

Product Line Engineering Digital Thread: Now and the Future

Presented by
Matthew Reilly (Northrop Grumman Corp.)
June Kobayashi (Northrop Grumman Corp.)
With Support from Paul Kepinski (Northrop Grumman Corp.)

GLOBAL PRODUCT DATA INTEROPERABILITY SUMMIT 2023



Presenters Bio

Global Product Data Interoperability Summit | 2023



Matthew Reilly is a Product Line Coach with Northrop Grumman's Product Line Center of Excellence within the Mission Systems sector. He works with product lines at various stages of maturity supporting them in the areas of business strategy, technical approach, and governance. Matt's professional experience spans across mechanical design, model-based systems engineering, and software engineering. Matt holds an MS in Aerospace Engineering and an MBA from the Georgia Institute of Technology.



Paul Kepinski is working Product Line Digital Thread and Integration for Northrop Grumman's Product Line Center of Excellence within the Mission Systems sector. He works on evaluating and road mapping out potential integrations with product line ideology and existing systems across engineering disciplines. Paul holds an MS in Mechanical Engineering from Florida Institute of Technology.



June Kobayashi is the Space Vehicle & Payload Products Digital Transformation and Product Line Engineering (PLE) Lead at Northrop Grumman Space Systems, where she stood up the processes and technology infrastructure to support PLE since 2015. She has trained and guided the team members for many product lines across the enterprise and advised best practices for across NG. Prior to this, she managed and developed RF and Mixed Signal electronics for Northrop Grumman and other defense and commercial companies for over 37 years. She has BSEE and MSEE degrees from the University of California in Los Angeles.

A product line approach can be seamlessly applied across proposals, development, production, and sustainment.

This is already resulting in **faster times to market** and **reduced costs**, but there is even greater potential still to unlock through

Digital Threads.

All this promise is contingent on one central question:

Can our tools pass data across all disciplines from engineering to business to production to supply chain?

What are Product Lines & Product Line Engineering?

Global Product Data Interoperability Summit | 2023

- **Product Lines**

- A family of similar products or systems with variations in features¹

- **Product Line Subfamily**

- A proper subset of the member products of a product line

- **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 while efficiently and systematically managing the **variation** among the system

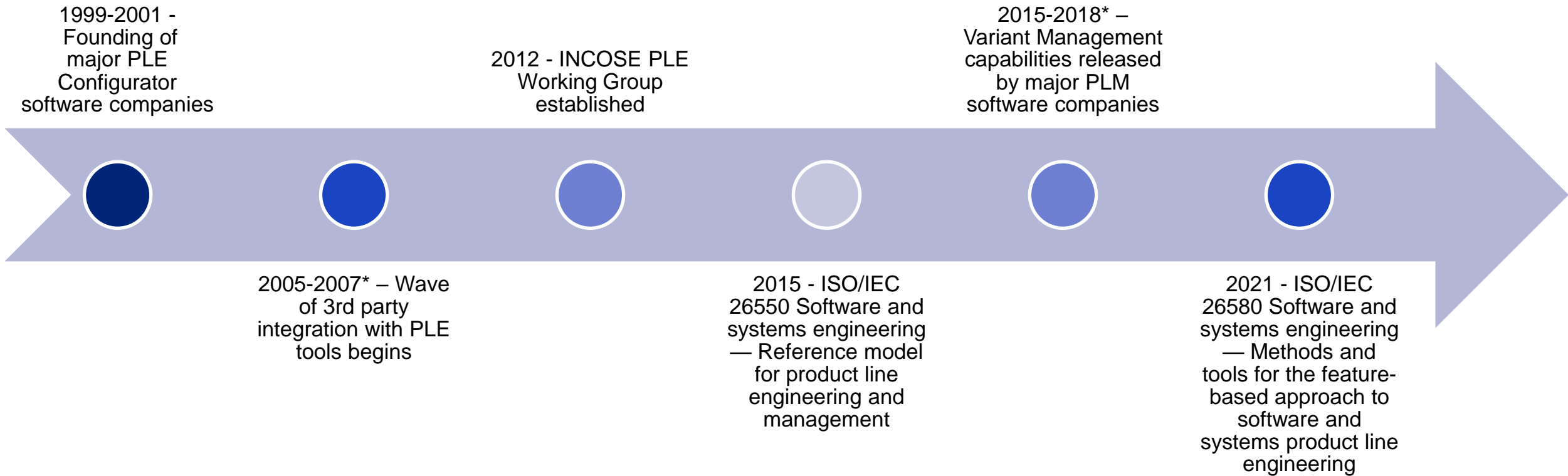
- **Shared Assets**

- Software and systems engineering lifecycle digital artifacts that compose a part of a delivered member product or support the engineering process to create and maintain a member product¹

1. "ISO/IEC 26580:2021." ISO, 21 Apr. 2021, www.iso.org/standard/43139.html.

A Brief History of Product Line Engineering (PLE) and Digital Threads

Global Product Data Interoperability Summit | 2023

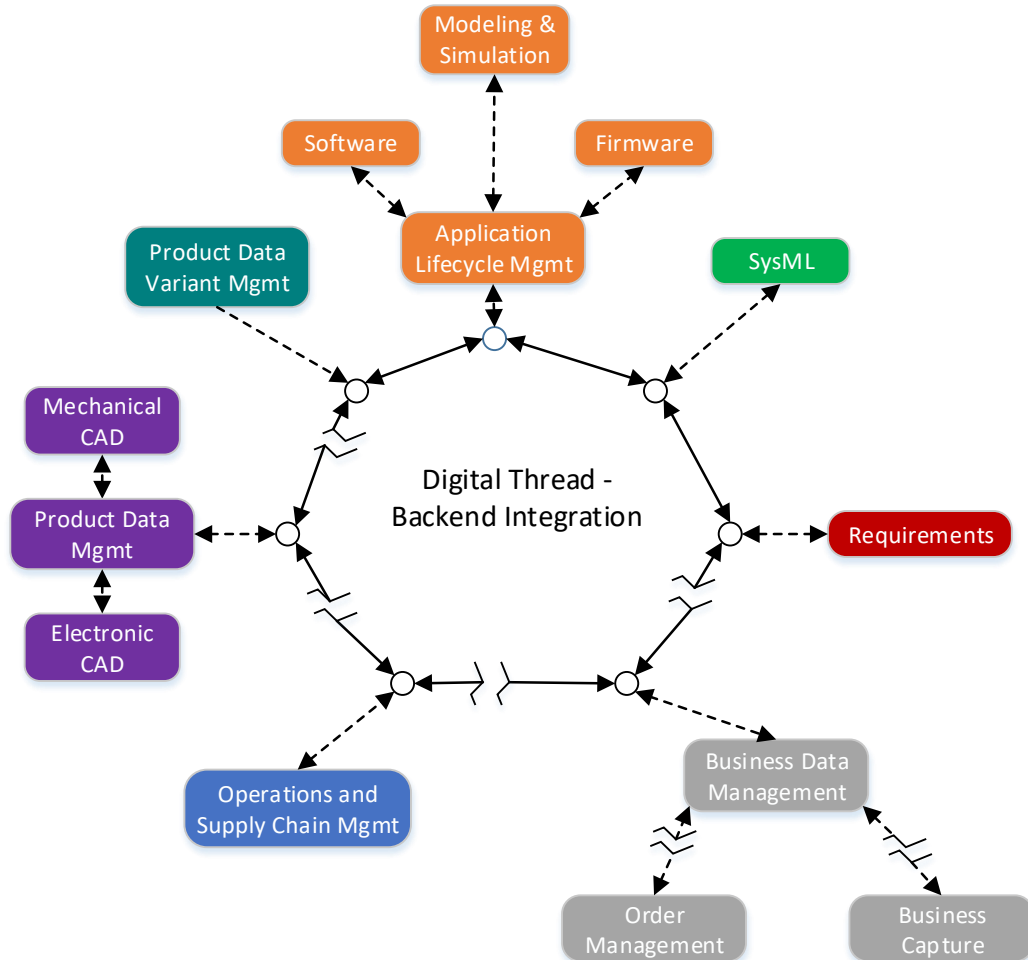


* Approximate dates provided based on available data

Existing State of Product Line Digital Thread

Global Product Data Interoperability Summit | 2023

Existing State

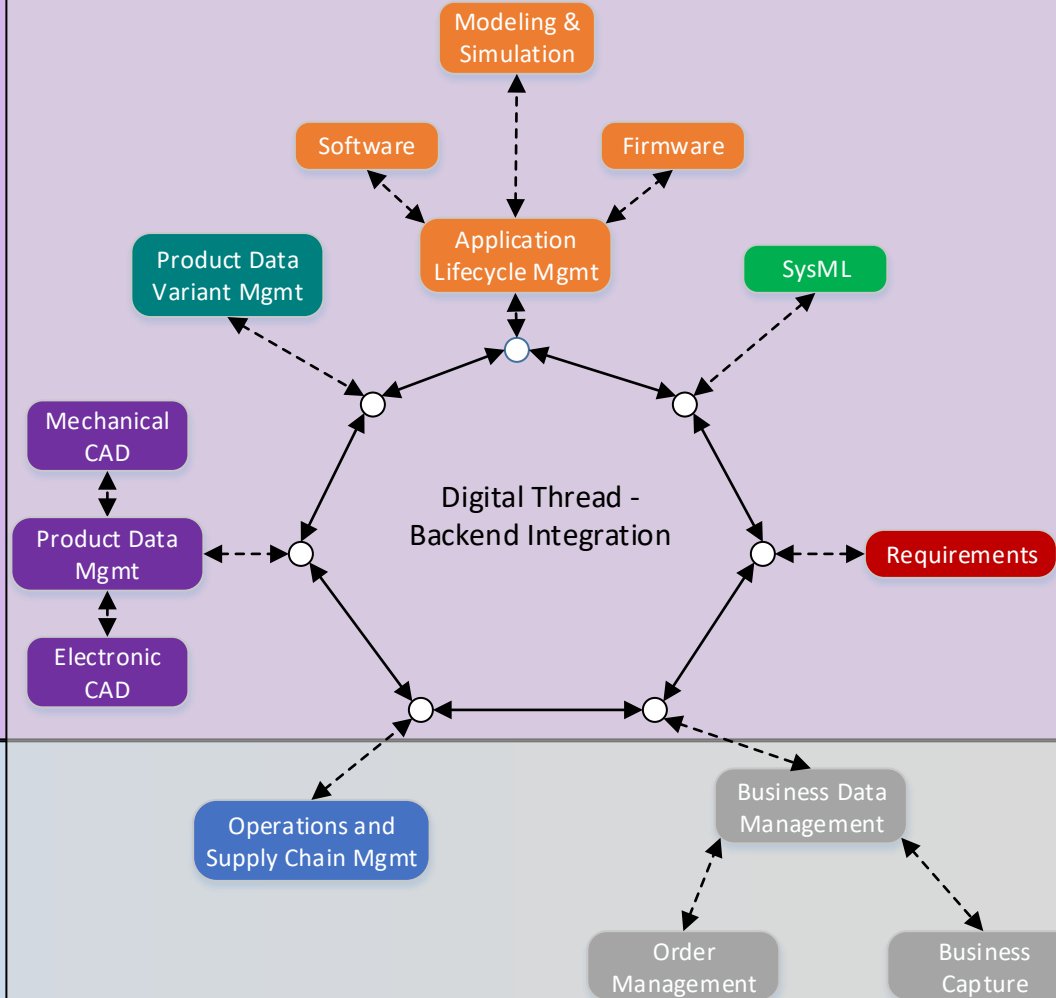


- **Importance of integrating variant data through various discipline ecosystems**
 - Single source digital thread for product line hierarchy
 - Enforcement of Product Line ideology throughout disciplines
- **What is missing?**
 - Universal Product Line data structure format (for example, some XML standard for PLE that allows export/import of product line structures between software/services that provide variant management of assets)
 - Native integrations between Variant Management and PLM/PDM, Model Server, and CM to drive Software/MCAD/ECAD
- **Definitions**
 - Product Line Portfolio – laying out the product lines, sub families, and existing product variants
 - Variant Management – building out product line structure and logic
 - PLM/PDM/Model/CM Server – ingesting the variant management digital thread to drive models in the various disciplines.

Where do we go from here?

Global Product Data Interoperability Summit | 2023

To reap the benefits of alignment across disciplines and provide additional cost avoidance, our product lifecycle management (PLM) tools must align with variation management strategies.



Engineering needs to leverage product line repositories and account for the benefits of reuse when assessing optimal solutions.

Business capture, investment, funding, order management, operations, and supply chain tools need to be configured for use by product lines.

Product Line Integration

Global Product Data Interoperability Summit | 2023



Product Line Integration with Product Lifecycle Management Systems

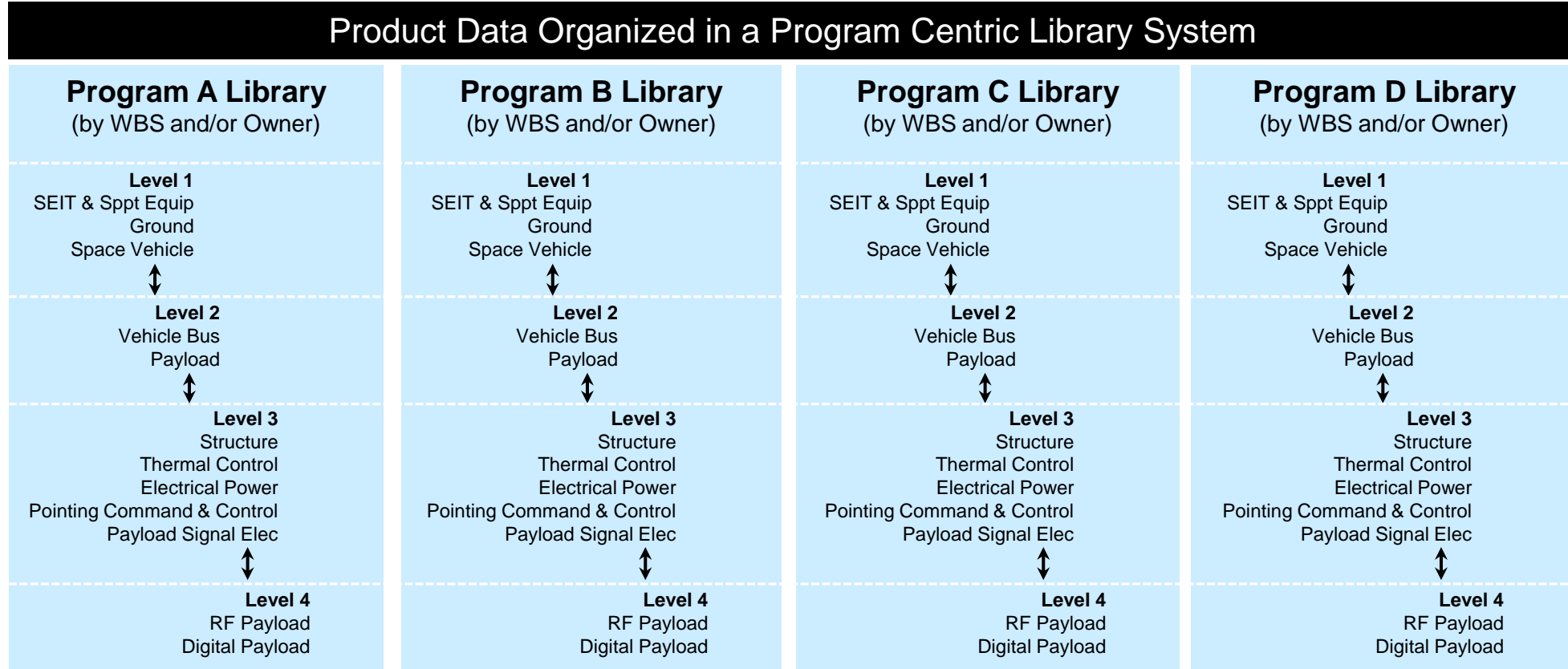


June Kobayashi

- NGSP/SSSD Digital Transformation Lead for DE&SP BU
- PLE Community of Practice Lead
- NGMS PLE Center of Excellence, Infrastructure member

Products Management & Data Structures Current Problem (Representative Structures and Data)

Global Product Data Interoperability Summit | 2023



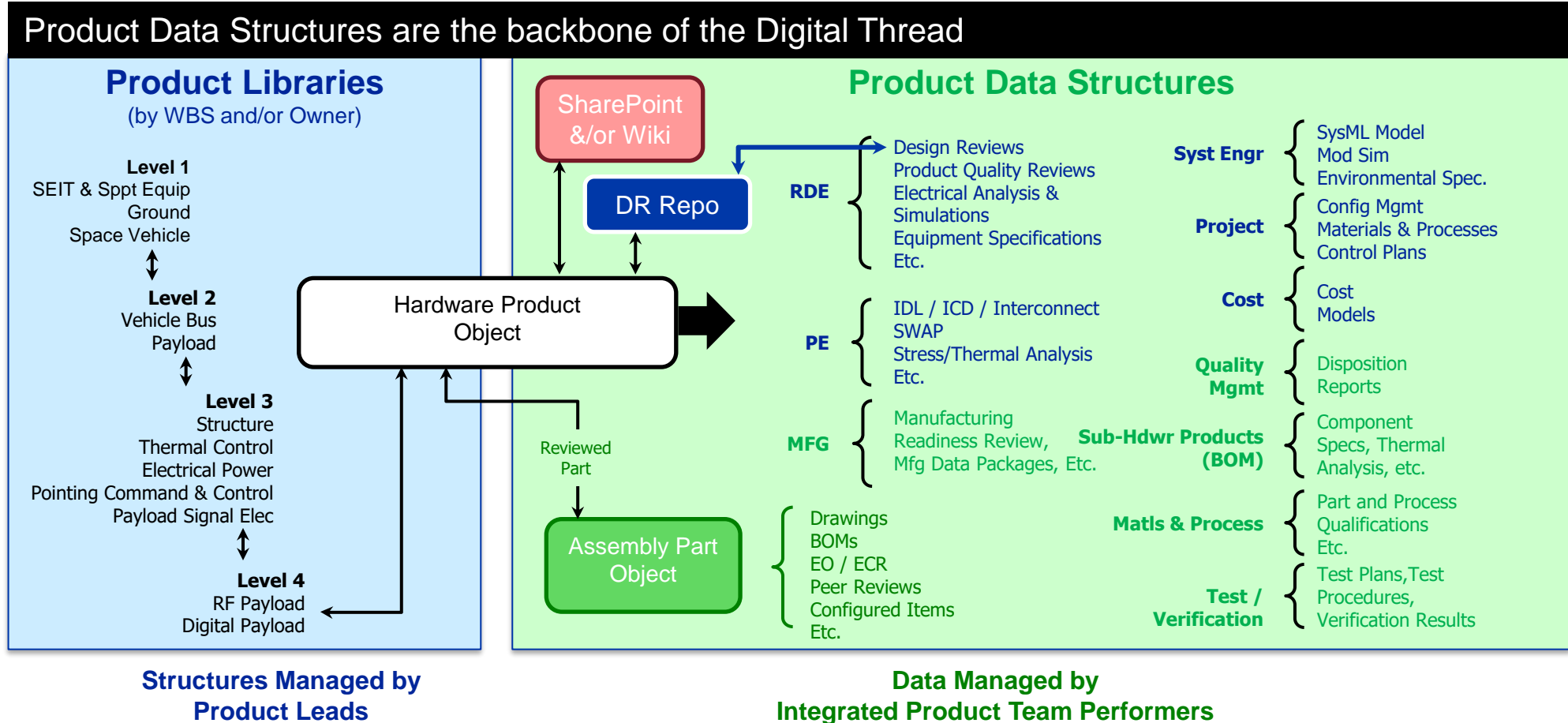
**Difficult to find essential engineering data to perform trade studies
Due to silos between product variants from program ownership and membership boundaries**

PLM
PDM
CM



Products Management & Data Structures Vision (Representative Structures and Data)

Global Product Data Interoperability Summit | 2023



Find essential engineering data more quickly to perform trade studies more efficiently to create proposals and develop related product variants

PLM
PDM
CM

PLM Tools Available to provide capabilities to enable a true Product Data Structure (PDS)

Global Product Data Interoperability Summit | 2023

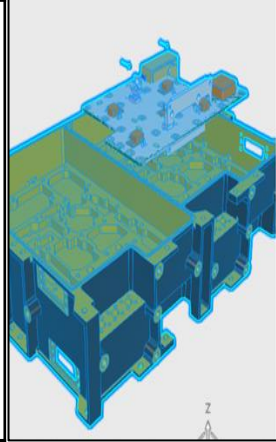
PLM/PDM System

Menu Items

Object	ID	Rev	Title	3D Overview Changes Where Used	Attachments
EPU Product Line	001	C	...		
EP CCA1 PL	002	B	...		
EP CCA2 PL	003	B	...		
EP PWB2-1	004	B	...		
EP PWB2-1-1	005	A	...		
EP PWB2-1-2	006	A	...		
EP CCA2-2	007	B	...		
EP PWB2-2	008	B	...		
EP PWB2-2 Part1	009	A	...		
EP PWB2-2 Part2	010	A	...		
EP PWB2-2 Part3	011	-	...		
EP PWB2-2 Part4	012	C	...		
EP PWB2-2 Part5	013	A	...		
...		

Attachments

- Specification
- Review 1 Docs
- Review 2 Docs
- Review 3 Docs
- Qualification part A
- Qualification part B
- Delivery Data Package
- PWB Analyses CCA 2
- PWB Analyses CCA 1
- Etc..



Specs	Dwg Model	Review	EE, PE Analysis	MFG	EIDP
Product Line / Family Level Artifacts					
Product Line / Family Level CCA Artifacts					
Product Variant Level CCA Artifacts					
Product Variant Level PWB Artifacts					
Product Variant Level CCA Artifacts					
Product Variant Level PWB Artifacts					
Product Variant Level Component Artifacts					
RDE SE	PE	RDE	EE, PE	MFG	QA

Siemens Teamcenter has

- Product Configurator plus
- Product Structure

Dassault 3DX has

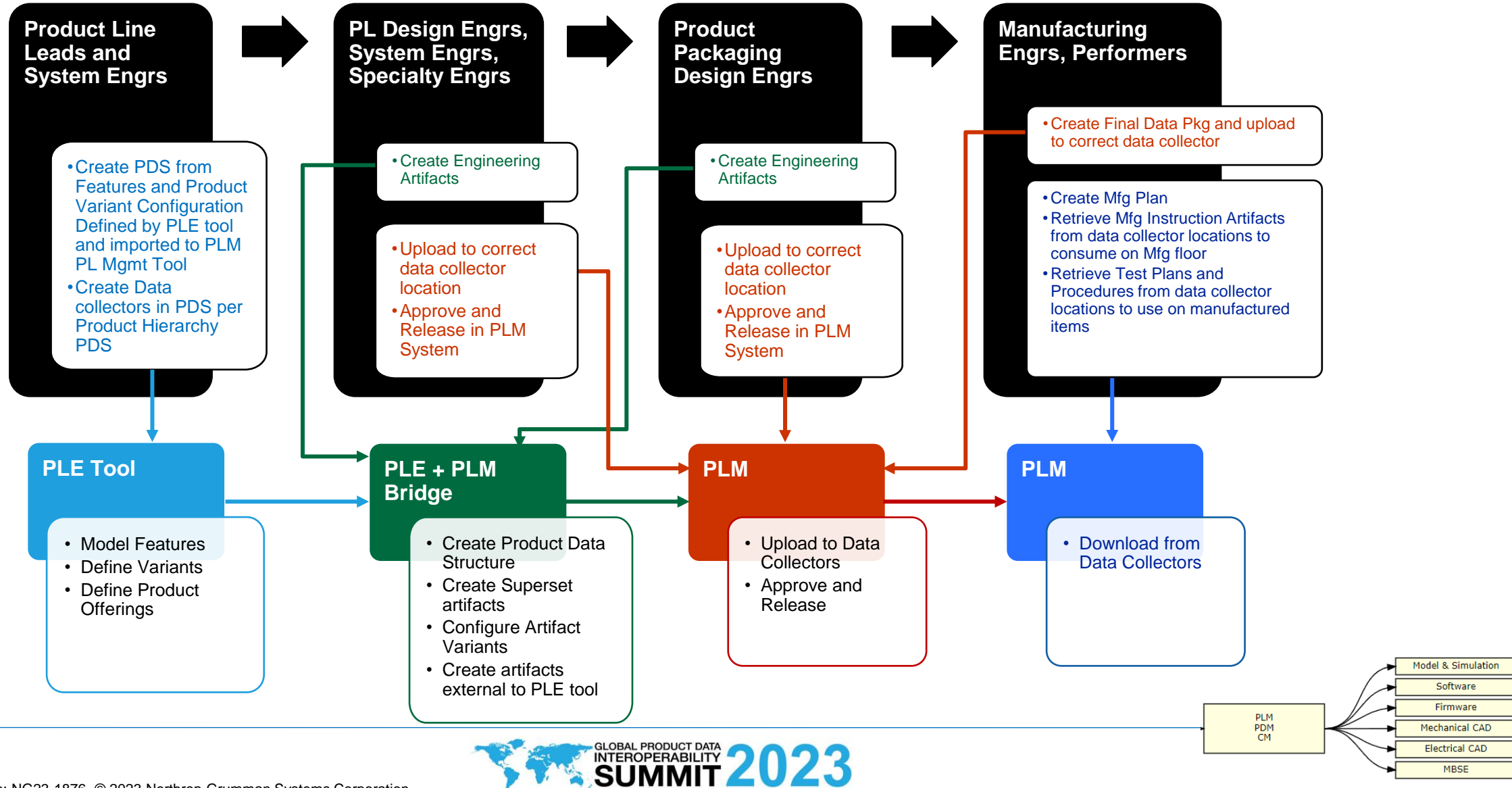
- Product Line Variant Management plus
- Engineering Item Structure

PTC Windchill has

- Product Variant Management

Product Data Management Swim Lanes and Process Flow

Global Product Data Interoperability Summit | 2023

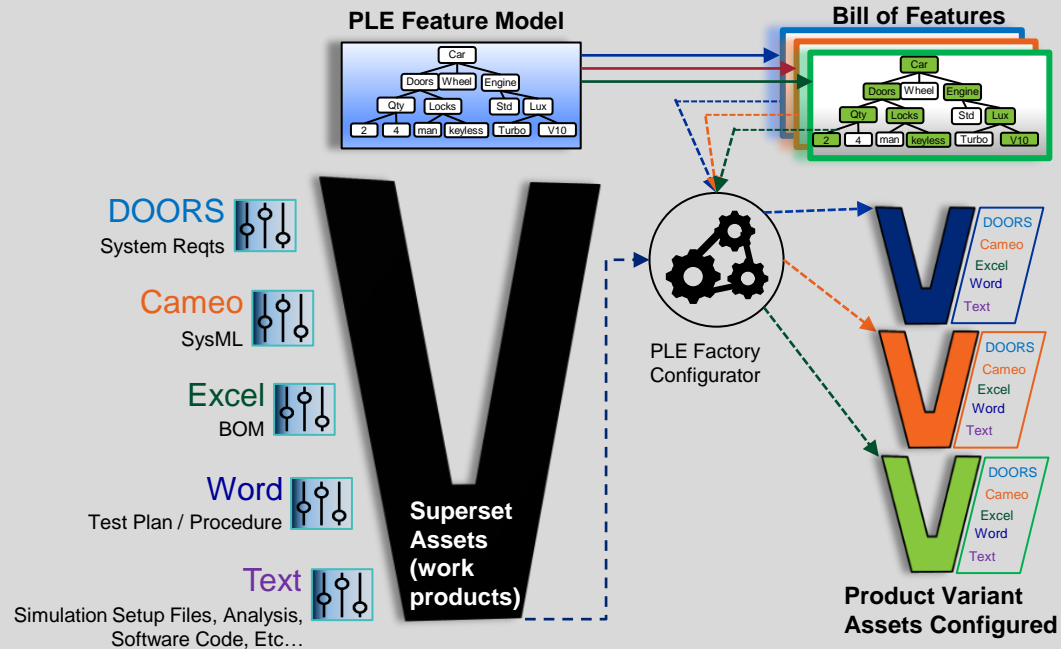


Future Vision of Integrating PLE tools and Product Line Data Mgmt tools in PLM systems

Global Product Data Interoperability Summit | 2023

Feature-based Product Line Engineering

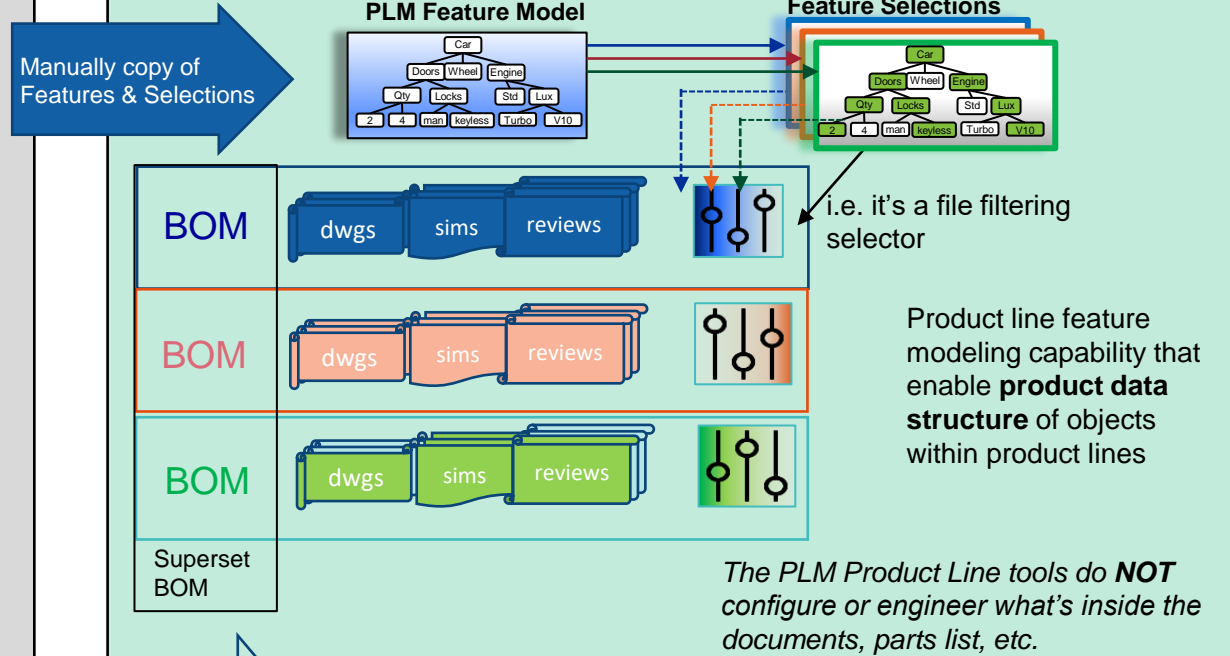
PLE Tool configures **authorship inside** superset asset templates and also selects between superset assets



Product Variants Created by the PLE Tool (Gears)

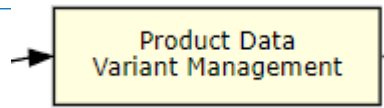
Feature-based Product Lifecycle Mgmt of Product Line

PLM Systems' Product Line portfolio tool configures which objects belong to a variant of a family of products in a product line



Product Variant Assets uploaded to PLM Systems for Configuration Management

Product Variants Configuration Managed by PLM Systems

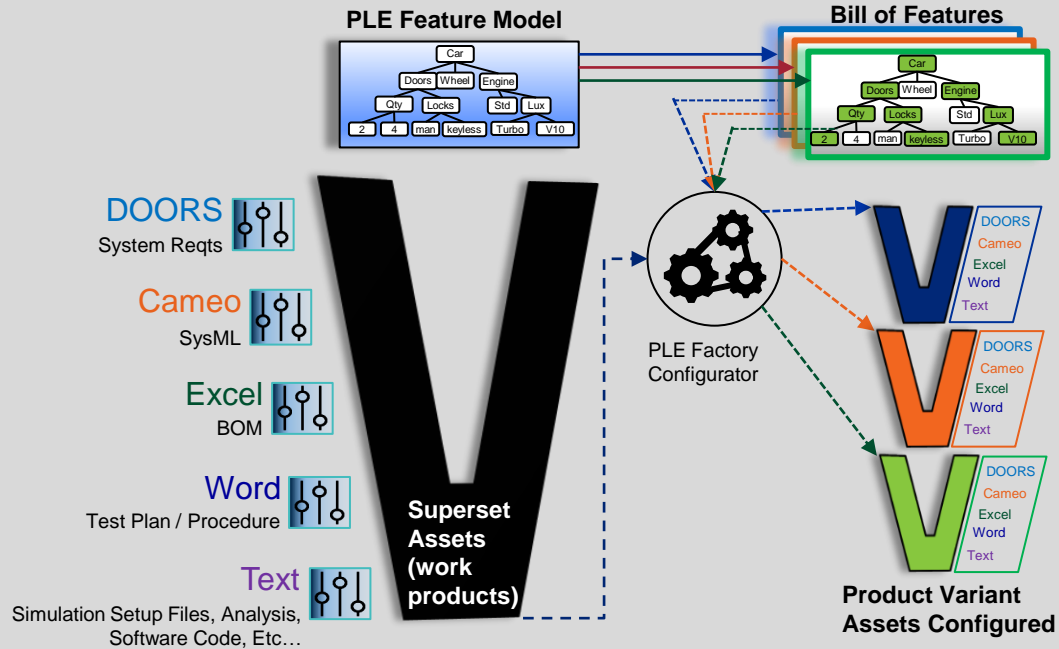


Future Vision of Integrating PLE tools and Product Line Data Mgmt tools in PLM systems

Global Product Data Interoperability Summit | 2023

Feature-based Product Line Engineering

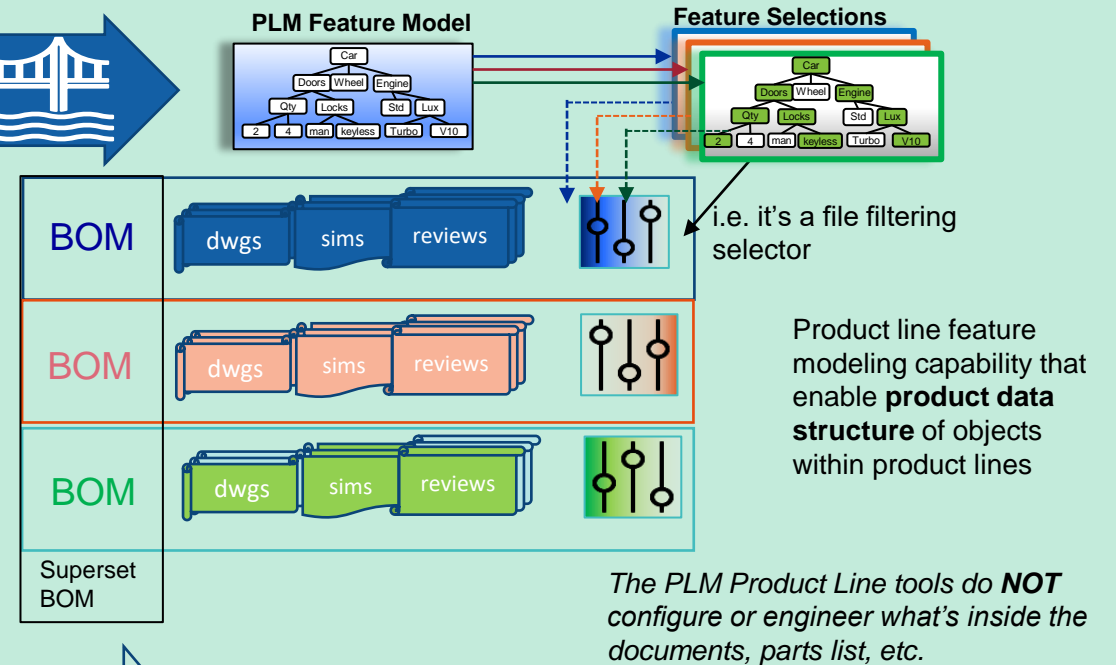
PLE Tool configures **authorship inside** superset asset templates and also selects between superset assets



Product Variants Created by the PLE Tool (Gears)

Feature-based Product Lifecycle Mgmt of Product Line

PLM Systems' Product Line portfolio tool configures which objects belong to a variant of a family of products in a product line



Product Variants Configuration Managed by PLM Systems

Product Variant Assets uploaded to PLM Systems for Configuration Management

Product Data Variant Management



Product Line Tools Integration and Roadmap



Paul Kepinski

- NGMS PLE Center of Excellence, Infrastructure Tools Lead

The need for Product Line integration with Business Data

Global Product Data Interoperability Summit | 2023

- **What level of product line data should we integrate at minimum?**
 - High Level product line structure (Product Line and Sub Families)
- **How should product lines be related?**
 - For opportunities related to the product line: Link product or sub family, link quantity, link cost per unit
 - For Investments, Project Proposals, or Planning related to the product line: Link product, sub family, or opportunity
- **What does linking Product Lines to Business data get us?**
 - Understanding of all business objects related to the given Product Line
 - Understanding of future business opportunity to plan for
 - Understanding for which Product Lines are commonly and consistently planning for similar opportunities
 - Understanding for customer crossover with Product Lines
 - If your systems track history: understanding of changes in product line business outlook over time
 - Unified single dashboard, that shows all business-related information for any given product line
 - Data can be rolled up to any business organizational unit (sector, division, org, etc...)


Business Management


Variant Management & Business Management Intersect


Global Product Data Interoperability Summit | 2023


Welcome to the Product Line Request Website

Home for our companies programs to request quotes, place orders and seek support for product line variants



 **Request a Quote**
Submit formal proposal estimate request

 **Place an Order**
Place a firm/forecasted order for the needs on your program

 **View Orders**
Check and track on the status of an existing order

Product Line Details

	Product 1	Product 2
Applications	Land	Sea
Architecture	x86	x86
Package Size	4 in x 5 in	6 in x 8 in
Typical Power	50 W	100 W
Power Frequency	60 Hz	90 Hz
Inputs	10 Analog, 5 Digital	
Tested Platforms	Windows, Linux	
Technology	10 nanometer	
Socket	Generic Style 1	

Product Catalog

The complete catalog of all current and future planned product configurations can be found here: [Product Line Roadmap](#).

Program Support

If none of the current product configurations meet your programs requirements or desired performance, please submit a request to have your program requirements reviewed with the product line team [here](#).

More Information

For more information on the product development, qualification and production activities, please visit the [Product Program Website](#).

Feedback

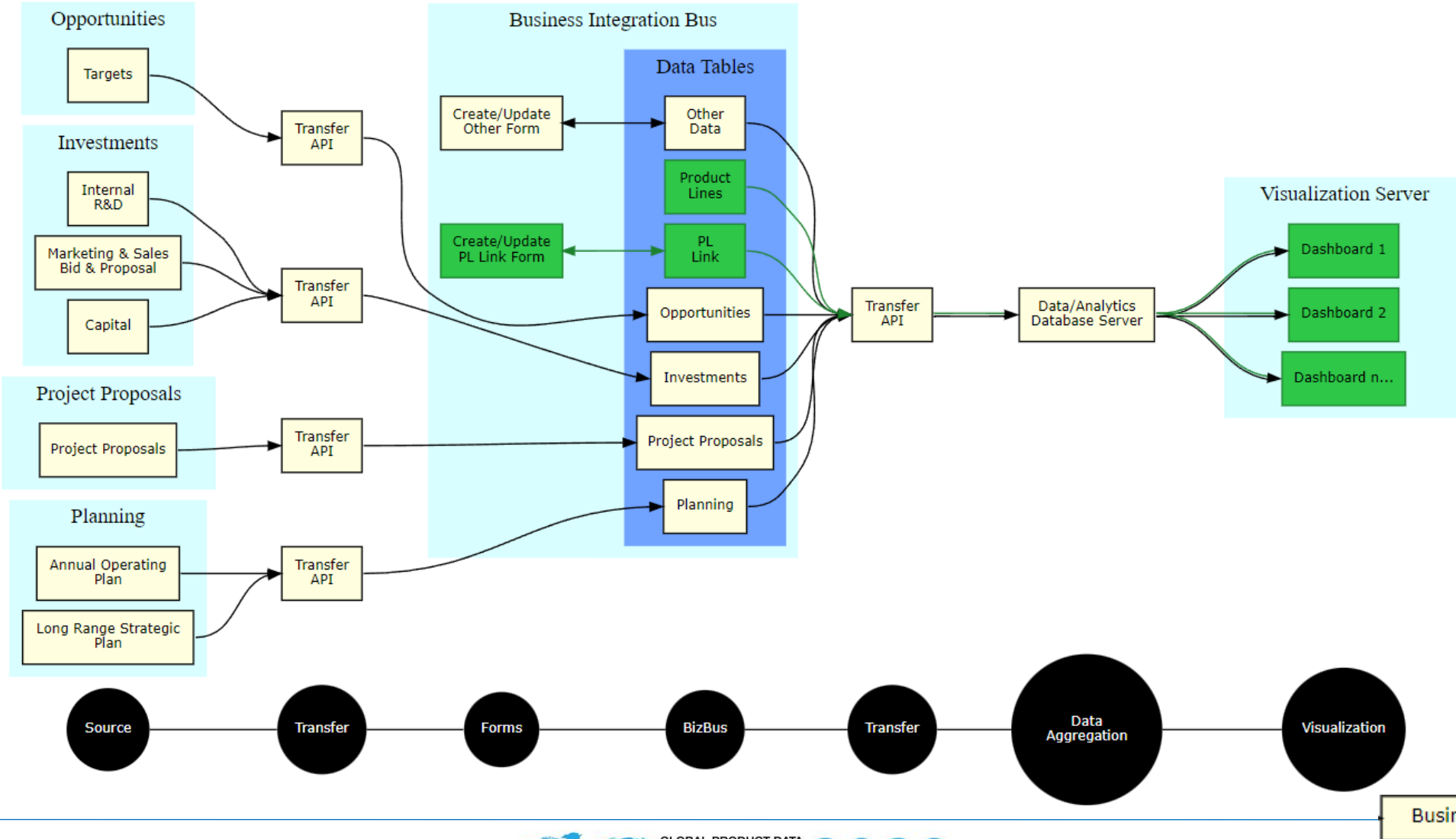
Report a bug or share your feedback [here](#).

- The intersect of Business Management and Variant Management for Product Lines is managing orders
- Customer Intake form for Product Line orders can help in several ways:
 - **Bid/Proposal:** Automated quote generation through integration with business and operations tools.
 - **Program Management:** Ensures data is kept accurate through automated check-in requests sent to customers and providing a single source of fact.
 - **Engineering:** Integration with engineering tools to auto-generate design artifacts.
 - **Production:** Assist in capturing customer demand and production planning.
- Ideal integration would automatically populate the available products using a company wide product line catalog.

Business Management

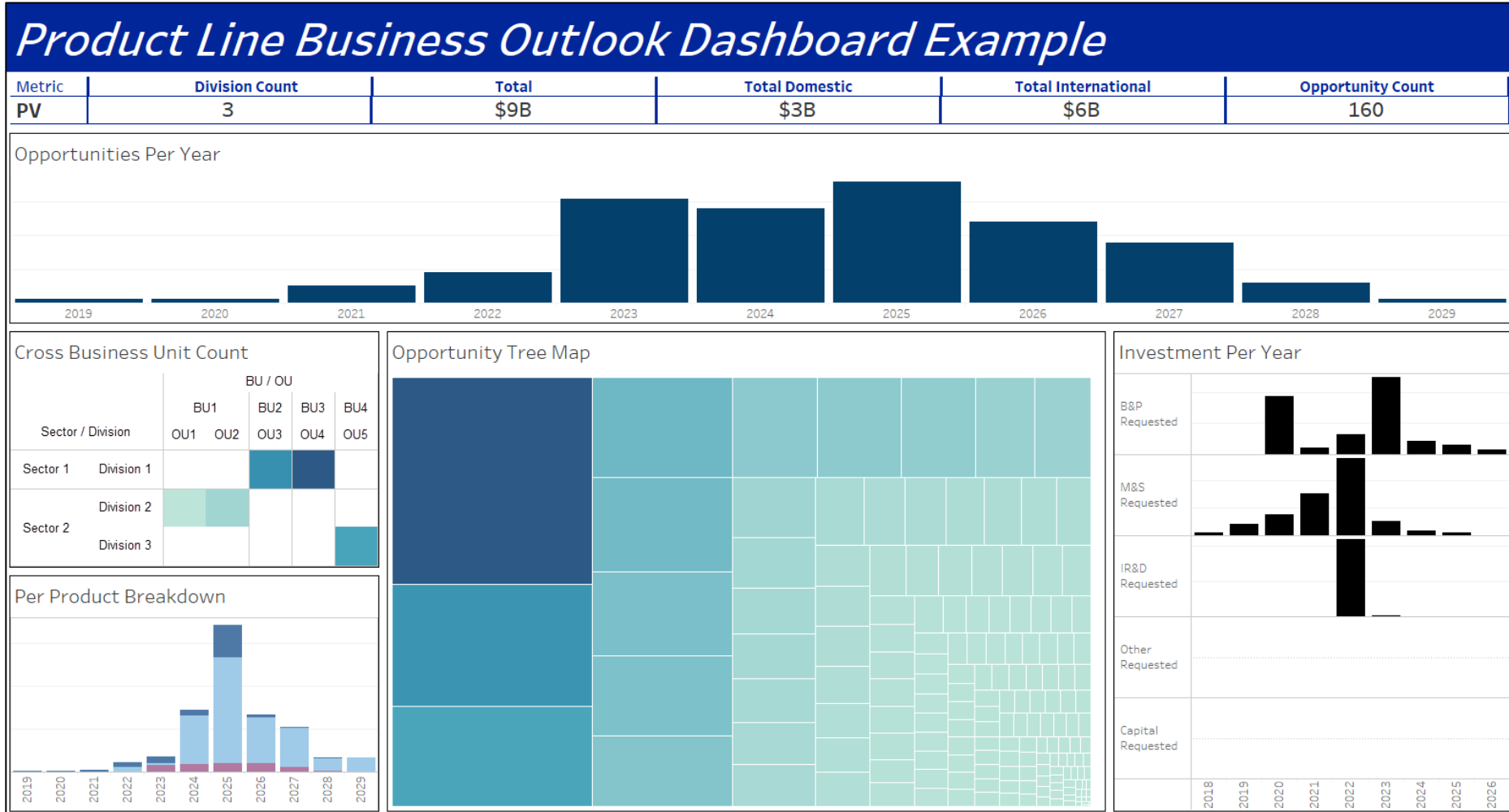
PLE/Business Integration Example Flow

Global Product Data Interoperability Summit | 2023



PLE/Business Integration Dashboard Example

Global Product Data Interoperability Summit | 2023



Business Capture





Leveraging Product Line Repositories & Accounting for Reuse



Matthew Reilly

- NGMS PLE Center of Excellence, PLE Coaching Lead

Bottom Line for Engineering Reuse

Global Product Data Interoperability Summit | 2023

1. We must enable efficient reuse

Targeting 50% labor savings compared to clone-and-own and 100% labor savings compared to clean sheet design

2. We must identify reuse opportunities and account for reuse savings in our engineering trade studies

- **Product Lines**
- **Modularity**
 - **Modular Open Systems Approach (MOSA)** - modular design that uses **major system interfaces** between a major system platform and a major system component, between major system components, or between major system platforms [2]
 - **Component Based Design** - approach to software development that focuses on building systems from reusable and self-contained software components. **Components encapsulate specific functionality** to perform specific behaviors and communicate with each other through well-defined interfaces. Interfaces specify how components interact and exchange data, serving as a contract. **So long as they adhere to the contract, components can be moved and reused freely** in a variety of systems.
- **Reuse Repositories & Ecosystems**
 - **More on next slide...**

1. "ISO/IEC 26580:2021." ISO, 21 Apr. 2021, www.iso.org/standard/43139.html.
2. [DSP :: MOSA \(dla.mil\)](https://www.dla.mil/dsp/mosa)

Implementing Efficient Reuse

Global Product Data Interoperability Summit | 2023

Reuse Repository¹

Reusable software assets are stored, along with the catalogue of assets. Everybody should be aware that it contains important company know-how, and should be able to access and use it easily.

Software Ecosystems²

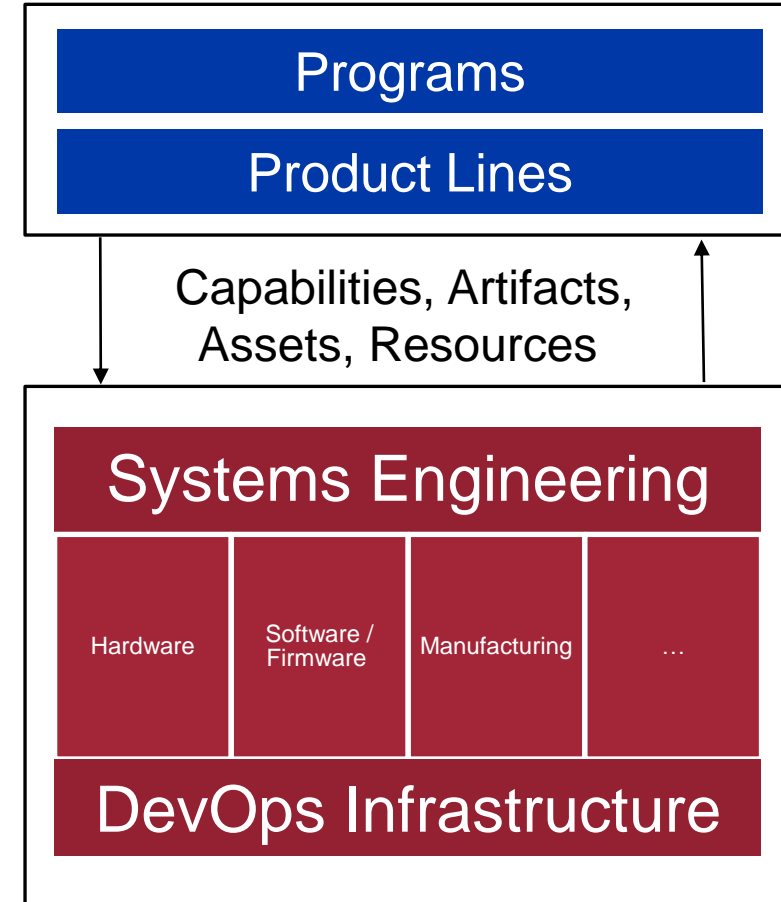
Set of businesses functioning as a unit and interacting with a shared market for software and services, together with relationships among them.

These relationships are frequently underpinned by:

- Common technological platform
- Operate through exchange of information, resources, and artifacts.

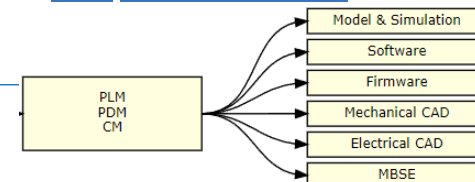
**Consumer /
Producer Tier:**

**Repository /
Ecosystem Tier:**



1. Ezran, M., Morisio, M., Tully, C. (2002). *Reuse Repository*. In: *Practical Software Reuse*. Practitioner Series. Springer, London. https://doi.org/10.1007/978-1-4471-0141-3_3

2. David G. Messerschmitt; Clemens Szyperski (2003). *Software Ecosystem: Understanding an Indispensable Technology and Industry*. Cambridge, MA, USA: MIT Press. [ISBN 978-0-262-13432-3](https://doi.org/10.1017/9780262134323).



Accounting for the Benefits of Reuse

Global Product Data Interoperability Summit | 2023

Where should we be accounting for reuse...

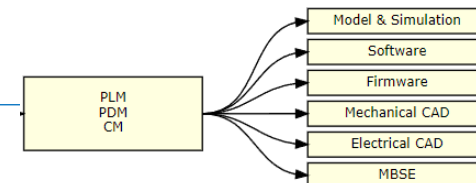
- Business Development & Management
 - Proposal artifact reuse
 - Business processes reuse
- Supply Chain
 - Combined buys
 - Strategic agreements
 - Consolidated supply base
- Manufacturing/Operations
 - Fewer learning curves
 - Machine, operations, and procedure reuse
- Engineering
 - Reduced Non-Recurring Engineering
 - Sustainment, global rollout of bug fixes
- Quality & Testing
 - Procedure reuse
 - Expediated verification
- Safety, Airworthiness, & Training
 - Fleet commonality
 - Expediated certification
- Customer
 - Affordable systems at the speed of relevancy

... Reuse can touch every aspect of the business.

Methods for Quantifying Value of Reuse

**Cost & Schedule Modeling
(Future Looking)**

**Estimating Actual Savings
(Past Looking)**

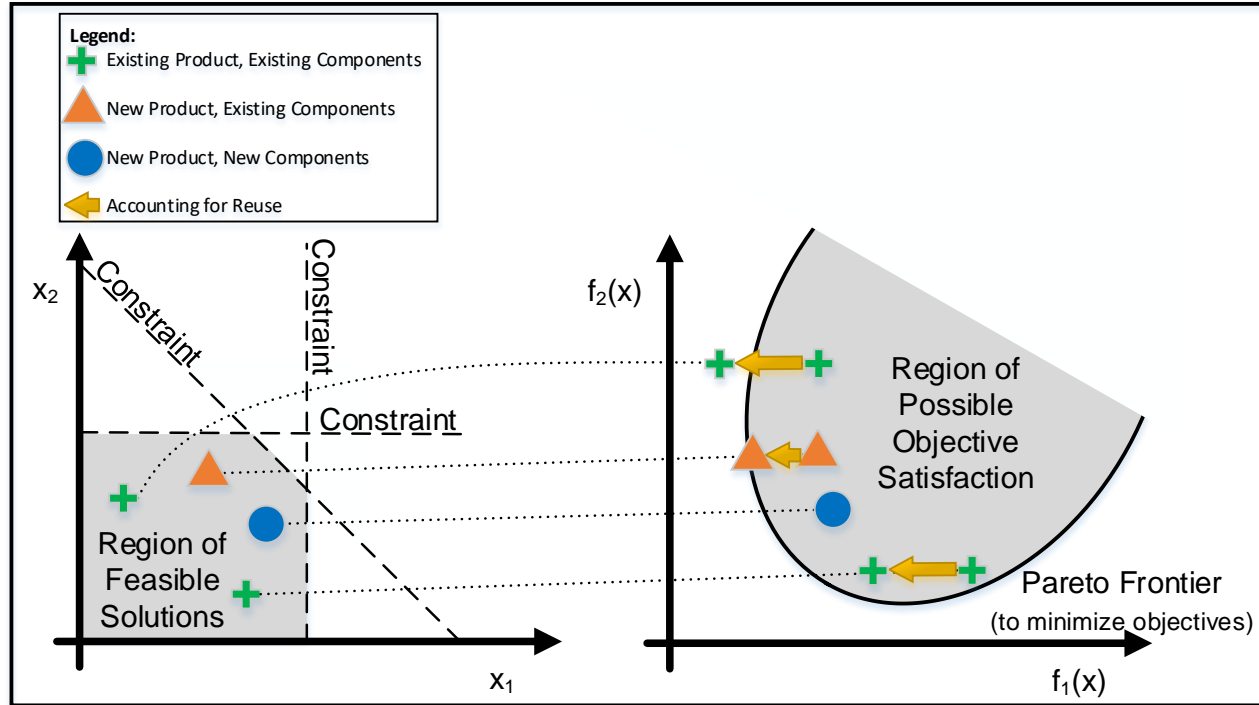
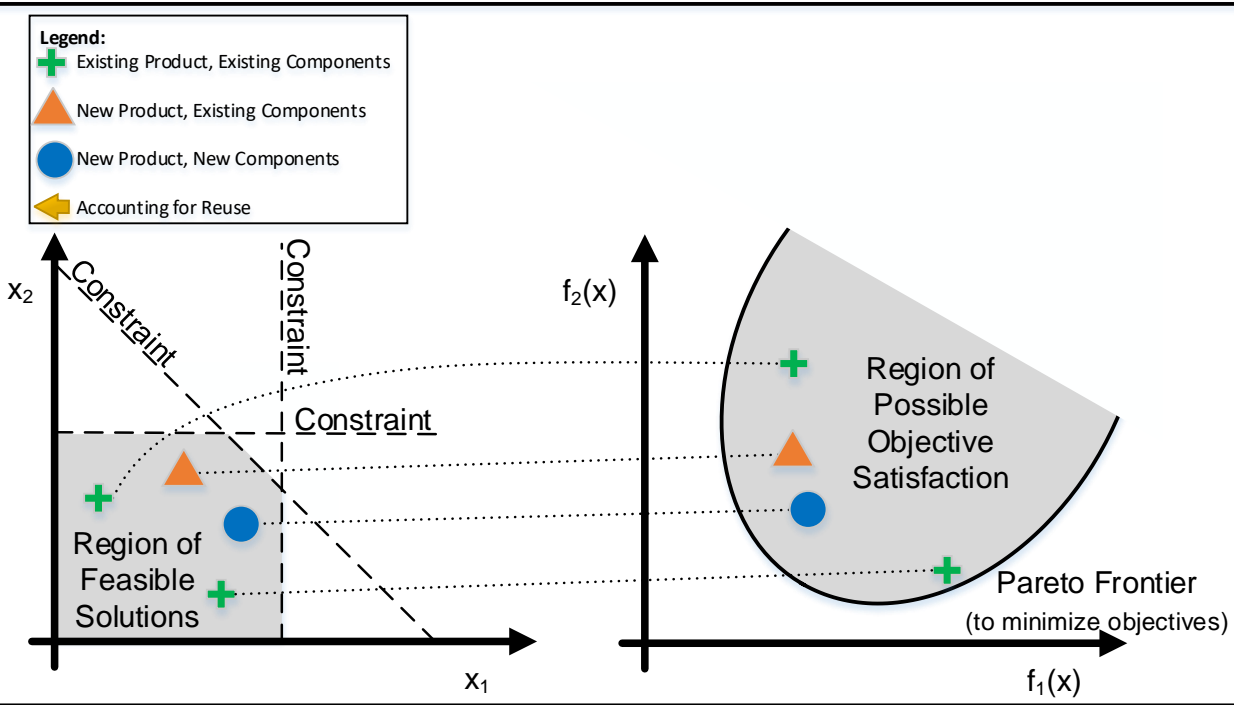


Vision for Engineering Trade Studies for Product Lines

Global Product Data Interoperability Summit | 2023

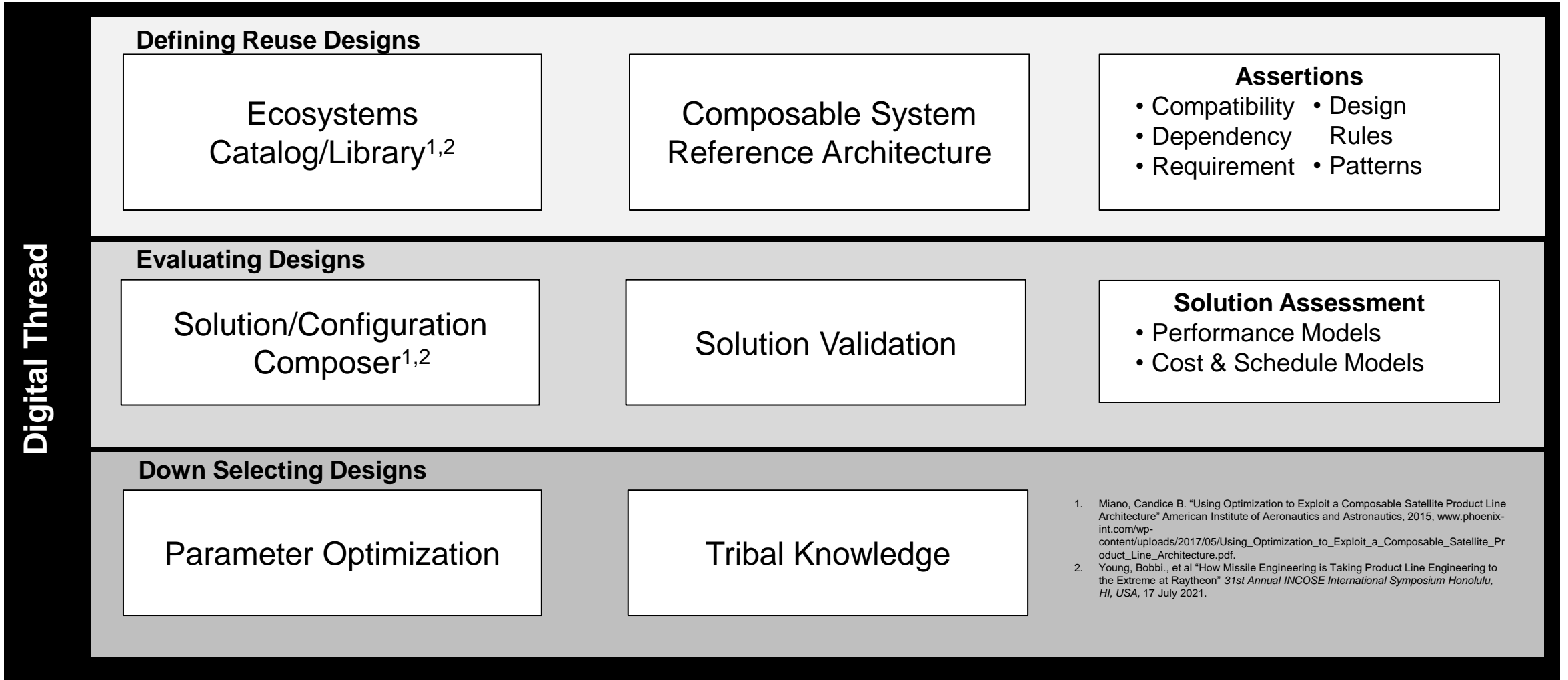
Level 1: Identify Reuse

Level 2: Identify Reuse + Account for Cost and Schedule Savings



Key Enablers for Accounting for Reuse in Trade Study Analysis

Global Product Data Interoperability Summit | 2023



Call to Action for the Industry Interoperability

Global Product Data Interoperability Summit | 2023

1. Enforce product line awareness through all discipline toolsets
2. Create a standard data format in defining and selecting features that can be passed between tools in the digital thread
3. Create digital thread between Digital Ecosystems, Digital Libraries/Catalogs, Reference Architectures, Solution/Configuration Composer, Cost/Schedule Modeling, Validation/Assessment M&S, and Optimizers

Similar to other popular engineering data exchange formats: STEP, IGES, STL, EMN/EMP, IDF, XML, JSON, etc...

Need Universal data exchange format for PLE data

Conclusion

Global Product Data Interoperability Summit | 2023



Implementing these approaches would be a monumental task for a single company, therefore a concerted effort across the industry, tool vendors, and the customer base must be pursued.