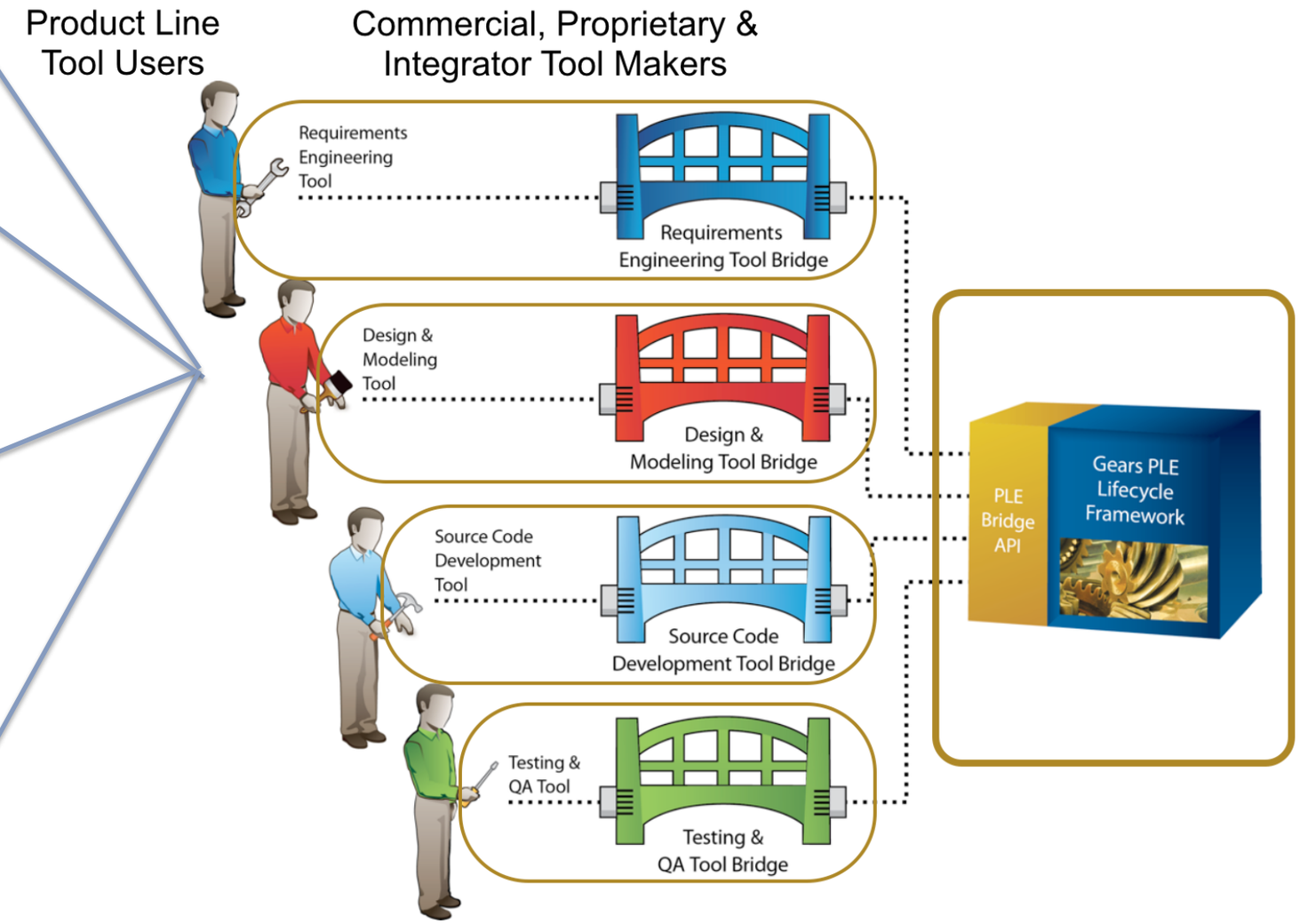
Enterprise Architect



SCADE



MagicDraw



Under this paradigm, design models can be included as shared assets using your favorite design tool.

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PLE and Agile

- Lockheed Martin is combining Agile and PLE on AEGIS
  - So far the results are overwhelmingly positive
- Each project inside the PLE factory can be run with Agile
  - PLE's regular build and release cycles become Agile sprints
  - Large PLE teams are decomposed into small Scrum teams
  - PLE projects are decomposed into epics, features, user stories, and tasks
  - Coordination of the many teams and tasks is handled with Scaled Agile Framework
  - Conflicts can be adjudicated by the PLE governance structures already in place
- Agile optimizes performance of PLE teams

Gregg, S., Scharadin, R., Clements, P. "The Best of Both Worlds: Agile Development Meets Product Line Engineering at Lockheed Martin," 26th Annual INCOSE International Symposium (IS2016), Edinburgh, July 18-21, 2016.

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INCOSE PRODUCT LINE ENGINEERING INTERNATIONAL WORKING GROUP

Organization & Activities

March/2016

Organization

Steering Committee

Chair/co-chairs: Hugo Guillermo Chalé Góngora (ALSTOM) / Charlie Krueger (Big Lever - INCOSE Central) /
Alain Le Put (AFIS WG)

Work products: Bob Malone (Boeing)

ISO committee rep.: Charlie Krueger (BigLever)

Outreach: Paul Clements (BigLever)

INCOSE Liaison: Matthew Hause-Trasnport/MBSE (PTC), Bill Bolander-Automotive (IBM), Jean-Claude Roussel-Requirements (Airbus), Anil Prasad-Healthcare (Medtronic plc), Tool interoperability - TBD, Guillermo/Raul Mazo (UP1)-Agile S&SE-, Guillermo-Patterns

Events: TBD

Webinars: Suresh Tirumalai (GE Oil&Gas), Konstantinos Vilaetis (NY AirBrake)

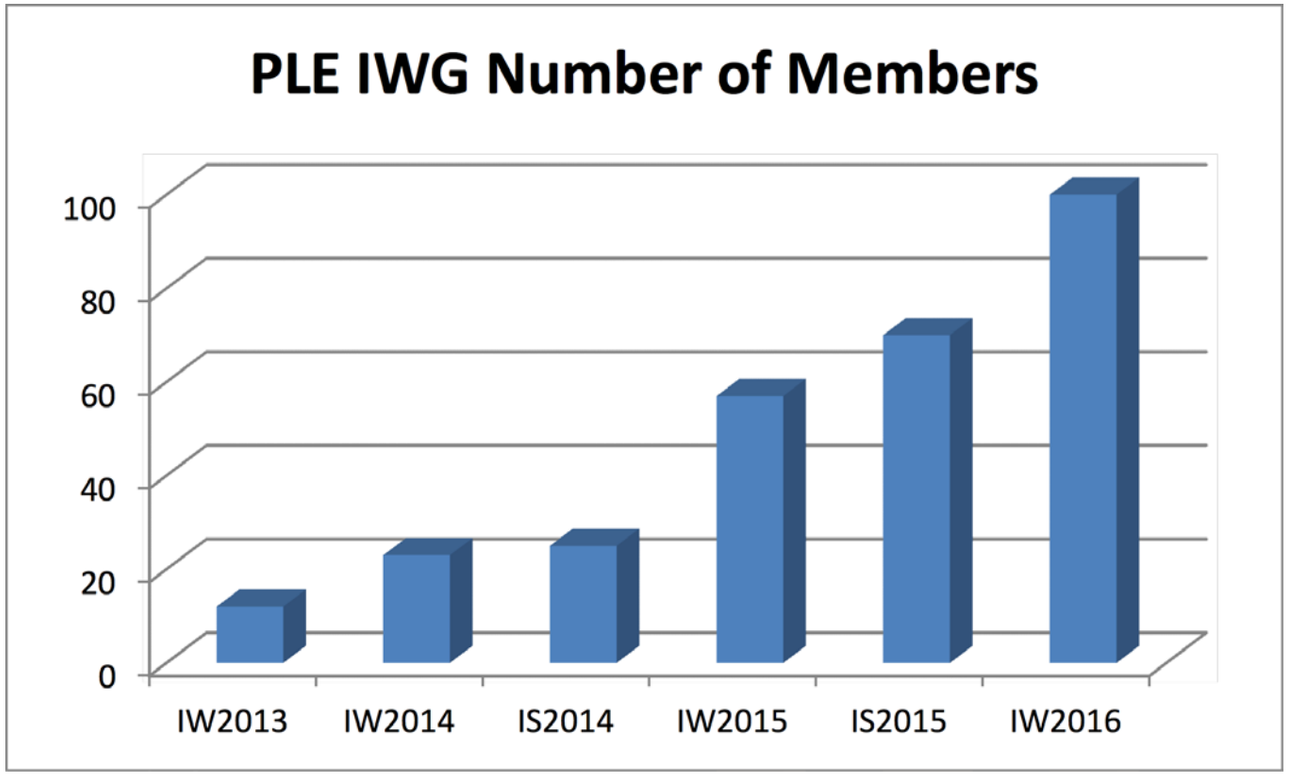
IT & Services: Barclay Brown (IBM), Karen Smiley (ABB Group)

PLE IWG Charter

- Purpose
  - To promote PLE and related SE best practices
    - **Coordinate activities** around PLE at INCOSE-international level and **make results available** for INCOSE members
- Goals
  - Help members acquire Know-How
    - Compare to the State-of-Art
    - Share concerns, experiences, good practices and traps to avoid
  - Provide guidelines to setup and evolve PLE in organizations
- Scope
  - All types of Systems, Markets & Organizations
  - All SE Processes (needs, requirements, architecture, integration and tests …)
  - All maturity levels of PLE, from opportunistic to fully integrated and anticipated strategies

Membership & IT

- Number of members: steady growth since IW2013



- IT services
  - Public web page published!
    http://www.incose.org/ChaptersGroups/WorkingGroups/industry/product-lines
  - INCOS Connect page and e-mail reflector: work in progress

Recent Activities

- **IS2015** PLE program
  - PLE IWG working meeting
  - Product Lines paper session
    - “Product Line Engineering Comes to the Industrial Mainstream”
    - “Model-based Product Line Engineering - Enabling Product Families with Variants”
    - “Multi-Level Product Platform Strategy for a Multi-Level Corporation”

Recent Activities

- Software Product Line Conference (SPLC) 2015
  - Included a SE track for the first time, plus a panel on PLE for large scale systems
  - Renamed to *Systems and SW Product Line Conference*
  - Communication path open (cooperation actions TBD)
  - 6 new members joined the PLE IWG

Recent Activities

- AFIS (Association Française d'Ingénierie Système) EMEA (Europe, Middle East, Africa) Workshop
  - Over 65 participants in the PLE interactive panel
  - Goal: To identify PLE topics to be covered
    - By the INCOSE PLE IWG or by local Chapters and WGs
  - Contributions
    - THALES, PTC, pure::variants & Bombardier
  - Main themes addressed
    - Challenges for implementing PLE
    - Strategies for the adoption of PLE
    - Cultural gaps, specialty domains…

Work Products

OTHER TOPICS / Work Products
Success stories, REX
Reference model/glossary (ontology) of PLE
Model-Based Product Line Systems Engineering
Tool interoperability
Product Line "Mission and Business Analysis"
Product Line Lifecycles
V&V artifacts reuse
"System Thinking" approach for Product Lines
Change & Configuration Management for PL
Building product lines from legacy assets
Standard/modular/configurable interfaces & Composable architectures
PLE standard proposal - ISO committee (to be detailed)
Inhibitors for PLE
PLE competency & training
Guidelines for an Effective implementation of PLE – PLE in practice
PLM and PLE
Innovation and reuse in PLE
Incremental design in product lines
Contribution to the SEBoK
Model Based Patterns

INCOSE
International Council on Systems Engineering

Work products planning
2016-2017

- PLE Lifecycle definition (basis for recommended guidance and ISO standard)
  - Lead-Charlie, Contributors-Len, Guillermo, Danilo (?), Eileen (TBC)
- Organizational and cultural change for PLE
  - Inhibitors, success stories & best practices
  - Lead-Len, Contributors-Harry, Charlie (inputs), Konstantinos (inputs), Guillermo (inputs)
- Configurable interfaces and *composable* architecture
  - Lead-Karen, Contributors-Len, Jonathan, Guillermo, AFIS MBSE WG

→ Inputs from AFIS MBSE WG

26th annual INCOSE international symposium

Edinburgh, UK

July 18 - 21, 2016

- PLE program
  - Welcome and Networking hour reception: Sunday or Monday evening
  - **PLE Panel / "knowledge café"**
  - PLE Paper session and PLE-related papers
  - PLE Working meeting
  - Working Group dinner

INCOSE International Council on Systems Engineering

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Product Line Engineering

Things to Think About

How can this be applied in your work environment?

What did you hear that will influence your thinking?

What is your take away from this presentation?

Please

The link for the online survey for this meeting is

www.surveymonkey.com/r/enchant_05_11_16

www.surveymonkey.com/r/enchant_05_11_16

Look in GlobalMeet chat box for cut & paste link.

Slide presentation can be downloaded now/anytime from:

The library page at: www.incose.org/enchantment

Recording will be there library tomorrow.