Consolidate.

Simplify.

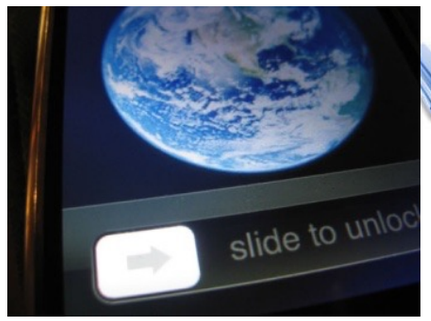
Leverage.

Product Line Engineering Comes to the Industrial Mainstream

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

To be competitive, most product development organizations deliver a product line –

a portfolio of similar products or systems with variations in features and functions

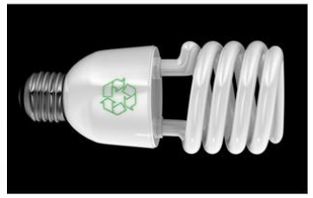








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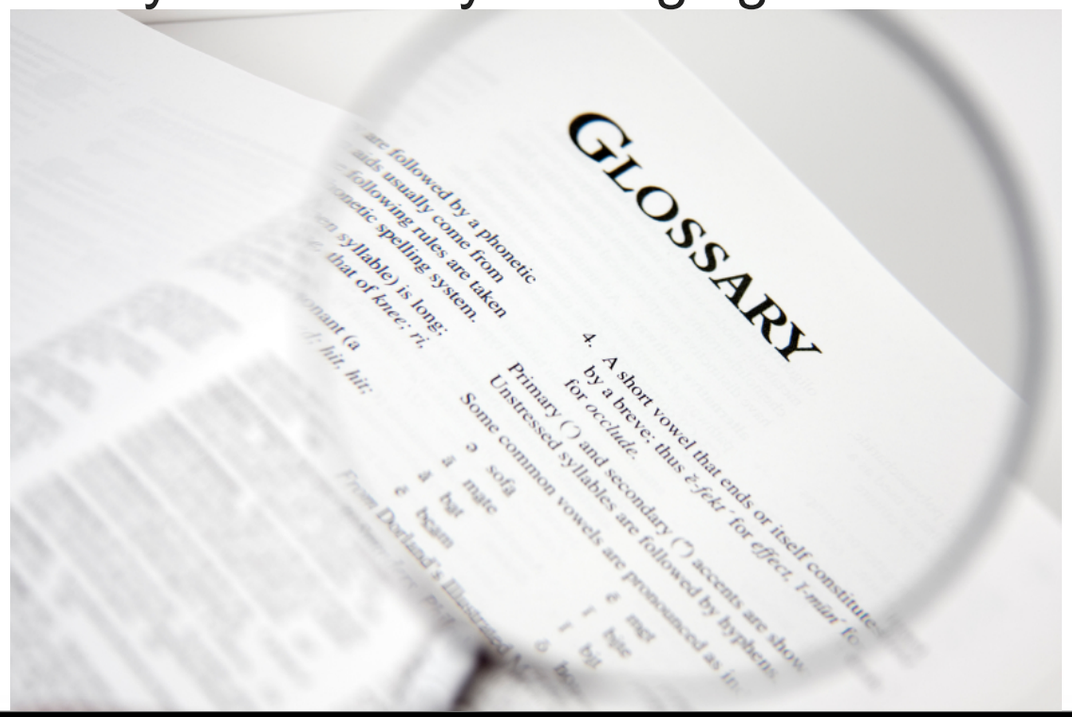
Product Line Engineering (PLE) Defined

- 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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Products

- Products can include any combination of
  - software

  - systems in which software runs

  - non-software systems that have software-representable artifacts (such as engineering models or development plans) associated with them.

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Why is PLE Important?

- PLE is of interest because of remarkable efficiencies it has shown in the development process:
  - Large-scale productivity gains
  - Decreased time to market
  - Increased product quality
  - Decreased product risk
  - Increased market agility and presence
  - Increased customer satisfaction
  - More efficient use of human resources
  - Ability to sustain unprecedented growth

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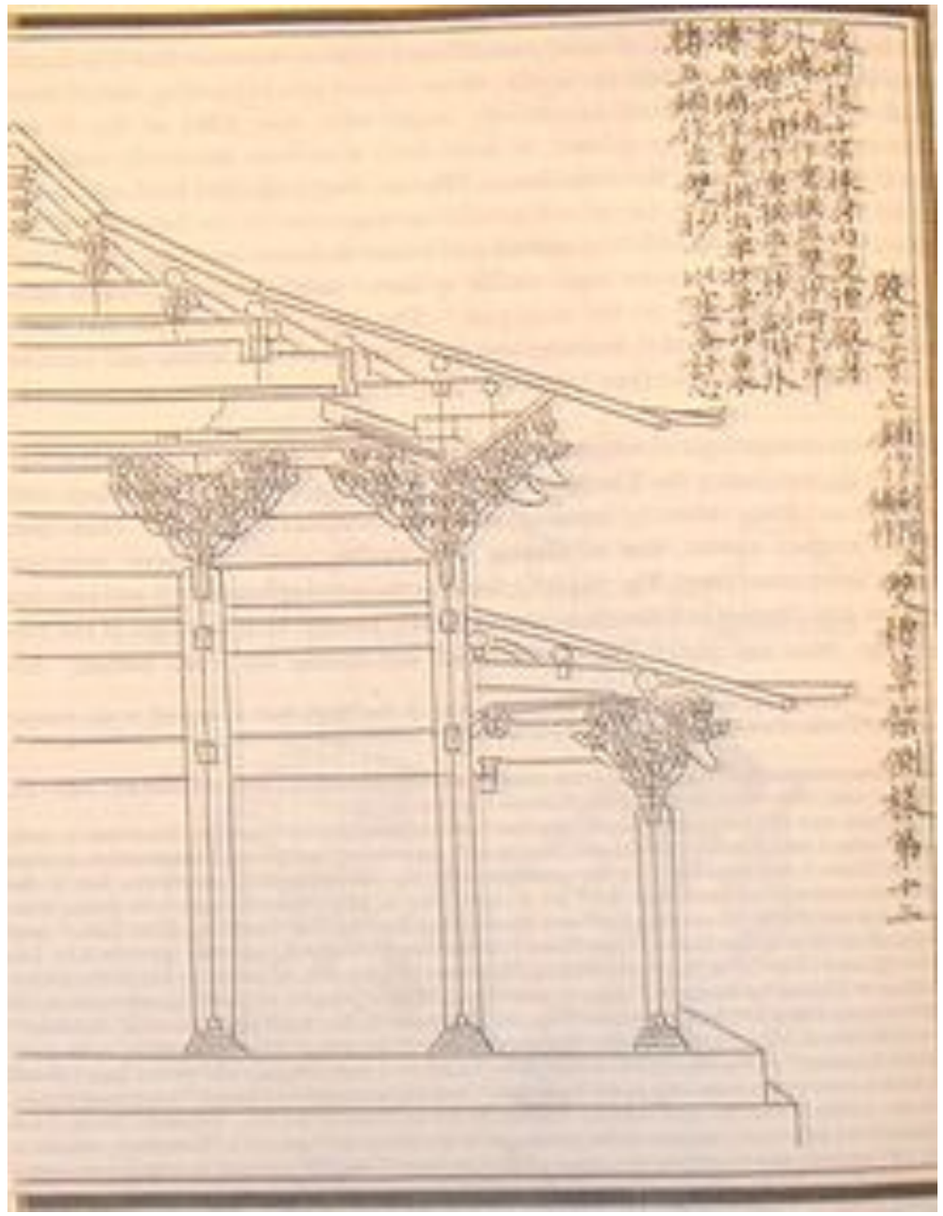
1103 AD: Ying tsao fa shih (營造法式)

- 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.
  - Emphasized 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.

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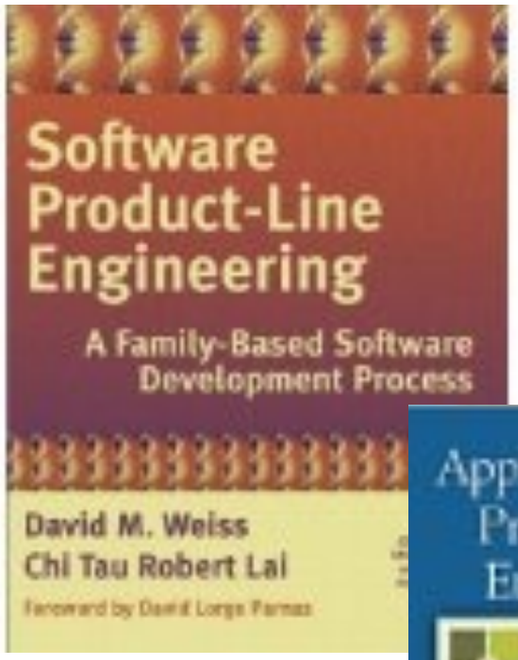
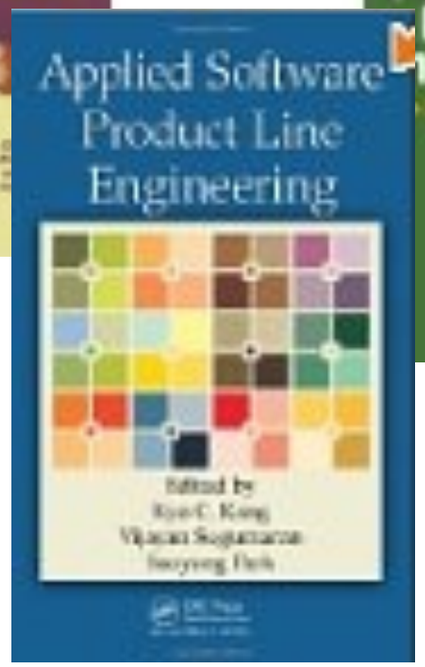
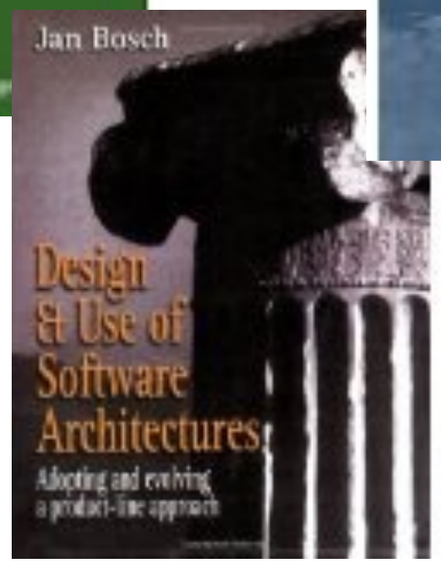
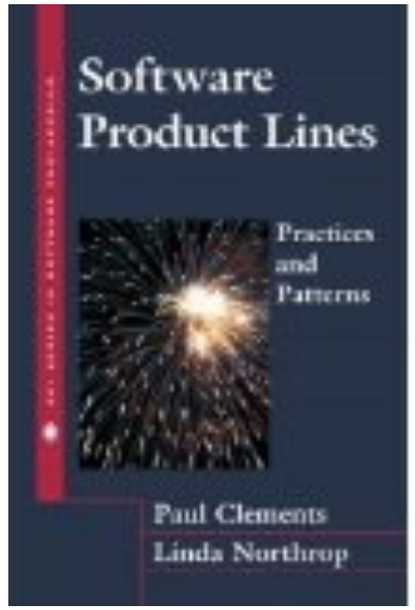
1990s-2000s:
Software Product Line Engineering









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Problems with early approaches

- No clear, prescriptive, repeatable methodology
- Case studies tended to show ad hoc approaches
  - Every one is different
- Emphasis on software is a serious limitation
- Automation is welcomed, but never embraced

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Second Generation PLE

Second generation PLE strongly embraces the *factory* paradigm.

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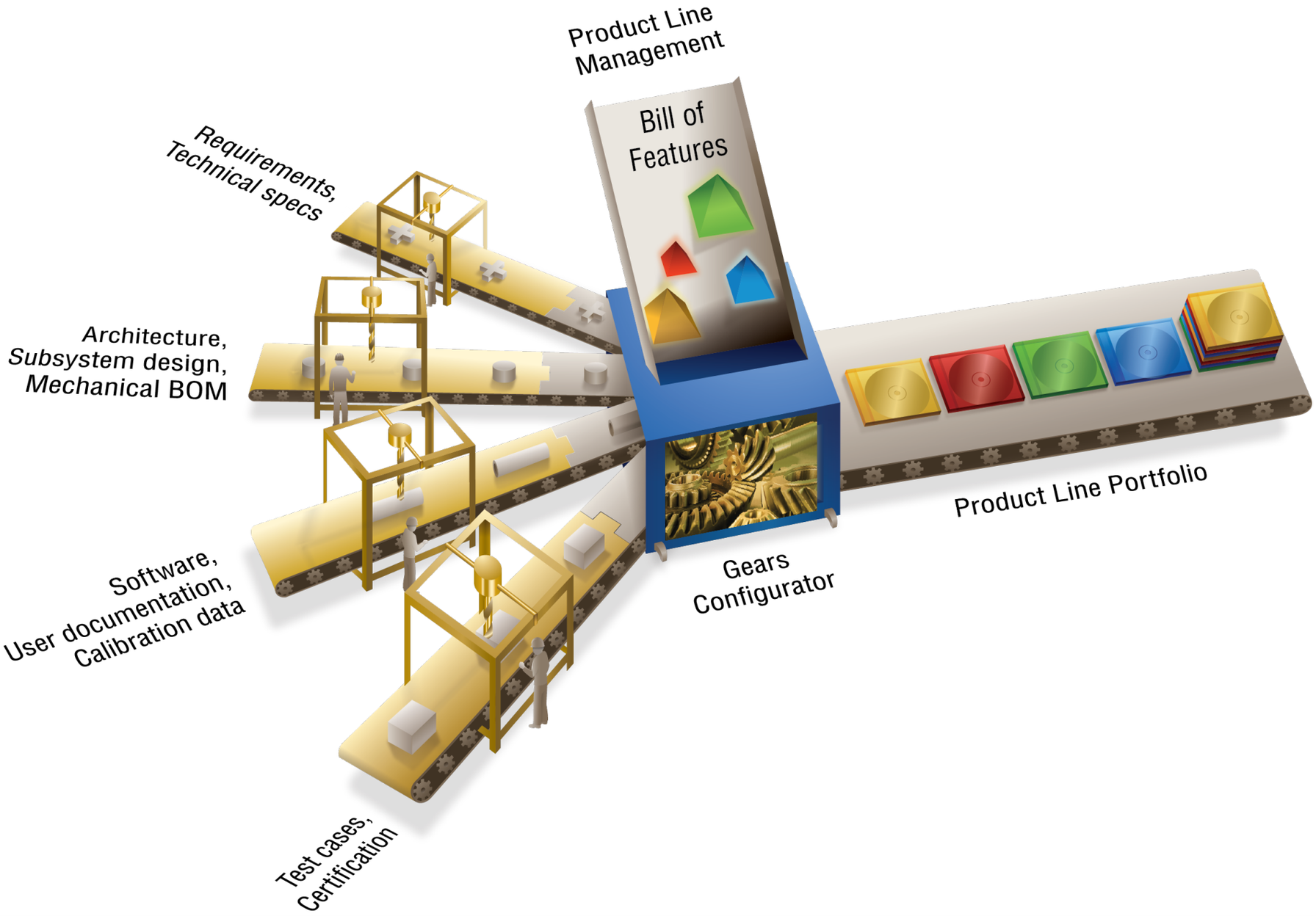
An Efficient Means of Production for Product Lines



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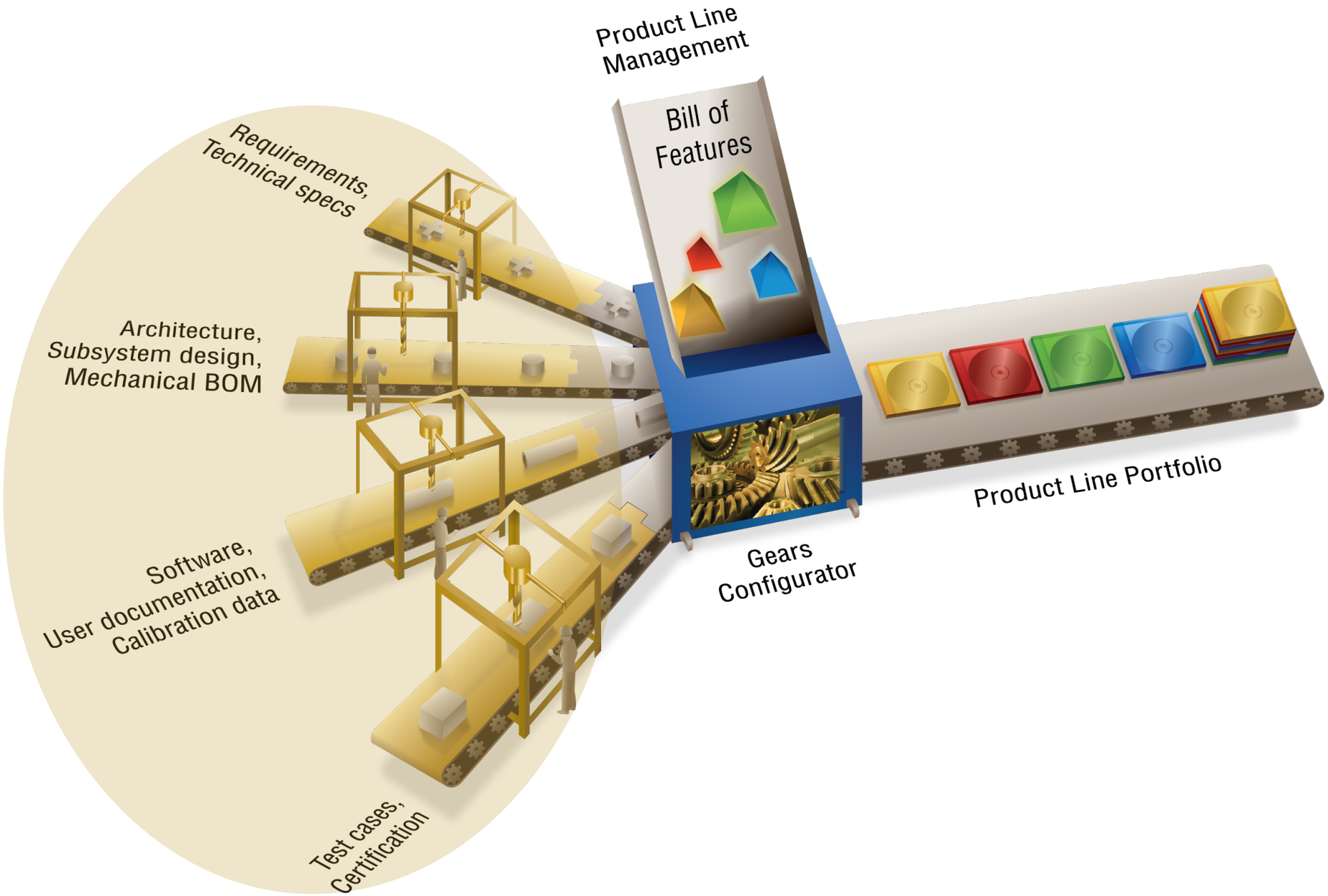
Shared assets are like the factory's supply chain.



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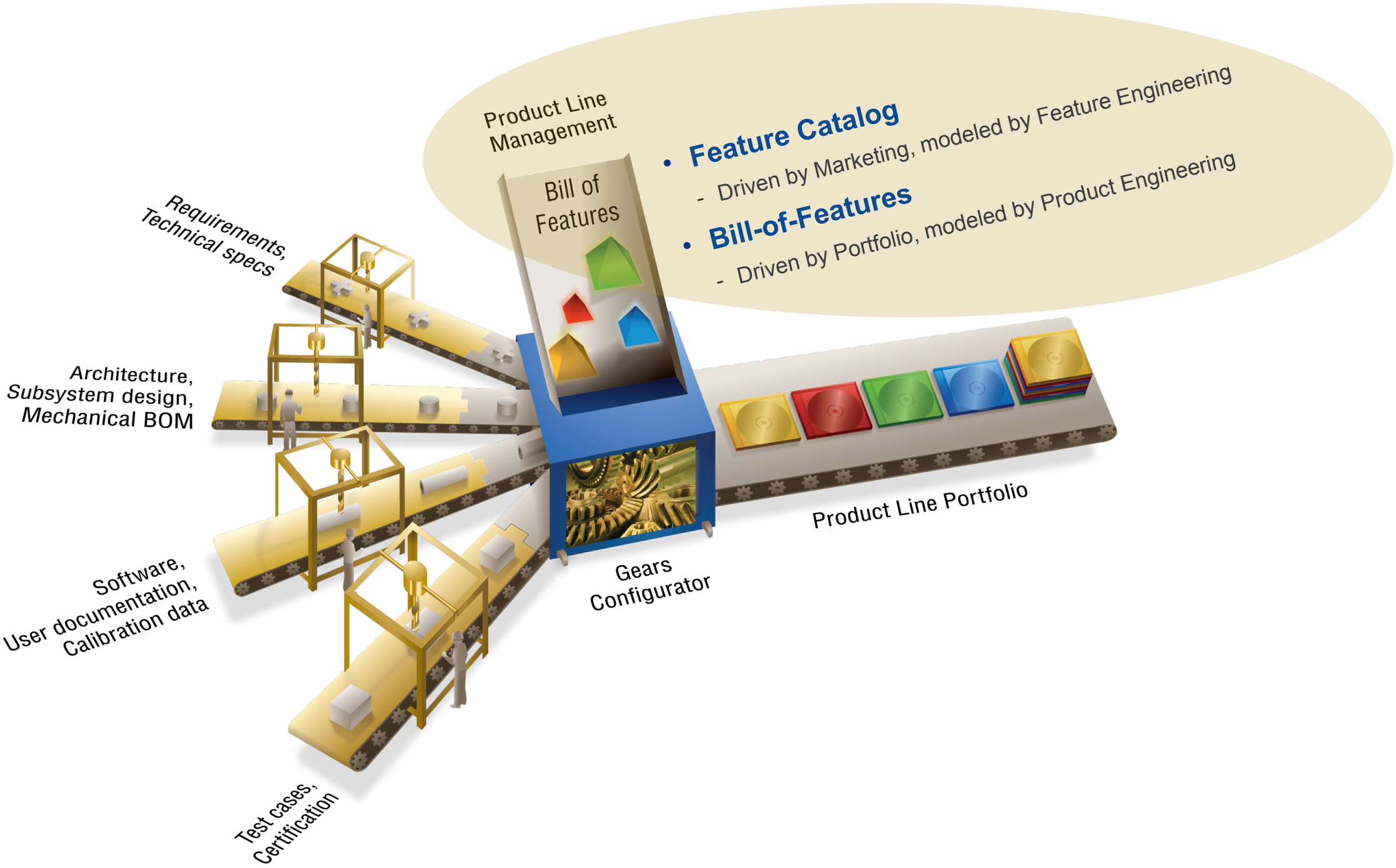
Features describe capabilities that vary among products.



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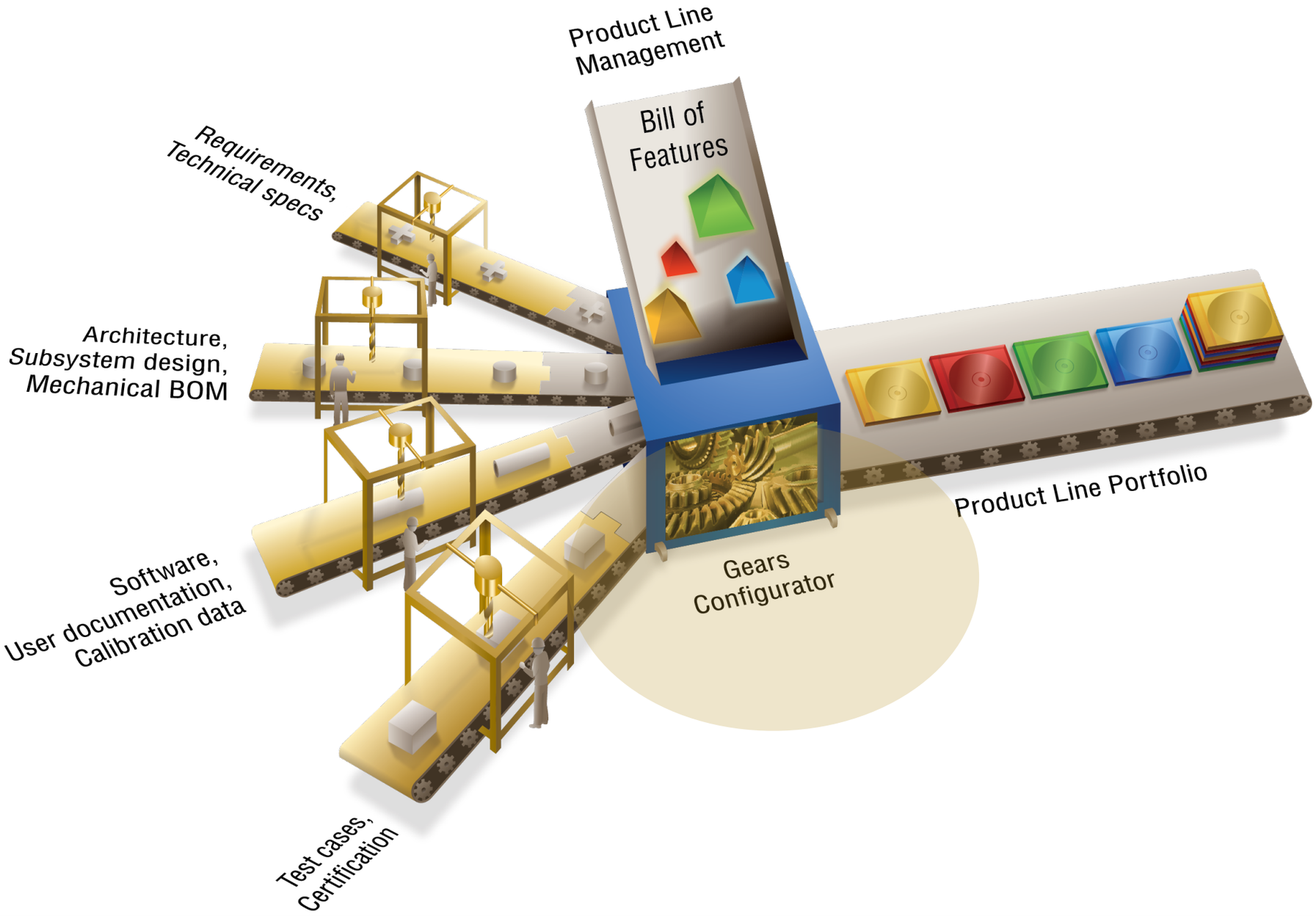
Assets are configured according to the *feature profiles* of the products you want build.



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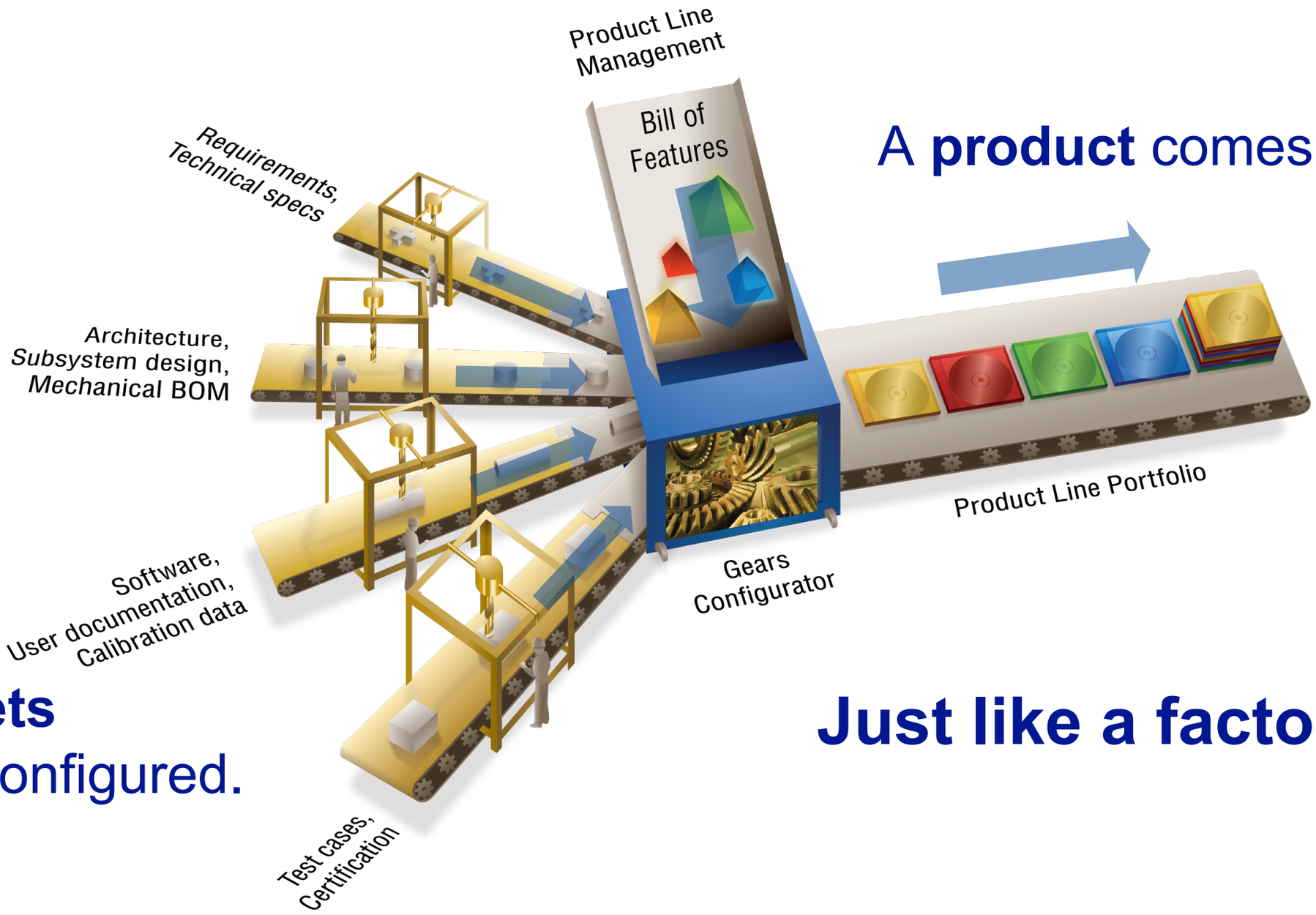
Features come in.



A **product** comes out.

Assets are configured.

Just like a factory.

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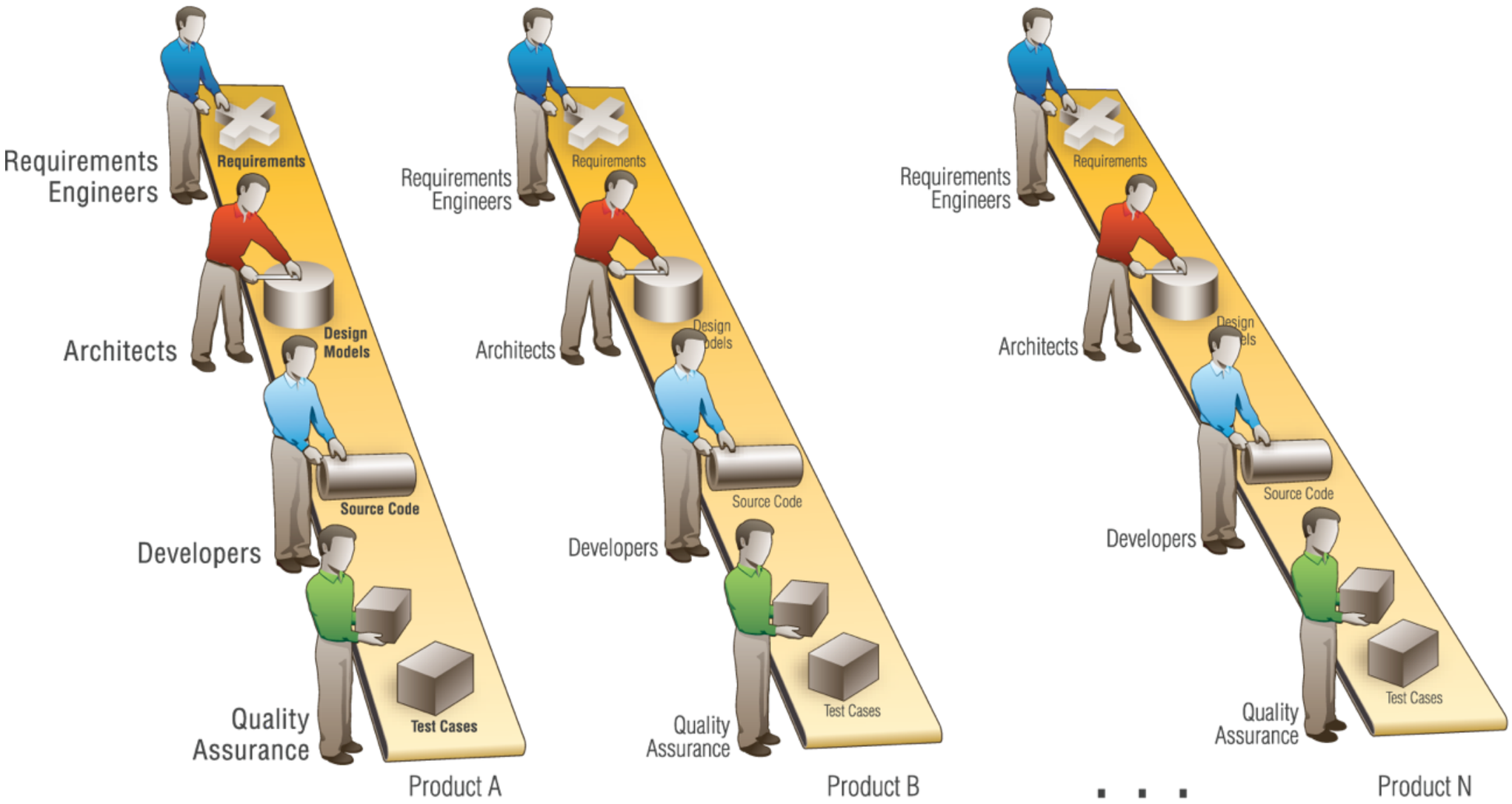
This is a move away from the traditional product-centric development silos.



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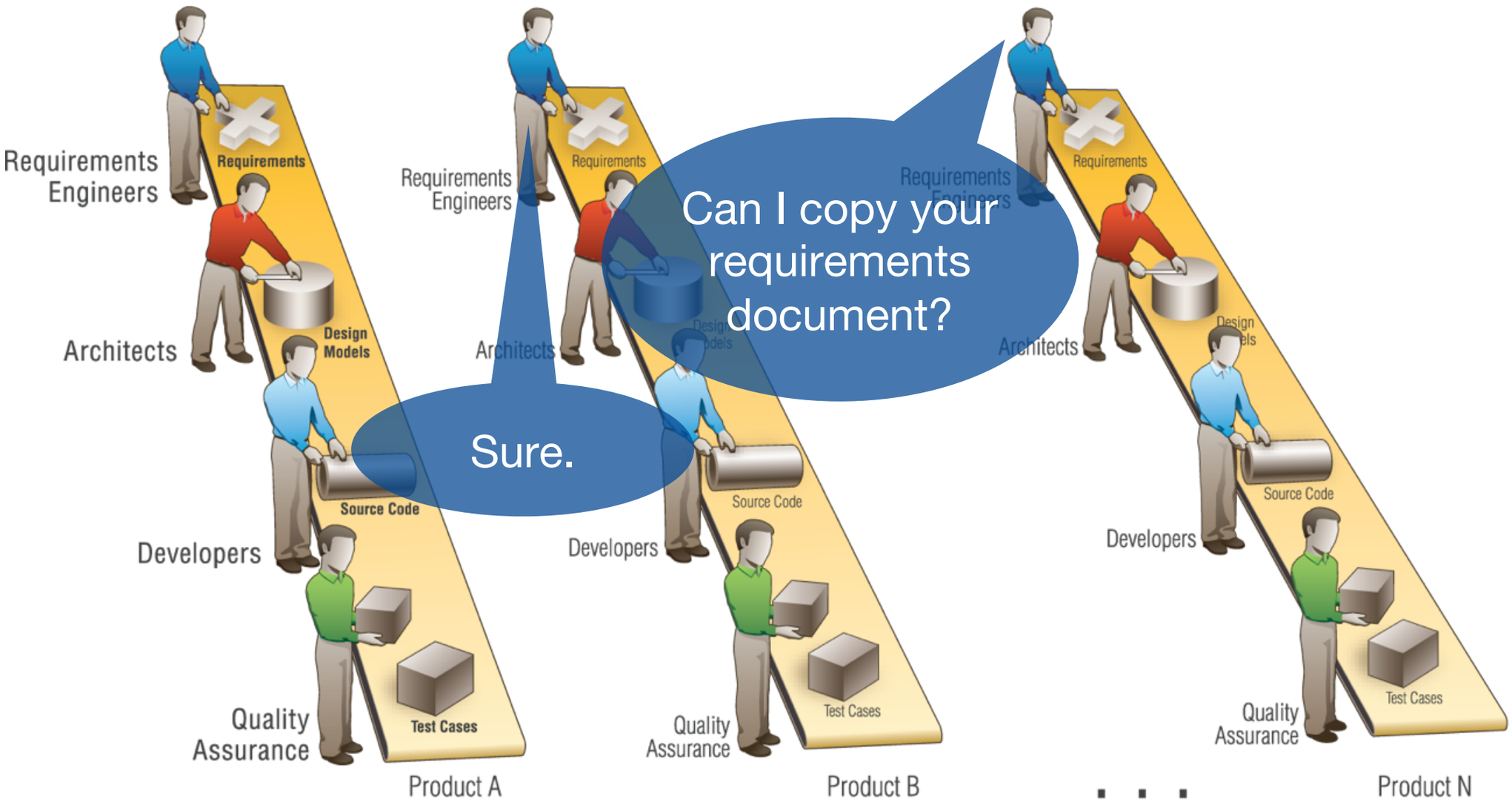
With traditional approaches there may be some reuse among products, but it's usually not systematic.



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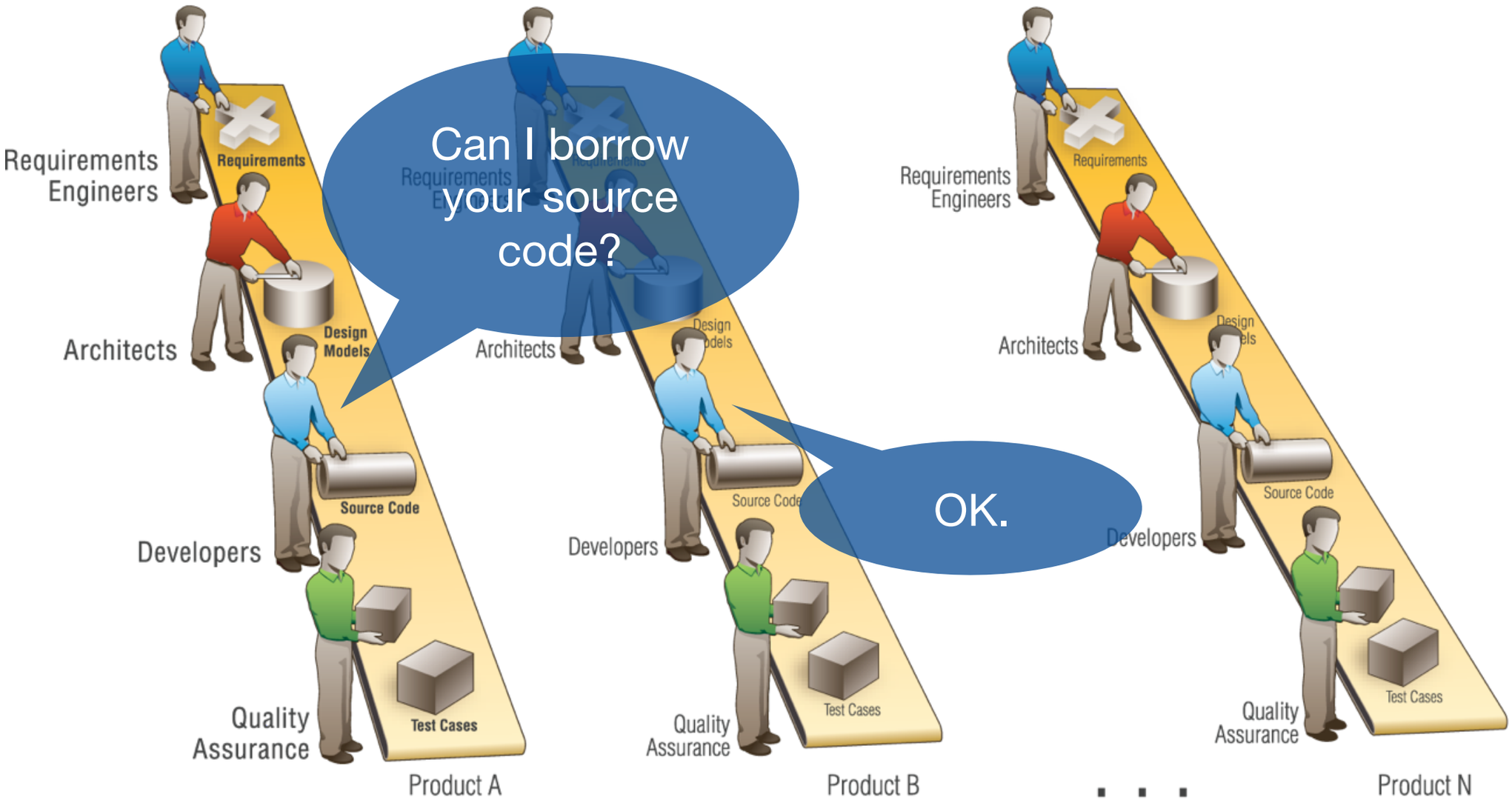

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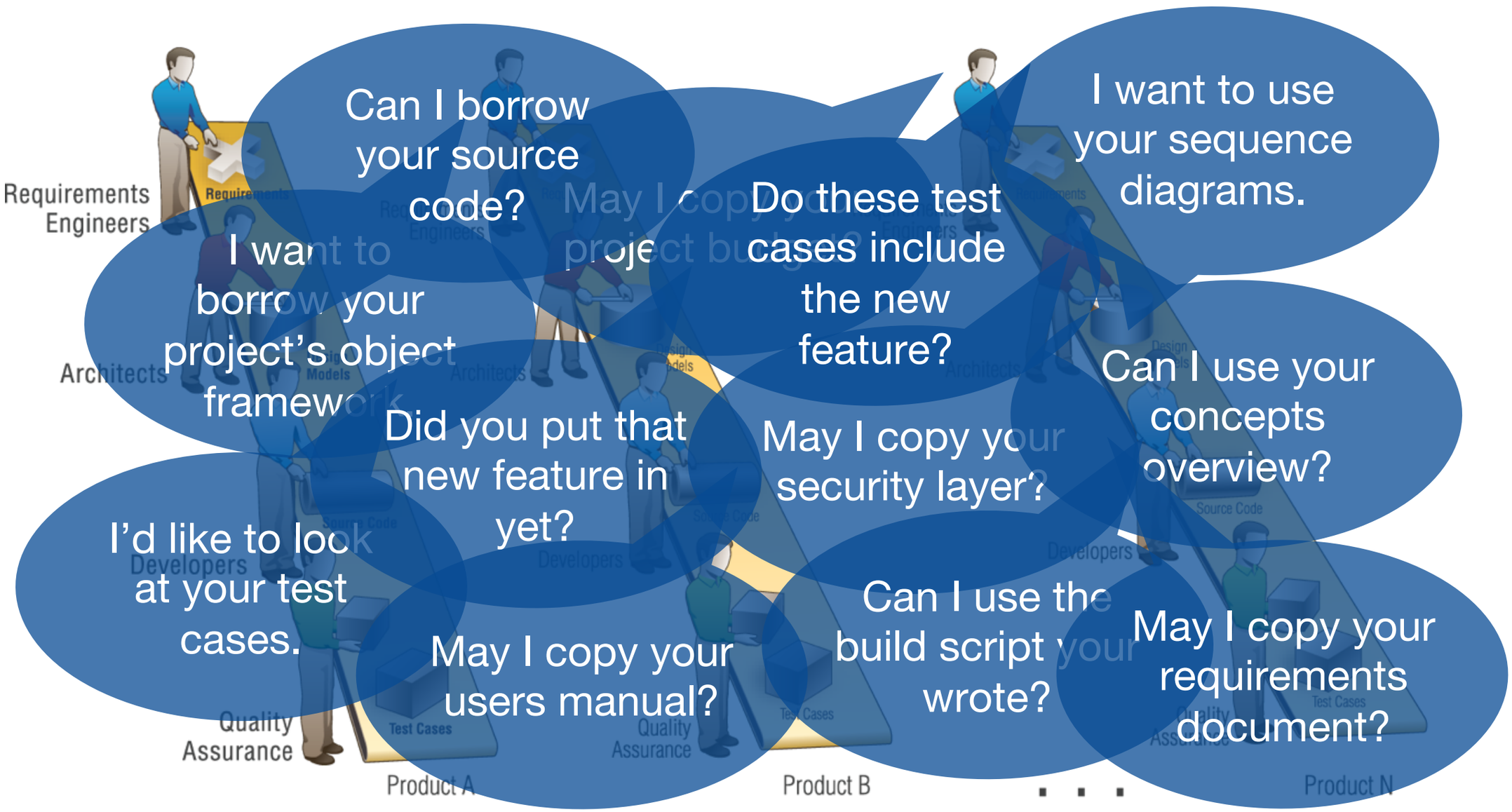
This doesn't scale very well.



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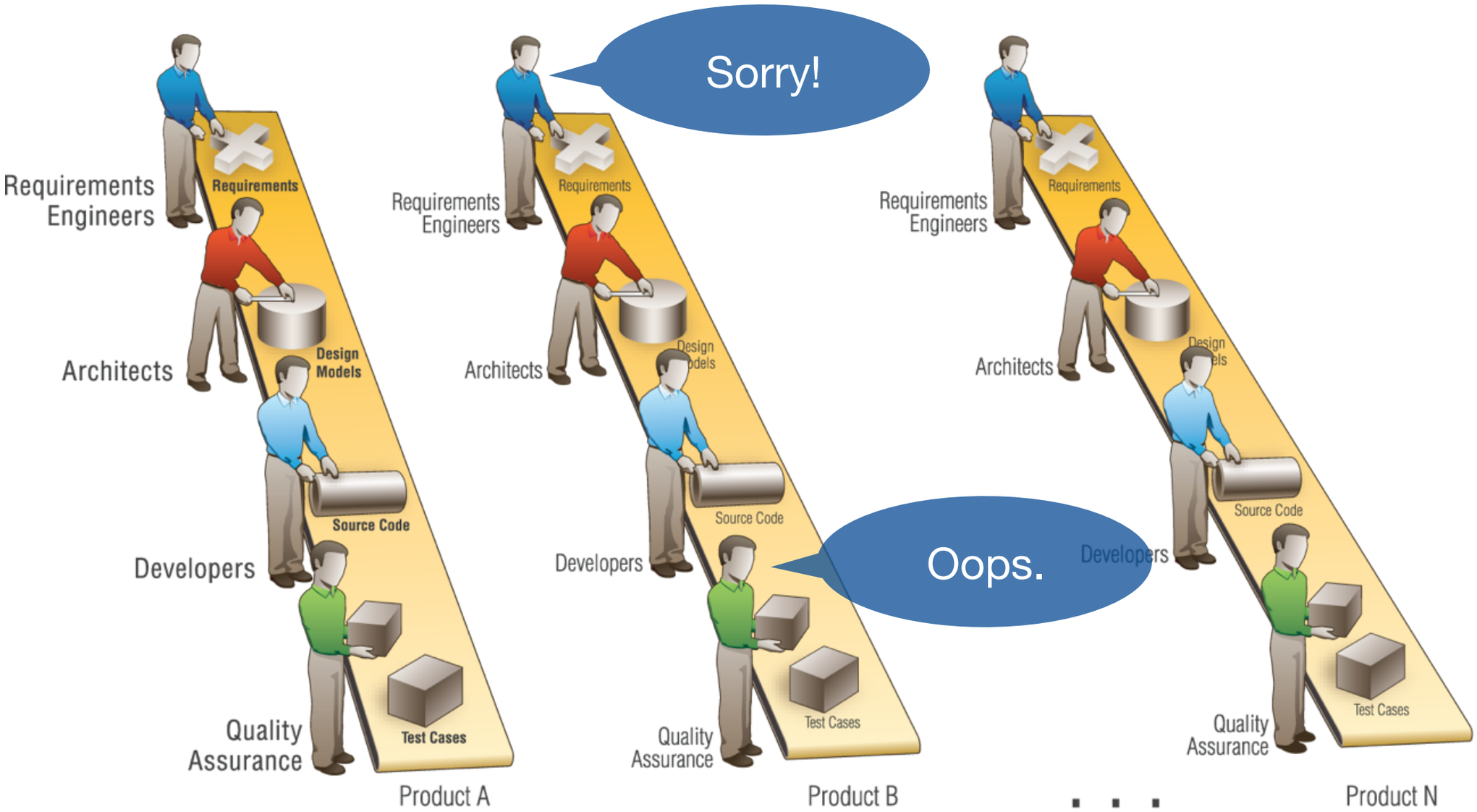
Suppose Product B has a defect.
Suppose it came from Product B's requirements.



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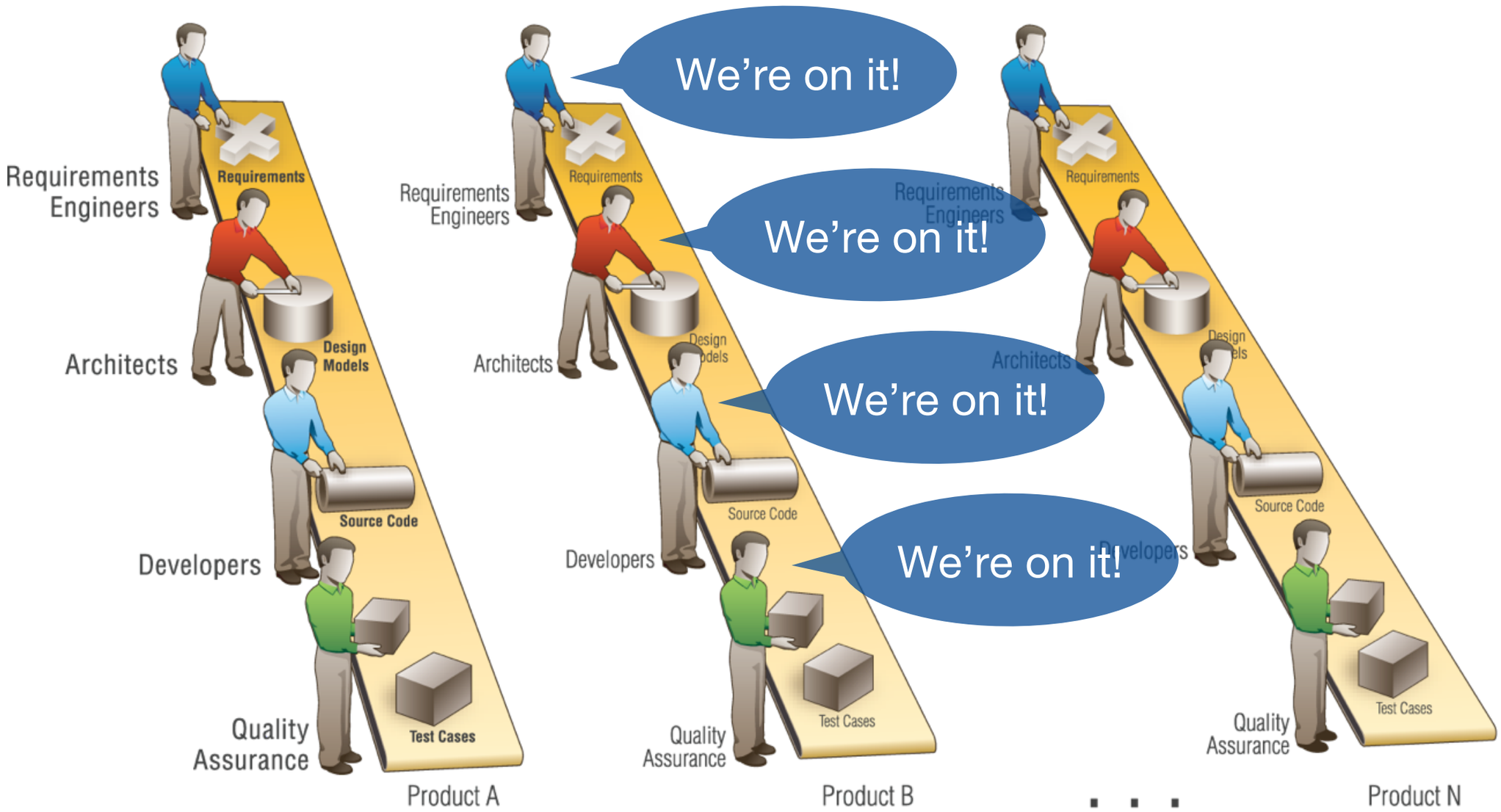
Team B can fix Product B.



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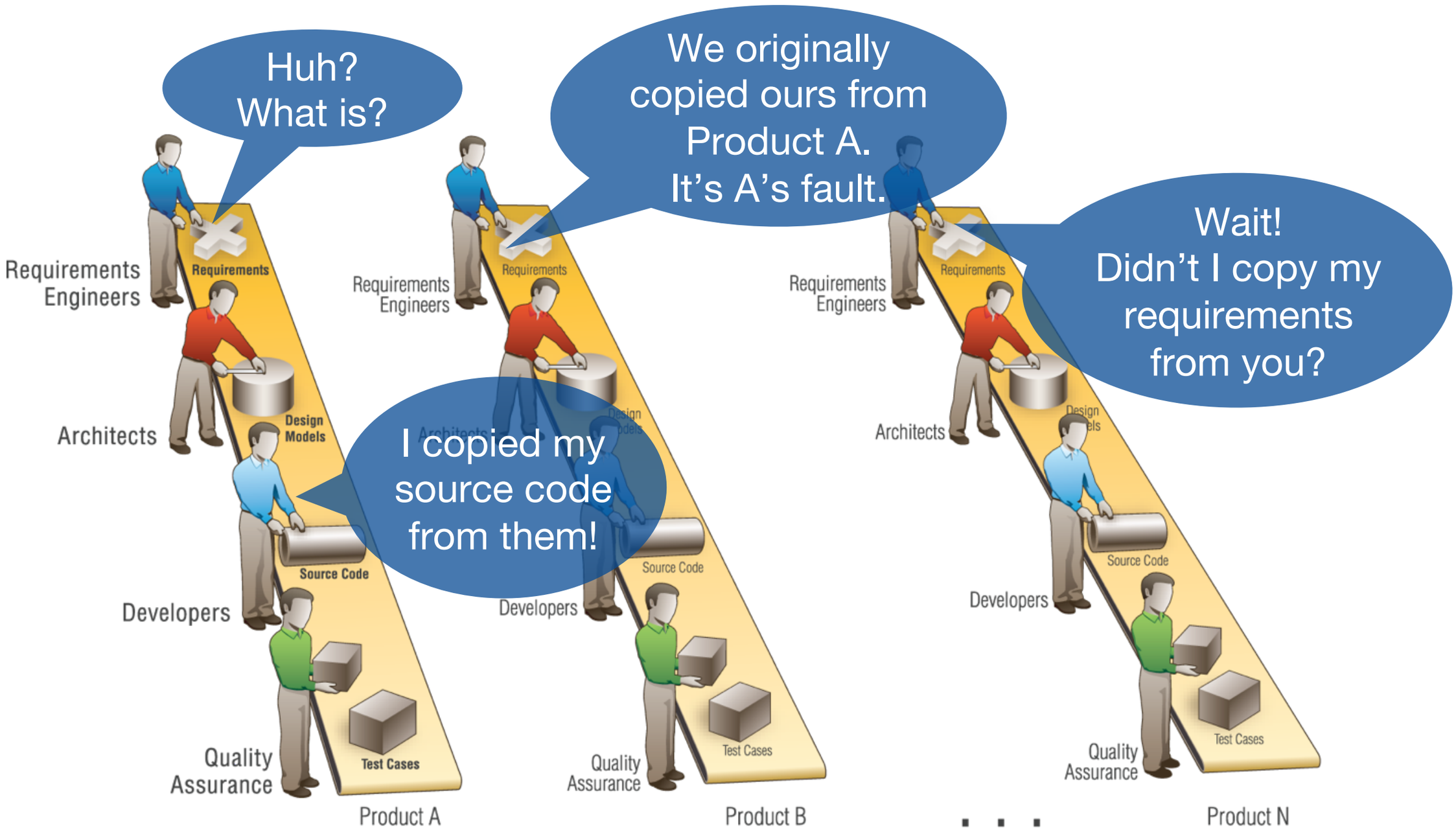
However…



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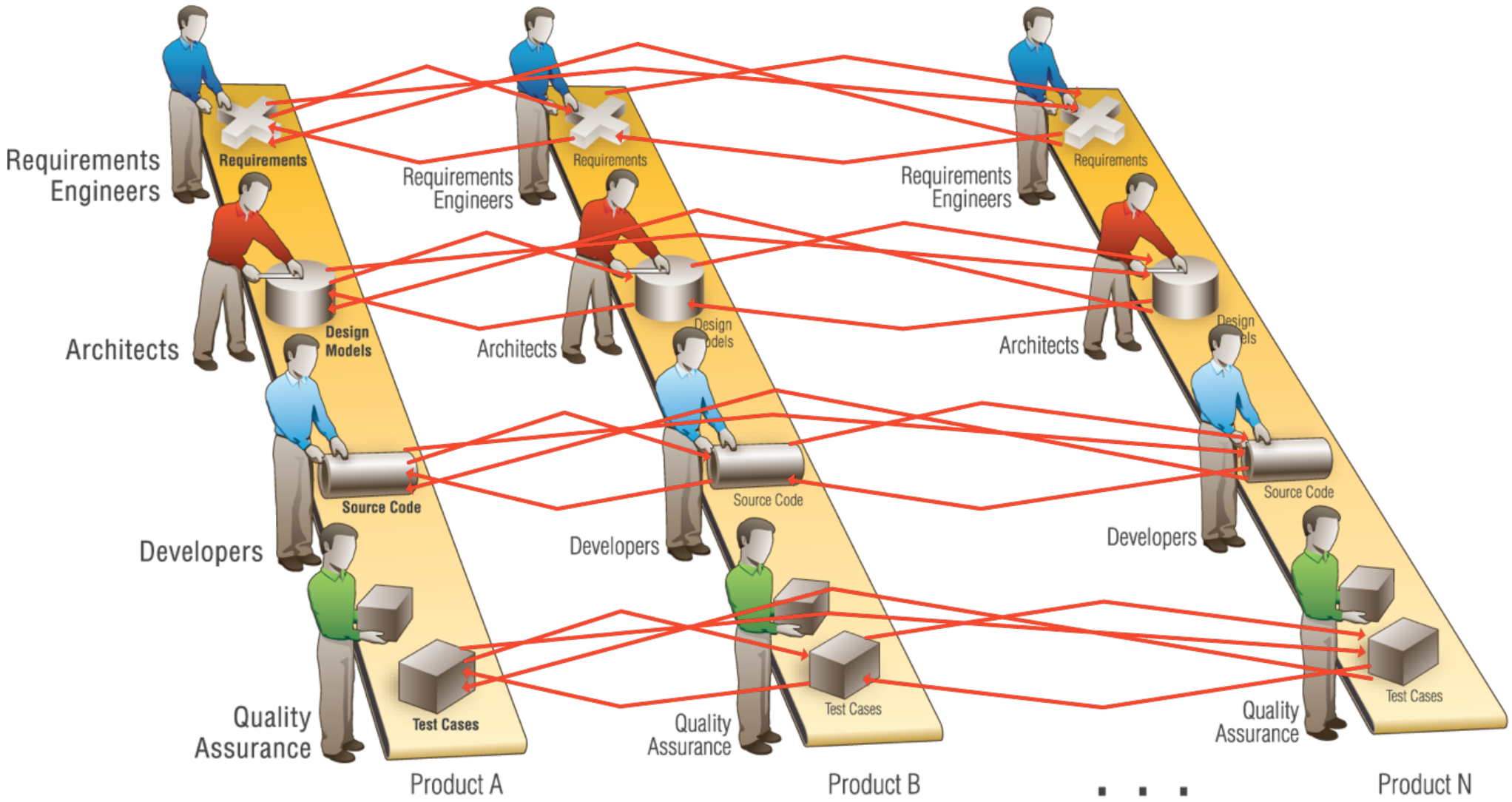
The communication and coordination that has to occur for a portfolio of **N products** is proportional to N^2



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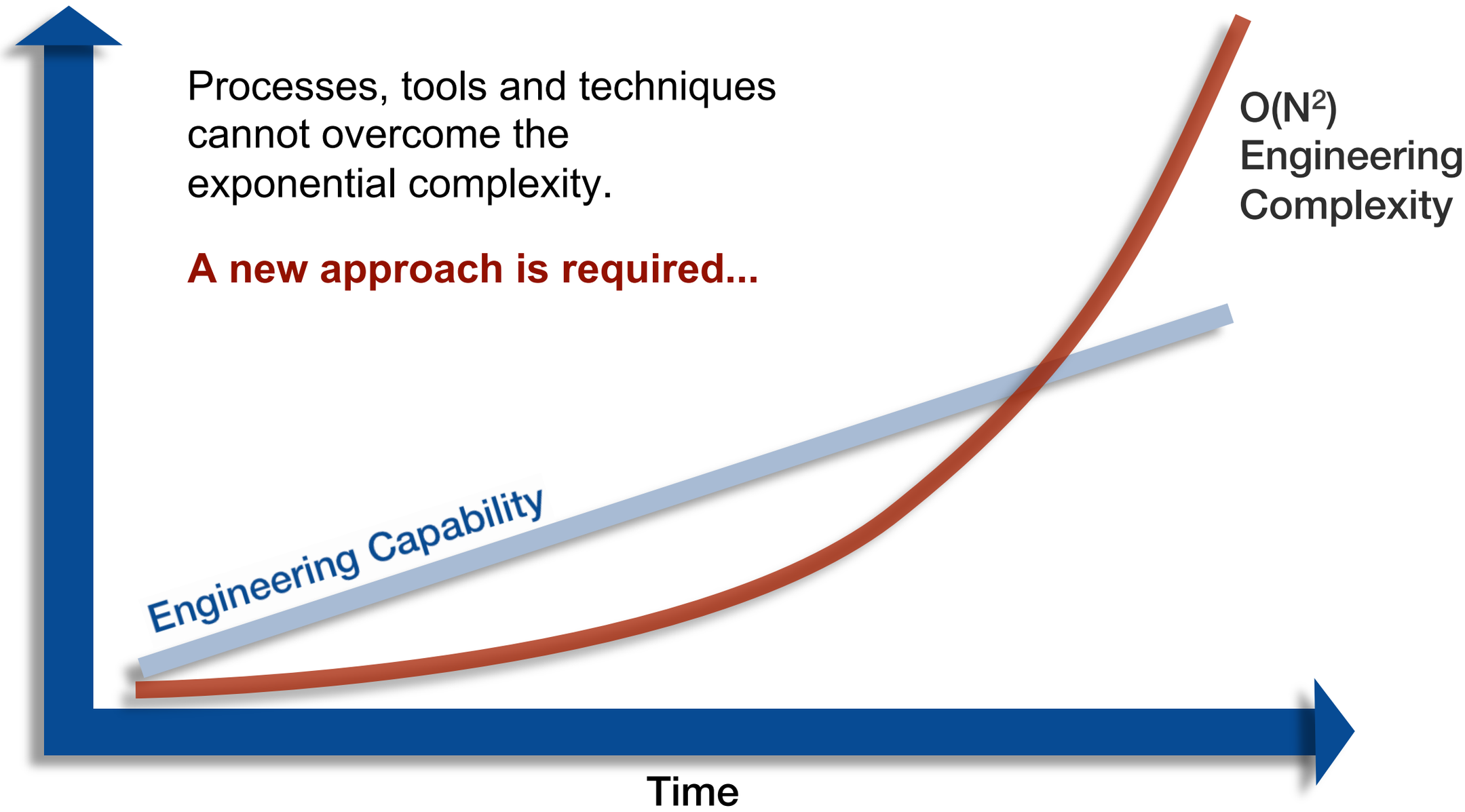
The Challenge of Product Line Engineering: Harnessing Complexity

Processes, tools and techniques cannot overcome the exponential complexity.

A new approach is required...



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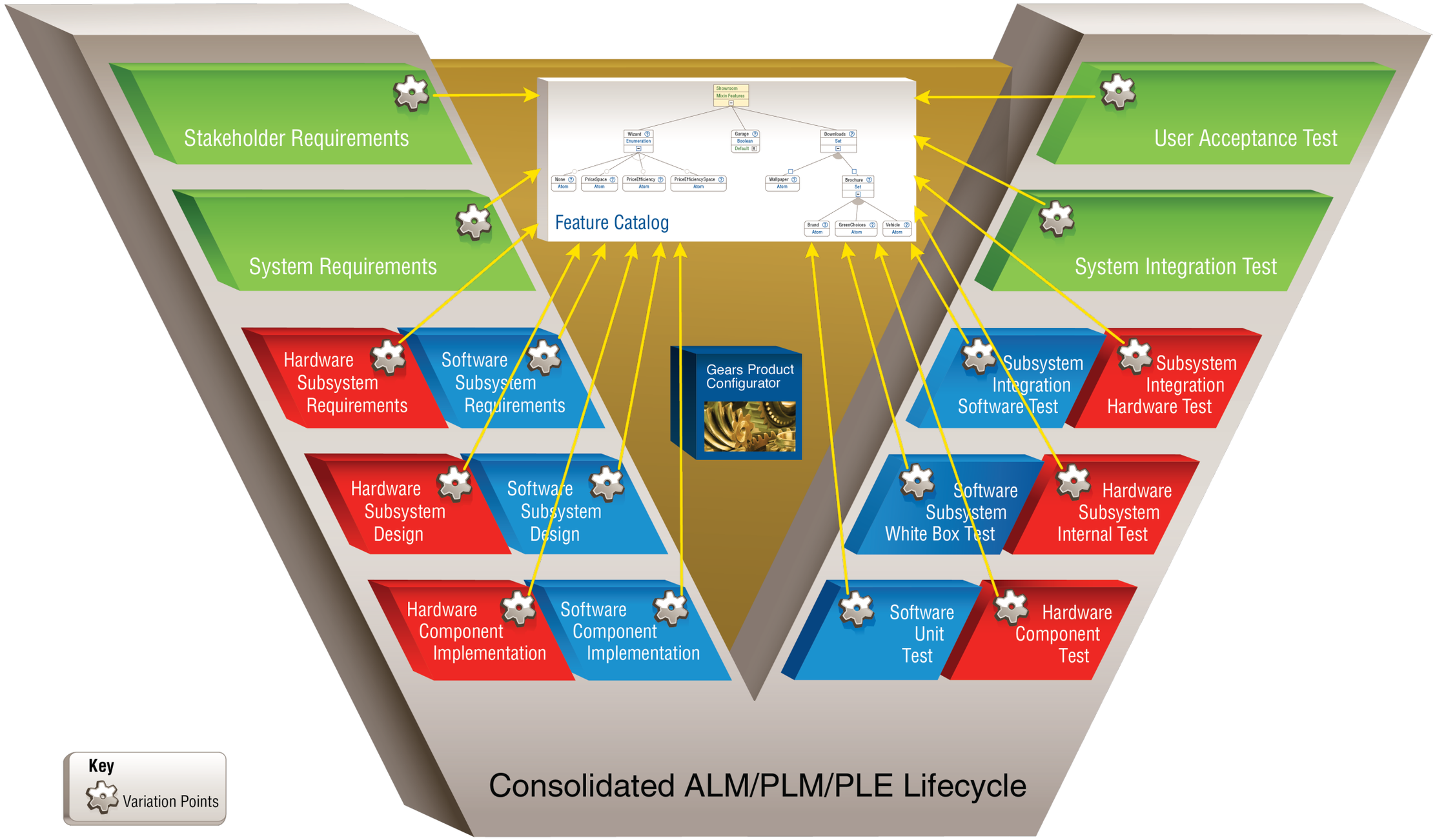
Feature catalog is the single source of feature truth across the entire engineering lifecycle



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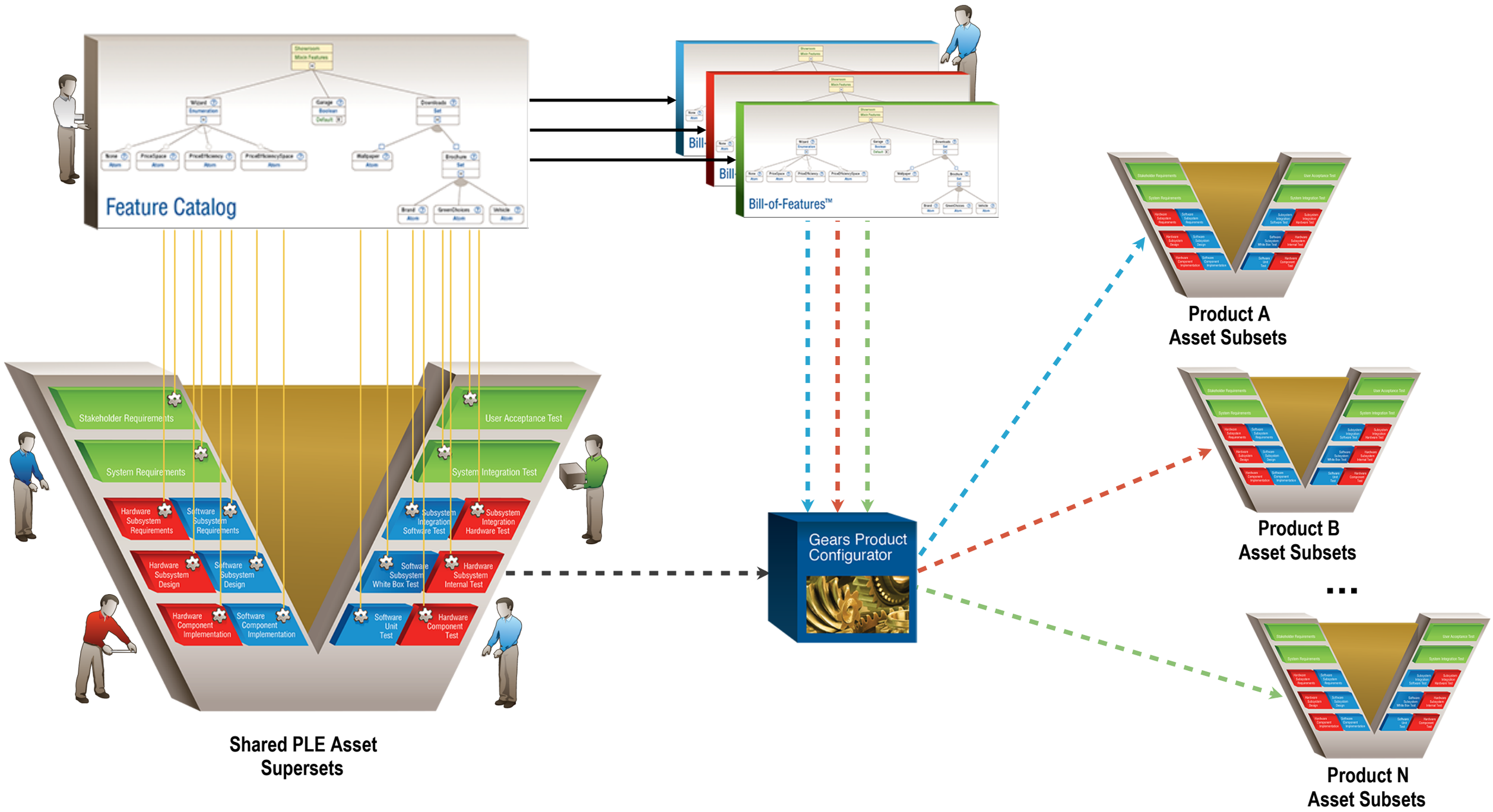
Multi-product Automated Production Line



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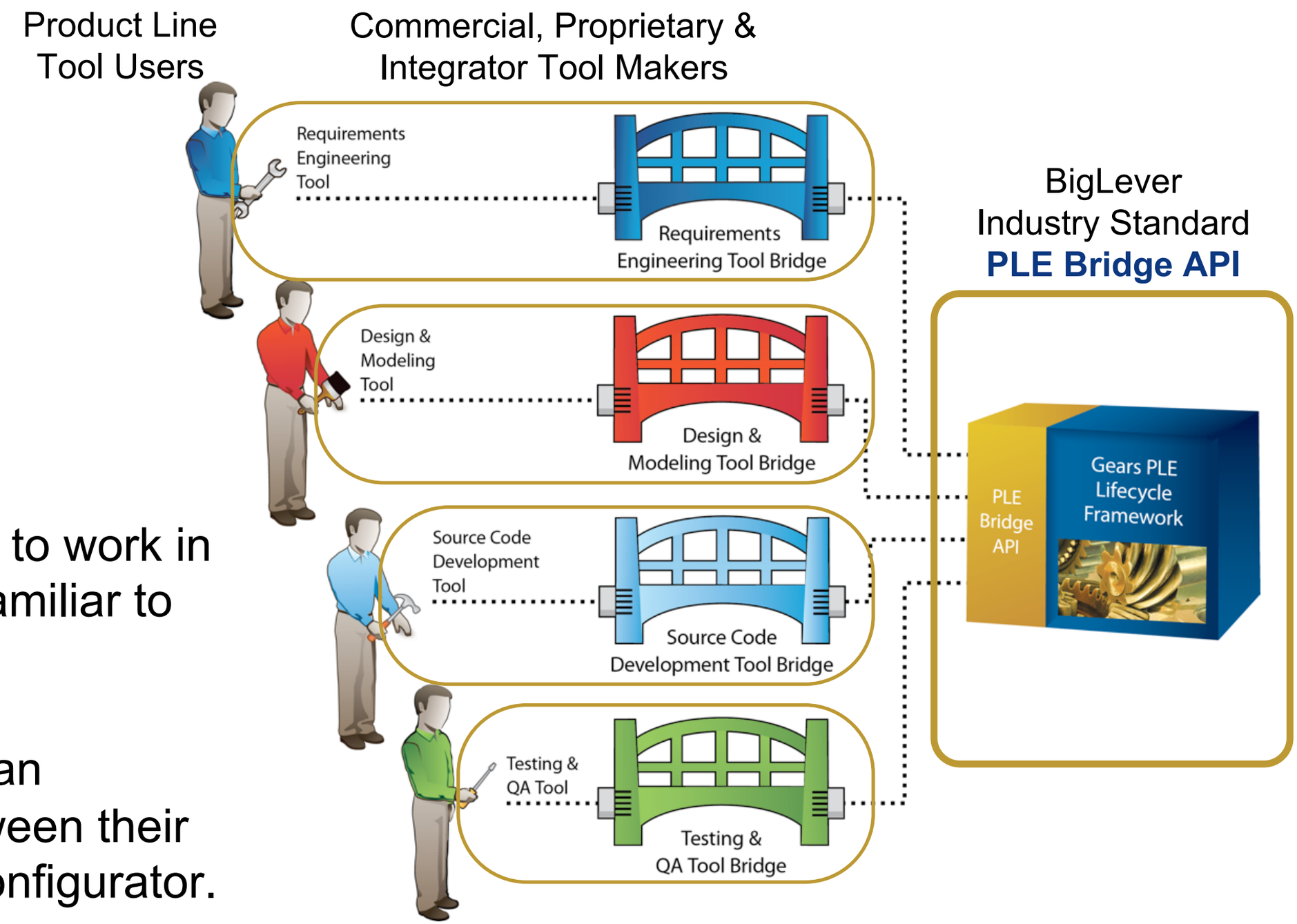
The PLE Ecosystem

Engineers want to work in environments familiar to them.

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



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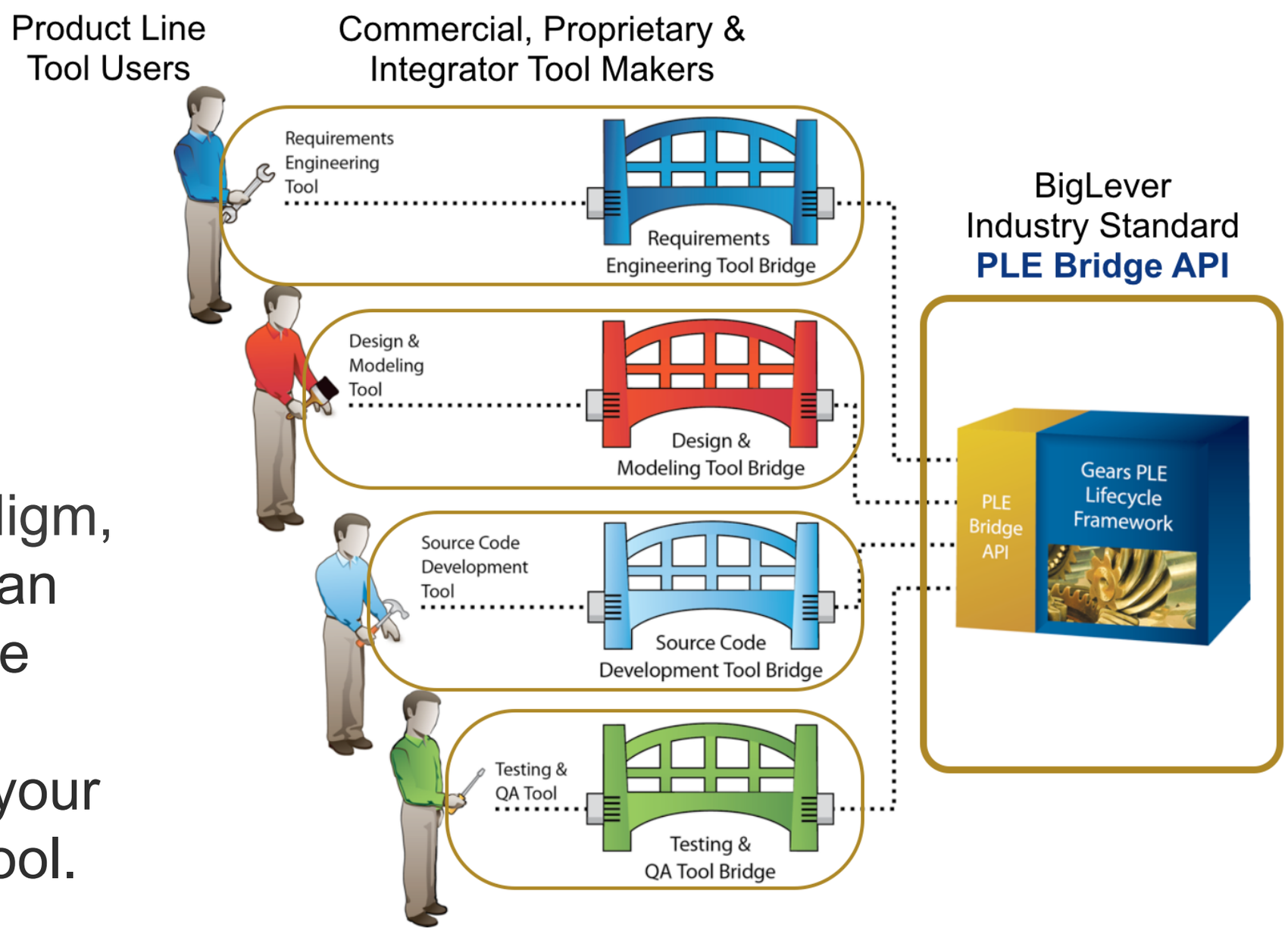
What about Model-based PLE?

- Under this paradigm, design models can be included in the shared asset collection using your favorite design tool.



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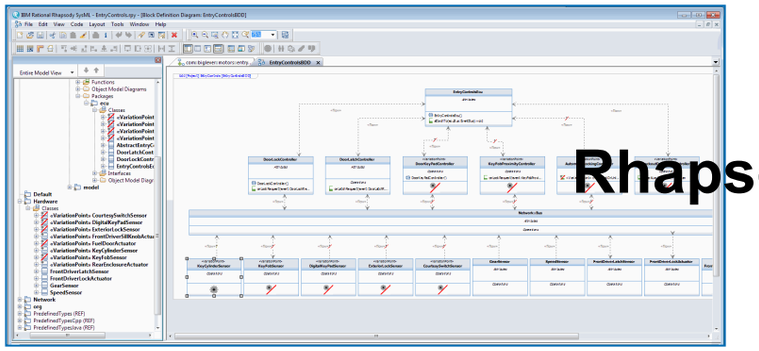
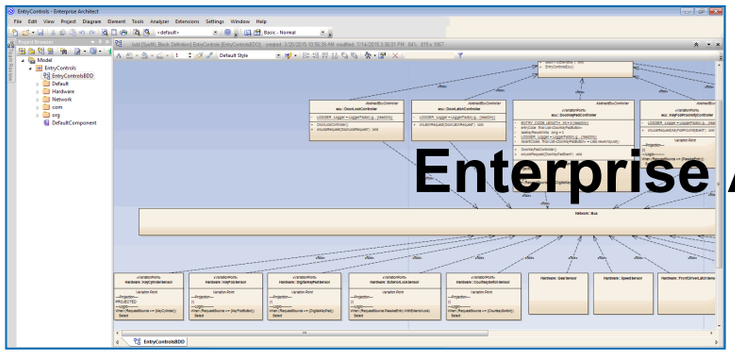
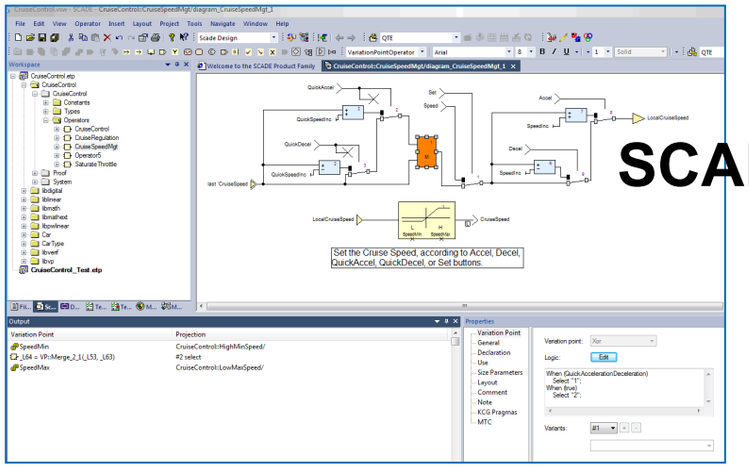
Open Model-based PLE



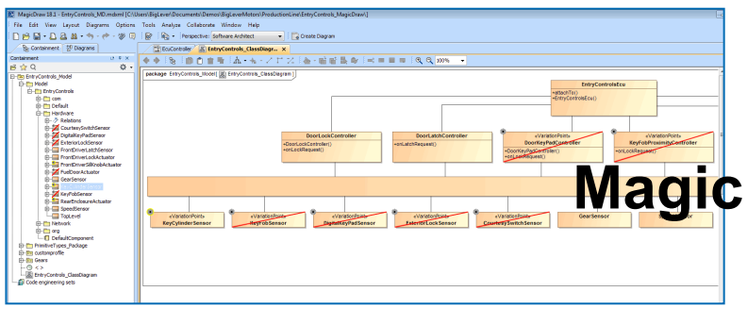
Rhapsody



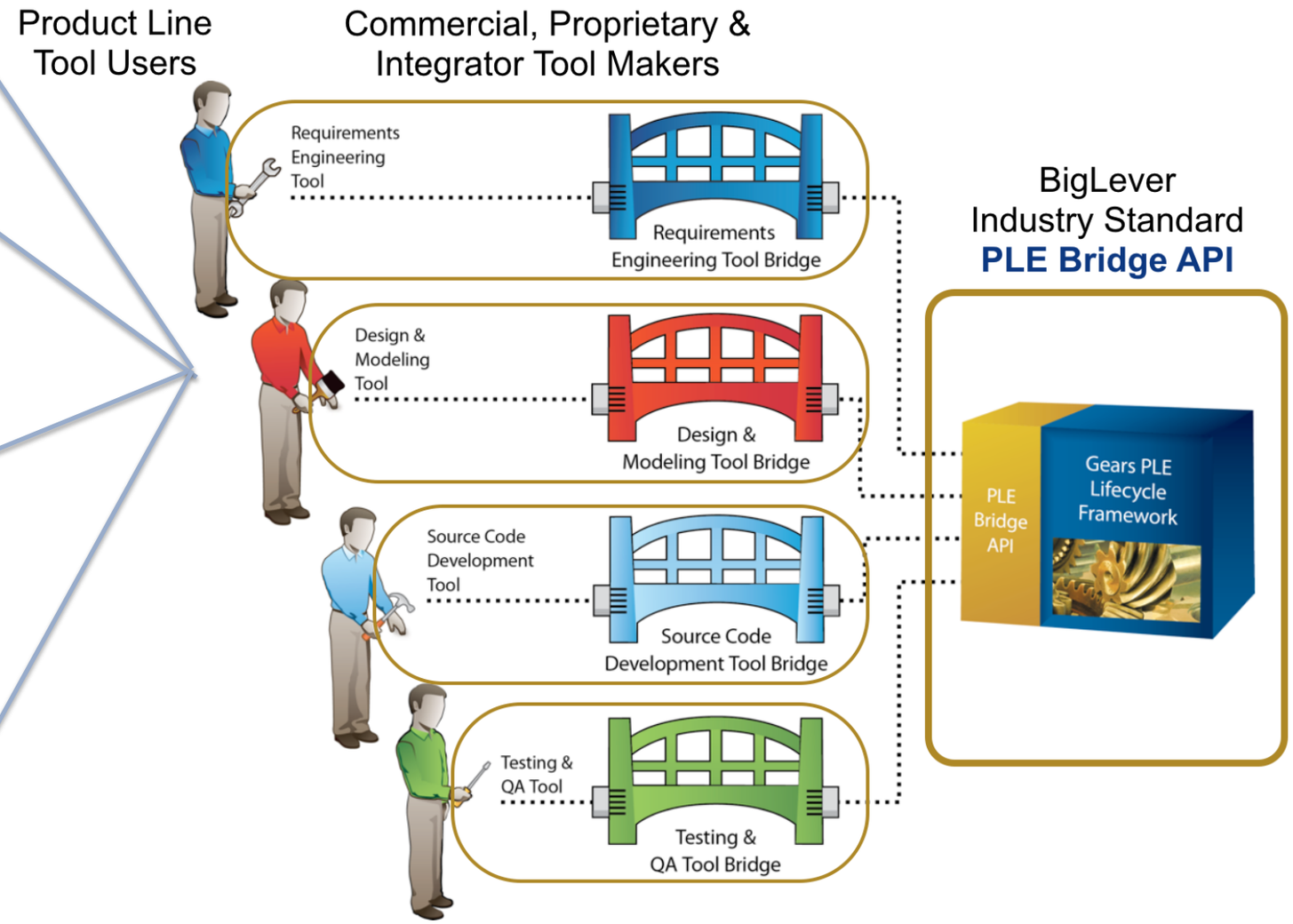
Enterprise Architect



SCADE



MagicDraw



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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.
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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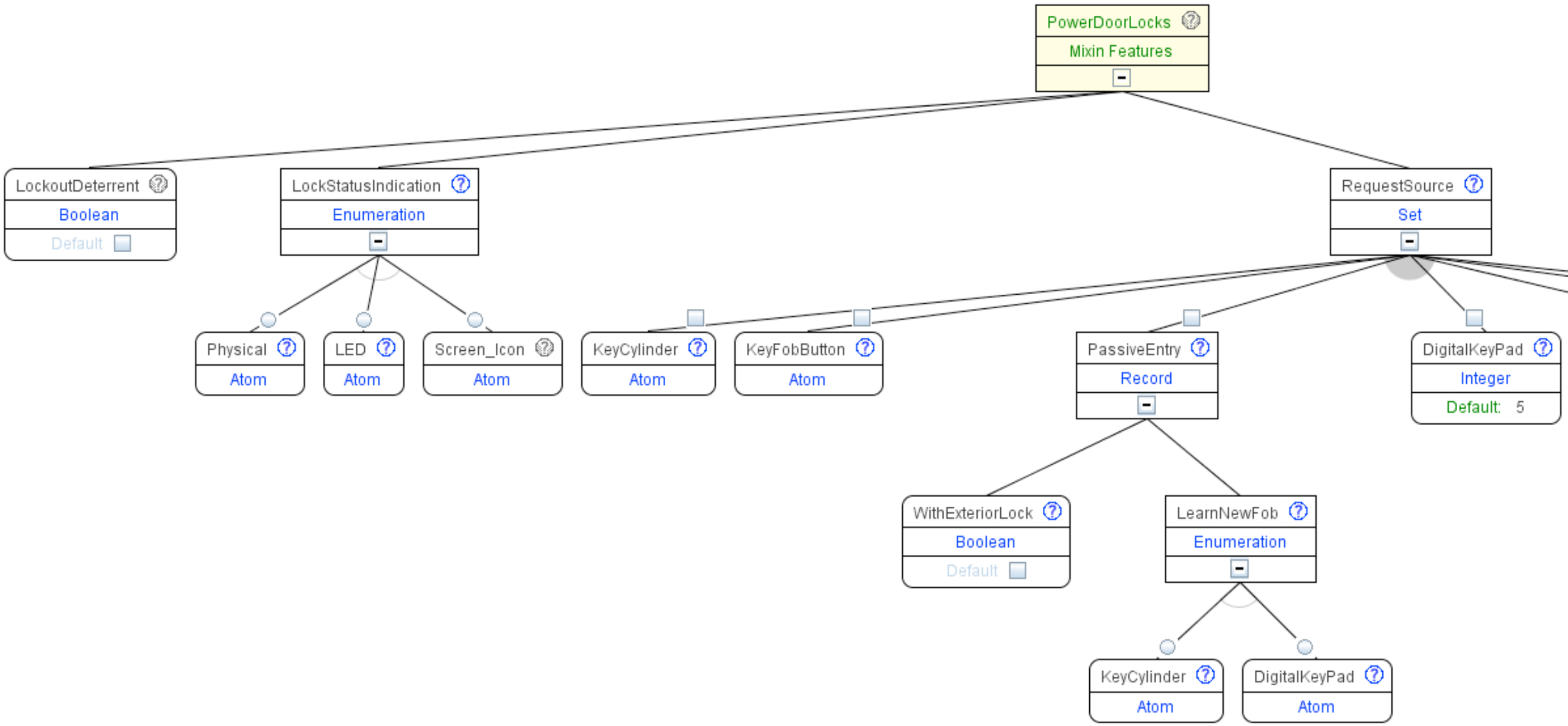
Feature model



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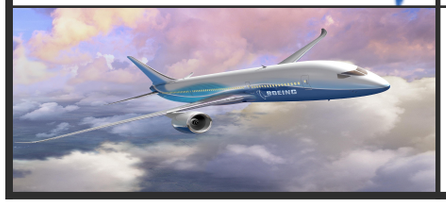
	Who are they?	What is their product line?	Driving problem	PLE results
LOCKHEED MARTIN	Worlds #1 defense contractor	AEGIS Weapon System	High cost of old approach threatened loss of entire contract	Over 100 ship deployments: $47 million saved per year[1,2,3]
GENERAL DYNAMICS	World's #4 defense contractor	Live Training Transformation, family of large-scale training systems for US Army, Air Force, and Marines	Innovative low-cost solution required to win and keep major contract	Over 300 training range deployments: $520 million saved over 12 years[3,4,5]
GM	World's #1 auto-maker	Largest, most complex product line comprising over 10,000,000 instances	Vehicles taking too long to bring to market; expensive and error-prone processes	Will save "hundreds to thousands of man/years per year, worth tens to hundreds of millions of dollars per year" for one asset type alone[6,7,8]
NetApp	World's #2 data storage company	High-end server storage systems	Unable to accommodate growth in market	2x-5x improvements in scalability, productivity, time-to-market, and product quality[9]
HomeAway	World leader in on-line vacation property rental	Product line of e-commerce web sites hosted in over 200 countries worldwide	Broad variation in sites around the world; needed to go live ASAP	First product went live in 60 days[10]
	Leading aviation supplier	Whole-aircraft avionics product line	High cost of product certification	8:1 improvement in time to produce certification documents

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LOCKHEED MARTIN

US Navy Aegis
Cruisers & Destroyers

US Navy Littoral
Combat Ships

US Coast Guard
Nat'l Security Cutter

Aegis Ships for
International Navies

Integrated weapons system for 100 ships

With PLE...

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 **$40M** cost avoidance per year

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Engenio Storage Division:

High-end server storage OEM for IBM, Teradata, Oracle, SGI, and more

NetApp

(previously LSI Logic Engenio)

- Software Product Line Hall of Fame
- 300 product line engineers
- Over 500K installed systems, worth over $25B

With PLE…

2x-5x improvements in scalability, productivity, time-to-market, and product quality

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ikerlan ALSTOM

Wind turbine control systems customized to optimize performance based on wind speed, temperature and other environmental factors

With PLE...

90% reduction
in development time

25% reduction
in development costs

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GENERAL DYNAMICS

Live Training Transformation (LT2) training systems for US Army

LIVE TRAINING TRANSFORMATION LT2 Family of Training Systems

PM CTIS

PM LT Product Manager Digitized Training

PRODUCT MANAGER LIVE TRAINING SYSTEMS

Family of training systems from single-soldier weapons trainers to brigade-level force-on-force exercises involving thousands of soliders.

With PLE, US Army projects **$520M** cost avoidance over 12 years and 300 training range deployments.

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HomeAway®

Worldwide leader for online vacation home rentals

- Software Product Line Hall of Fame
- 100 million users
- 1,000,000 properties in 200 countries
- $100B in travel bookings

200 different product instances engineered and hosted using BigLever's Gears and PLE methods.

Product line was up and running **60 days** after they adopted PLE.

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General Motors: Mega-scale PLE

- GM has 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
  - Tens-of-thousands of unique product variants
  - Dramatic increase in product line variation due to new propulsion systems and active safety
  - Global diversity in legislative regulations
  - Extreme economic and competitive pressures
  - Product line and feature set evolves annually
  - 15 concurrent temporal development streams

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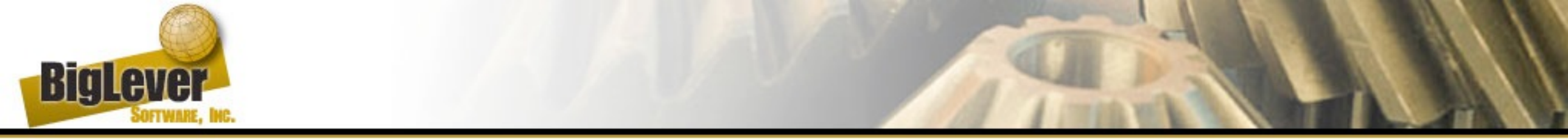

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