AVL LIST

04.02.2013

OUR EXPERIENCE FOR YOUR SUCCESS

- AVL achieves unique results as regards to the development and improvement of all types of powertrains as well as in the field of measurement and test technology.
- AVL – more than 60 years' experience
- Involved in more than 1.500 engine development projects
- More than 4,000 engine test bed installations

Challenges in Powertrain development

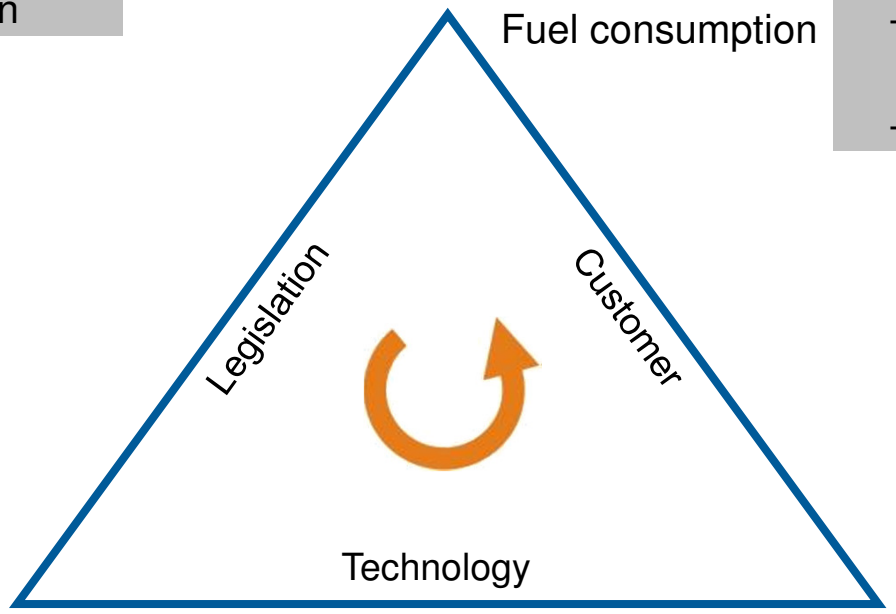
Increase of:

- Electrification
- Softwareintegration

Fuel consumption

Decrease of:

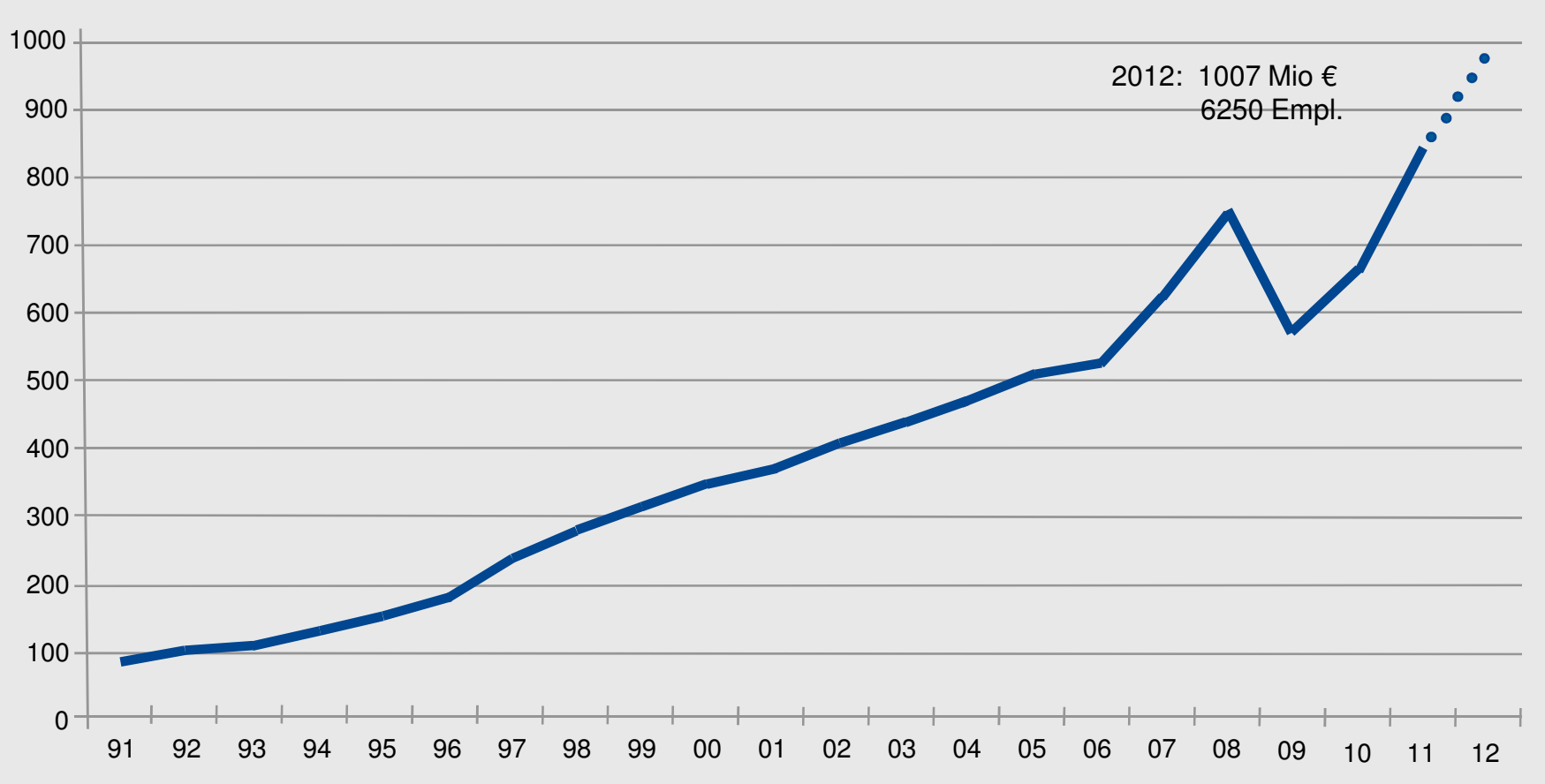
- Time to market
- Development time
- Development cost



Emission

Drivability
(Driving Fun)

ENTERPRISE DEVELOPMENT AUTOMOTIVE



- **Turnover**
  1991: 95 Mio. €
  2011: 830 Mio. €
- **Employees**
  1991: 950
  2011: 5.250
- **Average. R&D-Spending**
  10% of turnover

AVL COVERS ALL CUSTOMER SEGMENTS

Passenger Cars

2-Wheelers

Racing

Construction

Agriculture

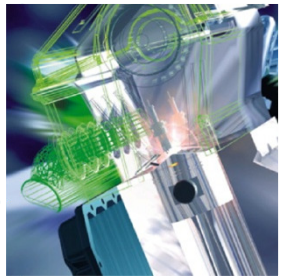
Commercial Vehicle

Locomotive

Marine

Power Plants

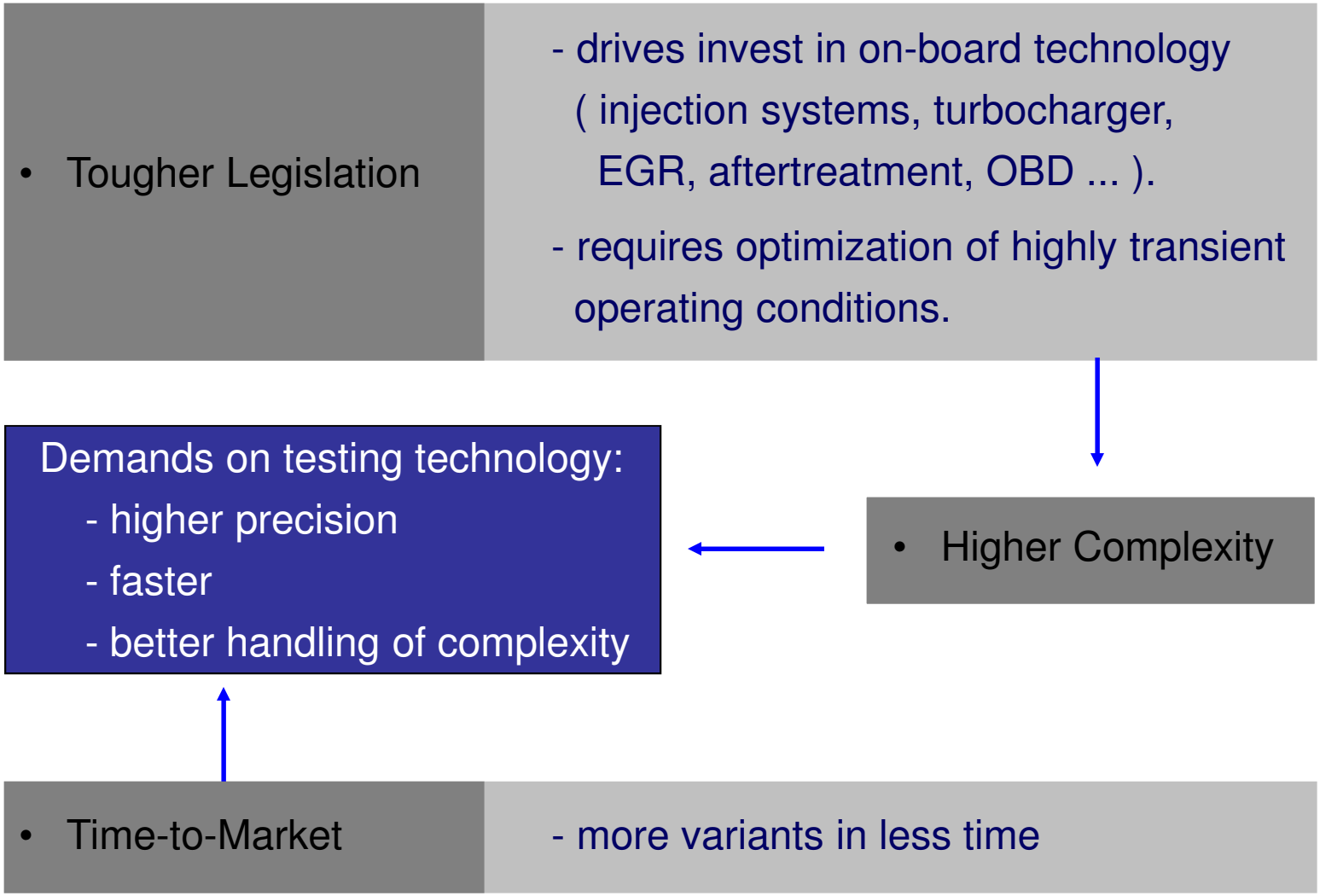
Engineering



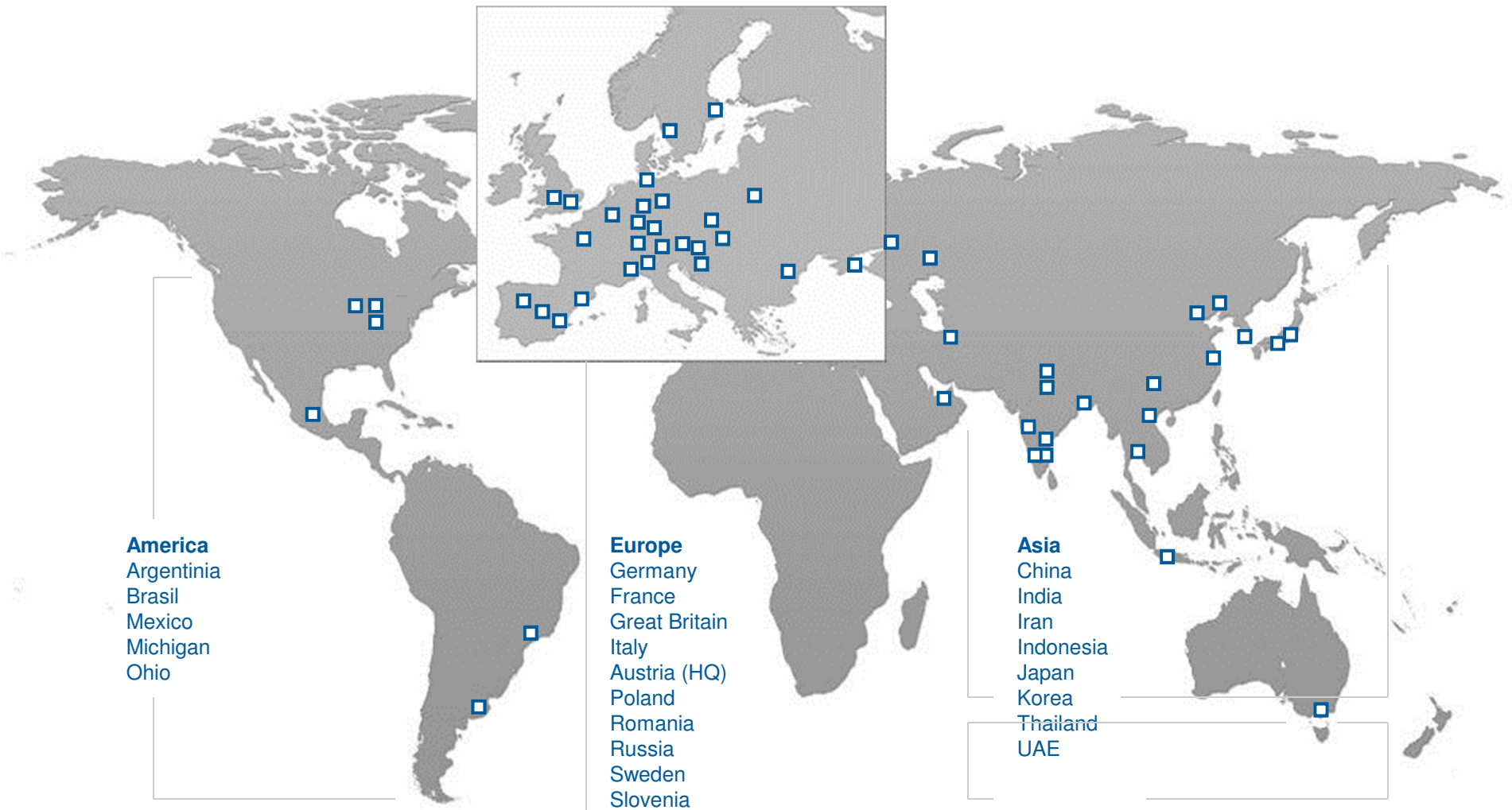
Simulation

Testing

Industry's Challenges



AVL – A GLOBAL PARTNER



America
Argentinia
Brasil
Mexico
Michigan
Ohio

Europe
Germany
France
Great Britain
Italy
Austria (HQ)
Poland
Romania
Russia
Sweden
Slovenia
Spain
Czech Republic
Turkey
Hungary

Asia
China
India
Iran
Indonesia
Japan
Korea
Thailand
UAE

Australia

AVL-TECHNICAL CENTERS POWERTRAIN


UK

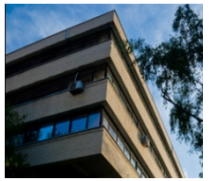

Ann Arbor,MI


Slovenia


Haninge


Södertalje

Schweden


Croatia


Hungary


Steyr


Headquarters Graz


Plymouth, MI

Moskau

Tokio

Nagoya


Korea


Lake Forest, CA


China


France

Sao Paulo

Deutschland


India


Neuenstadt


München


Regensburg


Stuttgart


Ingolstadt

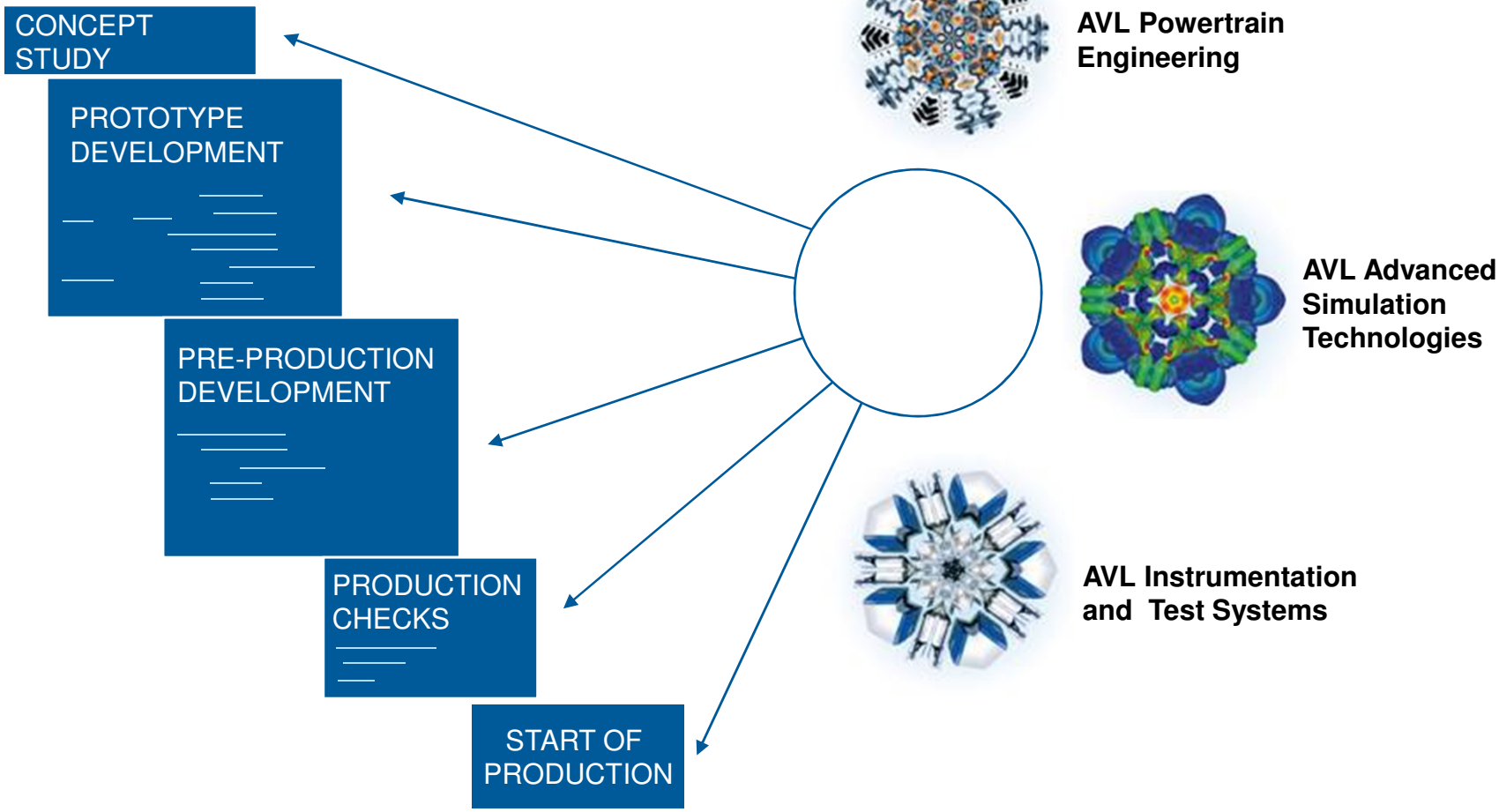

Remscheid


Turkey


Australia

DEVELOPMENT PROCESS AS THE BASIS OF SUCCESSFUL DEVELOPMENT PROJECTS

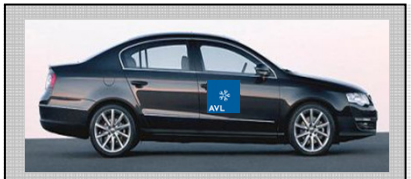
ENGINE DEVELOPMENT PROCESS



POWERTRAIN ENGINEERING

- The latest technology applied with the benefit of experience
  - Engine development through to production
  - Drivetrain optimization
  - Applications
- Flexibility through open project access for customer and suppliers
- Production support provided by highly specialized production engineers

AVL Gasoline PC Project History
Projects allowed to be communicated



AVL Low CO2 TGDI Demonstrator Car 2008

AUDI TT 1.8L TCI

Mini Cooper S

AUDI R8 V8/V10

AVL Turbo Hybrid Demonstrator 2009

FIAT FIRE 1.2/1.4L

FORD S-MAX 1.6L SGDI

ALFA 1.8L TCI

AVL EVARE Vehicle 2010

OPEL TWINPORT

CHERY 1.6L

FORD Galaxy 2.0L DISI

AVL Low Cost CDA Demonstrator Car 2011

BENTLEY W12 6.0L

BUGATTI VEYRON 8.0L

AUDI V6 3.0L TFSI

AVL HSDI PC Diesel Project History
Projects allowed to be communicated

AVL EU6 Demonstrator Car
2007/2008

M&M Scorpio 2.2 T2B5

Saab 9-3 EU5

BMW X1 18d, 20d, 23d EU5

AVL EU5/EU6 Demonstrator Car
2005/2006

SSANGYONG 2.7L CR TCI

AUDI V6 3.0L TDI

SSANGYONG 2.0L CR EU5

AVL Diesel Hybrid Vehicle - EcoTarget
2002/2003

ALFA 2.4L CR TCI

VOLVO 2.4L CR TCI

MERCEDES V6 3.0L TCI

First AVL HSDI prototype engine

1976

First HSDI in LDT

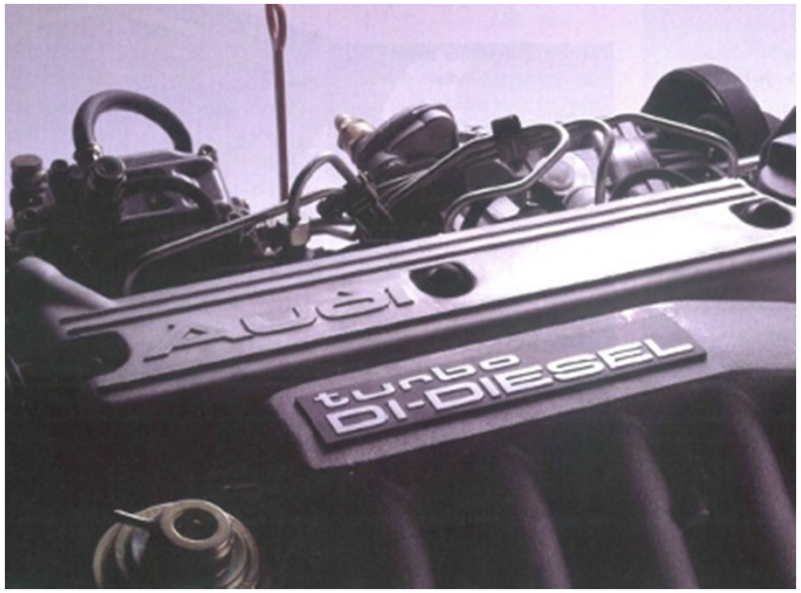
FORD 2.5L NA

AUDI 2.5L TCI

ROVER 2.0L TCI

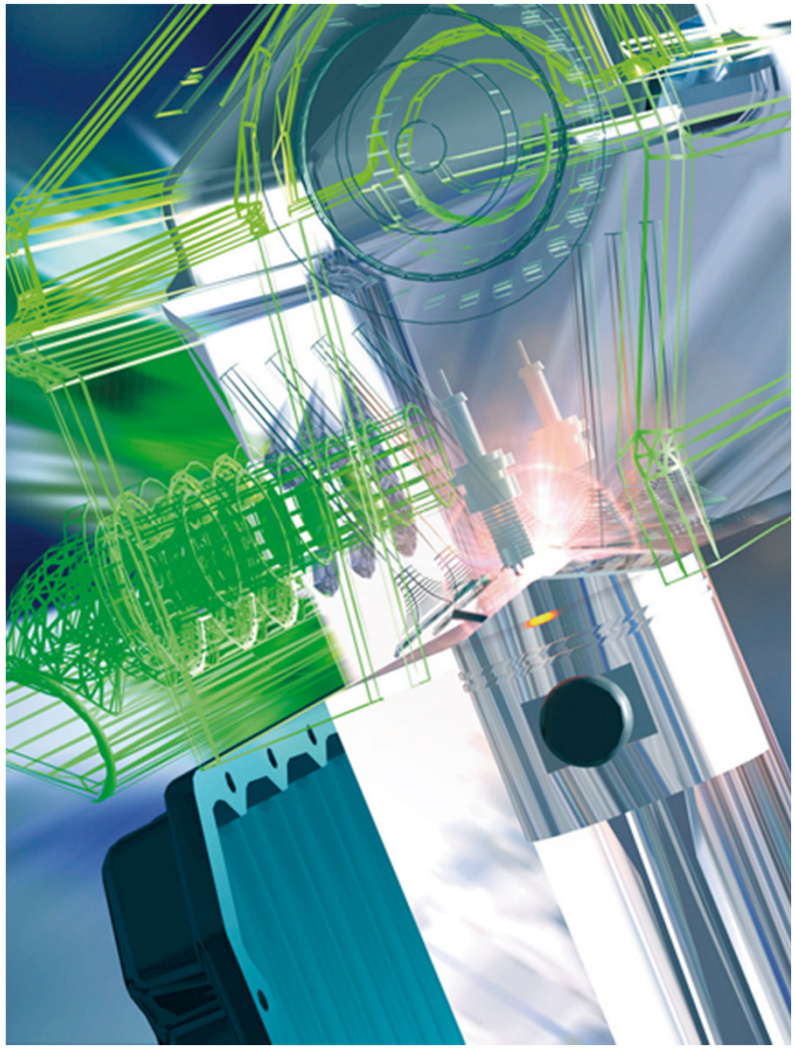
~220 Diesel Engine Development Projects

DIESEL TDI HISTORY - AUDI TDI



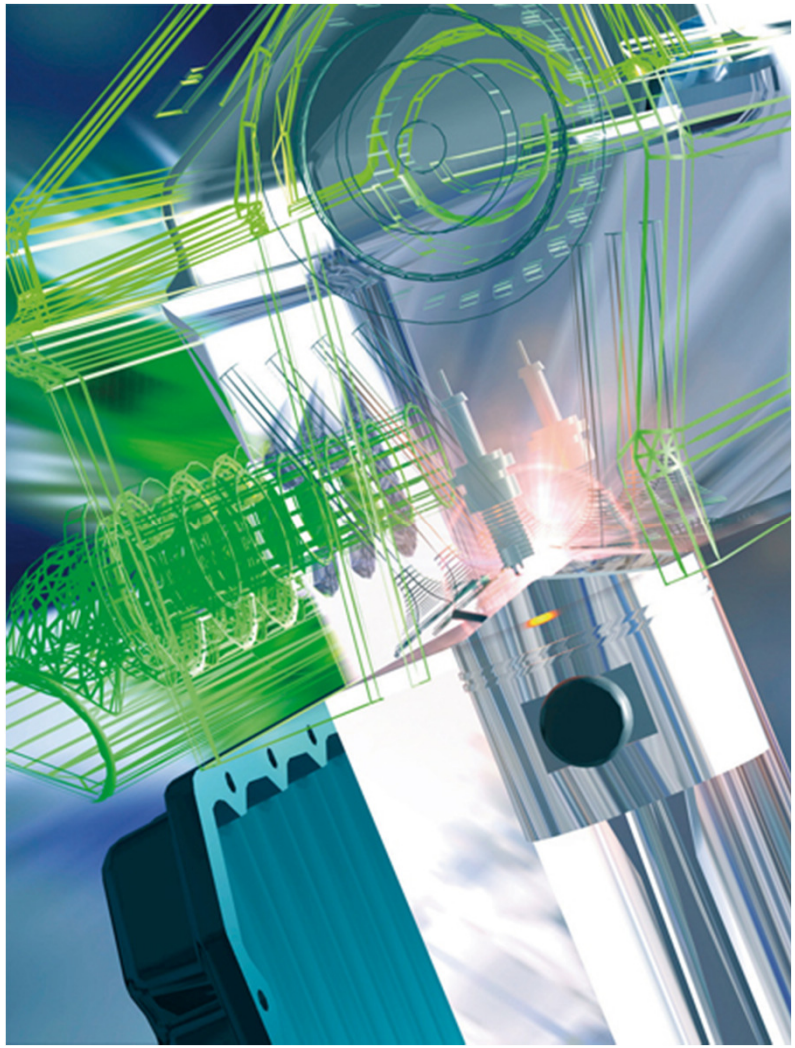
- AVL Development of turbo diesel direct injection technology by AVL.
- In 1989 Audi used this technology for the first time in series production.
- Since then we have been involved in more than 100 other development projects.

ADVANCED SIMULATION TECHNOLOGIES



- Process-optimized product development using the ‘Virtual Engine’ concept
  - Flow simulation
  - Structural & mechanical analysis
  - Acoustics
- Individual software products proven in a variety of applications
- Quality improvement through custom CAE solutions

ADVANCED SIMULATION TECHNOLOGIES



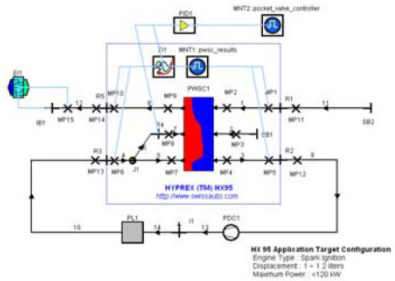
AVL BOOST

AVL CRUISE

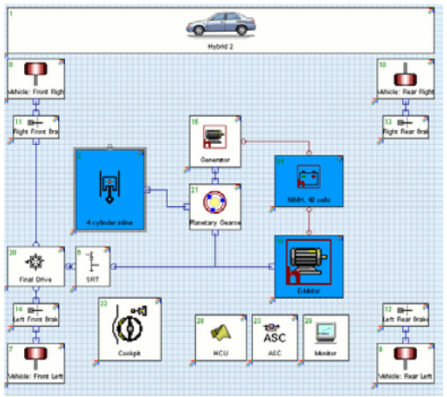
AVL EXCITE

AVL FIRE

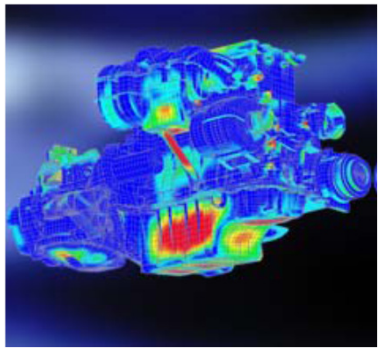
Simulation Technologies



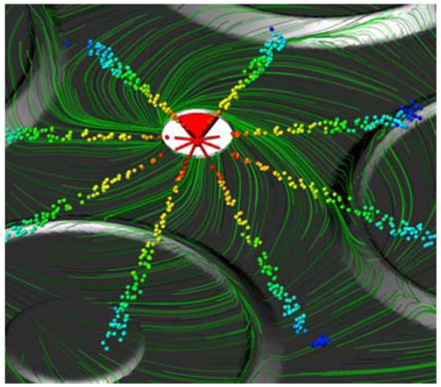
- AVL BOOST offers leading technology for the 1D simulation of gas-exchange, combustion and aftertreatment processes to support the design and optimization of all possible types of internal combustion engines on both a components' and system level. Outstanding models for gas-phase and heterogeneous surface chemical reactions, as well as particle loading and regeneration processes fully support the design and optimization of present and future aftertreatment devices. AVL BOOST also fully supports the implementation of user defined physical and chemical models and offers best computational performance in combination with an unprecedented level of usability.



- AVL CRUISE enables system analysis and optimization of vehicle and powertrain configurations. Based on its comprehensive set of models offering different refinement levels, AVL CRUISE is applicable during all stages of the product development process, such as e.g. in the early concept phase, during the market introduction phase or during product maintenance and further development. AVL CRUISE offers tailored solutions for SiL/HiL applications to support the development of conventional and advanced powertrain concepts including hybrid powertrains and offers dedicated models and methods for DoE based analysis and optimization



- AVL EXCITE is the leading software tool for simulation and analysis of strength, durability and NVH performance of engines and power units. AVL EXCITE offers multi-body dynamics simulation and a sophisticated set of models and methods related to the various applications during engine development, such as e.g. crank-train design, valve-train and timing drive dynamics, tribological analysis of engine lubricated contacts, piston and piston ring design, etc. In addition AVL EXCITE offers the highest flexibility with respect to its interfaces to leading FEA codes and tools for fatigue analysis.

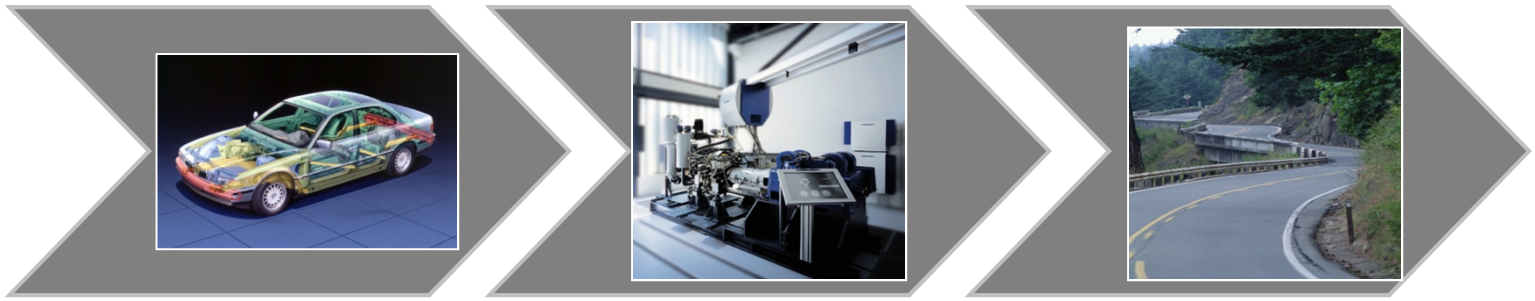


- AVL FIRE is well recognized as the technology leader in 3D-CFD simulation of the complex physical and chemical processes in internal combustion engines, such as e.g. cavitating injector flow, spray and wallfilm formation, combustion including emission formation and aftertreatment. The fully intuitive graphical user interface of AVL FIRE and the embedded automatic meshing technology for complex, moving engine geometries ensures ease-of-use and hence minimized training times. Open user interfaces provide access to all physical and chemical models in order to support easy implementation of user defined models.

INSTRUMENTATION AND TEST SYSTEMS

- Comprehensive technology for testing engines, gearboxes, transmissions and vehicles
  - Test bed systems
  - Instrumentation & diagnostics
  - Optimization technology
- Product innovations through close collaboration with pilot customers
- Maximum accessibility via comprehensive service offering

Industry Trends: Road - to - Rig

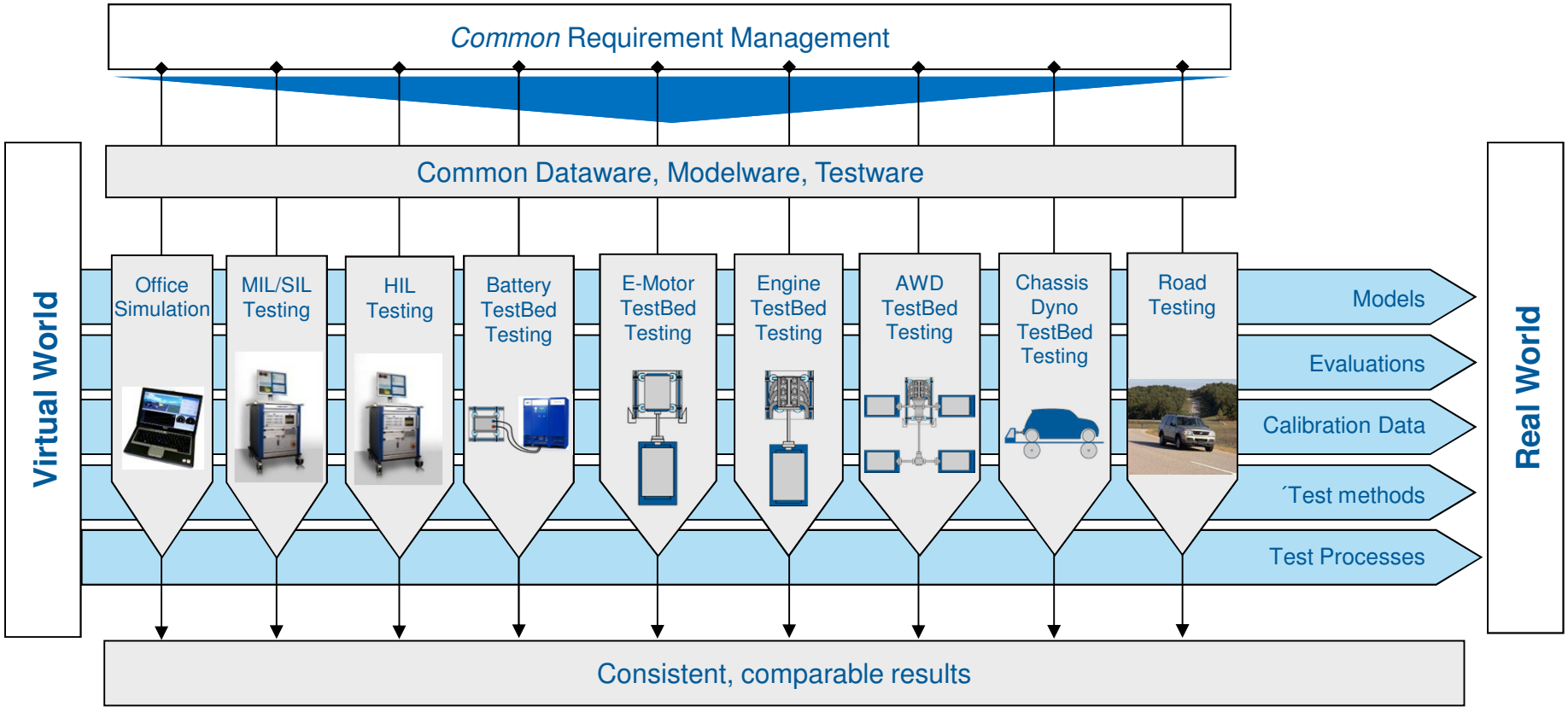


Moving tests to earlier phase:

- saves time
- saves expensive design loops

Automation, Simulation and Control Performance become key !

AVL OPEN DEVELOPMENT PLATFORM
Supports a seamless front loading oriented Development Process



AVL INSTRUMENTATION AND TEST SYSTEMS

consists of 4 Business Units:

BU-M

Instrumentation

BU-E

Emission Test Systems

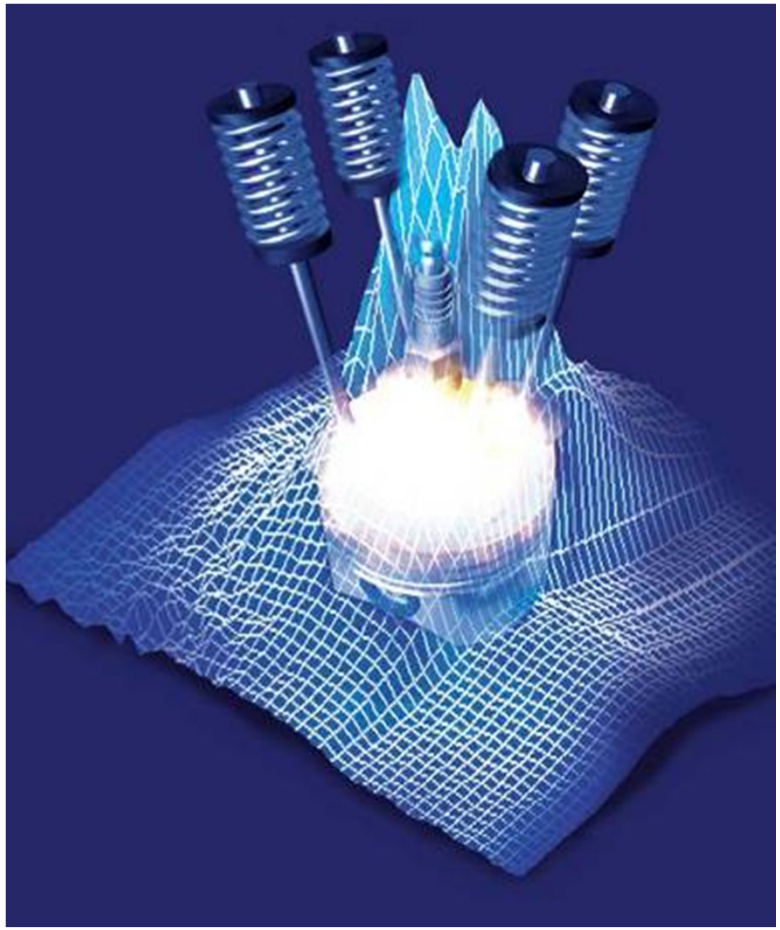
BU-P

Test Systems

BU-S

Customer Service

INDIcating is used for…



- development / analysis of new combustion processes (thermodynamic.)
- engine- / ECU-calibration
- monitoring of result limits (knocking, max. pressure, ...)
- analysis of emission (center of gravity of combustion.,...)
- optimization of injection
- rotary-, torsional vibration analysis
- fast data acquisition of dynamic behavior

MI Indicating tools and devices

MM Measurement Instruments

Blow By Meter

AVL has highest experience in the market

AVL is market leader in particulate measurement:

- 6950 Smoke Meter
- 2200 Opacimeter
- 580 Smart Sampler
- 600 Micro Soot Sensor
- 290 Particle Counter
- 80 PM PEMS
- 4 Gas PEMS

BUSINESS UNIT INSTRUMENTATION

Particulate Measuring Devices

Smoke Meter

Opacimeter

On Board Opacimeter

Partial Dilution Systems (AVL Smart Sampler)

Micro Soot Sensor

Particle Counter

BUSINESS UNIT INSTRUMENTATION

- **Consumption Measurement**

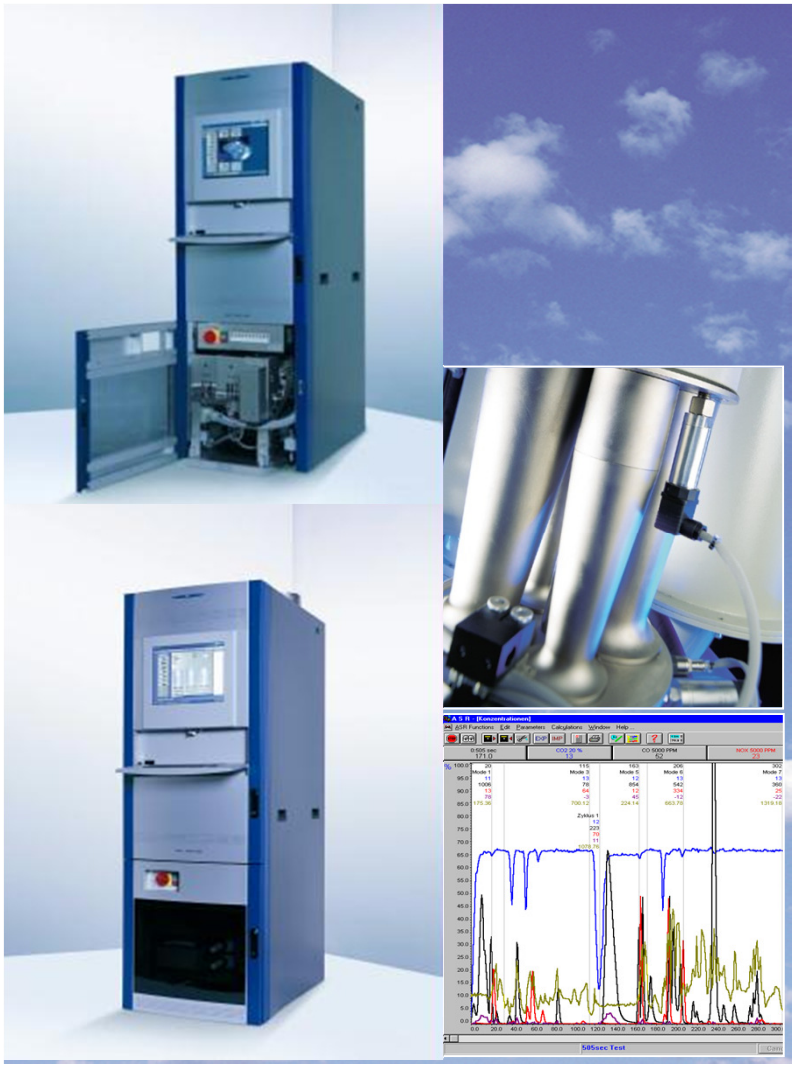
Fuel Consumption Measurement Devices including Temperature and Pressure Conditioning Units

Oil Consumption Meter

Combustion Air Consumption Measurement Unit

Blowby Meter

BUSINESS UNIT EMISSION TEST SYSTEMS (Neuss – Germany)



Complete Exhaust Gas Analysis Systems for Motorcycle, Light and Heavy Duty Engines according to European / US and Japan Regulation

Emission Benches suitable for Euro III, IV, V ULEV and SULEV level

CVS

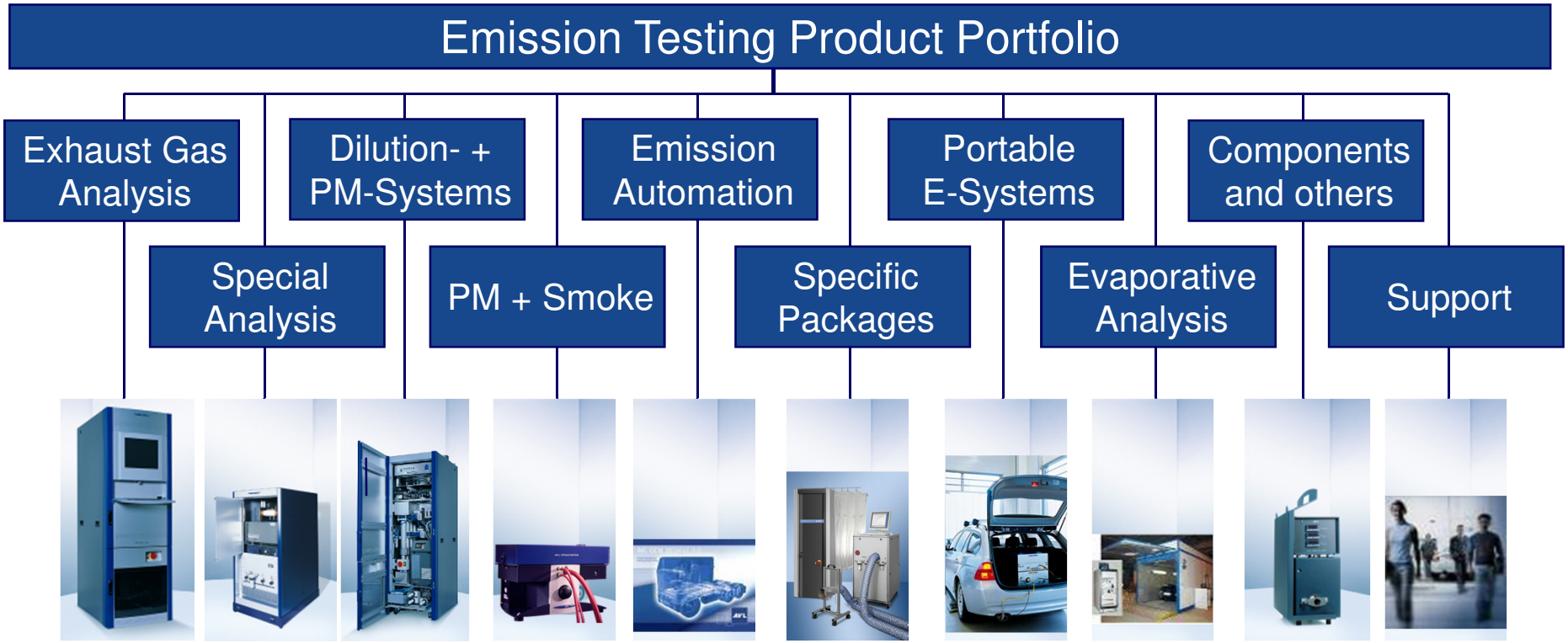
Particle Sampling Unit

Shed

GEM Emission Automation

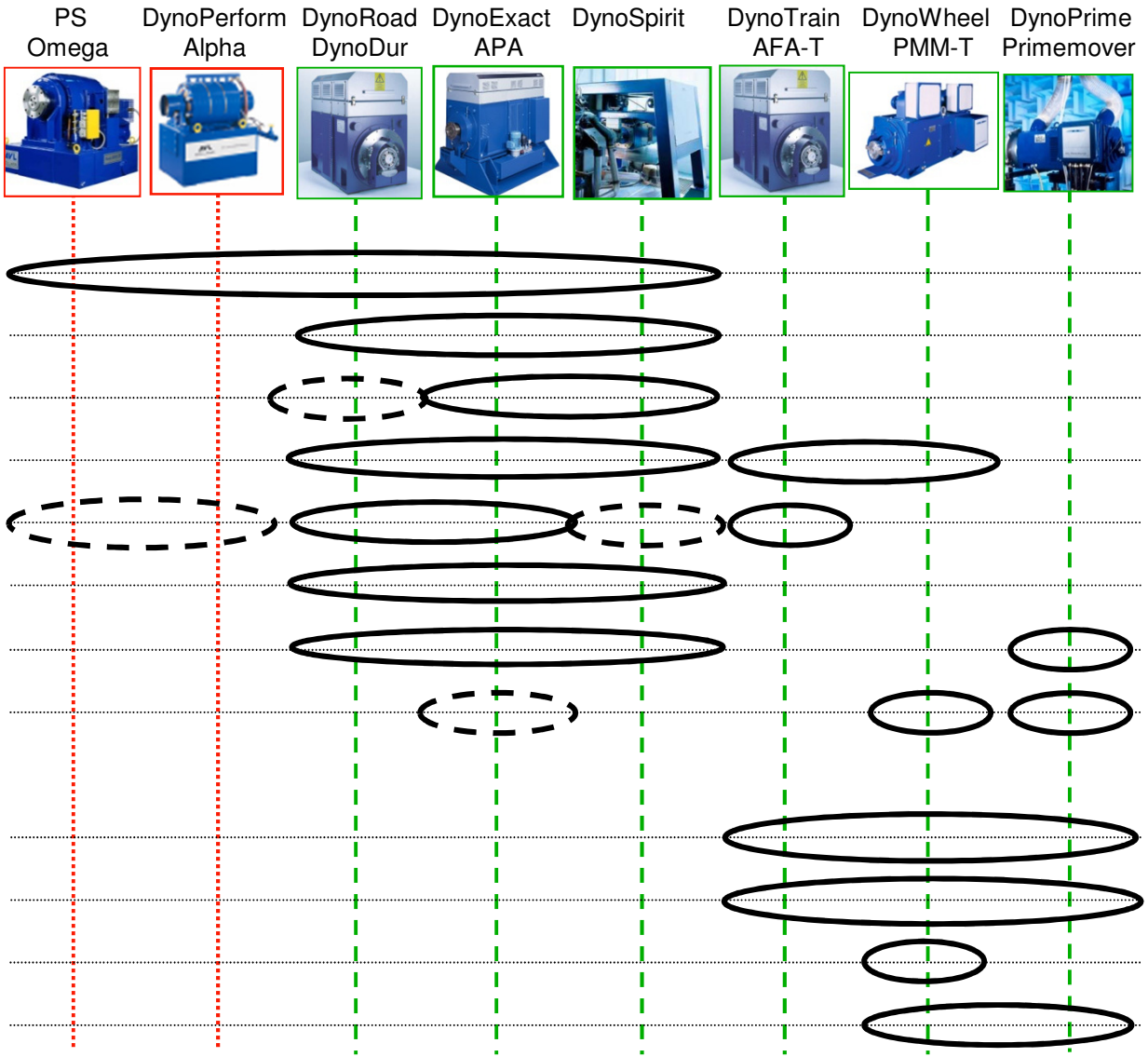
Fourier Transform Infrared Emission Analyser (FTIR)

AVL EMISSION TEST SYSTEMS
Produkt Portfolio



The most complete product portfolio for Emission Testing

Which Dynamometer for which Application



Passive dynos

Active dynos

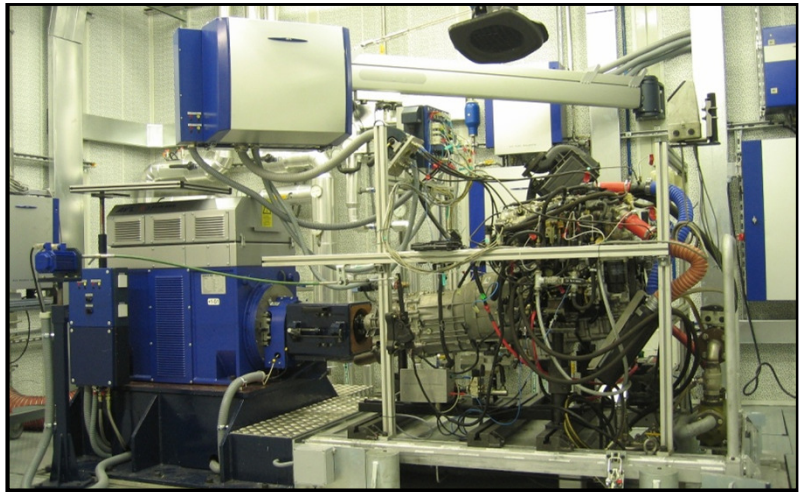
Engine tests:

- Steady state
- Dynamic vehicle simulation
- Dynamic + mass zero simulation. Driveability
- Passenger car emission
- Heavy duty emissions
- Engine friction testing
- Engine components testing
- Racing engine testing

Transmission / powertrain:

- Durability
- NVH
- High Dynamic (wheel simulation)
- Racing powertrain test bed

NISSAN TECHNICAL CENTRE EUROPE – Barcelona
OVERVIEW



- **Project:** New testing facilities for Diesel engines, powertrain and vehicle development
- **Customer and location**: NISSAN, Barcelona (Spain)
- **Engineering, Project Management and Construction** of 4 Engine Test Cells, Vehicle Chassis Dyno and Semi anechoic Chamber
- **2004-2006**

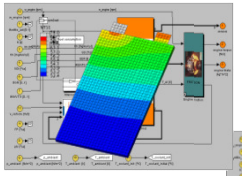
WE HAVE A NEARLY COMPLETE PRODUCT PORTFOLIO
INTEGRATION WILL BRING NEW PRODUCTIVITY LEVEL

AVL

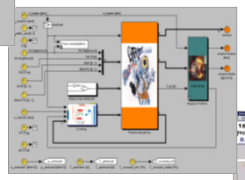
AVL Instrumentation for System Development & Optimization

AVL Engineering & Test Systems for System Development & Optimization

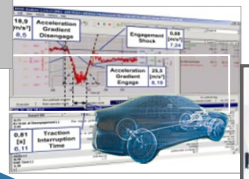
Cell/Module/Battery Simulation



Powertrain Simulation



Vehicle Simulation



Battery/Motor Testing / HIL

System Testing / HIL

Chassis Dyno

Vehicle Development

Vehicle Validation Prod. Signoff

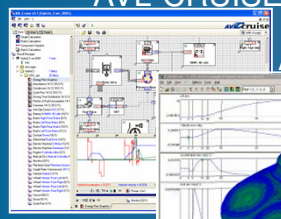
LYNX

BATTERY TESTBED

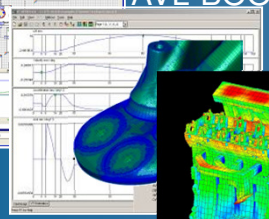
HIL DEVELOPMENT

POWERTRAIN TESTBED

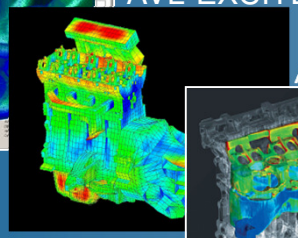
AVL-CRUISE



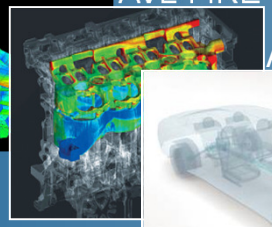
AVL-BOOST



AVL-EXCITE

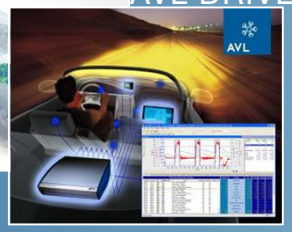


AVL-FIRE



AVL-CAMEO

AVL-DRIVE



CRUISE EXCITE BOOST FIRE®

AVL Software Tools for Powertrain System Development & Optimization

REFERENCES
DAIMLER MOTORENHAUS III

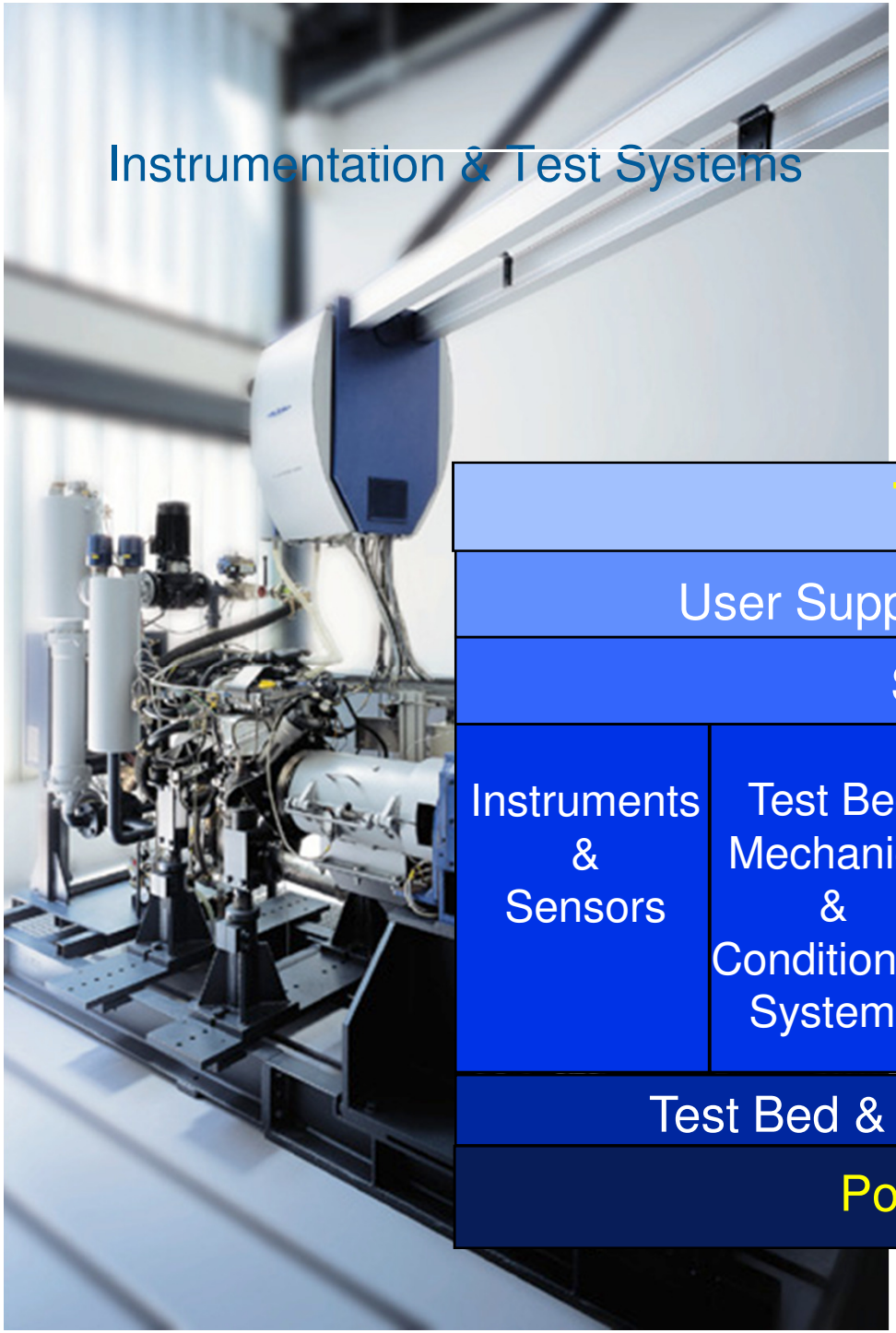
- AVL has built a turnkey Testing and Test Bed Center for Daimler (completion date 2004).
- It is a seven-storey Testing and Test Bed Center with 10 powertrain and 62 engine test beds.

Test Beds built as Modules

Test Beds in individual Cell Construction

Value adding solutions ...

Instrumentation & Test Systems



Turn Key Projects

User Support / Maintenance Contracts

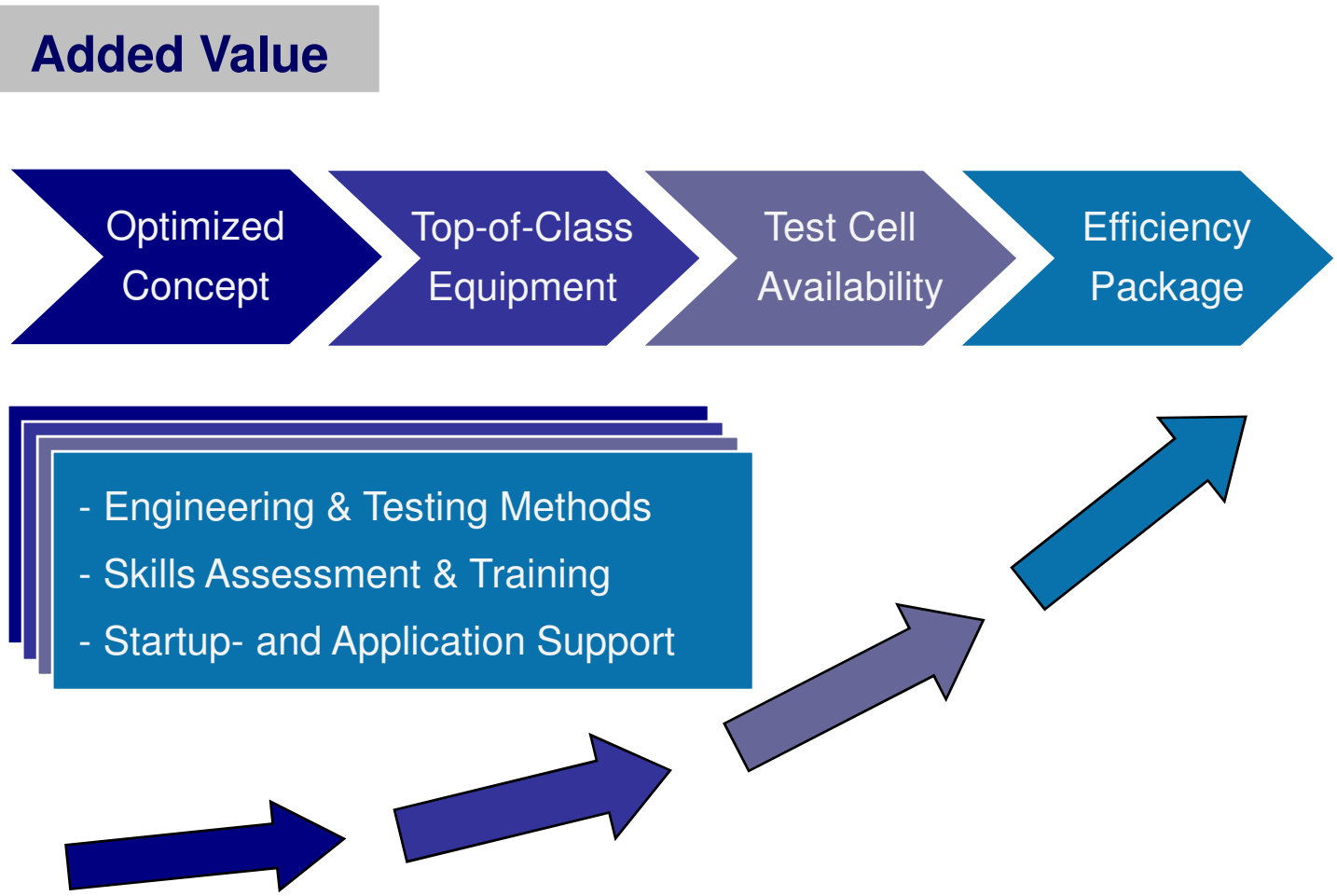
System Integration

Instruments & Sensors	Test Bed Mechanics & Conditioning Systems	Test Bed Automation, Control & Simulation	Emissions Test Systems	Engine & Chassis Dynos

Test Bed & Instrumentation Development

Powertrain Engineering

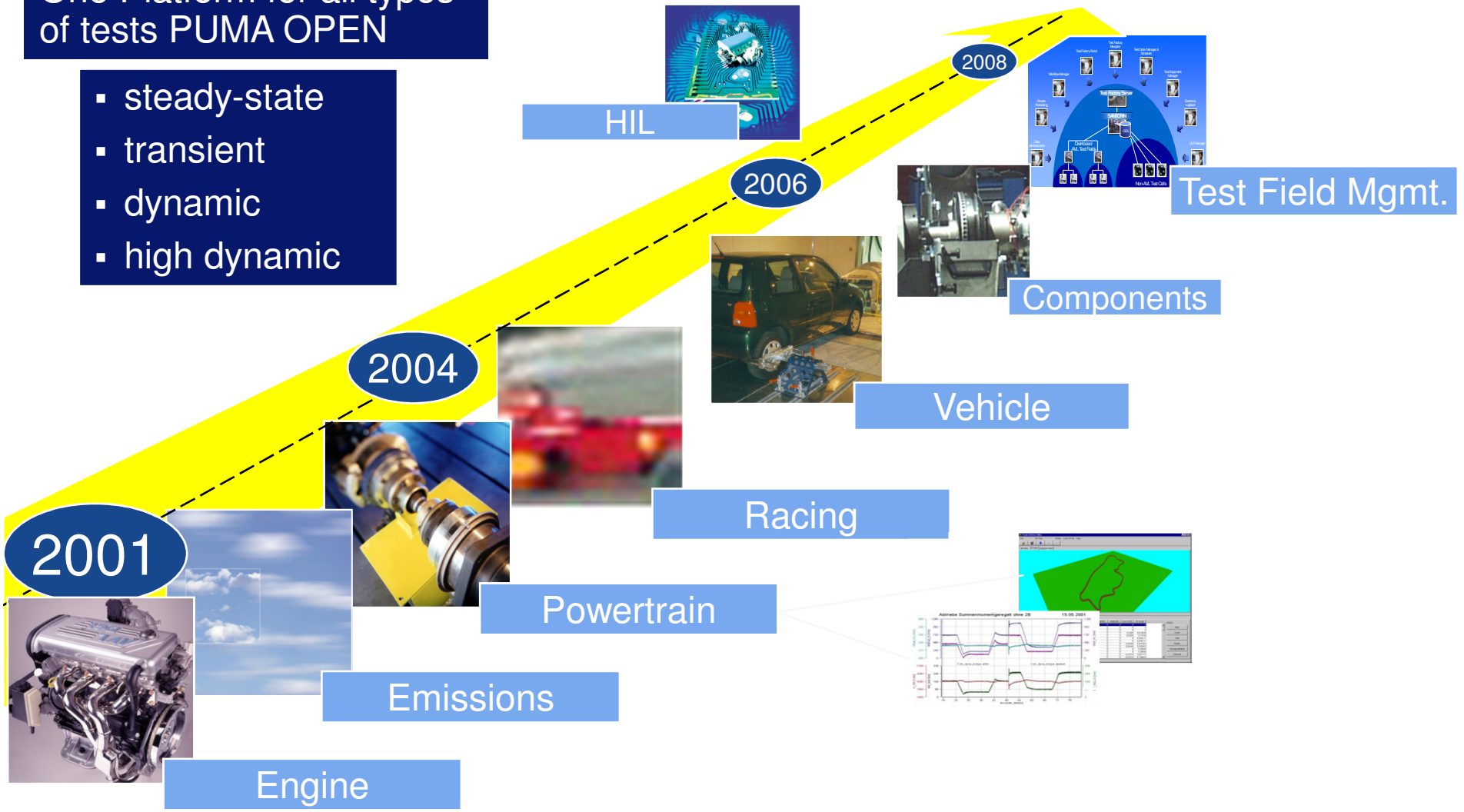
Summary: AVL Added Value



Test Systems Roadmap

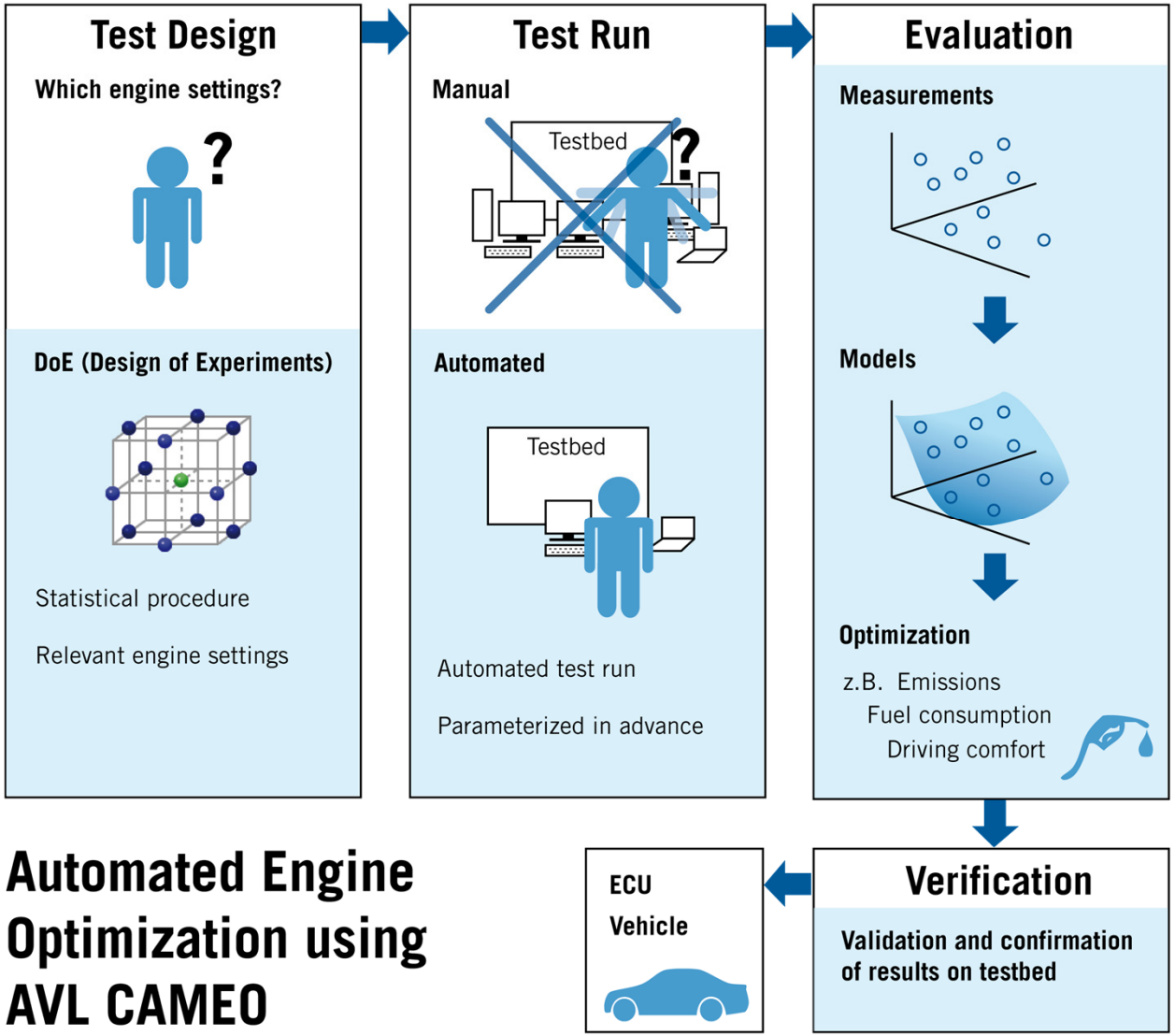
One Platform for all types of tests PUMA OPEN

- steady-state
- transient
- dynamic
- high dynamic

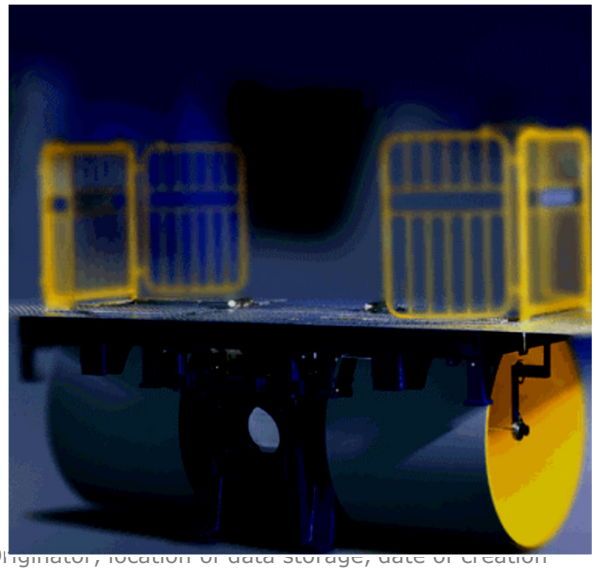


What's CAMEO?

A Calibration Tool designed to increase the productivity in the calibration process



Vehicle Testing



Chassis Dynos

for Emission Certification

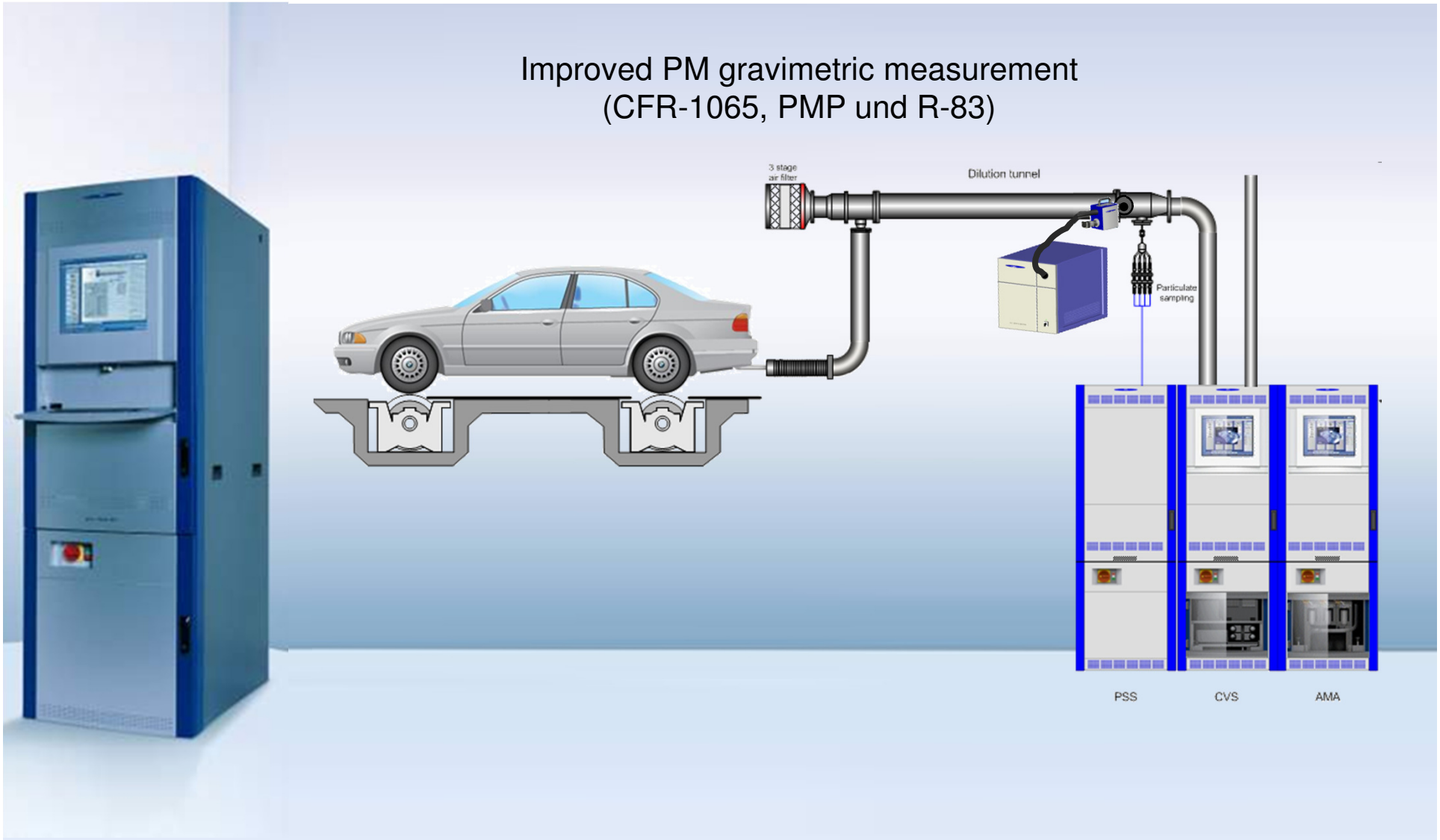
Electromagnetic Compatibility EMC

Acoustics Engineering

Mileage Accumulation

Vehicle Performance

LIGHT DUTY CERTIFICATION



DIESEL TDI HISTORY - AUDI TDI

- AVL Development of turbo diesel direct injection technology by AVL.
- In 1989 Audi used this technology for the first time in series production.
- Since then we have been involved in more than 100 other development projects.

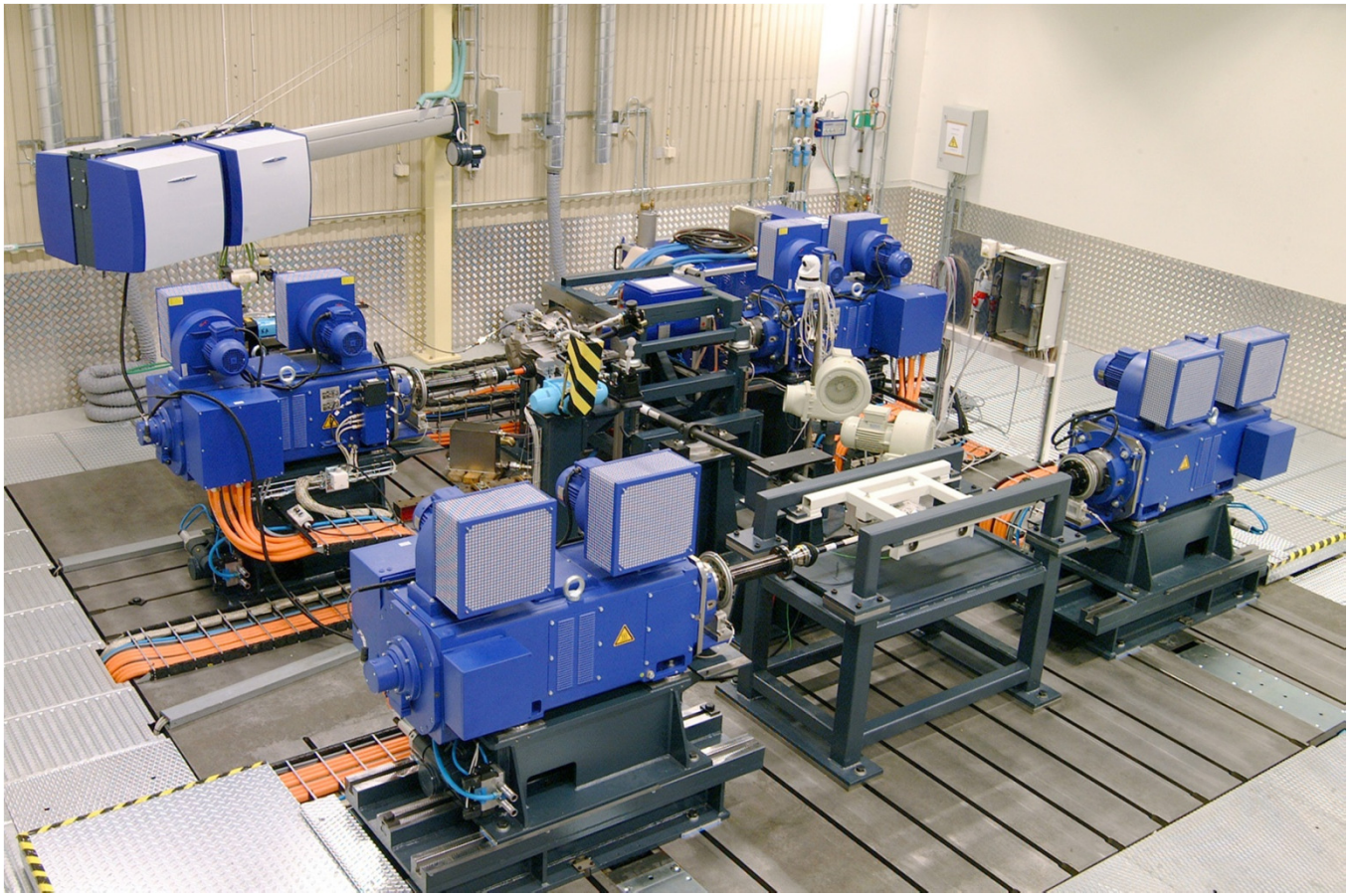
HYBRID DEVELOPMENT AT AVL

Electric Vehicle with AVL Range Extender below Booth

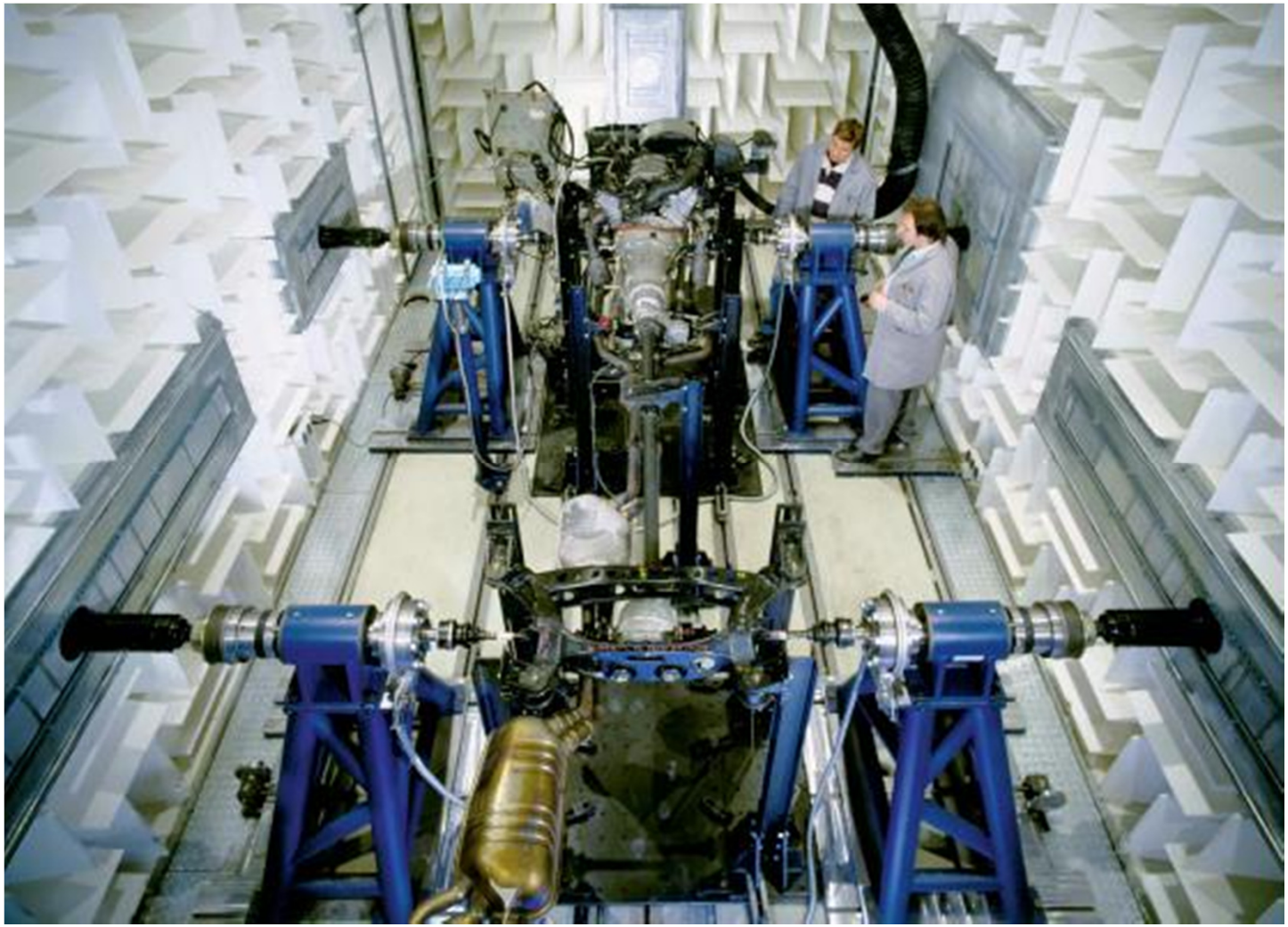
Anchoic Chamber Chassis Dyno

Vehicle – Powertrain Test bed for road simulation

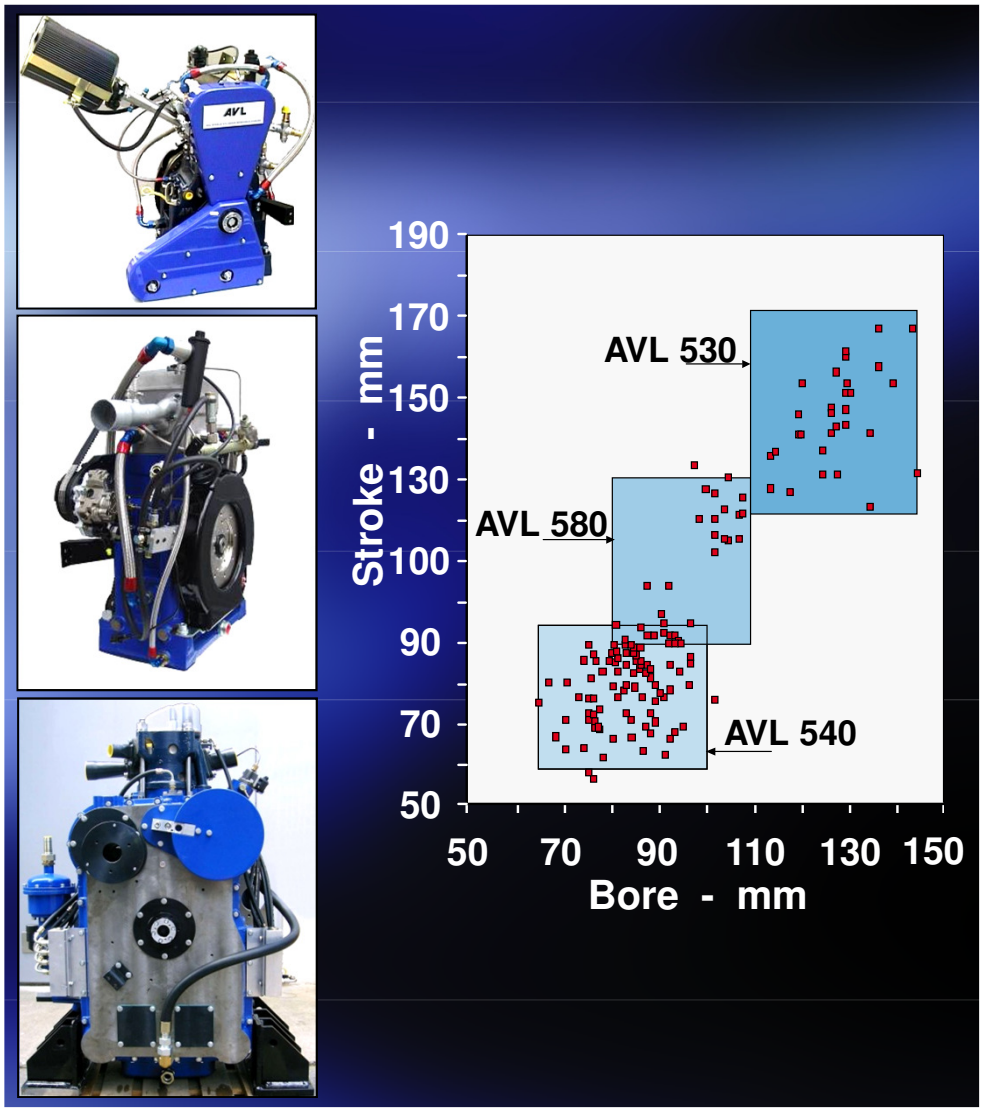
SAAB TESTING LABORATORY



Anchoic Chamber Powertrain Test Bed



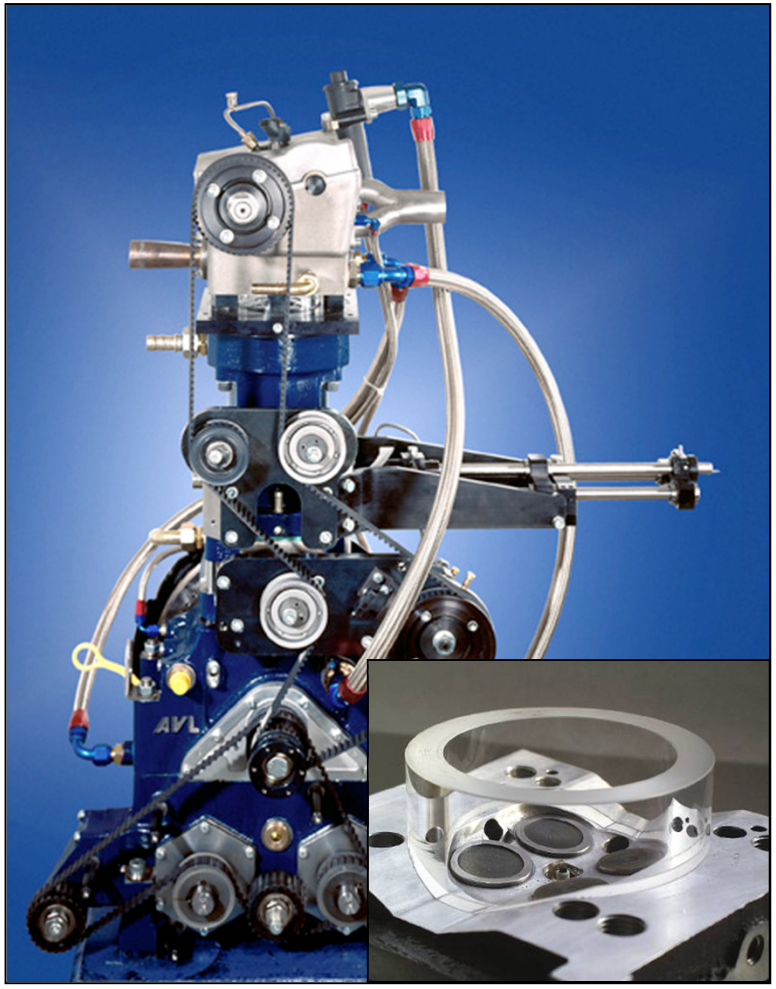
Single Cylinder Research Engines



- Single Cylinder Research Engines available as customer-specific solutions or standardised research engine versions.

- Three sizes of Single Cylinder Research Engines:
  - 540 small passenger car engines
  - 580 light duty engines
  - 530 heavy duty truck engines

Transparent Research Engines



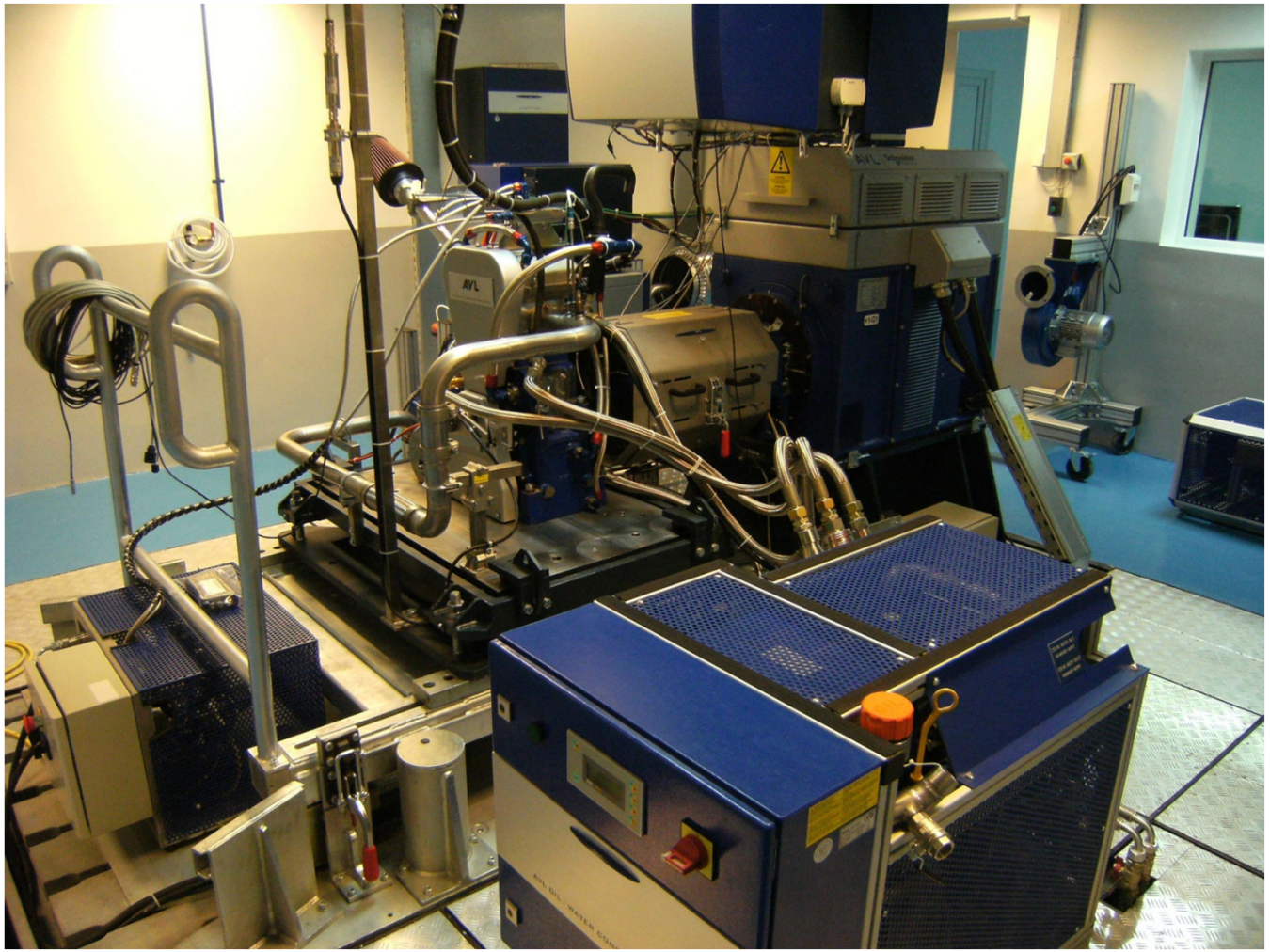
- AVL has developed window techniques for its well-known single cylinder research engines which allow simultaneous optical access to the combustion chamber through cylinder liner and piston.
- Over many years AVL has made substantial contributions to combining the needs of both the optical measurement systems and the engine operation requirements.

Single Cylinder Compact Test Bed

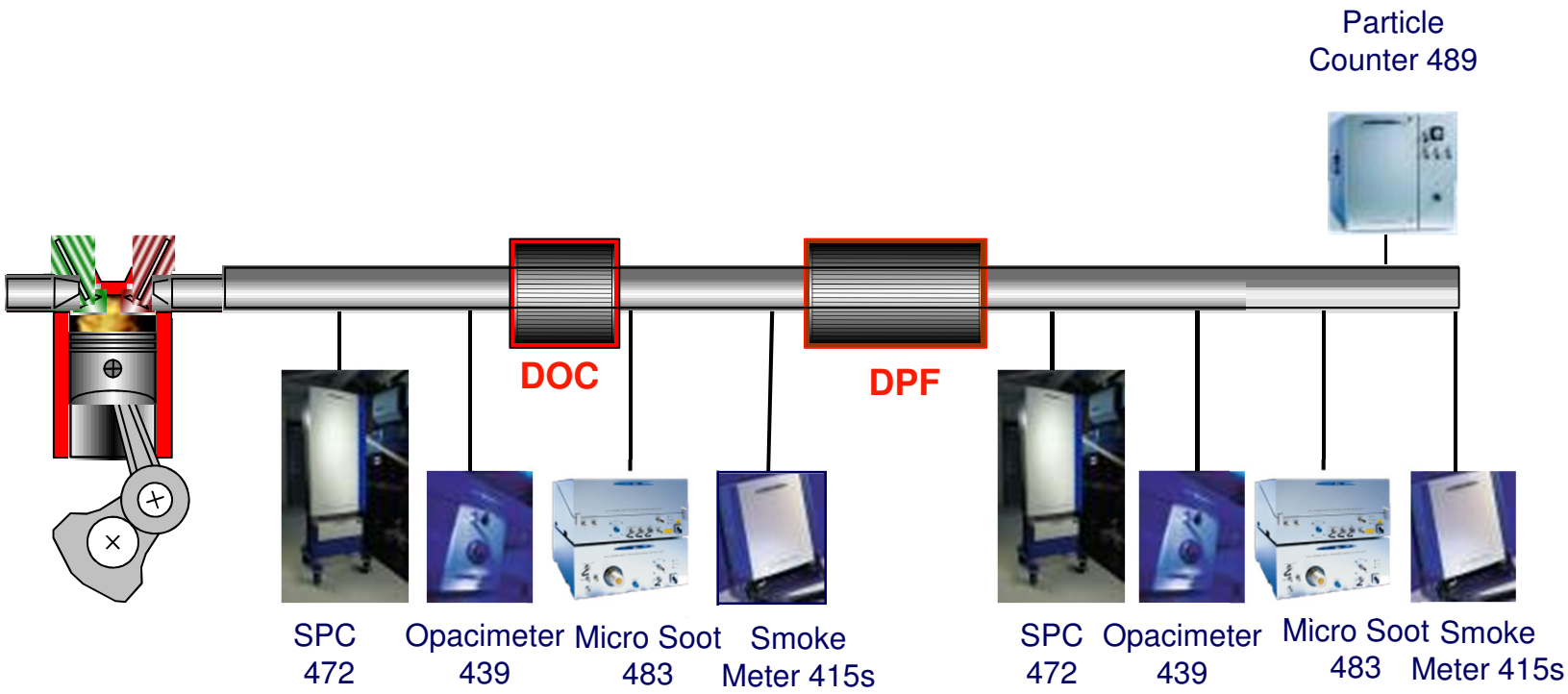
- The Single Cylinder Compact Test Bed has been developed as a flexible modular system:
  - standard low cost solution
  - upgraded customised version

- Able to accept a wide range of single cylinder engine sizes and also suitable for small multicylinder engines and other applications requiring a drive unit, e.g. friction tests.

Test bed for single cylinder engine & 4 cylinder engine



R&D APPLICATION



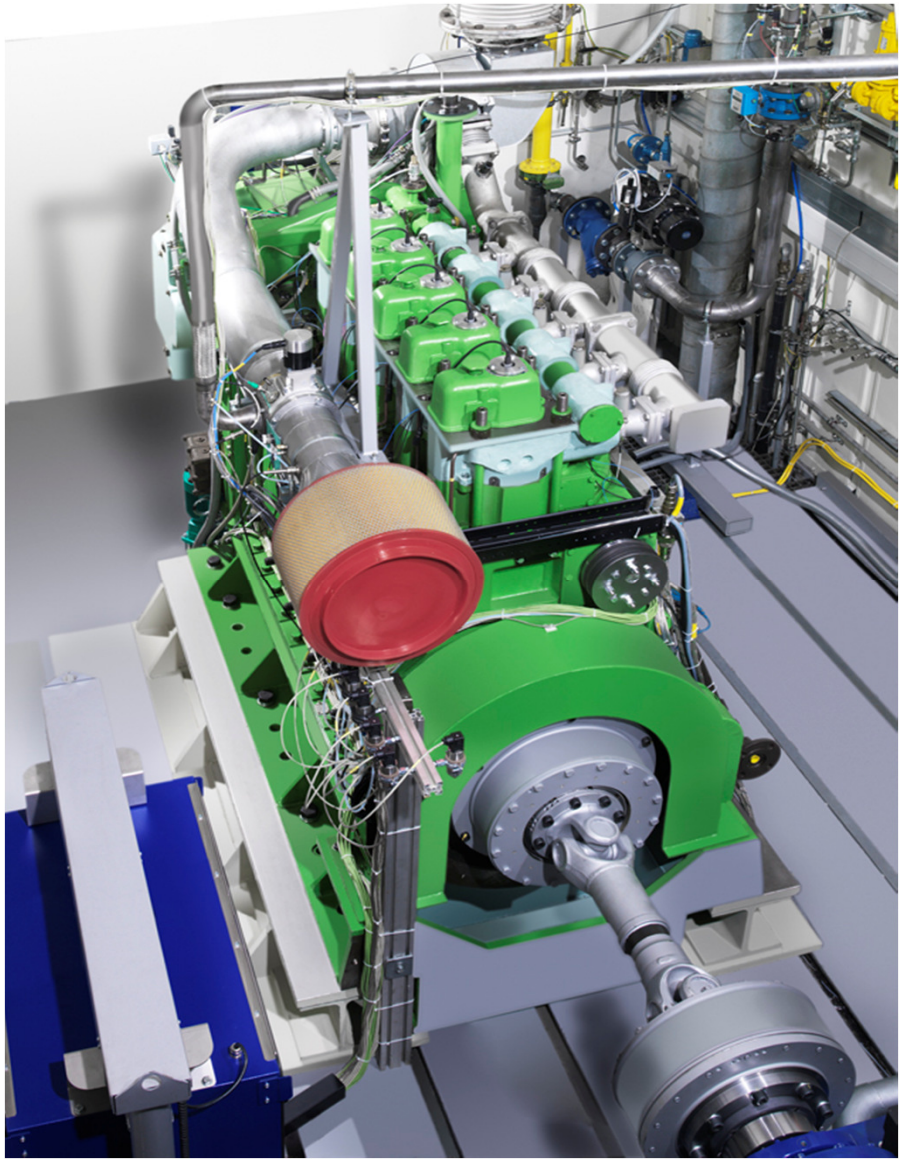
DOC …Diesel Oxidation Catalyst

DPF… Diesel Particulate Filter

Large Engine Single Cylinder Test Bed

AVL EPOS CONDITION MONITORING SYSTEM WITH ENGINEERING INTELLIGENCE

FIRST GAS ENGINE OF HHI - H17/24G



- Concept Design
- Combustion Development
- Spark Plug Tests
- Optimization of Turbo Charging
- Optimization of Valve Timing

MARKET REQUIREMETS – EOL End of Line Testing

Engine Production Tooling and Assembly Lines

EOL Engine Testing

MARKET SEGMENTATION

- **Passenger car engines / Light Duty commercial engines**
- **Racing high performance engines (gasoline)**
- **Mid Range - Heavy Duty commercial engines**

EACH TYPE OF ENGINE REQUIRE DIFFERENT TEST METHODOLOGIES TO ENSURE PRODUCTION & PRODUCT QUALITY

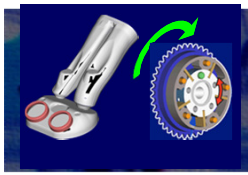
AVL Cold Test Characteristics Summary -Technology

Electrical Continuity Test

e.g.: Glow plugs, injectors, fuel sensors, ...

Mechanical Test

e.g.: Starting Torque, Intake/Exhaust Press., NVH ...

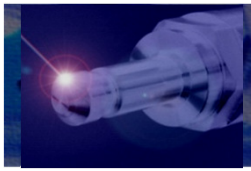


Actuators Test

e.g.: Throttle, PDA, CVCP (VVT), EGR, ...

Common Rail Test

e.g.: Rail leakages, high pressure pump & injectors functionality, ...



Ignition Test

e.g.: Standard and Pencil Coil, ...

Turbocharger Test

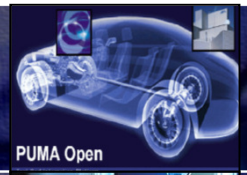
e.g.: Functional Test, NVH, ...

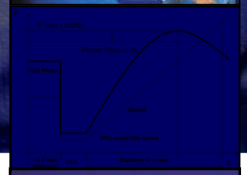
AVL Hot Test Characteristics Summary - Technology

- Verification of
  - Torque,
  - Speeds,
  - Power,
  - Pressure,
  - Temperatures,
  - Fuel consumption,
  - Smoke,
  - Blow By,
  - Full load power test

- Engine power calibration

- Pallets, match plates, shuttle for engine IN/OUT, mechanical & system engineering




AVL HD TRANSMISSION ENGINEERING

- Synchromesh transmissions
- Powershift transmissions
- Continuously variable transmissions
- Manually operated transmissions
- Automated manual transmissions
- Automatic transmissions

EXAMPLES – PASSENGER CAR

Central Integration Platform

AVL M.O.V.E System Control

- Data acquisition
- Online calculation and display
- Device integration and monitoring
- Communication to INCA
- Integration of GPS & Ambient Information

- RT Option DriCon (Driver Controller) Application:
  - Record & Play of real test profiles
  - Accurate and reproducible test execution

Emissions

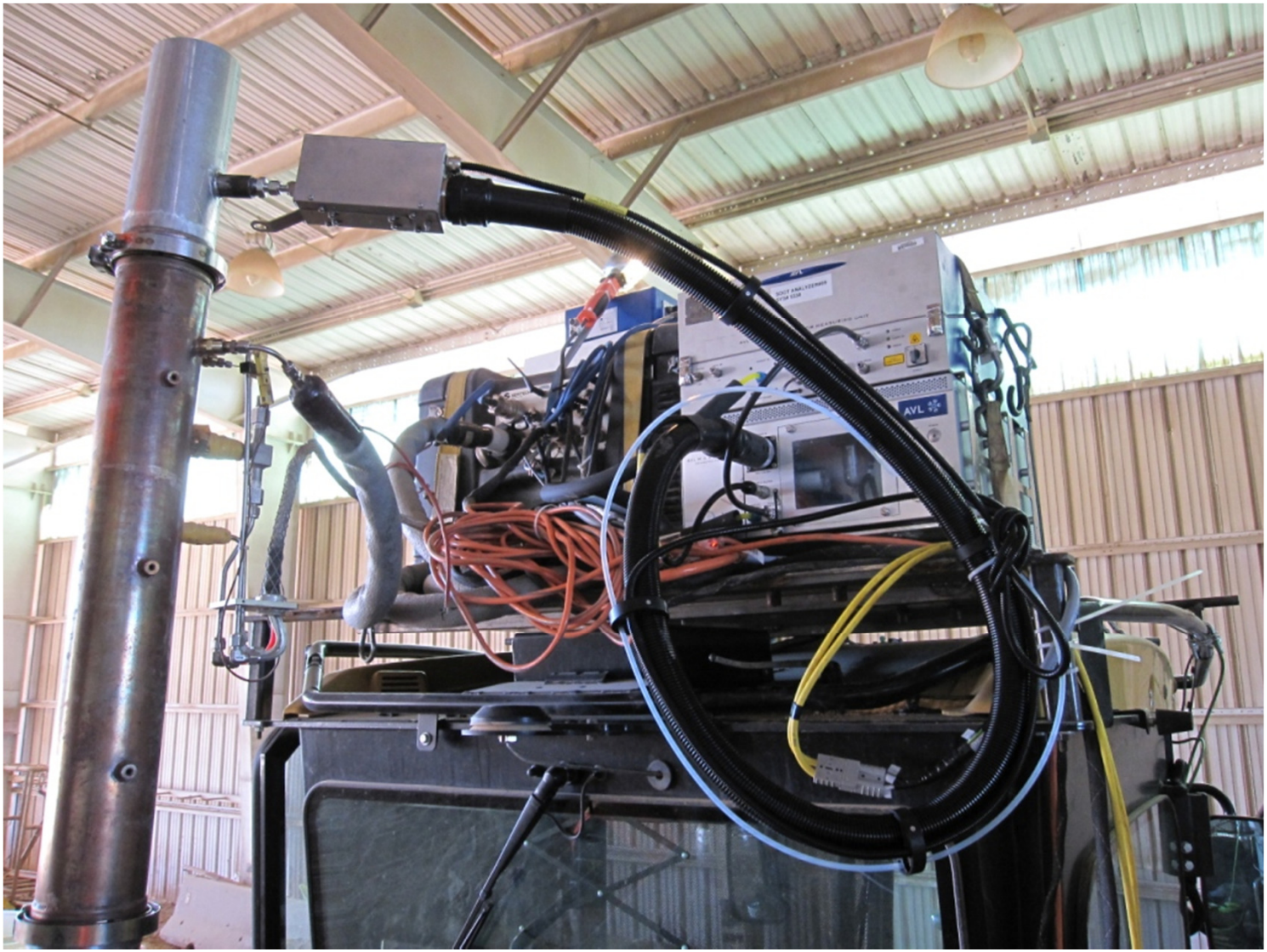
AVL M.O.V.E GAS PEMS

- Measuring gaseous emissions under real conditions
- NO/NO2, CO/CO2 and THC
- High measurement accuracy even at the low measurement range
- Low span and zero drift of analyzers

AVL M.O.V.E PM PEMS

- Measuring Soot- and PM-Emissions under real conditions
- Combination of AVL Micro Soot Sensor and gravimetric measurement of particles
- Compact dimensions and low weight
- Approved by US EPA since 10/2010

HDIUT EXAMPLES – OFF ROAD



TESTING SOLUTIONS ELECTRIFICATION
Products 2011

Virtual Vehicle Platform
AVL InMotion™

Battery Test Bed	E-Motor Test Bed	Inverter Test Bed	Engine Test Bed	Transm. Test Bed	Power Train Test Bed	Vehicle Test Bed
						

DC Power Supply
e-Storage Tester™
Battery Emulator

CONTINENTAL E-Motor Testbeds

EUROPEAN COMMISSION, JOINT RESEARCH CENTRE ISPRA VELA 7

Project: VELA 7 - Chassis dyno climatic chamber for trucks & buses at the Research centre of the European Union.

Location: Ispra (VA) Italy

Turn-key delivery by AVL Italy including Design, General Facilities and Equipment for a special 2WD Climatic Chassis Dyno Climatic Room (-30°C to +50°C).

Volume app. 4.5 M€

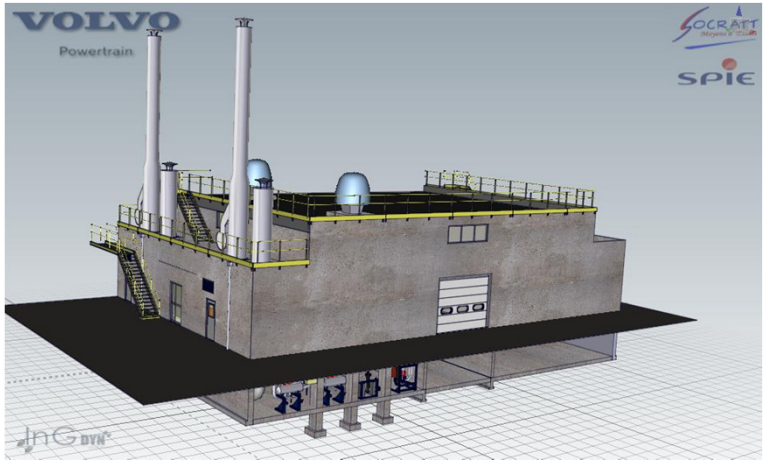
2007-2008

Accessibility: usually granted after alignment with customer

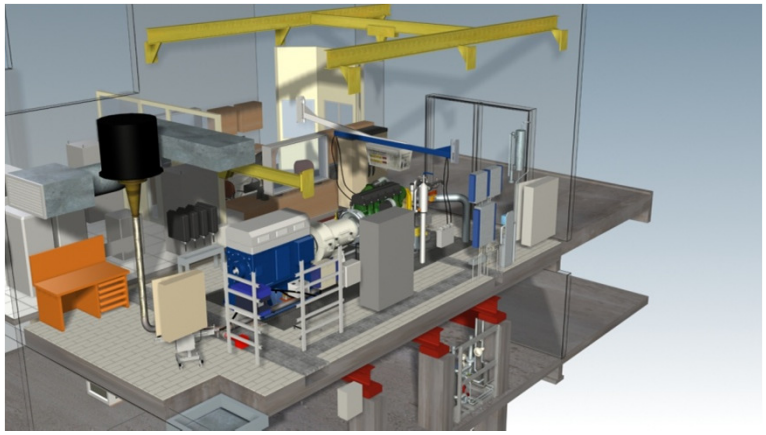
VVETB TU DARMSTADT

- High dynamic testbed for feasibility studies and concept evaluation
- Location Darmstadt (Germany)
- Scope: Dyno, mechanical components, automation system and high dynamic controller setup
- Volume app. 1M€
- 2008 - 2009
- Accessibility: usually granted after alignment with customer (University)

REFERENCES
Volvo Powertrain V^3 (Volvo Virtual Vehicle) Project



The building from outside



A view of one test cell

Performance and simulation test cells for Heavy Duty applications

Location Lyon – Rhône (69), France

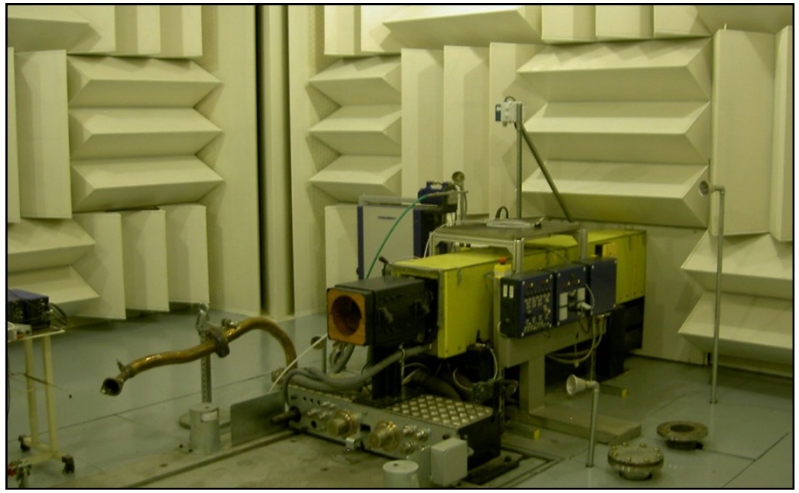
Two test beds and one off-line simulator delivered with PO141 and InMotion

2007 - 2009

REFERENCES
V³ Project – Lyon

Offline Simulator

NISSAN TECHNICAL CENTRE EUROPE – Barcelona
CHRONOLOGY

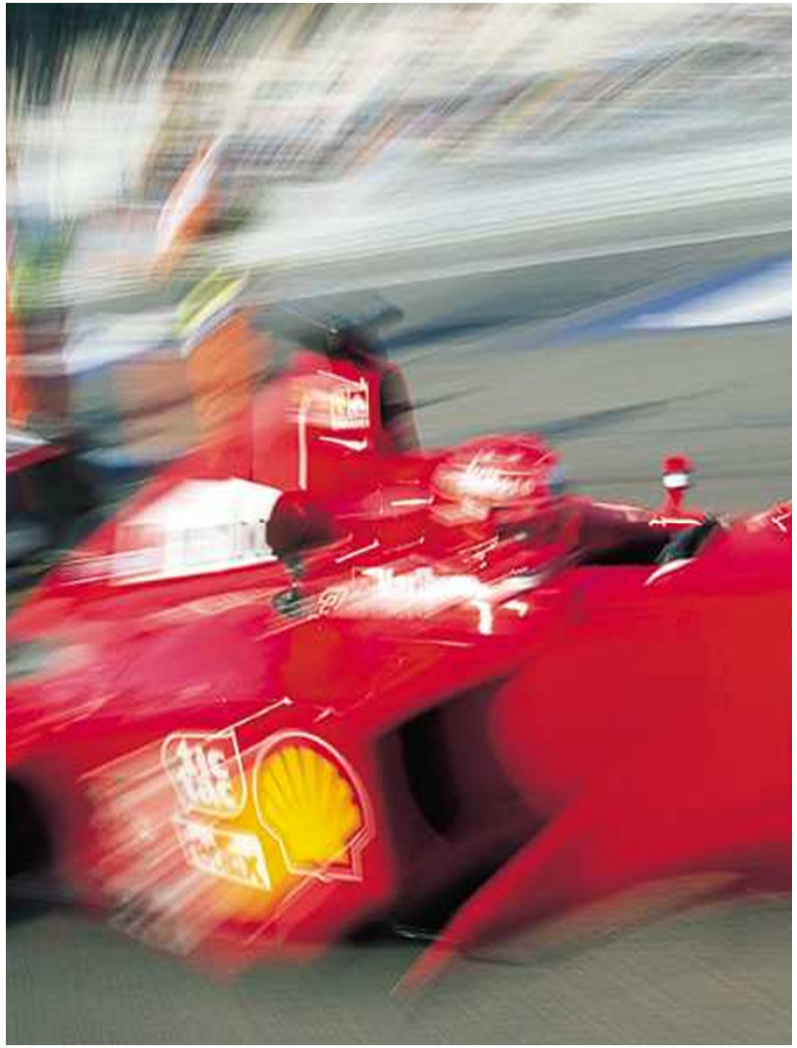


2005-2006 in a second phase **AVL Ibérica** carried out a **turn-key project** for four Engine Test Cells and a Semi anechoic Chamber whose **main features** are:

- Automation platform PUMA Open 1.3 with HOST
- DynoRoad 204/8 and THA100 Actuator
- Media and consumption measurement: 733S+753, Smoke Meter, Opacimeter 439,
- Indicating equipment: Noise meter, K-Check 610 and Indimaster 620 (soft. Indicom v1.4)
- Test Bed Sensors and Transducers: F-FEM
- Optimization tool CAMEO (including soft. CARE)
- Mechanical systems including trolley system and automated docking

An important design criteria that involved the project from the beginning was the need of the customer to **reduce the exchanging time of an engine inside test bed**. This goal implied an special attention to the design of the trolley and the shaft.

REFERENCES
FORMULA 1 – ENGINE DEVELOPMENT



- The driveability of Formula One cars was improved using AVL driveability technology.
- „The development approach was used in the 2000 season to improve engine driveability of the Ferrari Formula 1 engine 049, this was a contribution in the final success of Michael Schumacher and the Ferrari Formula 1 team.“

  Ing. P. Martinelli, Ing. M. Bollini, Ferrari Gestione Sportiva, Maranello

- **www. avl.com**