31st Annual INCOSE international symposium

virtual event

July 17 - 22, 2021

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Innovative Approaches to Superset Asset Templates using Feature-Based PLE

Outline

1. Overview of Feature-based Product Line Engineering

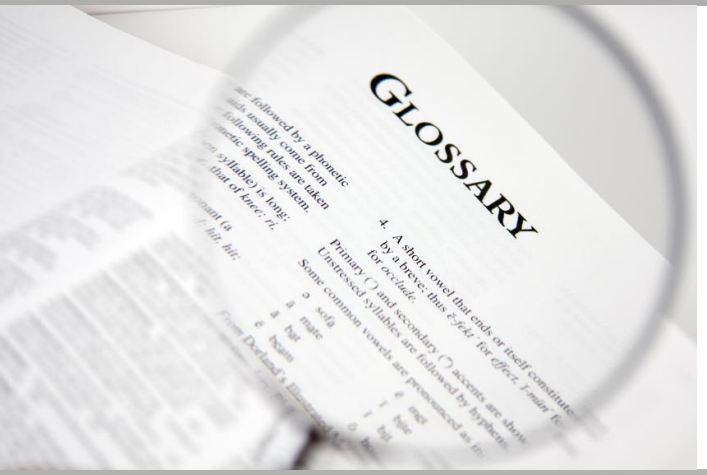
2. Case Study – CFS Product Line

3. Innovative Methods to Utilizing Product Line Configurator

4. Cost Savings of Product Line using Feature-based PLE

Product Line Engineering (PLE) Defined

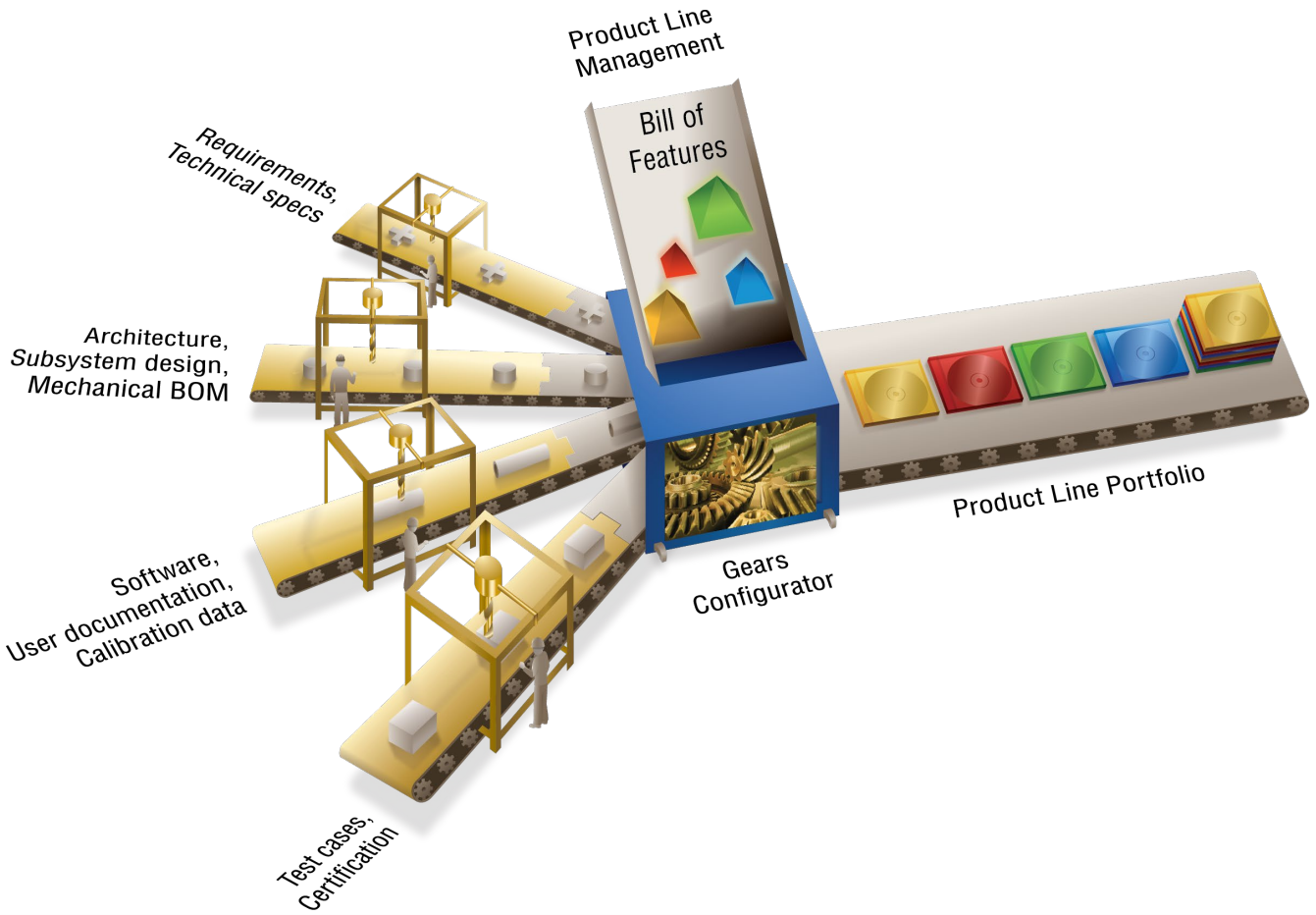
Product Line:
a family of similar products or systems with variations
in features and functions



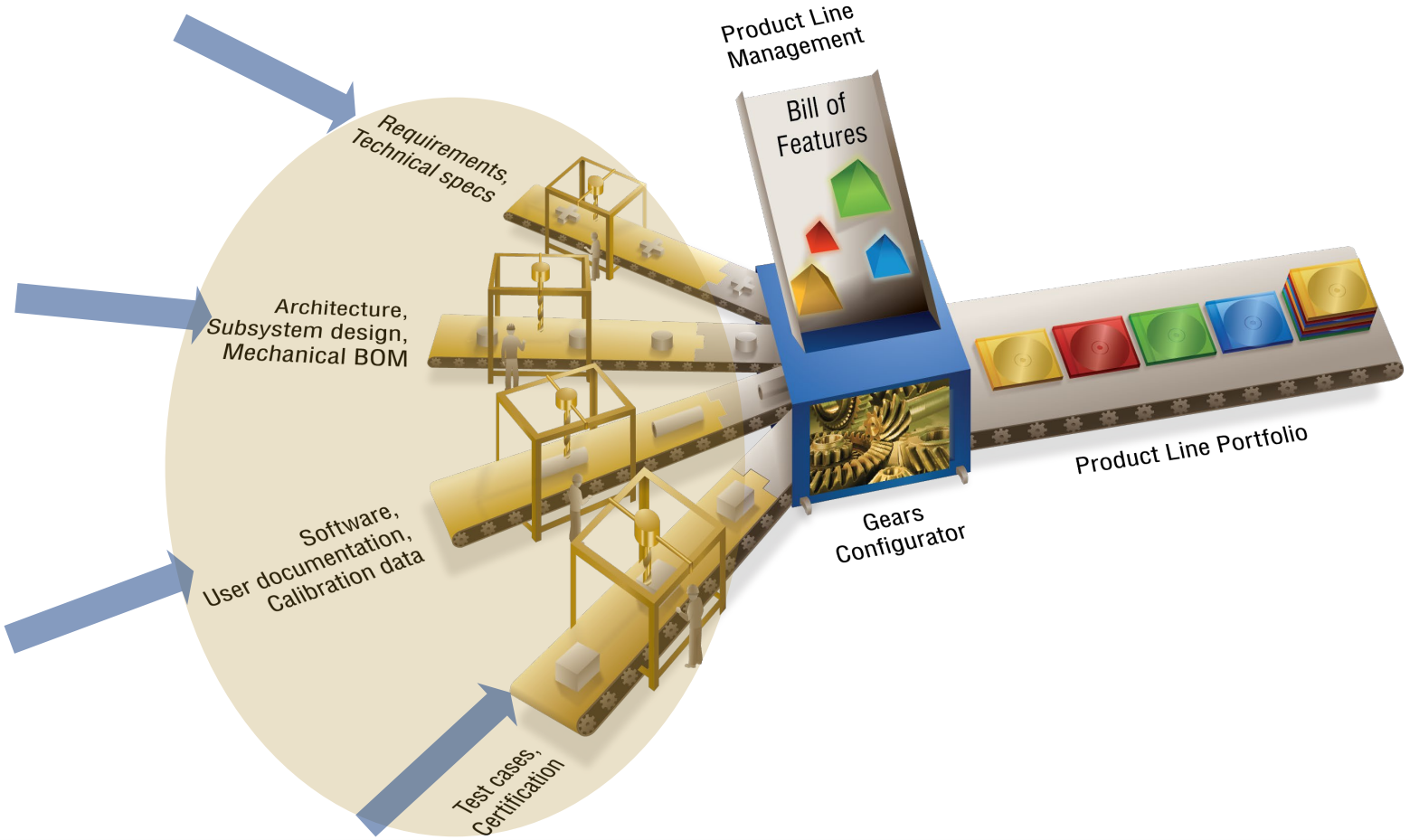
Feature-based
Product Line Engineering:
the engineering of a product line using
a *shared set of engineering assets*,
a *managed set of features*, and
an *automated means of production*…

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

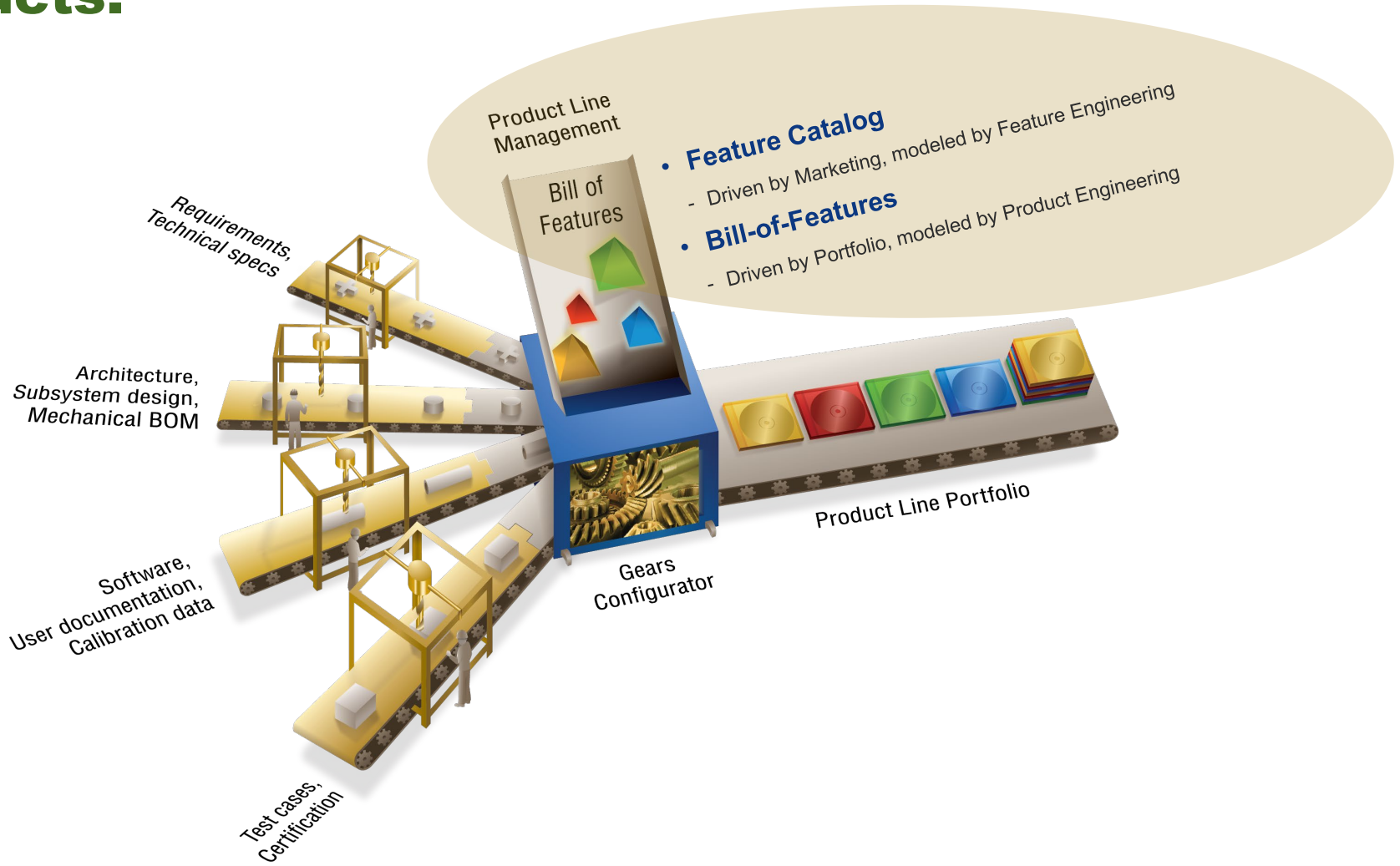
The PLE Factory



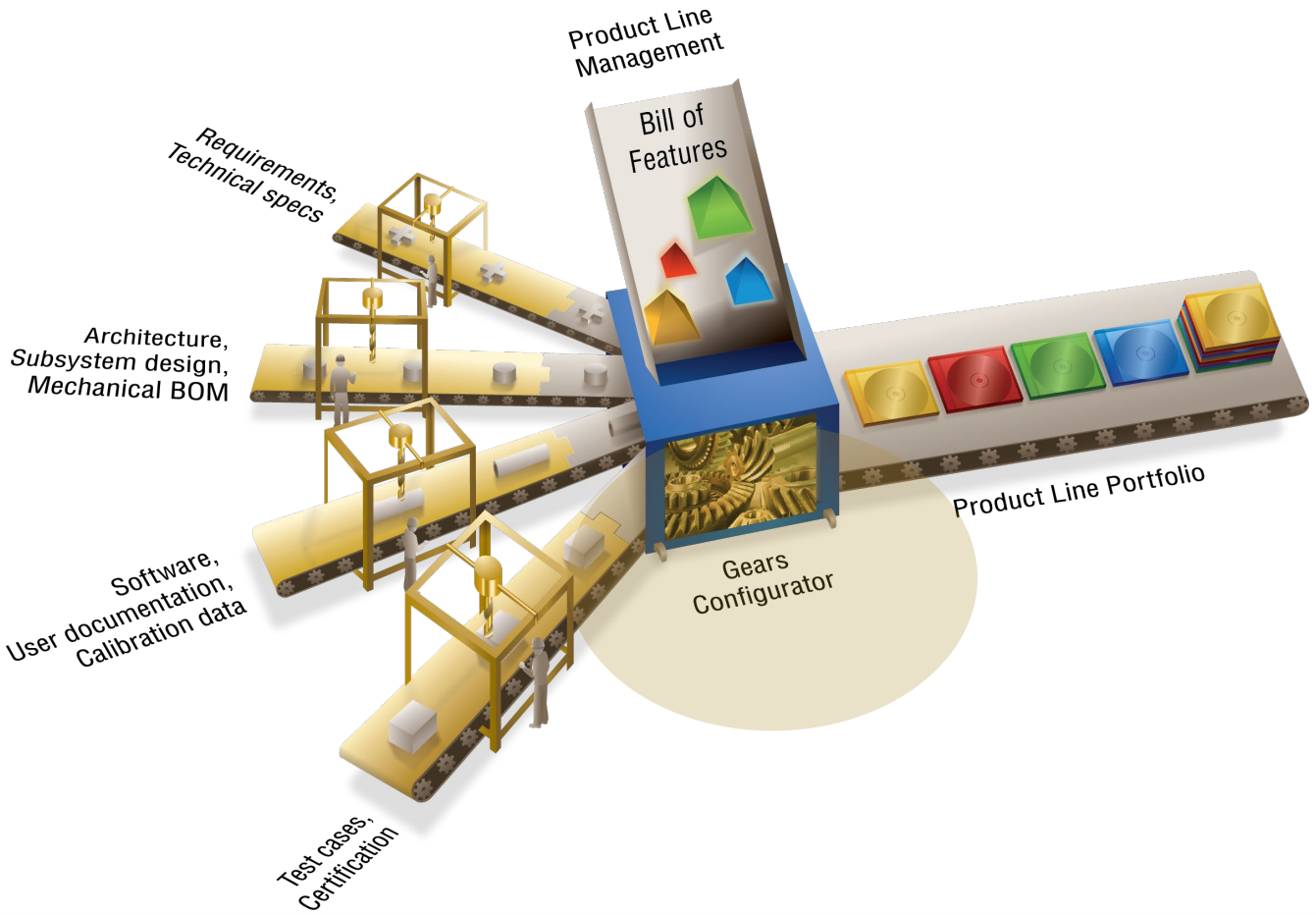
Shared assets are like the factory's supply chain.



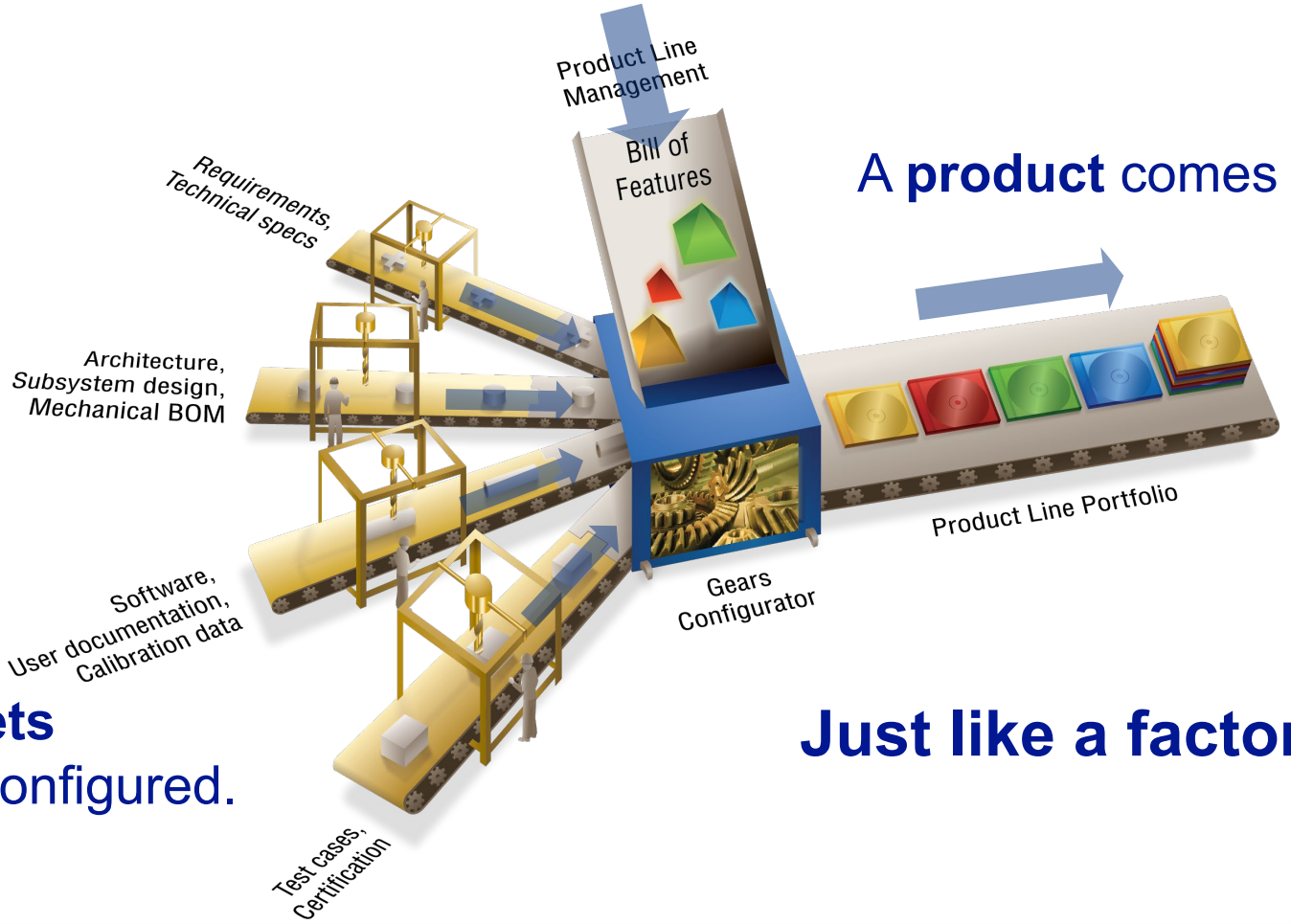
Features describe capabilities that vary among products.



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



Features come in.



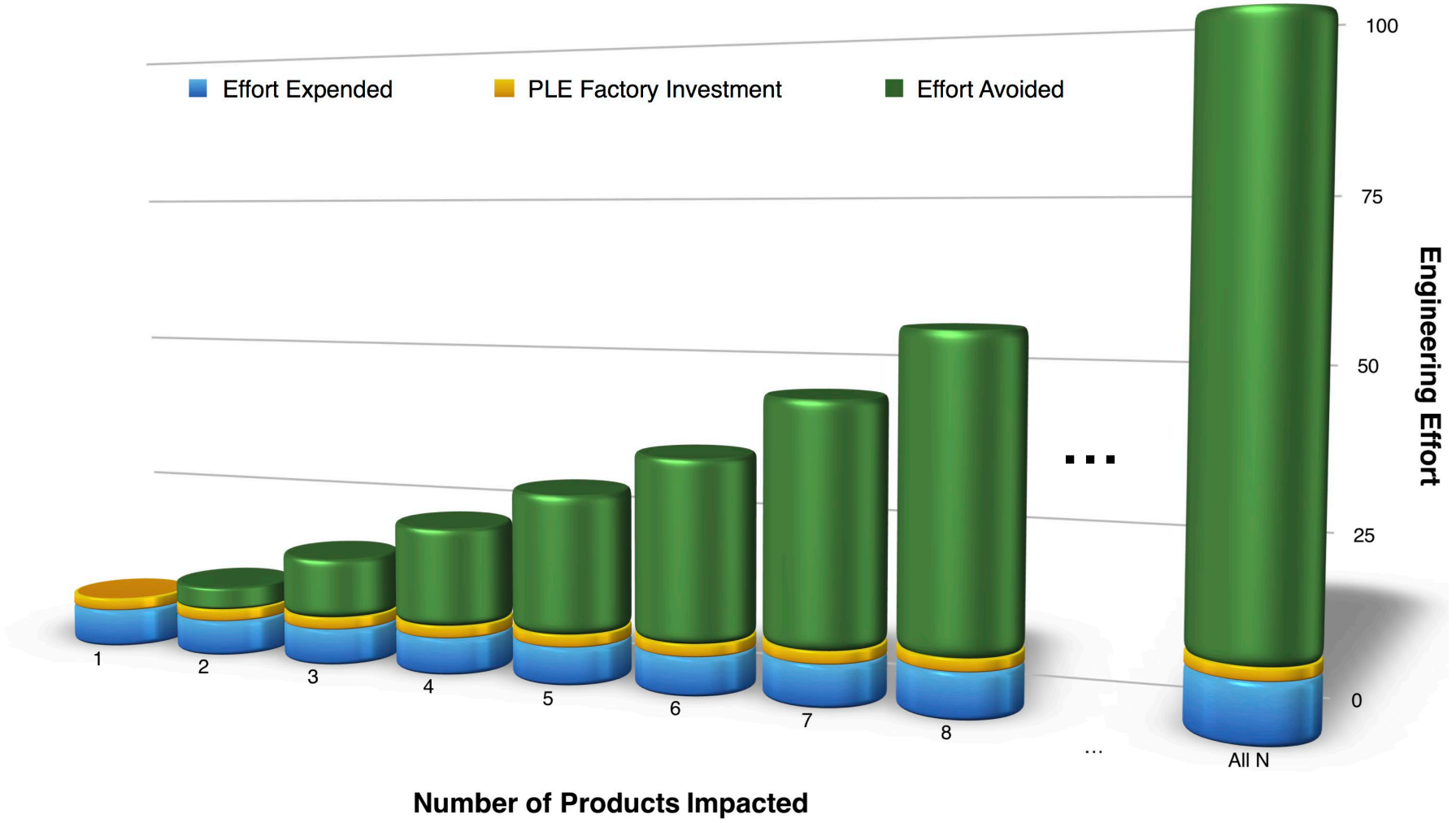
A **product** comes out.

Assets are configured.

Just like a factory.

Feature-based PLE Effort Avoidance

Root-cause Benefit Metric



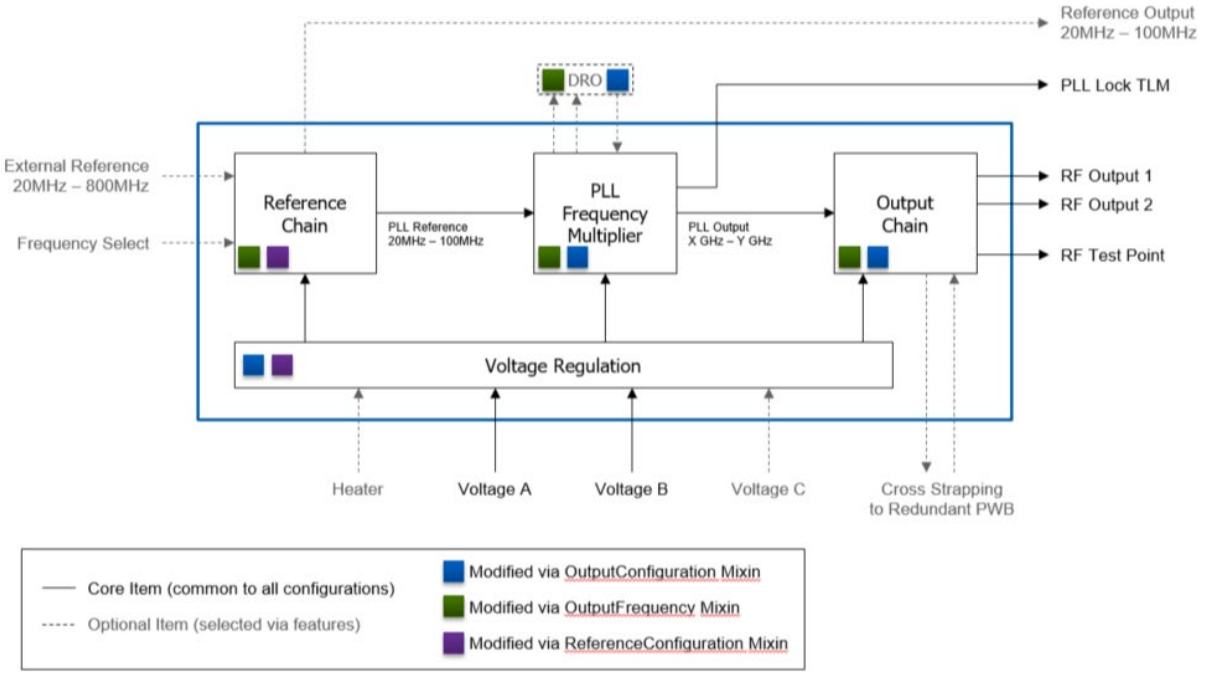
Process Governance

Case Study of the CFS Product Line

Common Frequency Source (CFS)

- Product Line offering hardware modules that includes:
  - Reference Chain
    - Amplify and condition input reference signal
  - Phase-Locked Loop (PLL) Multiplier
    - Multiplies input ref frequency and locks it to the DRO/VCO frequency
  - Output Chain
    - Conditions output signal to required RF output power level and spur suppression
  - Voltage Regulation
    - Conditions input voltage with filtering and regulation of DC voltage levels

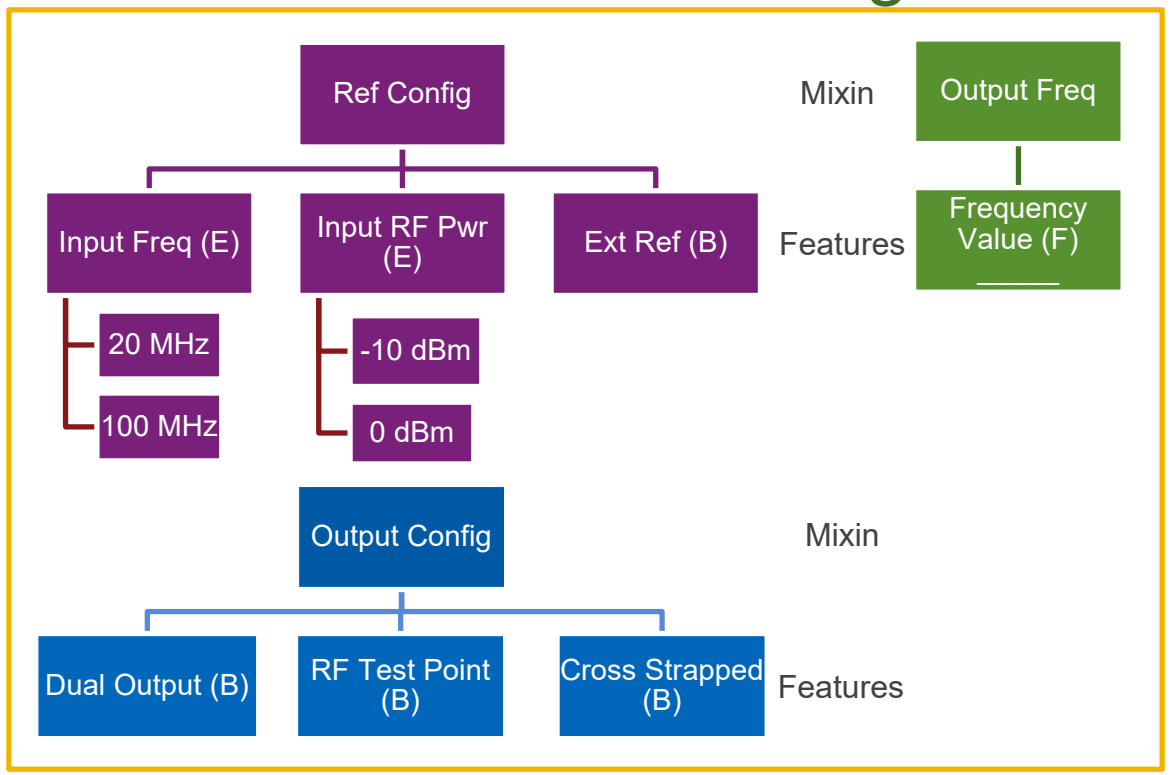
CFS Product Line Architecture



Superset block diagram showing variation points and which feature model Mixin (collection bin) is defining that block

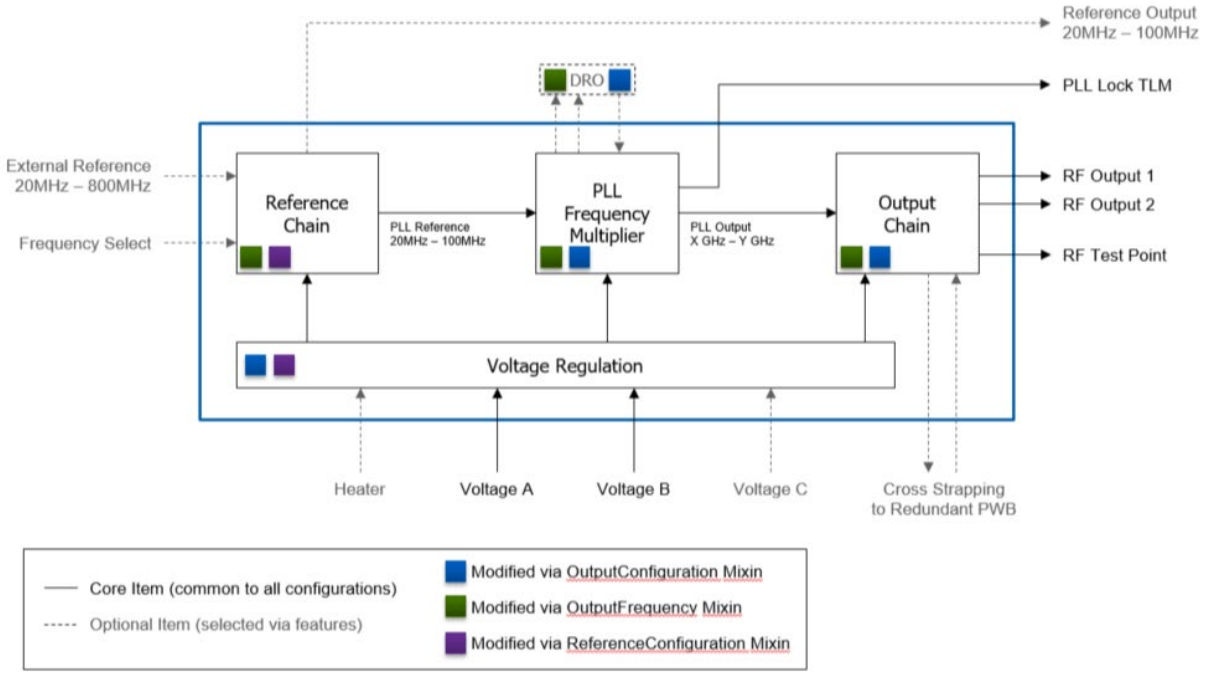
Case Study of the CFS Product Line

CFS Feature Catalog



(E) Enumeration (select from a number of choices)
(B) Yes/No
(F) Float (enter floating point number)

CFS Product Line Architecture



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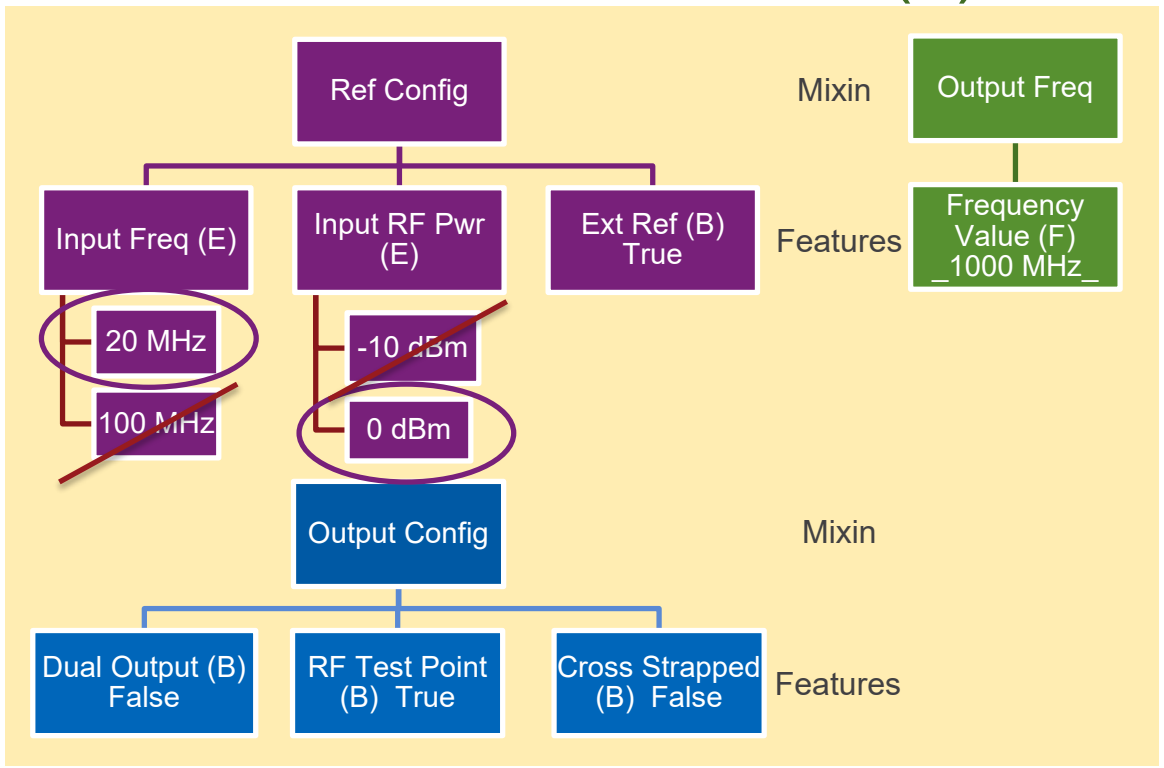
Case Study of the CFS Product Line

CFS Bill of Features (1)



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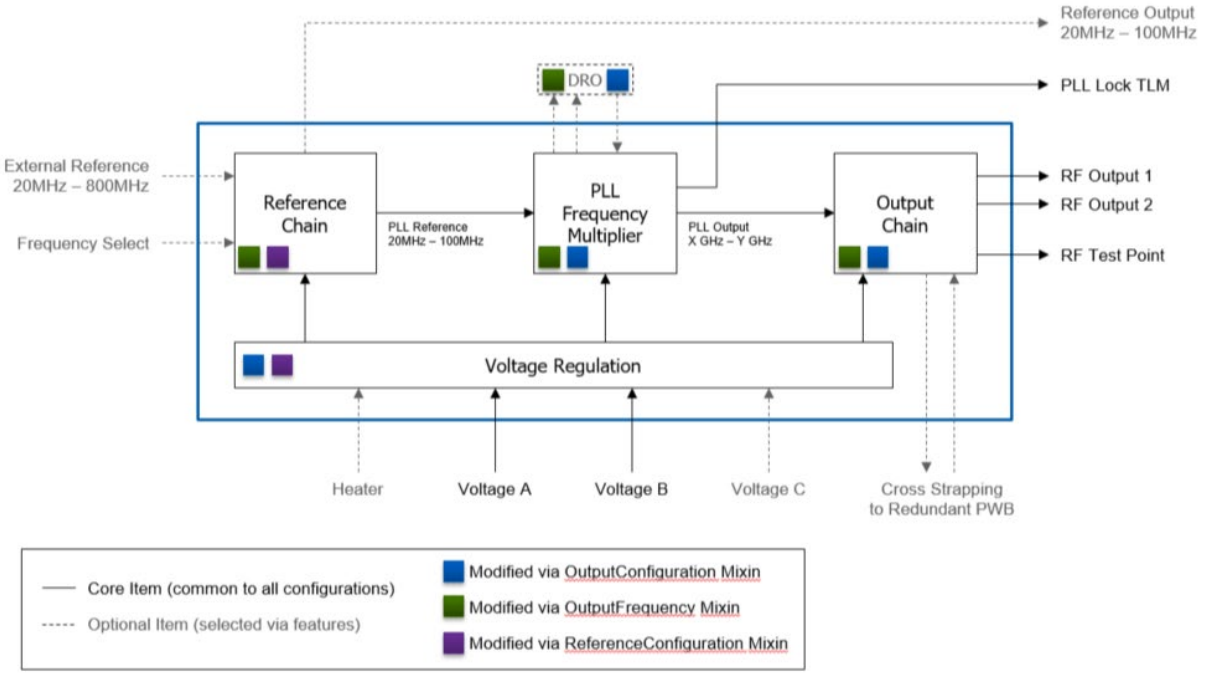
CFS Product Line Architecture



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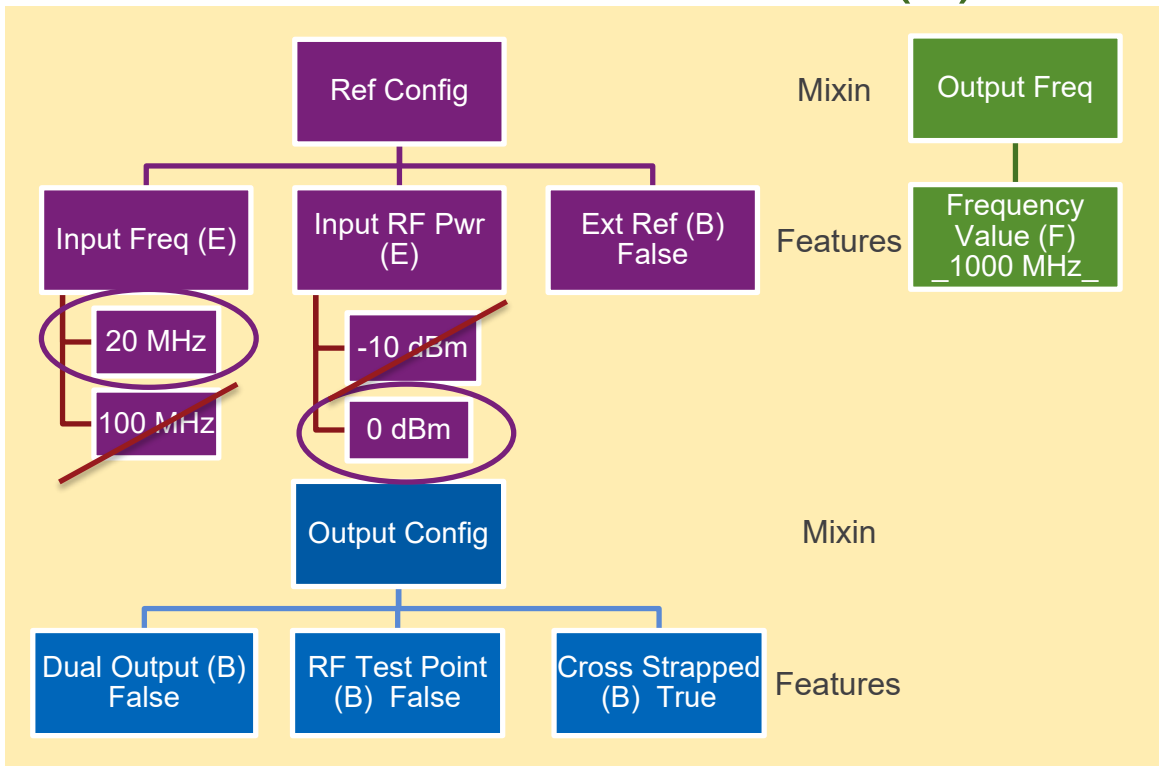
Case Study of the CFS Product Line

CFS Bill of Features (2)



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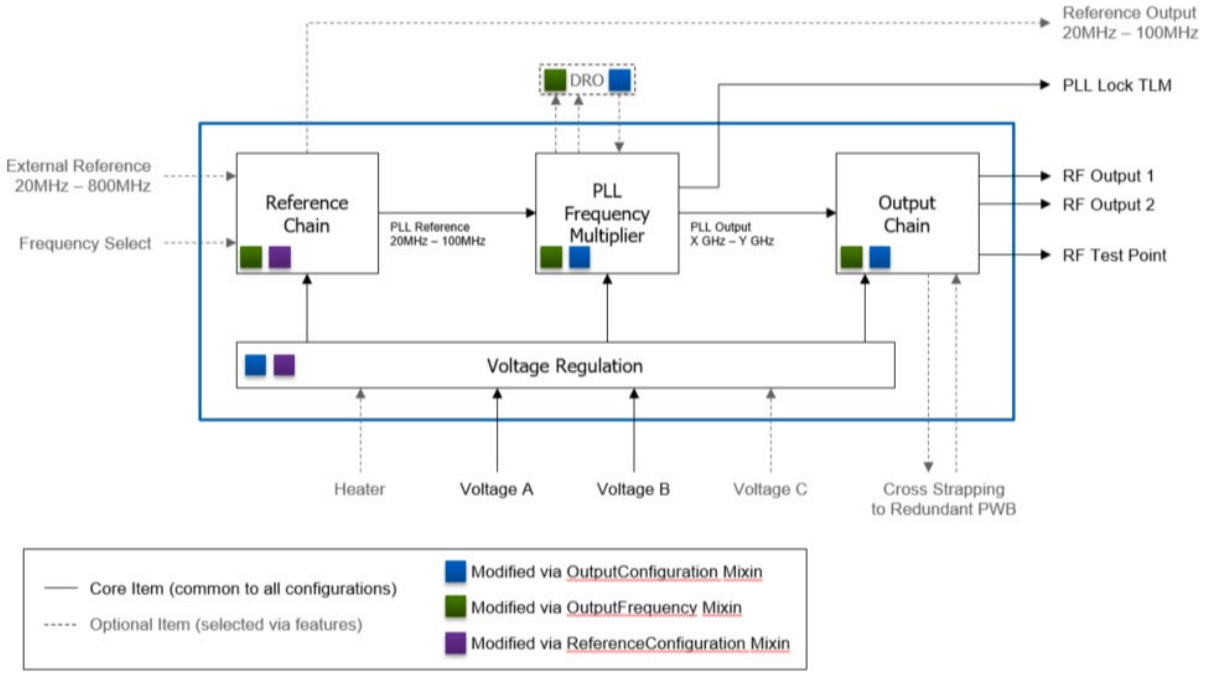
CFS Product Line Architecture



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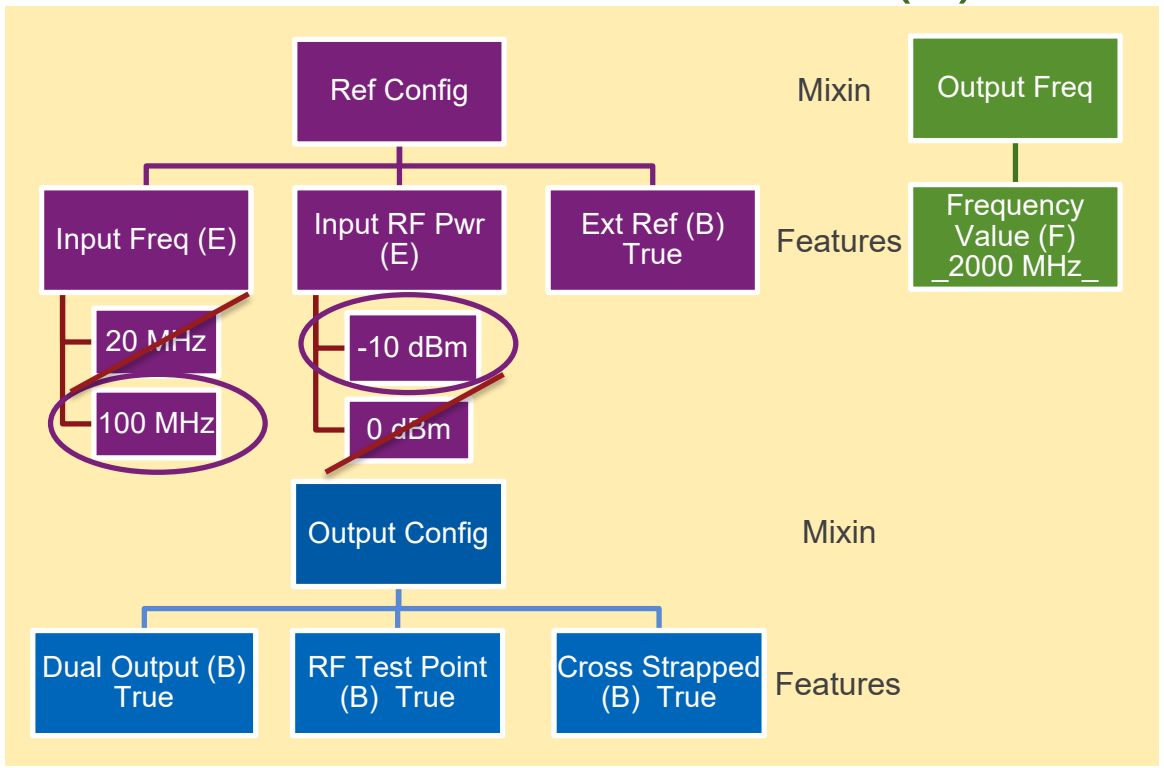
Case Study of the CFS Product Line

CFS Bill of Features (3)



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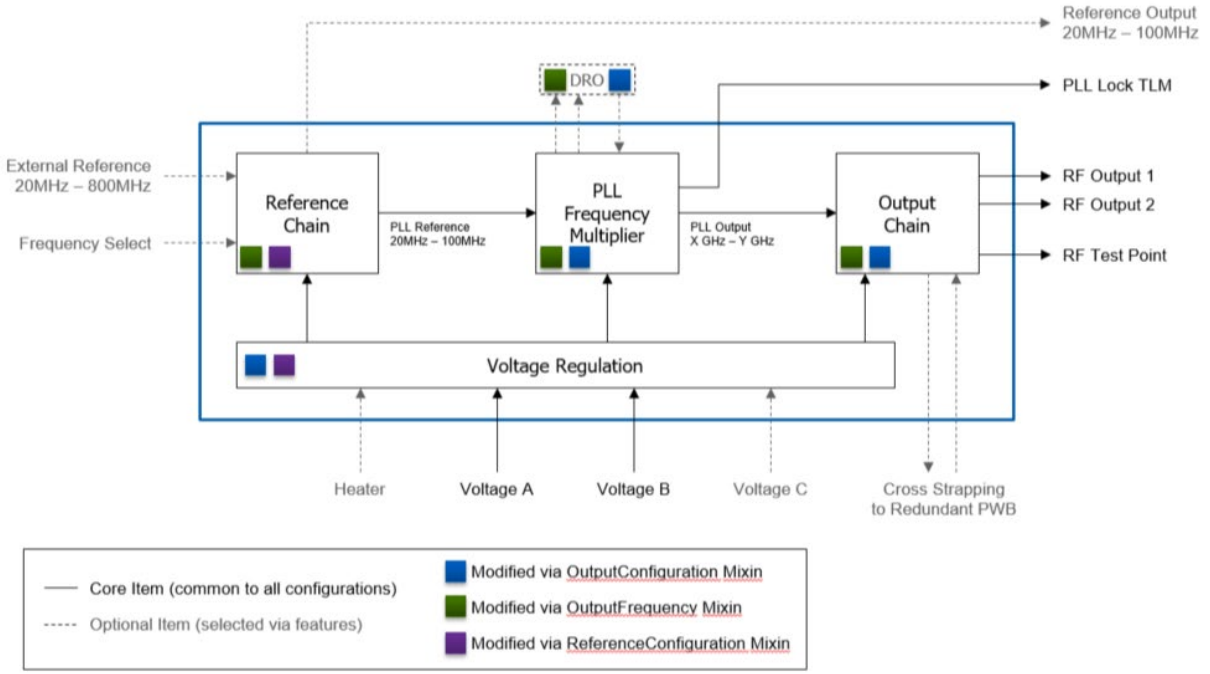
CFS Product Line Architecture

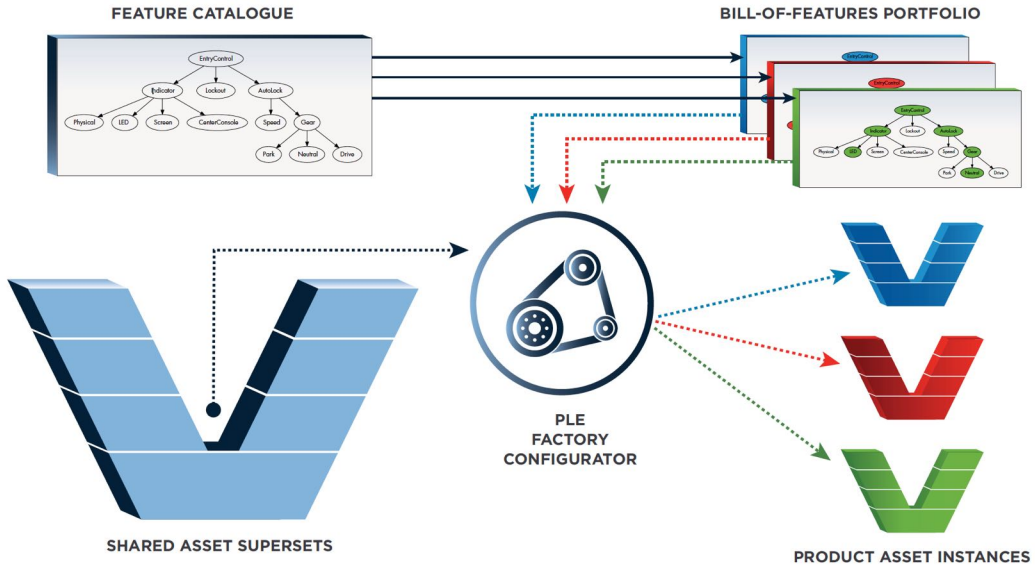


Superset block diagram showing variation points and which feature model Mixin (collection bin) is defining that block

Product Line Superset Shared Assets

What is a Superset Shared Asset?

- Each superset shared asset is treated as a template
  - Product variant specific asset instances can readily be produced by the configurator



CFS PL Superset Shared Assets

Shared Asset Type	Authoring Tool	Number of Assets	Number of Files
Module Specification	IBM Rational DOORS	1	1
Description Documents with Block Diagrams	Microsoft Word	1	1
Component Specifications	Microsoft Excel	3	5
Interface List	Microsoft Excel	1	1
Engineering Bill of Materials	Microsoft Excel	1	3
Analyses	Microsoft Excel	7	14
Inputs to Simulators	Microsoft Text	2	8
	Total	16	33

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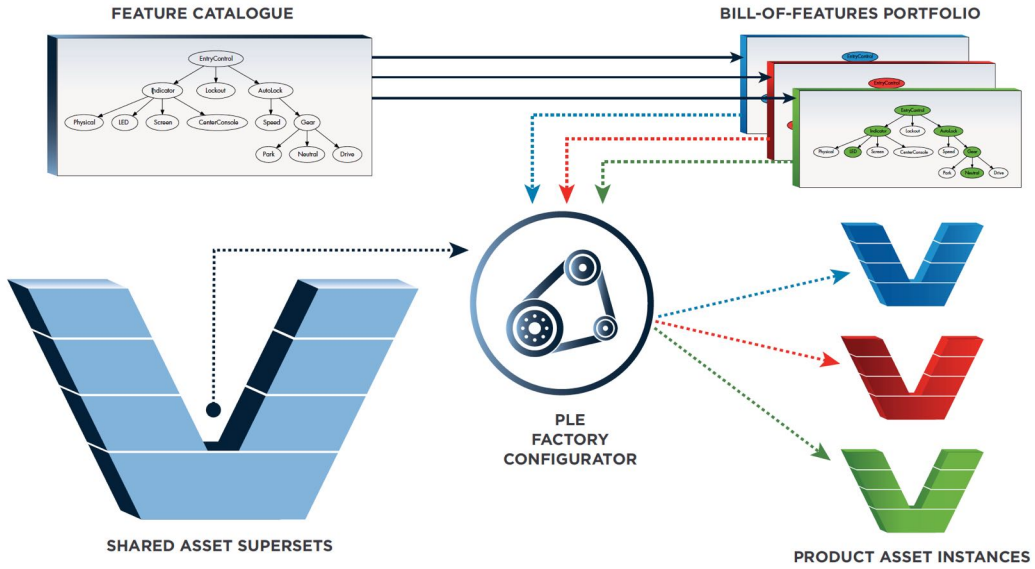

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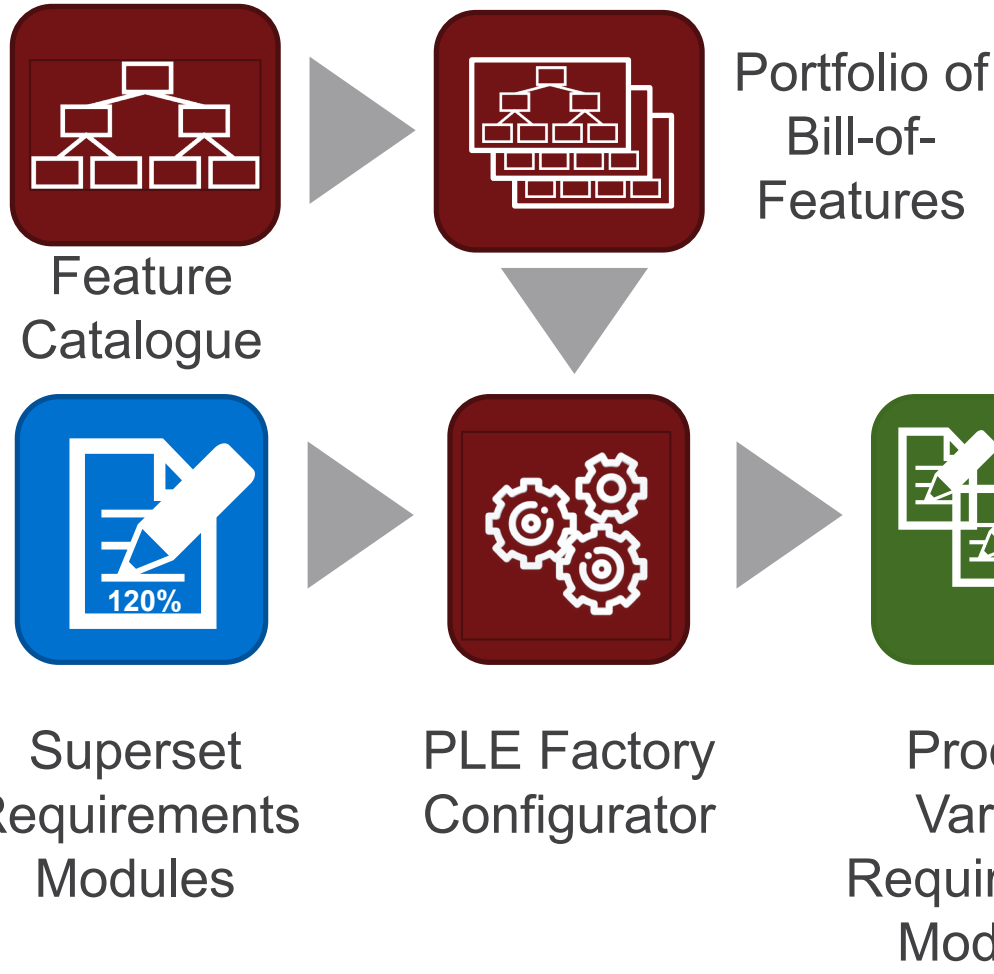
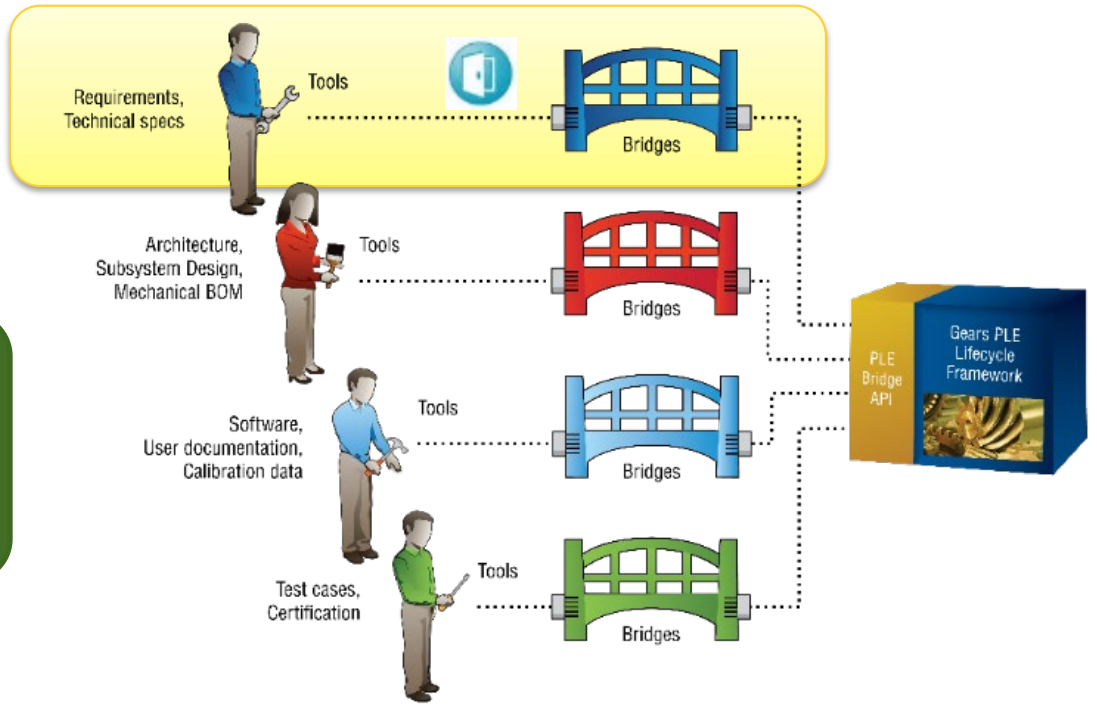
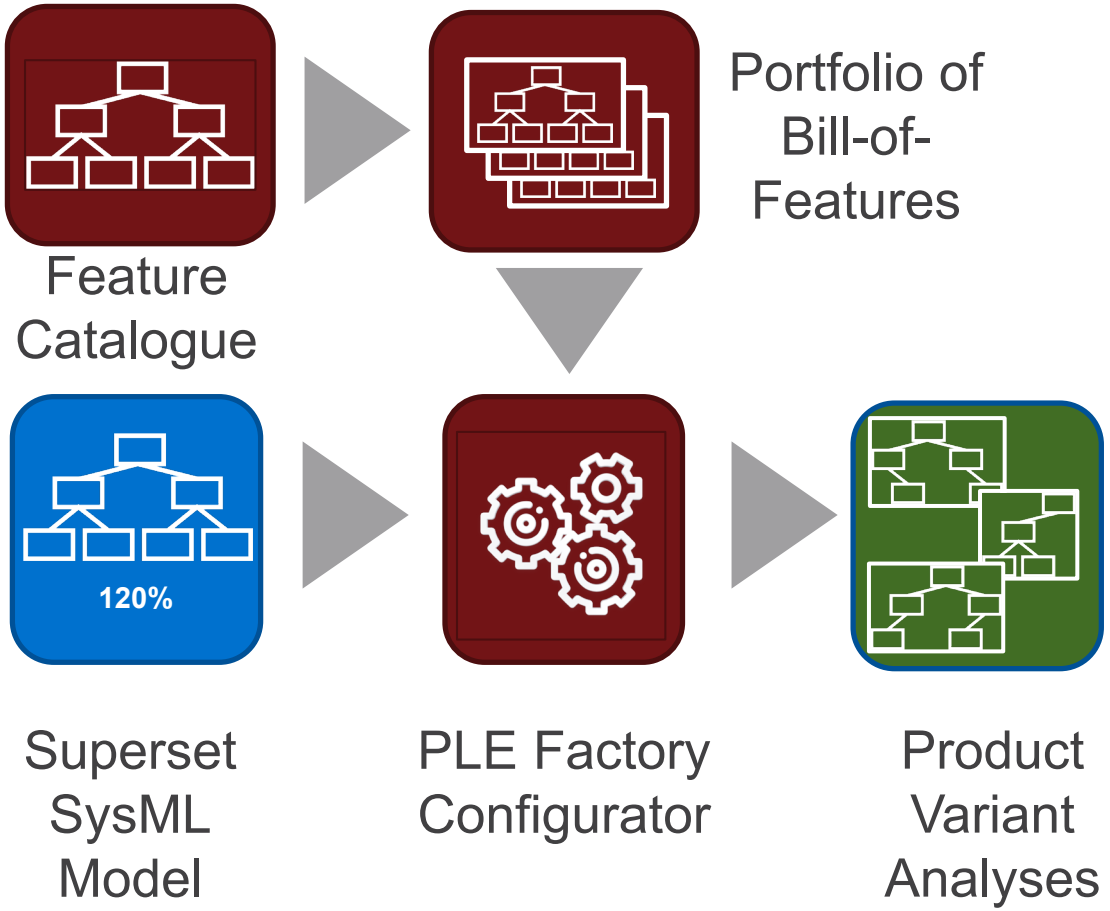
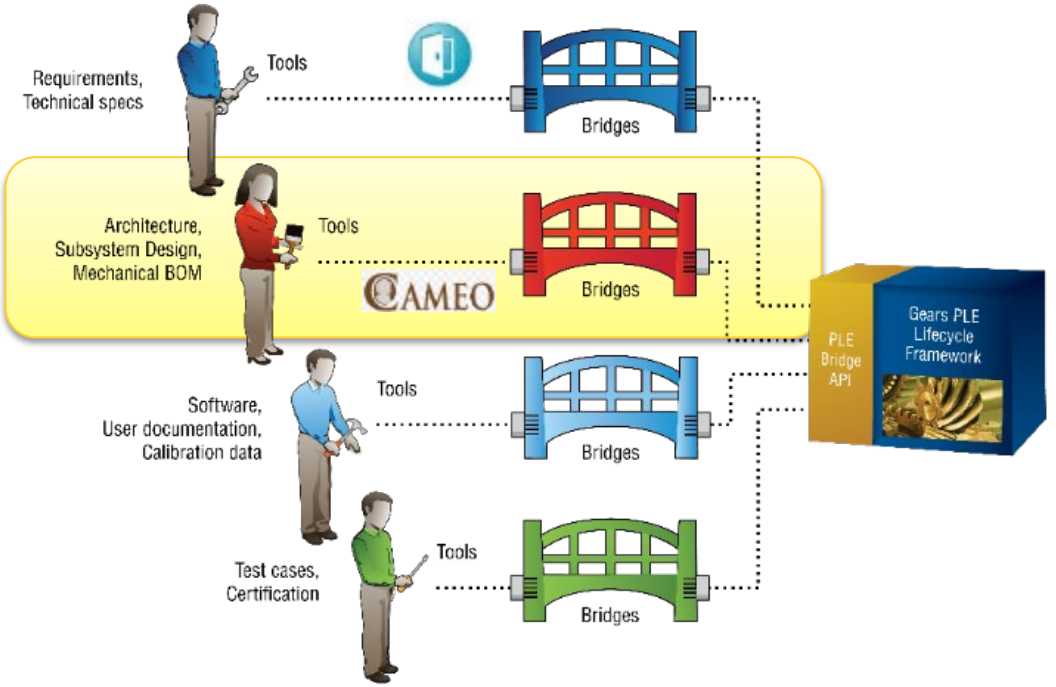
The Feature-based PLE Factory



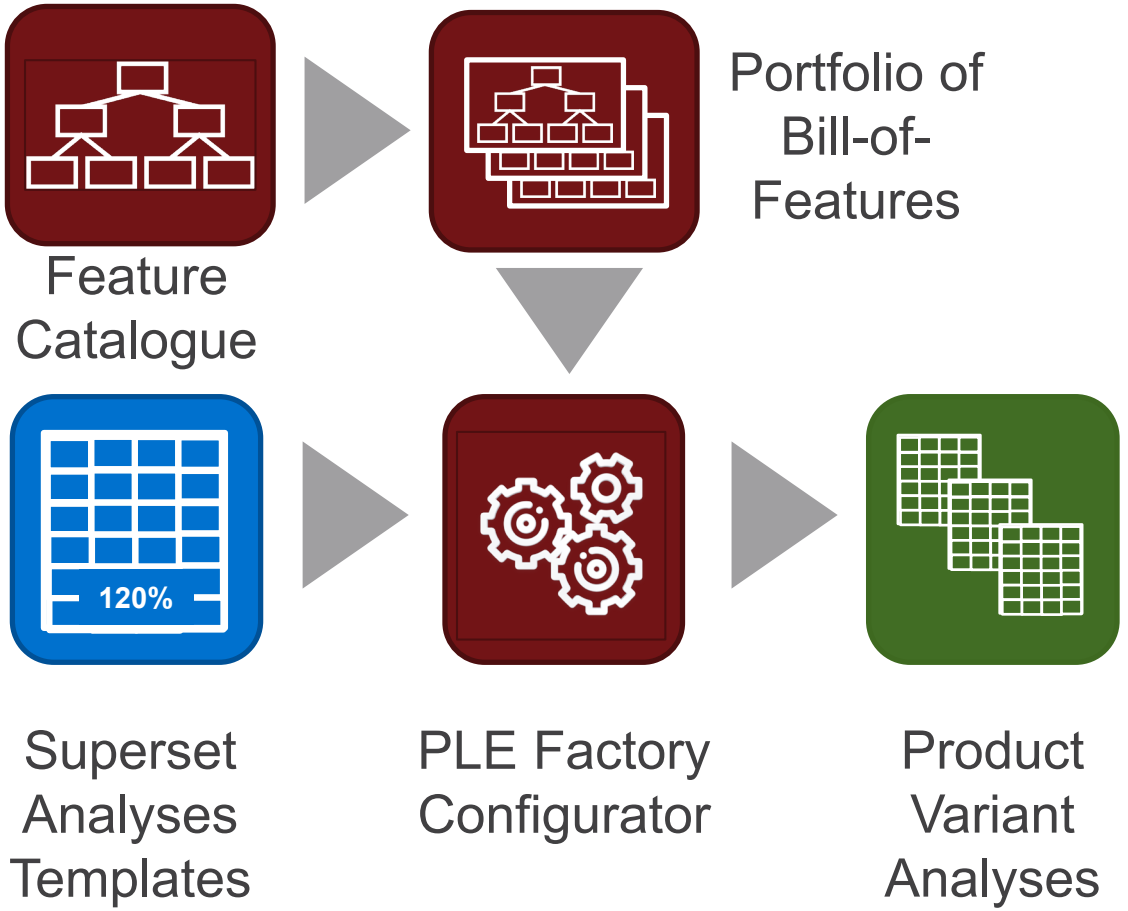


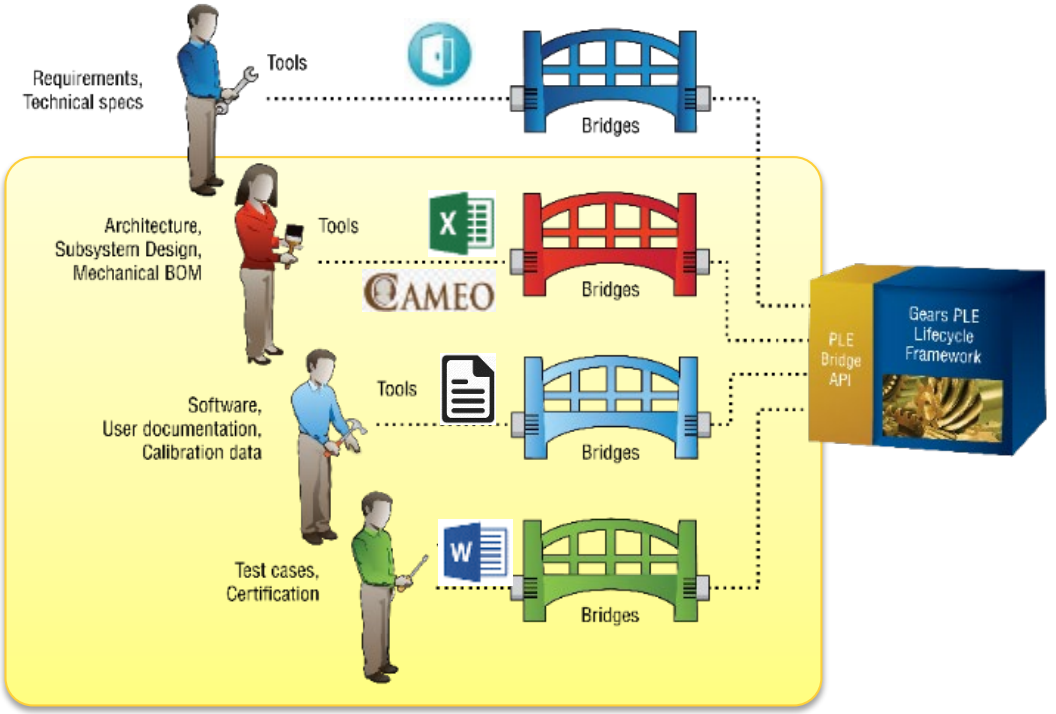
The Feature-based PLE Factory



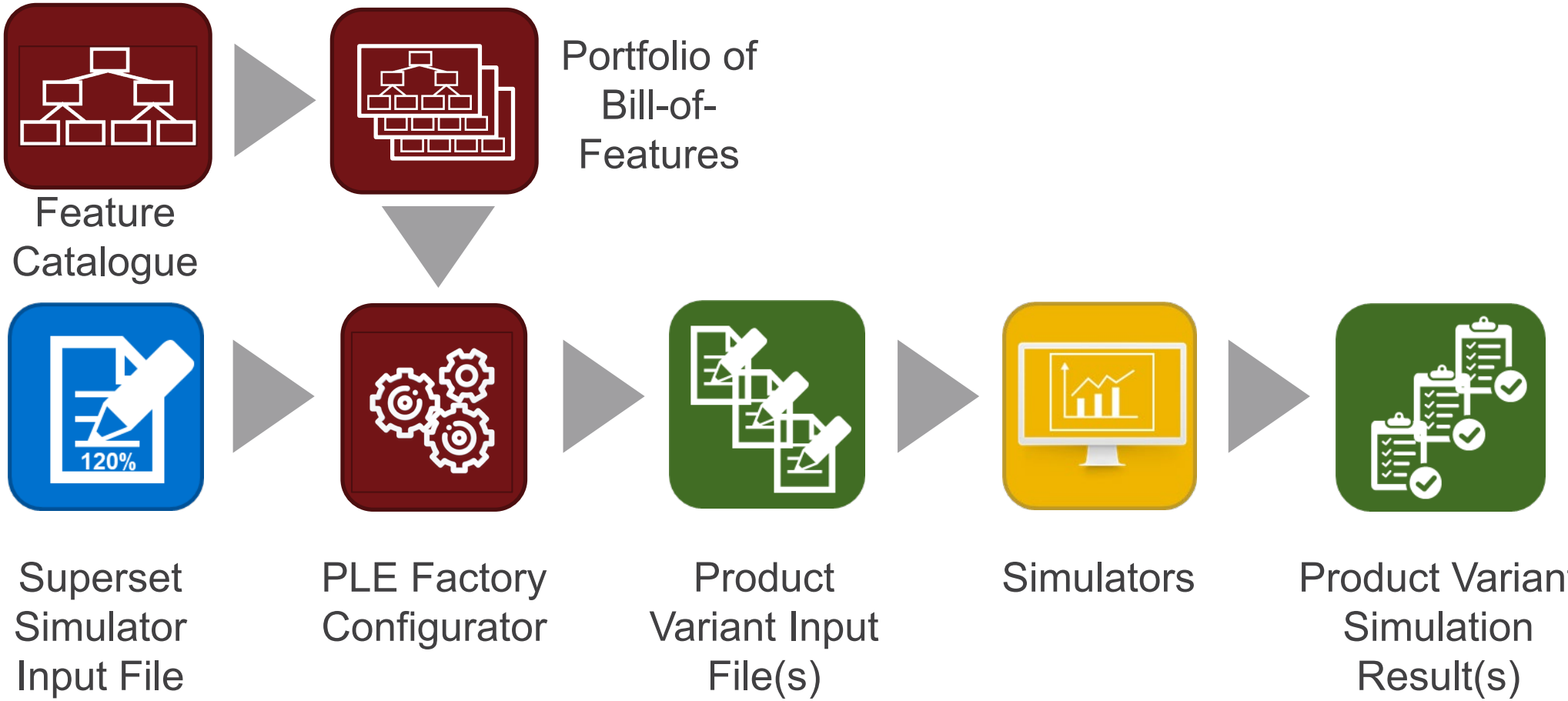


The Feature-based PLE Factory

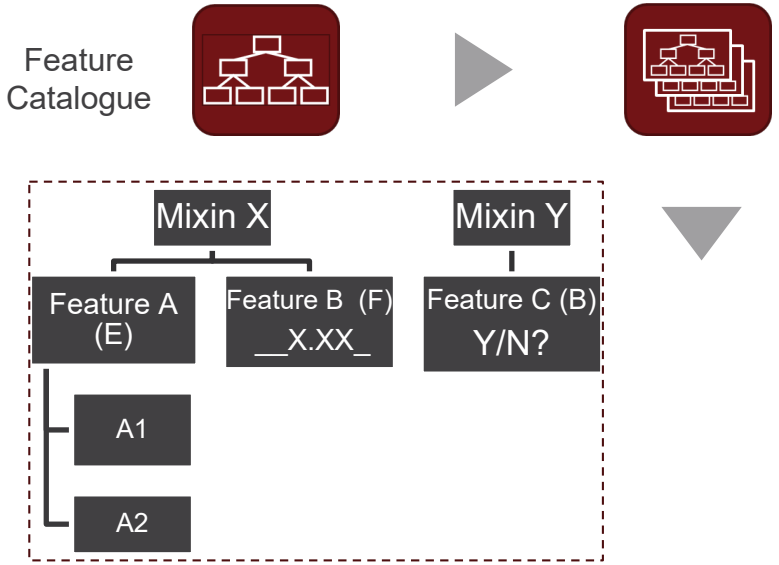




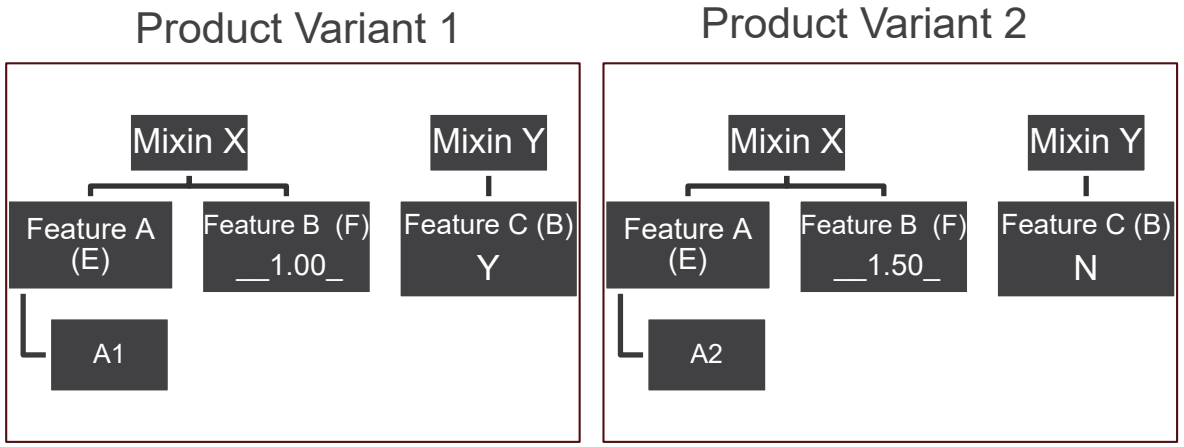
Innovative Use of Feature-based PLE Factory

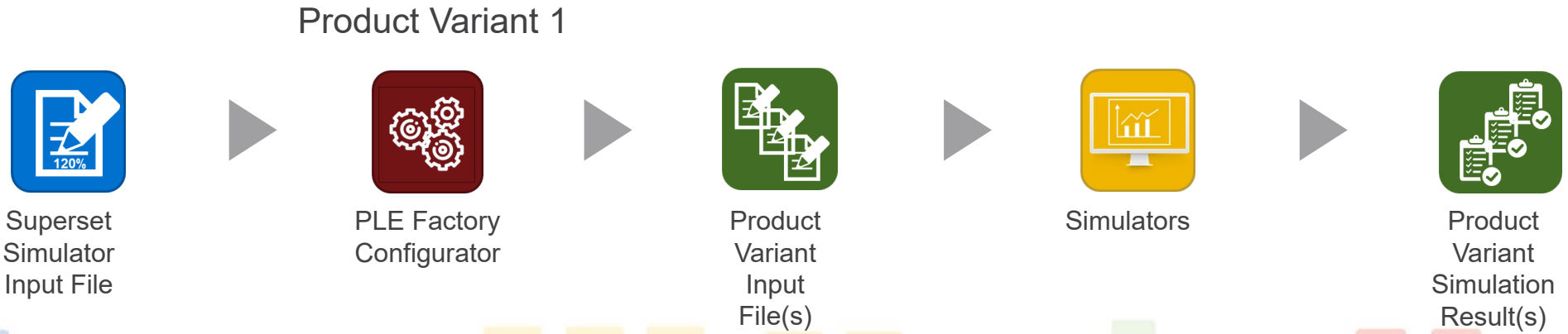


Innovative Use of Feature-based PLE Factory



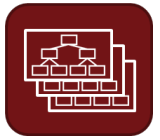
Portfolio of Bill-of-Features





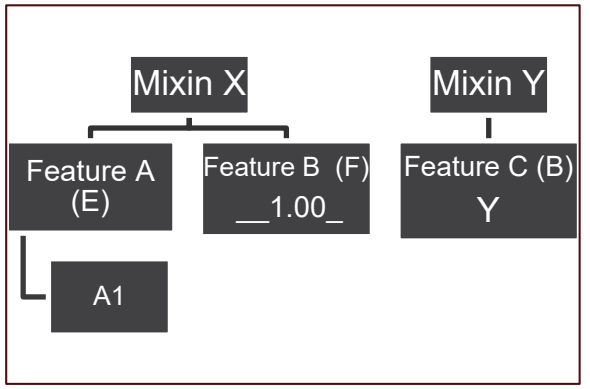
Innovative Use of Feature-based PLE Factory

Feature Catalogue

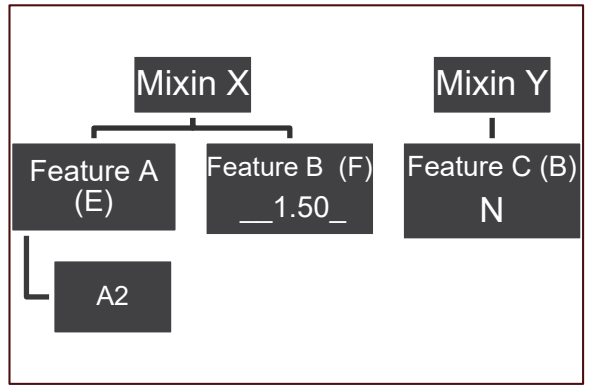


Portfolio of Bill-of-Features

Product Variant 1



Product Variant 2




```
.PARAM B = %FeatureB
** BeginGearsBlock PSpice A_REF **
.PARAM F_A1REF = 10
** ElseGearsBlock PSpice A_REF **
.PARAM F_A2REF = 200
** EndGearsBlock PSpice A_REF **
```

PLL.inc

.inc files for PSPICE

```
B = %FeatureB **
**BeginGearsBlock PLLblk C
C = 100
** EndGearsBlock PLLblk C
```

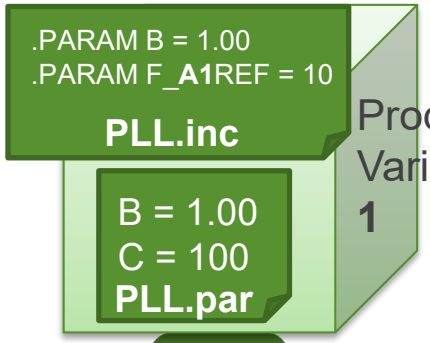
PLL.par

.par files for Gain/Phase Sims

Product Variant **1**

Superset Simulator Input File

PLE Factory Configurator

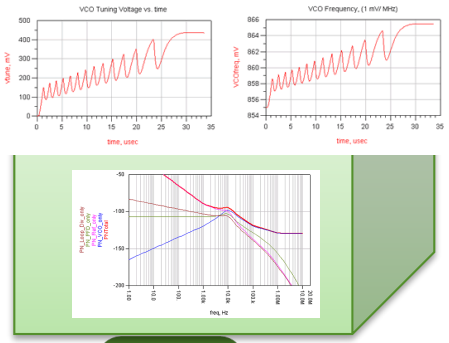


Product Variant **1**

Product Variant Input File(s)

OrCAD PSpice®

Simulators



Product Variant **1**

Product Variant Simulation Result(s)

Example plots** for illustration purposes only. Not real data.

** Knowledge Center - Keysight

Innovative Use of Feature-based PLE Factory

Feature Catalogue

Portfolio of Bill-of-Features

Product Variant 1

Mixin X
Feature A (E)
Feature B (F) __1.00_
A1
Mixin Y
Feature C (B) Y

Product Variant 2

Mixin X
Feature A (E)
Feature B (F) __1.50_
A2
Mixin Y
Feature C (B) N

```
.PARAM B = %FeatureB
** BeginGearsBlock PSpice A_REF
.PARAM F_A1REF = 10
** ElseGearsBlock PSpice A_REF **
.PARAM F_A2REF = 200
** EndGearsBlock PSpice A_REF **
```

PLL.inc

.inc files for PSPICE

```
B = %FeatureB **
**BeginGearsBlock PLLblk C
C = 100
** EndGearsBlock PLLblk C
```

PLL.par

.par files for Gain/Phase Sims

Product Variant **2**

Superset Simulator Input File

PLE Factory Configurator

```
.PARAM B = 1.50
.PARAM F_A2REF = 200
```

PLL.inc

B=1.50

PLL.par

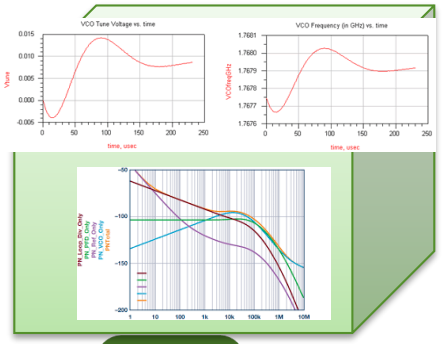
Product Variant **2**

Product Variant Input File(s)

OrCAD PSpice®

PLL Sim

Simulators



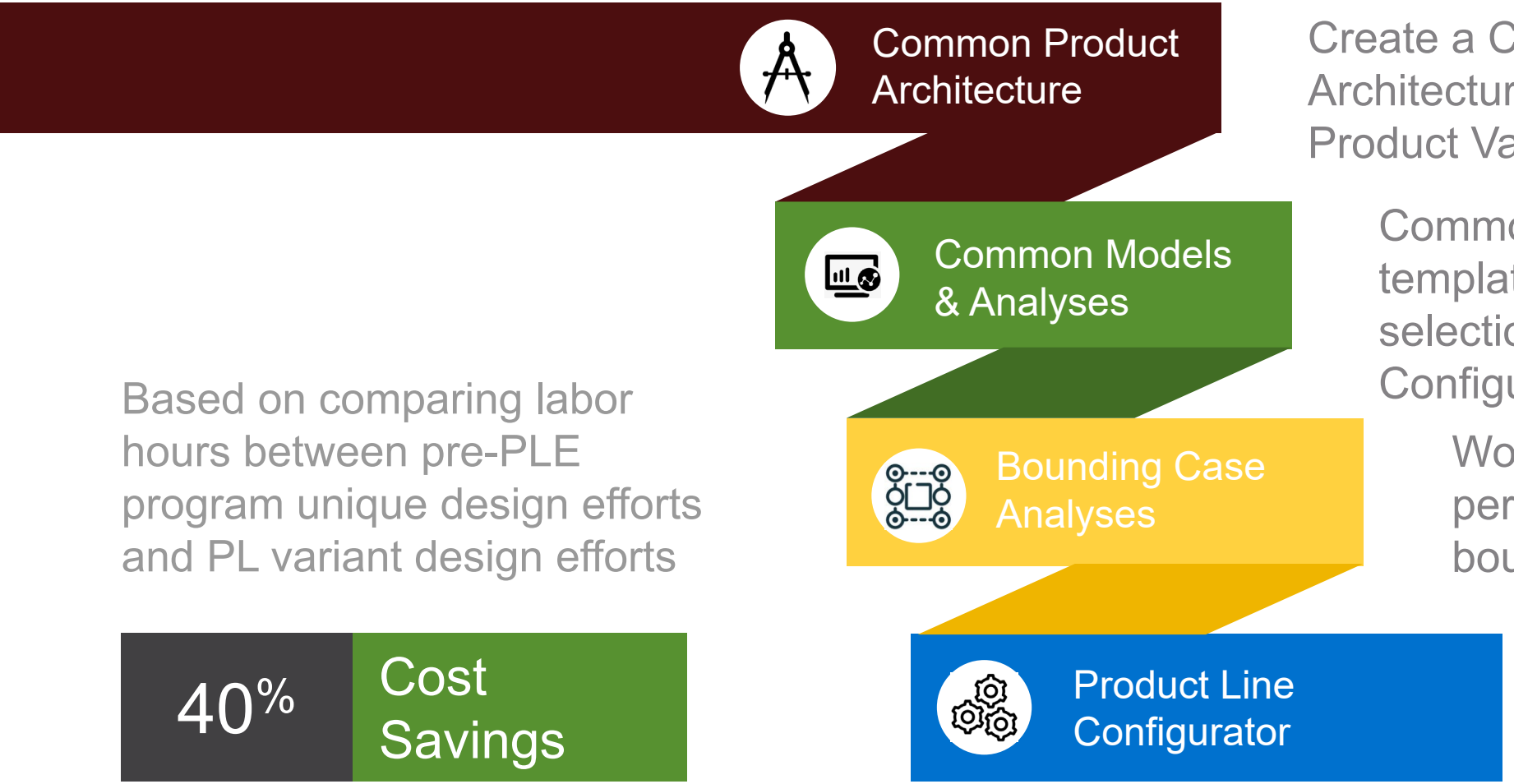
Product Variant **2**

Example plots** for illustration purposes only. Not real data.

Product Variant Simulation Result(s)

** Knowledge Center - Keysight

CFS was able to see significant cost savings



Create a Common Product Architecture for all applications → Product Variants across wide range

Common models and analyses templates driven by feature selections in the PL Configurator

Worst case analyses performed on superset bounding requirements/cases

Utilizing Shared Assets and Feature Model in the PL Configurator

Based on comparing labor hours between pre-PLE program unique design efforts and PL variant design efforts

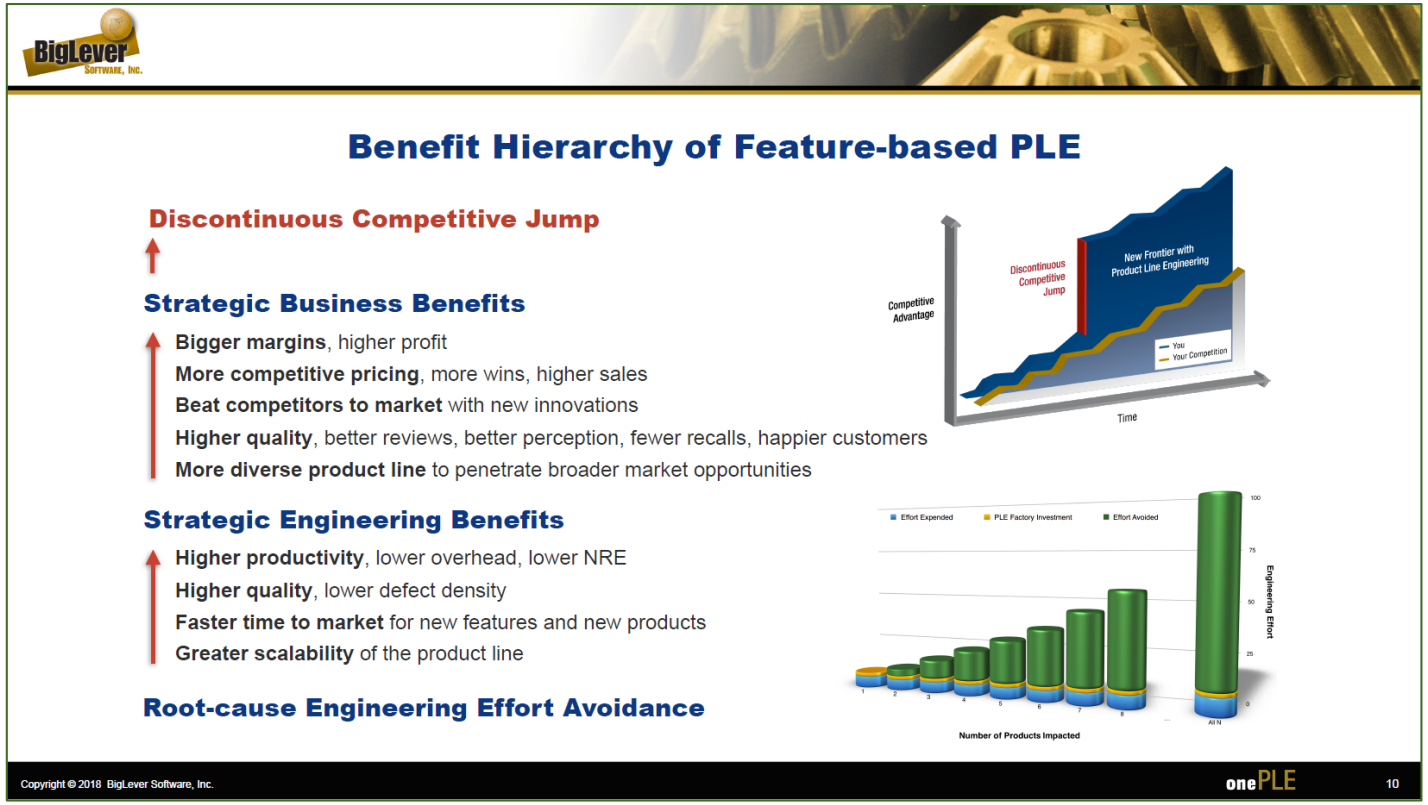
40% Cost Savings

Benefits of Feature-based PLE Factory

The more shared assets you integrate into the PLE Factory Configurator and

the more product variants are offered,

the more you save $$$



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