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hybrid event

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

Product Line Engineering Digital Thread:

Now and the Future

NORTHROP GRUMMAN

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:

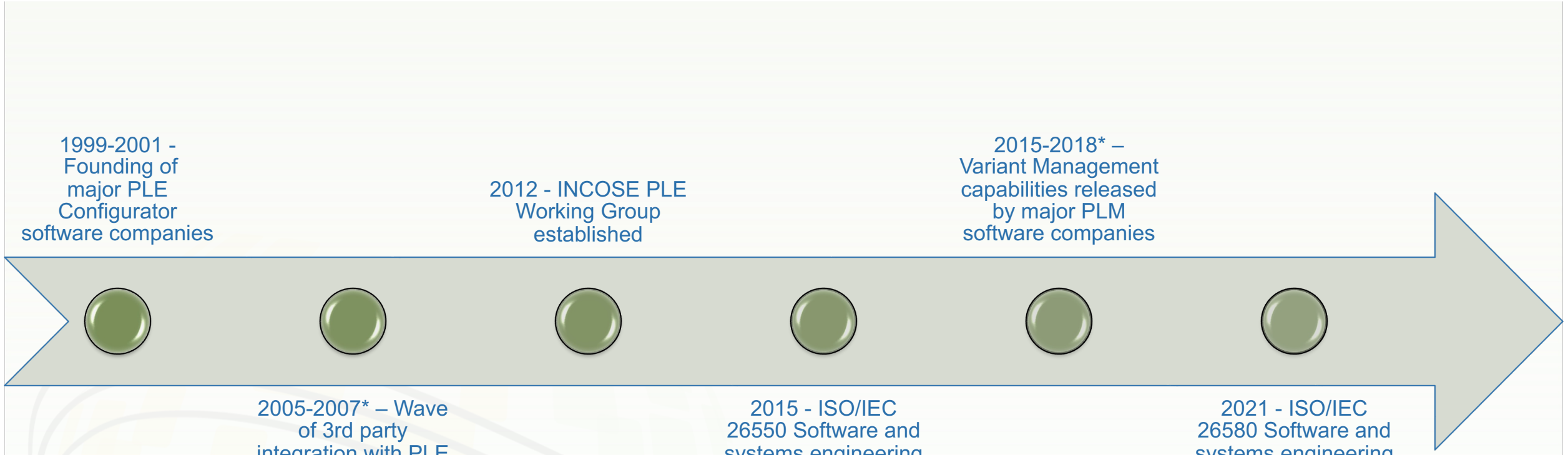
Can our tools pass data across all disciplines from engineering to business to production to supply chain?

What are Product Lines & Product Line Engineering?

- **Product Lines**
  - A family of similar products or systems with variations in features[1]
- **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 product[1]

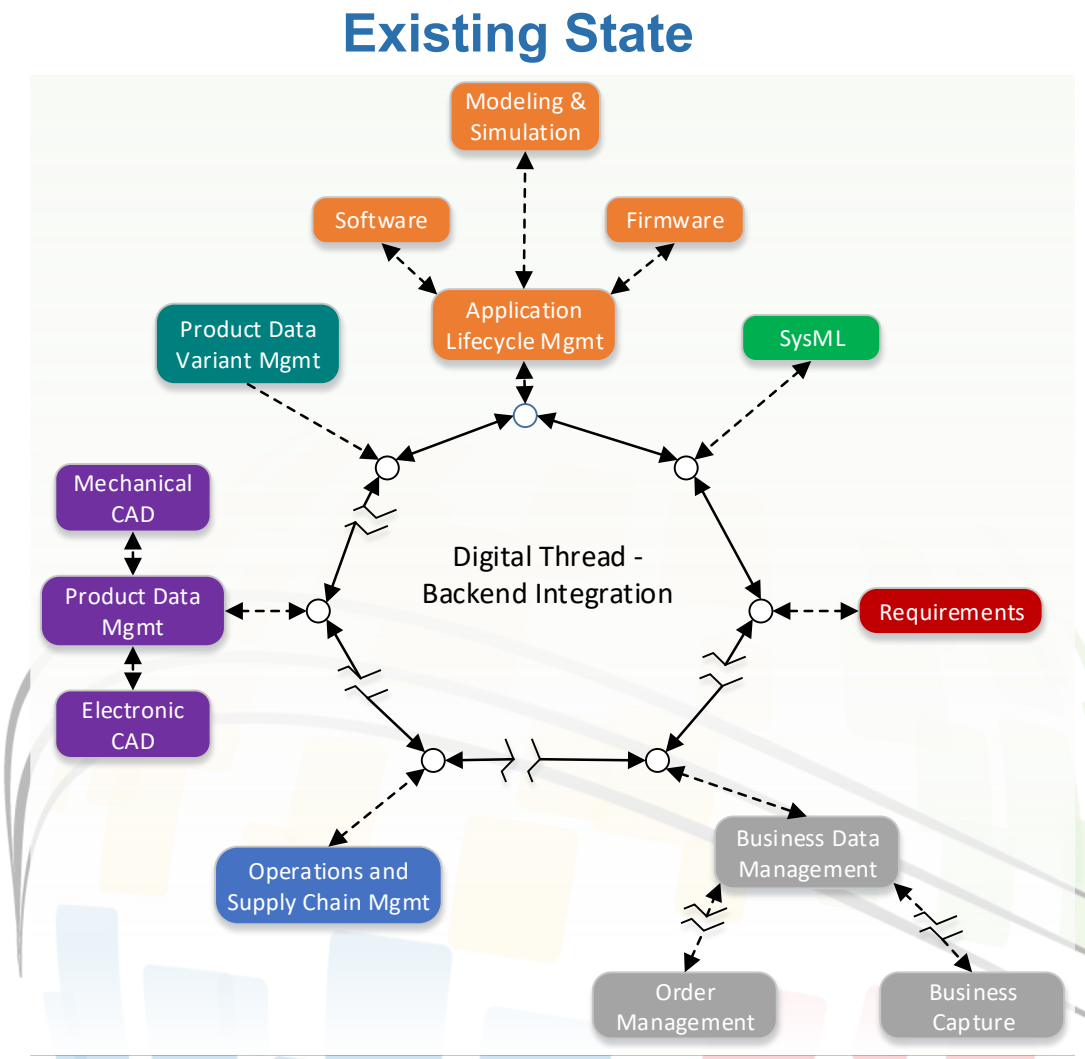
1. "ISO/IEC 26580:2021." *ISO*, 21 Apr. 2021, www.iso.org/standard/43139.html.

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



* Approximate dates provided based on available data

Existing State of Product Line Digital Thread



- 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?

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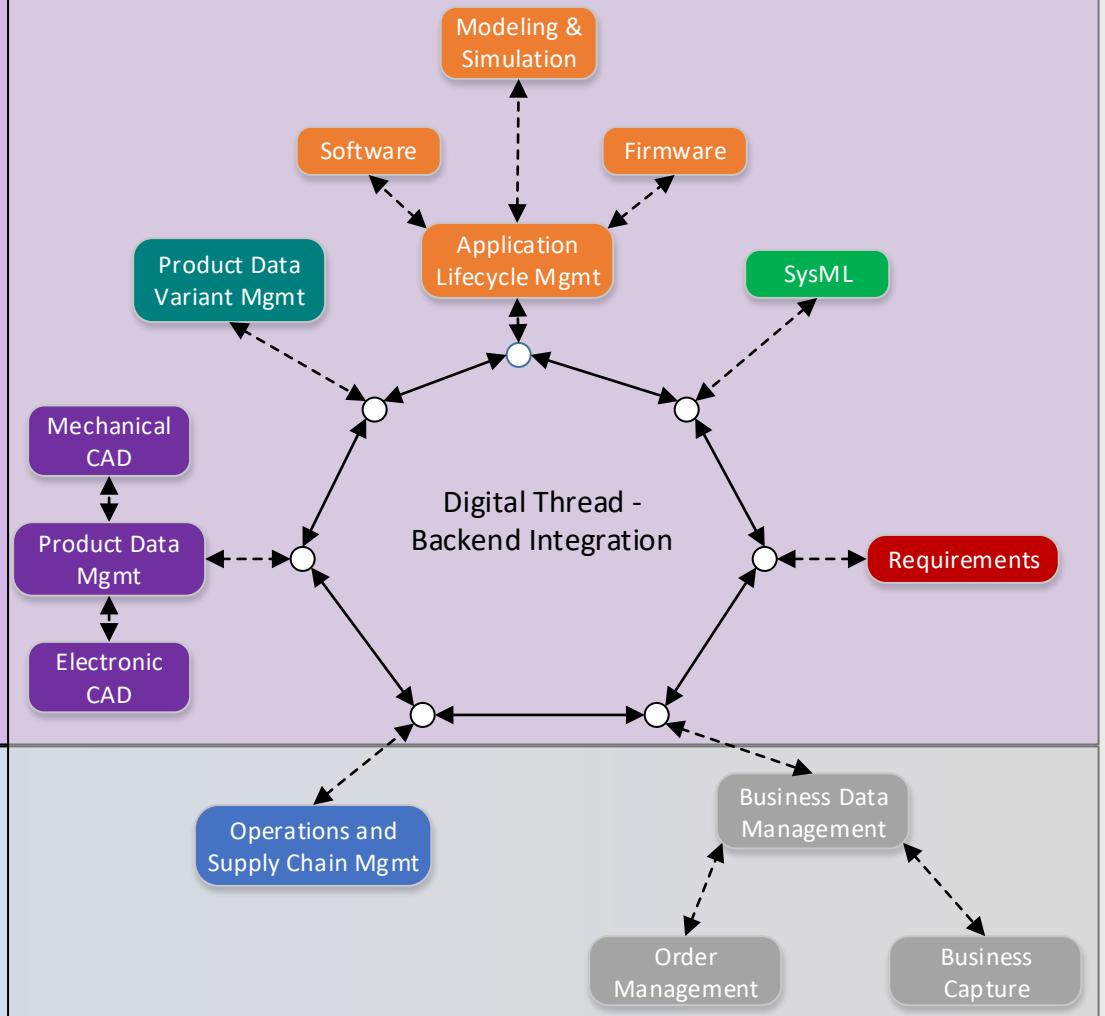
To reap the benefits of alignment across disciplines and provide additional cost avoidance, our product lifecycle management (PLM) tools must align with variation management strategies.



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

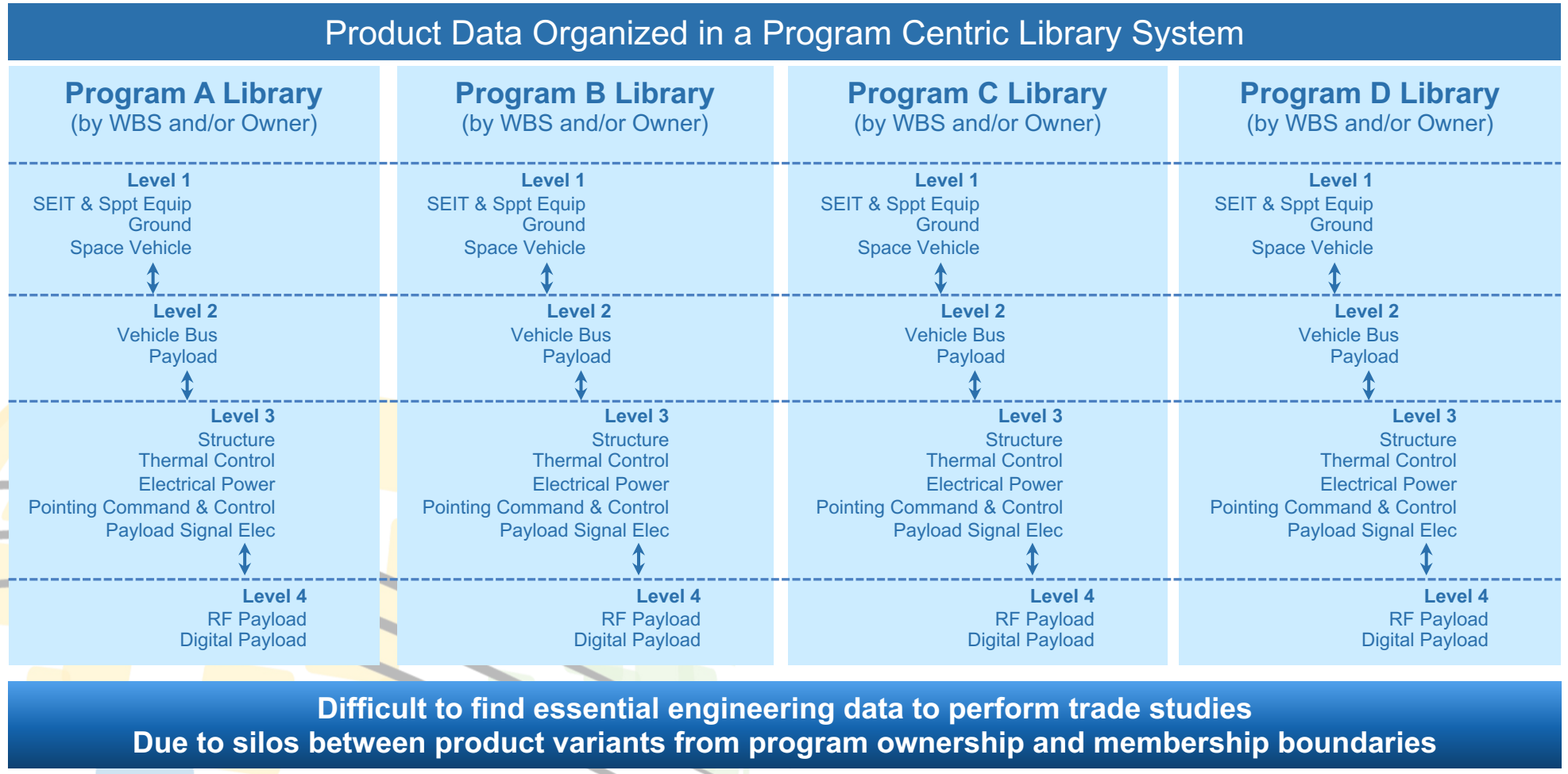
Business capture, investment, funding, order management, operations, and supply chain tools need to be configured for use by product lines.

Product Line Integration with Product Lifecycle Management Systems

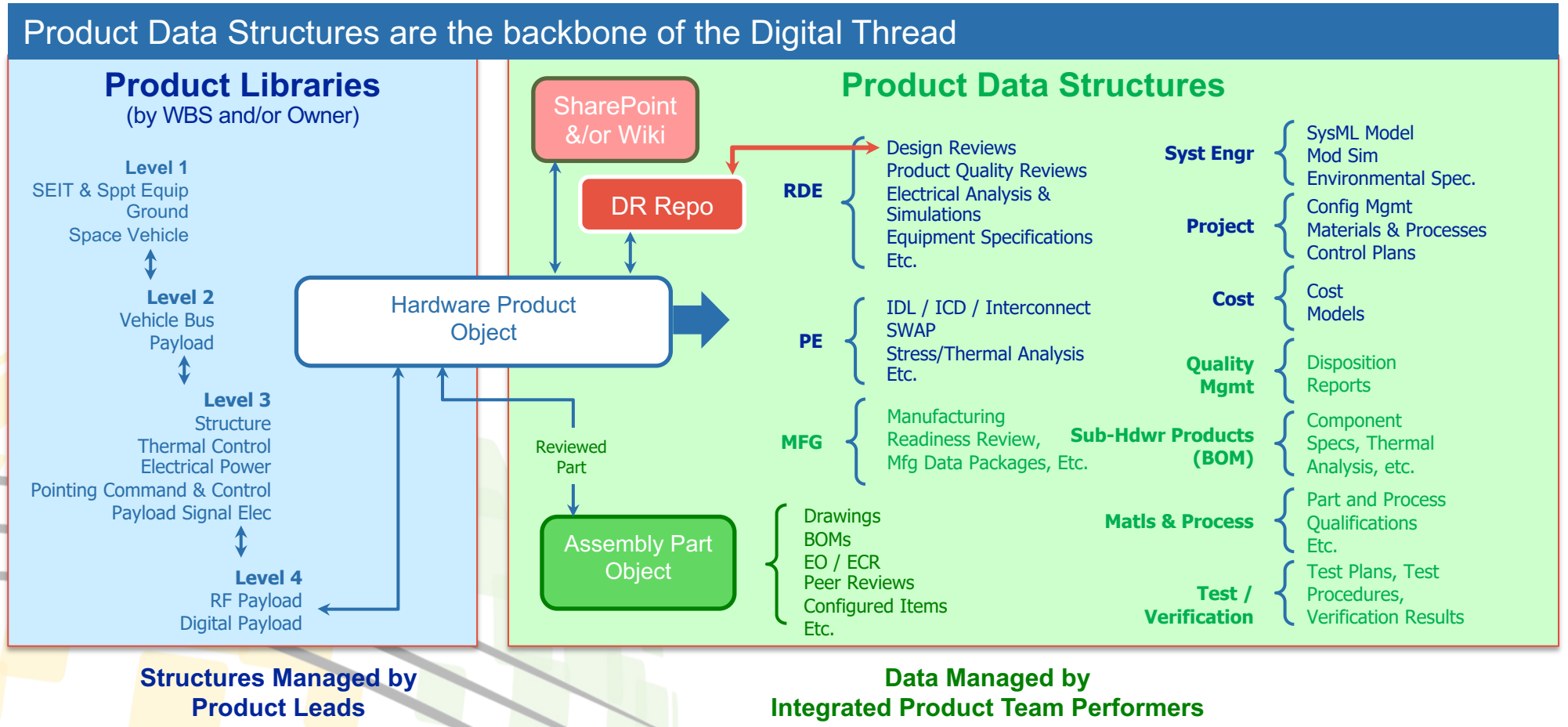
June Kobayashi

- NGSP/SSSD Digital Transformation Lead for Common Products
- PLE Community of Practice Lead
- NGMS Product Line Alignment Team, Infrastructure member

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



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

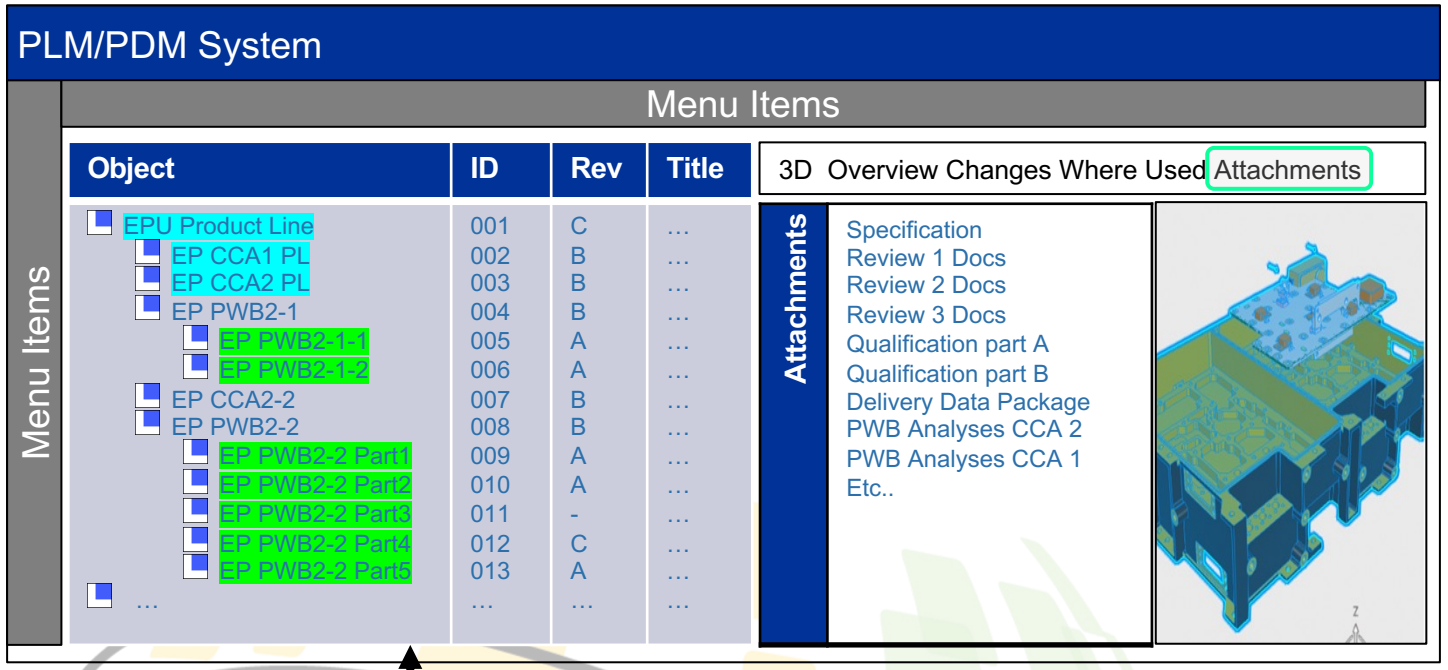


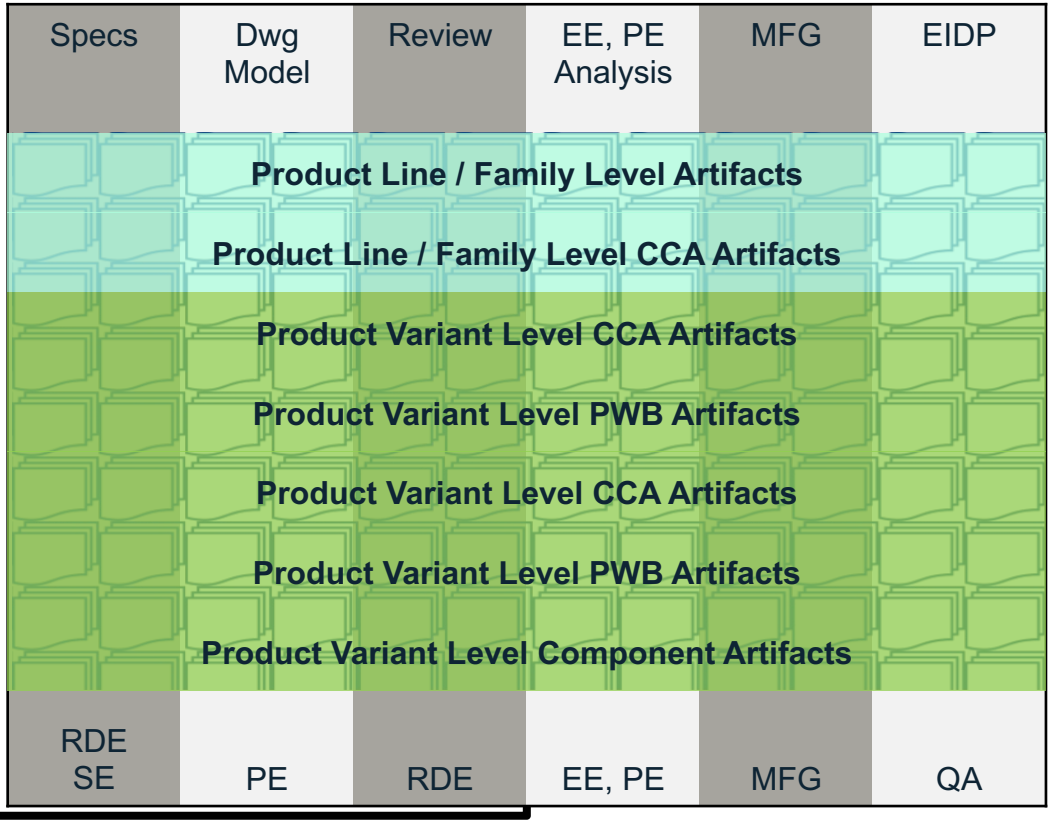
Structures Managed by Product Leads

Data Managed by Integrated Product Team Performers

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

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





Siemens Teamcenter has

- Product Configurator plus
- Product Structure

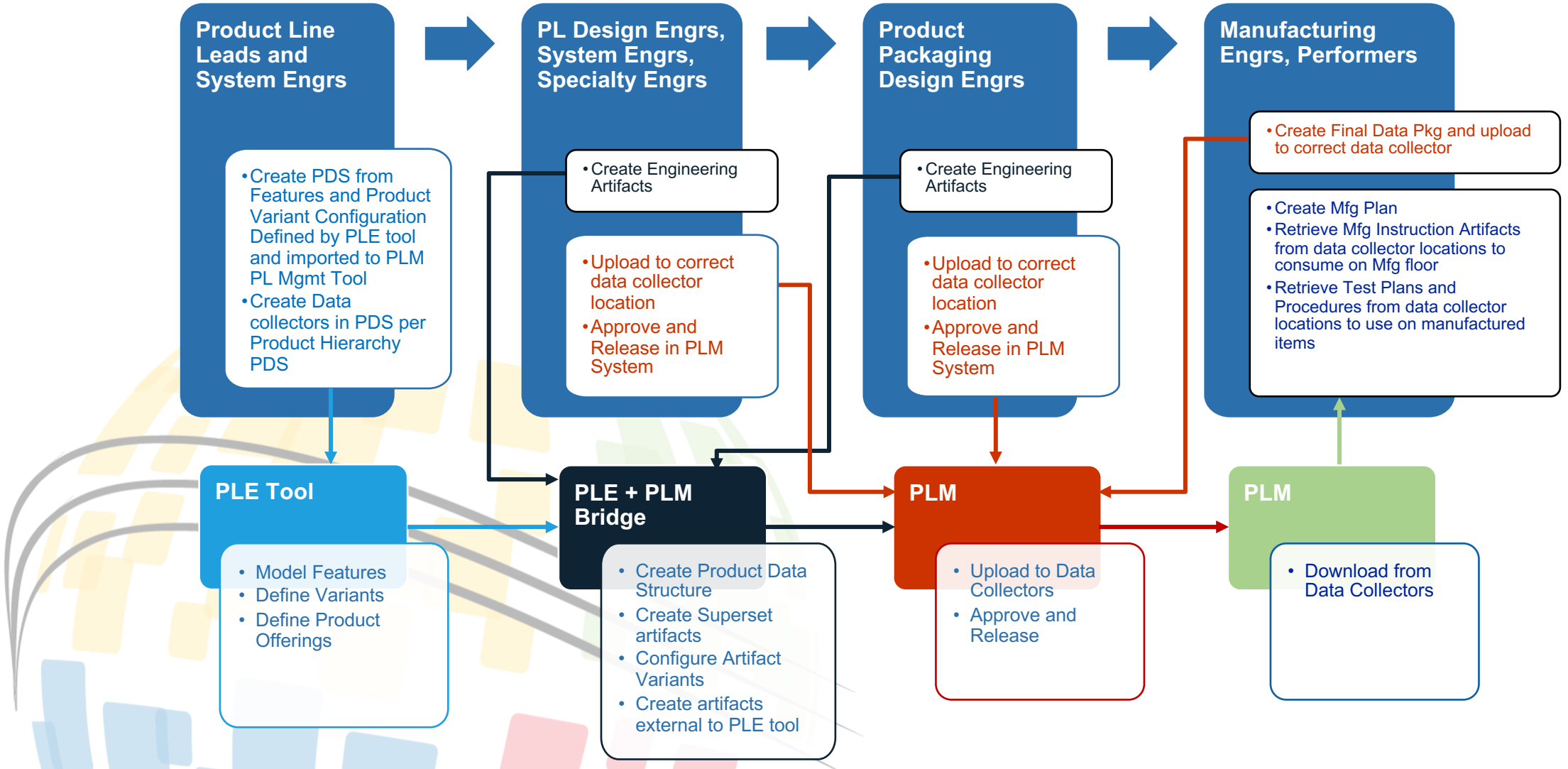
Dassault 3DX has

- Product Line Variant Management plus
- Engineering Item Structure

PTC Windchill has

- Product Variant Management

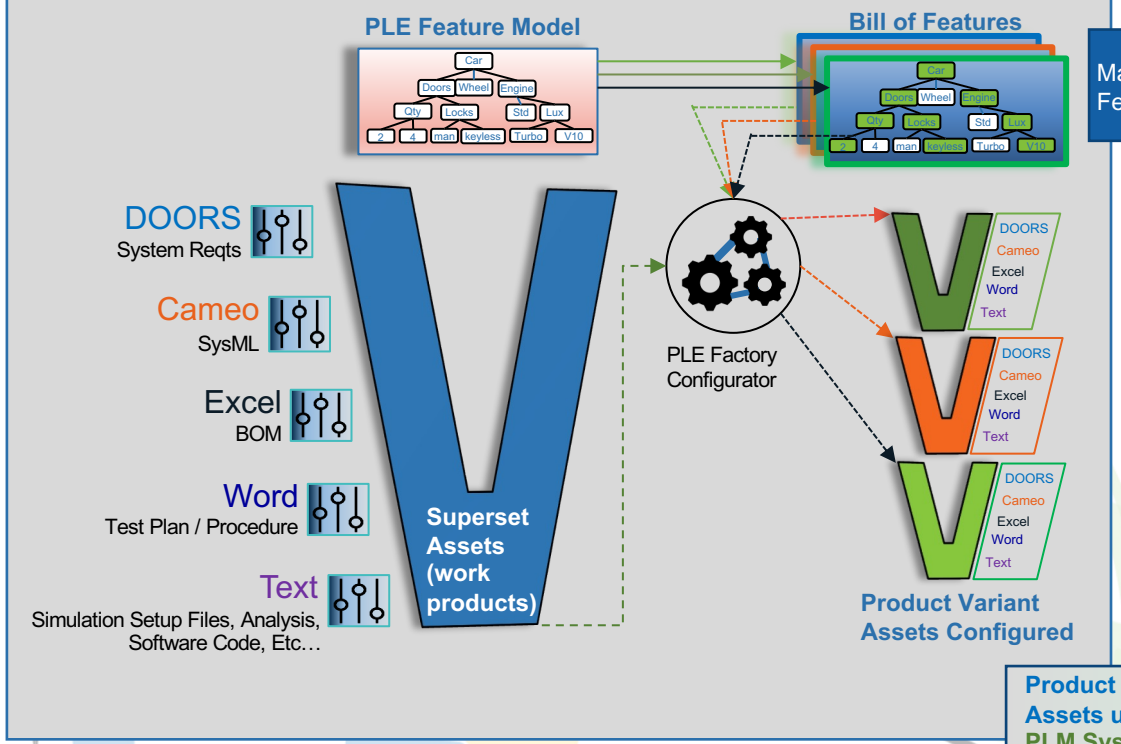
Product Data Management Swim Lanes and Process Flow



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

Feature-based Product Line Engineering

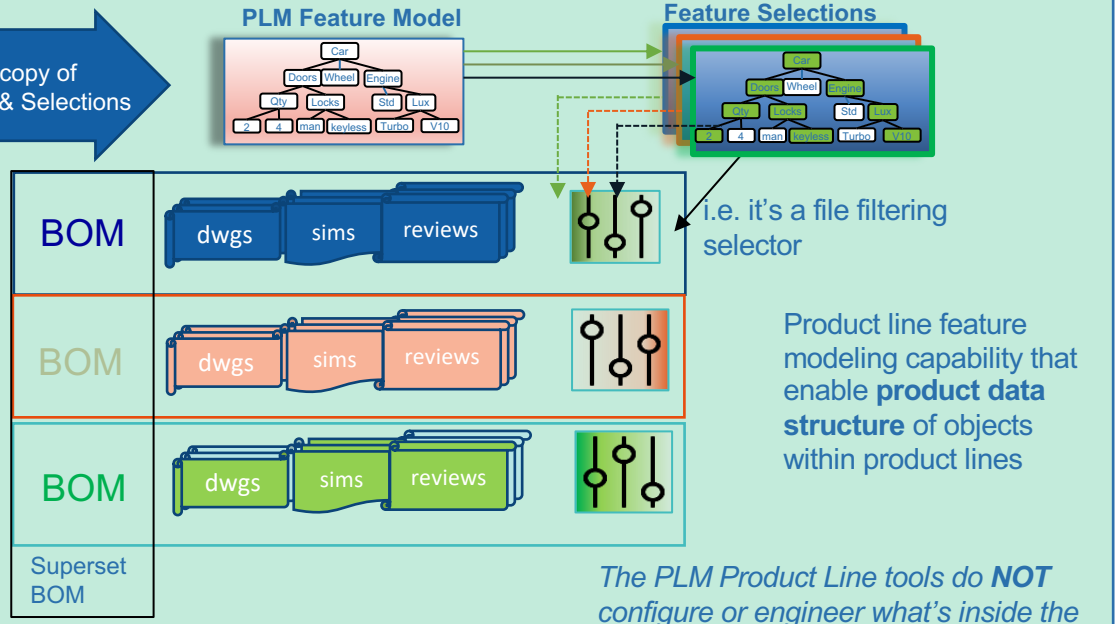
PLE Tool configures **authorship *inside*** superset asset templates and also selects between superset assets



Manually copy of Features & Selections

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



i.e. it's a file filtering selector

Product line feature modeling capability that enable **product data structure** of objects within product lines

*The PLM Product Line tools do **NOT** configure or engineer what's inside the documents, parts list, etc.*

Product Variant Assets uploaded to PLM Systems for Configuration Management

Product Variants Created by the PLE Tool

Product Variants Configuration Managed by PLM Systems

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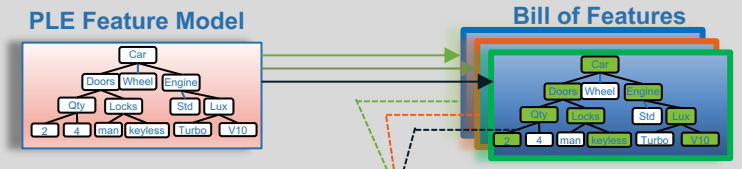

DOORS
System Reqts

Cameo
SysML

Excel
BOM

Word
Test Plan / Procedure

Text
Simulation Setup Files, Analysis, Software Code, Etc…

Superset Assets (work products)

PLE Factory Configurator

DOORS
Cameo
Excel
Word
Text

Product Variant Assets Configured

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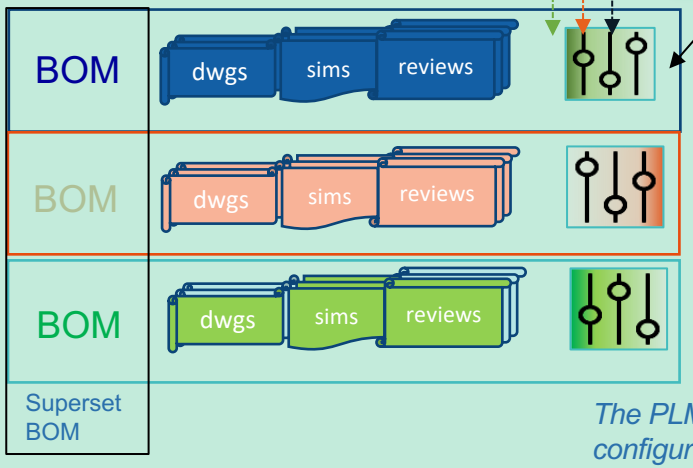

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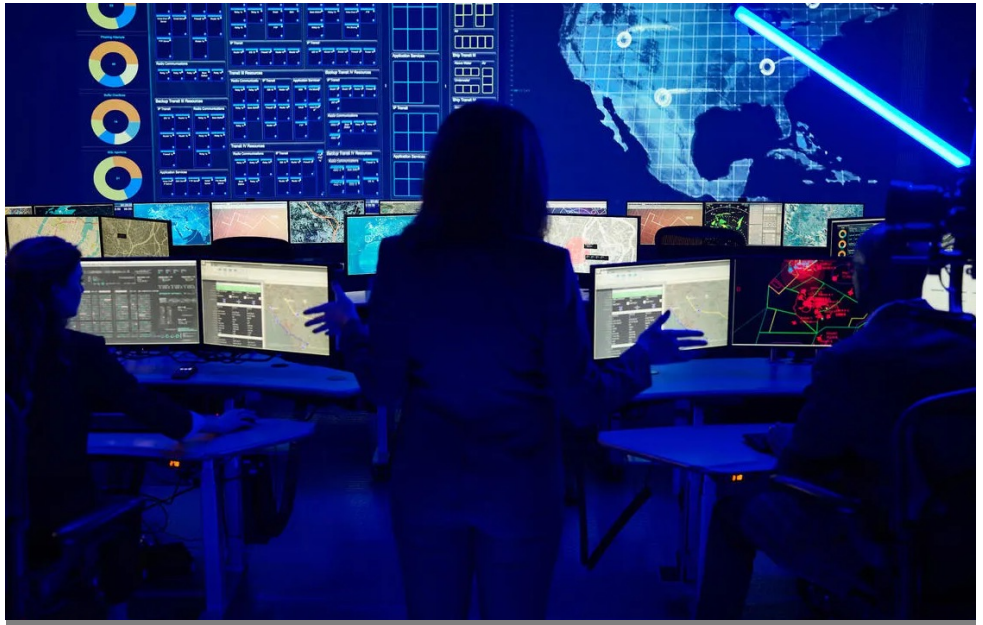
Product Line Tools Business Integration and Roadmap



Paul Kepinski

- NGMS Product Line Alignment Team, Infrastructure Tools Lead

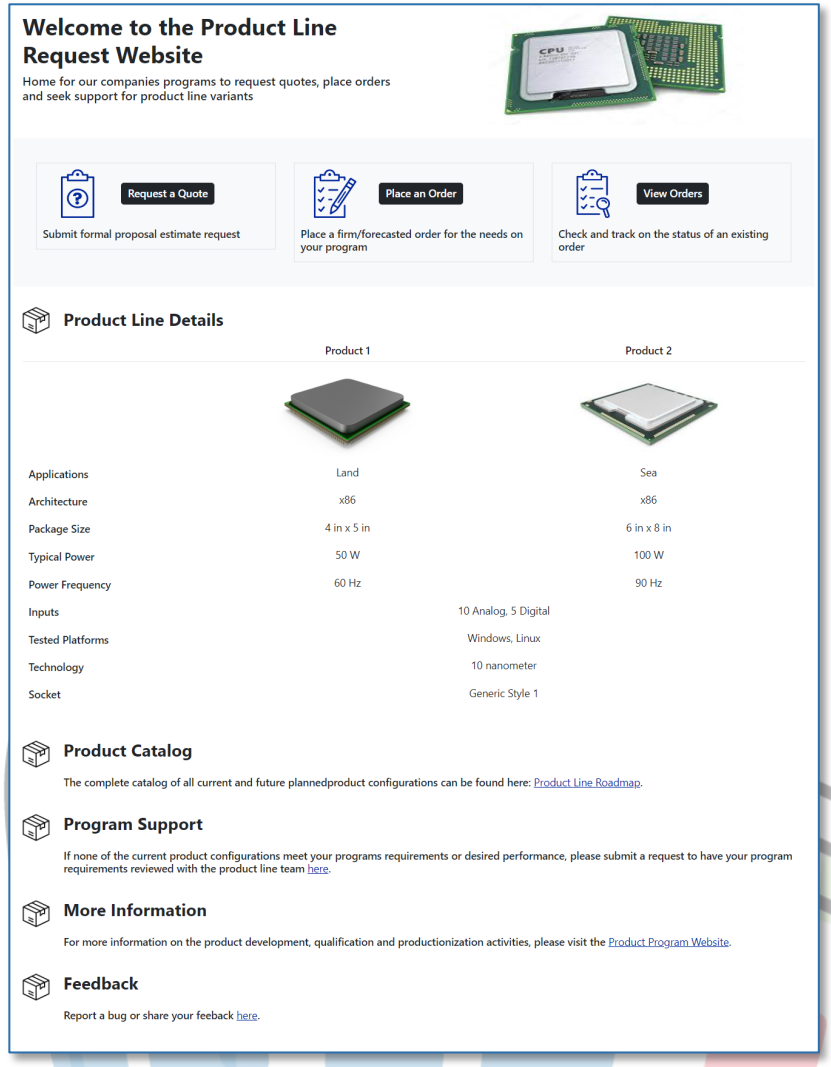
The need for Product Line integration with Business Data

- **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…)

Variant Management & Business Management Intersect



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 plannedproduct 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

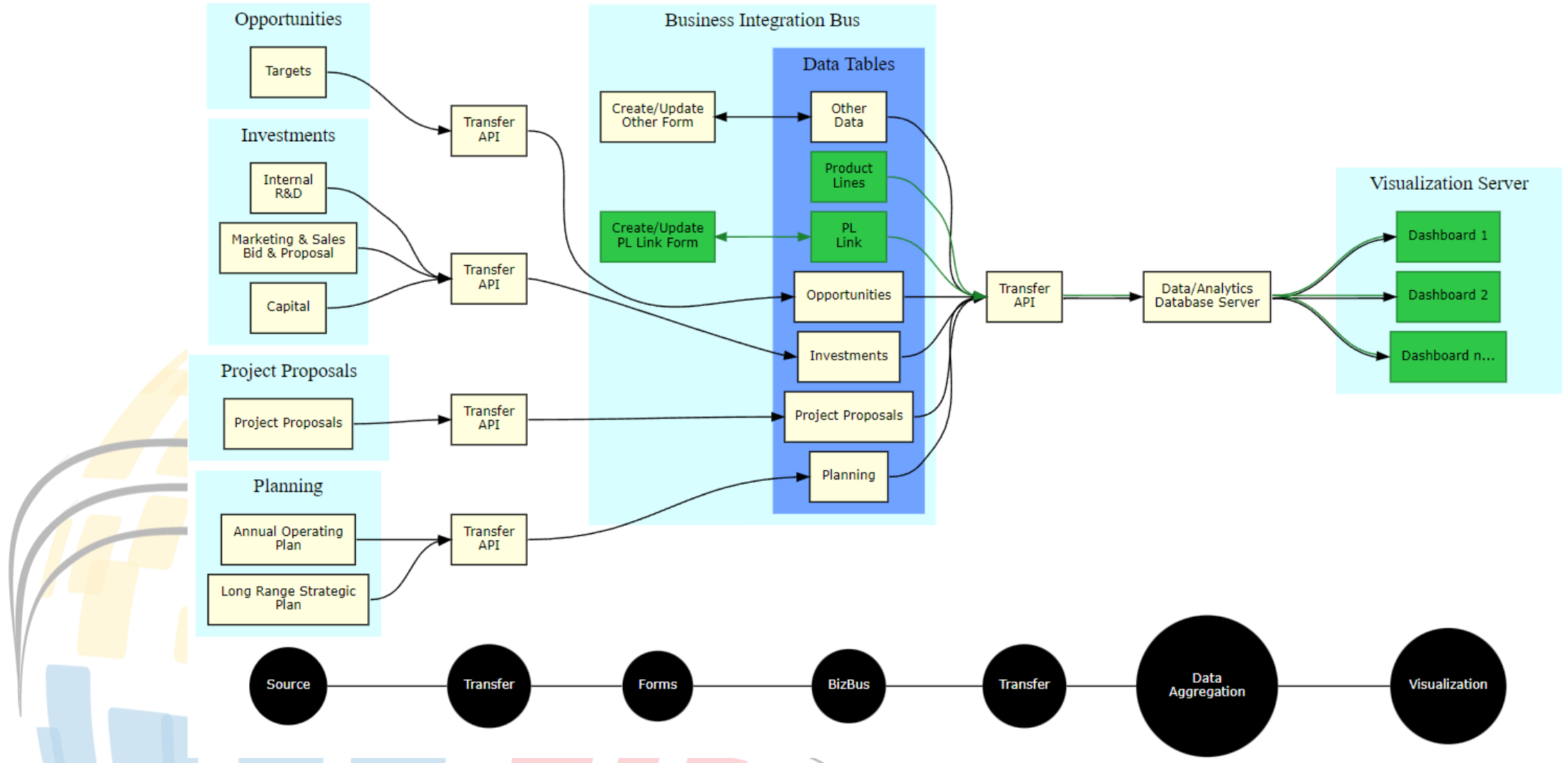
For more information on the product development, qualification and productionization activities, please visit the Product Program Website.

Feedback

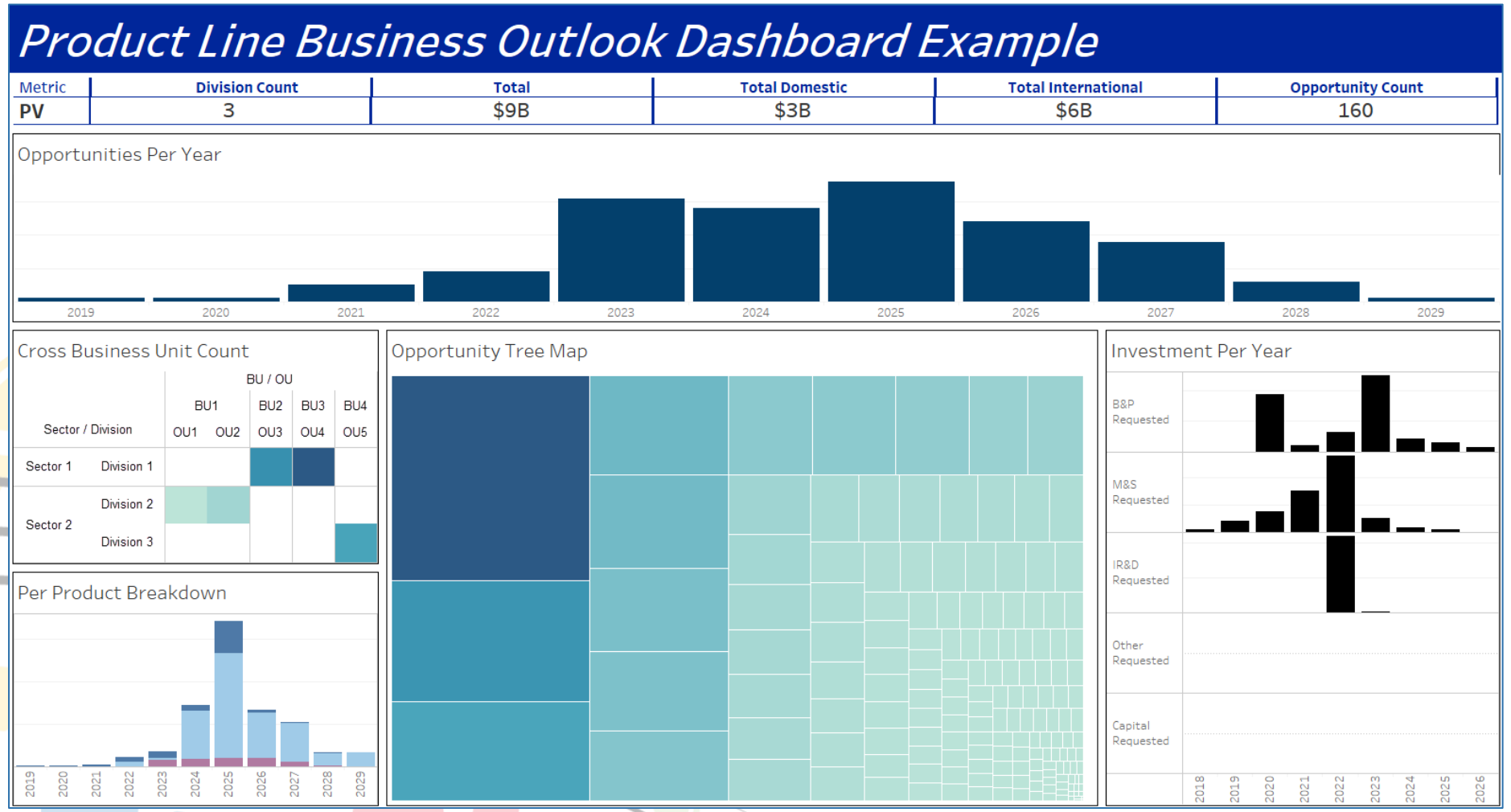
Report a bug or share your feeback here.

- 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.

PLE/Business Integration Example Flow



PLE/Business Integration Dashboard Example



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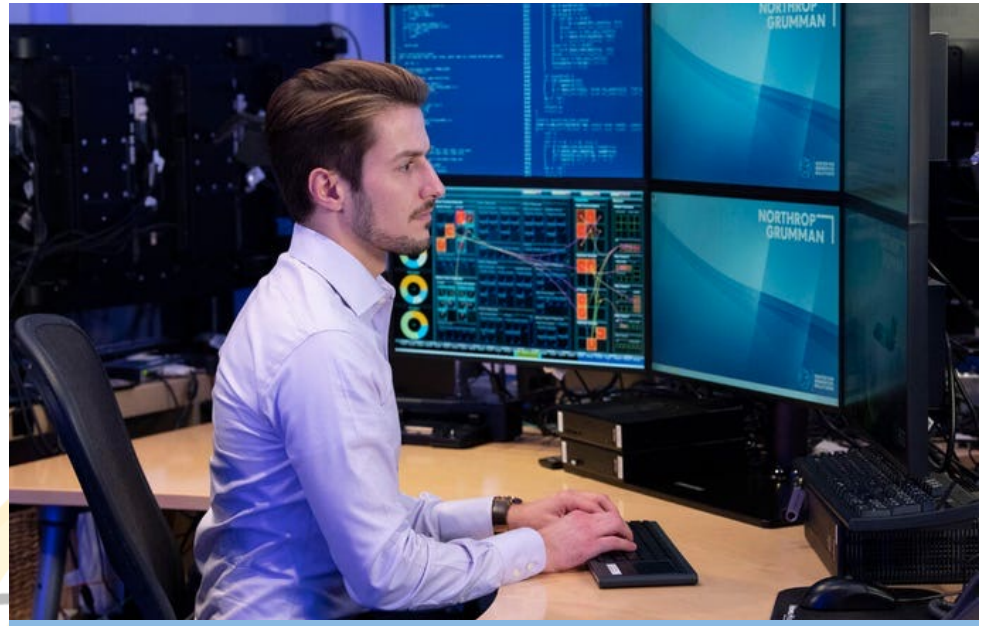

Leveraging Product Line Repositories & Accounting for Reuse

Matthew Reilly
- NGMS Product Line Alignment Team, PL Coaching Lead

Bottom Line for Engineering Reuse

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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**

Reuse Enablers

- 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)

Implementing Efficient Reuse

Reuse Repository[1]

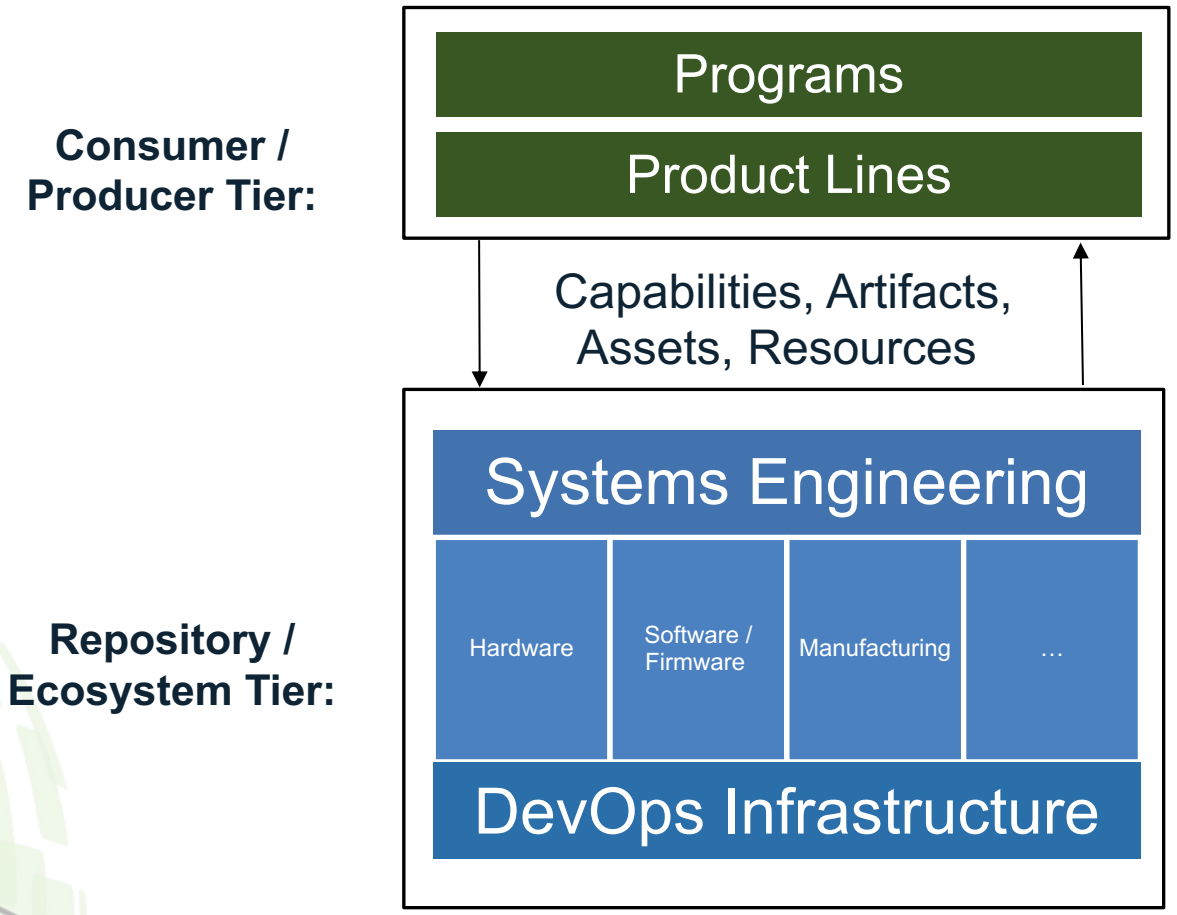
Reusable software assets are stored, along with the catalogue of assets. Everybody should be aware that it contains important company know-how, and should be able to access and use it easily.

Software Ecosystems[2]

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.



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.*

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Accounting for the Benefits of Reuse

Where should be we 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.

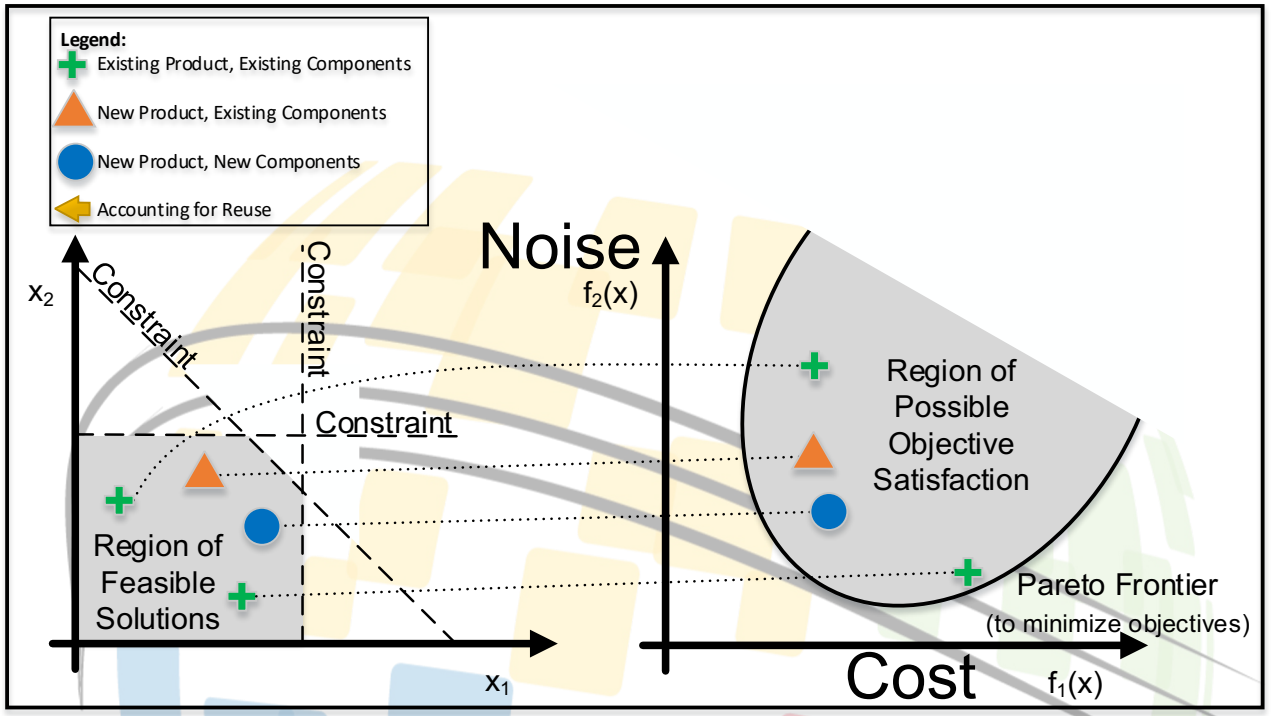
Methods for Quantifying Value of Reuse

Cost & Schedule Modeling (Future Looking)

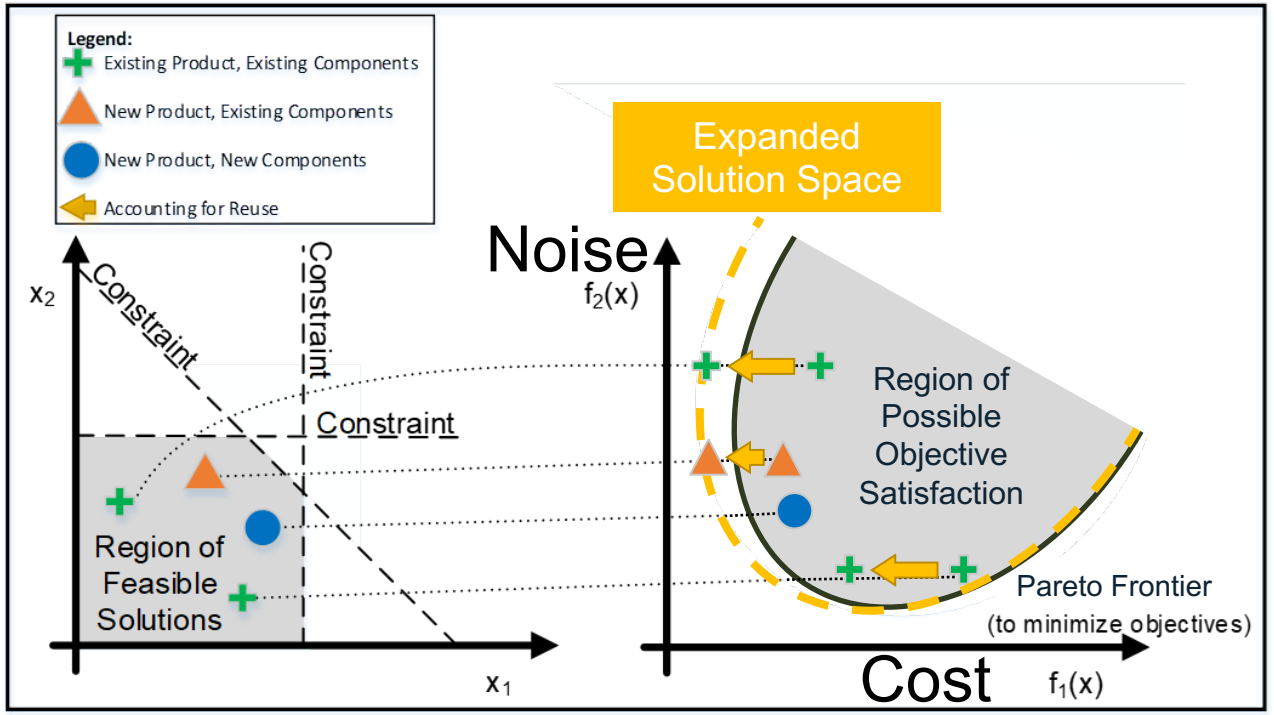
Estimating Actual Savings (Past Looking)

Vision for Engineering Trade Studies for Product Lines

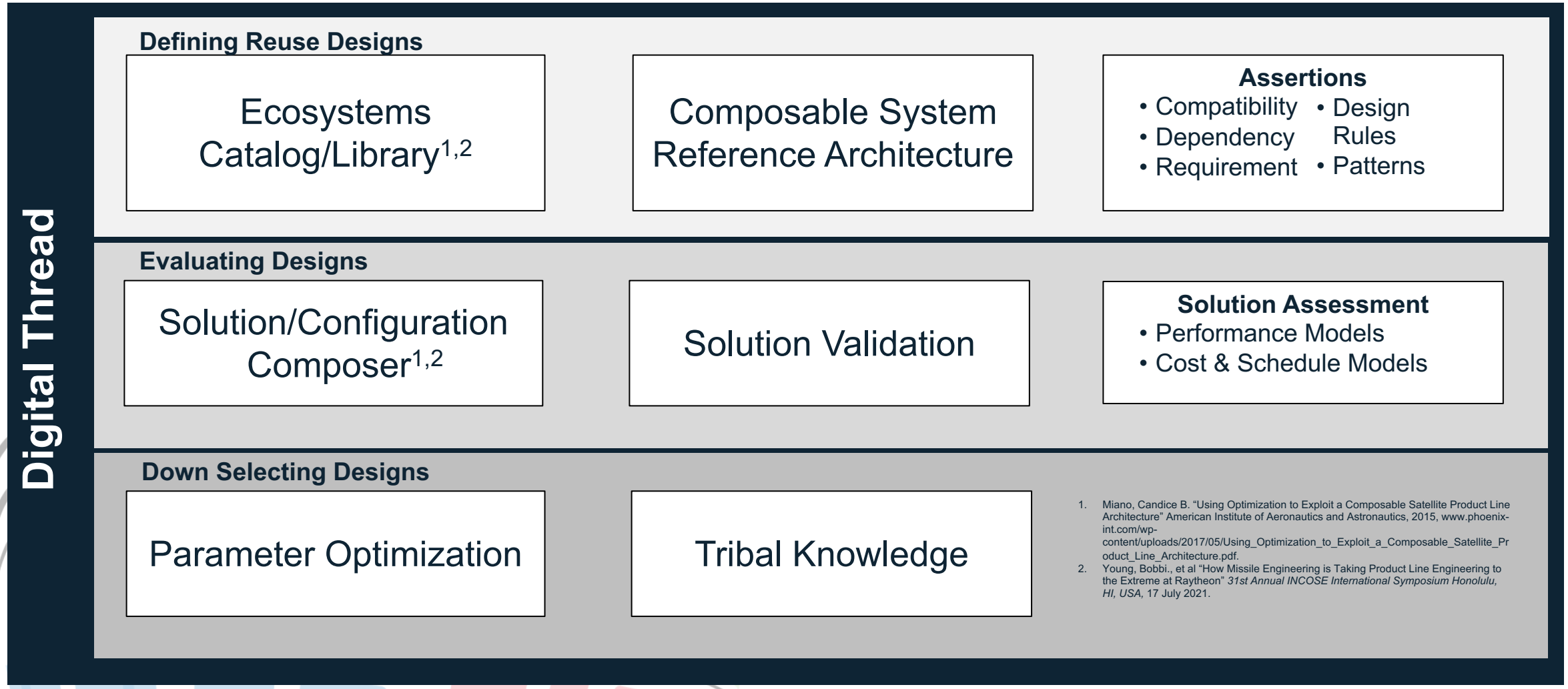
Level 1: Identify Reuse



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



Key Enablers for Accounting for Reuse in Trade Study Analysis



1. Miano, Candice B. "Using Optimization to Exploit a Composable Satellite Product Line Architecture" American Institute of Aeronautics and Astronautics, 2015, www.phoenix-int.com/wp-content/uploads/2017/05/Using_Optimization_to_Exploit_a_Composable_Satellite_Product_Line_Architecture.pdf.
2. Young, Bobbi., et al "How Missile Engineering is Taking Product Line Engineering to the Extreme at Raytheon" *31st Annual INCOSE International Symposium Honolulu, HI, USA*, 17 July 2021.

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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

Universal Exchange Example – Feature Model

- Elysium-Suzuki-Spreier-ExploitingDigitalDataandStandards-MBE-Open.pdf (gpdisonline.com)

Export

Exchange Format Example

```
<element name="FeatureModelName" type="feature">
    <relation class="children" range="[0,n]" type="optional">
        <target>Feature1</target>
        <target>Feature2</target>
    </relation>
</element>

        <element name="Feature1" type="feature">
            <relation class="parents" type="parent">
                <target>FeatureModelName</target>
            </relation>
            <relation class="children" range="1" type="alternative">
                <target>Feature1a</target>
                <target>Feature1b</target>
            </relation>
            <vname><mimedesc mimetype="text/plain">Feature1</mimedesc></vname>
            <desc><mimedesc mimetype="text/html">&lt;p&gt;Feature1 Description Text&lt;/p&gt;</mimedesc></desc>
        </element>

                <element name="Feature1a" type="feature">
                    <relation class="parents" type="parent">
                        <target>Feature1</target>
                    </relation>
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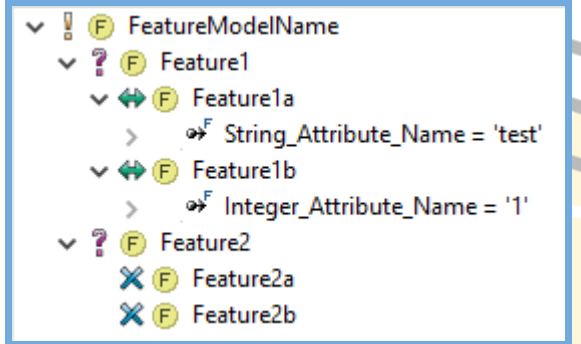
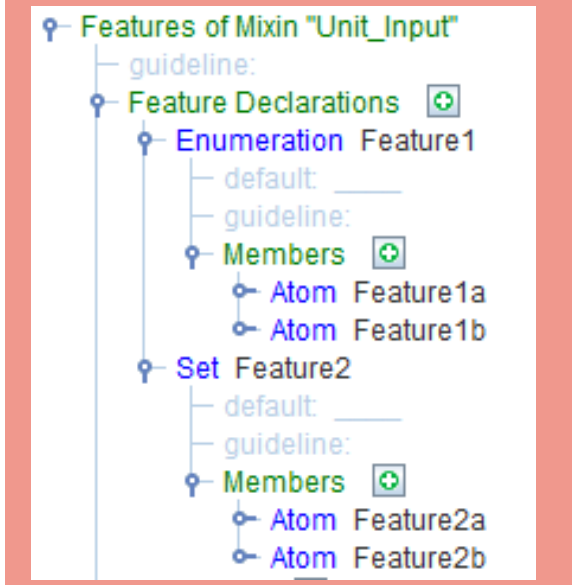
Import

PLE Tool A



PLE Tool B



Conclusion

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.