Method Park, Product Lines in the Park
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Model-Based Electrical System and Software Engineering
INTRODUCTION
DESIGNING A GLOBAL ELECTRICAL ARCHITECTURE -
TOOLS TO ENABLE MAXIMUM REUSABILITY OF GM ASSETS

System Engineering for ECS Tools

- GM Requirements
  - DOORS
- Feature-Based Program Content
  - Gears (BigLeverSoftware)

- Functional System Design
  - Rhapsody (IBM) / PREEvision (Vector)
- Physical System Design
  - Capital (Mentor)

- Software Design
  - Rhapsody (IBM)
- Hardware Design
  - Capital (Mentor)

- Change / Configuration Management
  - RationalTeam Concert (IBM)

Global Electrical Architecture
Supporting
GM Vehicle Solution Sets
TOOL FOCUS AUTOMATION AND AUTOMOTIVE STANDARDS

A key area of focus of GM’s *Process and Tools* strategy is in support of **automotive industry standards**
- We see tremendous opportunity in sustained convergence of the industry to a highly effective foundation for our features and customer-facing value

Examples
- GM is a core partner in **AUTOSAR**, the leading global automotive software architecture standard.
- The Open Diagnostic Data Exchange (**ODX**) specification contains the data model to describe all diagnostic data of a vehicle

Our tools support the use of the standard by automating the generation of **standard** system descriptions.
TOOL AUTOMATION ENABLES TRANSFORMATION TO STANDARD EXCHANGE FORMATS

The standards provide a common language to effectively communicate with our global supplier base.
APPLICATION OF PRODUCT LINE ENGINEERING @ GM

Capturing Features and Variability across the Engineering Life Cycle
### PRODUCT LINE VIEW

Explain the multi-levels of features and content in a vehicle

- Profiles capture valid Feature configurations
- Features can be bundled

<table>
<thead>
<tr>
<th>Feature Behavior</th>
<th>Technology-based</th>
<th>Deployment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profiles</td>
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Products combine Feature Profiles
When decisions are made is not necessarily related to when configurations are bound.
VARIABILITY IN GM SYSTEM DESIGN

Driven by optional functionality which
- May or may not be used on any particular vehicle or
- The same functionality which is deployed to different ECUs for different vehicles (often driven by the presence/absence of other features in the vehicle).

The variability manifests itself in the Global B topology as:
- Mutually exclusive ECUs
- Co-Existing ECUs with one ECU always present
- Component deployment variation across ECUs
- ECUs with common functionality differing due to location in vehicle
- I/O variation
- Cross-domain features
Based on vehicle’s feature content:
- Components are allocated to ECUs
- NW Signals are Tx/ Rx on busses
- Actuators/ Motors are driven by ECUs
VARIABILITY IN DEPLOYMENT – EXAMPLE

Based on vehicle’s feature content:

- Components are allocated to ECUs
- NW Signals are Tx/ Rx on busses
- Actuators/ Motors are driven by ECUs
• TCM is not included in Manual Transmission configuration
• Function B and triggering of associated NW Signals are allocated to ECM
• The specification of ECM varies by configuration
AUTOSAR VARIABILITY HANDLING
AUTOSAR VARIABILITY HANDLING

The motivation for Variant Handling in AUTOSAR is to build a bridge between OEMs and suppliers, to avoid redundancy between artifacts, and to provide a basis for expressing basic product lines in AUTOSAR.

OEMs must manage product features, variability, etc. across their full product line. (Manufacturing, Sales, Engineering, etc.)

Though variant handling concepts do already exist at most companies, they are typically not standardized (beyond company borders), and thus it is difficult for OEM’s and suppliers to talk to each other on this subject.

Variant handling in AUTOSAR is about documenting variants at the ECU level to describe design information.
COMMUNICATING SYSTEM DESIGN VARIABILITY - USE A STANDARD!

Features/ Variation/ Configurations

Functional System Design

Convey System Design Variability

Supplier ECU Design

AUTOSAR Standard

- Feature Exchange Format
- Variant Handling
VARIABILITY IN AUTOSAR

Specifications
- Feature
- Feature Selection
- Feature Map
- System Constants

Variant Handling in Generic Structure Template
- System Constants
- Variation Points
  - Binding Times
  - Binding Expressions
- Variation Point Patterns
- Evaluated Variants
- Predefined Variants

Feature Exchange Format
The AUTOSAR Feature Model Exchange Format establishes an efficient way to exchange feature models between different feature modeling tools.
- Features reside in the “problem domain” independent of the “solution domain” (implementation and product architecture)
- An individual product can be described by selecting a set of features.
- A mapping from features to variation points specifies which variation points are affected by the selection

Variation Points
An AUTOSAR model with variation points describes a set of AUTOSAR models which have a common structure but differ at certain locations.
- A variant-free AUTOSAR model is created from such a model by binding the variation points, that is, by keeping some variations and discarding others.

Variants
AUTOSAR defines means to express what constitutes a specific variant, for example which variation points are selected in an “economy” variant versus a “luxury” variant.
- An AUTOSAR model with variation points may describe a very large number of variants, but few of them are actually used.

System Constants
The variations are described by sets of system constant values. Hence, there is a need to describe which combinations of system constant values are valid.
- This provides the basis for OEMs and suppliers to exchange information on this subject in a standardized way.
TOOLING SUPPORT FOR AUTOSAR VARIABILITY HANDLING

**OEM**
- Feature Definition
- Variability Definition, Product Configurations

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

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

**Supplier**
- AUTOSAR BSW Configuration
  - Implement ECUs Superset, Partially Bound Superset, or Variants
APPLYING PLE TO SYSTEM DESIGN MODELS
SYSTEM/ SOFTWARE DESIGN VIEW

System Interfaces

System SIG
Serial Data SIG
NWT SIG :SD SIG
NW2 SIG :SD SIG

Topology

ECUs
Network Connections (NW CAN)
Network Connections (NW LIN, NW Ethernet)

System Component Design and Allocation

SYSC A - System Component
SYSC Alloc
• SYSC A
• SYSC N

ECU1_SYS
Serial Data
NW1 SIG :SD SIG
NW2 SIG :SD SIG

Software Component Design and Allocation

SW SIG

SWC A - Software Component
SWC Alloc
• SWC A
• SWC N

ECU1_SW

Network Management
Signal Framing

Modeling Topology Establishes Important Relations Between:
• ECUs – Networks
• Networks – Network Signals
• Network Signals - ECUs

System Interfaces

ECU 1
ECU 2

SW SIG

SWC A - Software Component

Networks
NW LIN
NW CAN
NW Ethernet

Network Connections (NW LIN)
Network Connections (NW CAN)
Network Connections (NW Ethernet)

System Component Design and Allocation

SWC A - Software Component

Software Component Design and Allocation

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Network Management
Signal Framing

Modeling Topology Establishes Important Relations Between:
• ECUs – Networks
• Networks – Network Signals
• Network Signals - ECUs
Variation Points
- Logic (In terms of Features)
- Binding Time

Captures how/when System Design components support features
ECU FAMILY HIERARCHY VIEW

ECU Family

ECU Deployment 1
- ECU Deployment 1.1
- ECU Deployment 1.2

ECU Deployment 2
- ECU Deployment 2.1
- ECU Deployment 2.2

Deploy System Components

ECU Deployment 2
- itsSystem Component

GENERAL MOTORS
Serial Data Message = A collection of Network Signals

Increased granularity
TOOLING SOLUTION

The overall purpose of the project is to define required tool capability to manage variability across the Global B Electrical Architecture system design level. The existing tool chain includes the following tools:

**Gears** – Product Line Engineering
- Feature trees,
- Feature profiles,
- Feature assertions,
- Product configurations

**Rhapsody** – Functional System Design
- System Components,
- Interfaces,
- Global B Topology (ECUs, Networks and connections)
- System Template ARXML output to PREEvision

**PREEvision** – Network Design and AUTOSAR System / ECU extracts
- PDU Design and Timing
- Frame Design: ID, PDU Position, Byte Order
- Synthesis of PDU/Frame Transmissions
- Gateway Routing Entries for Frame/PDU
- Design of Partial Network, Network Management, Transport Protocol

These tools must support the capture of variable information and produce appropriately detailed outputs to convey variability to downstream implementers.
ELECTRICAL FUNCTIONAL SYSTEM DESIGN - SUPERSET
APPLYING VARIABILITY TO ELECTRICAL FUNCTIONAL SYSTEM DESIGN

Gears
- Features
- Profiles
- Matrix

Rhapsody
- SYSCs
- Signals
- Deployments
- ECU
- Networks
- VP(Features)

AUTOSAR Variability
- Feature Extract
  - Feature Models
  - Feature Selections
  - Feature Map
- Variant Handling
  - System Constants
  - Predefined Variants

System Template
- ARXML
- System Constants
- Predefined Variants
- Content w/ Variation Points

PREEvision
- ECU
- Networks
- PDU
- SW Compositions
- VP(System Constants)

XForm
- Gen
- ECU
- Extract
- ARXML
- PreDefinedVariant 1
- PreDefinedVariant 2
- PreDefinedVariant n

Gen
- Import
- PreDefinedVariant 1
- PreDefinedVariant 2
- PreDefinedVariant n

ECU 1
- Extract
- ARXML

ECU m
- Extract
- ARXML
BILL OF FEATURES
PLE ENABLES BILL OF FEATURES CONCEPT
DESIRED STATE

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