Sviluppo di un sistema di sospensioni semiattive mediante Model-Based Design con architettura AUTOSAR e conforme allo standard A-SPICE

Milano
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Roma
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Presented by:

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Marelli - Ride Dynamics

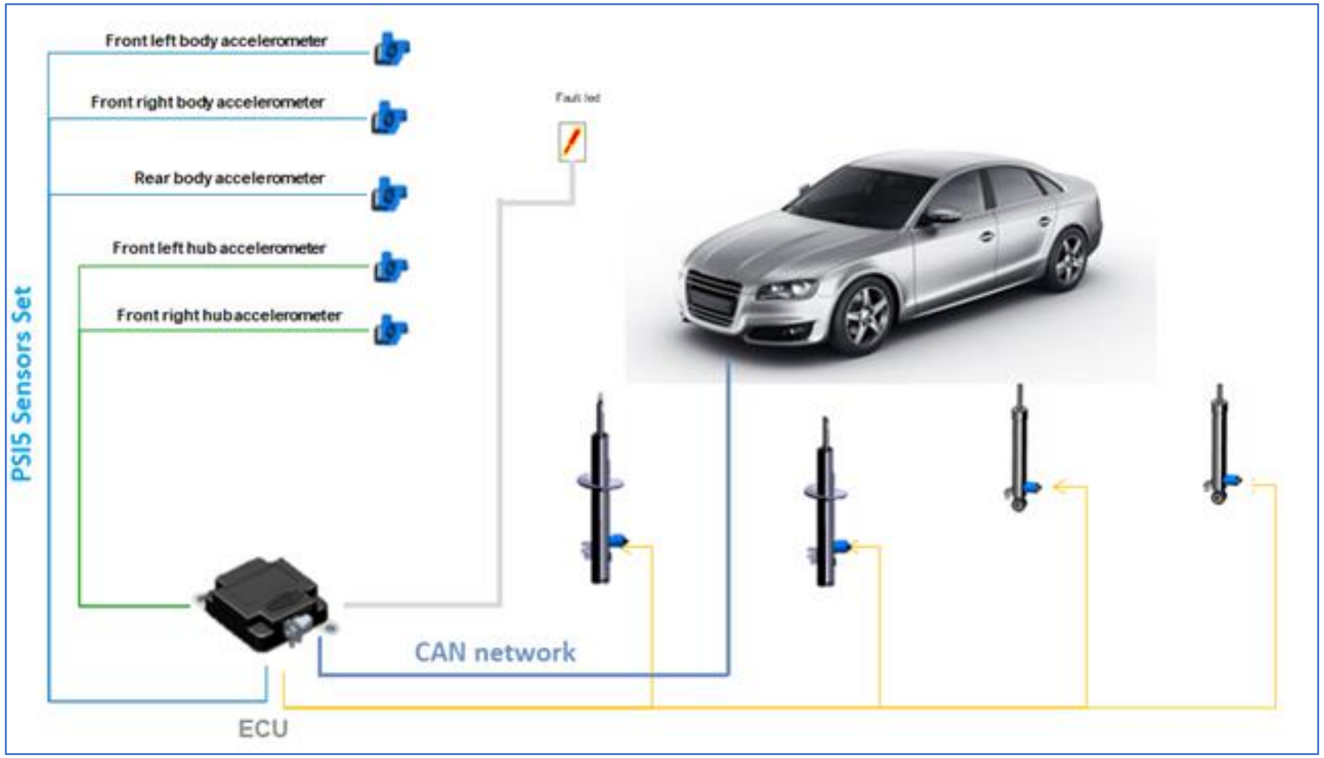
- Marelli – Ride Dynamics – Mechatronic team
  - ➢Design and development of semi-active suspensions system
  - ➢Responsible for the whole system

- Mechatronic's team is based in Turin

- ECU Application Software development
  - ➢Shock Absorber damping force control strategies and diagnosis

Smart Damping Control System

- SDC system consists of
  - ➢4 shock absorbers with one proportional EV each
  - ➢5 accelerometers
  - ➢ECU for closed loop damping control



Key Takeaways

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- ➢"State of the art": AUTOSAR and A-SPICE development process
- ➢Short time to market
- ➢Focus on bidirectional traceability
- ➢One single development environment for all SW related processes

Software development: goals and challenges

- State of-the-art for embedded automotive application software
  - Model-Based Design and automatic code generation
  - AUTOSAR Software architecture
  - Development process compliant to A-SPICE reference model
- Such a development process and SW architecture are required by main OEMs
- Constraint: Short time to market

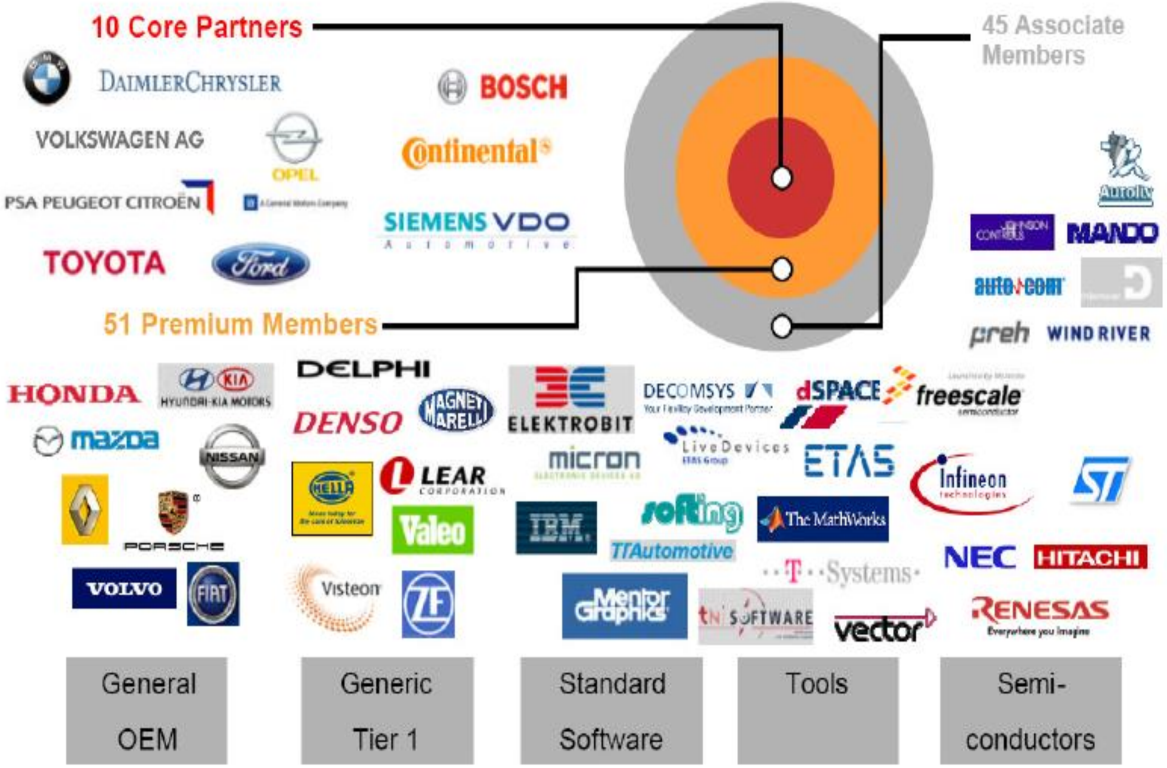
AUTOSAR

What is AUTOSAR?

AUTOSAR – AUTomotive **O**pen **S**ystems **AR**chitecture

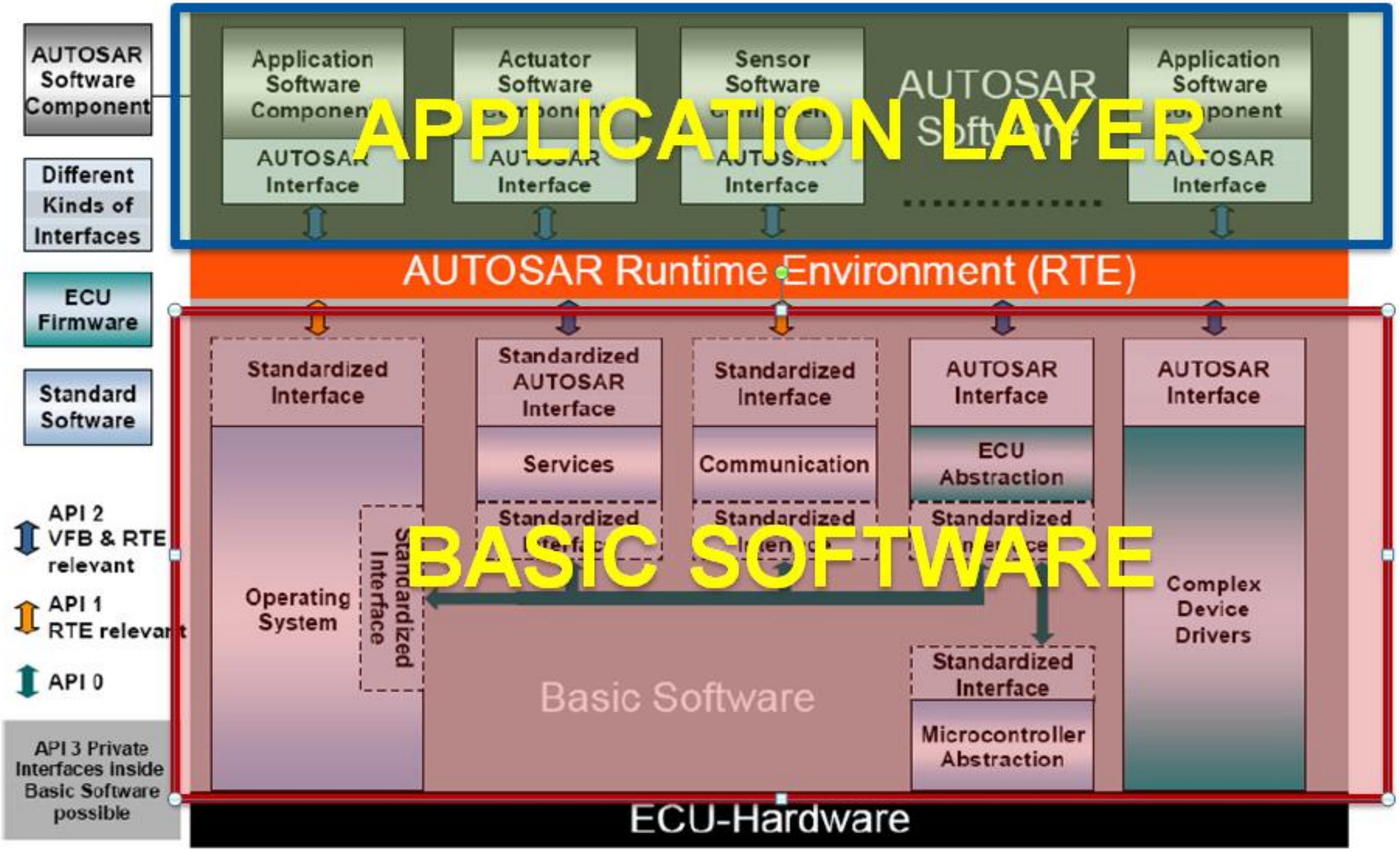
Middleware and system-level standard, jointly developed by automobile manufacturers, electronics and software suppliers and tool vendors.
More than 100 members

Motto: "*cooperate on standards, compete on implementations*"
Reality: current struggle between OEM and Tier1 suppliers

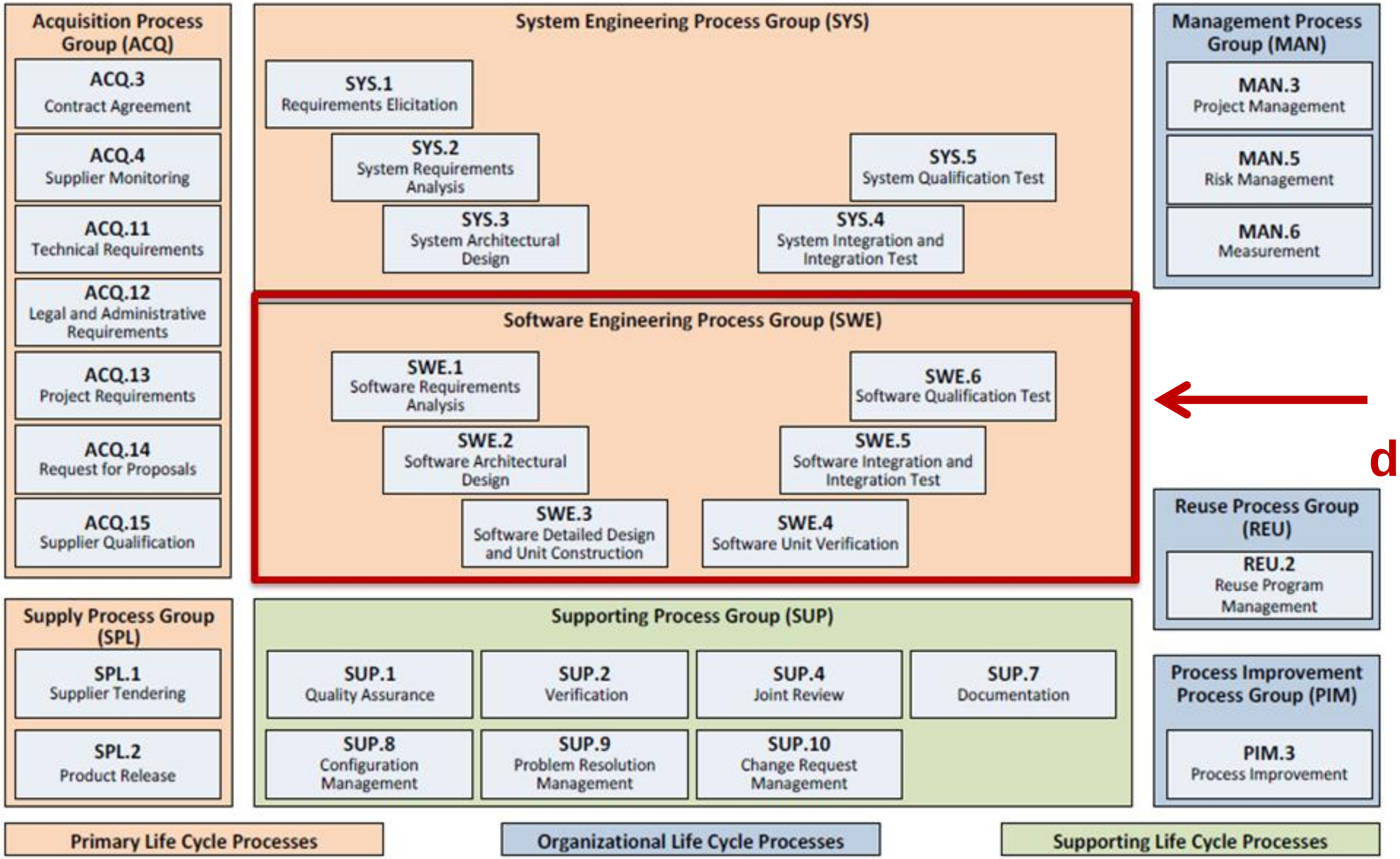


Target: facilitate portability, composability, integration of SW components over the lifetime of the vehicle

AUTOSAR ECU SW architecture



Automotive SPICE process reference model



Focus on Software development

Subset of recommended A-SPICE base practices

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- Specify software requirements
- Structure software requirements
- Establish **bidirectional traceability** between
  - software and system requirements
  - software requirements and software architectural element
  - software requirements and software units
  - software detailed design and the unit test specification
  - elements of the software architectural design and test cases
  - software qualification test specification and software qualification test results
- Develop a detailed design for each software component
- Define interfaces of software elements
- Define interfaces of software units.

Focus on traceability

Whole SW development tool set based on MATLAB & Simulink R2018a

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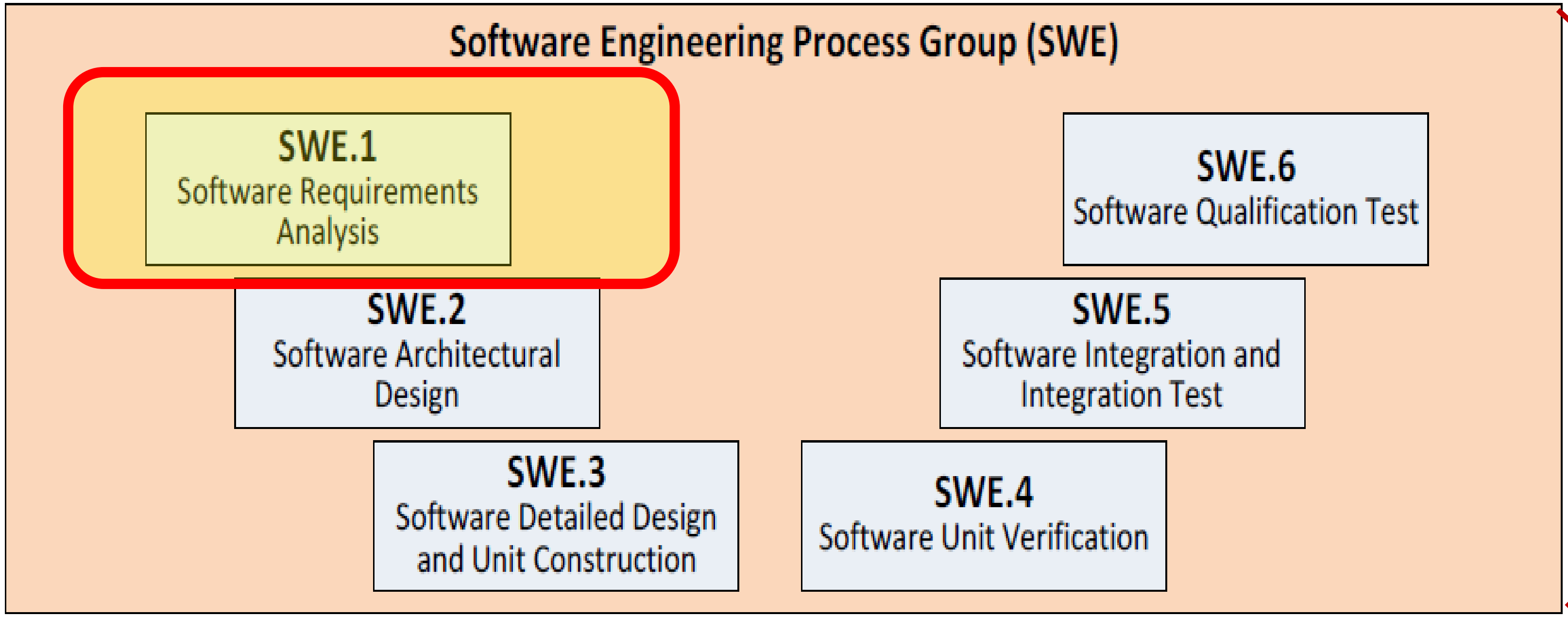
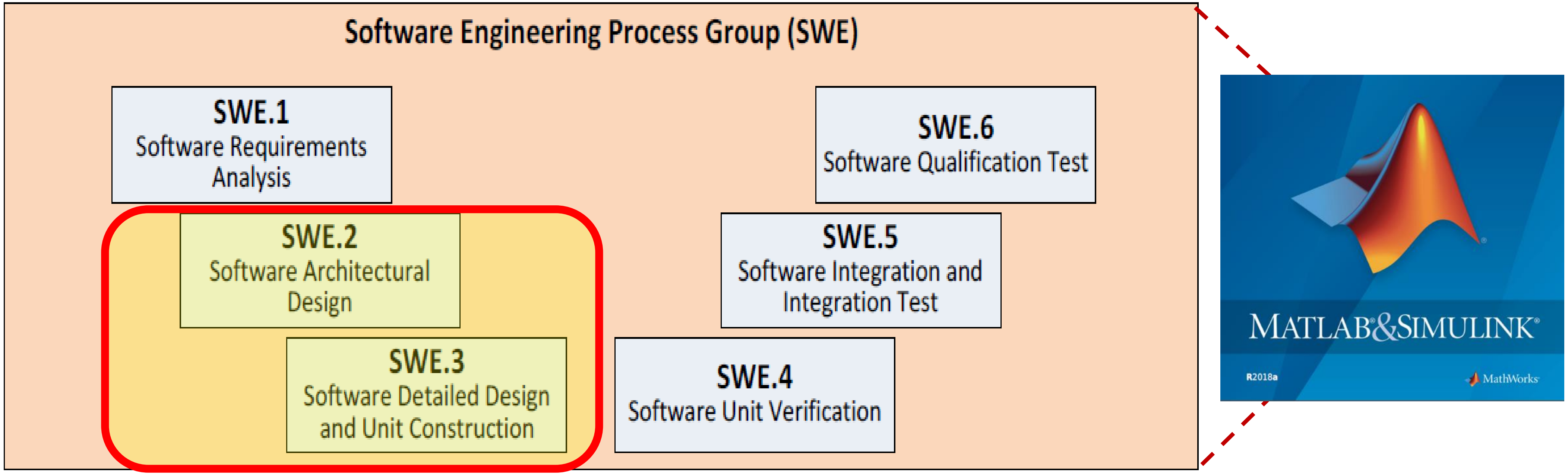


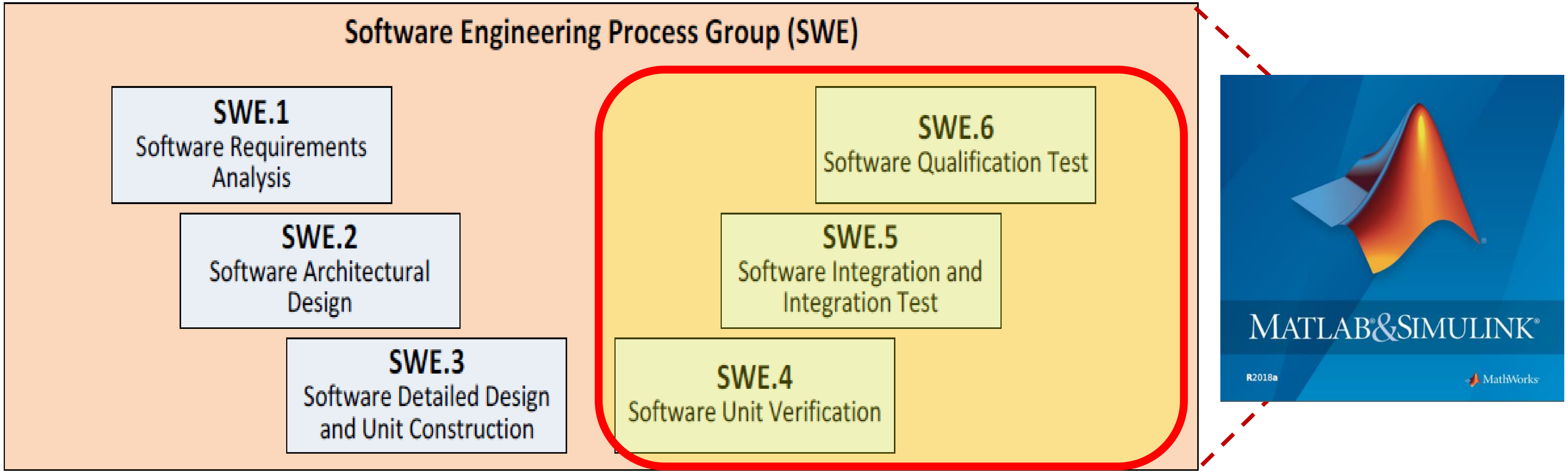
Simulink Requirements: requirements specification

Whole SW development tool set based on MATLAB & Simulink R2018a



- Simulink – Stateflow: SW units design and simulation
- Simulink Check and Design Verifier : coding guidelines check- Simulink model analysis
- Embedded Coder - Support package for Autosar: SW Components' AUTOSAR interfaces design and C-code autogeneration

Whole SW development tool set based on MATLAB & Simulink R2018a



- <u>Simulink Test</u>: Unit testing – MIL testing
- <u>Simulink Coverage</u>: for testing coverage metrics

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Requirements' structure: three levels

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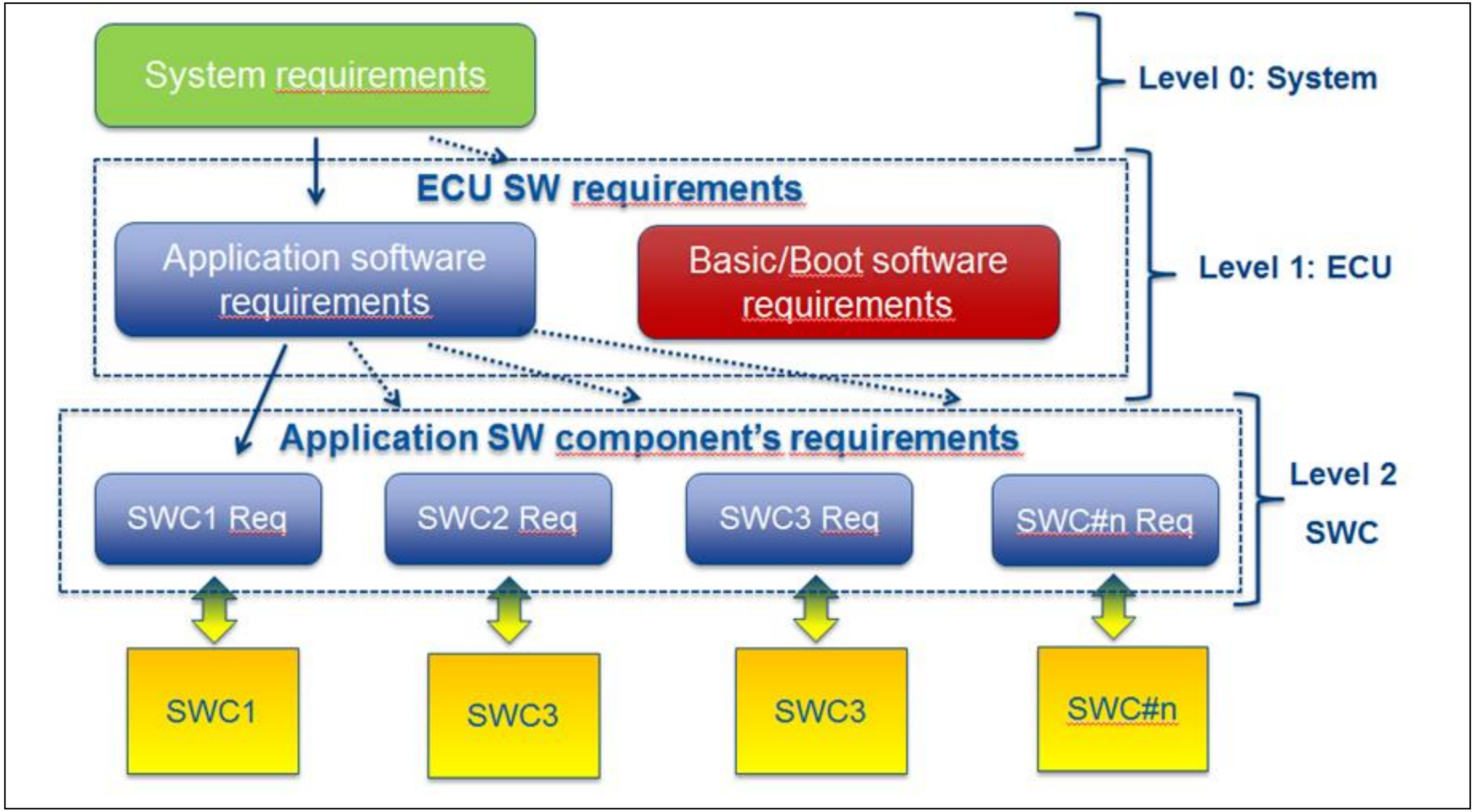
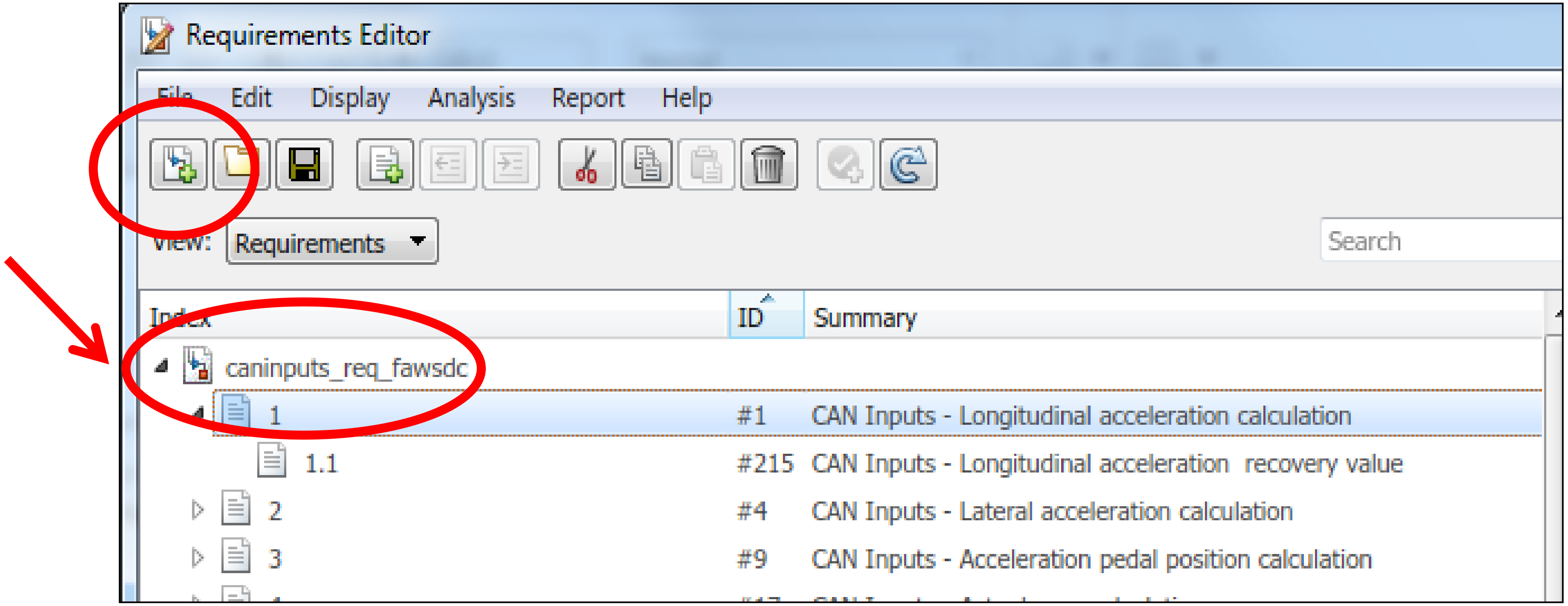
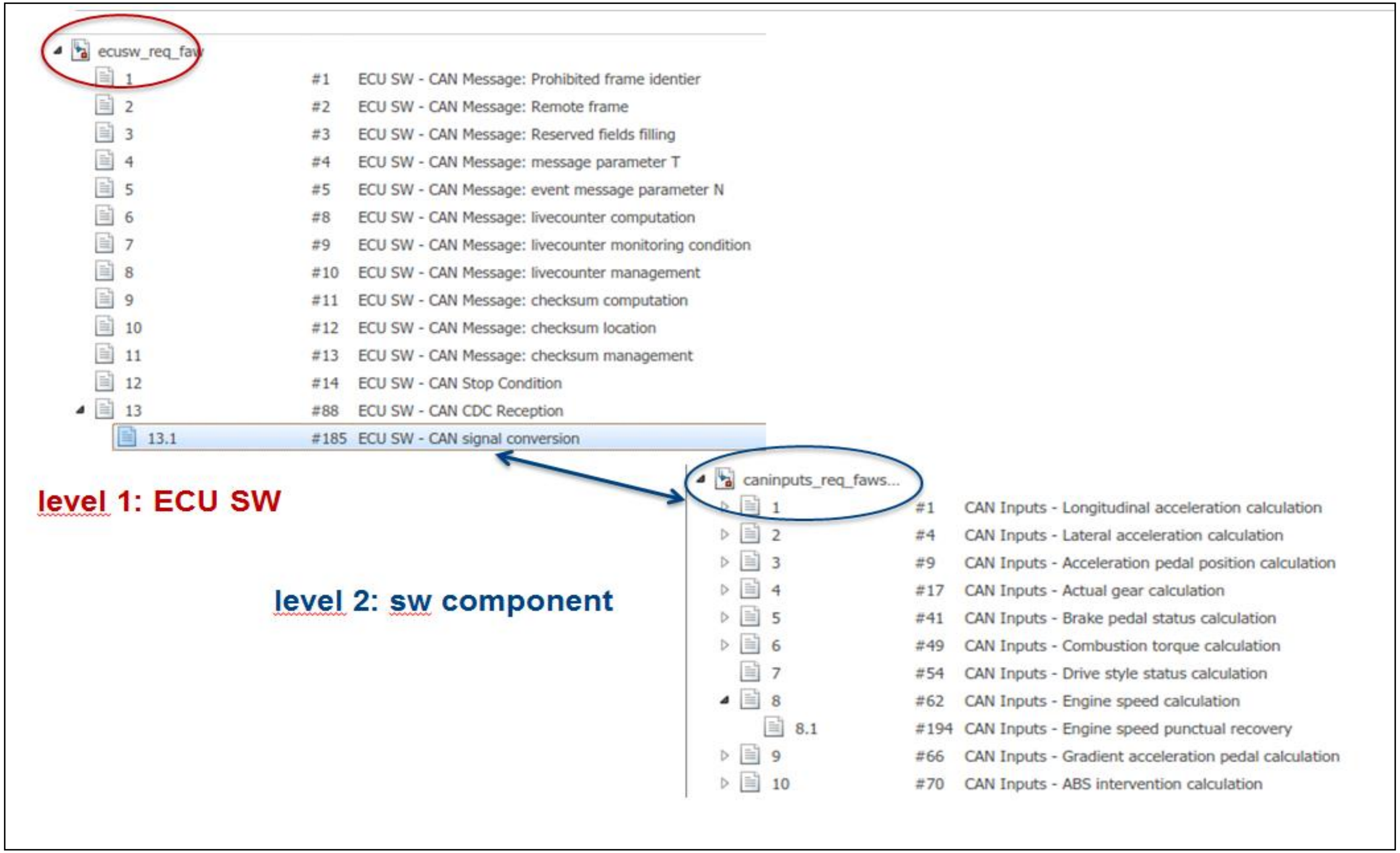


SW requirements specification

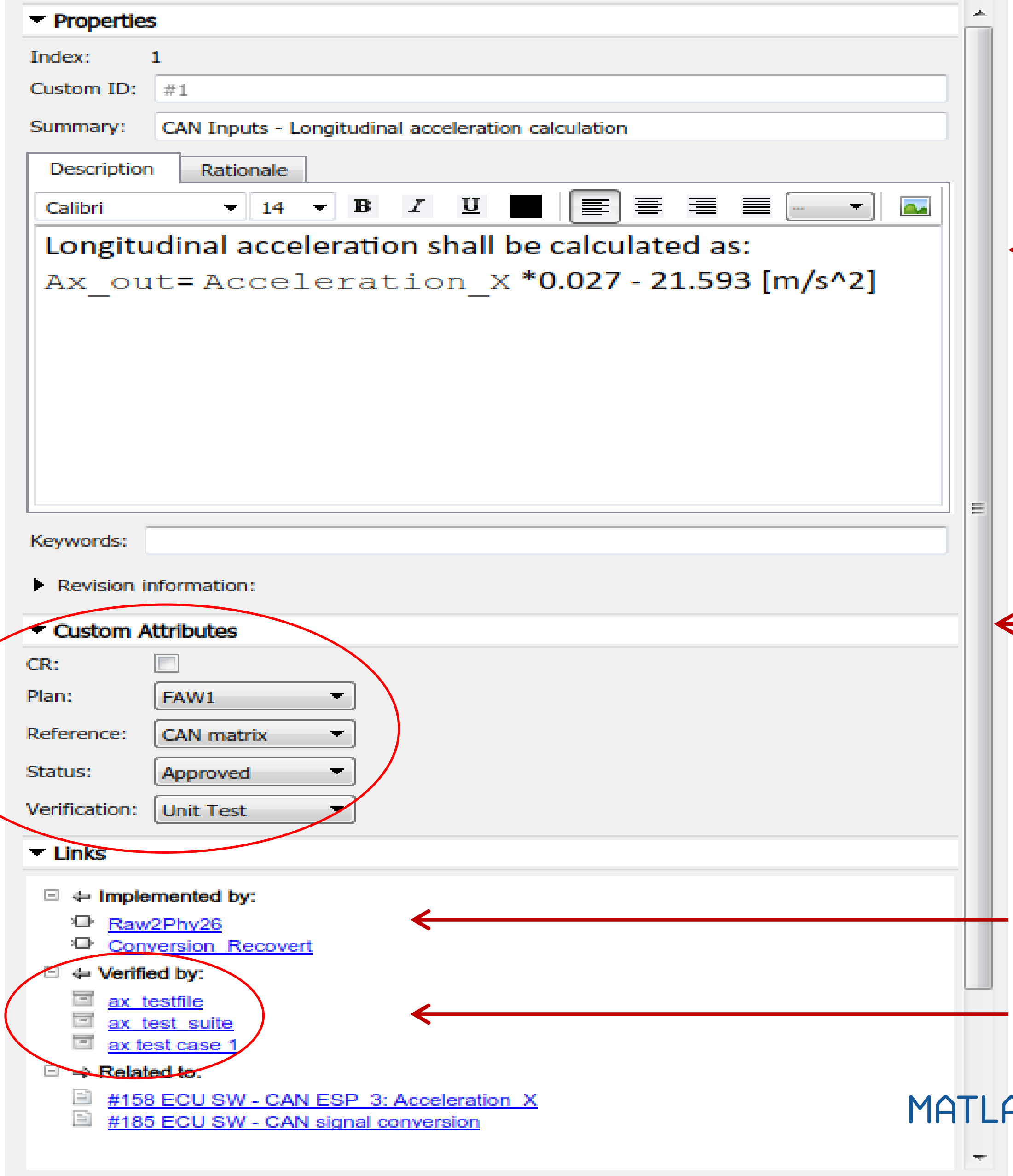
- Simulink Requirements is used for requirements specification and linking
- Several “Requirement sets” used for grouping requirements
- One requirement set for every SW Component



Requirements set: example



Bidirectional traceability: Simulink Requirements view



Requirement specification

Additional information

BIDIRECTIONAL LINKS

- link to implementation Simulink model
- link to verification harness model

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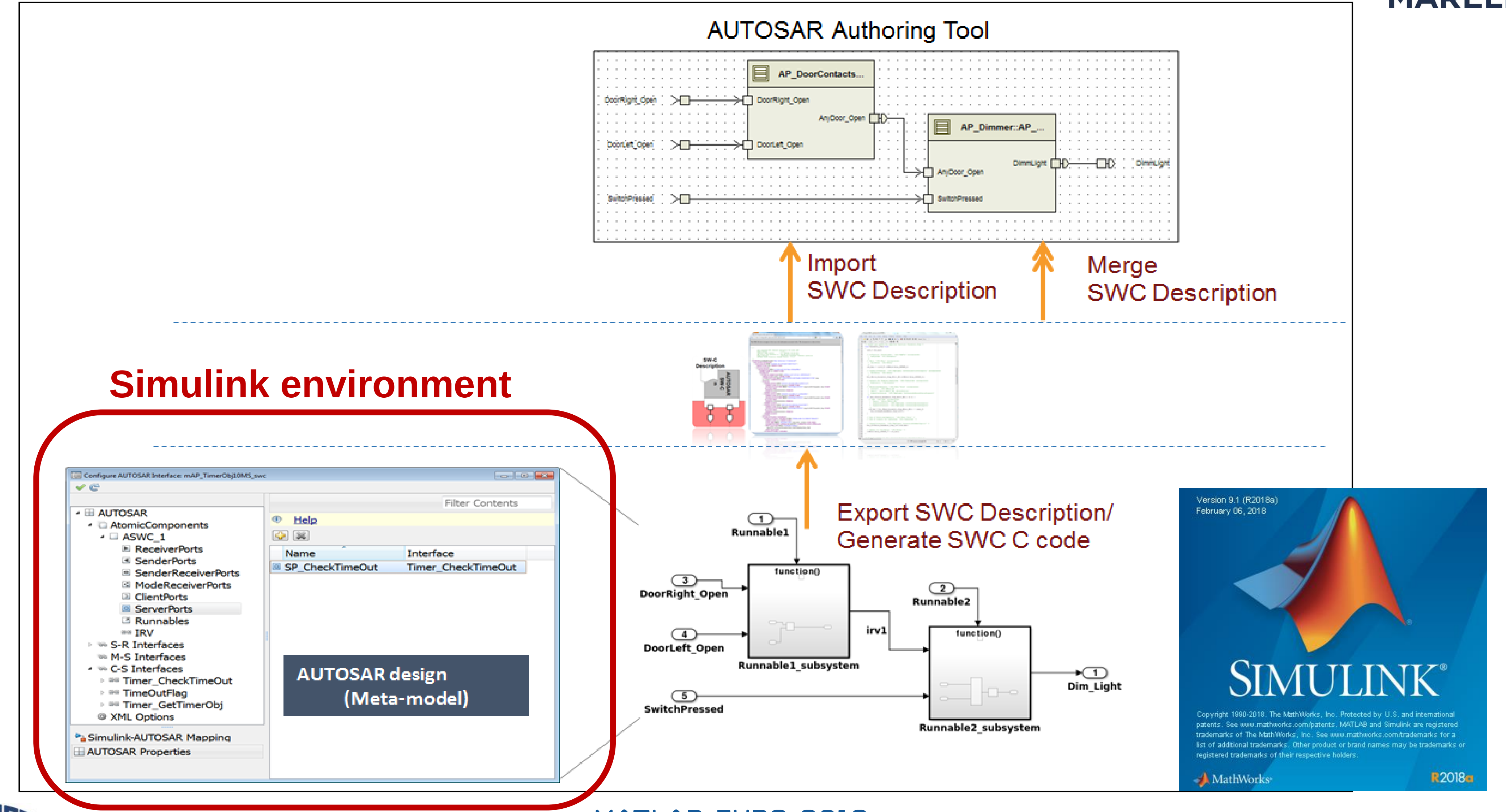
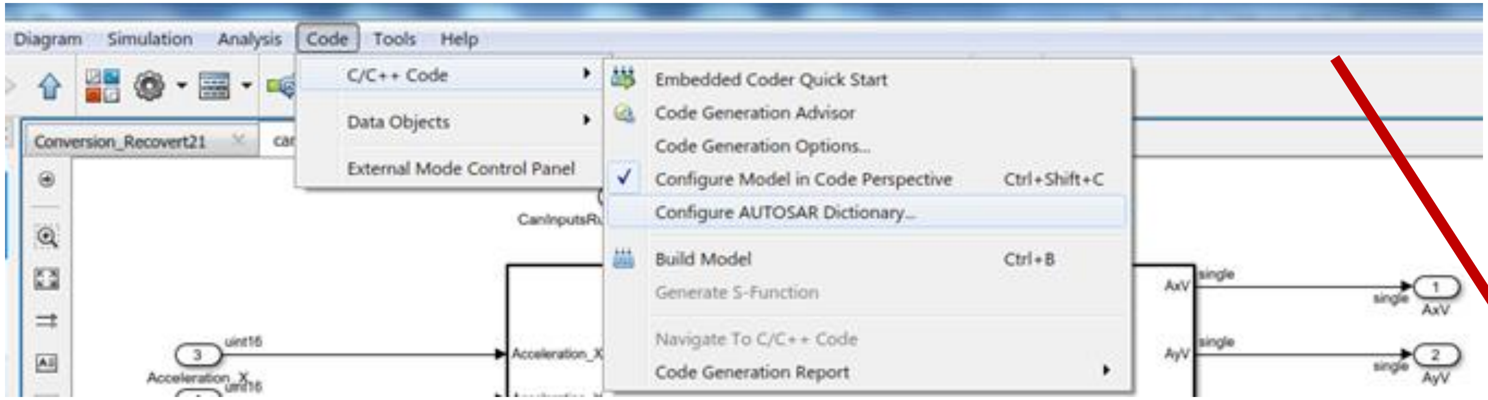
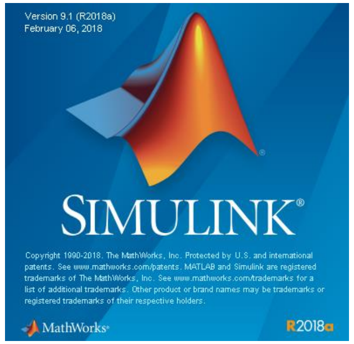
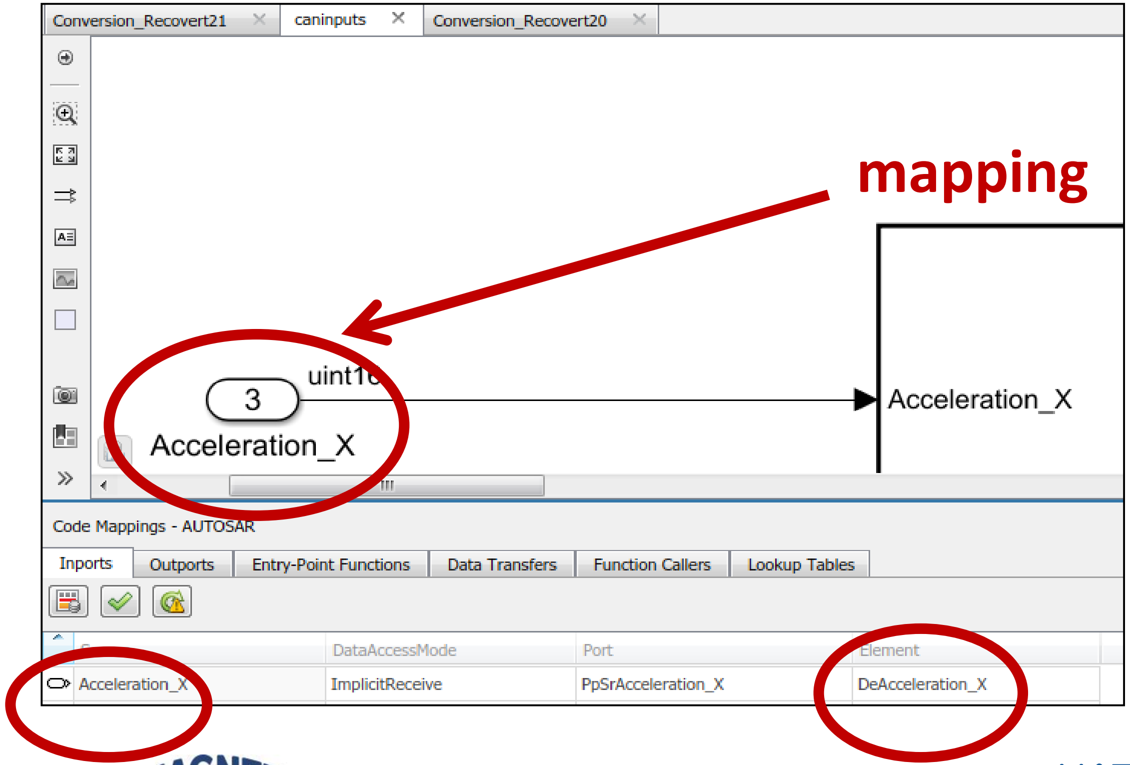
AUTOSAR INTERFACES design : BOTTOM-UP APPROACH

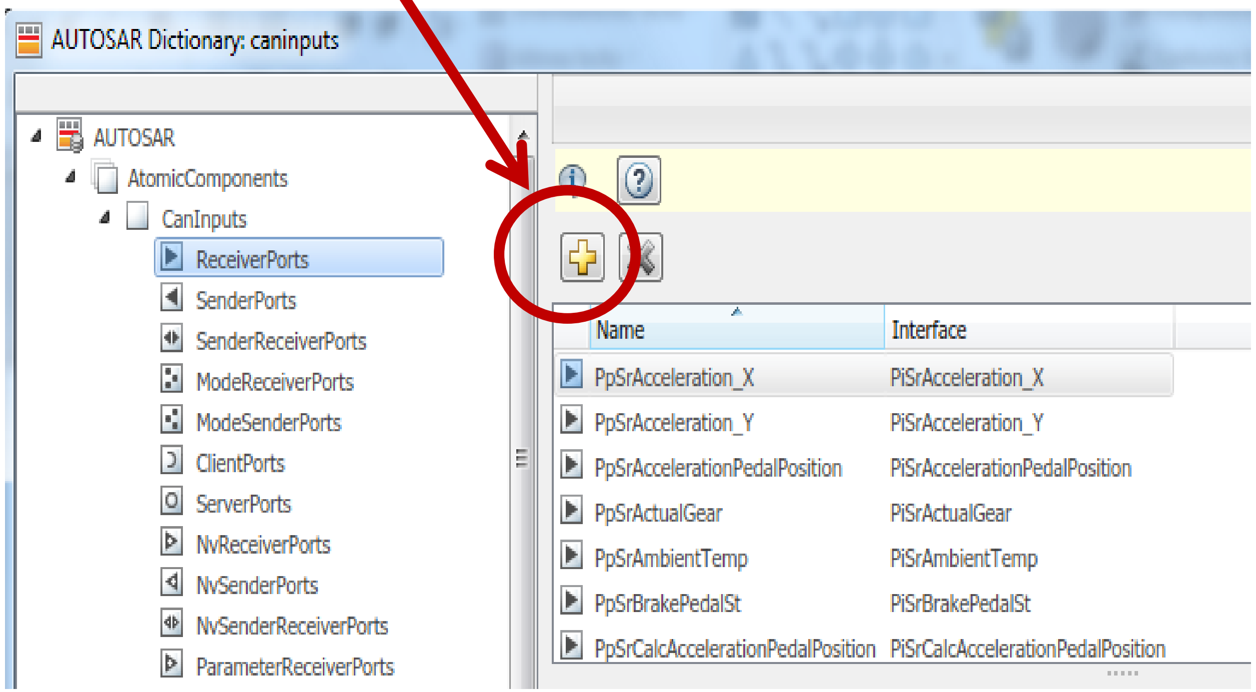


Adding and mapping an AUTOSAR PORT



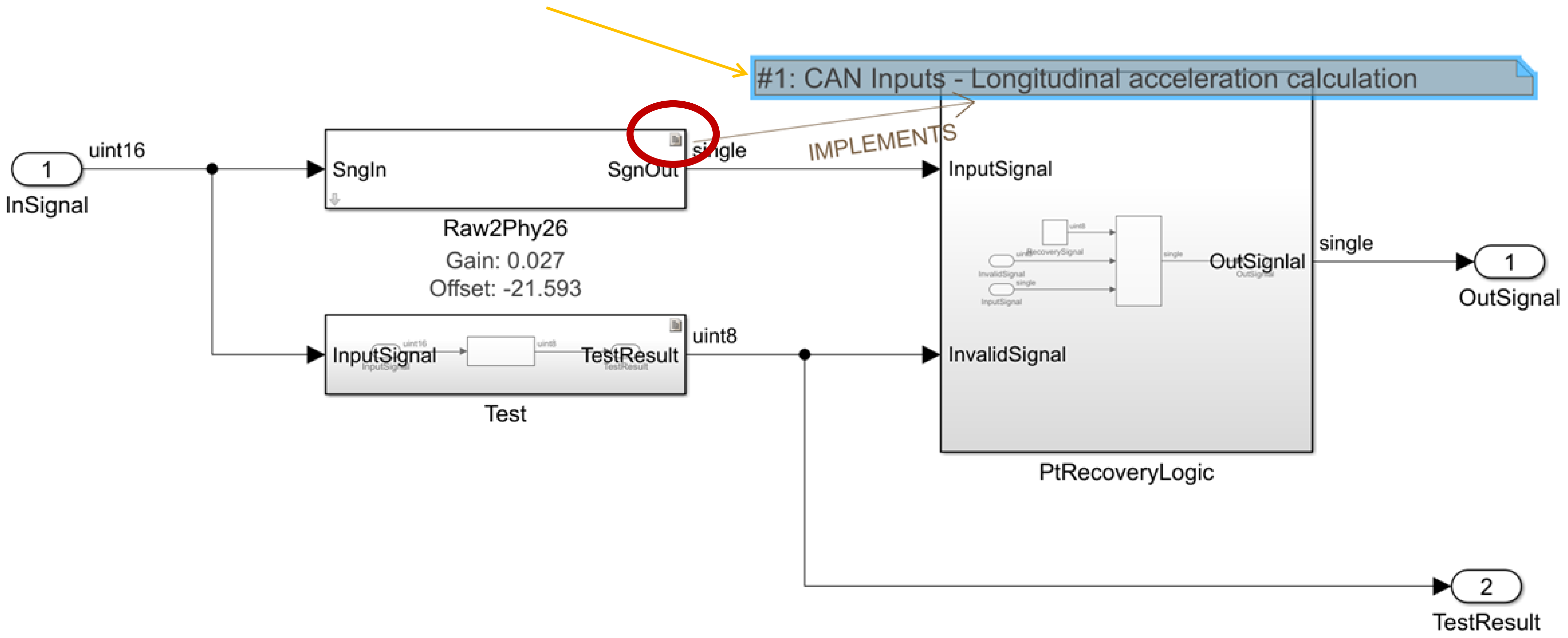






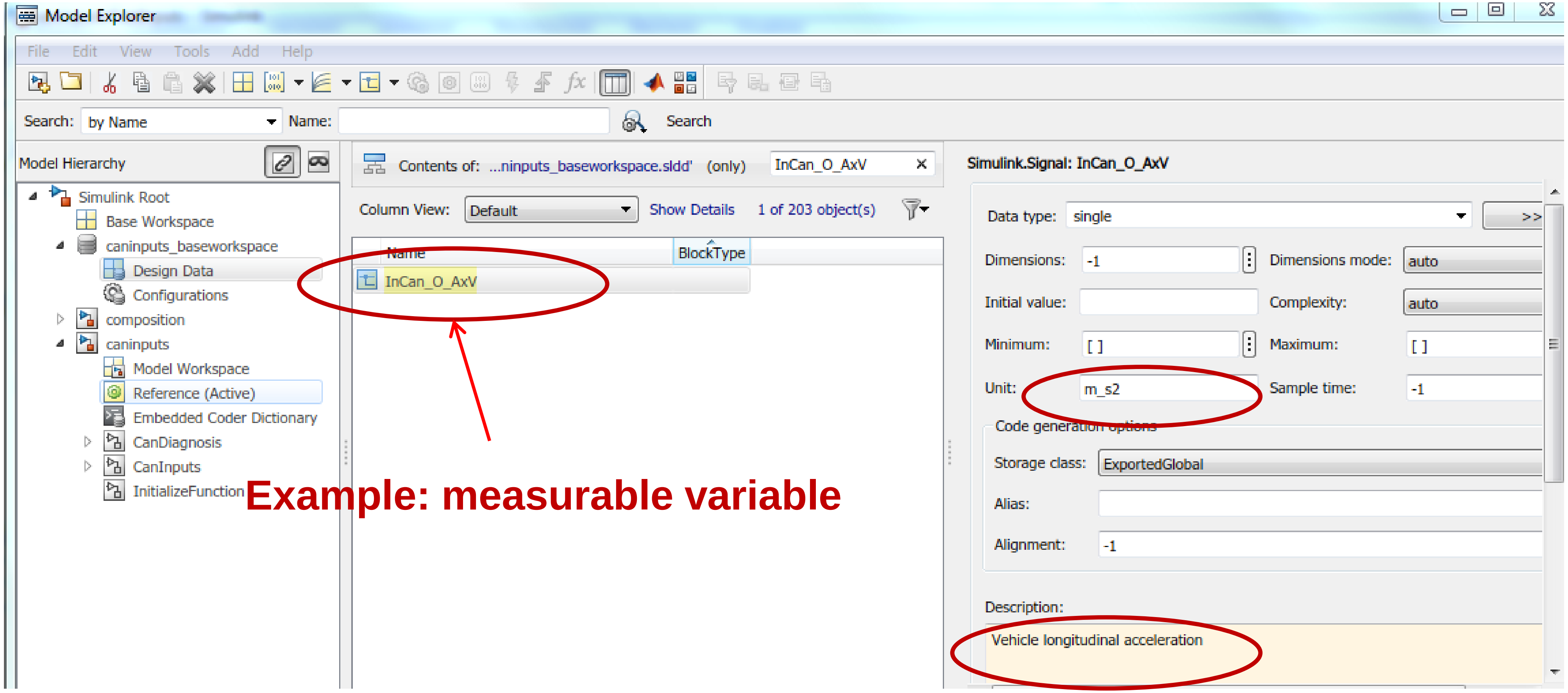
Detailed design

Bidirectional linking to implemented requirement



Data dictionary

Data Dictionary specifies: tuneable parameters, measurable variables, constants, bus object …



Model Advisor: Model check before code generation

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Modeling standards: MAAB

- MAAB/JMAAB Checks
  - Check for indexing in blocks
  - Check for prohibited blocks in discrete controllers
  - Check for prohibited sink blocks
  - Check positioning and configuration of ports
  - Check for matching port and signal names
  - Check whether block names appear below blocks
  - Check for mixing basic blocks and subsystems
  - Check for unconnected ports and signal lines
  - Check position of Trigger and Enable blocks
  - Check usage of tunable parameters in blocks
  - Check the display attributes of block names
  - Check display for port blocks
  - Check subsystem names
  - Check port block names
  - Check character usage in signal labels
  - Check character usage in block names
  - Check Trigger and Enable block names
  - Check orientation of Subsystem blocks
  - Check usage of Relational Operator blocks
  - Check font formatting
  - Check transition orientations in flow charts

Model Advisor Report - caninputs.slx

Simulink version: 9.1
System: caninputs

Run Summary

Pass	Fail	Warning	Not Run	Total
55	0	14	0	69

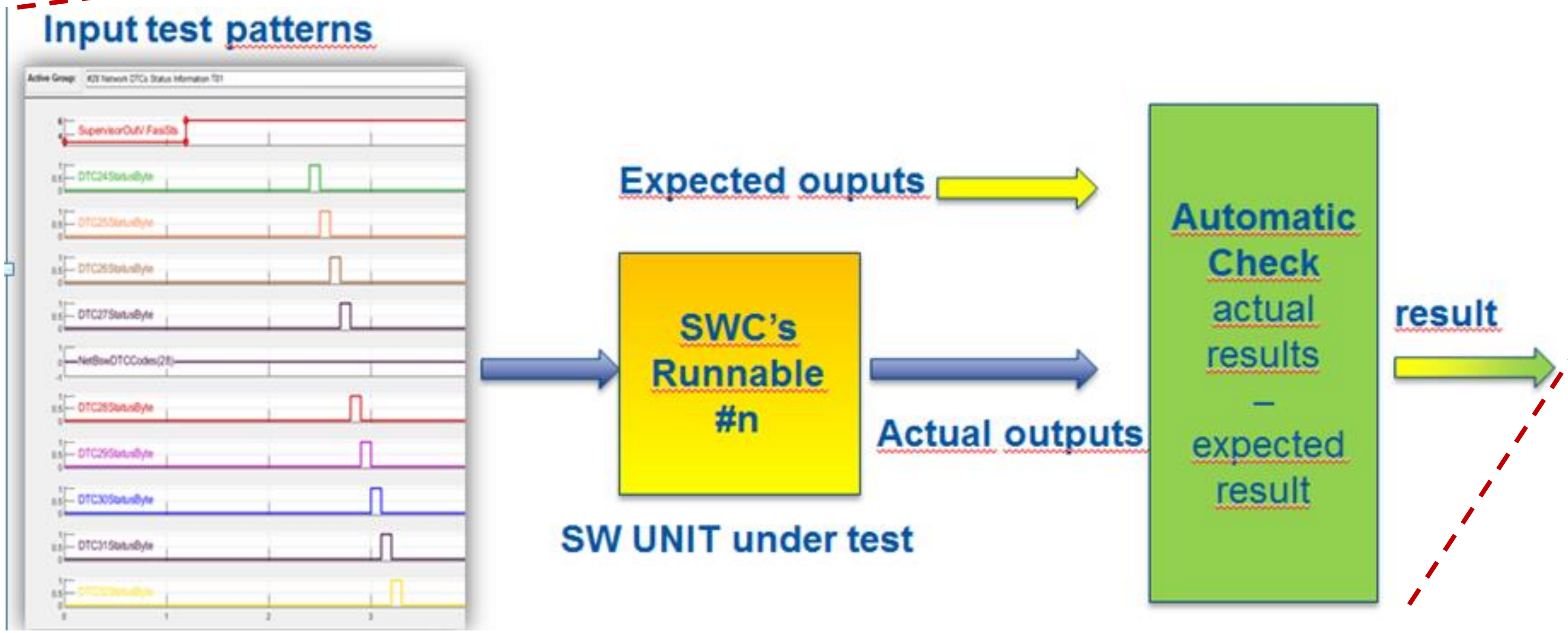
⊟ **MAAB/JMAAB Checks**

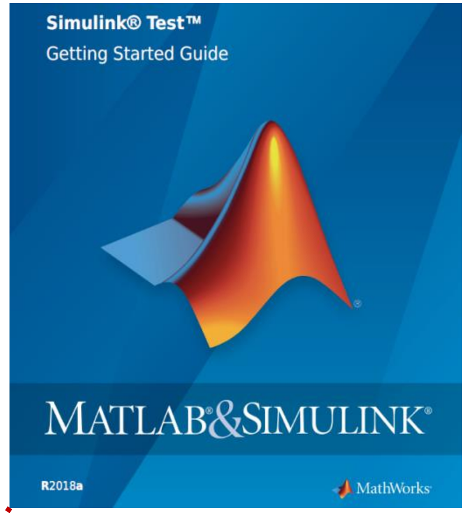
Automatic report

MAAB rules automatically checked

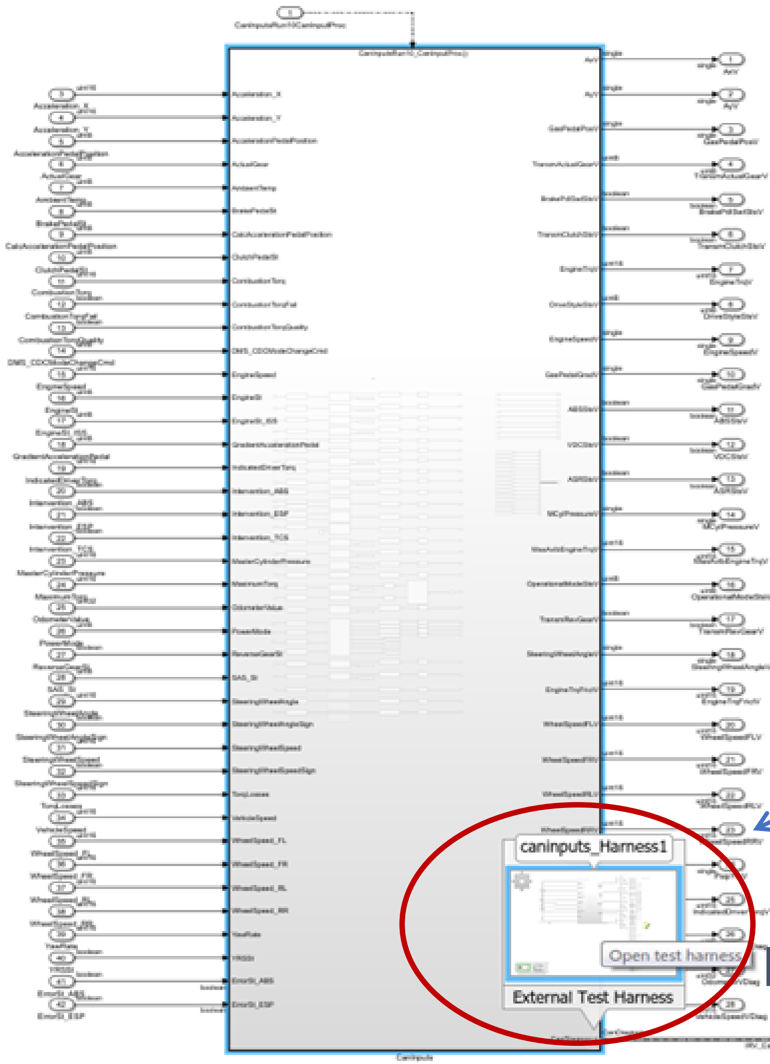
Unit testing: Harness Model

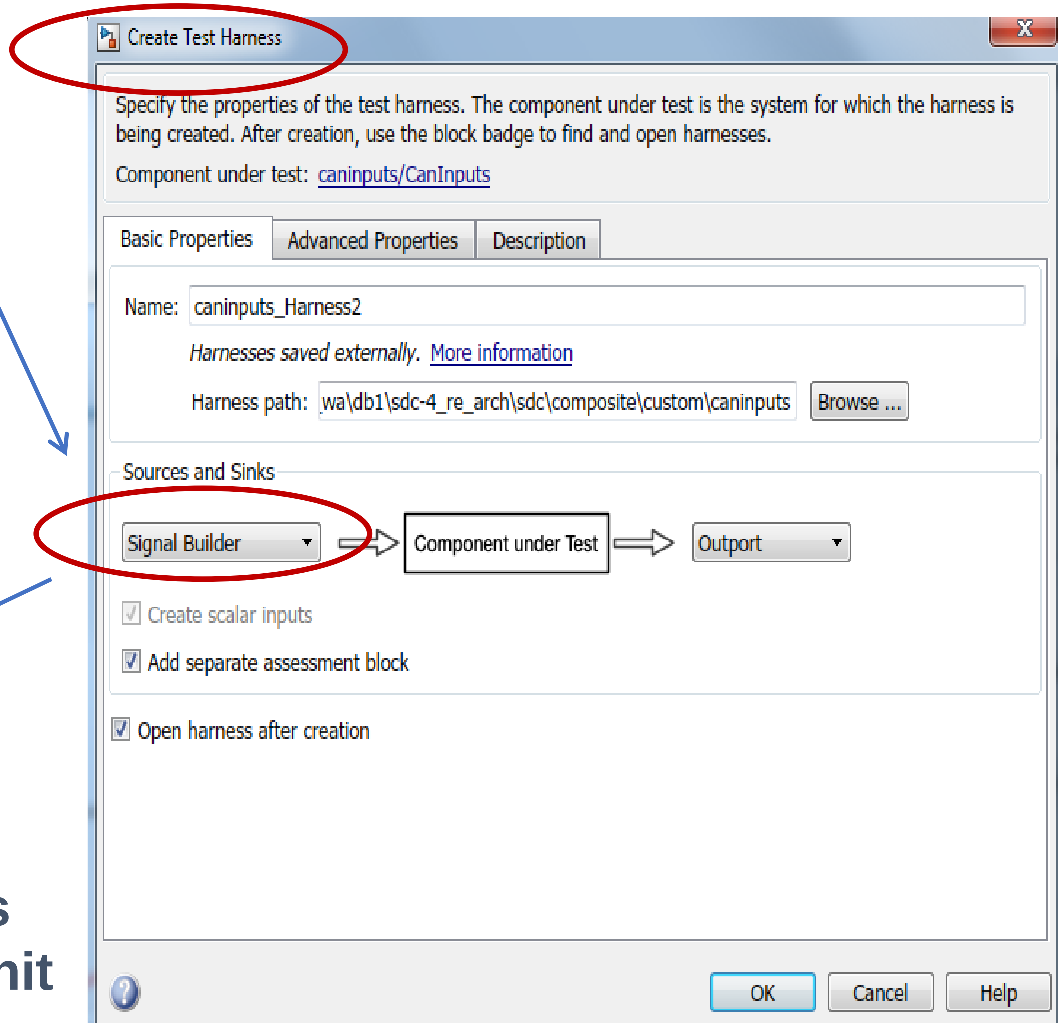
[Simulink Test](#) automatically generates
the HARNESS MODEL





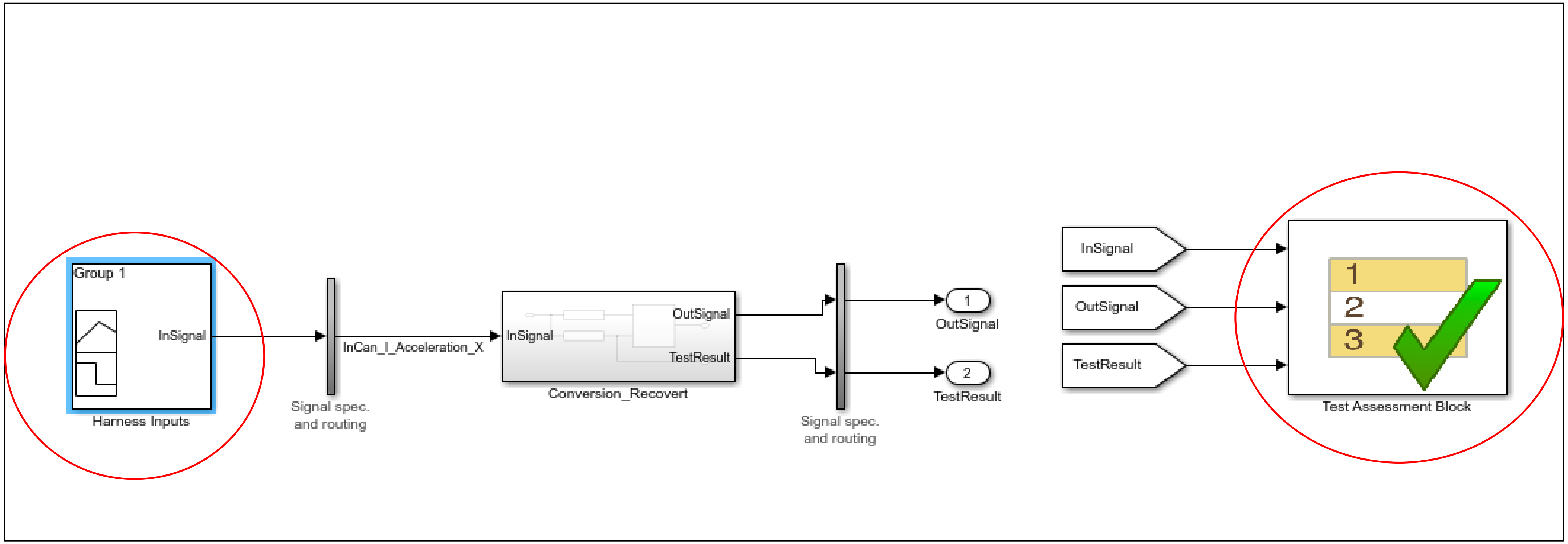
Creation of harness model





Harness model is linked to the SW unit

Harness Model: example

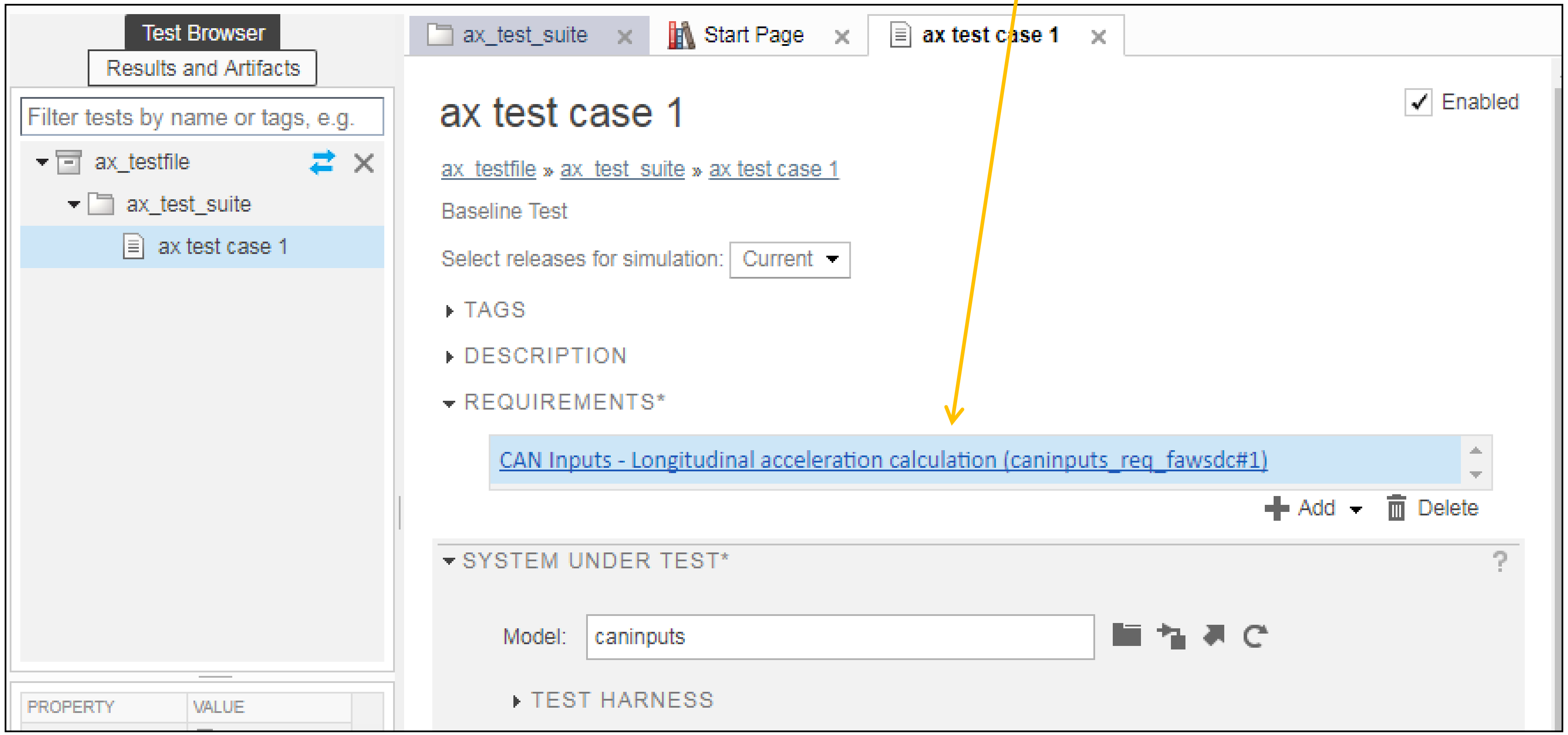


Input test patterns

Assessment block: expected result evaluation

Simulink Test - Test Manager

Link to requirement under test



Unit Testing status: example

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Index	ID	Summary	Implemented	Verified
caninputs_req_fawsdc				
1	#1	CAN Inputs - Longitudinal acceleration calculation		
1.1	#215	CAN Inputs - Longitudinal acceleration punctual recovery		
2	#4	CAN Inputs - Lateral acceleration calculation		
3	#9	CAN Inputs - Acceleration pedal position calculation		
4	#17	CAN Inputs - Actual gear calculation		
5	#41	CAN Inputs - Brake pedal status calculation		
6	#49	CAN Inputs - Combustion torque calculation		
7	#54	CAN Inputs - Drive style status calculation		
8	#62	CAN Inputs - Engine speed calculation		
9	#66	CAN Inputs - Gradient acceleration pedal calculation		
10	#70	CAN Inputs - ABS intervention calculation		
11	#76	CAN Inputs - ESP intervention calculation		
12	#81	CAN Inputs - TCS intervention calculation		
13	#86	CAN Inputs - Master cylinder pressure calculation		
14	#90	CAN Inputs - Maximum torque calculation		
15	#94	CAN Inputs - Operational mode calculation		
16	#100	CAN Inputs - Steering wheels angle calculation		
17	#104	CAN Inputs - Steering wheel angle sign calculation		
18	#109	CAN Inputs - Torque losses calculation		
19	#112	CAN Inputs - Front left wheel speed calculation		
20	#115	CAN Inputs - Front right wheel speed calculation		
21	#118	CAN Inputs - Rear left wheel speed calculation		
22	#121	CAN Inputs - Rear right wheel speed calculation		
23	#124	CAN Inputs - Yaw rate calculation		
24	#173	CAN Inputs - Clutch pedal status calculation		
25	#179	CAN Inputs - Driver torque calculation		
26	#204	CAN Inputs - WheeSpeed_FL and WheelSpeed_FR invalid		
27	#205	CAN Inputs - WheeSpeed_RL and WheelSpeed_RR invalid		
28	#206	CAN Inputs - WheeSpeed_FL and WheelSpeed_RR invalid		
29	#207	CAN Inputs - WheeSpeed_FL and WheelSpeed_RL invalid		
30	#208	CAN Inputs - WheeSpeed_FR and WheelSpeed_RL invalid		
31	#209	CAN Inputs - WheeSpeed_FR and WheelSpeed_RR invalid		
32	#210	CAN Inputs - WheeSpeed_FR, WheelSpeed_FL and WheelSpeed_RR invalid		
33	#211	CAN Inputs - WheeSpeed_FR, WheelSpeed_FL and WheelSpeed_RL invalid		
34	#212	CAN Inputs - WheelSpeed_RR, WheelSpeed_RL and WheelSpeed_FL invalid		

Simulink Requirements: overall view

Embedded Coder: code generation

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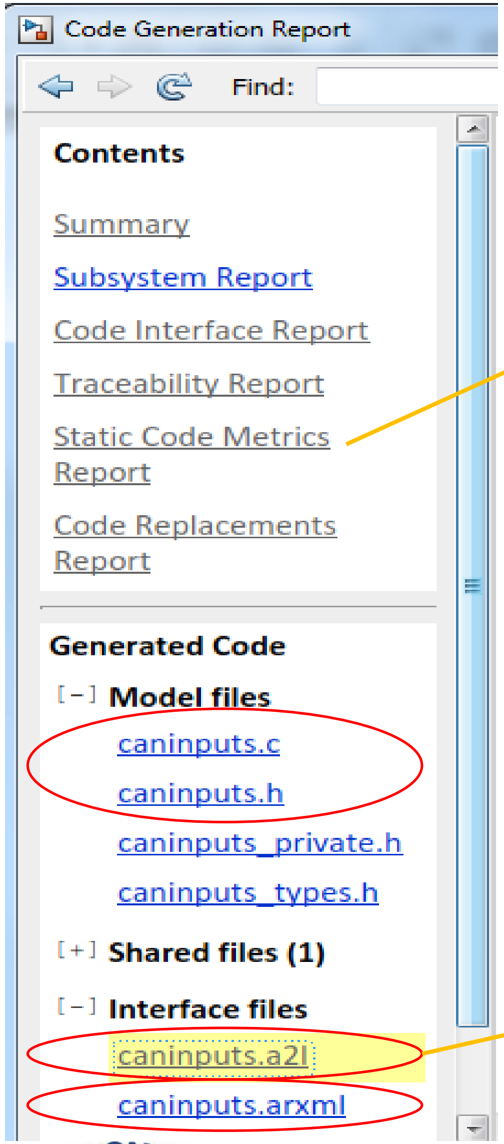
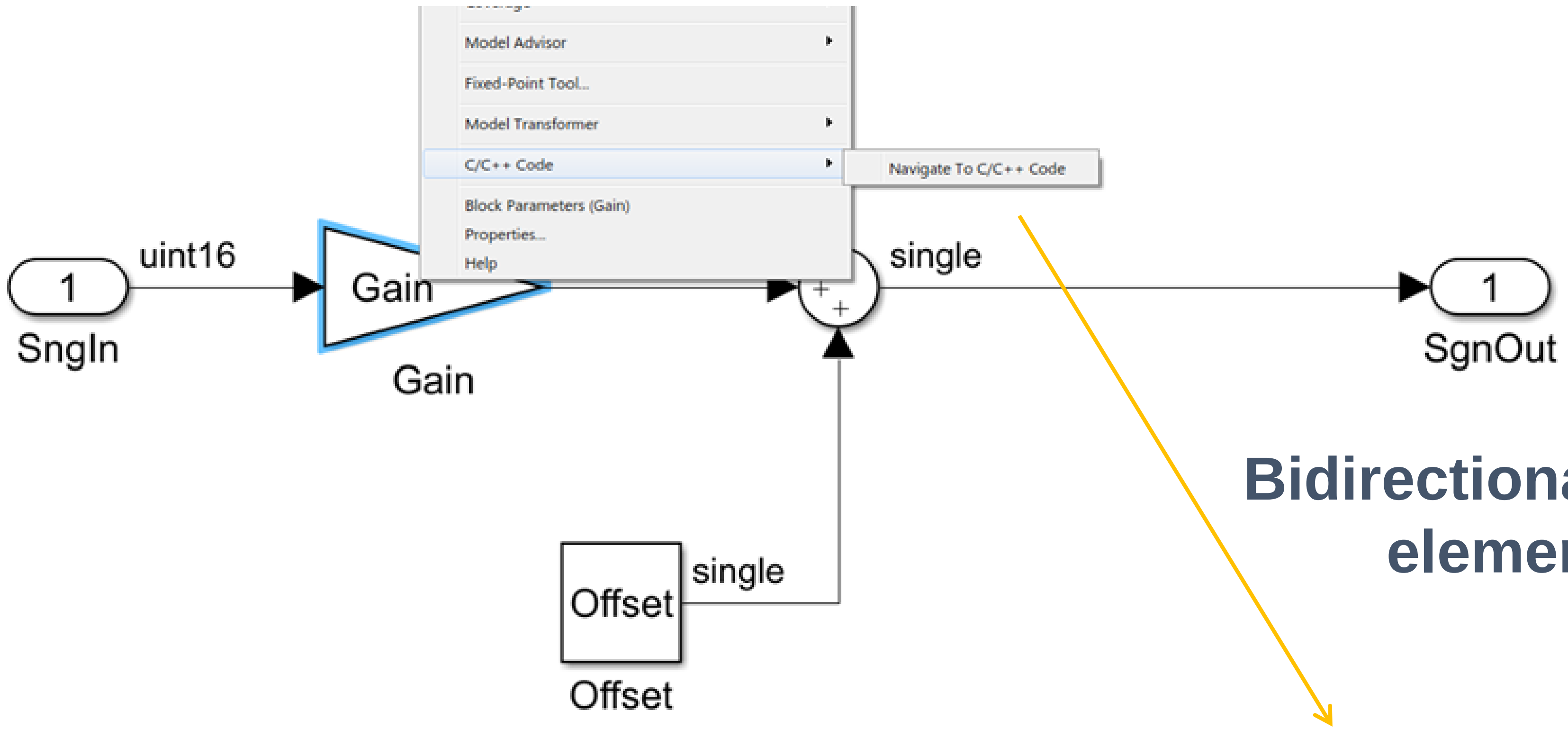


Function Name	Accumulated Stack Size (bytes)	Self Stack Size (bytes)	Lines of Code	Lines	Complexity
[+] CanInputsRun10CanInputProc	70	70	370	1,009	38
[+] CanInputsRun10CanDiagnosis	14	14	55	145	6
CanInputs_Runnable_Init	0	0	0	4	1

```
/begin MEASUREMENT
  /* Name                   */      InCan_O_AxV
  /* Long identifier        */      "Vehicle longitudinal acceleration"
  /* Data type              */      FLOAT32_IEEE
  /* Conversion method      */      caninputs_CM_single_m_s2
  /* Resolution (Not used)  */      0
  /* Accuracy (Not used)    */      0
  /* Lower Limit            */      -3.4E+38
  /* Upper Limit            */      3.4E+38
  ECU_ADDRESS                       0x0000 /* @ECU_Address@InCan_O_AxV@ */
```

Embedded Coder: code generation

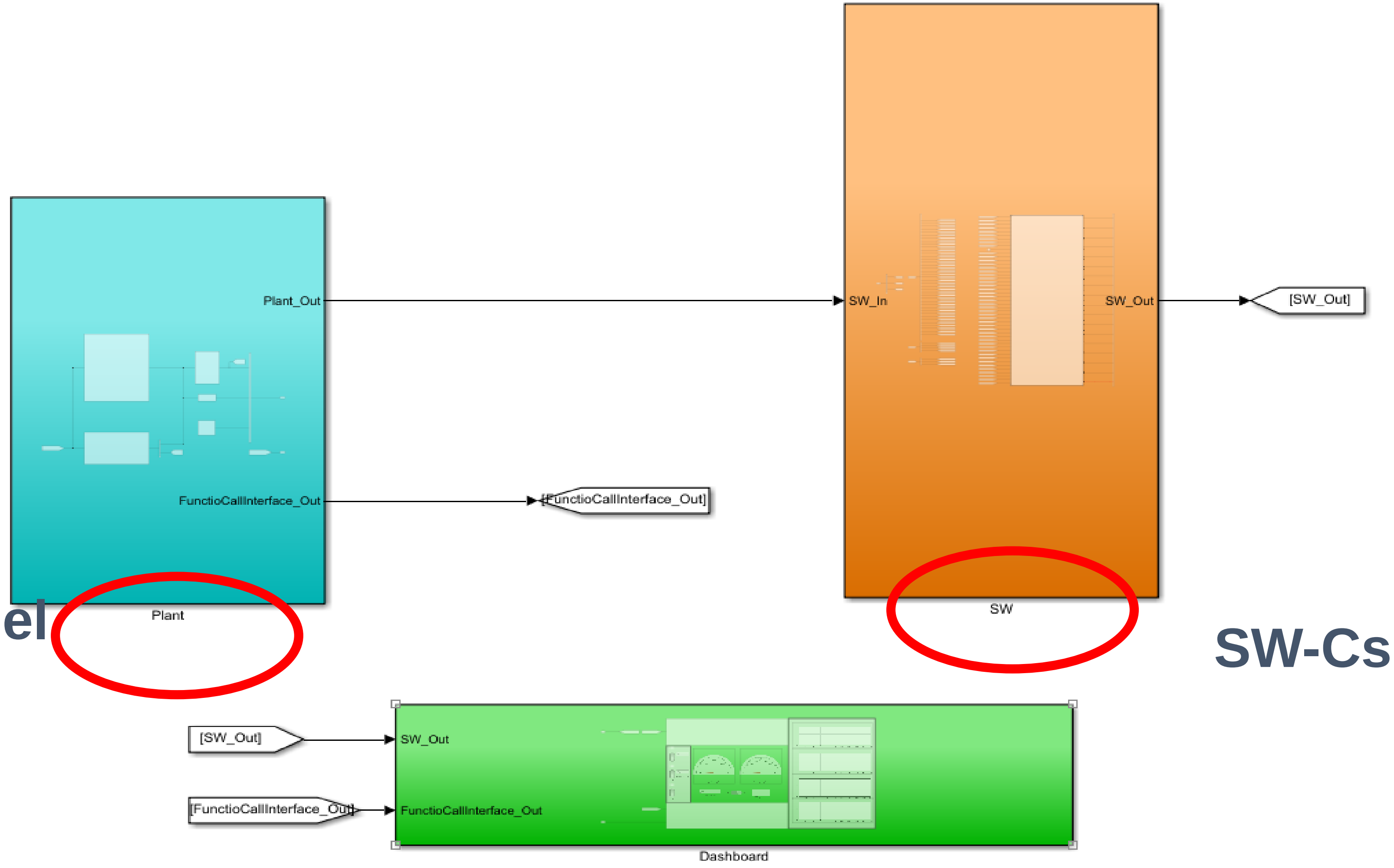


Bidirectional link between SW element and C-code

```
if (Can_rtb_Compare_dw > 0) {
  InCan_O_AxV = 0.0F;
} else {
  InCan_O_AxV = 0.0269999504F * (real32_T)InCan_I_Acceleration_X + -21.593F;
}
```

MIL testing

Testing of the whole application layer: level 1 requirements



Plant model

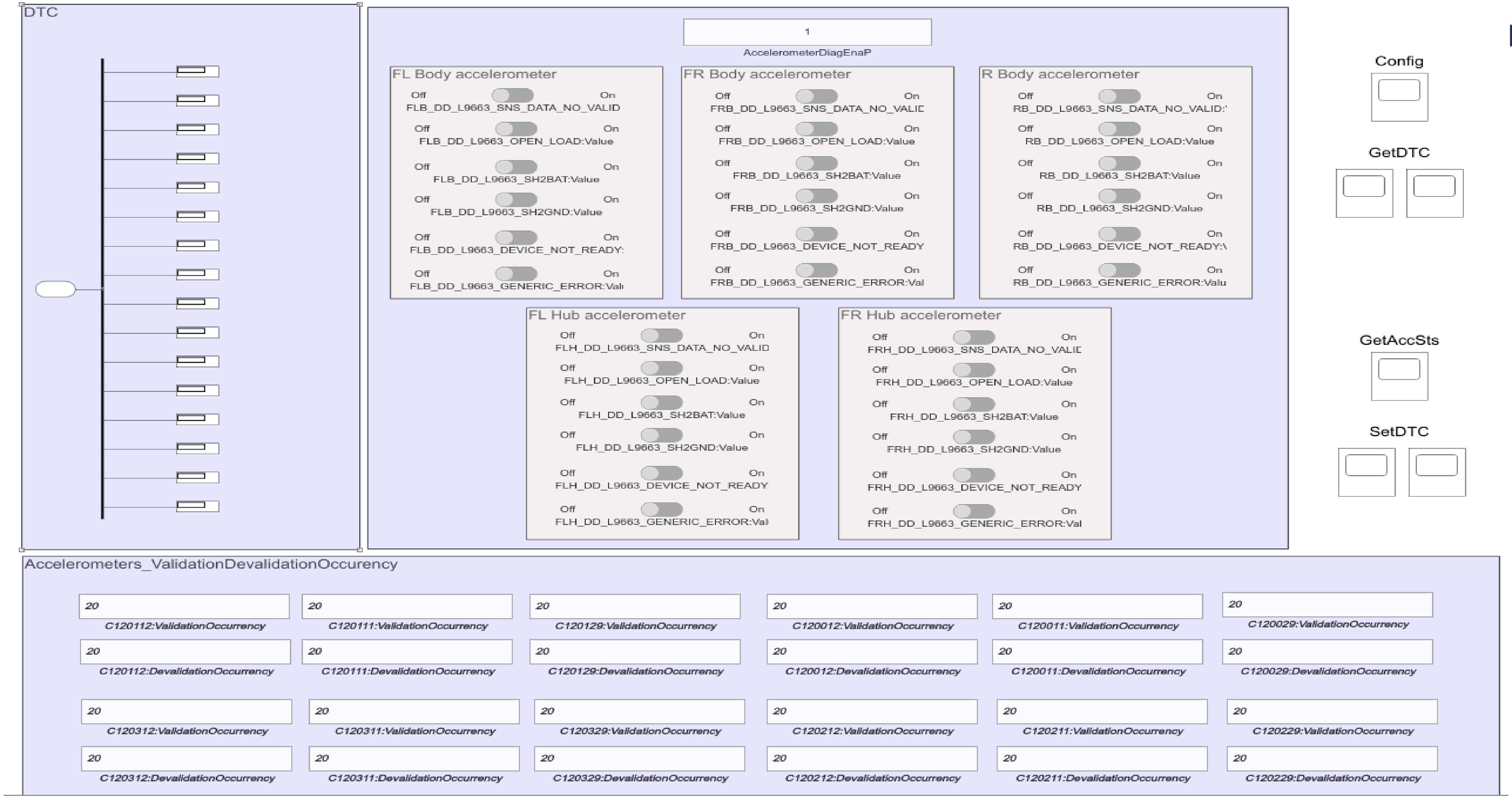
SW-Cs composition

MIL testing

- Function callers blocks are used for simulating AUTOSAR S/R and C/S ports
- It is not needed to configure models for MIL
- Same models used for code generation are able to run even in MIL environment

AUTOSAR's interface simulation

MIL testing example: fault injection



Achievements and Outlook

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- **ECU SW put in production in April 2019**

- **18 months of development**

- **Technical, organizational and business results.**
  - The standardization of development environment and the “bottom up” approach has increased the cross-competence inside the SW team
  - No need of other tools for AUTOSAR architecture design as regards to application SWCs
  - One single data base for requirements, software models, code and testing results
  - Cutting of time needed for documentation since it is automatically generated

Achievements and Outlook

- Integrated toolchain based on Simulink environment for SW development made traceability easier to achieve

- Use of the tool's standard features only, avoiding customization (scripts) made the toolchain lean and easier to update

- Bottom – up approach made AUTOSAR SW components design quicker

Forward-looking plans

- Use of new and upcoming MathWorks tools as System Composer for
  - ➢System design in accordance with A-SPICE requirements

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THANK YOU FOR YOUR ATTENTION