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Leveraging MBD, auto-code generation and AUTOSAR to architect and implement an Engine Control Application for series production

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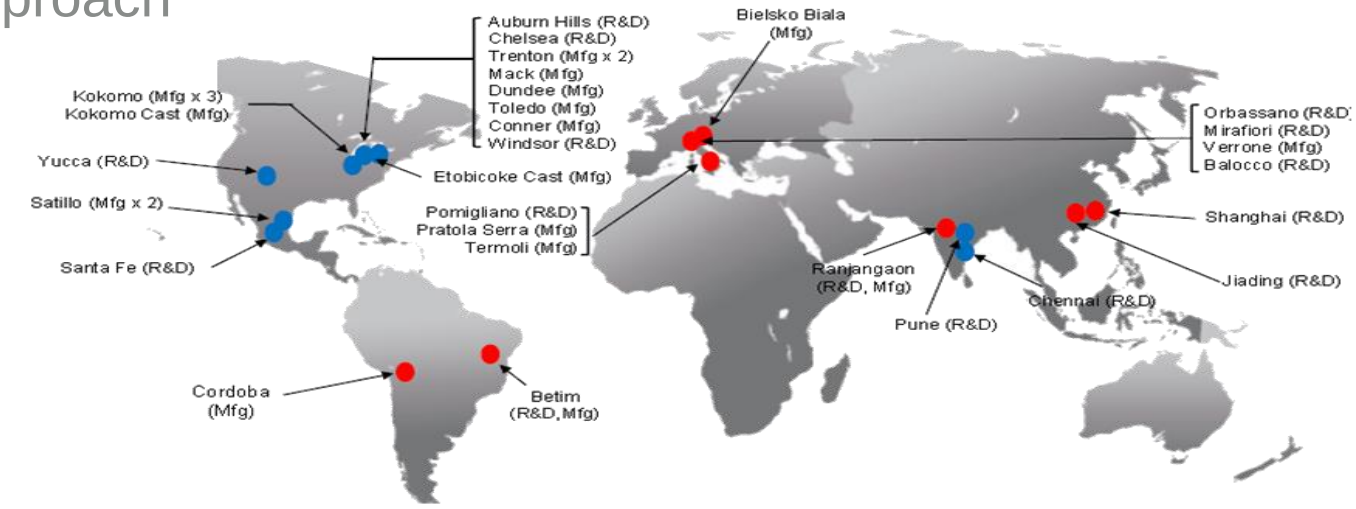
Index

- FCA Global Powertrain Controls
- Development process overview
- Definition of Software Architecture with AUTOSAR
- Model-based design and auto-code generation
- Challenges in R2016a
- Conclusions and next steps

FCA Global Powertrain Controls

- We’re a global team whose mission is to build propulsion Control Systems, leveraging the specific competences in the organization
- We’re using common development processes and tools to design, implement and deliver high quality products
- We’re building the foundation for next generation of FCA Powertrain Control Systems adopting a modular and scalable approach

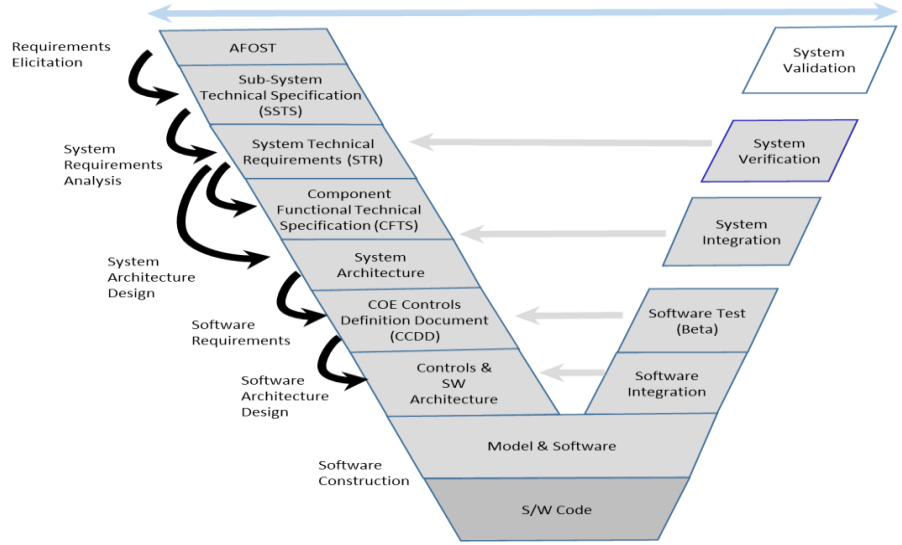


Index

- FCA Global Powertrain Controls
- **Development process overview**
- Definition of Software Architecture with AUTOSAR
- Model-based design and auto-code generation
- Challenges in R2016a
- Conclusions and next steps

Development process overview (1 / 2)

- Centers of Excellence (COEs) are geographically distributed teams to leverage the key competences in each Region
- More than 200 developers spread among Italy, USA, Brazil, India
- Global governance and a rigorous process have been established, to manage the project plan and deliverables across all the stages
- Software Tools have been adopted to implement process and traceability in the development
  (Application Lifecycle Management)



Development process overview (2 / 2)

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Powertrain
Requirements Collection

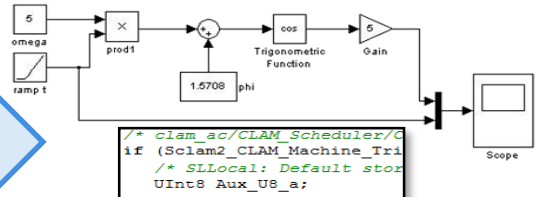
COE A

COE B

COE C

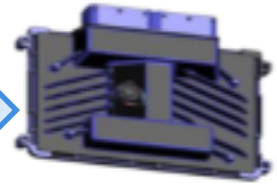
AUTOSAR
Architecture

Model Based Design



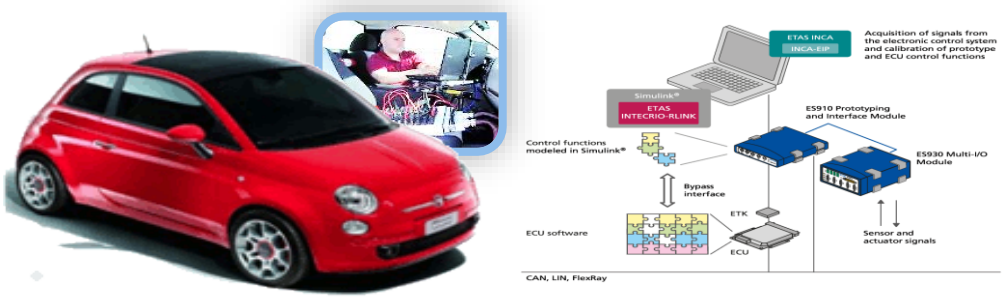
Automatic code generation

Software build on
production ECU



Virtual Verification
Virtual calibration

Hardware-in-the-Loop verification



In-vehicle calibration and final
validation

Index

- FCA Global Powertrain Controls
- Development process overview
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- Model-based design and auto-code generation
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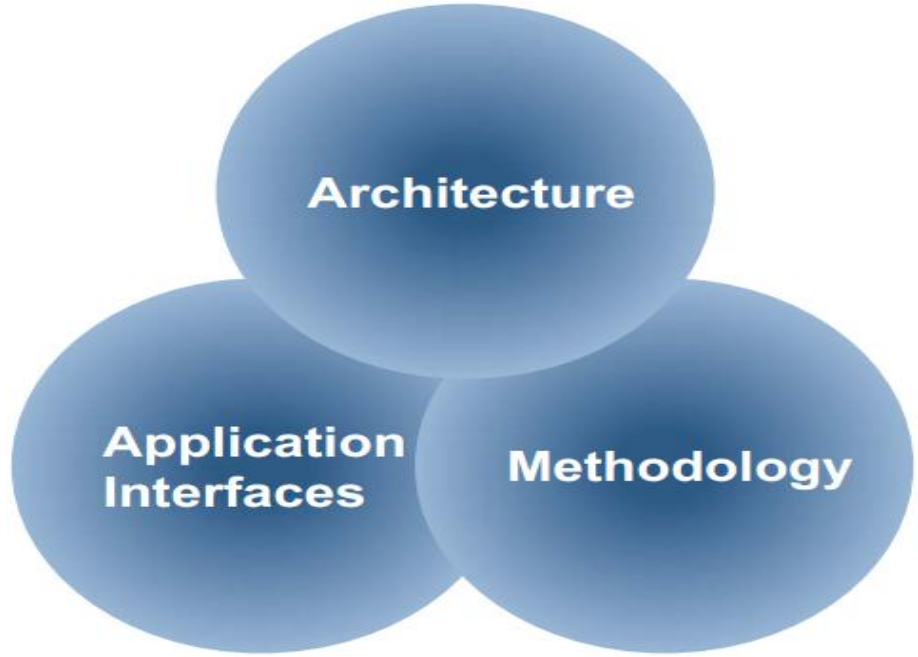
AUTOSAR Overview (1 / 2)

AUTOSAR (**AUT**omotive **O**pen **S**ystem **AR**chitecture) is an open and standardized automotive software architecture, jointly developed by automobile manufacturers, suppliers and tool developers.

Key features

- **Exchangeability** and **Integration** of functions between car makers and ECU suppliers
- **Increased scope** of automatic code generation and configuration
- **Implementation** and **standardization** of SW architecture and basic functions
- Increased use of Commercial **Off-the-shelf** Hardware



AUTOSAR provides a common software infrastructure for automotive systems based on a

- **standardized architecture**
- **application interfaces**
- **defined methodology**

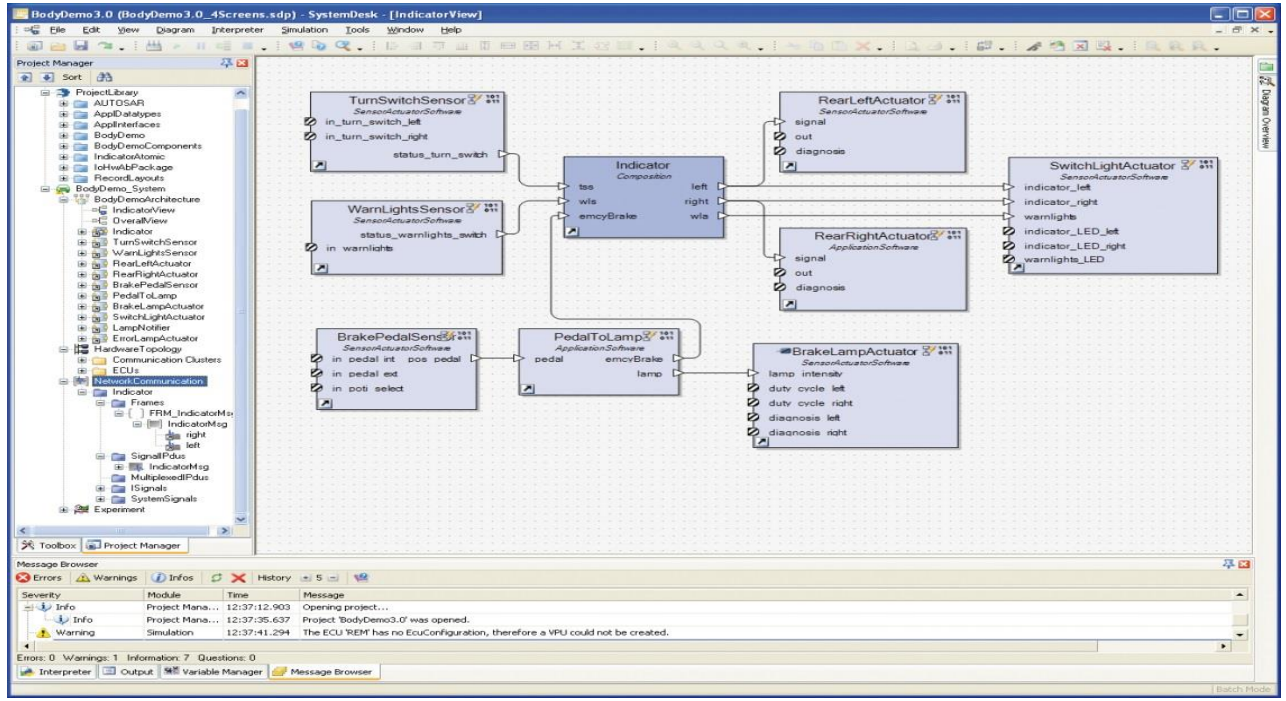
AUTOSAR Overview (2 / 2)

AUTOSAR requires a **complete, exact definition** of the entire SW Architecture, including :

- Hundreds of SW Components
- Thousands of ports and interfaces
- Hundreds of data types, ranges, scalings
- Complete interconnection of SW Components
- Configuration of Real-Time Operating System
- Configuration of the Basic SW

It's a **tool-driven approach** :

- Architecture Authoring Tools
- Configuration Tools
- Code Generation Tools



AUTOSAR SW Architecture

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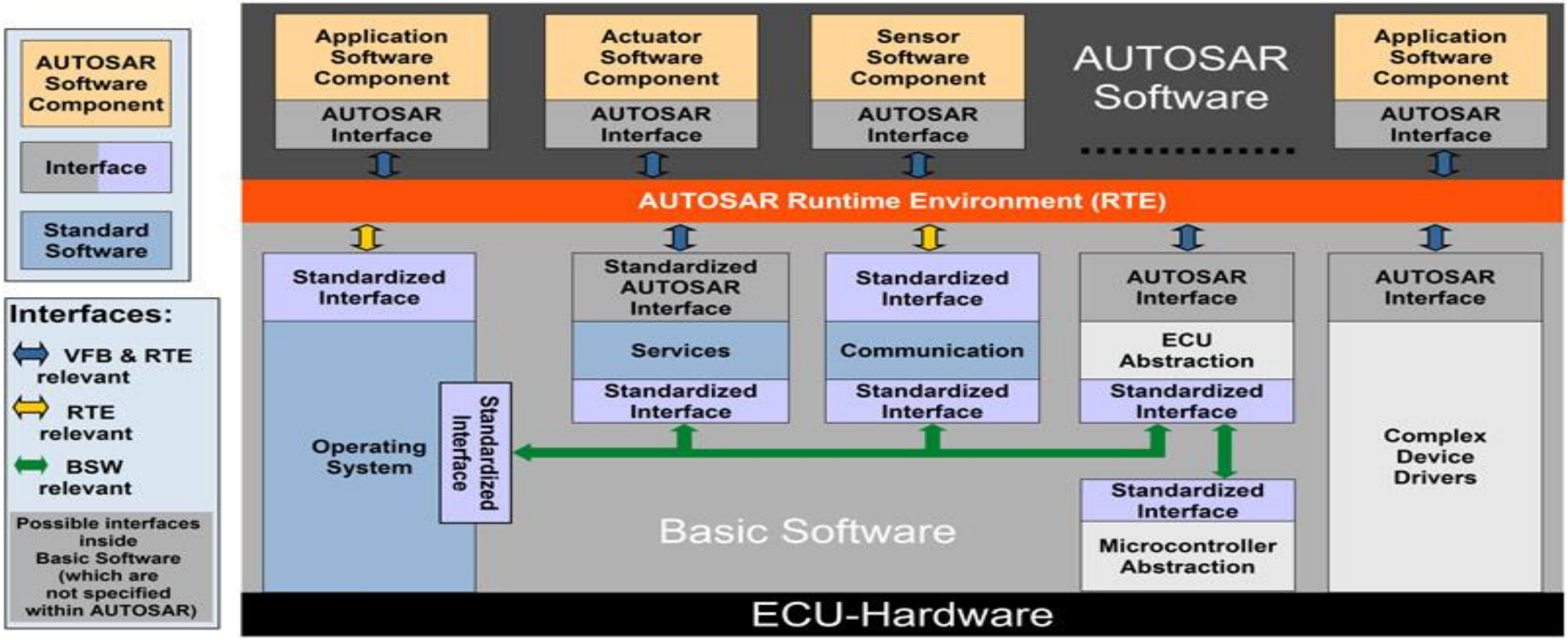
Interfaces
Components and interfaces view (simplified)



AUTOSAR @ FCA Powertrain Controls

AUTOSAR is a (complex!) methodology to **handle complexity**.

Some **advantages** for FCA PWT :

- It provides a formal language to design complex SW systems that can be **shared** and **understood across distributed teams** (using the proper tools)
- It requires to define the SW architecture up-front (top-down), so that possible **integration problems** among components are **discovered and fixed early**
- It facilitates **reuse of SW components** across **different applications and different ECUs**
- It increases the **scope and amount of automatic code generation**, from Application components only to interconnection generation, operating system, communication and basic SW configuration
- It increases the **scope of simulation** from Application components only to almost the entire ECU SW → **Virtual Verification**

Index

Model-based design and auto-code generation

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AUTOSAR Architecture

dSPACE SystemDesk

ARXML files

Custom Scripts

#scripts > 200

Controls modeling

MATLAB SIMULINK **R2015b/R2016a**

Custom Library

#blocks ~ 150

Data dictionary

Custom Storage classes

Autocoding

Embedded Coder AUTOSAR

Model .slx /.dd
Documentation

MIL/SIL Simulation

Code: .c /.h
.arxml

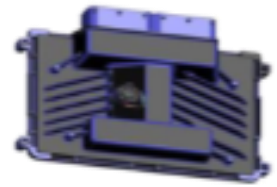
Software Integration

Application - RTE - BSW

CFG **Vector DaVinci**

Configurations

MIL/SIL/PROD

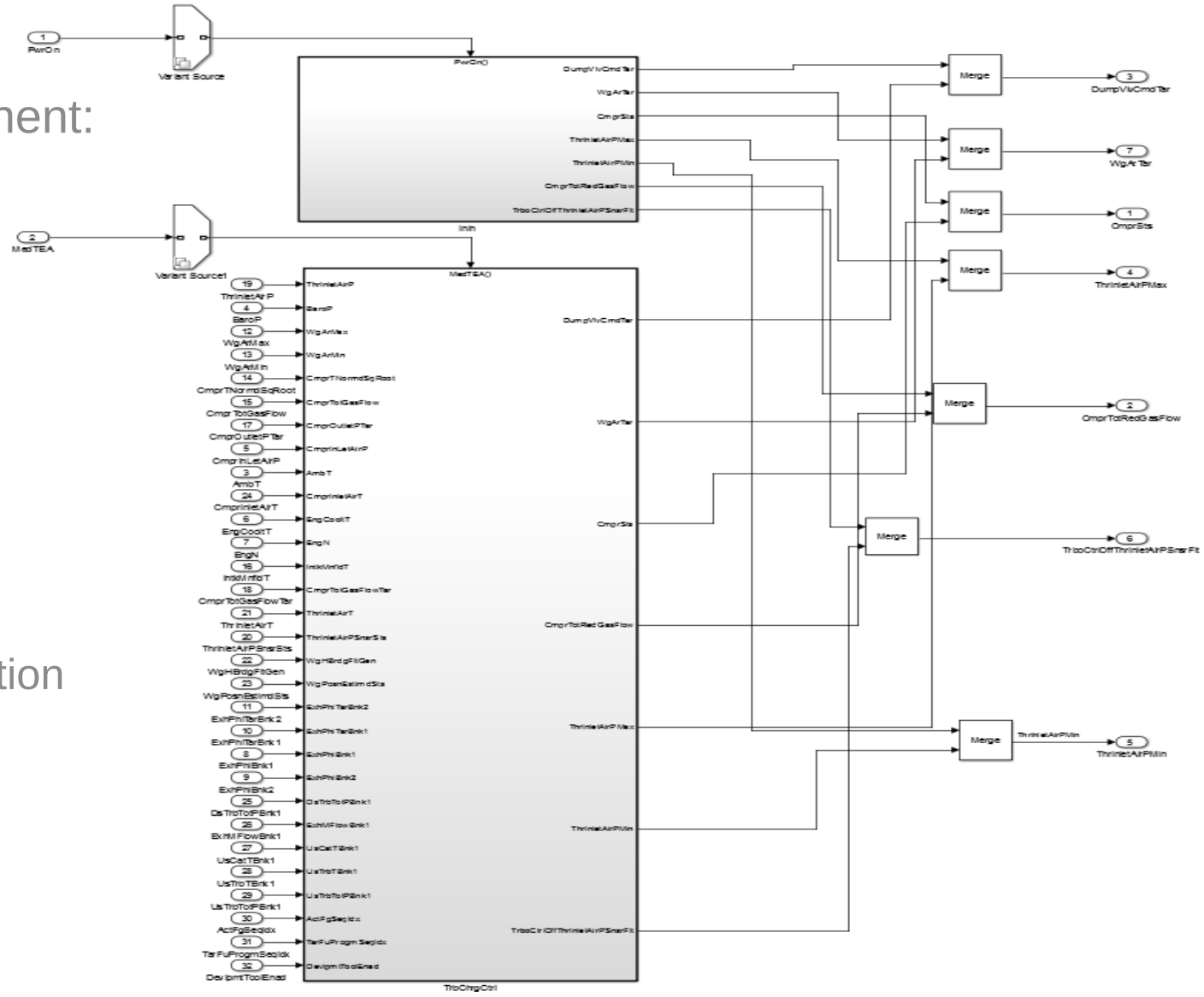


INCA

Production code: s19/a2l

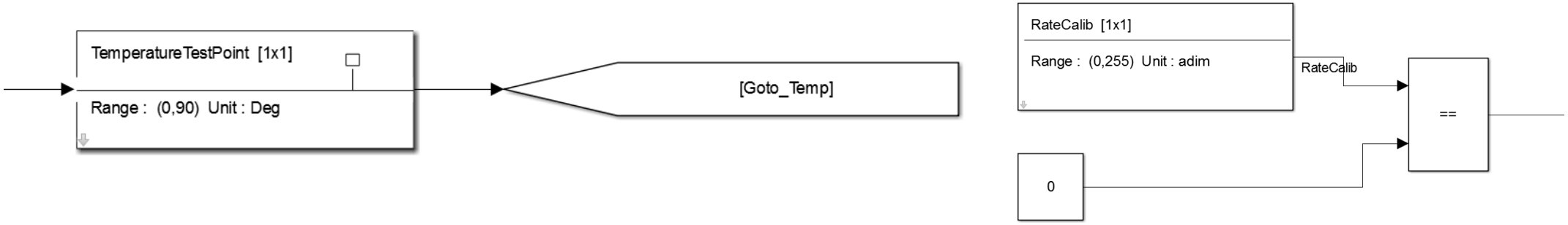
Model-based design and auto-code generation

- AUTOSAR Software Component:
  - Runnables
    - ▲ Event Triggers
  - Sender / Receiver Ports
    - ▲ Inputs/Outputs
  - Variant Management
  - Client / Server communication



Model-based design and auto-code generation

- Internal Behaviour (Control logic)
  - Application of modeling rules



  - Usage of FCA Custom Block Library and Simulink Data Dictionary
    - Test Point (linked to Data Dictionary)

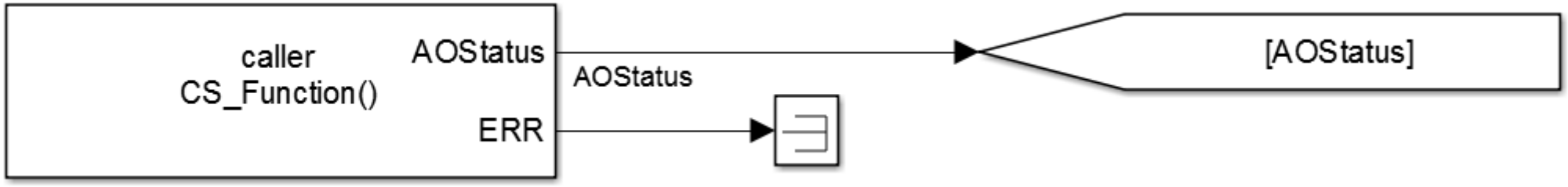
Name	Status	Value	DataType	Min	Max	Dimensions	Unit	StorageClass
TemperatureTestPoint	Mod		single	0	90	[1 1]	Deg	FCALocalSignal (Custom)

    - Calibration (linked to Data Dictionary)

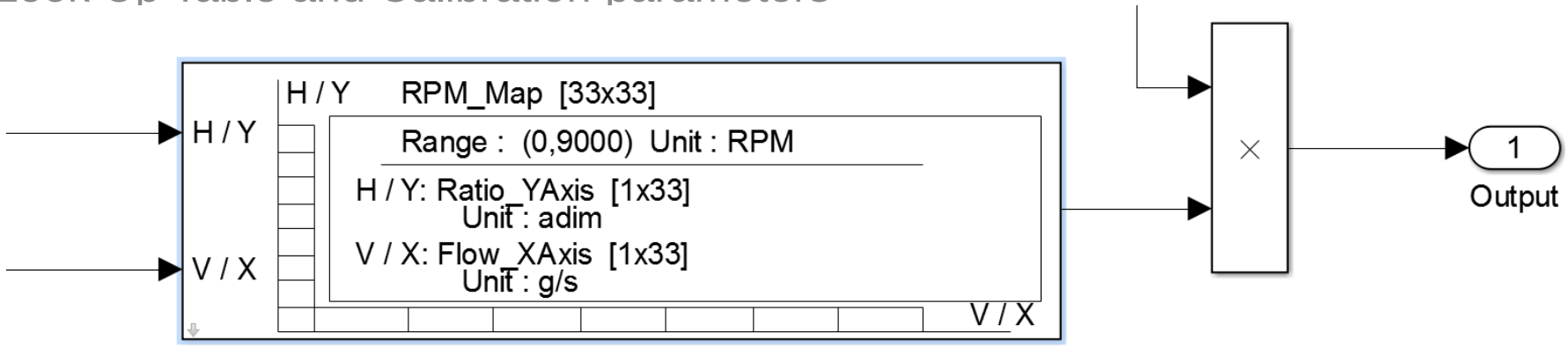
Name	Status	Value	DataType	Min	Max	Dimensions	Unit	StorageClass
RateCalib	Mod	8	single	0	255	[1 1]	adim	FCALocalParameter (Custom)

Model-based design and auto-code generation

- Internal Behaviour (Control logic)
  - Access to AUTOSAR server function through «function caller» block



  - Look Up Table and Calibration parameters

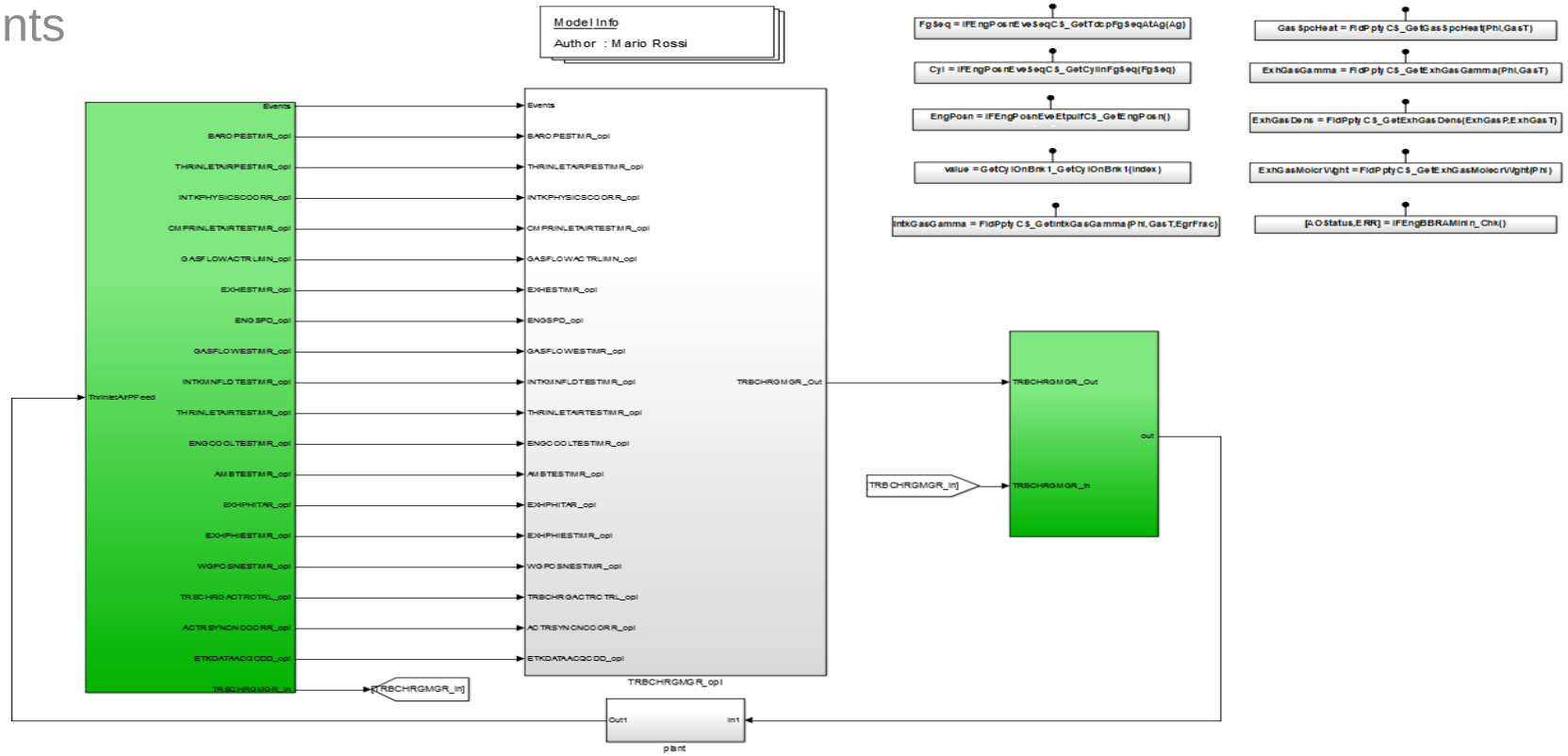


Model-based design and auto-code generation

- An «Harness» Model is required to simulate the Control logics

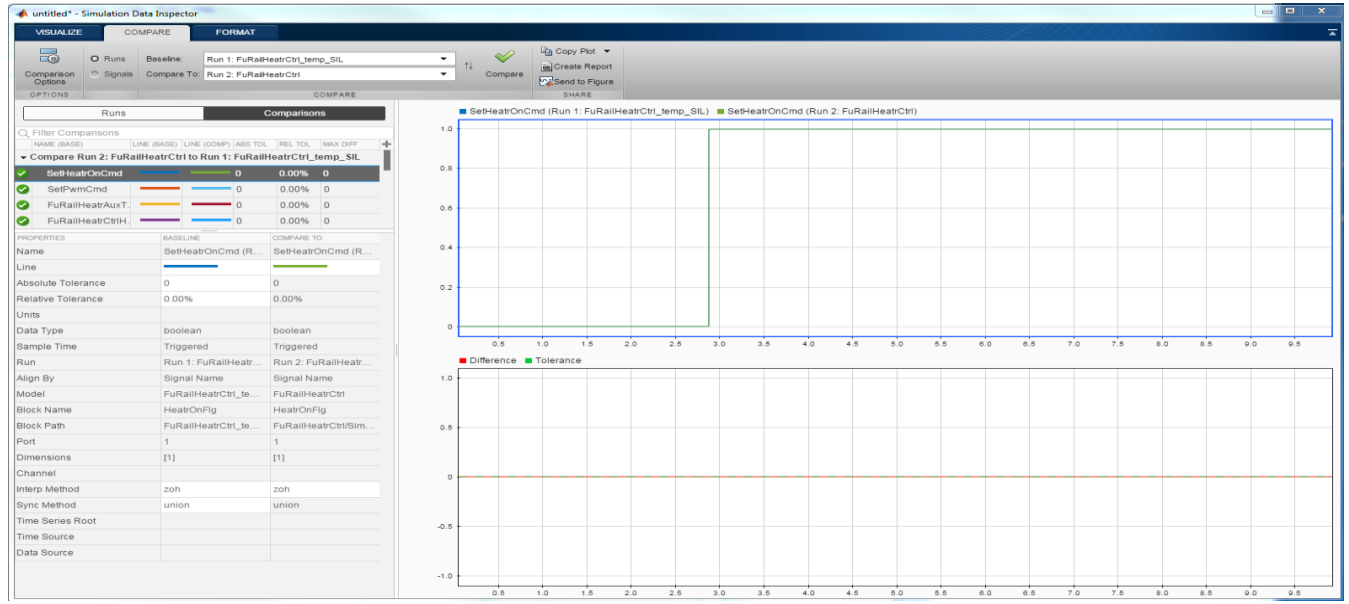
  The «harness» contains:

  - Link to referenced model (Autosar Sw-Component)
  - AUTOSAR Servers (Simulink functions)
  - Inputs and Events
  - Outputs



Model-based design and auto-code generation

- Model vs Code verification through simulation with Simulink Data Inspector
  - MIL vs SIL comparisons
  - Documentation report

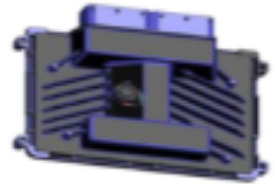


- Model Coverage is computed to ensure the model has been extensively tested

Model-based design and auto-code generation

- Code Generation
  - A specific model configuration is used
  - Only for referenced model (AUTOSAR Sw-C)
  - Floating point, ANSI C code
    - Only counters and boolean variables in fixed point
  - Deliverables : Source code (.c / .h) + .arxml

- Software Integration
  - Application SW + BSW + RTE (automatically generated)



- SW Configuration and Version management
  - RTC (IBM) is used for workflow instantion, change management and SW repository
  - 200+ Sw-C's (Simulink models, generated code, test reports, documentation…)
  - Basic Software (BSW)
  - Custom tools and libraries

Index

- FCA Global Powertrain Controls
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Challenges in R2016a

Given to the **complexity** and **number** of models, a close **collaboration** between FCA and MathWorks is necessary to tailor the tool-chain to specific FCA **requirements** and to address tool-chain **improvements.**

Some examples of **expected functionalities** not present in 2016a:

- logging internal signals in SIL;
- support to AUTOSAR Data Type Record across referenced models;
- mature support of AUTOSAR Variants;

A **weekly meeting** occurs to communicate issues and new requests from FCA to MathWorks:

- issues are reproduced and analyzed, **workarounds** or **patches** are provided in the AUTOSAR Support Package;
- new **requirements** are collected, submitted to Mathworks developers and released in the new MATLAB releases (2018a provides the above functionalities).

Index

Conclusions and next steps

- FCA Global Powertrain has embraced **AUTOSAR** and **model-based design** to build the **foundation** of next generation Control Systems

- Adoption of AUTOSAR enables the design of **complex and re-usable** SW applications, developed by **geographically distributed** teams

- Model-based design enables the development of **high quality code**, AUTOSAR compliant, through graphical design, simulation and code generation

- FCA Global Powertrain is further leveraging the AUTOSAR tool-driven approach to building **Virtual ECU**'s for early verification and calibration of **entire ECU production SW** in a Desktop PC environment