A View on Tool Interoperability Solutions at Ford Motor Company

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Distributed Development

- Software Engineering
- Systems Engineering
- Project Management
- Production
- CAD/CAE
- Powertrain Controls

Key Components:
- Active safety
- Reliability
- Fuel consumption
- Maneuverability
- Mass
- Profit
- Production rate
- Passive safety
- Geometry
- Cost
- Regulatory compliance
- Robustness
Old Landscape

Some Partial Integration
Mostly Information Silos
Current Landscape
VSEM Supported Integration

**SW System Development**

**Product Development**
- Functional Requirements
- Executable Models
- SW Parameters
- Calibration Data
- Configuration Data/VSCS
- Test Vectors
- Sensors
- Actuators
- Circuits/Devices
- ECUs
- Connectors
- Grounding & Fusing
- EE Load Characteristics
- Feature/Functions
- Feature Dependencies

**Software Release**

- In-Vehicle Software Release
  - E/E System BOMs (HW & SW)
  - Dependency Data
  - Service Actions
  - Coordinated Action Groups
  - VSCS Files
  - SW Binaries Files
  - Calibration Files
  - Configuration Files
  - Primary BL
  - Secondary BL

**Assembly Plants**

**Software Update**

**Dealerships and Web-Services**

- FIA Dealer Updates
- FoE Dealer Updates
- FSA Dealer Updates
- FAP Dealer Updates

**SyncMyRide USB Updates**

**Cloud Based Services**

**VSEM - EE System Artifacts that derive a Released BOM (As-Designed)**

**VSEM - IVS Vehicle SW BOMs (As-Released)**

**In-Plant SW Part Provisioning (As-Built)**

**VSEM – GIVIS Global Dealerships & Customer Updates (As-Modified)**
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

- Powertrain Controls
- Climate Controls
- Infotainment
- Active Safety
- Chassis Controls
- EESE
Interoperability Goals
Goal 1: Inform About Dependencies

- Software Engineering
- Project Management
- Production
- Systems Engineering
- Powertrain Controls
- • Vehicle Controls
- CAD/CAE

Research and Advanced Engineering
Goal 2: Manage Change Across Disparate & Heterogeneous Models
Goal 3: Make Decisions Based on Information from Multiple Data Sources

- Overall fuel Efficiency
- Solution to overlapping concerns
- Changing an ECU
- Requirements coverage

Decision Maker

- System Engineering
- Analysis
- Software Development
- CAD/CAM

Research and Advanced Engineering
Goal 4: Facilitate Data Exchange AboutManaged 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

Common Vocabulary

Domain Vocabulary
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

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

Addresses top of 'Vee'

Contributor: Bailey, W.
Integrated Vehicle Analysis - Process

- **SysML Specialized Analysis Architecture (FE, Perf)**
- **SysML VMA Reference Architecture**
- **Domain Dymola Plant Template**
- **Physical Component Models**
- **Domain Simulink Control Template**
- **Simulink Subsystem Control Models**
- **Vehicle System Model**

**Domain model developers then add content to the model templates.**

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

If I/O changes are required, they must come from the shared SysML model.

*Analysis Suite*

- **Test(s) Execution**
- **Analysis Control**

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Research and Advanced Engineering
Example 3: Hybrid Approach - Models as Graphs

Requirements

CAD Geometry Model

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