Model-Based Product Line Engineering with Modelica and FMI – In a Regulated Context

Dassault Systèmes
David Guzinsky VP A&D Solutions
Garrett Thurston A&D Strategy

Modelon
Hubertus Tummescheit CEO

Biographies

Dr. Thurston is the North America Aerospace & Defense Strategy Director

At Dassault Systèmes Dr. Thurston works with Clients to maximize their derived value, and shorten the value realization time resulting from their investments.

Key focus areas include regulated context Systems and Software product lines, Model-Based Enterprise.

He has worked at Textron, ISI/Windriver, Hamilton Sundstrand, in various roles and led the Aerospace, Defense, & Security P&L at a Boston-based Product Consulting and Development firm.

His Doctoral Dissertation was developing a distributed parameter control system in support of a DARPA program. He also has a MS in Engineering, and a BS in Chemistry.

Dr. Tummescheit is the Chief Executive Officer of Modelon Inc., and one of the founders of Modelon AB

He has been involved in the Design of the Modelica language and the FMI standard from the beginning. In 2003 he worked as a research scientist at United Technologies Research Center and returned to Sweden in 2004 to start Modelon AB, the first company fully dedicated to tools and services based on Modelica and FMI.

Dr. Tummescheit has served as the CEO of Modelon in Sweden and moved to the United States in 2013 to establish Modelon as a lead player in system simulation here.

Dr. Tummescheit has an MSc in Mechanical Engineering from Germany, and a PhD in Automatic Control from the University of Lund, Sweden.

BIOGRAPHIES

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David Guzinsky
Vice President, A&D Industry Solution Experience
Aerospace and Defense

- **Following the 2013 acquisition of his company, Strategic Business Solutions, Inc. (SBS) David Guzinsky joined Dassault Systèmes as Vice President of Aerospace & Defense Industry Solution Experiences, focused on business development and portfolio strategy.**

- **As President and CEO of SBS, Dave led the company from 1998 through 2013 in its mission to provide multidisciplinary service and solutions to the aerospace commercial and defense segments as well as to provide general engineering expertise. With deep domain knowledge the Aerospace & Defense Industry's needs and best practices, David led his R&D team through the ideation, development, and deployment of many market-leading solutions -- including the ENOVIA A&D Accelerator, ENOVIA IP Export Classification and ENOVIA IP Enforcement solutions, and ENOVIA Program Cost and Budgets for Earned Value Measurement -- part of the Dassault Systems' portfolio.**

- **An internationally-recognized executive within the A&D Industry, David works with most of the world's preeminent Aerospace & Defense powerhouses including: The Boeing Company, Northrop Grumman, Lockheed Martin, Sikorsky Aircraft Corporation, Boeing Helicopter, as well as major equipment manufacturers and suppliers such as Pratt and Whitney, Honeywell, Raytheon, Orbital Sciences, and Harris among others. He also Interfaces with industry associations and government personnel – in both the Department of Defense (DOD) and the National Aeronautics Space Administration (NASA) -- on topics related to progressive industry methodologies and interrelationships including, but not limited to: Systems Engineering, Configuration Management, Data Management, Technical and Contract Compliance and Earned Value Methodologies.**

- **David's unique visibility into all tiers of the A&D industry as well as its diverse business processes allows him rare insight into the best ways to integrate processes and tools across functional organizations. David has decades of experience architecting business transforming enterprise business applications in the Product Lifecycle Management (PLM) environment.**

- **Prior to SBS, David was Program Manager of Spares and Logistics Programs, International Space Station (ISS), which allowed him to manage, develop, and implement ISS Spares and Logistics Support contracts..**

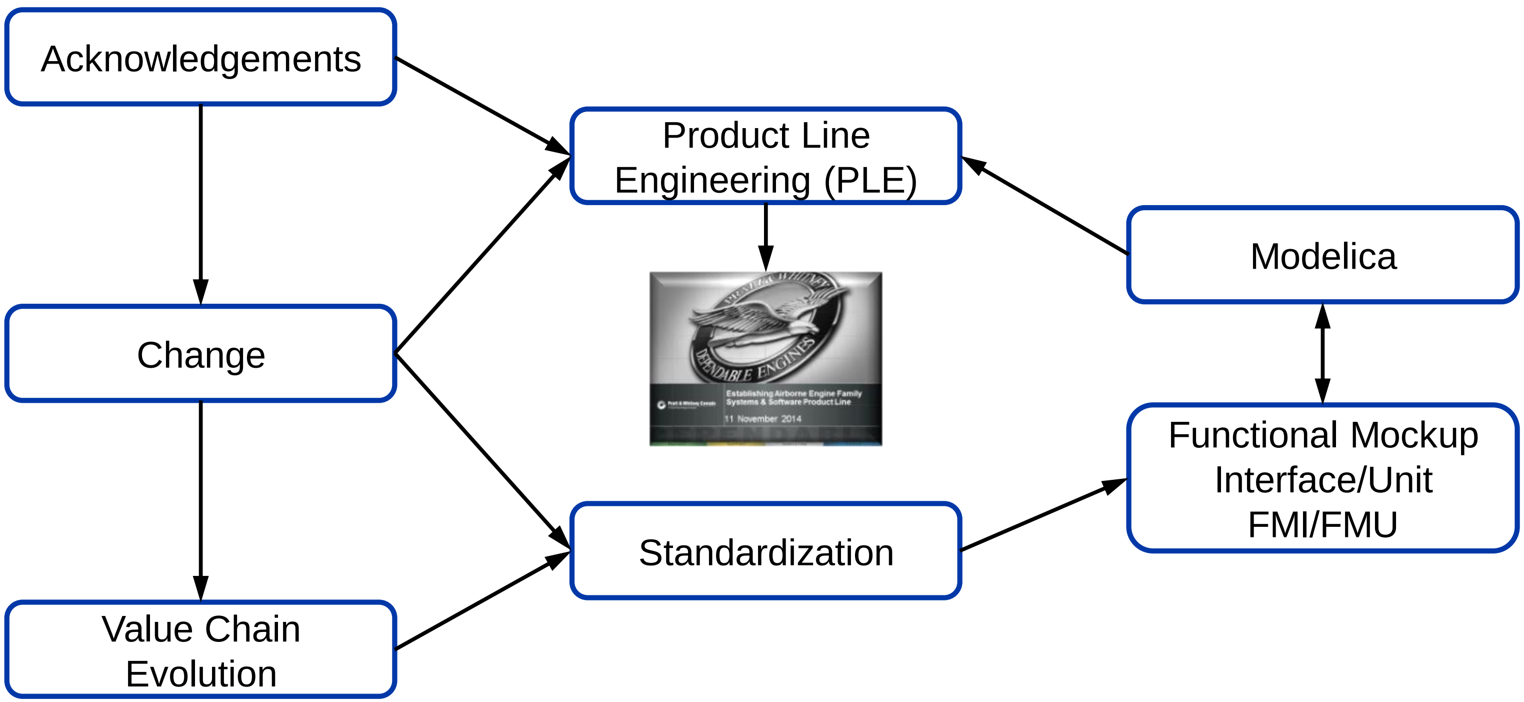
- **Another highlight of his ten-plus years at The Boeing Company, was David's role as Engineering Operations and Configuration and Data Manager on the V-22 EMD, There, he was responsible for the management of the Program's Configuration Management, Data Management, Technical Compliance, and Engineering Cost and Schedule activities for the company.**

- **David is a member of multiple industry-specific associations such as the National Defense Industry Association, The Program Management Institute, and the National Contracts Management Association. A Combat Veteran of the United States Marine Corps, David was a Force Reconnaissance Operator.**

Key Take-Aways

- **Product lines affect positive business outcomes.**
- **Capability maturity models are key to sustained transformation.**
- **Product lines include all assets.**
- **Asset Management is a key building block.**
- **Deliberate reuse depends on revalidation.**
- **Model-based definition facilitates early validation.**
- **Models need to be deployable in different contexts.**

Agenda


Acknowledgements
Product Line Engineering (PLE)
Modelica
Change
Functional Mockup Interface/Unit FMI/FMU
Standardization
Value Chain Evolution

Acknowledgements

"If we reach high, we do so only because we stand on the shoulders of those who went before"
-- Albert Einstein

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Patterns of Adoption

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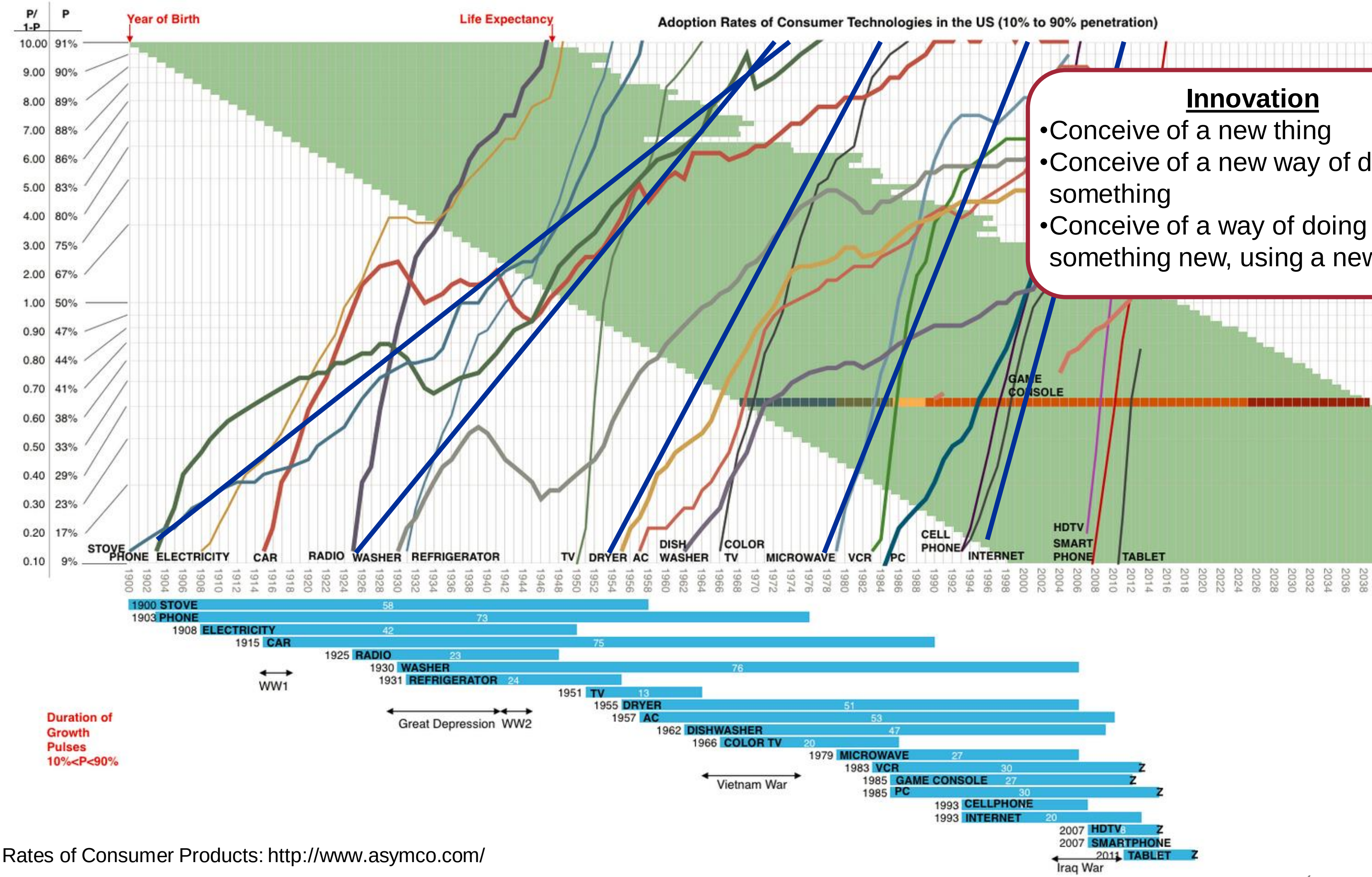

Innovation

- Conceive of a new thing
- Conceive of a new way of doing something
- Conceive of a way of doing something new, using a new thing

Adoption Rates of Consumer Products: http://www.asymco.com/

Value Chain Evolution

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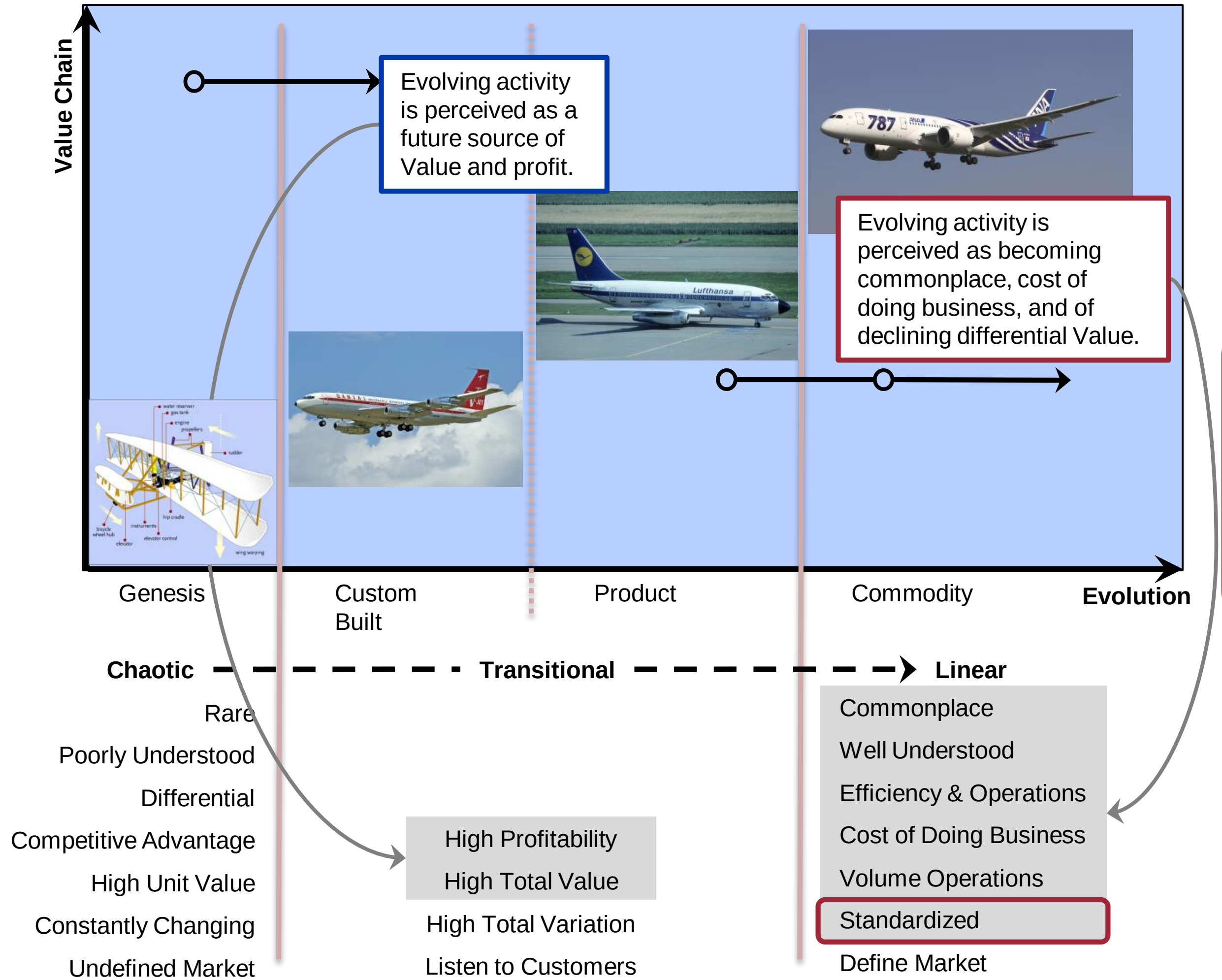

Herbert Simon
Theory of Hierarchy:

- The creation of a system is dependent upon the organization of its subsystems.
- As an activity becomes increasingly commoditized and provided as ever more standardized components, it not only allows for increasing speed of implementation but also rapid change, diversity and agility of systems built upon it.

Adapted from Bits & Pieces Blog
http://blog.gardeviance.org/2013/01/evolution-begets-genesis-begets.html

RADAR Screen

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Availabl
external
standar

- Today's Focus
- STEP
- ASD S-Series
- TSCP
- 3D visualisation
- LOTAR

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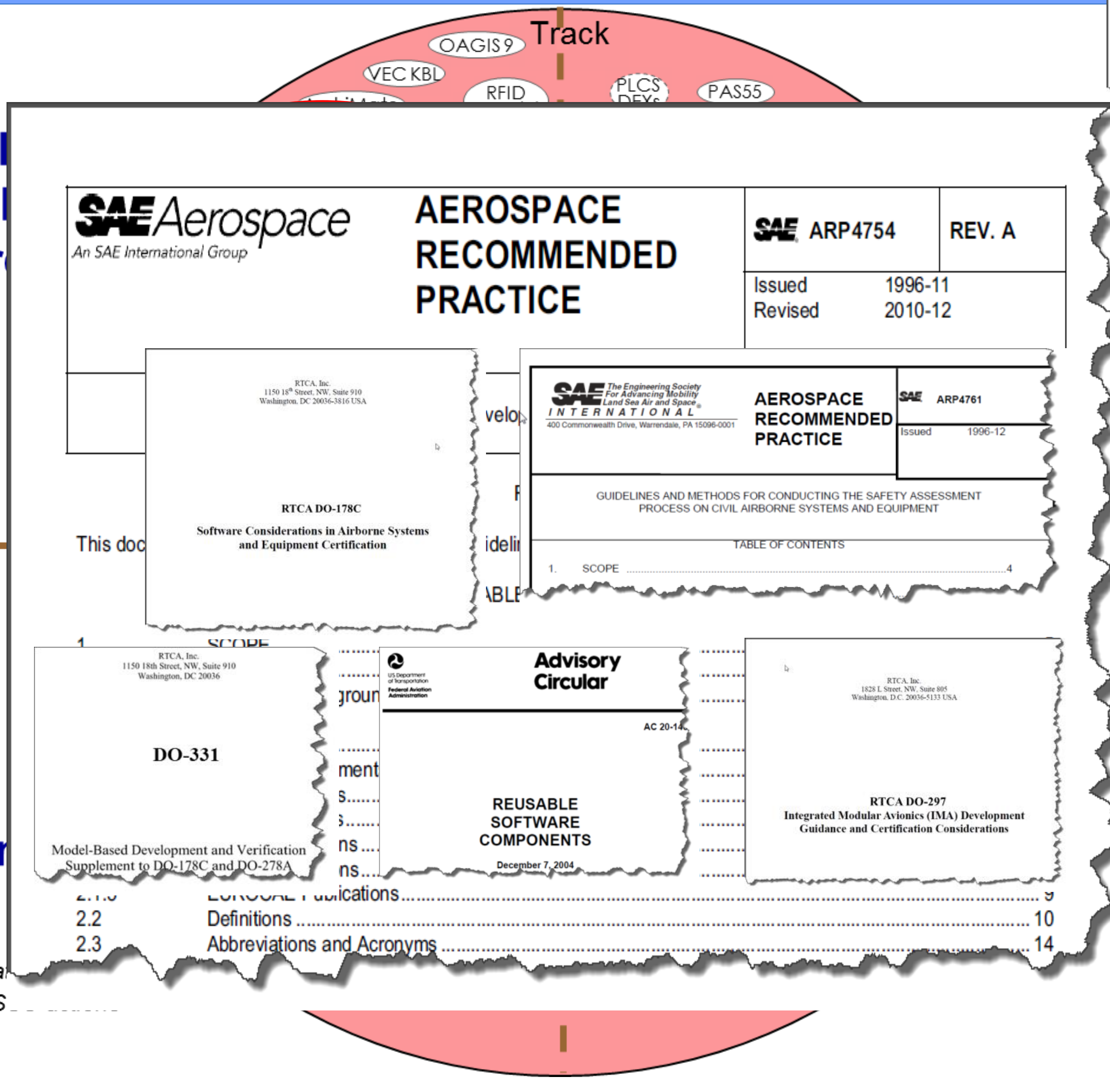
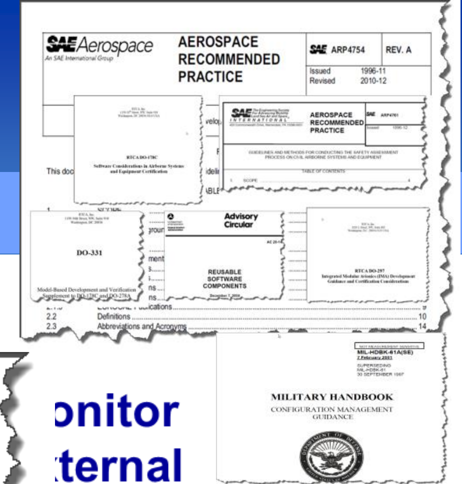
Blip available
Blip in prepara
Current ASD S

Version: V1.7





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Supply Chain: Adapt

Tier One Suppliers had to change from being a **systems supplier** to a **systems integrator—** *arguably a tectonic shift* **—**in the blink of an eye

Systems **supplier**

- Greater levels of integration
- New technologies
- Increased complexity
- Increased reliance on their own supply chain

Systems **integrator**

Change

FMI enables system integrators to perform virtual validation using subsystem models from their supply chain

Developing Efficiency at the Expense of Adaptability

Any customer can have a car painted any color that he wants, so long as it is black.
--Henry Ford

The production of Henry Ford's Model T was the archetypal example of developing efficiency at the expense of adaptability.

In pioneering mass production, Ford produced more than 15 million Model T's over 19 years.

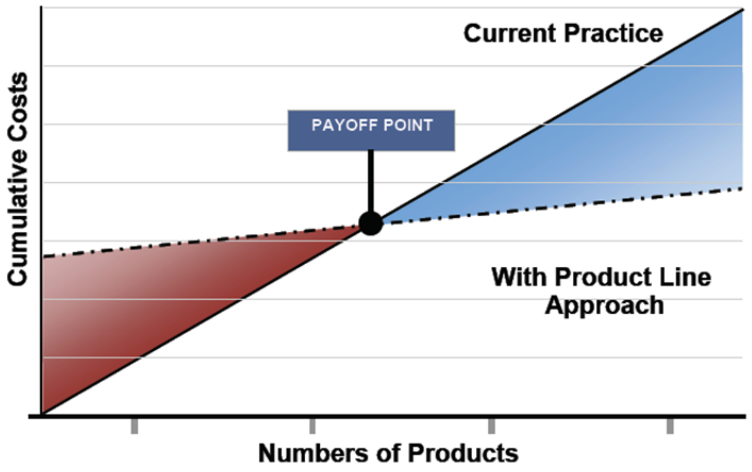
By 1927, the car had fallen behind its competitors, because production had been geared toward efficiency rather than flexibility.

The company was forced to close all its factories down for six months in 1927 to retool for the Model A, perhaps the most costly model changeover in history.

Why Product Lines?

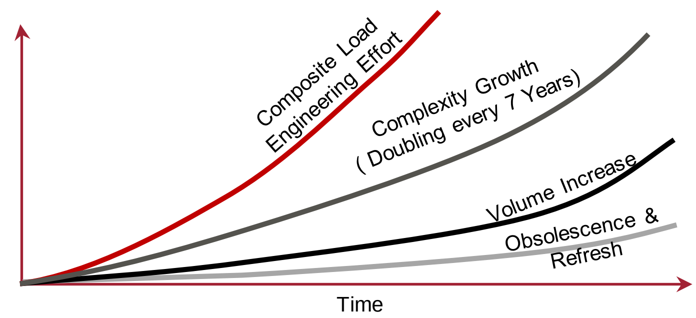
Business Drivers

- **Build a culture of commonality and variability to leverage common methods and infrastructure to enable improved execution.**
- **Deliberately harvest latent IP, through architected variability.**
- **Drive down instance cost, improved asset management and leverage.**
- **Improve the ability to engage and understand customer needs.**
- **Identify innovation opportunities through customer co-creation.**
- **Improved customer satisfaction through enhanced ability to meet customer commitments.**
- **Improve the ability to plan and estimate product development efforts.**
- **Enhance the way in which Risk and Opportunities are Identified, anticipated/planned for, and managed.**
- **Enable the successful execution of a larger number of increasingly complex product development projects while managing head-count.**



Weiss. D.M. & and Lai, C.T.R..
Software Product-Line Engineering: A Family-Based Software Development Process
Reading, MA: Addison-Wesley, 1999.

Implications of Complexity on Engineering Load



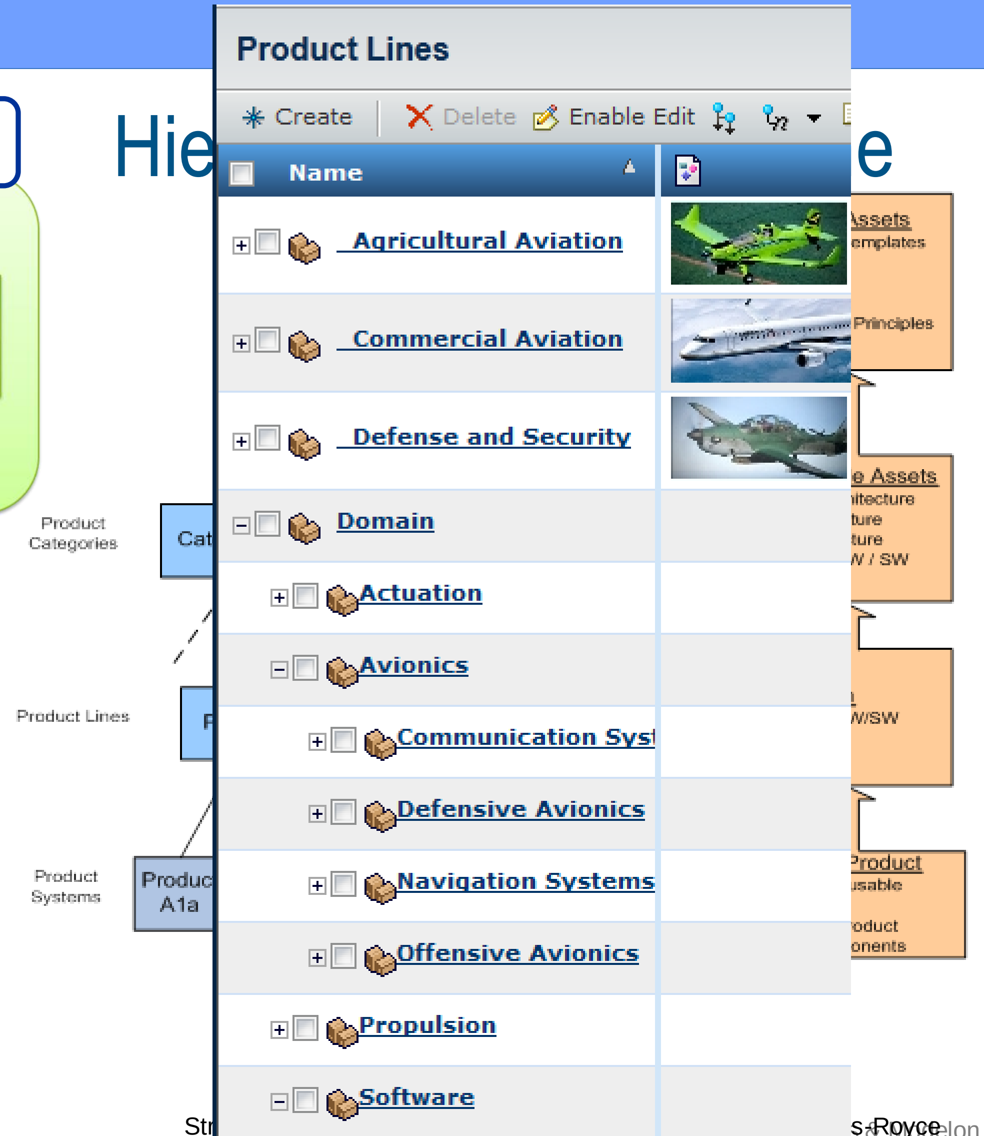
Product Line

Illustrates Different Deployment Contexts

C-130 Hercules Aircraft Platform Configurations
Satisfying Profoundly Different Mission Objectives

AC-130	AC-130A	EC-130E	JC-130	JC-130
Gunship Ground Attack	Airborne Drone Control	Airborne Battlefield Command and Control, & Electronic Warfare	Maritime & Ice Patrol	Mid-Air Retrieval

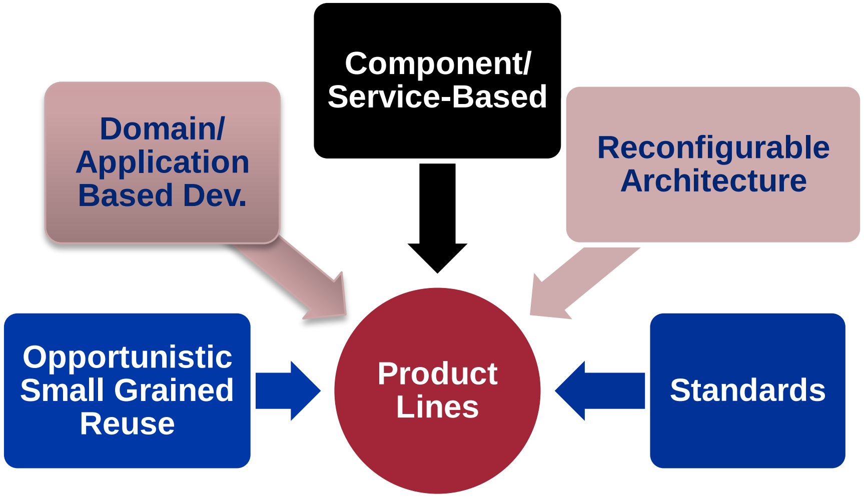
A product line is a set of systems, software, and hardware assets that share a common, managed set of features satisfying the specific needs of a particular market segment or mission (scope) and are developed from a common set of assets in a prescribed way.



It is instructive to understand what product lines aren't.

SEI provides good guidance on What Software Product Lines are NOT

- fortuitous, small-grained reuse (e.g. libraries)
- single-system development with reuse
- just component-based or service-based development
- just a reconfigurable architecture
- releases and versions of single products
- just a set of technical standards



What are the Key Product Line Organization Questions?

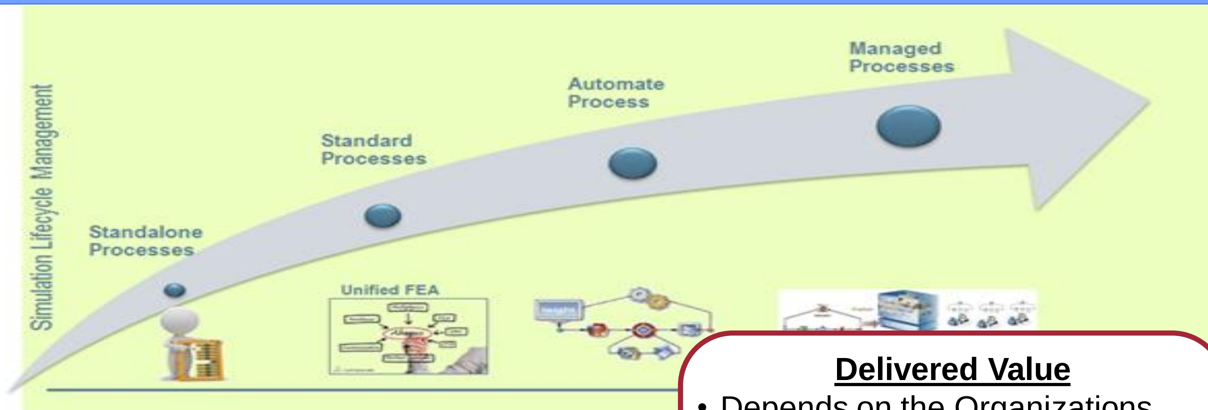
Define

1. What is a Product Line?
2. What does a product line affect?
3. What is the scope of the first product line?
4. Why this scope?
5. What does a mature product line look like?

Operationalize

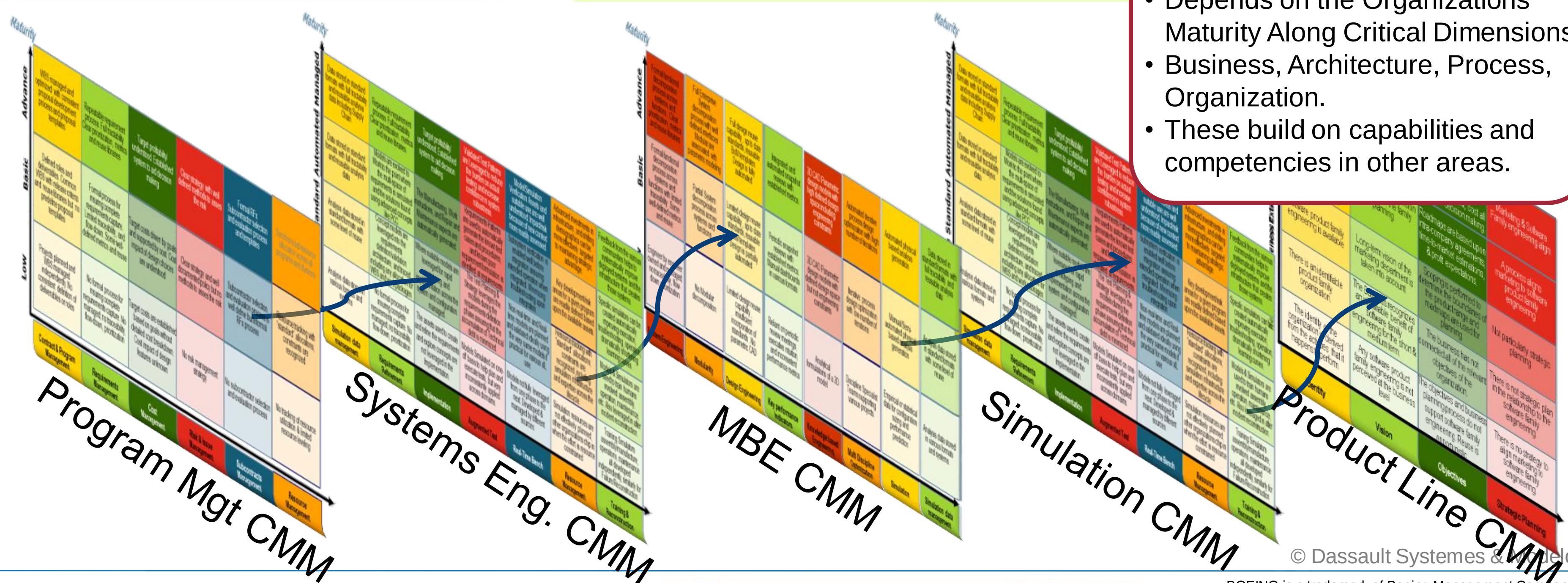
1. How are product lines (Orgs.) Funded?
2. How do you work with product lines?
3. How do I create products from product lines?
4. Who Leads Product Lines?
5. How do we organize around product lines?
6. What is an asset?
7. What is a product line asset?
8. What if a core asset doesn't do what I want it to?
9. What if no asset does what I want it to do?
10. What is different developing using product lines?
11. How does the product line meet customer needs?
12. What if customer insists upon "X"?
13. How do I change the product Line Asset?

Product Line Capability Maturity Builds upon Others



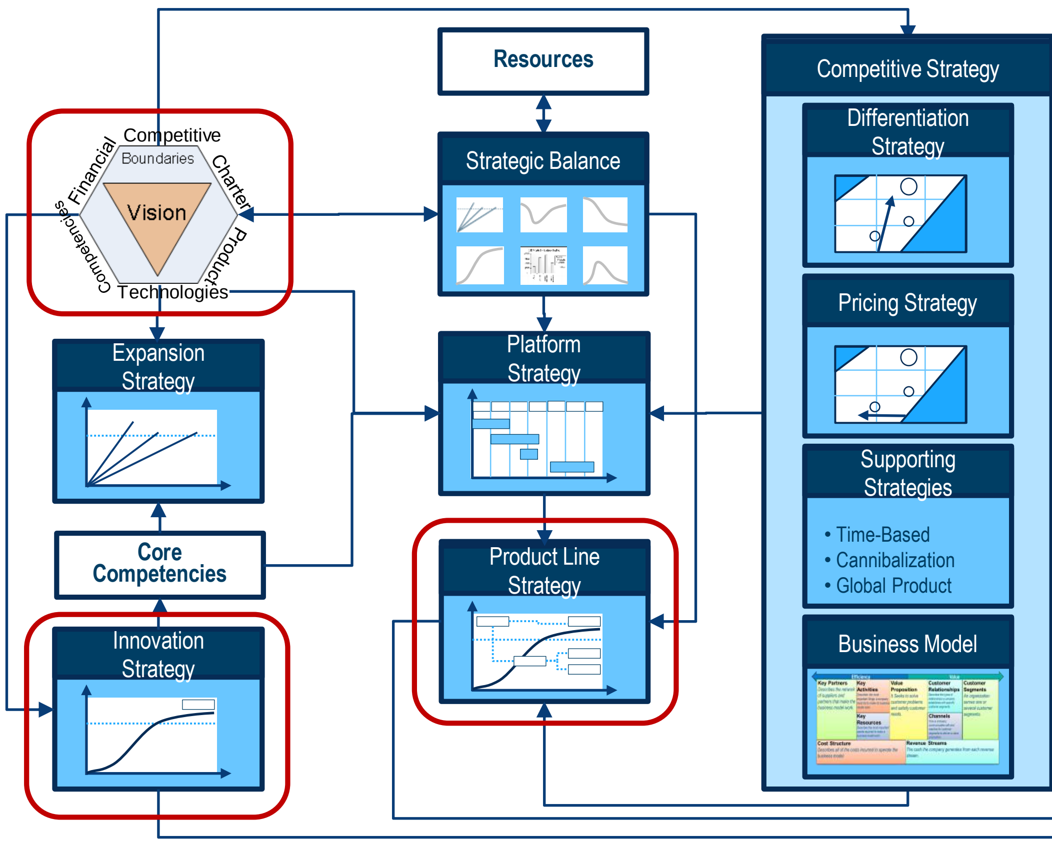
Delivered Value

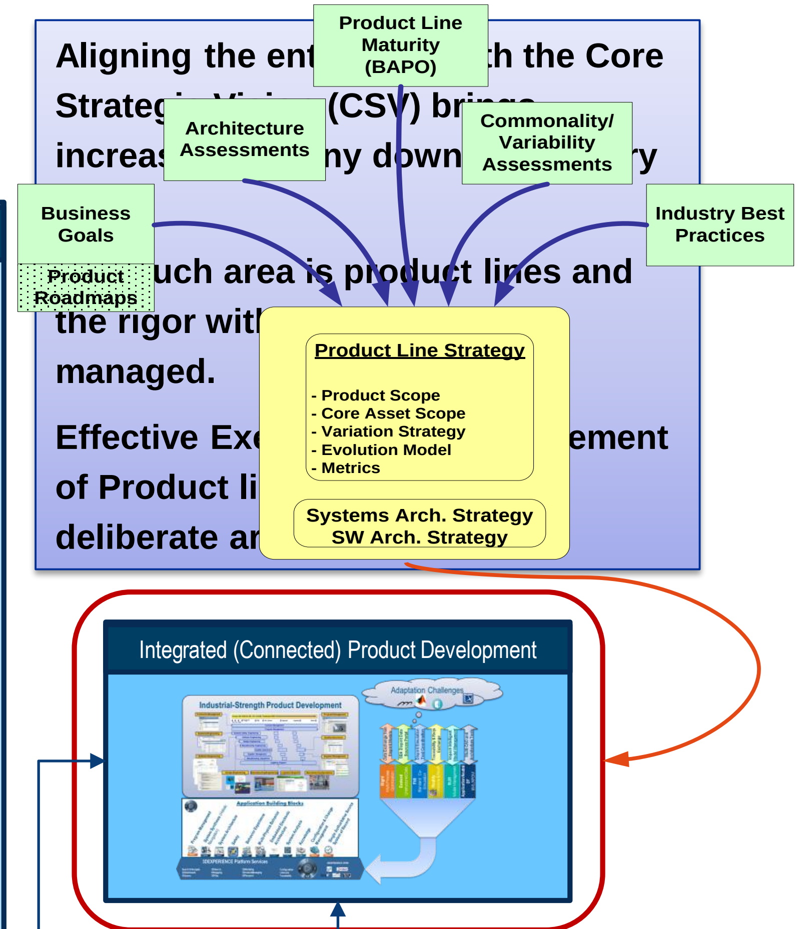
- Depends on the Organizations Maturity Along Critical Dimensions
- Business, Architecture, Process, Organization.
- These build on capabilities and competencies in other areas.



Strategic Product Development & Management

“There is no favorable wind for a rudderless ship.”
-- Hopley Yeaton, First Commodore of the USCG





Strategic Product Lines Credit Foliage (Hersey/Alfred) and Rolls Royce

Adapted From: PRTM High Technology Companies CSV Product Strategy

Product Line Organizational Implications

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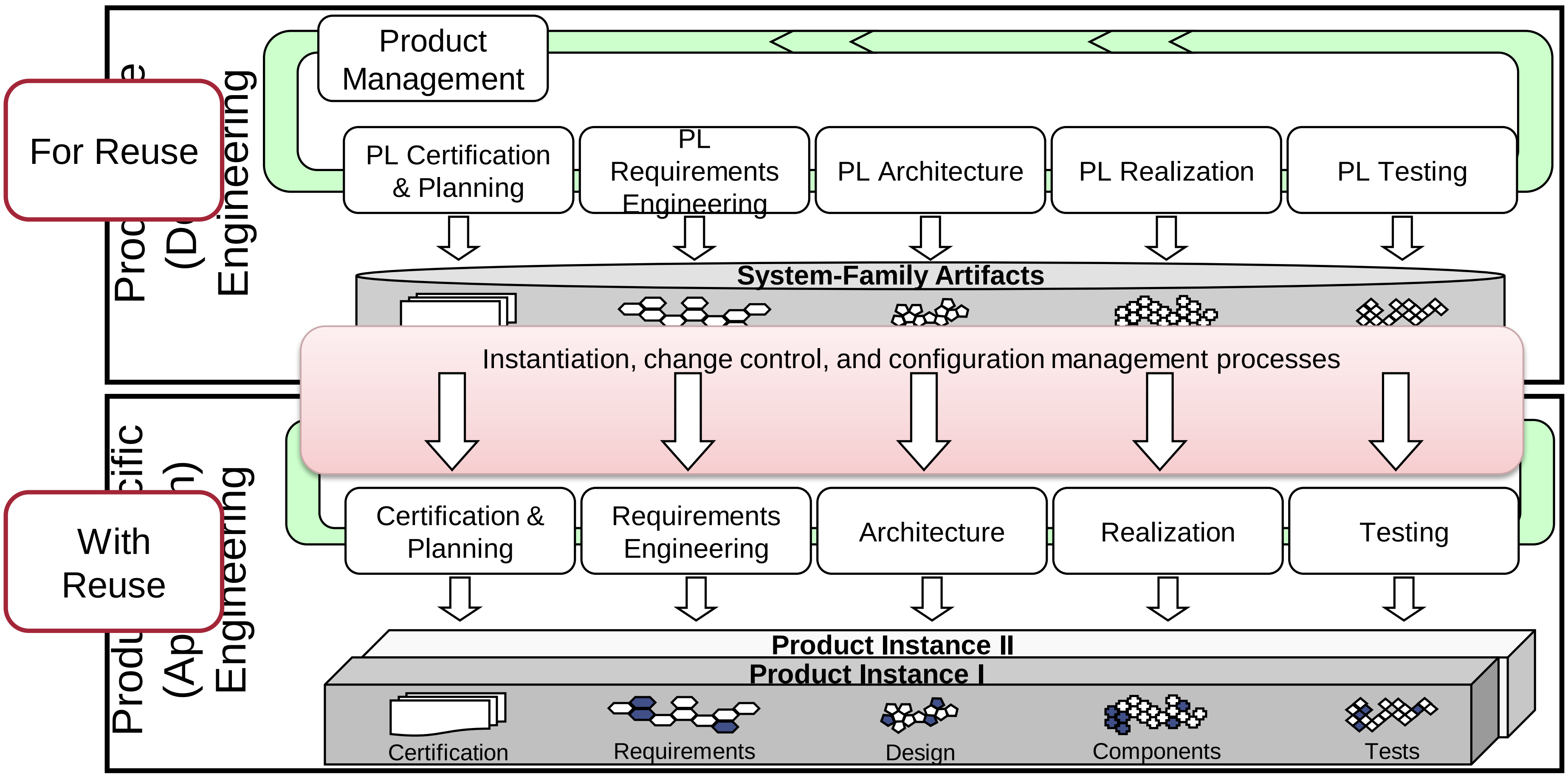
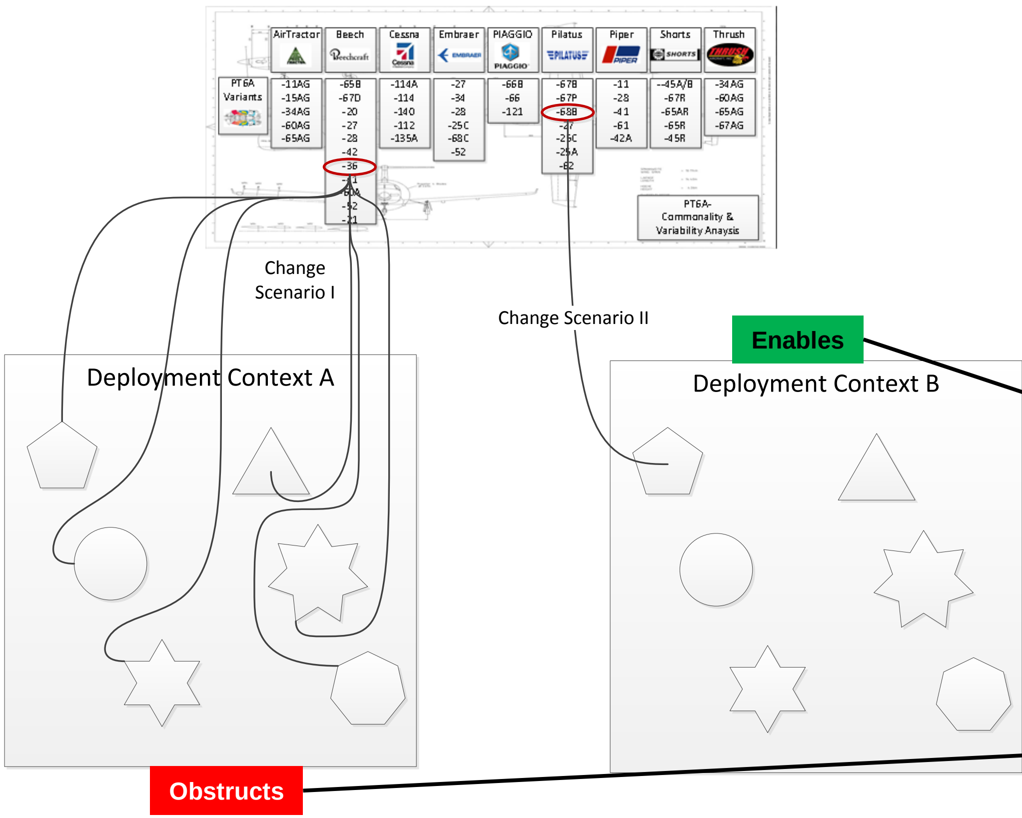


Art based upon Frank Van der Linden Graphic

Domain Analysis “Latent IP”: Change Implications

The process of identifying, collecting, organizing, and representing the relevant information in a domain.

The study of existing systems
- ✓ development histories,
- ✓ knowledge-captured from domain experts,
- ✓ underlying theory,
- ✓ emerging technologies within the domain.



Trade Matrix / Success Criteria		Additional Detail	Option 1 Direct Connection	Option 2 Serial to Interface Box	Option 3 A/C Avionics
			Alternatives		
Mandatory	Safety		0	0	-1
Mandatory	Certifiability	Other reg (e.g. Military or EASA)	0	0	0
Critical	Certifiability	FAA Cert - ease of certification	1	0	-1
Critical	Exportability	No ITAR restrictions and compliant with compartmentalization strategy	0	0	0
Critical	Product Cost (BOM)		-1	-3	1
Critical	Schedule	TTM (both PL and reuse)	0	-1	0
Necessary	Agility	Developability - Upgrade / Modular / Low Risk	0	0	-1
Necessary	Maintainability / Serviceability	HW Upgrade / Obsolesce	0	0	0
Necessary	Product Line NRE		0	-3	0
Necessary	Reliability		0	0	1
Necessary	Ease of retrofit		3	3	-3
Necessary	Schedule	Predictability	0	-1	0
Necessary	Technology Readiness		3	0	0
Necessary	Variability		0	0	0
Important	Extensibility	Unplanned Variability	0	1	0
Important	Performance	Engine or Control System	1	0	0
Important	Size and Shape		0	-1	1
Important	Weight		-1	0	1

ATAM Matrix Credit Foliage and Rolls-Royce

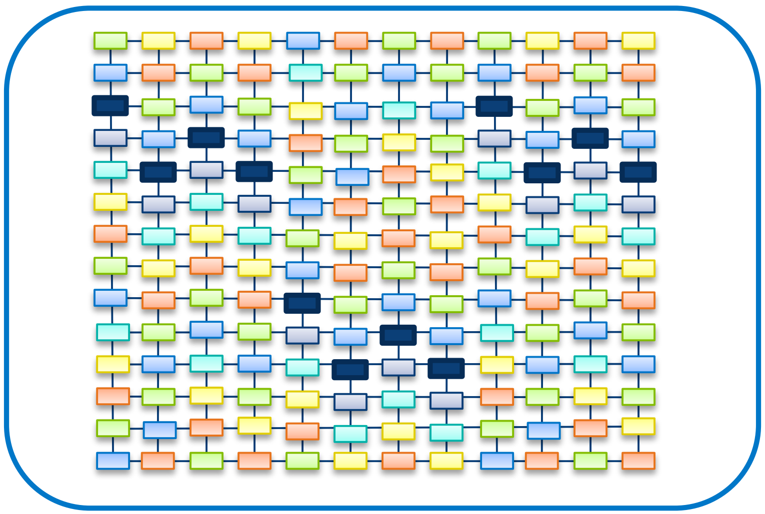
Domain Analysis Example Engine Variants Credit PWC Web Site

System Requirements Validation: “Reuse”

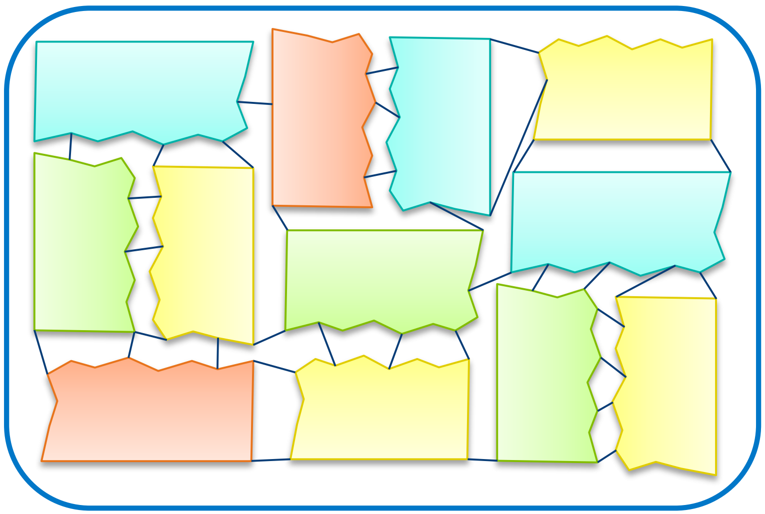
The ***reduced diversity*** *impact of feature-oriented development*

“There is a deep and fundamental mismatch between the information that requirements specifications contain and the information that architects need.”

Requirements-Driven
Fine-Grained Development

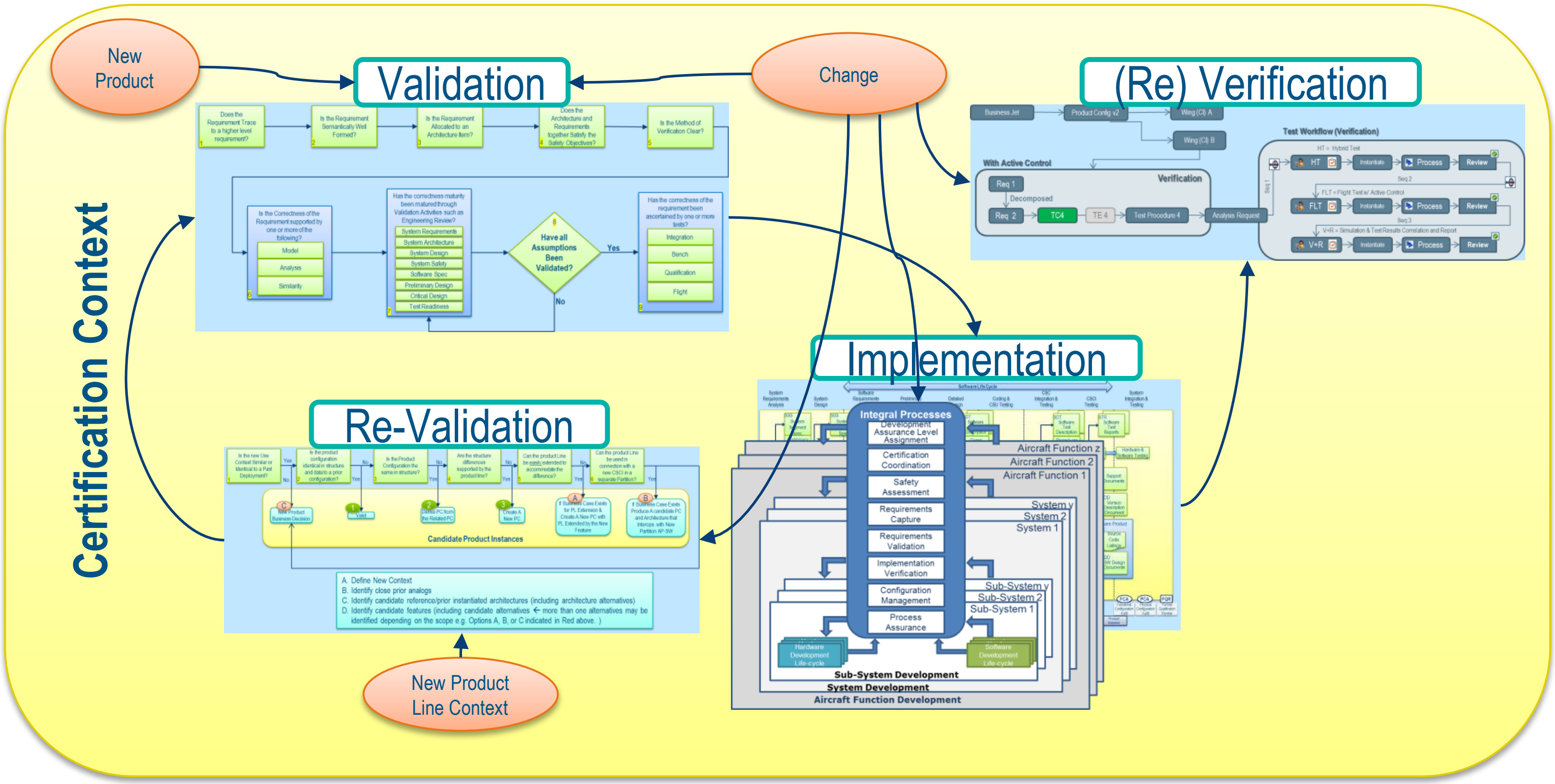


Feature-Driven
“Chunky” Development



Product Value Chain including Change and Deliberate "Reuse"

ARP4754A—RValM (MATTERS) → ARP4754A/DO-178C—RVM (AIDT)
Includes Product Line Engineering (PLE) in a Regulated Context



Product Line Features and Variability

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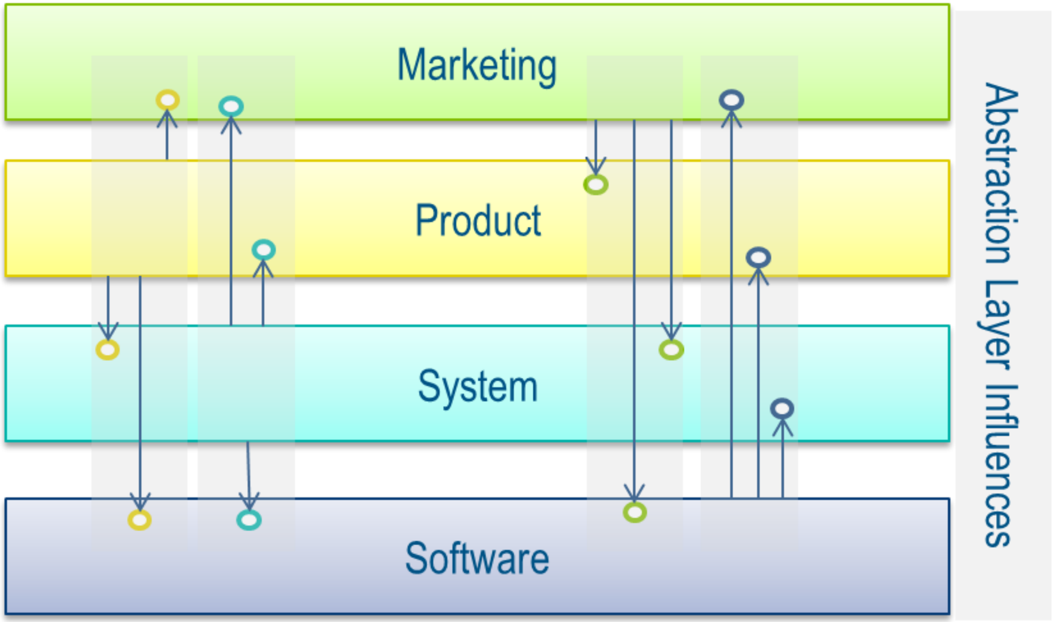
Product lines need to be considered at any number of abstraction levels; in A&D, frequently the entry point is at the platform level or at the the Systems & Software level which includes safety.



Feature Modeling:

- Low level implications at times need to be exposed at higher levels to afford decision making, the corollary is that high-level decisions can have low-level implications.
- The variation elements trace from the features to the architectures, requirements, and implementation.
- This includes related Models and other assets used for Validation, Implementation, and Verification.

Regulated Process

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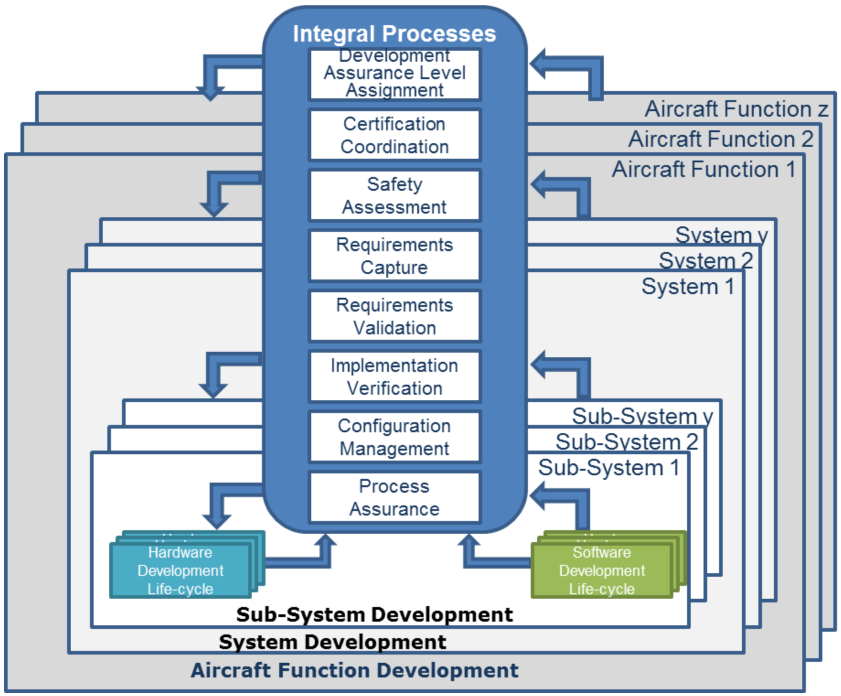
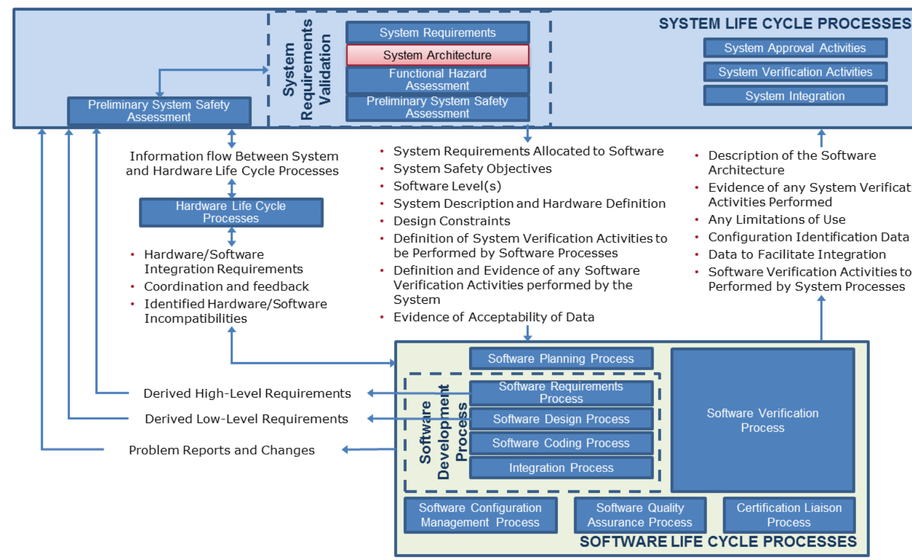
Product lines fit into the regulated process. The business process demands increased emphasis on the architecture since it is the architecture that has to support the expected product line scope and deployment contexts. **This means the architecture is vetted across more than one product or program.**



Systems and Software Lifecycle Information Exchange



It is the regulated process and the intended avoidance of technical debt that results in the creation of many assets to support process planning, adherence, and assurance through the creation of objective evidence.

Core Assets – *More than just code*

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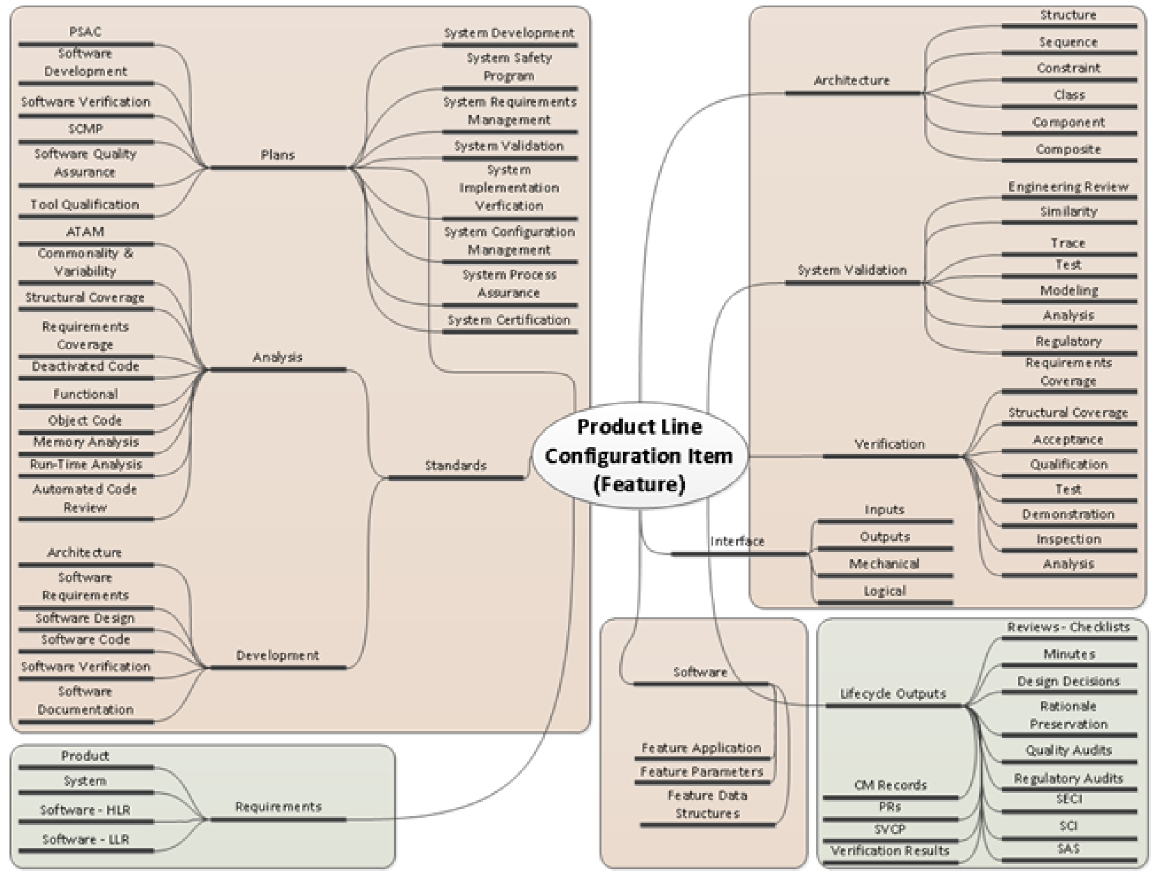
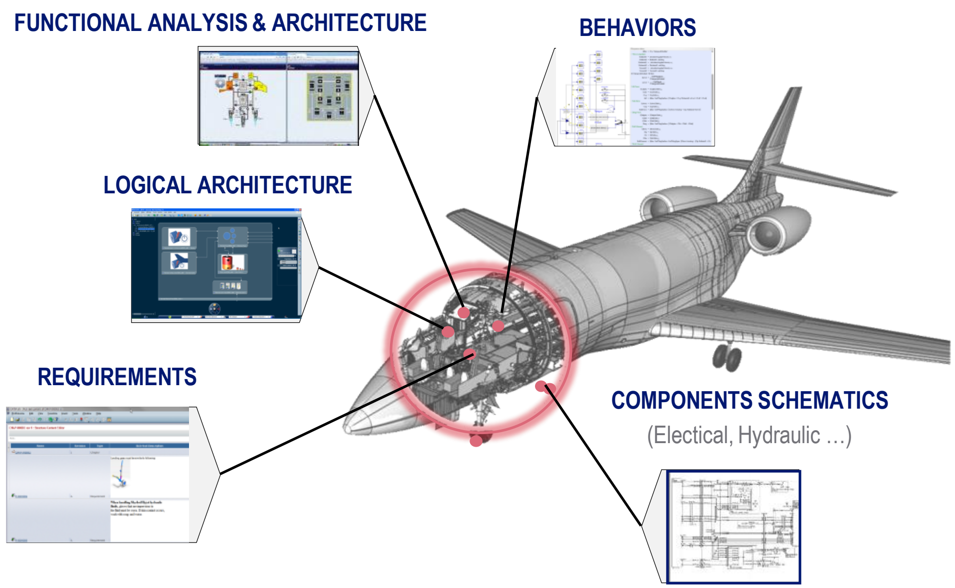
- **Requirements**
- **Architectures**
- **Components**
- **Modeling and Analysis**
- **Testing**
- **Planning**
- **Lifecycle Processes**
- **Program Tasks & CSA Roll-ups**
- **Earned Value**
- **People**



Introducing the System Digital Mock-Up (S-DMU)

- **Collaborative platform enabling systems architects and discipline experts to define and validate upfront the structuring systems matching requirements**
- **Maintain consistency between requirements (customers, business, regulation), Systems 3D layout definition and Digital Mock-Up for preliminary & detailed design**
- **S-DMU is a construct that is native to Dassault Systèmes' 3DEXPERINCE platform which is composed of enabled organizational and activity archetypes (called Industry Solution Experiences) focused on the "*Job to be done.*"**
- **Operationally, the S-DMU is initiated in *Winning Program* and consumed (& transformed, translated & matured) by *Co-Design To Target*, *Test to Perform*, *Licensed to Fly & Keep Them Flying*.**



The **System-DMU** is the 3DEXPERIENCE **referential** for **MBSE**

Model-Based Requirements Validation & Verification ARP4754A – MATTERS/AIDT

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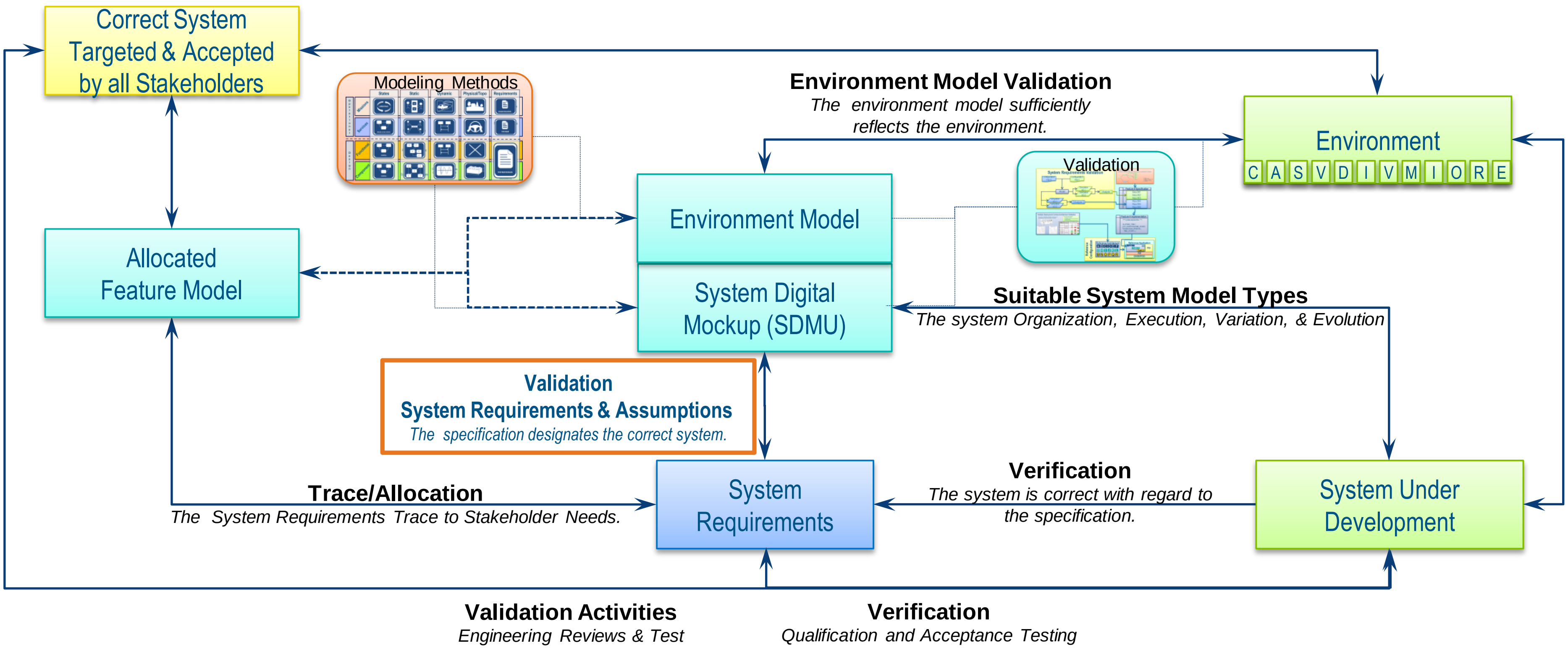

Pratt & Whitney Canada: Industry Case

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Innovation
- Conceive of a new thing
- Conceive of a new way of doing something
- Conceive of a way of doing something new, using a new thing

Lead, Follow, or Get Out of the Way

Regulatory Trends, MBSE, Formal Methods
--FORESIGHT--
Product Line Architecture Enablement
Technology Trends
--COMPETITIVE ANALYSIS--
Key Trends
--MARKET ANALYSIS--
Market Segments, e.g. OEM & MRO
More integrated Supply Base
Market, Customers, Regulatory Authorities
Industry Forces
Competitors
Substitute Products & Services
Standardization

With Existing Cost Structures Large Variant Numbers are Unaffordable

P&WC Proprietary Information

Why?

Requirements Modeling – Ongoing

- Systematically honing legacy requirements to create more refined requirements that explicitly incorporate variation.
- Outcomes include:
  - reducing the total number of Requirements that need to be managed across the deployed products
  - Improved feature model organization and allocation.
  - Enhanced validation applicability
  - Improved verifiability including automatically generating application-specific VTP

P&WC Proprietary Information | Export Classification: No Technical Data | 26

Product Lines Building Blocks

Product Lines have emerged as a leading approach to increased reuse. Architecture and Requirements are tw… building blocks to managing commonality and variability using a feature model.

Architecture capt… execution, variati…

Requirements need to be…
- reducing the total num… deployed products
- Improved feature mod…
- Enhanced validation a…
- Improved verifiability i…

These elements working to build

Requiremen…

Feature Oriented Domain Analysis

1. Car shall have automatic transmission
2. Car shall have manual transmission

SW-System Jointly-Deve…

Improved Opera… Capability, Cap… Efficiency, and Ni…

Product Lines | Automatio…
Architecture | Requireme…
Organization | Process

P&WC Proprietary Information

Strategy is on… Product line rec…

- To offer a catalog o…
- To improve the abili… create with the Cust…
- To improve the abili… product developmen…
- To improve the way **Opportunities** are … and managed
- To enable the successful management of a larger number of increasingly **complex** product development projects
- To leverage **common** methods and infrastructure and enable improved execution in meeting customer commitments

P&WC Proprietary Information | Export Classification: No Technical Data | 22

- Identify requirements for the products and features
- Capture requirements in the context of the architecture and trade studies
- Requirements are decomposed from product specs into system specs and into sub-system specs

Export Classification: No Technical Data | 25

What?

How?

"Reuse is a double-edged sword, if its not right early, you are reusing the mistakes of the past."

© Dassault Systemes & Modelon

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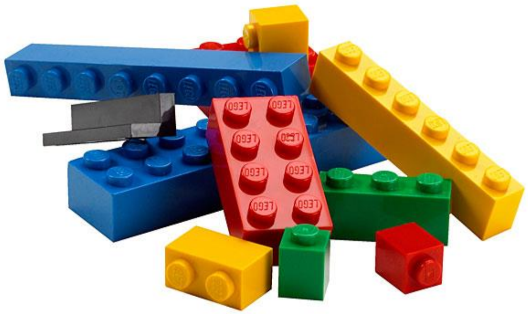
Modelica

- **The LEGO analogy is frequently used when discussing reuse and Product Lines.**
- **Modelica: a programming language for modeling cyber-physical systems.**
  Modelica is vendor-neutral standard
  - Multi-domain
  - Object-oriented
  - Non-causal and equation-based
  - Consistent graphical and textual system representation
  - Supported by many tools

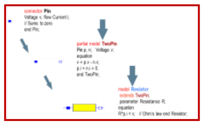


Modelica is like LEGO for Physical Systems Modeling

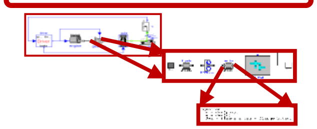
Multiple Deployment Context Model-Based PLE Enablement

Architecture Contexts

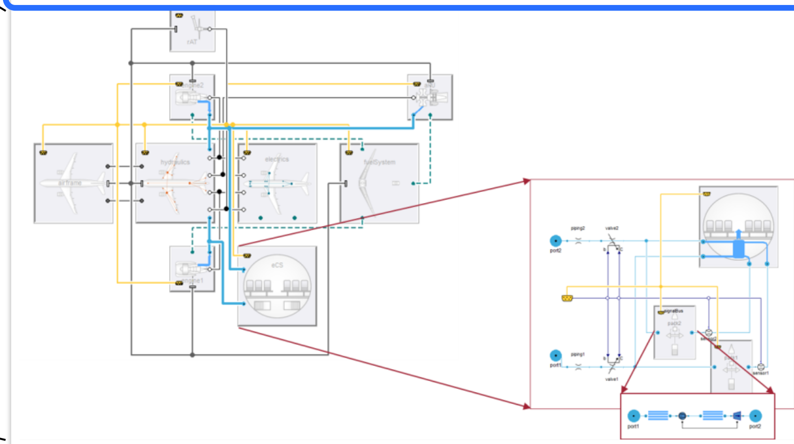
- Inheritance



- Abstract Types
- Definition: Use: Occurence



Modelica Product Line Suitability



Mechanical Problem Contexts

- **forward problem:** compute positions from applied drive torques
- **inverse problem:** Solve needed drive inputs to follow desired trajectory
- **estimation problem:** compute friction parameters in joint from model + measured data.

Electrical Problem Contexts

- **acausal**: Same model for voltage- or current sources
- **Inverse problem:** to Design circuit to spec
- **estimation problem:** actual circuit parameters from data & model

Thermo-Fluid Problem Contexts

- **acausal**: Same model pressure losses for given flow, or solve pump sizing problem
- **Inverse Problem:** Solve sizing & interaction problem
- **estimation problem:** actual thermo-fluid parameters from data & model

Organization Use Contexts

- **xIL:** Model, Software, Hardware in the loop leverage models across value-chain
- **tightly coupled model connectivity:** FMI/FMU Exchange & Co-Simulation Interoperability
- **model creation & management:** Domain Development, and application development Allocated Models

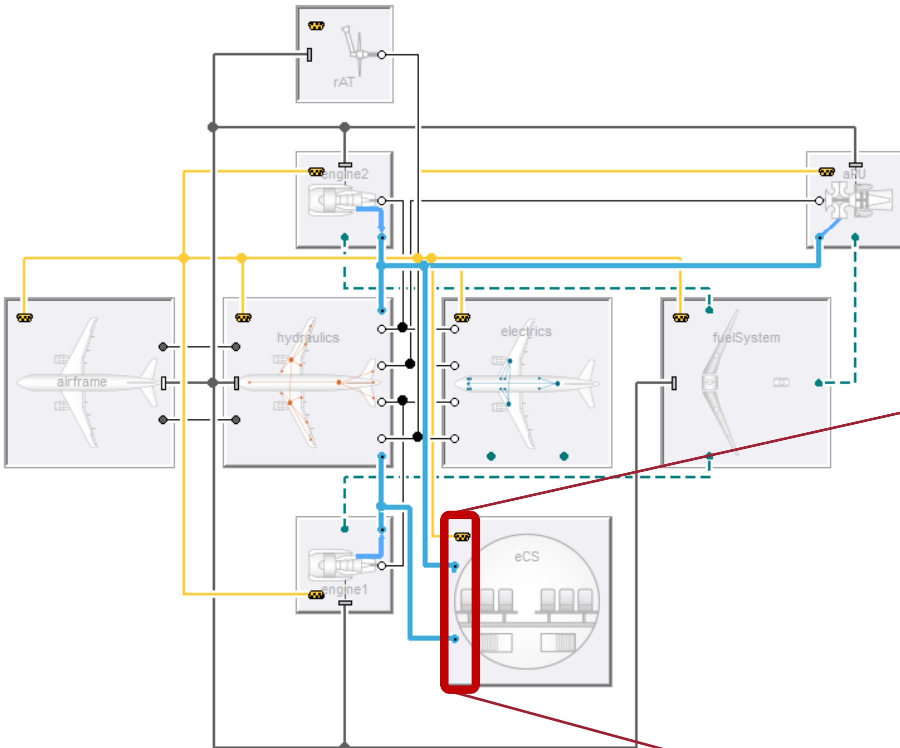
Modelica Language Object Oriented Illustration

connector **Pin**
Voltage v; flow Current i;
// Sums to zero
end Pin;

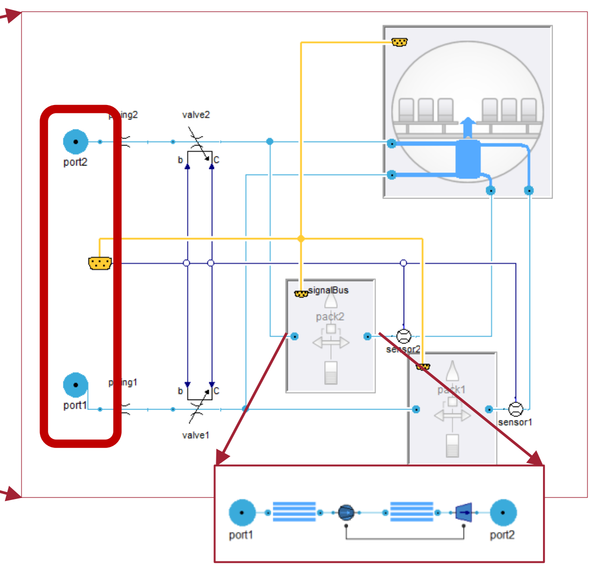
partial model **TwoPin**
Pin p, n;   Voltage v;
equation
v = p.v - n.v;
p.i + n.i = 0;
end TwoPin;

model **Resistor**
extends TwoPin;
parameter Resistance R;
equation
R*p.i = v;   // Ohm's law end Resistor;

MODELICA SYSTEM REFERENCE ARCHITECTURES



Organization of model into interfaces and templates promotes broader applicability and reusability reducing modeling effort in a product line context for re-validation.



Modelica language support for abstract typing; strong typing (informal, guarantees for plug-compatibility of models) enables rigorous checks for subsystem compatibility and interface consistency

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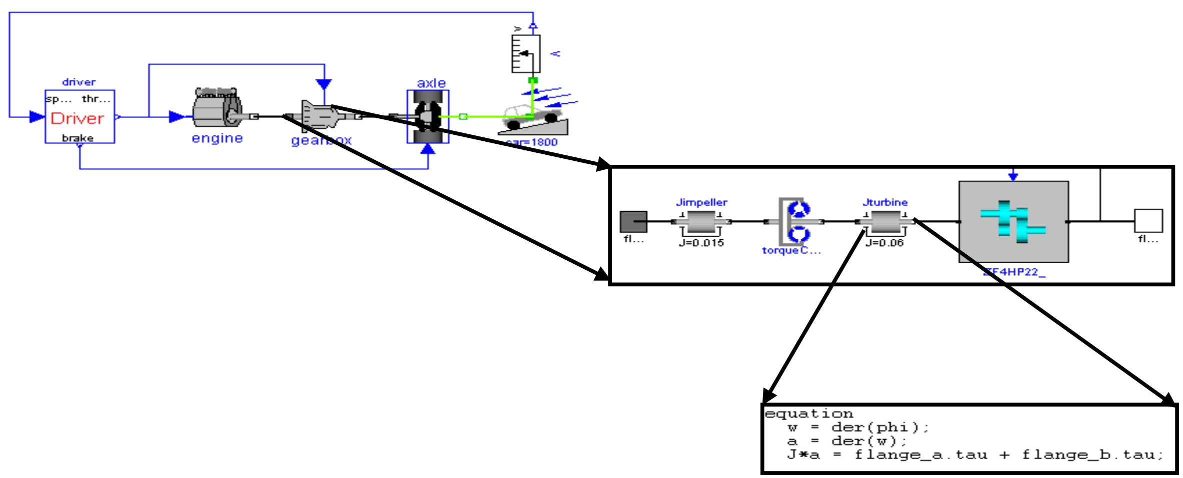
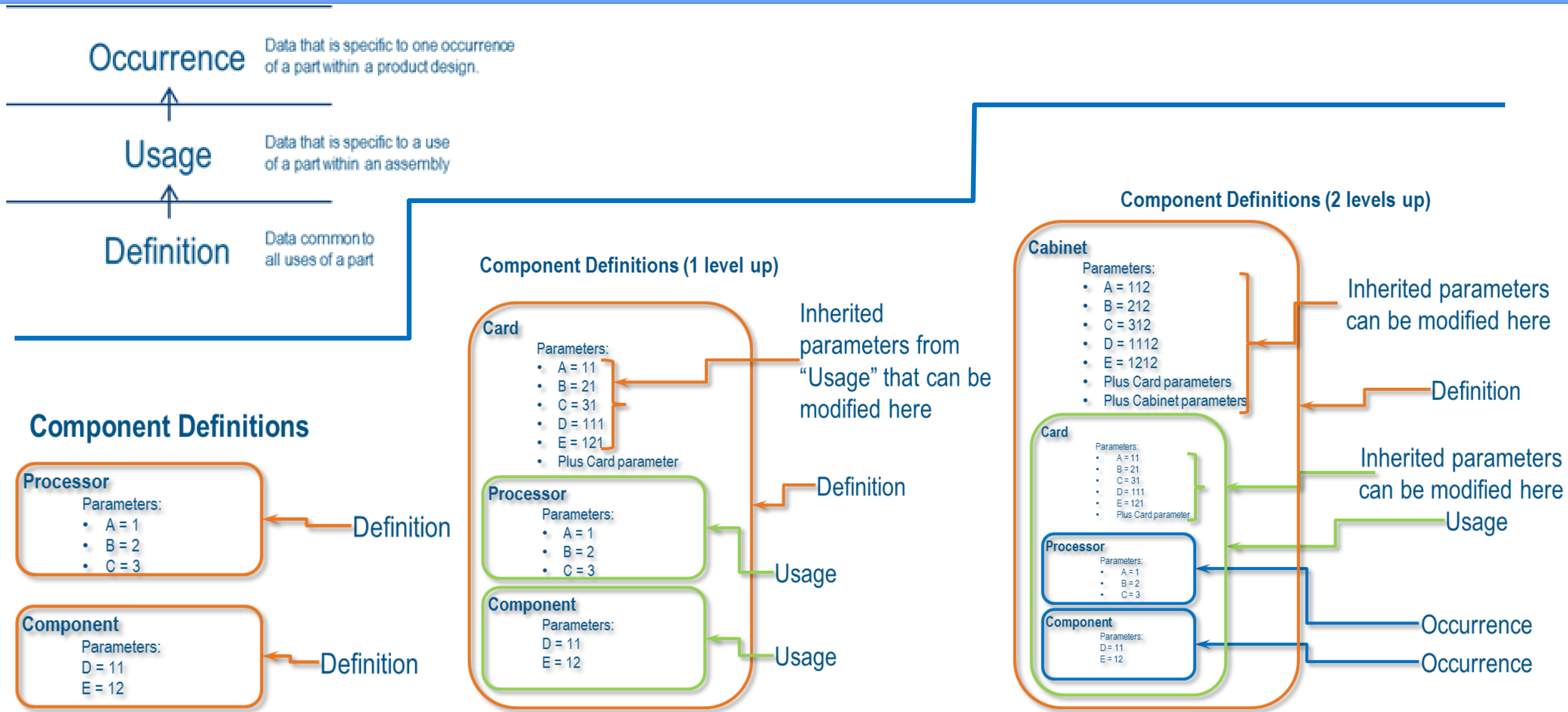
OCCURRENCE MODEL IN MODELICA

- **Occurrence is similar to Modelica components. When you use it, it inherits the default values and definition but you can modify the exposed parameter. The definition does not change.**
- **At a higher level these new values become defaults but you can still modify them.**



BUILDING THE OCCURRENCE MODEL



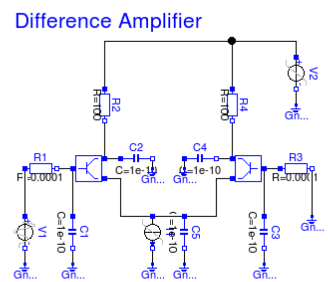
Callahan, Sean, "*Extended Generic Product Structure: An Information Model for Representing Product Families*", Journal of Computing and Information Science in Engineering, Vol 6, September 2006; ASME.

Modelica Deployment for Multiple Contexts

- Equation based: improved reuse of models for different purposes through all design phases

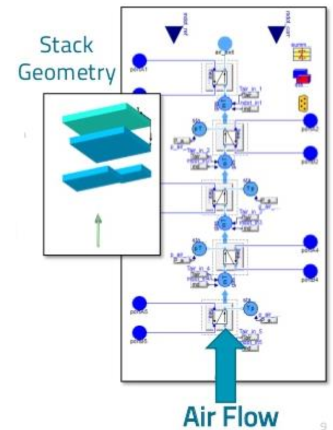
Robotics/Mechanics re-use examples (same model):

- **Solve the forward problem:** compute positions from applied drive torques
- **Solve the inverse problem**: Solve needed drive inputs to follow desired trajectory
- **Solve an estimation problem:** compute friction parameters in joint from model + measured data.



Electric/Electronic re-use examples (same model):

- Same model for voltage- or current sources
- Simulate model performance
- Design circuit to spec by embedding in optimization
- Estimate actual circuit parameters from data & model

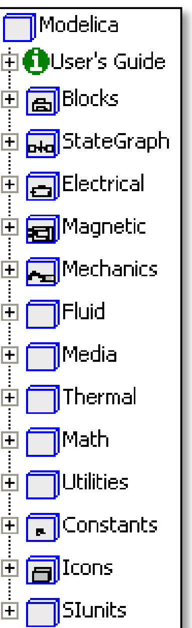


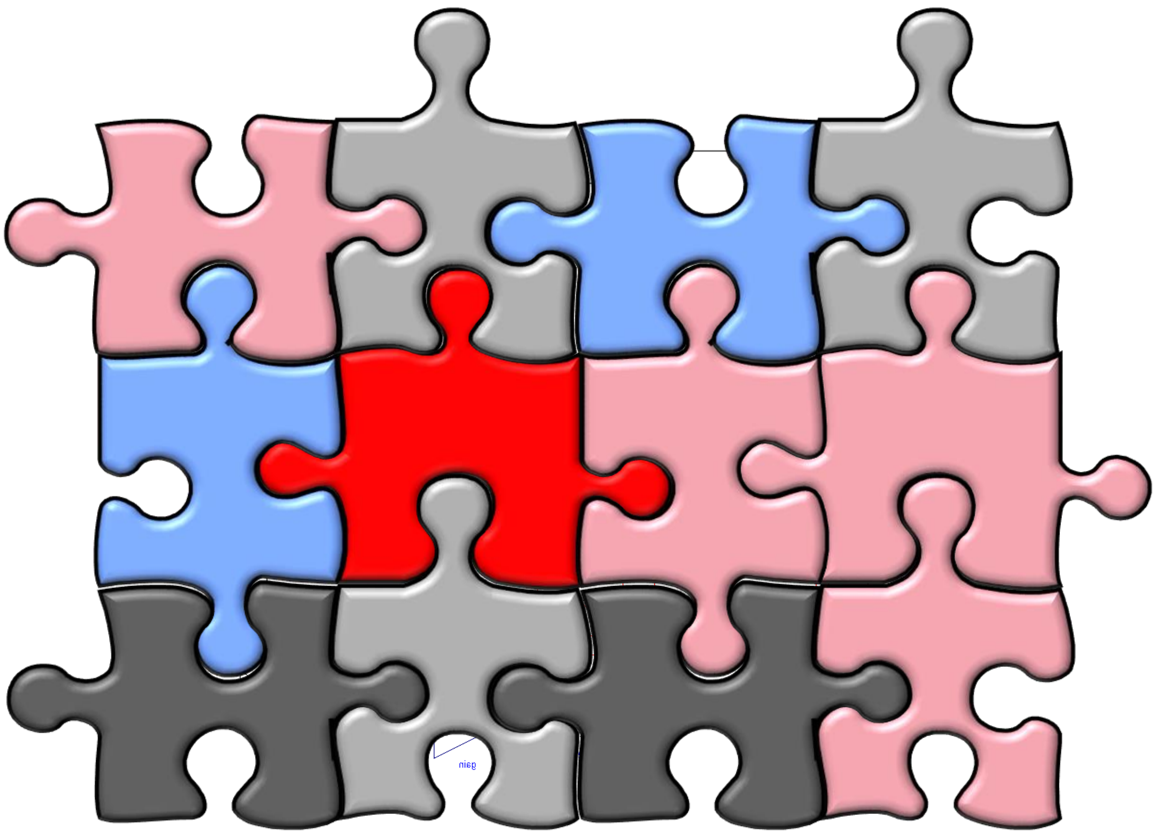
Thermal management re-use examples (same model):

- Same model to compute pressure losses for given flow, or solve pump sizing problem
- Simulate model performance
- Solve sizing & interaction problem by embedding in optimization
- Estimate actual system parameters from data & model

ECOSYSTEM LEVERAGE WITH MODELICA/DYMOLA

- **Reusable models in standard Modelica language**
  - **Off-the-shelf model libraries and components, focus on core knowledge, innovative systems from standard component models**





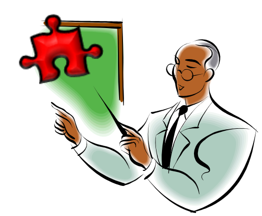
Free open source

Commercial off-the-shelf

Consulting services

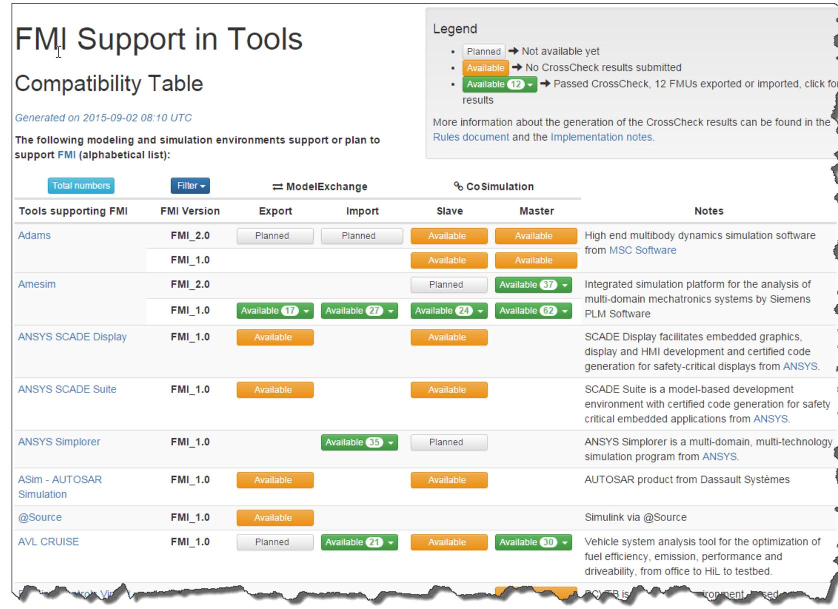
Partners/suppliers/ customers/academia

In-house



The Functional Mockup Interface: FMI

- FMI is a standard interface to enable the exchange of compiled models beween tools, and for co-simulation
  - Has been adopted by ~ 70 CAE tools as a supported interface
  - Is propagated by several industrial consortia
- The FMI licensing model revolutionizes the business model for enterprise model deployment
  - Model content and execution can be shared freely within the extended enterprise
  - Model authoring is done on CAE tools suitable to the domain
- FMI is applicable to a much broader set of tools than Modelica: FEM, CFD, Controls & Software development, …



FMI Support in Tools

Compatibility Table

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The following modeling and simulation environments support or plan to support FMI (alphabetical list):

Legend
- Planned → Not available yet
- Available → No CrossCheck results submitted
- Available 12 → Passed CrossCheck, 12 FMUs exported or imported, click for results

More information about the generation of the CrossCheck results can be found in the Rules document and the Implementation notes.

Total numbers | Filter

Tools supporting FMI	FMI Version	ModelExchange Export	ModelExchange Import	CoSimulation Slave	CoSimulation Master	Notes
Adams	FMI_2.0	Planned	Planned	Available	Available	High end multibody dynamics simulation software from MSC Software
	FMI_1.0			Available	Available	
Amesim	FMI_2.0			Planned	Available 37	Integrated simulation platform for the analysis of multi-domain mechatronics systems by Siemens PLM Software
	FMI_1.0	Available 17	Available 27	Available 24	Available 62	
ANSYS SCADE Display	FMI_1.0	Available		Available		SCADE Display facilitates embedded graphics, display and HMI development and certified code generation for safety-critical displays from ANSYS.
ANSYS SCADE Suite	FMI_1.0	Available		Available		SCADE Suite is a model-based development environment with certified code generation for safety critical embedded applications from ANSYS.
ANSYS Simplorer	FMI_1.0		Available 35	Planned		ANSYS Simplorer is a multi-domain, multi-technology simulation program from ANSYS.
ASim - AUTOSAR Simulation	FMI_1.0	Available		Available		AUTOSAR product from Dassault Systèmes
@Source	FMI_1.0	Available				Simulink via @Source
AVL CRUISE	FMI_1.0	Planned	Available 21	Available	Available 30	Vehicle system analysis tool for the optimization of fuel efficiency, emission, performance and driveability, from office to HiL to testbed.

https://www.fmi-standard.org/tools

Total number of *tools* and broken down by the FMI variants and directions.	FMI_1.0 67 (24)	22 (11)	30 (15)	32 (11)	40 (18)
	FMI_2.0 23 (11)	5 (5)	6 (3)	11 (8)	17 (7)

We add green and orange available to compute these numbers (number proven with CrossCheck in parentheses).

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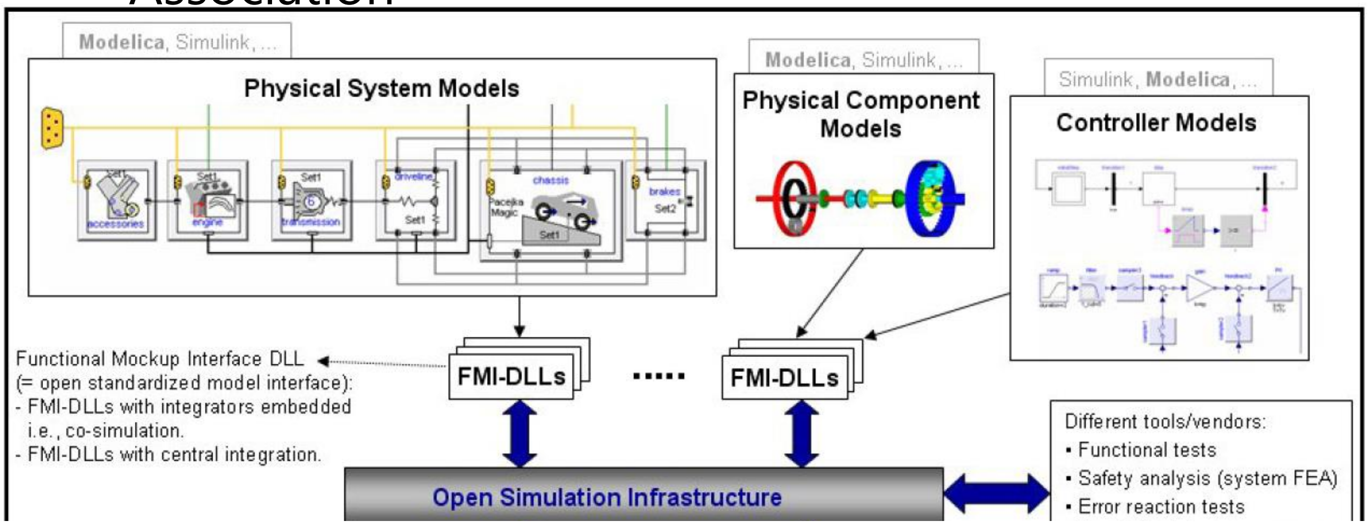
FMI Use cases: Model Exchange

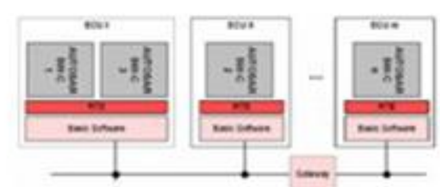
Overall goal of the FMI project in the Modelica Association



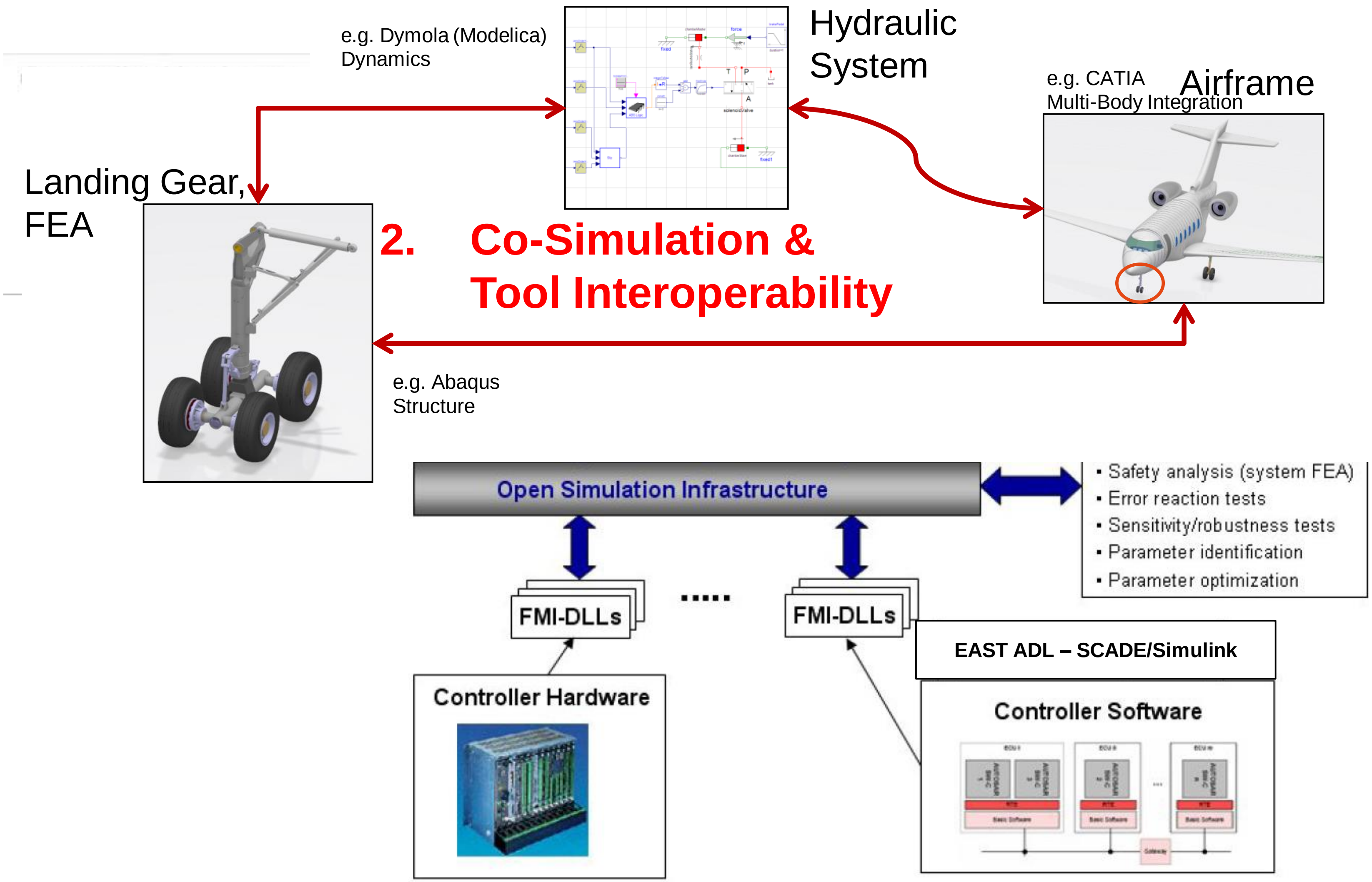
Controller Hardware

1. **Model-in-the-loop**
   Software-in-the-loop
   Hardware-in-the-Loop

Controller Software

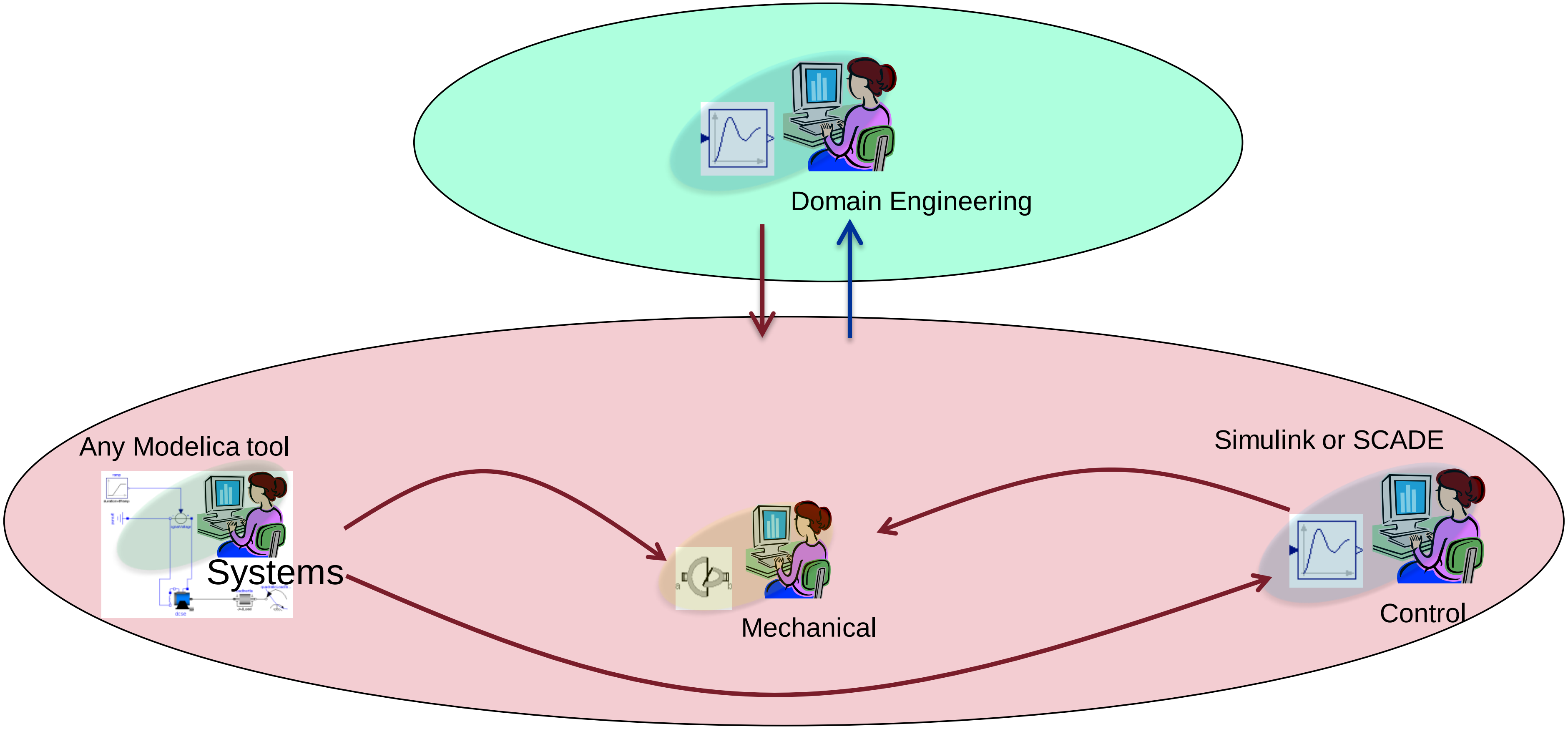


FMI Use Cases: Tool Interoperability



FMI Use Case: Enterprise Model Deployment

3. Standardized deployment of models inside and in-between organizations



FMI: A BUSINESS MODEL INNOVATION

1. Separate the model authoring tool from the model execution tool.
2. Free the model unit (FMU) from license restrictions
3. Make the standard widely accepted: https://fmi-standard.org/tools

FMI enables system-level validation through the connection of executable, connected models of subsystems and control software

Modelica & FMI Summary

- Modelica matches the requirements for efficient modeling of product lines
- Modelica & FMI are already widely used in a number of competitive industries: there are no competing standards
- FMI has a high potential being widely accepted in the CAE world:
  - A cost-effective way to deploy models
  - A standard way of model exchange and co-simulation
  - Defined in close collaboration of different tool vendors.
  - FMI can already be used with many CAE tools: several Modelica tools, Simulink, multi-body and more.
- A business model revolution, enabling the sharing and deployment and Management of analytic models across the enterprise.

With material from the official FMI

Conclusions

- **Product line approaches have demonstrated delivery of key enterprise business values; such as improved nimbleness, efficiency, and reduced development cost of variants.**
- **Capability maturity models help to provide long-term guidance for building key competencies.**
- **Full value delivery can only be achieved by looking at more than just the delivered article as an asset.**
- **Improved management of all assets are important for successful product line.**
- **Deliberate reuse depends critically on the revalidation of the intended features in the new context.**
- **Descriptive & Simulation Models are increasingly relied upon for such early validation.**
- **Modelica's architecture is well suited to supporting the product line approach.**

- **Thank you for your attention.**
- **Please feel free to offer suggestion and thoughts**
- **If there are any questions we would be pleased to attempt to answer them.**
- **We can also forward to Hubertus if it is down his alley of expertise.**