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Crafting the Core

Transmission Control Unit Use Case for Virtual ECUs and SSP-based Collaborative Development

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Virtual ECU Introduction

Shift-Left with Virtual ECUs

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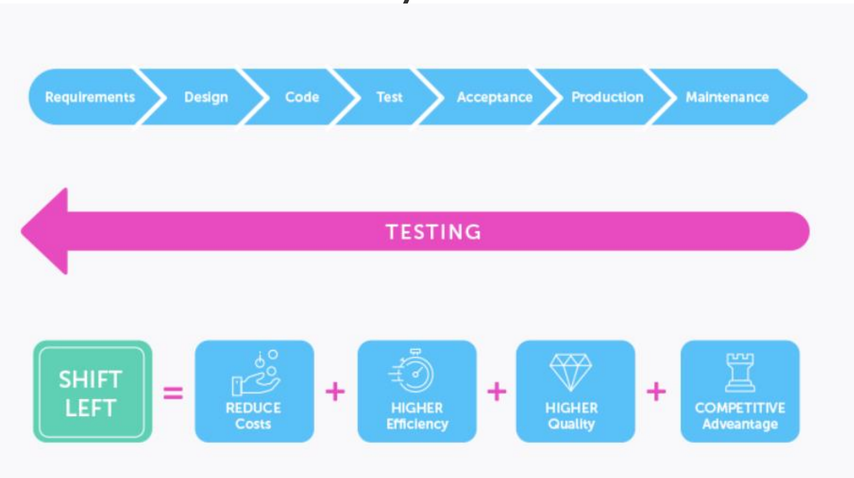
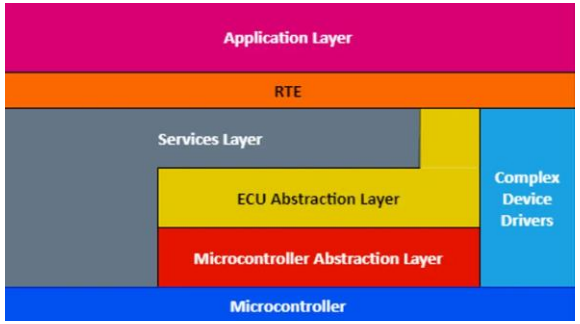
ECU virtualization is a key to **shift-left** in automotive industry.

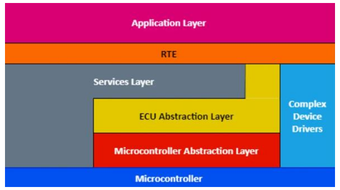


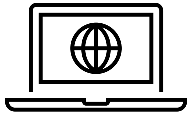
Physical (real) ECU has several layers, to integrate application SW into the product HW



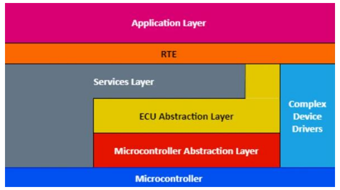
A Virtual ECU (vECU) is an **abstraction** that contains all the SW parts needed to simulate specific aspects of a real ECU.

Physical ECU
–real-

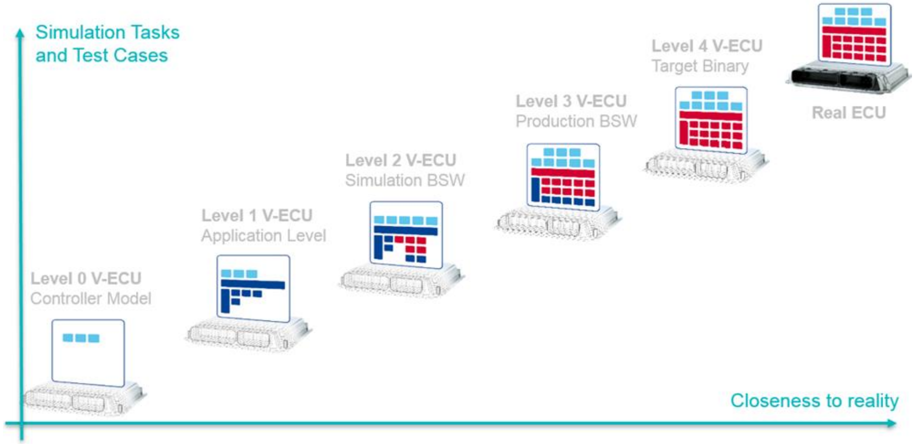




Virtual ECU (Lvl4)
-simulated-



This **abstraction** can be at different **levels**.



Abstraction Levels vs Applications

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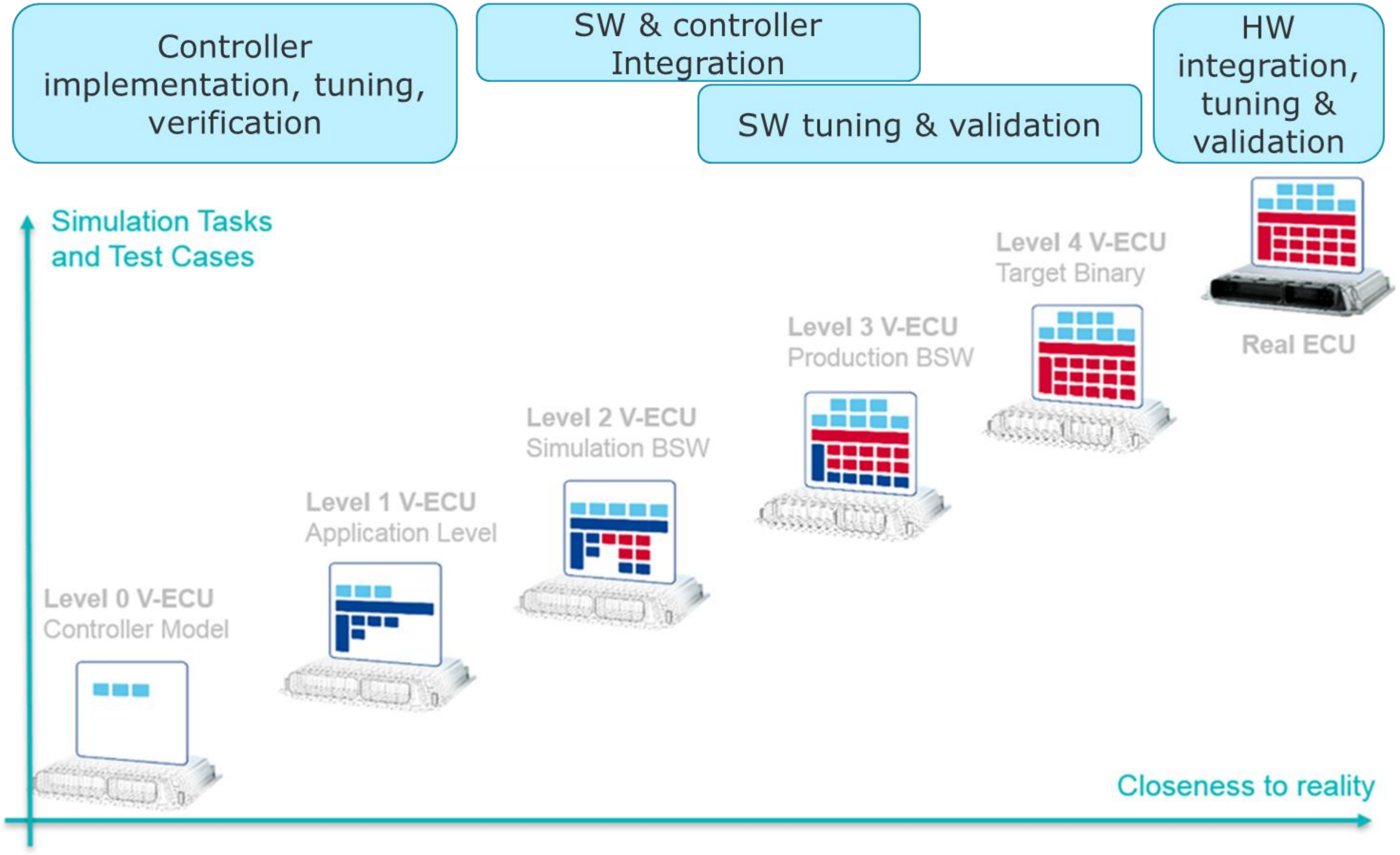
The required level of abstraction depends on the testing target

Higher the level, closer to the real behavour, but more complex simulations



Level 0
Controller model, no production code

Level 1
Application code as production, no basic software

Level 2
Application + Simulation Basic SW

Level 3
Application + Production Basic SW

Level 4
Application + BSW as target binary code

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Use Case: Transmission Control Unit Design

Proof of Concept (PoC) Development for TCU Design

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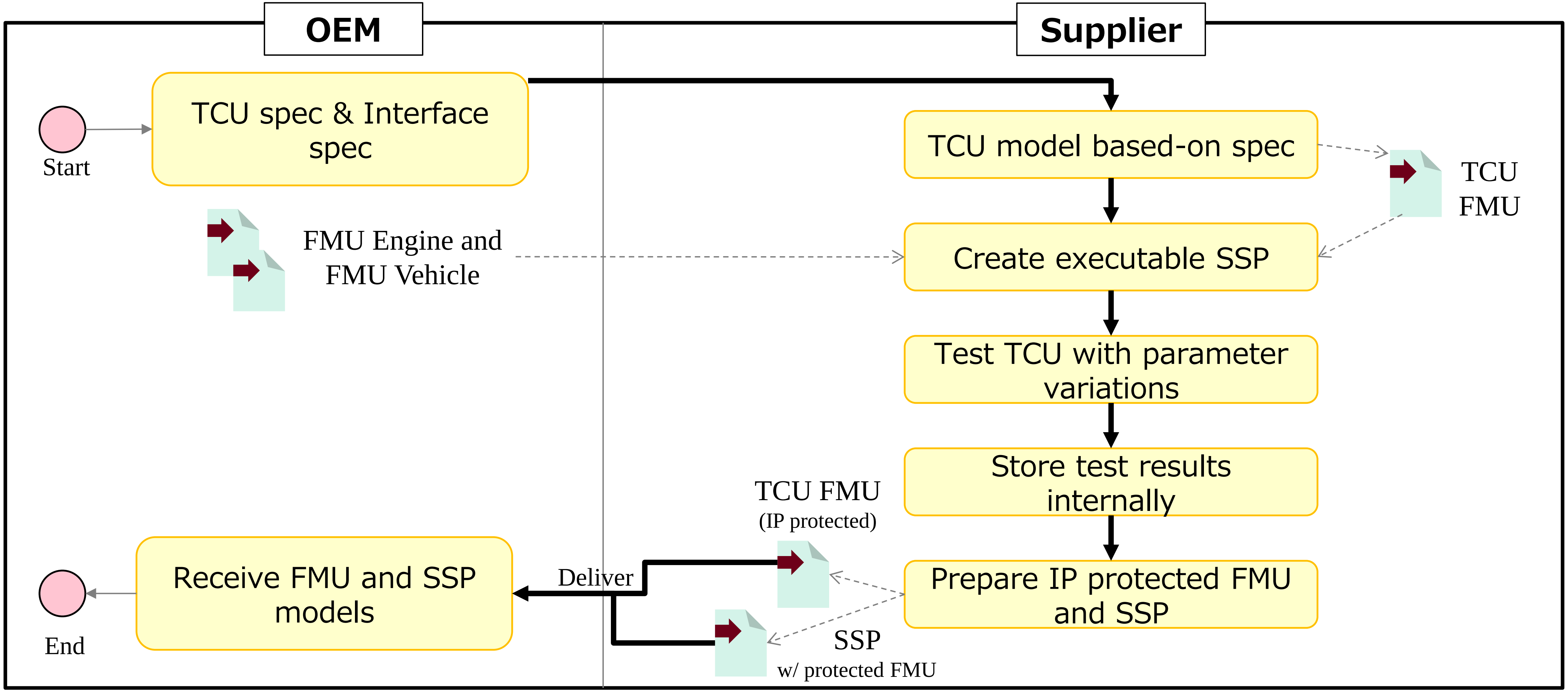
Use Case*: Supplier to design, test and calibrate Transmission Control Unit (TCU) based on OEM specifications and requests.

*This is an example use case. It does not represent any real business case.



System Model

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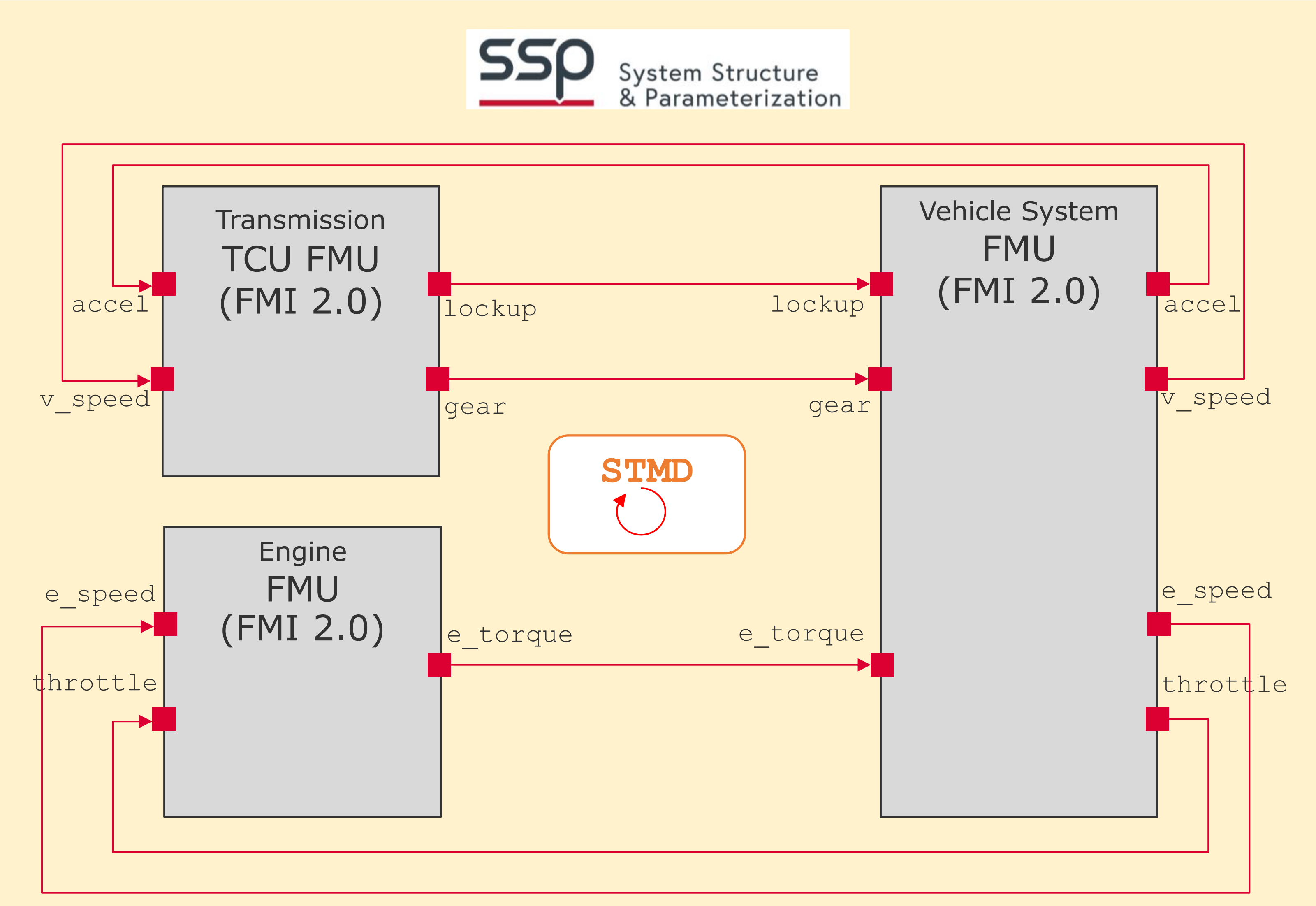
Overall system architecture is defined in SSP format. Component FMUs are integrated into the architecture:

- Engine FMU (Amesim)
- Vehicle FMU (Matlab)
- TCU model (FMU, Matlab)

STMD is implemented for traceability of system requirements, design goals, implementation details,…etc.



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Virtual ECU for TCU Design

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Virtual ECU for TCU Design

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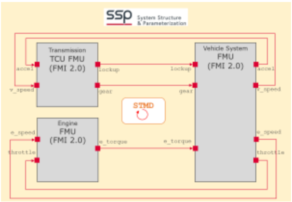
Based on TCU SSP Design and prostep ivip vECU levels, different vECU uses cases are defined and implemented definitions



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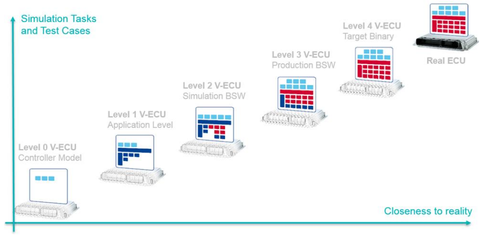
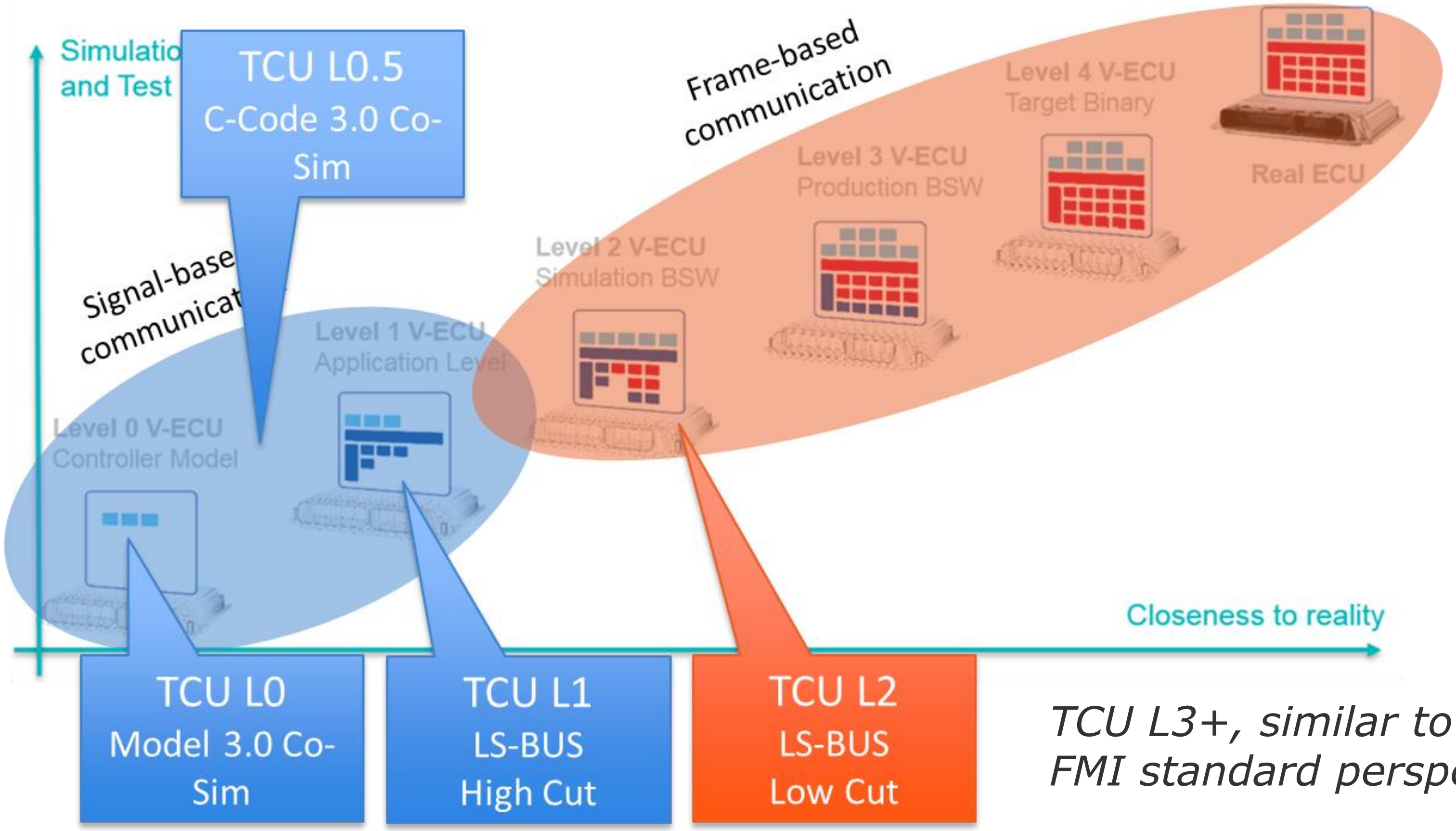
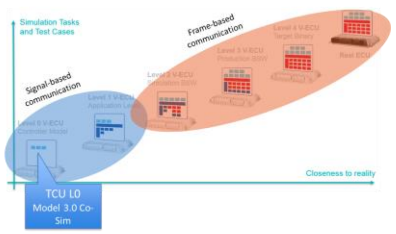




TCU L3+, similar to TCU L2 from FMI standard perspective

TCU L0 – vECU



Starting Model:
SmartSE TCU SSP

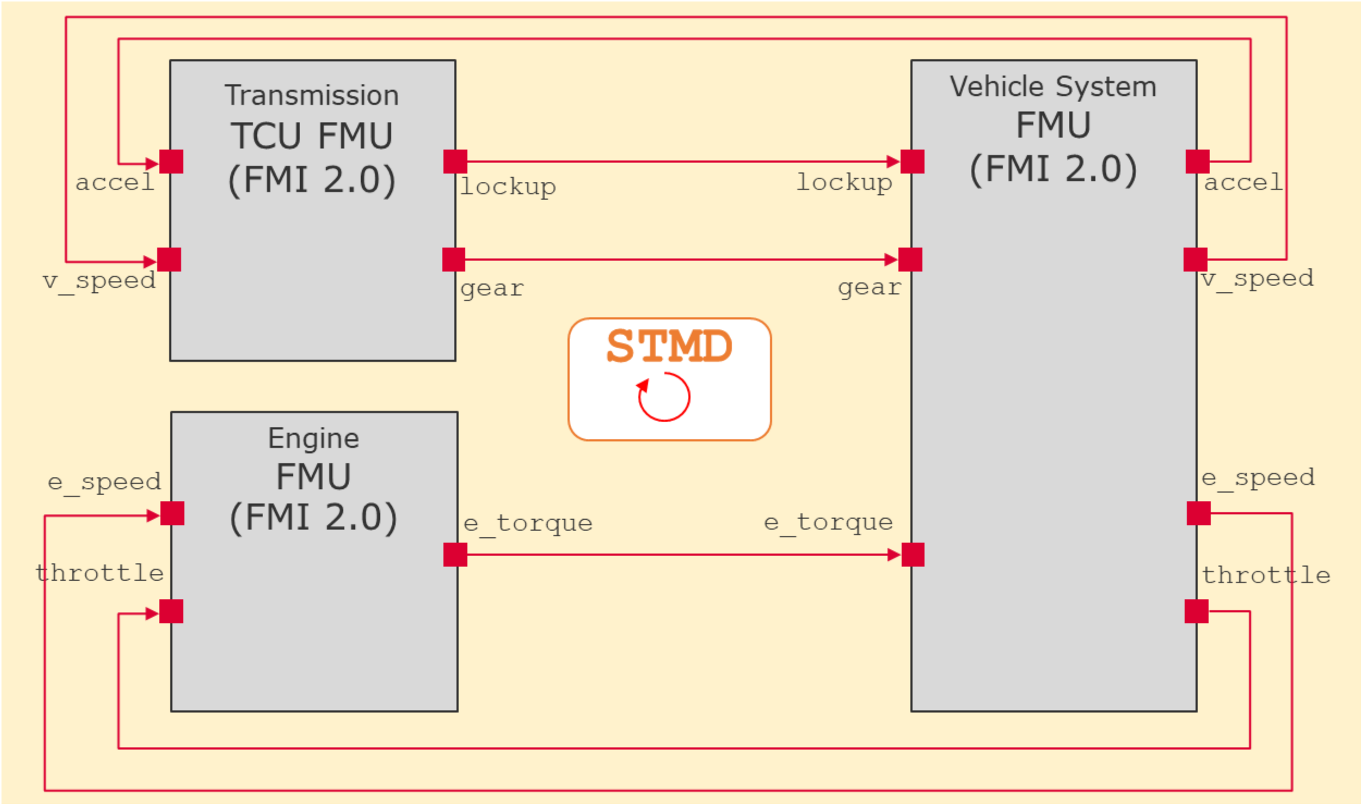
Added vECU feature:
-

Use Cases

- Controller design and initial tuning
- Validation of control algorithm
- Robustness testing of control strategy

Restrictions

- No runtime performance or timing artefacts
- No implementation code, basic SW
- No bus communication



TCU L0.5 – vECU

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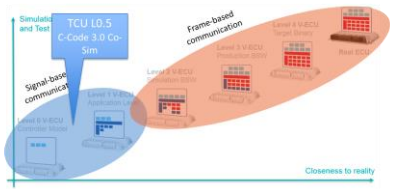


Starting Model:
SmartSE TCU SSP

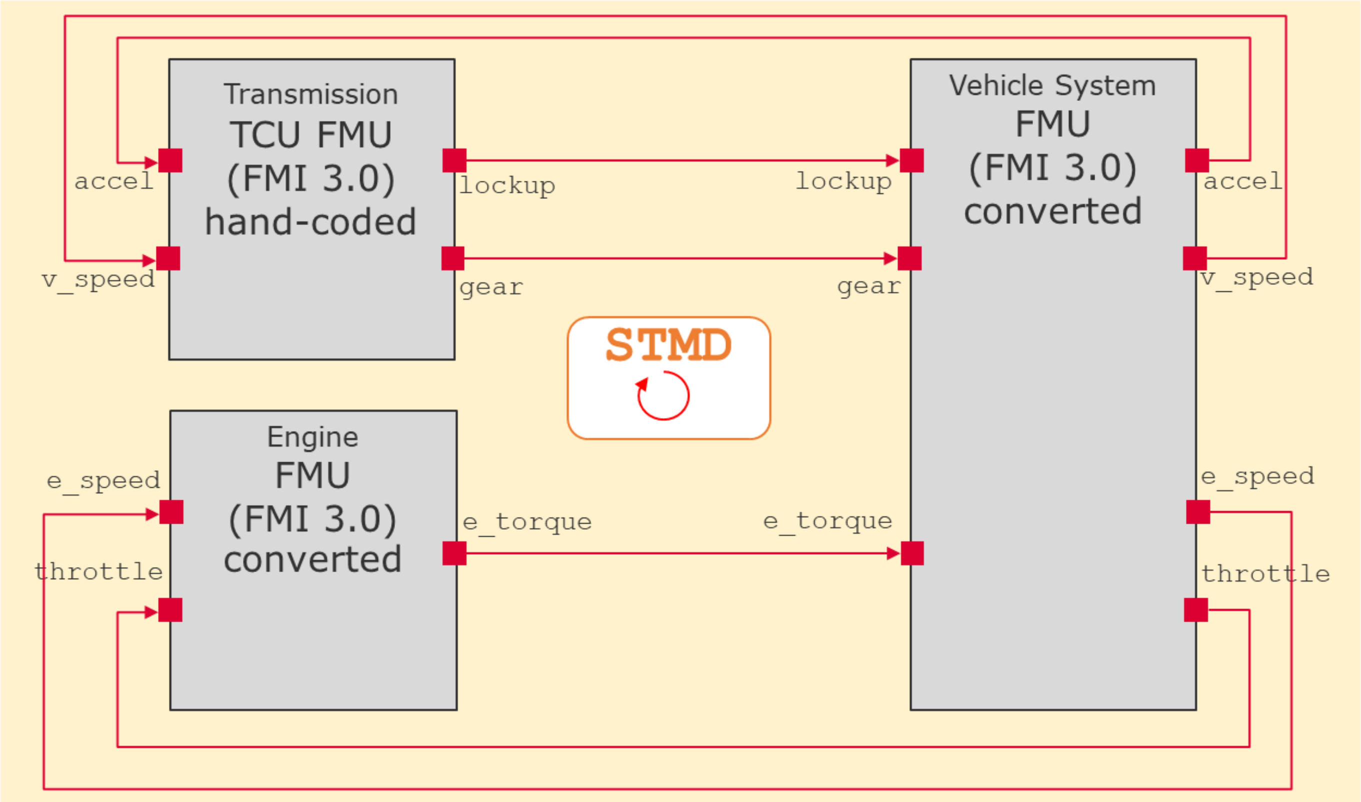
Added vECU feature:
vECU Level „0.5"
C Code Hand-Coded 3.0
Co-Sim TCU FMU

Use Cases

- Controller implementation design and initial tuning
- Validation of control algorithm implementation
- Robustness testing of numeric code

Restrictions

- No runtime performance or timing artefacts
- No scheduling, basic SW
- No bus communication



TCU L1.0 – vECU

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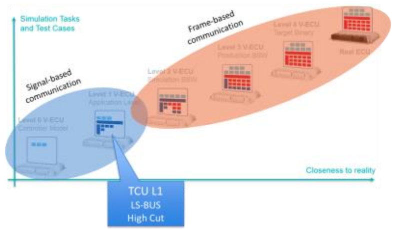


Starting Model:
TCU-L0.5 vECU

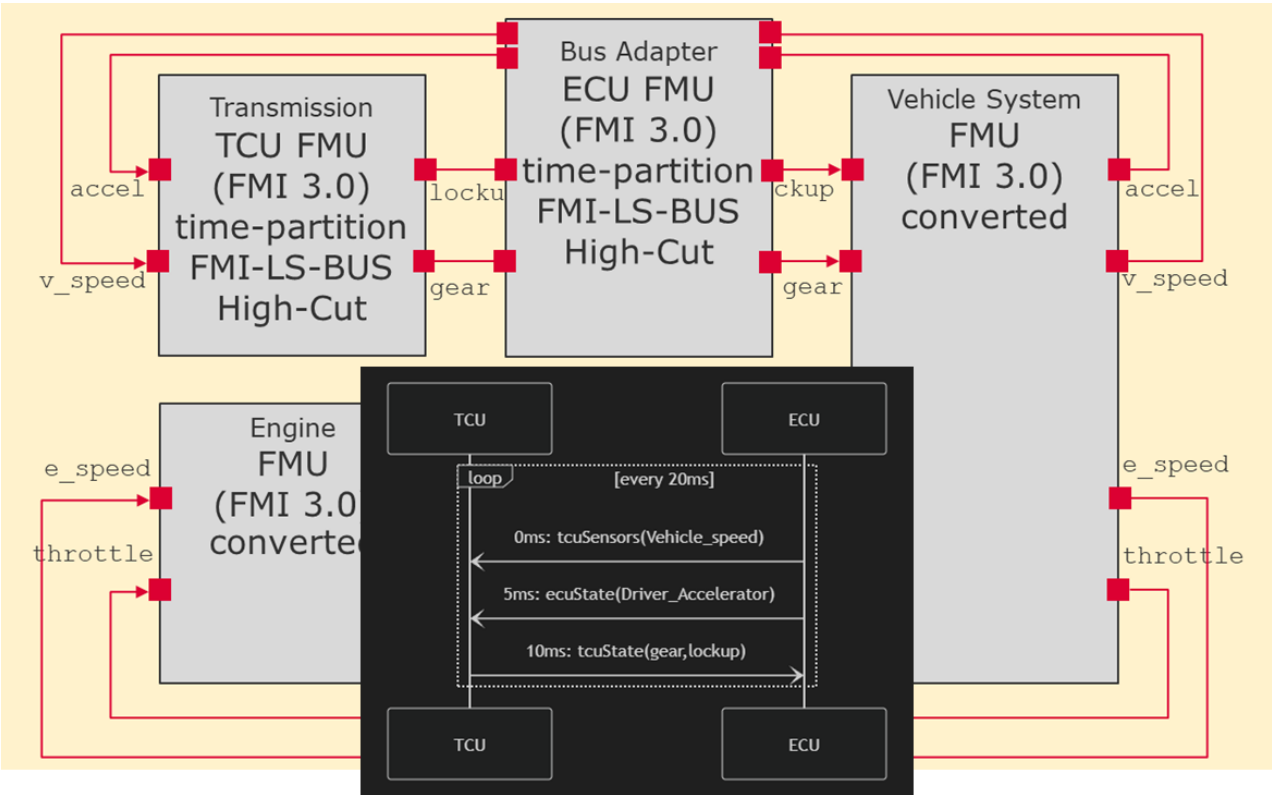
Added vECU feature:
vECU Level 1
Time Partitioned, Clocked Co-Sim
LS BUS High-Cut

Use Cases

- Controller implementation design and initial tuning
- Validation of control algorithm and schedule implementation
- Robustness testing of numeric code and basic scheduling

Restrictions

- No runtime performance, limited timing artefacts
- Only basic scheduling, no full basic SW stack
- Idealized bus communication, no error situations, collisions, net startup



TCU L2.0 – vECU

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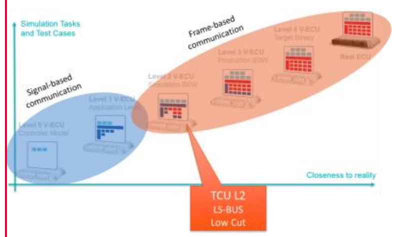
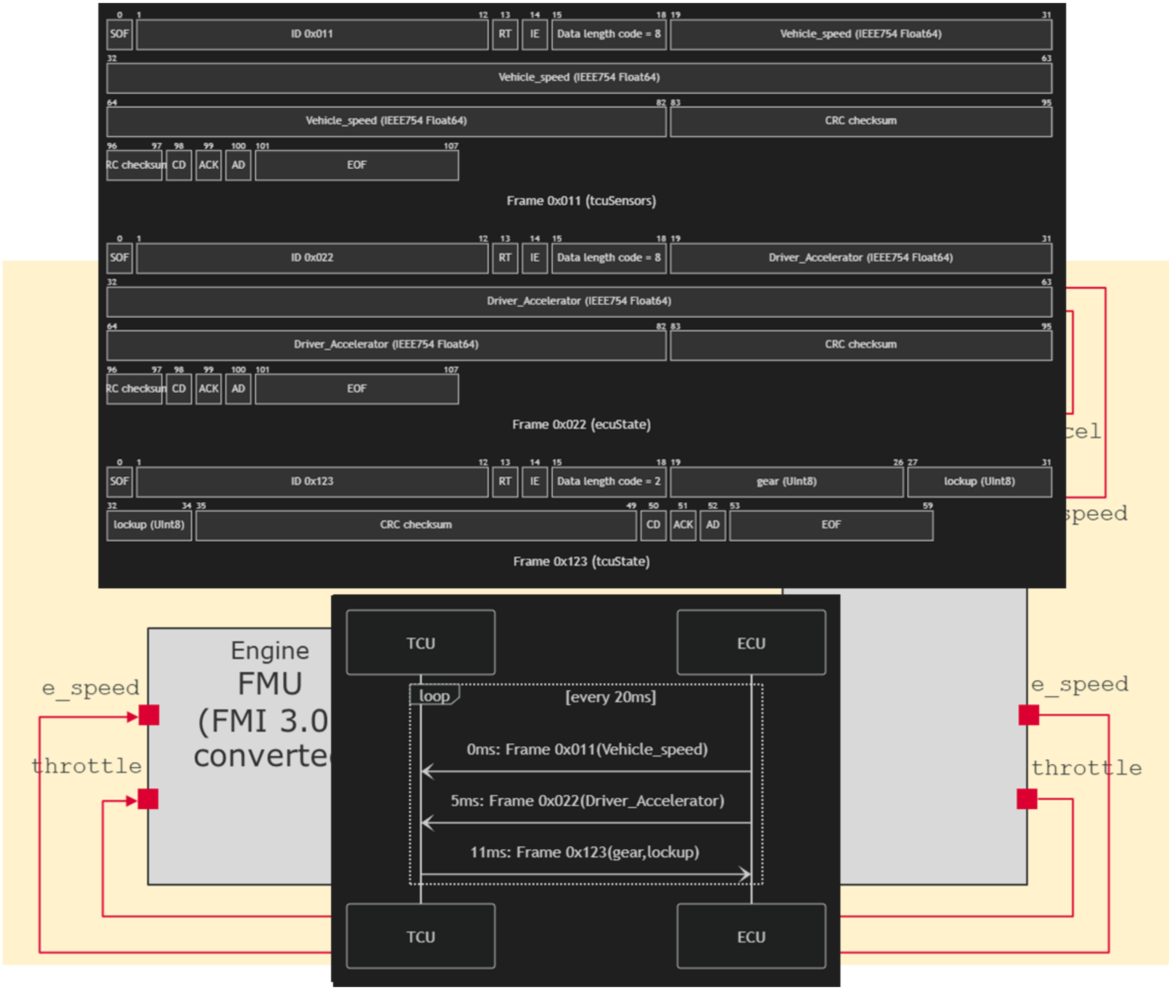


Starting Model:
TCU-L1.0 vECU

Added vECU feature:
vECU Level 2-3 (4)
LS BUS Low-Cut (CAN)



Use Cases

- Full controller, basic SW implementation design and tuning
- Validation of controller and basic SW configuration
- Robustness testing of network communication and non-runtime related scheduling

Restrictions

- No runtime performance, only non-related timing artefacts
- Only partial basic SW stack, no drivers/HW, production compilers

Calibration Virtual ECUs using XCP

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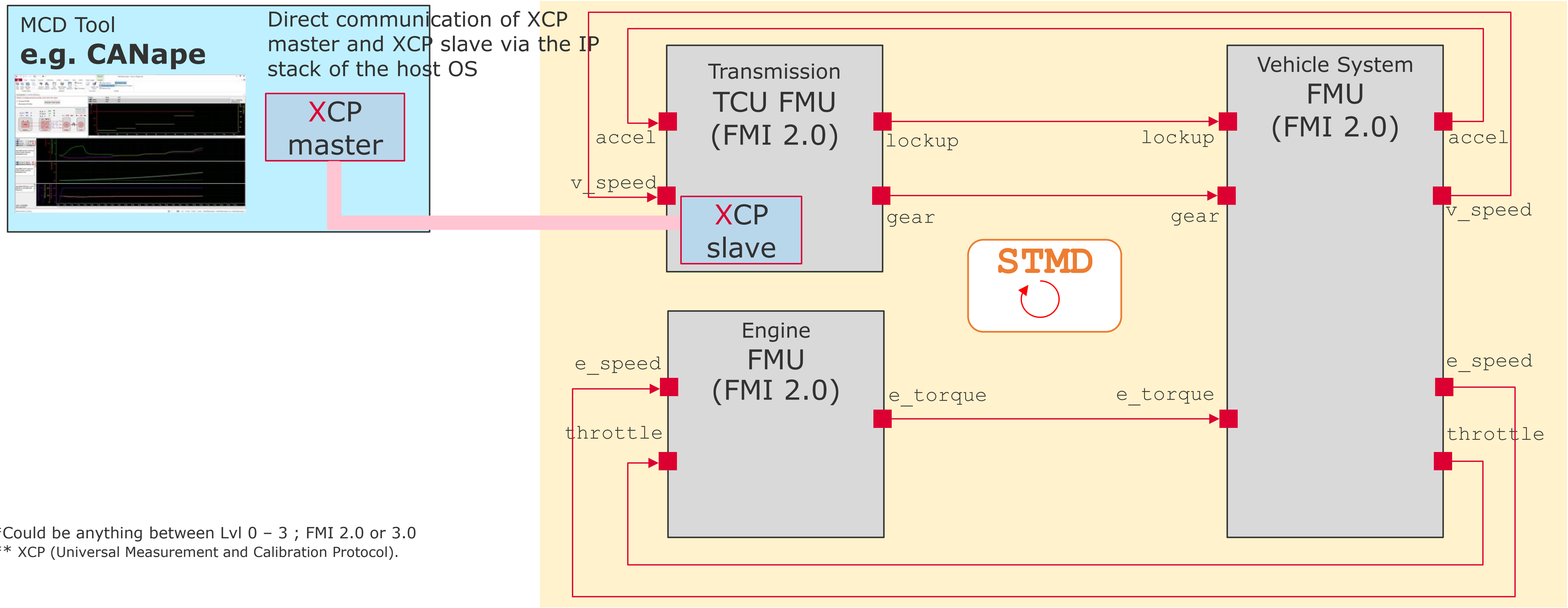
TCU vECU* parameters can be calibrated via FMI-LS-XCP, implementing XCP**. This would allow access to controller internal calibration and measurement via the usual ECU calibration tools like Canape/INCA/…demonstrating that the overall approach can be used at SIL, vECU and ECU levels



*Could be anything between Lvl 0 – 3 ; FMI 2.0 or 3.0
** XCP (Universal Measurement and Calibration Protocol).

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vECU in Prostep SmartSE

Prostep Smart Systems Engineering

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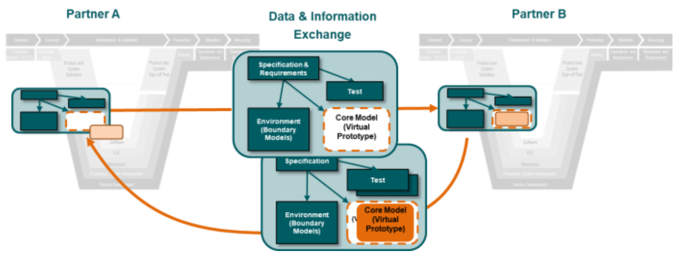
SmartSE Mission & History (2012-2024)

Focuses on industrialization of MBSE standards and collaborative development between EU OEMs and suppliers



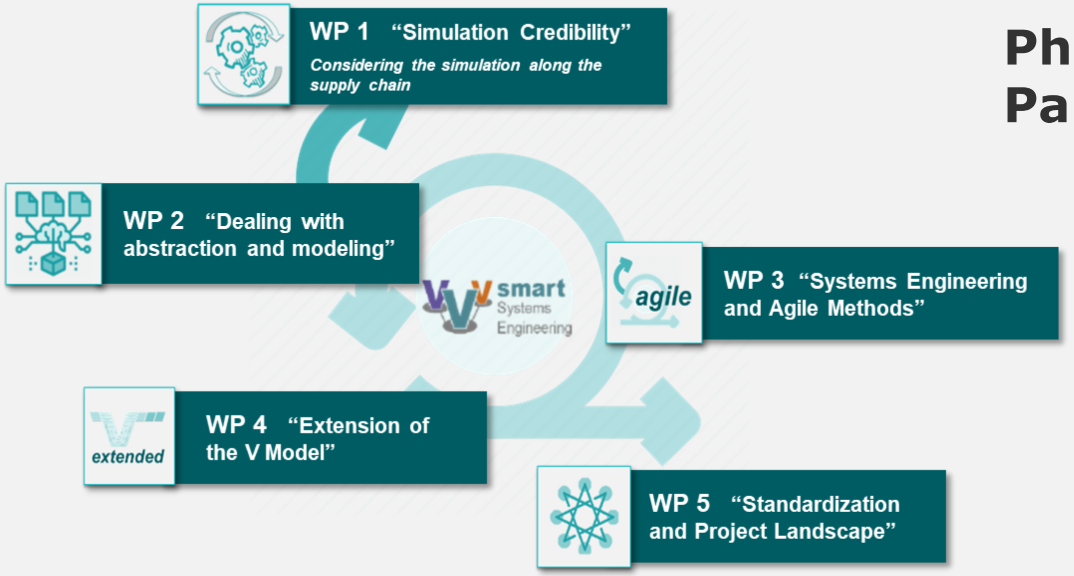
2012 **Phase-I, II** — **FMI Industrialization;** industry best practices to ease the exchange of models and smooth process integration between the engineering disciplines and partners

2016 **Phase-III** — Recommendations for industry for **model exchange**. Intensify the cooperation activities with other projects

2019 **Phase-IV** — Extensions towards **autonomous systems, vECUs**, and Modelica **SSP**

2022 **Phase-V** 2024 — Enabling **collaborative development** and validation of complex products by simulation along a multi tier supply chain.

Phase V Scope:



Phase V Partners:

Prostep Smart Systems Engineering

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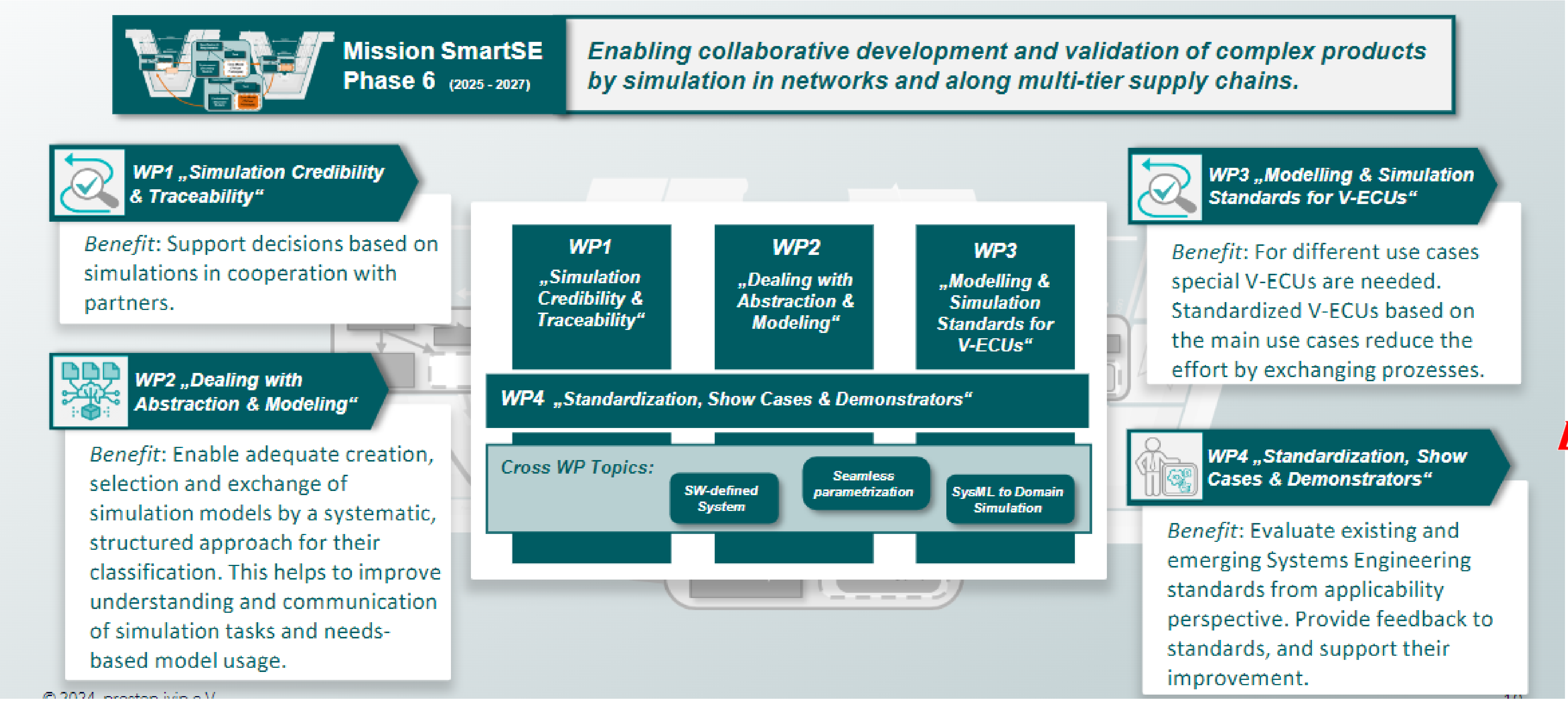
SmartSE Future – Phase VI (2025-2027)



Crafting the Core

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Conclusion & Outlook

Conclusion

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- ECU virtualization is a key to **shift-left** in automotive industry.
- The **required level of abstraction depends on the testing target** → Higher the level, closer to the real behavior, but more complex simulations
- **FMI 3.0 and layered standard FMI-LS-BUS** enables realization of **vECUs up to Lvl 2**
- **FMI-LS-XCP enables the calibration of vECUs** in a same as calibrating real ECUs
- SSP 2.0 will enable packing **multiple virtual ECU together** under a system architecture

Outlook

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- In prostep SmartSE we started now discussion on next application examples
  - Which **level of vECU** and modeling abstractions for which **applications**?
- Higher level virtualizations:
  - Integrate **production base SW to test L3 vECUs**. Potential use cases :
  - Integrate **production Base SW + Target Drivers, Emulator to test L4 vECUs**.

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