Software and Testing Solution Catalogue

TESTING SOLUTIONS FOR FUTURE MOBILITY

CONTENTS

CONTENTS

» OUR SYNERGIES CREATE ADDED VALUE FOR OUR CUSTOMERS

Our aim is to boost the efficiency of our customers' development and testing facilities.

The target today, for our customers and for us, is to innovate in order to remain competitive. There is no longer space on the market for a large but commonplace portfolio of products and test cells: What our customers need now is testing solutions which help them to excel.

What is unique at FEV:

> **Test centers designed by a testing expert**

- We run seven test centers around the world and more than 240 test cells on a daily basis
- Based on this expertise, our test center solutions provide unmatched efficiency

> **A model-based collaborative framework to boost the development process**

- A unique software environment for the complete validation of the powertrain: From desktop to road, engineers from different areas can easily share their knowledge to prepare a common solution: Define and validate a new e-powertrain concept or a new hybrid architecture, define the control laws of an ECU and calibrate it with a new engine.
- FEV expertise inside: Calibration and testing methodologies validated in FEV Technical Centers are offered to our customers, embedded in this software environment. The customer can decide whether to use their own methodologies or FEV's.

We invite you to discover the various and powerfull solutions that FEV is proud to propose to its customers.

» FEV OFFER

A three chapter approach:

1- TEST CENTER

As an example, DLP – a FEV test center – achieves more than 85% test bench utilisation (24/7): FEV offers its unique expertise in test center management to its customers.

> Read more in pages 36-49

2- TEST CELLS running in the test center

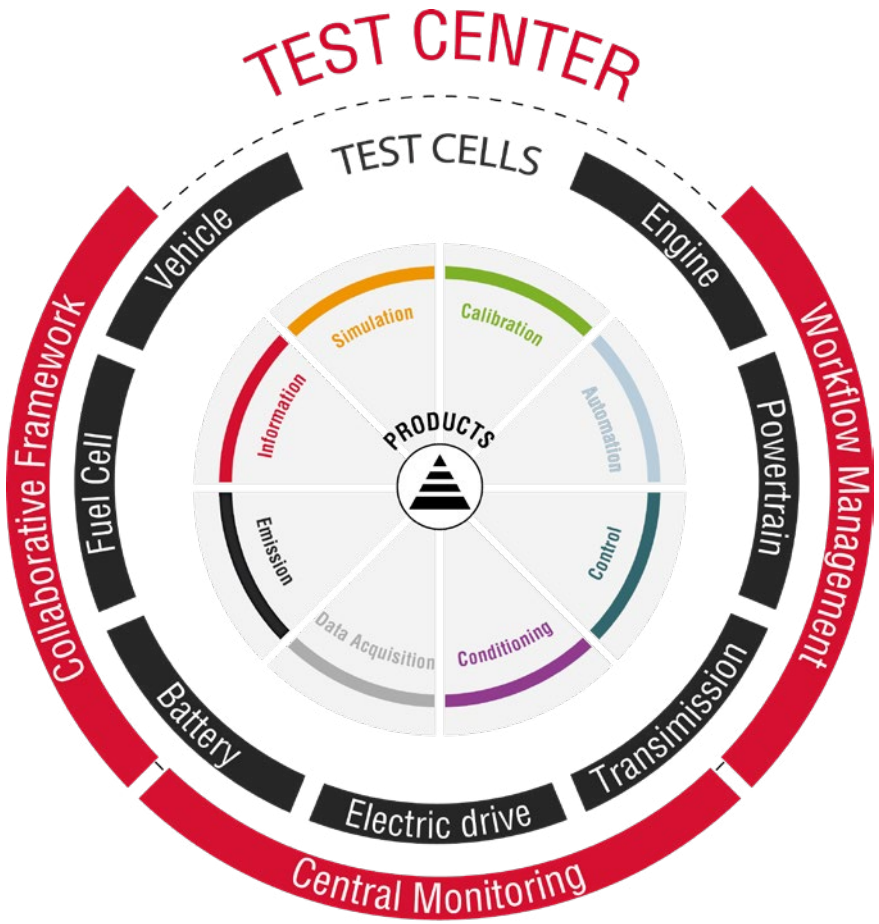
High-tech test cells have been proven in FEV test centers first – with all of FEV's powertrain knowledge inside.

> Read more in pages 50-79

3- PRODUCTS covering the requests of the development teams,of the test center and of the test cells

As an example, one of FEV's major customers uses FEV MORPHEE AuSy in its 150 test cells: thanks to FEV's solution, only one operator is needed for 20 test cells. MORPHEE currently represents 10,000 users and 12 million running hours each year.

> Read more in pages 80-147



» ON THE WAY TO ELECTRIFICATION

In the North Sea oil country Norway, all new vehicles sold must be electric by 2025. The C40Cities association, which groups 94 major cities around the world, plans to ban diesel engines by 2025 as well. In the European Union, the EU's target of an average CO2 emission of 95 g/km for all new cars by January 2021 is leading European manufacturers to accelerate the electrification of their range. Especially since by 2030, a further 37.5% reduction in CO2 emissions is expected. In China, the central government is facing unprecedented pollution in cities. Since this year, it has imposed draconian quotas for the production of electrified cars on all manufacturers. These OEMs have multiplied the number of subsidiaries dedicated to the electrical sector to expand their offer. China, in this area, should be the country that will lead the way.

It is not possible to go below 4 litres per 100 km without electrification: in 2030, global vehicle production of less than 6 tonnes will probably have less than 10% of fully conventional motor vehicles. From Mild Hybrid to pure electric, electrified vehicles will experience a unique leap forward.

To respond to this systemic change, there are many technological, economic, and even geostrategic challenges. The main pitfall is the battery. The reason why electricity had not previously been broken through was simple: there was 40 times more energy in a kilogram of gasoline than in a kilogram of lead-acid batteries, there are 20 to 30 times more energy than in the Li-Ion batteries currently used for electric vehicles. The autonomy of a purely electric vehicle is now a limiting factor: vehicles with the highest range report 300 to 500 km, but they are luxury vehicles. Most of them range from 100 to 150 km. Another limiting factor

is speed: the power of an electric motor, like any power, is proportional to the cube of speed. This means that speed not only decreases autonomy, but also exponentially when high speeds are reached. If the battery has a reduced autonomy, one could expect a quick recharge, to avoid long stops, especially for long-distance travel: this is not impossible, but it means a huge electrical infrastructure to be put in place. Furthermore, to get closer to the price of vehicles with conventional engines, it is necessary to reduce the price of batteries by 4.

It is likely that these various technological challenges will be partially resolved. Other difficulties may arise, such as access to the raw materials necessary for the manufacture of batteries and electric motors. These various factors combined will undoubtedly lead to new uses in the automotive industry. Pure electricity is well suited for shorter distances. In some cases, you will no longer own your car, but will move to sharing systems, such as the urban mobility concept SVEN by FEV (https://sven.fev.com). The hybrid can be a good solution for long distances. For this type of engine, developments to achieve the Euro 6d standards - and their subsequent ones - including the RDE (Real Driving Emissions) procedure will remain more necessary than ever.

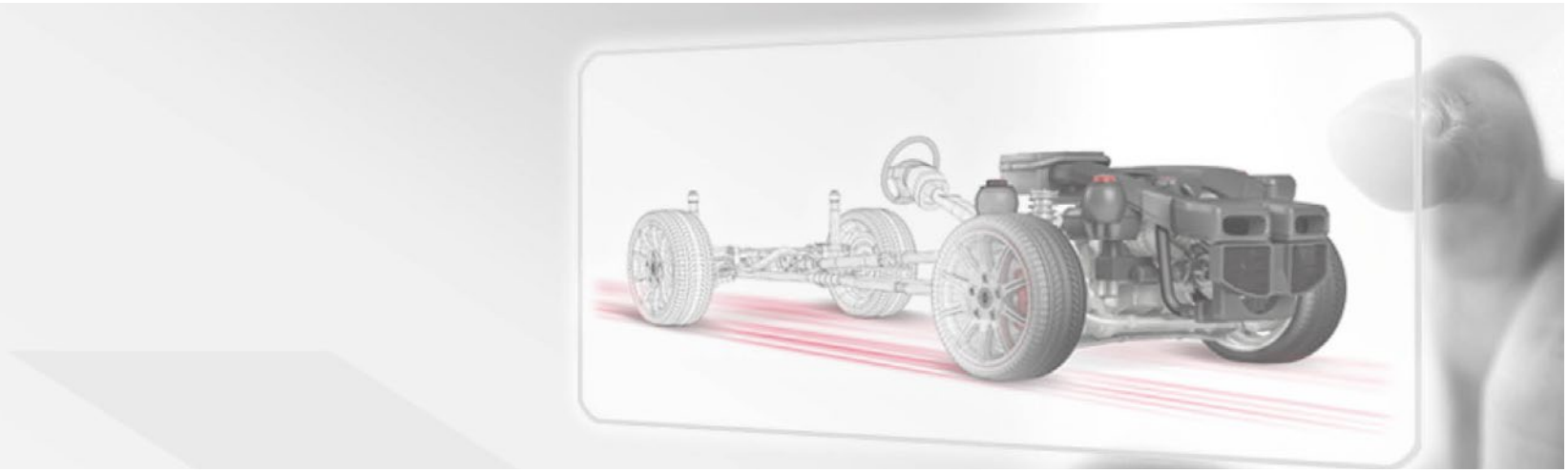
» NEW TECHNOLOGIES, NEW USAGE

The powertrain industry is influenced by global mega trends and resulting drivers that will shape future vehicle & powertrain development

» THE TREND TO VIRTUALIZATION

Prof. Dr.-Ing. Wolfgang Heilmann, Vortrag Motortechnisches Seminar 27.06.1988 LAT RWTH Aachen:
¨In the foreseeable future powerful calculation and simulation methods will make significant amounts of today's still common extensive experimental testing procedures in modern internal combustion engine development programs to a high degree obsolete!¨

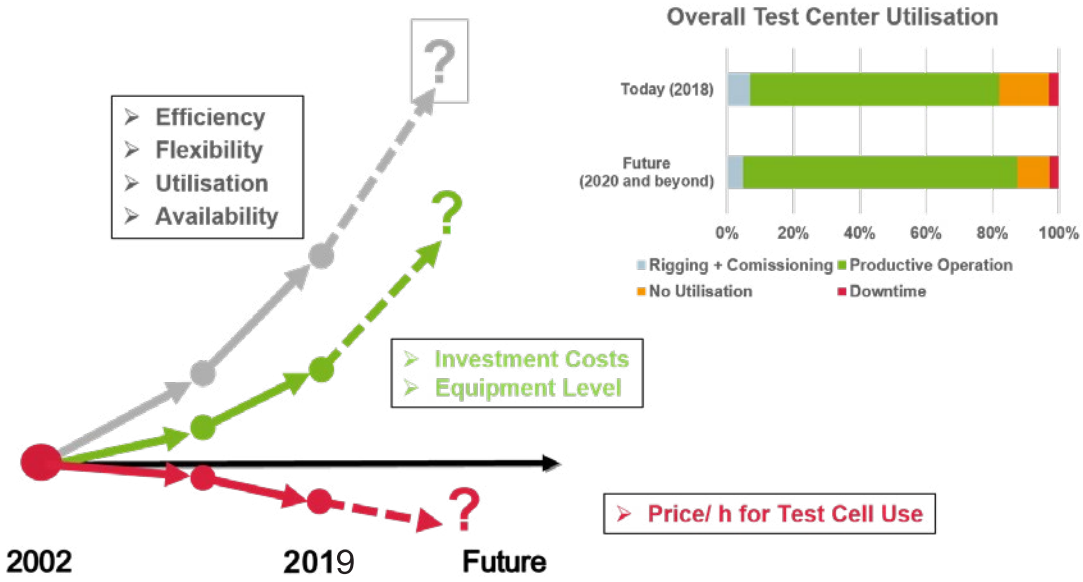
Davy Politsch, FEV Product Director, in Spectrum n°62 20.04.2017:
Developers are facing an increasing complexity of systems and a multiplication of powertrain variants while time-to-market is shortened more and more. In the past, this contradiction was addressed via frontloading of development steps in the sequential V-cycle of powertrain development and via raising the efficiency of testing facilities.
With the recent introduction of RDE (Real Driving Emissions) cycles and the inclusion of e.g. temperature and altitude influences, the contradiction is even magnified and emphasizes the need for new approaches in powertrain development. Frontloading must be combined with a parallelization of development steps, thus leading to a multidimensional Road-to-Rig-to-Desktop approach.
A decisive enabler for this multidimensional approach is the exchangeability of models as well as a continuous improvement of these models between sequential and parallel development steps. Another challenge is the usage of linked benchmark, simulation and measurement data in the development.



» THE TEST CELL TRADE-OFF OF PRICE–COST–EFFICIENCY

The advent of purely electric vehicles such as the development of hybrid vehicles does not simplify the development and testing process. While the architecture of a purely electric vehicle may seem simple at first glance, the battery is a complex element, which will require major developments over the next 20 years. Battery tests become a central element of the test strategy. The test of electric motors at speeds above 20,000 rpm is required. The unit, with its gearbox, must also be tested. In the case of hybrid vehicles, all this must be combined with the combustion engine: we are in a complex architecture, where a system approach is necessary. In the context of a combustion engine, the RDE procedure complements the current laboratory-based procedure to check that the vehicle emission levels of nitrogen oxides (NOx), and subsequently also particle numbers (PN), measured during the laboratory test, are confirmed in real driving conditions.

In this context, the cost of powertrain validation could explode without the advent of new test methodologies. Complex powertrains with elaborate after-treatment systems or hybrid architectures require flexible validation processes, with parallel tasks and the possibility to adjust the project at any time. Conventional approaches to drivetrain or vehicle development — for example, elaborate summer and winter test drives — will no longer be feasible in the same form in which they have been conducted in the past. Instead of such conventional development methodologies, combinations of intelligently-connected processes consisting of simulation and experimental testing technology will be increasingly used. These are called “Road to Rig to Desktop” processes.

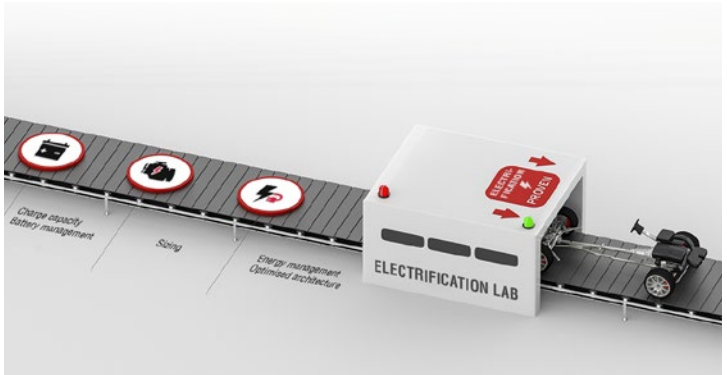


» THE FEV COLLABORATIVE FRAMEWORK, A SOLUTION FOR ROAD TO RIG TO DESKTOP

The FEV Collaborative Framework revolutionizes current development and validation processes. Until now, the processes were sequenced with separate development teams and stages and validation milestones at each stage. There were two reasons for this: first, the presence of physical prototypes bringing each validation stage to an end; and second the inability of software tools to be cross-disciplinary from design to validation on the road, and thus to accompany the models and test procedures with any degree of precision to the test beds and the road. This is no longer the case with the FEV collaborative framework, which calls on the MORPHEE software suite.

> MORPHEE, the first cornerstone

MORPHEE is a transversal tool that can be used in the office, on the bench or on the track. This is not the only cross-cutting tool, but it was able to meet one of the major technological challenges. Until now, the major disadvantage at this stage is very often the necessity to simplify respectively downgrade the models, to ensure real time model execution at the test bed. As a result, the tests become less representative. This is where the FEV framework, based on MORPHEE, distinguishes itself: FEV's solution is 10 to 40 times faster than anything else available on the market. As a result, the precision of the model is retained in its entirety because even complex models can be executed in "hard" real time at the test bed. We are facing an increasing complexity of hybrid and electric powertrains while challenging legislative WLTP and RDE cycles are introduced: in this context, the FEV approach is a must.



» THE FEV COLLABORATIVE FRAMEWORK, A SOLUTION FOR ROAD TO RIG TO DESKTOP

Without executing complex models in hard real time, it is impossible to obtain precise results on the HiL or on the test bed: quick prototyping on the HiL test bed or calibrating the EMS would no longer be an option. MORPHEE xMOD enables satisfactory results even under complex and challenging conditions

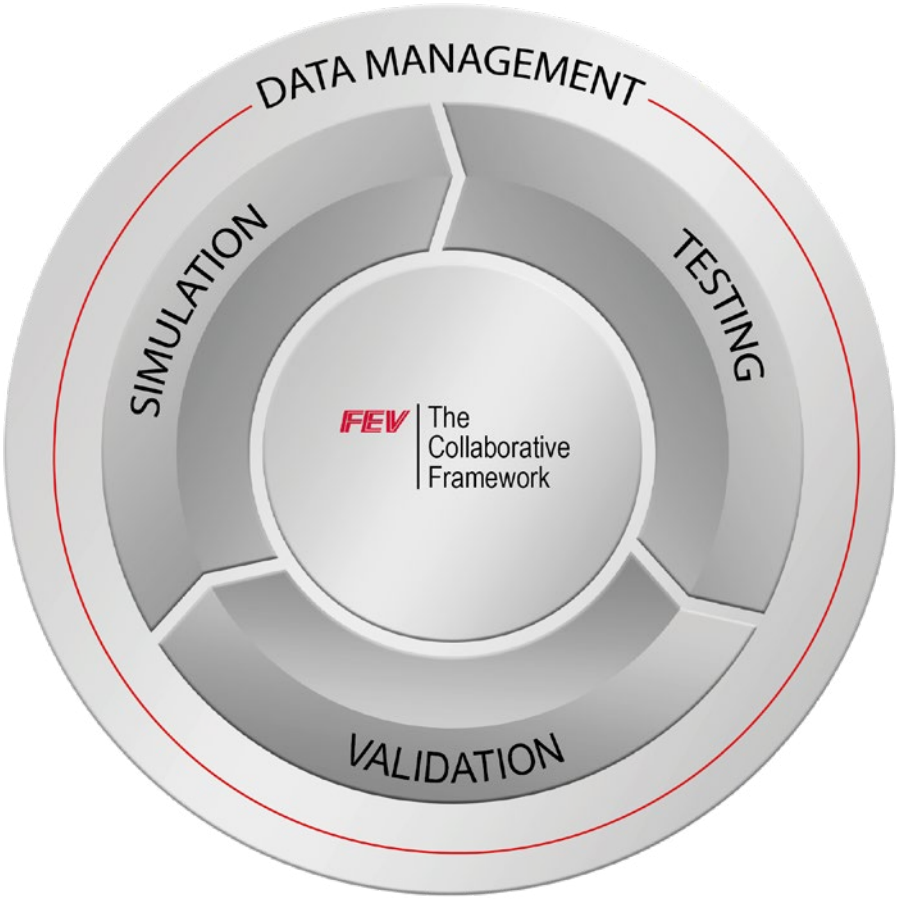
> Proven for more than 10 years

This framework has been used very successfully on numerous projects for more than 10 years and has undergone constant improvement and enhancement.

> FEVFLEX, the second cornerstone

This continuous process, where data (e.g. models, methods, calculations, tests, testing procedures, component specifications) need to be shared at any time, requires an efficient information system, linked to the complete development chain. FEV has developed FEVFLEX, a comprehensive information management system.

> To learn more about the FEV collaborative framework, read pages 80-85



» WORLD CLASS TESTING: BOOST THE EFFICIENCY OF TEST CENTERS

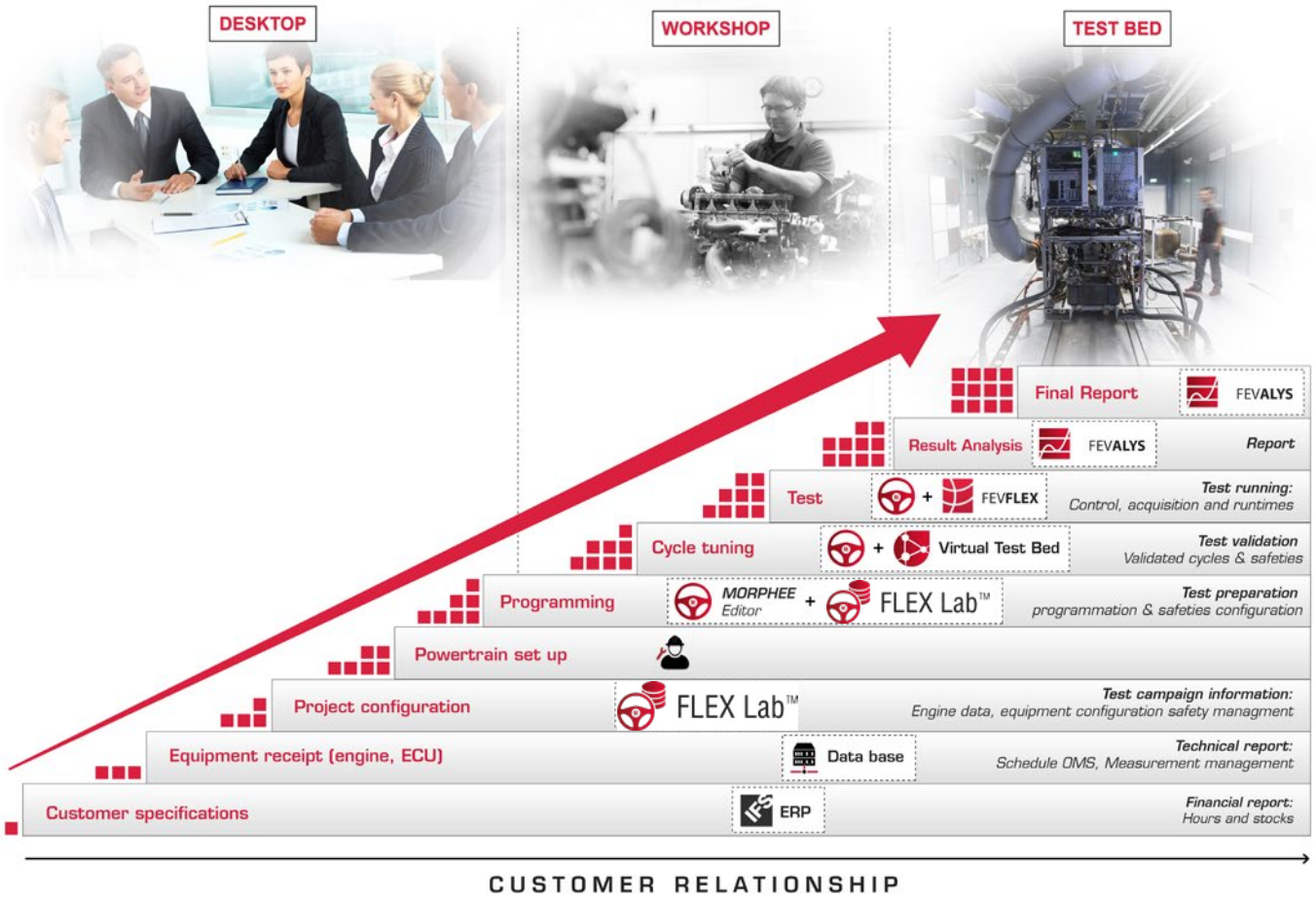
As a leading development service provider with more than 240 of its own test cells and more than 400 experts in its Software and Testing Solutions Business Unit, FEV has extensive expertise related to the requirements and operation of a modern test center. In this area, FEV offers, among other services, turnkey test field planning from a single source, which is extended, as needed, throughout the planning and implementation process and ensure the realization of highly efficient laboratories with maximized user benefits.In addition to technically equipping test benches and test facilities, the operational organization, the technical and functional infrastructure, and logistics topics are becoming increasingly important to supporting complex test requirements with high efficiency and in a timely and cost-effective manner.

> The key to success: information

The central factor for an efficient test center is the software network infrastructure, and the handling of all data at each step of the process. Through FEV's information system, FEVFLEX, and its connected tools, all projects follow an integrated process. As a first step, the customer specifications and information (e.g. schedule, equipment (battery, e-motor, e-axle, engine, BMS, ECU etc.) is entered into the database. Then, at each subsequent step (defining the required equipment and test bed, powertrain set-up, programming, testing, analysis of results etc.), new data will be added and shared in the same area, automatically. The Unit Under Test data, equipment configuration and safety management is defined in the MORPHEE Data Manager; the configuration and test programming are then validated on a virtual test bed before starting the real test on the test bed before starting the real test on the test bed with the MORPHEE Automation System. The results are then sent, recalculated and analyzed thanks to REV report tools. All these tasks are performed automatically: once an item of data is entered anywhere in the database, there is no need to enter it again during another step of the process.

> To learn more about FEV's world class testing, read pages 36-49.

» WORLD CLASS TESTING: BOOST THE EFFICIENCY OF TEST CENTERS

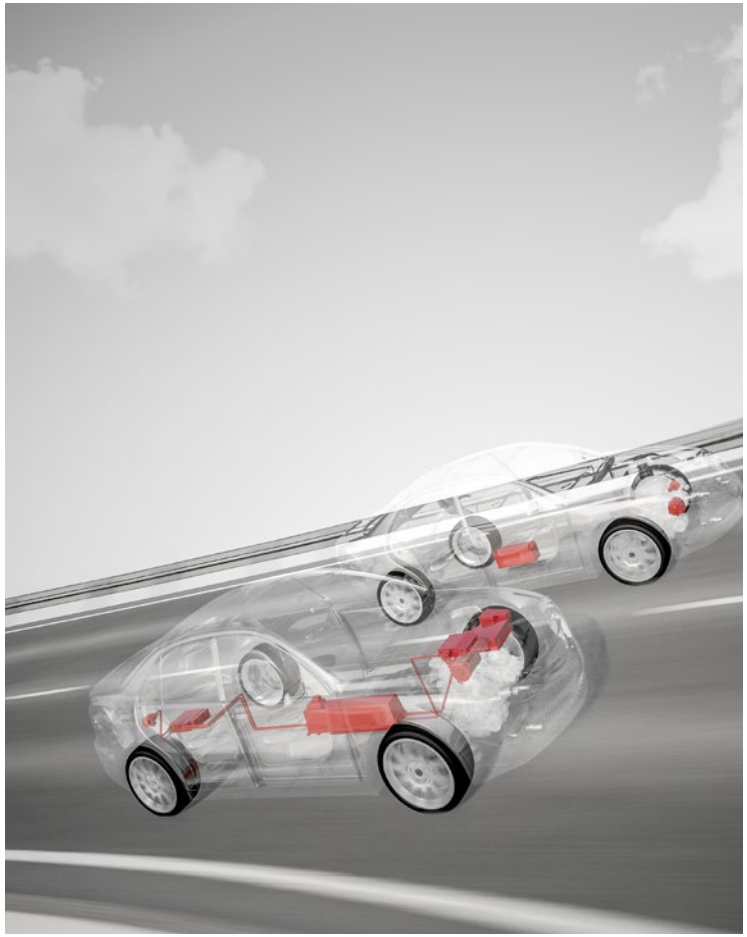


» ELECTRIFICATION CALLS FOR NEW TYPES OF PROCESSES, METHODOLOGIES AND TOOLS

The transfer of technology from combustion engines to electric or hybrid engines has resulted in the development, validation and optimization of numerous new concepts and new powertrain architectures. FEV considers there to be two main points concerning management of these changes.

> The methodologies and tools to be used cannot solely be generic solutions on the market. They must integrate the particular features and knowledge specific to electric technology adapted to the transport field. This involves **close cooperation between the engineering teams** specializing in powertrains and those developing tools and equipment used on test benches, in test centers, on test tracks and during road tests. This is where a partner like FEV, capable of managing these different aspects, is the best solution to support manufacturers in their electrification strategy. For answering that goal, a complete dedicated suite of software, measuring devices and test beds solutions have been designed.

> As part of this approach, the **development of simulation** models throughout the development process is a key element, given the increasing complexity of the powertrain system and the constraints in terms of time and cost. This is compounded by the advent of autonomous driving systems. Together with simulation tools, it is necessary to add the need for an information system enabling data to be shared throughout the entire process. FEV's strategy in this area, the FEV Collaborative Framework, is based on two key products – MORPHEE and FEVFLEX – and on FEV's expertise in process management.



» ELECTRIFICATION CALLS FOR NEW TYPES OF PROCESSES, METHODOLOGIES AND TOOLS

The challenge

Developing an electric or a hybrid powertrain system based on simulation, starting with a 0D/1D first loop, then progressing to a multi-dimensional loop:

> allows virtual prototyping to be carried out at a stage of development where the CAD plans do not yet exist;

> requires a clear process concerning the contribution of each trade: mechanics, engine manufacturers, electricians, chemists, electronics etc.;

> avoids the pitfall of monolithic models which are difficult to handle and make inefficient use of IT resources.inefficient

FEV's solution

> **Multi-disciplinary teams**: e-mobility engineering, control, calibration, testing, on-road validation, methods and tool development, test bed and test center engineering etc.

> **The FEV Collaborative Framework**, based on the MORPHEE Process system and FEVflex Data Information System share your models, tests, methods and algorithms throughout the entire process. This solution has been tried and tested in multiple applications over 10 years.

Make up your choice: in-house or subcontracting

> In your facilities: use your models inside the FEV Collaborative Framework, ask support from FEV experts for specific tasks, use battery and e-motor test bed solutions designed and produced by the FEV testing facilities engineering team

> At FEV: ask us to handle the complete project, and benefit from the extra facilities of our in-house laboratories: engine test centers, battery test center, powertrain test bed etc.

Feasibility & Pre-Concept
zero-dimensional open loop

- Check of vehicle targets
- Comparison vs competitors
- Sensitivity analysis of key factors

Concept
zero-dimensional closed loop

- Selection of system topology
- Component sizing & selection
- Operation strategy optimization

System Freeze
multi-dimensional closed loop

- Detailed system analysis
- Analysis of critical missions
- Plant model for Mil / Hil

The simulation process for a e-mobility development

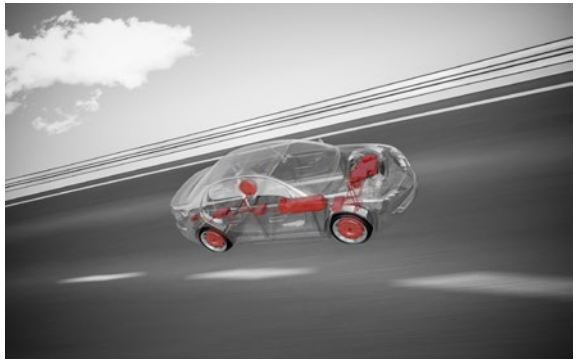
» TEAMS OF EXPERTS

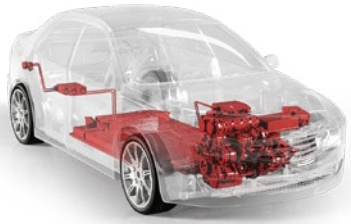
> Hybrids and e-mobility

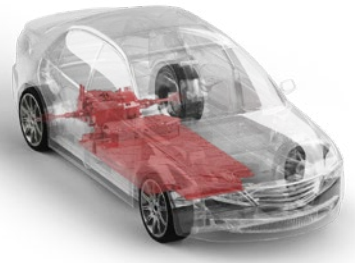
Electrified powertrains have resulted in lower emissions and reduced carbon footprints for passenger cars and light-duty vehicles. FEV has been responsible for a large number of development programs for hybrid and all-electric powertrains as a turn-key development partner for international customers. Starting with start/stop systems, our experience comprises micro, mild, full and plug-in hybrids as well as battery electric vehicles (with and without range extender modules). FEV also engages in internal R&D projects to evaluate fuel cell technology for our clients. In combination with our transmission system experts, FEV has contributed a considerable number of advantageous hybridized transmission solutions. In all of our global development centers, we have employed rapidly growing teams and continuously extended our test facilities to meet these needs.

> E-tractive batteries

FEV offers the development of entire battery systems, including the Battery Management System (BMS) and battery testing. While FEV can access standard modules and its own BMS (FEV LiiONMAN), it also offers the services of new product development. Within the framework of a safety agenda according to ISO 26262, all of the required steps are taken from the technical specifications through the scheduling, completion and documentation of validation activities and reviewing of suppliers of safety-relevant parts. The FEV Battery Management System battery control unit (FEV LiiONMAN) combines the surveillance of all critical values with operational strategies to create a performance projection. This enables safe operation and optimized utilization of the cell's capabilities.







» HYBRIDS AND E-MOBILITY AND SMART VEHICLES FEV ROADMAP FOR PASSENGER CARS

EU

	2015	2020	2025
	130 Euro 6	95 Post Euro 6	78
Electrification			
Mild hybrid	48V BSG, e-charger Premium segment (comfort)	48 V (ISG), predictive energy Premium segment (comfort)	48V, all segment
Full/Plug-in hybrid	HEV PHEV (50km AER)	HEV, PHEV (70-100 km AER) Fast charging	HEV, PHEV, Inductive charging
Battery electric vehicle	Range Extender	> 300km AER Post Li-Ion Technology	FCEV
Smart vehicles			
ADAS (safety/comfort)	Warning (Blind Spot)	Interfering (adaptive light, park assist)	Take over (collision avoidance, autonomous braking)
Autonomous driving	Piloted(Lane departure warning)	Partly automated (Lane Keeping, traffic jam assist)	Highly automated
Connectivity	Local (bluetooth)	Connected downstram (BYOD, e-call, cloud services)	Fully connected (Car to car, car to infrastructure)

Current Mainstream Technology/Focus
Next Generation Mainstream Technology/Focus
Future Mainstream Technology/Focus

» FEV PROCESSES AND TOOLS: MODEL IN THE LOOP

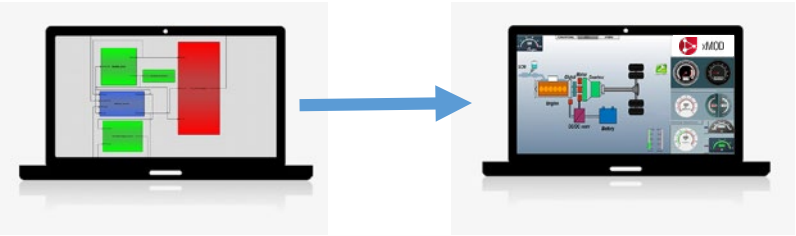
> **Goal:** Design and optimization of e-motor and hybrid powertrains by simulation

> **Tools:**
- Custom internal tools (Hybrid Optimization Tool)
- Multi-model integration and application platform (MORPHEE xMOD)
- All current market tools

> **Proposed services and expertise:**
- Complete Powertrain energetic design (thermal engine, electric motor(s), transmission (automatic gearbox, CVT, power split), battery)
- Optimization of each element capacity or power

Energy management optimization

> **Possible use-cases for a customer:**
- From scratch: design of a complete and optimized hybrid and e-motor vehicles (components and energy management) in order to assess component or architecture capabilities
- From an existing vehicle: (conventional or hybrid or e-motor), optimization of the vehicle components or energy management system



Model in the Loop **Software in the Loop**

BENEFITS OF FEV SOLUTION

> **Save time and Money:**
- State-of-the art tools and workflow
- Dedicated tools and simulators
- Generic Control structure
- Existing validation platforms (MiL to HiL)

> **High quality granted:**
- Validated Simulator Database
- FEV experienced engineers
- Reference projects

» FEV PROCESSES AND TOOLS: MODEL IN THE LOOP

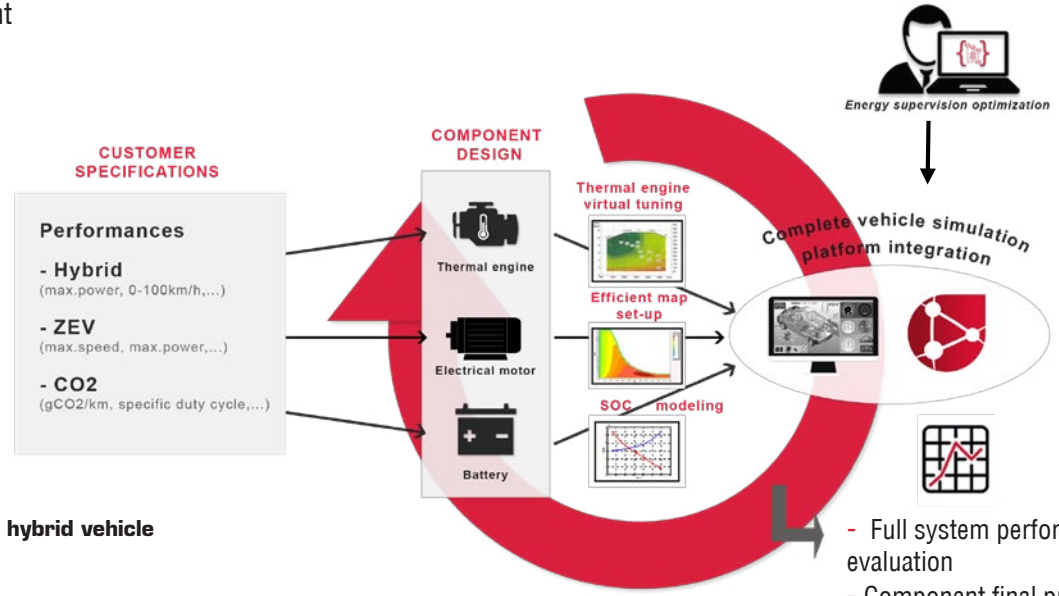
Use-case

> Specification of battery capacity, electric motor and thermal engine maximal powers & energy management optimization

> Deliveries:

- Full vehicle virtual specification and first dynamic performance and consumption assessment

-Hybrid vehicle platform usable for energy management system on-line development and validation.



Use case for a hybrid vehicle

- Full system performance evaluation
- Component final pre-sizing Energy Management System ready to be tested at Engine in the Loop

» USE CASE: HYBRID VEHICLE OPTIMIZATION FOR A SPORT CAR

0D simulation is the right approach for saving cost and time in complex powertrain development: FEV has recently helped a major car manufacturer to evaluate and optimize an innovative hybrid powertrain concept for the specification of a concept car.

> 0D simulation

The goal was to design a high-performance, plug-in hybrid vehicle with very low C02 emissions, by using an engine equipped with turbo-compound technology, derived from Formula one, coupled with a powerful high speed electric motor.

The system was complex: not only each component needed to be optimized, but also the energy supervision. For this purpose, a 0D simulation approach was used, allowing for fast computation times and therefore increased efficiency in the iterative process of powertrain optimization.

>15% energy recuperation

As a first step, and thanks to its specialized tools (xMOD and industry-standard system simulation software), FEV specified each component of the turbo-compound by matching turbine, compressor and electric motor to reach a goal of more than 15% energy recovery from exhaust gas by the Turbo-Generator unit. This was achieved by optimizing the engine operating point and the compressor and turbine choice, and allowed for a drastic consumption reduction, estimated up to 30 % when using the engine at high power.

Once this critical part was realized, an overall powertrain optimization was done in order to reach both consumption and dynamic requirements. A key part of this optimization was the battery specification in order to minimize the battery size and weight while keeping both a sufficient capacity to reach CO^2 requirements and a sufficient discharge power to reach dynamic requirements.

The electric motor and gearbox have been optimized in order to achieve sports-performance requirements such as a high level of maximum vehicle speed, or short acceleration time for 0 to 50 km/h in full electric mode for instance.

> Energy management

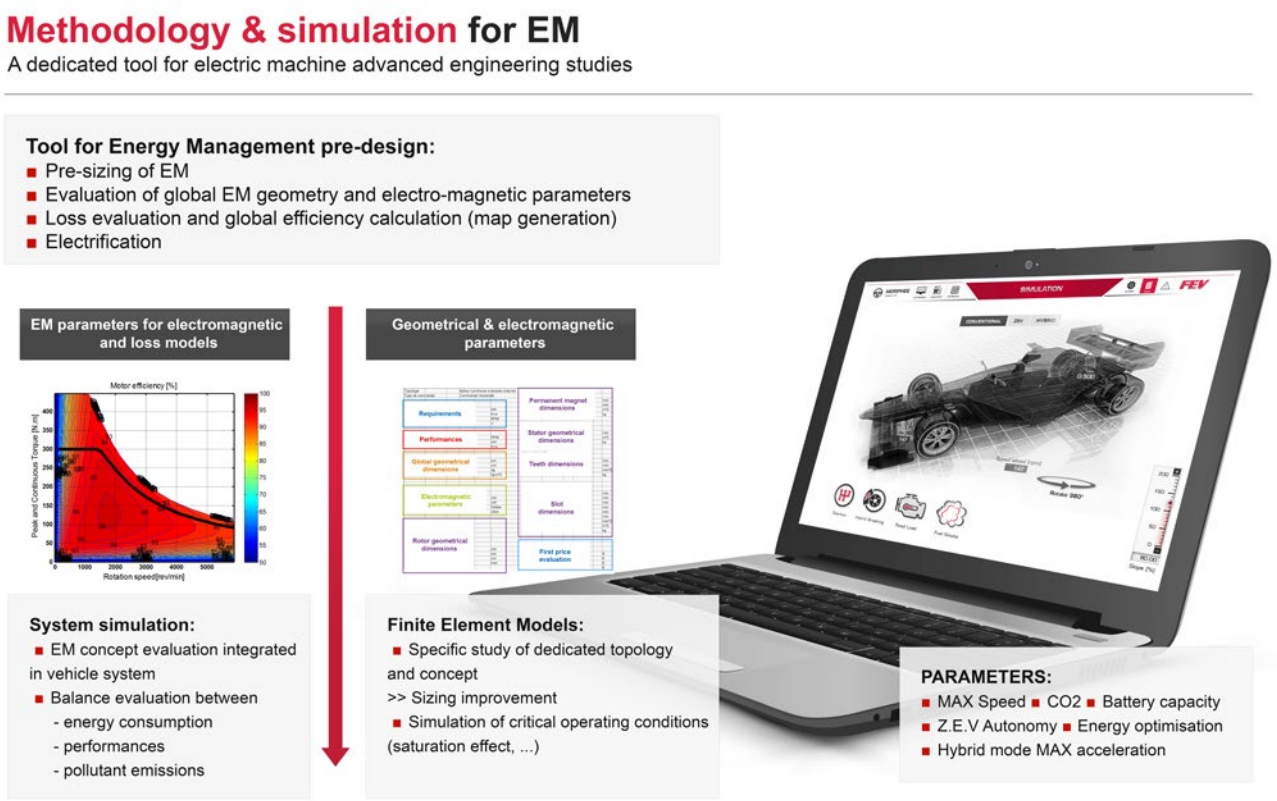
Energy supervision was equally a focal point: considering a large variety of driving styles, which control strategies to select for optimizing energy management in order to minimize consumption? For that purpose, FEV proposes a specific workflow, coming from its expertise: it optimizes torque repartition between each component, following different types of cycles for various battery State-of-Charge conditions, and then generates specific energy management strategies to optimize vehicle consumption.

Moreover, a mode was added to optimize vehicle performance on track, by using the most of each component without discharging the battery, allowing the pilot to have the same torque available throughout each lap. Simulations have been done to validate this strategy on the Nürburgring Nordschleife circuit, considered as one

» USE CASE: HYBRID VEHICLE OPTIMIZATION FOR A SPORT CAR

of the most challenging tracks in the world, showing encouraging lap time besides relative high weight of the vehicle due to hybrid components. This was achieved thanks to electric power coming from the Turbo-Generator unit at high power and by reduced response time of the turbocharger during accelerations.

Thanks to the optimization of each part of the powertrain, a first selection of components has been made, while energy supervision for this complex vehicle has also been roughly determined. These tasks were achieved in a few months' time, making for a fast and cost effective predevelopment of this "balanced" sports performance – low CO^2 hybrid vehicle.



» FEV PROCESSES AND TOOLS: E-POWERTRAIN OPTIMIZATION

> **Goal:**

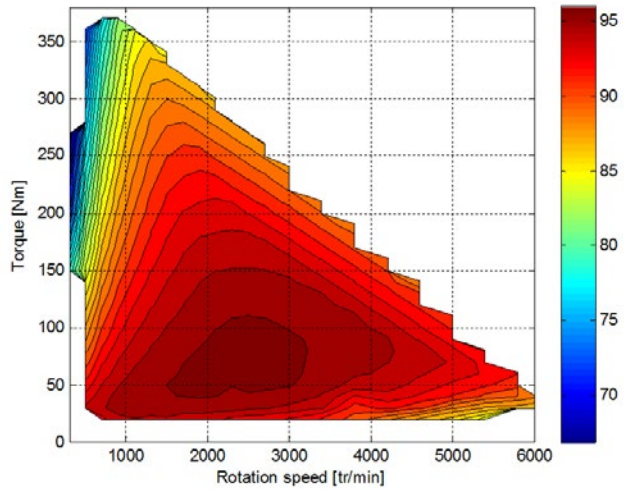
- Characterization of the inverter and the e-motor: it permits to build models. These models will be then used in two cases in the future steps of development: first, in an Engine In the Loop test bed, with a real engine, for simulating an hybrid vehicle but keeping the real combustion engine, as the most difficult component to modelize; secondly, at the desktop or HiL test bed, in the case of a pure EV vehicle, for modeling the complete EV vehicle. In both case, the goal is the definition of the Control Laws of the EMS (Energy Management System).
- Optimization of the efficiency of the e-powertrain, considering several use cases (motorway, urban, rural), with the calibration of the inverter: voltage and current signals, frequency versus angular position and speed, transient torque management, …
- Durability tests, with mechanical cycles - vibrations, reducer, differential - and thermal shock - cooling, rotor thermal management…

> **Tools:**

- E-motor test bed, with specific dynamometers for medium or high speed: an e-motor test bed permits to characterize the inverter and e-motor, in the previous steps of the development.
- E-axle test beds, with wheel speed dynamometers. The E-axle test bed tests the complete powertrain system, including the drive line.
- Use of MORPHEE, linked to a control application tool for EMS calibration, especially for the typical rotor and stator thermal management operations.. Thermal management, with derating operations, permits to prolong e-motors life and keep the vehicle's autonomy at an acceptable level during its complete life.. Thanks to its power and versatility, MORPHEE, connected to the application tool, is here a must for doing this type of operations

OSIRIS Power Analyzer: OSIRIS measures and analyze the efficiency of the e-powertrain system by measuring the power before and after the inverter, and before and after the e-motor.

- Battery simulator and climatic system



Analysis of e-motor temperature

» FEV PROCESSES AND TOOLS: HARDWARE IN THE LOOP

> **Proposed services and expertise:**
E-motor development: design, E-motor calibration and optimization, E-axle validation
Benchmark between different e-motor or hybrid powertrain
E-motor and E-axle modelization

> **Possible use cases for a customer:**
Reengineering of an engine powertrain to a hybrid powertrain
EV development

> **Benefits of FEV solution:**
- **Save time and Money:** reduce your development and validation phases:
Simulation platforms already existing in our data base
Continuous workflow enabling quick and safe iterations if needed

» FEV PROCESSES AND TOOLS: HARDWARE IN THE LOOP

> **Goal:** Validation of Energy Management System (EMS) in real time and preparation of the models before running at the engine test bed

> **Tools:**
- For modeling: customer tools (AMESim, MATLAB/Simulink®, Dymola, GT suite …)
For platforms: coupling customer tool (dSpace, ETAS) to an optimized and state-of-the-art FEV simulation platform (xMOD) or do it directly with FEV HiL platform (see page 52)

Re-use of the simulation platform designed at the MiL stage

» FEV PROCESSES AND TOOLS: HARDWARE IN THE LOOP

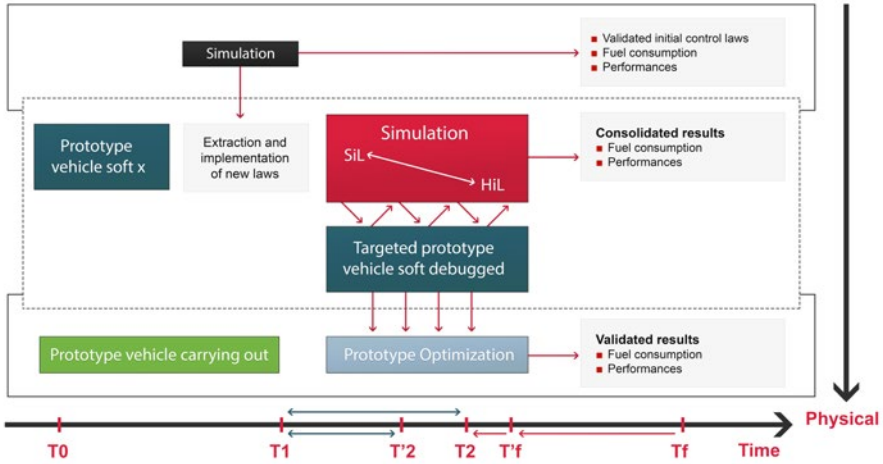
> **Proposed services and expertise:**
- Set up HiL platforms, for hybrid components to full powertrain validation
- Skilled engineers in simulation and control of hybrid powertrains

> **Possible use cases for a customer:**
- Adaptation of a current MiL or SiL simulation platform to HiL use
- Set up of a complete modeling environment in order to couple it to the real EMS (in SiL and/or HiL)

> **Benefits of FEV solution:**
- **Save time and Money:** reduce your development and validation phases
Based on simulation platforms developed at previous step
Continuous workflow enabling quick and safe iterations if needed
Preparation of future HiL bench platforms
- **High quality granted:**
Validated Simulator Database
FEV experienced engineers
Reference projects

> **Use Case**: description
Upgrade of an existing simulation platform and set up of a new environment to address continuously the development from the MiL to the vehicle with a strong use of HiL
- Deliveries:
Customized platforms for MiL to HiL EMS validation
New workflow

HARDWARE IN THE LOOP – From software to hardware

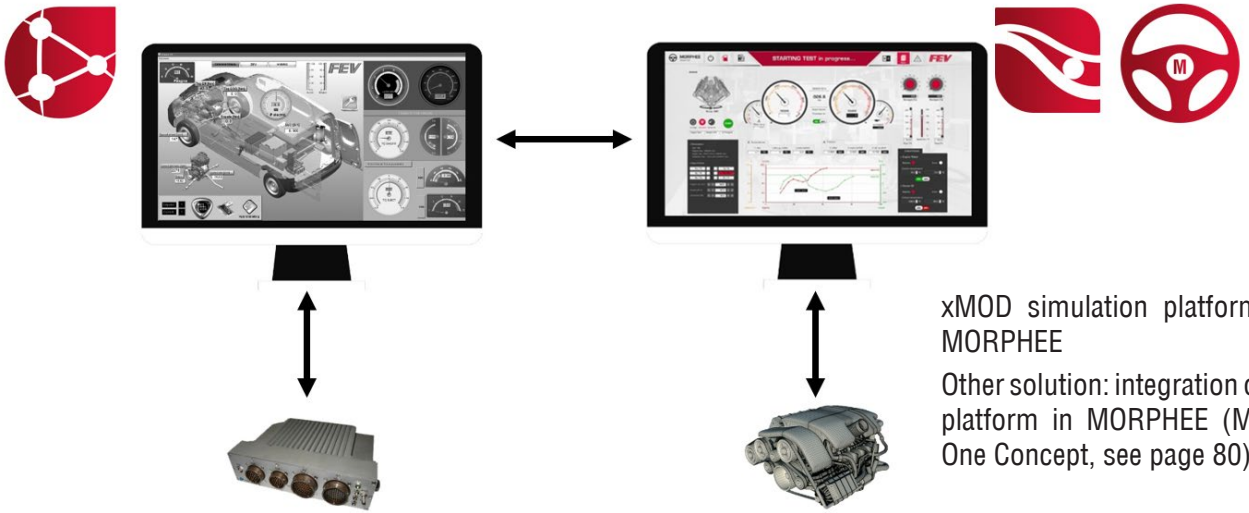


» FEV PROCESSES AND TOOLS: ENGINE IN THE LOOP

> **Goals:**
- Assess the hybrid powertrain capabilities considering real fuel consumption and emissions
- Adjust the EMS considering a real thermal engine
- Freeze the powertrain architecture

> **Tools:**
- For modeling: customer tools
- For platforms: coupling customer tool (dSpace, ETAS) to an optimized and state-of-the-art FEV simulation platform (xMOD)
- For AUSY: any compatible system (MORPHEE and third party suppliers)
- For calibration: FEV's xCAL

> **Proposed services and expertise:**
- Set up the HiL platform and connect it to your AUSY
- Calibrate the engine and the EMS
- Update easily and quickly the models and the HiL platform if needed



xMOD simulation platform connected to MORPHEE

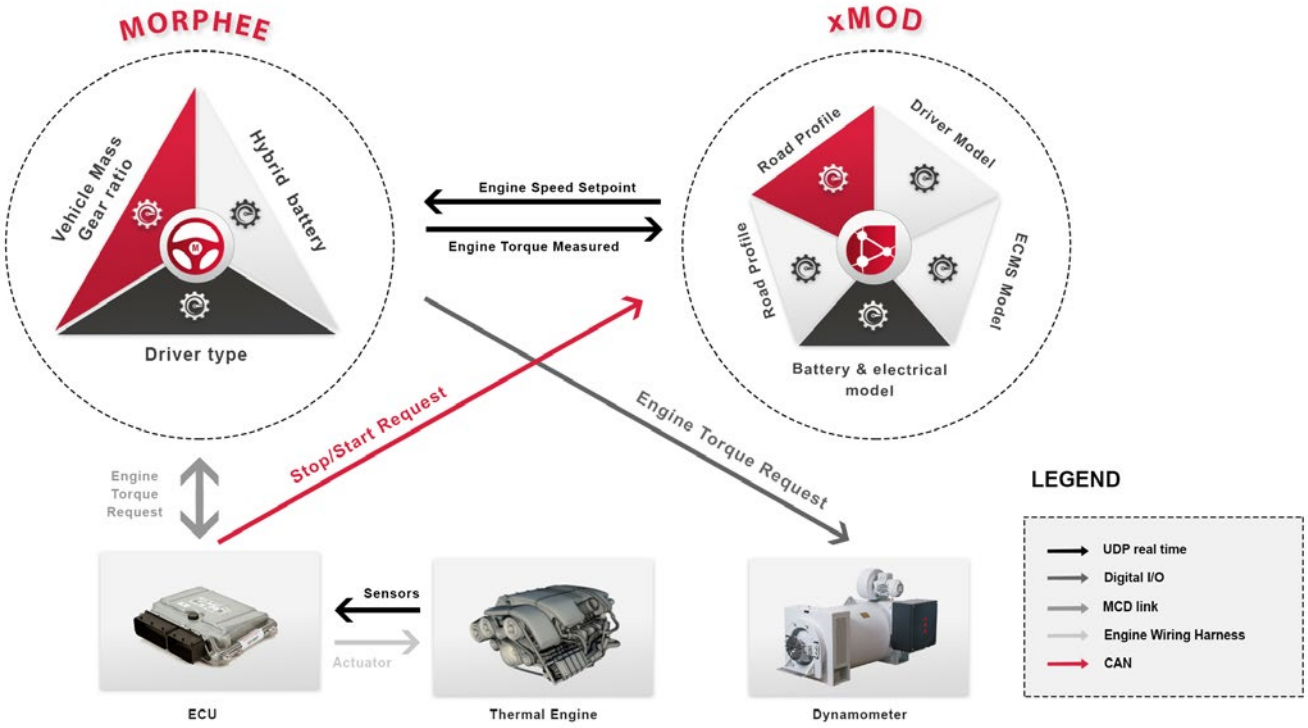
Other solution: integration of the simulation platform in MORPHEE (MORPHEE All In One Concept, see page 80)

» FEV PROCESSES AND TOOLS: ENGINE IN THE LOOP

> **Possible use cases for a customer:**
- Validate your vehicle EMS at the engine test bench
- Evaluate your hybrid powertrain performances in several virtual vehicle configurations

> **Benefits of FEV solution:**
- **Save time and money:**
  - Continuous workflow using the already validated simulation platform than previous steps
  - First hybrid powertrain validation and assessment in a vehicle configuration at engine test bench
- **High quality granted:**

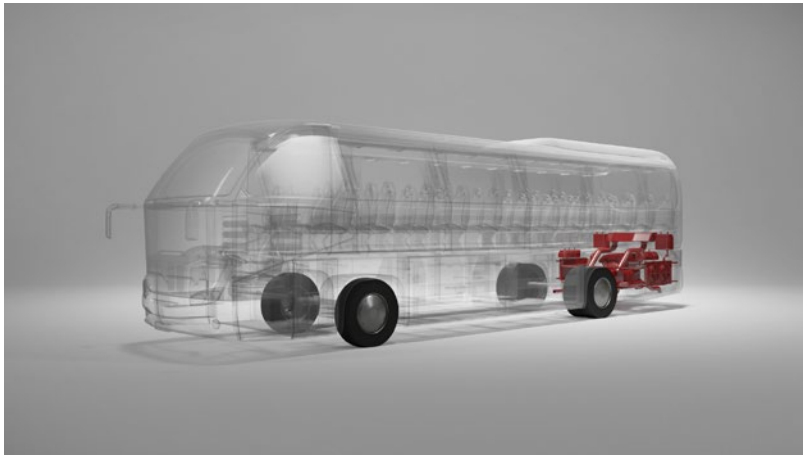
The accuracy of the models is kept and played in Real Time



Typical use case, with the simulation platform connected to the automation system

» USE CASE: EIL IMPLEMENTATION FOR A URBAN TRANSPORT RESEARCH PROJECT

The CITYBRID project, led by Renault Trucks in partnership with IFP Energies nouvelles, SAFT, Carrosserie Vincent, Frappa, and G2ELab, illustrates extremely well the capabilities of the FEV tools. Its objective was to evaluate the impact of hybridisation on pollutant and CO_2 emissions of a heavy duty vehicle. The project was successfully completed and the FEV tool MORPHEE, was a key part of this success.



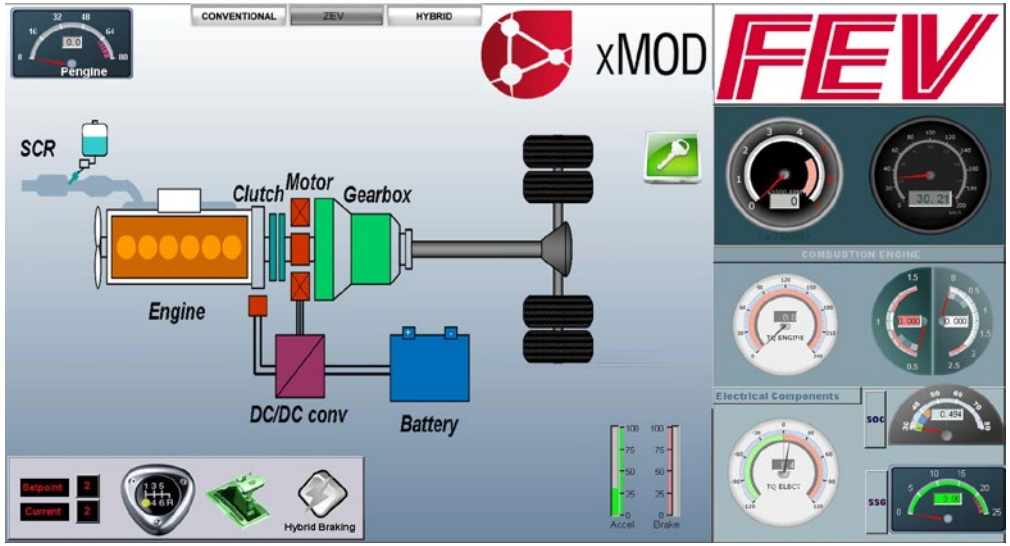
A first milestone was the modelling of the entire test bed for a preliminary SIL validation (Software In the Loop) validation, including: the heavy duty vehicle model, models of the engine, battery, electric motor, transmission, driver and the test bench itself, as well as the simulation of the vehicle CAN and UDP networks. All models are hosted inside MORPHEE xMOD, co-simulation and virtual experimentation platform, and the ensemble is commanded via MORPHEE Automation System, with exchanges between the systems at 1 kHz. Thanks to xMOD, numerous skills from varying sources from now on communicate together: it accommodates models derived from Simulink or AMESim just as well as models coming from GT suite and Dymola for example.

> MORPHEE, a cornerstone for optimising electrification

The second stage takes place on the engine test bed, allowing the final validation of the supervision strategies: it is the HiL phase (Hardware in the Loop). A prototype is expensive; as well as is a chassis dynamometer, especially a heavy duty one.

» USE CASE: EIL IMPLEMENTATION FOR A URBAN TRANSPORT RESEARCH PROJECT

The high-dynamic engine test bed eliminates the need for the one and allows postponing the other as an ultimate step. But for that, certain conditions have to be met in order to approach a real-world vehicle environment in a convincing fashion. This is achieved first thanks to a highly dynamic FEV 530 kW dynamometer controlled by the highly responsive FEV Control Unit. Then, MORPHEE xMOD already used during the first phase, is „copy-pasted“ onto the test bed, with its models and their impressive ability to reproduce the dynamic behaviour of the vehicle, driver and road testing.



> On-line assesment of emissions and fuel consumption

As an output, the tests performed on the test bed allow to assess the emission levels and the fuel consumption of heavy-duty vehicle configurations and then, in an iterative manner, to modify the parameters of engine control, or even modify the components – an overheating battery, an e-motor with insufficient efficiency, a non-optimal torque-split strategy… - until reaching the satisfactory result. From the virtual SiL test bed to the real HiL engine test bed, the process is continuous and the feedback immediate: the concrete impact on the vehicle of the work done on the dimensioning of the battery cells/pack, e-motor and transmission can be witnessed almost instantly.

» FROM CONCEPT TO SOP: BATTERY DEVELOPMENT COMPETENCES IN THE FEV GROUP

Since building its first in house EV fleet in 2010, FEV has been deeply involved in numerous high voltage traction battery programs. To date, FEV has performed 46 projects, 14 of which are related to various OEM mass production programs. Behind the success of these programs stands an experienced battery development team that is distributed worldwide. This team uses established FEV methods and is eager to support OEM and Tier 1 supplier customers in developing advanced and robust battery technologies.

> Pushing the limits

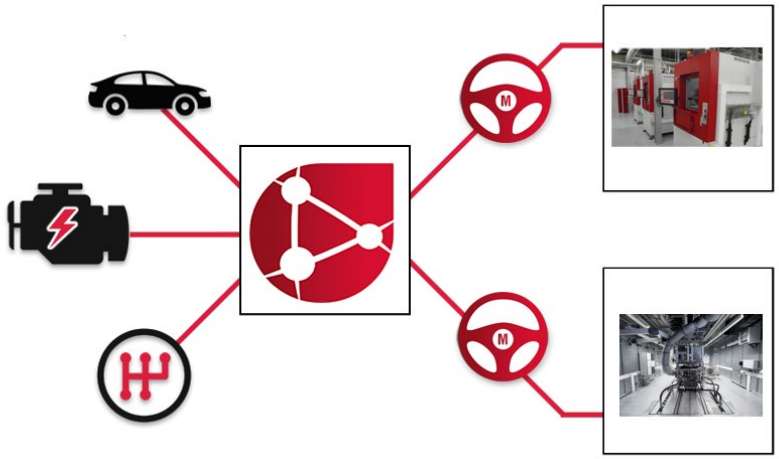
As a premium battery development partner, FEV's battery experts are keen on pushing the boundaries and getting seriously and serially involved in developing the next generation of batteries. FEV project teams are flexible in terms of planning and the focus of each project phase. Resources can be dynamically allocated as needed to meet challenging customer schedules and milestones.

When working with FEV, short development cycles can be expected, especially in the early proof of concept and functional validation phases, where aspects such as cell selection, performance/cooling, packaging/production feasibility and cost are quickly elaborated. FEV can efficiently select a cell from a continuously updated database that considers key cell supplier technology, roadmaps and the results of internally-performed tests. Using FEV's effective 1D simulation models, the system performance and cooling concept can be validated, considering the natural cell aging behavior over the system lifetime.

» FEV PROCESSES AND TOOLS: BATTERY VALIDATION

FEV offers a flexible solution based on its expertise in the field of testing and electrification. The Knowledge in the testing equipment market, allows FEV to propose a solution adapted to the technologies, objectives and needs of customers. Our expertise in the testing field, gives a real experiment in every testing ways. FEV adapt its offer, whatever the cells size, number current or voltage. We can meet all requests thanks to our MORPHEE® automation software. It can integrate all the equipment available on the market, so that tests are not limited by the hardware aspect. No need to reprogram from one equipment to another. This system therefore allows a quick preparation of the test. It facilitates the management of the test centre and makes it possible to be mobile on the test benches. MORPHEE® manages the equipment, benches, tests, simulations and data.

FEV therefore provides an efficient offer that can meet and adapt to all current market demands while saving time.



Physical testing (battery, IC engine) connected to virtual testing (vehicle, e-motor and transmission)

» FEV PROCESSES AND TOOLS: BATTERY VALIDATION

> **Possible use cases for a customer:**
Development of a unique powertrain platform for application on several vehicles with a highly accurate system when integrated in each vehicle;
The powertrain is tested in all the scenarios of use to validate the battery and BMS performance.

> **Benefits of FEV solution:**
- Test architecture is easy to set up;
- The vehicle performance can be tested in all the battery climatic conditions that significantly affect its efficiency. This reduces the time spent with a car on a climatic chassis dynometer test bench or test campaign.

FEV Battery Testing Center in Paris, France

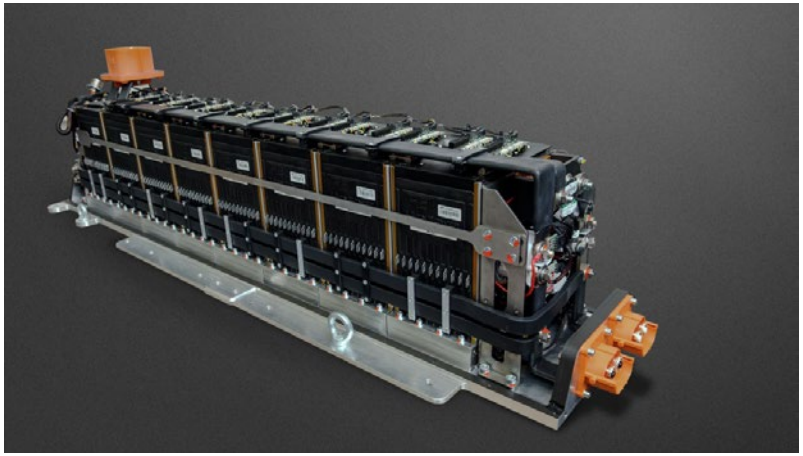
» USE CASE: VALIDATE YOUR ENERGY MANAGEMENT SYSTEM

Simulation is a good and less expensive means of defining energy management laws, but alone is not sufficient. At some point in the process, it is necessary to validate these laws and to optimise them in relation to the most sensitive physical elements which are the most difficult to simulate. What are these elements today? There are two: the battery and the combustion engine, including the implementation of its after-treatment system. Once these have been relatively well defined – for example when the prototype for the combustion engine exists or when a battery pack cell is available – it is interesting to combine their use in real conditions together with other purely virtual elements.

So why not combine FEV engine and battery package or cell test beds and bring them together in a common architecture? Thanks to its tool MORPHEE, FEV can make two test benches into one and simulate the entire vehicle using the physical engine and battery: chassis and axle assemblies, transmission, electric motor and the power control unit (the interface between battery and electric motor / generator). In this innovative architecture, there is no need to test the battery as a whole: a single battery cell is enough for any type of combustion conditions.

Naturally, variants are also possible. The complete power unit can be used on the test bench or the combustion engine can be simulated while the battery is real.

In this way, the energy management laws can be validated and optimised on the test bench in all types of condition, be it for a standardised cycle for which it is possible to know the future or for a real operating cycle where one of the main difficulties is to anticipate the road profile and the user‘s driving style.



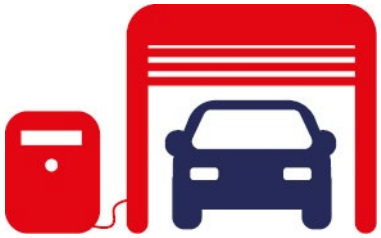
» FEV PROCESSES AND TOOLS: ENERGY MANAGEMENT SYSTEM VALIDATION

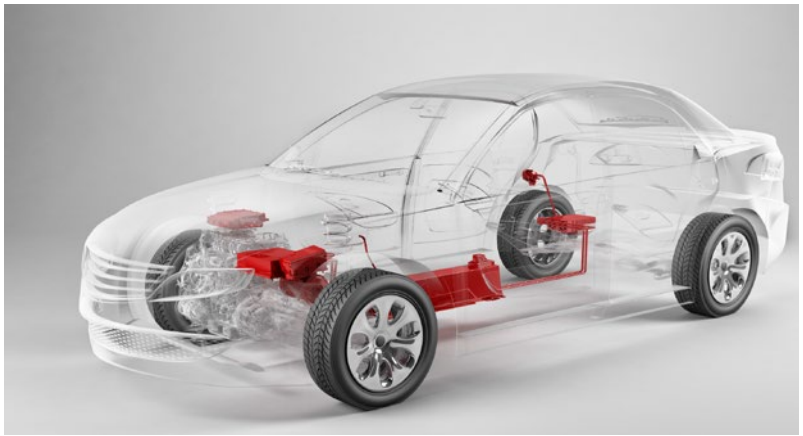
> **Goals:**
Implement the Energy Management System (EMS) without the constraint of the battery's State of Charge, i.e. the long time to recharge it.
When the battery pack is well known, it can be simulated.

> **Context:**
The best EMS strategy cannot be found without knowing the future.
The aim is to be able to test the majority of possible scenarios of use to ensure the efficiency of the EMS in every real scenario of use.
The State of Charge management of a battery is not compatible with test productivity: the battery has to be simulated.

> **FEV solution:** we gain time by avoiding the issue of using the real battery (State of Charge issue)
Our highly accurate battery simulation saves a great deal of time because we don't have to charge or discharge the battery to reach a SOC request. This is the fastest way to develop an EMS strategy.

> **Tools:**
- MORPHEE automation system
- xMOD to simulate the battery (cells and Battery Management System)
- Power supply (battery hardware simulator) controlled by MORPHEE.





» USE CASE: DEFINE BATTERY MANAGEMENT SYSTEM STRATEGIES AT THE TEST BED

The Battery Management System (BMS) design phase, and in particular the definition of the best models for a given battery intended for a specific vehicle, is complex, due to its chemical structure: it is not an exact science but a process of refinement by iterations between the design of the model and its validation on the test bench.

The first function is to measure - and control - the voltage, current and temperatures of each battery cell. Depending on these measurements, it will also perform safety-related tasks (passive and active protection) in relation with the vehicle's control unit. It will also be responsible for balancing the voltage of all the cells while monitoring the state of health of each cell. Finally, it will inform the vehicle's computer of the maximum power available and the remaining autonomy according to an estimate based on advanced calculation algorithms.

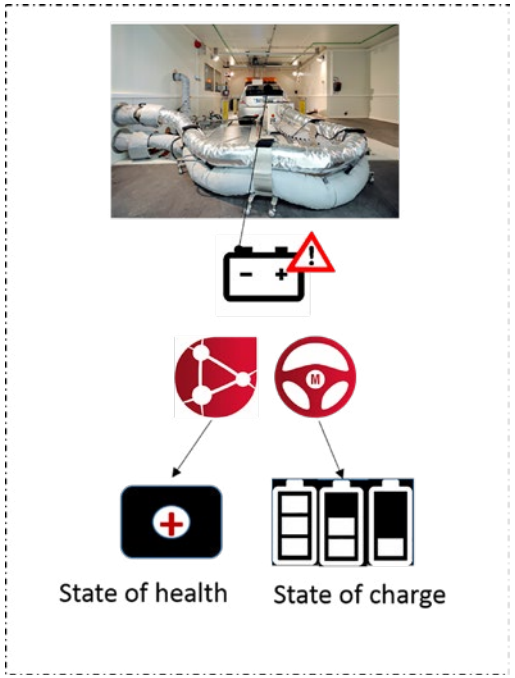
> Rapid prototyping

FEV proposes innovative, rapid prototyping solutions reducing the time required to refine these different functions in the BMS, by replacing it by the real-time test bench automation and simulation system MORPHEE The main advantage of MORPHEE is the interconnectivity between all the constituent elements of a battery test bench, irrespective of the type of connection (CAN, EtherCAT, Profibus, etc.): power cabinet, climatic chamber, battery cooling system, domestic charger, the BMS (one or more) and any system specific to the battery manufacturer. This allows the elements to interact and the tests to be targeted intelligently according to the battery's behaviour.

The second aspect of MORPHEE - in its xMOD version - concerns its capacity to incorporate real-time simulation models into the test bench. A HIL (Harware In the Loop) structure can be implemented quickly between MORPHEE and a wide range of models (Amesim, GTpower, Matlab, etc.) which can be compiled in the xMOD multi-model platform.

Thus, MORPHEE centralises all the procedures and collects all the information like the BMS with the added advantage of flexibility. The models and strategies of the future BMS change as the tests are conducted: there is no need to develop specific equipment.

Once the model has been validated in a simulation, the BMS hardware and software can be implemented with the certainty of a suitable strategy.



Simulation of the battery at the test bed, reducing the time of refinement

» THE TOP SOLUTIONS FOR TEST CENTER EFFICIENCY, OFFERING A RAPID RETURN ON INVESTMENT

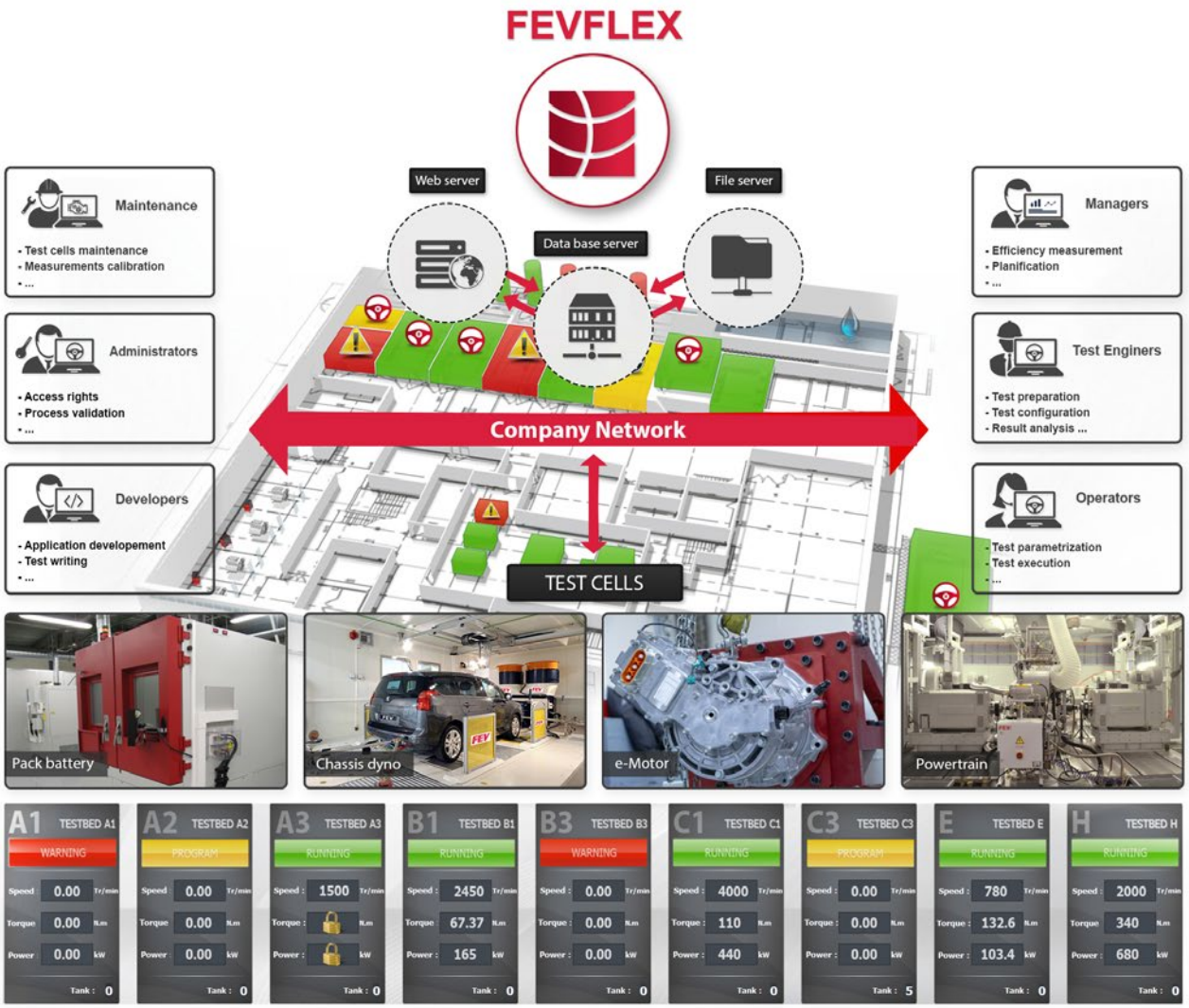
The seven FEV test centers, including their 240 test cells, run daily around the world. FEV boasts over 30 years of expertise in building and operating test cells and testing facilities for powertrains. Its excellence in organization, workflows, logistics and human resources management in testing facilities is well proven.

As an example, the DLP test center offers a unique global concept for operating test centers efficiently:
> Three shifts, 7 days per week (24/7), 365 day/year and optimized human resources,
> Ten years of experience with real implementation in DLP.
This experience acquired by FEV teams in testing center solutions is then passed on to customers by offering consulting services as well as complete turnkey centers.

FEV test facilities engineering team

THE SCOPE OF SUPPLY

> Functional specification
> Technical boundary conditions
> Approval/Legislation boundary conditions
> Process description
> Room book
> Electric engineering
- Media supply
- Energy supply
- Test bench equipment
> Calculation of media and energy supply systems
> Safety concepts and equipment
> 2D and 3D Planning documents
> Conceptional design of building management systems


FEVFLEX
Web server
File server
Data base server
Maintenance
- Test cells maintenance
- Measurements calibration
- ...
Administrators
- Access rights
- Process validation
- ...
Developers
- Application developement
- Test writing
- ...
Managers
- Efficiency measurement
- Planification
- ...
Test Engineers
- Test preparation
- Test configuration
- Result analysis ...
Operators
- Test parametrization
- Test execution
- ...
Company Network
TEST CELLS
Pack battery
Chassis dyno
e-Motor
Powertrain
A1 TESTBED A1 WARNING Speed 0.00 Tr/min Torque 0.00 N.m Power 0.00 kW Tank : 0
A2 TESTBED A2 PROGRAM Speed 0.00 Tr/min Torque 0.00 N.m Power 0.00 kW Tank : 0
A3 TESTBED A3 RUNNING Speed : 1500 Tr/min Torque : N.m Power : kW Tank : 0
B1 TESTBED B1 RUNNING Speed : 2450 Tr/min Torque 67.37 N.m Power : 165 kW Tank : 0
B3 TESTBED B3 WARNING Speed : 0.00 Tr/min Torque : 0.00 N.m Power : 0.00 kW Tank : 0
C1 TESTBED C1 RUNNING Speed : 4000 Tr/min Torque : 110 N.m Power : 440 kW Tank : 0
C3 TESTBED C3 PROGRAM Speed : 0.00 Tr/min Torque : 0.00 N.m Power : 0.00 kW Tank : 5
E TESTBED E RUNNING Speed : 780 Tr/min Torque : 132.6 N.m Power : 103.4 kW Tank : 0
H TESTBED H RUNNING Speed : 2000 Tr/min Torque 340 N.m Power : 680 kW Tank : 0

EXAMPLE OF TEST CENTERS MADE BY FEV

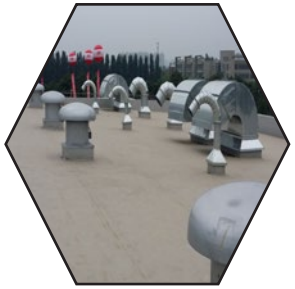
» FEV TEST CENTER AT YANJIAO (BEIJING, CHINA)

Main entrance

Upper floor

Test bed

Control room



Evacuation

Ground floor

Fuel distribution

Utilities

DESCRIPTION OF THE YANGJIAO TEST CENTER

Yanjiao provides in total 9 test benches

- 2 Heavy-duty test benches
- 5 Light-duty test benches
- 1 Axle-gearbox test bench
- 1 Battery test bench (climate)

- 4 Emission analyzer (2 line direct analyzer)
- 4 Combustion analyzer
- 3 Combustion intake air condition system
- 12 Fuel tank (Gasoline, Diesel)
- Vehicle filling station
- 8 BEV charging station

» VDC: VEHICLE DEVELOPMENT CENTER IN AUBURN HILLS,MI , MADE BY FEV

FACILITY SPECIFICATIONS - EMISSIONS CHASSIS DYNAMOMETER

> 2 axles with 48“ diameter each
> FWD, RWD & AWD
> Max. speed: 200 km/h
> Wheel base: 1800 mm to 4400 mm
> Max. weight: 2500 kg per axle
> Power: 270 kW
> Emissions: Diesel and gasoline for SULEV and Euro - 40 CFR Part 1066 compliant. All regulated pollutants including PM/PN and Formaldehyde
> -20°C to + 40°C temperature range

FACILITY SPECIFICATIONS - COLD CHAMBER

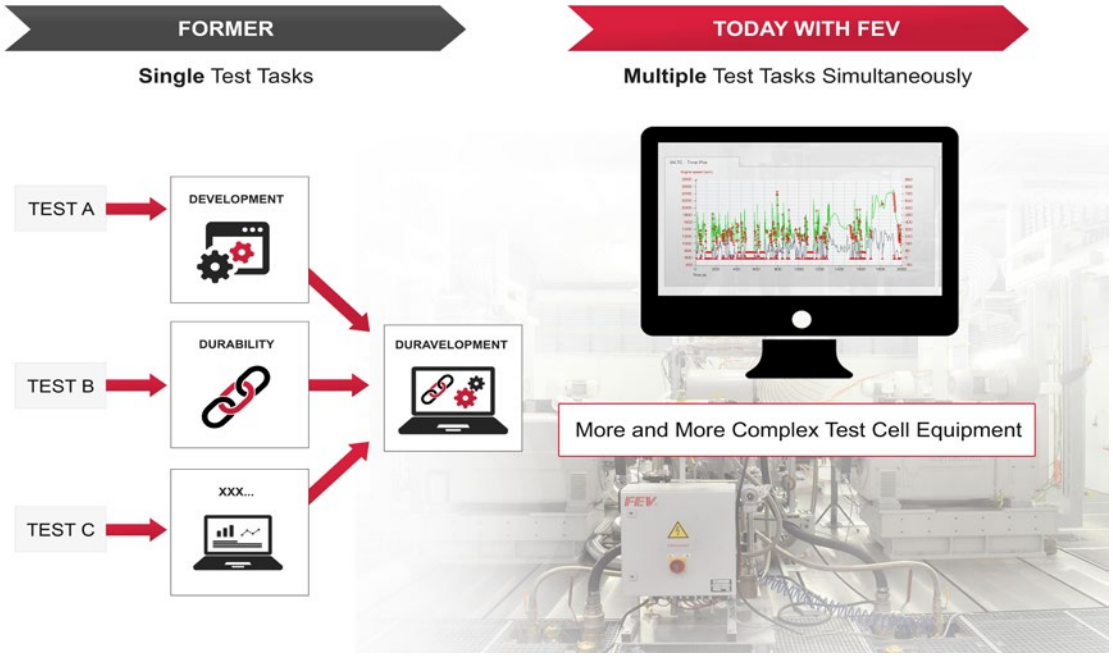
> -10°C to + 30°C temperature range
> 12 ft. high x 14 ft. wide chamber entrance and dyno entrance doors
> Insulated chamber located adjacent to the chassis dyno
> Fast roll-up door for ingress and egress

» PRELIMINARY PHASES, DECISIVE STEPS

The main market drivers that influence the test center concept, design, equipment, and operational organization of future test fields and planning include: cost, limited project time frames, legislation and new technology.

Conceptual defects attributed to inadequate specification and conception in the early planning stages can only be corrected later with great difficulty or, in some cases, not at all. Due to the high capital expenditures for buildings, technical facilities, and testing facilities - in addition to the resulting long depreciation periods - test centers must be quickly and easily adaptable to changing testing tasks. Functionally-organized basic structures, modular design, reserves for changing equipment needs as well as an intelligently-structured supply infrastructure are all key factors for efficient test centers.

On that topic, the interests of the users usually differ from the requirements of the operators: while the user will require for example fast changing test tasks, extensive and sometimes expensive instrumentation, the operator will be looking for a high standardization level, no un-used equipment, low down-times…



» LIST OF INPUTS TO CONSIDER FOR DEFINING THE TEST CENTER CONCEPT

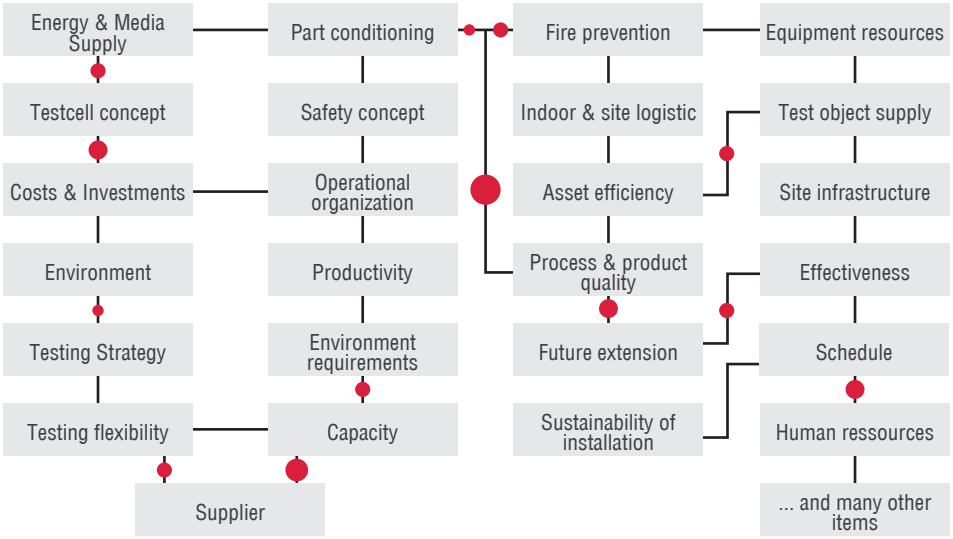
STRATEGIC FACTORS

> Modular design for flexible usability
> Fully implemented efficient processes and organisational structures
> Uniform system standards for high-quality test results
> Implementation of different user/customer-specific standardized test runs for a broad range of vehicle and powertrain variants
> Continuous training and specialization of test center staff
> Continuous consideration of demographic status of staff, the building, technical infrastructure, equipment

OPERATIONAL, ORGANIZATIONAL AND TECHNICAL FACTORS

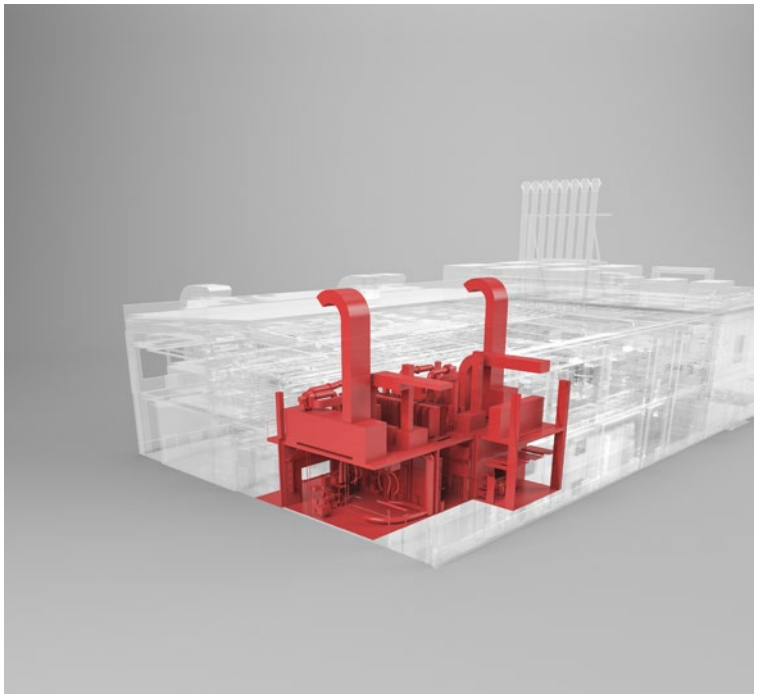
> Highly sophisticated process integration
> Reproducible and stable test conditions
> Highly accurate, high-performance, fully integrated measuring systems
> High-performance and fully flexible test bench automation system (one standard)
> High-performance data management
> Fully integrated test standards, testing and test data evaluation tools
> Increasing integration of all auxiliary load units on test benches
> Availability of a wide range of different fuels

Tightening of overall development process including fast iterations
Reduction of cost-intensive prototypes
Shifting calibration to earlier development phases
Time and cost reductions in setup changes
Increase level of automation
Method development for lean and efficient testing



» FEV EXPERTISE: FROM TEST BEDS TO ...

On the basis of best practice solutions and years of experience, FEV plans tests beds and entire test centers. On one hand, this is done at the request of the client; on the other, it enables FEV to expand its own testing capacities. This is how, in automotive centers across the globe, engine, transmission, full powertrain, battery, and end-of-line test beds are being created in various configurations. These test beds allow efficient development work in accordance with existing and upcoming legal requirements. Whether the Center for Mobile Propulsion at the RWTH Aachen or the FEV Endurance Test Center in Brehna: some of the most advanced test centers in the world have been created by FEV and implemented by its multi-disciplinary project teams in collaboration with the respective local experts, The heart of a successful project is the Consulting, where the specification is created and the layout of the test center is determined. Thanks to a tightly-knit network of experts, FEV cover all typical phases of a project and offers to perform partial projects as well as full turnkey implementation projects, depending on the customer's needs. FEV has successfully completed more than 300 such projects worldwide over the past decades.



> From the first sketch to commissioning

As a leading development service provider with more than 240 of its own test cells and more than 400 experts in its Software and Testing Solutions Business Unit, FEV has extensive expertise related to the requirements and operation of a modern test center. In this area, FEV offers, among other services, turnkey test field planning from a single source, which is extended, as needed, throughout the planning and

» ... STATE OF THE ART TEST CENTER

implementation process and ensure the realization of highly efficient laboratories with maximized user benefits. In addition to technically equipping test beds and test facilities, the operational organization, the technical and functional infrastructure, and logistics topics are becoming increasingly important to supporting complex test requirements with high efficiency and in a timely and cost-effective manner

AREAS OF EXPERTISE

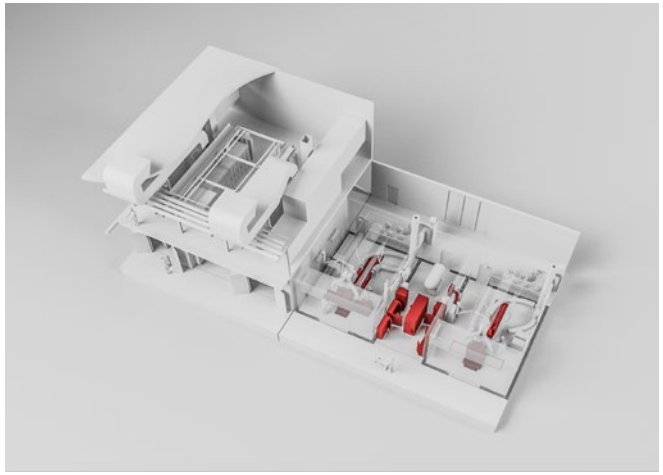
> Demand analysis, specifications, concepts
> Test Cell layout, test center layout
> HVAC, media supply, energy supply
> Special systems and solutions (gas supply...)

FEV Test Center at Yanjiao (Beijing, China)

» LEAN FLOW, OPTIMIZED LOGISTICS

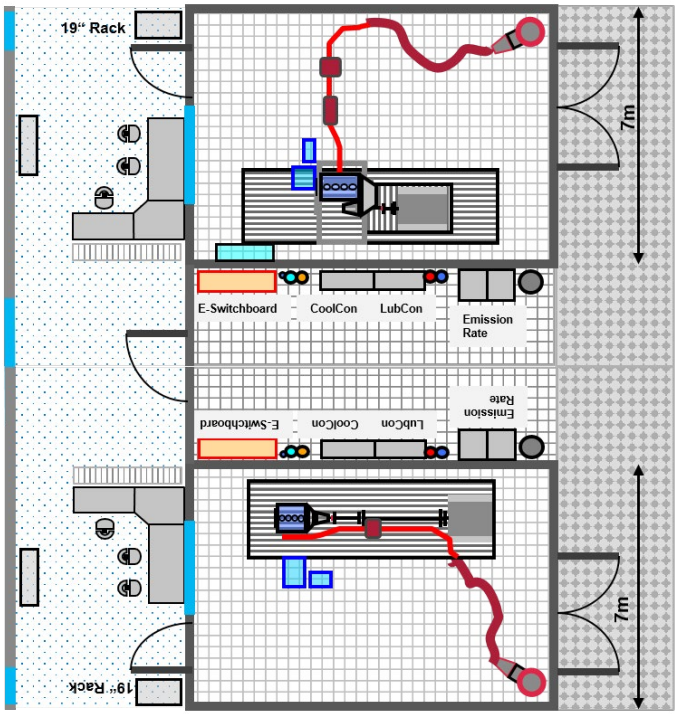
FEV's solution optimizes the flows.

Here is an example of the solution selected from the Test Center in Brehna. One central hall offers easy access to the test beds for the UUT and to the emissions benches and the other devices.
The first floor houses all the large equipment: 1000 to 400 v converters, drive cabinets, air conditioning etc. Two narrow aisles are located on each side of the test center, with one monitor giving the main information about the test bed/tests.



> Example of FEV layout for Test Center, with easy access to the test bed for the test object from a central hall, main commodities located above and the monitoring from a narrow aisle on the opposite side

Test Cell transversal installation „Front Wheel Drive"



Test Cell longitudinal installation „Rear Wheel Drive"

» UNIQUE CONTROL ROOM AND COLLABORATIVE WORK

This efficient test center organization is supported by an innovative global control room concept: Instead of having one control room for each test bed – and considering that a test center is increasingly a global entity, with continuous sharing of data, tests, equipment– FEV concluded that it made sense to unify the test bed operations in a single control room. This concept enables human resources to be optimized and also reduces noise and safety constraints in the test cell environment; this then means that investments inside the plant can be reduced.

Last but not least, the concept fully enables the test center - or even several test centers - to be connected to other engineering offices, such as the calibration team office... Remote users are being connected online to the test field through a virtual control room, from which they can view the tests –

> BREHNA DLP TEST CENTER

10 years of return of experience with real implementation

unique global concept to operate efficiently, cost effective, 3 shifts test centers

» LEAN FLOW

The study of production flows has made considerable progress in recent decades, particularly with the concepts of lean management and just in time, now commonly used in production. FEV adapts these concepts to the field of test centers and considers the current and future flows that the center will have to manage. First, it determines each stage of the process and the intervention of the various actors.

Depending on this, it can then determine the size of the various work and storage areas of the center, and their respective locations.

This study must take into account future developments of the center, which are in part difficult to comprehend. This is where the FEV experiment proves to be valuable, allowing it to design a test center capable of evolving, while keeping the project within reasonable limits.

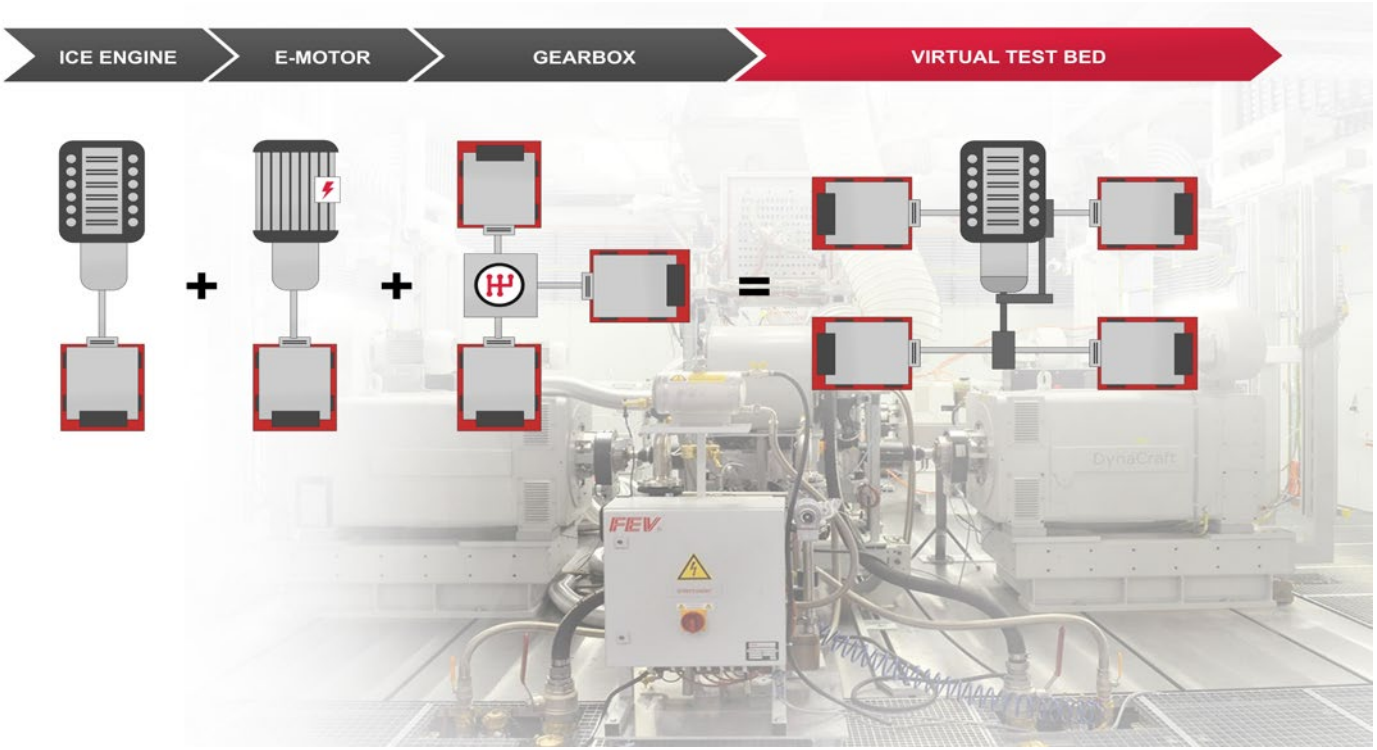
Room description	Area [m²]	Temp.	Remark
Test bench			See room book
Control			See room book
Storage test equipment			See workflow incoming parts
Storage oil & operating material	40	RT	
Disposal	40	RT	
Buffer after testing	70	RT	

Example of analyis of the Work Flow and the subsequent determining of the storage and working areas.

» VIRTUAL SHAFT

Another concept created and implemented by FEV is the real-time coupling of individual, specialized test rigs with subsystem tests into one complete system.

This type of "virtual shaft"connection was recently realized by FEV in the "Center for Mobile Propulsion" (CMP) at the Institute for Combustion Engines of RWTH Aachen University (VKA). This type of solution can be easily extended to the use of pure simulation components: methodologies, combinations of intelligently-connected processes consisting of simulation and experimental testing technology are increasingly used.



Virtual shaft concept used at the CMP „Center for Mobile Propulsion" at Aachen

» THE DIFFERENT STEPS OF A TEST CENTER BUILDING PROJECT

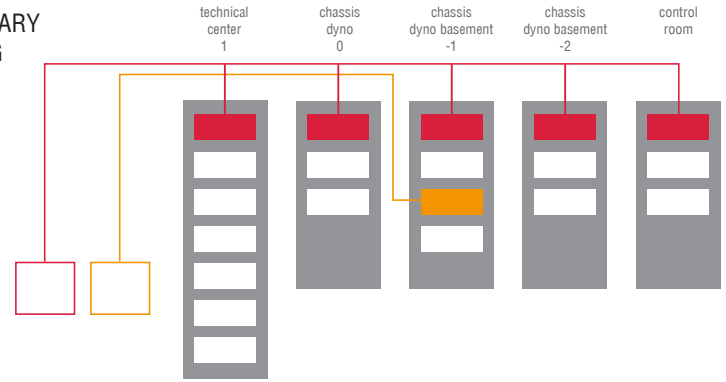
There are two main phases involved in creating a new test center: the first phase comprises defining and planning the project and its completion is marked by provision of the specifications; the second comprises execution of the project in its current form.

> Planning and consulting

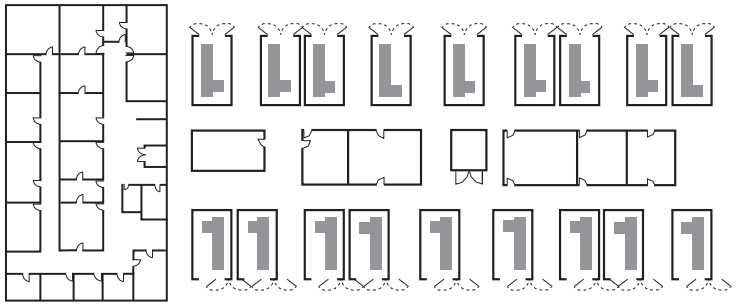
A successful project is one where the planning phase has been carefully managed and where nothing has been left to chance. Conceptual defects attributable to inadequate specification and design in the early planning stages can only be corrected later with great difficulty or, in some cases, not at all. Here, similar to the construction of a home, the general “rule of 10” can be applied – the cost to correct errors increases by a factor of ten with each subsequent phase of construction.

Initially, it is necessary to specify the need, end use of the center, types of engine program to be handled, both now and in the future. In-depth consultations take place with the customer, and are summarized in a specifications document detailing the precise requirements. On the basis of this document, a preliminary planning is drawn up and shared. The focus is then on predesigning the concept, with two main deliverables: a functional analysis and diagrams comprising a 2D concept plan of the center, and also the benches, equipment required and air/energy distribution systems, etc. At this stage, this involves seeing where the developed concept leads us and providing an estimate of costs, and considering whether any major reassessments of the initial draft are required. The next phase is the blue print planning phase: during this stage, all the elements are precisely defined, in

PRELIMINARY PLANNING

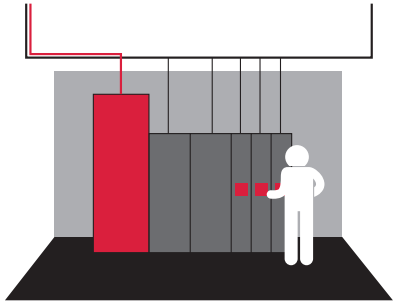


2D CONCEPT

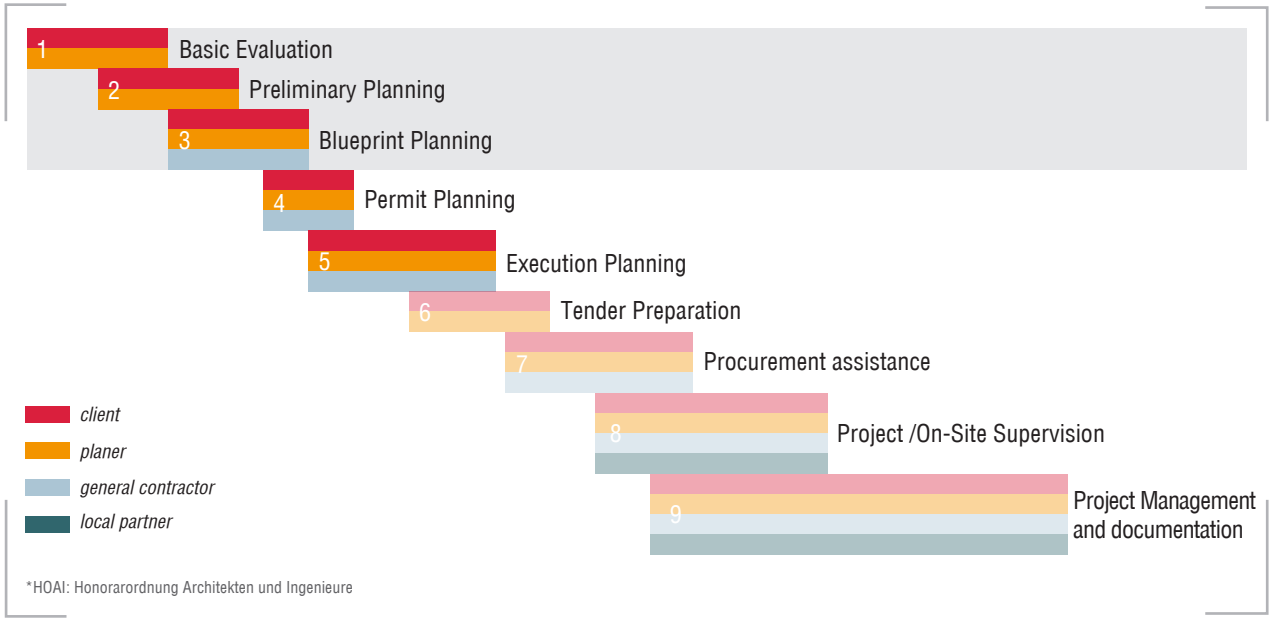


» THE DIFFERENT STEPS OF A TEST CENTER BUILDING PROJECT

BLUEPRINT PLANNING



particular the benches and their equipment, 2D and 3D execution plans are created, the air conditioning and energy needs and other requirements are precisely defined, and an accurate estimate of the cost of the project is calculated. Armed with this information, it is then possible to draw up the planning application and establish dialog with public authorities: here, FEV can provide technical support to the customer who is, of course, responsible for the planning application. During the next steps, the various specifications, with the implementation plans are drawn up, with an accurate schedule. Everything is then ready in order to consult and select the suppliers who will be involved in the project.



> Project implementation

During this phase, all of the expertise of the men in the field is put into practice, from management of the project through to its acceptance. A works foreman will be tasked with liaising between the customer and suppliers. The project manager will ensure tasks are performed effectively, including creating the necessary documentation.

» PROVEN IN FEV TEST CENTERS

Modern test cells often need to perform highly complex test methodologies, while keeping high efficiency goals.
As a powertrain engineering provider, FEV masters the powertrain methodologies.

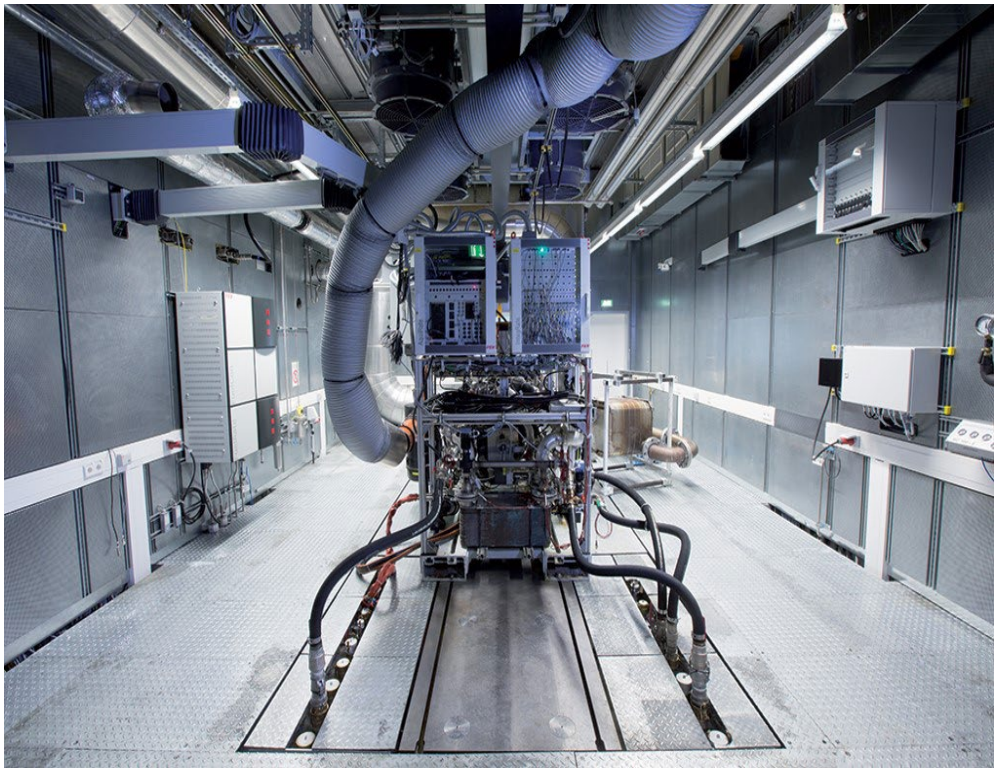
» PROVEN IN FEV TEST CENTERS

FEV test bed solutions, initially designed to meet the company's own needs, offers unique capacities for running complex tests, with a high level of efficiency.

Due to the modular design, these solutions are flexible, from turnkey test cells to easy refurbishment of existing test cells.
The FEV test bed is based on distinct and standard modules: Information, simulation, automation, etc.

This structure enables both the specifications of each customer to be taken into consideration and the efficiency of the test center to be enhanced.

Indeed, as the modules and interconnections are standard, it favors an easier centralized management and boosts the efficiency of the test center.
These open modules easily integrate existing test cells for refurbishment requests.



ONE CYLINDER, A HUNDRED APPLICATIONS

FEV has developed a family of single cylinder engines (SCE) for combustion research, functional testing, and continuing development of engine components. Six research engine size variants with cylinder bores ranging from 65 mm to 530 mm are available for sale, covering a wide spectrum from passenger cars to large engines. Single cylinder motor test results can be subsequently transferred to all common multi-cylinder derivatives. The modular SCE design makes it possible to adapt the engines to individual client needs with little effort. This makes very specific analyses of almost any component possible, from various piston shapes to modified valve timing. With the help of optical visualization, the tool also allows fundamental combustion research.

> Fast and Reliable Tools

The simplified structural design with only one cylinder shortens both the set-up times as well as the component costs. In addition, the reduced fuel consumption (only one cylinder operating) reduces the maintenance costs. The unique layout enables a separation of the various parameters that influence the combustion process. At the same time, disturbing influences can be effectively minimized and new design concepts can be examined on the test bench at an early stage of development

> Flexibility is key

FEV's single cylinder engines are available with bore-diameters ranging from 65 mm up to 530 mm. In combination with various strokes, cylinder displacements between 0.2 and 155 liters can thus be achieved, with each single-cylinder motor covering a broad displacement range.

> FEV Service from Planning to Commissioning

Over time, FEV has put over 160 single cylinder systems into service. It has completed over ten installations of the new single-cylinder engine family, covering all sizes and various fields of application; These ten most recent installations alone have operated for more than 12,000 hours, demonstrating the system's practicality and efficiency.

> Customer Projects

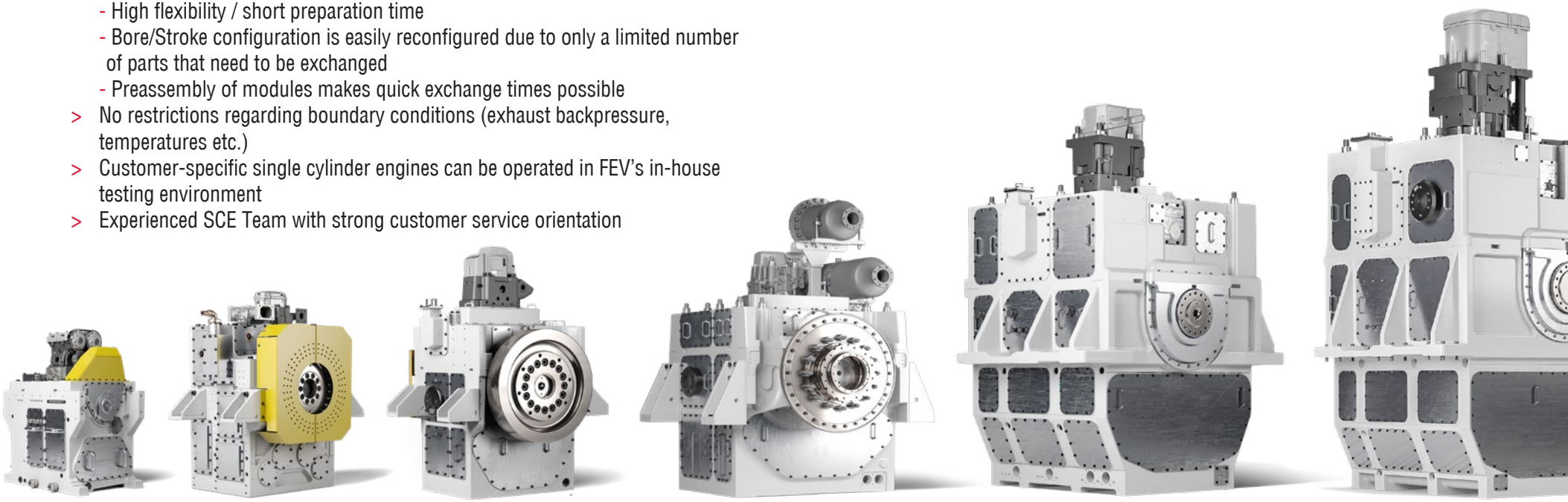
The FEV service portfolio goes far beyond installation. FEV's experts develop comprehensive solutions: In addition to a need-based design of the single cylinder engine, FEV's services also include integration of the engine into a new or existing test facility. In addition, FEV operates customer-specific single-cylinder engines within its test facilities. To guarantee rapid implementation of the projects, FEV has base modules in various sizes available, which can be used and adapted for customer projects.

BENEFITS

> More conclusive test investigation
> Flexible test bed variation
> Optimized interaction between numerical simulation and experiments
> Enables combustion development and hardware testing at an early stage of development
> Allows advanced combustion research with the help of optical visualization
> Fully modular design
- High flexibility / short preparation time
- Bore/Stroke configuration is easily reconfigured due to only a limited number of parts that need to be exchanged
- Preassembly of modules makes quick exchange times possible
> No restrictions regarding boundary conditions (exhaust backpressure, temperatures etc.)
> Customer-specific single cylinder engines can be operated in FEV's in-house testing environment
> Experienced SCE Team with strong customer service orientation

CHARACTERISTICS

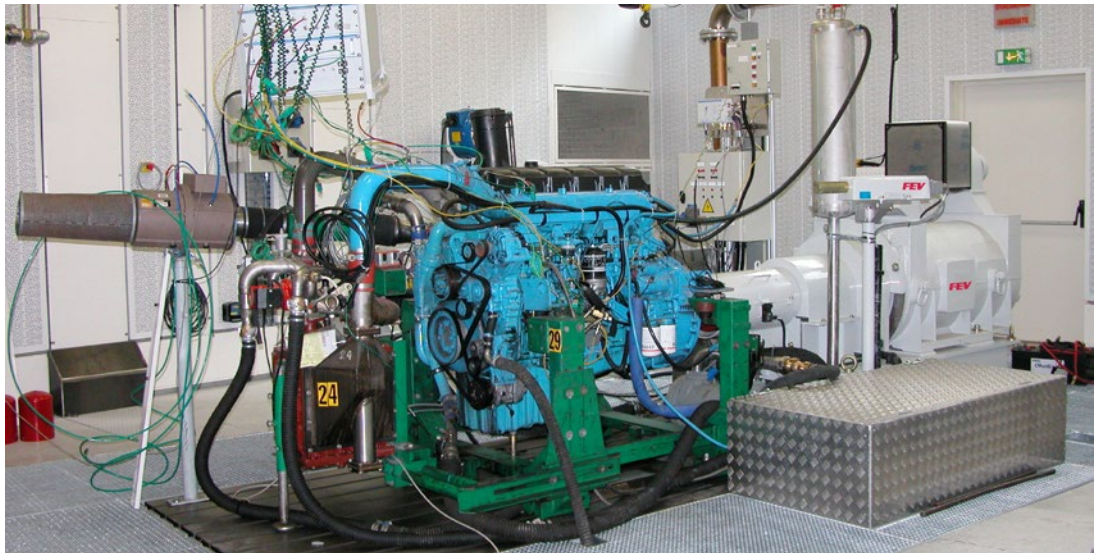
> Bore-diameters: 65 mm to 530 mm.
> Cylinder displacements between 0.2 and 155 liters
> Design protects for operation at high loads (300 bar PFP) and engine speeds



» FULL PACKAGED SOLUTIONS FOR NEW STANDARDS

The market for heavy-duty test beds is changing fast. The market is experiencing globalization and the environmental goals are becoming increasingly ambitious.
For test centers, this means:
- A greater diversity of standards that increase the number of test types to be performed and their complexity: Euro 6-7, US transient, JE05, WHTC and more.
- Increased demands on productivity, test bed rotation and operational maintenance.

Our heavy duty test bed solutions are based on a three-pronged approach:
- Open and packaged test bed automation system
- Reliable and efficient test bed equipment
- Utilities of the test bed, designed by FEV as modules



BENEFITS

> **Operational:** Maximum operating time of the test cell due to reliability of the solutions and no engine stop during modifications.
> **Proven:** More than 1200 test beds installed with automation systems. More than 600 complete test beds installed: automation, dynamometers, commissioning, etc..
> **Packaged:** On-road and off-road applications that are fully automated for the world, European, North-American and Japanese regulations.
> **Expert:** Experienced test bed engineers. An expertise in the field of shaft line and bearings calculations.
> **Dynamic:** A line of highly dynamic and reliable asynchronous machines for passenger cars and heavy-duty engines.
> **Modular:** A modular design of utilities (ventilation, exhaust extraction, fluids...)
> **Packaged:** On-road and off-road applications that are fully automated for the world, European, North-American and Japanese regulations.
> **Simulation friendly:** Very easy application of models on the engine test bed

» COMBINE VARIETY OF TESTS AND MAXIMUM OPERATIONAL TIME WITH HIGH PERFORMANCE

The engine test beds for passenger cars cover a wide range of situations: From the single test bed of an independent research center to numerous test beds working together in an OEM test center. Several standard solutions have been designed to cover normal requests, while in the same time the expertise acquired in our test centers enables us to meet more specific needs.

CHARACTERISTICS

- All types: Durability, calibration, R&D...
- Generic testing
- Easy interface with all major tests equipment
- Easy application of models
- Compliant with ASAM-MCD3 standards

BENEFITS

- Time savings: Generic tests
- Productivity: Chaining of tests
- Modular and flexible
- Dynamic (dynamometers) and high performance (1 to 5 kHz, more on request)

» HIGHLY RELIABLE AND REPEATABLE TEST CELLS

Quality assurance and control in engine and component production put high demands on the respective testing facilities. High reliability and repeatability, a high automatization degree of mechanical processes and the test run itself, automatic docking, filling and draining of the test object and the suitable control and data management system are characteristics of production hot test facilities provided by FEV.

We cover a wide range of applications starting from small gasoline to large heavy duty engines and provide different kinds of handling equipment, from a largely manual operation to fully automatic conveyor and distribution systems.

Common to all applications are our components proven in hundreds of applications all around the world, our design expertise which allows flexible adaptation to the individual project and test object needs, and our global after sales and service network.

CHARACTERISTICS

> Low to High Automation Grade
> Short set-up time
> Modular design
> Safe investment
> High flexibility
> High throughput

BENEFITS

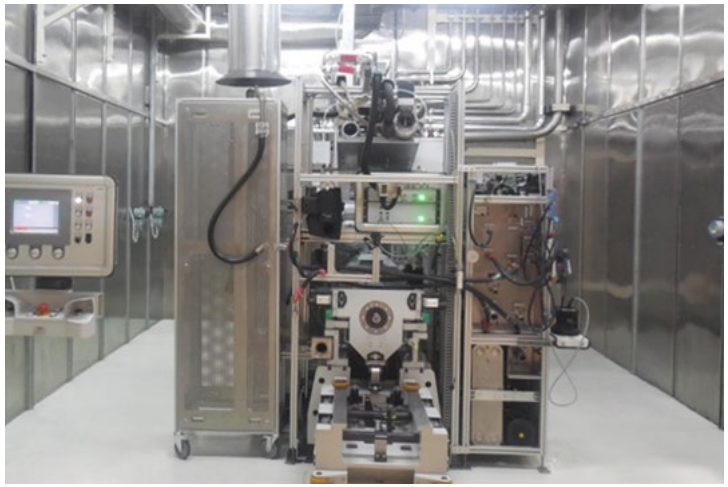
> High reliability of the test facility (up to 98 % up-time)
> Short cycle times for low investments
> Suitable degree of automation
> Reliable results
> Flexibility in adaptation to different engine types
> Fast and easy extension with growing production figures

» HEAVY DUTY DIESEL ENGINES

End of line hot calibration test beds

End of line hot calibration test bed

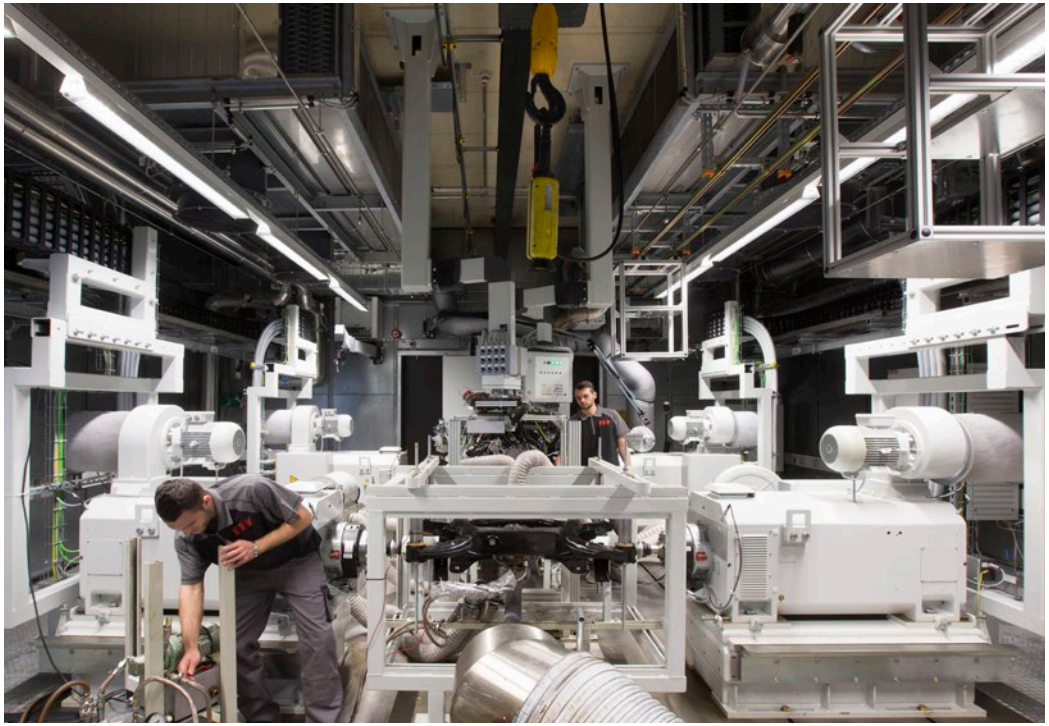
» PASSENGER CAR ENGINES



End of line for Testing Passenger car test bed

» FROM THE ROAD TO THE POWERTRAIN

For the last 15 years, the drive system has seen profound changes, especially with the development of electronic driving aids. Using chassis dynamometers for on-road testing is very time-consuming and requires the availability of the entire vehicle – the powertrain test bed is a good solution for testing the powertrain in its entirety. The advent of hybrid powertrains makes this type of test bed even more necessary.



CHARACTERISTICS

> Steady state, transient & dynamic applications, including hybrid and electric vehicles.
> Available with drive track, road load and driver simulation
> Transmission: Steady state to simulation

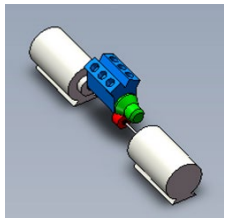
BENEFITS

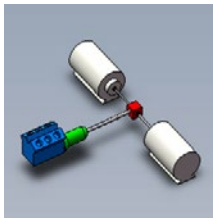
> Anticipation of tests which are usually performed on the road or on chassis dynamometers
> Efficient hardware solutions, with FEV dynamometers and model-based controllers.

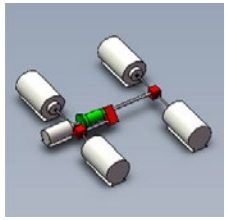
» ONE SOLUTION, MULTIPLE CONFIGURATIONS

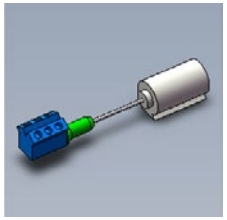
The FEV software solution for powertrain and transmission tests provides a powerful and highly flexible software tool for any customer to handle. It covers many possible test object layouts. The Graphical User Interface (GUI) comfortably allows all common layouts such as powerpack, FWD, RWD and AWD to be selected. Moreover, the GUI supports the detailed configuration of the equipment at he test bench. Herewith, all equipment (dynamometers, gear-change robot, battery simulator etc.) can be easily adapted to the current testing programme, test object etc.

Building on its experience providing and controlling systems, FEV offers proven powertrain test bed solutions.

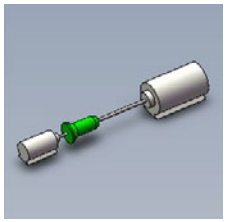

Front wheel drive

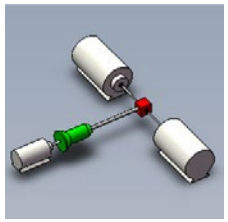

Rear wheel drive

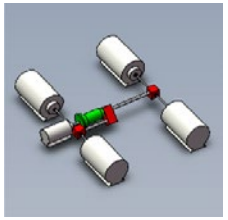

All wheel drive

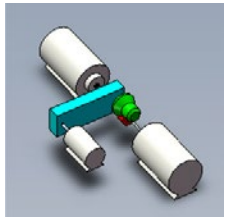

Powerpack drive

Powertrain test bench


Front wheel drive


Rear wheel drive


All wheel drive


Powerpack drive

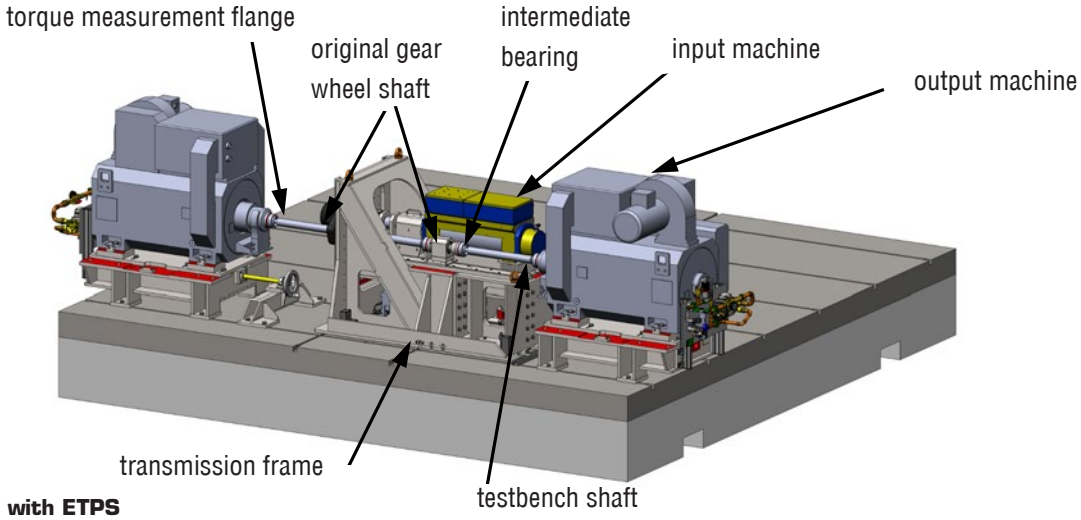
Transmission test bench

» ENGINE TORQUE PULSATION SIMULATION

In addition to traditional use cases, at transmission test cells also the combustion engine behavior has to be simulated. This behavior has to be simulated towards its inertia behavior during gearshifting and towards its torque pulsations. This way, transmissions can be tested realistically already during early development stages even if the combustion engine is not yet available.

The Engine Torque Pulsations Simulation (ETPS) application in TOM (see page 119) allows the simulation of typical harmonics - e.g. 1st, 2nd and 4th order for 4-stroke 4-cylinger engines - at the transmission input. While the prime-mover provides constant input torque, the controller detects actual shaft position. Based on shaft position (phase), a pulsation is generated on top of the input torque. ETPS can be used both in speed or torque control of the prime-mover at driveline test benches. A real-time closed-loop control based on an FFT ensures the demanded intensity of the harmonics.

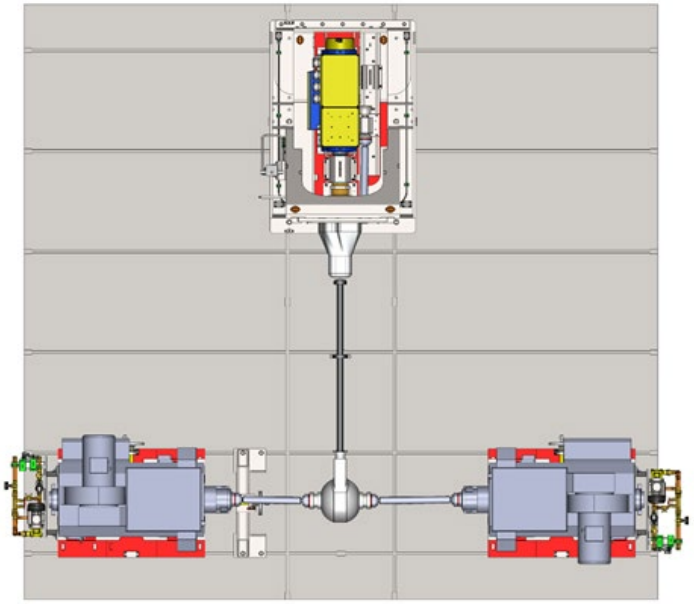
The Graphical User Interface (GUI) comfortably allows all settings to be parametrized (amplitude and phase angle). By applying these pulsations, Gear-Rattle and Whining effects can be triggered and investigated. Of course, also the mechanical layout of the test bed will to be designed with special care towards this use case.



Transmission test bed with ETPS

» INERTIA SIMULATION

For FEV DynaCraft Systems a function called Inertia Simulation is available. This functionality compensates the dynamometer inertia forces during accelerations and decelerations at the test bench. Because of such inertia forces, the test object (an engine or a transmission) would be loaded in a different way than in a real vehicle. The Inertia Compensation ensures that the test object is loaded realistically. The physical inertia of the dynamometer can be decreased or increased to a simulated inertia being up to 4-8 times smaller or bigger.
The demand inertia can be configured via the GUI of the test bench controller TOM.



Transmission test bed: the inertia compensation

RESULTS

> Given a physical inertia of 2,4 kg m², values between 0,3 kg m² and 9,6 kg m² could be successfully realized
> Available with road load and driver simulation
> Transmission: Steady state to simulation

BENEFITS

> Simple simulation of any engine on the transmission test bench
> The enhanced simulation on transmission test bench supports the location of gearbox weaknesses gearbox early. The individual variation of amplitude and phase angle also enables to identify and analyze gearbox vibrations
> Easy to handle, controlled by TOM
> Combustion engine inertia behavior during gearshifting can be simulated by input dyno at transmission test beds
> Dynamometer inertia can be decreased or increased for different types of combustion engines (engine test beds) resp. different wheel inertias (driveline test beds)
> Speed dynamics can be improved
> Compensation of inertia forces during ETPS operation allows realistic torques directly at the shaft

TURBOCHARGER FRICTION LOSS

» TARGETED OPTIMIZATION

Turbocharger bearing friction losses impact the overall turbocharger performance. Therefore, an in-depth understanding of bearing systems and their characteristics is essential in order to drive future improvements.

One important tool for these investigations is FEV's turbocharger friction loss test bench. In contrast to more typical turbocharger test procedures, in which performance maps are measured on a hot gas test bench, the compressor and turbine wheels are removed from the Turbocharger shaft on the friction loss test bench in order to measure only the mechanical losses. Turbine efficiencies measured on a hot gas test bench do not reflect the pure aerodynamic values because they are superimposed by adiabatic effects and mechanical losses.

CHARACTERISTICS

- Maximum speed: (turbocharger)
  passenger car: 140,000 rpm
  heavy duty 80,000 rpm
- Maximum bearing power loss:
  passenger car: 1.2 kW
  heavy duty: 2,5 kW
- Oil temperature range: 40 - 110°C
- Coolant temperature range 40 - 100°C
- Thrust load range: -100 to + 100 N

» FLOW, SWIRL AND TUMBLE

The automotive industry is facing stricter carbon regulations and emission standards. Modern combustion processes place increasing demands on charge motion in the cylinder. For example, requirements differ significantly for a turbo-charged, direct-injection gasoline engine as compared to a naturally-aspirated engine with port-fuel injection. Novel combustion processes with early or late intake valve closing extend the parameter space even further. A needs-based assessment of the charge motion is made possible with flow test rigs that are developed at FEV, both for the development process as well as for end-ofline testing.

FEV flow test benches enable the analysis and assessment of cylinder-head flow, tumble, and swirl performance under steady-flow conditions. This represents an indispensable tool for port development and quality assurance. The fundamental concept and detailed solutions are based on many years of experience in FEV's flow laboratory.

CHARACTERISTICS

> End of line testing
> Fully automatic change of testing objects
> Customizing: Design, Soft- and Hardware
> Valve actuator design for hard springs
> Measurement Method:
  - Paddle Wheel Swirl and Tumble
  - Honeycomb Swirl and Tumble
> Bore Range from 60 mm to >190 mm
> Flow rate up to 1,600 m^3/h

BENEFITS

> Time savings: Generic tests
> Productivity: Chaining of tests
> Modular and flexible
> Dynamic (dynamometers) and high performance (1 to 5 kHz, more on request)

WATER SEPARATOR FILTER

A HIGHLY AUTOMATIC SOLUTION, FOR A LARGE VARIETY OF TESTS

This test bench is capable of carrying out tests intended to measure the efficiency of the system of water separation of the gas oil filters operating under pressure and in the presence of different fuels.

This test facility is also capable of receiving all of the diesel fuel filters on the market, including those of last generation operating under pressure, in order to quantify their efficiency in separating the water from the various gas oils.

The basic principle is to make a mixture of fuel and distilled water to a controlled level, to circulate it through the filter under test in order to measure its retention rate of the water contained in the fuel.

CHARACTERISTICS

- Compliant with the ISO 16332 and SAE J 1488-10/2012
- Three modes: automatic, manual and maintenance
- Fuel flow: 30 to 900 l/h
- Water injection flow: 0.04 to 18 l/h

BENEFITS

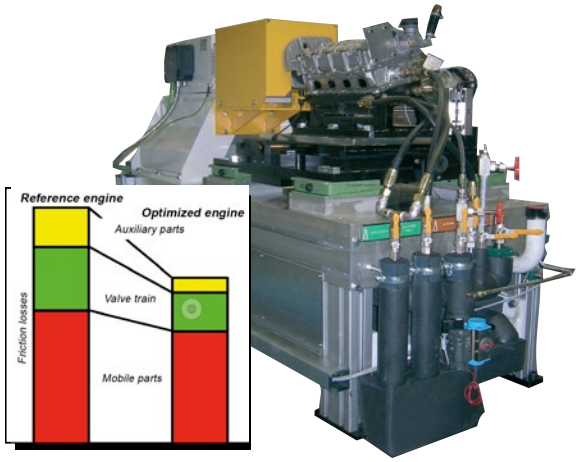
- Very highly automated solution, enabling to increase the productivity of tests
- Automatic report generation after completion of the certification tests.
- Multi-purpose test bench: large variety of tests are possible

» FEV METHODOLOGIES INSIDE

Friction investigations on combustion engines and their components are gaining increasing importance in terms of the fuel economy improvements required to reduce CO2 emissions. Friction test benches at FEV fulfill all of the requirements that must be met for precise investigation into friction. Depending on the measurement task, various test bench types are available for either full engine or component-level friction investigations.

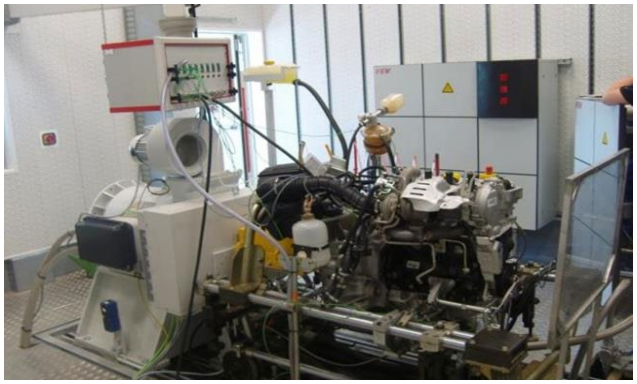
The motored engines or engine components are driven by means of asynchronous machines with high-precision torque measurement. An extremely rigid machine frame prevents cross influences on the torque measurement and thus ensures constantly high measurement accuracy.

Media conditioning systems are implemented to allow adherence to very tight boundary conditions for oil and coolant, allowing even the most precise requirements to be met. Temperature control for oil is possible in a range of 20 to 150 °C and for coolant in a range of 20 to 120 °C. Temperature control accuracy is better than < ±0.5 °C. By means of an additional cooling unit, cold start investigations can additionally be performed at temperatures as low as -30 °C.



BENEFITS

- Stable test boundary conditions ensure high repeatability and shorten test run times
- Optimized for high-precision torque measurement
- Large range of applications – for both full engines and engine components
- Sturdy, high-quality and low-maintenance equipment, tried and tested over many years in FEV's own test field



» DURABILITY AND EMISSIONS

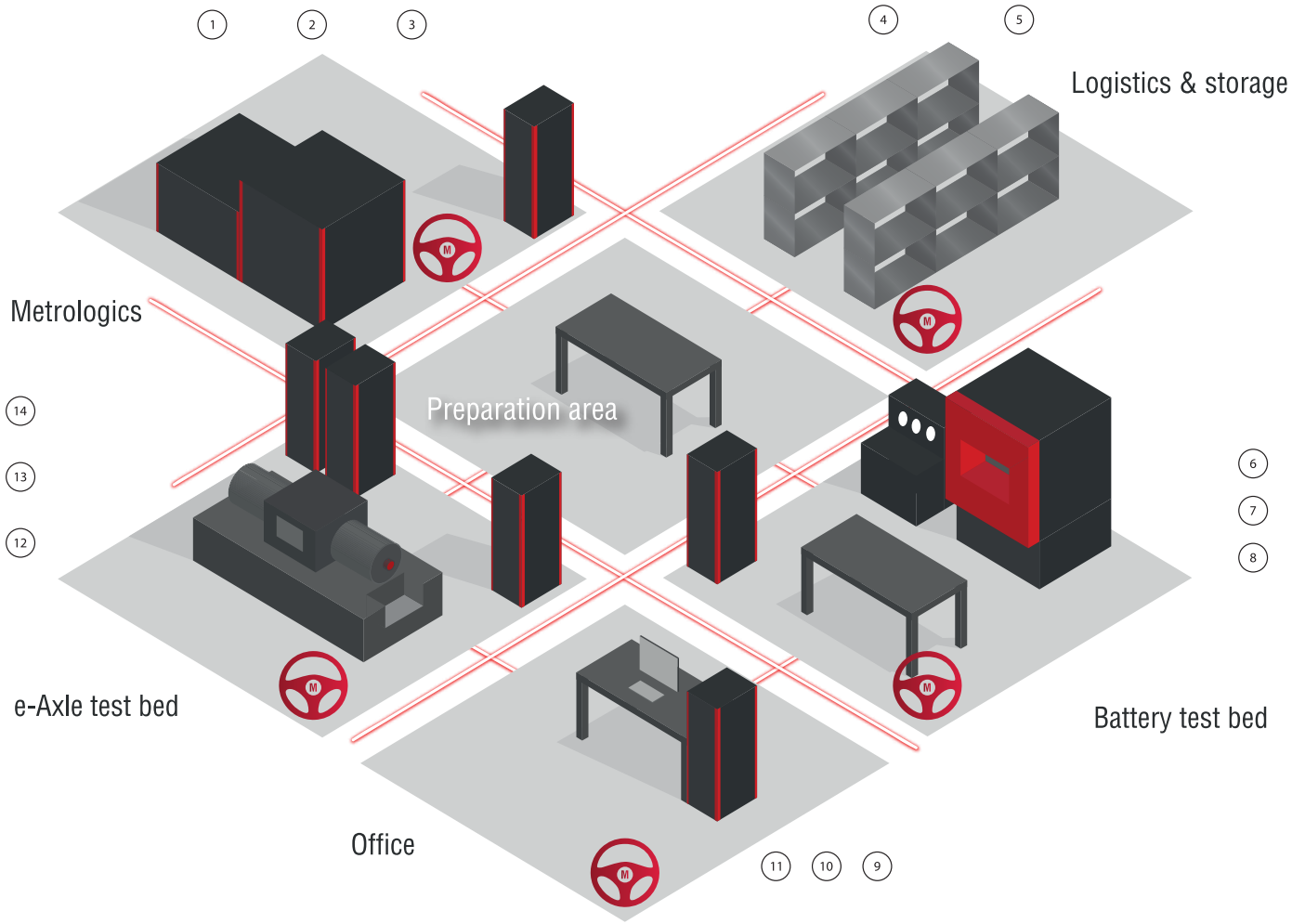
Even if the new certifications give more significance to on-road tests, chassis dynamometers remain an essential tool for engine testing. FEV's versatile solutions meets the various needs encountered during testing: Durability and emissions tests, in various climatic and altitude conditions.

CHARACTERISTICS

- Any type of emissions tests can be performed
- Complete CVS and gas analysis system (gasoline and diesel tunnels)
- Two monorollers for testing any type of vehicle configuration (front or rear wheel drive, 4WD, hybrid)
- Climatic test cell (40 °C, 50% humidity, -7 °C)
- Continuity of driver's assistance from chassis dynamometers to on-road testing (RDE)

KEY BENEFITS

- Integration of a complete diesel/gasoline exhaust gases analysis system
- Centralized management of testing and of results, with the MORPHEE automation system, in combination with TEST MANAGER.
- R&D testing, modal analysis, thanks to MORPHEE's flexibility configuration (front or rear wheel drive, 4WD, hybrid)
- Mobile radiator grill ventilator
- Solutions tested in our centers



Case 1 : Sensors tracking and calibration
Case 2 : Equipment booking
Case 3 : Deliveries and UUT identify
Case 4 : UUT measurement, qualification and recording.
Case 5 : UUT location
Case 6 : Loading UUT and required equipments connection
Case 7 : Running test cycles and test equipments in monitored and safe environment.
Case 8 : Starting test cycles.
Case 9 : Preparation of the testing project.
Case 10 : Supervising of all running equipment and testing progress from one point.
Case 11 : Report and analysis
Case 12 : Interfacing & controlling any testing equipment.
Case 13 : Reliable and proven real time interface.
Case 14 : Test field extension.

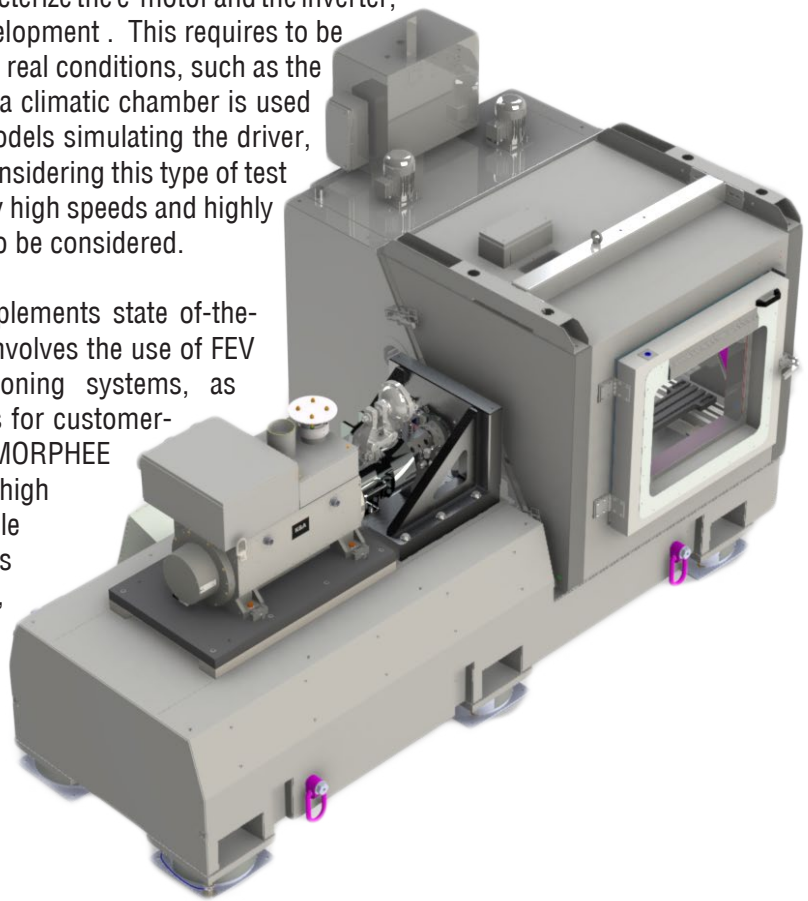
FLEXFLEX™ & FLEX Lab™ manage all the flows, processes and datas of testing project. MORPHEE®, the FEV automation software, monitored all equipments and test beds of the test center.

» E-MOTOR CHARACTERIZATION

> High-speed e-motor test benches

E-motor testing aims to characterize the e-motor and the inverter, in the upstream steps of development . This requires to be as close as possible from the real conditions, such as the climatic ones – in that case, a climatic chamber is used – or the driving in itself – models simulating the driver, the road…. The key factor considering this type of test bed is its ability to test at very high speeds and highly dynamically. Vibrations are to be considered.

FEV operates, plans and implements state of-the-art e-motor test beds. This involves the use of FEV dynamometers and conditioning systems, as well as tailor-made solutions for customer-specific requirements. The MORPHEE automation system offers a high degree of flexibility and simple configuration for various test beds types. At present, FEV has built e-motor test bed solutions that enable rotational speeds of 24,000 rpm and above.



CHARACTERISTICS

- > Dynamic e-motor test beds of 24 000 RPM and above
- > MORPHEE for E-mobility (Automation, Simulation and Calibration)
- > Preferred models for electric drive chains
- > Various architectures evaluated
- > EtherCAT
- > Good accuracy for speed control for low speed (0…1000 rpm)
- > ECoolCon for Water and oil conditioning with 1…3 circuits, with automatic fill and drain
- > OSIRIS power analyzer
- > Battery simulator
- > Option: climatic chamber (temperature range : -40 up to 120 °C)

KEY BENEFITS

- > State-of-the-art solutions
- > Solutions based on robust and validated products
- > Flexibility and scalability of MORPHEE: A test bed that follows changes in technologies

» VALIDATION OF THE COMPLETE DRIVELINE

> E-axle test benches

In this configuration, this is not only the e-motor that is tested but the complete drive chain (electric motor, transmission, inverter and control unit). It permits, in the downstream steps of the development, to test the complete system. The calibration of the inverter is done, with the goal to increase the global efficiency of the system. Power analysis is needed.

>FEV operates, plans and implements state of-the-art e-axle test beds. This involves the use of FEV dynamometers and conditioning systems, as well as tailor-made solutions for customer-specific requirements. The MORPHEE automation system offers a high degree of flexibility and simple configuration for various e-axle test beds types.

CHARACTERISTICS

> Maximum speed usually 2 500 rpm, with 3000 Nm for the torque
> MORPHEE for E-mobility (Automation, Simulation and Calibration)
> Preferred models for electric drive chains
> Various architectures evaluated
> EtherCAT
> ECoolCon for Water and oil conditioning with 1…3 circuits, with automatic fill and drain
> OSIRIS power analyzer
> Battery simulator
> Option: climatic chamber (temperature range : -40 up to 120 °C)

KEY BENEFITS

> State-of-the-art solutions
> Solutions based on robust and validated products
> Flexibility and scalability of MORPHEE: A test bed that follows changes in technologies

BATTERY

» FROM DURABILITY TO RESEARCH TESTS

FEV has created a multi-stage solution. It takes into account the need for benches to develop from endurance tests to research tests. As it is an open and scalable solution, it can be adapted to all bench equipment, present and future: Power drives, climactic chambers, cooling systems, etc. Its flexibility and performance allow it to change with future methodologies: More complex testing procedures, robust databases, integration of models in real time on the bench, etc.

The battery tests are performed either on a complete battery — called a pack — or on one or more cells that make up the battery. To optimize the cost of tuning the battery, it is better to work on the cell than on the pack. Simulating and integrating models therefore allows the cell's full environment to be considered.

CHARACTERISTICS

> UUT = Battery cell, module or pack
> Low, medium and high voltage application
> From cell voltage (Li-ion) = approx. 3.6 V
> Up to traction battery with 600 V, 800 V or more
> DC current up to 1000 A and more
> Battery management system BMS

KEY BENEFITS

> State-of-the-art solutions
Choose a one-shop supplier, from hardware to software
> Solutions based on robust and validated products
> Flexibility and scalability of MORPHEE: A test bed that follows changes in technologies
> Complete or partial simulation (State of Charge, Temperature, Road Load Simulation: Reduce development costs

Cells Testing
> 0 - 6 V / 300 A for each channel
> Up to 288 channels
> 3 climatic chambers -30°C to +70°C - 8 channels each
> 3 climatic chambers -40°C to +120°C - 12 channels each
> 19 moderate temperature chambers +10°C to +70°C - 12 channels each

Each chamber equipped with neutral gaz automatic and independant extinguishing system

King size - Storage area
> Pack testing: 0 - 500 V / 600 A / 120 kW channels
> 2 Climatic chambers - Internal volume : 3,6 m^3
> Temperature range: -30°C to +70°C
> Specific Fire Safety Management
> Battery cooling system
> Storage and manual working area

TEST CELLS -BATTERY

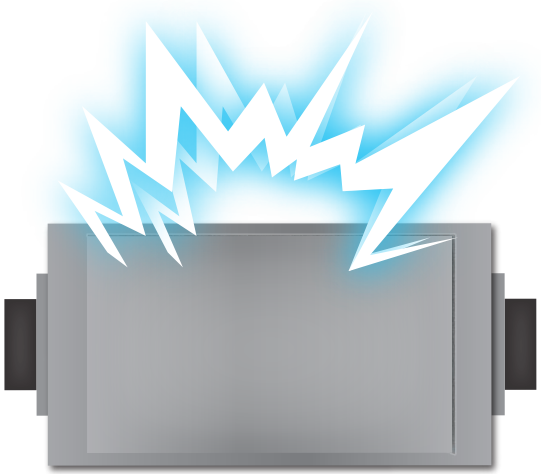
BATTERY TEST CENTER

Walk-In Chambers

> Pack testing: 0 - 1000 V / 1200 A / 400 kW channels
> 4 climatic chambers - internal size : 2300 x 5000 x 2000
> Temperature range: -40°C to + 120°C
> Specific Fire Safety Management (Water flooding inside the chamber)
> Battery cooling system and chillers on the first floor

Safety concept: FEV standard solution

Step 1 : gaz, smoke or flame detection nitrogen injection in the chamber
Step 2 : high temperature in the test cell (or smoke in the chimney TBD) water injection in the climatic chamber with chimney opening
Step 3 : Firefighters operation with manual external water connection for injection.

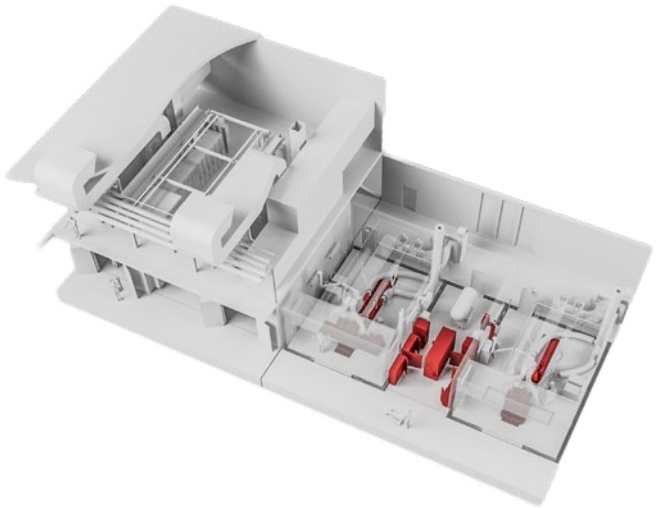


» COMBINE PROVEN TEST BED TECHNOLOGY TO ADVANCED SOFTWARE SOLUTIONS

Take a dynamic engine test bed. Control it with the FEV MORPHEE automation system. Prepare models of the hybrid drive chains: Electric engine, battery, gearbox, energy management, etc. Integrate them in MORPHEE and execute your simulation in real time on your engine testing test bed: You now have a veritable hybrid vehicle (simulated) on your test bed.

Since the whole thing can be run through a Euro 6-7 standardized cycle, it is then possible to easily carry out a certification test, without a prototype or a real vehicle.

For the development of future vehicles, it enables rapid evaluation of various hybrid architectures. It is possible to integrate new models and changing parameters, such as the engine power or the vehicle mass, etc., all of which are operations that are impossible to achieve with such flexibility with a prototype or even a powertrain test bed.



CHARACTERISTICS

> Dynamic engine test bed with MORPHEE
> Models of the hybrid drive chains prepared: Electric engine, battery gearbox, energy management, etc.
> Various hybrid architectures evaluated

BENEFITS

> Eliminate technical risks at an early stage of project development.
> Reduce the number of unknowns and parameters difficult to control in a fully simulated environment.
> In comparison with a purely simulated system, obtain pollutant emissions measurements instantaneously and with great accuracy, all the while controlling the combustion engine conditions.
> Test strategies for energy management and evaluate their feasibility with engine control.
> Make communication transparent between your teams by using a unique development platform.

VCAP, VIRTUAL CALIBRATION PLATFORM, REAL RESULTS: A SOLUTION FOR NEW REGULATIONS (WLTC, WHTC, RDE)

vCAP, the virtual calibration platform, can be used to calibrate ECU functionalities by means of simulation in accordance with the new transient WLTC, WHTC operating cycles thereby saving up to 30% of the physical tests.

> vCAP can save up to 30% of the physical tests

This is directly done on the computer or HiL test bed, instead of on the engine test bed, vehicle test bed or on the road: it models all the physical elements of the test bed or road test (e.g. the combustion engine, its air loop and the exhaust gas aftertreatment system, the vehicle and its driver). This platform is unique, as the various tasks can be performed from a single PC and using a single co-ordination software, MORPHEE. This is the major innovation offered by vCAP: it speeds up exchanges between the simulation, control, calibration and testing teams; it enables engineers to concentrate on their work and not on their tools; it reduces the risks of errors inherent when working with multiple software systems; thanks to the outstanding time-management capabilities of MORPHEE, it retains the initial accuracy of the models, thereby ensuring optimal representativeness of the tests. This results in a 3 to 10% difference in NOx emissions depending on DoE reference test repeatability, which meets the required performance level for calibration tests.

To properly understand the advantages of vCAP, we must compare it, for example on a HiL test bed, to a calibration process using simulation and without the FEV approach. While the usual process requires four CPU and five different software tools (a simulation tool, a calibration tool, an automation tool…), FEV's solution uses only one PC and one software for all these operations, in addition to that used for the application software.

> Easy interfacing with 3rd party components

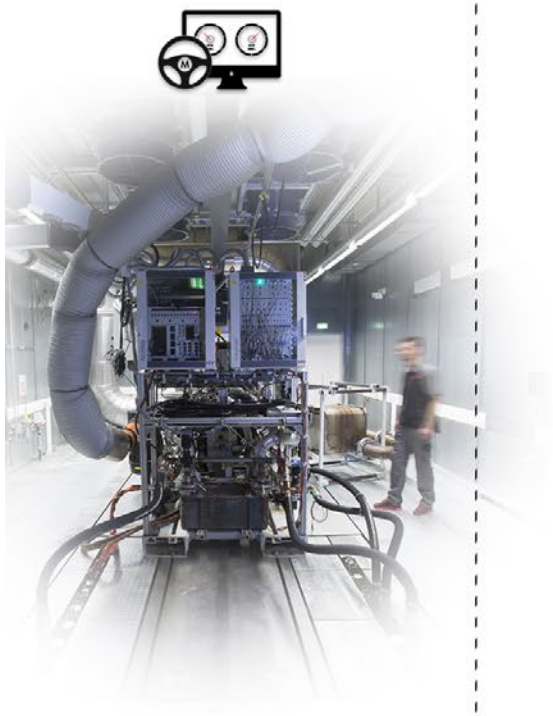
If a customer already has a hardware solution which he wants to keep, vCAP is flexible: the MORPHEE software can interface with it. Other scenarios: the customer has a calibration or automation system which he has been using for years, and he wants to keep it to avoid disruption to his test bed teams. In this case, MORPHEE can exchange with his systems, most of which it knows well.

vCAP can also be offered as a standalone solution where the user would be responsible for integrating his own models, or alternatively he could use our powertrain engineering service: the teams at FEV have been using extremely elaborate models for years, for example for combustion, the air loop or the exhaust gas aftertreatment system. FEV provides a full know how transfer to allow the customer to realize the creation and the integration of new models.

VIRTUAL POWERTRAIN CALIBRATION PLATFORM

1 REAL TEST BED

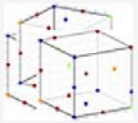
Global DOE(s)



2 MORPHEE

MODELS

DOE



Physical model

Engine

After treatment

PARAMETERS

Applications

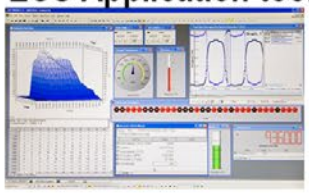
Extreme conditions RDE

OBD

Aging / Dispersion

ECU Mapping

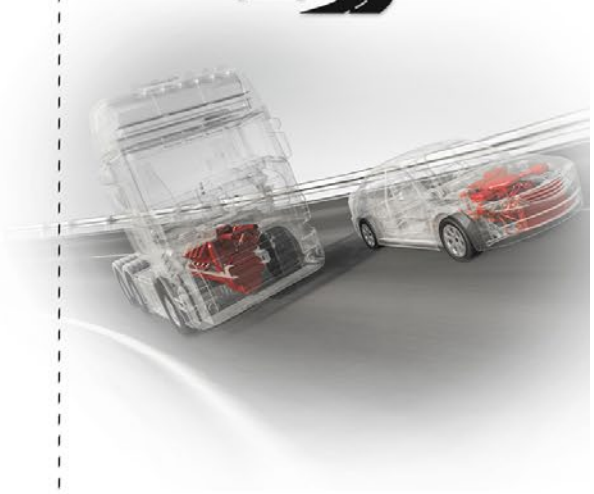
ECU Application tool



ECU

3 VEHICLE VALIDATION

Calibrated powertrain & ECU



HIL TEST BEDS WITH VIRTUAL POWERTRAIN

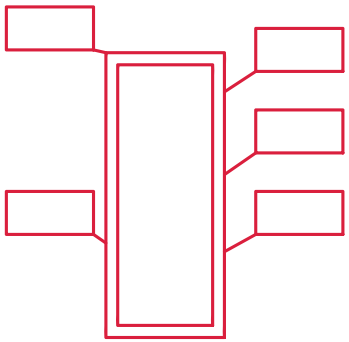
» FOUR STEPS TO SET UP A vCAP

> vCAP Definitions & Specifications
Definition of the platform architecture that is best adapted to the customer application.

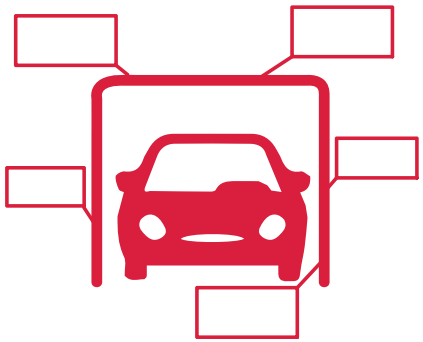
> Bench Test Specifications
Specification of the needed tests to be performed from DOE to EATS tests to vehicle tests.

> MiL Stage Development
Analysis of existing customer plant models to be refurbished and integration of FEV models.

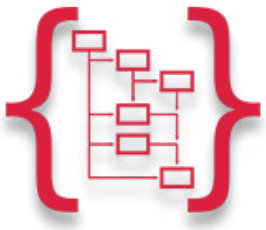
> MiL Stage Development
Integration of plant models, ECU and harness into vCAP hardware.



1- vCAP Definitions & specifications



2- Bench Test Specifications



3- MiL Stage Development

4- HiL Stage Development

» TEST BED FUNCTIONALITIES

ECU mapping

Performed with engine model instead of real engine testing on test bed
Usual soaking (WLTC, NEDC…) not needed
Error occurring during repeat testing are avoided

Environment conditions

For RDE, high altitude and winter/ summer testing are required
With the Virtual engine, testing (load profile simulations – WLTC, NEDC, WHTC, …) can be performed easily by changing parameters at any time at virtual engine test lab

OBD and PEMS

To be performed partly at the virtual engine test bed instead of the real engine test bed and the real vehicle.
Can be tested: production tolerances, actuator failures, …

Aging Checks

Aging to be carried out only by parameter changes

ECU software

For ECU software logic checking (only three days of automation tests expected instead of two weeks of engine test bed and vehicle tests)

The vCAP HiL cabinet is available as a standard FEV solution: As such it is available in a trolley version connected to the ECU, and also to other accessories (e.g. injectors, throttle, EGR valve and the actuator of the turbocharger) on the version including the engine wiring harness. The cabinet includes all the FEV (MIO) input and output and simulation signal modules, including common rail pressure, intake air pressure, particulate filter pressure; the position of camshaft and crankshaft; e.g. catalytic converter inlet and outlet temperatures.

» AN ADJUTABLE SOLUTION

Besides modularity, flexibility is a growing demand for future engine test fields. This also applies for the size of a test field and the number of test cells. FEV has developed the FEV ModuTainer, a modular and flexible test cell housing based on the experience of many years in setting up and operating engine test cells. Size can be widely adapted to customer needs, covering the whole range from passenger car up to heavy-duty diesel testing. The FEV ModuTainer can help shorten installation times on site and reduce disturbance to the existing facility.

CHARACTERISTICS

- For engine power up to 1,000 kW
- Maximum length 10m, maximum width 4 m, maximum height 4 m*
- Noise insulation: 30dBA
- Fire resistance: up to IE 90
- Ambient conditions: -25... + 40°C

* For standard transport Europe. For customized design, dimensions can exceed

KEY BENEFITS

- State-of-the-art solutions
  Choose a one-shop supplier, from hardware to software
- Excellent noise insulation
- High fire resistance
- Flexible adjustment to customer demands
- Short installation and commissioning at customer site
- Easy maintenance
- Modular media interfacing
- Outdoor installation possible

Container system for battery testing

» THE FEV COLLABORATIVE FRAMEWORK

The new challenge is "Road to Rig to Desktop": performing tasks on the rig instead of on the road, and on the desktop instead of on the rig. The goal is to unify teams from different outlooks: simulation, control, calibration, testing teams.

FEV has built its product offer considering this inescapable market trend. This is the so-called FEV Collaborative Framework, a software architecture based on the following points:

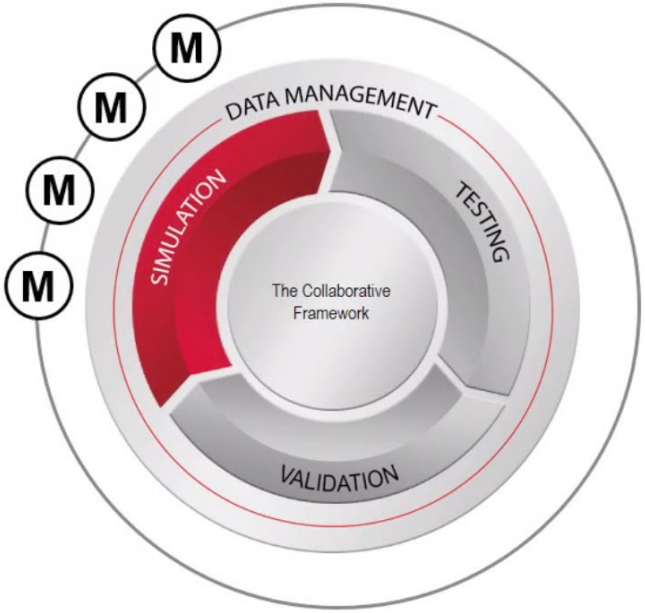
> **Technologies**: A unique collaborative platform, based on FLEVFLEX information management software and MORPHEE technology (MORPHEE, xMOD, xCAL on line)

- integrating models in the same platform and making them run together;
  - defining control rules for the EMS, BMS and ECU and rapid prototyping;
  - testing EMS, BMS and ECUs, performing calibration and durability tests on the test bed;
  - performing real vehicle certification tests on the road;
  - **all this in one environment:**
    - models used in the first steps (driver, gearbox etc.) are run in real time with the same level of accuracy on the test bed,
    - the tests, processes and screens defined in the Software in the loop (SiL) step can also be reused on the engine test bed.
  - with easy connection to hardware and test equipment.

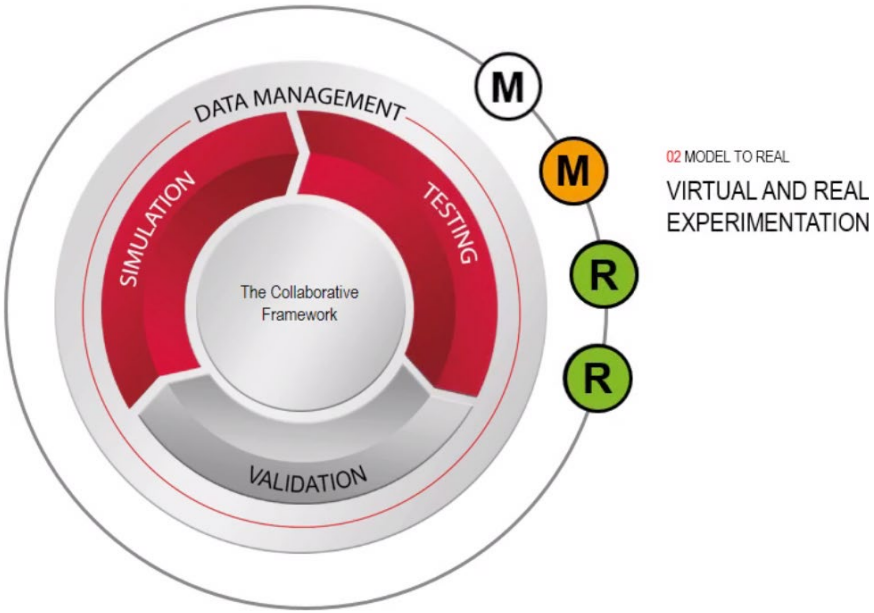
> **Services**: Skilled consultants and experts to implement the "Road to Rig to Desktop" approach. FEV has multi-disciplinary teams benefiting from 40 years experience, used to working together.

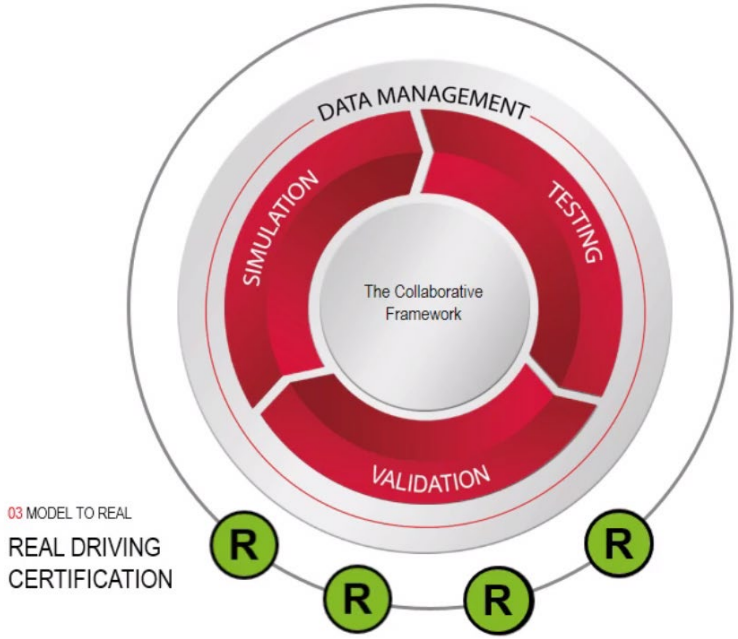
In the next pages, the software tool suite that forms the FEV Collaborative Framework is presented, with FEVFLEX and products based on MORPHEE technology (MORPHEE, xMOD, xCAL on line).

01 MODEL TO REAL
MULTI-MODEL
CO-SIMULATION



During the initial simulation stage at the desktop, different models created via different tools interact on the same platform. The vehicle and the different engine components are represented and their interactions are simulated. The FEV Collaborative Framework can be used e.g. to validate a new hybrid powertrain concept or to scale the air circuit of a new engine, its turbo and its EGR system by evaluating pollutant emissions and fuel consumption, etc.





In the subsequent stages at the test rig (Hardware in the Loop, Engine in the Loop), the physical components are introduced: These components include the ECU (engine control unit), the EMS (energy management system), the BMS (battery management system) and the internal combustion engine, the electric motor, the battery, etc. The physical components are combined with simulated models representing the vehicle, the driver or the road: at each stage, the physical component can be validated in an environment extremely close to that of the entire vehicle and to real driving conditions.

In the final stages of validation, the remaining calibration tasks can be operated on the road, and the vehicle is validated on the road. Calibration tests are performed in real driving conditions. The tests developed in the subsequent steps can be reused. Able to operate as a non-intrusive and stand-alone system, FEV solution guides the driver through test cycles. The system can be supplied with in autonomous power supply unit to avoid any vehicle power consumption. All standard emission test cycles are available for European, Japanese and USA regulations.

» MORPHEE ALL IN ONE

With FEVFLEX, MORPHEE is the cornerstone of the FEV Collaborative Framework. This new 64-bit version is in line with Windows 10 operating system and boosts outstanding performance with 5 mega samples/sec, e.g. 2500 channels at 2 kHz.

It offers the opportunity to develop new automation concepts for future test beds while taking current and upcoming emission and testing standards such as Euro 7, RDE, etc. into consideration. Furthermore, it is a powerful tool for new powertrain calibration methodologies, such as Road to Rig. Relying on its established qualities of openness and performance, MORPHEE extends its functionalities to allow the use of the same interfaces, the same models and the same tools throughout the entire development process. As a result, the new MORPHEE generation will become a unique platform for validation, combining the three functionalities of test automation, on-line calibration operations at the test bed and real-time simulation.

> All-in-one system with modular configurations

Based on this “all-in-one” system, numerous configurations are possible depending on the customer’s individual testing environment. As a result, it is possible to combine these three functionalities on a single platform which is installed for an engine test bench — or the three can be operated separately, using third-party tools.
For example, in a calibration configuration, the MORPHEE calibration platform usually operates with third-party automation tools.

> Reuse of data and simulations

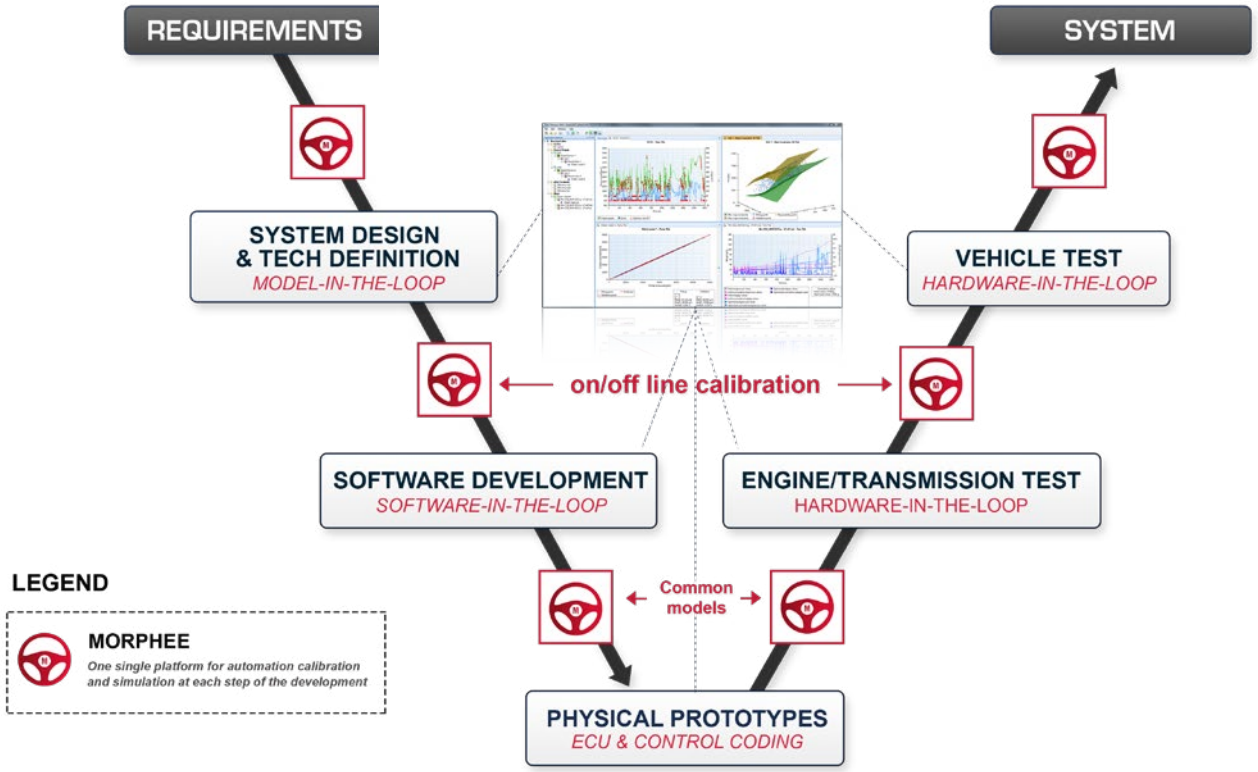
In a co-simulation configuration, the platform is able to accommodate several third-party simulation tools to create a complex simulated system, such as a hybrid powertrain, in the initial steps of development – i.e., model in the loop, software in the loop applications. Afterwards, this simulation platform can be reused for the subsequent development steps on a hardware in the loop test bed and an engine test bed.

The new MORPHEE generation focuses on segmentation, which more appropriately resembles the current workflow of the latest generation of test centers.

The new, independent structure of MORPHEE includes:
• An expert development environment, which will allow access to all functions of MORPHEE;
• A hardware configuration module for interfacing, configuration and calibration of all equipment and acquisition hardware available on the test bed;
• A test bed environment module for repatriation, configuration, execution, real-time testing, storage and visualization of results, with the optional addition of calibration and simulation functions
• Dedicated expert modules for simulation and calibration

It is up to you:
- Choose the all in one concept with MORPHEE automation, calibration or simulation together,
- Or use supply standalone MORPHEE based system for automation, calibration (xCAL) or simulation (xMOD).

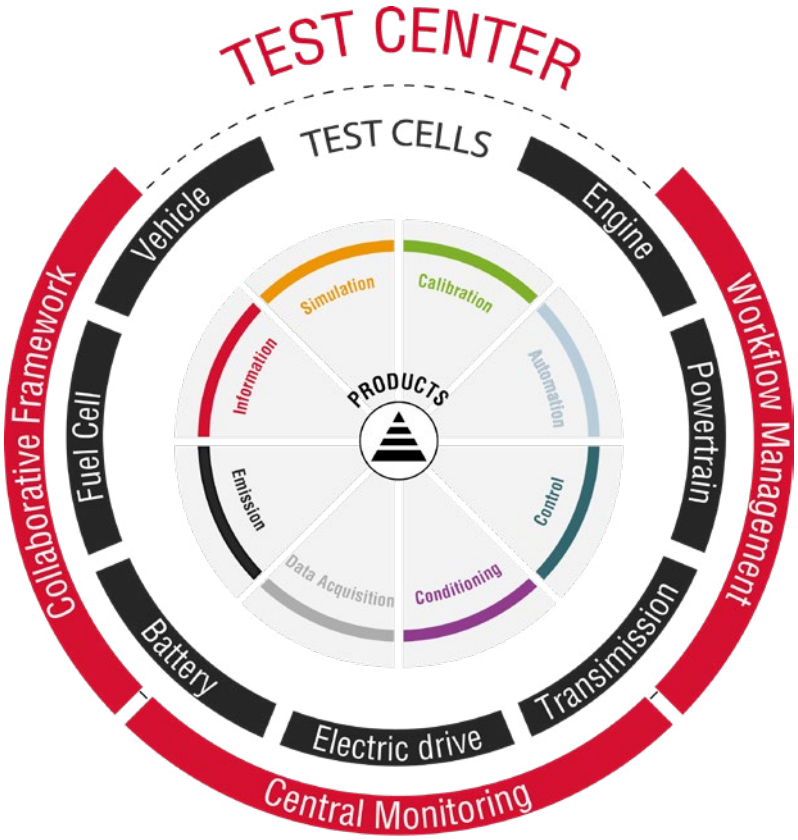
» MORPHEE ALL IN ONE: A UNIQUE WORKFLOW COVERING AUTOMATION, ECU CALIBRATION AND REAL TIME SIMULATION



» A RANGE OF PRODUCTS TO BUILD YOUR DEVELOPMENT CENTER

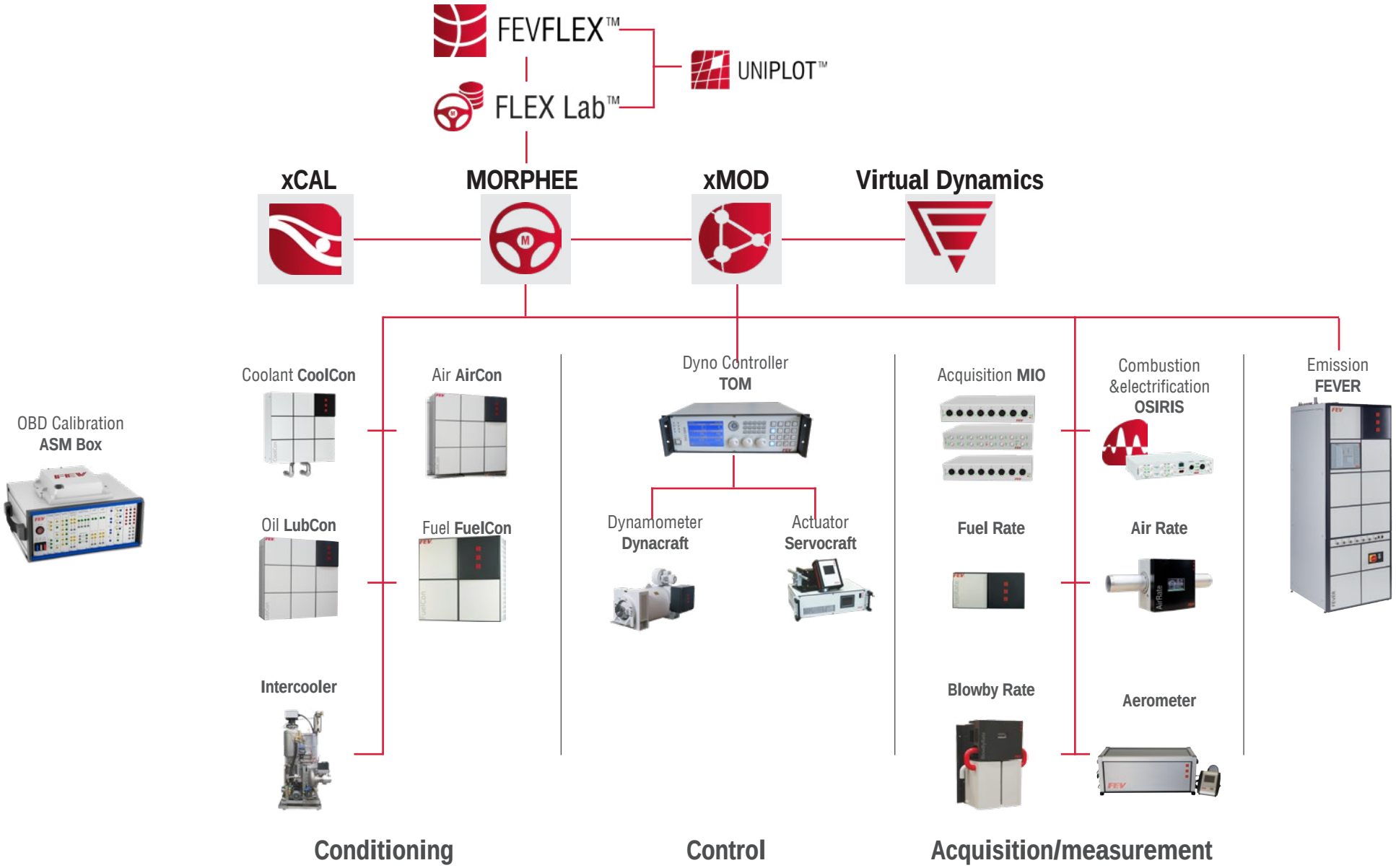
FEV offers a large selection of modular solutions which are easy to integrate and fully compliant with other equipment and software on the market.
Our goal is to make things easy – as it has been since the very beginning of our history when MORPHEE was created. At that time it was the first real-time test cell automation system under Windows.

Our product range works like a pyramid representing functions of a test cell, with MORPHEE at the heart of it, the application solutions at the top and the hardware interfaces as the foundation.



FEV PRODUCT OFFER

SOFTWARE AND TESTING SOLUTIONS



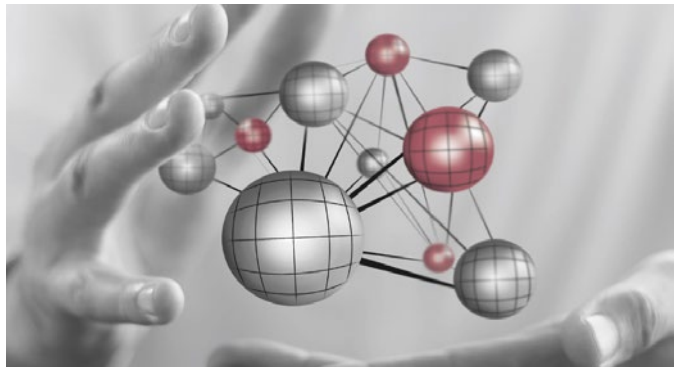
» TEST FIELD MANAGEMENT 4.0

FEVFLEX - Integrated Software to Manage Your Test Field
Fast access to complex data is an important component in modern test field management.
FEVFLEX guarantees an optimal output of all available data: Measurement data are automatically connected and integrated into a central database. All information is linked efficiently and visible at a glance. This modularly based information management solution combines operational simplicity and complex functions. The modular composition is customisable and allows for the creation of a unique product according to the customer‘s individual business purposes.

FLEXibility
The stored data model is dynamic and can be expanded at any time without any software changes - even during live operation. User interfaces are individually modifiable. Modules can be combined according to the customer‘s needs. The integrated permission management ensures safe handling of sensitive data.

Easy-To-Use Concept
FEVFLEX benefits from our easy-to-use concept. This intuitive operation concept offers fast navigation and a short learning curve. Full-text search, filter options, linking functions and much more are the gateway to your requested information. Tables can be edited directly, attachments can be stored and excel exports are possible, too.

Adaptability
FEVFLEX consists of an open software architecture which allows for alterations that can directly be performed by the operator. Multi-language options, display feautures and operating modes can be set. If desired, units can be adjusted and converted as well. Fully automatically!



HIGHLIGHTS

- Modularly customisable test field management
- Dynamic data model, modifiable without software update
- Powerful performance
- Fast, efficient permission management
- Versioning module based on long-term experience
- SCRUM-agile development

» MODULES

FLEXibility

Base
Work Order & Tasks
Resources
Media
Product & Parts
Planning
Test Results
FEVMOVE
Reporting
Benchmarking

- Optimize your utilization
- Save time and resources
- Improve your workflows

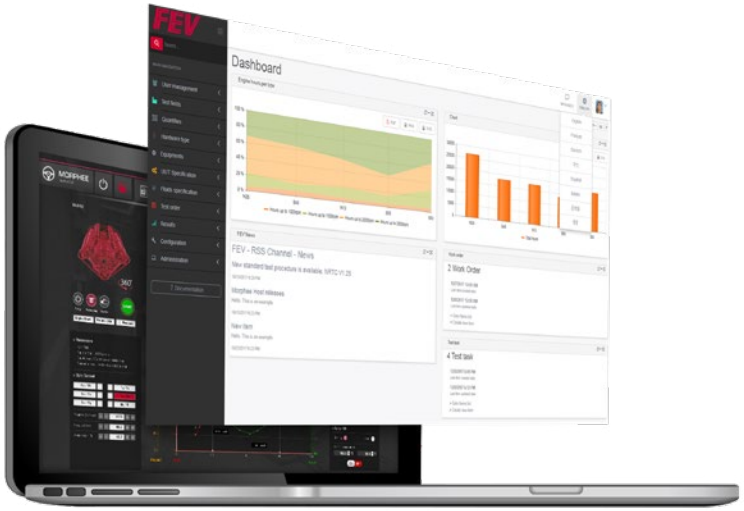
PRODUCTS - INFORMATION

FLEXLAB

FLEX Lab™ is a web based technology solution to manage all test rig data which are using MORPHEE® Automation system.It is easy to deploy, no need to install the software and moreover it is a multiplatform system, so it can be used on all devices with internet connection. FLEX Lab™ uses an application server connected to the client that stores all the datas, it allows a centralized and secured data management.

It is an easy-to-use fully configurable tool using dashboards in which the customer can prepare a definition of the test request without stopping the bench. All settings and equipment configurations can be customized within FLEX Lab™, they can then be defined as standard and stored. It therefore facilitates internal decision-making, which makes it possible to be faster and avoid wasting time by searching for data or redefining configurations and parameters.

However, FLEX Lab™ goes further. It allows a total management of the test centre or test bench thanks to a global view. This view is a live monitoring of any systems that allows the user to see all his test centers around the world, and more precisely to see his benches. The user thus sees the results directly from his various centres.



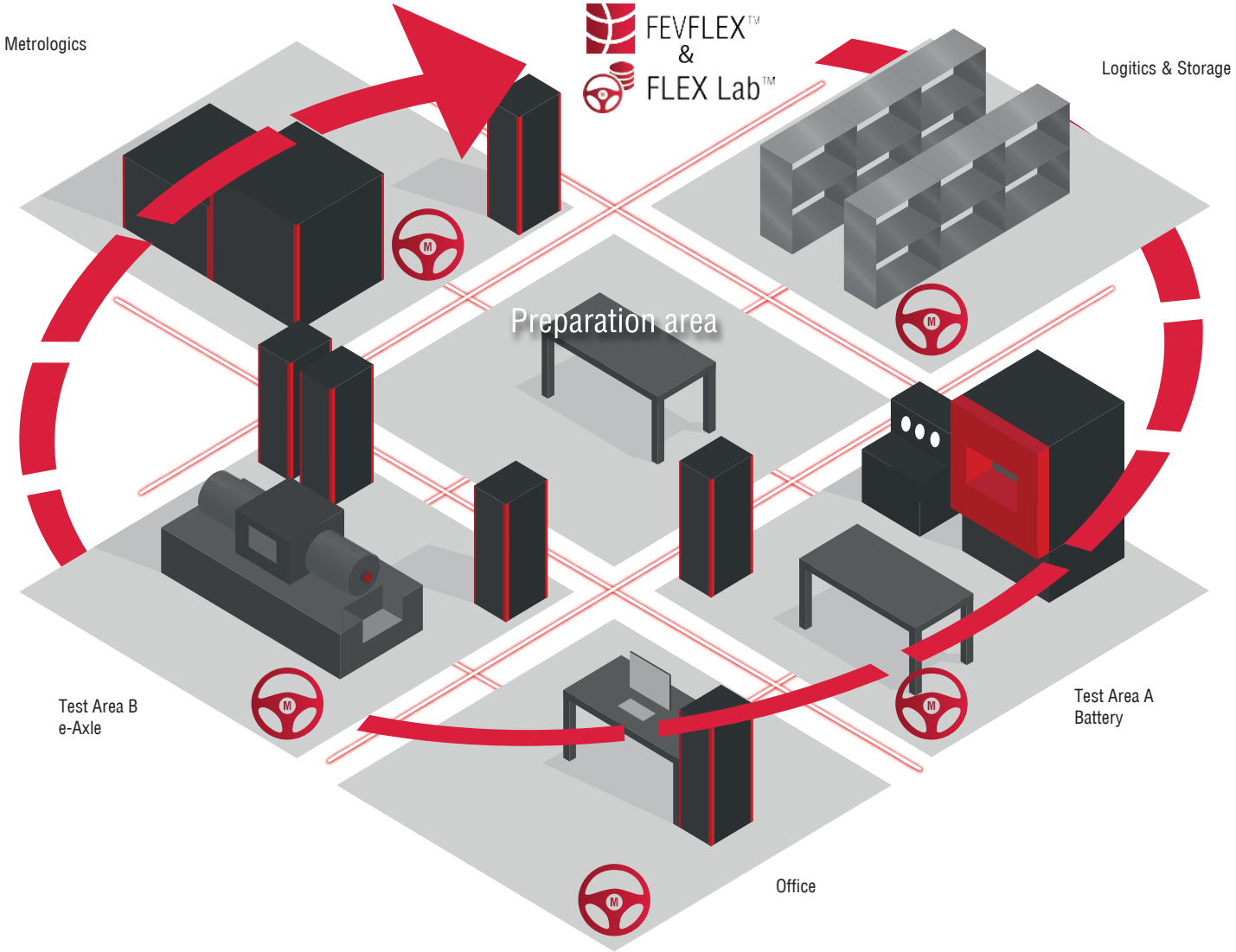
> The test engineer can define preparation task, test requests and have quick and secure access through extensive search capabilities to measurement data.

> The administrator manages test cell data from a single location: Norm-name, formula, libraries, unit under test specifications and parameters, testing equipments…

> Support personal can have access to test cell statuses and all Morphee logs and data to troubleshoot issues.

> Managers can have access to lab operations status and extract all metrics regarding lab efficiency.

Management of all flows in the test center: before, during and after the test



Free Trial Version
FEVALYS
Data Evaluation & Reporting

» ANALYSIS AND VISUALIZATION

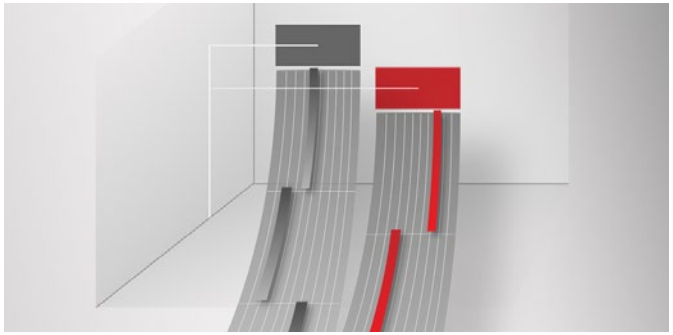
Tailor-made Test Data Analysis
Being an elementary component within the value chain, analysis of test data is an often neglected field of automation data management. Fortunately, professional analysis processes can be both, simple and effective.

FEVALYS is our modularly based evaluation software for the calculation and visualisation of meta information, measurement data and calculation data. Take one step forward and close the gap between data recording and test result presentation.

More Than just Data Preparation
Developed on the basis of the standard software DIAdem, FEVALYS offers an integrated solution in order to analyse complex test data. And yet, FEVALYS exceeds the mathematical and graphical preparation of data: Information can be analysed easily and reported directly. Templates, predefined formulas and a Workflow Editor ensure fast and yet thorough data evaluation.

Customisable Workflows
FEVALYS is a highly configurable solution. Layout templates as well as the formula catalogue itself are directly accessible and possible changes storable. The FEVALYS Sequence Quick Starter allows to create individual evaluation procedures within the Workflow Editor without programming skills being required.

Certification Cycle Reports
FEVALYS has an integrated reporting function for emission cycles ready for certification. Your data will be combined with regulatory limits and processed according to legislative framework.



HIGHLIGHTS

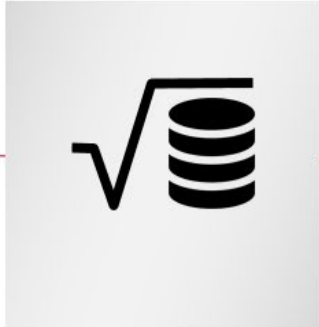
- Calculation, visualisation and reporting
- Workflow Editor
- Certification Cycle Reports
- Individually editable functions – also directly by the customer
- Integrated namemapping
- Quantity based calculations and layouts
- Analysis of multiple measurements at one time

» ANALYSIS WORKFLOW BY FEVALYS

Data

- Database information
- Measured data, calculation results & descriptive information
- High integrability with FEVFLEX

Calculation



- Templates
- Predefined & accessible formula catalog
- Statistics, curve fitting, signal analysis

Visualization

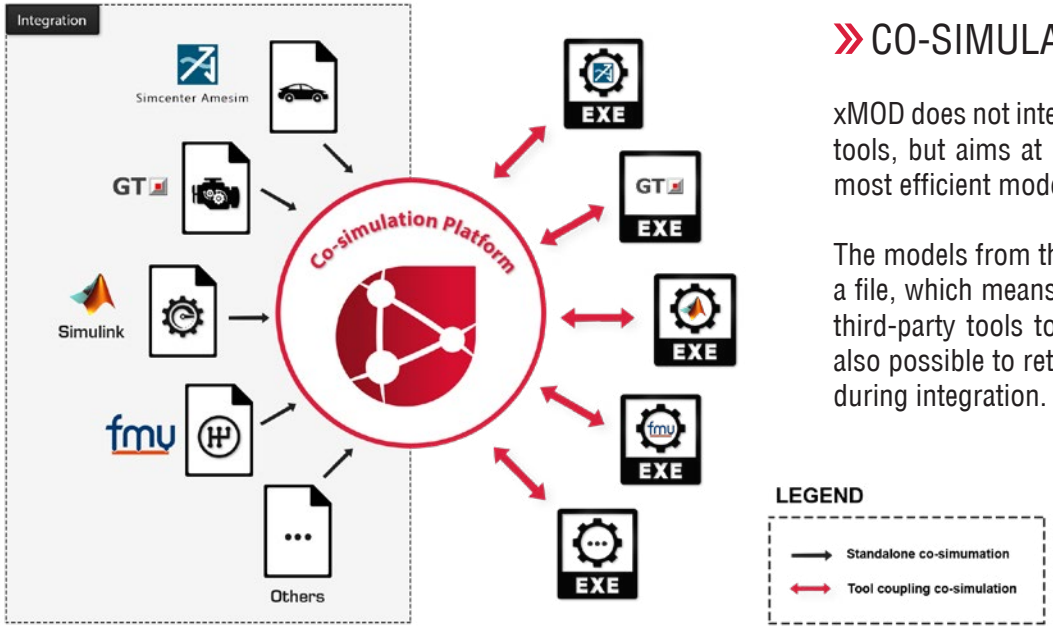
- Templates & individual layouts
- Filtering, panning, data zoom
- 2D, 3D, waterfall, tables, figures

Reporting

- Certification cycle reports
- Templates & individual, storable layouts
- Name mapping

A MULTI-MODEL INTEGRATION & VIRTUAL EXPERIMENTATION PLATFORM

The xMOD application software, based on MORPHEE technology, facilitates the integration of heterogenous models and co-simulation between several simulation tools. The integration process does not require tools. The platform can be used throughout the whole development process. While in the initial development phases, it enables collaborative work between the different professions; in the subsequent physical powertrain and ECU validation phases, it facilitates the use of models on the test bed which were developed during the design phase without any loss in quality.The new 2018 64 bit version has been merged with MORPHEE: they are now sharing 100% of their codes: it means that the simulation and control design teams, as well as test enfgineers , can work in a simlar environment with the same software, tests, models, screens, configurations and processes.



CO-SIMULATION

xMOD does not intend to replace the original modeling and simulation tools, but aims at promoting their coexistence. Feel free to use the most efficient modeling tool/language.

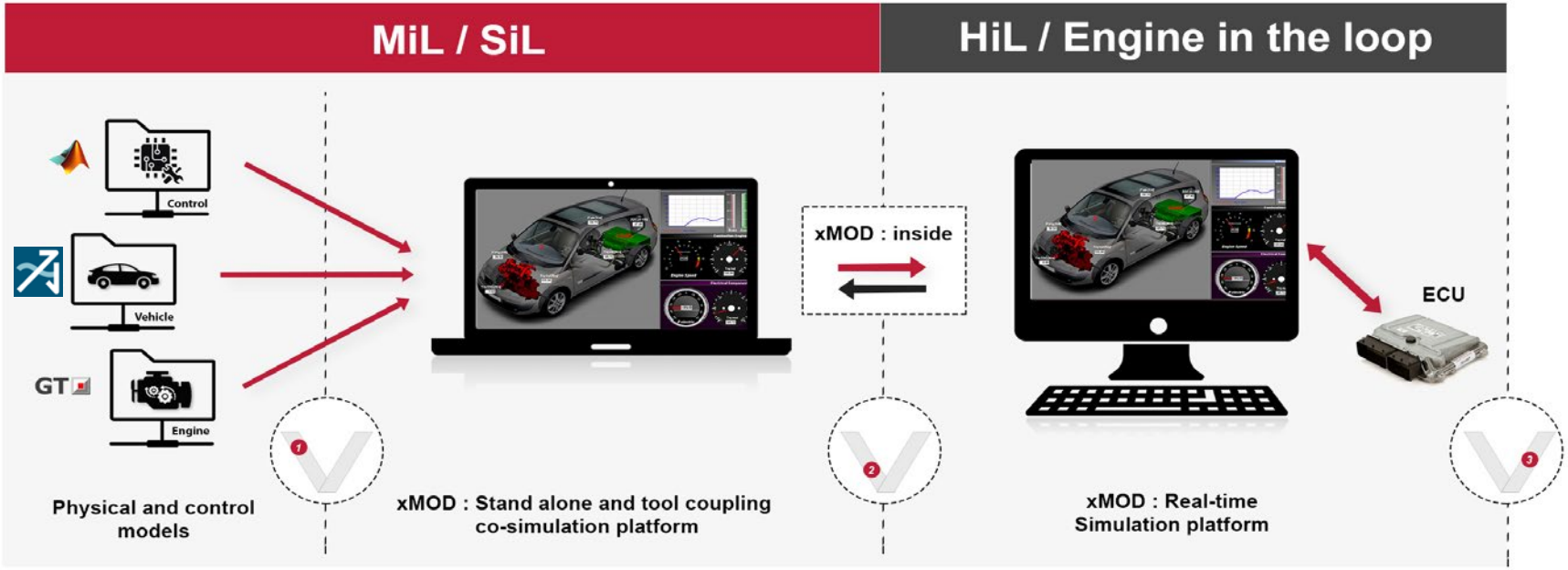
The models from third-party tools can be incorporated in the form of a file, which means that there is no need for the presence of the real third-party tools to simulate the system as a whole. However, it is also possible to retain the third-party models in the original software during integration.

» VIRTUAL EXPERIMENTATION

Models are becoming more and more complex and include a high level of detail.
This is why the idea of implementing these complex models in real time with real components is attractive. However, due to the complexity of the models, a simplification process usually has to be applied with the potential to implement simplified models in real time.As a result, the tests become less representative.

Without implementing complex models in hard real time, it is impossible to obtain a high level of precision on the HiL or engine test beds; rapid prototyping on the HiL test bed or calibrating the ECU on the engine test bed is no longer possible. By using FEV real time MORPHEE technology, The xMOD platform enables the real-time connection of hardware and models without compromising the quality and representativeness of the tests as the precision of the model is retained and can be reproduced directly in hard real time and, in a deterministic way, on the test bed. To guarantee this, unique features have been incorporated that allow multi-solver and multi-core execution with advanced algorithms for data prediction.

With xMOD, it is possible to validate a new hybrid powertrain concept or scale the air circuit of a new engine, its turbo, and its EGR system by evaluating pollution emissions and fuel consumption long before the physical existence of the parts or the system.



» HIGH QUALITY SIMULATION - RAPID LOW-COST POWERTRAIN DEVELOPMENT

What is Virtual Dynamics?
Virtual Dynamics is an advanced simulation software for dynamic analysis of powertrain, driveline and their components. It is a suite of products composed of Virtual Engine and Virtual Gearbox together providing all building blocks needed to create dynamic models of engine, transmission, conventional and hybrid-electric drivelines. Virtual Dynamics uses the core technology of the world leading Multi-Body-Simulation Software MSC Adams as numerical integrator, pre- and post-processing features. The template based architecture perfectly combines the advantages of single purpose software - ease of use and multi-purpose software - no limitations in extendibility.

Virtual Dynamics is a truly open system – featuring a powerful scripting language for task automation, the ability to customize the user interface, support for own solver routines and extending the modeling component library with own user-defined elements. Wizards automate and accelerate the creation of complex models like crank and drive trains. Models and corresponding data are organized in databases, strengthening data management even for global scale companies. Advanced generic 3D contacts plus fast analytical approaches for powertrain-specific contacts ensure a vast scope of application.

Powertrain dynamics in your hands

» INNOVATIVE KEY FEATURES

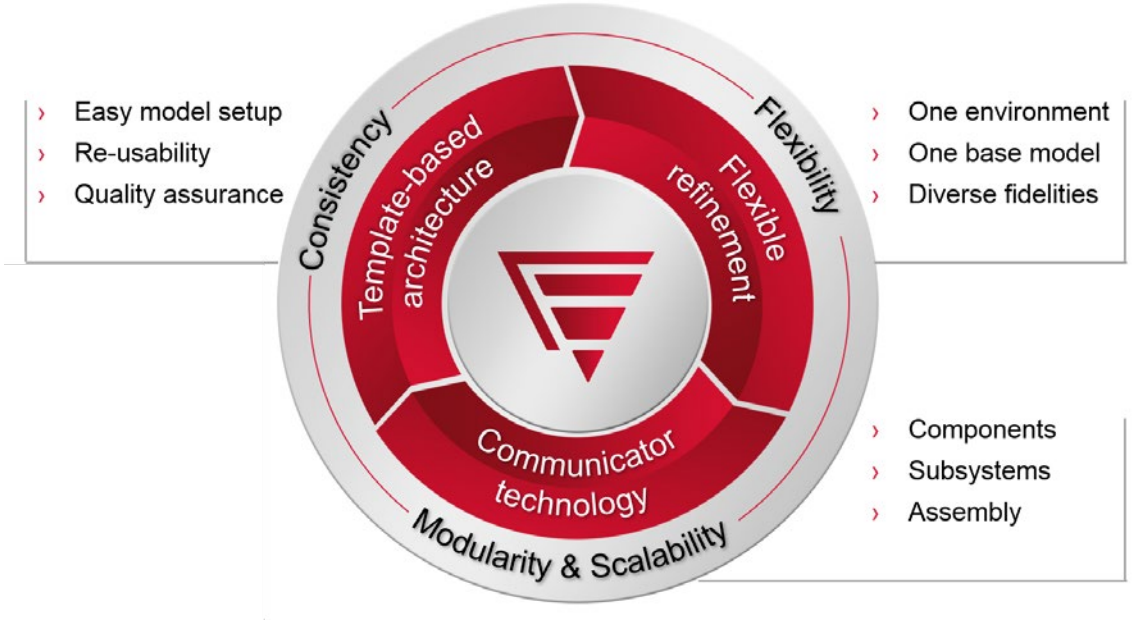
From powertrain engineers ***for*** powertrain engineers

Based on the state of the art GUI, solver and post processing technologies MSC Adams, Virtual Engine is:

> Easy to use in:
- Model set up and simulation
- Post-processing and result reporting

> Intuitive in workflows, fitting powertrain engineers' needs
> Integrated easily into existing processes
> One for all:
- One environment for all analysis
- One model for all phases of the development

> Proven technology: fast, reliable, and validated



BENEFITS AT THE GLANCE

> From project kick off to start of production
> With its advanced simulation tool "Virtual Engine" FEV provides:
- In shorter time
- Low cost
- High quality

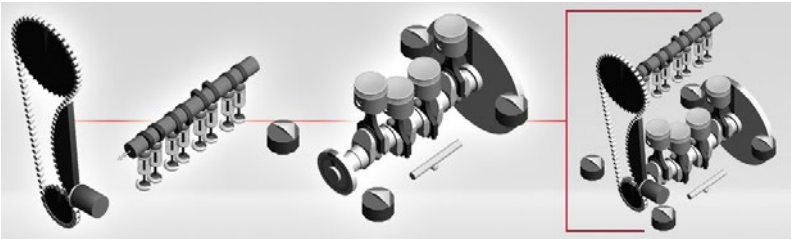
> Powertrain and driveline development

UNIQUE TECHNOLOGY

> From component to system level

> The unique communicator technology and the template-based architecture support modular modeling.

» FROM COMPONENTS TO SYSTEM LEVEL SIMULATION



Virtual Dynamics provides a modular modeling approach. One can build and analyze individual subsystems, which may consist of one component only or more. Virtual Dynamics is a so-called template-based product: every subsystem is derived from a template, which acts as blueprint for the subsystem and defines it's topology. Subsystems can be adjusted and refined to different fidelities as appropriate for the desired analysis. The unique communicator technology and the exceptional template-based architecture enable both modular and scalable modeling that correspond to both user's experience and functional simulation demands. Using the communicator technology complete powertrain can be built with the subsystems and run as a fully coupled model.

Virtual Dynamics and Adams Car share the template based architecture that perfectly combines the advantages of single purpose software-ease of use and multi-purpose software - no limitations in extendibility. Given the same template based architecture and communicator technology Virtual Dynamics powertrain model can be directly coupled to Adams Car`s vehicle model and this complete powertrain and vehicle system level model can be simulated dynamically.

» FIELDS OF APPLICATION

VIRTUALENGINE
Fields of application

E-mobility

Electric Motor | Hybrid | Range Extender | A48V HEV BSG

IC Engine

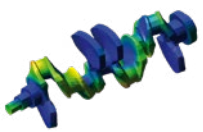
Valvetrain | Timing Drive | Cranktrain | Piston Group | VCR | Turbocharger

Driveline

Transmission | Testbench | Vehicle | A/C Compressor

» HIGH QUALITY SIMULATION

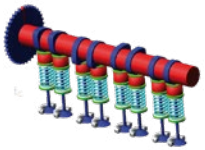
Cranktrain analysis



Virtual Engine supports modeling and simulation of all cranktrain types.

- > Load prediction
- > Firing order optimization
- > Crankshaft torsional vibration analysis
- > Crankshaft stress analysis
- > Cranktrain balancing
- > Connecting rod analysis

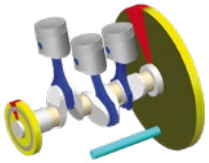
Valvetrain analysis



Virtual Engine supports multiple variations of valvetrain design.

- > Cam profile design
- > Optimum layout for best gas exchange
- > Maximum possible speed and seating velocity
- > Dynamic valve spring behavior
- > Friction prediction
- > Contact forces and hertzian pressures
- > Cam driving

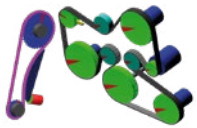
Piston and ringpack analysis



Virtual Engine predicts dynamics of the piston ring pack, piston, piston pin and connecting rod assembly

- > Piston slap & NVH analysis
- > Friction & wear prediction
- > Skirt profile and pin offset optimization
- > Ring pack optimization

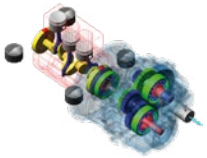
Timing and accessory drive



Virtual Engine builds complete, multi-staged timing and accessory drives.

- > Timing and accessory drive design
- > Chain / Belt dynamics
- > Belt life prediction
- > BSG start-stop systems
- > Drive layout
- > Tensioner system analysis

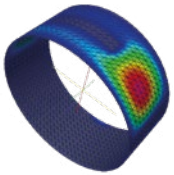
Geartrain and driveline



Virtual Engine provides complete tool set to build any type of geartrains and transmissions.

- > Transmission error and resulting speed irregularities
- > Gear whine & rattle
- > Backlash Studies
- > Tooth Loads

Bearing analysis

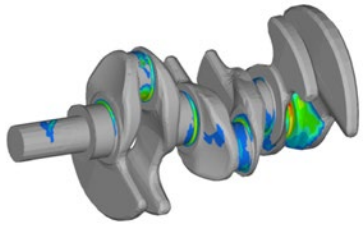


Virtual Engine has different fidelity levels bearing models.

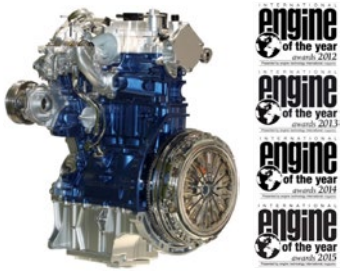
- > Minimum oil film thickness
- > Maximum oil and contact pressure
- > Displacements
- > Friction prediction
- > Wear prediction

» REFERENCES

From optimized component to award winning engine

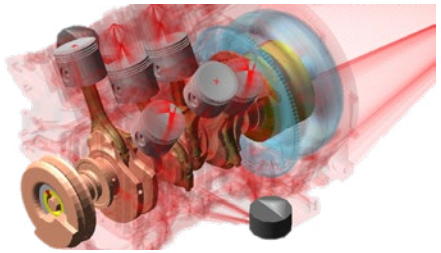


Friction optimized crankshaft
> Design & CAE for Pre-XO

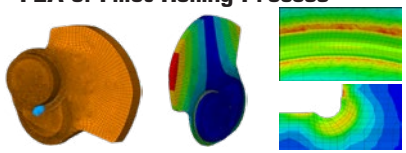


Friction optimized engine
> 1.0 l Ford EcoBoost, max. 103 kW/l*
> CO2 Emissions: 99-129 g/km

Dynamic Analysis of Fired Operation



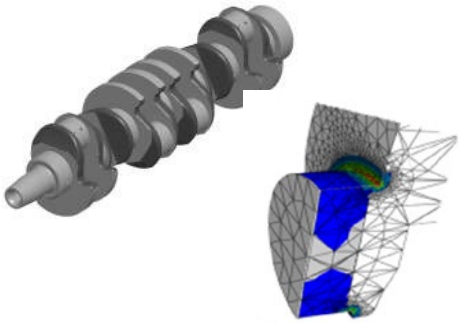
FEA of Fillet Rolling Process



Rolling Deflection Stress

> V6 Diesel Engine
> Optimization of Crankshaft Fatigue
> Elasto-dynamic Multi Body Simulations
> Explicit FEA of Fillet Rolling Process

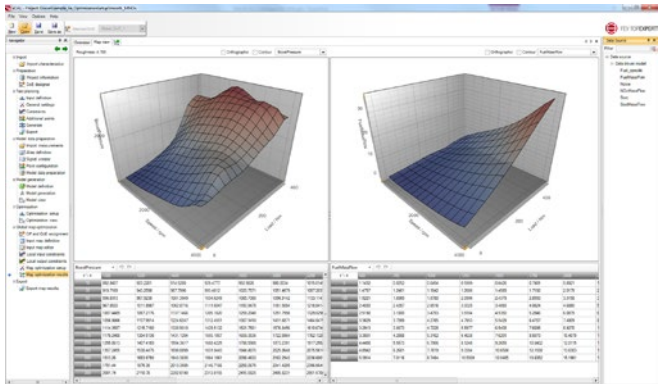
Optimized component layout for new engine derivate

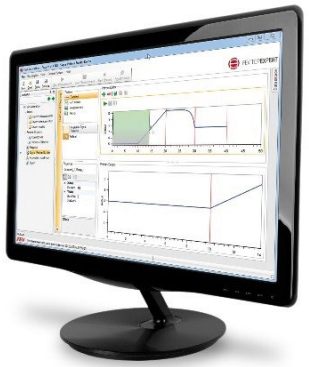


> Borderline crankshaft layout for conversion from I6 to V12 with identical bore pitch:

New engine: V12 16.8l EU Stage 4 / US T4f
> Bore / Stroke: 111 / 145 mm
> Rated Power: 440 – 750 HP @ 2.100 rpm
> Rated Torque: 3.000 Nm @ 1.500 rpm

» ADVANCED MODEL-BASED CALIBRATION





xCAL - Forward-looking DoE methodology

Thanks to impressive model quality and unique visualization capabilities, expenditures for tests and simulations can be drastically reduced

xCAL uses a high-performance DoE methodology to meet the special requirements of calibration engineers.

Special emphasis has been placed on developing fast and highly reliable modeling algorithms. xCAL makes it possible to quickly and conveniently investigate and optimize the engine's behavior.

MMBC – Morphee Model Based Calibration

Powerful algorithms are available in MORPHEE for online DOE, modeling and optimization.

Integration of advanced FEV algorithms direcly in Morphée in order to generate DoE, run the measurement phase safely according to engine hardware limits, model and optimize online.

MMBC provides the solution ensuring good model quality and additionally saving test bed and engineering time.

ASM Box – OBD Failure Simulation

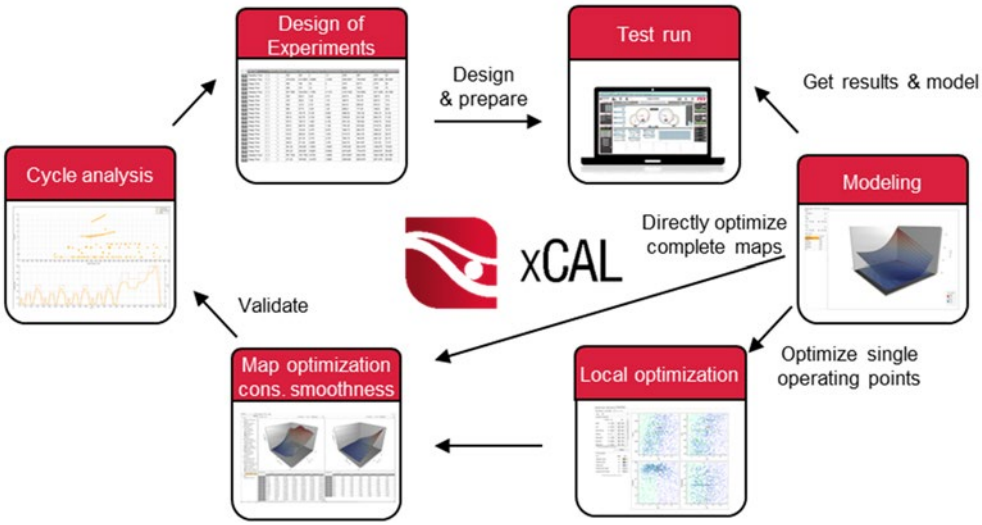
One Solution covering all signal failure pattern

The ASM Box allows efficient verification of PVE and OBD calibration via modulation of actuator and sensor signals, especially for U.S. homologation with government mode in addition to the common user mode. Because no faulty hardware is required for failure generation it achieves a cost savings of at least 20 percent in typical use cases. Using the ASM Box for automated drifting of sensor signals for robustness testing improves the quality as well as the efficiency.

> Easy realization of complex fuel system failure pattern:
> Injection cut-off
> Changing start of injection and injection duration
> Applicable for each partial injection
> Ignition turn-off

» CALIBRATION SOFTWARE

To meet the new regulations, and in particular the RDE (Real Driving Emissions) legislation, methodologies must change very rapidly: The use of modeling by experimental design and the generalized use of simulation are key elements. FEV has developed a series of methodologies which are incorporated into its software. A dual objective: To facilitate the task of the calibration engineer and to re-use these tests to simulate alternative cycles – and all within the framework of an increasingly multi-disciplinary and complex customer organization.
Limiting investment in new test resources initially means saving test bed time and, in particular, the time required for numerous iterations between the preparation for the tests in the design office and their implementation on the test bed. The FEV solution is based on two pieces of software: xCAL – the calibration platform with the initial role of defining the cycle then selecting and weighting the operating points to run at the test bed – and MORPHEE®, the automation system which also incorporates online calibration functions referred to as MMBC, MORPHEE® Model Based Calibration.



» XCAL: MODEL BASED CALIBRATION

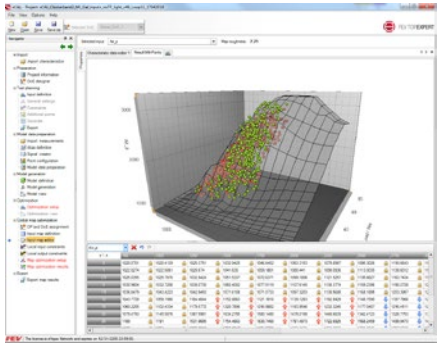
In response to increasingly stringent pollution standards and to optimally reduce fuel consumption, calibration processes have become extremely complex — both time-consuming and expensive. xCAL speeds the process up. For each stage, intuitive interfaces give control of the entire project back to the powertrain engineer. All data and results are available and shared on a single platform. Moreover, the tool integrates calculation algorithms and innovative modeling-based calibration methods throughout the process: cycle analysis, Design of Experiments, engine response modeling, control parameter optimization and new engine mapping with validation on the test bed. The tool comes directly from the expertise of powertrain engineers at FEV.

xCAL also enables this process to be improved by adopting a global approach, offering time savings of up to 50% on the test bed compared to a local approach: in contrast to a local approach where the engineer must optimise several engine operating points, a global approach allows the calibration engineer to optimise all the parameters across a broad scope of engine use with a single DOE. It should be emphasised that this approach not only allows the test time to be reduced but also improves the calibration process quality: FEV has observed fuel consumption gains of up to 7%.

BENEFITS

> User oriented workflow
> Rich graphical visualization options
> Advanced filtering and calculations of raw data
> Easy setup of complex design spaces
> Convex Hull based test plan.
> Best-in-class modeling algorithms (GP & Advanced GP)
> Multi-cycle and multi criteria optimization

Last but not least, xCAL is currently the only calibration tool fully integrated to optimise engine mapping in a single operation by taking account of the aggregate emissions at the outlet of the after-treatment system. Once again, gains of up to 10% can be expected thanks to improved engine/after-treatment compatibility.



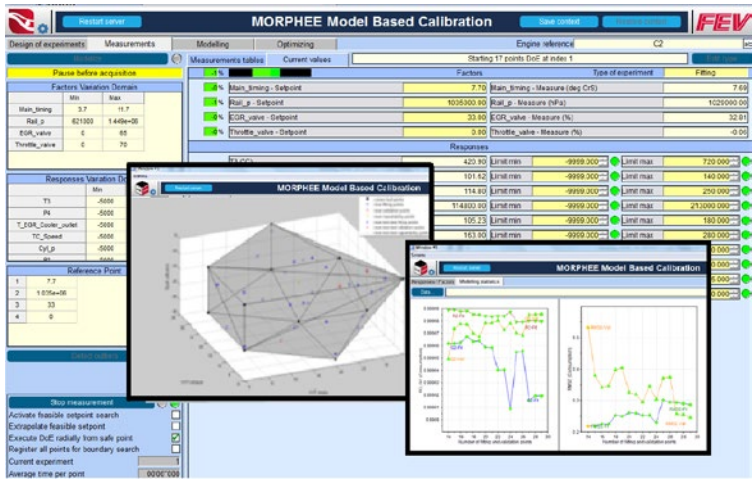
CHARACTERISTICS

> Cycle analysis
> Optimal and space-filling test designs
> Inputs domain limitation with convex hull based on measurment data.
> Multiple DoEs
> Design of Experiments
> Gaussian Processes model & Advanced GP
> Model export
> Multiple objective optimization
> Flexible calibration approaches
> Map smoothing & direct optimization
> Multi-cycle optimization
> After treatment efficiency taken into account

MORPHEE® Model Based Calibration (MMBC)

» MMBC USING MORPHEE TECHNOLOGY

MMBC enables online DOE to be generated at the test bed, evaluates model quality, and finds optima parameters for a target, validating the optimum without waiting. It uses the design of experiment, modeling, and optimization tool in the same software.



MMBC CHARACTERISTICS

> Generate online DOE: Base and adaptive
> Detect outliers automatically
> Model online any desired channel
> Validate prediction directly at test bed
> Evaluate model quality early on in the process
> Stop test if quality is enough and save time
> Find optimum parameters for a target and validate optimum without waiting

BENEFITS

> Generate online DOE: Base and adaptive
> Detect outliers automatically
> Model online any desired channel
> Validate prediction directly at test bed
> Evaluate model quality early on in the process
> Stop test if quality is enough and save time
> Find optimum parameters for a target and validate optimum without waiting

BENEFITS

Effective

The best of model based calibration for a standalone,
easy-to use,
powerful and flexible usage

Quality

Only one PC is running the test bed
>> cost effective, extremely fast set-up, and best possible real time solution

Efficiency

Flexible, simple, and independent solution:
>> create your desired procedure and controllers
MORPHEE is still the only master of the test

Scalability

Online DoE, modeling and optimization features directly in MORPHEE

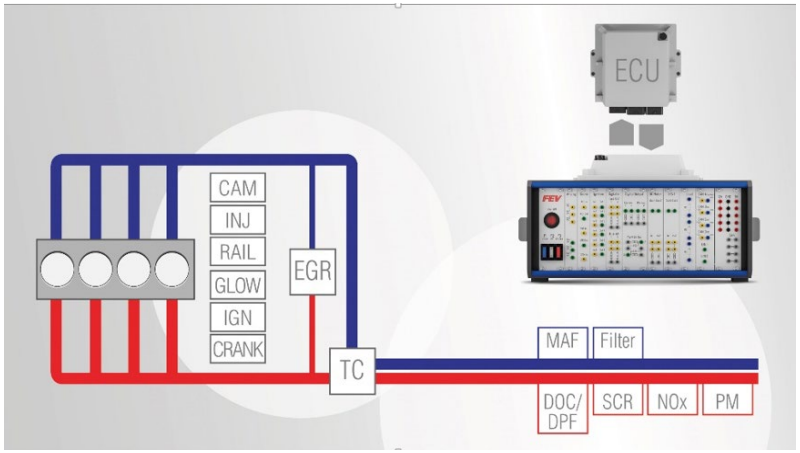
Open

Can run on different AuSy through a connection to an additional computer on which MORPHEE® is installed.

» OBD FAILURE SIMULATION

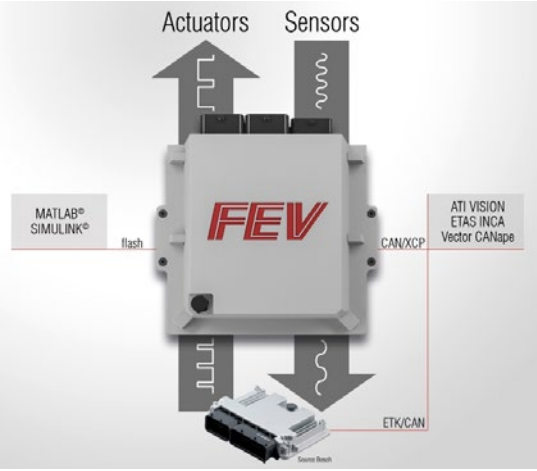
The system

The ASM Box allows efficient verification of PVE and OBD calibration via modulation of actuator and sensor signals, especially for homologation with government mode in addition to the common user mode. Because no faulty hardware is required for failure generation it achieves cost savings of at least 20 percent in typical use cases. Using the ASM Box for automated drifting of sensor signals for robustness testing improves the OBD system quality as well as the efficiency.



BENEFITS

> Easy realization of complex fuel system failure patterns:
  - Injection cut-off
  - Changing start of injection and injection duration
  - Applicable for each partial injection
> Ignition turn-off
> Convenient handling by versatile break-out box
> Full flexibility by failure pattern development in MATLAB/Simulink®
> Includes a base set of failure models
> XCP access for comfortable parametrization of failure models
> Binary oxygen sensor signal simulation
> Control system modulation e.g. SENT, LIN and CAN



» SUMMARY OF REALIZED SIGNAL FAILURE PATTERNS

The following signal failure patterns have been successfully realized with the ASM Box:

> CAN protocol for NOx sensors and PM sensors as well as modulation of any message on a powertrain CAN bus without interfering with other messages.
> For SENT protocol the feedback message of the Delta P sensor, EGR-LF and MAF sensor signals have been changed.
> Successful modulation via PWM signals of EGR-HF, AIR flap, MAF sensors, ignition and VVT actuators.
> Any temperature sensor and rail pressure sensor via analog signals.
> Oxygen sensor simulation for CJ135 has been realized for LSF, LSU4.9, LSU5.1 and LSU-ADV.
> One of the highlights are injection system failure patterns for both Solenoid and Piezo injectors. The common misfire patterns are realized as well as complex scenarios such as shifting the start and end of injection.

ASM Box is available in three variation

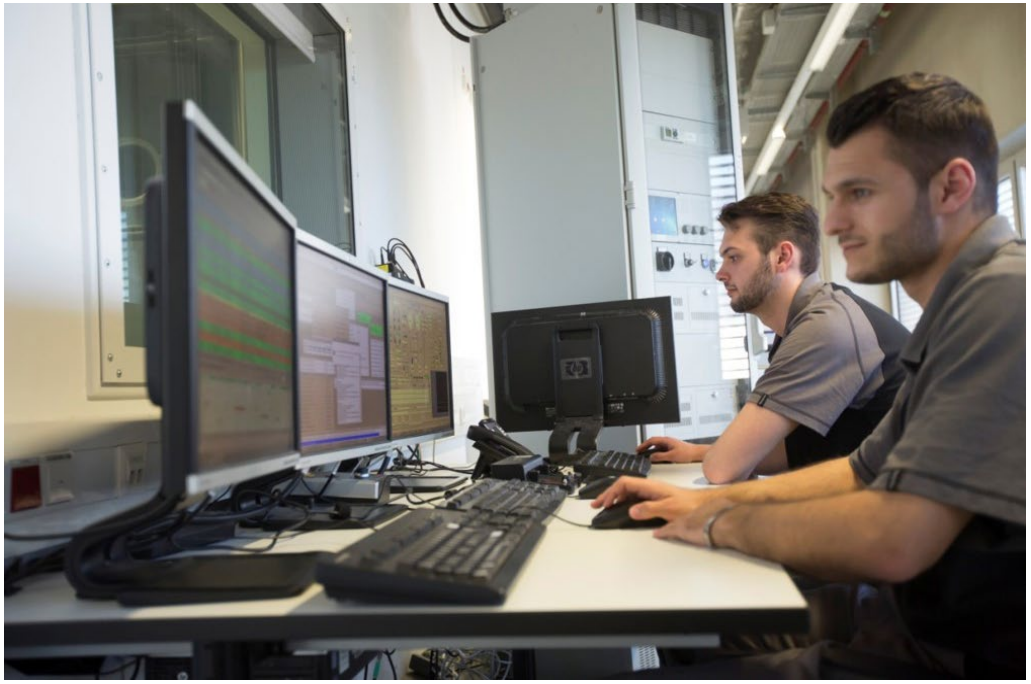
Special configurations on request.

ASM BOX product family

	ASM Box Solenoid	ASM Box Piezo	ASM Box Compact	ASM Box Misfire	ASM Box Motor-cycle
Analog I/O	6 / 3	6 / 2	8 / 4	x	4 / 4
Digital I/O	10 / 6	10 / 6	8 / 8	x	4 / 4
Speed sensor I/O (VRS & Hall)	1 / 1	1 / 1	x	x	x
Injectors I/O	6 (+2) Solenoid	6 (+2) Piezo	x	8 / 8 Piezo & Solenoid	8 / 8 Piezo & Solenoid
Ignition signal I/O (5V & 12V)	6 TTL	6 TTL	x	8 / 8 CoP & SoC	8 / 8 CoP & SoC
CAN I/O	4 / 4	4 / 4	4 / 4	x	4 / 4
LIN I/O	1 / 1	1 / 1	x	x	x
SENT I/O	2 / 2	2 / 2	2 / 2	x	1 / 1
LS switch I/O	2 / 2	2 / 2	2 / 2	x	2 / 2
LH switch I/O	2 / 2	2 / 2	2 / 2	x	2 / 2
DC motor I/O	2 / 2	2 / 2	1 / 1	x	1 / 1
Break-out Box	standard	standard	optional	x	x
Homologation View ComModule	standard	standard	optional	Misfire	Motorcycle
ASM Box models	standard	standard	optional	Misfire	Motorcycle
ASM Box model generation toolkit	standard	standard	optional	x	optional
Cables and plugs	optional	optional	standard	standard	standard
Lambda Module	optional	optional	optional	x	optional
Case	optional	optional	standard	standard	standard

» AUTOMATION

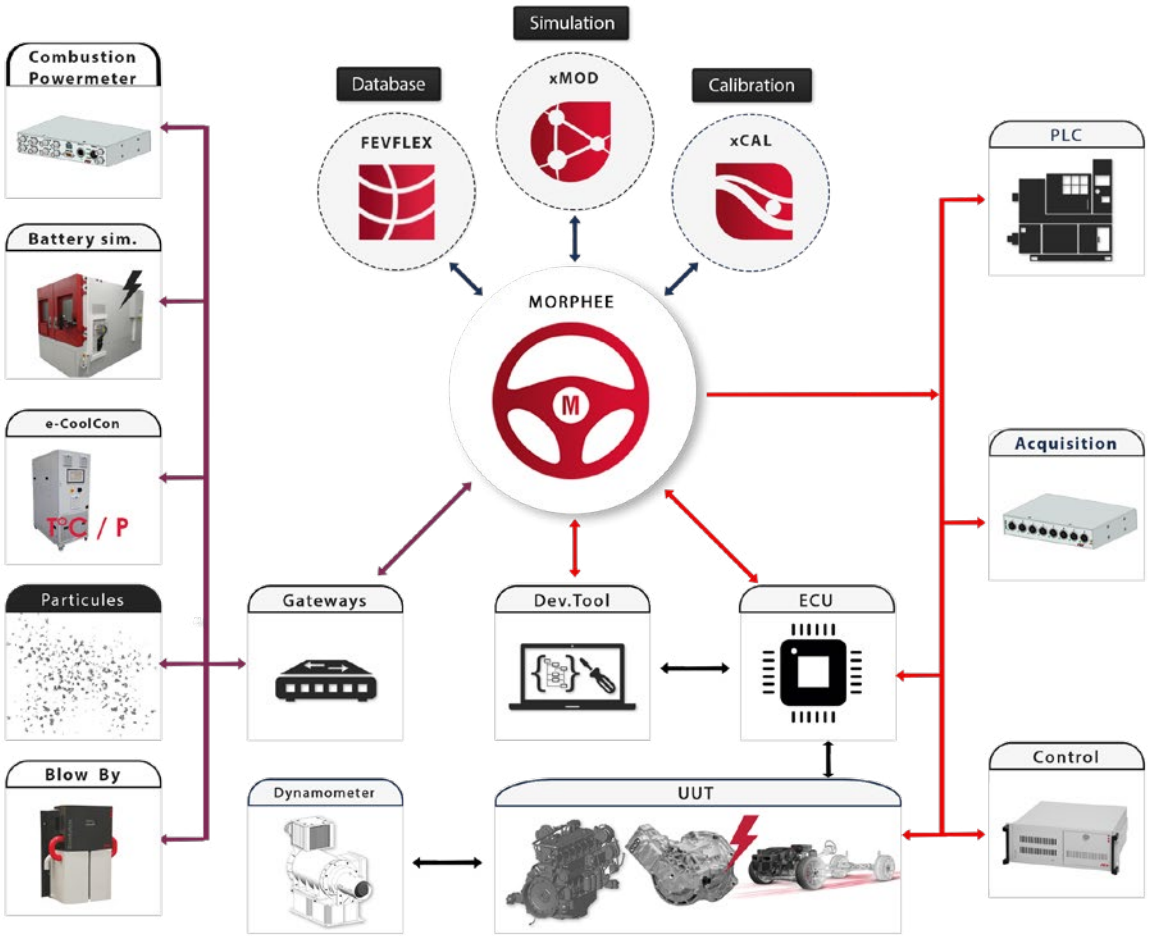
For more than 25 years, MORPHEE has been an established international reference for real-time automation of test cells under Windows. Being reliable, powerful, open and scalable, MORPHEE controls the test cells as safely as it can be.
Whatever kind of test facility, MORPHEE adapts to the customer working methods and provides the customer with the latest technology in order to reduce the development time. What makes MORPHEE unique, compared to other systems, is its ability to perform automation tasks, ECU calibration and real-time simulation in one single environment and PC (see page 80-85).



Where different software is often used on test cells, MORPHEE adapts to any type of UUT (Unit Under Test): ECU (HIL test bed), component, engine, powertrain, vehicle, etc. Due to its versatility, it is currently used in a number of different markets, including the automotive, aerospace, marine and energy sectors.

MORPHEE

> A unique system for automation, calibration and simulation
> 2900 licenses installed since 1991, 10,000 users and 12 million test bed running hours per year
> 5 mega samples per second
-->The most open system on the market

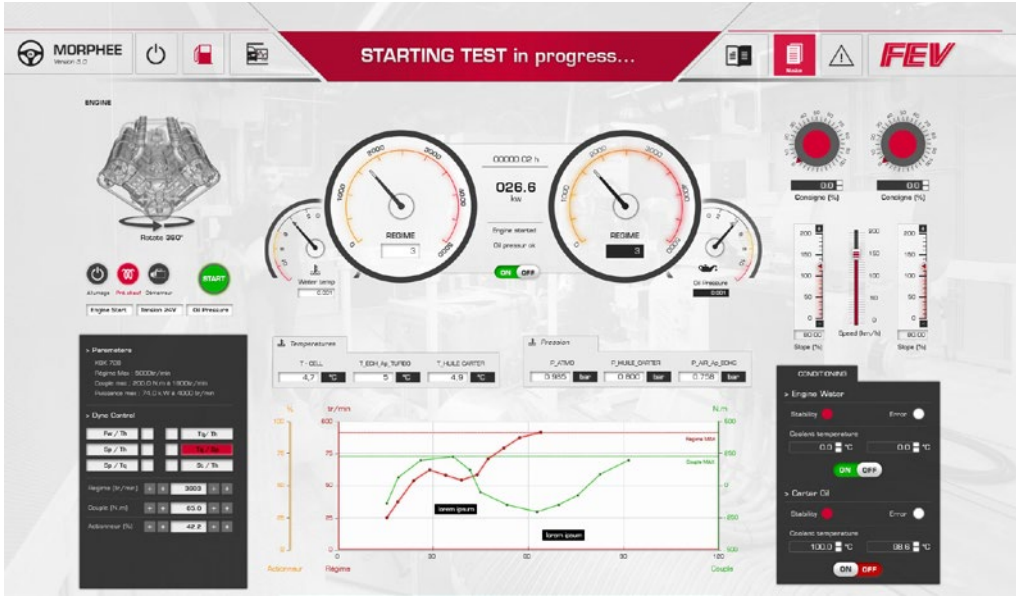


Typical MORPHEE architecture

FACTS

- > Easy communication thanks to MORPHEE architecture with third party products
- > A large range of standard drivers developed with the main equipment of the market
- > Always maintained and extended
- > Recognized characterisitics: the openess of the system means that MORPHEE is compliant with the standard interfaces

» AUTOMATION



MAIN FEATURES

> Measurements acquisition and storage
> Rolling data acquisition or post-mortem analysis
> Control of all kind of external devices (analog setpoints, digital commands, etc.)
> Monitoring of parameters, with several stop levels in case of an alarm
> On-line DOE testing and optimization
> Real time execution of models from simulation tools such as Matlab/ Simulink®/Amesim
> Etc...

» BENEFITS

Real time

Real-time system up to 10 kHZ; Typical 2kHz
Reliability: A system proven on more than 2,900 test beds
Efficient use of multi-processors, with selective tasks allocation

Future proof „old“ tests

Backward compatibility for your tests
Regular software updates based on the latest IT standards

Multimode

Actuator test bed: simple management, with just one mode
Engine test bed: advanced management with three modes.
- 1- test bed preparation, 2- manual test preparation and performance,
3- automatic testing
- The advantage: between two tests, no more need to stop and restart

Pro-active service

Hotline available to our maintenance contract customers

Future proof „new“ tests & equipement

Openness and flexibility for integration with any type of interface, equipment, etc.
Object-oriented structure (for managing measurement equipment)
Unlimited number of measuring/calculated channels, allowing tests to evolve
Easy test writing and modifi cation: graphic, through instructions, in VB.NET or C#.

Simulation

Real-time performance on test bed model using simulation tools
You can use your own models
HIL (Hardware In the Loop) tests

Standard

Libraries of standardized tests with emission calculations
Fast access to the ECU to reduce calibration time on the bench
A test editor structured like Windows Explorer, with all available files on a single screen

Autonomous

Independently describe your tests according to your own methodologies

» SOFTWARE PACKAGES FOLLOWING TYPE OF TESTS AND TEST CELLS

MORPHEE applications are fully packaged solutions for different types of tests, test beds an devices, following their level of complexity and purpose. A complete packaged application can be built with three levels of packages, the first one for the main structure and communication:

> The office package enables test engineers to prepare a batch of tests before launching them at the test bed.

> The lab package is the right solution for very simple component test bed, without the need of real time.

> The bench 1 package is usualliy dedicated to more complex components tests, such as pumps , battery (in case of durability tests...), running in real time

> The bench 2 package perform steaty state tests, for engine durability tests, and simple characterisation and calibration tests.

> The bench 3 package covers high dynamic tests, including simulation features (for example, the integration of models such as the driver...) and on-line calibration operations, with a direct link with ECU, the ECU application tool and the calibration system, such as xCAL Online (see pages 102-104)

SCALE: STANDARD AND CONFIGURABLE APPLICATION FOR LABORATORY ENVIRONMENT

The second level refers to the application following the Test Object - Gear box, Engine, Chassis dynamometers, battery, e-motor- and the type of tests - durability, calibration, performance characterization ... - They all have their dedicated screens, tests and processes.

The third level covers several functionalities - fuel measurement, raw or diluted emission measurements, combustion - and their related devices.
It means that when you enter in a MORPHEE environment, you have always a solution corresponding to your specific needs. This involve a clear view of the content of the offer, with no surprise, and a gain of time at the commissioning step. Communication, tests processes, screens are pre-defined and tested: the quality is improved, and the commissioning time is reduced. This advantage provided by FEV results of years of experience in test writing, preparation and commissioning in a very large scope of situations.

SCALE Component	SCALE Engine	SCALE Powertrain	SCALE Chassis Dyno	SCALE Battery	SCALE e-Motor
Available	*Available*	*12/2018*	*06/2018*	*06/2018*	*06/2018*
» Gearbox	» EOL, Durability	» 2 – 4 WD	» Durability	» Durability	» Durability
» Emission	» Transient	» IC simulation	» Emission	» R& D	» R & D
» Power	» Calibration	» High Dynamic	» Power		

COVERED FUNCTIONALITIES AND RELATED DEVICES

- Fuel measurement
- Conditioning
- Smoke measurement
- Blow By
- Opacimeter
- Particulate sampler
- Particulate counter
- Combustion
- Dyno control
- Emission (raw measurement)
- Emission (diluted measurement)
- Constant Volume Sampler (CVS)
- Power measurement

» PACKAGED APPLICATIONS FOLLOWING TYPE OF TESTS AND TEST BEDS

MORPHEE packages are fully packaged solutions for standard component and engine test beds including drivers, communication interfaces and test bed functions (component for devices such as emission benches, smoke meters). MORPHEE applications are standard pre-defined tests, including the screens.

EMISSIONS TESTS FOR HEAVY DUTY

MORPHEE emissions tests provide the highest level of automation on the market. The test procedure is fully automated, the de-normalization of the cycle is automatic. This is a flexible solution, with the possibility to execute not the complete, but only partial cycles, to calculate the emissions during the test in real time and to validate in real time that the test cycle driving is correct. It is compatible with trucks, buses and non-road applications.

Technical specifications

– Regulation associated with each Emission Test

Name		Regulation references
	ESC	European Directive 2005/78/EC
	ELR	European Directive 2005/78/EC
	ETC	European Directive 2005/78/EC
	NRSC_EU	European Directive 97/68/EC from march 2010 & ECE R96 Rev3
	NRTC_EU	European Directive 97/68/EC from march 2010 & ECE R96 Rev3
	SSC	Regulation and test cycle: EPA 40CFR 86N Engine testing procedure : 40 CFR 1065
	HD FTP 2007	Regulation and test cycle: EPA 40CFR 86N V2007 Engine testing procedure : 40 CFR 86 – raw gas emission analysis: ISO 16183 (Dec. 15th 2002)
	HD FTP 2010	Regulation and test cycle: EPA 40CFR 86N Engine testing procedure : 40 CFR 1065
	FST	EPA 40 CFR 86 2010 edition
	NRTC_US 2010	Regulation and test cycle: EPA 40CFR 1039 & ECE R96 Rev3 Engine testing procedure : 40 CFR 1065 & ECE R96 Rev3
	NRSC_US	Regulation and test cycle: EPA 40CFR 1039 – 1042–1045–1048–1051–1054 & ECE R96 Rev3 Engine testing procedure : 40 CFR 1065 & ECE R96 Rev3
	JE05	MLIT Publication 619 2002 : appendix 41
	WHSC	UN ECE R49 revision 6 from March 4th 2013
	WHTC	UN ECE R49 revision 6 from March 4th 2013
	WNTE	UN ECE R49 revision 6 from March 4th 2013

MORPHEE PACKS

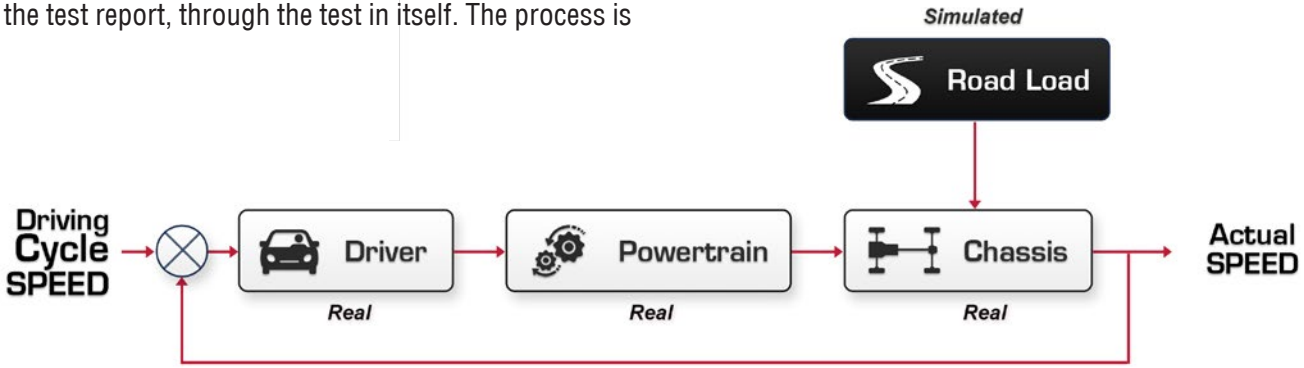
> Component Test Bed
> Standard Engine Test Bed
> Steady State Engine Test Bed
> Transient Engine Test Bed
> High End (All options)

MORPHEE APPLICATIONS

> Emissions Tests for Passenger Cars
> Emissions Tests for Heavy Duty
> Dynamic Simulation
> Chassis Dynamometer
> Battery Tests

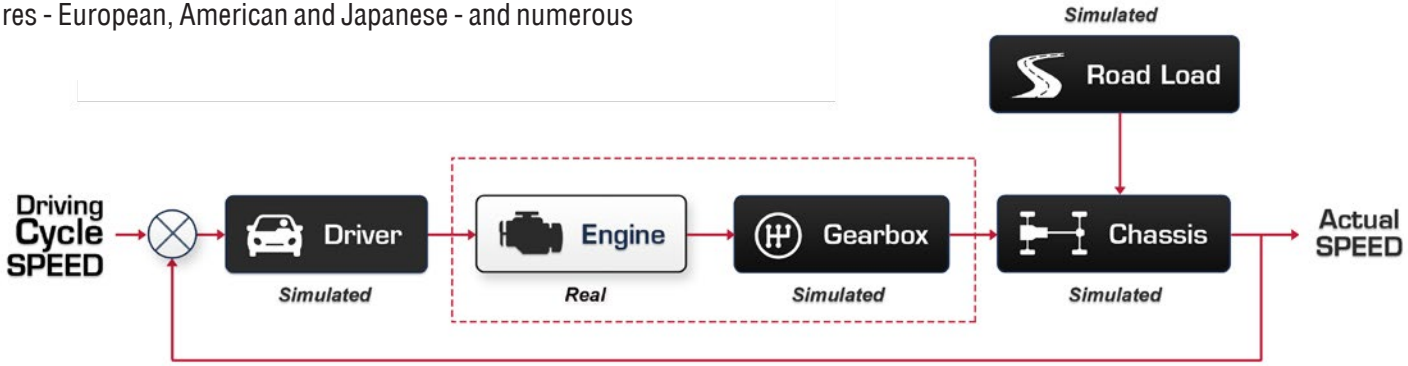
CHASSIS DYNAMOMETER

MORPHEE CHASSIS DYNAMOMETER covers the entire process, from the arrival of the vehicle to the test report, through the test in itself. The process is fully automated. The application follows the latest standards, including WLTP.



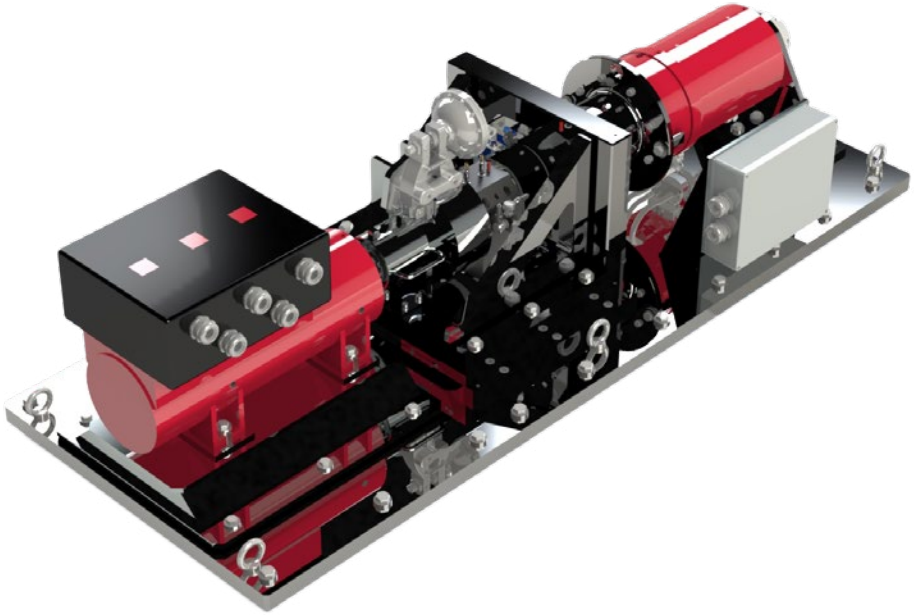
MORPHEE DYNAMIC SIMULATION

MORPHEE DYNAMIC SIMULATION allows to run at the engine test bed the tests usually performed on the chassis dynamometer: the reproduction of the vehicle dynamics is excellent, the cost is reduced - as it is a MORPHEE application - and the pollutant emissions are calculated automatically during the test. The application covers vehicle, driver and gear box models. Numerous standards test procedures - European, American and Japanese - and numerous emissions calculations - NOx, CO, CO2, HC, CH4, NMHC are available. The solution can be adapted to your specific needs: the vehicle models can be customized by various physical parameters, and it is possible to integrate customer's models.



» DYNAMOMETERS AND CONTROLLERS

The reliability of our dynamometers determines the rotation rate for your test beds.
Their dynamic, combined with effective control, allows the most demanding calibration and certification tests to be carried out on powertrain, engine, e-motor and component test beds.



DYNAMOMETERS

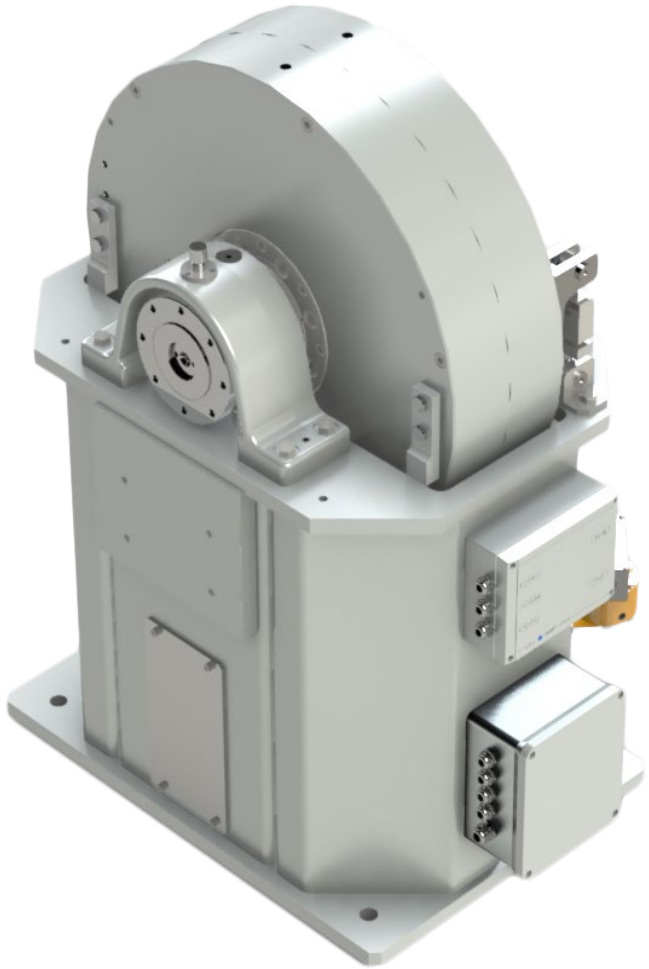
> Asynchronous, Eddy current and permanent magnet
> Expertise in vibration, shaft design, and ball bearing calculations
--> limited maintenance, and increased safety

CONTROLLERS

> All possible control (speed/torque/current)
> Adapted to a large range of drives and machines
> High performance thanks to EtherCAT link

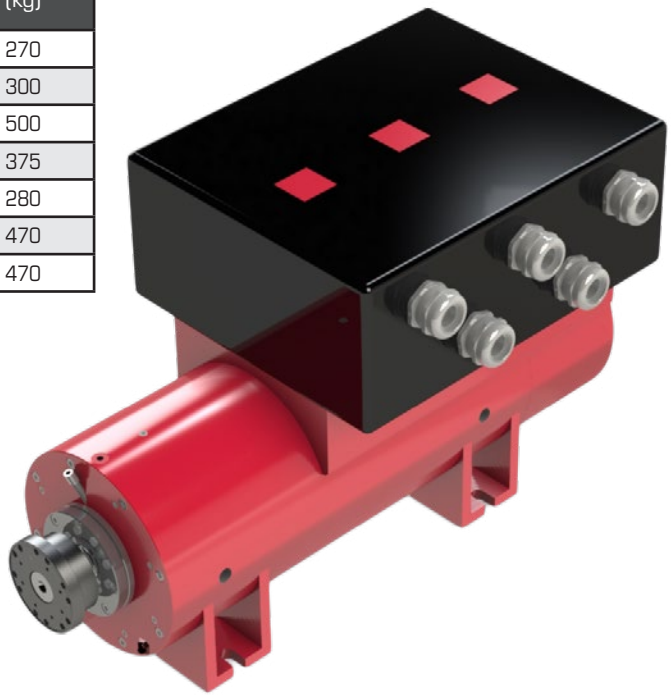
» DYNACRAFT - EDDY CURRENT DYNAMOMETERS

	Coupling	Rated Torque (N.m)	Speed range of max. torque (rpm)	Rated Power (kW)	Speed range of max. power (rpm)	Inertia (kg.m²)	Water flow rate (l/min)	Weight (kg)
DE 80	DIN90	200	2,500 … 3,800	80	3,800 … 2,000	0.02	40	300
DE 160	DIN120	400	2,000 … 3,500	160	3,500 … 10,000	0.09	135	520
DE 300	DIN150	900	2,000 … 3,200	300	3,200 … 10,000	0.18	135	600
DE 450	DIN180	2,000	1,100 … 2,150	450	2,150 … 8,000	0.95	290	1,300
DE 450 HT	DIN180	2,500	1,100 … 1,500	450	1,500 … 8,000	1.06	290	1,300
DE 500-2	DIN150 (M12)	1,250	1,500 … 3,800	500	3,800 … 8,000	0.38	300	800
DE 900	DIN180	5,500	1,125 … 1,600	900	1,600 … 4,000	4.05	500	2,200



» DYNACRAFT - e-MOTOR

	Rated power (kW)	Rated Torque (N.m)	Max Speed (rpm)	Nominal Speed (rpm)	Inertia (kg.m²)	Gradient (rpm/s)	Weight (kg)
DX170-01	175	200	20000	8350	0.063	30315	270
DX240-01	245	385	18000	6100	0.085	43252	300
DX250-01	250	450	20000	5300	0.139	30914	500
DX270-01	270	510	21000	5055	0.136	35810	375
DX270-02	270	390	20000	6670	0.086	43304	280
DX400-01	400	550	24000	7000	0.131	40100	470
DX430-01	430	700	20000	5900	0.131	51026	470



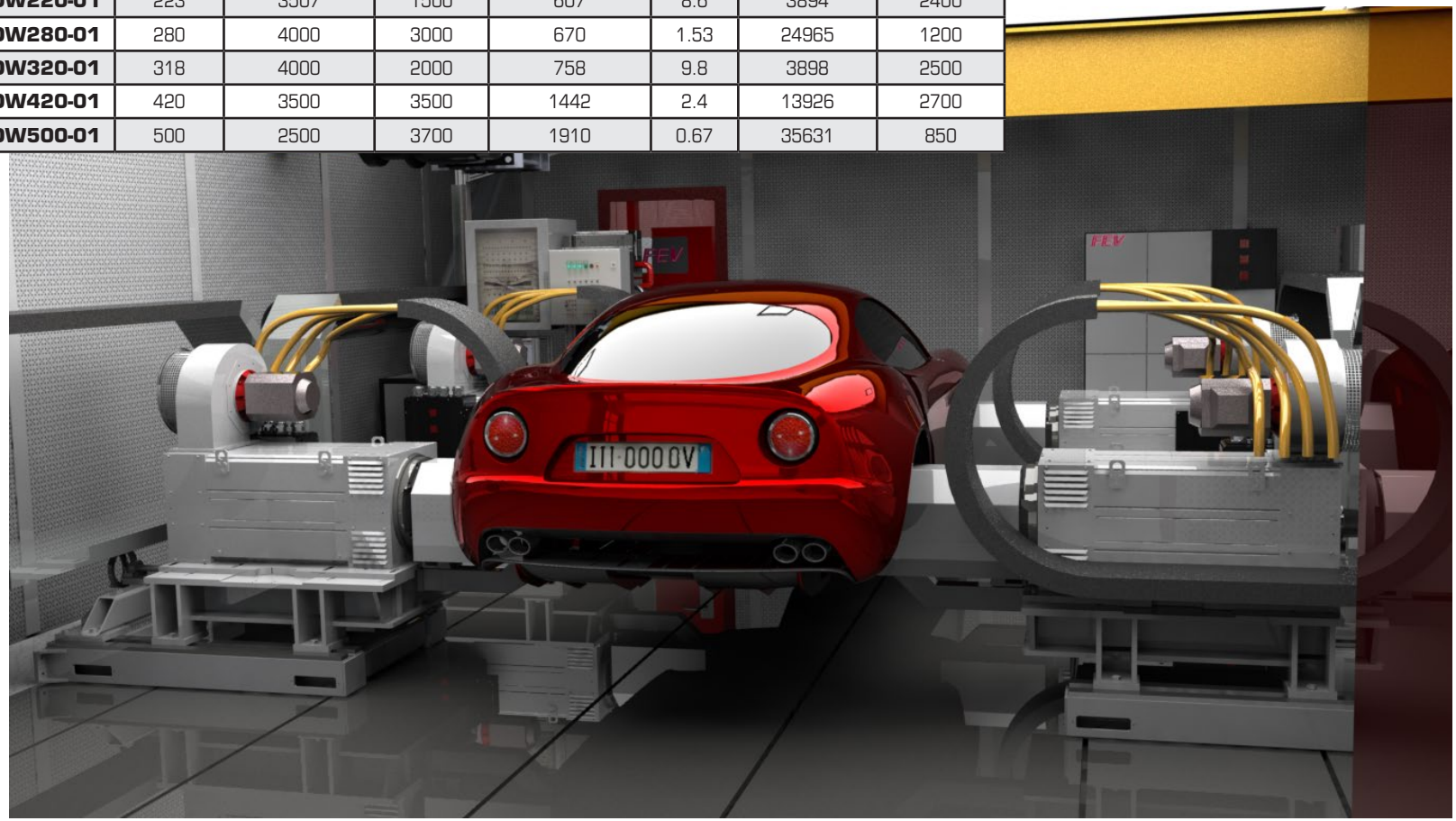
» ASYNCHRONOUS DYNAMOMETERS

	Rated Power (kW)	Rated Torque (Nm)	Max. Speed (rpm)	Inertia (kgm²)	Rotational Speed (rpm)	Gradient (rpm/s)	Weight (kg)
DM60-01	66	154	9000	0.11	4110	13369	310
DM130-01	132	250	10000	0.12	5021	19894	650
DM150-01	151	327	10000	0.20	4402	15613	600
DM160-01	160	350	10000	0.22	4370	15192	850
DM250-01	250	550	10000	0.29	4340	18111	900
DM250-02	252	473	10000	0.30	5090	15056	740
DM300-01	300	700	10000	0.65	4090	10284	1200
DM350-01	350	732	9000	0.65	4566	10754	1000
DM380-01	380	815	10000	0.65	4450	11973	1200
DM400-01	409	794	9000	0.85	4914	8920	1350
DM450-01	452	1000	9000	0.85	4312	11234	1350
DM500-01	500	1100	8500	0.90	4340	11671	1450
DM600-01	600	1350	6000	1.15	4240	11210	1550

	Rated Power [kW]	Rated Torque [Nm]	Max. Speed [rpm]	Inertia [kgm²]	Rotational Speed [rpm]	Gradient [rpm/s]	Weight [kg]
DM250-03	250	1100	8500	0.9	2170	11671	1500
DM300-02	300	1400	7500	1.8	2040	7427	1600
DM380-01	380	1800	7500	2.3	2015	7473	1700
DM470-01	470	2200	7000	2.7	2040	7781	1900
DM530-01	530	3000	65000	3.0	1740	9549	2000
DM630-01	630	3500	4500	4.5	1720	7427	2700

DYNACRAFT WHEELS

	Rated power (kW)	Rated Torque (N.m)	Max Speed (rpm)	Nominal Speed (rpm)	Inertia (kg.m²)	Gradient (rpm/s)	Weight (kg)
DW200-01	200	2500	3000	765	0.67	35631	790
DW220-01	223	3507	1500	607	8.6	3894	2400
DW280-01	280	4000	3000	670	1.53	24965	1200
DW320-01	318	4000	2000	758	9.8	3898	2500
DW420-01	420	3500	3500	1442	2.4	13926	2700
DW500-01	500	2500	3700	1910	0.67	35631	850



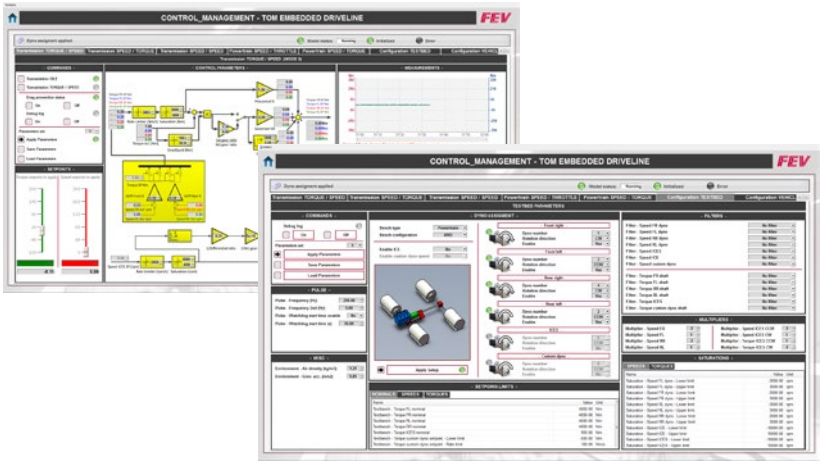
» TOM, A MODEL-BASED CONTROLLER FOR UP TO 5 DYNAMOMETERS

The scalable controller

TOM is a universal controller unit that can handle all types of loading units and test objects; as well as be seamlessly integrated into any testing environment. All established control modes are available and can be switched bumpless during operation. TOM can be operated either remotely via the automation system; locally or optionally via an external control panel.

TOM offers integrated basic monitoring of the tested object, where, in case of a limit violation, it responds in a way to secure the test object by bringing it into a stable operating condition. The TOM is modularly extendable; and compiled real-time models can be integrated easily.

Real time networking allows for engines, e-motors and transmission test benches to be connected in one virtual overall system.



TOM BENEFITS

- Compatible for e-drive and hybrid
- High-speed performance in real-time allows integrated execution of MATLAB/Simulink models
- High dynamic simulations (wheel slip, RLS, Inertia, ETPS)
- Secure operation via the integrated multi-layered test object monitoring
- Integrated limit observation with selectable error reaction
- Easy online tuning
- Pre-defined test object configurations can be stored locally or be loaded via network
- Flexible scope for engine test benches
- Modular framework allows tailor-made configurations
- Pre-integrated selection of standard devices and actuators as well as easy integration of new test bench devices and actuators
- Integrated Restbussimulation Devices
- Highly flexible dyno assignment functionality for multi-machine control
- Easily extendable by different hardware interfaces

» DCU 3000, THE CONTROL UNIT FOR EDDY CURRENT DYNAMOMETERS

The Digital Control Unit DCU 3000 is a cutting edge technology system dedicated to the controlling of an Eddy Current dynamometer and an IC engine. It manages all the control modes of your engine test beds in a fully secure and highly precise manner.

The DCU uses EtherCAT bus, an open high performance Ethernet-based field bus system. It enables to support higher frequency, up to 10kHz. Its main goals are to have shorter data update times and to have low communication jitter without increasing wiring and hardware costs.

DCU 3000 BENEFITS

- All control modes are possible for speed, torque and current
- High performance thanks to EtherCAT bus
- Dedicated filtering for engine applications
- Integrated alarms management for secured test bed shut downs

» SERVOCRAFT, THROTTLE ACTUATOR

The FEV ServoCraft is a universal linear-actuator for operation of throttle valves and injection pumps for combustion engines. The actuator consists of a brushless servo motor.
The rotary motion is transformed into a highly accurate linear motion with integrated position feedback signal.
The control and power unit is a compact 19“ rack of 3 HU while the included remote control can be placed close to the actuator for easy adjustment and maintenance.

SERVOCRAFT BENEFITS

- Highly accurate linear drive unit,maintenance-free construction
- Easy operation
- Graphical 3,5“ full colour QVGA touch-screen user interface
- Drive mode selectable between set-up and operation
- External set point input and position feedback
- Setup operation manualy or automatically
- Actuation force adjustable

» EPS 3000, ELECTRONIC ACCELERATOR PEDAL FOR ENGINE TESTS

The EPS 3000 is an easy to use and efficient system dedicated to simulate the behavior of a vehicle pedal on a test bed. It controls the load set point of an engine, either by direct connection to the ECU or through a mechanical actuator.

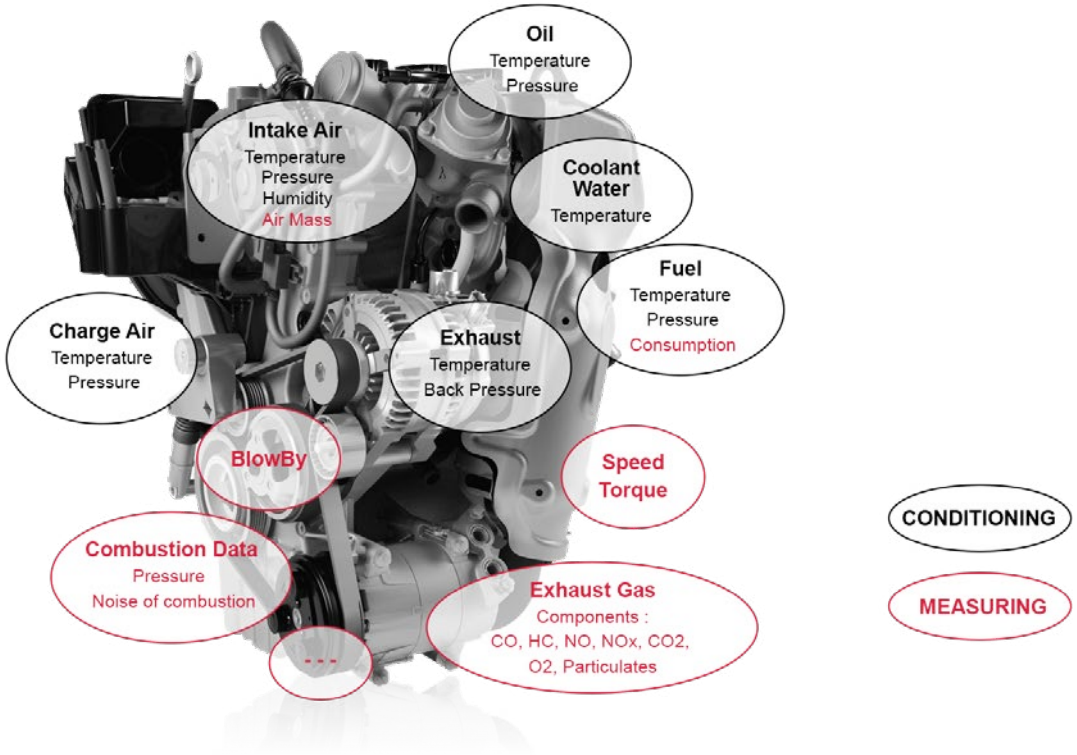
EPS 3000 BENEFITS

- Direct connection to the ECU
- High protection for installation very close to the engine
- Two independent and isolated output signals
- High resolution control
- Fast response time
- Configuration either by points or by segments Display of load level

» CONDITIONING

The FEV conditioning units range provides constant boundary conditions to achieve representative and reproducible test results. As a result, it reduces the number of necessary measuring points for validation of small changes in measuring results.

It also reduces the measuring time as it reaches the desired constant measuring boundary conditions faster. Testing lead time is reduced, along with resource requirements (personnel, test bench, equipment). The other functionality of the conditioning units is to establish defined starting conditions through engine preconditioning.
This improves the utilization of measuring equipment which has a shorter lifetime or is susceptible. It also improves the utilization of test cells which require defined starting conditions (e.g. cold starts)



» WHERE TO USE CONDITIONING UNITS

	AirCon	ChargeCon	CoolCon	CoolCon Basic	LubCon	LubCon Basic	LubCon Trans	FuelCon	E-CoolCon
EU6 / EU7 test bench	Required		Required		Required			Required	
Durability test bench			Recommended	Required		Recommended		Required	
Single cylinder test bench	Required	Required	Required		Required			Required	
Hybrid test bench			Recommended	Required			Recommended	Required	
End of Line test bench			Recommended	Required				Required	
Friction test bench			Required		Required			Required	
Power train test bench			Required		Required		Recommended	Required	
Transmission test bench							Recommended		
E-axle test bench									Required
Hybrid drive trains test bench									Required
Battery test bench									Required

» AIRCON: COMBUSTION AIR PRESSURE, TEMPERATURE AND HUMIDITY CONTROL

Combustion air pressure, temperature and humidity have a significant influence on an internal combustion engine's power output and exhaust emissions. To gain a good reproducibility of measuring results, and with this an increased test cell utilization these conditions have to be kept constant within narrow limits.

The combustion air conditioning system FEV AirCon meets this demand by controlling the combustion air temperature, pressure and humidity (option) independently of climatic and engine operating conditions.

The control and regulation of the system is performed by an on-board controller mounted in the control cabinet. For communication with the test bench computer several interfaces (TCP/IP-CSM, TCP/IP-AK, EtherCat, CANraw, ProfiBus) are available which enable direct connection to test bench computers that support these interfaces. A discrete interface (option) enables simple communication with the system by means of analogue and digital signals.

For quality assurance we supply the FEV AirCon pre-commissioned and with pre-defined PID parameters to guarantee quick and easy installation on site.

AIRCON BENEFITS

- Stable experimental conditions reduce test cell time
- Wheel base enables flexible use at different test cells
- Simple operation
- Low maintenance
- Wide range of application

» COOLCON: COOLANT TEMPERATURE CONDITIONING

Coolant temperature has a significant influence on the thermodynamic and mechanical behavior of an internal combustion engine (e.g. BSFC and emissions). To increase test cell utilization, coolant temperature is to be controlled exactly.

The coolant conditioning system FEV CoolCon performs this function automatically by controlling the coolant temperature independently of engine operating conditions. The control and regulation of the system is performed by an on-board controller mounted in the control cabinet.

For communication with the test bench computer several interfaces (TCP/IP-CSM, TCP/IP-AK, EtherCat, CANraw, ProfiBus) are available which enable direct connection to test bench computers that support these interfaces.

For quality assurance we supply the FEV CoolCon pre-commissioned and with pre-defined PID parameters. This guarantees quick and easy installation on site.

COOLCON BENEFITS

- Stable experimental conditions reduce test cell time
- Wheel base enables flexible use at different test cells for mobile coolcon version
- Simple operation
- Low maintenance
- Wide range of application

» INTERCOOLER: CHARGE AIR TEMPERATURE CONDITIONING

Charge air temperature has a significant influence on the thermodynamic and mechanical behavior of an internal combustion engine (e.g. BSFC and emissions). To increase test cell utilization, charge air temperature has to be controlled exactly.

FEV's charge air conditioning system "InterCooler" performs this function automatically by controlling the charge air temperature, independent of climate and engine operating conditions.

FEV InterCooler offers a compact and space-saving design. Installation is quick and easy. Only the power supply and a control line as well as the cooling system and piping between the engine and the system need to be connected.

For communication with the test bench computer several interfaces (TCP/ IP-CSM, TCP/IP-AK, EtherCat, CANraw, ProfiBus) are available which enable direct connection to test bench computers that support these interfaces.

For quality assurance we supply the FEV InterCooler pre-commissioned and with pre-defined PID parameters to guarantee quick and easy installation on site.

INTERCOOLER BENEFITS

- Stable experimental conditions reduce test cell time
- Quick and easy installation
- All system components easily accessible (maintenance friendly)
- All components are either maintenance-free or require only low maintenance levels
- Compact and space saving design
- Simple operation

» RACECON: FAST CONTROL OF COMBUSTION AIR PRESSURE, TEMPERATURE AND HUMIDITY

Combustion air conditions have a significant influence on the performance of an internal combustion engine. For certain applications, e.g. for race engines, combustion air conditions can change very fast, depending on the different driven speeds. For reproducible testing and calibration of these engines under “real world” conditions a steady state controlling of the combustion air parameters is not sufficient. In this case a very fast control of the combustion air conditions is necessary.

To meet these dynamic requirements FEV has made a further development of the FEV AirCon. The FEV RaceCon improves the velocity of combustion air pressure control significantly. The control and regulation of the system is performed by an on-board controller mounted in the control cabinet.

For communication with the test bench computer several interfaces (TCP/IP-CSM, TCP/IP-AK, EtherCat, CANraw, ProfiBus) are available which enable direct connection to test bench computers that support these interfaces.

For quality assurance we supply the FEV RaceCon pre-commissioned and with pre-defined PID parameters to guarantee quick and easy installation on site.

RACECON BENEFITS

> Dynamic control of combustion air pressure
> Wheel base enables flexible adaptation for different test cells
> Simple operation
> Low maintenance
> Wide range of application

» CHARGECON

Test engineers face special problems during the first stages of the development of a new supercharged engine. Either a matching turbocharger is not available in time or the charge air conditions have to be varied over a wide range, independent of the engine's operating point, the ambient pressure or test cell temperature.

The variable boosting system FEV ChargeCon solves these problems. It provides the required levels of combustion air pressure and temperature. It maintains these levels over a wide range within narrow limits. The control and regulation of the system is performed by an on-board controller mounted in the control cabinet. For communication with the test bench computer several interfaces (TCP/IP-CSM, TCP/IP-AK, EtherCat, CANraw, ProfiBus) are available which enable direct connection to test bench computers that support these interfaces.

CHARGECON BENEFITS

> Stable experimental conditions reduce test cell time
> Wheel base enables flexible use at different test cells
> Simple operation
> Low maintenance
> Wide range of application

» LUBCON

Lube oil temperature and pressure have a significant influence on the friction behavior, resulting in deviations of BSFC and emissions. To increase test cell efficiency, the conditions of the lubrication oil have to be controlled exactly.

The lube oil conditioning system FEV LubCon performs this function automatically by controlling the lube oil temperature and pressure independently of engine operating conditions. Due to the system design, oil quality is not affected during the heating process. The control and regulation of the system is performed by an on-board controller mounted in the control cabinet.

For communication with the test bench computer several interfaces (TCP/IP-CSM, TCP/IP-AK, EtherCat, CANraw, ProfiBus) are available which enable direct connection to test bench computers that support these interfaces.

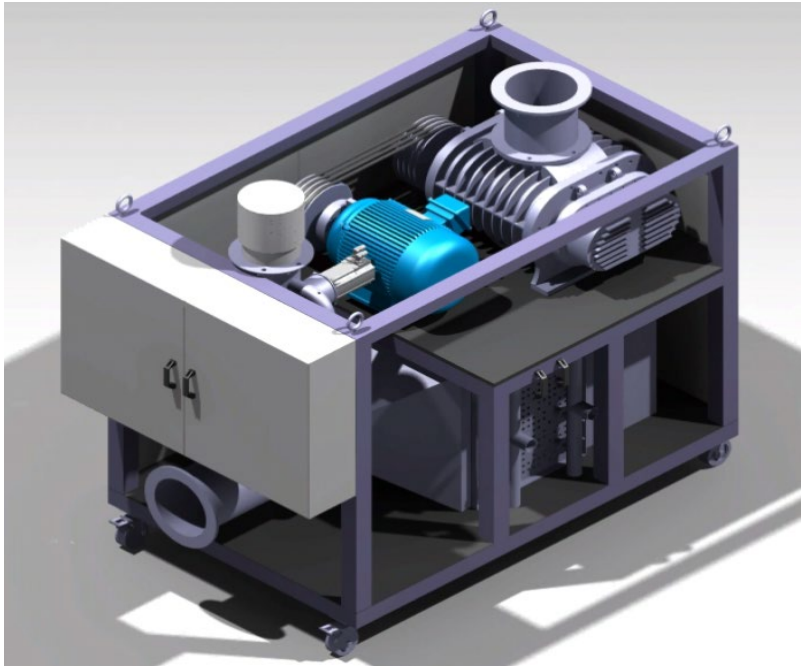
For quality assurance we supply the FEV LubCon pre-commissioned and with pre-defined PID parameters to guarantee quick and easy installation on site.

LUBCON BENEFITS

- Stable experimental conditions reduce test cell time
- Wall mounted or stand-alone design allows flexible adaptation to different testing purposes
- Intermediate circuit avoids oil cracking during heating
- Simple operation
- Low maintenance
- Wide range of application

» HIGH ALTITUDE SIMULATION SYSTEM

The altitude significantly affects the emissions from the engine. With the emission legislations getting stringent day by day, it has become imperative to calibrate & validate the engines at a wide range of altitudes.
To reduce the time and cost to test the units at different altitudes, it is preferred to simulate the different altitude conditions and keep them constant and reproducible.
To meet this requirement, FEV has developed a system for altitude variation in order to simulate the effect of different altitudes on the engine by varying the pressure on the engine exhaust and air intake.
The control and regulation of the system are done by an on-board controller mounted in the control cabinet. For communication with the test bench automation system, several interfaces (TCP/IP-CSM, TCP/IP-AK, EtherCat, CANraw, ProfiBus, ProfiNet) are available which enable direct connection to test bench computers that support these interfaces.
For quality assurance we supply the ASS pre-commissioned and with pre-defined PID parameters to guarantee quick and easy installation on site.



Your Benefits

> Stable experimental conditions reduce test cell time
> Wheel base enables flexible use at different test cells
> Simple operation
> Low maintenance

Technical Specifications

> Altitude simulation from 0 to 5000m from sealevel (others on demand)
> Flowrate - 1250 kg/hr @5 000m from sealevel
> Temperature control in combination with Combustion Air Conditioning System

» FUELCON / FUELRATE

In the race to reduce CO2 emissions, the optimization of fuel conditions and the precise measurement of fuel during engine development are becoming increasingly important. Moreover, modern engines must be designed to save resources by reducing fuel consumption significantly.
To meet these ever increasing challenges, FEV has significantly improved the well established fuel-conditioning and consumption measurement system, FuelCon and FuelRate, by simplifying the overall design and modularizing the entire system. Design simplification and modularity make the new systems highly scalable and a safe investment.
The FEV FuelRate has numerous benefits only a modern device can offer: high accuracy, excellent reproducibility, robustness, high resolution... The FuelRate can be used for stationary and dynamic testing.

FUELCON BENEFITS

> Excellent fuel temperature control
> Fuel circuit free of non-ferrous metal
> Easy to maintain, lean layout
> Excellent price - performance ratio

FUELRATE BENEFITS

> Dynamic mass flow measurement
> High accuracy – excellent repeatability
> Broad range of applications (gasoline, diesel, alcohols)
> All fuel conducting components are free of non-ferrous metals
> Easy calibration of the measuring chain
> Low maintenance
> Excellent price-performance ratio

» AEROMETER GAS CONTENT DETERMINATION OF LUBRICANT

For more than a decade, the FEV Aerometer has represented a reliable solution for the determination of the gas content in lubricants during engine operation. Its unique capability to consider not only the free (dispersed as bubbles) portion of the gas, but also the fraction that is dissolved in the oil as well as the standardization of the measurement result, have established the FEV Aerometer as the standard for the development and optimization of lubrication system performance in the field of oil aeration at OEM sites all over the world

AEROMETER HIGHLIGHTS

> Automatic withdrawal of oil sample from engine lube system under operation condition
> Evacuation of oil sample for extraction of dissolved air from the oil
> Volumetric determination of gas content under standard pressure of 1013 mbar and to standard temperature of 293 K

AEROMETER FEATURES

> Easy operation by automatic control unit
> Reliable and reproducible rating of oil aeration performance of any engine type on base of entire gas content in the oil (free and dissolved)
--> This determination of total gas content is recognized and defined as standard by many renowned OEM's worldwide

» AERO2METER : GAS CONTENT DETERMINATION OF LUBRICANT

Although the current FEV Aerometer is well suited for manually conducted investigations, it requires a manual recording of the oil column height and manual value input into the control unit after the measurement cycle. These features disqualify it for fully automated test runs. In order to fill this gap, FEV has developed the new FEV Aero2meter (Fig. 1). While retaining the volumetric measurement principle of the absolute gas content, the design of a new cylinder unit incorporates a new drive concept and an additional compressibility test device while allowing elimination of the manual read out and value input step. As a result, the new FEV Aero2meter now is capable to conduct fully automated measurements, which allows implementation into fully automated unmanned test bench surroundings.

AERO2METER HIGHLIGHTS

> Fully automatic withdrawal and analysis of oil sample from engine lube system under operation condition
> Capable of being integrated in test cell automation system with additional stand-alone data acquisition
> Evaporation of oil sample for extraction of dissolved air from the oil and volumetric determination of gas content related to ambient conditions

AERO2METER FEATURES

> Adoption and improvement of measuring principal of original Aerometer with following key advantages
- Fully automatic unmanned operation
- Improved operating conditions (max. oil pressure: 10bar (+2 bar), max. oil temperature: 150 °C (+30 °C)
- No compressed air supply needed
- Compact design

» BLOW BY MEASURING SYSTEM

The FEV BlowByRate provides continuous measurement of BlowBy gases leaking into the crankcase during combustion engine operation.

Combustion engine cylinder gases can leak into the engine crankcase in a variety of ways – including around the pistons, piston rings, and valve guides. In supercharged engines with a turbo charger, gases can also leak through the bearing and bearing gaskets. BlowBy gases, once in the engine crankcase, will leak out of the engine through the crankcase ventilation system.
Experience shows that measuring the amount of BlowBy gases during engine operation provides a very good method for determining the integrity of pistons, piston rings, and the cylinder wall. Continuous monitoring for increased or decreased BlowBy levels can provide immediate indication that changes in the engine may have occurred. The amount of BlowBy can increase for a number of reasons including a reduction of the mobility of the piston rings due to oil carbon buildup or a lack of the lubrication and seizing of the pistons or the piston rings.
The amount of BlowBy can decrease due to deposit formation along the bottom of the piston ring grooves.
Early detection of engine changes using the FEV BlowByRate can lead to a reduction in test times and prevention of test object damage. The FEV BlowByRate is a robust, reliable, and user friendly system providing accurate BlowBy measurement in spite of contamination from BlowBy gas.

» AIR MASS FLOW MEASURING SYSTEM

Increasing demands to the protection of the environment require more and more complex measures to lower the fuel consumption and emissions of internal combustion engines. Even small changes to an engine have to be validated in thorough tests on engine test benches. In this process the accurate measurement of the combustion air mass flow is extremly important. For this purpose FEV has developed the FEV-AirRate, which meets all current demands concerning a state of the art measuring system for combustion air mass flow. The FEV-AirRate measuring principle is based upon contactless measurement of gas velocity, pressure and temperature and provides the actual combustion air mass flow in kg/s.
The ultrasonic gas flow meter with 4 measuring paths enables a high accuracy air mass flow metering over the whole measuring range. The very fast response time of the system assures reproducible test results, even during high dynamic engine test cycles. The low pressure drop of the system does not influence the engine behavior.

The newly developped AirRate XT is based on the AirRate DN100 and enables operation within a pressure range of 450 to 1300 hPa and temperature range from -40°C to 50°C. This also enables the AirRate XT to operate in the field of altitude simulation. The FEV-AirRate XT is easy to install because of the very compact size of the unit.
Due to the integrated flow rectifier, the FEV-AirRate XT can also be mounted directly behind a pipe bend without increasing the steadying length.

The newly developed AirRate DN200 enlarges the AirRate measuring range up to 5000 kg/s and thus makes FEV AirRate suitable for large heavy duty and off road engines. The new design combines a compact size with low weight that makes installation easy. Due to the integrated flow rectifier, the FEV-AirRate can also be mounted directly behind a pipe bend without increasing the steadying length.

E-COOLCON

» E-MOBILITY COOLCONS

Use of FEV E-Mobilty CoolCons for:
> Development and testing of e-Axles
> Development and testing of hybrid drive trains
> Development and testing of batteries

» TEMPERATURE CONTROL IN E-AXLES

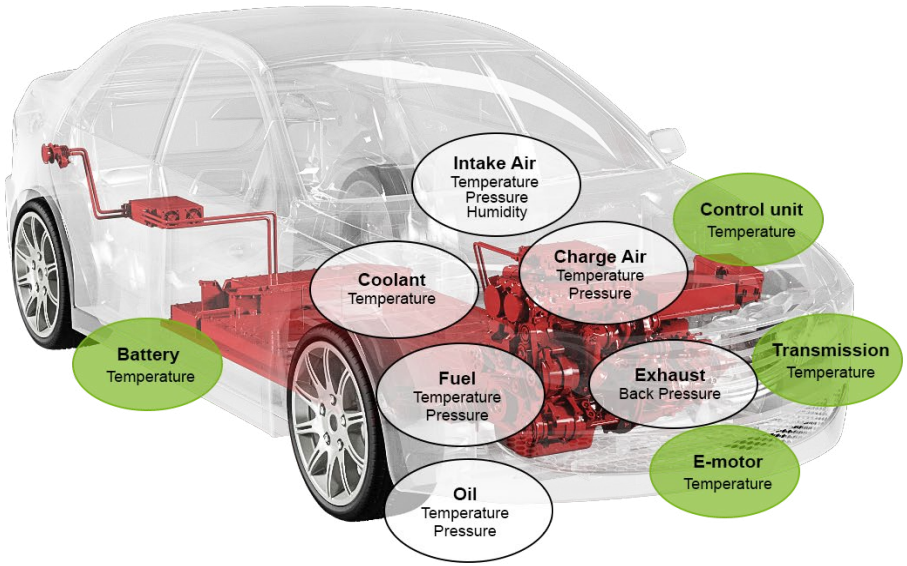
In the fast growing E-mobility market, the development of E-axles for electric vehicles is of extreme importance. To investigate temperature influences on these E-axles special conditioning units haven been developed which enable an exact temperature control over a very wide range in the E-Motor and the control electronics. Additionally the flow of the cooling fluid and the pressures have to be controlled in narrow ranges.
These operations are realized by a FEV conditioning unit which is specially developed for this purpose. This module allows automatic coolant filling and draining of Unit Under Test.

» TEMPERATURE CONTROL IN HYBRID DRIVE TRAINS

Hybrid drive trains become more and more common in passenger cars, small delivery vans and heavy duty trucks. Development of these drive trains requires an exact temperature control over a very wide range in the E-Motor, the control electronics and possibly the transmission.. Additionally the flow of the cooling fluid and the pressures have to be controlled in narrow ranges. This is realized by a FEV conditioning unit which is specially developed for hybrid drive trains..

» TEMPERATURE CONTROL IN E-MOBILITY BATTERIES

The battery is one of the key parts in the E-mobility developments. In the race to higher energy densities and lower battery weight extensive tests have to be performed, in which a precise control of the battery temperature is very important. Additionally the flow of the cooling fluid and the cooling fluid pressures have to be controlled in narrow ranges.
This is realized by a FEV conditioning unit which is specially developed for testing batteries



E-MOBILITY BENEFITS

> Stable experimental conditions reduce test cell time, along with resource requirements (personnel and equipment).
> System control and regulation by a cabinet mounted on-board controller.
> Several interfaces available (TCP/IP-CSM, TCP/IP-AK, EtherCat, CANraw, ProfiBus, ProfiNet) for communication with test bench computer
> Simple operation and low maintenance
> Wide range of application
> Excellent price - performance ratio

» A COMPLETE RANGE FOR MEASUREMENTS ACQUISITION AT THE TEST BED

Measurement quality is an essential element of the test bench. The immediate answer to accurately acquire the different sensors in a simple and intuitive way in MORPHEE is MIO. Compact, scalable, and easy to install, each module locally acquires each signal and transmits them to the EtherCat network* to the Automation system. It is also possible to address the different actuators of the bench as well as the logic inputs/outputs.

With the FEV solution, each acquisition module is seen as an independent slave on the communication bus, and MORPHEE is the master. As a result, each module is diagnosed and processed independently.

EtherCAT (Ethernet for Control and Automation Technology) is an Ethernet solution for industrial automation offering exceptional performance while being very easy to use. The master bus requires no additional extension board, and can be easily implemented on any Ethernet adapter. EtherCAT is especially well-suited to control-command systems that use remote I/O, such as engine test beds.

MIO MORPHEE APPLICATIONS

- Simple and reliable
- High measurement quality
- Electrically Isolated
- Easy integration in MORPHEE
- Direct EtherCAT connectivity
- Standalone modules
- Modular and mobile system

» BENEFITS

Quality

Suitable for most used sensors
Isolated solution
Factory calibrated
Direct MORPHEE integration

Modular & Compact

19'' or semi 19'' housing
Infinitely cascadable

Flexible

Simplified connectivity
Extension possibility through dedicated connectors

Reliable

High operating range
High measurement accuracy
High insulating capacity
Stability over time

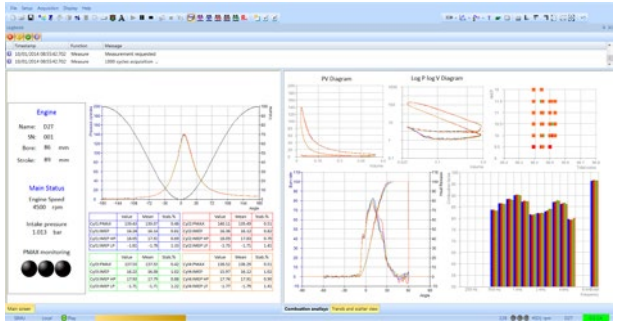
MIO Range:

» COMBUSTION ANALYSIS

OSIRIS is a very fast ready-to-use acquisition system. Originally designed to sample data at each engine revolution crank angle, it fits with user needs for combustion analysis. Due to its time-based mode, the system can be used to measure signals at high frequency as an oscilloscope.
The latest evolution of the system allows to perform the main power calculation for the characterization of E-motors. In this configuration, OSIRIS acts as a powermeter.
Quick to install and easy to use, it covers all the needs of engine engineers during every step of a powertrain development.

OSIRIS as COMBUSTION ANALYZER

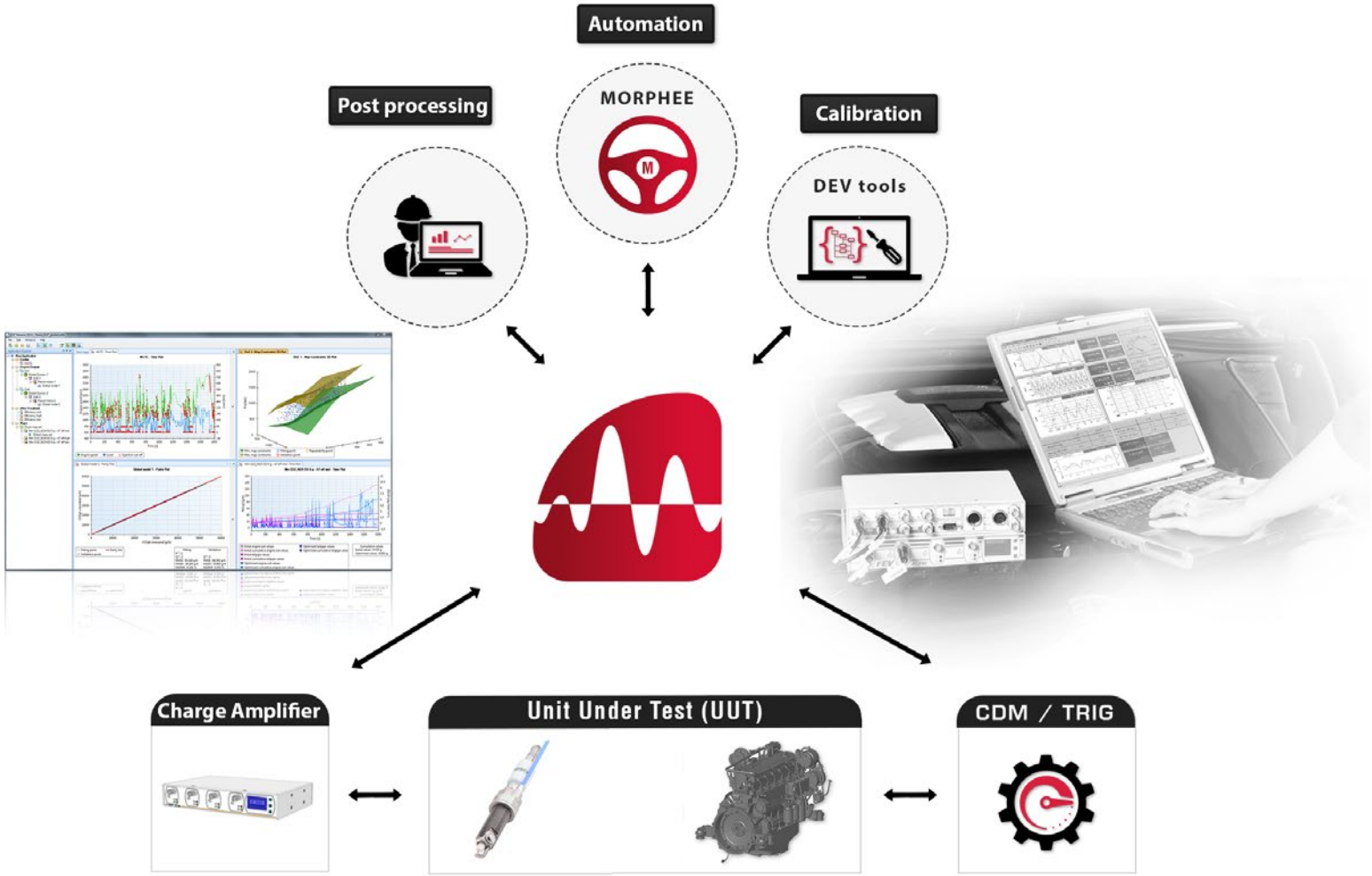
> Combustion analysis system (indicating system or combustion analyzer)
> Acquires engine signals (cylinder pressure, injector commands, engine revolution)
> Is based on time or crank angle
> Calculates engine-specific values (IMEP, CA50, Pmax, Knock, etc.)
> Can be remotely controlled by other test cell systems



OSIRIS as POWERMETER

> Powermeter for E-motors
> Acquires E-motor signals (high voltage, high current)
> Is based on time
> Calculates engine-specific values (active, reactive and apparent power, etc.)
> Communicates with other test cell systems

» INTEGRATION INTO EXISTING ENVIRONMENTS



» COMBUSTION ANALYSIS

Multi-agile
OSIRIS is an efficient and cost rational data acquisition solution which, due to its comfortable size, can be used directly at the test bench or also on-board.

Indication
By deciding for an OSIRIS system you get not only an indicating system, but also an oscilloscope. OSIRIS offers the same time mode measurements as an oscilloscope (from 1kHz to 1MHz). Furthermore it provides a huge data storing capacity for all cylinder pressure data.

Calculation
Benefit from the largest range of calculations, developed with the major OEMs.

Hardware
Select a flexible and economic hardware platform which is scalable to your needs from 8 to 16, 24 or 32 channels. Encoder installation is not necessary.

Communication
OSIRIS has a multiple interface to the most common automation systems. It offers furthermore an interface for all the principle charge amplifiers available on the market and is able to evaluate TEDS data.

Integration
Keep the same system in test beds as well as on-board. Supported by an identical file format for calculations and results, OSIRIS is a convenient solution for your needs.

OSIRIS HIGHLIGHTS

- Includes flywheel pickup converter (no need of encoder)
- Works at high frequency (up to 1MHz; 0.1° / 16 600 rpm)
- The performance at best quality/cost ratio
- Combustion analysis in a test cell or on-board a vehicle.
- About 600 installed systems since 1995

» PERFORMANCE AT BEST COST RATIO

Benefits

> Modular and compact system
> Crank angle based, time based, both crank angle and time based acquisition
> Signal conditioning close to the engine
> Monitoring of all calculation types (Knock, Pmax, IMEP, CA50…)
> Embedded electronic encoder (FFR-M)
> Compatible with the main angular encoders on the market
> Interface with most of the commonly used charge amplifiers
> Provides standard, editable file formats (ASCII, IFILE)
> Compatible with main data acquisition & control systems
> Simulation mode free of charge

Applications

> Design to be used in test bench & in-vehicle
> Manage safeties upon abnormal combustion (Knock, Misfire, Pmax)
> Use as an oscilloscope
> Manage cold start measurement
> Analyse injection system using both crank angle & time based acquisition

» POWERMETER

Shared solution
OSIRIS™ POWERMETER complements the existing version of OSIRIS™ fast data acquisition system with regard to analyzing signals for electrical applications.
OSIRIS™ POWERMETER has all the classic functions of a wattmeter and is compatible with all types of application: e-motor, e-axle, inverter and battery. It performs in real time the usual power measurement calculations used to evaluate the performances at output of converters, and electric motors, such as active power, apparent power, reactive power and the power factor.

Calculation
Perform standard power calculation to evaluate the perfomance and the efficiency of your inverter and your electric motor.

> Active power
> Apparent power
> Reactive power
> Power factor
> RMS value
> Crest factor
> Cos Phi

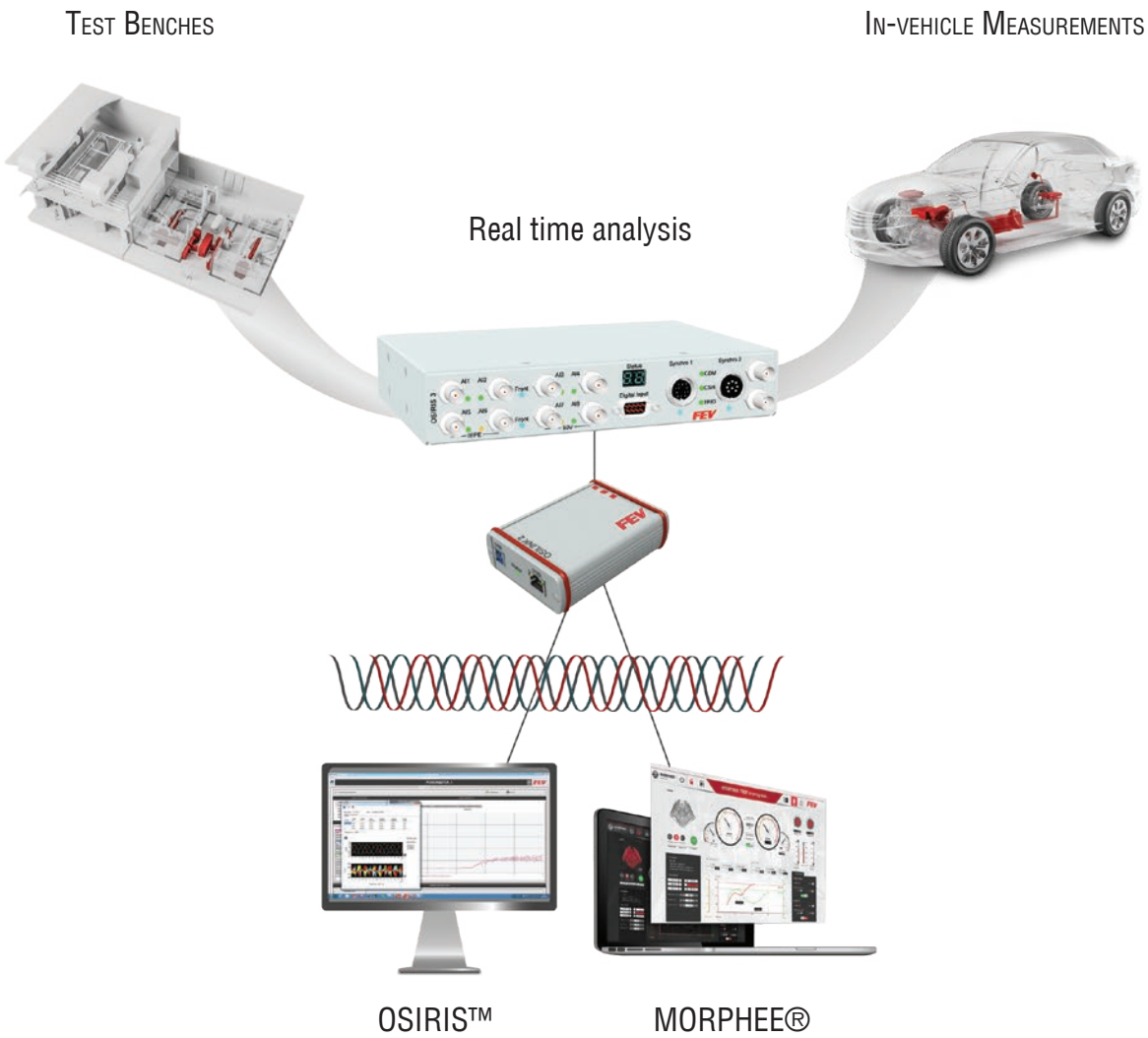
Measurement
To handle high voltage and high curent signals, the system uses independant probes and curent clamps. It allows fitting with the level of voltage and curent of your unit under test from 48 V to 1200 V/1200 A.

Applications
> Design to be used in test bench & in-vehicle
> Compatible with all types of application: e-motor, e-axle, inverter and battery
> Manage several e-motor wiring (star, star with neutral, delta)
> Adapted to tests performed on the electric powertrain: dynamic real time power meter calculations, variable speed and torque

BENEFITS

> Real time dynamic calculation and transfert to AuSy up to 1kHz
- Calculation executed for each electric cycle
- Directly integrated into MORPHEE AuSy
> Compatible with other AuSy through OSIRIS software communication protocols
> Share hardware with combustion analysis and electrical motor needs
> Management of 6 phases motor in one system

» OSIRIS FOR ELECTRIC APPLICATIONS



ACQUISITION

CALCULATIONS

RESULTS

» ACPM

A simple and efficient solution for instantaneous and maximum cylinder pressure measurements.

The ACPM is a Piezoelectric Multichannels Charge Amplifier. It makes it possible to condition up to 4 cylinder pressure sensors, while offering monitoring capabilities (Pmax and speed). Simple and user-friendly, the ACPM is compatible with all combustion analysis systems and more especially tailored for OSIRIS and FEVIS.

ACPM BENEFITS

> Simple integration with FEV Combustion analysis systems
> Compatible with all piezoelectric pressure sensors
> Standalone for Pmax and engine speed monitoring (relay outputs)
> Direct visualization of user interface, on-line visualization and monitoring of:
- Instantaneous or maximum pressure
- Engine speed
> Front face reset button
> Built-in calibration function
> Flexible and powerful

ACPM APPLICATIONS

> Condition in-cylinder signals for combustion analysis:
- Test bed
- In-vehicle
> Provide Pmax analysis for preventive maintenance (on-board, industrial engines...)

» MIO F01

The MIO F01 module is a standalone device providing four frequency inputs for conditioning of torque, speed, position, and frequency measurements. It provides advanced conditioning functions of target signals, such as torsion measurements and crank angle signals management.

The result of the calculations can be distributed via EtherCAT network. Integrated safety functions switch up to 8 digital outputs or redirect the results to one of 4 available analog outputs.

The system impresses with its variability. Signals with up to four singularities are safely processed in the entire frequency range to a resolution of up to 0.1 °.

For comfortable, front, cabling of the outputs, this module can be extended with a MIO E01 to a 19 ‘’ x 1HE module.

F01 BENEFITS

> Polyvalent: suitable to condition all frequency measurements needed at test cell in one device:
- Speed measurement
- Torque measurement
- Torsional analysis

> Easy integration: standalone (analog and digital outputs)or integrated into an EtherCAT network

> Modular, compact and mobile

> Advanced integrated calculation possibilities on measured signals

F01 APPLICATIONS

> Condition torque and speed measurements for control loop at test cell

> Manage safeties upon thresholds overshoots(given examples: over-speed, torque)

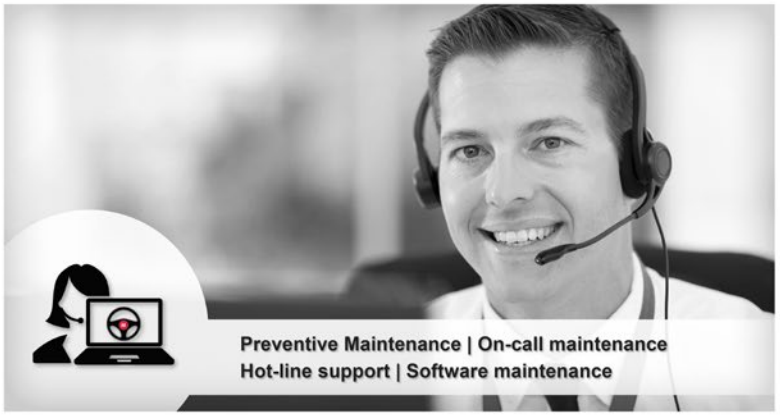
> Allows a torsion analysis of the whole shaft line attest cell (from dynamometer to engine), gear boxes analysis, clutch analysis, acyclism measurement

> Provides engine synchronization signals like CDM and TRIG to combustion analysis systems

» ALL SERVICES

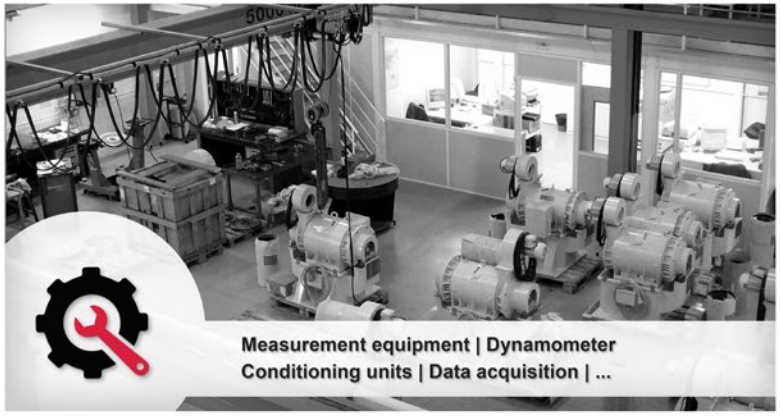
Resident Services

Service Contracts



Repair Services

Spare Parts and Renting Services



Resident Services

For capacity outsourcing or for specialty outsourcing, FEV can take on all or part of the operations at testing facilities, offering a range of associated skills in order to generate performance gains in quality, performance testing in the organization and methodology, in order to optimize overall operations of facilities, a team, or a project.

Service Contracts

Customers can benefit from maintenance services that are dedicated to meeting client needs, from simple software update, a hotline for a quick fix of bugs or for advice on using our software to maintenance plans for complete test bed systems. FEV will also help you to better utilize your testing facilities – an essential approach to maximizing your productivity and the quality of your testing.

In addition, our experts can meet with you at your development and testing sites to provide on-site assistance.

Repair Services

Our engineering teams can respond to a variety of repair needs:

> Hardware repair
> Dynamometer overhaul
> Device and test bed overhaul

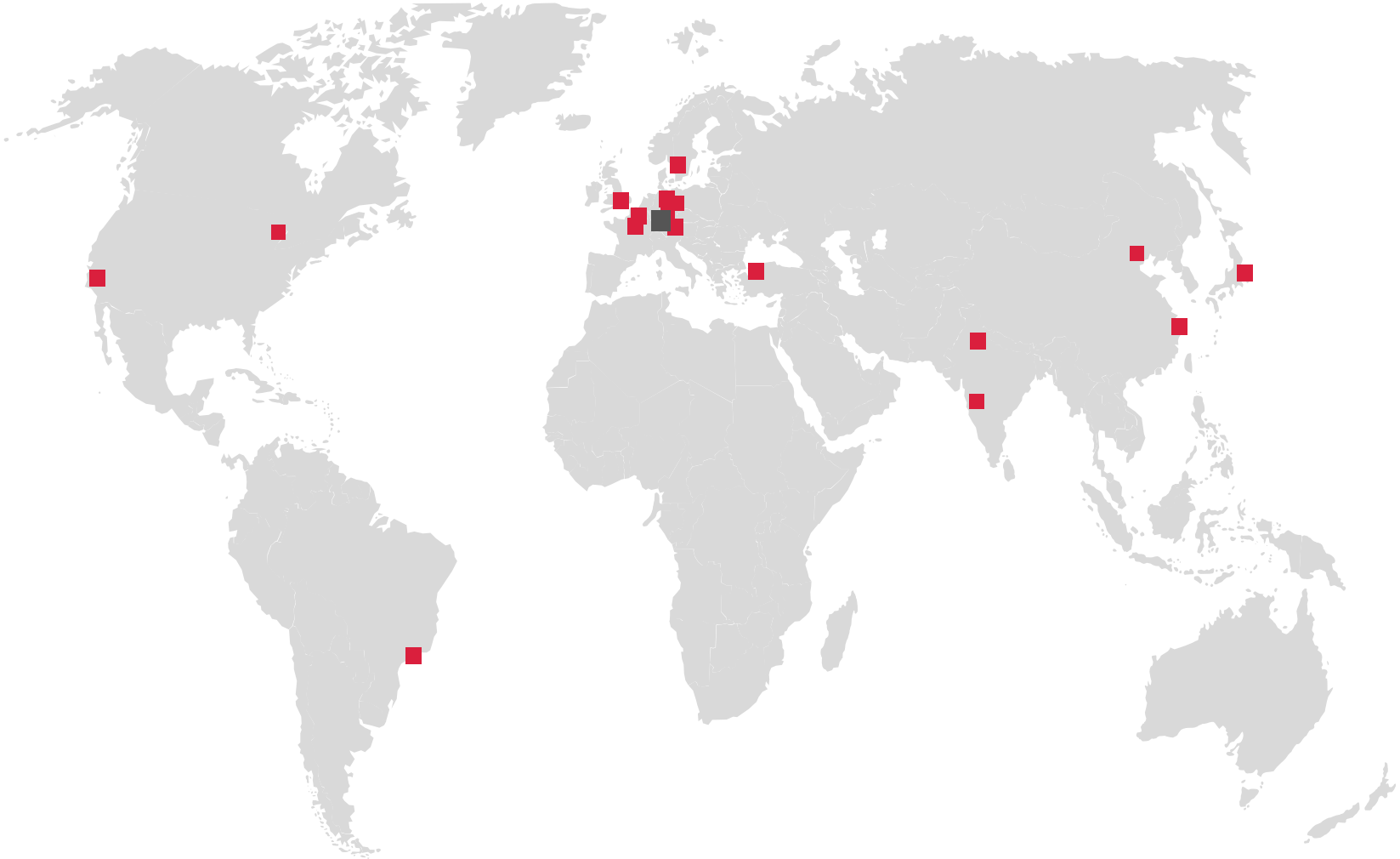
Spare Parts and Rental Services

FEV can offer all spare parts for products or rental services for products listed in the catalog, including:
Measurement equipment
Dynamometer
Conditioning unit
Data acquisition and communication boards

Training

All year long, we organize training for our customers. At your site or ours, these training programs help optimize use of our products and equipment on your test beds (MORPHEE, OSIRIS, Eddy Current dynamometers, etc.). We offer a whole range of training that's right for the knowledge level acquired and the skill level desired. Available in both English and French, they are aimed at powertrain engineers, testing managers, operators, and at people entrusted with maintaining and calibrating the beds — basically anyone who works at a test bed.

» FEV WORLDWIDE CONTACTS



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