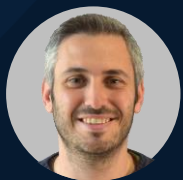


I V E C O • G R O U P

Accelerating development of VCU software of IVECO eDaily with Model-Based Design

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(He/Him)

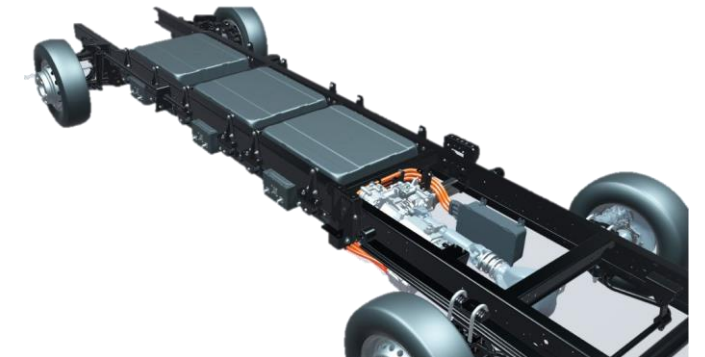
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Agenda

- Context – eDaily and eVECOP
- Software architecture
- SW Component and Data Dictionary
- SW Development process
- Verification and Validation workflow
- Continuous Integration / Continuous Testing Pipeline

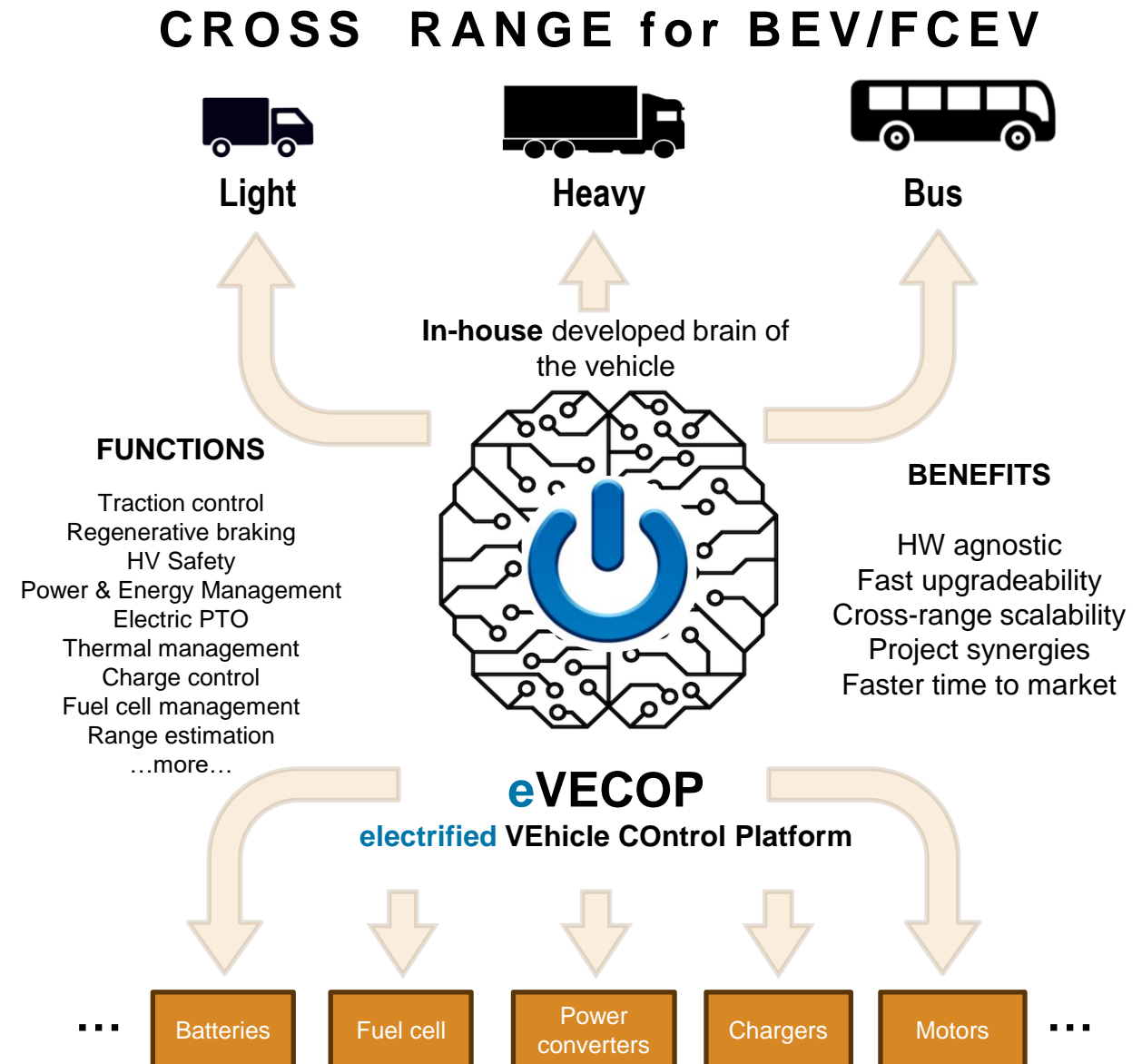
Context – eDaily

- Electric version of the Daily, IVECO's Light Commercial Vehicle
- Launched in 2022
- Up to 400 Km of range, with 1 to 3 batteries
- Up to 7,2 tons of gross vehicle weight
- Up to 3,5 tons of towing capacity
- Up to 15 Kw of electric power take off
- 140 Kw eMotor power

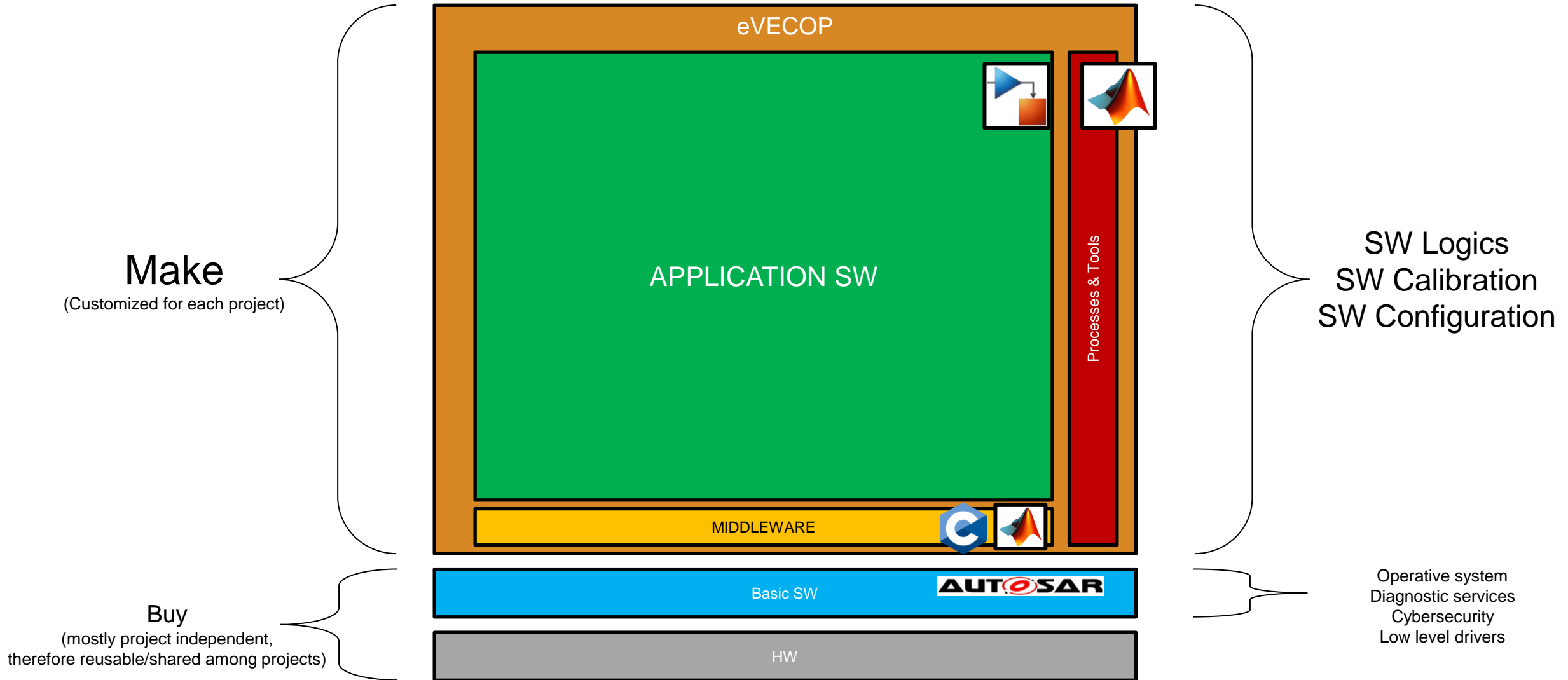


Context – VCU and eVECOP

- The VCU (Vehicle Control Unit) is the central brain of the vehicle
 - Center of a Star based control System
 - Having full control over its SW is strategic
- The application SW of the VCU is a SW **platform** called **eVECOP** designed in-house
 - Easily reusable over different vehicle types
 - About 90 functions implemented
 - 90% designed in Model Based Design using Mathworks tools

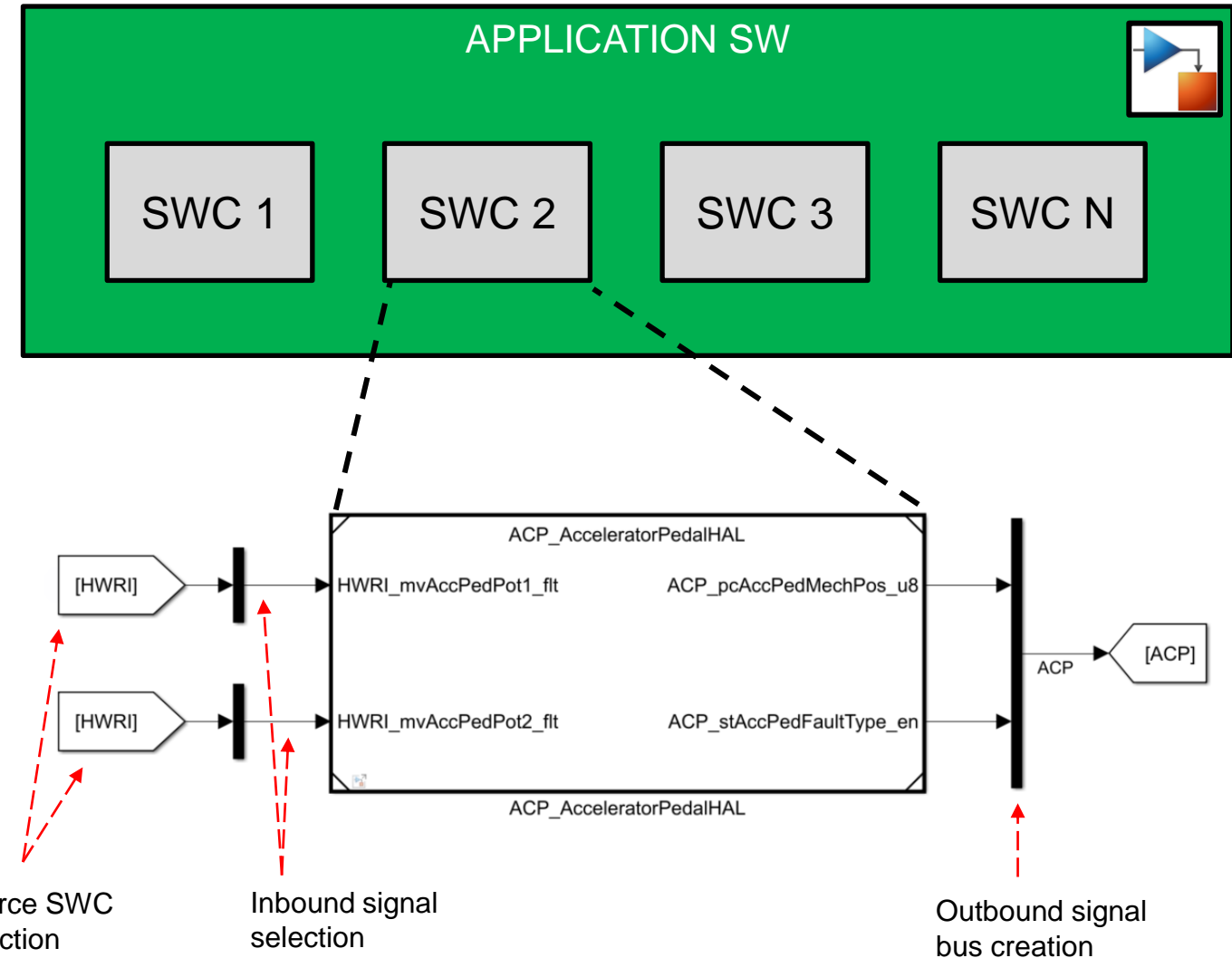


VCU high level architecture



Application SW structure

- One Simulink integration model, which references multiple SW Components as **Model References**
 - Each model in a separated file
 - Easier versioning
 - Faster code generation
 - Self consistent
 - Matlab toolboxes (such as Simulink Design Verifier, Embedded Coder, etc...) don't need additional context-related information
- All the output signals of a SWC are grouped in a bus
- All the input signals are extracted from the bus of the SWC which produces them
- Very agile integration model



SW Component

- The integration model belongs to a **Simulink Project...**
- ... where each SWC is a **folder** added to our **Simulink Project path**
 - All required folders gets added to the path automatically when opening the Simulink Project
 - Easier dependency tracking
 - Integration with versioning tools
- Each SWC Folder contains
 - Documentation
 - Requirements
 - Tests (Model-In-the-Loop)
 - Data dictionary
 - The SWC model
- A clear naming convention is used

Current Folder		
	Name ^	SVN
+	RNG_RangeCalculation	■
+	SCS_SystemCurrentStatus	●
+	SLS_SpeedLimitSelector	●
+	SPL_SpeedLimiter	●
+	SRS_SystemRequestedStatus	●
+	STAT_Statistics	●
+	SYN_Synchronization	●
+	TBX_TransferBoxHAL	●
+	THE_ThermalManagement	■
+	doc	●
+	req	○
+	test	●
	THE_dataDictionary.slidd	■
	THE_ThermalManagement.six	○
+	TMR_TorqueMerge	●
+	TQF_TorqueRequestFilter	●
+	TQL_TorqueLimitation	●
+	TQM_TorqueMode	●
+	TQS_TorqueSplit	●

Data Dictionary

- A repository of data relevant for a Simulink model

Design Code Generation

Value: 15

Data type: int8

Dimensions: [1 1]

Minimum: []

Unit: degC

Description: Battery temperature above which the heater is turned off.

Design Code Generation

Storage class: ConstVolatile

Custom attributes

HeaderFile: VMU_param_8bit.h

DefinitionFile: VMU_param_8bit.c

Owner:

Preserve array dimensions

Identifier:

Alignment: -1

Parameters **Signals**

Column View: Dictionary Objects

Name
THE_degBatTempHVHoff_i8_c
THE_cPtcCabinTrgTemp_ft
THE_LUTCompPwr_It
THE_HeaterbuttonStatus_ent

Enumerations **Lookup Tables**

Enumerated Type: THE_HeaterbuttonStatus_ent

Design Code Generation

Enumeration

Name	Value
NOT_PRESSED	0
PRESSED	1

BRRH_stBRControlSetpointMode_en_ov POWER_DOWN

Design Code Generation

Data type: single

Dimensions: 1

Initial value: 0

Minimum: -50

Unit: °C

Description: PTC cabin trigger temperature

Design Code Generation

Storage class: ExportToFile

Custom attributes

HeaderFile: VMU_variables_32bit.h

DefinitionFile: VMU_variables_32bit.c

Owner:

Preserve array dimensions

Identifier:

Alignment: -1

Simulink.LookupTable: THE_LUTCompPwr_It

Table and Breakpoints Code Generation

Number of table dimensions: Breakpoints specification:

1 Explicit values Support tunable size

Table

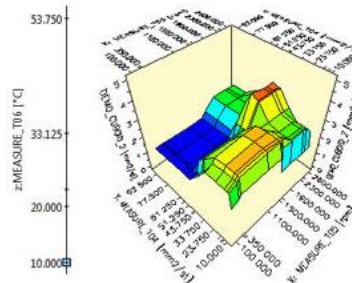
Field name	Data type	Dimensions	Min	Max	Unit	Description
1 THE_kwEacPwLim...	single	[4 1]	[]	[]	kW	Compressor powe...

Breakpoints

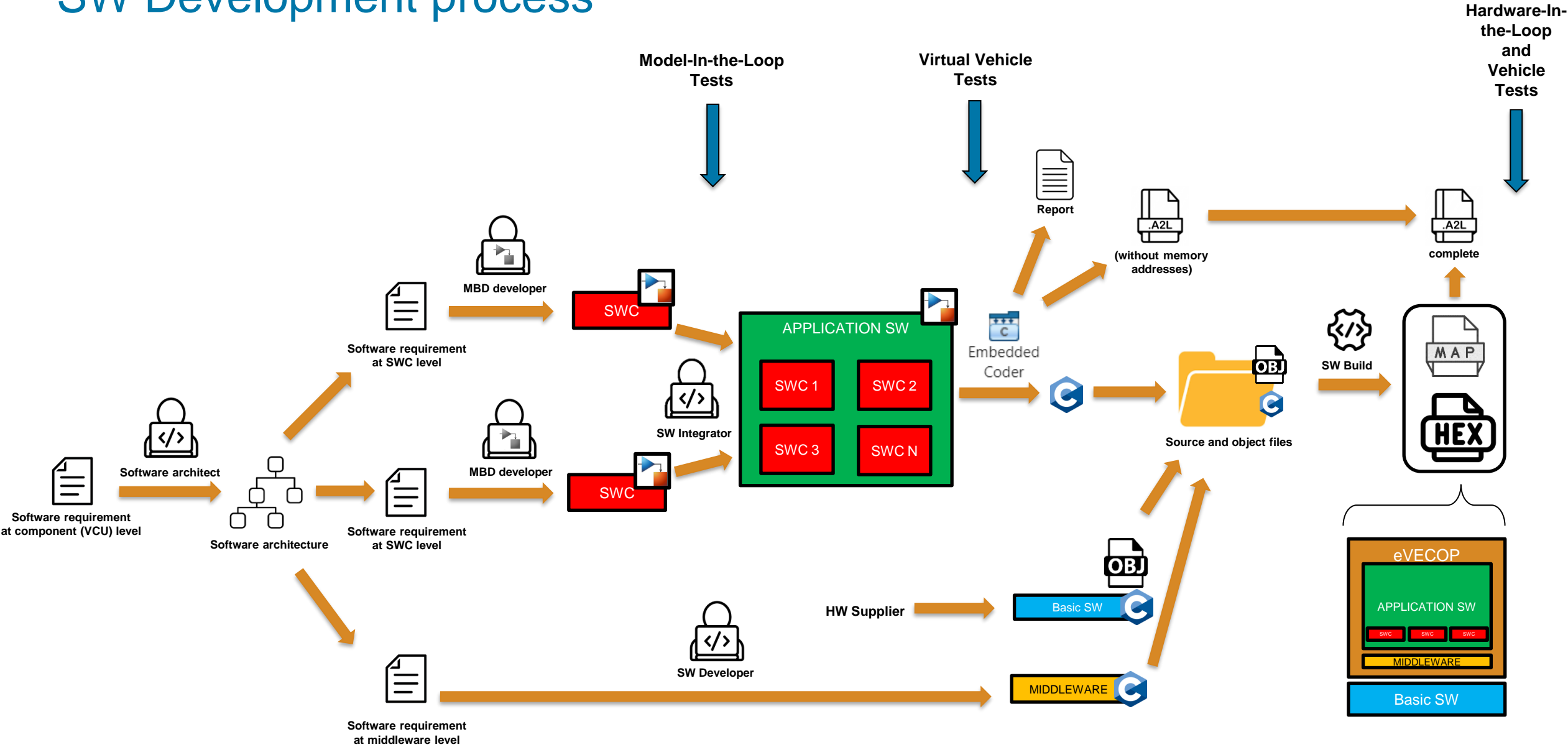
Field name	Data type	Dimensions	Min	Max	Unit	Tunable size name	Descript
1 THE_rpmEleCom...	uint16	[4 1]	[]	[]	rpm	N1	Compressor :

THE_kwEacPwLim_ft Type MATLAB expression and press Enter

kW	rpm
1	4e+3
2	5e+3
3	7e+3
4	8e+3



SW Development process



Verification & Validation workflow

VIRTUAL
Model-In-the-Loop
 / Software

VIRTUAL
Virtual vehicle

SEMI-VIRTUAL
Hardware-In-the-Loop

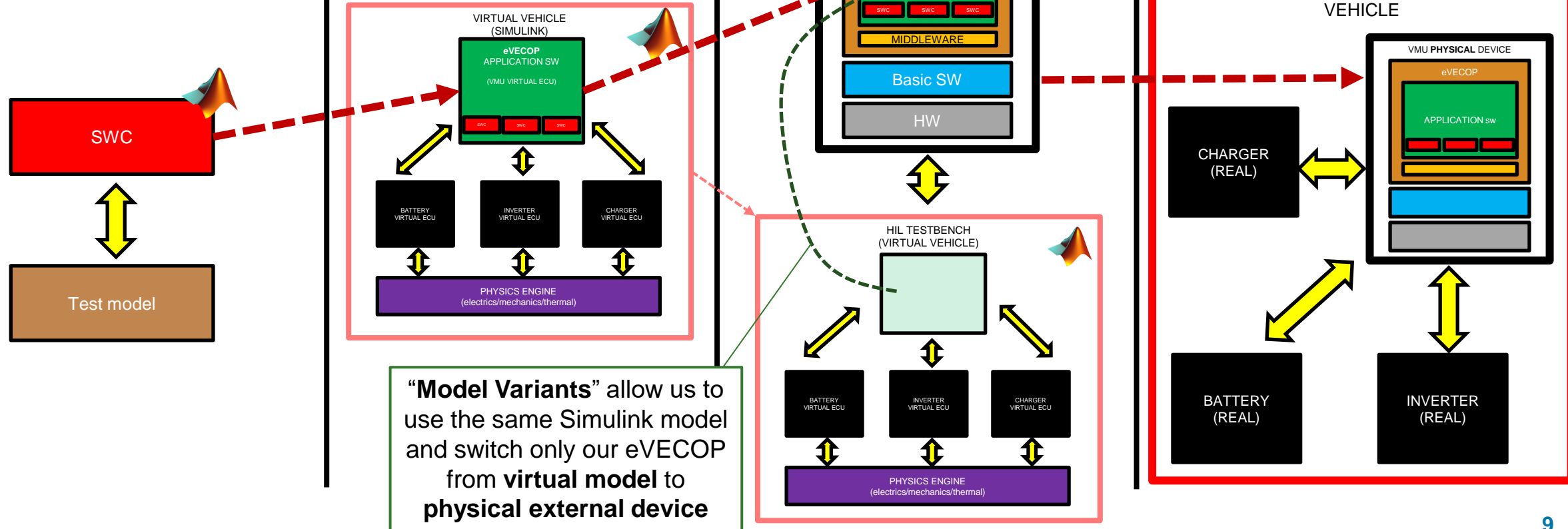
REAL
Vehicle validation
 (or real integration bench)

One single software component (SWC) is tested using a test model which provides stimulus and reads outputs of the SWC

The whole integrated application SW is tested in a virtual vehicle

The SW is flashed on the physical VMU and tested as a standalone component on a testbench.

The VMU is tested on the vehicle or on a physical integration bench.

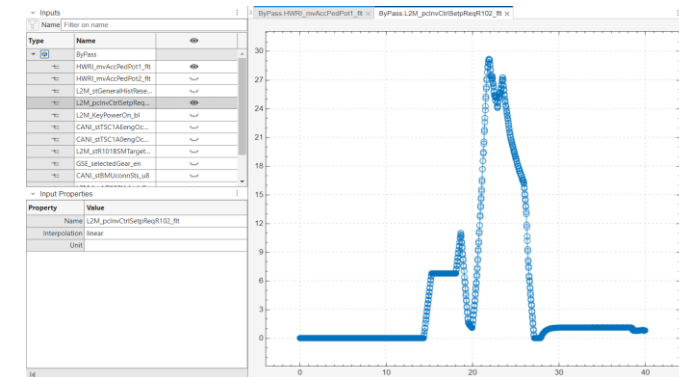
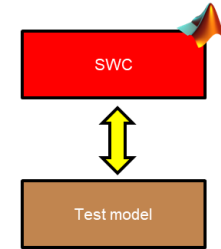


“Model Variants” allow us to use the same Simulink model and switch only our eVECOP from **virtual model** to **physical external device**

V&V workflow – MIL/SIL

- With **Simulink Test**, we create **Test Harnesses** around each SWC
- **Signal Editor** is often our preferred choice to create the input signals
 - Full control on input values
 - Possibility to import and modify real world data.
- Test results are evaluated with two methods:
 - **Logical and Temporal Assessments** to quickly verify responses to triggers
 - **Test Assessment block** when more complex verifications are needed.
- **Simulink Coverage** is employed to assess the completeness of the test scenario and to filter out irrelevant elements with coverage filters

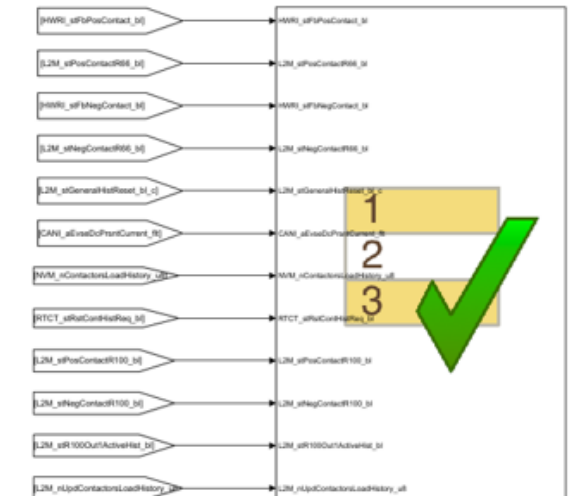
VIRTUAL
Model-In-the-Loop



▼ AGGREGATED COVERAGE RESULTS

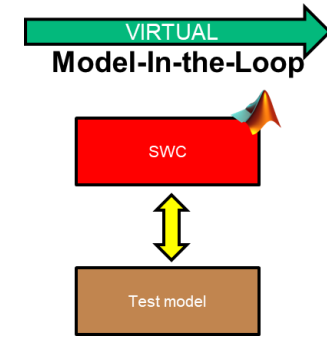
Create a coverage report from coverage results to justify or exclude missing coverage. The filters and updated coverage values will be displayed with this result.

ANALYZED MODEL	REPORT	COM...	DECISION	CONDITION	EXECUTION
L2M_6_Level2Monitor/L2M_6_Level2Monitor/SSR_131		14	100%	100%	100%
L2M_6_Level2Monitor/L2M_6_Level2Monitor/SSR_15		27	100%	100%	100%
L2M_6_Level2Monitor/L2M_6_Level2Monitor/SSR_37		17	100%	100%	100%
L2M_6_Level2Monitor/L2M_6_Level2Monitor/SSR_55		6	100%	100%	100%
L2M_6_Level2Monitor/L2M_6_Level2Monitor/SSR_58		10	100%	100%	100%
L2M_6_Level2Monitor/L2M_6_Level2Monitor/SSR_62		12	100%	100%	100%
L2M_6_Level2Monitor/L2M_6_Level2Monitor/SSR_63		8	100%	100%	100%



V&V workflow – MIL/SIL

- We use **Simulink Check** to verify the compliance of the model with modeling guidelines provided by Mathworks for compliancy with ISO26262.
 - Suggests recommended actions to solve problems
- An additional final check is performed with **Simulink Design Verifier**
 - Check for design errors such as dead logics
 - Automatic test case creation to achieve full test coverage
- At the end of the process, **Simulink Report Generator** generates a comprehensive report, summarising the results.



Summary

Name	Outcome	Duration (Seconds)
Results: 2024-Feb-22 15:26:15	56 ✓	92.008
<ul style="list-style-type: none"> Test Case SSR 108 SSR 108 ByPass SSR 108 Limits SSR 108 TimeOut 	3 ✓	4.214
<ul style="list-style-type: none"> SSR 109 ByPass SSR 109 OutOfLimits SSR 109 TimeOut 	3 ✓	4.163
<ul style="list-style-type: none"> SSR 108 ByPass SSR 108 Limits SSR 108 TimeOut 	3 ✓	4.163
<ul style="list-style-type: none"> SSR 109 ByPass SSR 109 OutOfLimits SSR 109 TimeOut 	3 ✓	4.163

Model Advisor Report - L2M_Level2Monitor.slx

Simulink version: 10.5
 System: L2M_Level2Monitor
 Treat as Referenced Model: off

Model version: 3.203
 Current run: 23-Feb-2024 10:06:44

Run Summary

Incomplete	Failed	Warning	Justified	Passed	Not Run	Total
0	0	29	0	70	13	112

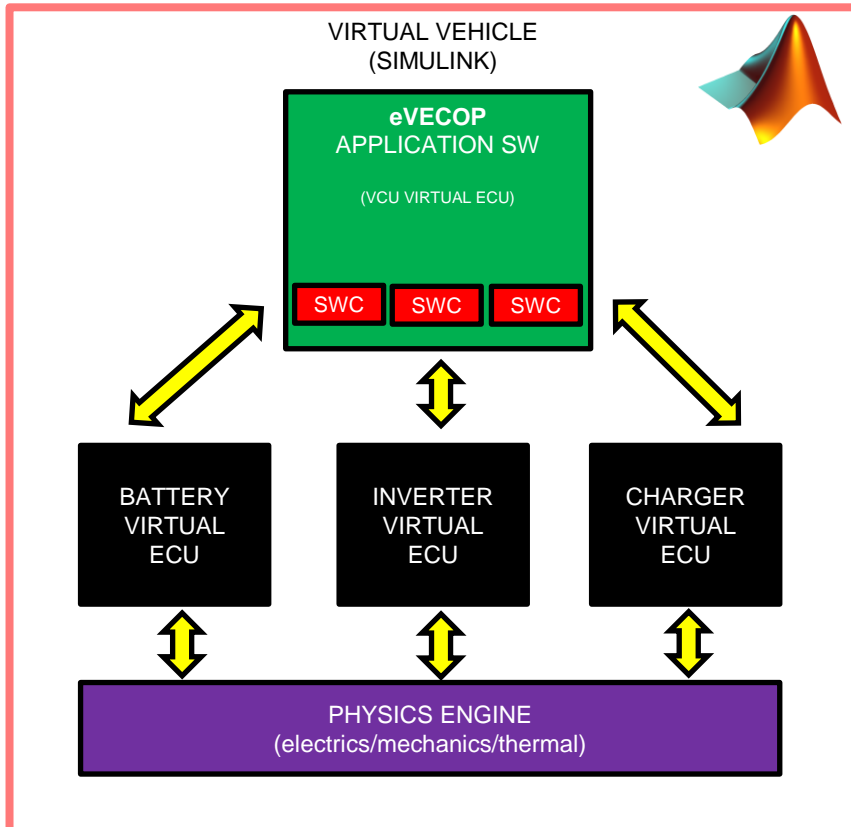
Aggregated Coverage Results

Analyzed Model	Sim Mode	Comple	Decision	Conditio	Executio
		xity	n	n	n
L2M 2 Level2Monitor/L2M 2 Level2Monitor/SR 49	Normal	6	100%	100%	100%
L2M 2 Level2Monitor/L2M 2 Level2Monitor/SR 36	Normal	6	100%	100%	100%
L2M 2 Level2Monitor/L2M 2 Level2Monitor/SR 24	Normal	10	100%	100%	100%
L2M 2 Level2Monitor/L2M 2 Level2Monitor/SR 31	Normal	16	91%	97%	100%
L2M 2 Level2Monitor/L2M 2 Level2Monitor/SR 12	Normal	10	94%	78%	100%

V&V workflow – Virtual Vehicle



The whole integrated application SW is tested in a virtual vehicle



- The virtual vehicle simulates both
 - Physics (Mechanics/electrics/thermal*)
 - **Simscape** libraries used
 - E/E systems logics (Virtual ECU)
- The VCU logics are the **real** ones
- The other Virtual ECUs are designed according to requirements
- Perform on the virtual vehicle the **vast majority of** (preliminary) **software validation**
- Advantages
 - No need for special HW costs/spaces
 - Let developers be **autonomous** in this preliminary validation and iterate releases fast
 - Capable to detect 80% of SW integration problems
 - Virtual tests can be part of a build pipeline

The screenshot displays the Simulink GUI for a vehicle control system simulation. The interface is organized into several key sections:

- Simulation Controls:** Located at the top, featuring a toolbar with 'Simulate', 'Step Back', 'Continue (Paced)', 'Step Forward', and 'Stop' buttons. It also includes a 'Pause Time (sec)' field and 'Animation speed' settings.
- Model Browser:** A sidebar on the left listing various model components such as 'PAAS_PaasManagement', 'PDUM_PowerDistributionUnitM', and 'VirtualSensor_AccPot'.
- HYDROGEN Panel:** Displays fuel cell power (0 kW), battery current (1.4544e+03 A), and fuel cell status (OFF). It includes 'REFUEL' buttons and 'EV_mode' controls.
- KEY Panel:** Shows ignition status (OFF/ON) and cranking status (OFF/ON).
- MASSA VEICOLO Panel:** Displays vehicle mass (3500 kg) and road slope (0%).
- GEAR Panel:** Features a gear selector (D, N, R) and driving modes (Normal, Regenerative, Power).
- DRIVE Panel:** Contains a speedometer (0 kph), tachometer (0 rpm), and accelerator/brake pedal indicators.
- RECHARGE Panel:** Shows AC/DC Recharge Mode (0) and plug status (On/Off).
- HVAC Panel:** Includes heater and temperature controls.
- BATTERY Panel:** Displays SOC % (50%) and emergency buttons (EmergencyButton, EmeButton).
- REMOTE REQUEST Panel:** Shows mode selection (Normal, Regen, Eco, Power).
- CRUISECONTROL Panel:** Features cruise control on/off and SET/Reset buttons.
- SPEED LIMITER Panel:** Shows speed limit requirements (0 km/h).
- INLET FEEDBACKS Panel:** Displays status for various lamps and icons.

The bottom status bar indicates the simulation is 'Paused' at 'T=0.020*'.

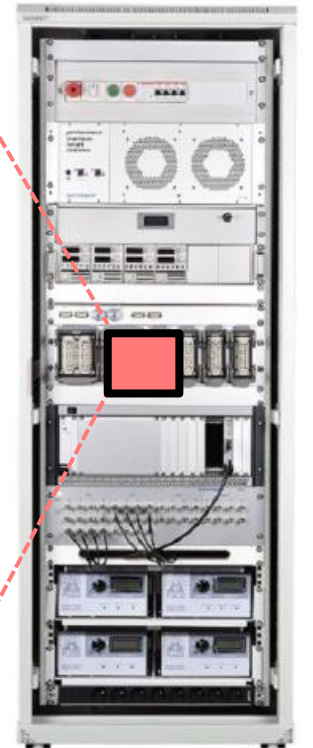
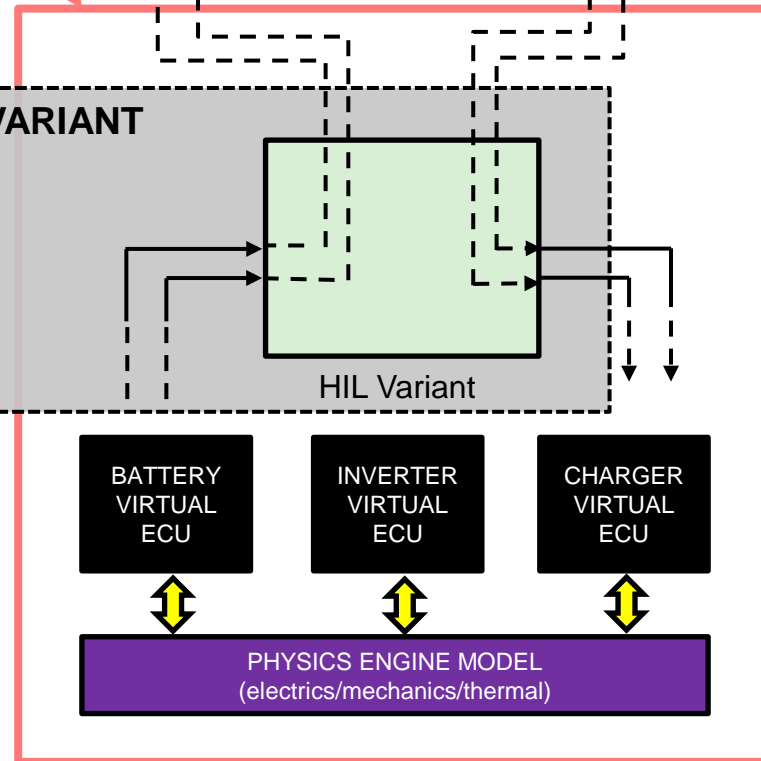
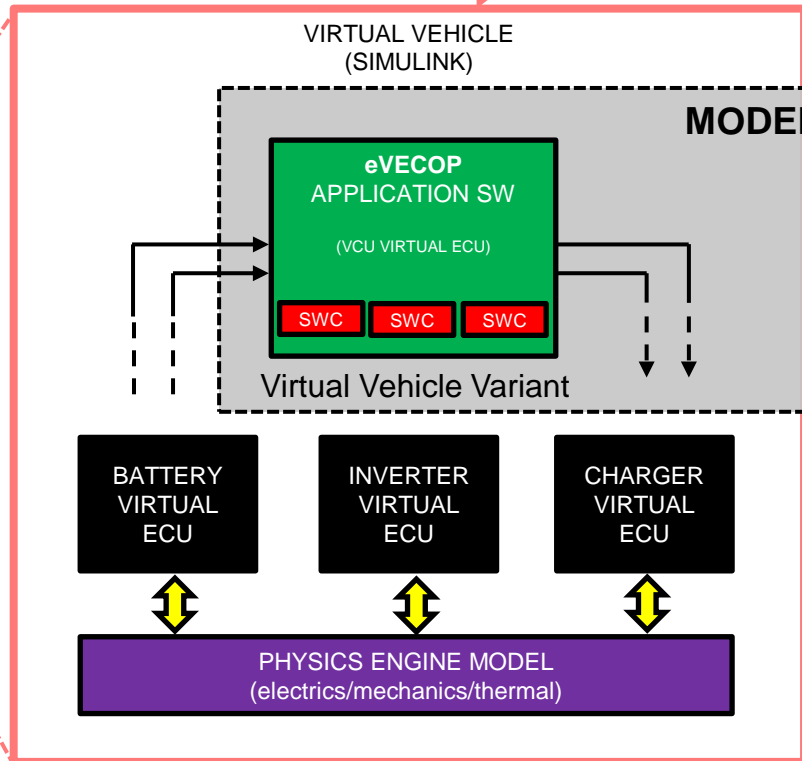
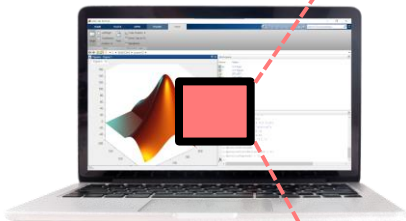
V&V workflow - HIL

Hardware-In-the-Loop

Virtual vehicle

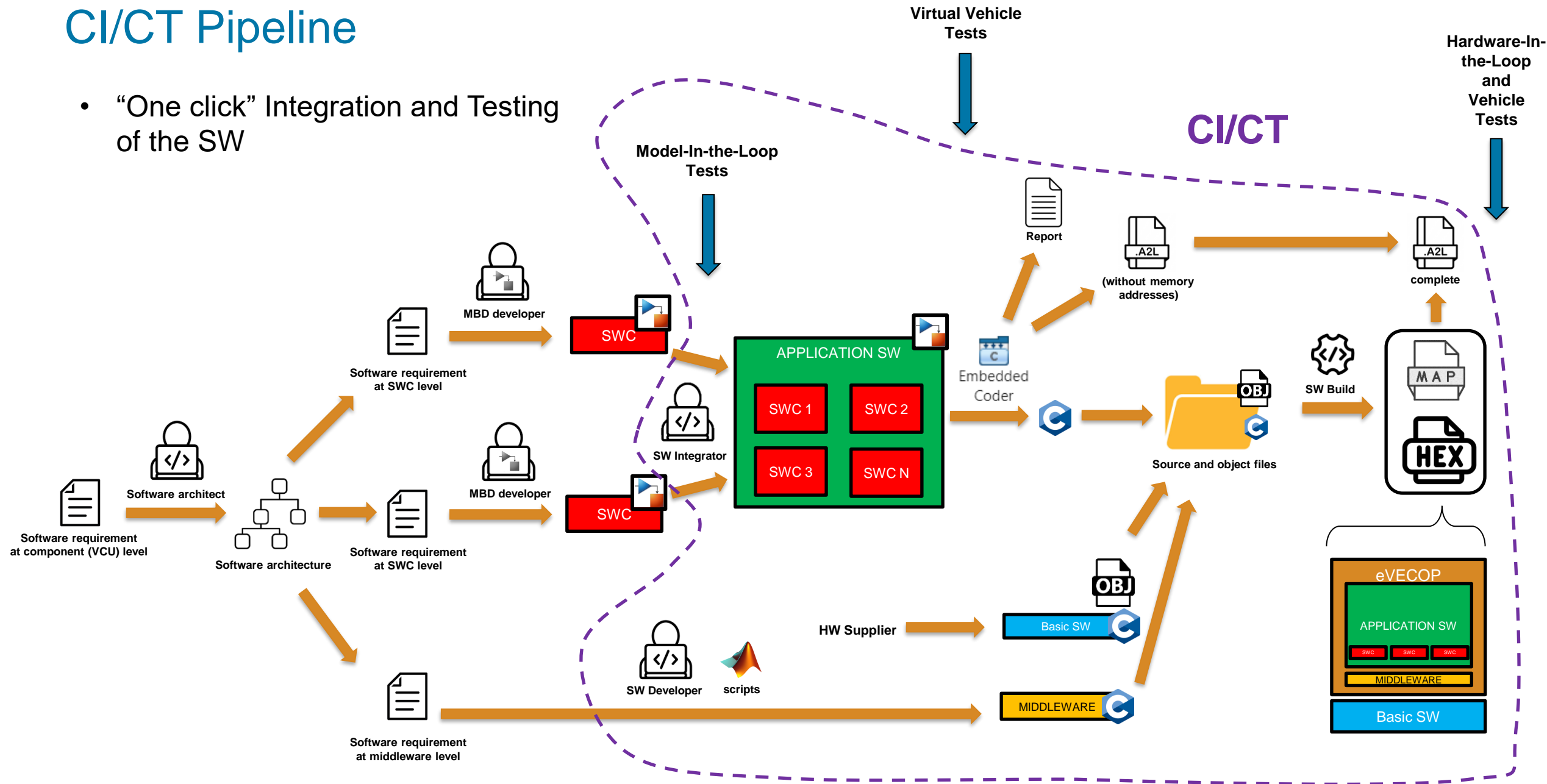
Same base model

Reusage of logics
Reusage of tests



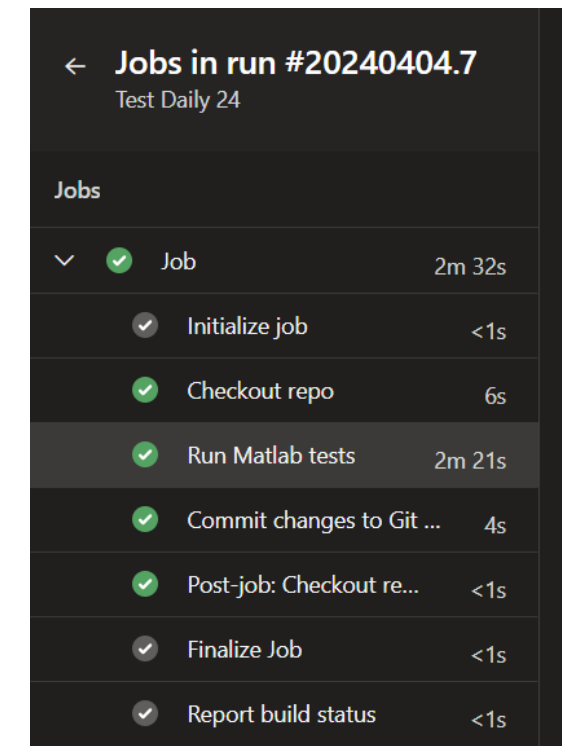
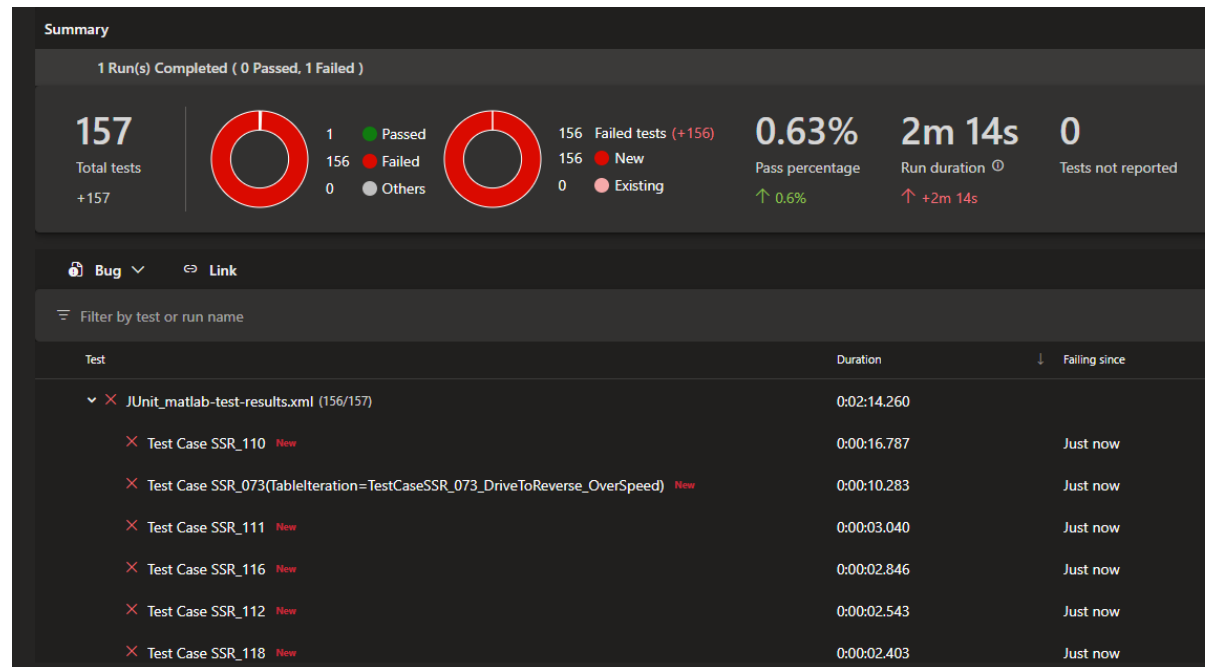
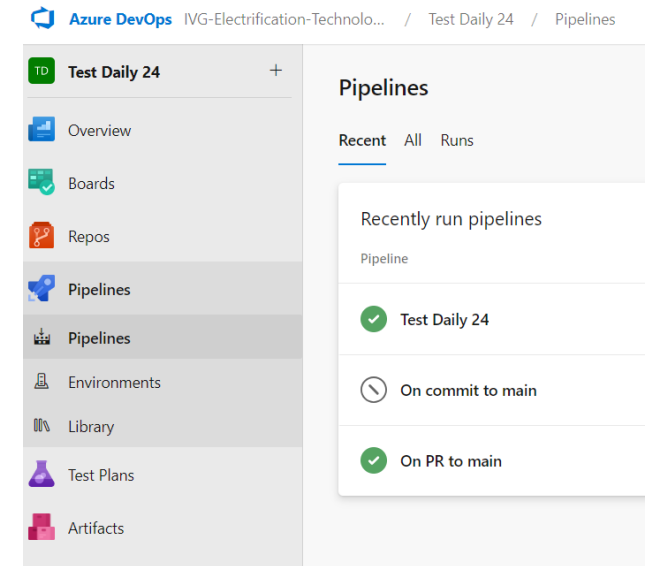
CI/CT Pipeline

- “One click” Integration and Testing of the SW



CI/CT Pipeline

- Our CI/CT tool is Azure Pipelines, from the Azure DevOps platform
- The SW is versioned in a Git repository of the platform
- At every commit/pull request of a SWC , Azure pipelines triggers a job which
 - Calls a set of tests defined in **Simulink Test** for that SWC
 - Test results are given in **XML** format and are shown on the DevOps Dashboard
 - Potentially any matlab script can be called
 - Triggers the code generation of **Embedded Coder**
 - Triggers powershell scripts that build the software



Key takeaways

- The application SW of the VCU of the IVECO eDaily is completely designed in MBD
- SWC are tested via a combination of Simulink Check/Verifier/Test/Coverage
- The SWC are integrated at Simulink level, thus obtaining the Virtual VCU model
- A Virtual Vehicle is used to find and fix 80% of the SW integration issues
- Model Variants are used to easily switch between Virtual Vehicle and HIL tests
- A CI/CT pipeline was created to accelerate SW integration and testing activities

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Thank you

