

Shift Gears: Modernizing Legacy Labs for Next-Gen-Propulsion

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Agenda

- 1 Global Automotive Landscape**
- 2 Navigating Market Challenges**
- 3 From Legacy to Leading Edge**
- 4 How to Modernize Existing ICE R&D Testbeds**
- 5 Best Practice & Key Takeaways**

Today 's Presenter



Werner Fuchs

Education

- **[1998]** – Master's degree Electrical Engineering, TU Graz & UPC Barcelona
- **[2008]** – AVL Management Development Program

Experience

- **[AVL List GmbH]** Product Manager, Application Manager
- **[AVL List GmbH]** Team Leader Product Management Automation
- **[AVL List GmbH]** Head of Product Management and Operations
- **[AVL List GmbH]** Department Manager Sales and Operations

Technical Expertise

- **Automation**
- **Artificial Intelligence**
- **System Integration**



Shift Gears:
Modernizing Legacy Labs for Next-Gen-Propulsion

About Us

AVL at a Glance



1948

Founded



30

Countries
Represented



12,000

Employees Worldwide



11 %

Of Turnover Invested
in Inhouse R&D

75+

Years of Experience

50+

Global Tech and
Engineering Centers

67 %

Engineers and
Scientists

2,300

Granted Patents
in Force



Global Automotive Landscape

Global Automotive Landscape 2026

Electrification
Accelerates

Software-Defined
& Connected

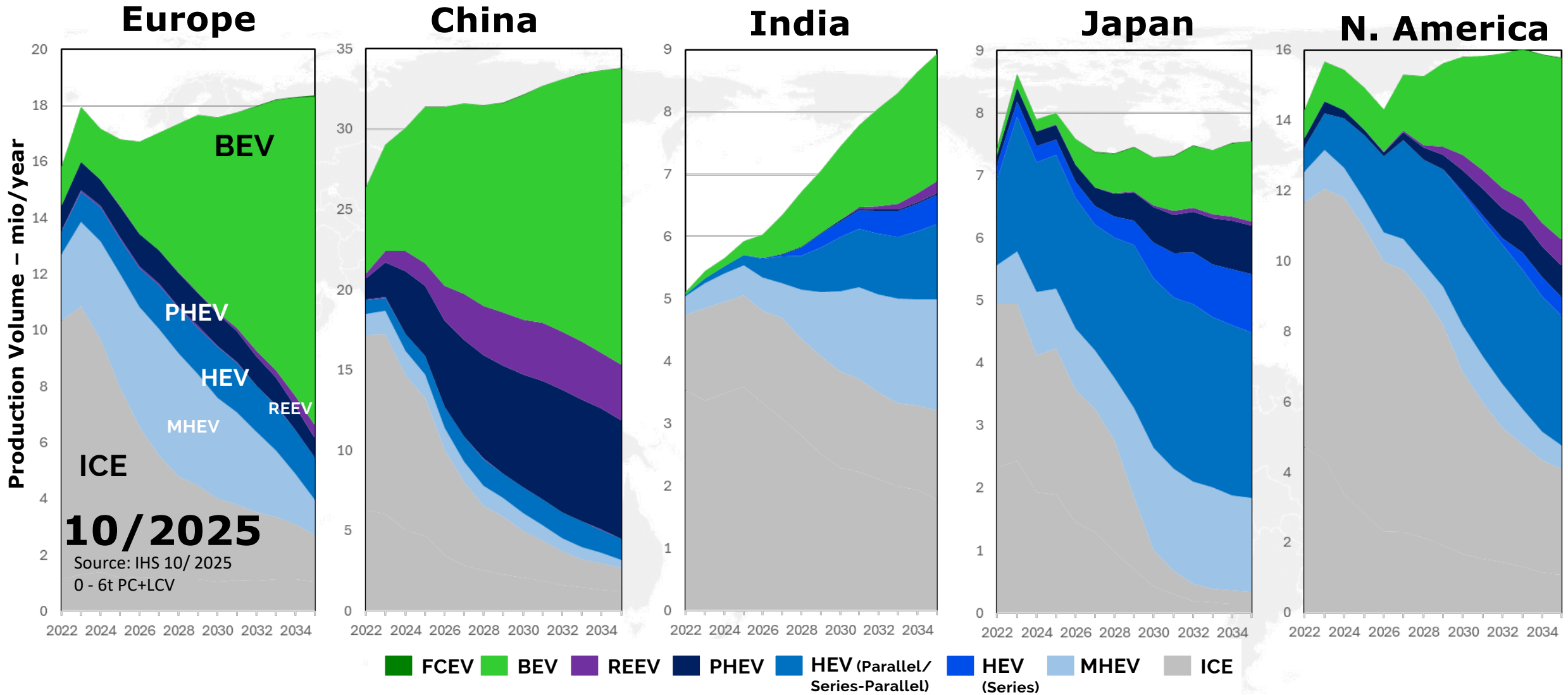
ICE Powertrains
Reinvented

Regulation in Flux

Testing Transformed



Passenger Car Expected Technology Split - Production Volumes (IHS 10/2025)





Navigating Market Challenges

Navigate Market Challenges

01

Unavailability of spare parts
Lack of support



02

Security
threats



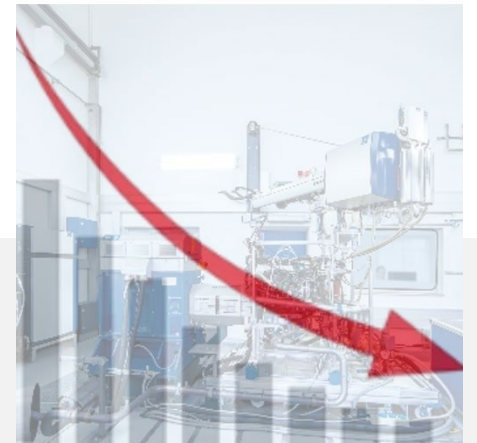
03

Non-compliance with
legislative regulations



04

Inefficiency



Current Challenges

01

Unavailability of spare parts
Lack of support

- Missing spare parts cause long downtimes and high costs
- Delays threaten project timelines (SOP) and customer trust
- Lack of support due to supplier exiting the market
- Risk of data loss or complete testbed failure



Current Challenges

02

Security threats

- SW runs on outdated platforms and is not supported by current IT standards
- Lack of updates reduces performance and reliability
- IT departments restrict usage due to security threats
- Non-compliance may lead to legal issues and reputational damage



Current Challenges

03

Non-compliance with legislative regulations

- Test cycles do not fulfill required emission legislation – failure to comply with regional standards
- Measurement devices lack required conformity resulting in false compliance reports
- Risk of failed homologation causing recalls, significant financial loss and reputational damage

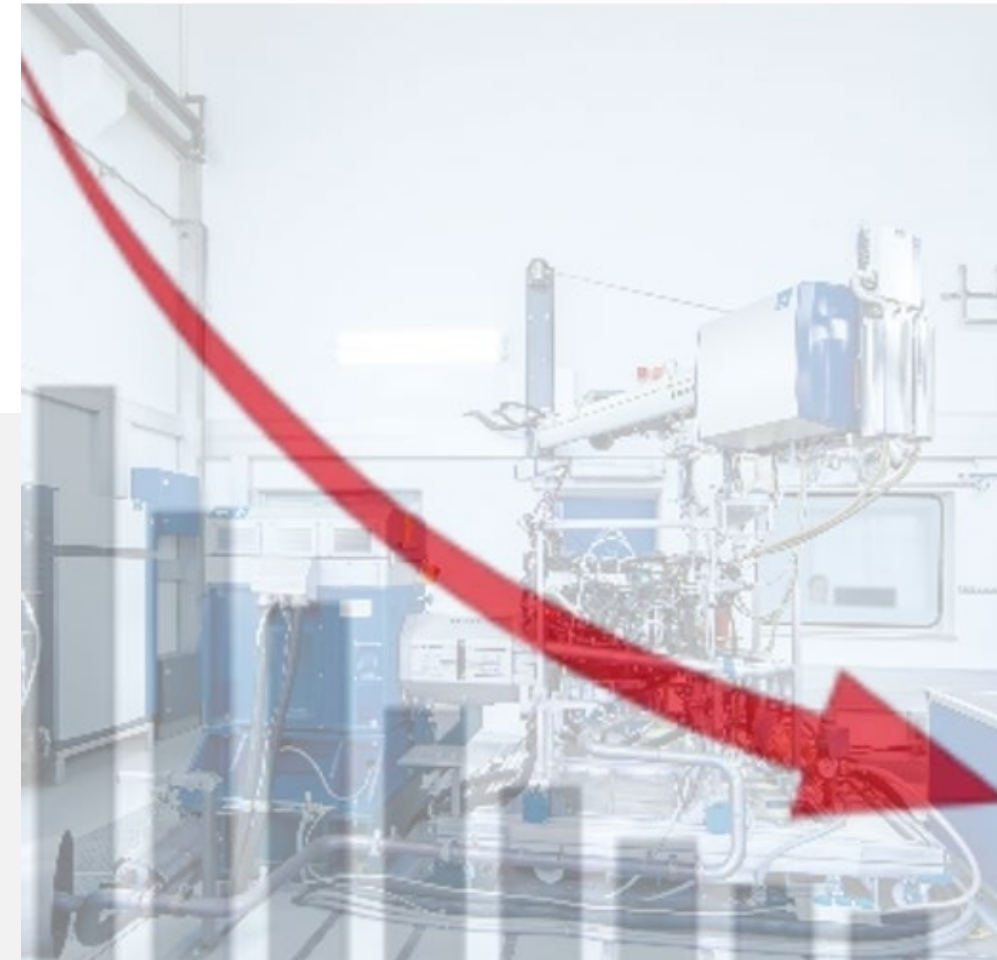


Current Challenges

04

Inefficiency

- Inconsistent software tools increase complexity and require expert knowledge
- Administrative tasks reduce testbed availability
- 24/7 operation demands high staffing; work-around for remote monitoring is inefficient



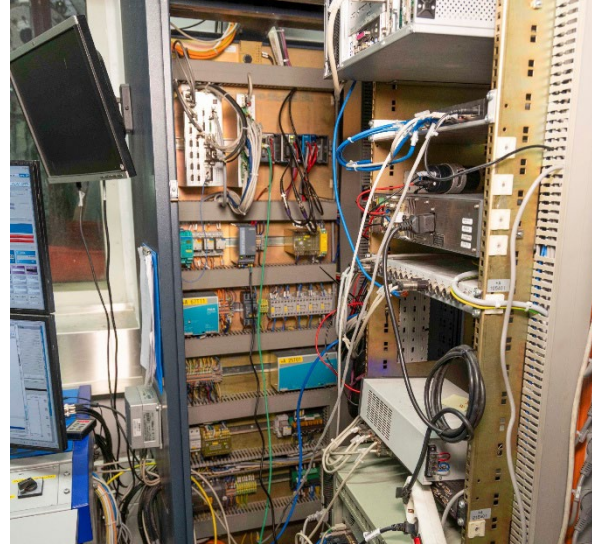
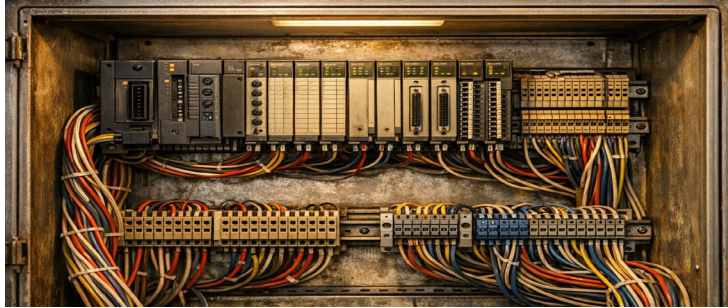


From Legacy to Leading Edge

Why Modernize a Running System...



Assessment of Existing Testbed

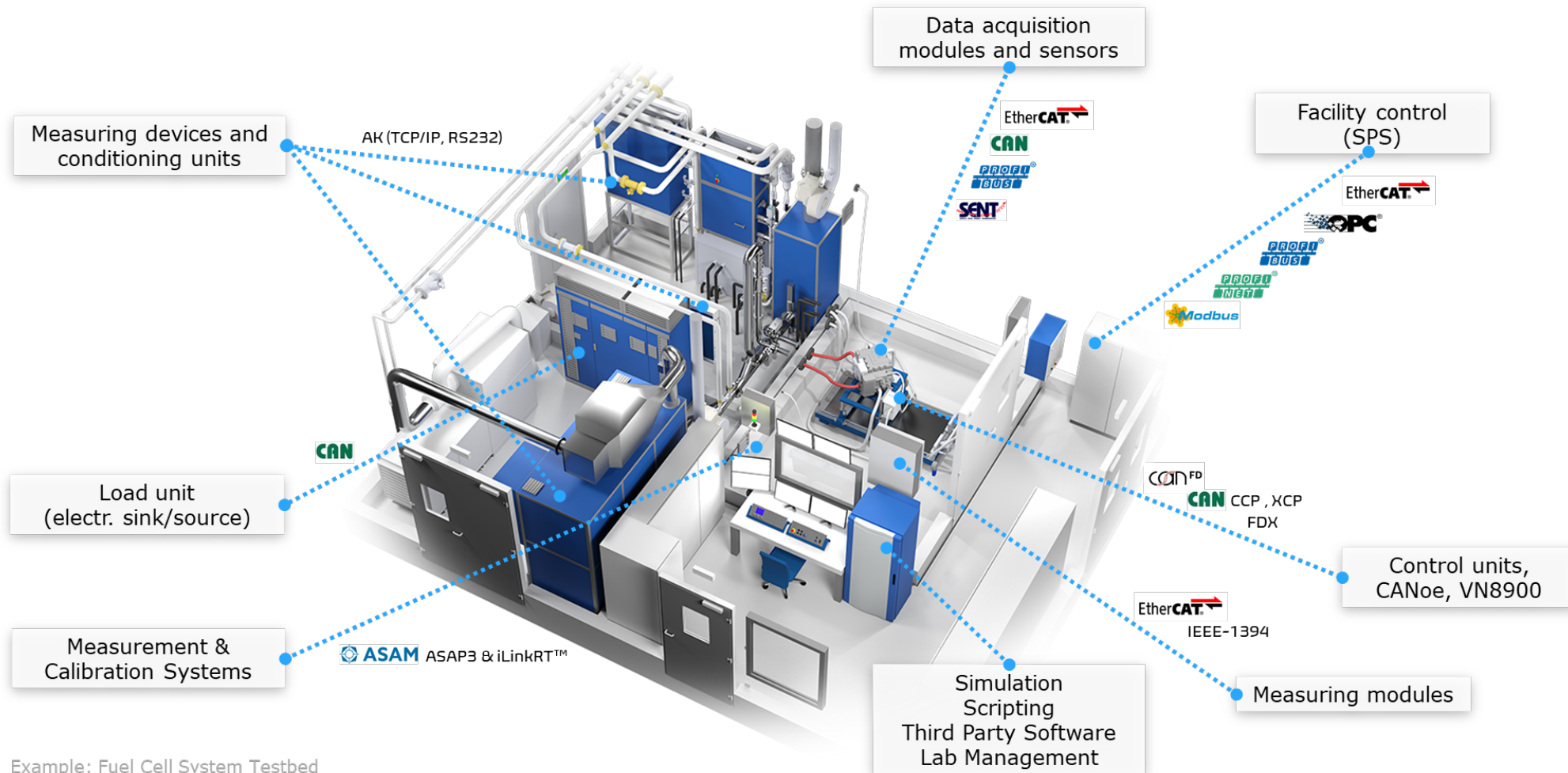


Evaluate current engine testbed capabilities and identify areas that need technological upgrades for modernization, like

- **Electrical Dynamometer**
- **Data Acquisition / IO**
- **Measurement Devices / Conditioning / Actuators**
- **Safety / PLC**

High Variety of Interfaces

for integration of equipment and various test systems



Example: Fuel Cell System Testbed

One Hardware



19^c ORACLE
Database



Capable and certified Workstation

Automation



Control



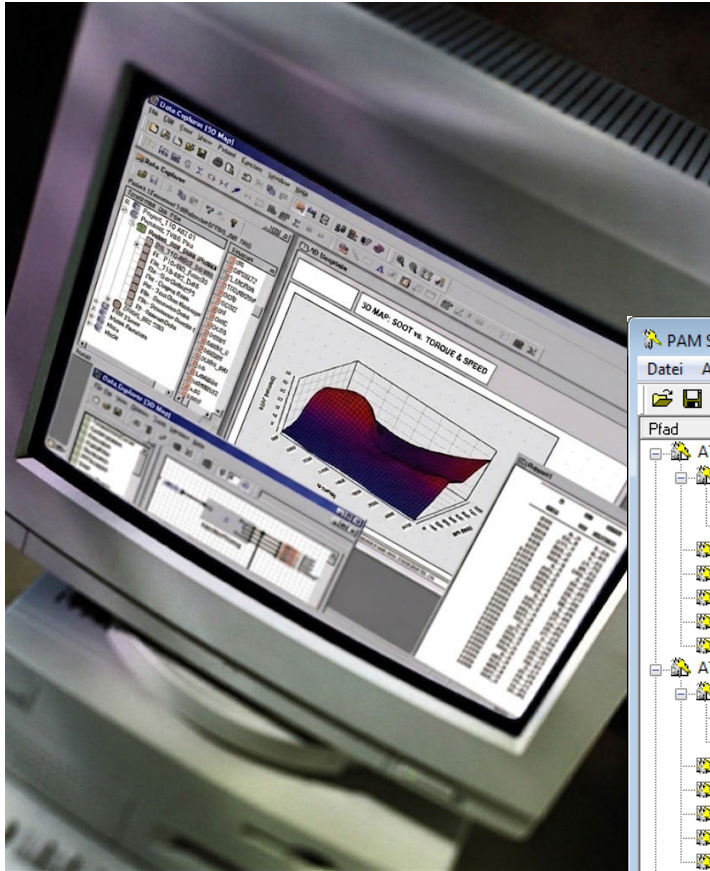
Emission



Simulation



Legacy Automation & Inconsistent SW Toolchain



Data Manager - \\Servers\NewServer\TestSerie

Id	Name	StartTime
1	Test_Cell_Diaries	2013-01-16 14:10
2	Engine_Diaries	2013-01-16 14:10
3	po	2013-02-18 11:40

sfi400k.dbl - Notepad

```
*: <0000>, <129282|SV_EXTCONT_LIFESIGNAL_FEEDBACK>, <194817|SV_EXTCONT_LIFESIGNAL_STATE>, <200000>
*: ----- System monitor -----
*: DA max. 80 Lines
*: iSvid int %06d 1
*: cText char %32s 32
*: iControl int %01d 1 1=monitoring, 0=no monitoring
*: iMvalue int %05d 1 Value for reaction
*: iQuantity int %02d 1
*: iDelayidx int %04d 10
*: iActionidx int %04d 1
*: iSvidTbmState int %06d 1 State information for Puma Testbed monitoring
$: <DA>
```

Replikationsstatus

Datei	Aktion	Ansicht
-------	--------	---------

PAM Sicherheits-Manager [AVL/Level:4/AVL] - [ATPARAMETER]

Sicherheitseinstellung

- ATRDetails
 - GearNo
 - Read S00,S01,S02,S03,S04,...
 - Update S99,U01,U02,U03,U04
 - Delete S99,U01,U02,U03,U04
 - Execute S99,U01,U02,U03,U04
 - Insert S99,U01,U02,U03,U04
 - Read S00,S01,S02,S03,S04,...
 - Update S02,S05,S06,S99,U01,...
 - ATRHeader
 - Description
 - Read S00,S01,S02,S03,S04,...
 - Update S02,S05,S06,S99,U01,...
 - Delete S99,U01,U02,U03,U04
 - Execute S99,U01,U02,U03,U04
 - Insert S99,U01,U02,U03,U04
 - Read S00,S01,S02,S03,S04,...
 - Update S99,U01,U02,U03,U04
 - ATRTiptronic

PAM SICHERHEITS-MANAGER

Benutzerebene

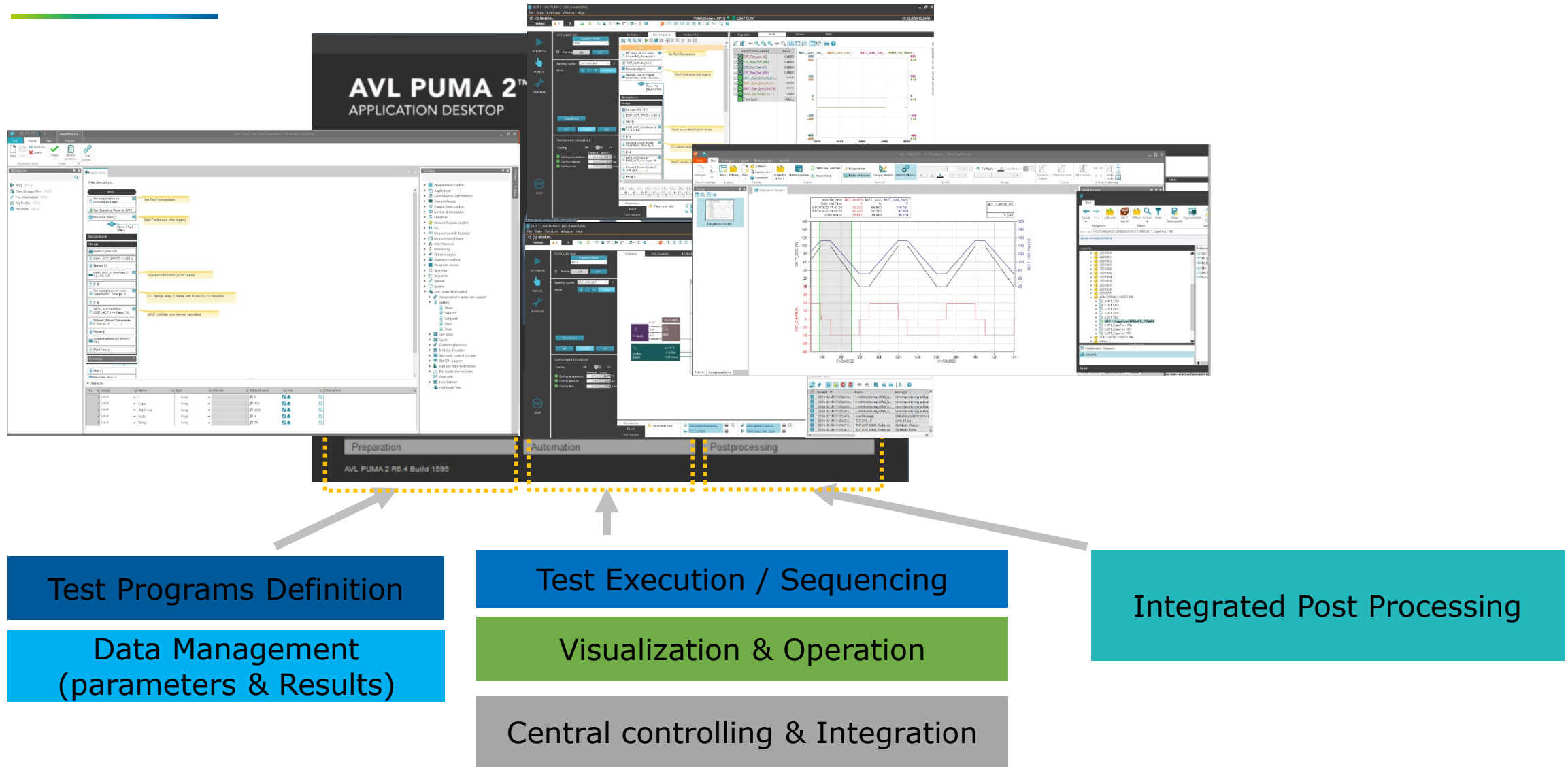
- Benutzerebene 1 (Bediener)
- Benutzerebene 2 (Ingenieur)
- Benutzerebene 3 (Prüfstandsadministrat
- Benutzerebene 4 (Projektadministrator)

```
DA_SV_WATCHDOG_MODULE_STATE>, <Watchdog does not work| >,<1>,<2>
SV_SYSTEM_MONITOR_STATE_17>, <Emergency stop| >,<1>,<0>
SV_SYSTEM_MONITOR_STATE_18>, <Stop| >,<1>,<0>
SV_SYSTEM_MONITOR_STATE_24>, <SS1-Message only| >,<1>,<0>
SV_SYSTEM_MONITOR_STATE_24>, <SS1-Stop triggered| >,<1>,<0>
SV_SYSTEM_MONITOR_STATE_24>, <SPS-Failure| >,<1>,<0>
SV_SYSTEM_MONITOR_STATE_25>, <Reduced speed mode selected| >,<1>,<1>
SV_SYSTEM_MONITOR_STATE_26>, <Reduced speed mode not selected| >,<1>,<0>
SV_SYSTEM_MONITOR_STATE_19>, <Thr.Act. error| >,<1>,<0>
SV_SYSTEM_MONITOR_STATE_20>, <Thr.Act. warning| >,<1>,<1>
ADB_SV_SPEED_SIGNAL_CHECK1>, <Safety speed check| >,<1>,<1>
CC_SV_PUMA_ALIVE>, <PUMA not ok ...STOP| >,<1>,<1>
CC_SV_PUMA_ALIVE>, <PUMA not ok ...WDog| >,<1>,<1>
CA_SV_STATE>, <Panel not ok| >,<1>,<3>
DB_SV_OVERLOADED_FLASH_STATE>, <N lt Nmin| >,<1>,<1>
BAC_SV_Dyno_OnOff_s>, <Dyno off in Manual| >,<1>,<0>
GBA_SV_DI_TRC_EXIST_STATE>, <TRC monitoring| >,<1>,<0>
CC_SV_STATUS_USER1>, <Dyno switched OFF| >,<1>,<0>
CC_SV_STATUS_USER2>, <Dyno overtemperature| >,<1>,<0>
utrch
```

Local: localhost (ATGRZWD507181)

PUMA 2 Automation – Tasks of the Software

One software for all tasks, workflow oriented



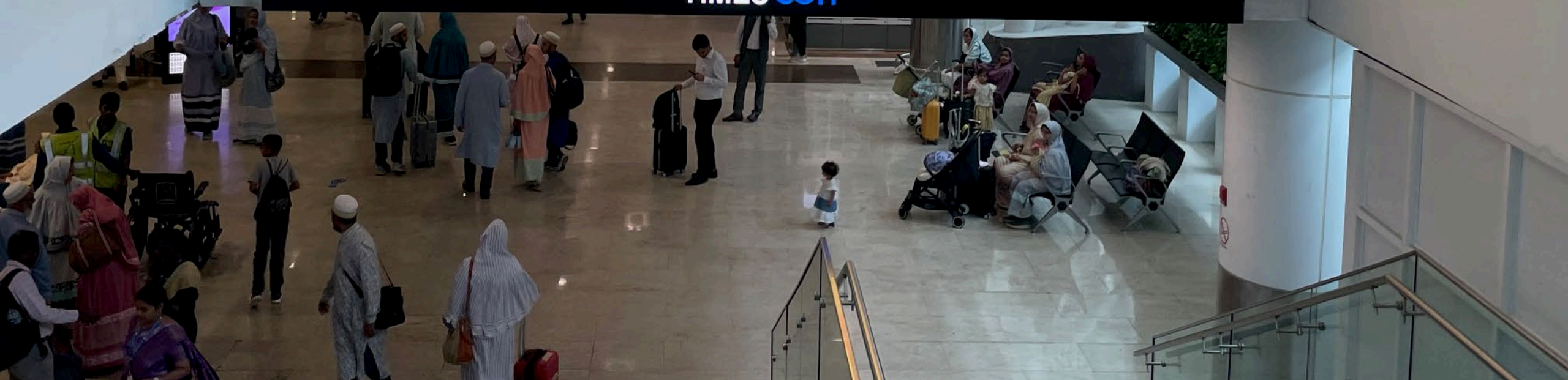
Every 30 seconds,
a business in India
falls to ransomware.
Protect yours.

ManageEngine
Endpoint Central



Source: Data Security Council of India - India Cyberthreat Report 2025

TIMES COH™



SW Security Tool Chain - Details

sonarqube

Visual Studio

GitHub Copilot

Visual Studio Code

JFrog Xray

Source Code

3rd Party Software Components

Vendor Software

Operating System

Hardware

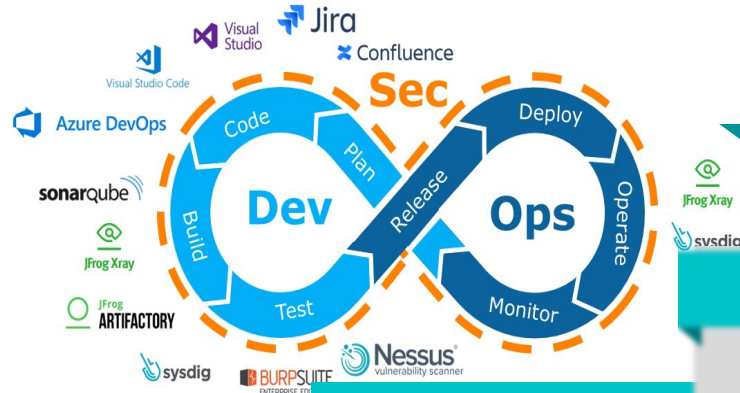
Nessus[®]
vulnerability scanner

Hardening Checklist

Penetration Tests via external Company

SW IT Security Means Value for Customer

Value in every maintenance release via SW Maintenance Contract



Release	Month	Key Features
R6.3	Decem	<ul style="list-style-type: none"> PUMA 2 E-Powertrain: Tailored package E-Axis Configuration with single E-Motor PUMA 2 Battery for Cell Testing (16 UUTs) Integration of new AVL Cell Tester (CTS6) CAN driver supports "Container POI" API "Seed & Key" support for XCP OPC UA Server: enhancements supporting Data Access and Server methods, Security PUMA 2 Vehicle /VECON 2: Architect. Imp customer PUMA 2 E-Motor: Extensions with control Torque Support, ISAC high dynamic speed PUMA 2 Inverter: Support active load / ps and Profile Sequencer (FSQ), support ISA PUMA 2 Fuel Cell: Support Profile Sequen-FC System Simulation Model PUMA 2 Production for Battery: Additional HV insulation measurement device (Stahl) Flexible environment to provide a testbed to specific powertrain or powertrain elements IT Security: P2Share: enhanced HTTPS FRED Enhancements, T.C Embedded: Site simulation based on a trigger
R6.4	Decem	<ul style="list-style-type: none"> PUMA 2 Vehicle /VECON 2: Chinese Perform supporting latest legislation, EURO 6e compl PUMA 2 E-Powertrain: E-Axis Configuration with twin E-Motor, Fuel EMCON 6: Improved anti-windup by addition PUMA 2 Fuel Cell: Standalone Degradation P application for Degradation Detection and A PUMA 2 Integrated for Battery Cell Testing (with cus. specific functionality) New web-based editor for easy creation of te Integration of new AVL Cell Tester (CTS6) Integration of DC Source ITECH 600x Support of Invoence dyno converters OPC UA Client: supporting Data Access Improvements in event-based recording Precision Time Protocol (PTP) - Win based as (compatible with FEM 4 I/O) Support of XCP over CAN FD / CAN / Ethernet IT Security: Ongoing vulnerability management + Ingress Open Authentication, certification handling ASAM ODS B support result data access (cus option) IT Compliance: PUMA 2 Vehicle / VECON 2: Windows 11
R6.5	July	<ul style="list-style-type: none"> PUMA 2 Machine Learning: new appl. for online mont Battery and E-motor testing, usage at simu environ. PUMA 2 Live: Visualize std. timers, start/stop test req ISAC for E-Axis Testing: single & dual e-motor confg Simulation for E-Axis single e-motor conf. via model T.C Embedded: support FMI 3.0 standard (basic FMU functions); import & visualize model metadata in HDX PUMA 2 Production: Dispersion graph for statistic dat analysis, additional test library for Battery Testing PUMA 2 E-Motor: advanced health check with integri monitoring and continuous statistical analysis PUMA 2 Back-To-Back E-Motor: cus. solution to test > single axis up to 8 E-Motors paired in 828 configurat PUMA 2 Vehicle /VECON 2: dew point monitor, China PUMA 2 Powertrain / E-Axis: support stationary SSQ PUMA 2 Inverter: EME - support asymmetric phase rs model and Dual-UUT power supply; ALC new firmwar PUMA 2 Battery Cell Testing: indep. control of power Spectra DCS as DC supply (1 channel support) Integration of R&S EMC measurement toolchain ASAM I/LiART3.0 (basic), ASAM X3, MA Port (read/write sign) IT Security: ongoing vuln. management + hardening checks support .net 8
R6.6	Decem	<ul style="list-style-type: none"> PUMA 2 Vehicle /VECON 2: Rotating Veh Determination PUMA 2 Production for E-Axis testing PUMA 2 Machine Learning: Feature Impo Decision Trees PUMA 2: Native Vibration Monitoring AI PUMA 2 Live: Start/stop test requests, In-operating commands PUMA 2 Powertrain / E-Axis: support sb E-Axis: Position Control, Standardized H Limits, Enhanced Guidance for Parametr Testbed.CONNECT Embedded: NaN data outputs, ARTMI models can trigger POI r PUMA 2 Battery: Test battery cells, mod independently with one software, COF/XCP available in UUT Context Battery Pack TS with Modular Power Sup Integration of AVL Cell Tester Eco Line Serial Operation of power channels for A Line ASAM I/LiART3.0 (maps & curves) IT Security: Replication via HTTPS (RPC management) IT Compliance: PUMA 2 Share support u 17hr
R7.0	July 2025	<ul style="list-style-type: none"> PUMA 2 Vehicle / VECON 2: New architecture supporting 3-axis, 6-machine configurations Brake Wear Testing: Standard solution with integrated control and simulation Back-to-Back E-Motor: Single automation system for up to 8 motors in 4 828 pairs Torque Oscillation Monitoring: Advanced algorithm AI powered to prevent damages on UUT and equipment PUMA 2 Live: Faster testbed overview, signal presets across testbeds, connection diagnostics PUMA 2 ML: Feature correlation matrix and improved setup Flexible Configuration: Easy switch between E-Motor, ICE, and Powertrain setups E-Axis: Position control with differential distortion and ratio observation PUMA 2 Inverter: New Active Load Cabinet features AVL Virtual Studio: New application window and Co-Sim add-on (formerly ISAC / T.C. Embedded) Standard Delivery: FEM 4 I/O modules only DC Devices: Support for up to 4 GE (LVB) and AVL SET (ISC) units EMCON: Improved high-frequency limit monitoring and torque correction (Config. 400) IT Security: OAuth2 single sign-on, continuous vulnerability management IT Compliance: InTime 7 support

Interoperability





How to Modernize Existing ICE R&D Testbeds

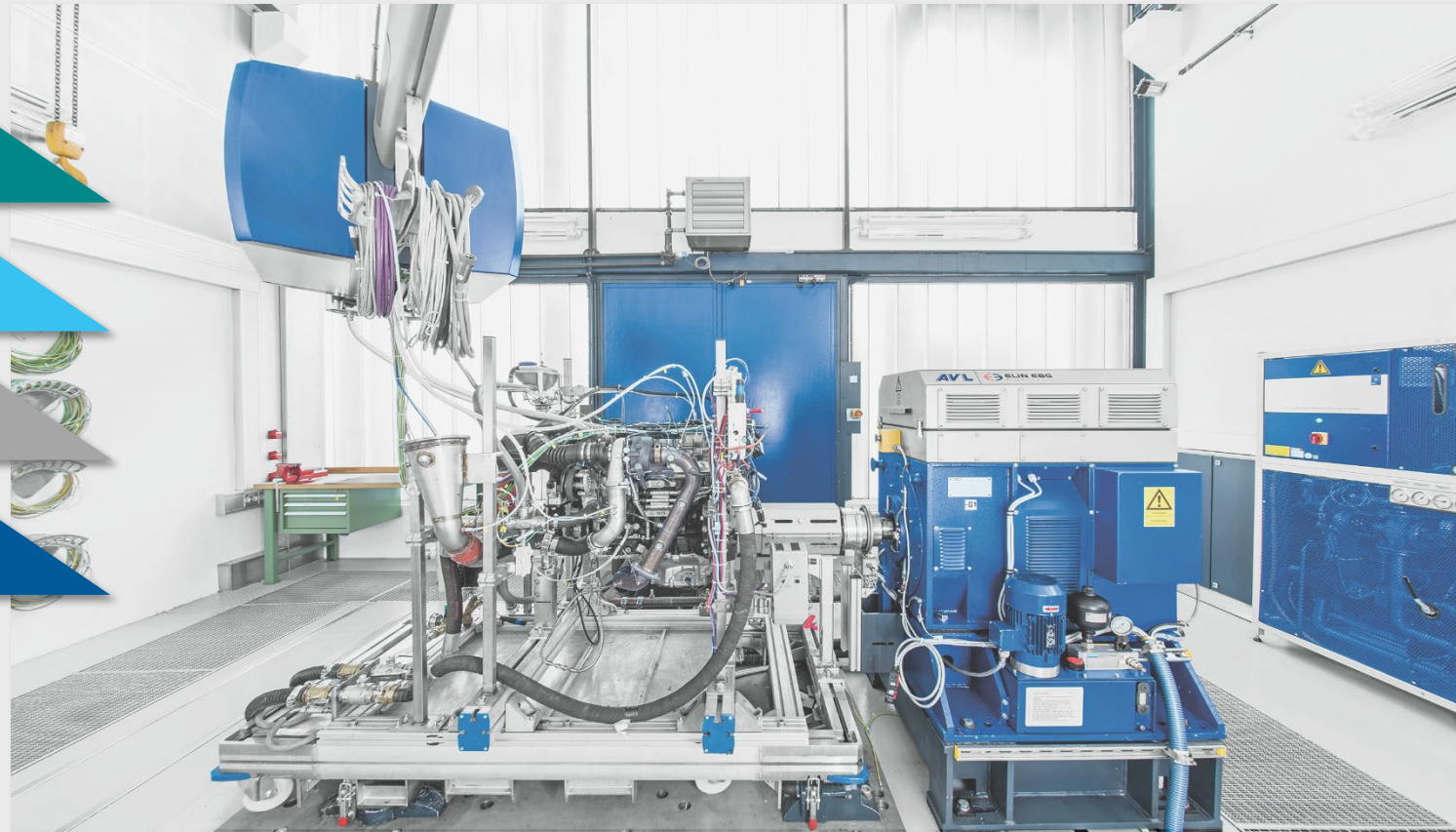
Enhance Existing Engine Testbeds Towards...

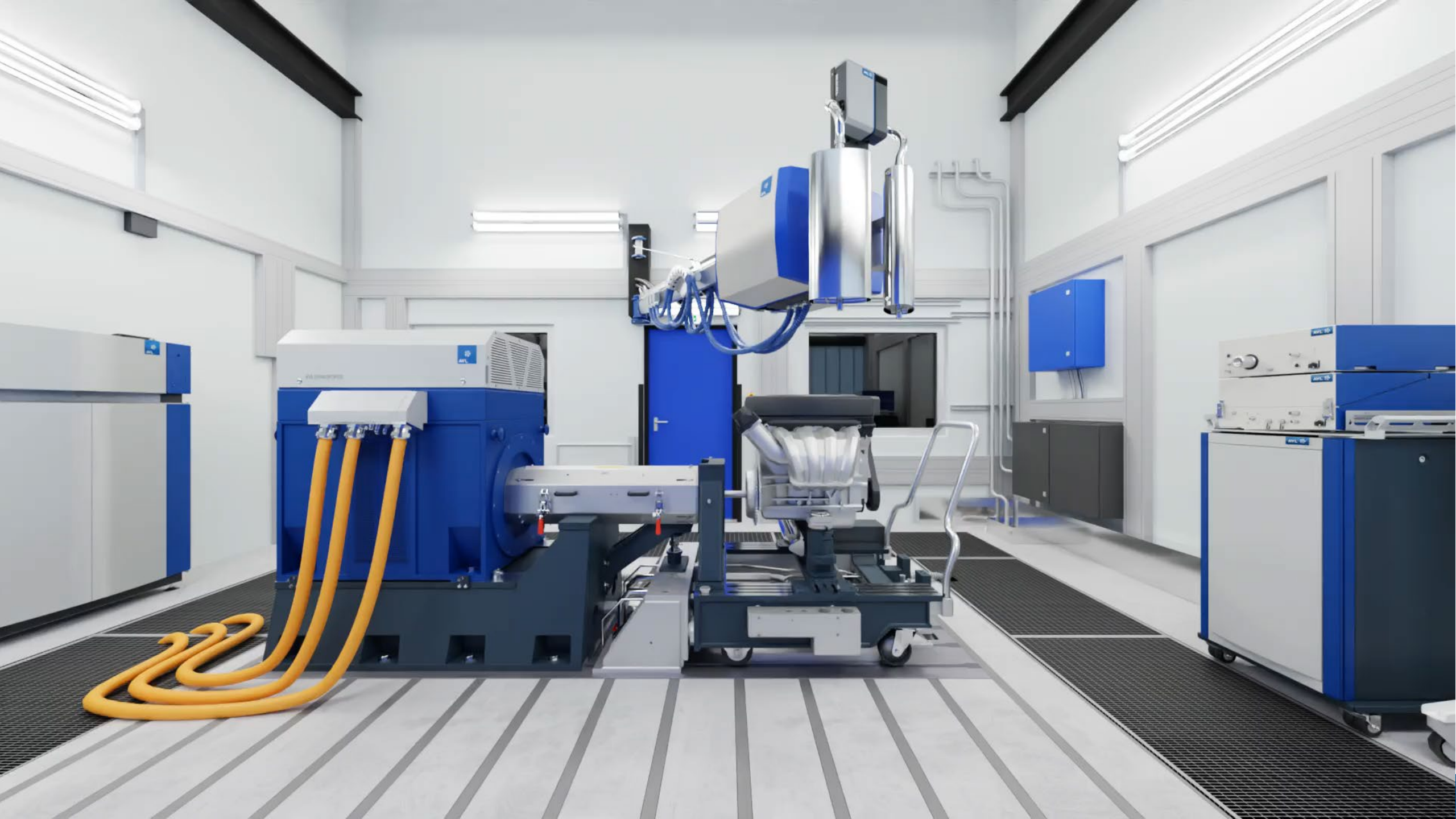
Mild Hybrid
Testing

Full Hybrid
Testing

H₂ ICE
Testing

Brake Wear
Testing

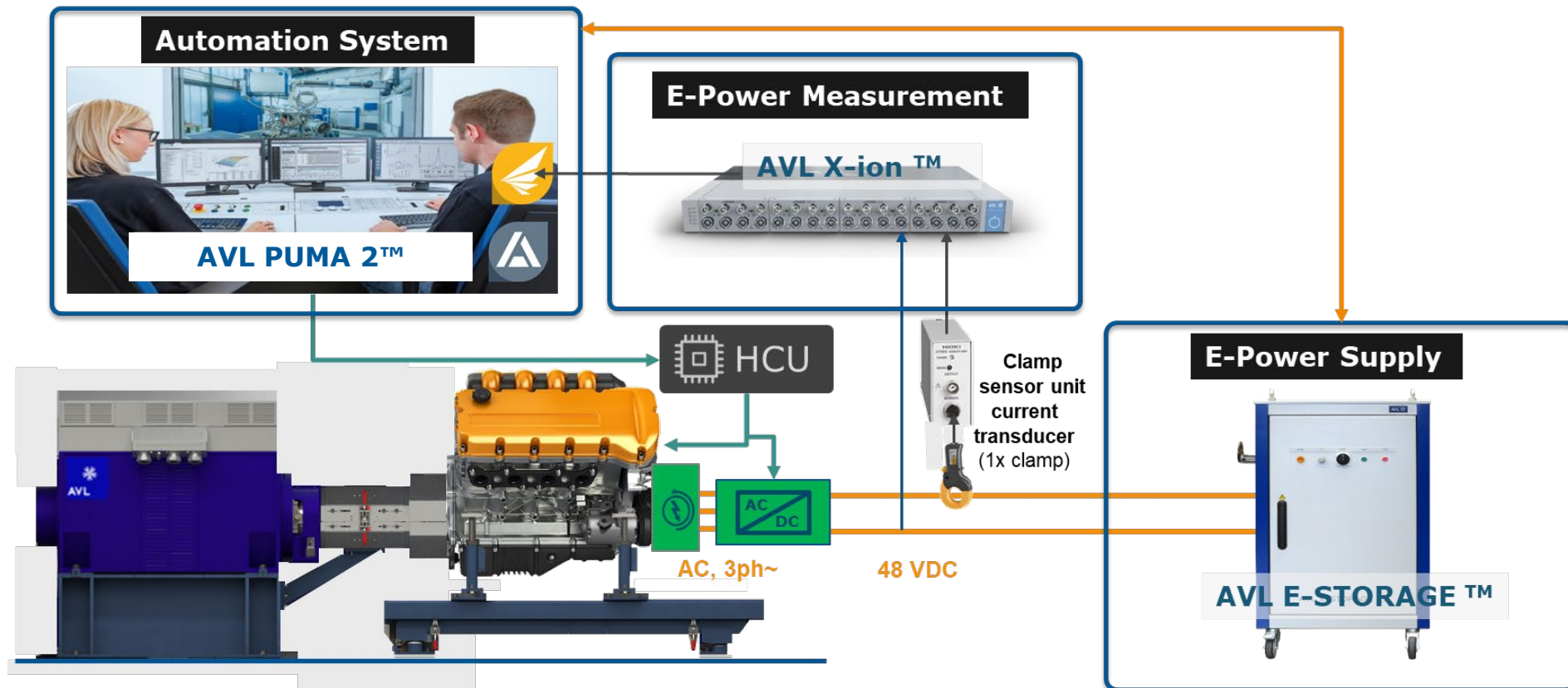




Mild Hybrid Engine Test Environment

Mild Hybrid Testing

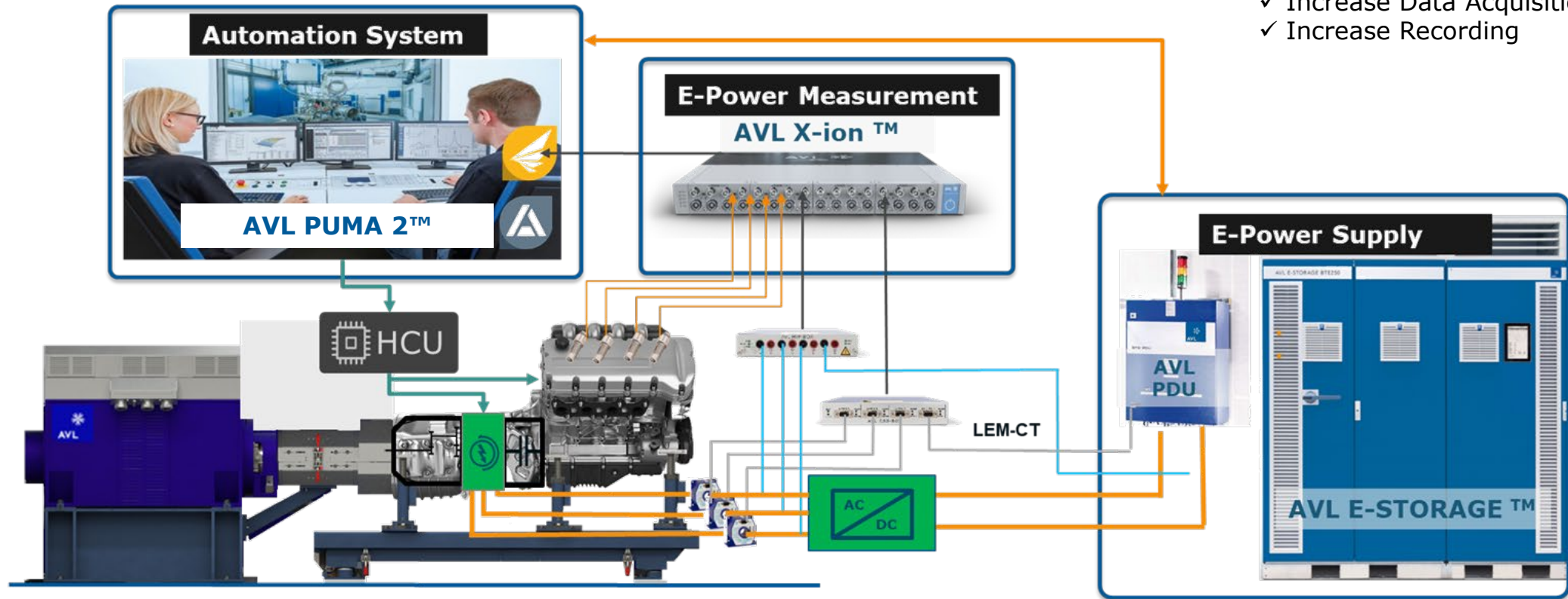
- Automation Capabilities:
- ✓ Driver LV/MV E-Storage System
 - ✓ Interface E-Power Measurement
 - ✓ ILinkRT IF to Hybrid Control Unit





Full-Hybrid Engine Test Environment

Full Hybrid Testing

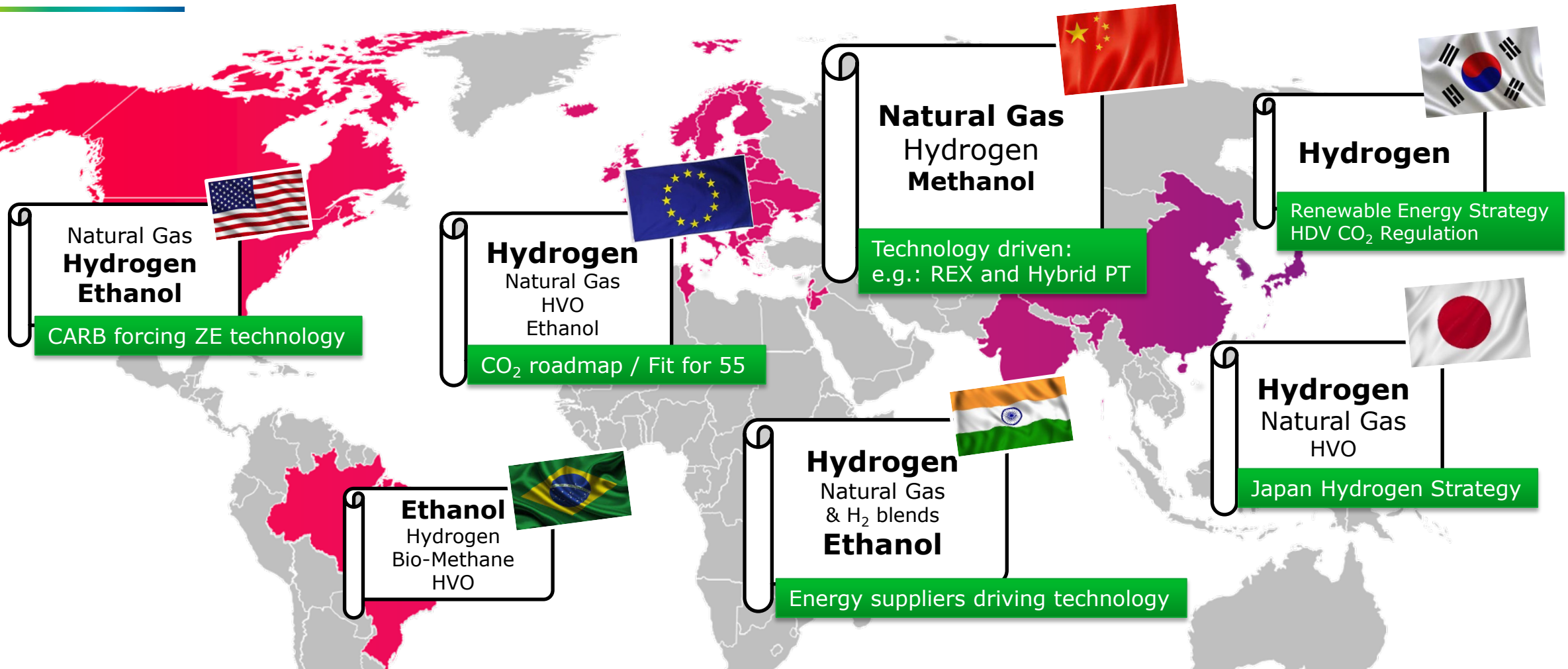


Automation Needs:

- ✓ Driver HV E-Storage System + PDU
- ✓ Interface E-Power Measurement
- ✓ ILinkRT IF to Hybrid Control Unit
- ✓ Increase Data Acquisition
- ✓ Increase Recording

AVL Commercial Vehicle Technology

Commercial Applications: Global fuel alternatives overview



Different markets and applications ask for different solutions

Overview Engine Test Facility

H₂ ICE



Combustion air Meas. & Conditioning

Check size!

Intake Air Charge Air (T)

Testcell Ventilation / ATEX

Check capability!

Air Handling Unit ATEX Ventilator Exhaust Extraction

Exhaust

Back- Pressure Adjustment Exhaust Extraction / Altitude Sim.

Measurement and Conditioning

H₂ Ready

Blow By

H₂ Consumption

Fuel Consumption

Engine Lubricant (T) Engine Coolant (T)

Combustion Analysis

Pressure Transducer Fuel/CHG

Testcell Safety System

Automation System Safety PLC

Automation Control Indicating Calibration Emission Automation

Update AuSy Check capability and Safety PLC

Emission Measurement

FTIR Gas Analyzer Gas Analyzer

Particulate Sampling UREA Consumption

Particulate Number Concentration

Baseline Measurement

H₂ compliant types!

Cable Boom with Front-End I/O & Sensors (P,T,Rh) Pressure Measurement xCU Restbus



Non-Exhaust Particulate Emissions from Road Transport

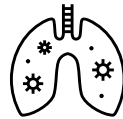
...can contribute up to **55%** in urban areas

Source [oecd.org](https://www.oecd.org)

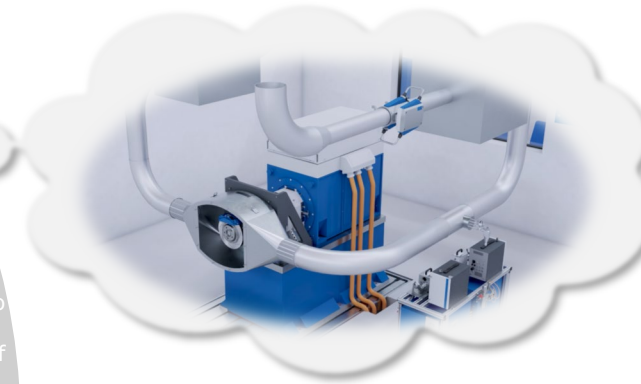
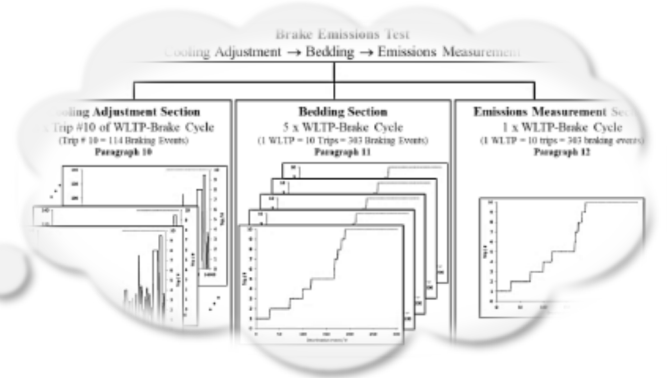
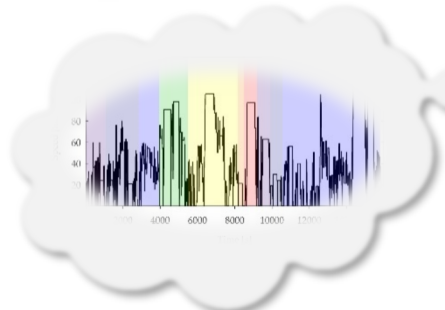
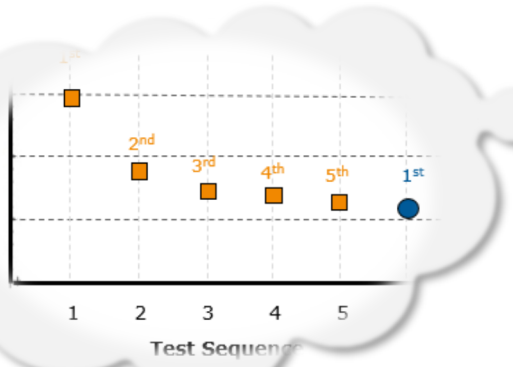
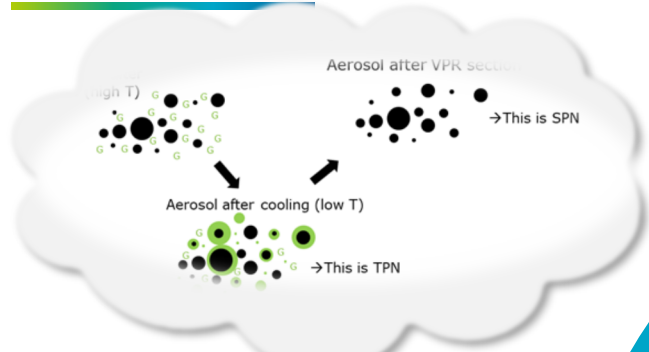


...brake dust from cars can be **more harmful** to human health than diesel fumes

Source [sciencealert.com](https://www.sciencealert.com)



Brake Emissions Challenges



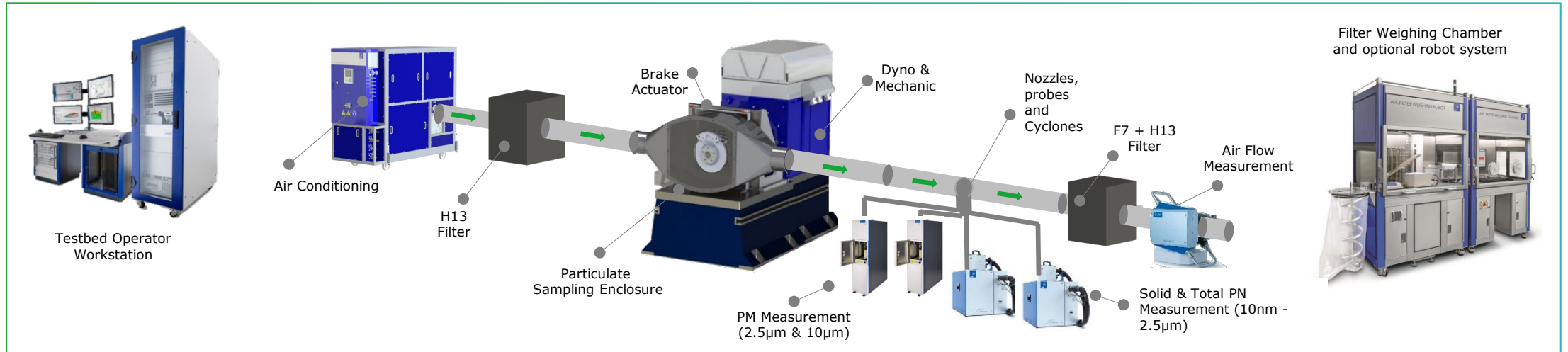
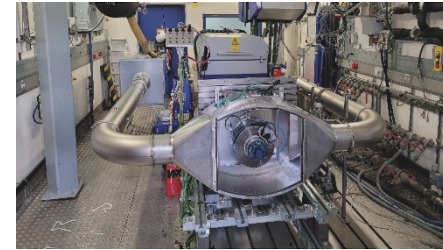
Why AVL?

Complete and comprehensive Tool Chain

From single Instruments...



...to Testbed upgrades...



Testbed Automation



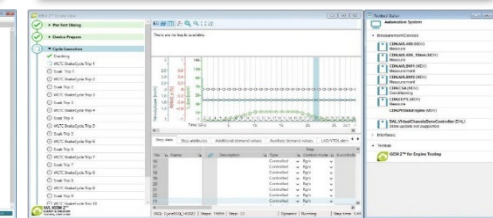
- Central operator interface
- Testbed and test parameter handling
- Testbed equipment and Measurement device control (Automatic Test runs)
- Data recording and storage
- User definable limit monitoring and reactions

- GTR 24 compliant test preparation
- Incl. emission device handling
- GTR 24 compliant test execution
- GTR 24 data analysis and reporting

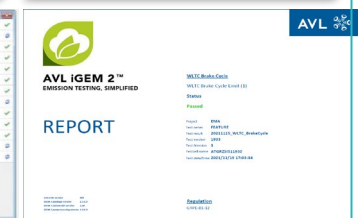
Parametrization



Test Execution



Reporting



Variety of Solutions



Virtual Testing



Component Testing



Transmission Testing



Engine/Hybrid Testing



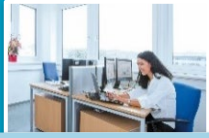
Inverter Testing



Battery Testing



Fuel Cell Testing



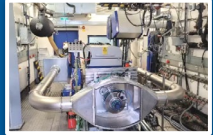
PUMA 2 Office

Prepare & Manage



PUMA 2 Live

Monitor & Operate



Brake Testing



E-Motor/
Back-To-Back Testing



E-Axle Testing



Powertrain Testing



E-Integration Testing



Vehicle Testing



End-of-Line Testing



PUMA 2 Share

Test Field Server



PUMA 2 Machine Learning

Detect anomalies



Virtual Studio

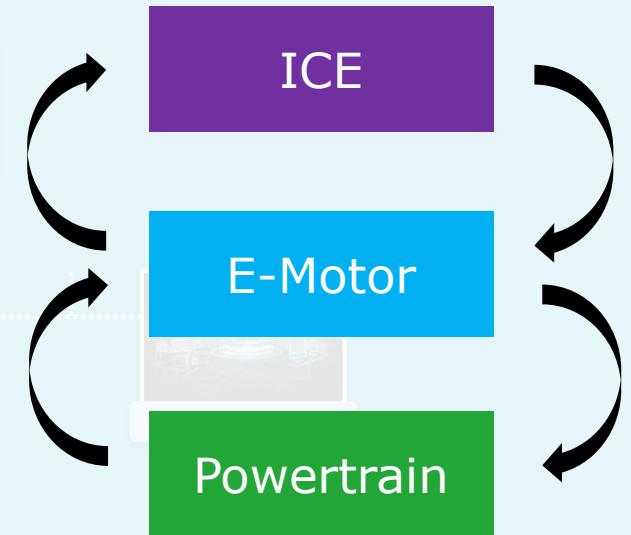
Simulate

ENHANCED productivity

Multi Solution Capability

Install ONE single automation system on ONE single workstation

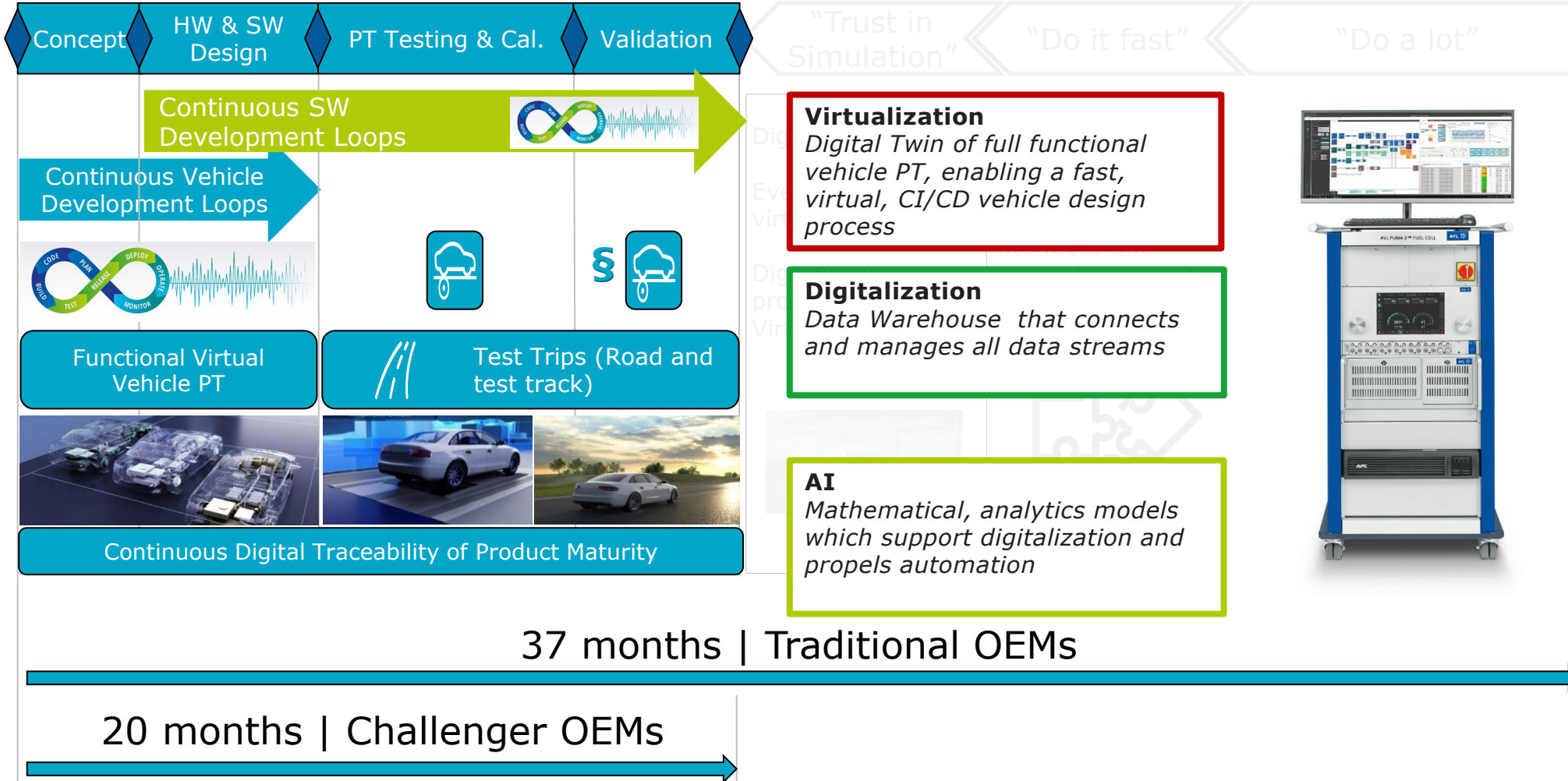
...configure the AuSy for the desired UUT by loading the right parameters



Benefits : reduce cost, reduce space, no downtime due to configuration switch, easy maintenance

Digital Twins are key enablers to reduce time-to-market significantly

Concept defined Start of testing Data freeze SOP



AVL Virtualization

Shift left. Scale Instantly. Boost Quality. Reduce failed tests.



SHORTEN TIME-TO-MARKET

- Shift-left moves critical developments and testing tasks earlier
- Massive parallelization enabled by MiL | SiL | HiL environment
- Scalability with marginal cost
- Immediate availability of virtual components
- >20 % V&V time reduction



COST REDUCTION

- >30% cost reduction
- More efficient hardware and facility usage
- Reduced number of failed physical test
- Broad parallel development



Best Practice & Key Takeaways

Global Best Practices

Different Reasons to Modernize

1. Original supplier is no longer active in the market

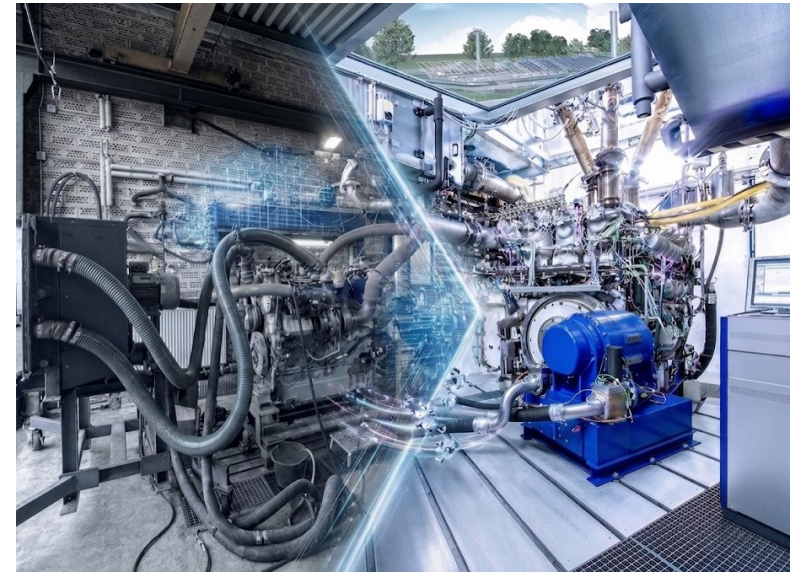
- Outdated Software / No more support from supplier
- New legislative regulations

2. Multi supplier strategy towards single supplier to operate TBs with reduced team capability

- Harmonization of test procedure
- Reduction of maintenance effort

3. Self-developed in-house solution

- Existing Software was not capable for new testing demands



What our Customers say



“AVL PUMA provides the flexibility to seamlessly transition between certification and development testing in our engine dyno testbeds.”

ISUZU

“PUMA 2 great in managing whole test field and very stable. Big step in efficiency!”

Alpina

“PUMA 2 is super stable, open and future-proof. “PUMA mobile” – a unique solution we developed ourselves!”

INNIO

“With PUMA 2 we successfully do dynamic tilted and roll powertrain testing.”

Volvo

What our Customers say



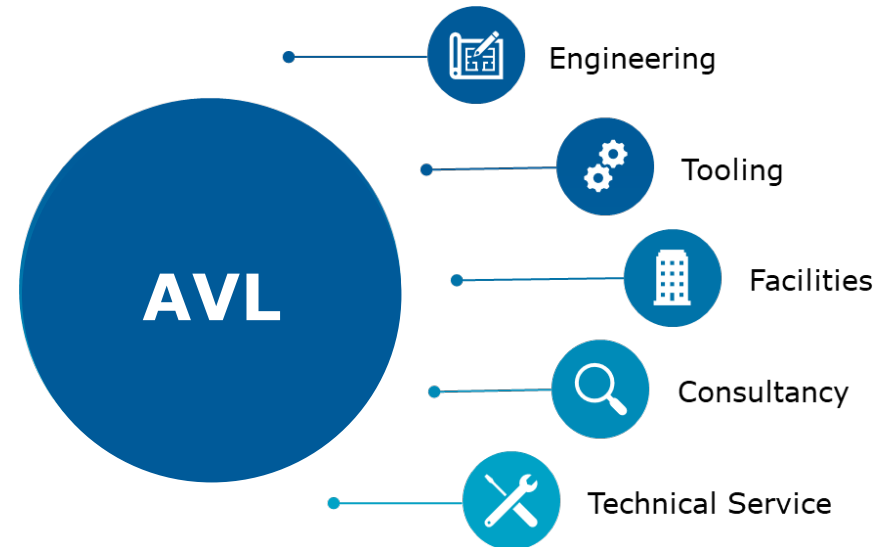
“ We have achieved an efficiency increase of 20% in our global test field with PUMA 2 compared to previous automation versions.”

Michael Hausmann, Skill Team Leader PTE Tech Center Support, AVL List GmbH

Key Takeaways

AVL ensures a smooth transition to future-ready testbed operations.

- Open system architecture
- Integration of 3rd party I/O and HW
- Step by step approach
- Application-specific guidance & support





Testbed Modernization

Q&A

Contact



LOCATION

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Hans-List-Platz 1
8020 Graz
Austria



CONTACT US



EMAIL

werner.fuchs@avl.com



WEBSITE UTM Link

[https://www.avl.com/en/
testbed-modernization](https://www.avl.com/en/testbed-modernization)

Thank you



www.avl.com