eFMI® tutorial part 5 (industry case-study):

eFMI based thermal management system (TMS) development for fuel cell electric vehicles (FCEV)

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16th International Modelica & FMI Conference, 2025

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Contents

1. Motivation

- **Challenge for ATV(FCEV) Development**

1. Temperature Range

ATV must operate reliably in extreme temperatures, including **very low temperatures (below -30°C)** and **high temperatures (above 50°C)**. This requires optimized heating and cooling systems for the fuel cell stack and vehicle components(Battery etc).

2. Altitude Variation

ATV should be able to drive in both high-altitude and low-altitude regions.

3. Road Conditions

ATV must drive well on **paved roads, unpaved roads, snowy surfaces, and icy roads**.

Heat Generation in FCEV Powertrain Systems During **Harsh Driving**

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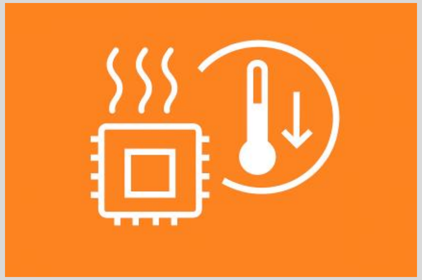
Necessity of a Thermal Management System (TMS)



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Ensuring **Optimal Driving Performance** in FCEVs

2. Objective

- **Project Objectives:**
  1. Develop a Thermal Management System (TMS) controller to efficiently operate cooling components in hydrogen-powered light tactical vehicles.
  2. Optimize hardware and software design to meet essential control requirements such as safety, cooperative control, and reliable communication.
- **Technical Objectives:**
  1. Control the temperatures of the fuel cell stack, battery, BOP, and FDC **within ±5°C.**
  2. Maintain stable **thermal balance** under various driving conditions.
  3. Achieve a real-time control cycle of the ECU **within 10ms.**

The electrification of existing internal combustion engine-based light tactical vehicles to FCEV vehicle models.

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The thermal management of the FCEV powertrain is necessary.

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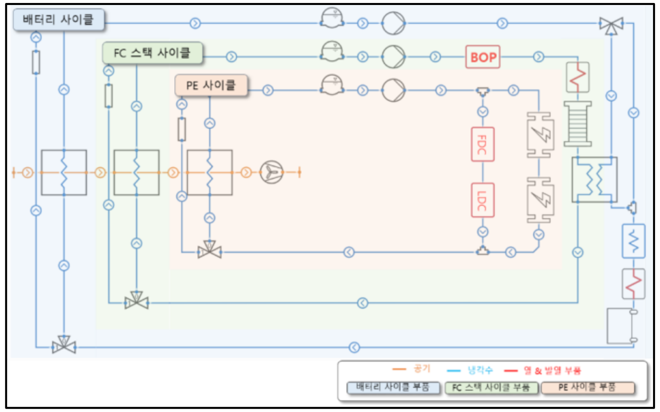
The development of the FCEV TMS controller.

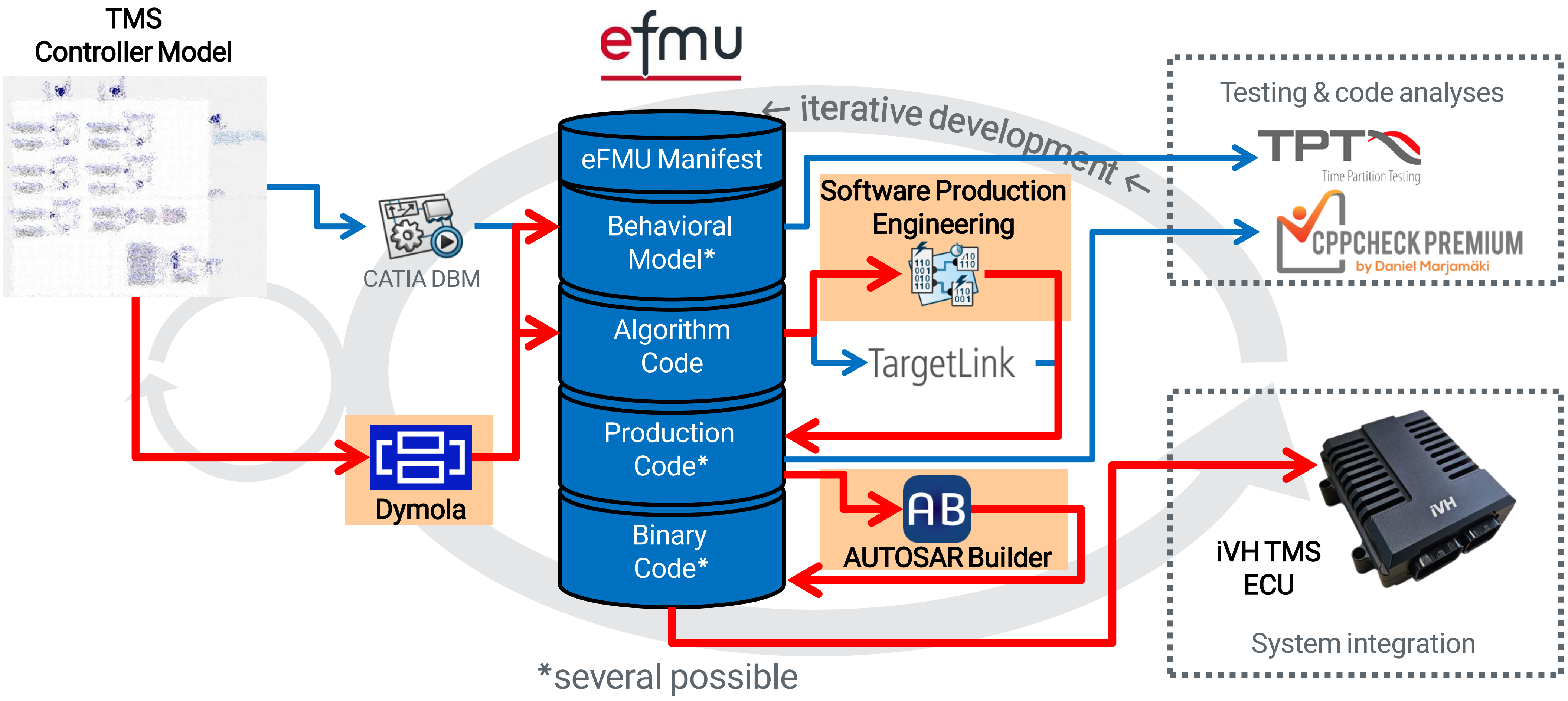


3. Approach

eFMI Workflow

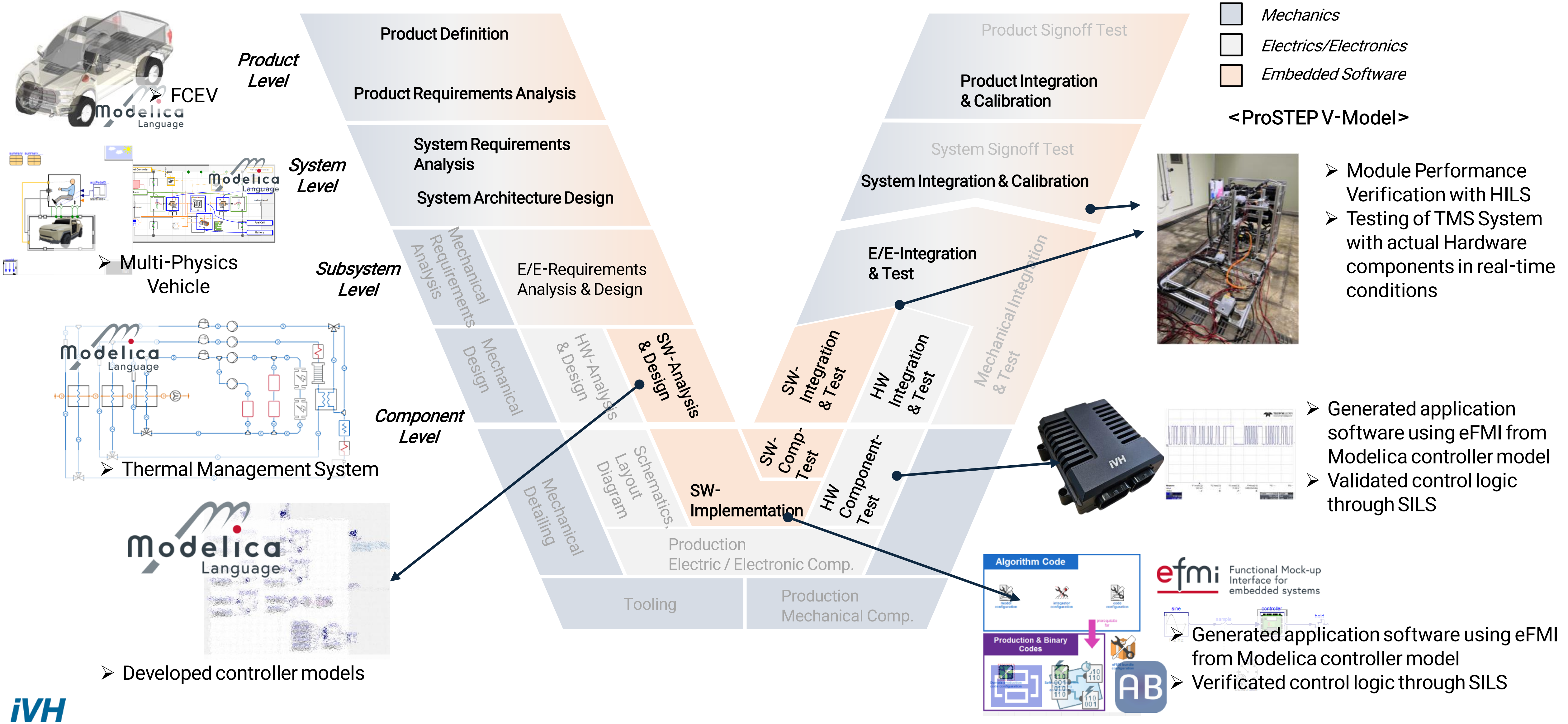
➢ **Background**

- iVH is a model developer skilled in physics modeling using Modelica, but lacks knowledge and experience in controller code development.
- So, we applied the **eFMI** workflow.



3. Approach

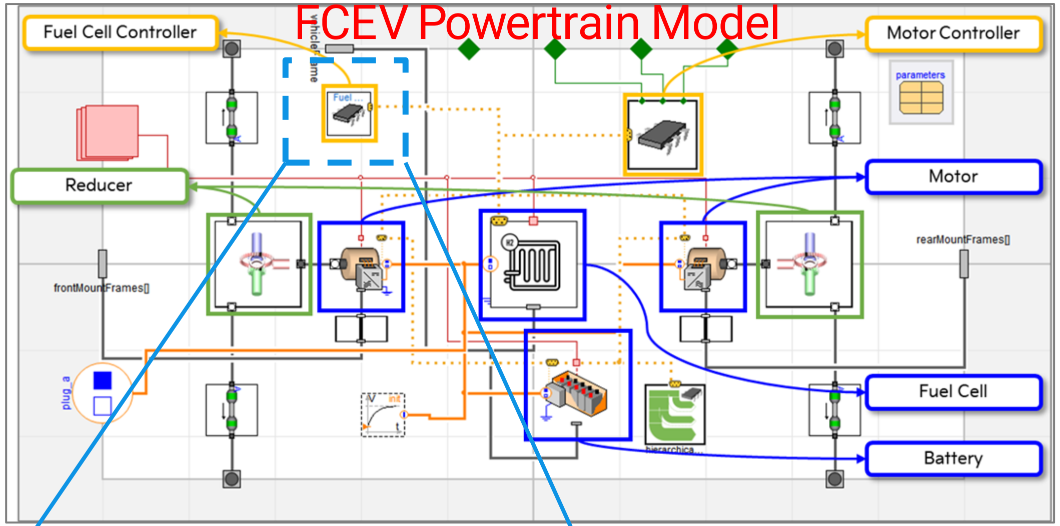
V-Cycle Based Development Process

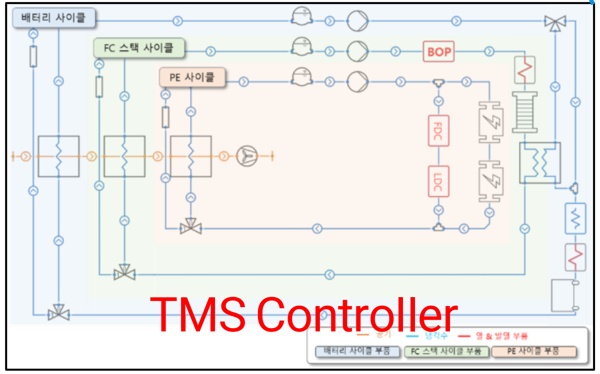


4. Results

Model Configuration & Test Conditions

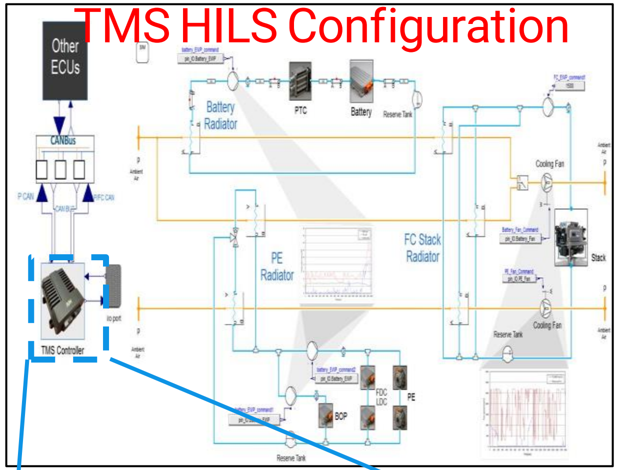
Simulation In the Loop

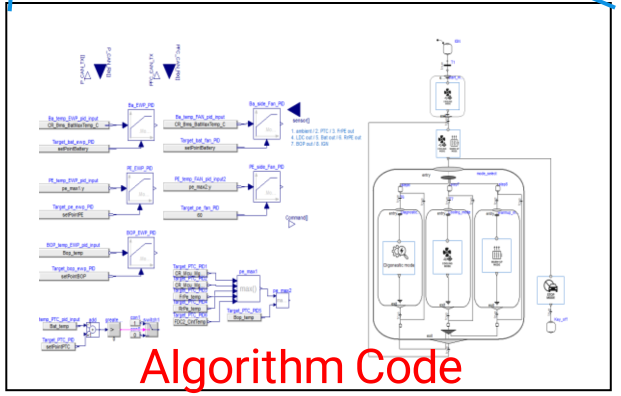




- **Simulation Condition**
  - Medium : Ethylene Glycol 50%
  - Ambient Temperature : 43℃
  - Component & Coolant Temperature : 43℃
  - Drive Cycle(Heat Cycle) : WLTC 2 Cycle(3600 seconds)

Hardware In the Loop





- **Test Condition**
  - Medium : Ethylene Glycol 50%
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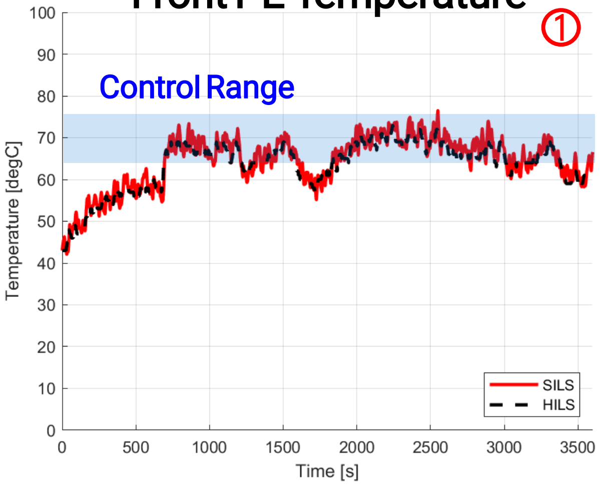
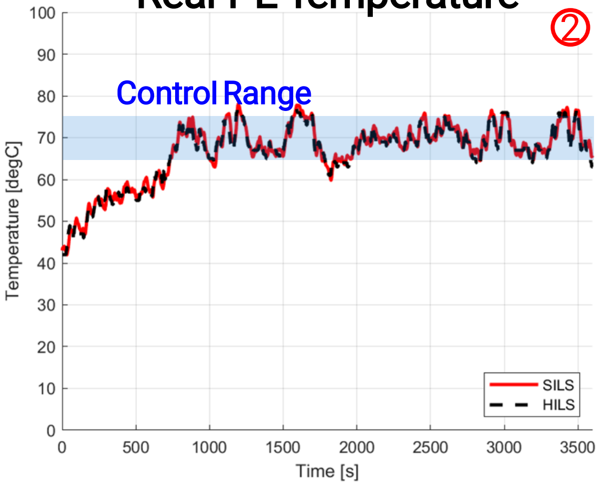
4. Results

Extreme Hot

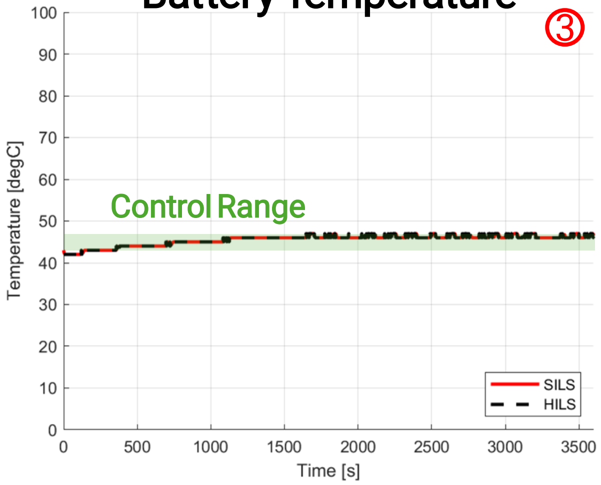
Front PE Temperature

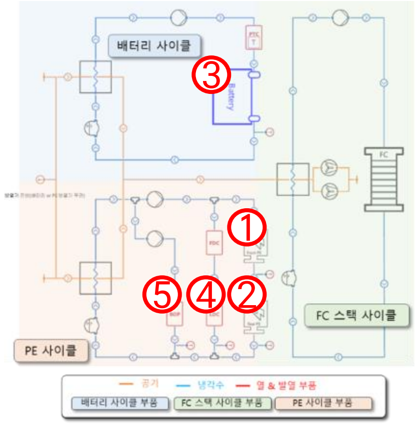


Rear PE Temperature

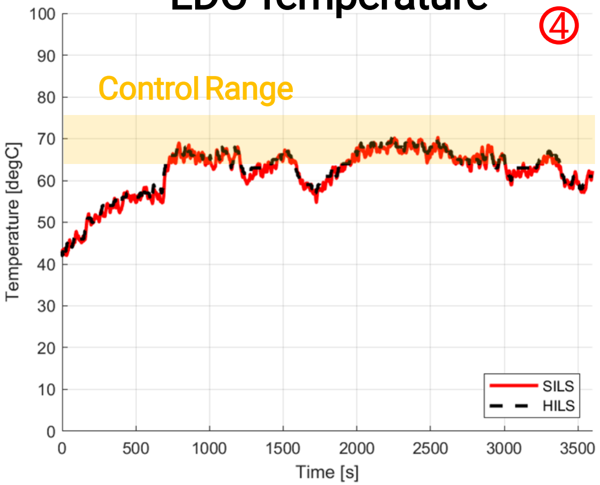


Battery Temperature

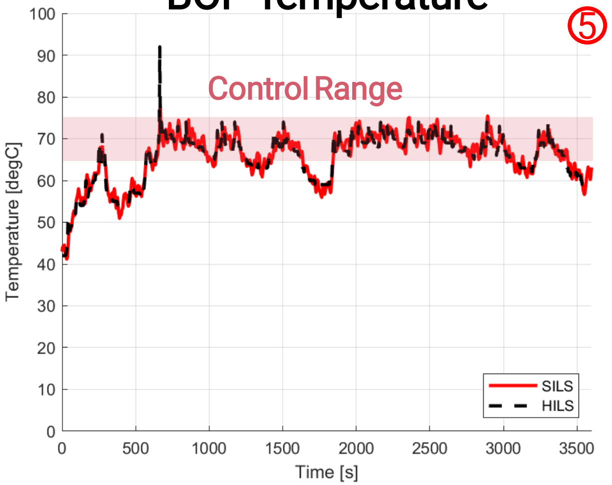




LDC Temperature



BOP Temperature



- Each heat source is controlled to maintain temperature within its appropriate **control range**
- The **battery** is cooled via a **cooling cycle**, and its **target temperature is set slightly higher than ambient air**

5. Conclusion

eFMI Success in TMS ECUs

eFMI has proven effective in Thermal Management System ECUs, enabling standardized component communication.

Continuous Validation and Verification

Ongoing testing throughout development increases confidence and reduces project risks.

Comprehensive Integration Approach

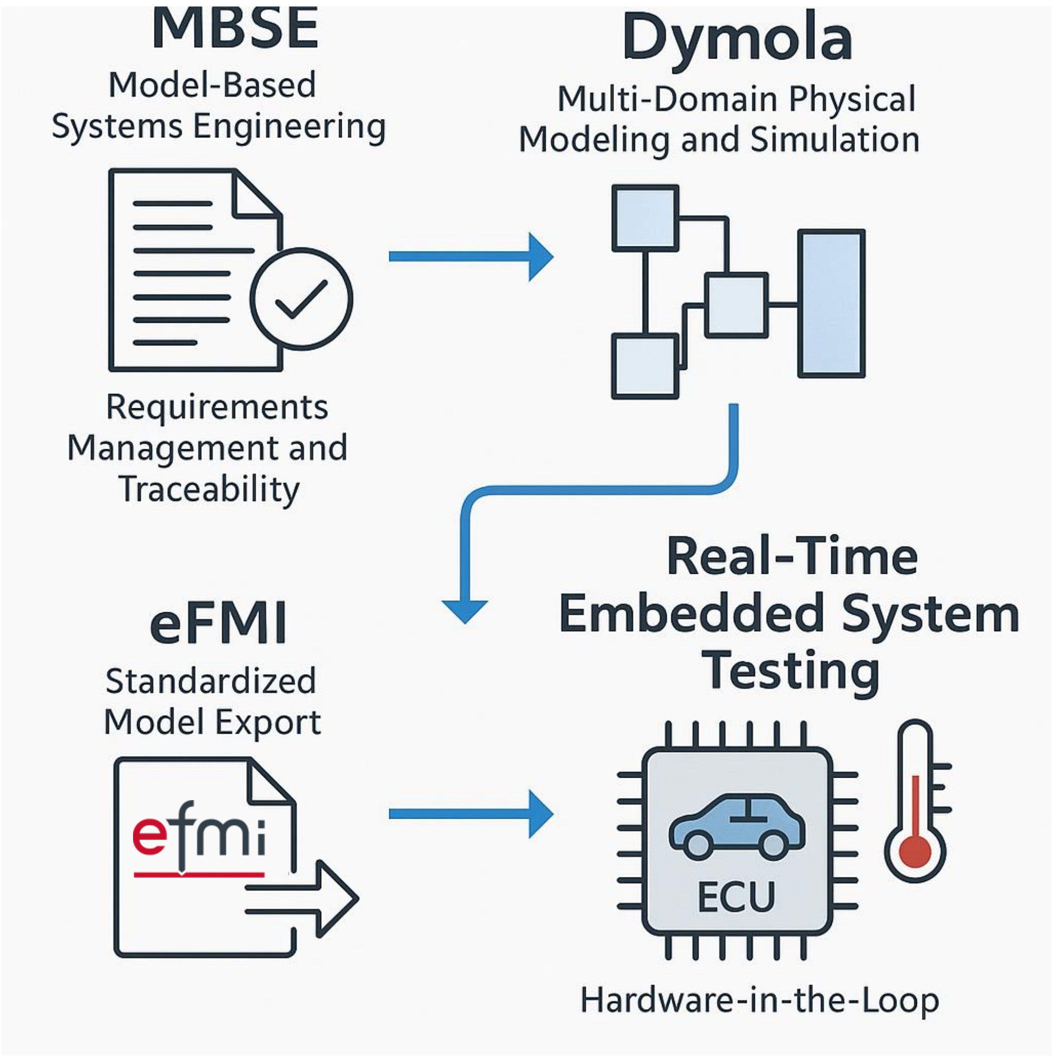
Combining multiple methodologies offers a robust solution to complex ECU development challenges.

Ensuring Efficiency and Quality

This integration promotes improved efficiency and high-quality outcomes in automotive system development.

Future-ready Electrification

Adopting these technologies prepares automotive development for future electric vehicle advancements.



THANK YOU