

# Designing Systems & Software for Smart, Connected Systems

## An MBSE Approach to IoT

James Hummell

Principal Solutions Engineer, MBSE

# GLOBAL PRODUCT DATA INTEROPERABILITY SUMMIT 2015



ELYSIUM

Darker Aerospace

NORTHROP GRUMMAN

BOEING

ELYSIUM

Darker Aerospace

NORTHROP GRUMMAN

BOEING

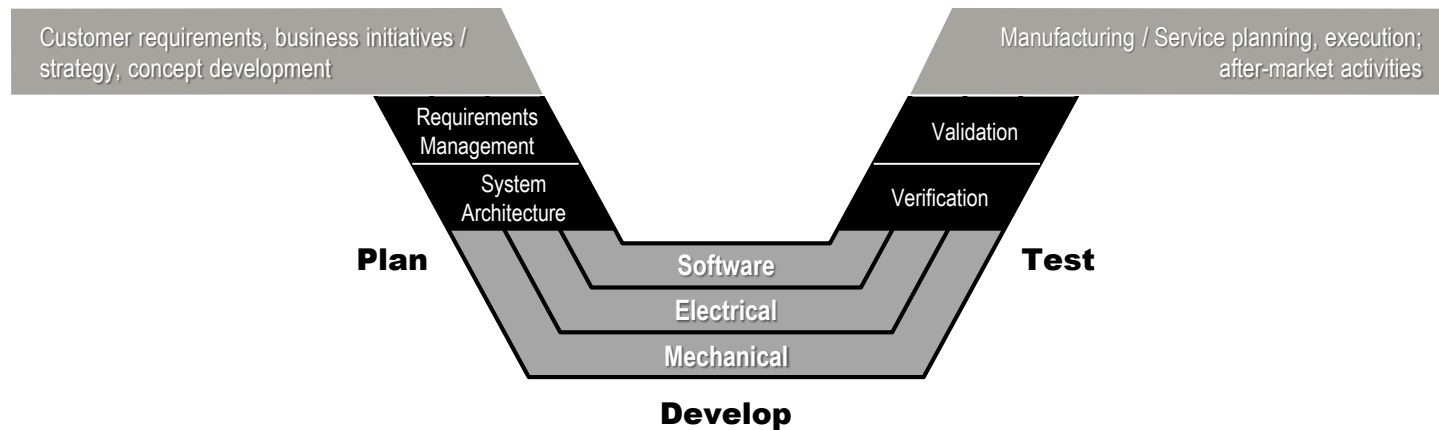
# Agenda

Global Product Data Interoperability Summit | 2015

- **PTC Vision of Smart Connected Systems**
- **Software/Systems Modeling (UML/SysML)**
- **Model transformation**
- **Product Line Engineering**
- **ThingWorx (IoT)**
- **Smart Connected System**
- **PTC ThingWorx Neuron**

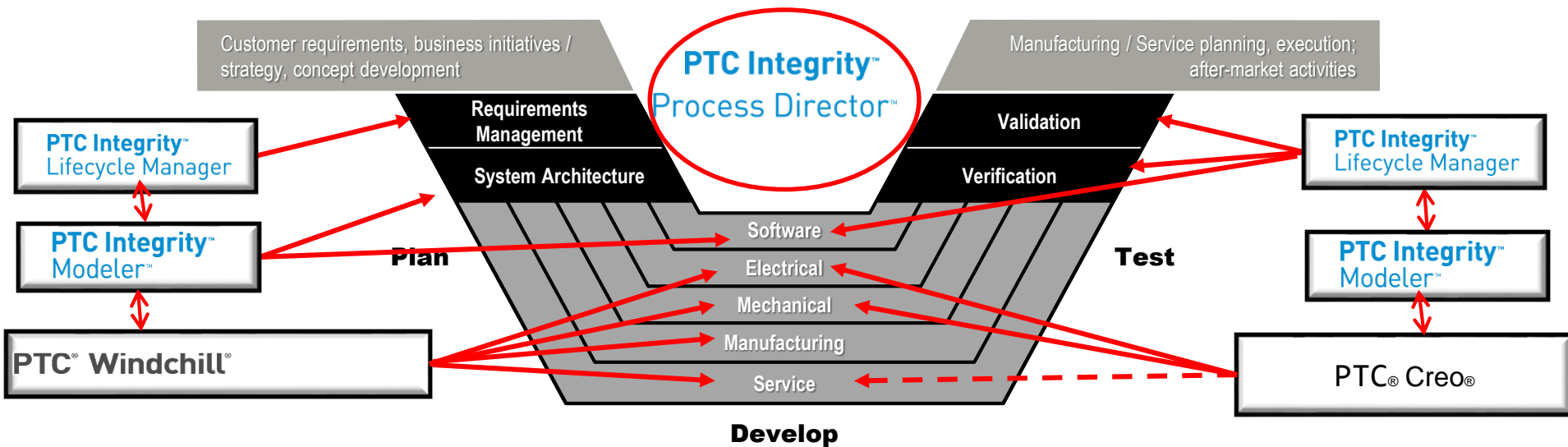
# Standard Systems Engineering “V”

Global Product Data Interoperability Summit | 2015



# Extended Systems Engineering “V”

Global Product Data Interoperability Summit | 2015

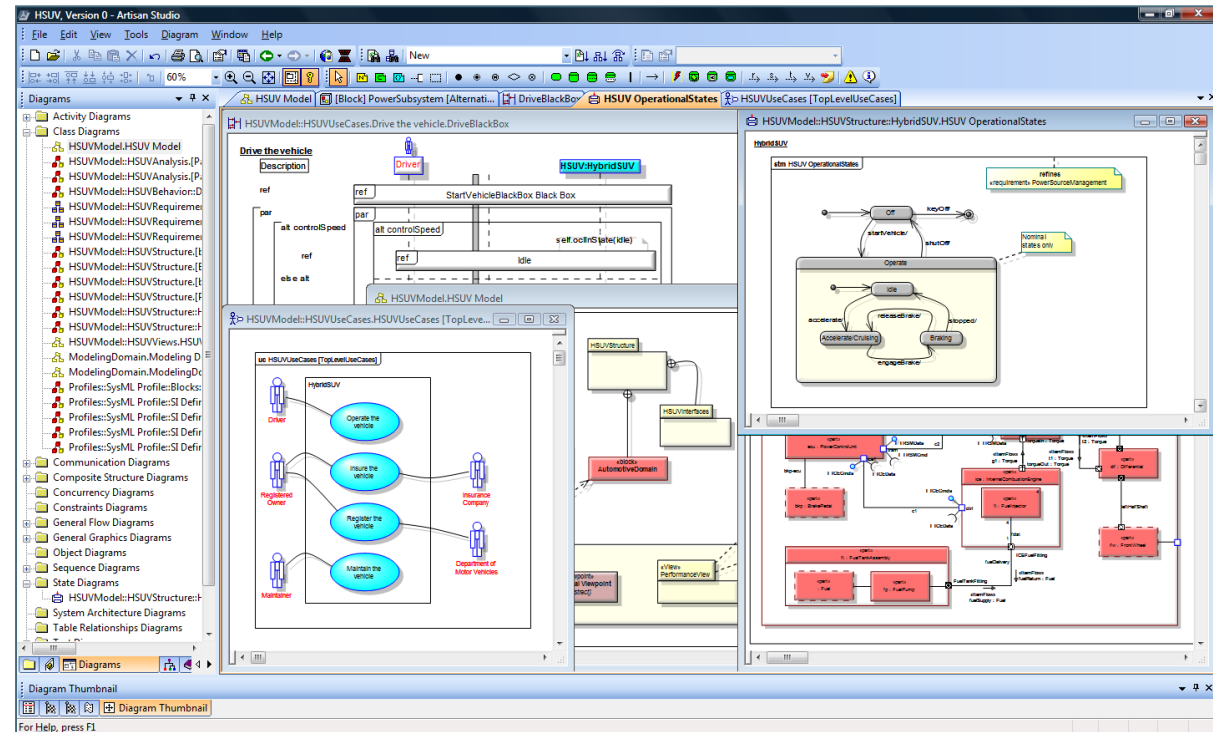


# PTC Integrity Modeler

Global Product Data Interoperability Summit | 2015

## CAPABILITIES

- Scalable UML, SysML, UPDM
- Repository Collaboration
- Built-In Traceability
- Document Generation
- Automated Design Review
- System



## BENEFITS

Improved Quality through Early Design Review and Consistency

Bring Systems to Market Faster with Parallel Design Effort

Cost Reductions from Design and Development Automation

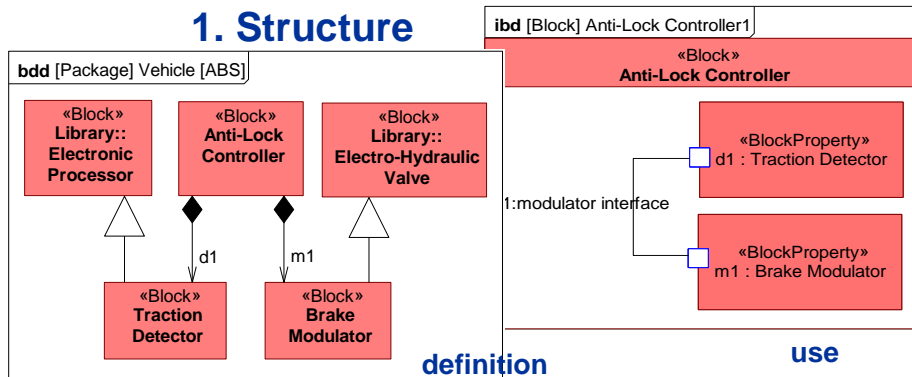
## Global Product Data Interoperability Summit | 2015



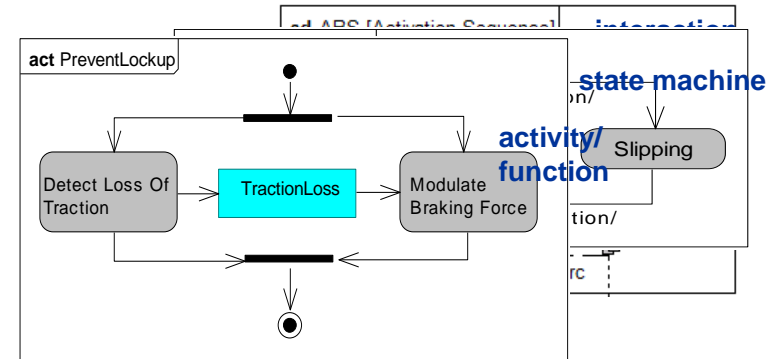
# The Four Pillars of Systems Modeling (SysML)

Global Product Data Interoperability Summit | 2015

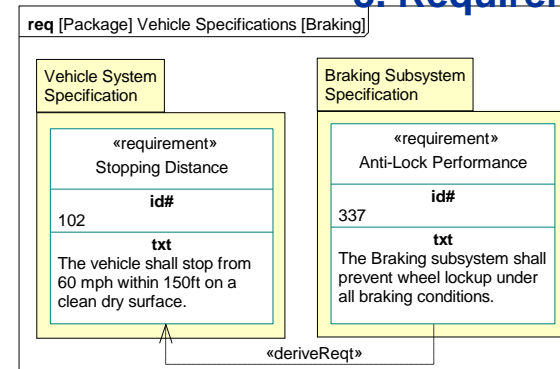
## 1. Structure



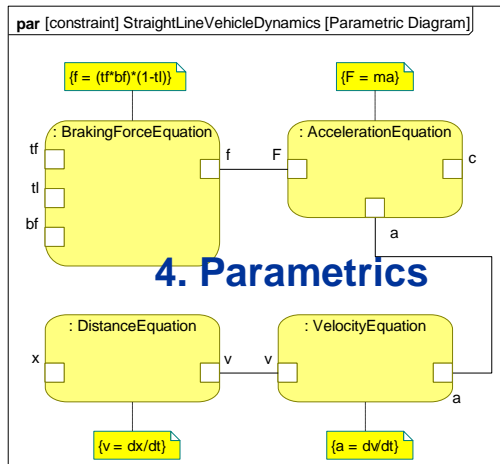
## 2. Behavior



## 3. Requirements

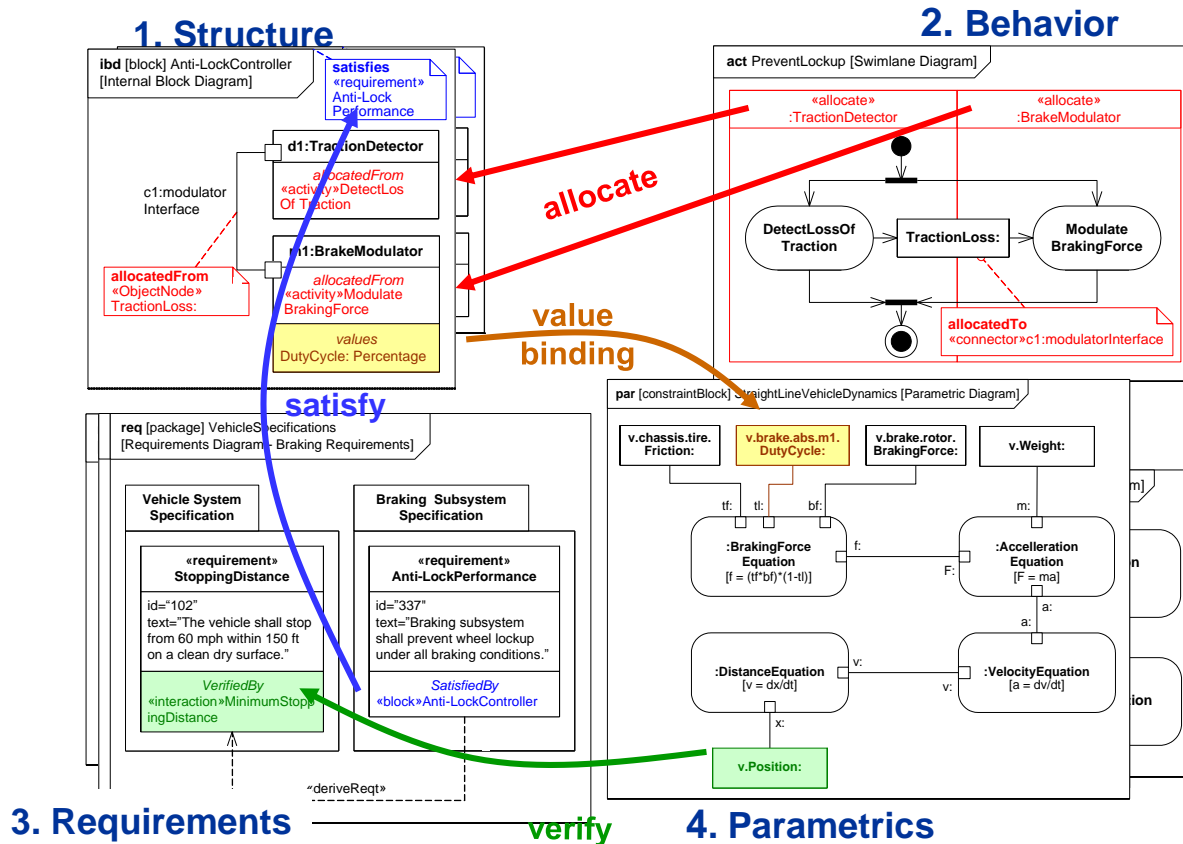


## 4. Parametrics



# Cross Connecting Model Elements

Global Product Data Interoperability Summit | 2015





# Why use modeling tools?

Global Product Data Interoperability Summit | 2015

Support the automatic generation of “things” from the model

Ada

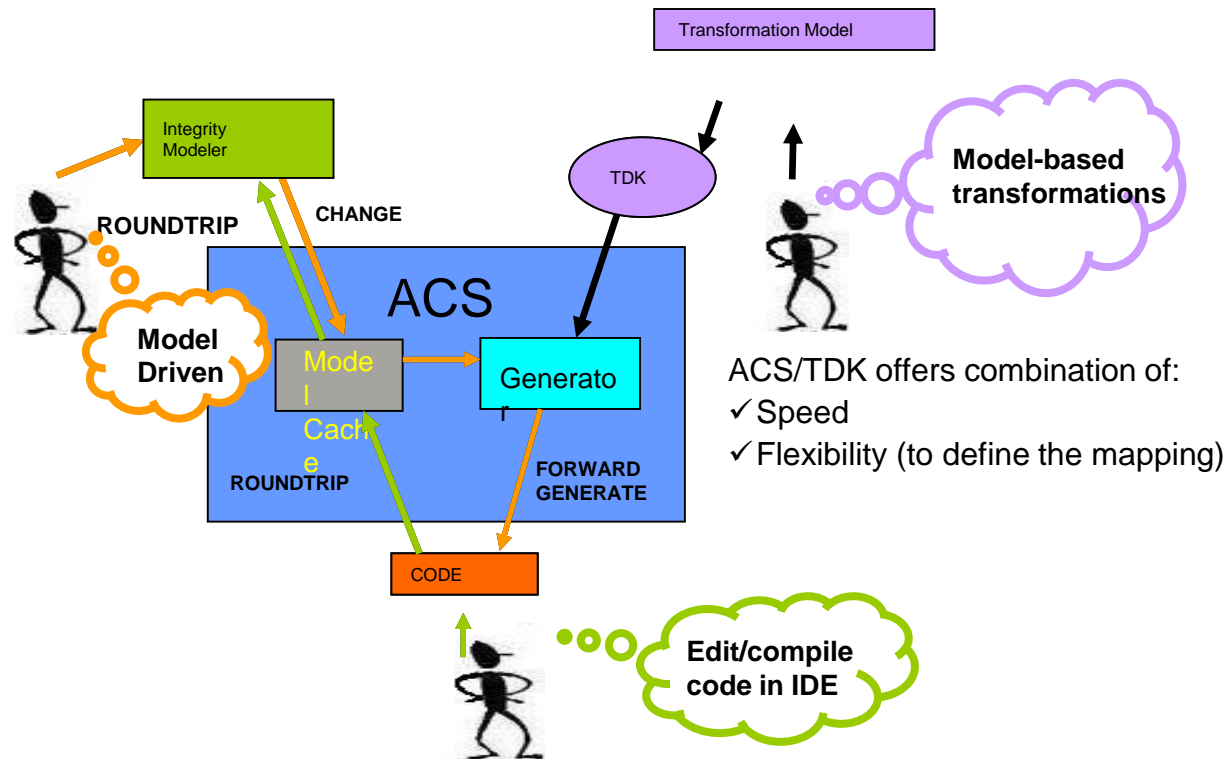
Java

C/C++

C#

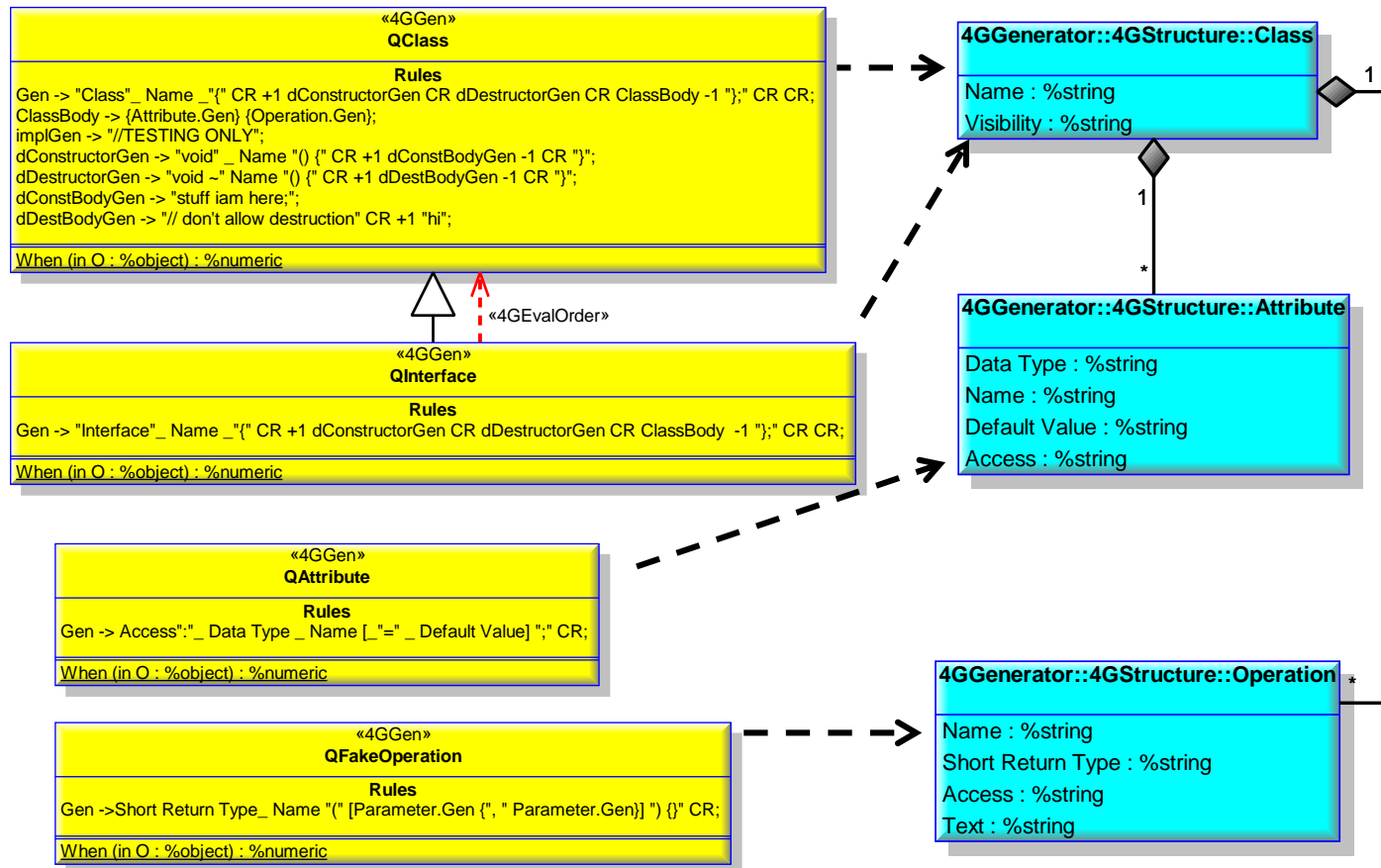
Visual  
Basic

IDL/  
IDL3+



# Code Generation Customization (Transformation Model)

Global Product Data Interoperability Summit | 2015

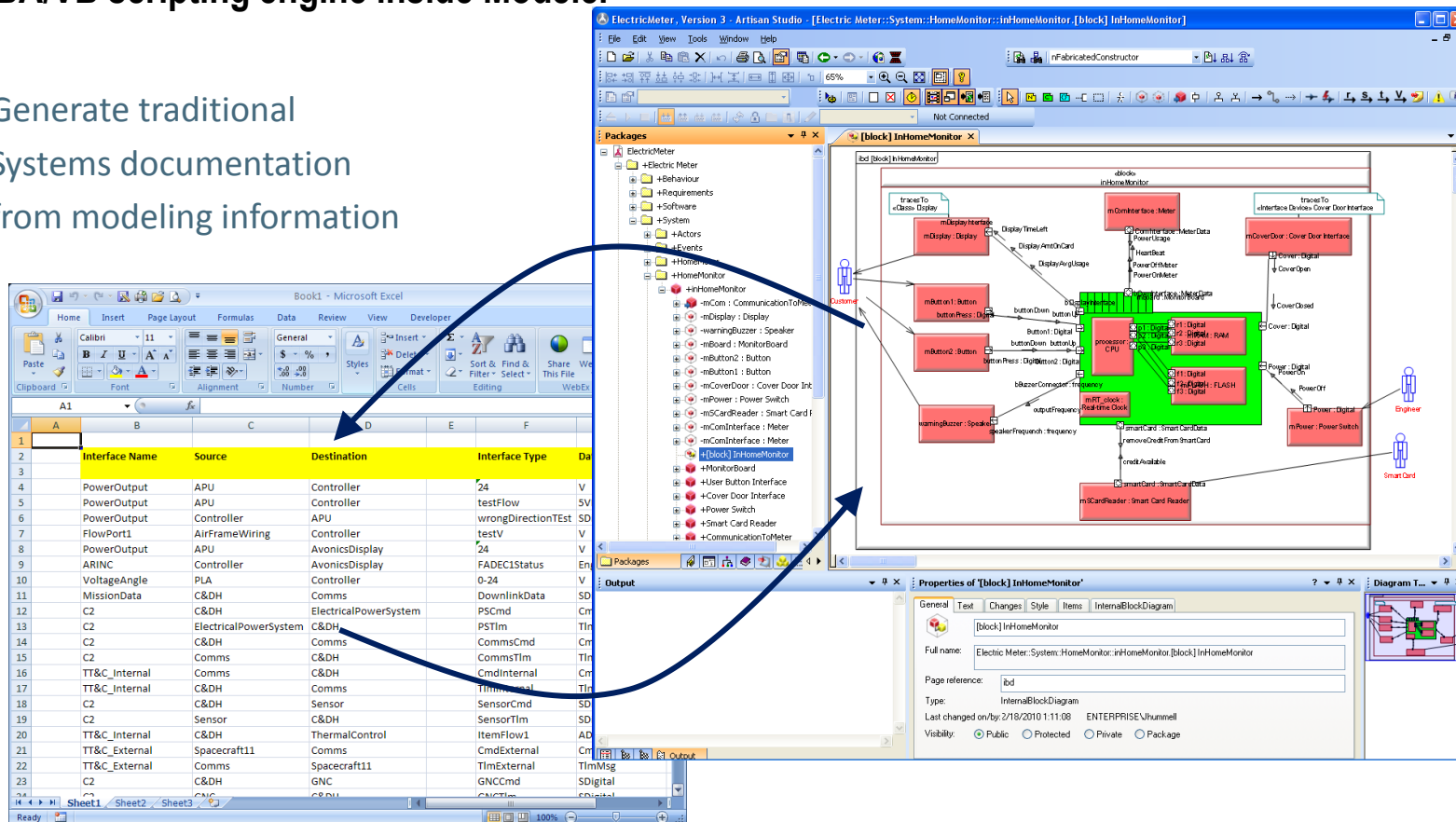


# Data Mining/Data Analysis (ICD Generator)

Global Product Data Interoperability Summit | 2015

## VBA/VB scripting engine inside Modeler

- Generate traditional Systems documentation from modeling information



# Asset-Based Modular Design

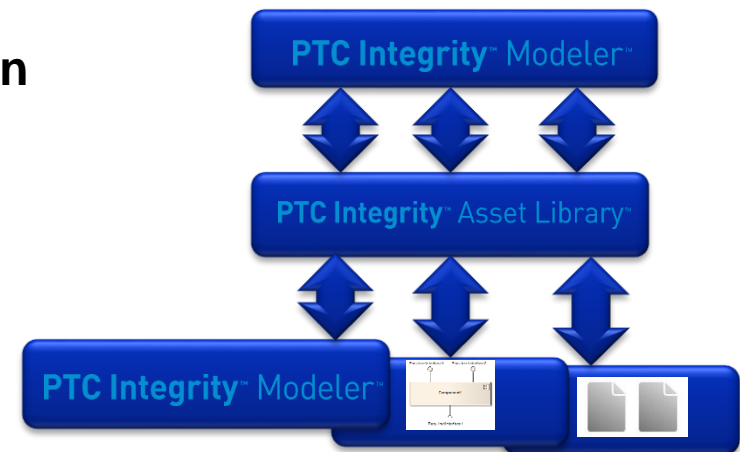
Global Product Data Interoperability Summit | 2015

- **Design the same way you Build**

- Construct Systems of Sub-Systems (SoS)
- Use Services to build your Application (SOA)
- Plug Components together (CBD)

- **Modular Design**

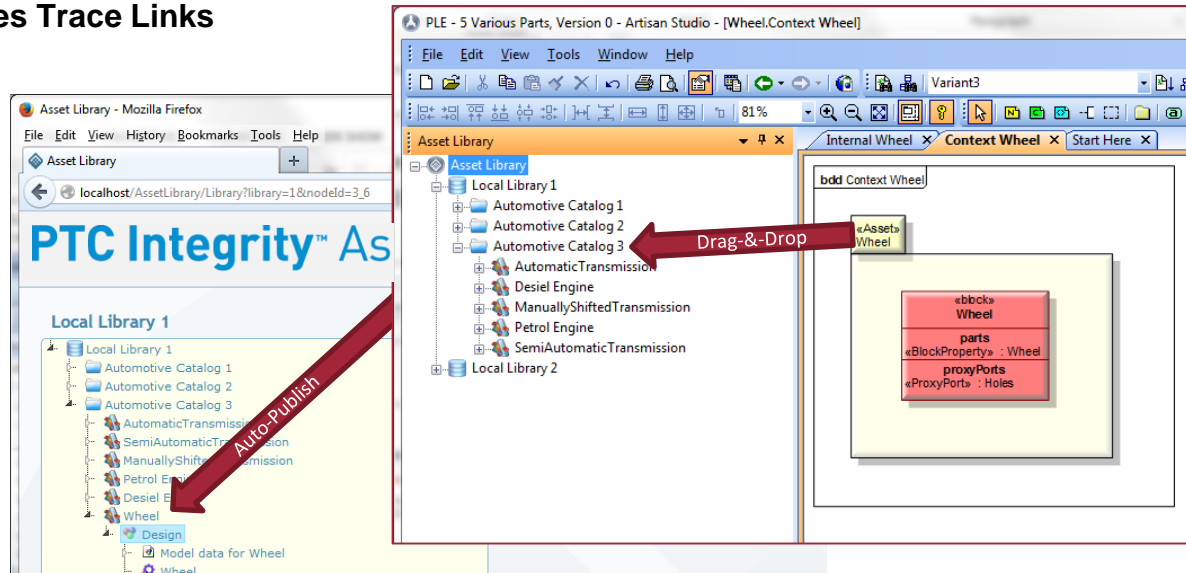
- Top-Down, Architected
  - Specification (& Requirements) Driven
  - Parallel Working
  - Separation of Concerns
- Bottom-Up, Asset Mining
  - Un-modeled Assets
  - Other Modeling Tools
  - Legacy Integration
  - Published Interfaces (e.g. IDL)



# Asset-Based Modular Design

Global Product Data Interoperability Summit | 2015

- Publish from Sub-system model into PTC Integrity Asset Library
  - Auto-creates Trace Links



# System Product Line Engineering (PLE) Challenges

Global Product Data Interoperability Summit | 2015

## Product line explosion

- Increasing number of product families
- Increasing number of products in families
- Understanding product similarity
- Maximizing reuse
- Understanding product variations
- Deciding between options
- Development cycle time
- Commercial product needs
  - Customize existing capabilities to suit client requirements
  - Redeploy common systems & software to the Market
  - Time from requirements to cash

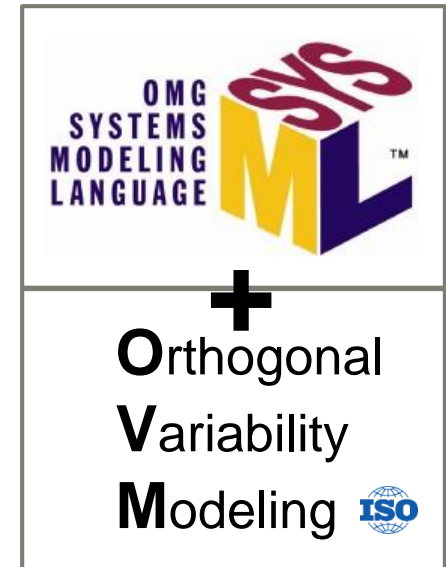


# The Solution ... Model-Based Product Line Engineering

Global Product Data Interoperability Summit | 2015

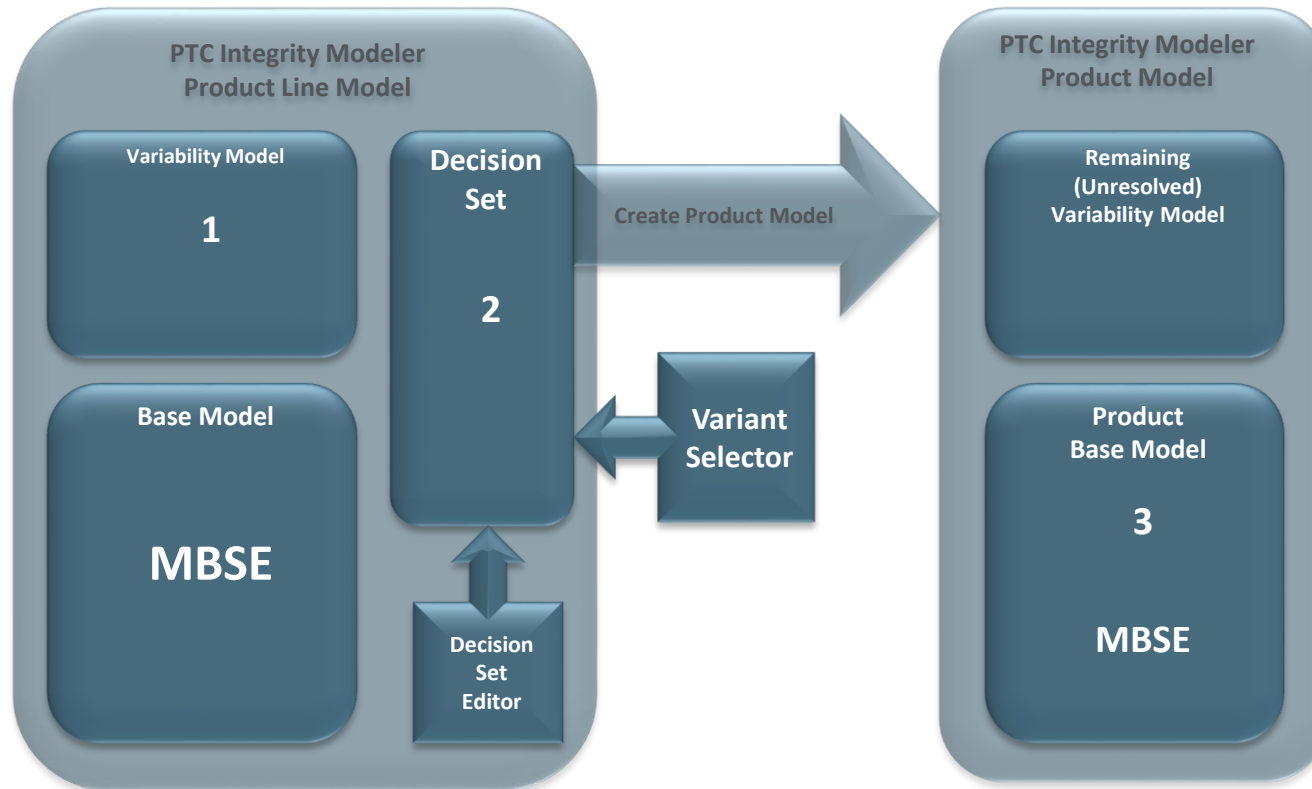
**Designing a single system platform rather than as creating a multitude of products**

- **MBSE + Modular Design + Variation**
  - Common language improves
    - Communication
    - Collaboration
    - Stakeholder buy in
  - Architected modular design & reuse
  - System product lines designed up front
- **Maximum commonality & minimal variation**
  - Less duplicated effort with optimized reuse
  - Parallel working through 'design by contract'
  - More commonality between designs and implementations
  - Managed product line complexity
- **OVM Standards Based**
  - ISO 26550:2013 Software & Systems Engineering – Reference Model for Product Line Management & Engineering
  - PALUNO, The Ruhr Institute of Software Technology
  - Software Product Line Engineering (Pohl et al - Springer 2005)



# Modeling Product Lines

Global Product Data Interoperability Summit | 2015

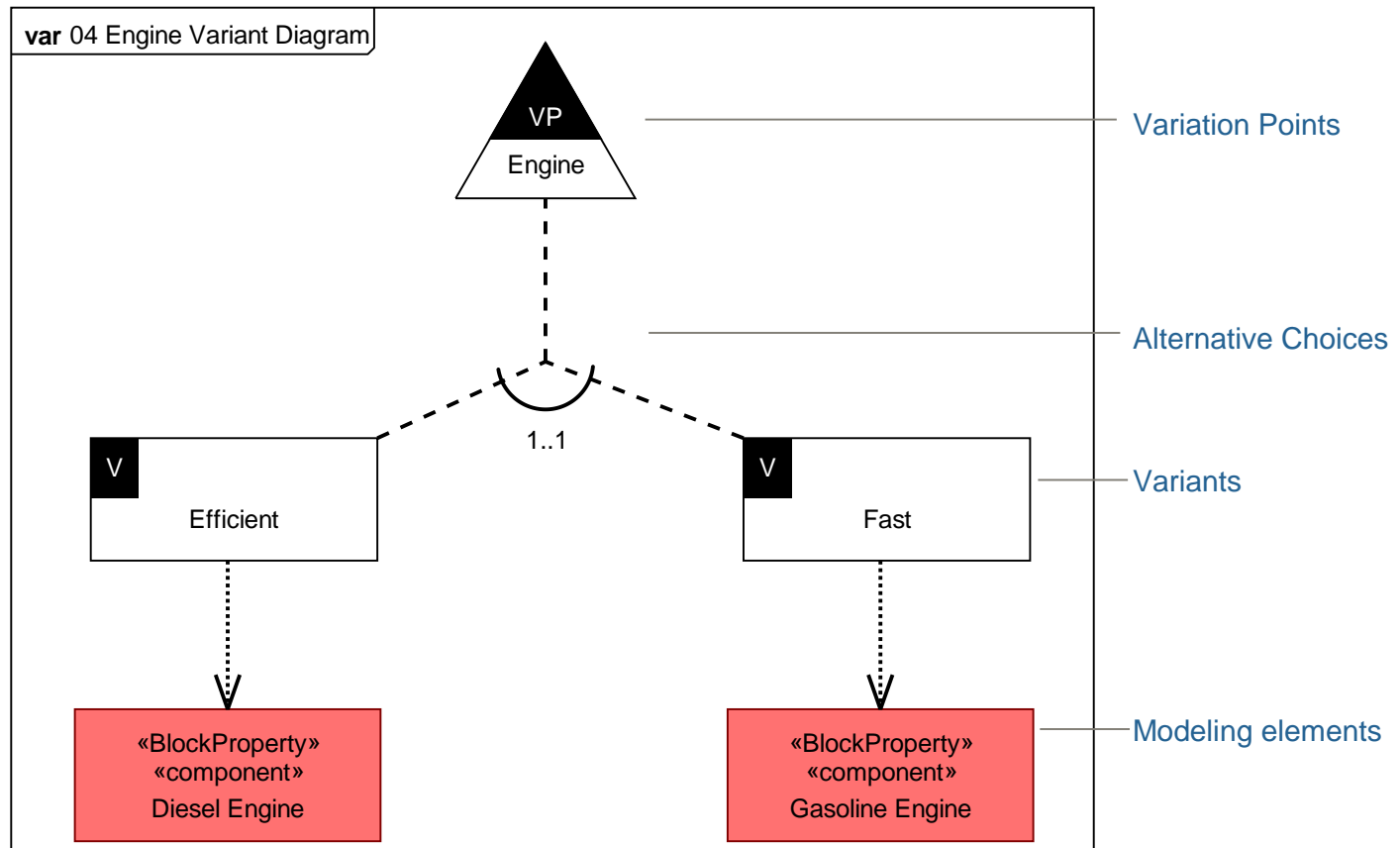




# Modeling Variability

Global Product Data Interoperability Summit | 2015

- Engine variability along with model dependencies



# Decision Set Editor Variant Selector Examples

Global Product Data Interoperability Summit | 2015

Name	Decision	Status	Included By	Excluded By	Reason
<input type="checkbox"/> Dynamic	?	Excluded			
<input type="checkbox"/> Luxus	?	Excluded			
<input type="checkbox"/> Keyless Entry Option	?	Excluded			
M E <input type="checkbox"/> Line		Included	Variable		
<input type="checkbox"/> Base	Include	Included			
<input type="checkbox"/> Dynamic	?	Excluded			
<input type="checkbox"/> Luxus	?	Excluded			
M <input type="checkbox"/> Multimedia Supplier		Included	Variable	cheape	
<input type="checkbox"/> The well-known, expensive Brand	?	Excluded			
<input type="checkbox"/> The cheaper, better, but quite unknown Brand	Include	Included			
M <input type="checkbox"/> Battery Size		Included	Variable		
<input type="checkbox"/> 65Ah	?	Excluded			
<input type="checkbox"/> 44Ah	?	Included	Variable	Size.Alt	

Variants: 16/3 | Variation Points: 8/21 | Inconsistent: 0 | Undecided Mandatory Variation Points: 9

Variant Selector

Example Model for Atego Perspective, Version 4

Make it Cheap

- Car Types ☒ for the city
- Motor Type ☐
- Air Conditioning ☐
- Route Directives ☐
- Car Colour ☐
- Connectivity ☒ USB
- Bluetooth version ☐
- Data Input ☒ Keyboard
- Screenlock ☐
- External and Optional ☐
- External and Mandatory ☐
- Routing Options ☒ Voice
- Comfort Options ☐
- Keyless Entry ☐
- Line ☒ Base

Line

There are three main car equipment lines, from which one is to be chosen: 1. Base for the price-sensitive customer 2. Dynamic for the more sporty customer 3. Luxus for the customer who wants to equip the car with all the luxury possible

☐ Base  
☐ Dynamic  
☐ Luxus

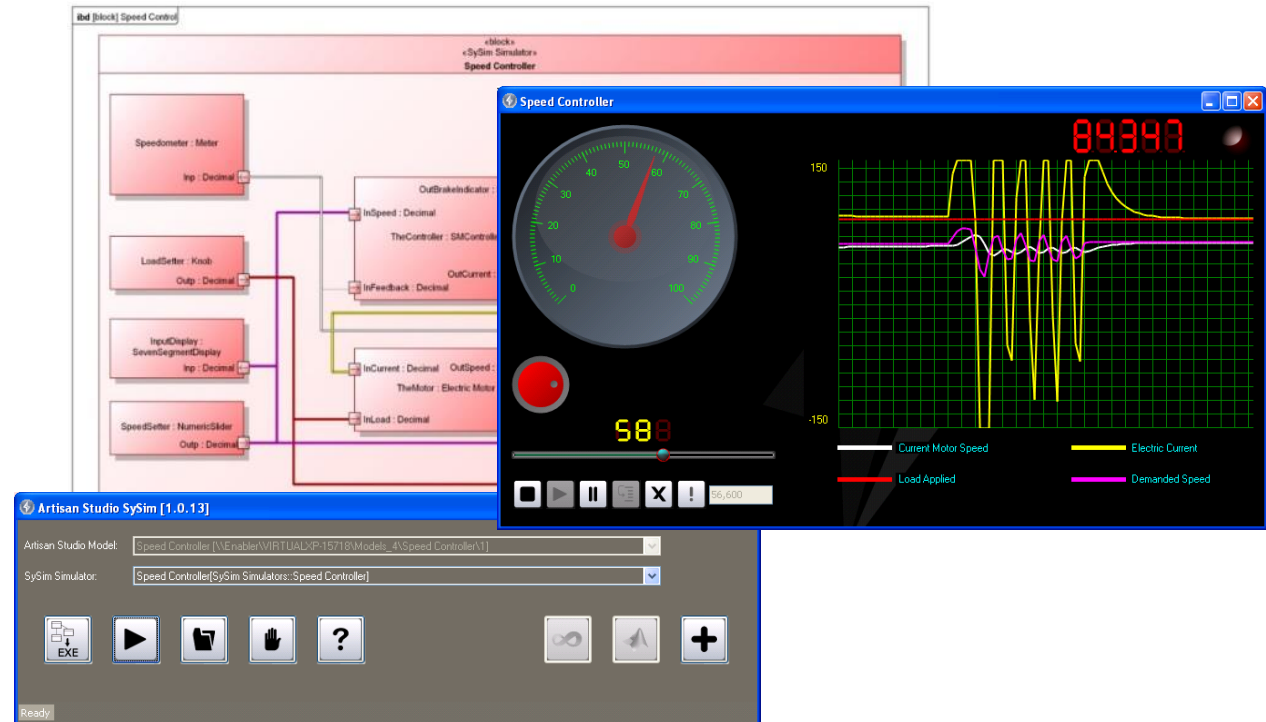
(8/21)

# PTC Integrity Modeler SySim

Global Product Data Interoperability Summit | 2015

## CAPABILITIES

- Early Complex Behavior Validation
- Block Level Reuse
- Drop-&-Play Simulation
- Connect to External Simulators
  - MATLAB Simulink™, etc.



## BENEFITS

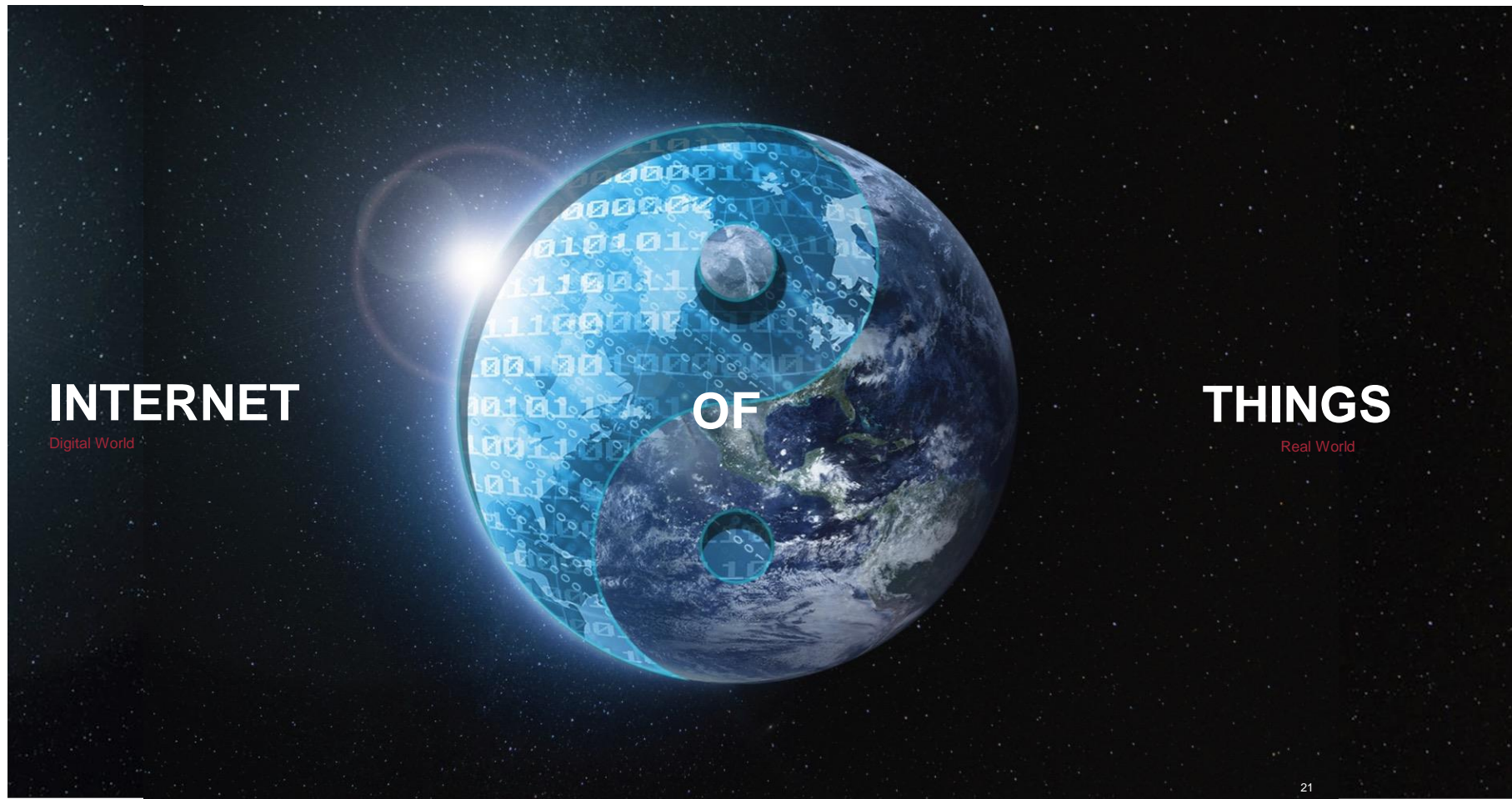
Typical 20% reduction in model 'Design Walkthrough' effort

Up to 30% reduction in design errors

Significant reduction in overall project costs

# New Reality: Distinct but Inseparable

Global Product Data Interoperability Summit | 2015

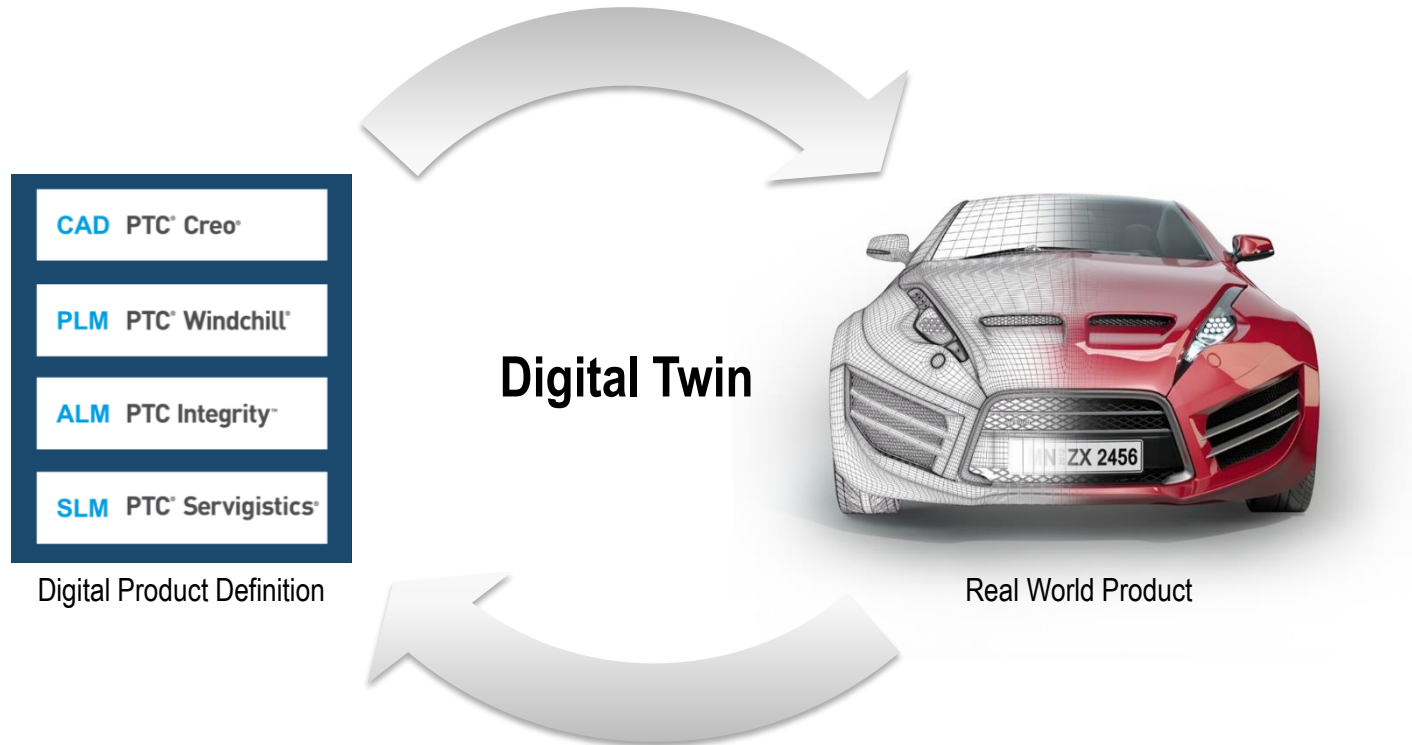


21

# PTC's Enterprise IoT Vision

Global Product Data Interoperability Summit | 2015

Produce and manage Smart, Connected Products



Leverage Smart, Connected Product data to improve products



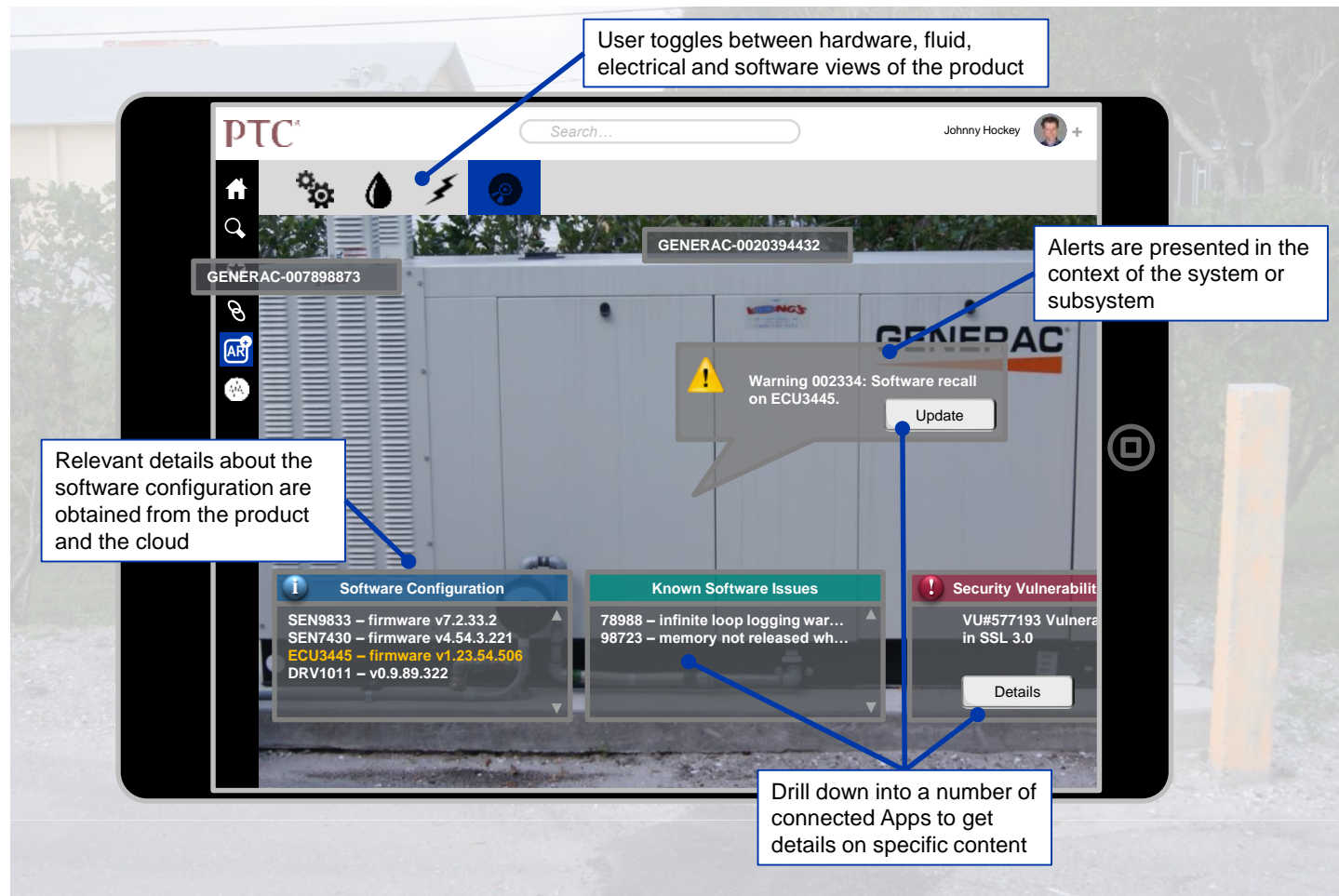
# With Augmented Reality (Software Configuration)

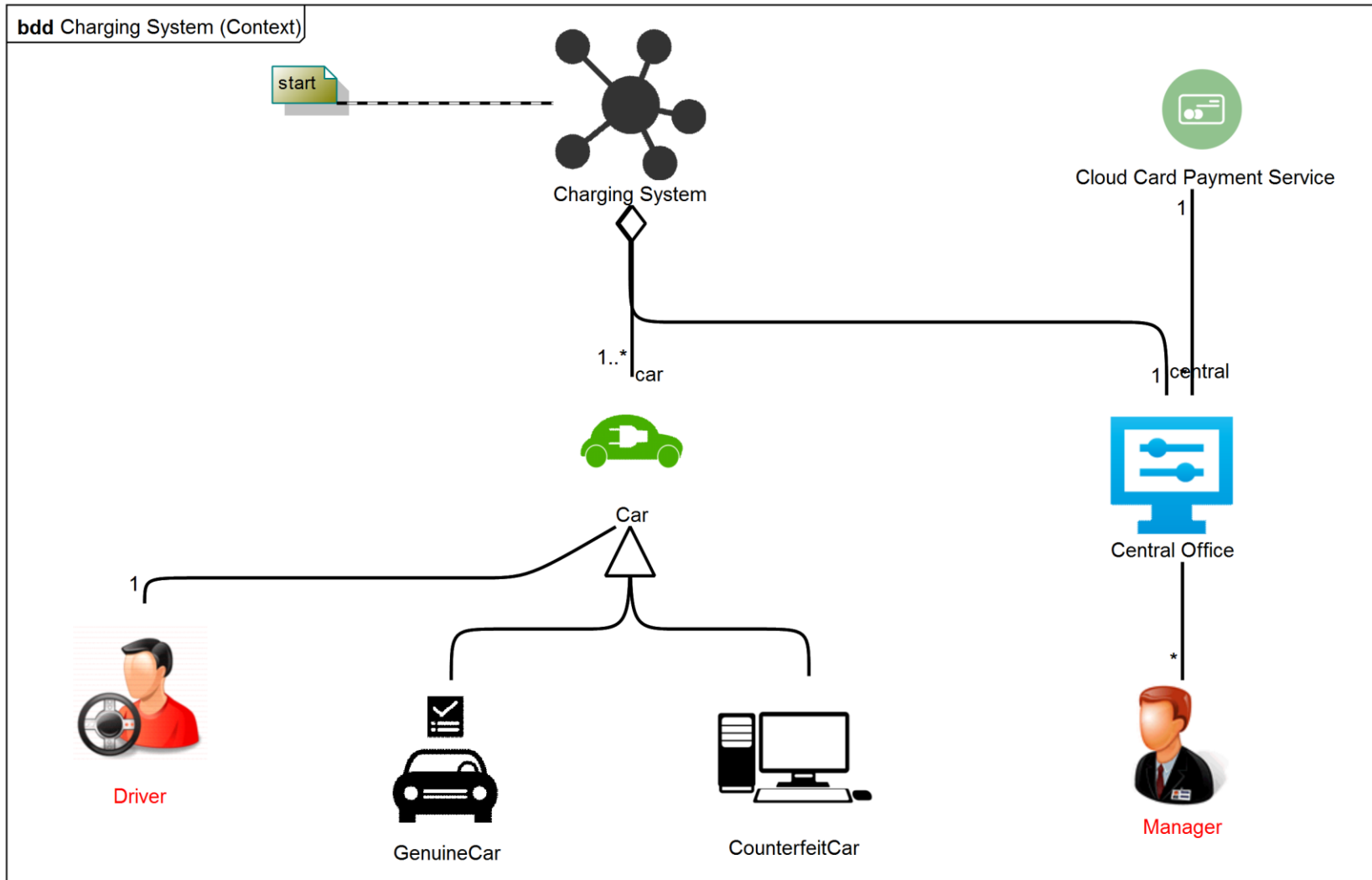
Global Product Data Interoperability Summit | 2015



# With Augmented Reality (Software Configuration)

Global Product Data Interoperability Summit | 2015

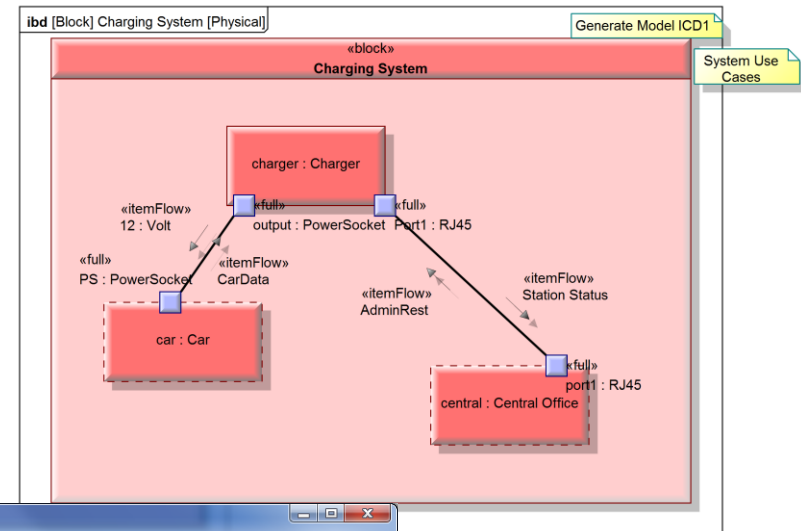
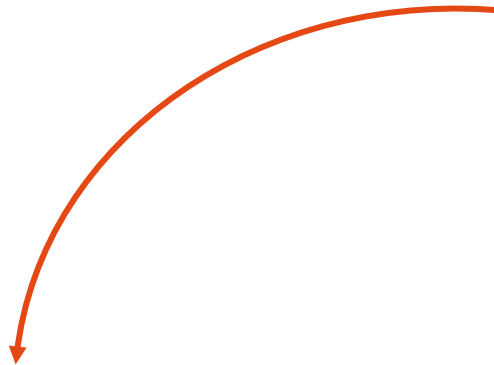






# Model Data Mining (ICD)

Global Product Data Interoperability Summit | 2015

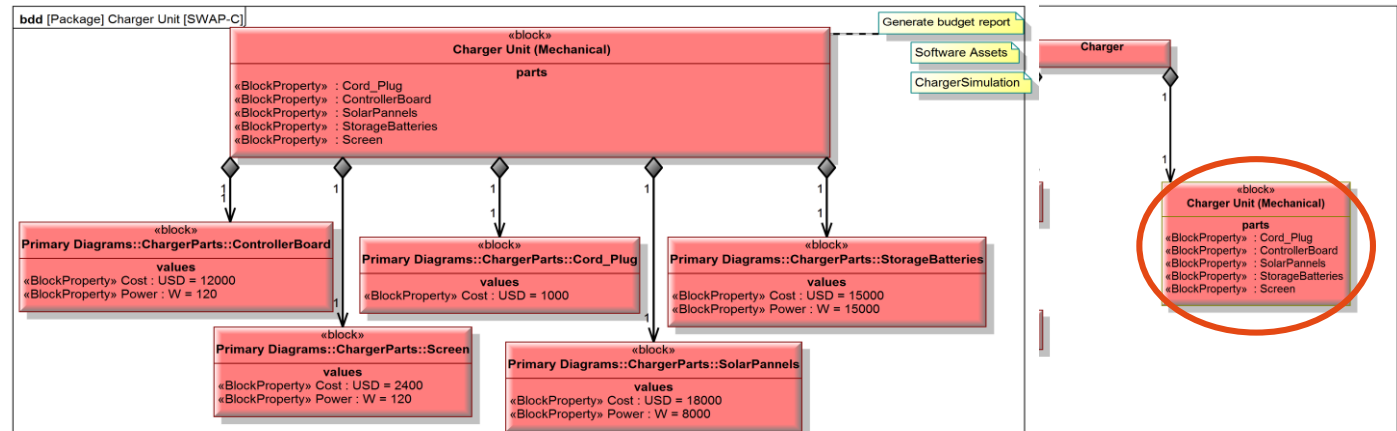


Book1 - Microsoft Excel (Product Activation Failed)

Interface Specification Matrix								
Source Interface Name	Source Interface Type	Source Element Type	Destination Element Type	Destination Interface Name	Destination Interface Type	Item Flow Name	Item Flow Type	
port1	RJ45	Central Office	Charger	Port1	RJ45	AdminRest	TWData	
Port1	RJ45	Charger	Central Office	port1	RJ45	Station Status	TWData	
output	PowerSocket	Charger	Car	PS	PowerSocket	12 Volt		
PS	PowerSocket	Car	Charger	output	PowerSocket	CarData	TWData	

# Model Analysis (SWAP-C)

Global Product Data Interoperability Summit | 2015



Book2 - Microsoft Excel (Product Activation Failed)

FileHomeInsertPage LayoutFormulasDataReviewViewDeveloperAdd-Ins

Paste

Cut

Copy

Format Painter

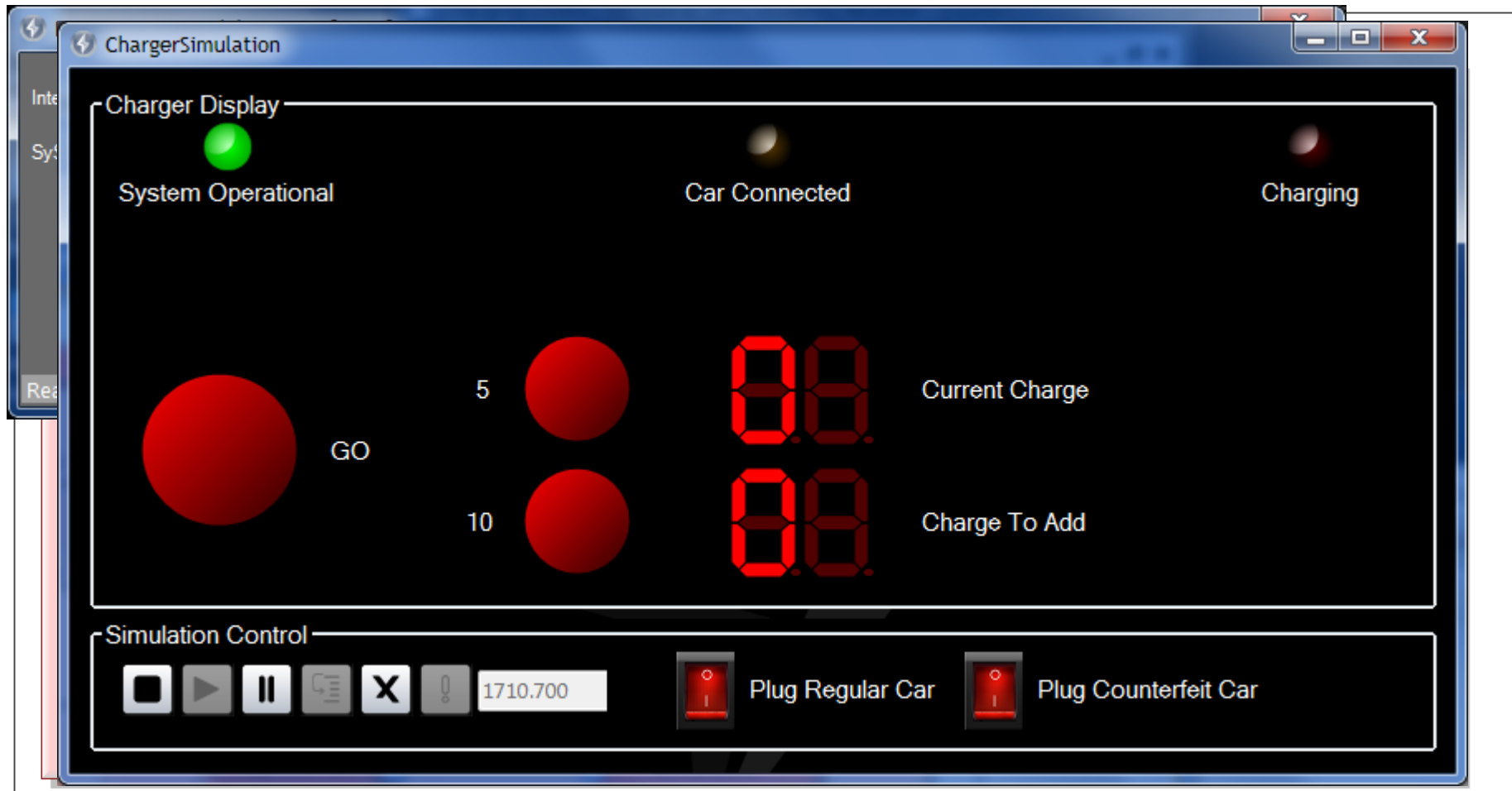
Clipboard

Calibri

11

# Simulation Analysis (SySim)

Global Product Data Interoperability Summit | 2015



# IoT Visualization (ThingWorx)

Global Product Data Interoperability Summit | 2015

The screenshot displays the ThingWorx Composer web application. The browser address bar shows the URL `localhost:8081/Thingworx/Composer/index.html`. The application header includes the ThingWorx logo and a search bar. The main workspace is titled 'Chargers' and contains a mashup named 'SySimChargerShape'. The interface is divided into several sections:

- Left Sidebar:** Contains a 'Widgets' panel with various widget categories (Proportional Chart, Radio Button, Range Chart, Remote Access, Repeater, Shape, Slider, SQUEAL, Status Message, Tabs, Tag Picker, TagCloud) and a 'Mashup' panel with a table of mashup properties.
- Central Workspace:** Displays a mashup preview. It includes a 'Refresh Now' button, a table with columns 'Station Name', '#', 'Address', and 'Status', a map of the United States, and two input fields labeled 'Car Identifier' and 'Car Current Charge'.
- Right Sidebar:** Contains a 'Data' panel with a list of data sources (ThingTemplates\_ChargerStation, GetImplementingThingsWithData, DynamicThingTemplates\_ChargerStation) and a 'Session' panel with a table of session information.

The 'Mashup' panel in the left sidebar shows the following properties:

Name	Value
-T- Id	mashup-root
-T- Type	Mashup
-T- DisplayName	Mashup
-T- Description	
Master	Search Mashups
Style	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
-T- BgImageRepeat	No Repeat
-T- BgImageSize	Auto
ShowDataLoading	<input checked="" type="checkbox"/>

# Simulate and Publish Data for IoT Subscribe

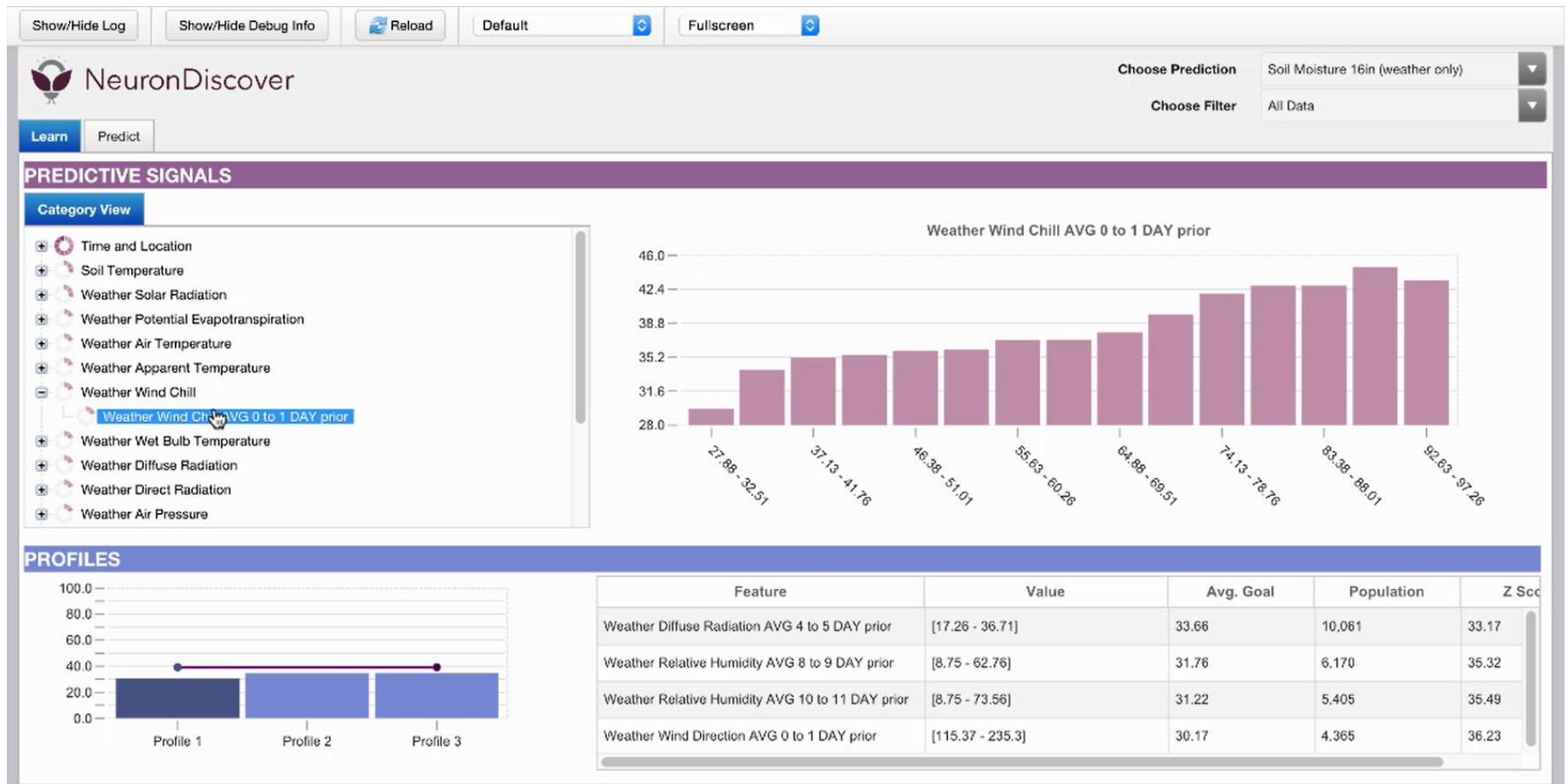
Global Product Data Interoperability Summit | 2015

The screenshot displays a software development environment with three main components:

- State Diagram (Left):** A UML state diagram for a car charging system. It starts with a 'GetInfo' state, followed by 'CheckCar' and 'DetermineChargeAmount'. The 'DetermineChargeAmount' state has a 'Preset' sub-state and a 'Charging' sub-state. The 'Charging' sub-state includes a 'SubCharging' state. The diagram ends with 'EndOfCharge' and 'ShuttingDown'.
- ChargerSimulation Window (Top Right):** A graphical user interface for simulating a car charger. It features a 'Charger Display' with a green light for 'System Operational', an orange light for 'Car Connected', and a red light for 'Charging'. The display shows 'PLUG CAR' and 'PLEASE UNPLUG CAR' in large yellow letters. It also displays 'Current Charge' (48) and 'Charge To Add' (15) in red digital numbers. A 'Simulation Control' bar at the bottom includes buttons for 'Plug Regular Car' and 'Plug Counterfeit Car'.
- Properties Panel (Bottom Right):** A panel showing the properties of the 'CarConnected' state. It includes fields for 'Full name', 'Page reference', 'Type', and 'Last changed on/by'.

# Predictive Signals

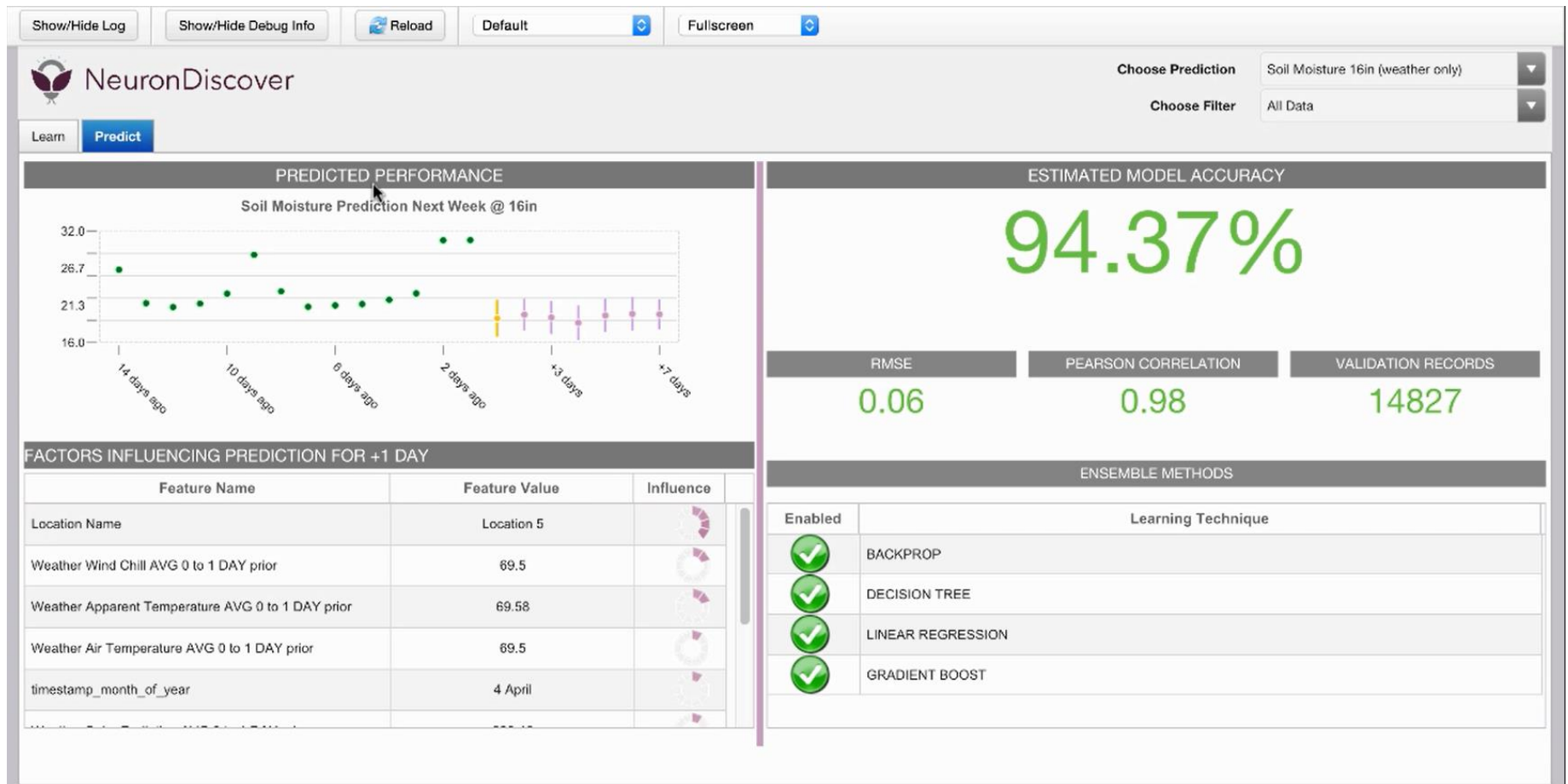
Global Product Data Interoperability Summit | 2015





# Predictive Analyzer

Global Product Data Interoperability Summit | 2015



# Questions and Answers

Global Product Data Interoperability Summit | 2015

