A View on Tool Interoperability Solutions at Ford Motor Company

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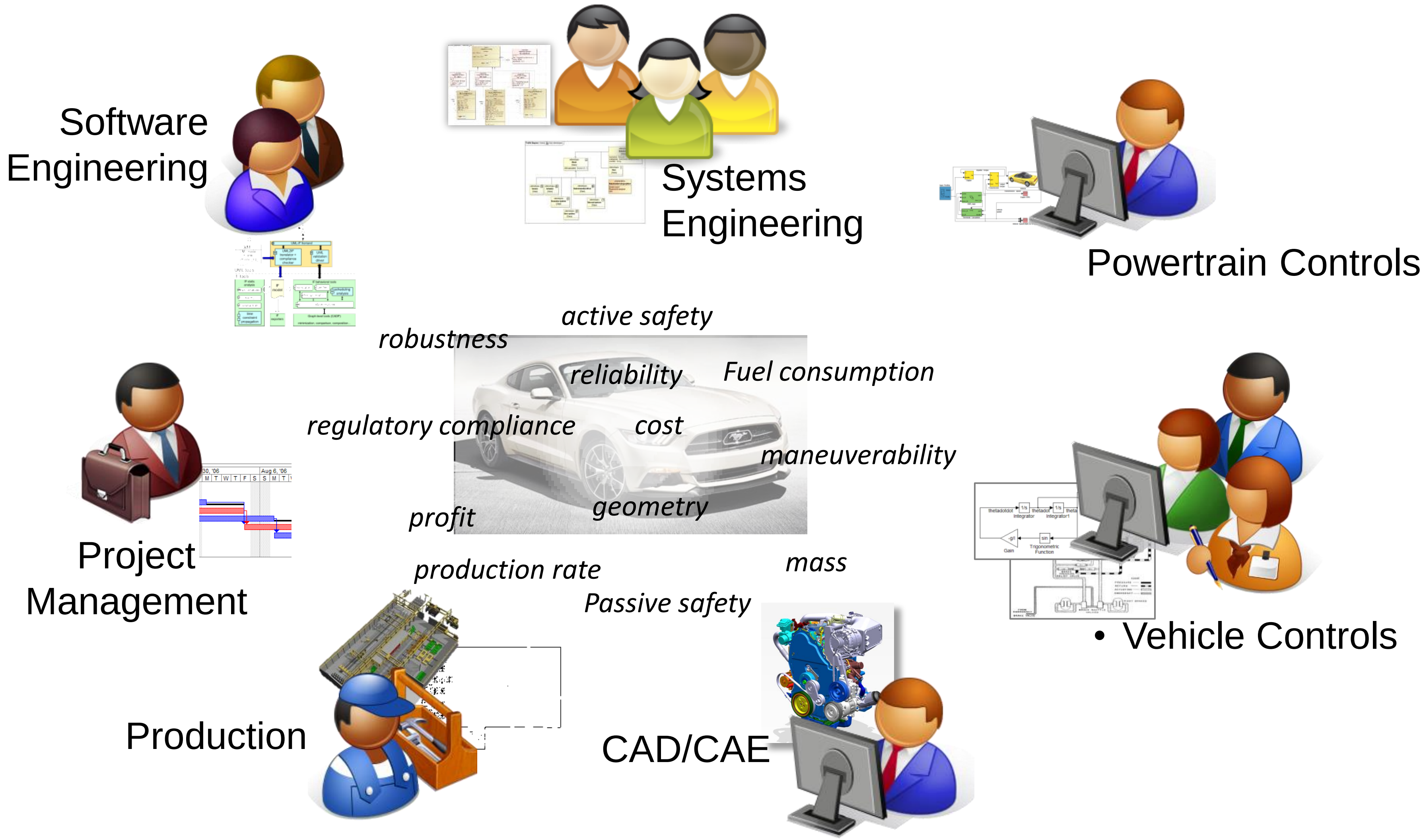
Distributed Development



Old Landscape

Stakeholder/Attribute Requirements

Functional Concepts

FMEA

Detailed Design & Analysis

Support & Maintenance

Production Plan

Quality

Supply Chain

Calibration

Old Landscape

Stakeholder/Attribute Requirements

Functional Concepts

FMEA

Detailed Design & Analysis

Some Partial Integration
Mostly Information Silos

Support & Maintenance

Production Plan

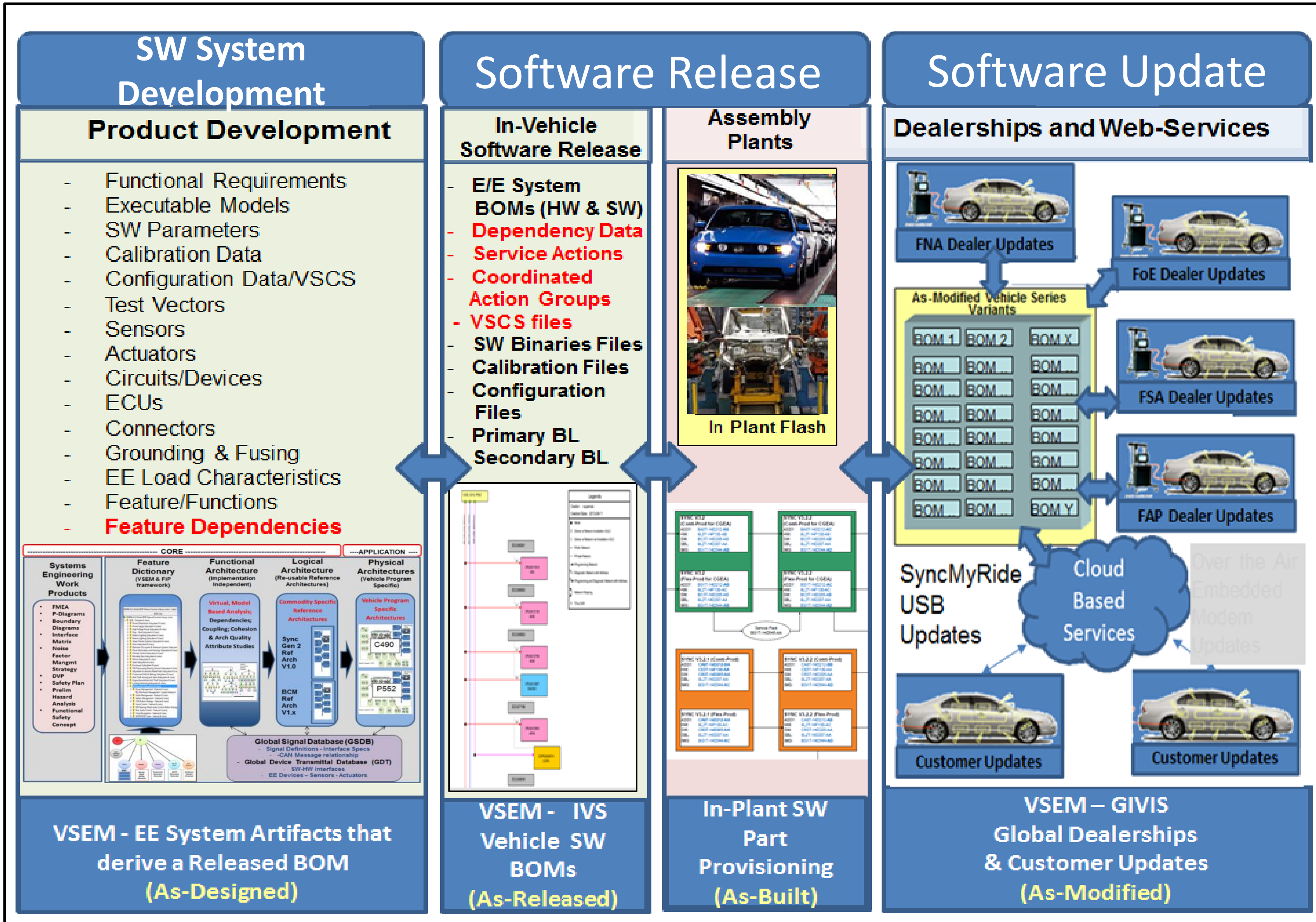
Quality

Supply Chain

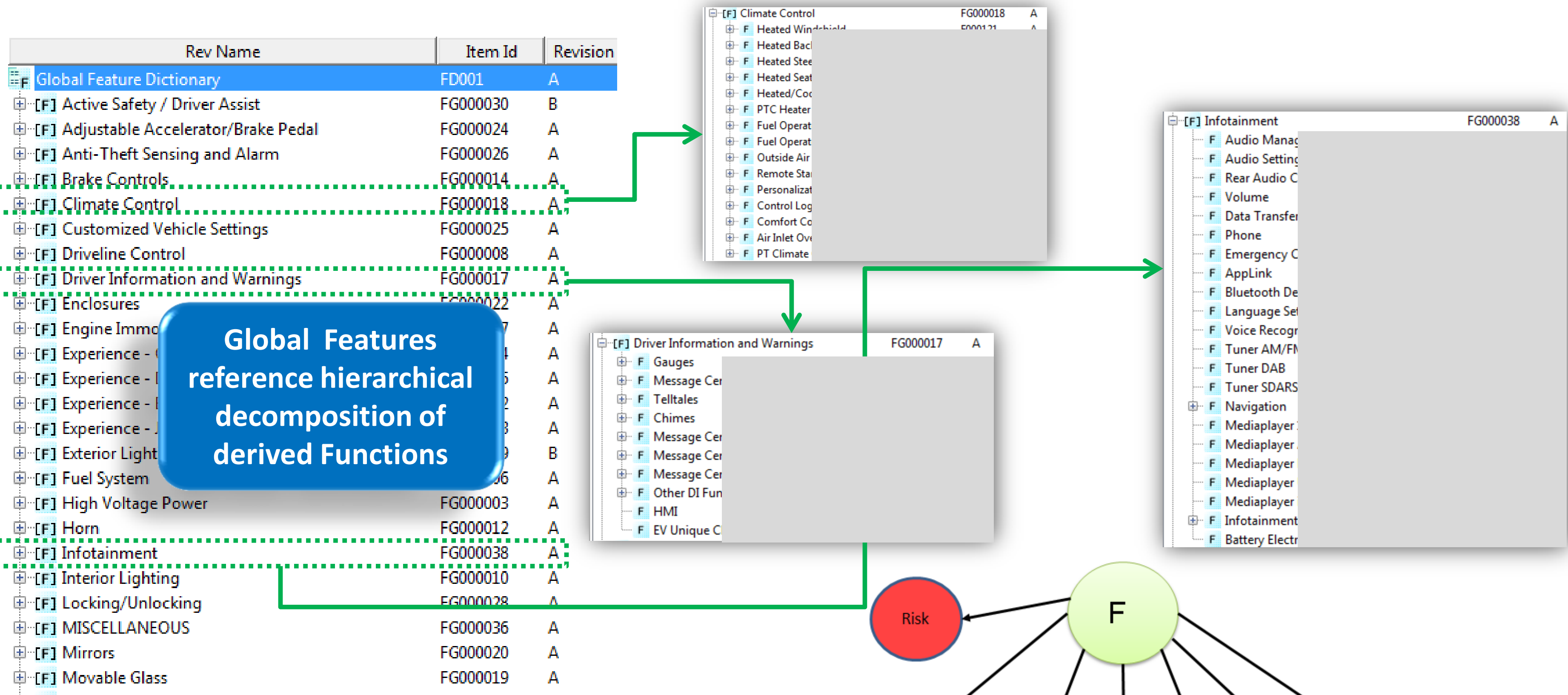
Calibration

Current Landscape

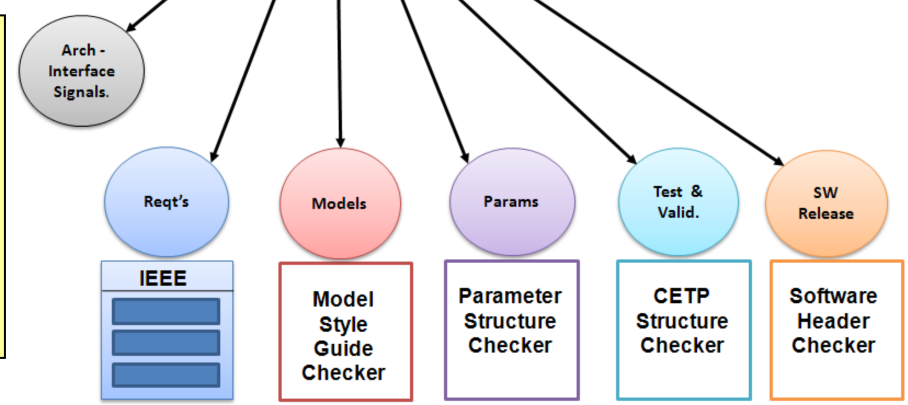
VSEM Supported Integration



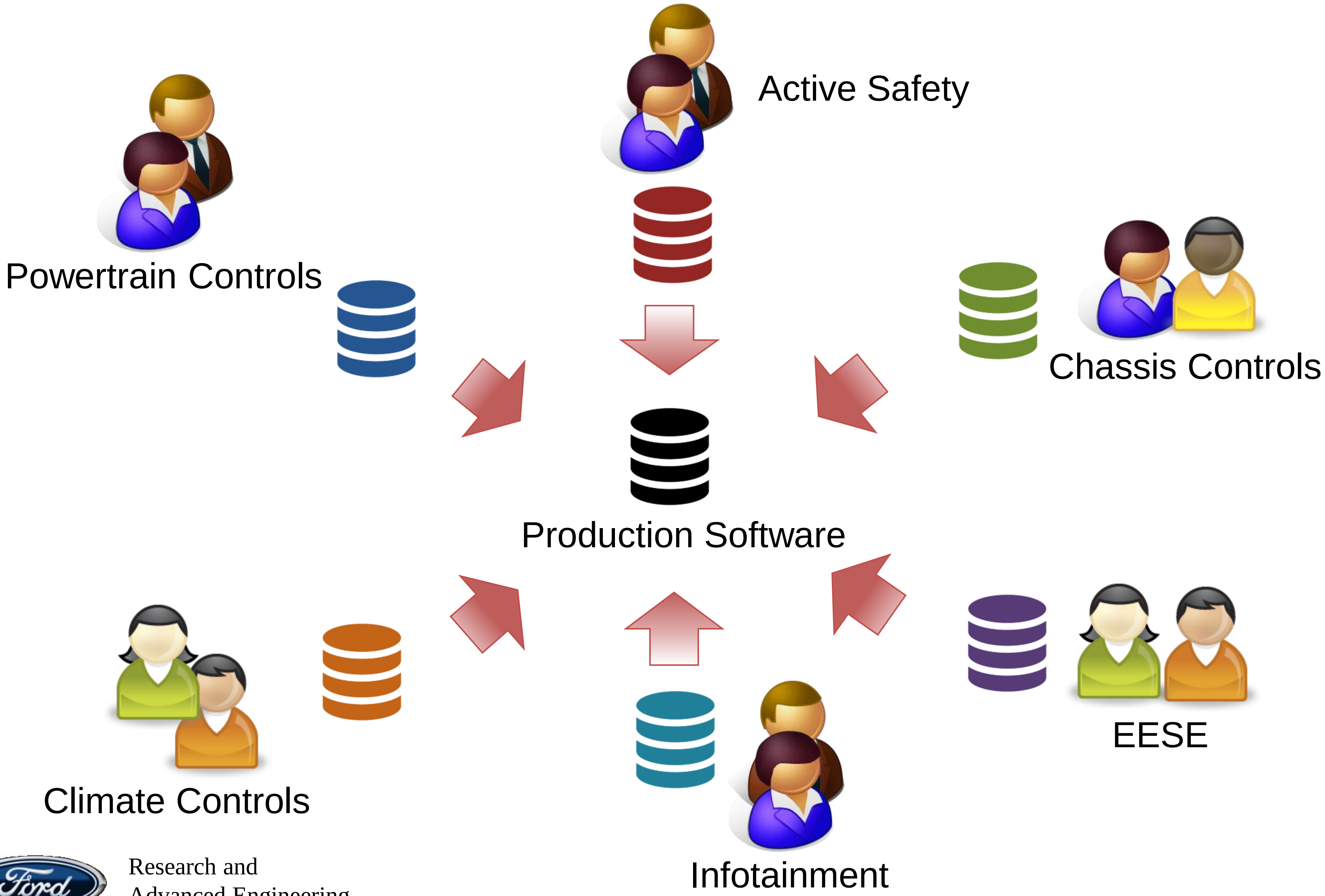
VSEM – Global Feature Dictionary



- **The VSEM Feature- Function Architectural Framework supports:**
  - **Software System Feature development lifecycles that are decoupled from traditional hardware component based engineering.**
  - **Engineering Work Products to be immediately accessible and re-usable based on Feature mapping.**

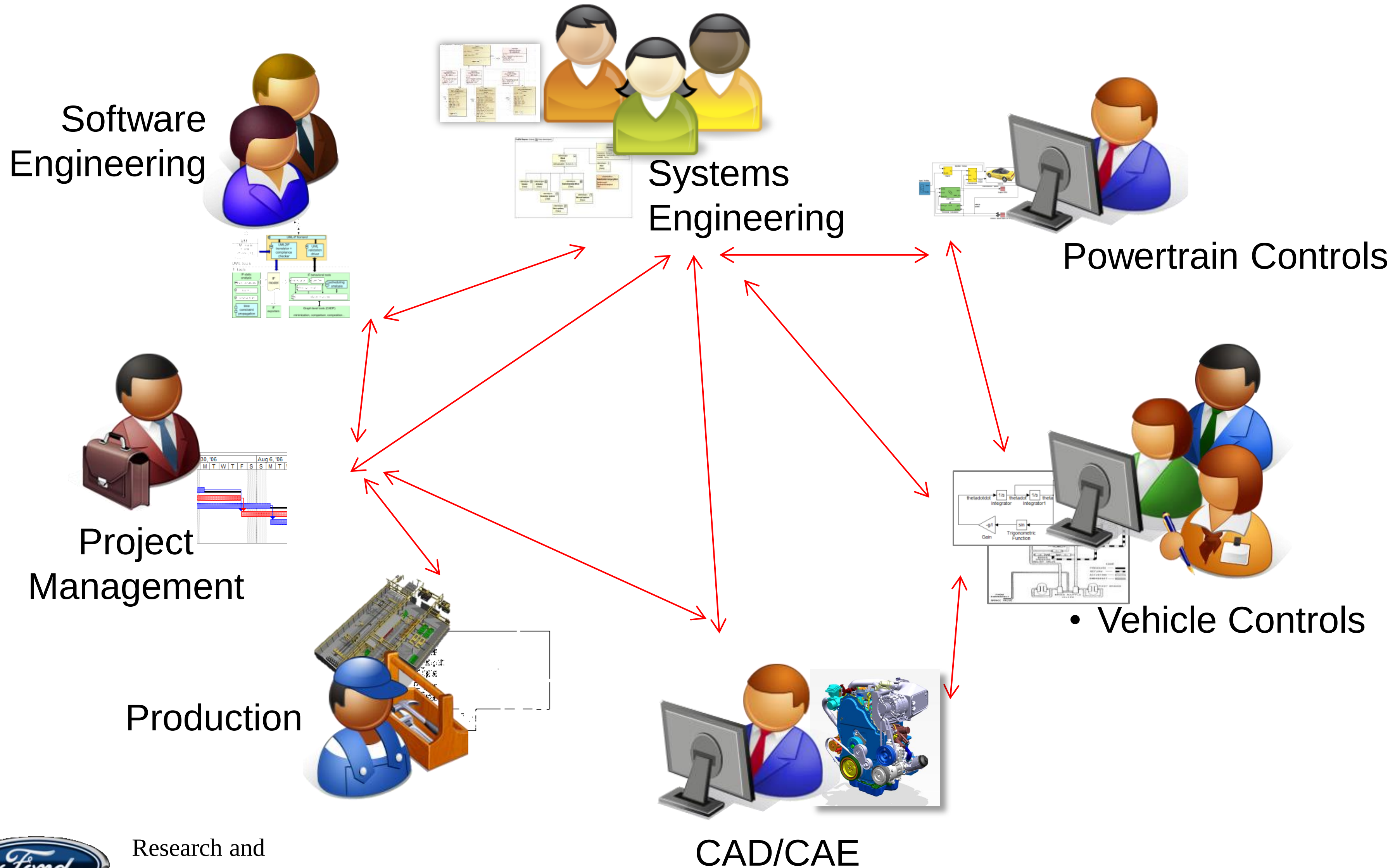


VSEM Supported Software Delivery



Interoperability Goals

Goal 1: Inform About Dependencies



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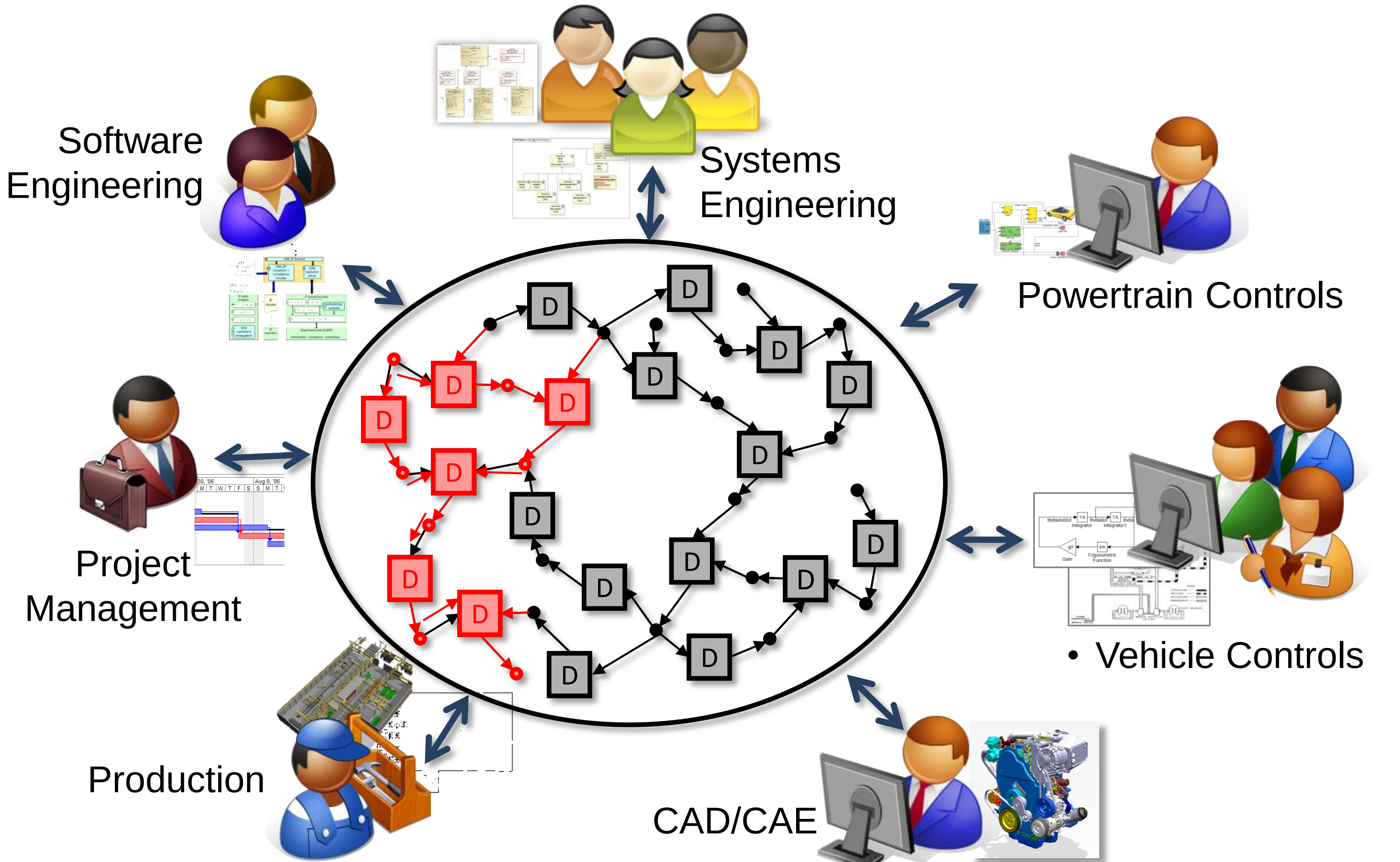
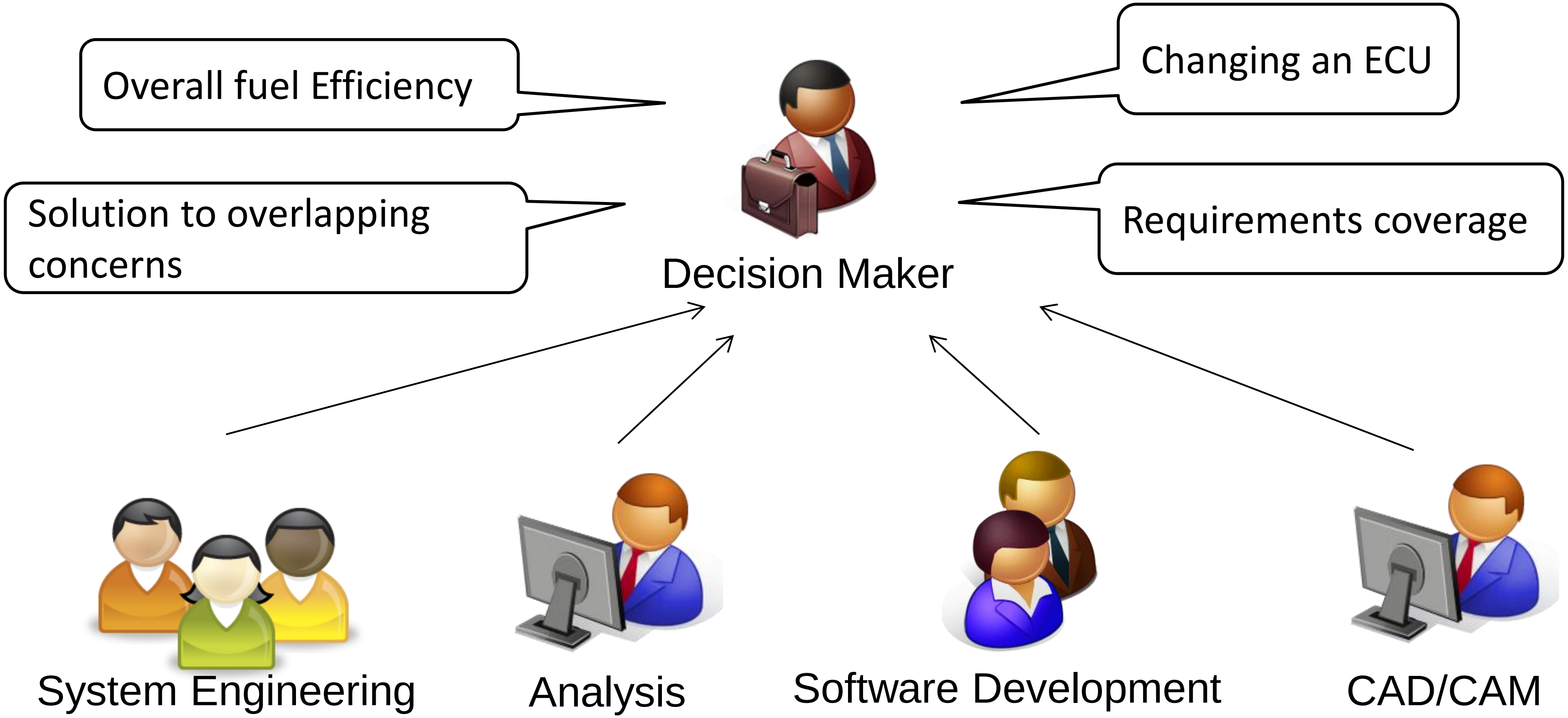
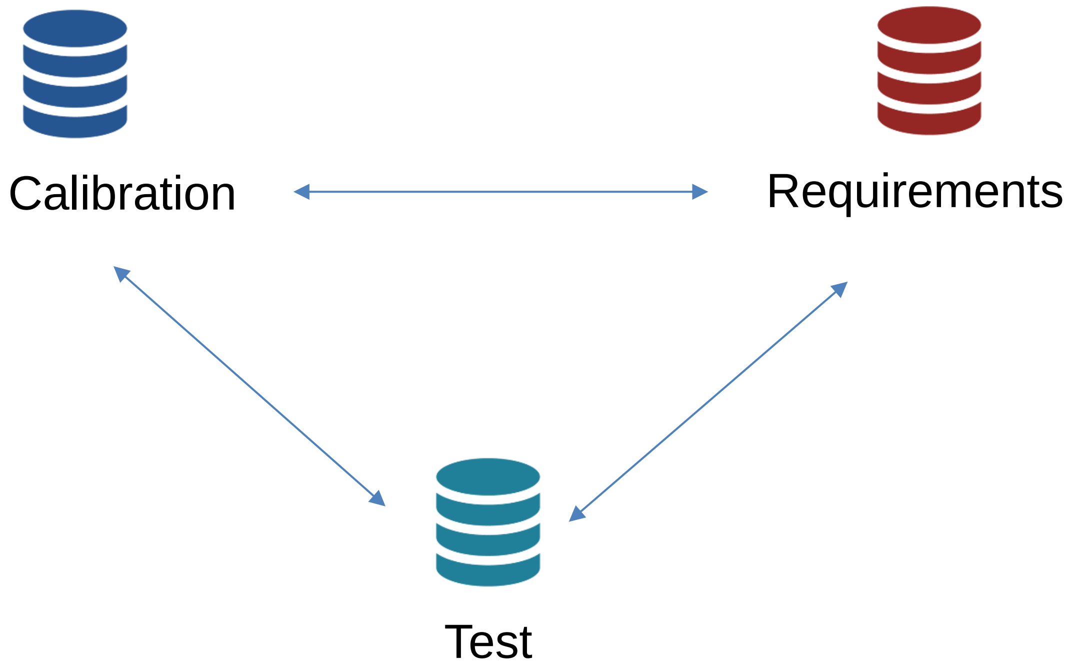
Goal 2: Manage Change Across Disparate & Heterogeneous Models



Goal3: Make Decisions Based on Information from Multiple Data Sources



Goal 4: Facilitate Data Exchange About Managed Artifacts Between Different Enterprise Systems



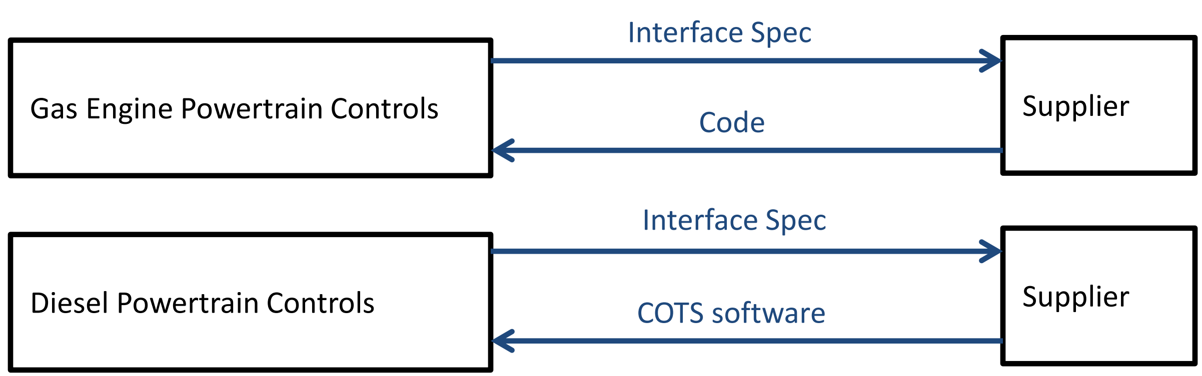
Current State of Data Exchange Standards

- Limited to exchange of geometric and configuration data
  - STEP AP203 (Mechanical), AP 209 (Structural), AP 210 (Electro-Mechanical), AP 239 (PLCS), JT – visualization
  - STEP AP 233 – systems engineering –> slow uptake
- Product data exchanged in native file formats, informal communication or document-based
- Standards mostly focus on how to move data from one place to the other
- Not (always) necessary to migrate data
  - OSLC – web of engineering data -> lightweight

Interoperability With Suppliers

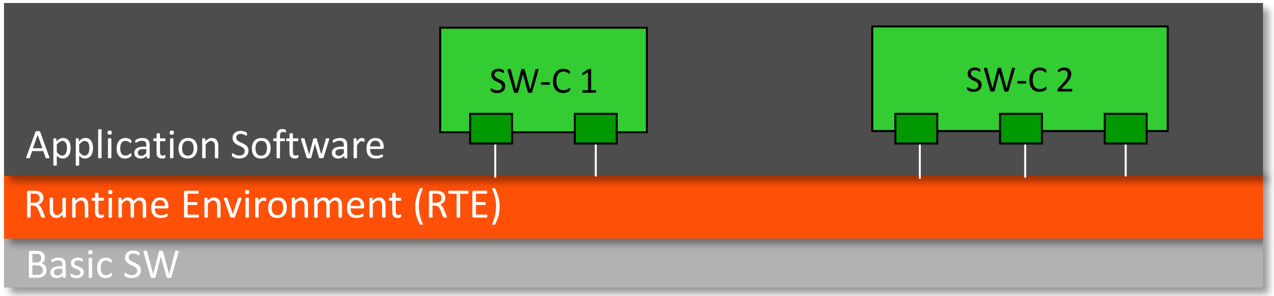
Powertrain Controls

- Most of the code done in-house
  - A mix of model-based code generation and hand code
- Gas powertrain
  - Driver software (which is hardware dependent) is supplier-developed
  - Interface specifications provided to the supplier (document-based)
- Diesel powertrain
  - Supplier-built software (COTS)
  - Mostly model-based, but also hand code
- Gasoline Models are not shared with suppliers, but Diesel's are
- Migrating towards AUTOSAR in the near future



Advantages with AUTOSAR

- Integration of new features on existing ECU's
- Tier-1 application software and OEM owned SW will co-exit on an ECU
- Transferring SW components between ECUs, supporting flexible architectures
- A HW independent RTE, based on SW components, with standardized data exchange

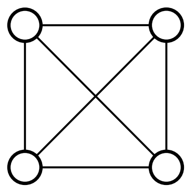


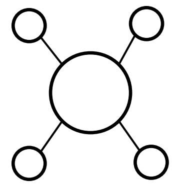
Electrical & Electronic Systems Engineering (EESE)

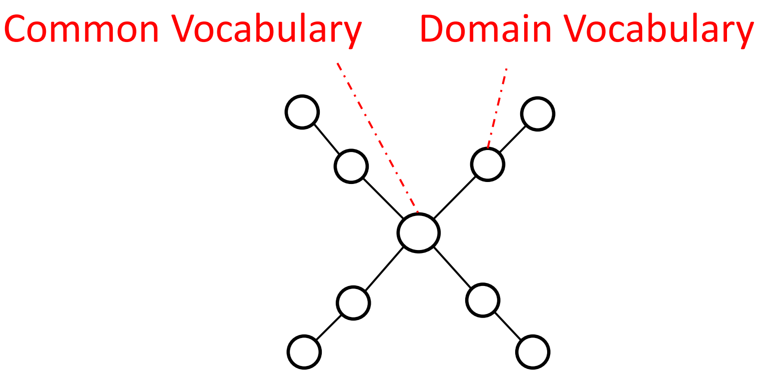
- Climate Control
  - Model-based design -> can leverage AUTOSAR components
- Infotainment
  - UML/SysML modeling is employed with Rational Rhapsody
  - UML model shared with the supplier -> code generated from UML to C
- Supplier is provided both models and documents providing interface specifications

Tool Integration / Interoperability Examples

Comparison of Integration Approaches



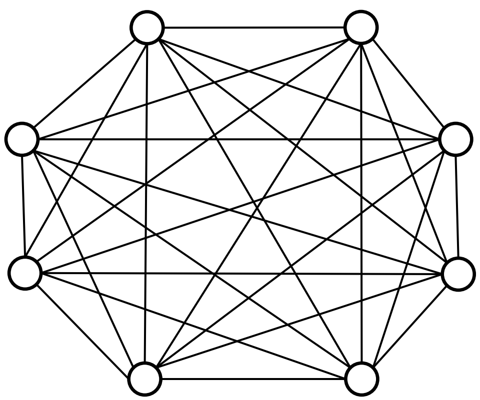


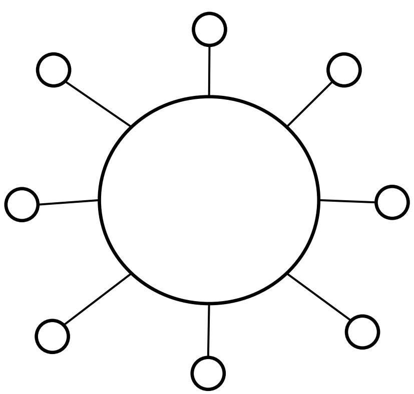


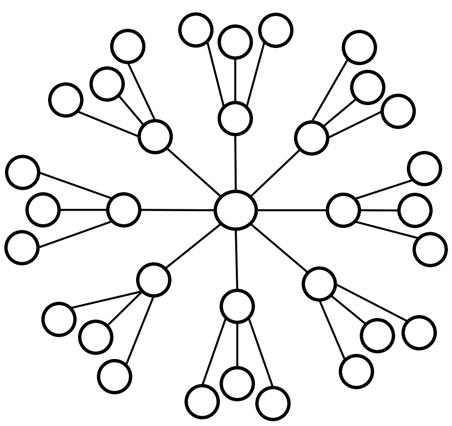
point-to-point

single shared meta-model

Hybrid





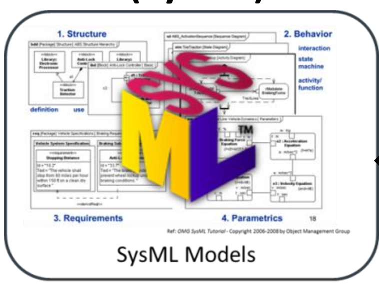


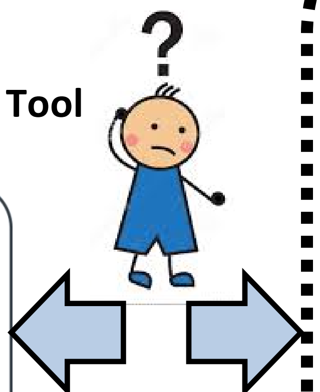
Example 1: Failure Mode Avoidance (FMA)

- FMA work is time consuming with specifications duplicated to FMA tools
- FMA tools disconnected from core design tools
- Mandatory FMA Rubric is needed
- Interoperability with FMA tools
  - Automatic import, export, and document generation

Solution

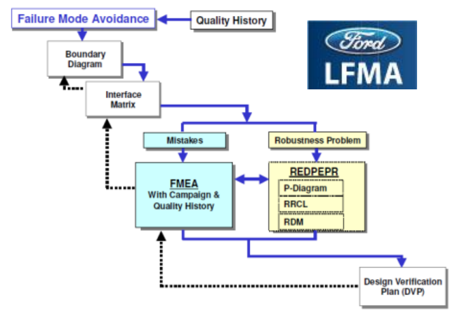
MBSE System Modeling Tool (SysML)



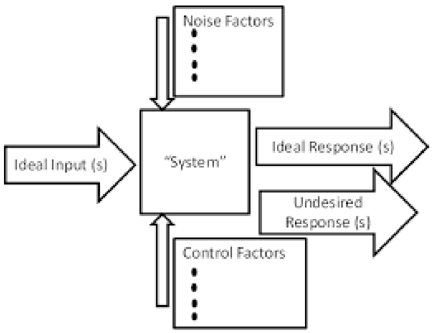


Failure Mode Avoidance Work

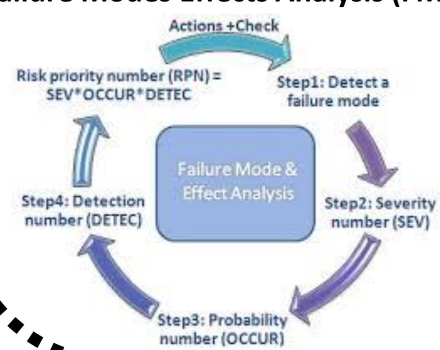
Lean Failure Mode Avoidance (LFMA)



Process Diagram (P-Diag)



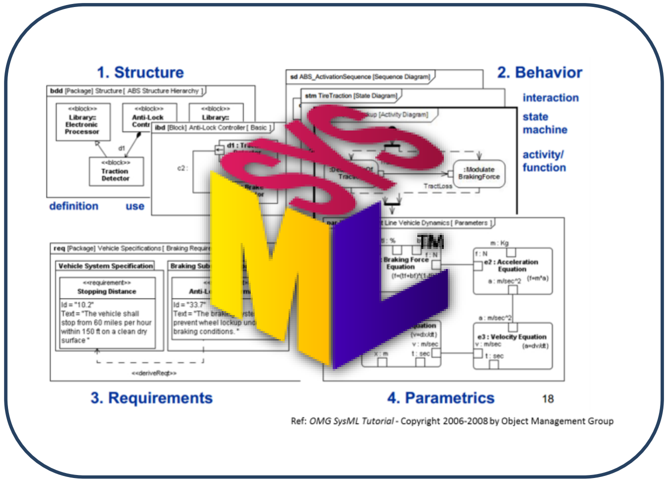
Failure Modes Effects Analysis (FMEA)



Reliability & Robustness Checklist (RCL)

Contributors: Walley, G., Meinhart, M., Corral, M., Nefcy, B., Davison, M., Stanek, J.

Interoperability Supported Through SysML

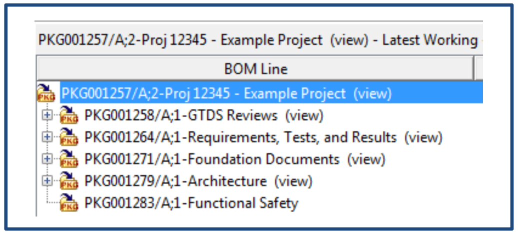


SysML Models

LFMA

- P-Diagrams
- FMEAs
- RCLs
- **Boundary Diagram**

LFMA

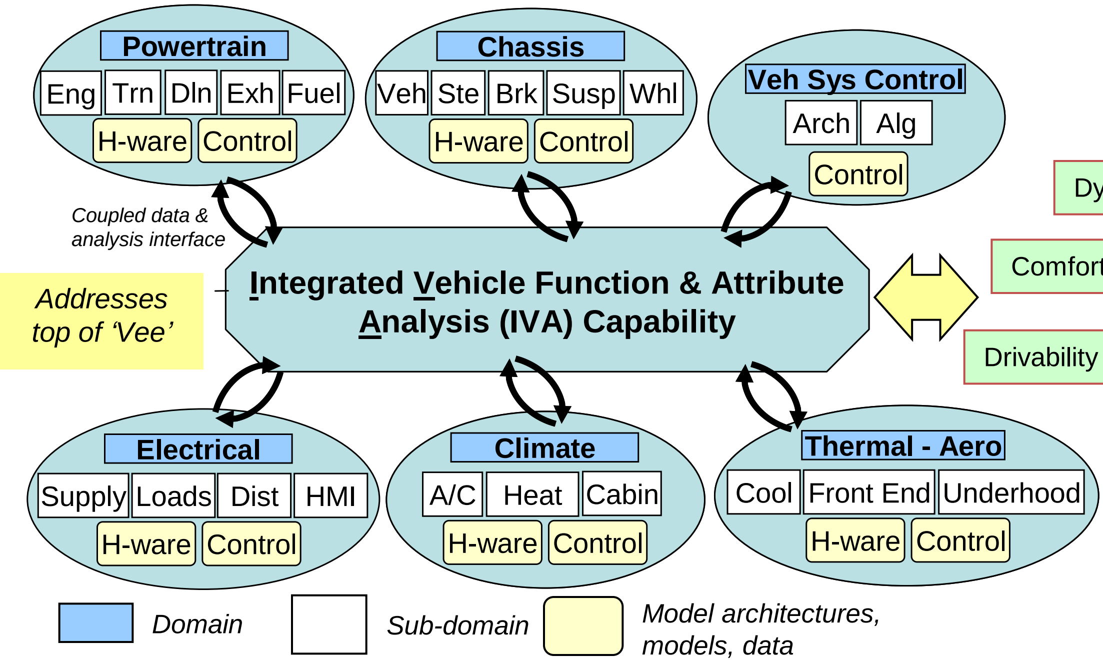


VSEM - Teamcenter

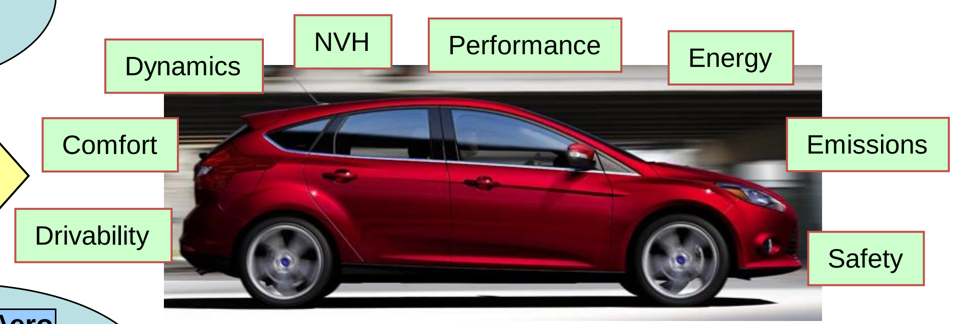
Example 2: Integrated Vehicle Analysis

- Vehicle Model composed of various HW and Controller domain models
  - Modelica for HW models
  - Simulink for controller models

Cross-Domain



Cross-Attribute / Cross-Function



Contributor: Bailey, W.

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Integrated Vehicle Analysis - Process

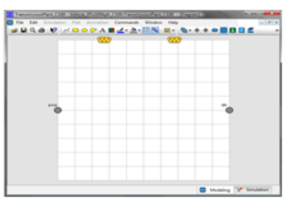
SysML Specialized Analysis Architecture (FE,Perf)

SysML VMA Reference Architecture

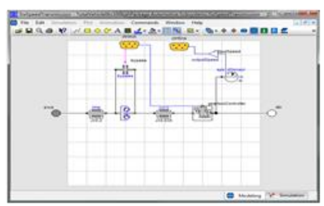
Domain model developers then add content to the model

Finally, models are integrated into a vehicle model and used to perform a system-level analysis

shared SysML model

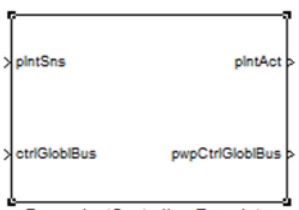


Domain Dymola Plant Template

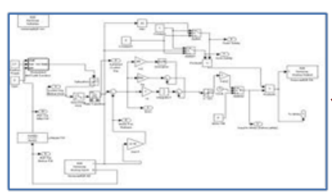


Physical Component Models

Vehicle System Model



Domain Simulink Control Template



Simulink Subsystem Control Models

Analysis Suite

Test(s) Execution

Analysis Control

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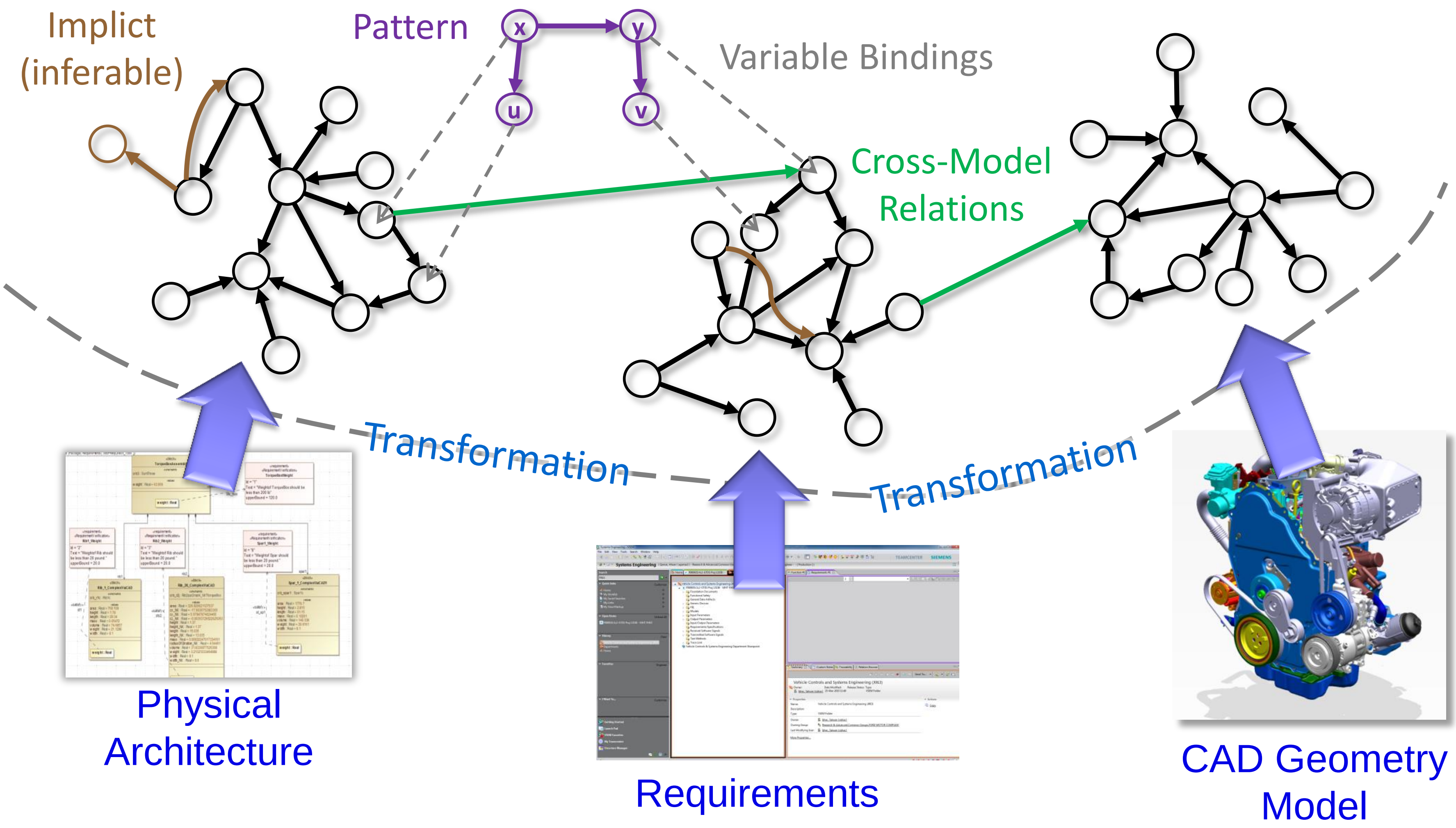
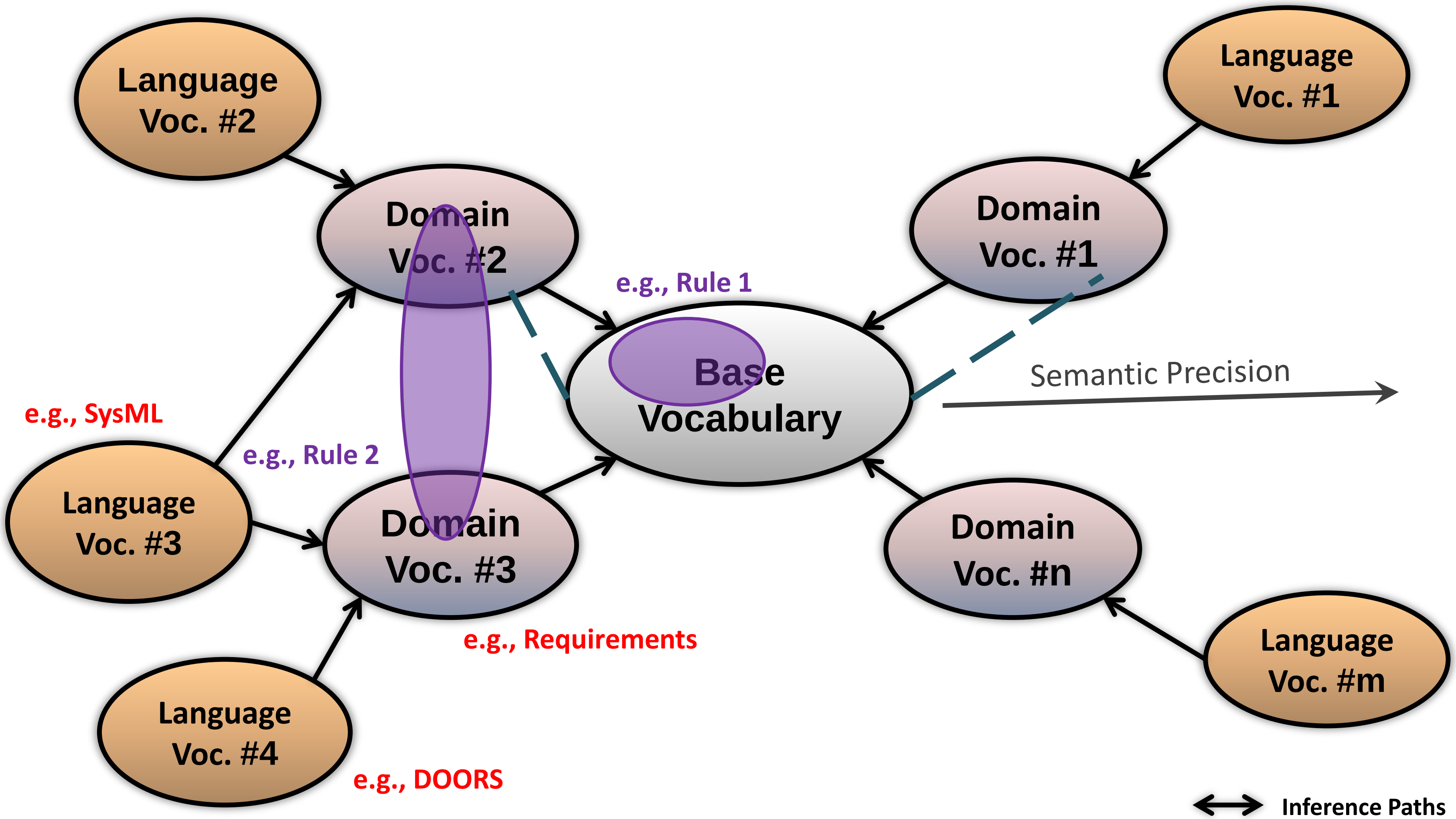
Example 3 : Hybrid Approach - Models as Graphs



Mediation Between Multiple Vocabularies



Herzig, S., Qamar, A., Paredis, C. , Inconsistency Management in MBSE, GPDIS 2014

Key Takeaways

- Data exchange standards have limited uptake
- Moving data Vs creating information traces
- Tool interoperability supporting product life-cycle and system engineering work is vital
- Reasoning over distributed sources with traceability
- Scalability of point-to-point vs single shared meta-model vs hybrid integration approaches