FLEXING THE AUTOMOTIVE SYSTEM / SOFTWARE VALUE CHAIN AT GENERAL MOTORS

Using AUTOSAR Feature Exchange Format and Variant Handling

Rick Flores
GM Technical Fellow
Model-Based Electrical System and Software Engineering

Laurent Balmelli, Ph.D.
Director, Strategic Business Development
Sodius Corp. www.sodius.com

Louis Talvande
Team Manager and AUTOSAR lead
Sodius Corp. www.sodius.com
Plan for this Discussion

**Feature Variation Management (FVM) at GM and Tool Chain**

**AUTOSAR Specifications for FVM and Tooling Support**

**How Engineers, System Design and Tools Interact to realize**

**AUTOSAR Variant Handling**

**Example of Electrical System Modeling at GM**

**Conclusions**
FEATURE VARIATION MANAGEMENT AT GM
Why is Feature Variation Management Essential at GM?

GM has one of the most complex systems and software product line engineering challenges in the world:

- 3000 product line engineers
- 300 hierarchical subsystems
- Thousands of variant features
- Millions of product instances per year
- Tens-of-thousands of unique product variants
- Dramatic increase in product line variation due to new propulsion systems, active safety, and autonomous vehicles
- Global diversity in legislative regulations
- Extreme economic and competitive pressures
- Product line and feature set evolves annually
- 15 concurrent temporal development streams
Feature Variation Management has a Central Role in GM’s Tool Chain

- **Feature-Based Program Content**
  - Gears (BigLeverSoftware)
  - Feature Variation Management

- **Functional System Design**
  - DOORS
  - RationalTeam Concert (IBM)
  - DOORS
  - Rhapsody (IBM)

- **Physical System Design**
  - Capital (Mentor)
  - Rhapsody (IBM)
  - Rhapsody (IBM)

- **Software Design**
  - DOORS
  - Rhapsody (IBM)
  - DOORS

- **Hardware Design**
  - Capital (Mentor)
  - Capital (Mentor)

- **Change Configuration Management**
  - DOORS
  - RationalTeam Concert (IBM)
Tool automation is enabled by the use of Standard Exchange Formats

Standard formats used for the Global Electrical Architecture design are:

**ARXML** AUTOSAR Exchange Format

**ODX** Open Diagnostic Data Exchange Format
Connecting Feature Variation Management to Assets

Feature Catalog

System Requirements
Subsystem Design Models
Software Component Models

Select Features
System Integration Test
Subsystem Integration Test
Software Unit Test

Bill of Features

= Variation Point
GM Plans to Leverage Feature Variation Management and Variant Handling

**Feature Variation Management** enables GM to
- Provide Program Teams with a *Catalog* of connected features
- Coordinate understanding of Features between marketing and engineering
- Improve accuracy and timeliness of information from upstream planning teams to downstream designers/implementers

**Variant Handling** supported by AUTOSAR tooling enables GM to
- Communicate features information across AUTOSAR E/E design tools
- Enables control of ARXML to suppliers according to our feature development strategies
- Avoid adhoc, informal methods of communicating variability information to our suppliers
- Model our systems as a superset avoid ‘Clone and Own’ techniques
AUTOSAR specifications for FVM and Tooling Support
How Does AUTOSAR Support Feature Management?
What is a Feature Map?

A feature map (FMFeatureMapElement) lets users choose values for a set of system constants and post build variant criteria if a certain combination of features is selected.
Feature map conditions to enable a value set for system constants
4. Each \textit{SwSystemconst} in $SC_i$ is used in the condition of one or more \textit{VariationPoints}. More precisely, the \textit{SwSystemconst}s are referenced from the \textit{ConditionByFormula} elements\textsuperscript{2} that are aggregated by the \textit{VariationPoint} in the role \textit{swSyscond}. Let $V_i$ be the set of these variation points for all elements in $SC_i$. 
AUTOSAR Variant handling

- Predefined Variants
- System Constant Value Sets
- PostBuildCriterion Value Sets
HOW ENGINEERS, SYSTEM DESIGN AND TOOLS INTERACT TO REALIZE AUTOSAR VARIANT HANDLING
GM Engineers author in their own domain-specific language

- **Feature Owner** – Feature Trees, Vehicle Configurations, Products

- **System Designer** – Functions, Compositions, Interfaces, ECUs, Networks
  - Variation points expressed in terms of Features (system constants)
  - Introduce variation points into the system at first occurrence of variance (up-stream)
Generative solution

- Use Model Transformation techniques to generate proper ARXML from domain-specific models
  - AUTOSAR Feature Exchange
  - AUTOSAR Variant Handling
  - Propagate variation point information to down-stream AUTOSAR elements
Example of Electrical System Modeling at GM
Variant-rich System Design Superset

- System Design Models capture the **superset** of global architecture solutions
- Add variation points based on Features

**Types of Variation Points in System Design**
- Functional Allocation Variation
- Port Variation
- ECU Variation
Side Detection Systems Feature + Supporting Radars

Side Detection Systems Feature Tree

Radar Feature Tree
Predefined Variants 1/2

Feature allocated to SBZA ECUs

Haptic seat commands from Requestor(s) to Commander
Haptic Seat Status from Commander to Requestor

Haptic Seat functionality in Body ECU

Haptic Seat functionality in Memory Seat ECU
Predefined Variant 3

ADAS Feature Bundle 1 distributed among SBZA ECUs and Radar ECUs
Predefined Variant 4

ADAS Feature Bundle 2 distributed among Radar ECUs, Supplemental Radar ECUs, Primary/Backup ADAS ECUs
# Predefined Variants

<table>
<thead>
<tr>
<th>Features/PreDefined Variants</th>
<th>PV1</th>
<th>PV2</th>
<th>PV3</th>
<th>PV4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side Detection Systems Feature</td>
<td>syscValueSet (RCTA)</td>
<td>syscValueSet (RCTA)</td>
<td>syscValueSet (ADAS FB 1)</td>
<td>syscValueSet (ADAS FB 2)</td>
</tr>
<tr>
<td>Radars</td>
<td>syscValueSet (SBZA ECU)</td>
<td>syscValueSet (SBZA ECU)</td>
<td>syscValueSet (SBZA ECU+ Radar ECU)</td>
<td>syscValueSet (SBZA ECU+ Radar ECU+ Supp Radar ECU)</td>
</tr>
<tr>
<td>Side Detection Feedback</td>
<td>syscValueSet (Haptic Seat)</td>
<td>syscValueSet (Haptic Seat)</td>
<td>syscValueSet (Haptic Seat)</td>
<td>syscValueSet (Haptic Seat)</td>
</tr>
</tbody>
</table>
Applying variant handling to variant-rich System Design Superset

Types of Variation Points in System Design
- Functional Allocation Variation
- Port Variation
- ECU Variation

Predefined Variants 1-4
Applicable Variation Point Binding Times

<table>
<thead>
<tr>
<th>Binding Time</th>
<th>Supported by AUTOSAR Variant Handling</th>
</tr>
</thead>
<tbody>
<tr>
<td>BlueprintDerivationTime</td>
<td>some features of variation points are also used here</td>
</tr>
<tr>
<td>FunctionDesignTime</td>
<td>no</td>
</tr>
<tr>
<td>SystemDesignTime</td>
<td>yes</td>
</tr>
<tr>
<td>CodeGenerationTime</td>
<td>yes</td>
</tr>
<tr>
<td>PreCompileTime</td>
<td>yes</td>
</tr>
<tr>
<td>LinkTime</td>
<td>yes</td>
</tr>
<tr>
<td>PostBuild</td>
<td>yes</td>
</tr>
<tr>
<td>Runtime</td>
<td>no</td>
</tr>
</tbody>
</table>

**Table 7.30: Binding Times**

**System Design** time binding time variation points
- Evaluated at ECU ARXML generation time

**Post Build** binding time variation points
- Evaluate at ECU Start-up
- Included in the ARXML as Post Build Value Criteria Value Set
Full Tool Chain Under Development

Gears
Features
Profiles
Matrix

Rhapsody
SYSCs
Signals
Deployments
ECUs
Networks
VP(Features)

XForm

AUTOSAR Variability
Feature Extract
Feature Models
Feature Selections
Feature Map

Variant Handling
System Constants
Predefined Variants

System Template
Template
Predefined Variants

ARXML
Content w/ Variation Points

PREEvision
ECUs
Networks
PDUs
SW Compositions
VP(System Constants)

Gen

F e a t u r e  M o d e l s
F e a t u r e  S e l e c t i o n s
F e a t u r e  M a p
S y s t e m  C o n s t a n t s
P r e d e f i n e d  V a r i a n t s

Gears: Features, Profiles, Matrix
Rhapsody: SYSCs, Signals, Deployments, ECU, Networks, VP(Features)
AUTOSAR Variability: Feature Extract, Variant Handling
PREEvision: ECU, Networks, PDUs, SW Compositions, VP(System Constants)

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CONCLUSION
Tooling support for AUTOSAR Variability Handling

Objectives:
- ARXML with Features/Variants and Variation Points
- Support of AUTOSAR Variant Handling by supply-base and tooling

OEM
- Feature Definition
- Variability Definition, Product Configurations

Variation Points in:
- Requirements,
- System Design,
- Software Design,
- Tests

Supplier
- AUTOSAR BSW Configuration
  - Implement ECUs
    - Superset, Partially Bound Superset, or Variants
Vehicle Product – Level
- Functional owners develop customer-facing Feature models
- Vehicle program teams select from a ‘Bill of Features’ to define content

Design - Level
- Full variation points/conditional expressions in Design elements
- Flexibility to generate ARXML, ODX
  - Superset with variation points
  - Partial superset with variation points
  - Variant-specific
- Support of AUTOSAR Variant Handling by supply-base and tooling