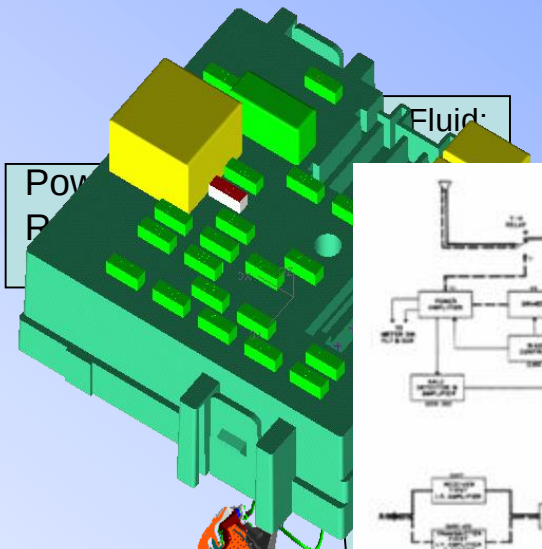
The Digital Enterprise Journey

Matthew Hause
PTC Engineering Fellow
MBSE Specialist

Integrated Systems Engineering Vision



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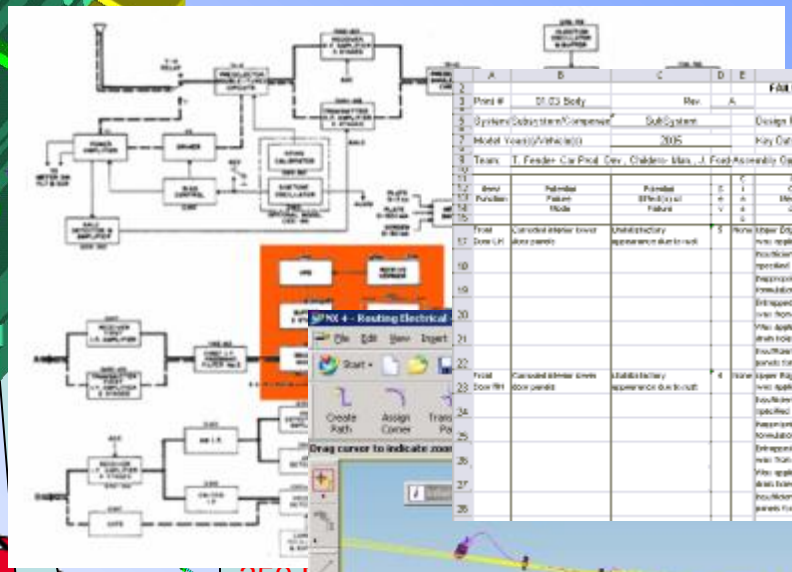
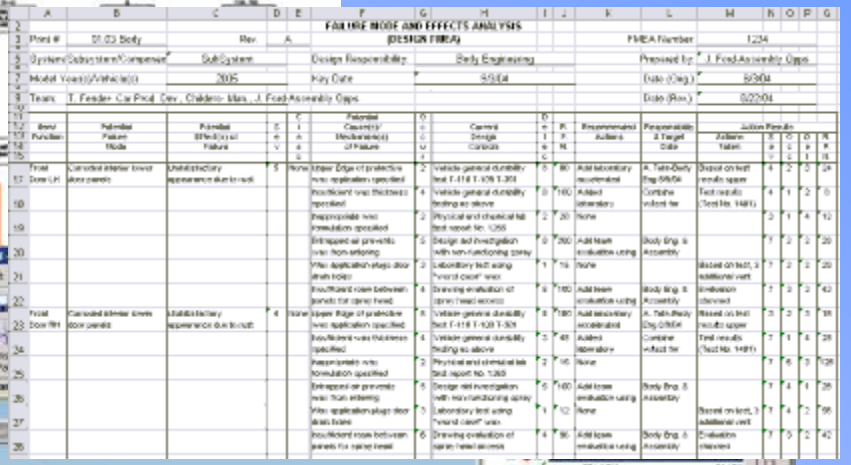
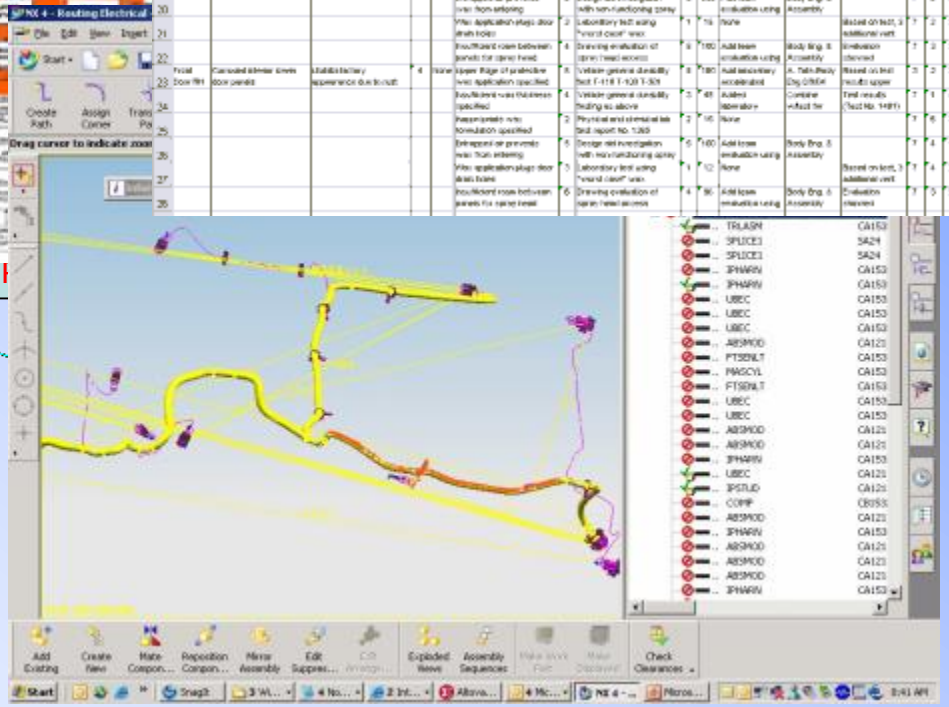






Sensor
MTBF:
3000 hrs

Minimum Turn Radius: 24 ft.
Dry Pavement Braking Distance at
60 MPH: ~~110 ft~~. 90 ft

Current Integrated Systems Engineering

- Current systems engineering tools leverage computing and information technologies to some degree, and make heavy use of office applications for documenting system designs. The tools have limited integration with other engineering tools

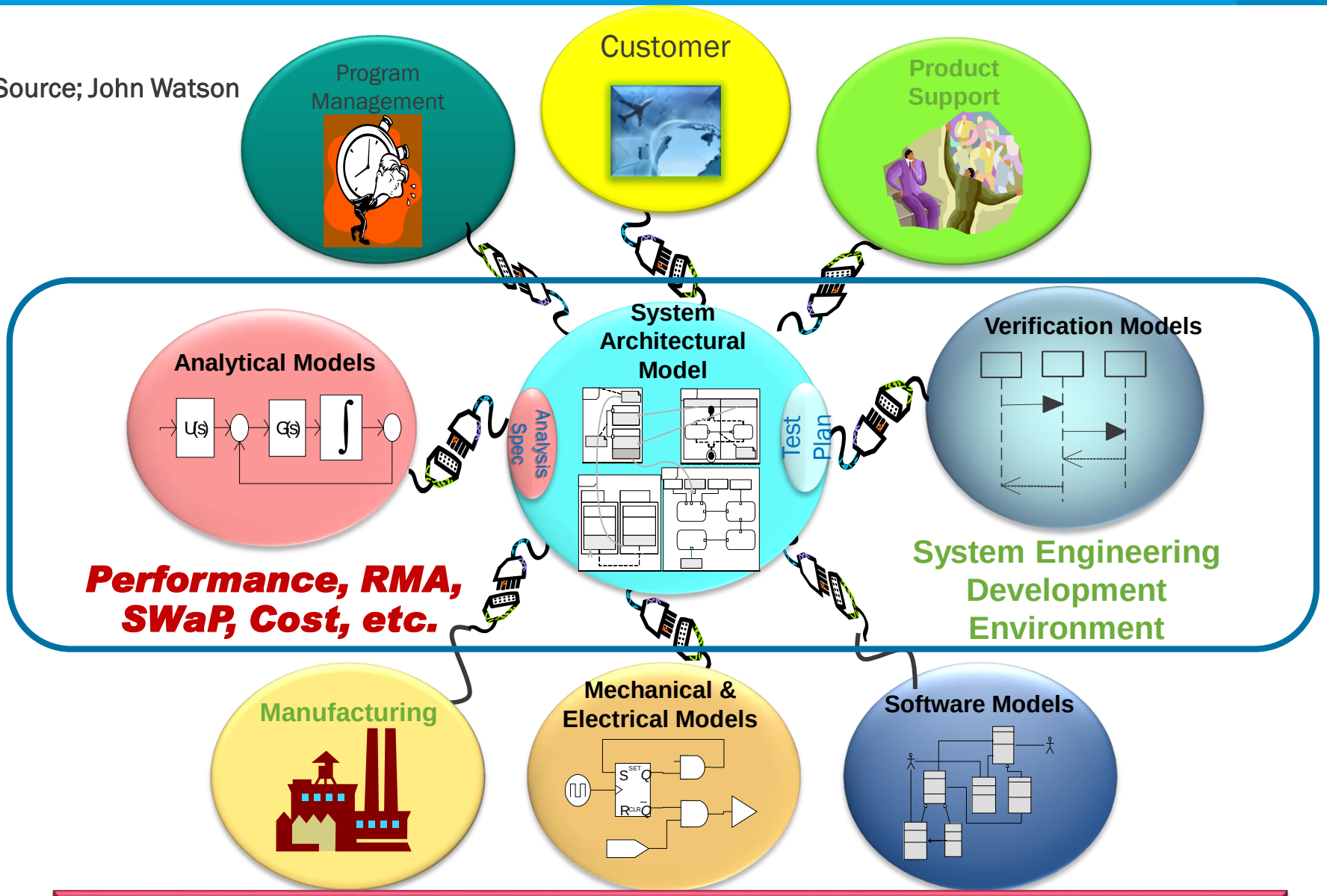

A WORLD IN
MOTION
INCOSE Systems Engineering Vision • 2025

Integrated Systems Engineering Vision 2025

- The systems engineering tools of 2025 will facilitate systems engineering practices as part of a fully integrated engineering environment.
- **Systems engineering tools will integrate with CAD/CAE/PLM environments, project management and workflow tools as part of a broader computer-aided engineering and enterprise management environment.**
- Systems engineering tools will support high fidelity simulation, immersive technologies to support data visualization, semantic web technologies to support data integration, search, and reasoning, and communication technologies to support collaboration.
- Systems engineering tools will benefit from internet-based connectivity and knowledge representation to readily exchange information with related fields.
- The systems engineer of the future will be highly skilled in the use of IT-enabled engineering tools.

EVOLVING MBSE USE CASES

Source; John Watson



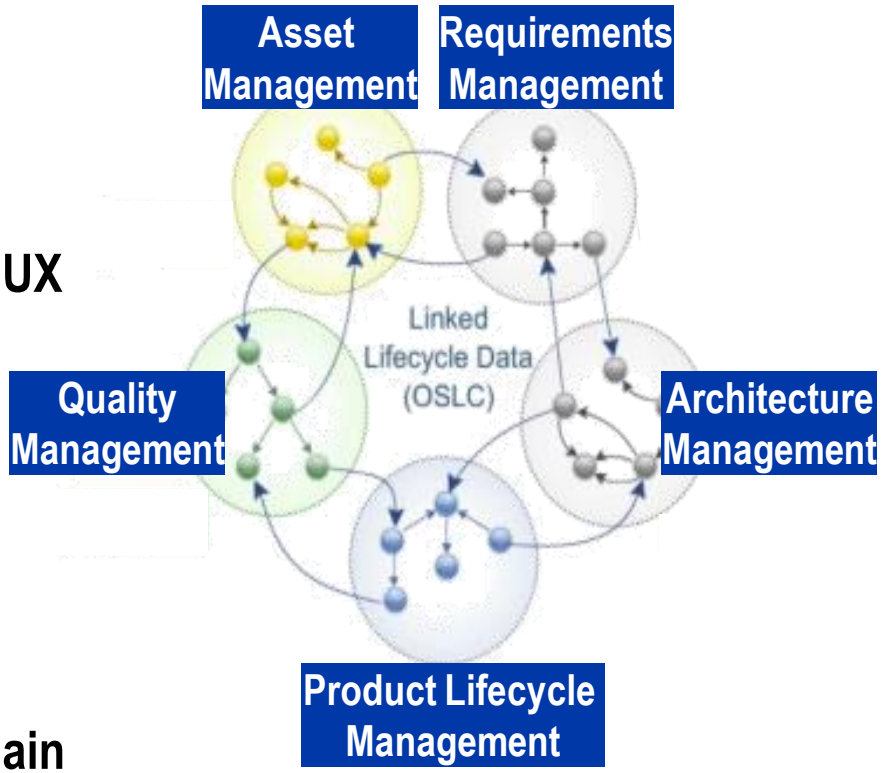
To measure MBSE effectiveness we need to understand the context of how it is used

Open Services for Lifecycle Collaboration

OSLC is being used as a foundational layer to satisfy key customer use cases – extended as needed to deliver more robust interoperability.

- **Standards-based**
  - Extends the value of ALM investments
  - RESTful Web Services architecture
- **Designed for maintainability**
  - Source application owns both data and UX
  - No data transformations, replication or synchronization
- **Open / extensible**
  - Enables use cases for cross-vendor interoperability
  - Supports N:N relationships – ideal for selective data sharing across supply chain

"Link, not synch"



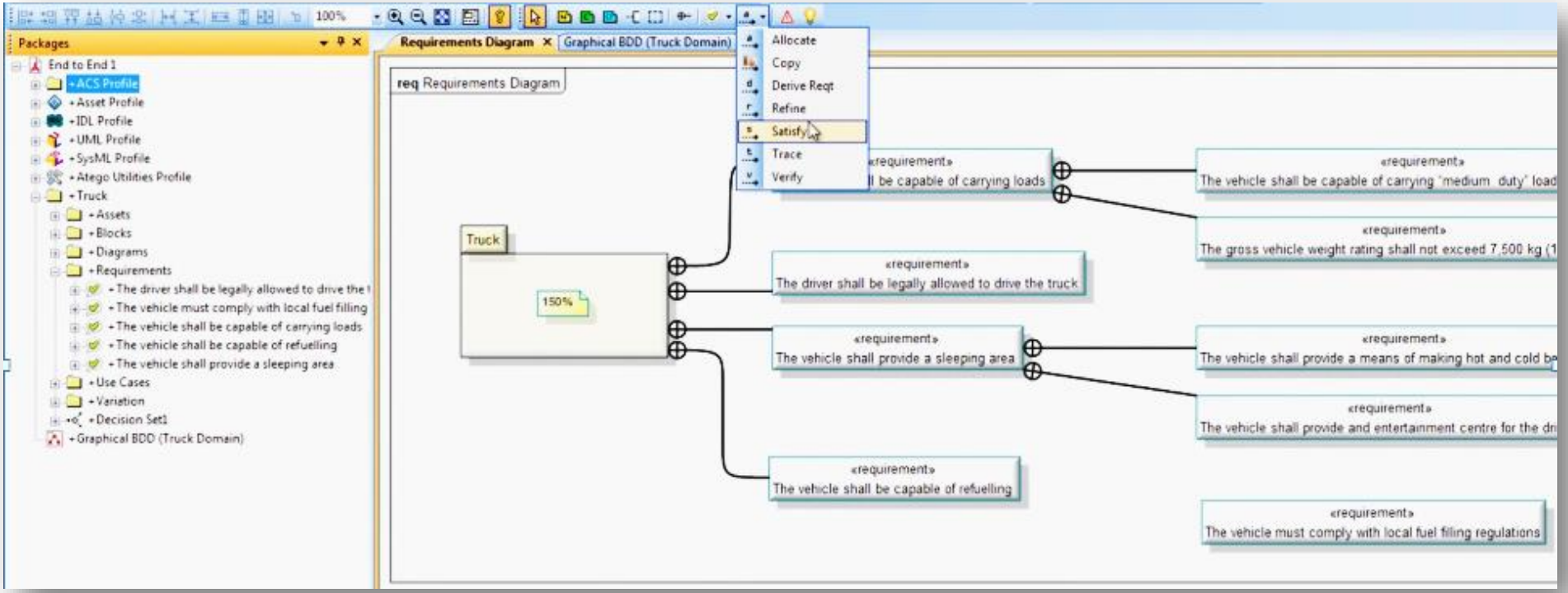
OSLC Groups

- ALM-PLM Interoperability (2nd edition)
  - Define Industrial relevant scenarios for interoperability of ALM and PLM engineering.
- Lifecycle Integration Patterns
  - A user group focused on finding and sharing of solutions to common lifecycle integration problems.
- Linked Data Platform
  - Writing a W3C specification for HTTP-based (RESTful) application integration patterns using read/write Linked Data.
- RDF Data Shapes
  - Writing a W3C Recommendation for describing structural constraints and validate RDF instance data against those
- Automation
  - Reducing manual interactions in all phases of software development and operations
- Change and Configuration Management
  - Tasks, defects, assets, and configurations at OASIS
- PROMCODE TC
  - Exchanging project management information across organizational boundaries
- Core
  - Common problems with finding, creating, and updating resources
- Architecture Management
  - Modeling, diagrams, and use cases for software development
- Automation
  - Plans, requests, and results for builds and deployments
- Change Management
  - Defects, enhancements, changes, and tasks
- Performance Monitoring
  - Watching availability, performance, and capacity
- Quality Management
  - Plans, cases, and results for ongoing testing
- Requirements Management
  - Define stakeholder needs and how to meet them
- Embedded Systems
  - Integrating dedicated components
- Mobile
  - Mobile-specific needs
- Asset Management
  - Reusable components, documentation, and representations
- Configuration Management
  - Snapshots, baselines, and versions
- Estimation and Measurement
  - Size, quality, time, and effort for making software

Application Lifecycle Management

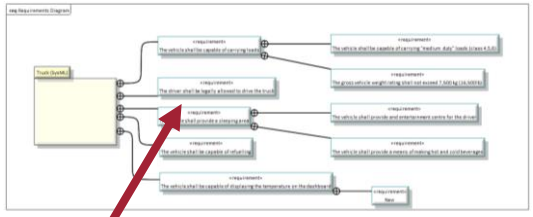
Requirements Modeling

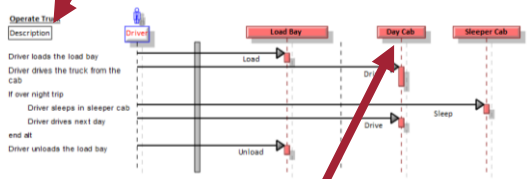
- **Model Requirements in SysML or**
- **Import from a Requirements Management tool**

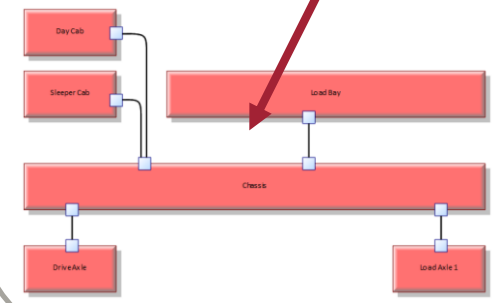


MBSE and Requirements Integration

MBSE Tool







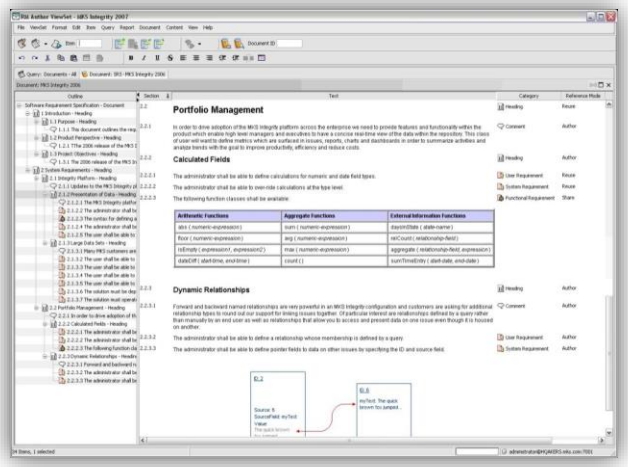
MBSE/Requirements Synchronizer

Requirements

Additional Model Elements

Model Trace Links

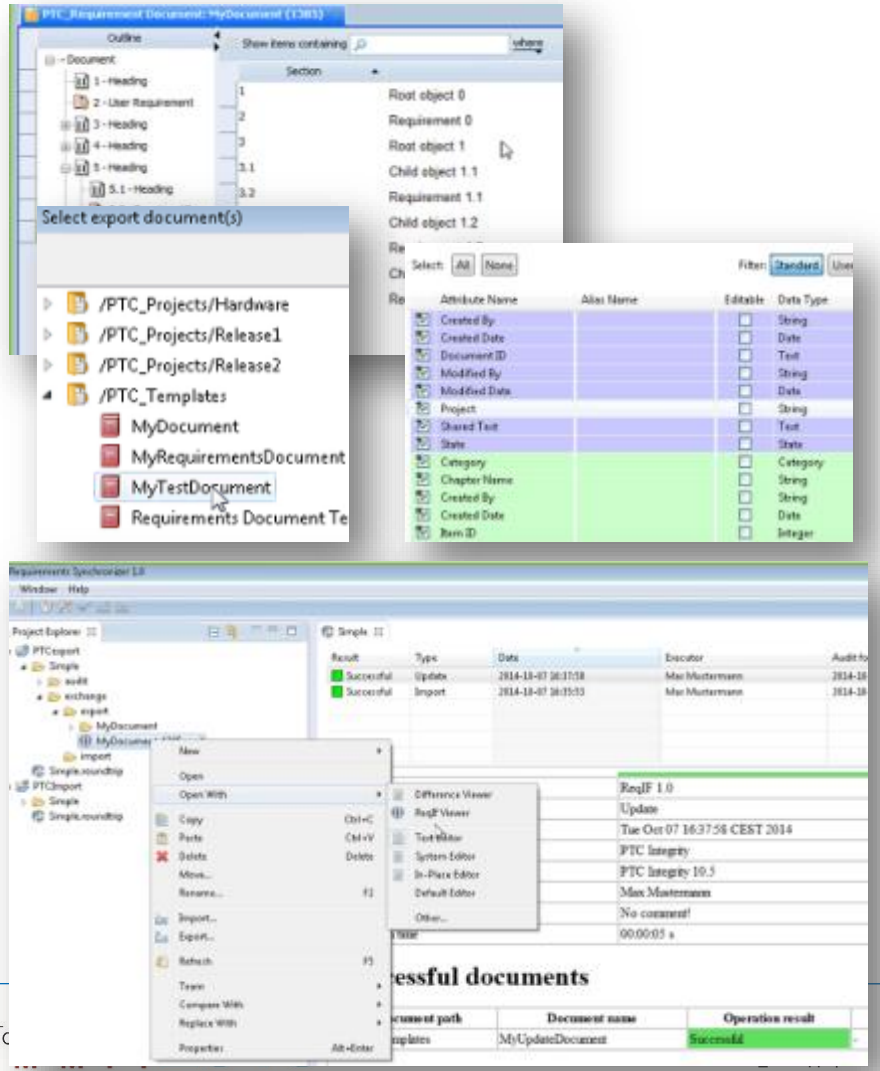
Requirements Management Tool



OMG ReqIF Requirements Interchange

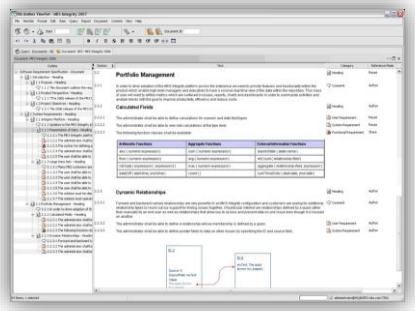
Challenge: Difficulty in exchanging requirements across various boundaries

- **Description of Problem**
  - **Customers increasingly need to exchange requirements and specifications between or within companies using the same or different requirement management applications**
- **Use Case(s)**
  - **Synchronize requirements for supported applications**
    - **IBM DOORs**
    - **PTC Integrity Lifecycle Manager**
  - **Imports and exports standard ReqIF (requirement interchange format) files**
  - **Support rich text, images, OLE, and relationship information**
  - **Independent viewer for standard ReqIF files**
  - **Flexible configuration and mapping of exchange information**
- **Customer Value**
  - **Enables organizations to interchange large amounts of requirements information on an on-going and managed basis over the lifetime of any particular project or product.**

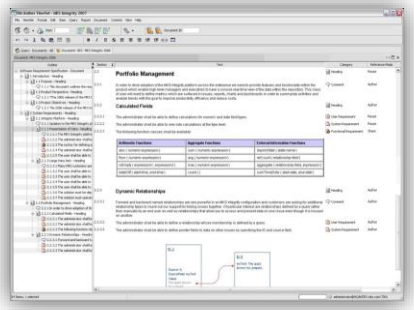


Requirements Interchange and Connection

PTC Integrity
Lifecycle Manager



PTC Integrity
Lifecycle Manager



IBM Rational DOORS

PTC Integrity
Lifecycle Manager Adaptor

PTC Integrity
Lifecycle Manager Adaptor

PTC Integrity
DOORS Adaptor

PTC Integrity
Requirements Connector

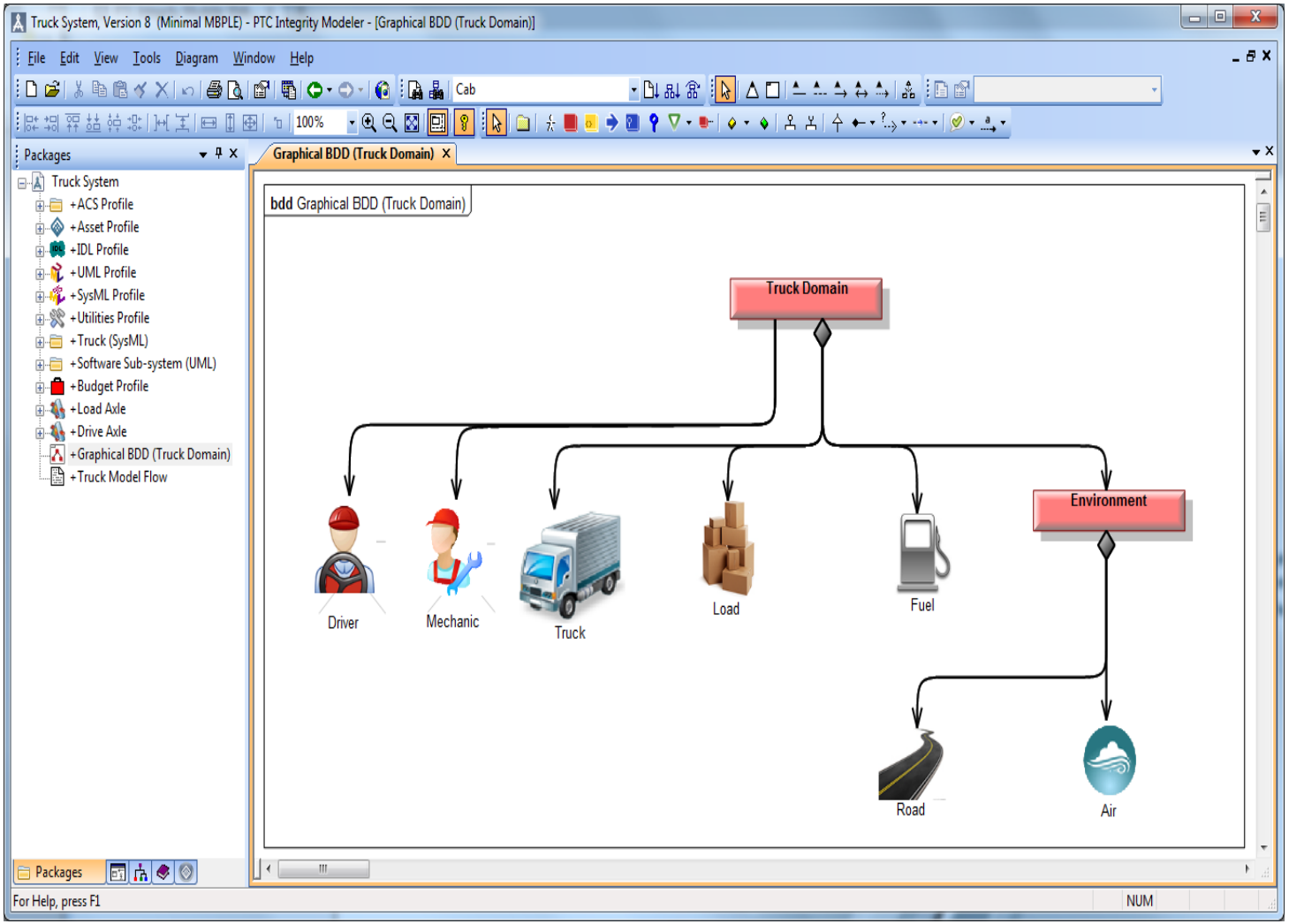
PTC Integrity
Requirements Connector

PTC Integrity
Requirements Connector

Requirements

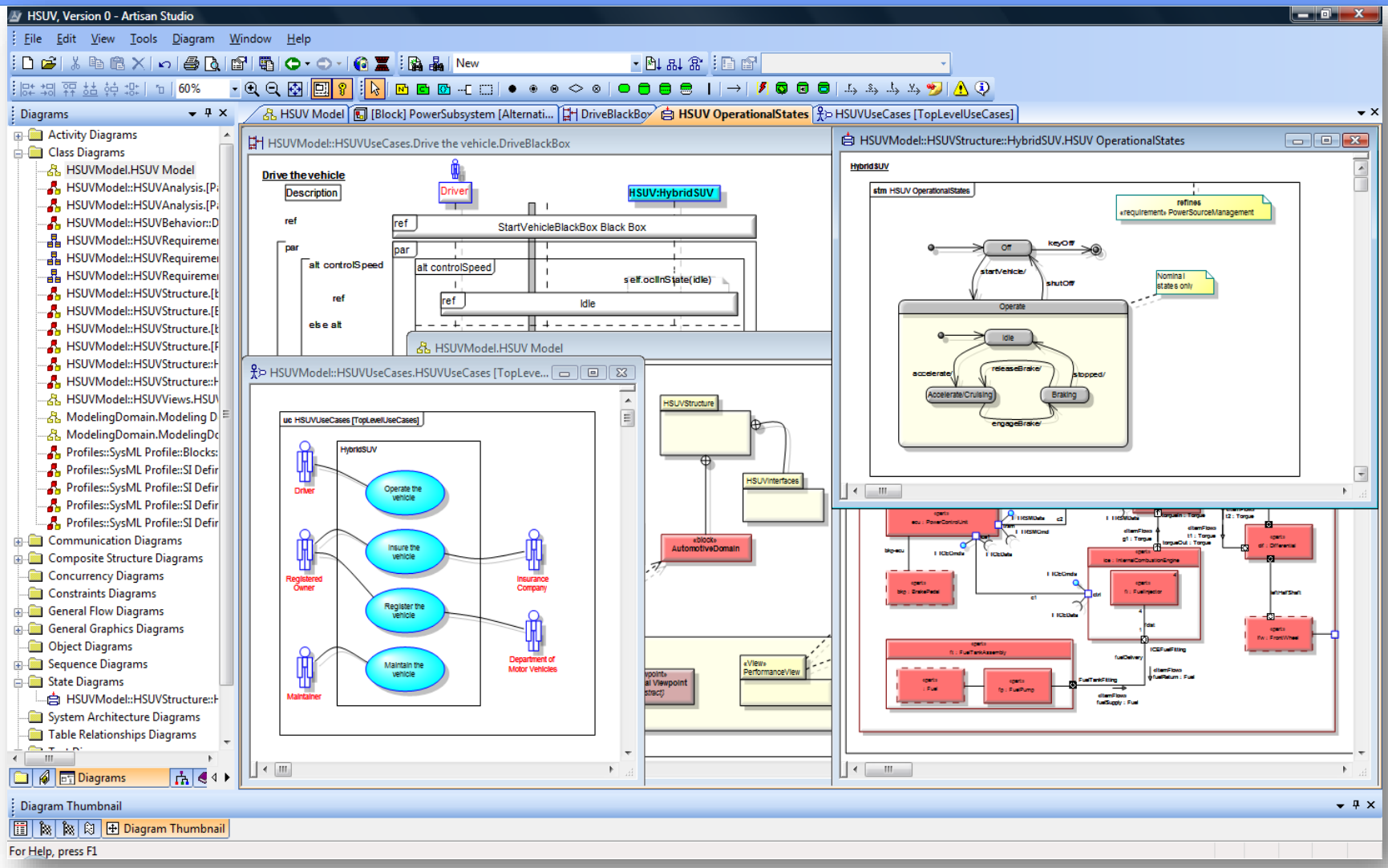
OMG
ReqIF

System Context Modeling

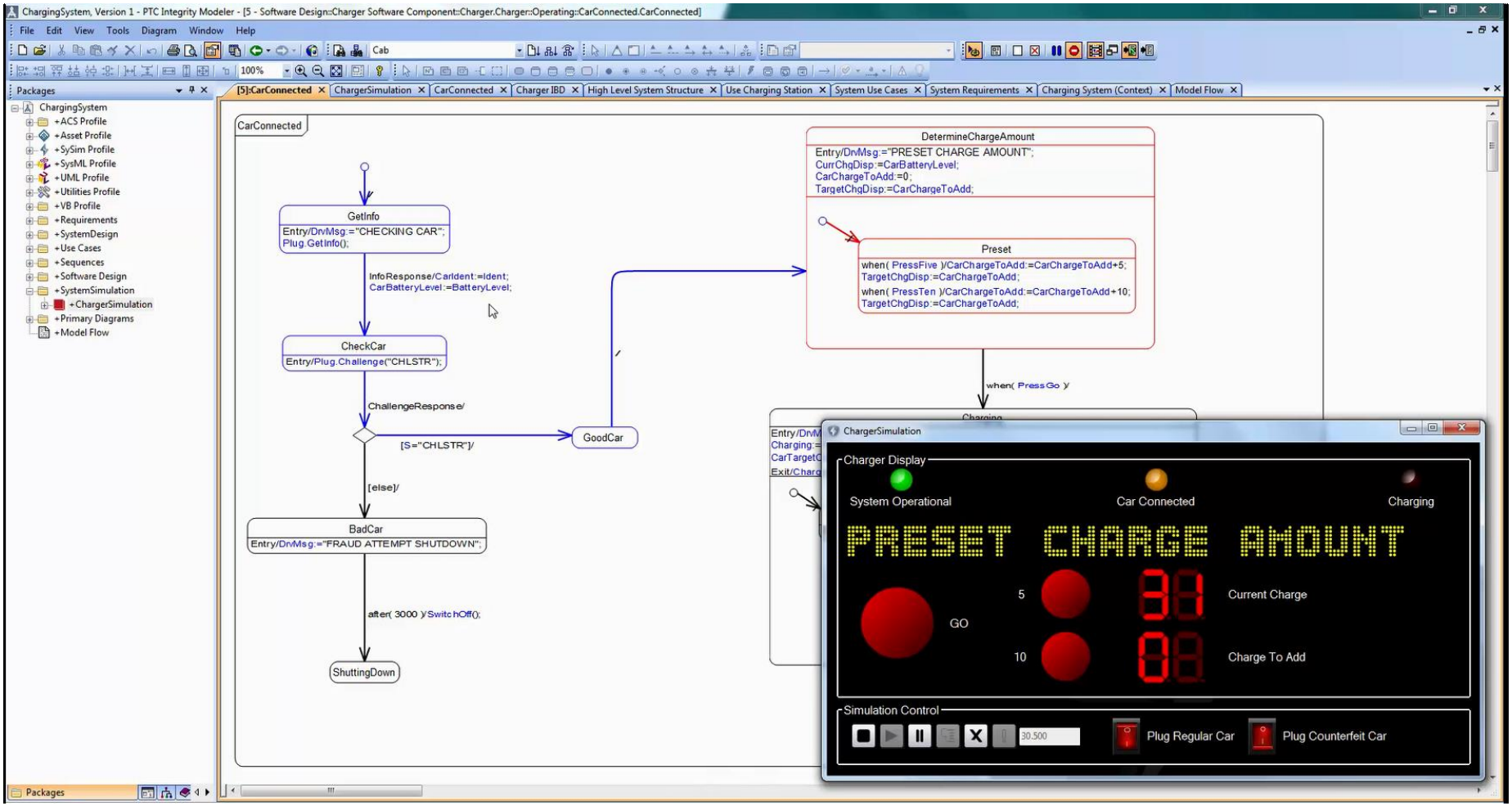


Structural and Behavioral Modeling

Global Product Data Interoperability Summit | **2016**

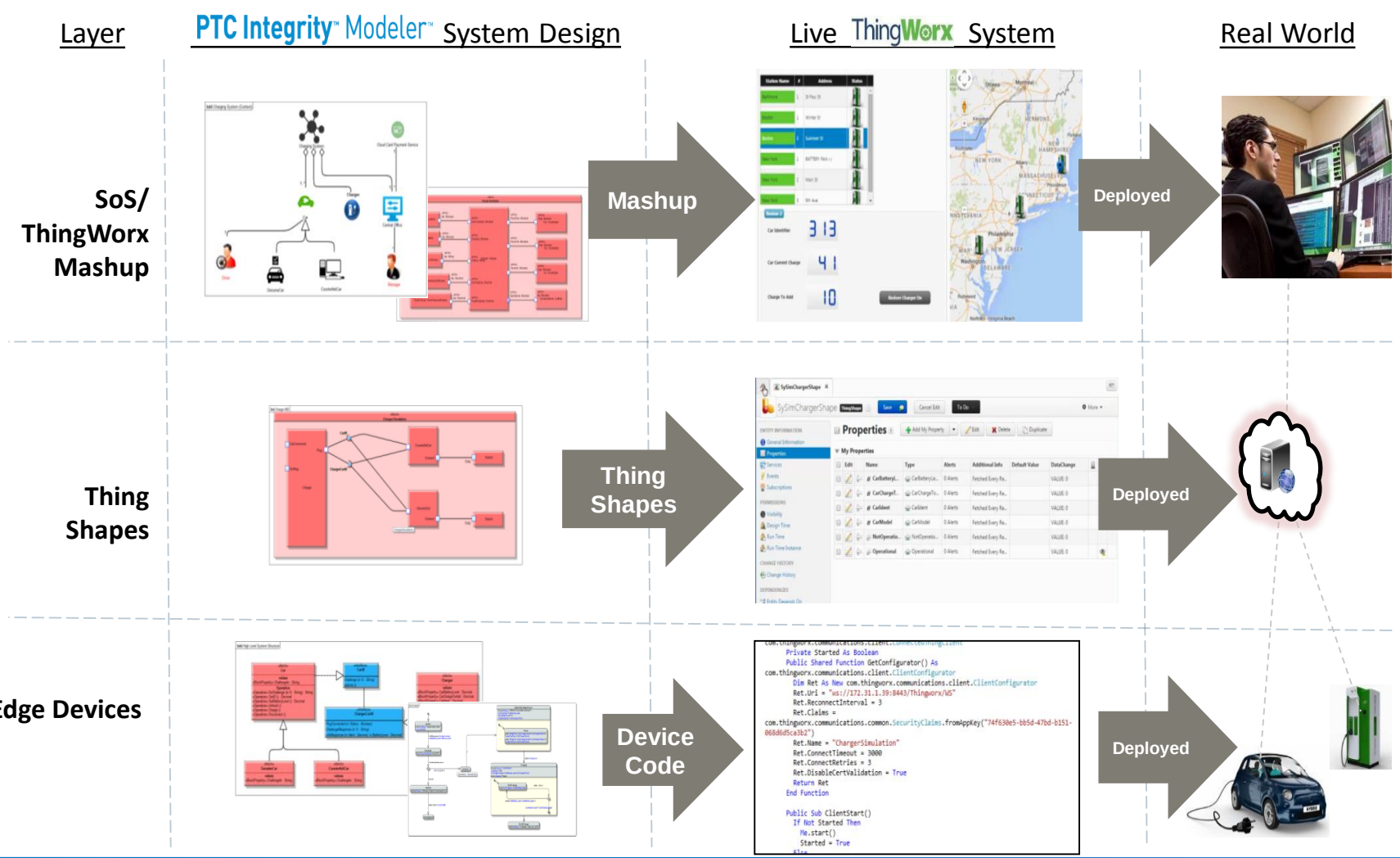


System Model Simulation



Systems Engineering and the Internet of Things

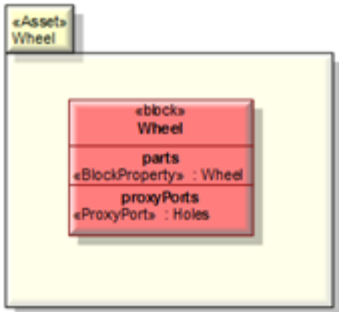
Global Product Data Interoperability Summit | **2016**



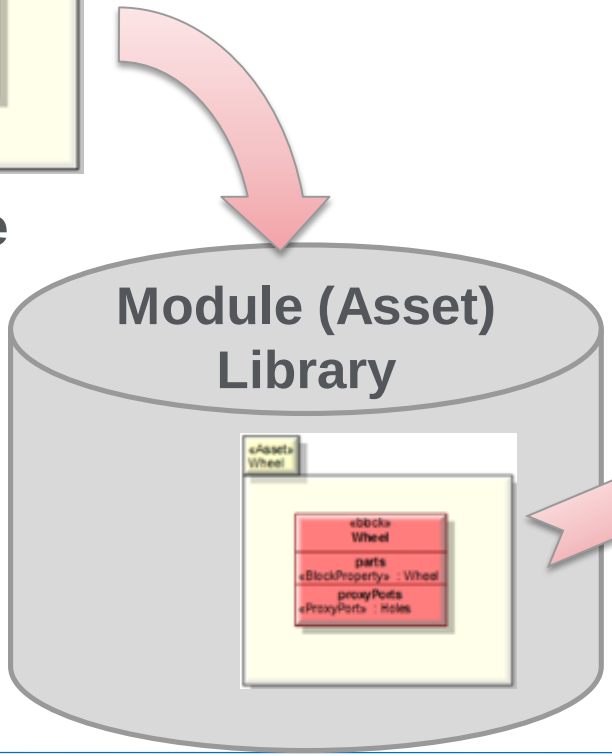
Product Line Engineering

OMG Reusable Asset Specification (RAS)

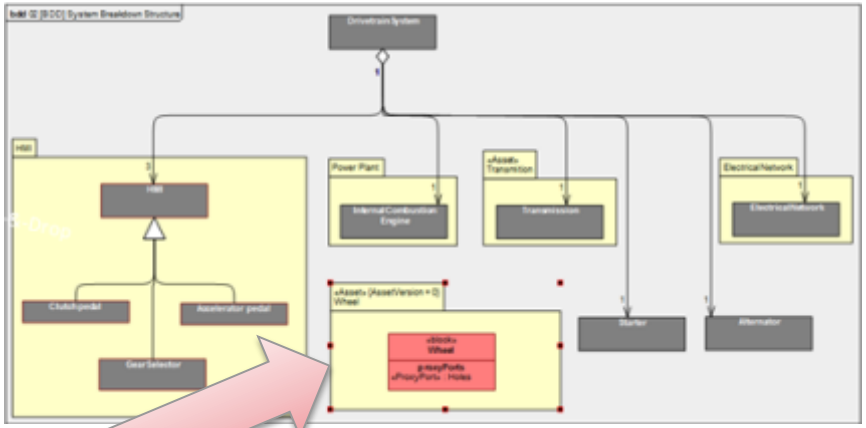
- Modular Design is an approach which segments the design of whole systems into linked, manageable and reusable sub-system designs



Module



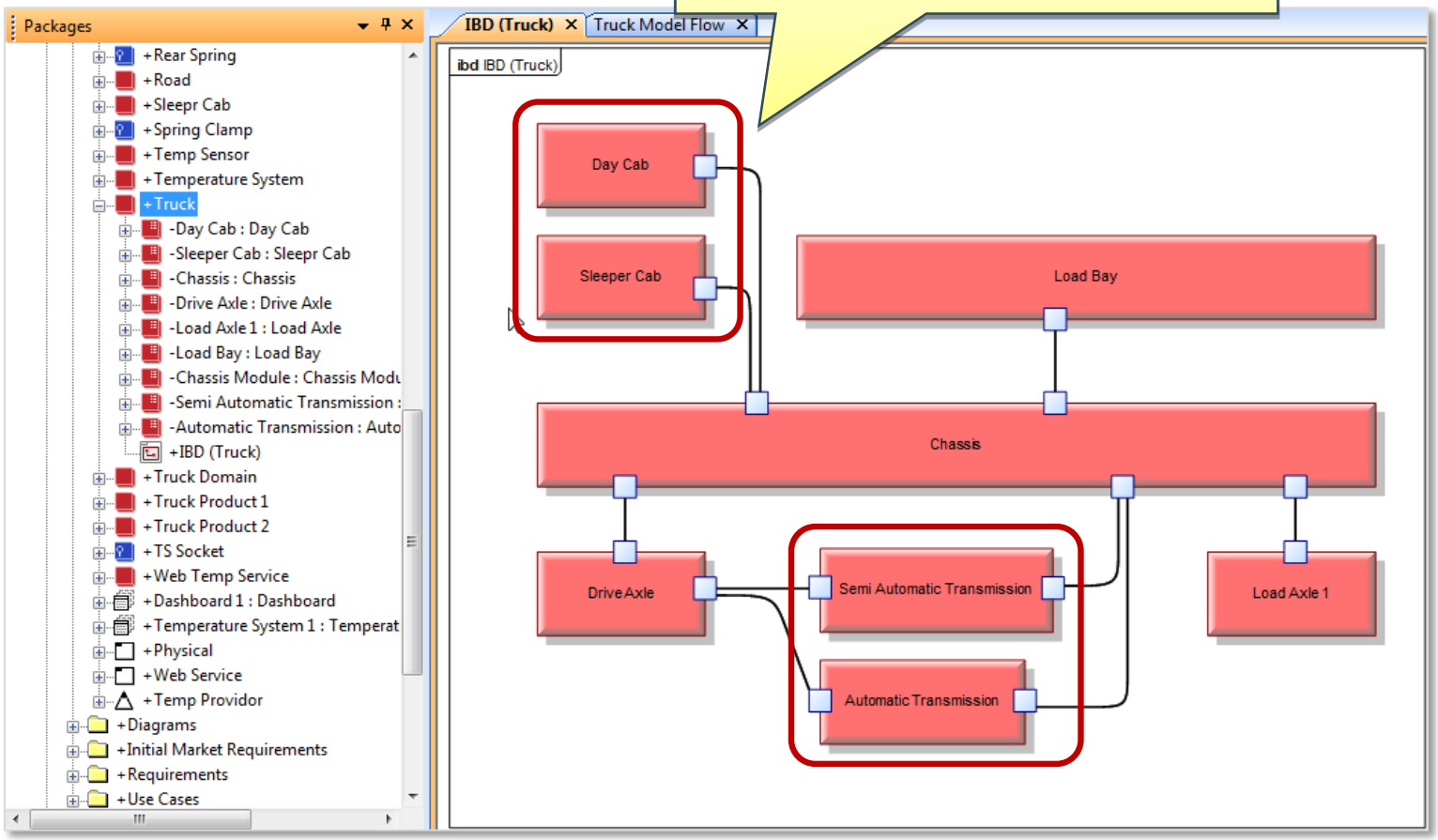
System Model



Expand product offering while reducing costs

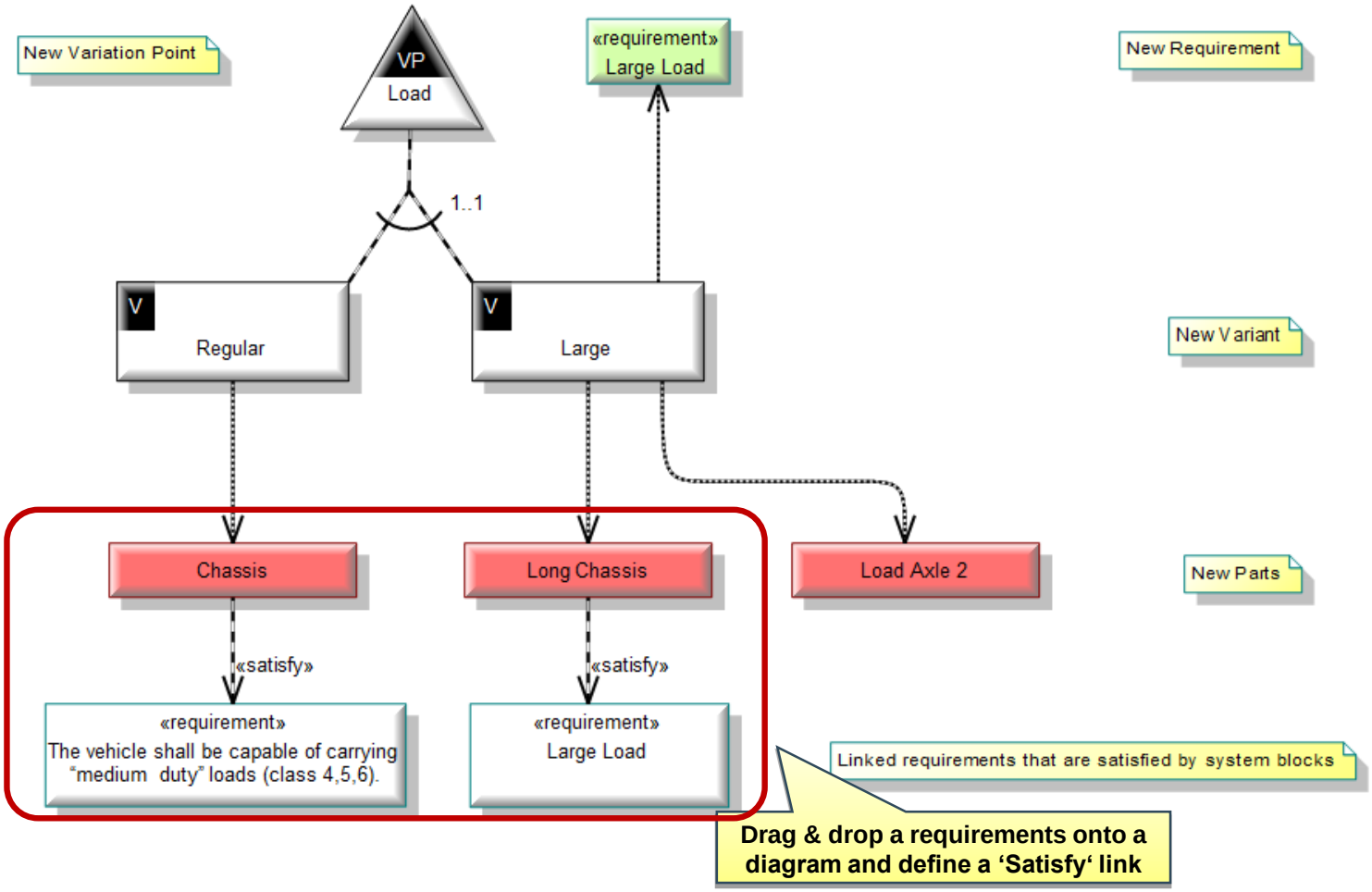
The Overloaded System Model

The resulting 'Overloaded' System Model created by using previously created System Blocks, or reused Library Assets

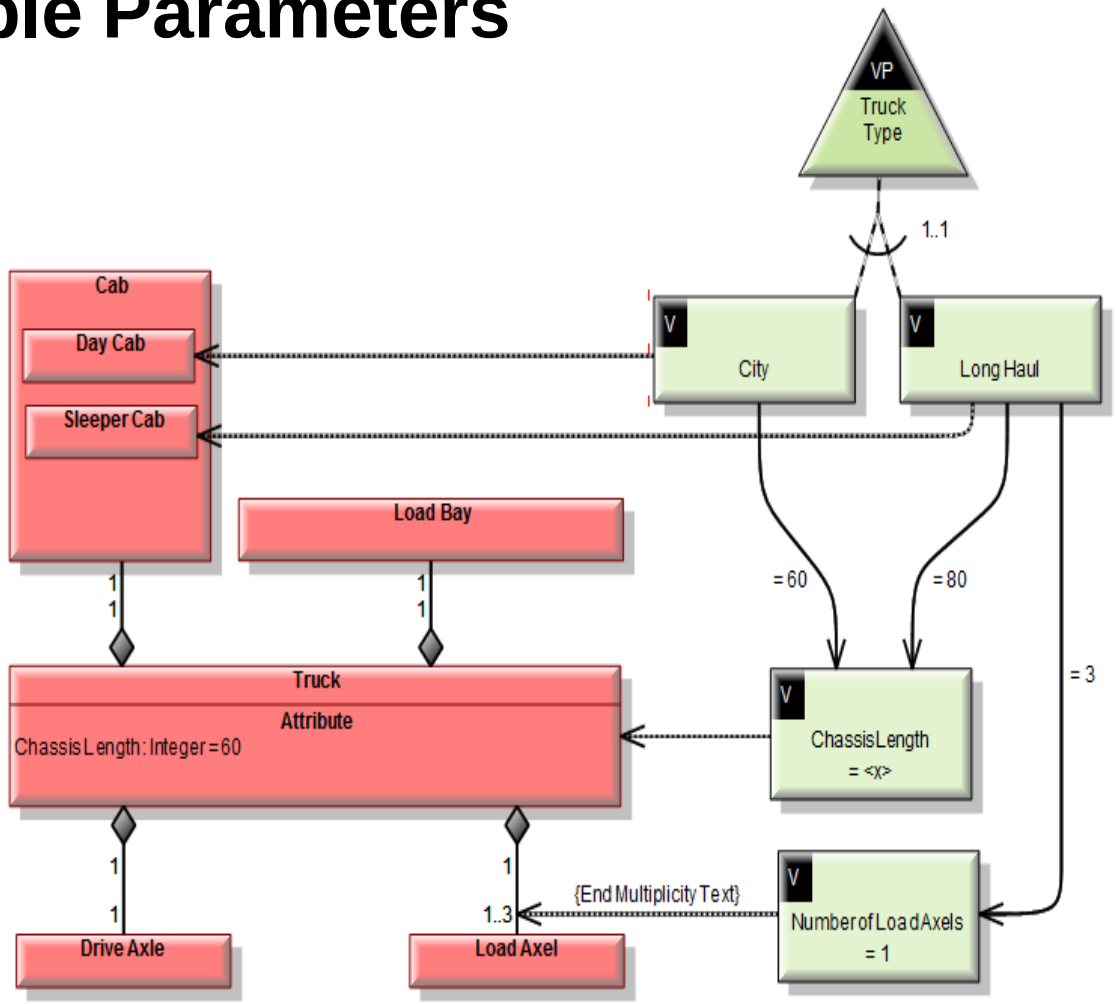


Model Based Product Line Engineering ISO 26550

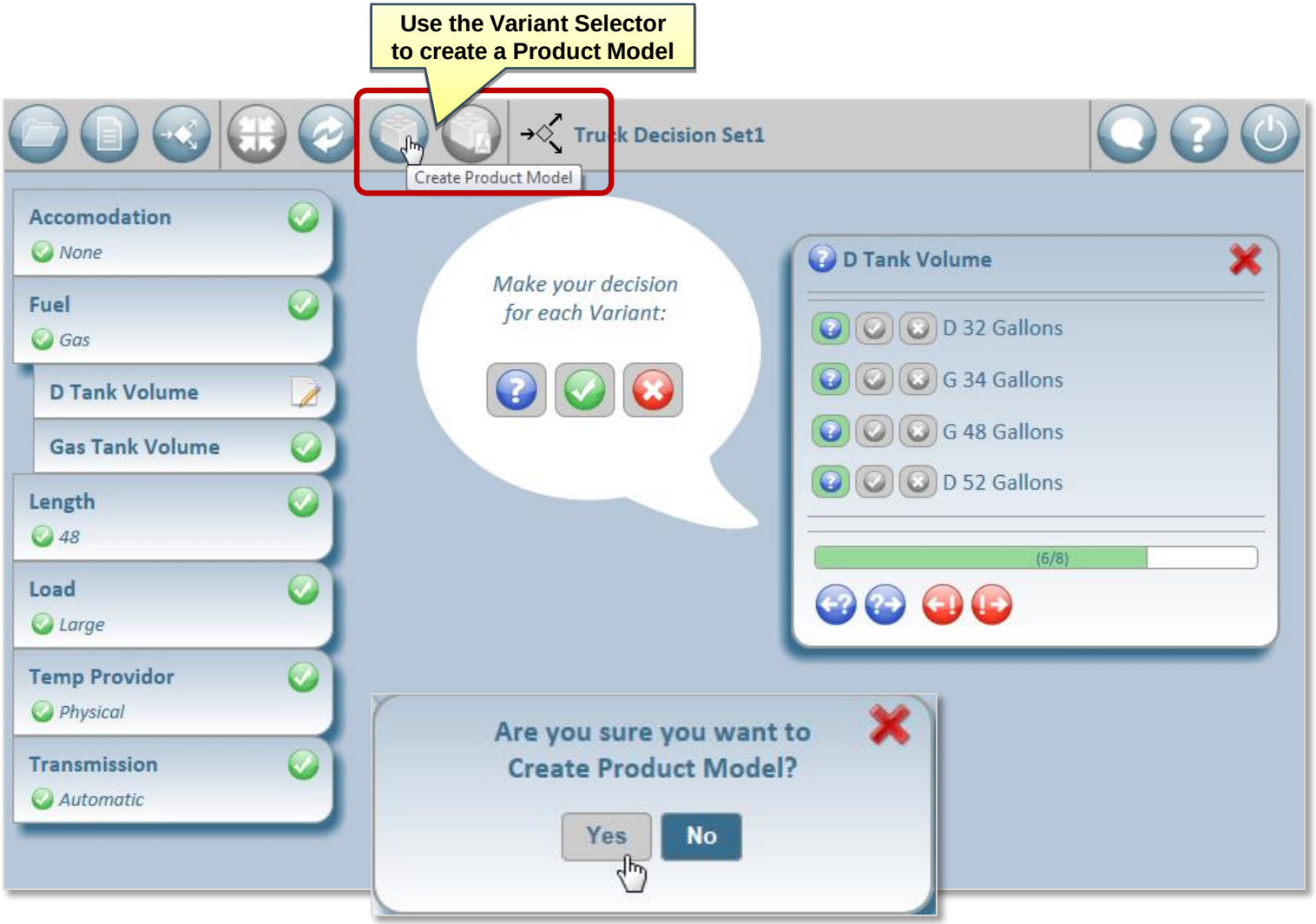
Orthogonal Variability Modeling (OVM)



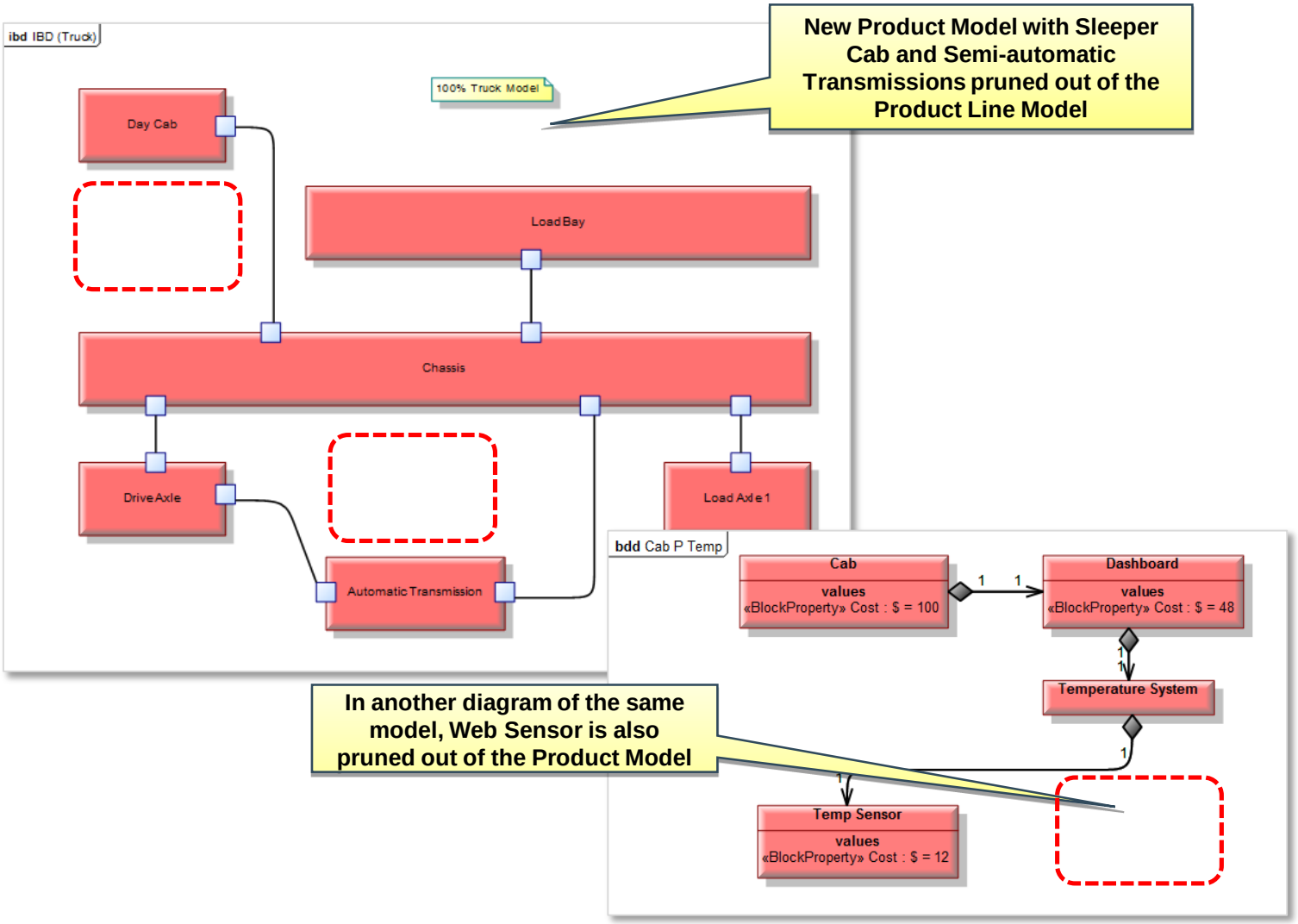
Variable Parameters



Generate the Product Model

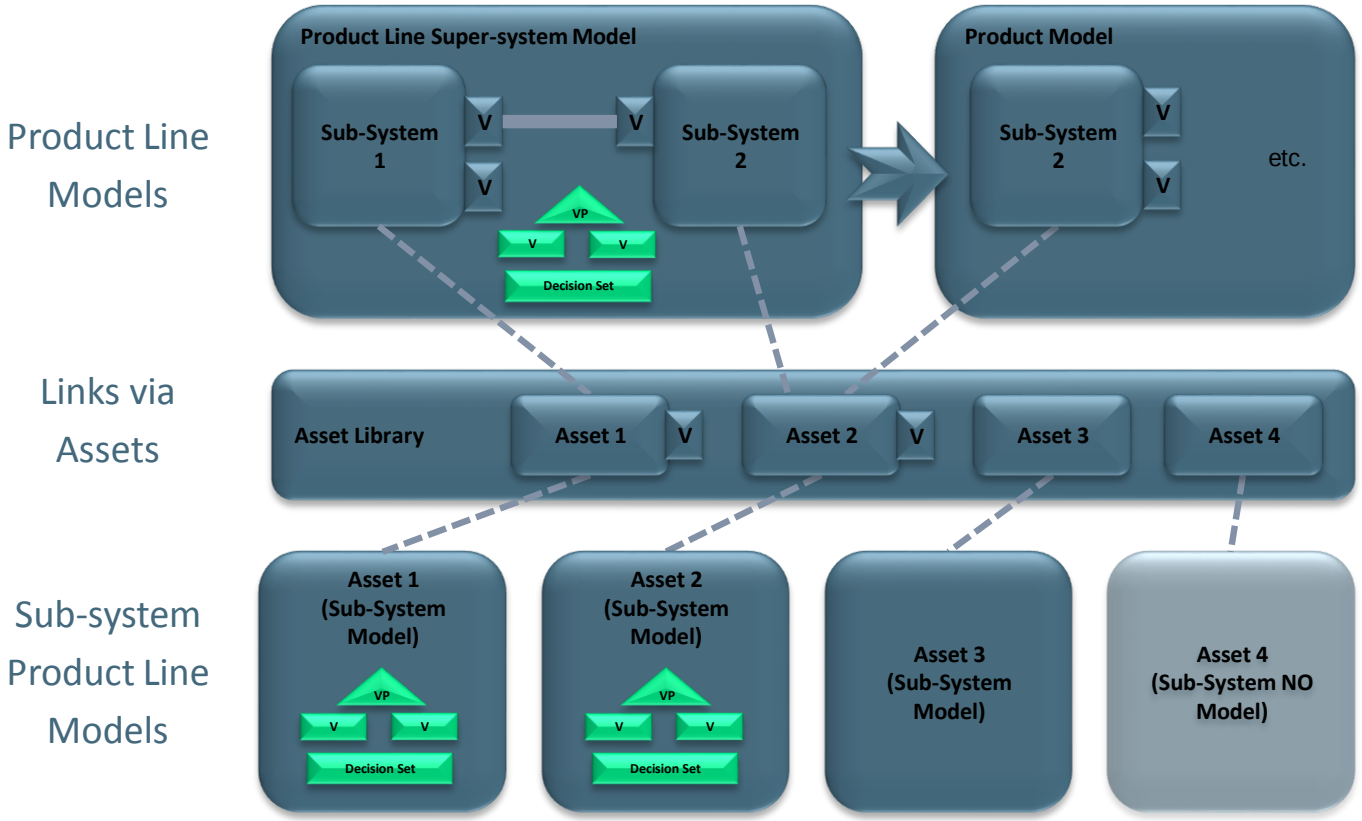


The Generated Product Model



Model- Based Product Line Engineering

- Integrated MBSE, Modular Design & Variability Modeling = Model-based Product Line Engineering



Product Lifecycle Management

Product Lifecycle Management (PLM)

- Product lifecycle management (PLM) is the process of managing the entire lifecycle of a product from inception, through engineering design and manufacture, to service and disposal of manufactured products. PLM integrates people, data, processes and business systems and provides a product information backbone for companies and their extended enterprise.

- Within PLM there are five primary areas;
  - Systems engineering (SE)
  - Product and portfolio m² (PPM)
  - Product design (CAx)
  - Manufacturing process management (MPM)
  - Product data management (PDM)

Current SysML / MBSE limitations

- SysML tools lack integration with other engineering tools and requirements management systems
  - Lack of standardized interfaces
  - Immaturity of model exchange
  - Problems handling large sets of structured requirement
- Lack of representation of artefacts from important disciplines:
  - Mechanical CAD, Geometry
  - Electrics, Electronics (ECAD)
- Insufficient support for the re-use for system models
- No encapsulation of SysML models
  - To support model assemblies like in 3D CAD
  - To build model libraries
  - To exchange model patterns
- Lack of variant-, configuration, and change management
- Lack of information traceability throughout the whole lifecycle, including maintenance, disposal

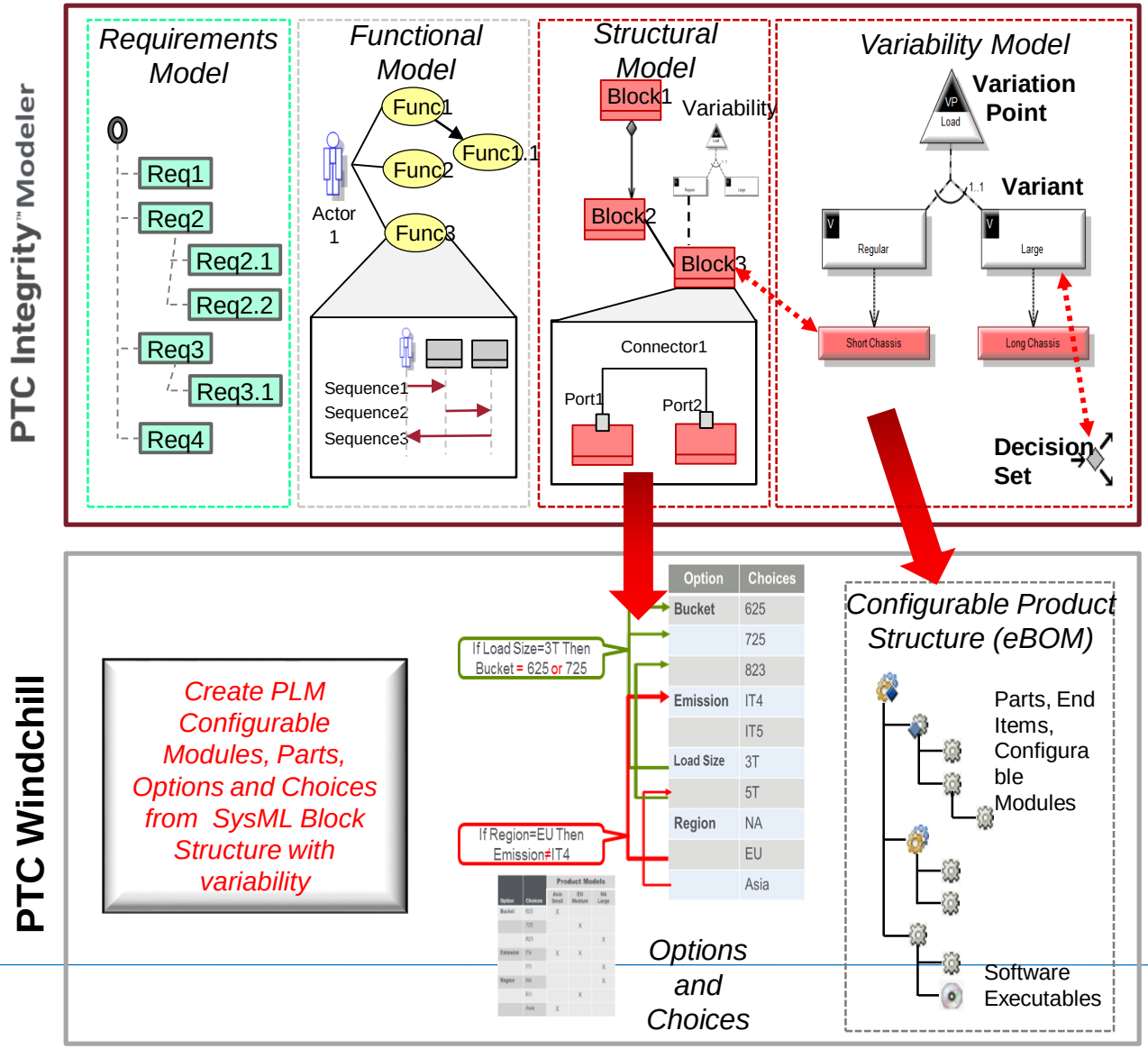
Facets of PLM-MBSE integration

Or: fundamental issues in product development that need to be solved

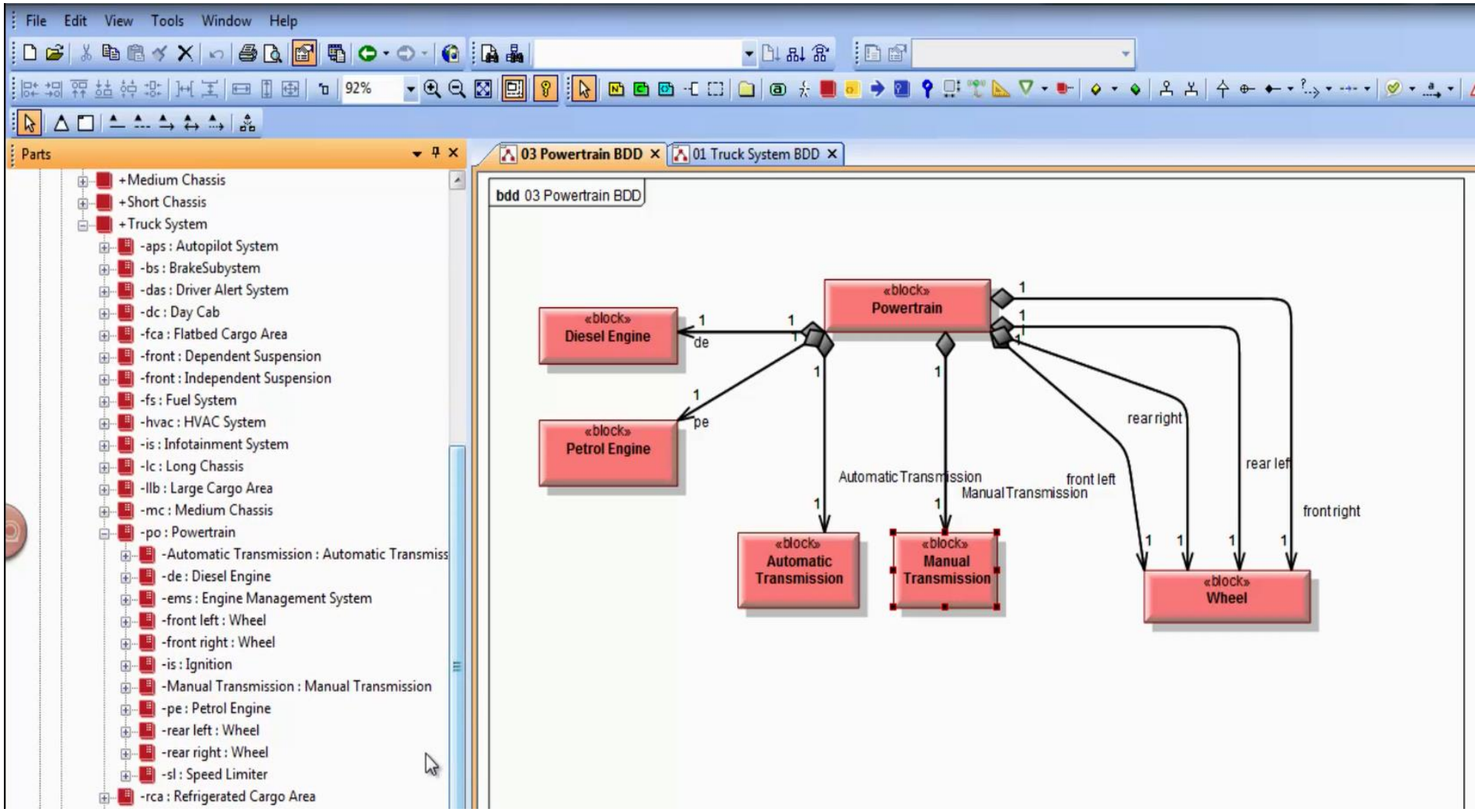
- Need for a holistic integrated system model
  - Multidisciplinary development needs common language
- Traceability
- Complexity management
  - Large sets of requirements
  - Many dependencies between system components
  - Collaboration between many development teams
- Co-Simulation
- Increase comprehensibility of a product/system
- Integration of enterprise and business aspects
  - Enterprise architecture
  - Business objectives
- Support for collaboration in MBSE
- Support management of MBSE artefacts

- ? Product line engineering = ALM

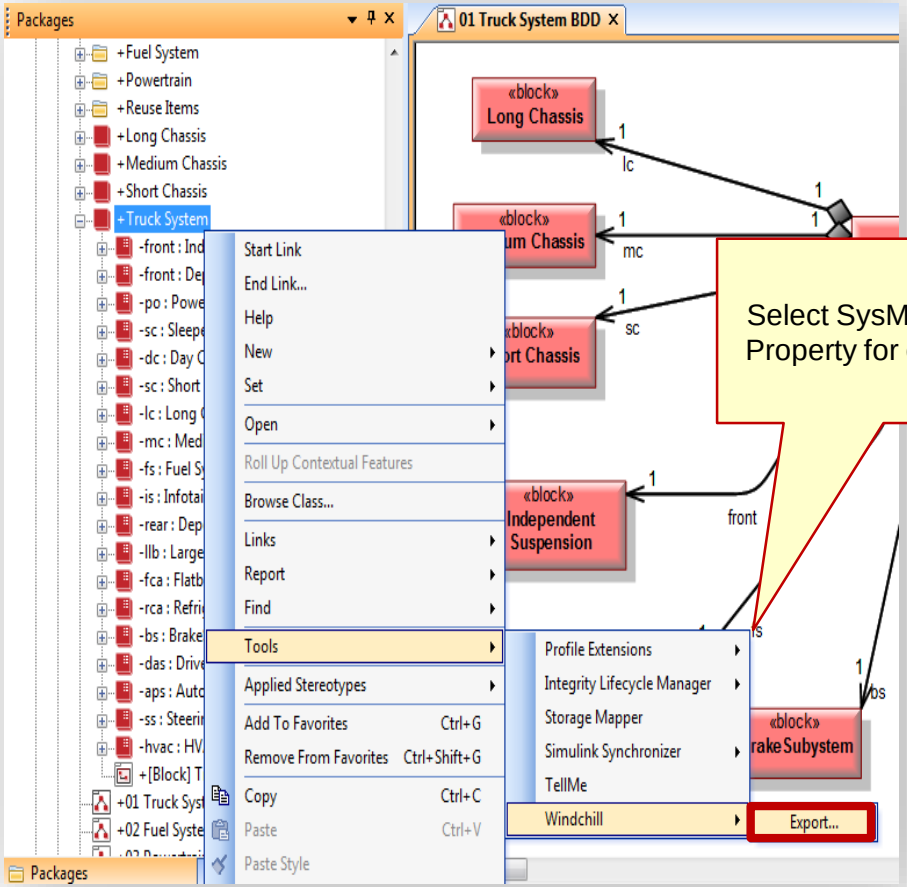
MBSE to PLM Productivity – High Level SCENARIO



Model and Part Structure in SysML



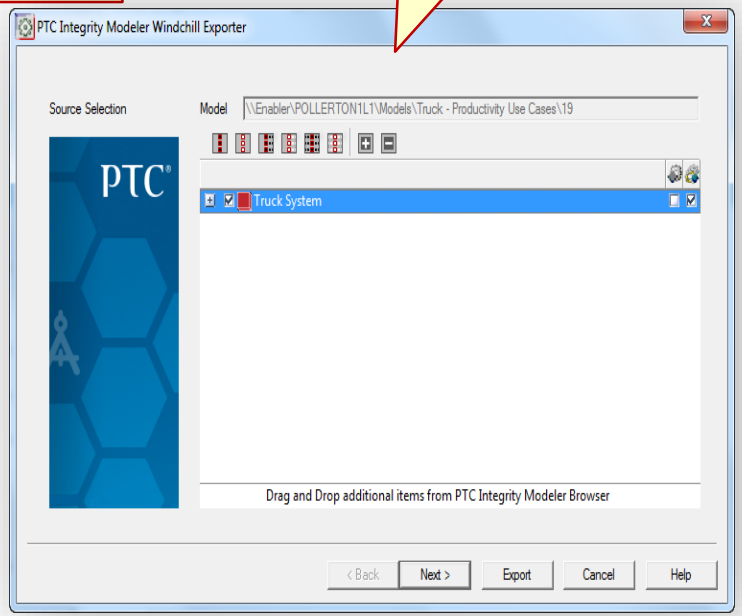
Export of MBSE Parts List to PLM



Select SysML Block/Block Property for export to PLM

Export tool will launch with the selected item and it's Block Properties

Can also be a Variation Point

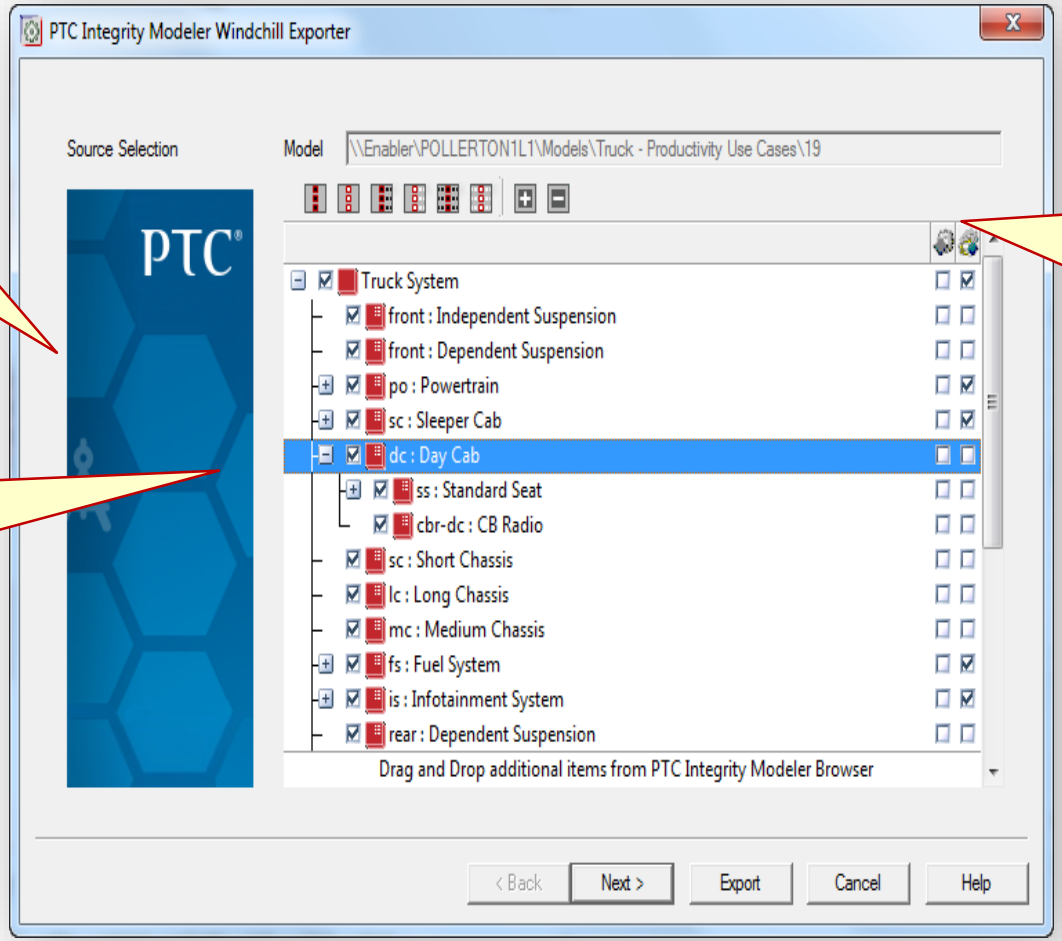


MBSE to PLM Selection of Parts

Review and confirm the items selected for export
Drag and drop additional items from standard Modeler Browsers

Structure can be expanded/collapsed

Items can be marked as included/excluded for export

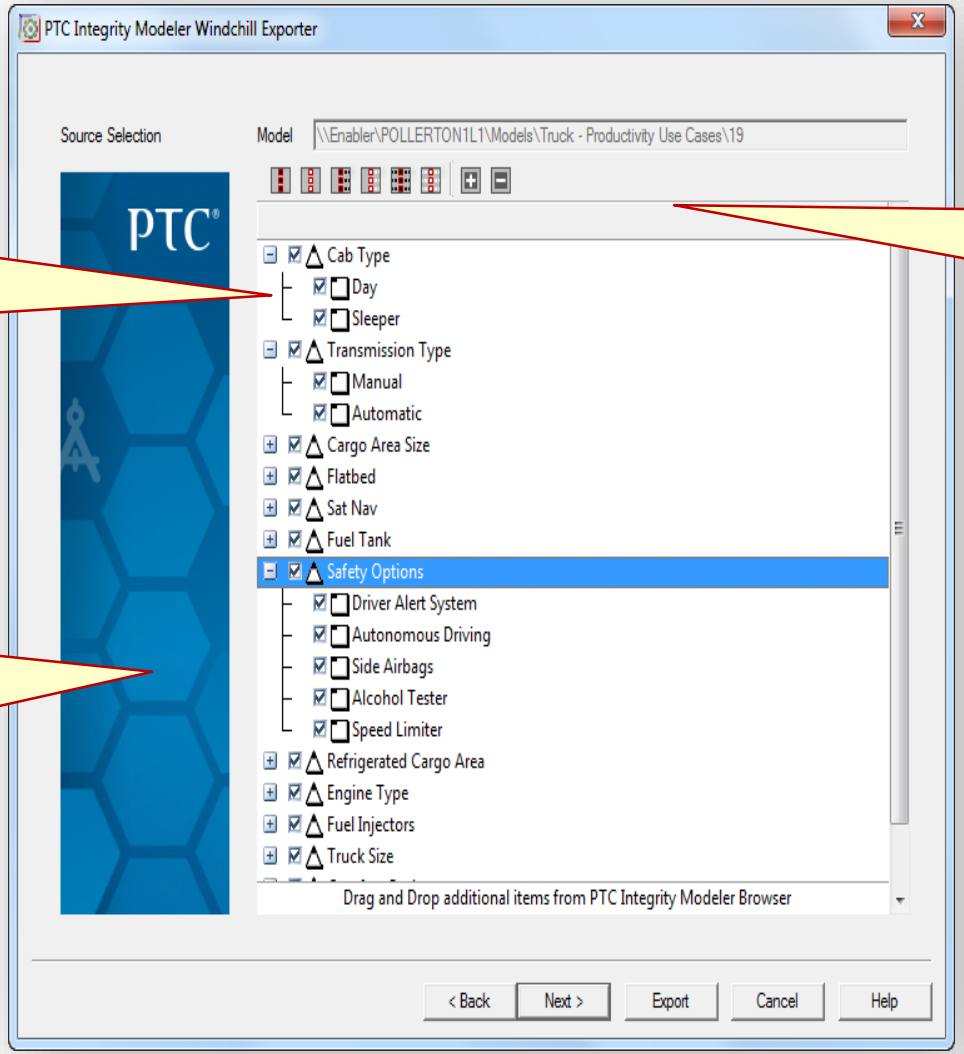


Items can be defined as Windchill PDMLink End Items or Configurable Modules

Export of MBSE Variability to PLM

If the included Blocks/Block Properties have related variability items, they are automatically included in step 2 of the Exporter

Review and confirm the variability items selected for export

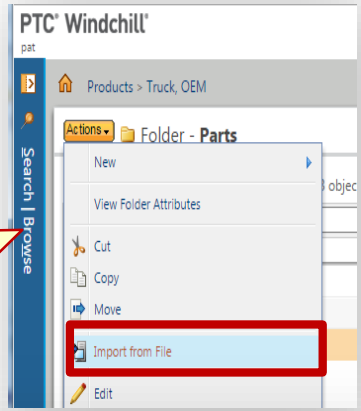


Structure can be expanded/collapsed

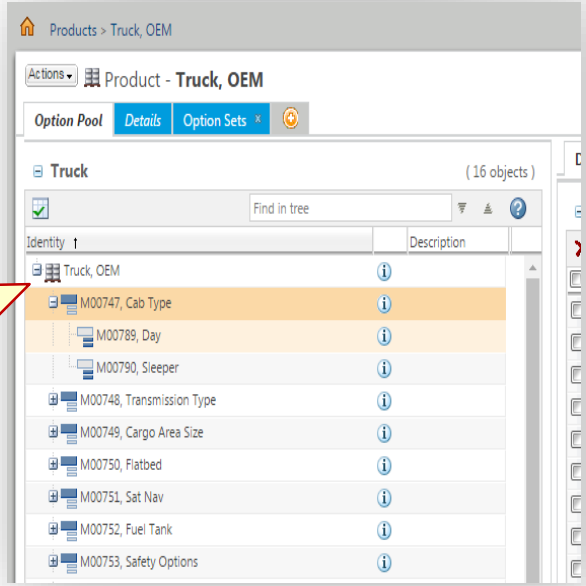
Items can be marked as included/excluded for export

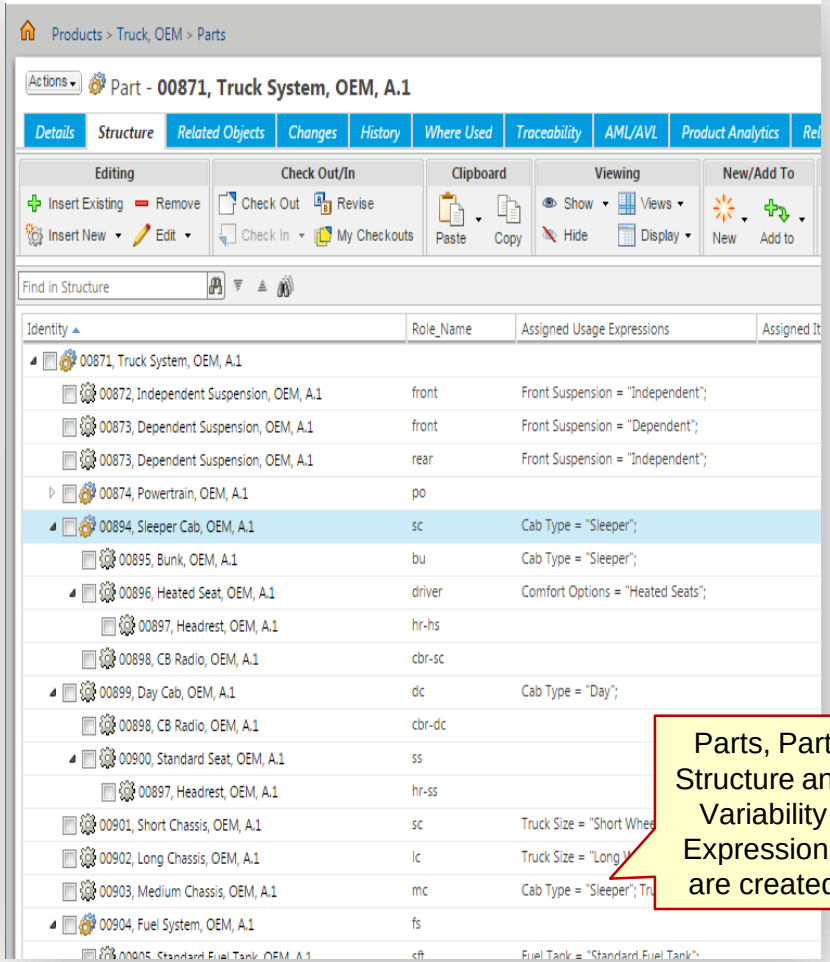
MBSE and PLM Traceability

MBSE SysML Structure is Imported into PLM



Options, Choices and Option Set are created



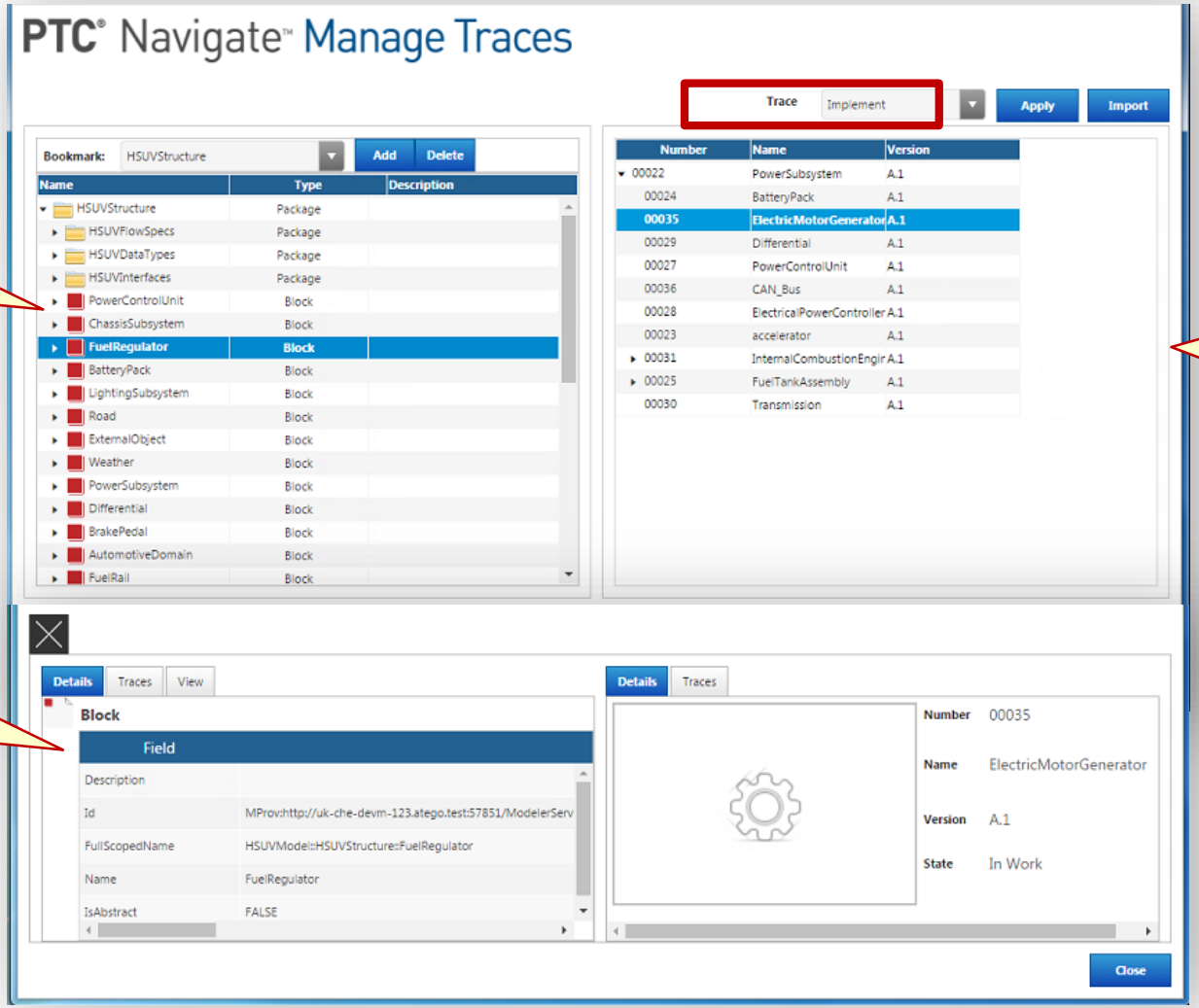


Parts, Part Structure and Variability Expressions are created

MBSE and PLM Bi-Directional Traceability

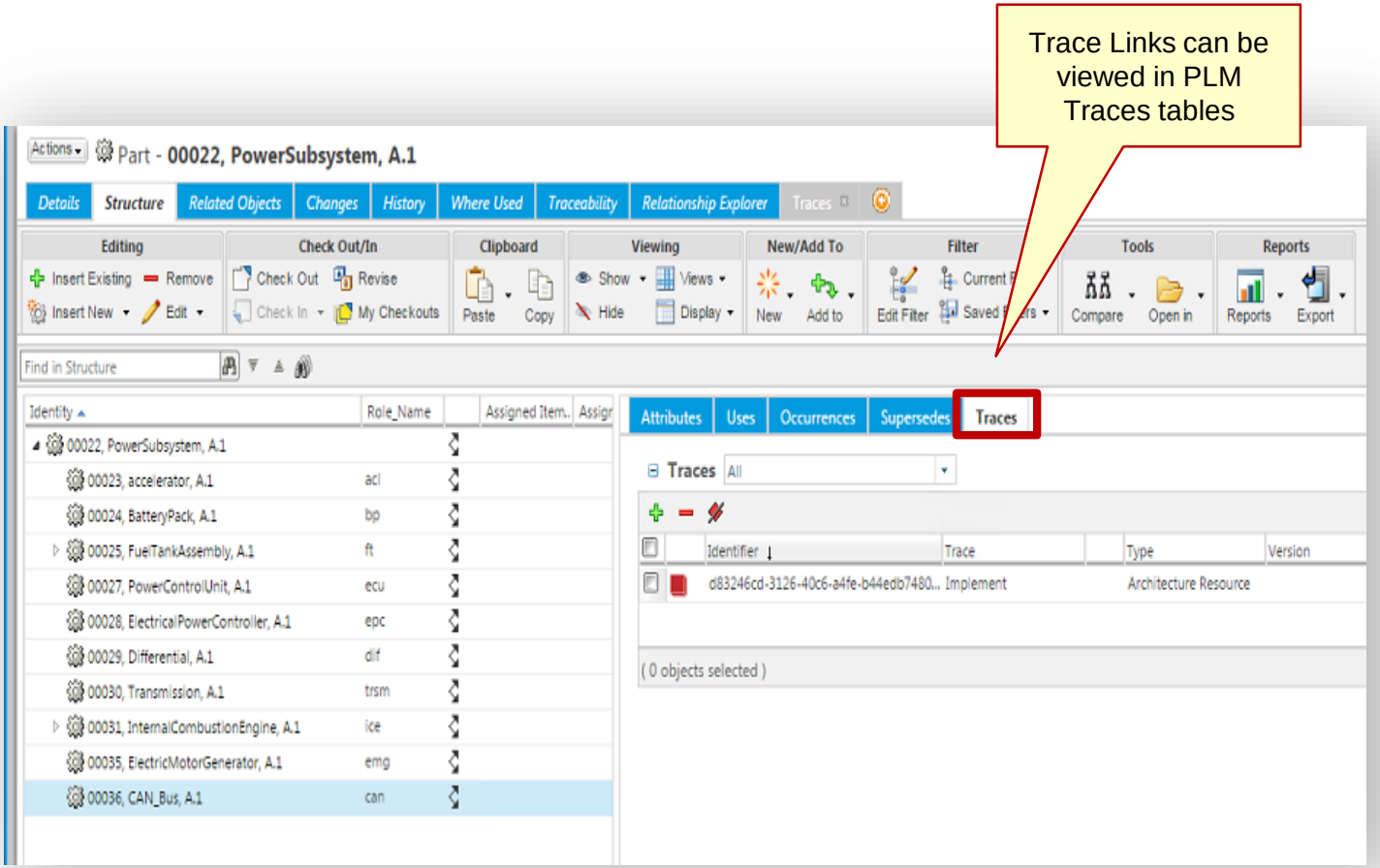
Browse Modeler data and select items

View details and existing traces for selected item

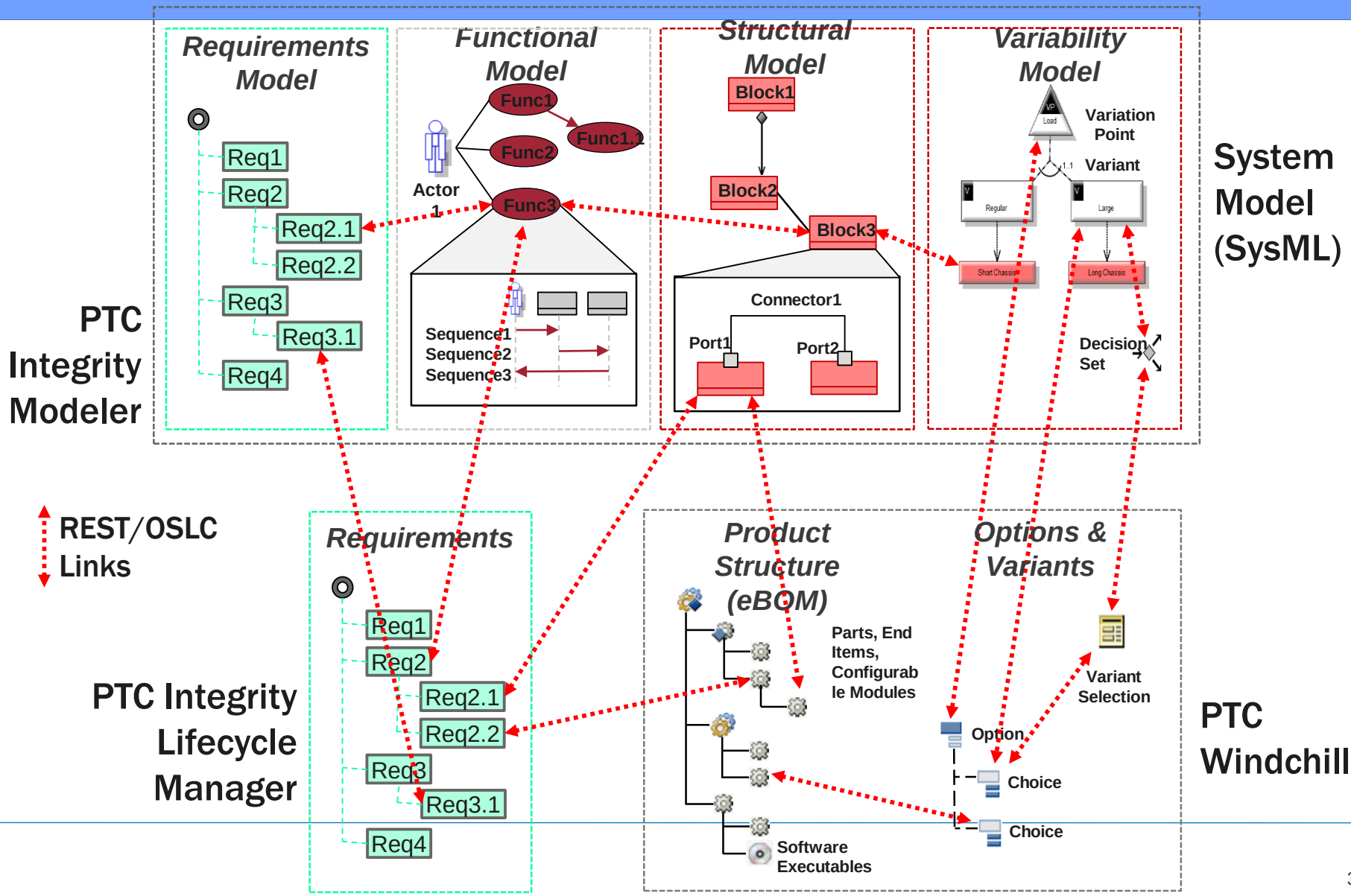


Select items on both sides and click Apply to create new trace links

MBSE and PLM Bi-Directional Traceability



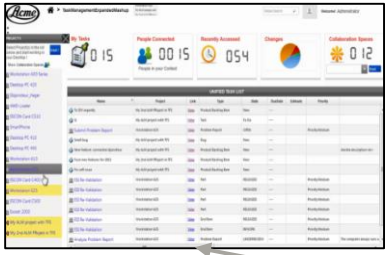
PLE integration across ALM, Modeling and PLM

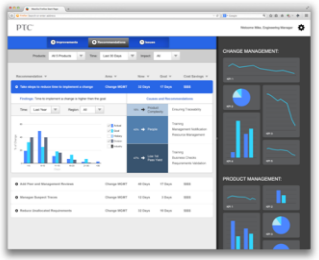


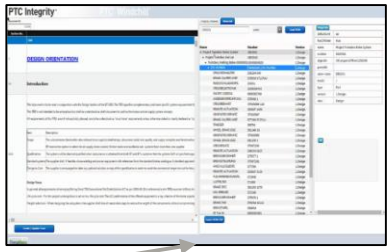
Integrated MBSE – PLM - ALM

OSLC

Task Based Web Apps (single or multiple data sources)







ThingWorx
A PTC Business

Other Web App Dev Tool

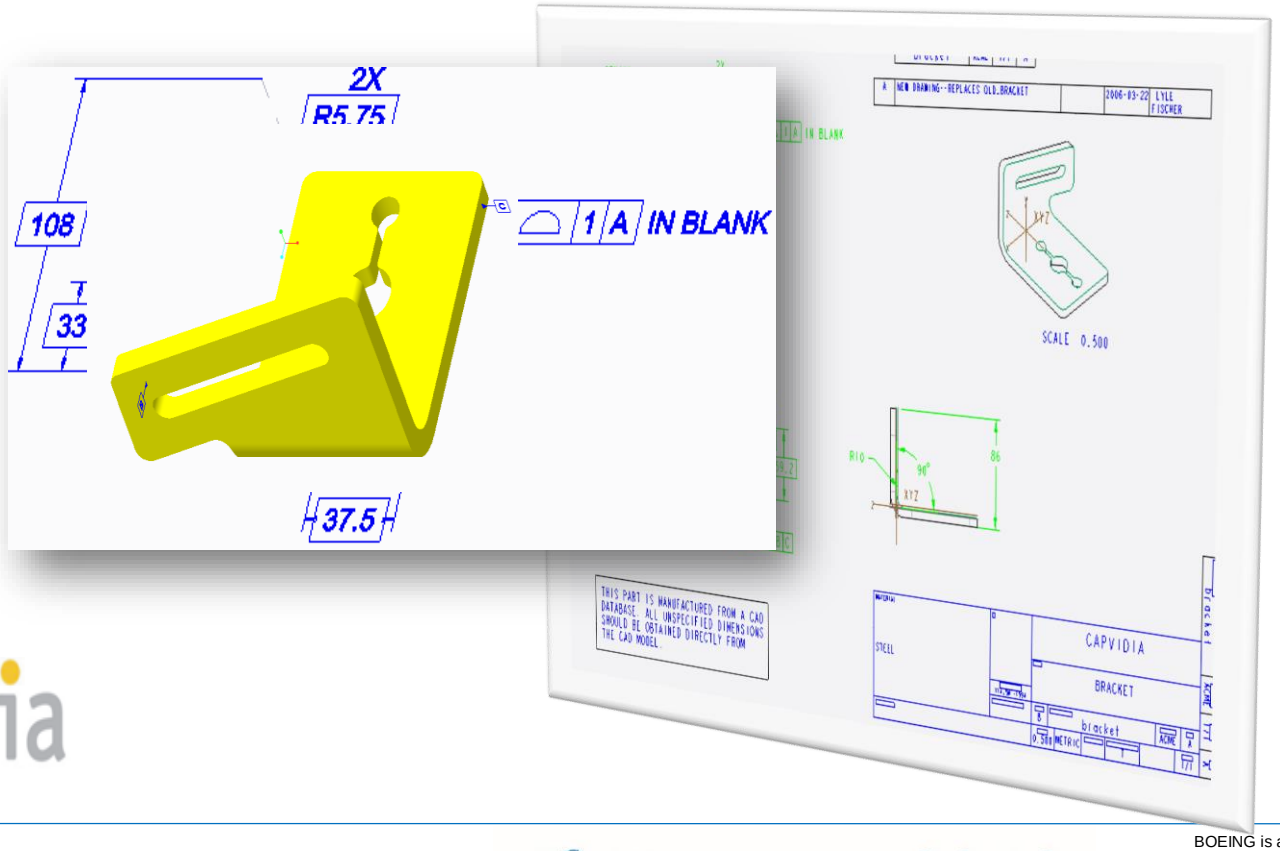
REST Architecture

Existing UI	OSLC Service ThingWorx	Delegated Web UIs	PTC Integrity Modeler
Existing UI	OSLC Service ThingWorx	Delegated Web UIs	PTC Windchill PDMLink
Existing UI	OSLC Service ThingWorx	Delegated Web UIs	PTC Integrity Lifecycle Manager
Tool UI	OSLC Service	Delegated Web UIs	3rd Party Tool

MBDVidia for PTC Creo

2D/3D Annotation Synchronization

- **Adds missing annotations from drawing to 3D model**
- **Corrects incomplete/incorrect annotations**
- **Creates combined states on 3D model from each drawing view**
- **Creates 3D cross sections from 2D cross sections**
- **Checks consistency between 2D & 3D annotations**



capvidia

LINKING DIGITAL ASSETS TO THE REAL WORLD

According to a study last year by Boeing and the University of Iowa, Augmented Reality can…

- Increase first-time fix rate by 90%
- Speed procedures by 30%

Visualize

Enhance the user's **view** of the physical world with the overlay of **actual** or **hypothetical digital information**

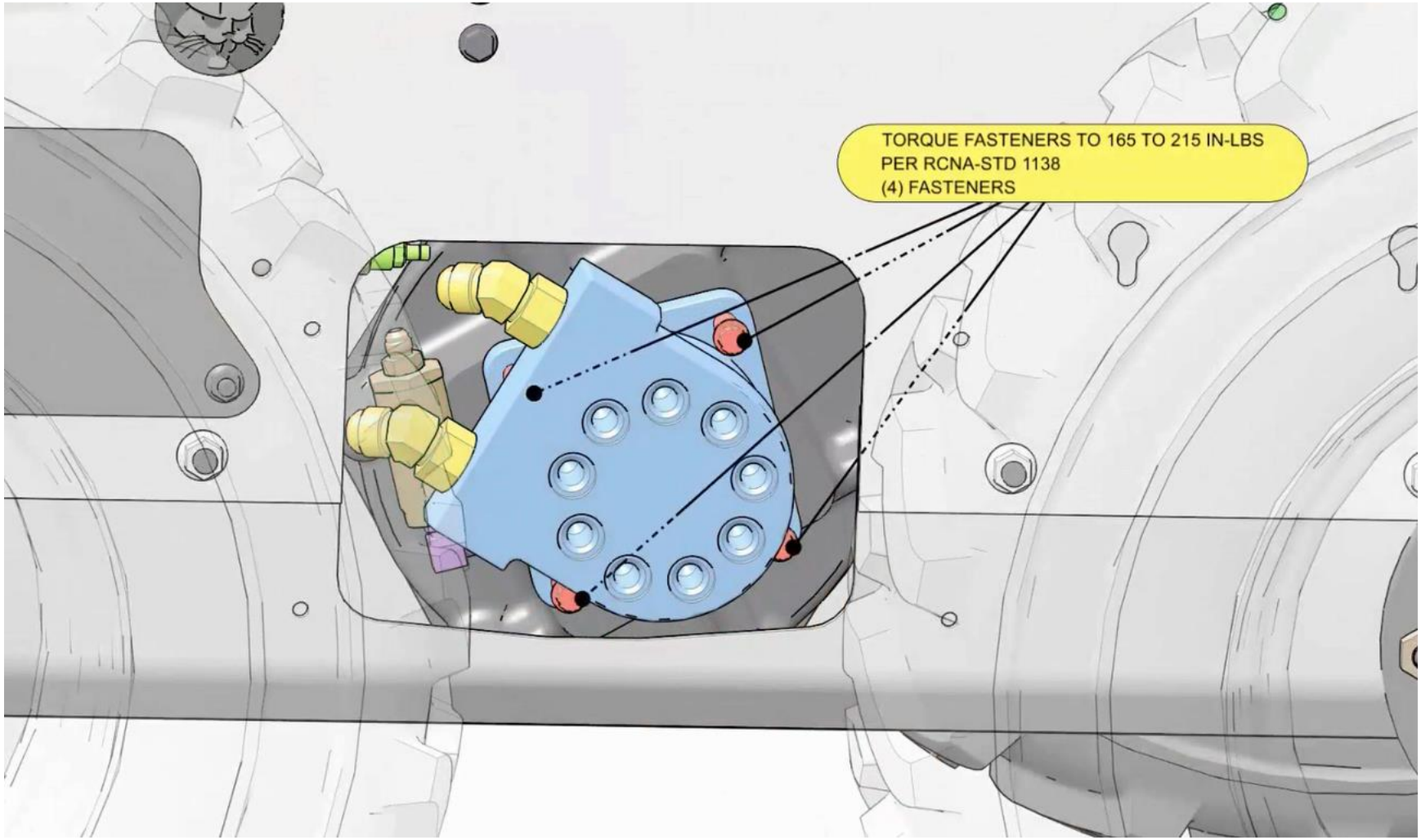
Instruct

Train or guide users on how to perform a task through the overlay of **graphical instructions** or **real-time expert guidance**

Interact

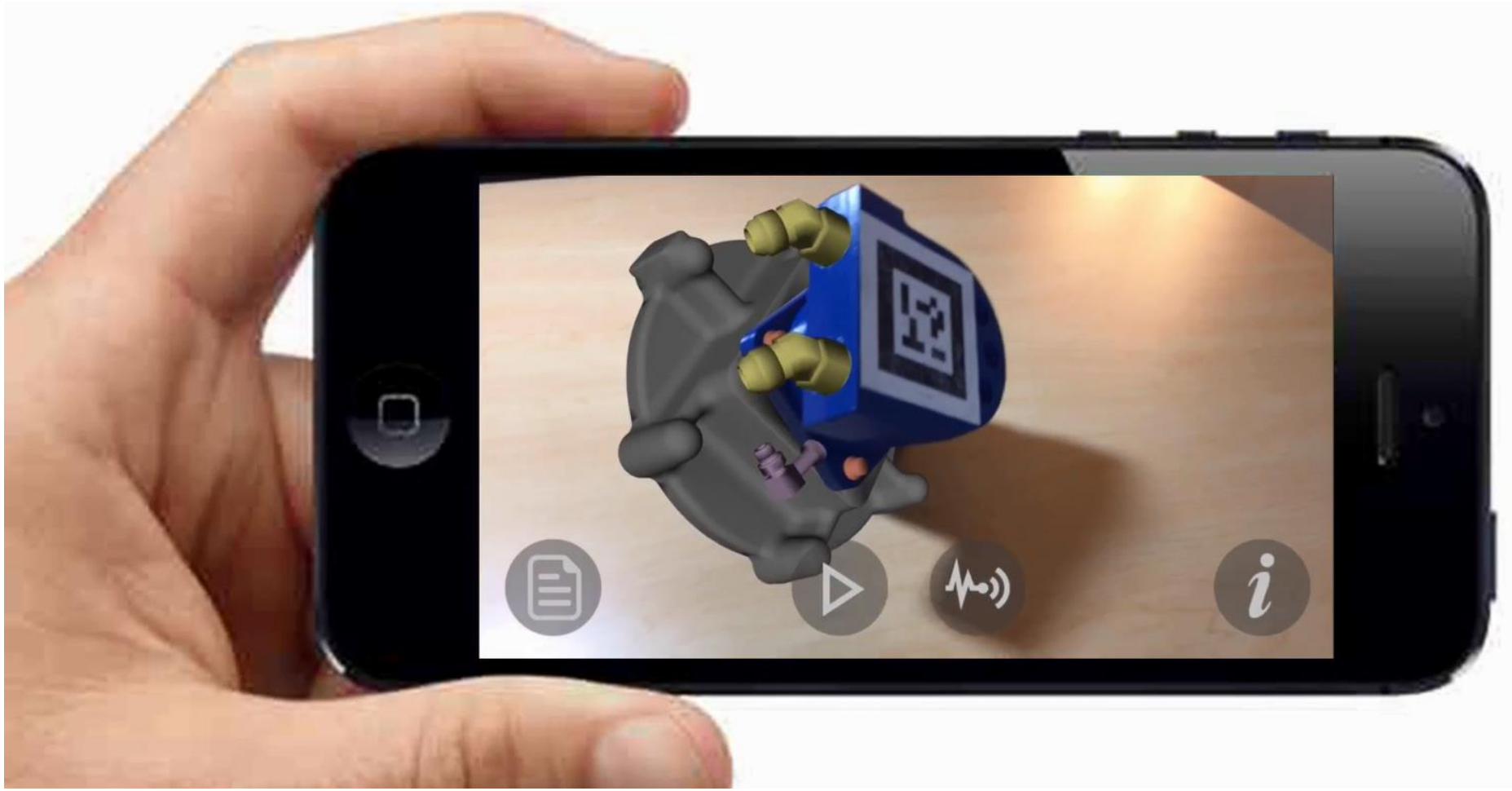
Manipulate digital information with natural user interfaces or **control** a product through an **augmented digital user interface**

Virtual Reality



Augmented Reality

- **Stop by the PTC booth for a demonstration.**



Service Lifecycle Management Portfolio

Connecting Products & Services

Service Information

Create, Manage, Deliver, and Advise

Service & Parts Information

Service Knowledge and Diagnostics

Service Event

Management & Execution

servicemax

Field Service Management

Service Parts

Optimization

Service Parts Management

Service Parts Pricing

Service Network Management

Smart, Connected Service for Smart, Connected Products

ThingWorx

A PTC Business

Machine Learning

ThingWorx

ThingX (Augmented Reality)

Connected Service Applications

servicemax

Connected Field Service

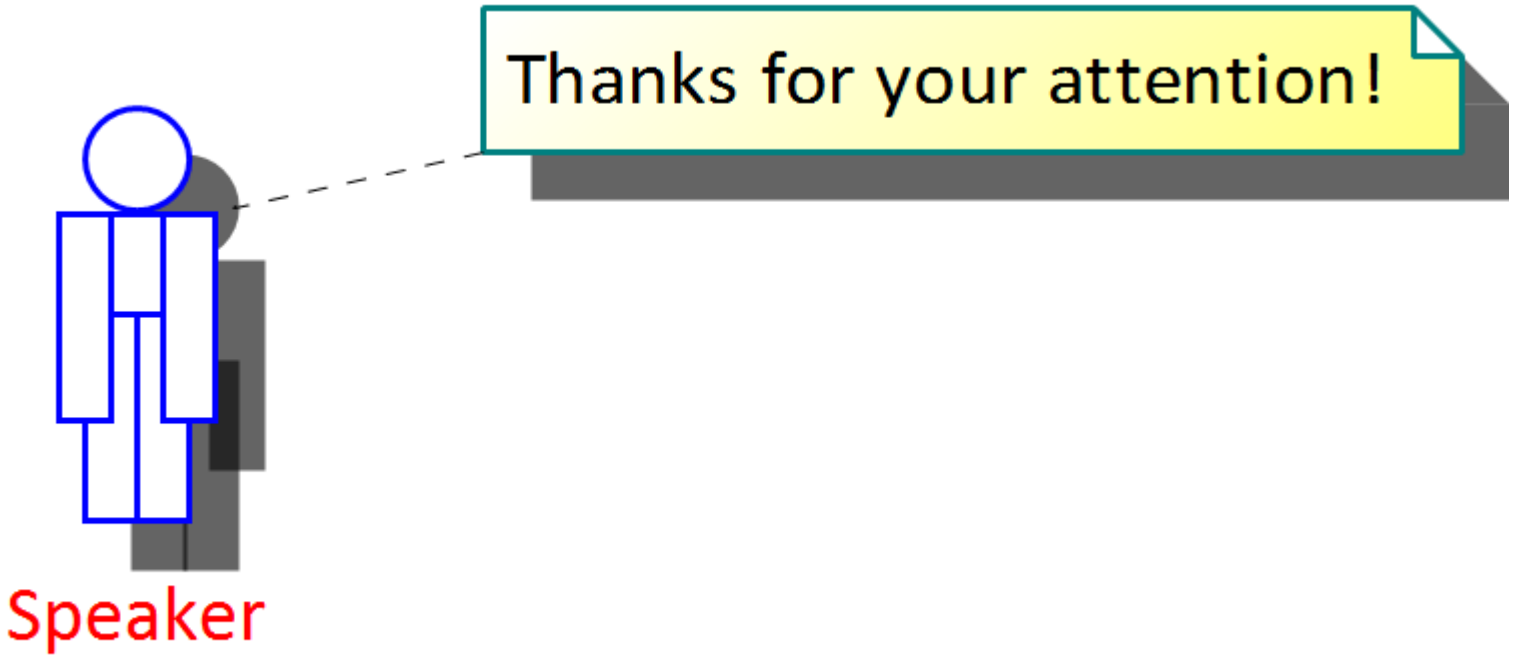
Remote Service

Connected SPM

Equipment Service

Predictive Service

Questions and Answers



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PRODUCT & SERVICE ADVANTAGE®