Enabling Design Reuse for a Complete Digital Thread

Sean Callahan, PhD, TF
Kevin Puterbaugh

RROI #17-00630

Biographies

- **Sean Callahan** is a Technical Fellow working for The Boeing Company. He has received a PhD in physics from the California Institute of Technology and an MBA from Seattle University. He has been at Boeing since 1988 and his research focuses on developing product information models to support design automation, knowledge-based engineering and computer aided engineering. He developed and patented Extended Generic Product Structure (EGPS) technology which solves the problem of sharing detailed design content between configurations (versions, variants and branches) of hierarchical, generalized product structures. EGPS has been implemented in a Boeing internal application that compares all design content differences between configurations of CATIA models of parts, assemblies and installations. He current focus is on applying this technology across abstractions levels of product design from requirements to functions to logical system designs to various physical levels of design representation. He has previously focused on high performance visualization, solid modeling, and rule-based, semi-automated design. Sean was the design data architect for a Boeing-developed system design tool being used on the 787 program, based on Siemens PLM's product SLATE, to capture a computer sensible representation of the system design. Sean has served as an associate editor for the Journal of Computer Science in Engineering (JCISE) in informatics and has published the results of his research in several publications.

- **Kevin Puterbaugh** is a research scientist working for The Boeing Company. He received a BS in Computer Science from Michigan State University. He has been at Boeing since 1986. His work focuses on large-scale visualization, product representation and design automation tools. He is the co-architect and lead developer for an advanced system that analyses fine-grain changes between general, hierarchical structures. He has implemented specific solutions of this tool for Autodesk Inventor, CATIA V5 and various EBOM structures. His work has resulted in several patents and journal publications.

Main Point

- **Major gaps in PLM data-management:**
  - **Fine grain design-reuse / change-analysis**
  - **Design change propagation**
  - **Sharing and remembering are mutually exclusive**
- **These gaps disables supporting digital twin and digital thread visions across lifecycle.**
- **This talk will present, Extended Generic Product Structure (EGPS) a patented, validated solution to these gaps.**

- **Part 1 – Business Case and High-level Technical Descriptions**

Boeing's Operational Foundation

Boeing depends on change analysis across business operations:

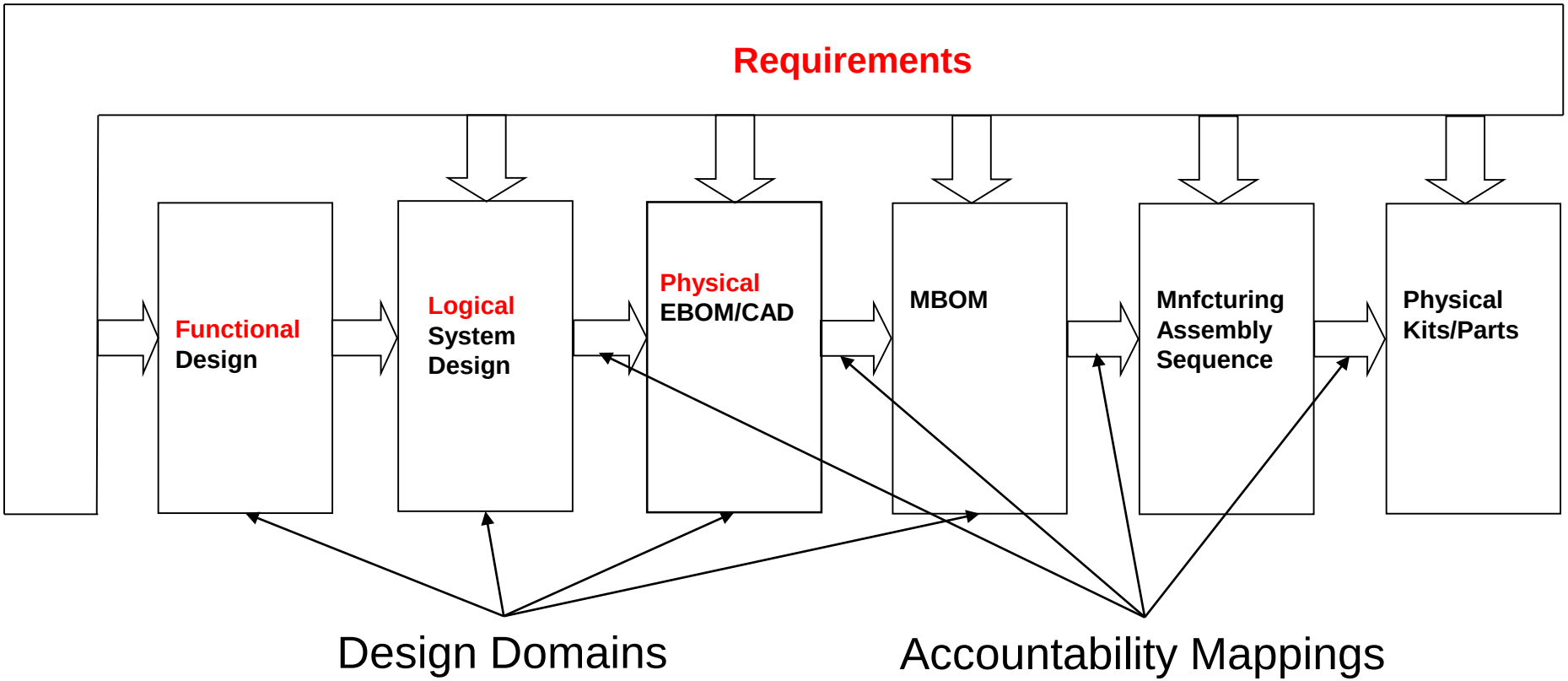
- Certification is net-change based
- Design review
- Manufacturing planning updates
- Part and material ordering
- Subassembly supplier cost adjustments (72 step process to determine change!)
- …
- **NOTE**: At companies that design and manufacture complex product families, workers can spend between 20-80% of their time understanding design change, before they can do their real job.

Key associated pain point and PLM gap:

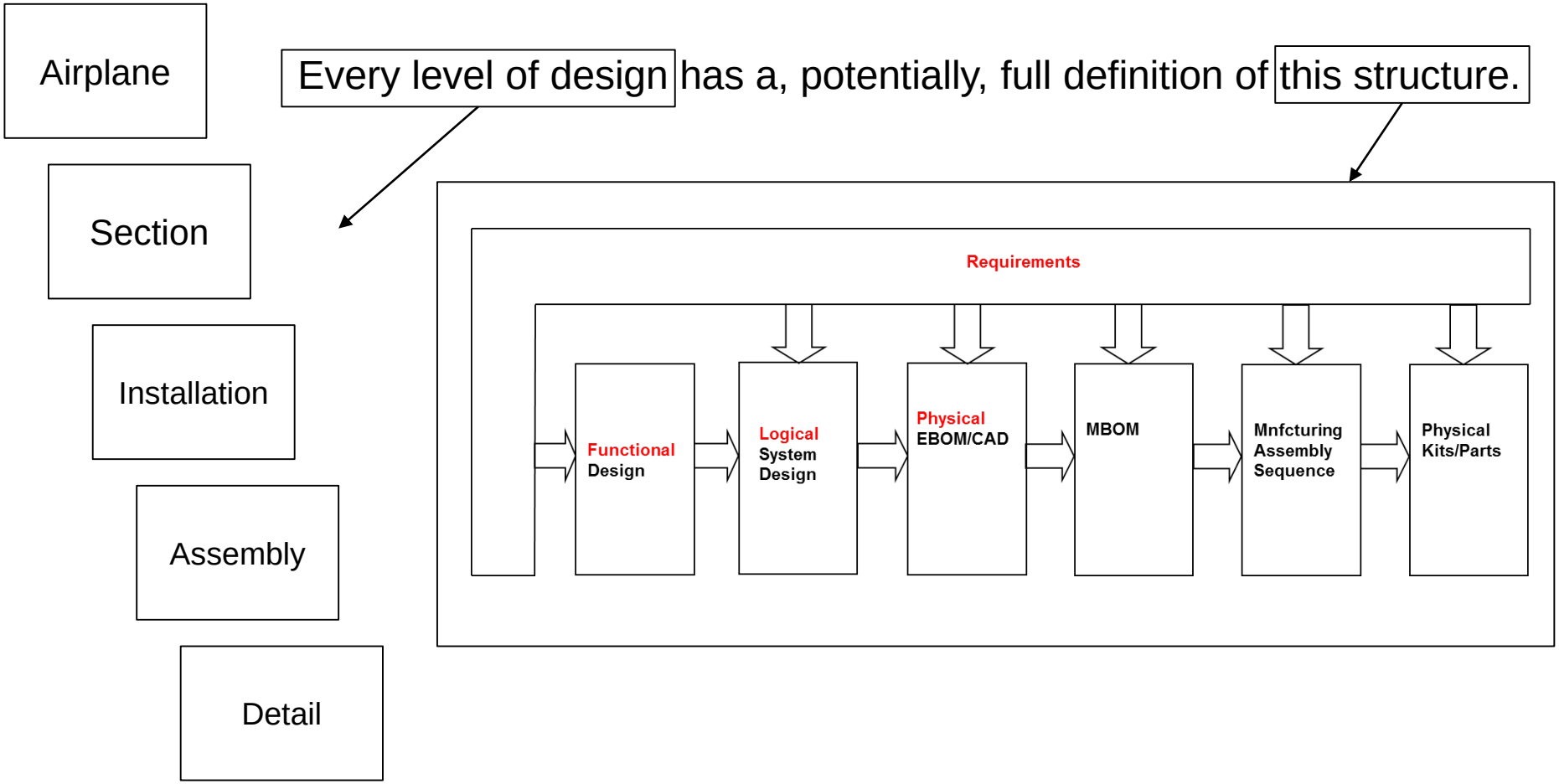
- COTS PLM systems' design reuse capabilities are insufficient to automate change understanding, **leading to manual labor, extra flow time and rework.**

The digital landscape

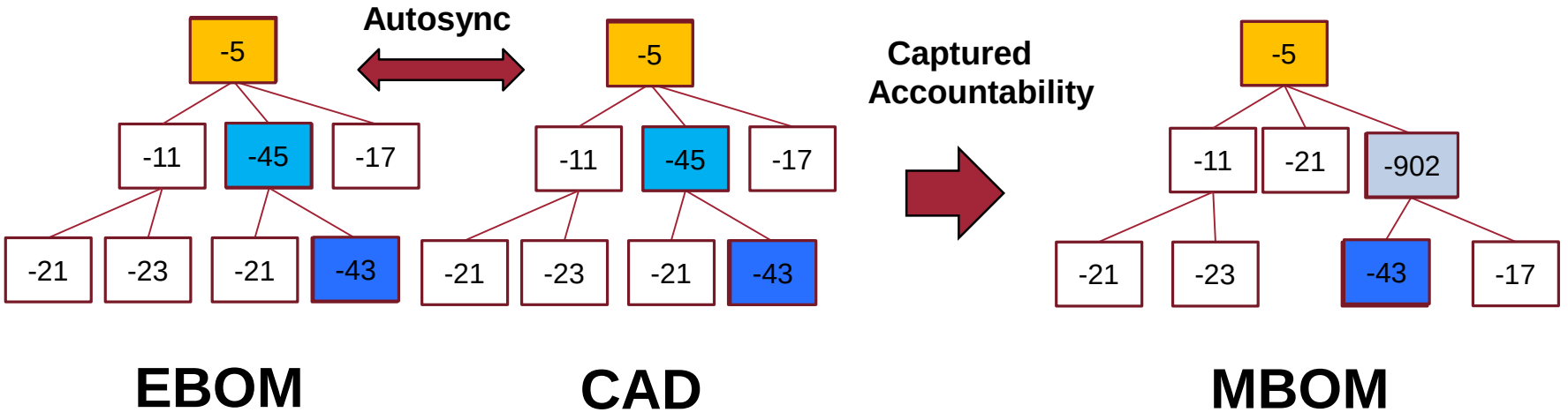
NOTE: There is no time in this picture



Single Source of Truth: Logical Design Data Reuse



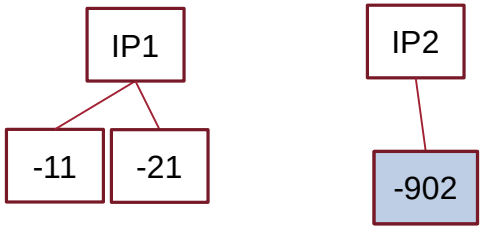
Abstracting the product enables design content sharing.



All instructions (text and geometric) are auto-updated with explicit call-out of change content.

Captured Accountability

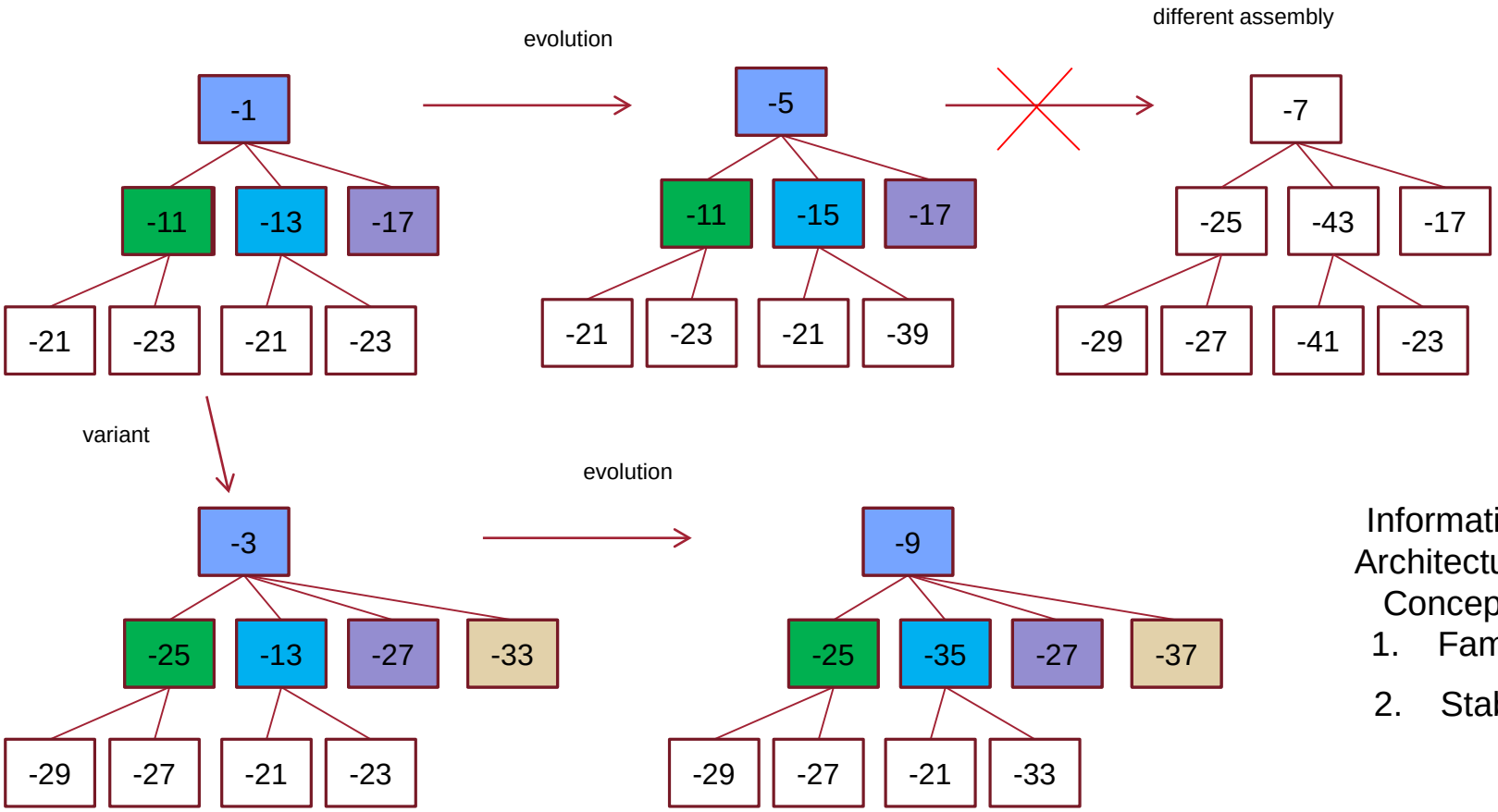
Plan



Minimal in-context instructions <u>not</u> requiring extensive research – "full kit"!!!

Abstracting the product enables design content sharing.

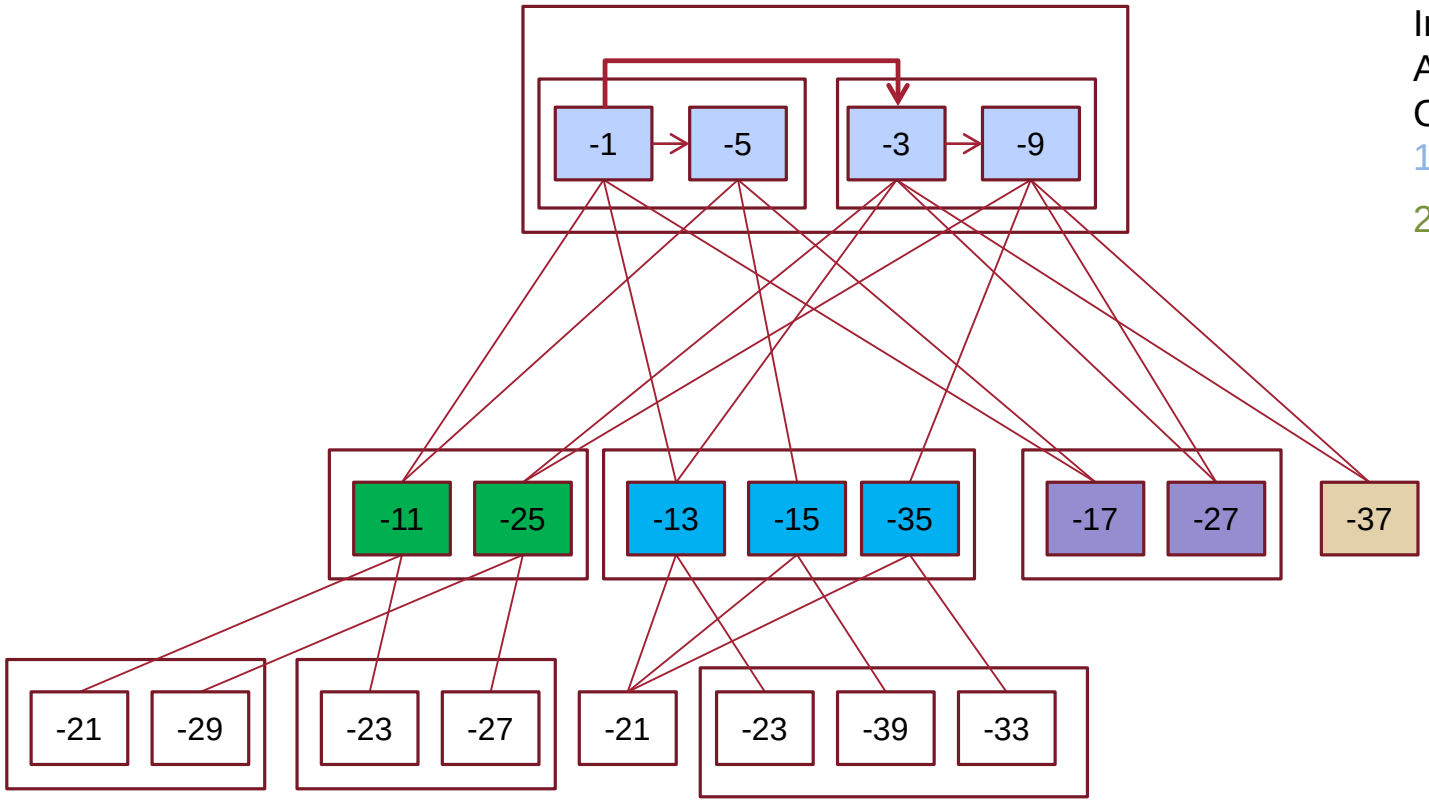
Variation of a product structure implies a logical structure



Information Architecture Concepts:

1. Family
2. Stable Usage

The logical structure can be constructed from configs



Information Architecture Concepts:

1. Family
2. Stable Usage

Twelve-brick Variant Comparison

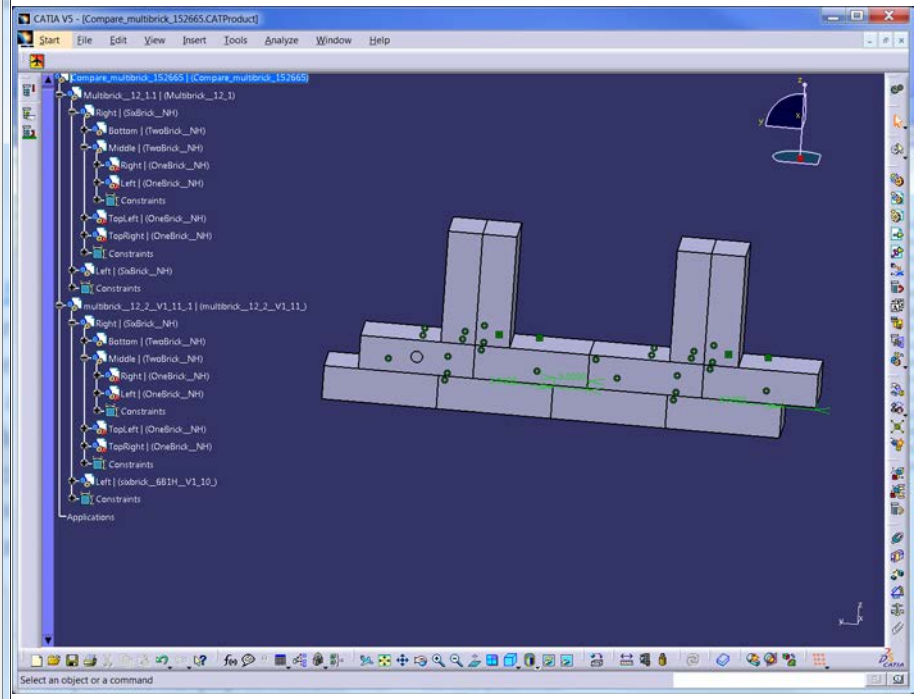
EBOM-CATIA: D:\CatiaData\Multibrick\egpsDB_12\data - [Part and Assembly Catalogue <MainLine>] - [Configuration Tree: ...

File Edit Options Windows EBOM-CATIA Help

Find Object | Refresh | Action Documention | Show All | Modified Only | All but Same

EBOM-CATIA: Comparing 2 versions of Module u'multibrick'

Status	Logical Structure	Reference Definition	Variant: 12_1	Variant: 12_2
Mod	multibrick	multibrick	12_1	12_2
Equiv	Properties			
Mod	Connections		12_1	12_2
	Properties			
	Coincidence.1		12_1	12_1
Mod	Fix.2		12_1	12_2
	Offset.6			
Ignore	Document		12_1	12_2
	Right	sixbrick	12_1 : 6BNoHoles	12_1 : 6BNoHoles
	Properties			
	Connections		^ : 6BNoHoles	^ : 6BNoHoles
	Bottom	twobrick	6BNoHoles : 2BNH	6BNoHoles : 2BNH
	Properties			
	Connections		^ : 2BNH	^ : 2BNH
	Right	onebrick	2BNH : NH	2BNH : NH
	Left	onebrick	2BNH : NH	2BNH : NH
	Middle	twobrick	6BNoHoles : 2BNH	6BNoHoles : 2BNH
	Properties			
	Connections		^ : 2BNH	^ : 2BNH
	Right	onebrick	2BNH : NH	2BNH : NH
	Left	onebrick	2BNH : NH	2BNH : NH
	TopLeft	onebrick	6BNoHoles : NH	6BNoHoles : NH
	TopRight	onebrick	6BNoHoles : NH	6BNoHoles : NH
Mod:R	Left	sixbrick	12_1 : 6BNoHoles	12_2 : 6B1H
	Properties			
Mod:R	Connections		^ : 6BNoHoles	^ : 6B1H
	Bottom	twobrick	6BNoHoles : 2BNH	6BNoHoles : 2BNH
	Properties			
	Connections		^ : 2BNH	^ : 2BNH
	Right	onebrick	2BNH : NH	2BNH : NH
	Left	onebrick	2BNH : NH	2BNH : NH
Mod:R	Middle	twobrick	6BNoHoles : 2BNH	6B1H : 2BH
	Properties			
Mod:R	Connections		^ : 2BNH	^ : 2BH
	Right	onebrick	2BNH : NH	2BNH : NH
Mod:R	Left	onebrick	2BNH : NH	2BH : H
	TopLeft	onebrick	6BNoHoles : NH	6BNoHoles : NH
	TopRight	onebrick	6BNoHoles : NH	6BNoHoles : NH
	ExtraBrick1	onebrick		
	OneBrick__NH.1	onebrick		



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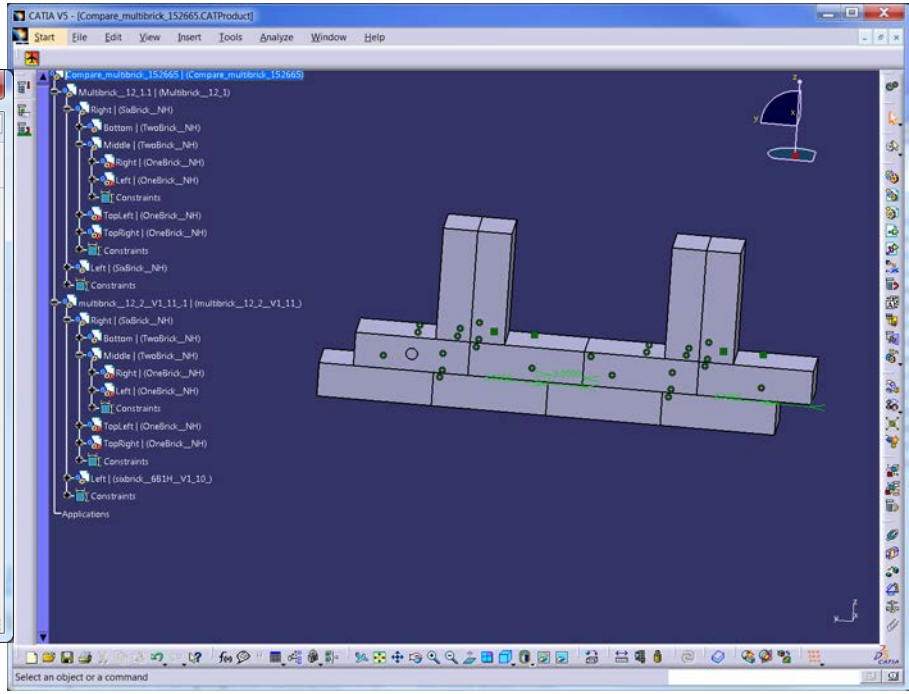
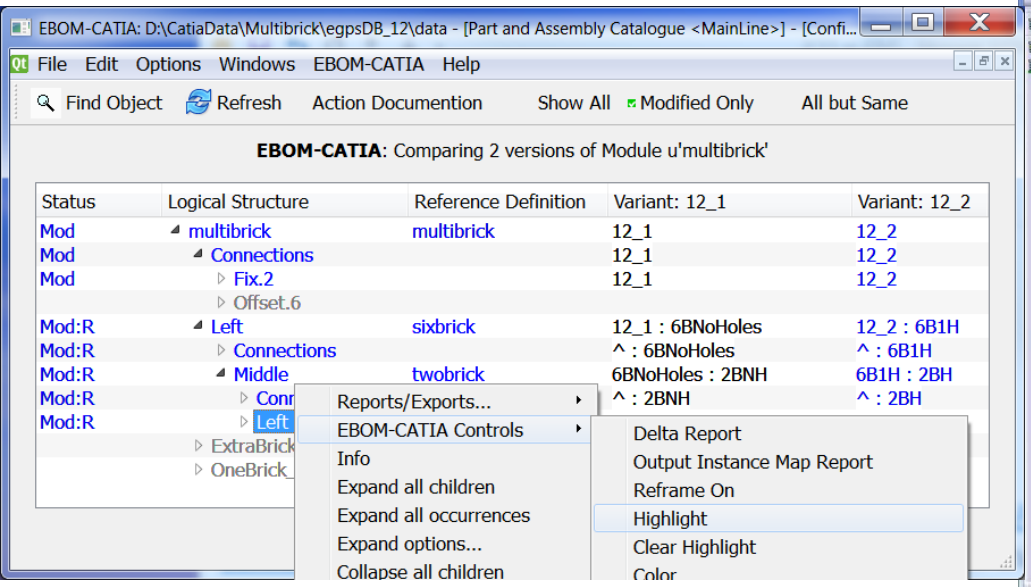
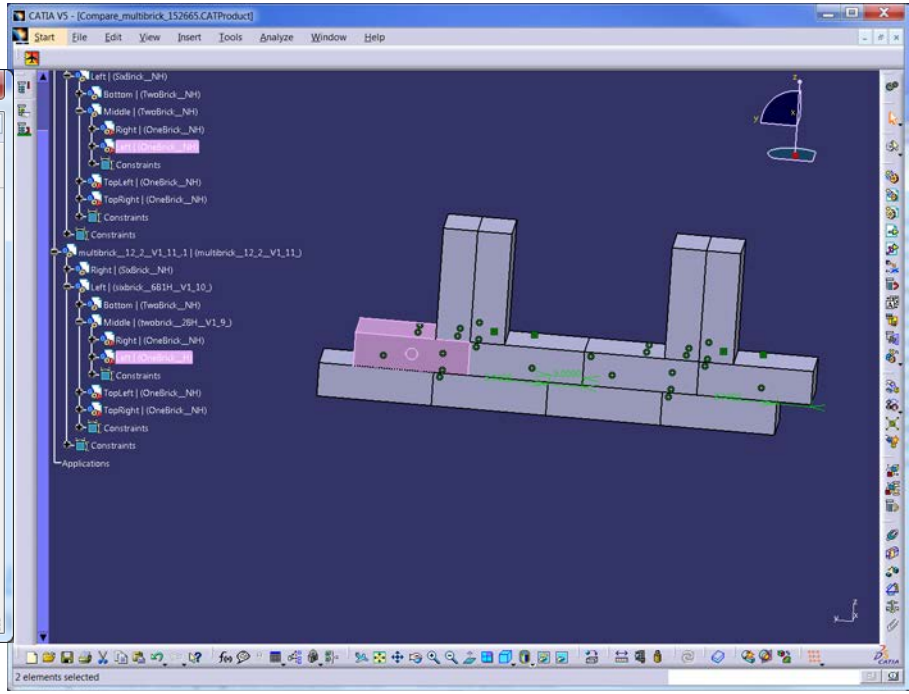


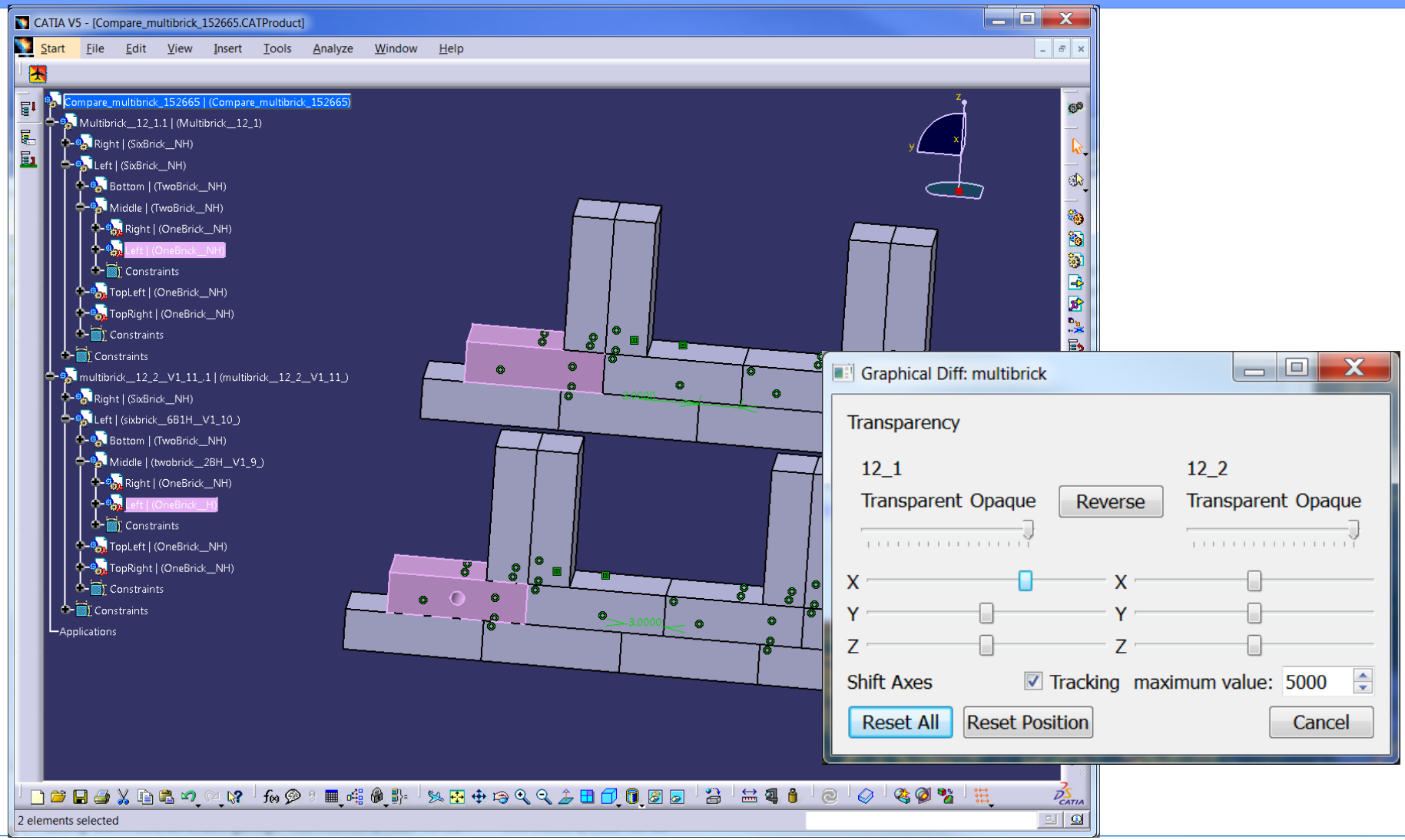
Twelve-brick Variant Comparison





Twelve-brick Variant Comparison

Global Product Data Interoperability Summit | **2017**



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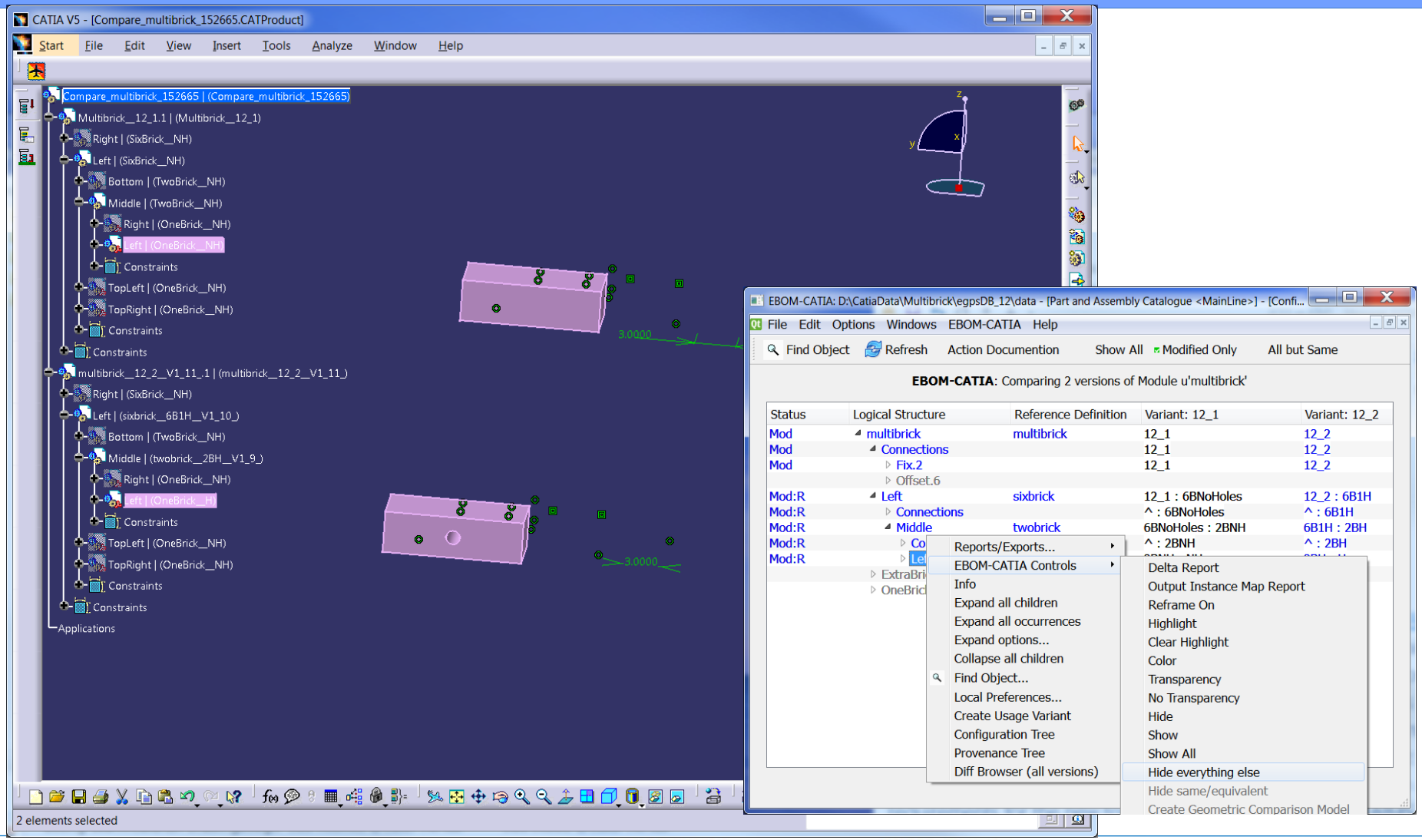
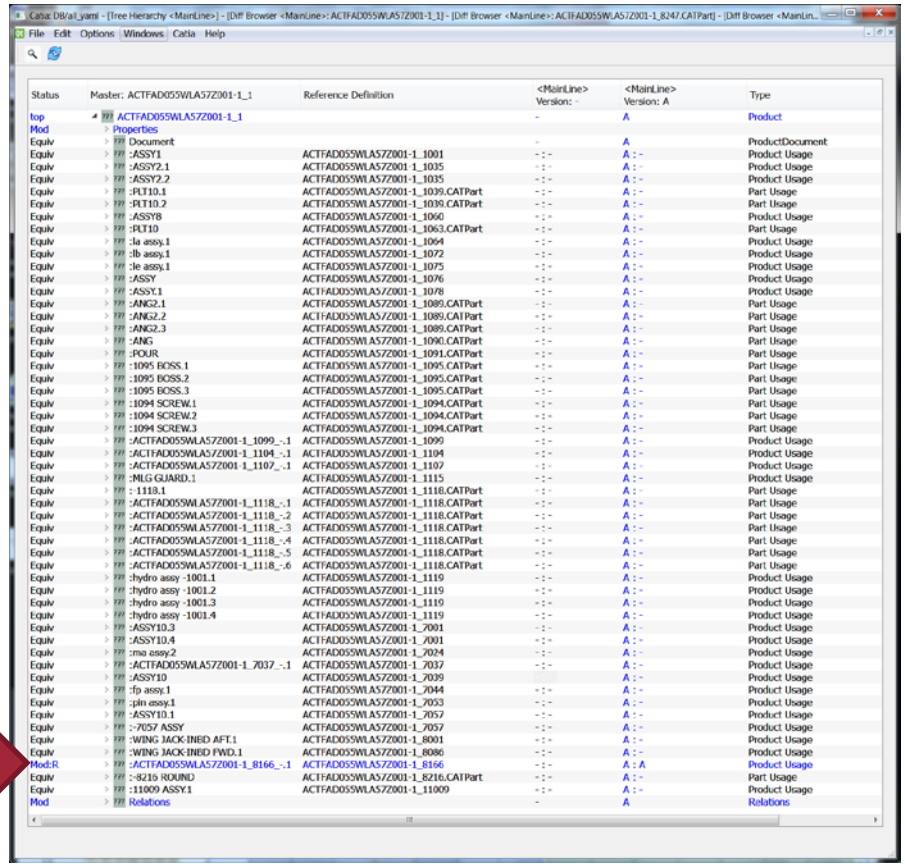


ChangeAnalysis Assembly Difference View

Actual change



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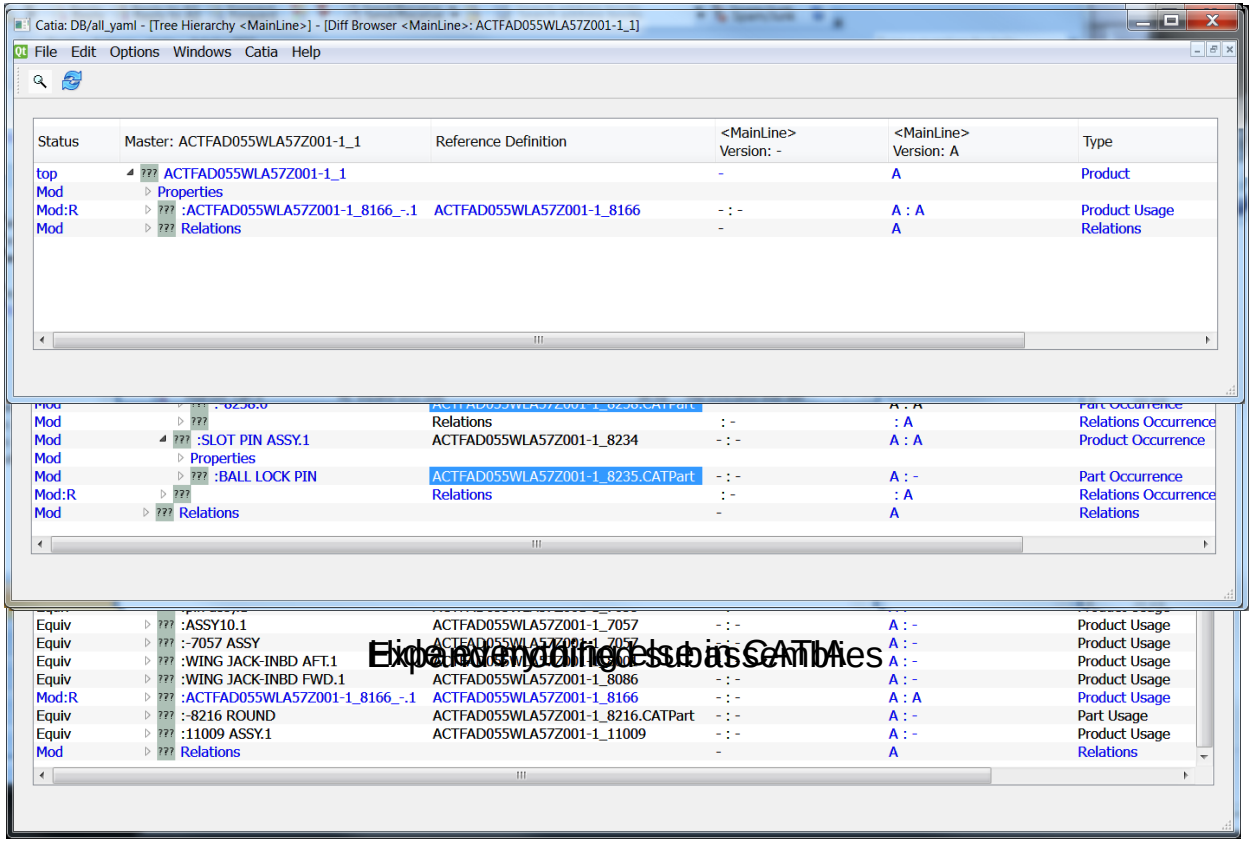
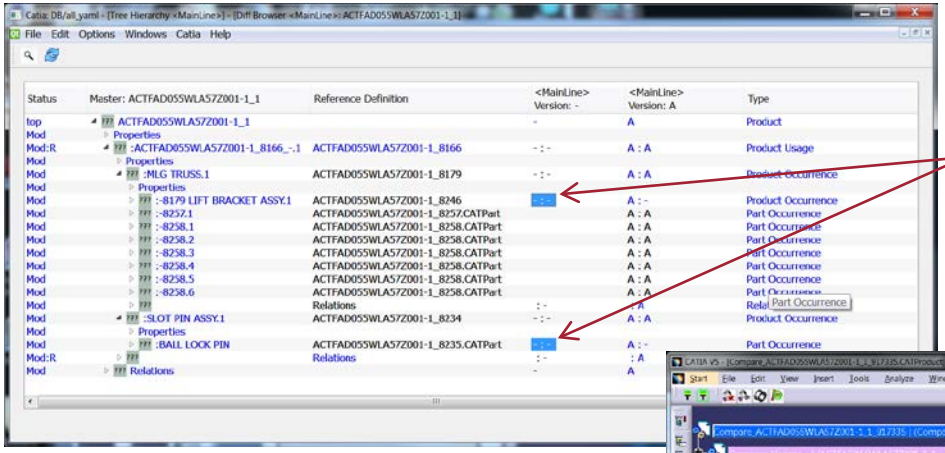
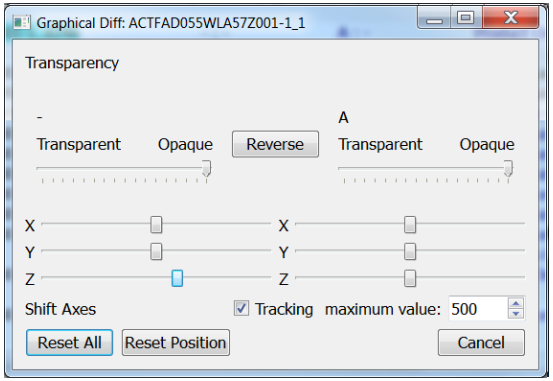


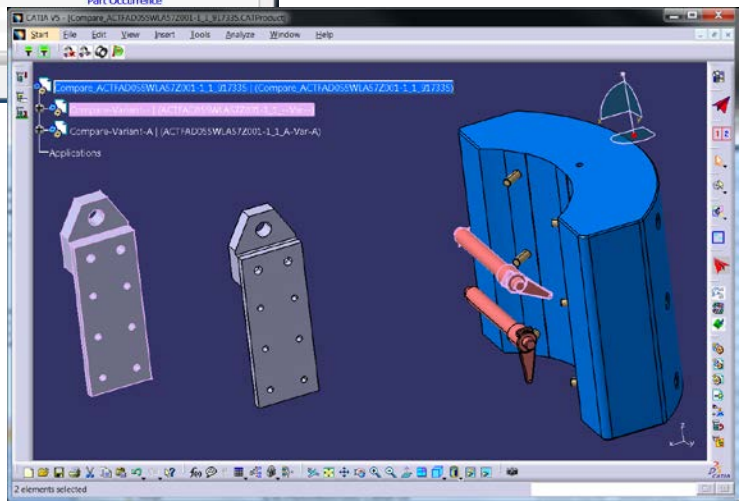
Turn off Same and Equivalent in browser

Zooming and Highlighting in Geometric Comparison

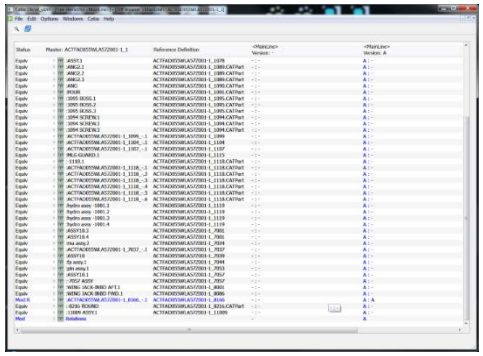


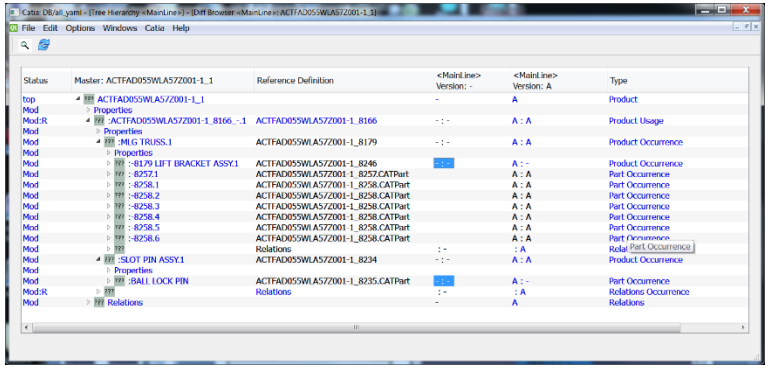
Highlight two common components in Rev-

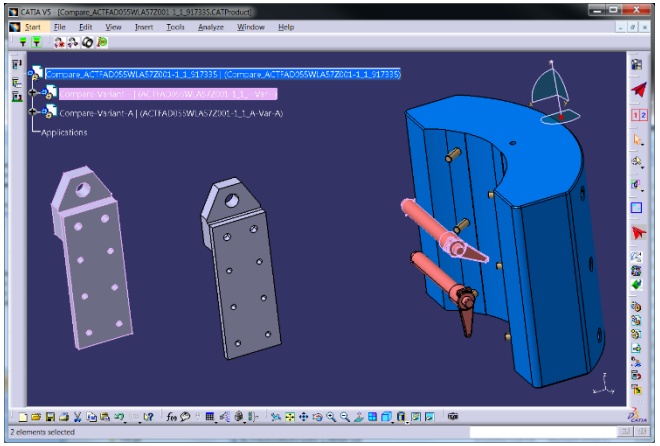




Summary of Drill Down Process







Conclusion

- **COTS tools do not support the kind of precise-configuration design-sharing presented here.**
- **They can either have “max-config” sharing or duplicated precise configurations.**
- **Extended Generic Product Structure offers a proven, implementable solution that enables design content sharing across the digital thread.**
- **Two implementation paths:**
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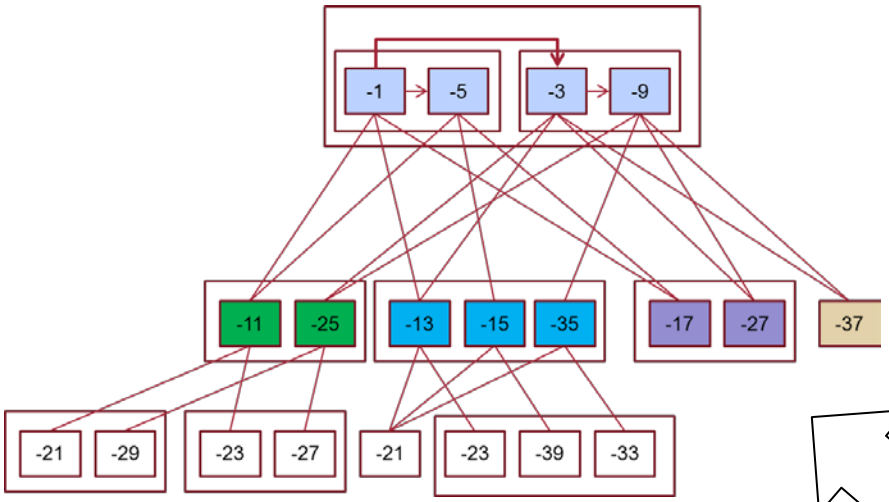
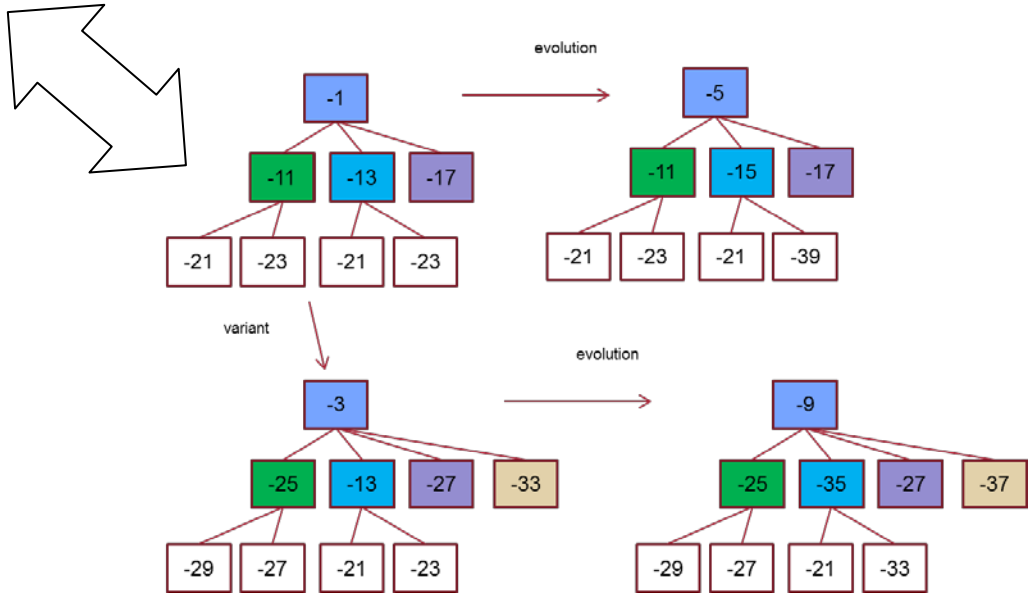
Duplication with Reuse Attributes

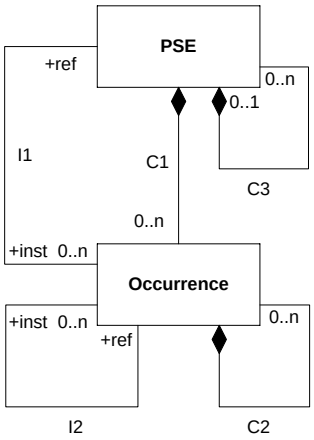


It is possible to derive complete shared representation is sufficient information is captured and managed at authoring time, in an duplicated representation.



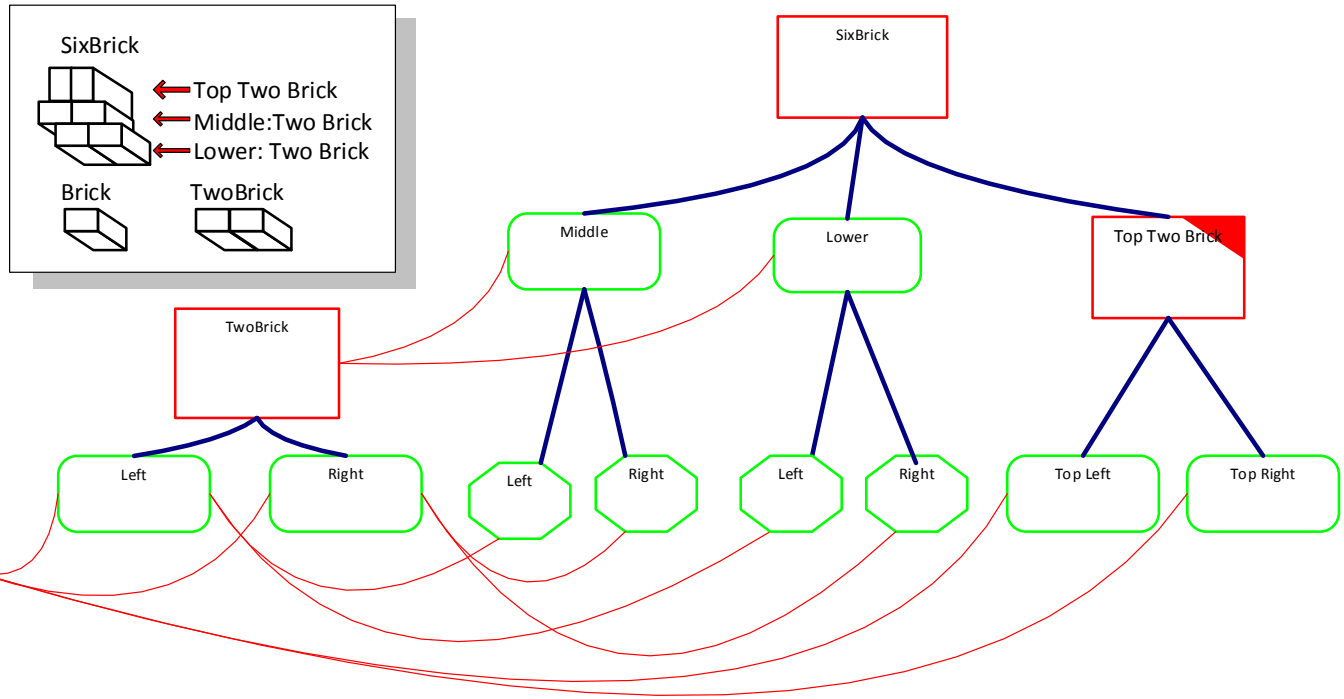
- **Part 2 – Technical Product Structure and Data Model Level Description.**

2005 Extended Generic Product Structure: SV

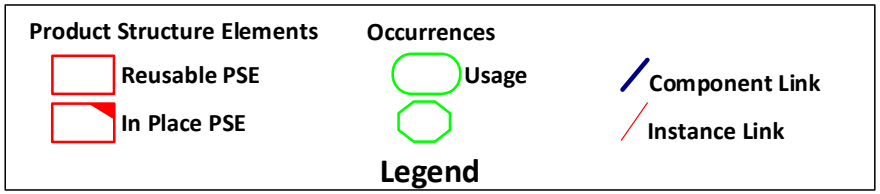


Single Variant Product Structure Pattern

C1, 2, 3 - Composition

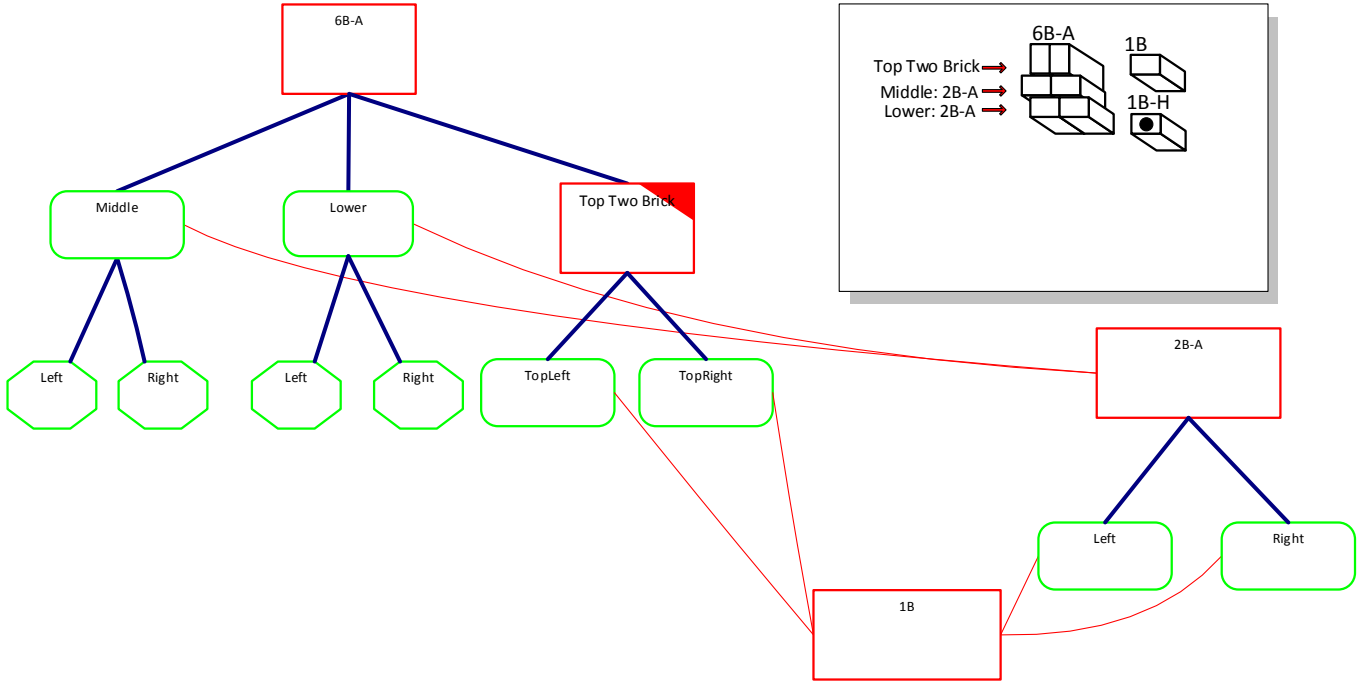


Part is a type (subclass) of PSE



2006 Publication: [Extended Generic Product Structure: An Information Model for Representing Product Families]

2005 Extended Generic Product Structure: SV Mess



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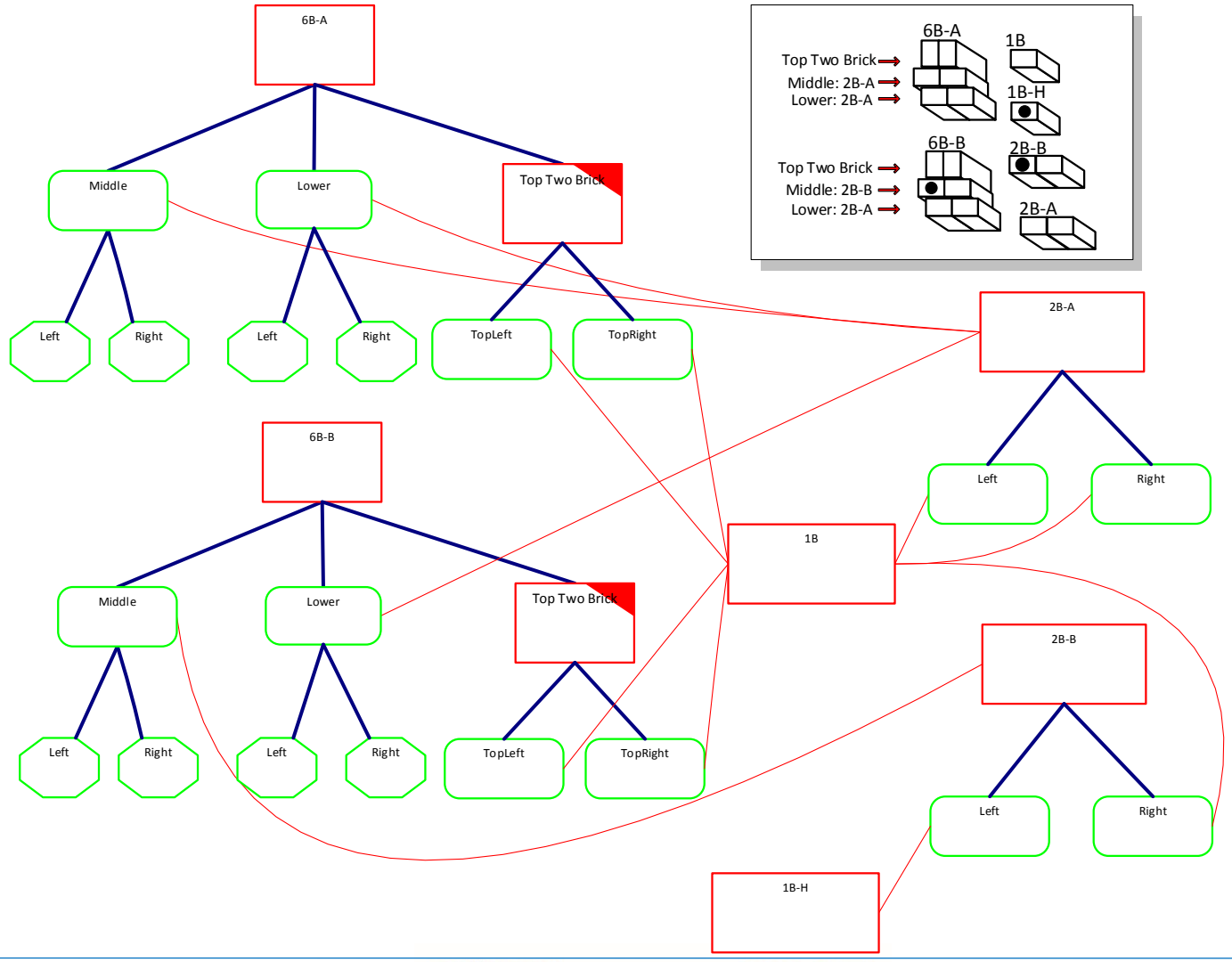


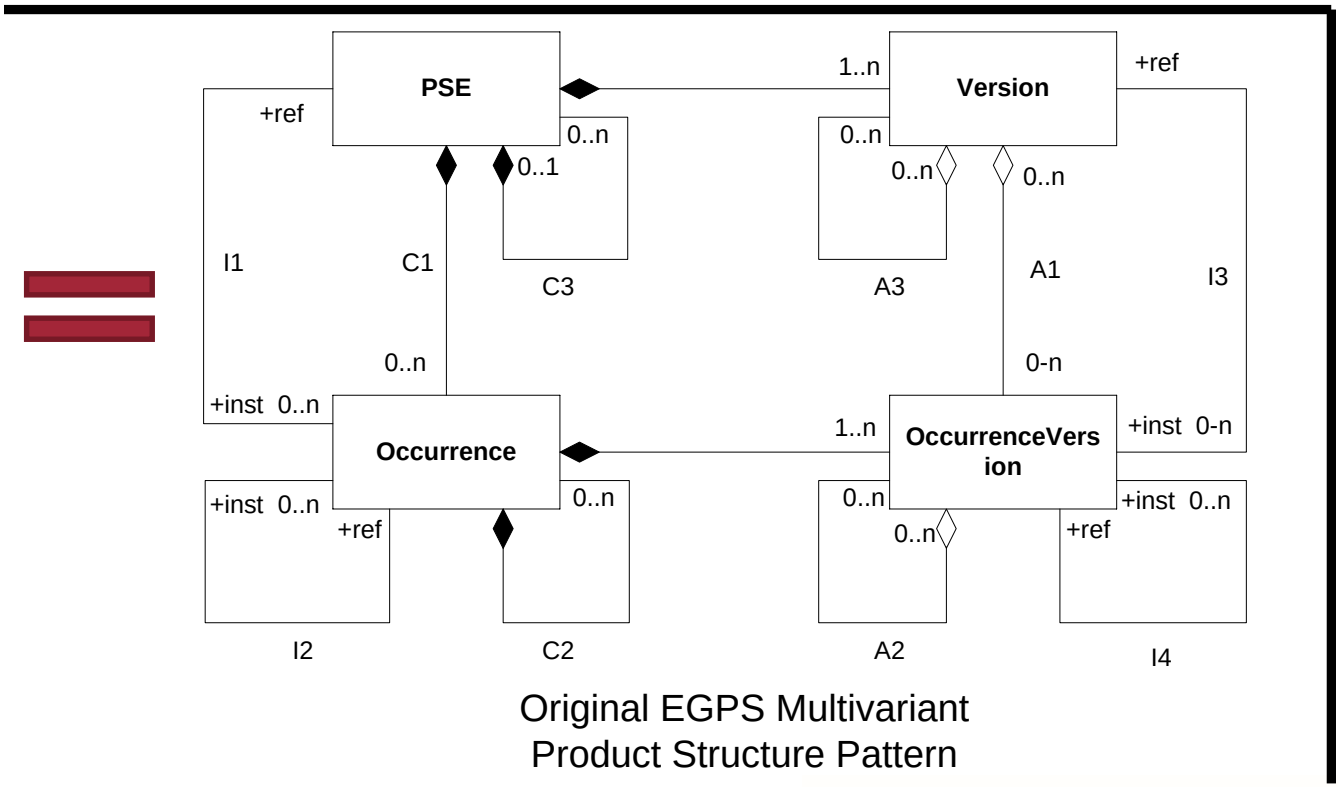
EGPS Patents and Applications Relevant to this Presentation

1. Sean Callahan, “A LOGICAL HIERARCHICAL DATA MODEL FOR SHARING PRODUCT INFORMATION ACROSS PRODUCT FAMILIES”, 2002, US Patent - 7085776.
2. Sean Callahan, APPARATUS AND METHOD FOR MANAGING MULTIVARIANT ASSEMBLY DATA MODELS, 2003, US Patent - 7038677.
3. Sean Callahan, “Methods and apparatus for information modeling”, 2006, US Patent – 8275799.
4. Sean Callahan, “Methods and apparatus for creating and utilizing templates in connection with information modeling”, 2008, US Patent – 8402007
5. Sean Callahan, “Model for Managing Variations of a Product Structure for a Product”, 2012, Application Number - 20130218527
6. Sean Callahan, Carl Pearson, John Monahan, “User Interface for Presenting Information About a Product Structure for a Product”, 2012, US Patent Pending – serial number 13/445227.
7. Sean Callahan, Carl Pearson, John Monahan, “User Interface and Method for Displaying Representation of a System Modeled According to a Plurality of Structural Elements”, 2010, US Patent Pending – serial number 12/714270.
8. Sean M Callahan, Kevin D Puterbaugh, “Model for managing variations in a product structure for a product”, 06/09/16 - serial number 20160162607

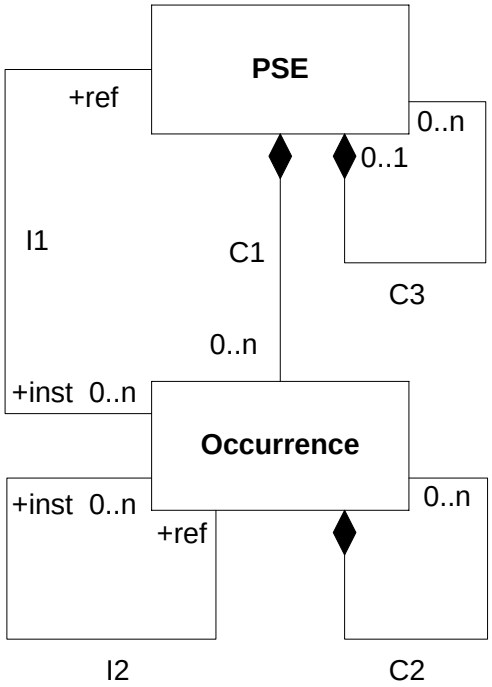
Publication covering 3-5, above:
http://computingengineering.asmedigitalcollection.asme.org/article.aspx?articleid=1400557

2005 Extended Generic Product Structure: MV

Traditional Master Version Model



Original EGPS Multivariant Product Structure Pattern



Single Variant Product Structure Pattern

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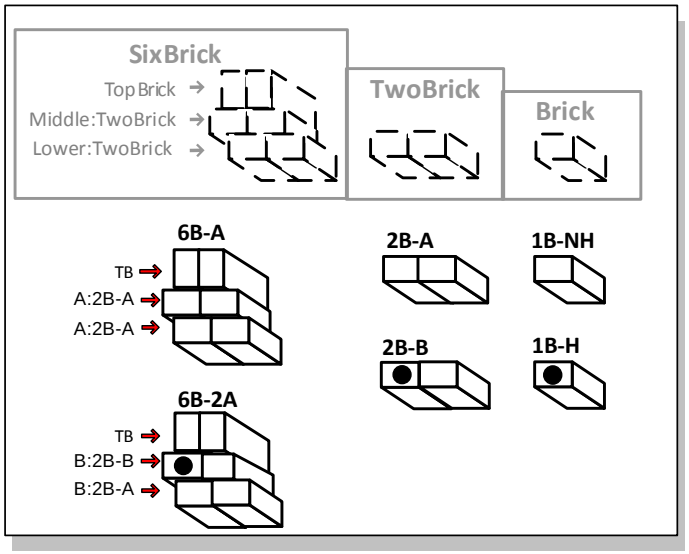

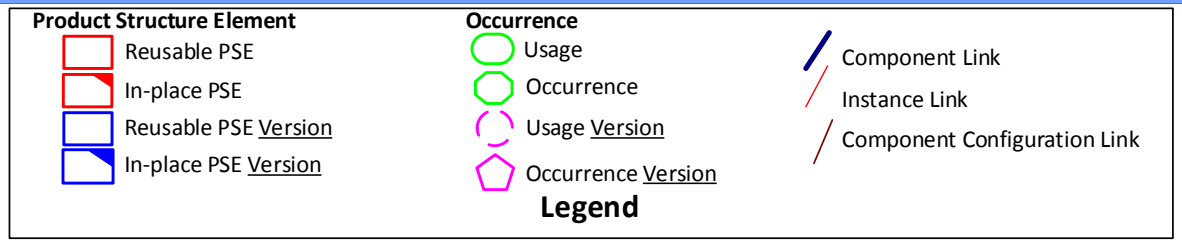

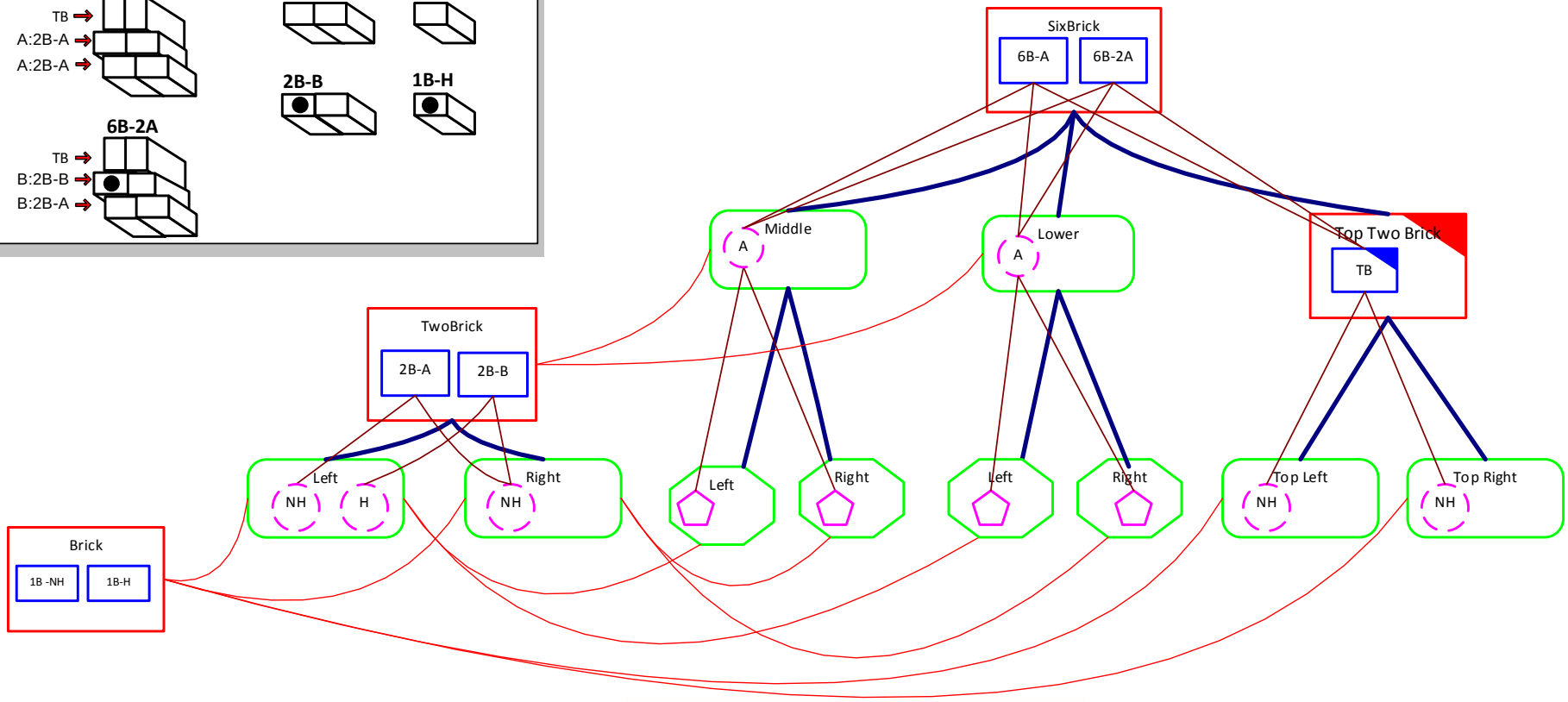

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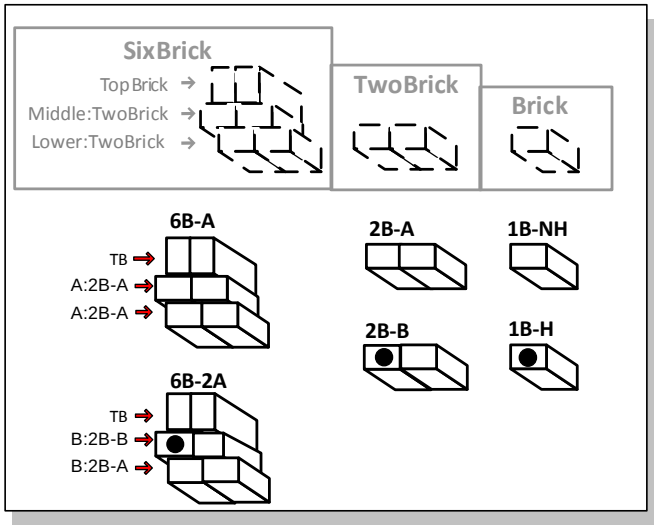
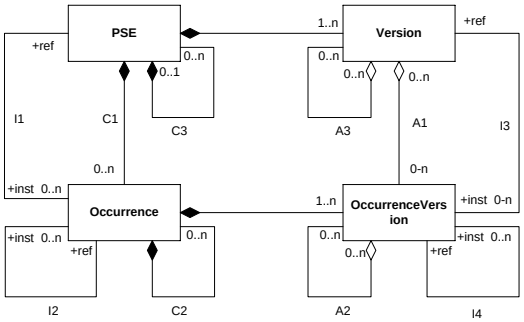




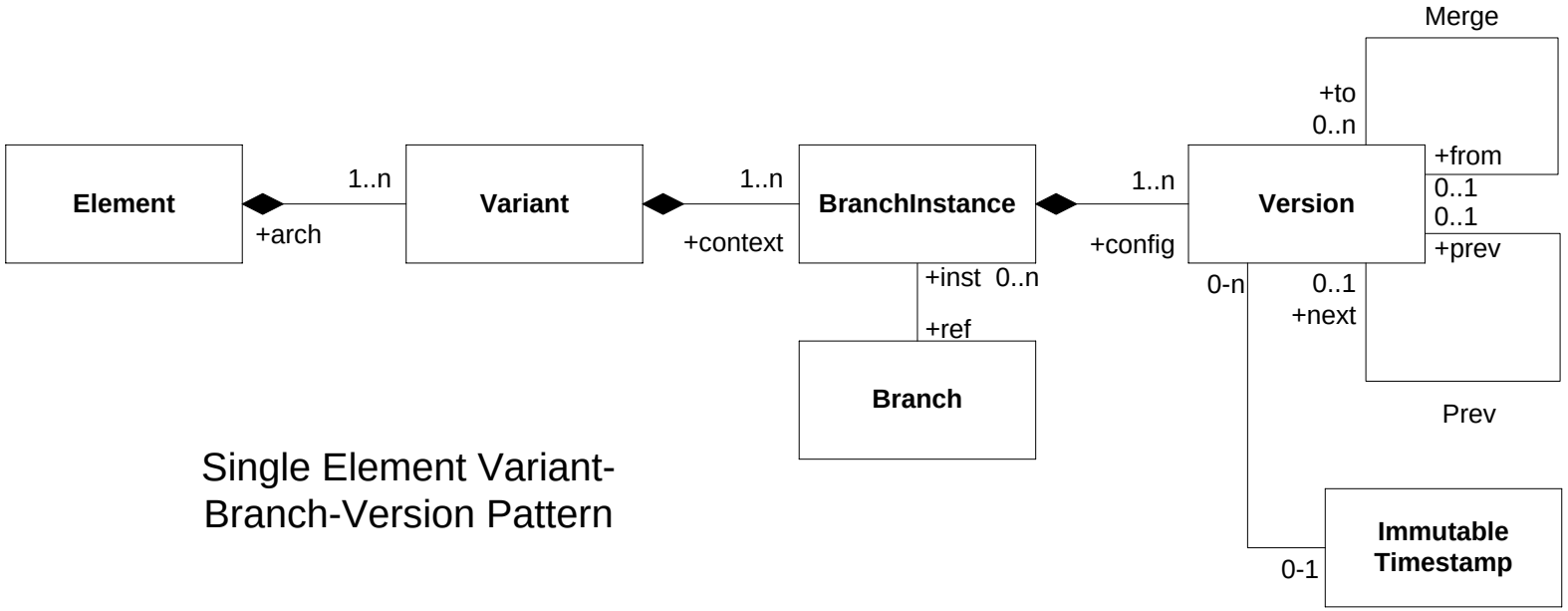
Original EGPS Multivariant Product Structure Pattern

2015 EGPS: Generalize Family Pattern

From

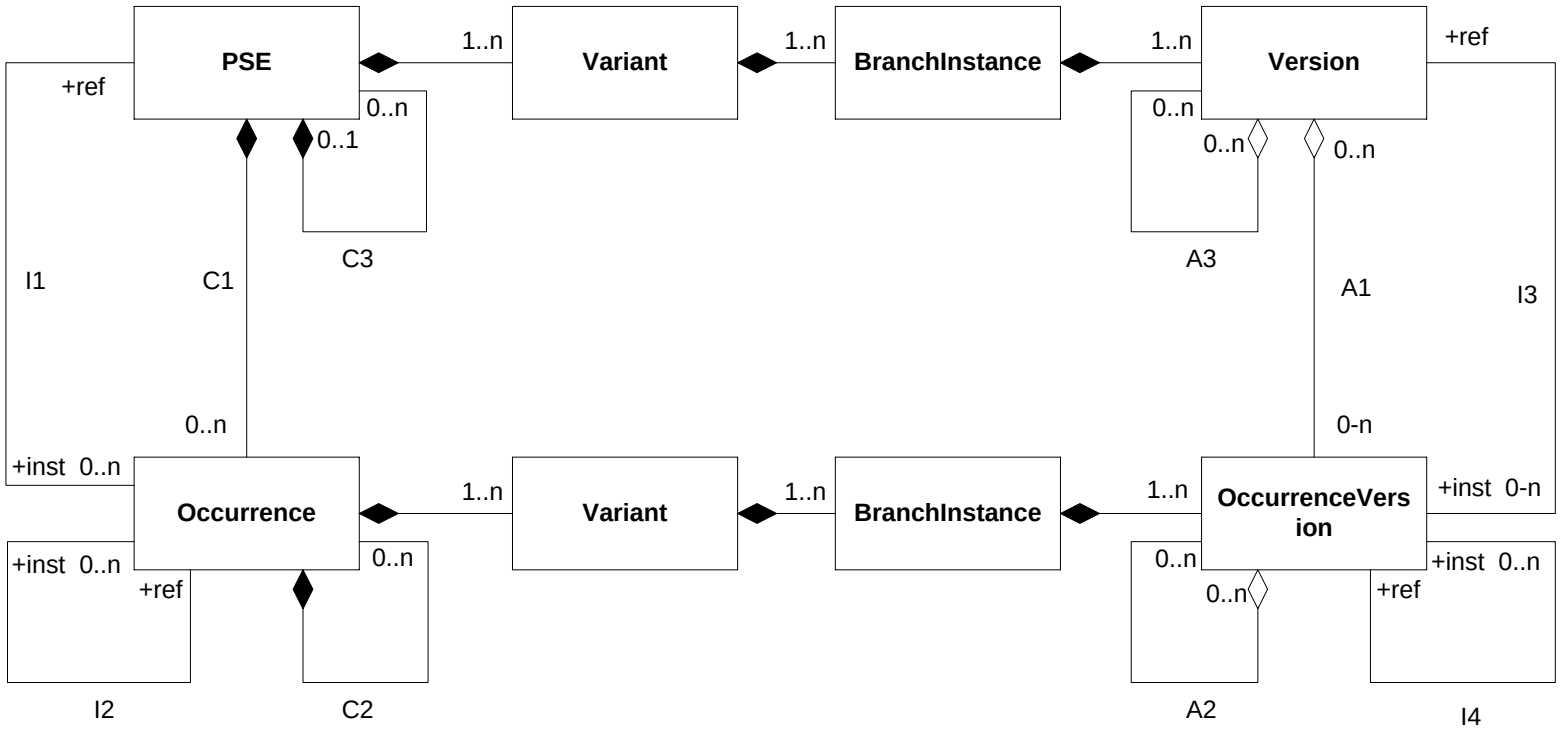
Traditional Master Version Model

To



Single Element Variant-Branch-Version Pattern

2015 EGPS: Variant, Branch, Version



Extended Generic Product Structure (EGPS) Pattern

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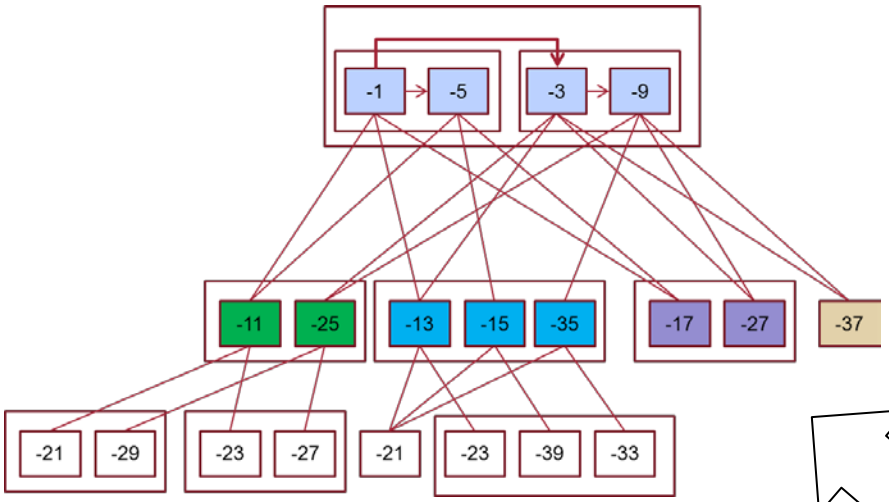

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