A Practical Path to Virtual Powertrain Development and Validation

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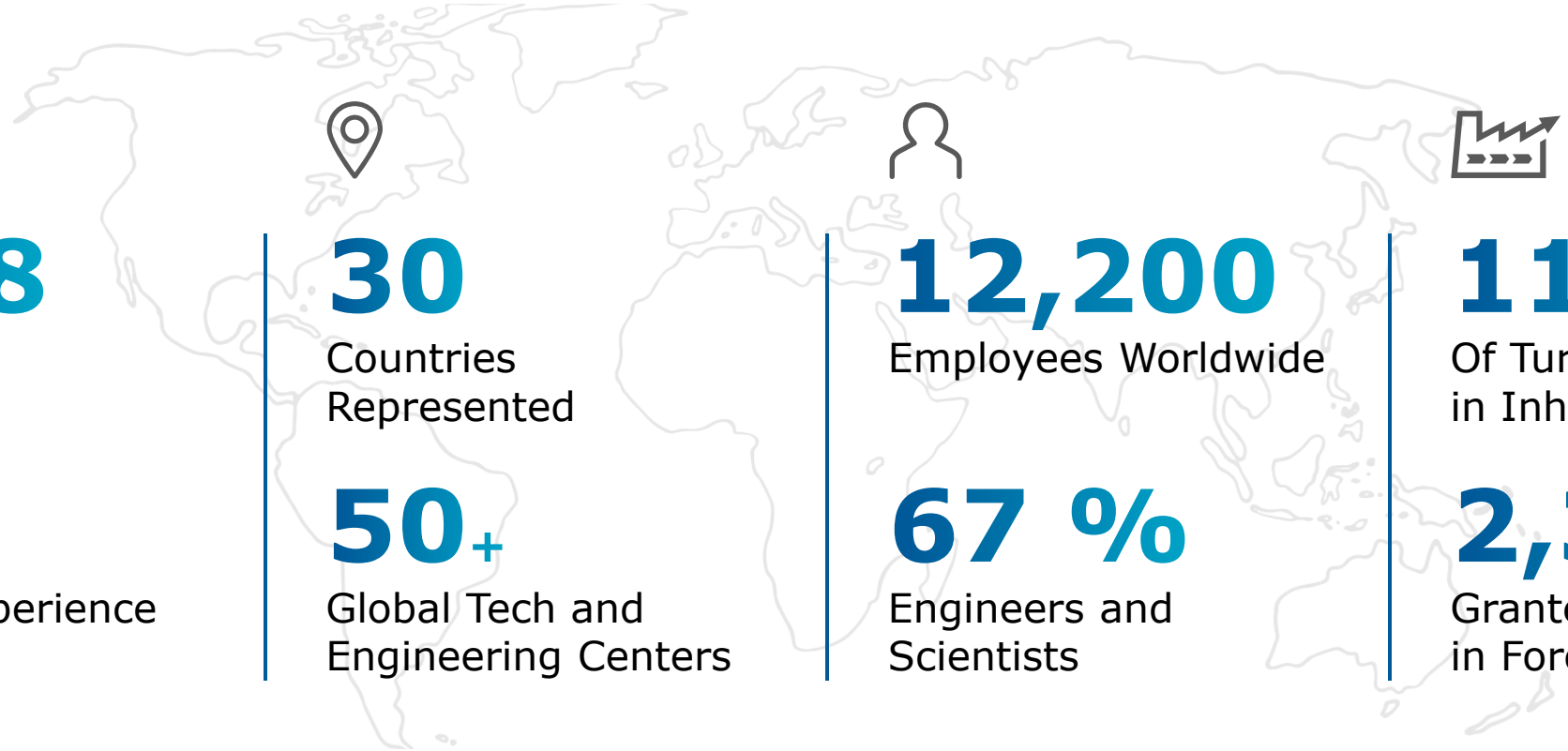
AVL at a Glance



1948
Founded

75+
Years of Experience

30
Countries Represented

50+
Global Tech and Engineering Centers

12,200
Employees Worldwide

67 %
Engineers and Scientists

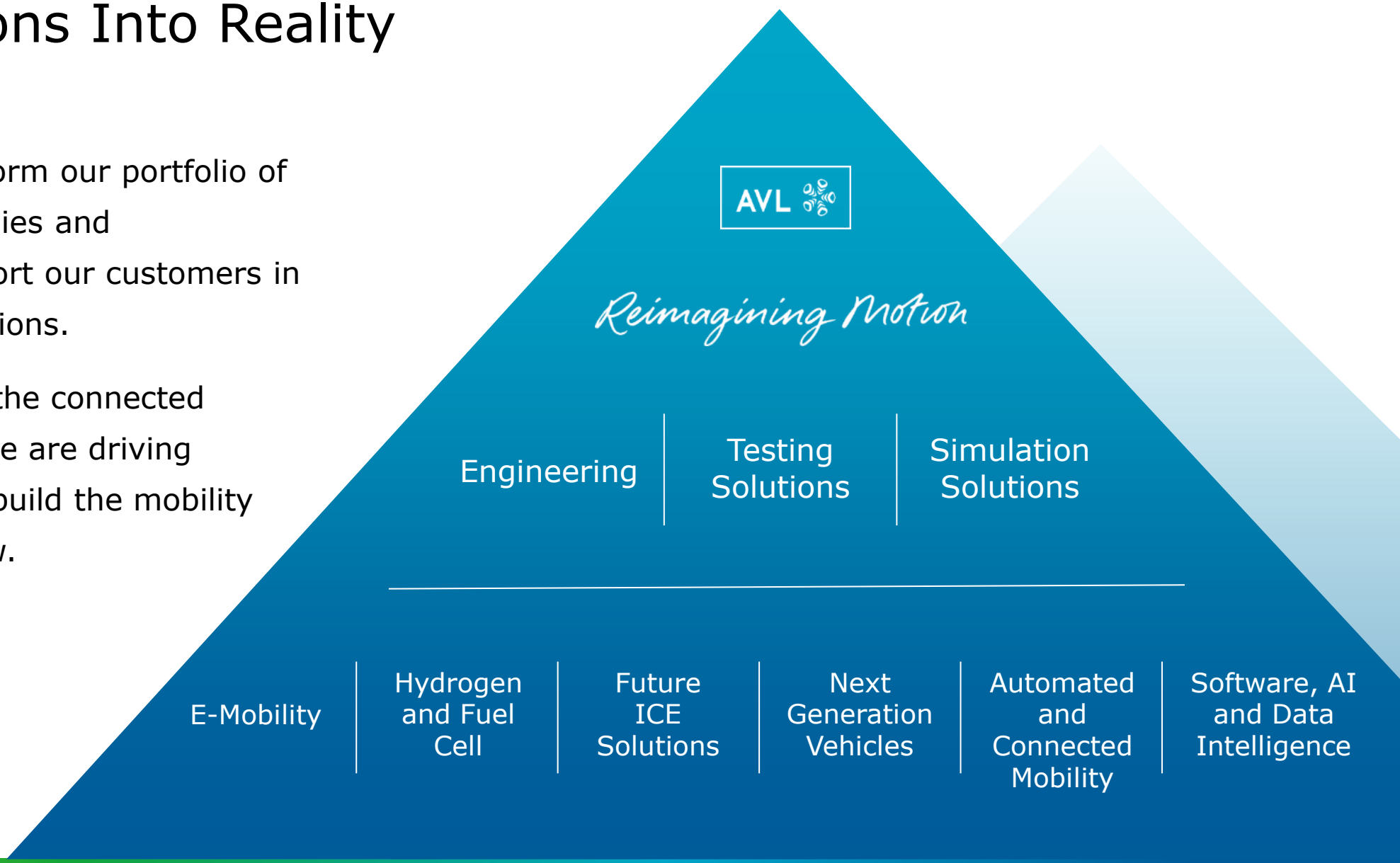
11 %
Of Turnover Invested in Inhouse R&D

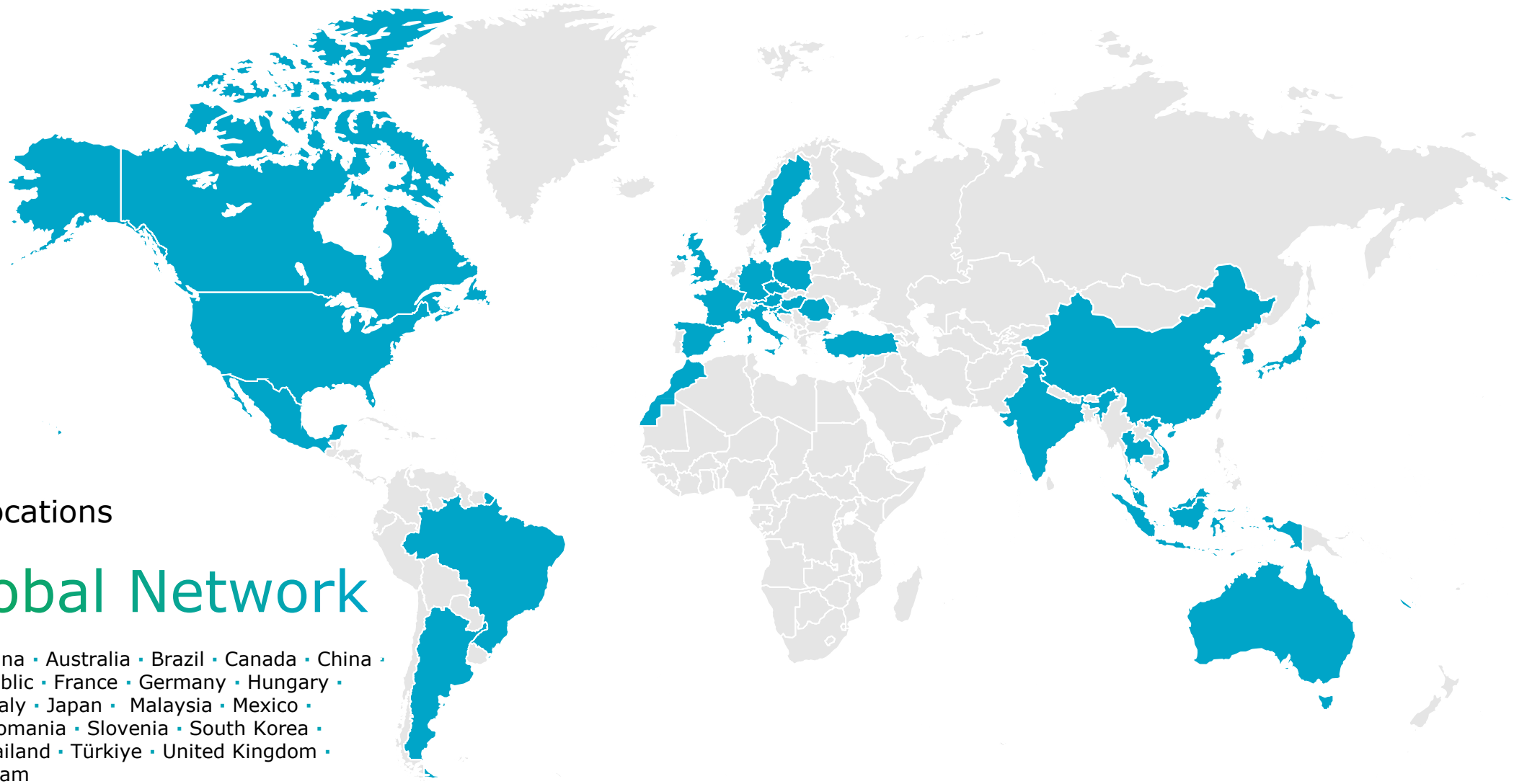
2,300
Granted Patents in Force

Turning Visions Into Reality

We constantly transform our portfolio of high-end methodologies and technologies to support our customers in achieving their ambitions.

From future fuels to the connected vehicle ecosystem, we are driving innovation today, to build the mobility concepts of tomorrow.





Worldwide Locations

Our Global Network

Austria, HQ | Argentina · Australia · Brazil · Canada · China · Croatia · Czech Republic · France · Germany · Hungary · India · Indonesia · Italy · Japan · Malaysia · Mexico · Morocco · Poland · Romania · Slovenia · South Korea · Spain · Sweden · Thailand · Türkiye · United Kingdom · United States · Vietnam

AVL

Automotive Product Development

Challenges

Public

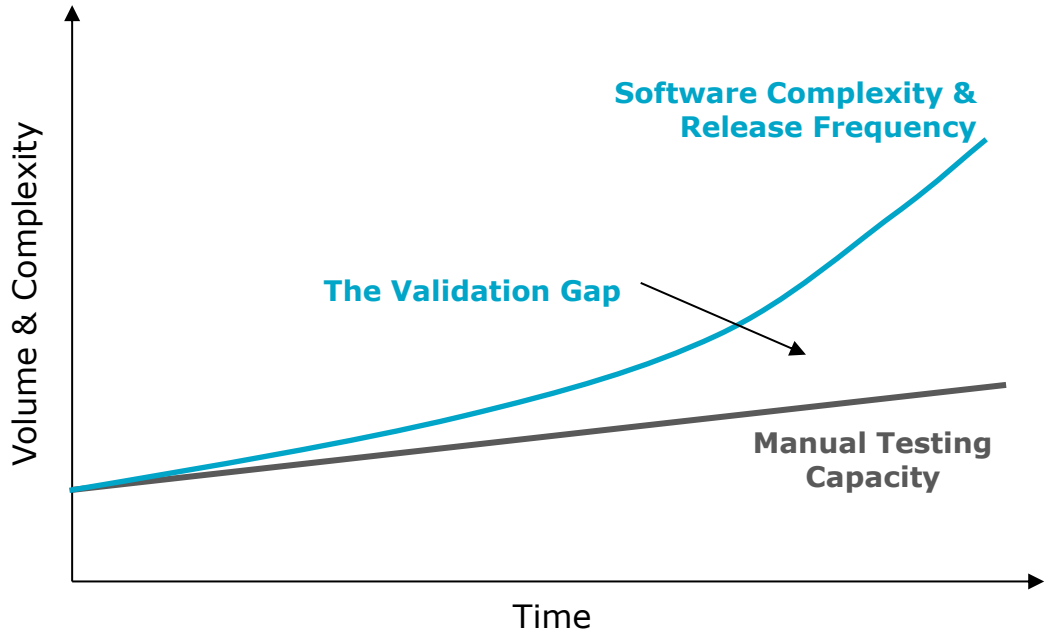
The Validation Gap:
Where Agile Speed Meets Physical Bottlenecks

The Reality:

- Development teams now work in agile sprint with bi-weekly release cycles.
- The demand for software/functional tests is increasing.
- Testing the software together with the system

The Problem: Traditional testing capacity is linear and mostly manual. It cannot keep pace with the growth

The Consequence: Testing with full coverage is becoming impossible, leading to delayed releases or compromise quality



Challenges - System Level Integration

Lack of collaboration & high degree of complexity make it difficult scale assets & artifacts within organisation.



Complexity of Integration
- *Multiple Components*
- *Dependencies*

Environment Configuration

Asset Management

Test Coverage & Automation

Security Testing

Resource Constraints

Operational Challenges



The E/E Integration Engineer

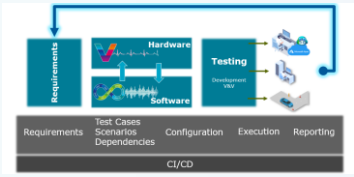
The Goal: Validate seamless interaction across multiple ECUs and distributed architectures.

The Pain: Integration issues appear late because system-level testing is fragmented across tools and teams.



The Test Automation Engineer

The Goal: Build scalable, automated test pipelines across multiple HiL systems.



The Pain: Test setups are inconsistent and hard to reproduce, requiring manual effort and reducing test coverage.



The Powertrain Validation Engineer

The Goal: Validate powertrain systems under realistic and edge-case conditions across lab and vehicle levels.

The Pain: Physical test systems are expensive and limited in availability, making field issue troubleshooting difficult and delaying root cause analysis



The SDV Software Engineer

The Goal: Enable continuous integration and deployment with fast feedback loops on vehicle software.



The Pain: HiL environments are not CI/CD-ready, slowing down testing cycles and delaying software releases.

Where Time Gets Lost in the Testing Workflow

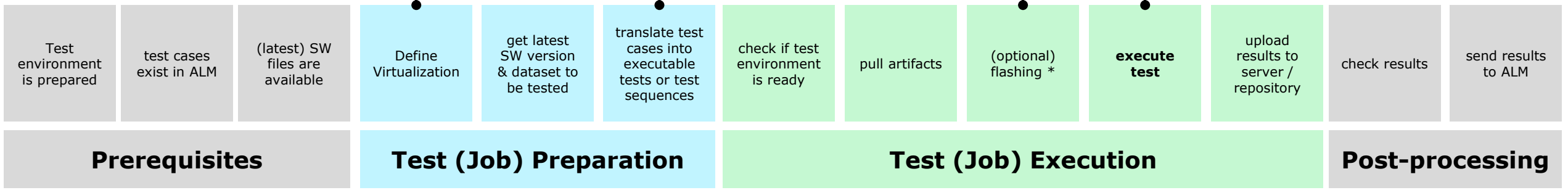
Creation of a gateway model, project configuration & plant model interfaces for a typical HiL can take up to **6 days**

- **OEM1: 60% of whole process** only for test case implementation
- **OEM2:** ~**75** supplier **engineers** for testcase implementation/maintenance
- Scripting of uncontrolled testcases and low standardization

Assuming 30 min per flash
- 1 flash per month = 6 hours per year
- 1 flash per day = **8 days per year**

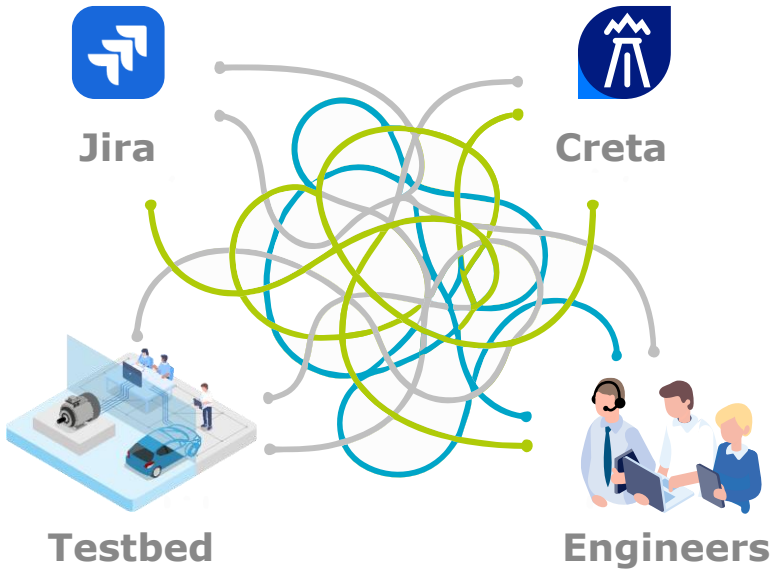
for 1 test environment

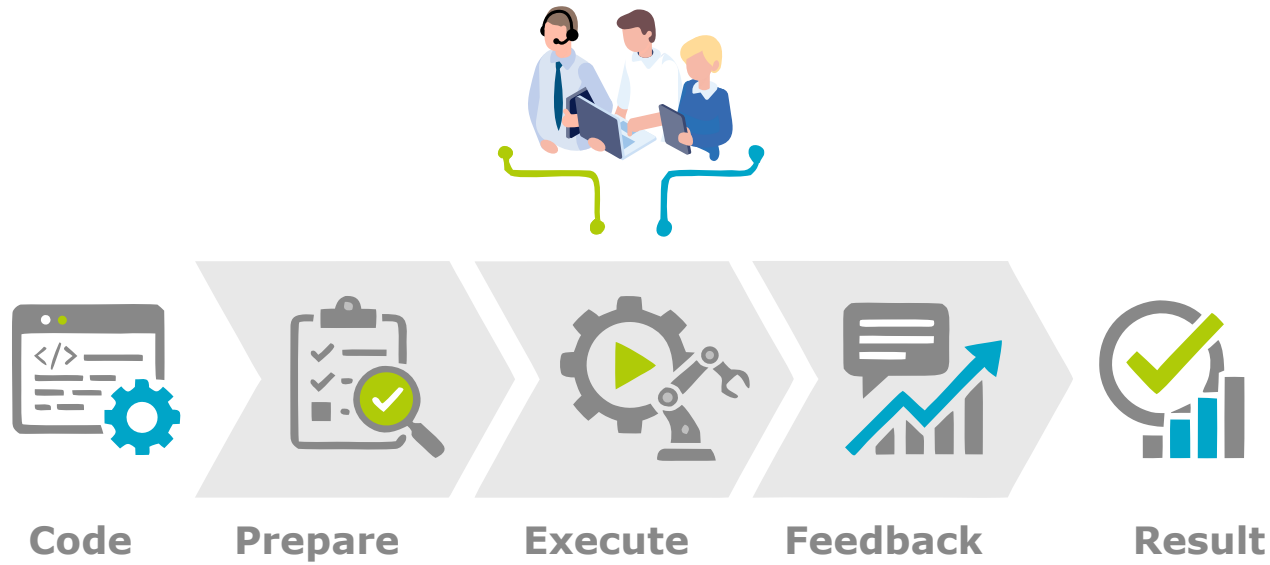
State of the art
Often the only task that is fully automated



Bottom Line: As release cycles speed up, manual work becomes a growing bottleneck

The Goal: A Software Defined Test Factory





Current State

isolated tasks, manual flashing, fragmented tools

Future State

a collaborative ecosystem

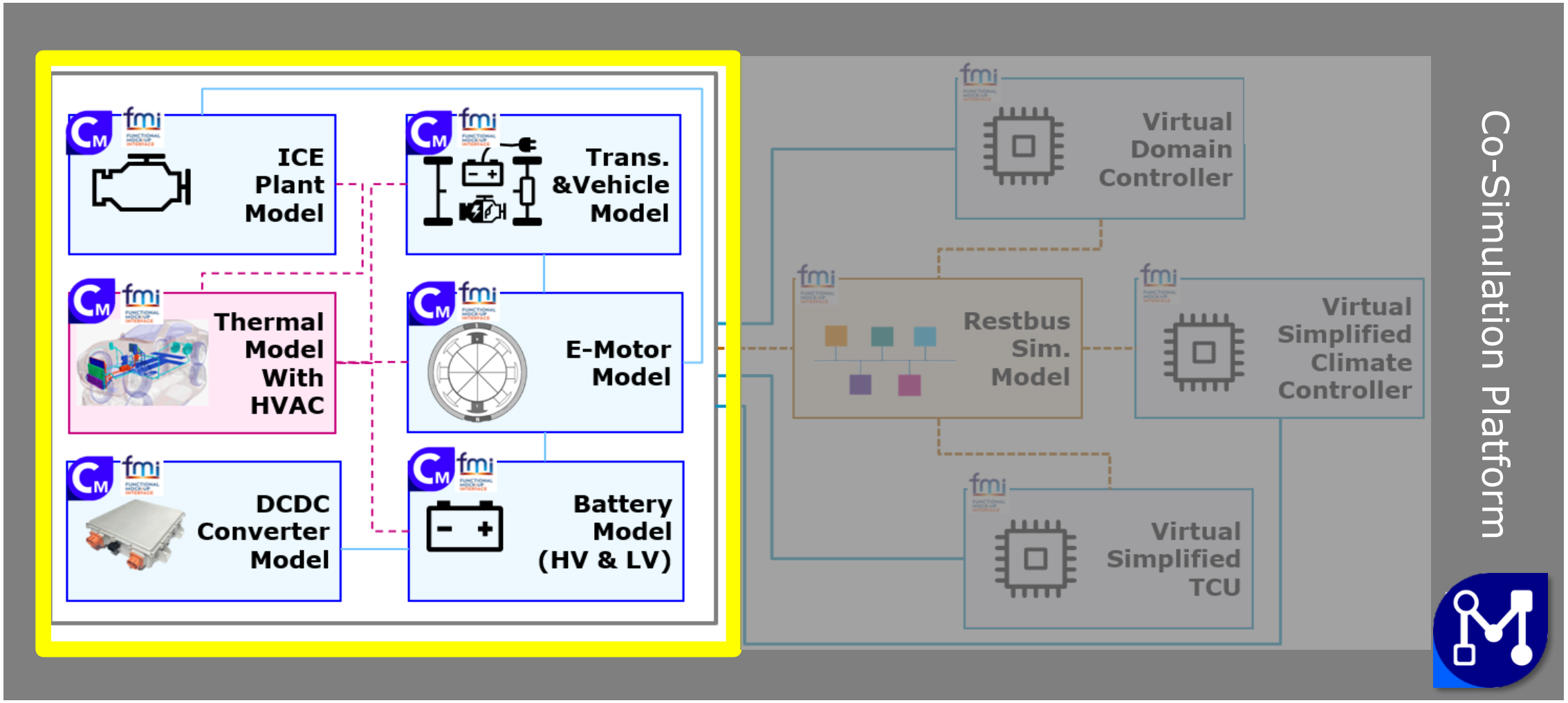
The Vision: align processes and tools to gain speed and obtain full traceability

Virtualized Powertrain Development and Validation

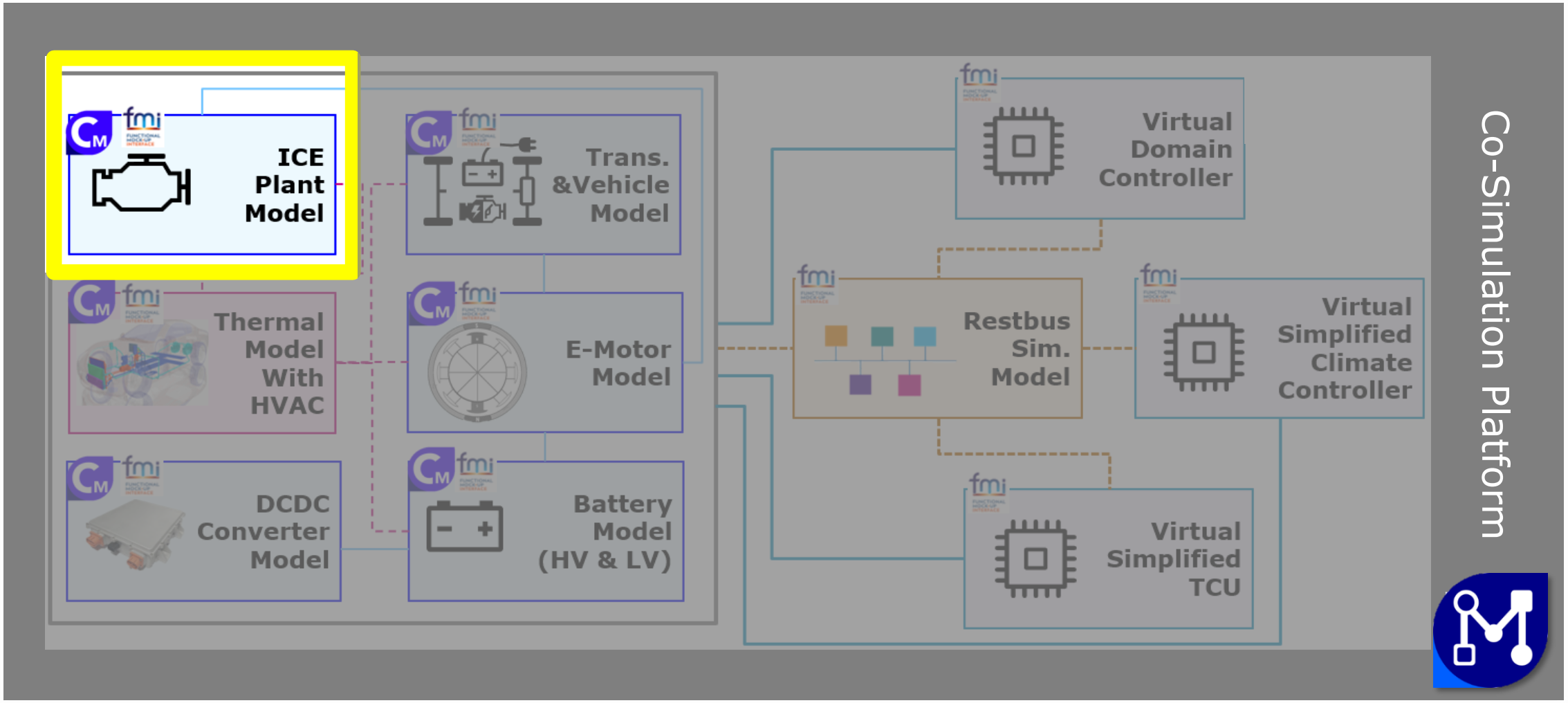
HEV Energy Management system

Public

Models Used Within the Project



Models Used Within the Project – ICE Plant Model



ICE Plant Model

INPUTS & OUTPUTS:
- Routing and calculations

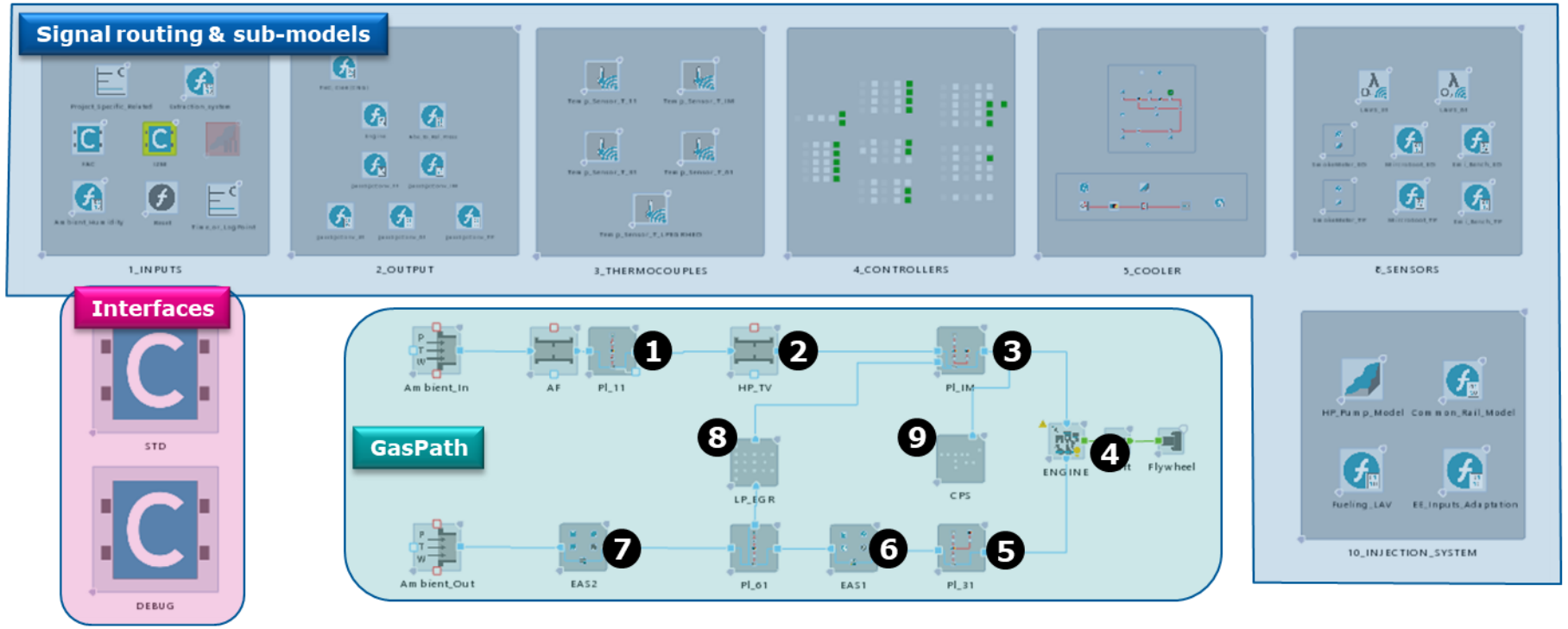
ICE Thermocouples:
- Intake and exhaust temperature sensors

CONTROLLERS:
- Parametrization maps/curves
- PID structures

Cooler:
- Underhood HT model
- Simplified cooler

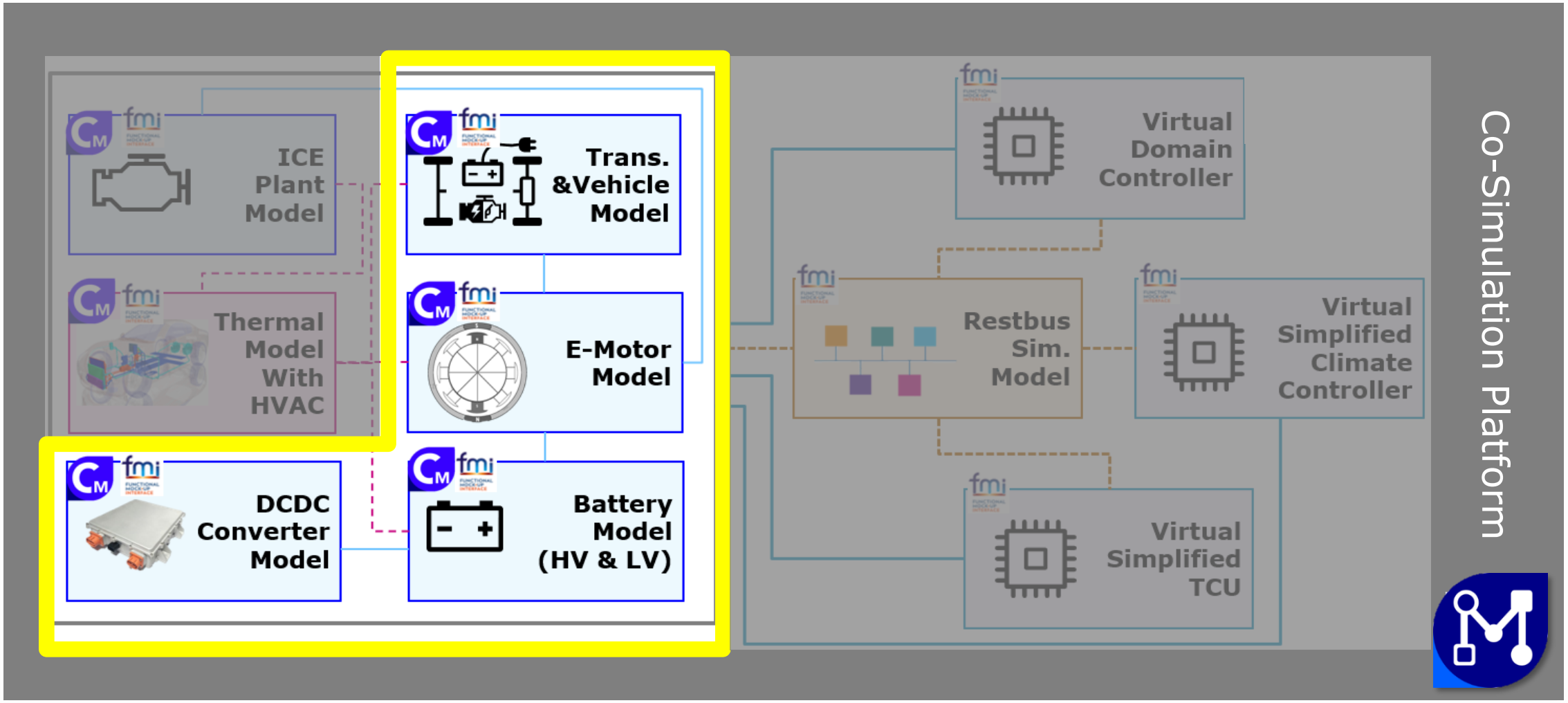
Sensors:
- Exhaust gas analysers
- Soot sensor
- Lambda sensors

Injection system:
- VVT calculations
- Fuel (lambda base)

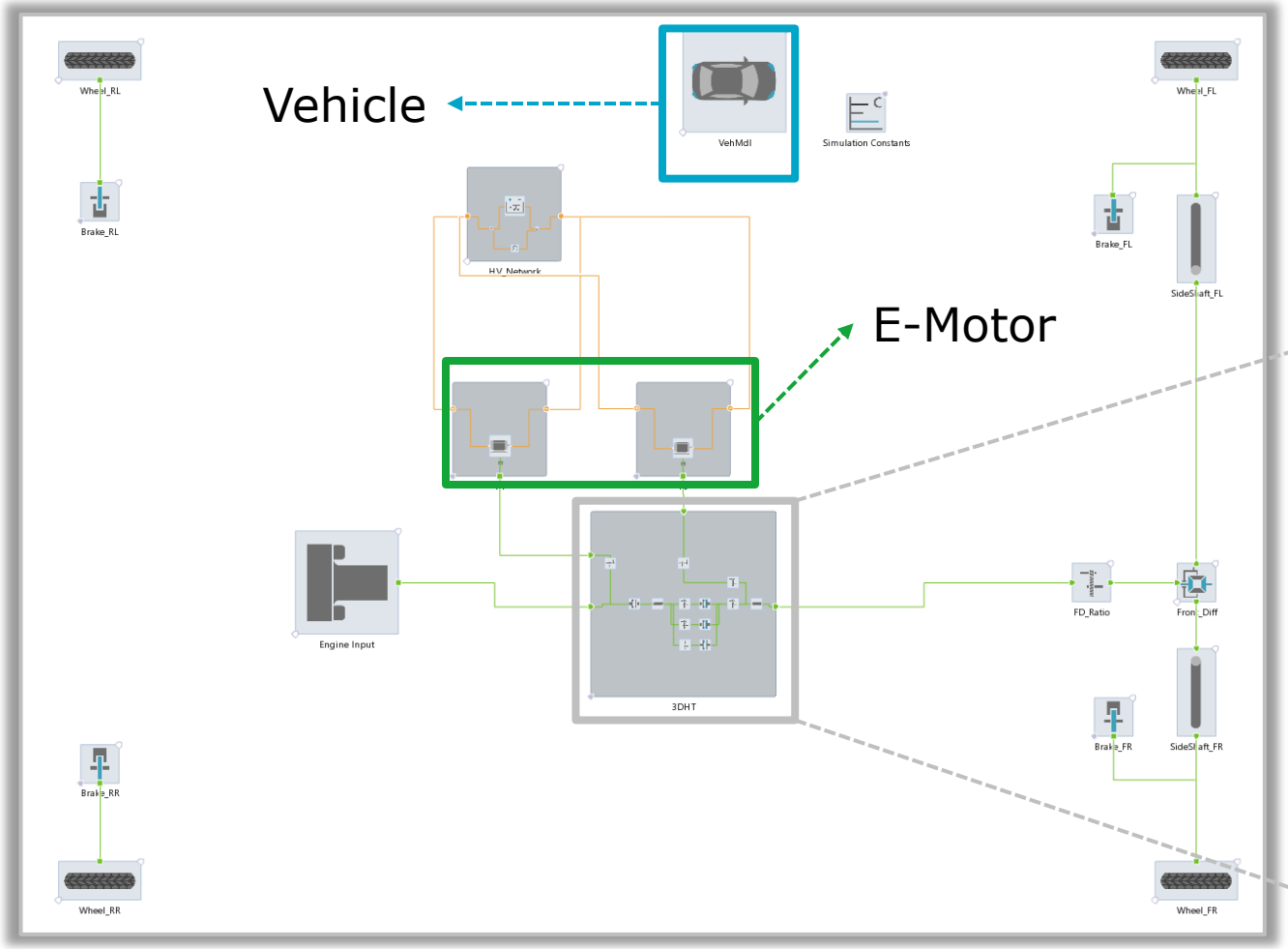


1. Air filter | **2. Throttle** | **3. Intake manifold** | **4. EE_Cylinder** | **5. Exhaust manifold** | **6. TWC** | **7. GPF** | **8. LP_EGR** | **9. CPS**

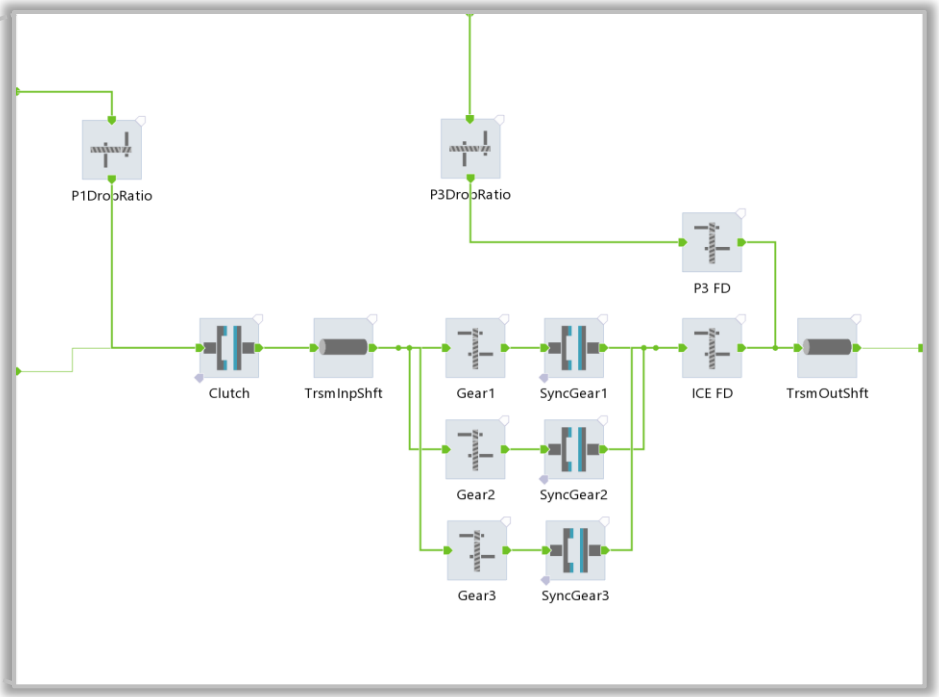
Models Used Within the Project – Hybrid Powertrain Model



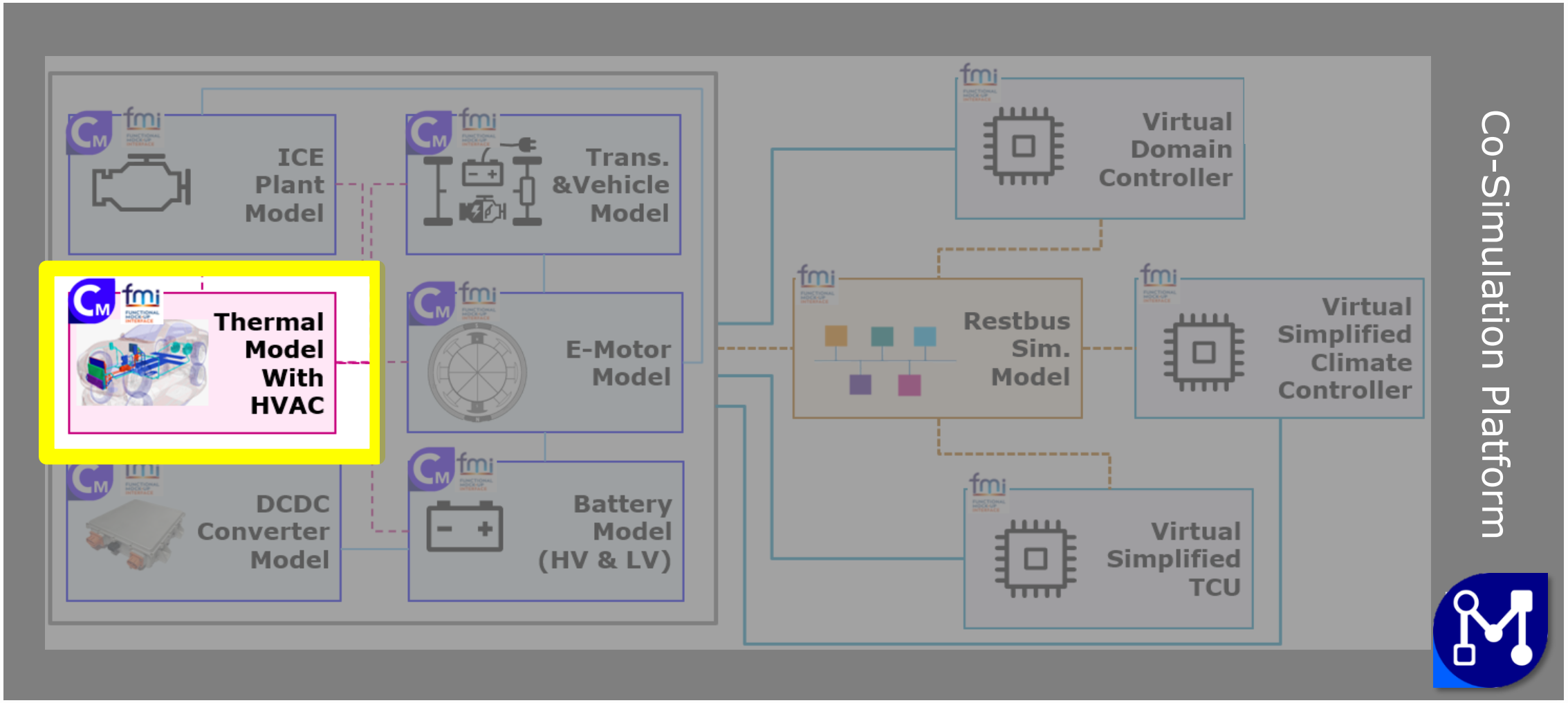
Powertrain Model (E-motor + Transmission + Vehicle)



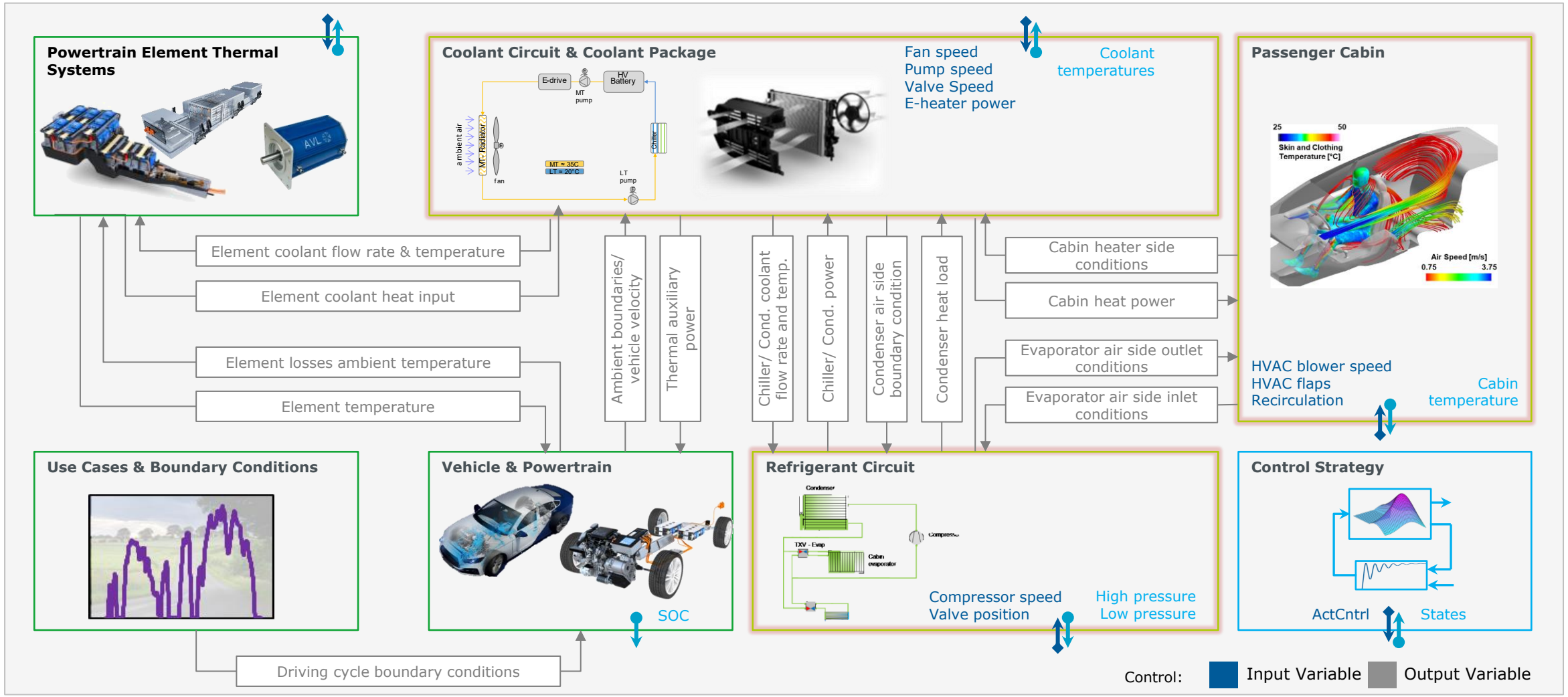
Transmission



Models Used Within the Project – Thermal Model



Thermal Model → VTMS model architecture development



Orchestrated, Automized and Traceable Powertrain Development and Validation

Hardware in the Loop Example

Public

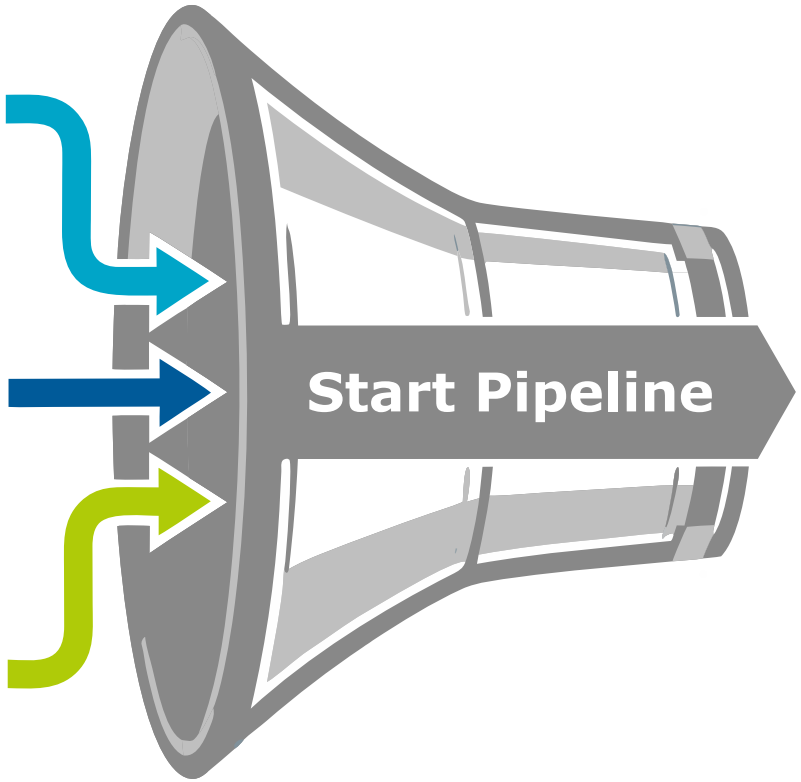
Step 1: The Trigger

Automation starts the moment a change is made

Software Change
(Git Commit)

Dataset Update
(AVL Creta)

On-Demand
(Web UI)

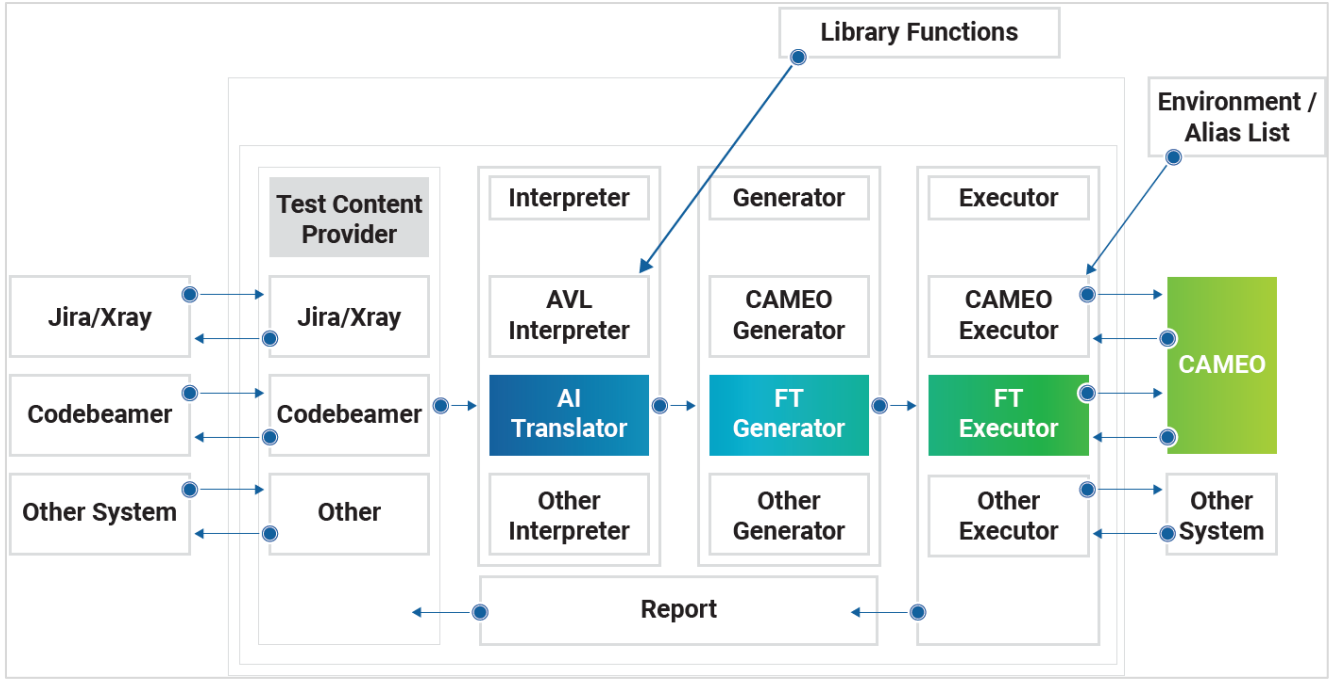


The journey begins automatically via standard development events:

- **A Software Change:** A new software is released to a Git repository
- **A Dataset Update:** A calibration engineer merges a new dataset in AVL Creta
- **On-Demand:** A user manually triggers a specific job via the Web UI

Step 2: Prepare & Translate Testcases
From human requirements to executable tests-automatically

- **Interfaces to ALM/PLM** trigger on demand AI supported test translation and execution via CI/CD pipelines
- AI driven test generation and test modification is **robust against different language, phrasing and flavors** of requirements
- AVL CAMEO supports test execution **seamless over different test environments**
- New or changed requirements will reflect in **testing within minutes** and provide most relevant feedback to engineers



New or changed requirements reflect in testing within minutes

Step 3:Automated HiL Configuration

AVL Nexus HiL™

- **HiL Box | Mini HiL | HiL Rack**
  Modular form factors for lab, desktop & full-scale validation.
- **Flexible & Scalable I/O**
  AI | AO | DI | DO on single card with software configurable architecture.
- **Multi-Domain | Multi-ECU**
  Powertrain, eDrive, Battery, ADAS, E/E integration in same platform.
- **Open & Vendor-Agnostic**
  Seamless 3rd-party integration, system-level interoperability.
- **Automation-Frameworks**
  CI/CD pipelines, remote access, global collaboration, increased test coverage.
- **Cost-Efficient & Future-Ready**
  Right-sized hardware, fast deployment, scalable architecture.

AVL NEXUS HIL™ DESKTOP



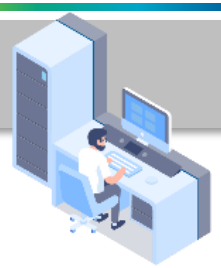
AVL NEXUS HIL™ MID RACK



AVL NEXUS HIL™ FULL RACK



Step 3:Automated HiL Configuration



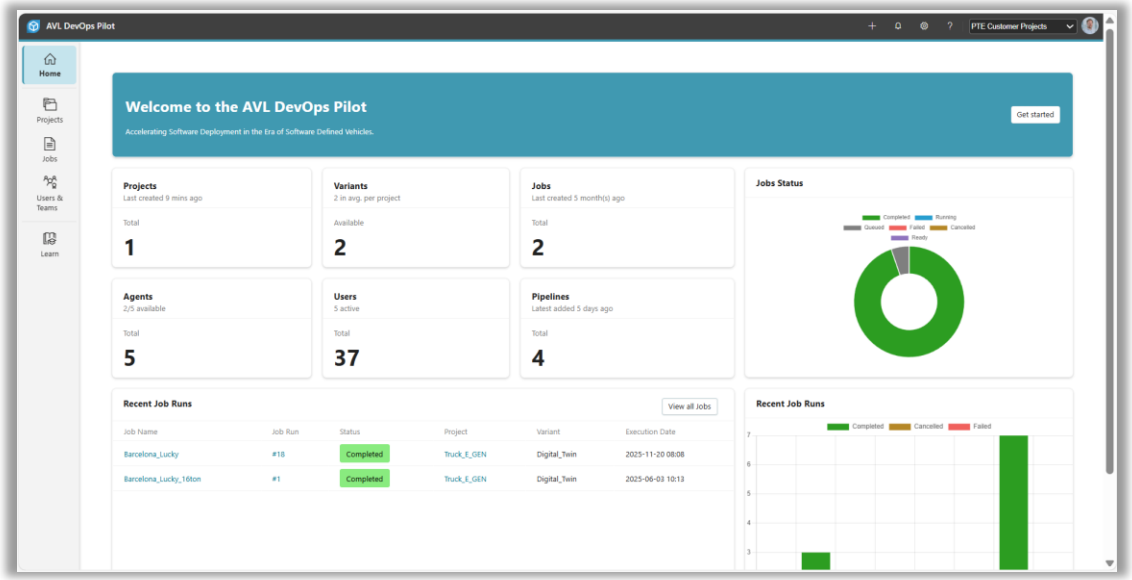
Example HIL Project
HEV domain with Engine and Powertrain ECUs

	Manual Workflow		Automated Workflow
Platform independent **gateway model**	Gateway model manually created for each ECU pin (HW, communication, plant model layer).	***~1-2 days*** → ***1-2 hours***	***Auto-generated*** *I/O model,* interfacing plant models and multiple ECUs; containing function specific subsystems (e.g. Analog, Digital, SENT, CAN, LIN).
HIL platform specific **project configuration**	Each configuration step handled individually for ECU topology, HW & communication functions, and models.	***~2-3 days*** → ***1-2 days***	***Auto-creation*** of HIL-specific project, based on user configuration & communication files, HW topology, simulation models. ***Auto-configuration*** from ECU pin to HIL module; mapping logical signal chain.
Integration of **plant model interfaces**	Plant model I/F manually linked to other models, HW I/O ports, and communication modules. Up to thousands of connections.	***~1-2 days*** → ***1-2 hours***	***Auto-linking*** of several plant models with respective interfaces (Model-to-Model communication)

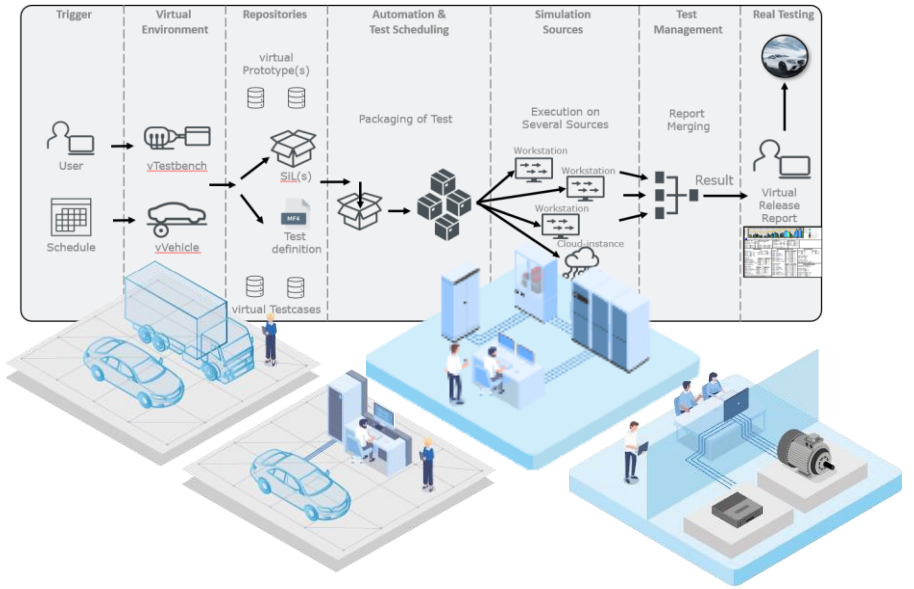
~40%
cost & time saving, overall

Indicative numbers
Based on reference projects

Step 4: Automated Execution



The Office

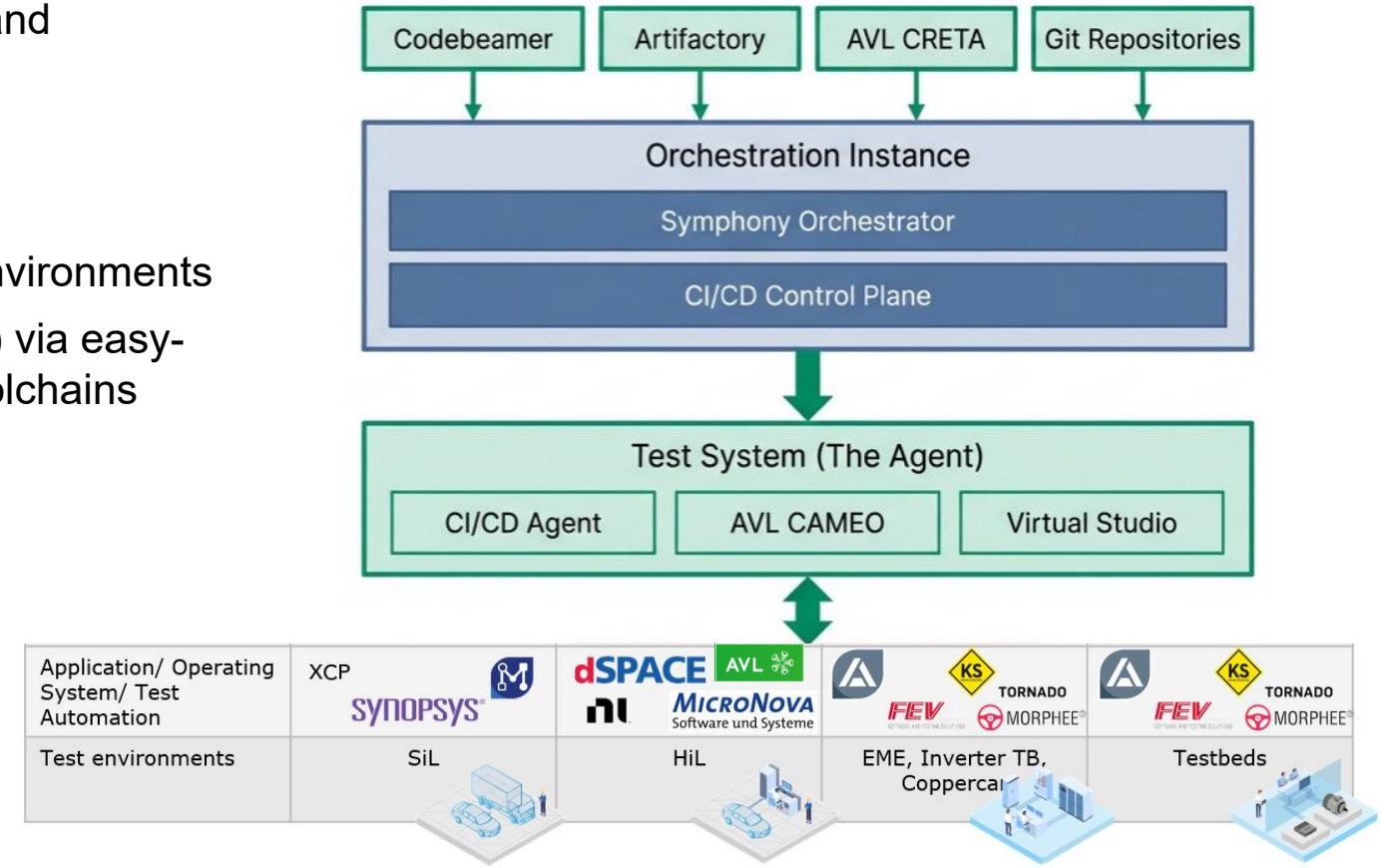


The Physical and Virtual Factory

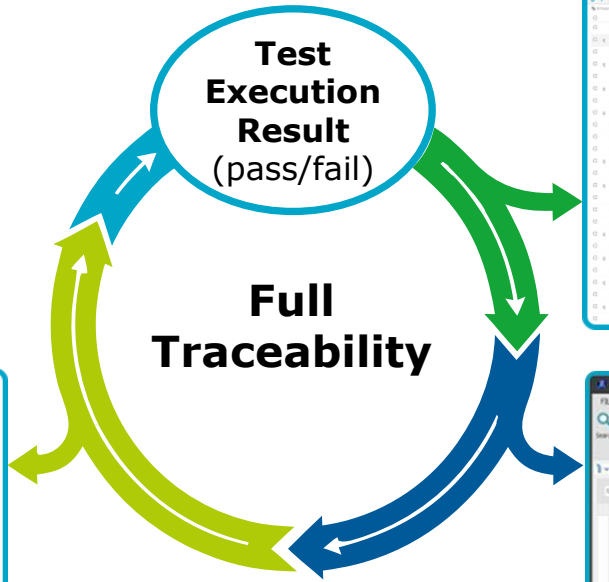
The engineer sits in the office while the test environment configures itself and runs the test sequence without human intervention.

Step 4: Automated Execution

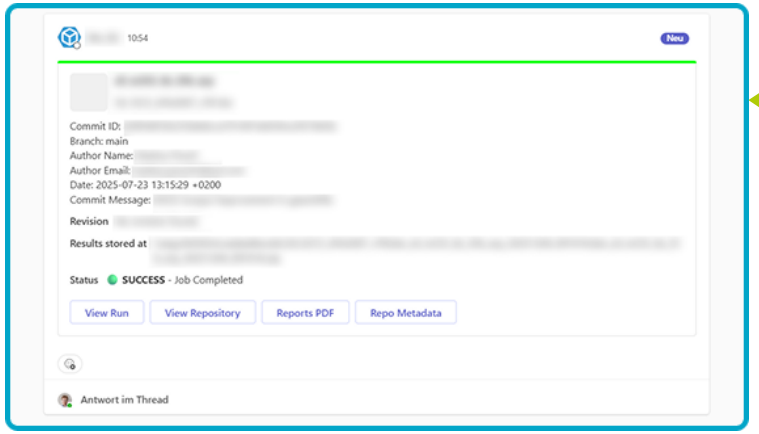
- Test environments are **automatically configured** and orchestrated.
- **End-to-end traceability** of all artifacts and results.
- **Integration** with AVL Creta
- **Neutral configuration layer** for SiL and HiL test environments
- **Focus on the end-user** (test/calibration engineers) via easy-to-use GUI (no experience with coding or CI/CD toolchains needed).
  - Job configurations
  - Environment configuration
  - Auto trigger jobs
  - Re-run jobs (reproduce tests)
  - Result/report upload to different locations

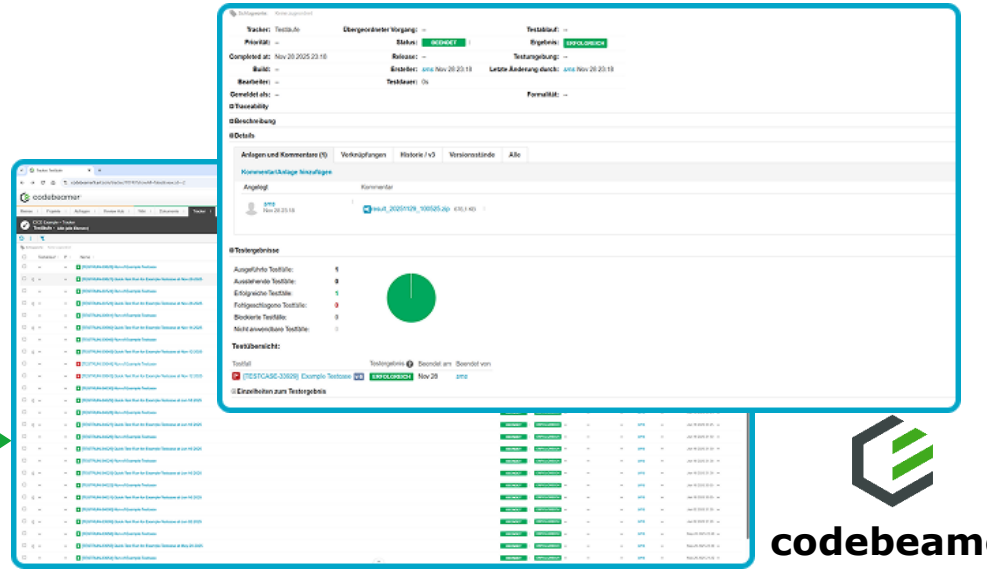


Step 5: Closing the loop

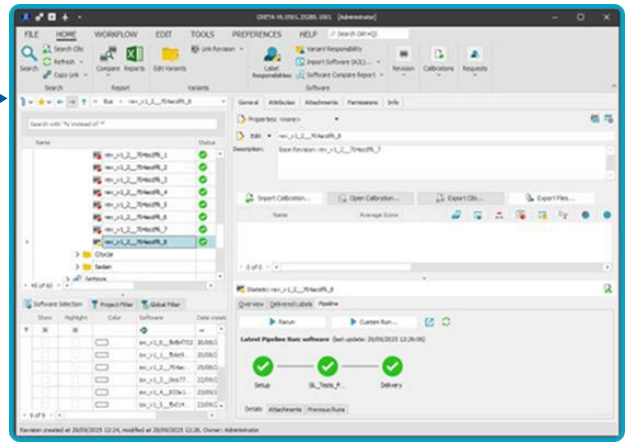


Microsoft Teams





codebeamer



AVL Creta

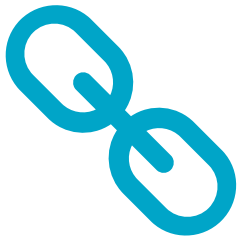
Result are distributed immediately, ensuring that every test is linked back to the specific requirement and dataset that triggered it.

Focus on engineering instead of configuration

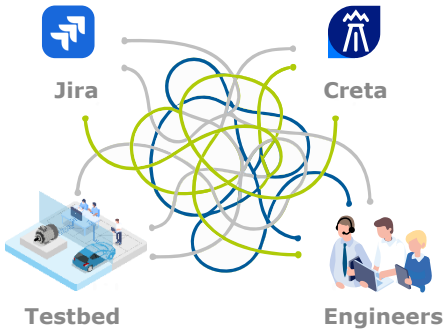
Common Orchestration Layer supports heterogeneous test environments

Application/ Operating System/ Test Automation	SIL	HiL	EME, Inverter TB, Coppercar	Testbeds
Test environments				

Full traceability of artifacts and results



Reduction of overhead and downtimes by automation of procedures, workflow management and orchestration of test environments



Enablement of calibration/test engineers and non-devops engineers by easy-to-use UI



Thank you



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