



# REINVENTING TESTING FOR FUTURE MOBILITY



Software and Testing Solutions Catalogue

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INTRODUCTION

» OUR SYNERGIES CREATE ADDED VALUE FOR OUR CUSTOMERS

The target today, for our customers as well as for us, is to respond to the new energy mix and to develop a new offer meeting the challenges of electrification and hydrogen. Because of its central position, FEV is at the crossroads of innovations and new developments in the field of mobility. From this daily experience, we have built our own testing solutions: test center, test cells and products. In this catalog, we introduce you to these solutions, adapted to the needs of our customers.

What is unique at FEV:

- > Test centers designed by a testing expert
  - We run eleven test centers around the world and more than 300 test cells on a daily basis
  - We have built the largest high voltage battery test center for our own needs: 54 climatic chambers, 30,000 kW electrical power, 350kN shaker, abuse tests, ... (pages 31-34).
- > Advanced software integrating FEV's know-how and methodologies
  - MORPHEE®Next, a software suite covering the entire validation process: from the arrival of the specimen to be tested to the test report,
  - Upstream and downstream of the validation process, software covering the design and modeling phases (0D, 1D, 3D) and the needs for benchmarking, on-track validation and fleet management.

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



INTRODUCTION

» FEV OFFER

A three steps approach:

1- A DATA DRIVEN TEST CENTER...

As an example, eDLP, the world's largest battery test center for high voltage batteries, was designed and built by FEV STS: FEV offers its unique expertise in test center management to its customers.

> Read more in pages 30-45

2- ... FOR ANY KIND OF TEST CELLS

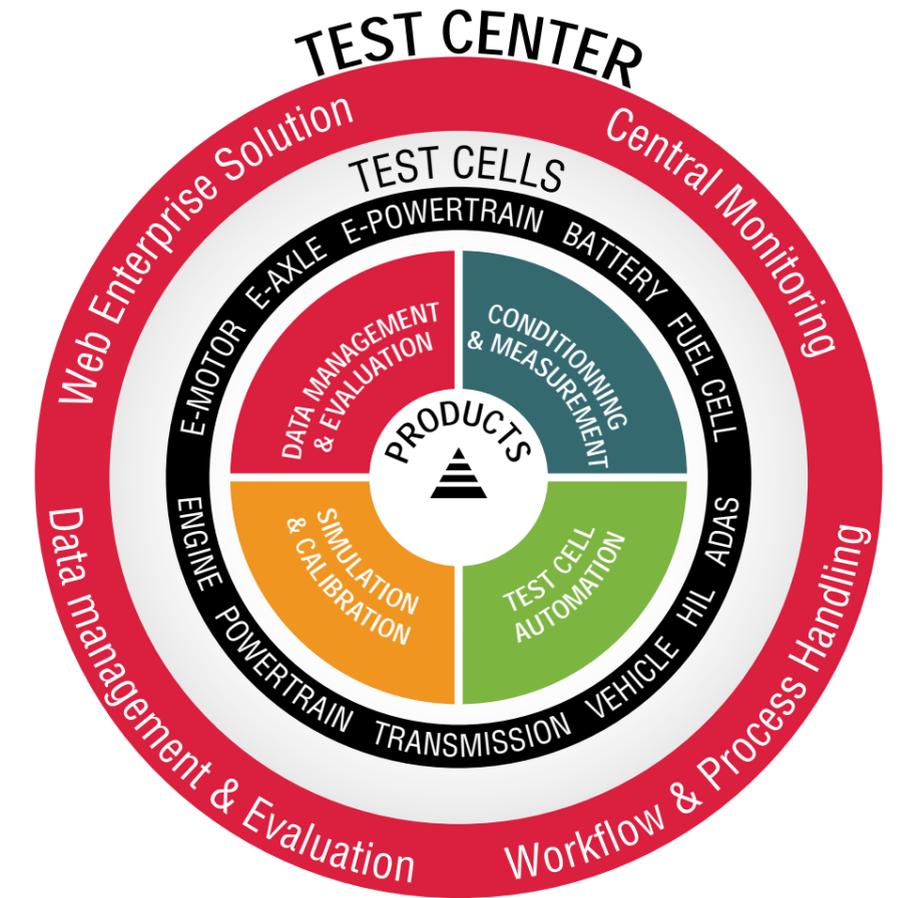
High-tech test cells have been proven in FEV test centers first – with all of FEV's powertrain knowledge inside.

> Read more in pages 46-93

3- ...BASED ON A COMPREHENSIVE PRODUCT RANGE

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 94-171



INTRODUCTION

MARKET DRIVERS

» FUTURE ENERGY CARRIERS IN THE MOBILITY AND TRANSPORT SECTOR

With the “Green Deal”, Europe has set the goal to reduce net greenhouse gas emissions to zero by 2050. For the mobility and transport sector, the 2050 target is a 90 percent reduction in greenhouse gas emissions compared to 1990. A key step in achieving this goal is the tightening of the previous overall emission reduction target for 2030. In April 2021 it was agreed to reduce emissions by 55 percent compared to 1990. It is not yet clear how much the individual sectors will contribute to this target by 2030. Furthermore, it is uncertain which energy carriers must be supplied for this purpose and to what extent.

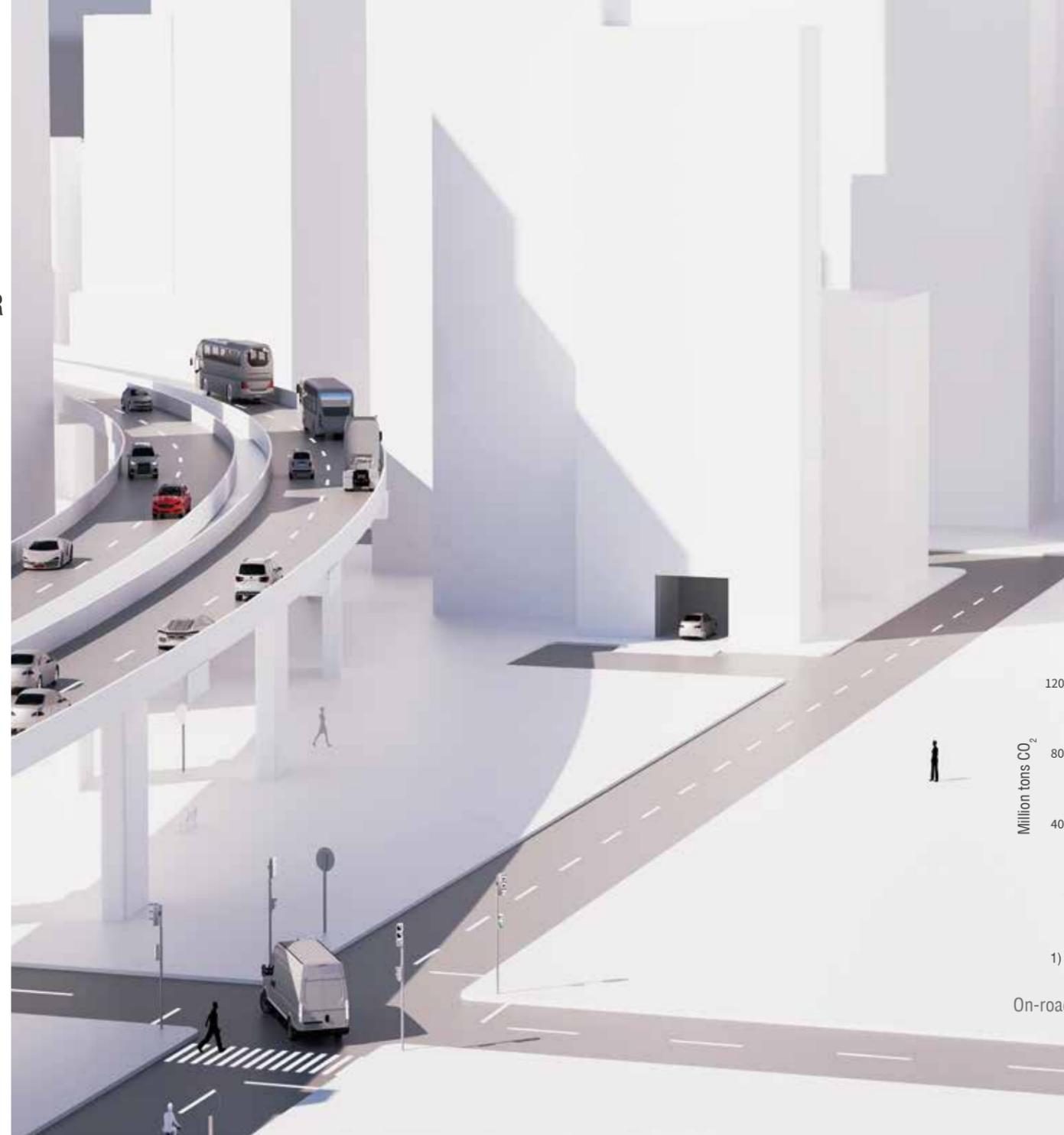
> Key challenges for the transport sector

Despite all efforts, emissions from European road traffic have not decreased since 1990. In fact, they have increased by more than 25 percent, creating an urgent need to switch to more climate-friendly technology solutions. A variety of policies and regulations are available to support this, including the taxation of CO<sub>2</sub>, fleet emission targets for new sales, and the frequently discussed registration ban of vehicles with internal combustion engines. One of the factors impeding the achievement of the targets is the continuous rise in mobility demand.

Several uncertainties go along with the regulations. Which powertrains are required to achieve the targets? Is it sufficient to rely on battery- and fuel cell electric vehicles? Or are liquid fuels from renewable energy required? How, where and in what form will the required energy be made available to the end customer?

It is certain that a very diverse mix of decarbonization technologies must be utilized in the transport sector to meet the ambitious targets.

To ensure the adequate supply of the transport sector with energy carriers in the future, it is crucial to estimate their demand already today. Unfortunately, this demand is affected by many uncertain boundary conditions, such as legislation, consumer behavior and technological development.

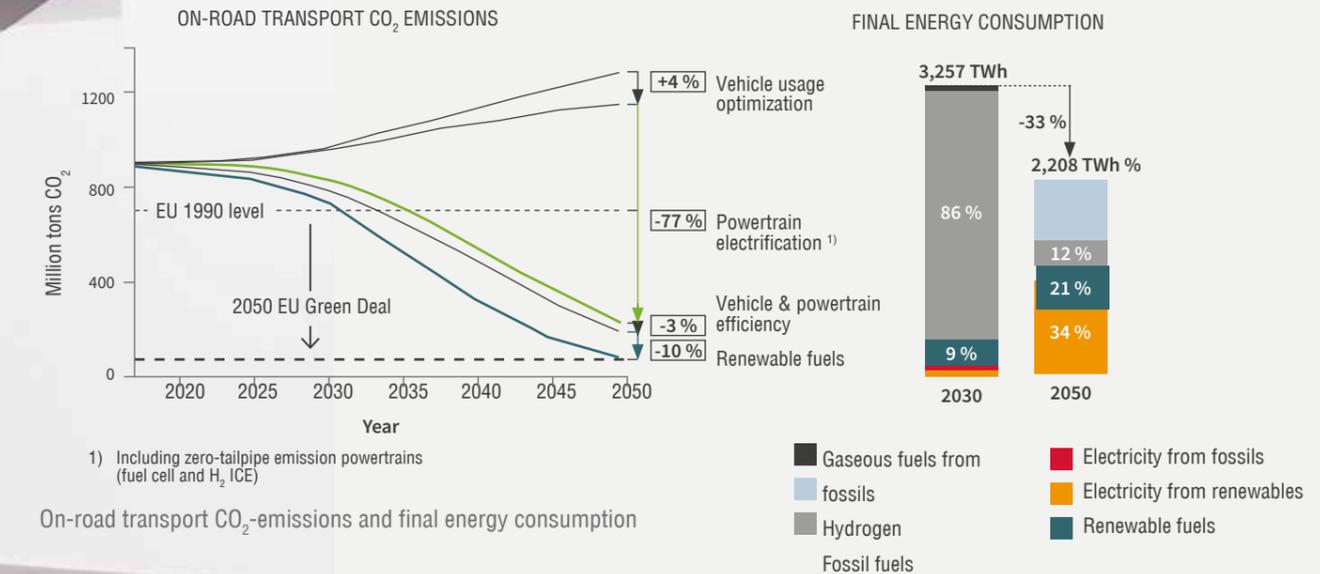


> Future demand of energy carriers

Using the “Energy Demand Model” and assuming vehicle emissions must decrease by 90 percent by 2050 compared to 1990, the illustrated demand for energy carriers results (see Figure 1). This result is based on the currently more likely scenario, which assumes accelerated electrification of the vehicle fleet and corresponding decline in new vehicles with combustion engines.

However, looking to the year 2030, it’s obvious that emissions will not fall below 1990 levels through electrification alone. Despite increasing sales of purely electric vehicles, a large proportion of the vehicle fleet is still powered by combustion engines at that point in time. If the transport sector is to contribute to the reduction of CO<sub>2</sub> emissions already in 2030 compared to 1990, the utilization of renewable fuels is unavoidable and its share must be increased even more.

In 2050, the transformation of the vehicle fleet to electrified vehicles will be largely completed. Also due to the higher efficiency, the final energy demand of the transport sector will decrease to 2,208 Terawatt hours (TWh) by 2050. Electricity and hydrogen will be the primary fuels, while liquid fuels will play a minor role with 730 TWh compared to 2030. However, demand for liquid fuels from renewable sources further increases.



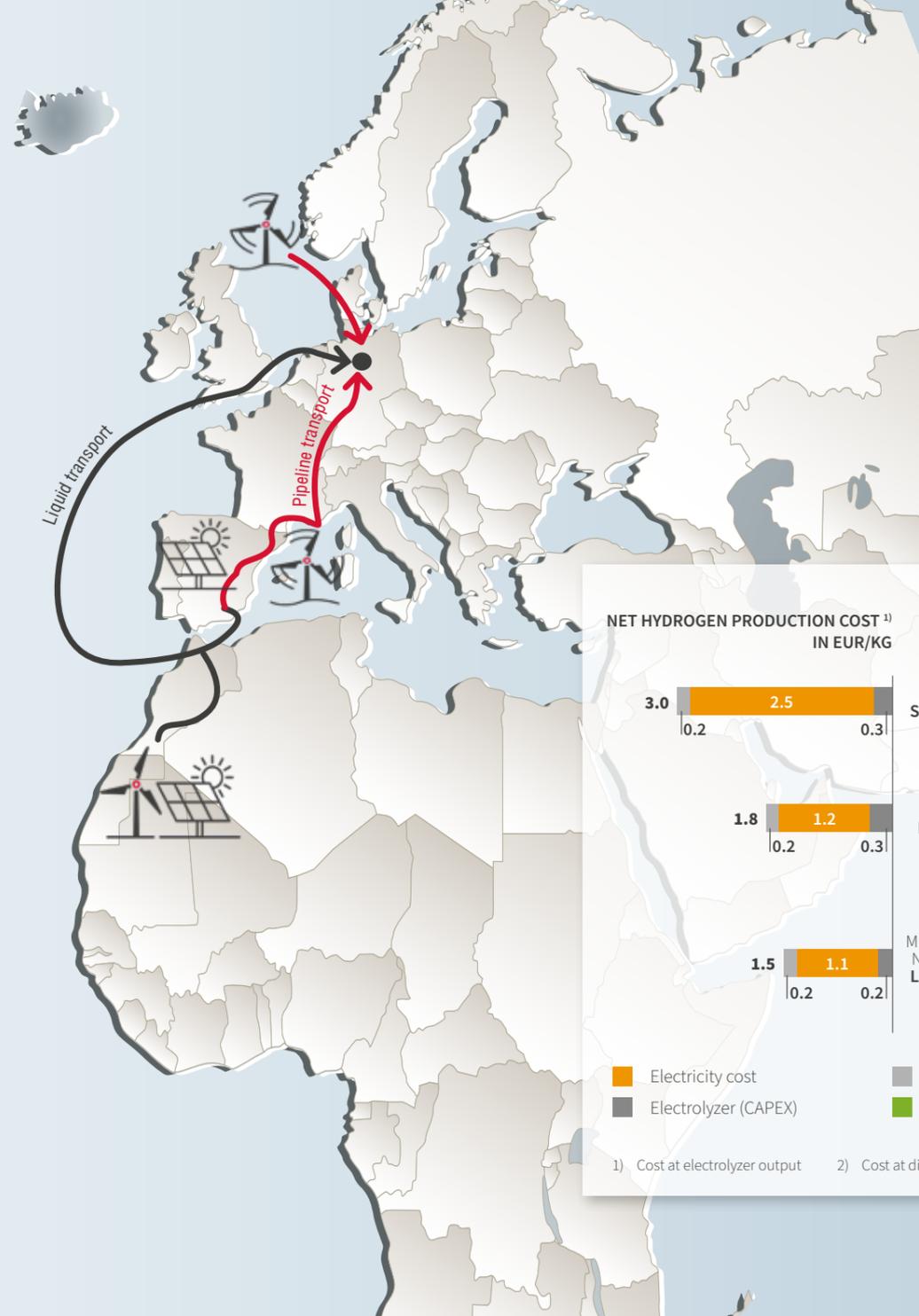
INTRODUCTION

MARKET DRIVERS

> Hydrogen - the energy source of the future

In addition to its use in today's CO<sub>2</sub>-intensive industries, such as steel and cement, the increased use of hydrogen as an energy carrier is also necessary in the transport sector. Apart from the reduction of CO<sub>2</sub> emissions through battery electric vehicles, electrification will need to be consistently implemented through fuel cells in commercial vehicles by 2025 and in passenger cars by 2030. For commercial vehicles and off-road applications, hydrogen can also be converted in a hydrogen combustion engine. All of this results in an increased European demand for hydrogen used in mobility applications to approximately 700 TWh per year by 2050.

However, for economic use and sufficient supply to occur, an appropriate infrastructure must be created. Apart from local and potentially decentralized production of hydrogen, additional international supply chains must be developed. The cost of electricity for electrolysis is crucial in the overall production costs of hydrogen. This means the construction of hydrogen production plants is most efficient in areas where renewable energy is cheap due to high full-load hours (e.g., for solar energy in Spain or North Africa). The lower production costs are expected to at least partially offset additional costs for transportation and distribution. Hydrogen produced at these plants can also be used to generate liquid fuels. This would enable even more favorable distribution, especially for long distances between primary energy conversion and the end consumer, which can use existing supply chains and infrastructure.



> Liquid fuels from renewable energie

Liquid fuels from renewable sources are also required to achieve the emission targets, especially for long-distance and heavy goods transport, which include shipping and air transport. In 2030, 290 TWh of liquid fuels are expected to be used in European road traffic. In 2050, the share will increase to approximately 460 TWh.

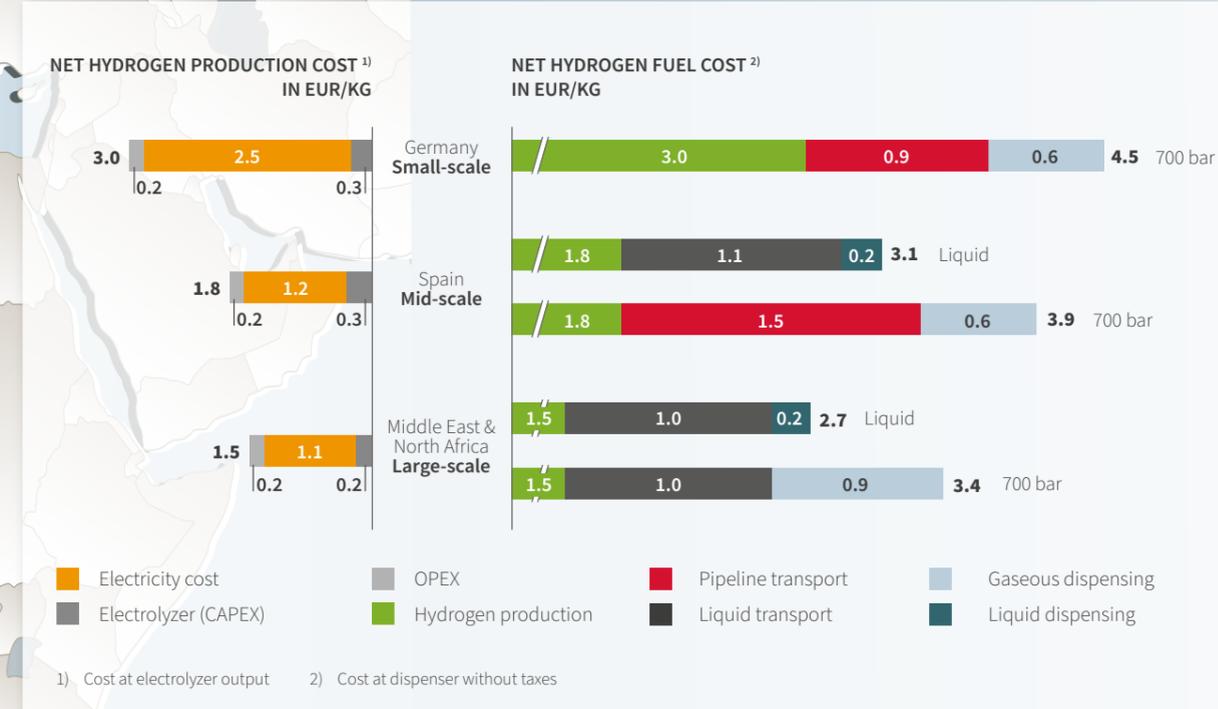
In addition to the biofuels already in the market, fuels produced from synthesis gas based on biomass (BtL fuels) or electricity and CO<sub>2</sub> (PtL fuels) are primarily under discussion. Key representatives are Fischer-Tropsch fuels, and fuels produced via the methanol route. Particularly in shipping, research is also being conducted to use ammonia, produced from hydrogen.

In terms of the availability of resources, the PtL approach is promising, as the feedstocks required in this process are theoretically available without limitations; whereas the use of biomass involves the risk of supply restrictions. However, production costs for PtL (Power-to-Liquid) fuels will be 2-3 times higher than for conventional fuels for the foreseeable future, depending on the production path. For BtL (Biomass-to-Liquid) fuels, cost parity or only a slight cost difference is regarded as possible.

To achieve the emission targets with the support of liquid fuels from renewable sources, various issues must be clarified in the short term. Is there sufficient biomass available to meet future demand with biofuels alone? If PtL fuels are also required, can production capacities be built up quickly enough and under which conditions does this result in an attractive business case for operators and investors?

Apart from these aspects, there are still ambiguities and a lack of incentives on the legislative side. Reasons why the actors in the energy sector are still reluctant to make the necessary investments, even despite the agreed fuel quotas.

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© Hydrogen costs for the mobility and transport sector

INTRODUCTION

MARKET DRIVERS

» VEHICLE ELECTRIFICATION: TRANSFORMATION OF THE POWERTRAIN

> Passenger Car Market

In 2020, the passenger car market was heavily influenced by the COVID-19 crisis. However, battery electric vehicles gained further market shares, especially in Europe. We expect a fast recovery of the sales volume to pre-COVID-19 scenarios, with an annual growth rate of 1.9%. This growth is dominated by the Chinese and Rest-of-World (RoW) markets, while US and European market are assumed with constant volume.

Moreover, the market growth is largely comprised of electric powertrain types, such as battery electric and fuel cell propulsion systems. The sales volume of vehicles with an ICE is expected to decrease by 16% by 2040 compared to 2019. The remaining powertrains with an internal combustion engine (ICE) will become electrified as well. We expect mild and full hybrids to be widespread.

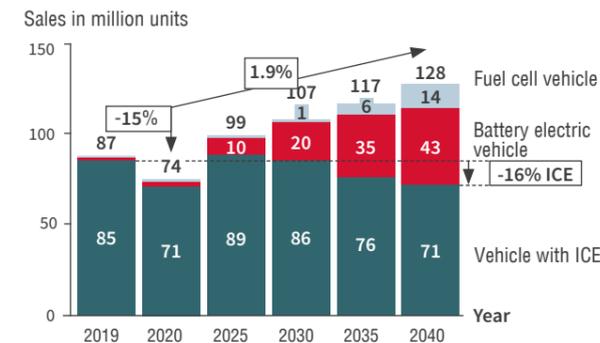
The shift of powertrain types is driven by the CO<sub>2</sub> emission reduction targets in the key market regions. In Europe, ambitions are the highest of all markets. By 2050, the transport sector (all vehicles on the road) should decrease CO<sub>2</sub> emissions by 90% compared to 1990 levels. This means that no new vehicle should have any CO<sub>2</sub> tailpipe emissions by 2040 at the latest, which can only be achieved by battery electric or hydrogen fueled vehicles. In addition, fuels from renewables (e.g., e-fuels) could also be CO<sub>2</sub> neutral, however their role in the regulations is currently under negotiation.

CO<sub>2</sub> targets in USA were relaxed under former-President Trump. The Biden administration has already announced that it will revoke said relaxation and return to more ambitious targets. California and some

supporting states are pushing for even more radical regulations, including a proposed ban of combustion engines.

In China the strategy appears more balanced, and the target of becoming CO<sub>2</sub> neutral has been shifted to 2060. The draft of the ostensible Roadmap 2.0 gives a push towards new energy vehicles (NEV) and those with reduced fuel consumption. In essence, the strategy supports the market introduction of battery electric, fuel cell, and hybrid powertrain vehicles.

In the year 2040, we expect that 57 million electric vehicles (battery and fuel cell) will be sold globally. The largest markets will be Europe and China with approximately 15 million units each.



① Worldwide Light-Duty<sup>1</sup> market vehicle sales forecast

1) Including passenger cars and light commercial vehicles up to 3.5t gross vehicle weight



INTRODUCTION

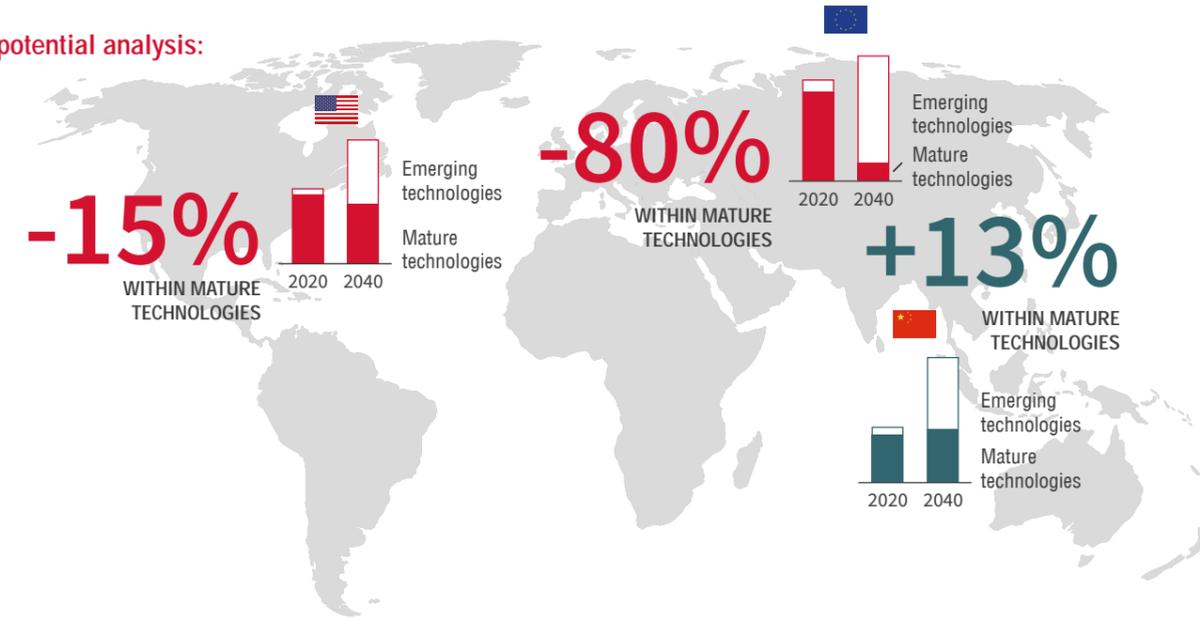
MARKET DRIVERS

> Business Impact

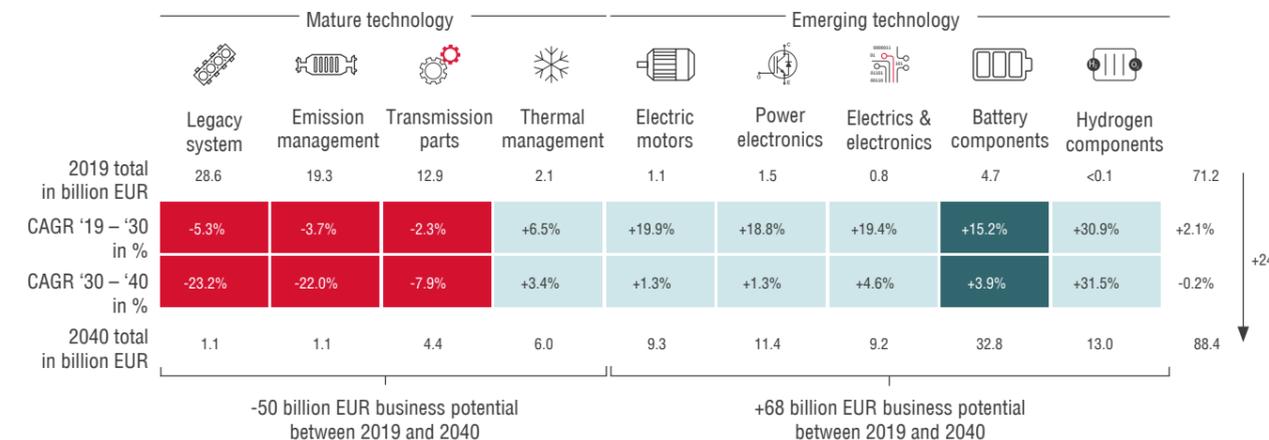
The shift of powertrain types has a dramatic effect on the business potential within the manufacturing value and supply chains. Mature or 'legacy system' technologies, such as base combustion engine components, emissions management systems, and transmissions, will suffer the most from this transformation. Between 2019 and 2040, we calculated a business potential reduction of 50 billion EUR for conventional powertrain systems. Although new technologies will be required to further improve engine efficiency, it will not be able to compensate for the reduction in sales volume. R&D and investment budgets are limited and shifting to electrified powertrain types; hence we expect a strong reduction of combustion engine-based powertrain variants as well. Consequently, we also expect to see extended usage of the existing production equipment. Only thermal management system components are believed to have increased business potential within the mature technology category, as those components are needed for electric vehicles too and are getting more complex in electrified applications. Not surprisingly, the emerging technologies are related to powertrain electrification. Battery systems, electric motors, and fuel cell components will create a rapid growth of business potential across the industry. Between 2019 and 2040, we anticipate an increase of 68 billion EUR for electrified powertrains. However, the growth does not necessarily translate into manufacturing value creation. The shift from manufacturing intensive components towards higher material intensity will cause the share to be reduced and move upstream in the supply chain (e.g., battery material processing).

Overall, we expect 24% business potential growth between 2019 and 2040. However, this growth happens in the period from today until 2030 only. Thereafter, the reduction of the business potential caused by the shift to electric powertrains cannot be compensated by an increase of combustion engine technology and hybrid powertrains anymore. The transformation towards electric vehicles is accelerated.

Business potential analysis:



Business impact:



> Key results

The transformation of the automotive industry prompted by the shift towards electric vehicles has had, and will continue to have, a strong impact on the supply chain. For battery systems, electric motors or electronic components, significantly different manufacturing processes are required compared those used for combustion engine components. These processes are also less labor-intensive. As a result, we estimate that 160,000 fewer jobs will be required in Europe by 2040 for the production of automotive powertrain and propulsion systems. The loss of 580,000 jobs within the mature technologies (e.g., combustion engines, transmissions) space cannot be fully offset by the expected 420,000 new jobs within the emerging technologies arena.

However, we expect additional jobs will be created in the upstream supply chain processes. For example, processing materials for battery cells or other raw materials required for production. The build-up and operation of charging and hydrogen infrastructure is expected to contribute as well. Finally, independent of the transformation, new business opportunities will be generated from connected vehicles and digital services.

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**12 BILLION € INVESTMENT**

CONSTANT AVERAGE ANNUAL INVESTMENTS IN EUROPE INTO MACHINES AND PRODUCTION EQUIPMENT REQUIRED



**50 € / kWh**

LONG-TERM AVERAGE BATTERY PACK COST EXPECTED TO BE REACHED UNTIL 2040



**-160,000 JOBS**

IN EUROPE; 580,000 JOBS LOST IN CONVENTIONAL TECHNOLOGIES, 420,000 JOBS CREATED IN EMERGING TECHNOLOGIES



**INFRASTRUCTURE & SERVICE**

OFFER FURTHER BUSINESS AND VALUE CREATION POTENTIALS FOR THE AUTOMOTIVE MACHINERY & COMPONENTS SUPPLY INDUSTRY

## » NO TIME TO WAIT

Industry players are faced with numerous challenges when creating or adapting test centers and test equipment for electrification: Achieving in 5 years for electric systems what it took 20 years or more to build for conventional engine systems; developing a fully automated test system, particularly in the field of battery testing; adapting existing technologies to the needs of the automotive and mobility sectors; converting conventional engine test benches to electric whenever possible, to manage costs.

The Covid pandemic accelerated the switch to electric: Major programs such as the NextGenerationEU recovery plan were

launched, precipitating the decline of conventional engines and the conversion of the transport sector to electric. This swift change in technology requires massive investment. In five years' time, we

**> Achieving in five years for electric systems what it took 20 years or more to build for conventional engine systems**

can expect most car manufacturers, for example, to have converted their powertrain test equipment to electric. In the lead-up to this, it took many years to gradually reduce the emissions and pollution from conventional engines, with new statutory standards being regularly introduced. The advent of the use of electronics enabled engines to be fine-tuned, and engine testing and calibration methodologies to be developed. The test equipment was updated accordingly.

Everything is quite different today: Alongside new plants manufacturing batteries, programs for dozens if not hundreds of battery test benches were launched in brand new test centers. Certainly, the increase in new battery technologies over the next 20 years will require installations to be regularly adapted, but it is now that the major investments are being made. These projects come with a high level of risk. The choice of test center materials and architecture is partly being taken blind: How can I size my equipment if I do not know my future needs? How can I choose the right configuration for my test center from the outset when the processes have not yet been fully tried and tested?

One thing at least is clear: With e-motor and e-axle test processes remaining similar to those for conventional engines, battery tests will require a highly

**> Developing a fully automated test system, particularly in the field of battery testing**

automated validation process. Of course, battery validation methods outside the automotive industry are well managed, but new problems have arisen as batteries have burst into the mobility sector: Batteries catching fire on the motorway, vehicle components being subjected to high voltages...

The safety standards have increased, but so has the electrical power being generated. Ensuring optimisation between the different cells in a pack requires even more complex test processes. The number of benches and the increase in the volume of test data to be processed

requires highly advanced management of logistics and data. This is where the battle for the centers productivity will be won.

## INTRODUCTION

## THE CHALLENGE

## » DON'T THROW THE BABY OUT WITH THE BATHWATER

## &gt; Adapting existing technologies to the needs of the automotive and mobility sectors

The technologies will also have to be levelled up. For example, while for combustion engines there is a single specimen to test for each test bench, there may be several in the case of a battery bench. The automation system must be capable of performing tests on several specimens at the same time. Another issue is the electrical outputs used on an electric vehicle, which create new technical constraints on a moving object. As a result, the test benches used for validation of electric engine systems have to be able to handle high voltages, which has repercussions for all of the equipment: Acquisition modules adapted to high voltage, high insulation, and the electrical safety standards, a system enabling the power electronics and electrical machines to be checked and simulated at high frequency...

## &gt; Converting conventional engine test benches to electric

The last challenge for the test center manager: Converting the existing installations to electric whenever this is possible, to reduce the investment costs. An in-depth analysis will, in certain cases, enable an engine bench, transmission bench or powertrain bench to be converted into an e-motor bench or an e-axle bench, or part of the installations to be reused.



Immersion test at eDLP

INTRODUCTION

FEV SOLUTIONS

» CONSULTING / PLANNING: DO IT RIGHT THE FIRST TIME

To meet these challenges, FEV offers solutions which align with five strategic actions: Specifying its requirements without rushing, placing the emphasis on the information system and on automation, using resources which offer simulation possibilities and, lastly, creating standards for each type of bench, to reduce the costs and ensure measurements are accurately repeatable.

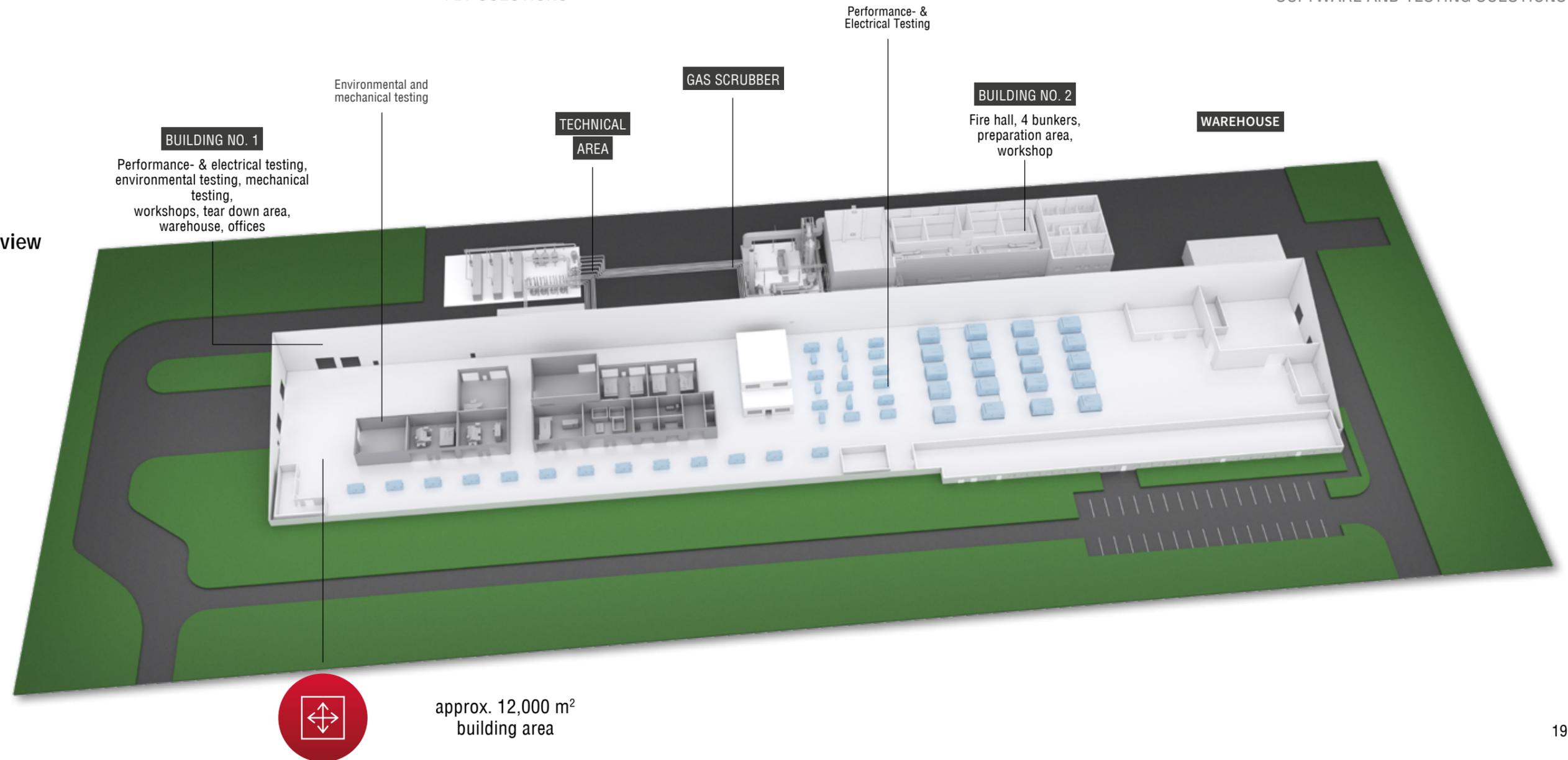
> More than 40 years of experience

As an industry player for 40 years, constructing then operating its own test centers FEV has developed methodologies and processes which can fully benefit the new battery test centers. In 2020, FEV opened the largest high voltage battery test center ever to date: the eDLP, close to the Germany city of Leipzig. This center spans a 41,000 m<sup>2</sup> site, with 50 climate chambers (-40°C to 100°C / 1.0 to 28.5 cbm), 10 chambers for environmental testing, 4 bunkers and a fire hall for abuse testing, and 160 electric tracks (up to 1000 V / 4000 A). It was built in 12 months and was – and is – the FEV laboratory specifically for developing the new battery test center and test bench solutions. With this facility, FEV has accumulated a wealth of unique experience for high voltage battery tests, in particular the processes and methodologies to be put in place, and the test equipment required for their implementation.

INTRODUCTION

FEV SOLUTIONS

eDLP global 3D view



approx. 12,000 m<sup>2</sup>  
building area

» DESIGN A TEST CENTER: NO SUBSTITUTE FOR EXPERIENCE

> A crucial step: Specifying the requirements

The first point – and this is not new, as eDLP is the seventh test center built by FEV for its own requirements, including one other battery test center – is the importance of the initial consulting/planning phase: Discussing how to create the set of specifications

for the center and the equipment with all stakeholders with the aim of putting forward a concept, evaluating it and sizing it correctly, before moving on to the actual project phase. You can find a detailed explanation of the processes followed by FEV on pages 44-45.

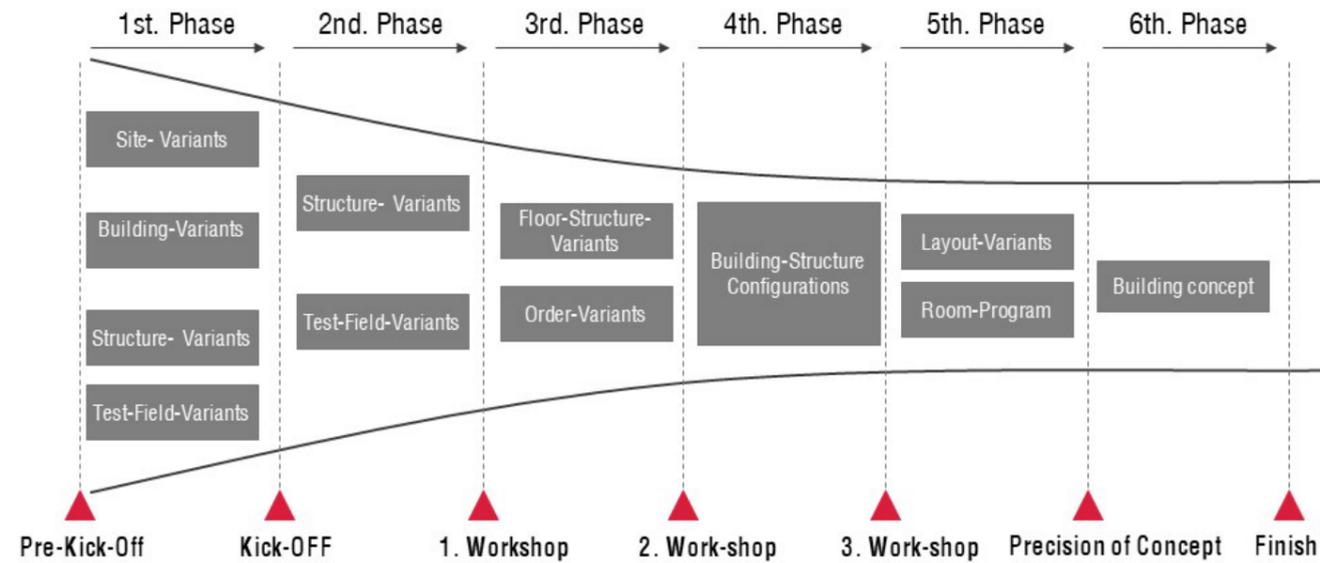


Diagram 1 -Specification process for test facilities

> Sizing the center for today and for the future

It must be noted that this process is based on the experience gathered by the Consulting/Planning team created in 1998. The correct use of tried and tested resources in the Consulting phase and in the Planning phase is key to success of the project. This experience is enriched in turn by that of the FEV test centers. Two concrete examples allow us to illustrate how the use of benches allows the correct sizing to be defined for the test center. For over ten years now, FEV has been operating the FEV battery test center in Saint-Quentin-en-Yvelines, which saw its capacities doubled recently. The measures undertaken in recent years clearly show that 99.9% of tests have been performed within a window of -30°C to +70°C, 93% of tests requested are for positive temperatures, while the requirement in the ISO12405 standard covers a range from -25°C to 45°C. This is an important piece of information to take into account when sizing the climate chambers to be provided. (diagram 1)

Another example: How can the electrical power required for correct operation of the center be calculated? The experience acquired by FEV can be used to assess requirements, avoiding any unnecessary costs generated by oversizing or, conversely, an installation which is too restrictive (diagram 2)

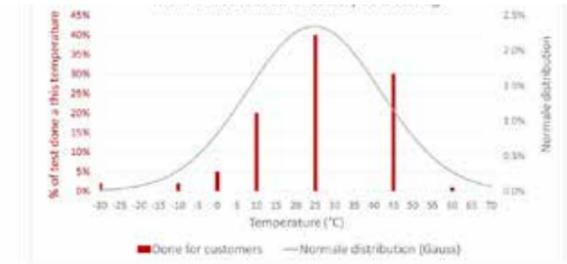


Diagram 1: Thermal distribution of battery cell testing

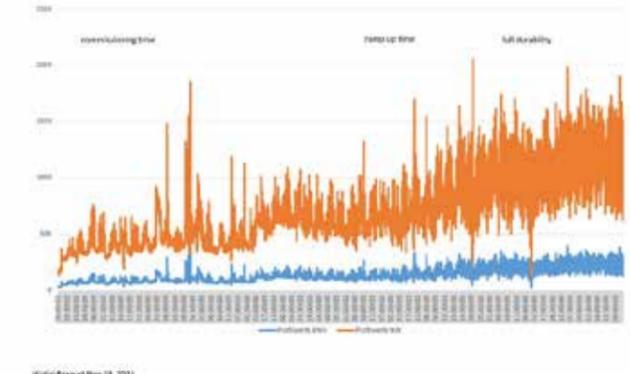


Diagram 2: Evaluation of power inside a test center - Load profile in kW

## INTRODUCTION

## FEV SOLUTIONS

## » AT THE HEART OF THE TEST CENTER: INFORMATION

Another essential point to be managed is the information system. While the heavy equipment may last up to 20 years, the computer equipment may have a much shorter lifespan, of approximately five years. Regardless of the circumstances, it is also subject to constant updates, both to improve performance and the software features and to update the battery optimisation requirements, which will be further refined. The choice of tools used in a test process is not immaterial. While a tool is chosen according to its process, the reverse is also true. The tools chosen can drive the processes in a certain direction: A given task is made possible thanks to a given tool, but is not possible with a different tool, or must be undertaken in a different, less efficient way. The investments made in heavy equipment therefore fix certain processes for good. However, the software choices and, to a lesser extent, the electronics choices, offer more flexibility. On the one hand, their lower cost may make new investments easier. On the other hand, they can themselves be altered: A new test sequence can be easily redefined.

## &gt; Battery tests: A complex process

Let us first go into more detail about the battery test requirements, to better understand the importance of automation. The first point relates to the type of specimens to be tested. There are three main types. The objective of testing elementary cells containing a battery is to characterise the cell according to its environment – temperature, pressure, etc. – and its ageing, either accelerated or in real-time. The tests on modules, grouping several cells, allow the actual integration

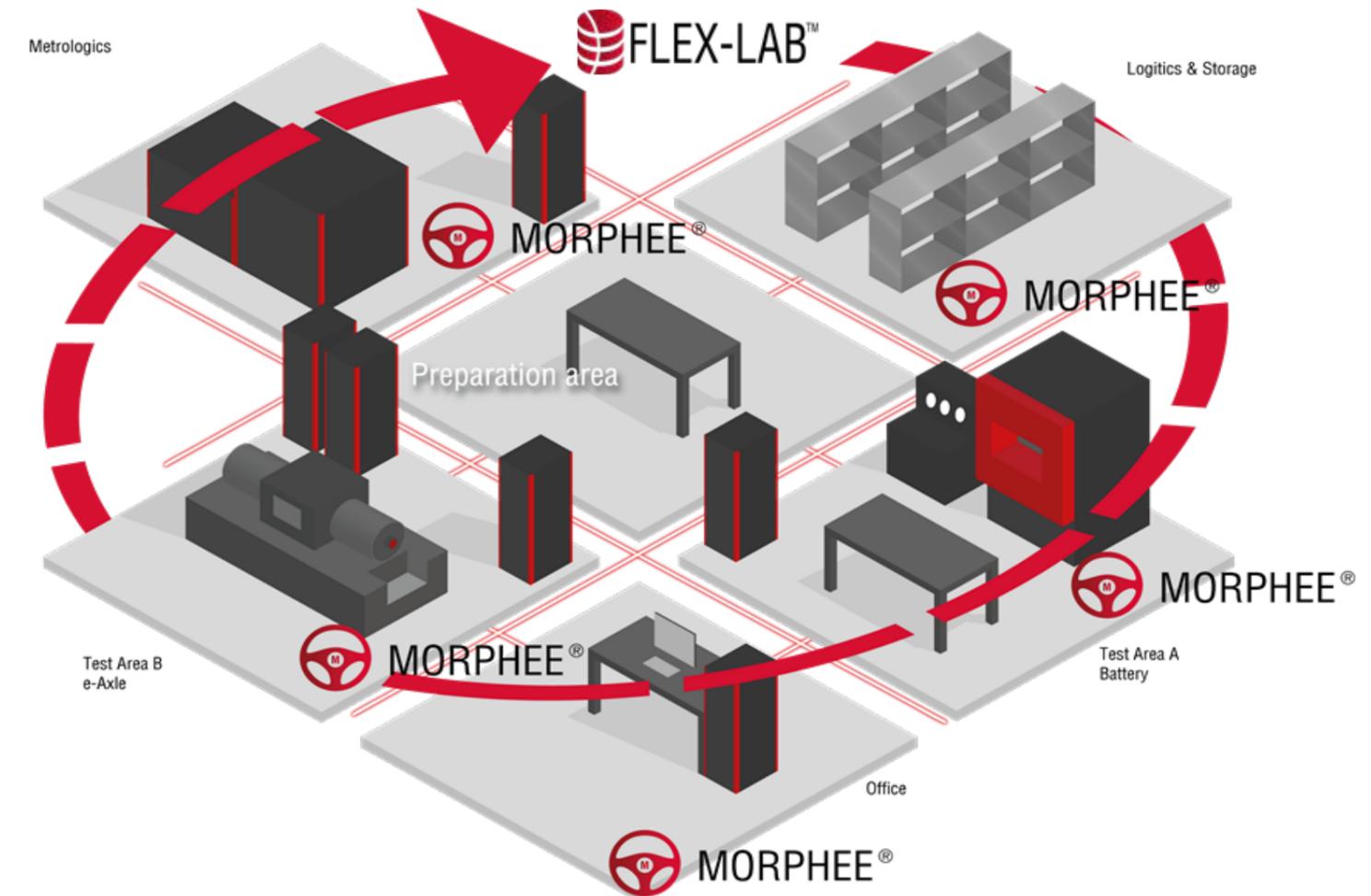
conditions to be characterised. Lastly, the pack tests – the complete battery with the different modules, along with the cooling system, the BMS (Battery Management System), and the network connection system – aimed at validating the entire battery: Here, we are mainly seeking to measure the lifespan of the battery and its capacity to retain good charging and discharging performances. We are also looking to test its ability to resist thermal runaway which would cause it to catch fire with dramatic consequences (explosion, emissions of toxic gases, etc.), and to draw up the corresponding protection strategies.

In the vast majority of cases, these different objectives require long-running endurance tests, over extended periods, with measurements recorded in real time. The amount of data to be gathered and processed can be very high: To be efficient, the process on a bench must be automated. Furthermore, a test program on a type of battery will require concomitant tests – either different or identical - on several benches.

## INTRODUCTION

## FEV SOLUTIONS

## » TRACKING THE SPECIMENS FROM THEIR ARRIVAL TO THE TEST REPORT



## INTRODUCTION

## FEV SOLUTIONS

## » AUTOMATING THE ENTIRE TEST PROCESS

This leads us to a requirement for test centers with numerous benches, either of a single type – a car manufacturer which does not manufacture batteries itself looking to validate the pack and the BMS, and their integration into the vehicle – or of several types, for a battery manufacturer which needs to manage the entire process itself.

As a result, we understand the importance of having an automated process which extends from reception of the specimen to delivery of the test report. The objective is not only to perform tests on the bench and gather measurements but also to manage all of the benches, workforce and specimens throughout the entire program: A true ERP for the test center.

In this process, simulation has a role to play, in two different respects: The first is importing a pack of models into the bench which enable the vehicle and the e-motor to be simulated, to ensure the tests are more representative; the second is to fine tune the BMS.

> **MORPHEE®Next, the suite of tools for integrated test processes**

For more than 30 years, FEV has been using MORPHEE®, its automation system which offers both unique real-time performances and a unique scope. To be able to offer a complete and efficient suite for test center requirements, FEV has closely integrated FLEX-Lab™, a web-based application, and UNIPLOT®, its data analysis and visualisation tool, in its test center ERP, to make it a comprehensive suite, comprising packaged battery applications, including a hardware-in-the-loop version. The codename for this suite of tools? MORPHEE®Next. Its first advantage is that it integrates the expertise and experience FEV

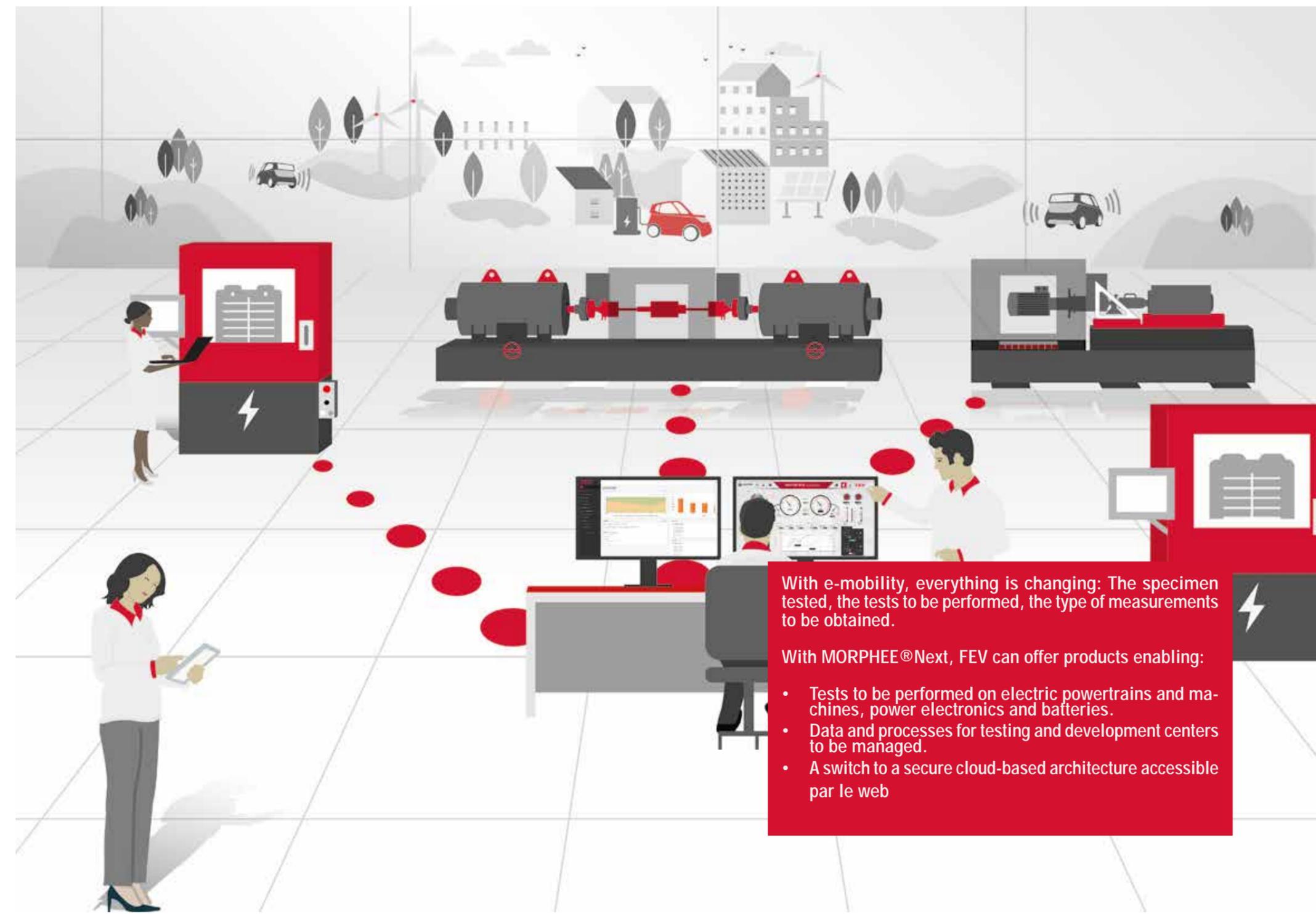
has built up in the domain of battery tests. The second is that it has been designed for quick installation in the test center, enabling the center to be up and running fast. The third is that it is scalable. As outlined previously, this is crucial. The era of the electric vehicle is only in its infancy: There will be many changes in battery technologies and test requirements along the way. MORPHEE®Next also includes other elements, such as the creation of a range of high voltage and high temperature measurement acquisition devices, MIO™.

Another essential component in the electrification of vehicles is the electric motor, linked to the entire powertrain. The electric motor is tested for characterisation purposes or, with the drive chain, for endurance capability:

- Mechanical cycles (vibrations, reducer, differential)
- Thermal shock (cooling, rotor thermal management)
- Characterisation and calibration of the inverter control (voltage and current signal, frequency vs. angular position and speed, transient torque management, etc.)

The goal is to increase the efficiency of the e-motor and the powertrain.

An in-depth reconfiguration of the tools was undertaken, with MORPHEE®Next e-drive, comprising the packaged MORPHEE® applications, an OSIRIS® Powermeter analysis tool, and a high-dynamic machine control system based on the FEV xMOD® simulation platform, allowing the models to be integrated and executed in real time.



With e-mobility, everything is changing: The specimen tested, the tests to be performed, the type of measurements to be obtained.

With MORPHEE®Next, FEV can offer products enabling:

- Tests to be performed on electric powertrains and machines, power electronics and batteries.
- Data and processes for testing and development centers to be managed.
- A switch to a secure cloud-based architecture accessible par le web

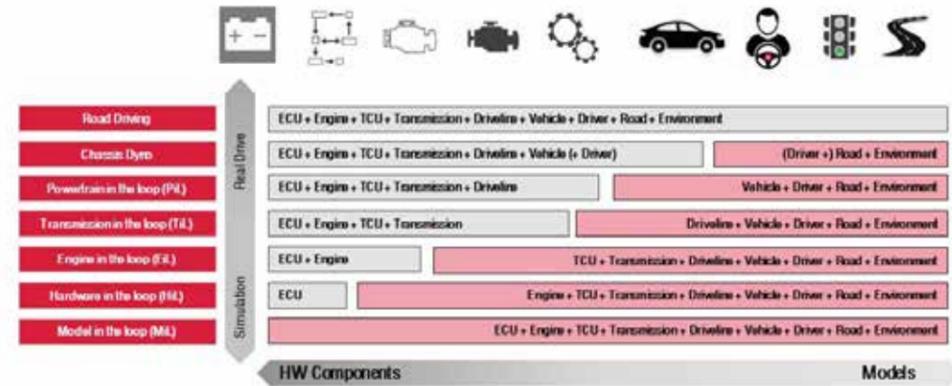
INTRODUCTION

FEV SOLUTIONS

» SIMULATION WITH FEV, A PROVEN SOLUTION

Alongside this approach, FEV has developed simulation methodologies applied to calibration. They are part of a continuous process (Diagram 1: Development process for virtual calibration), ranging from the design stages to road tests. Here we must dismiss the idea that the use of simulation eliminates the need for actual tests: Ultimately, they constitute the final proof. In this process, the various components of a vehicle – combustion engine, ECU (Engine Control Unit), transmission, TCU (Transmission Control Unit), drive train, vehicle, driver, road profile and environment – are completely modelled in the model-in-the-loop design phases. As we go through the process, the actual components replace the models, with the final validation stage on the track and road using the complete vehicle.

At the junction between the design and validation processes, the



XiL bench (X-in-the-loop, X being the tested specimen. Scheme 1, an example of an e-motor-in-the-loop test bench), is a key tool for the deployment of virtual calibration: it consists of standard bench testing of an actual component linked with virtual components. The xCAR™ range offered by FEV is comprehensive, covering all types of powertrain: Battery-in-the-loop, e-motor-in-the-loop, engine-in-the-loop, powertrain-in-the-loop...

It allows the specimen to be calibrated directly on the bench, from the first stages of development, even if certain components of the vehicle are not yet available (front loading). It also allows validations of critical driving that cannot be carried out safely on the road, and very accurate results to be obtained, in terms of measurements on the specimen (emissions, SOC, etc.). In fact, we actually benefit from the presence of the specimen on the bench, and therefore from actual measurements.

In addition, in comparison with road tests carried out by different drivers, the results provided have a high degree of repeatability from

INTRODUCTION

FEV SOLUTIONS

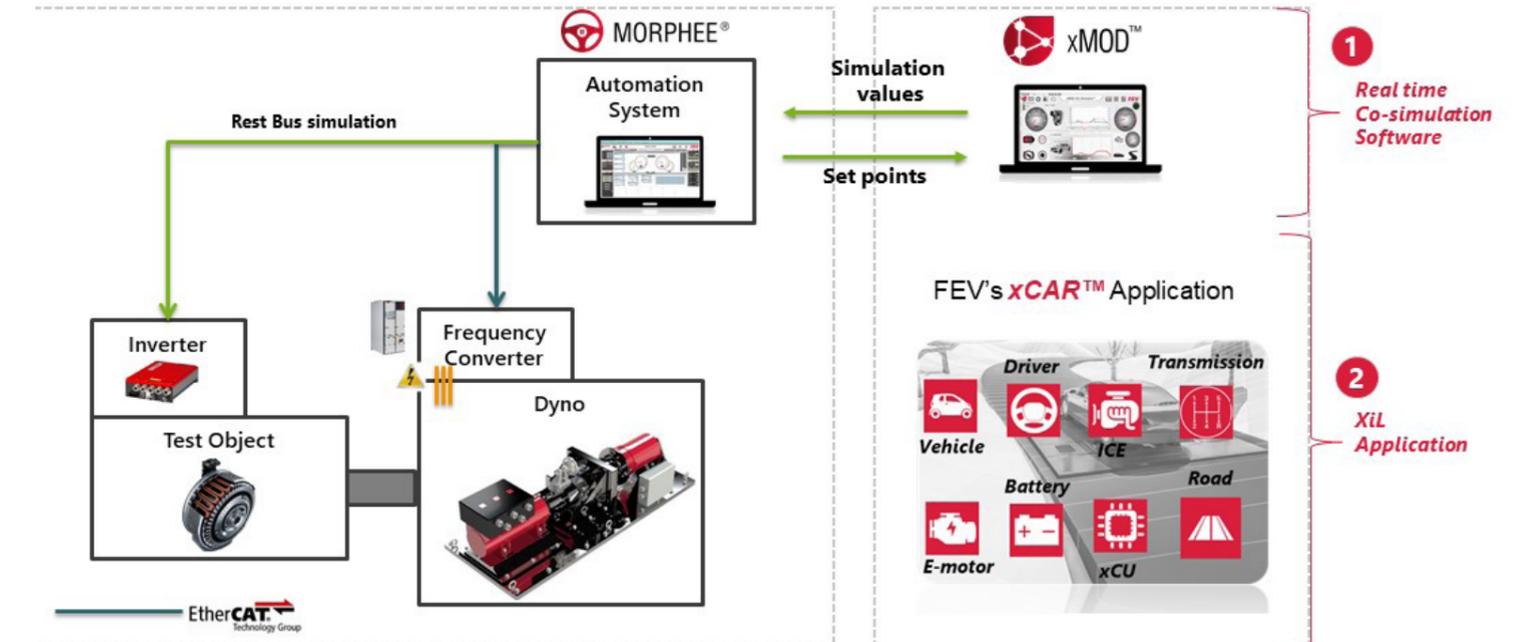
» REDUCING THE NUMBER OF PASSES ON THE BENCH AND THE TIME TAKEN

one test to another, since we are using a modelled driver, which can reproduce exactly the same behaviour for every single test.

Managing this type of bench requires expertise in a range of methods and technologies. In fact, performing a calibration involves handling a large amount of input and output data, and processing it according to complex mathematical methodologies such as DOE (Design of Experiments). FEV's development teams have developed the product xCAL™\* for this purpose.

In an XiL bench, the virtual world and the real world come together to create a single system, in this case, the vehicle. xMOD®, which is FEV's real-time software for co-Simulation and virtual experimentation, allows these two worlds to communicate with each other. It receives the measurements from the test bench via the automation system, and exports the simulated instructions to the bench. For example, in the case of an engine test bench, the automation system sends the torque measurements to xMOD®: This then returns the pedal and speed instructions for controlling the engine.

Scheme 1: Example of an e-motor-in-the-loop test bench



INTRODUCTION

FEV SOLUTIONS

» STANDARDISATION FOR RELIABLE BENCHES AND MEASUREMENT CHAINS

The creation of standard integrated benches allows costs to be managed. Combined with the measurement acquisition system and the entire measurement chain, the automation system outlined previously is, of course, the keystone of the bench: it enables the various elements of the bench to communicate with one another and repeatable measurements to be provided, whatever the bench. The choice of the elements which make up the bench is key.

For example, in a battery bench, this is the choice of the power generator, the climate chamber, and the safety system. At FEV, these are selected from solutions produced by international companies with highly qualified teams able to provide support anywhere in the world. The contract concluded with these companies ensures costs can be managed. Their communication interfaces with MORPHEE® are standardised. Of course, all their solutions have been validated in FEV battery test centers beforehand.

> Calculating vibrations: A challenge for e-motor benches

The installations required for e-motor and e-axle benches are similar to those for conventional combustion engine benches. For the e-motor benches, one technical difficulty to be overcome is the very high rotation speed of the element to be tested, which requires complete mastery of the kinematic chain and management of vibrations, so that speeds of up to 30,000 revs/minute can be reached. The industry is continuously making improvements here and, of course, FEV is in an excellent position in this respect, thanks to its extensive technical experience in mechanical

engineering and vibrations.

> Innovative FEV solutions: Back-to-back and multiplier benches

The similarity in the technology used for this type of bench and conventional engine benches allows original solutions to be envisaged. The test manager does not necessarily have to scrap all their old benches. Why not make use of a part of these? This is something that FEV is also invested in. With the back-to-back bench, FEV offers a solution enabling e-motor converter tests to be undertaken in certain cases without a battery simulator or a power drive. This original solution can reduce the price by two-thirds, and decrease the endurance test time by 50%!

Another innovative proposition from FEV is the multiplier bench: On an existing bench running at a certain speed, a multiplier is integrated to allow the speed to be doubled, for example switching from 10,000 to 20,000 rpm, with the torque reduced correspondingly, of course.

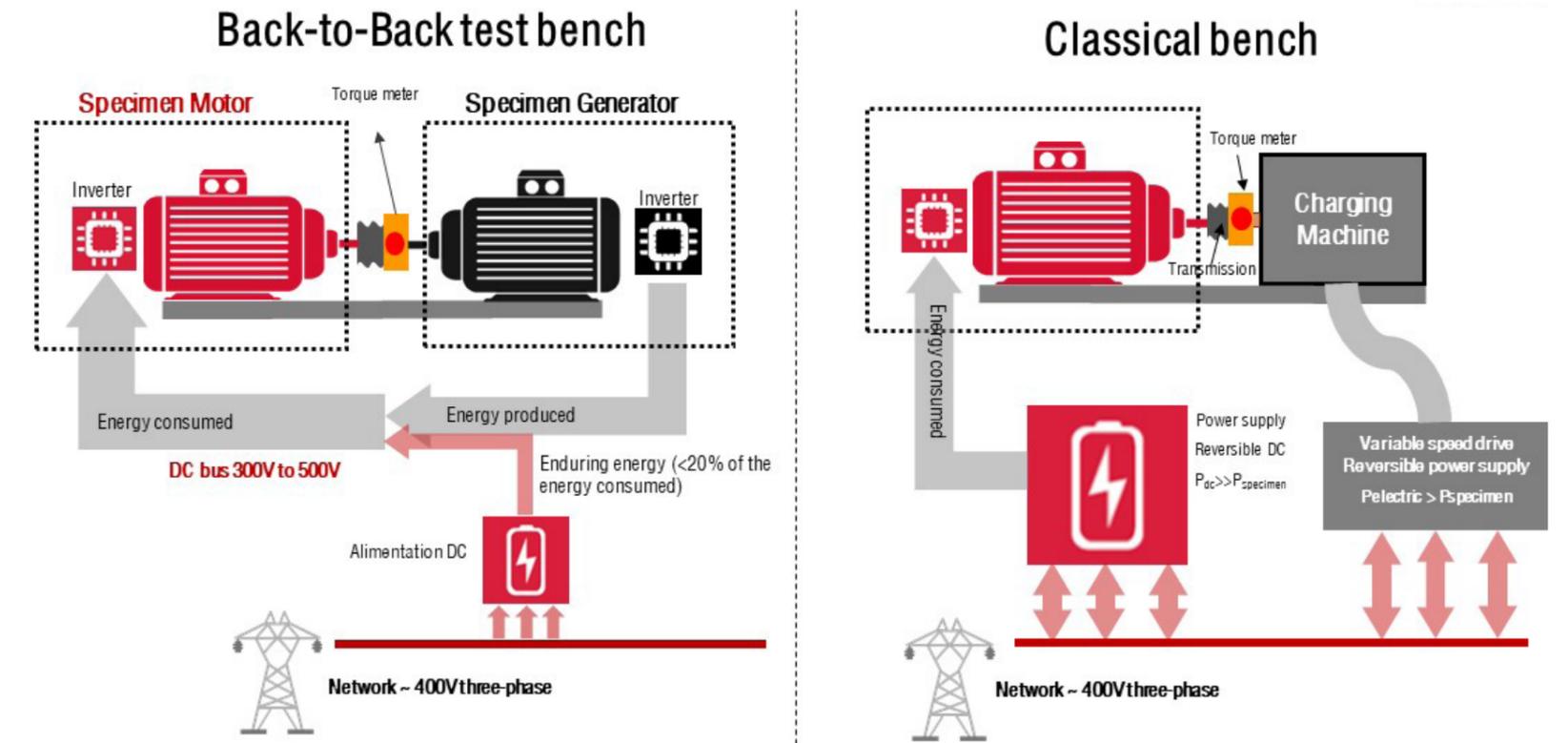
> Complete range of fuel cell benches

FEV has also developed a series of benches for fuel cells, from the cell to the complete system, and including the stack, with the hydrogen loop, the air loop, the thermal management system, and the bench measurement and control system.

INTRODUCTION

FEV SOLUTIONS

» EMOTOR & INVERTER TESTS WITHOUT BATTERY SIMULATOR AND EMOTOR EMULATOR: CUT YOUR COSTS BY 30%





FEV SOFTWARE & TESTING SOLUTIONS

TEST CENTERS

EFFICIENT BATTERY DEVELOPMENT  
AND TESTING CENTER: EDLP



THE LARGEST TEST CENTER FOR HIGH VOLTAGE BATTERIES IN THE WORLD\*.  
By FEV STS

FEV has built the world's largest development and test center for high-voltage batteries used in commercial and passenger vehicles. This center, which belongs to FEV, is located in Sandersdorf-Brehna which sits in a triangle between Halle, Dessau and Leipzig in Germany. It includes the most advanced battery testing technologies currently available, such as a 350 kN shaker and FEV MORPHEE® and FEVFLEX™ software, enabling tests to be thoroughly automated.

The 12,000 square meter complex contains facilities for the electrical testing of both modules and complete high-voltage batteries. This includes a test chamber volume of approximately 600 m<sup>2</sup>, distributed over 54 climatic chambers with an electrical output of 30,000

kW. The new development center will thus have the largest operational, independent battery testing facility in the world. Systems for validating all (international) environmental and 2 mechanical tests, as well as four bunkers will be installed. A fire hall for abuse tests, along with an associated disassembly and diagnosis workshop complete the spectrum. Together, these facilities cover every evaluation necessary for series production. The shaker enables combined mechanical and electrical tests in ambient conditions ranging from -40 to 100°C.

This center is the direct result of FEV's experience and thinking in the field of automotive battery testing: for the last 15 years, FEV has been creating battery test bench solutions for its own centers and those run by

other companies. It offers both standardised hardware solutions and software engineering adapted to each center and each test bench.

*\*For passenger car and commercial vehicles.*

TEST CENTERS - DESIGNED BY TESTING EXPERTS

EXAMPLE OF TEST CENTERS MADE BY FEV: eDLP, SANDERSDORF-BREHNA, GERMANY

Durability testing modules and packs



Battery testers



350 kN shaker



Walk-in chamber 22m3



500 kN crusher



Salt spray chamber 16m3



Salt spray chamber 2 400 liters



Underbody protection up to 1000 J



Cooling conditioning



Climate chamber 0,8m2



Dip tank 14m3



MORPHEE® Automation system



TEST CENTERS - DESIGNED BY TESTING EXPERTS

EXAMPLE OF TEST CENTERS MADE BY FEV : eDLP & SAINT QUENTIN-EN-YVELINES, FRANCE

THE SCOPE OF SUPPLY at eDLP

- > Durability testing for modules and packs
  - 19 walk-in chambers
  - 29 standard chambers: 7 x 800 l , 22 x 2 500 l
- > Environmental & mechanical testing for modules and packs
  - 1 shaker
  - 5 standards rooms for salt and climate chambers
  - 3 large and 1 small salt mist chamber
  - 1 Vacuum chamber
  - 1 flush water Wchamber
  - 1 dust chamber
  - 1 dip tank
  - 1 IP- tests areas
  - 1 rock fall test
- > Abuse testing
  - Overpressure test
  - Nail penetration tests
  - Impact test, Drop test
  - Crush test
  - Exposure to fire
  - Externer short circuit
  - Overcharge (time, voltage)...

THE SCOPE OF SUPPLY at Saint Quentin-En-Yvelines

- > Durability testing for cells, modules and packs
  - 108 channels for cells
  - 12 channels for modules
  - 6 test benches
    - 2 PHEV or EV test channels
    - 4 EV pack test channels



**SAINT QUENTIN-EN-YVELINES:  
CELL TESTING**

TEST CENTERS - DESIGNED BY TESTING EXPERTS

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 analyzers (2 line direct analyzers)

- > 4 combustion analyzers
- > 3 combustion intake air condition system
- > 12 fuel tank (Gasoline, Diesel)
- > Vehicle filling station
- > 8 BEV charging station

TEST CENTERS - DESIGNED BY TESTING EXPERTS

EXAMPLE OF TEST CENTERS MADE BY FEV

AUBURN HILLS:  
VEHICLE DEVELOPMENT CENTER

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



TEST CENTERS - DESIGNED BY TESTING EXPERTS

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

The eleven FEV test centers, including their 300 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 and vehicles. Its excellence in organization, workflows, logistics and human resources management in testing facilities is well proven.

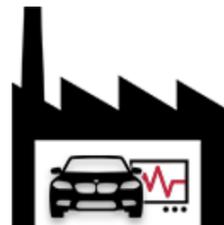
As an example, the eDLP battery test center offers a unique global concept for operating test centers efficiently:

- > Three shifts, 7 days per week (24/7), 365 day/year and optimized human resources,
- > Implementation of processes developed in the other FEV test centers.

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

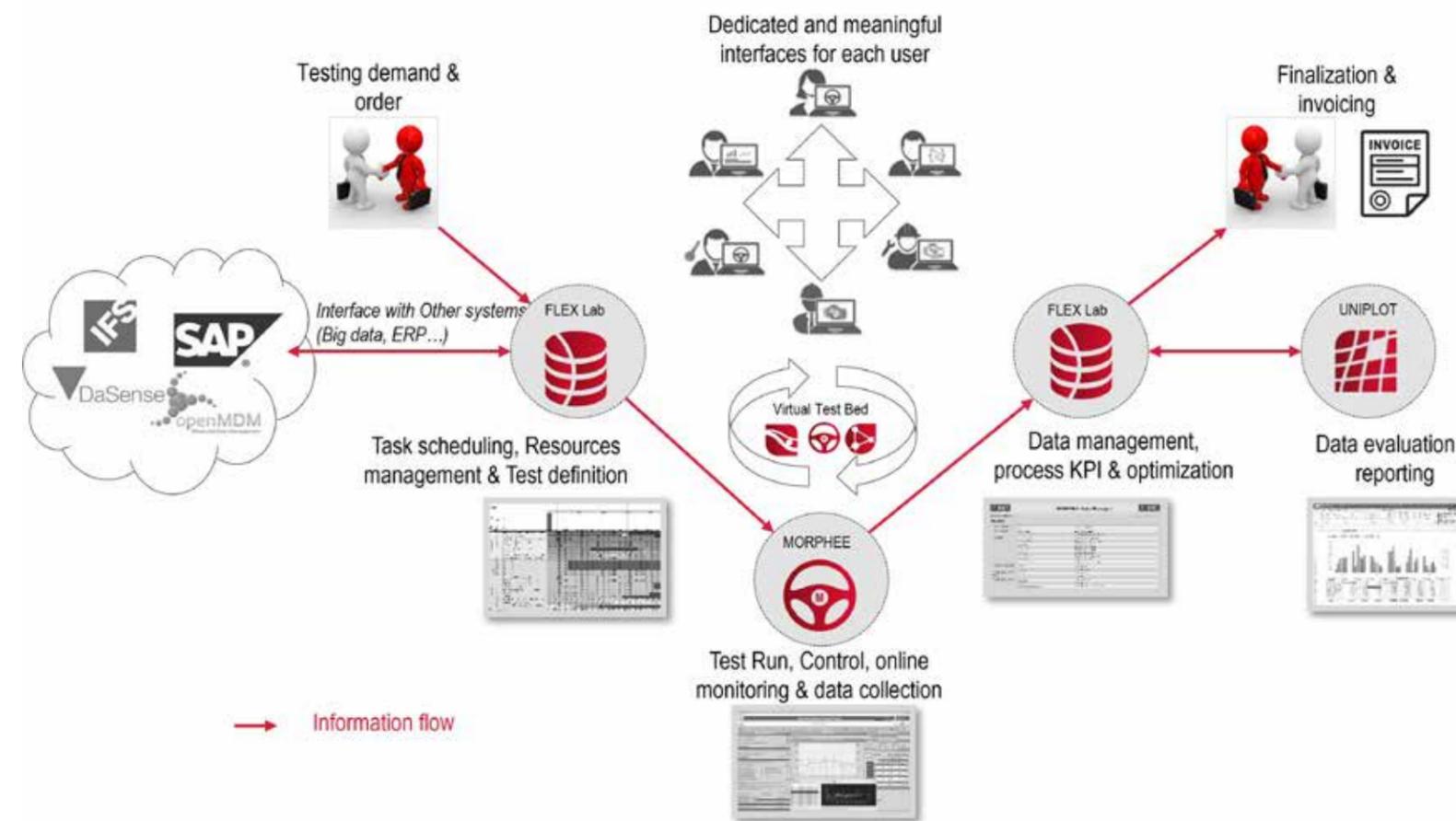


THE SCOPE OF SUPPLY

- > 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

TEST CENTERS - DESIGNED BY TESTING EXPERTS

» AN INTEGRATED TESTING PROCESS SUPPORTED BY THE SOFTWARE SUITE MORPHEE®NEXT



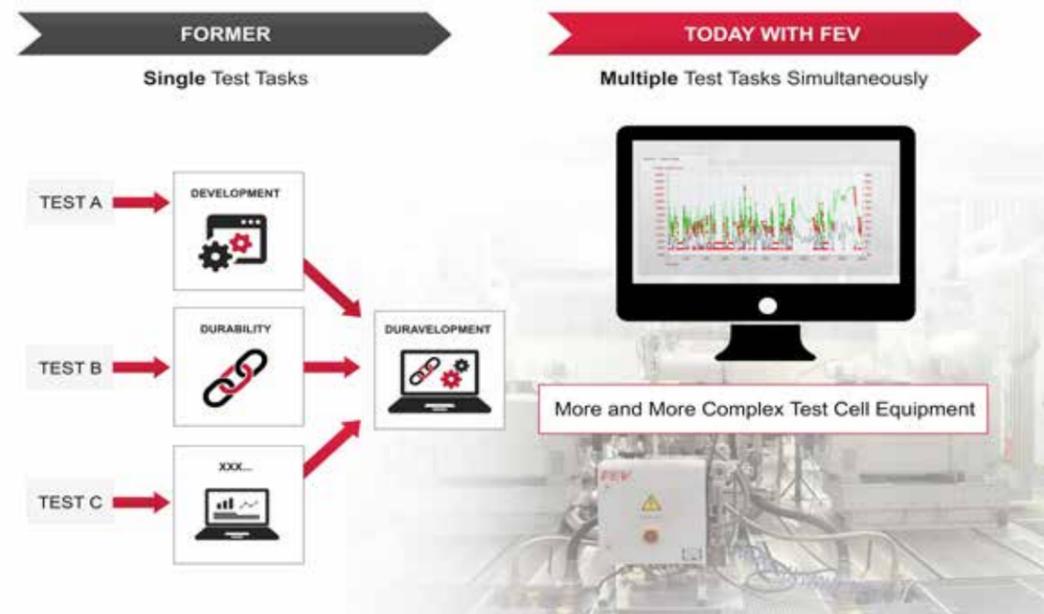
TEST CENTER

MAIN PROJECT DRIVERS

» 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...

TEST CENTER

MAIN PROJECT DRIVERS

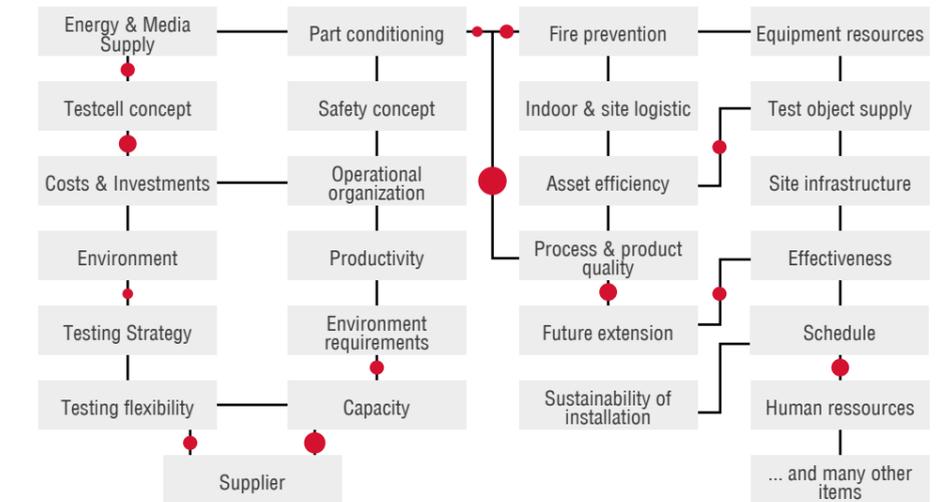
» LIST OF INPUTS TO CONSIDER FOR DEFINING THE TEST CENTER CONCEPT

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
- > 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
- > Method development for lean and efficient testing



## TEST CENTER

## FEV EXPERTISE

## » FEV EXPERTISE: FROM TEST BEDS TO ...

On the basis of best practice solutions and years of experience, FEV plans test beds and entire test centers, for its own needs or for answering customer requests. This is how, in test centers across the globe, battery, e-drive and fuel cell test benches are being created in various configurations. The heart of a successful project is the Consulting. It is where the specification is created and the layout of the test center is determined. As a leading automotive development service provider, FEV is constantly modifying the requirements of its own test capabilities to meet future needs. We use this knowledge in consultation with our customers to adapt current test benches to hydrogen applications, for example. Thanks to a tightly-knit network of experts, FEV covers 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.

## &gt; From the first sketch to commissioning

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.



## TEST CENTER

## FEV EXPERTISE

## » ... STATE OF THE ART TEST CENTER

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...)
- > Upgrading current facilities to the complete design of a new e-mobility test center



FEV Test Center at Yanjiao (Beijing, China)

TEST CENTER

INNOVATIVE CONCEPTS

» LEAN FLOW AND COLLABORATIVE WORK

FEV's solution optimizes the flows.

Here is an example of the solution selected from eDLP, the FEV Battery Test Center. One large hall offers easy access to the test beds for the UUT and to the climatic chambers and the other devices. The first floor houses all the large equipment such as the power units. At peak load, as much as 4,800 A and 1,000 kW of power can be supplied to test one battery by connecting multiple testing channels.



Power supply units on first floor



Unique control room

In some cases, FEV proposes 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.

TEST CENTER

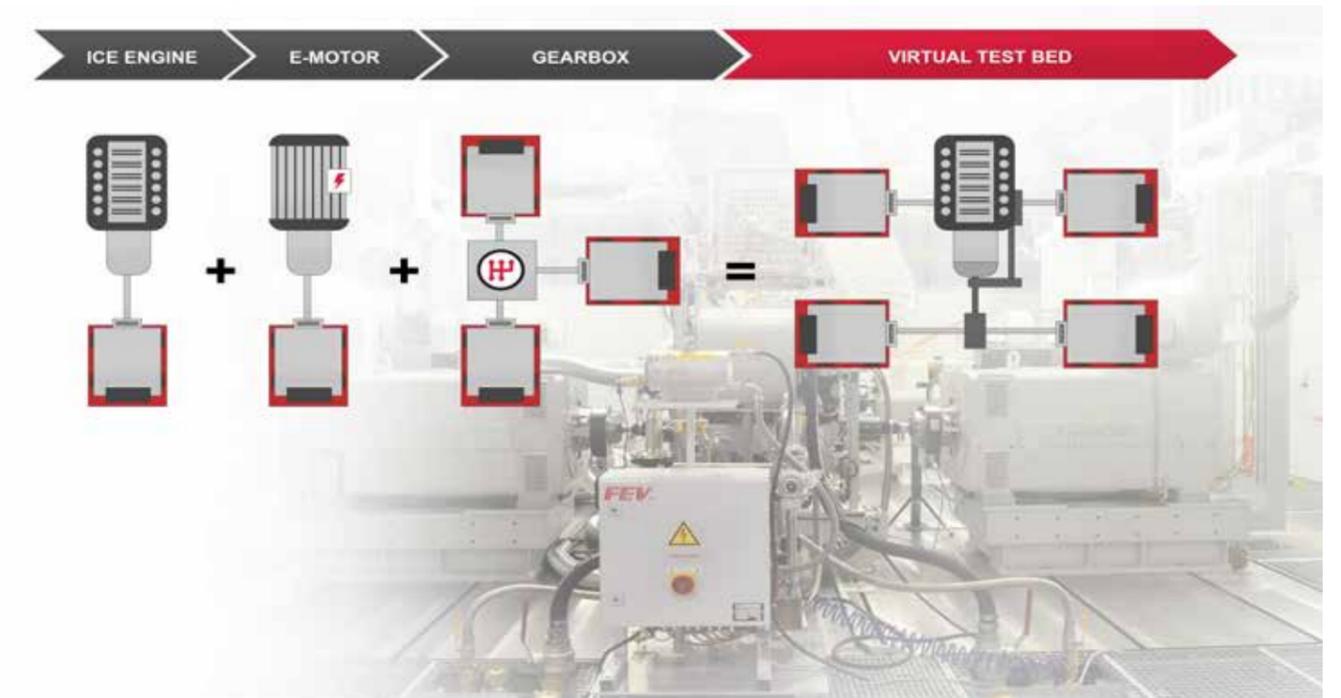
INNOVATIVE CONCEPTS

» 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

TEST CENTER

PROJECT PROCESS

» THE DIFFERENT STEPS OF A TEST CENTER BUILDING PROJECT

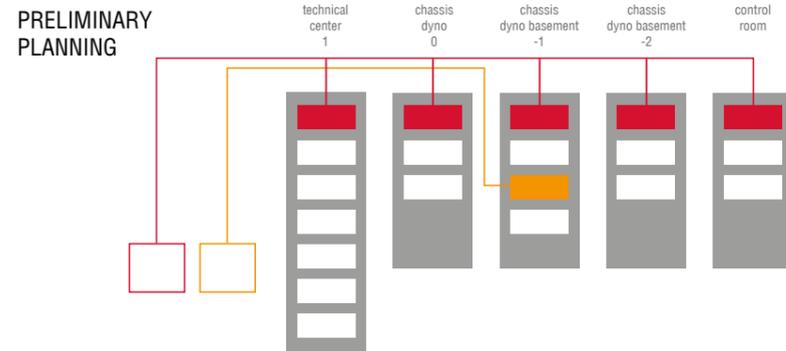
There are two main phases involved in creating a new test center: the first phase comprises defining and planning the project and its completion is marked by provision of the specifications; the second comprises execution of the project in its current form.

> Planning and consulting

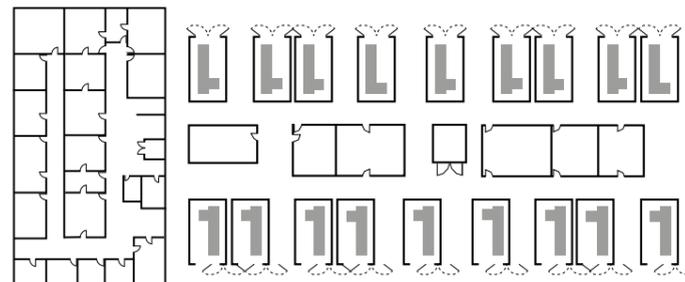
A successful project is one where the planning phase has been carefully managed and where nothing has been left to chance. Conceptual defects attributable to inadequate specification and design in the early planning stages can only be corrected later with great difficulty or, in some cases, not at all. 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



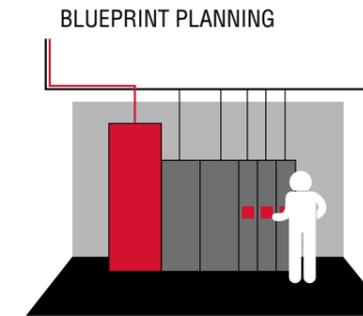
2D CONCEPT



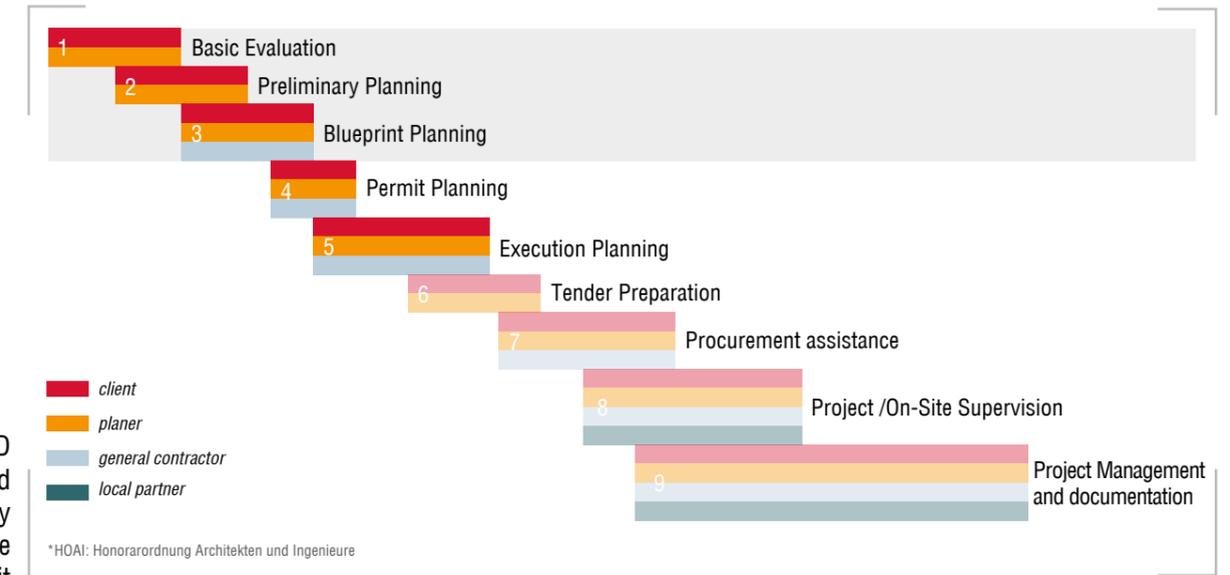
TEST CENTER

PROJECT PROCESS

» THE DIFFERENT STEPS OF A TEST CENTER BUILDING PROJECT



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.



**FEV SOFTWARE & TESTING SOLUTIONS**

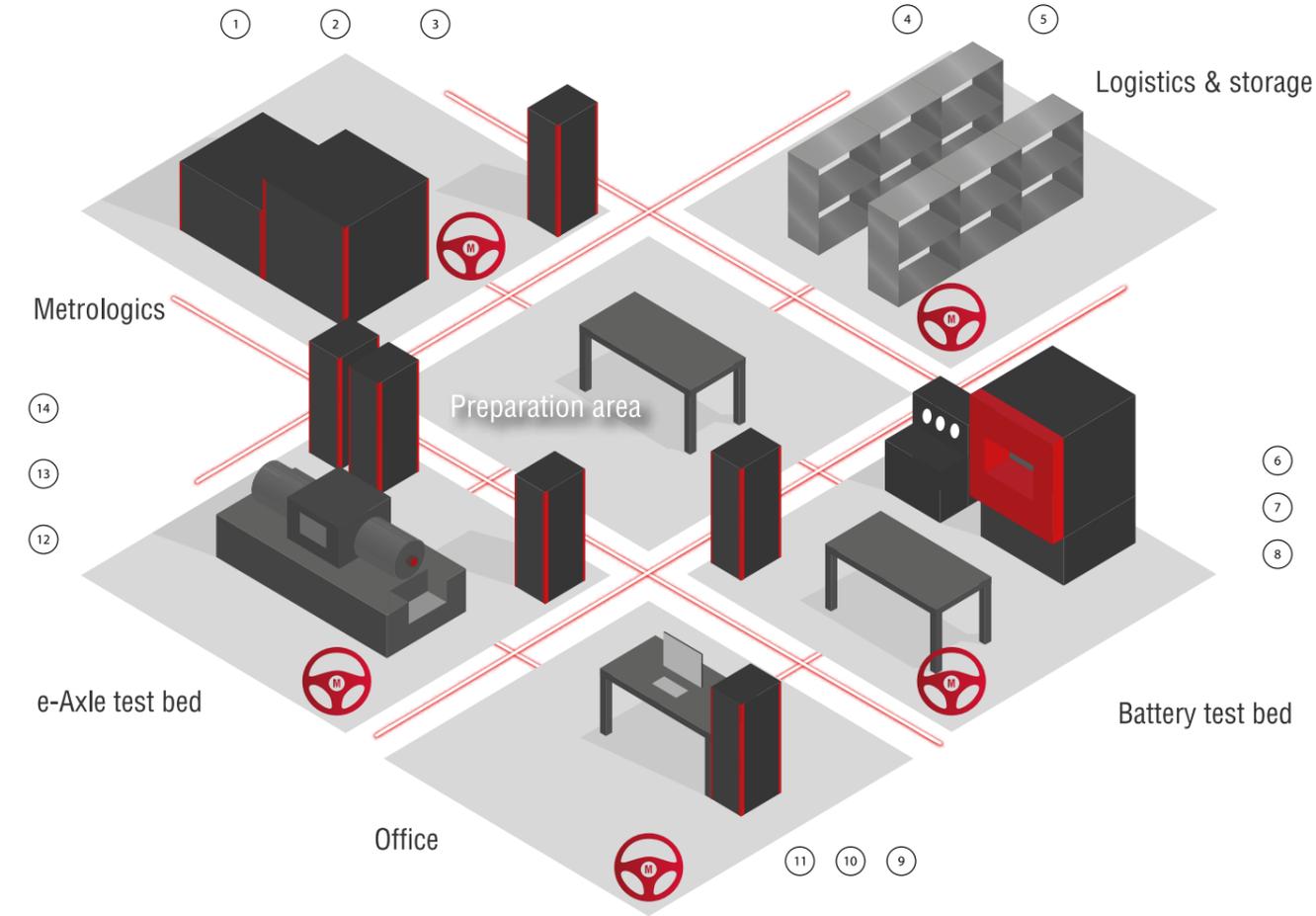
**TEST BENCHES**

**TEST CELLS - ELECTRIFICATION**

E-MOBILITY SOLUTIONS: BATTERY, ELECTRIC DRIVE



SOFTWARE AND TESTING SOLUTIONS



- 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.

## TEST CELLS - PROVEN IN FEV TEST CENTERS

## » 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.



## TEST CELLS - PROVEN IN FEV TEST CENTERS

## » 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.



## TEST CELLS - BATTERY

## 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. This is performed with the FEV XiL solutions. Other configurations are also possible, such as testing the BMS (Battery Management System) without the battery (page 68).



Exemple of FEV STS solution for a standard pack testing solution

## 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 1200 V
- > DC current up to 2400 A
- > Automation System by MORPHEE®, controlling 4 packs at the same time and independently.
- > Test field management by FLEX Lab™
- > Possibility to run models at the test bench (battery-in-the-loop) with xMOD®

## KEY BENEFITS

- > Thanks to the FEV software chain tools, up to 95% of operation rate.
- > Flexibility and scalability of MORPHEE
- > 1/36 cells, 1/12 modules, 1/4 packs
- > RT simulation
- > Solutions based on robust and validated products
- > Battery In the Loop solution with additionnal xCAR module.

ALL TYPES OF BATTERY TEST BEDS

CELL, MODULE OR PACK

## BATTERY TEST BENCHES

### BATTERY



#### 1 Cells

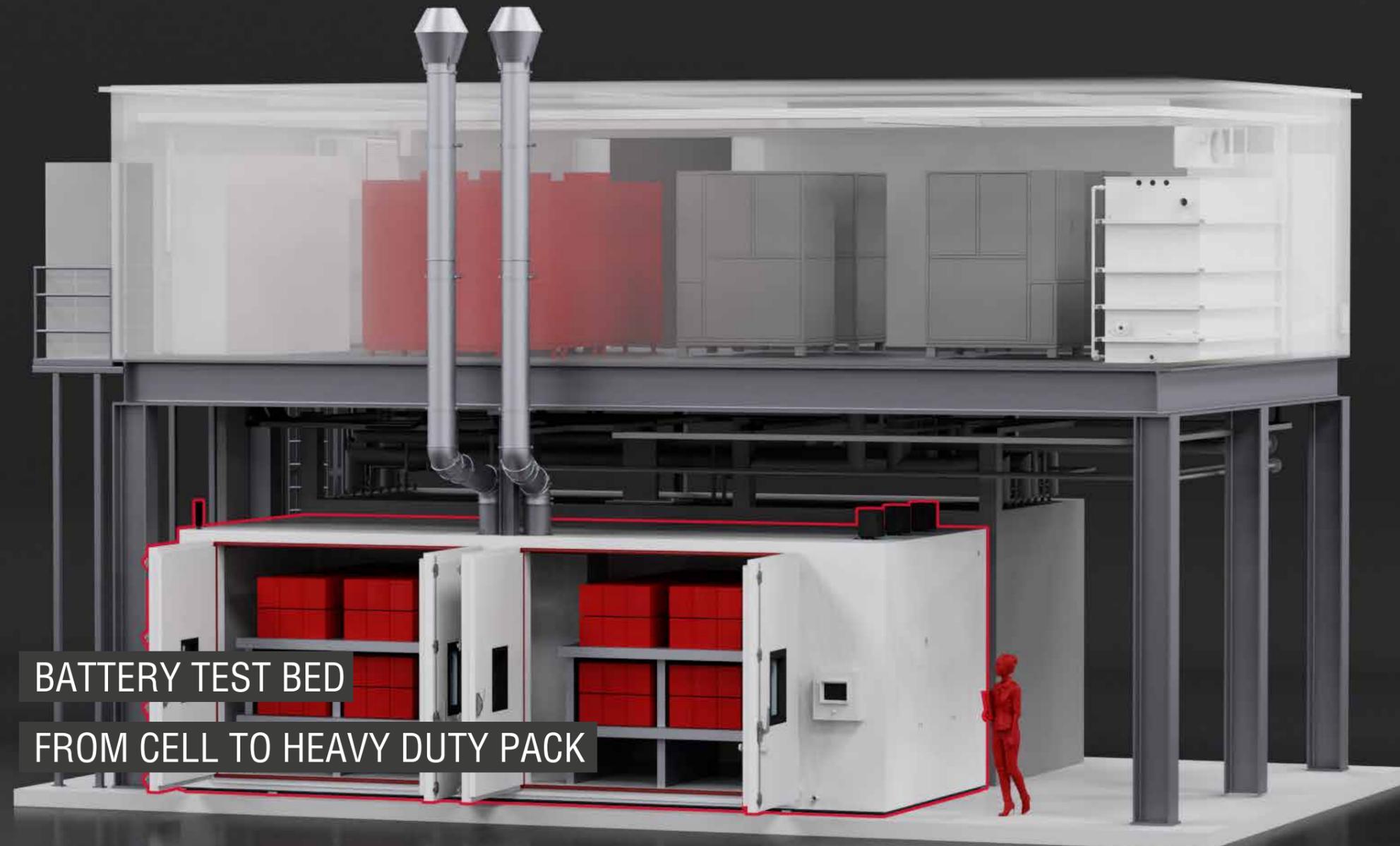
- > A 36 channels power unit
- > 0 - 6 V / 300 A for each channel
- > Climatic chambers -40°C to +80 °C, 0 °C to + 80 °C
- > Current nominal peak: 300 A
- > Current nominal continuous: 200 A
- > Current parallelization: up to 6 channels (1800 A peak)
- > 1 MORPHEE® Asy for the power unit, 3 for controlling 12 channels

#### 2 Modules

- > A 4 channels power unit
- > Voltage: 0 to 120 V
- > A climatic chamber: -40°C to + 80°C, or 0 °C to + 80 °C
- > Fire protection: Fire + smoke detection + CO<sub>2</sub> extinguishing system + smoke exhaust
- > Current nominal peak: 200 A
- > Current nominal continuous: 150 A
- > Current parallelization up to 2 channels (400 A peak)
- > 1 MORPHEE® Asy for 4 channels

#### 3 Packs

- > Charge/discharge cabinet, up to 1 200 kW, output voltage: 20-1200 V, output current: +/- 2400 A
- > Fully integrated solution with all safety components
- > Climatic chambers: Available in different sizes, including Walk-in Chamber
- > Safety solution includes a sensor system, an extinguishing system, fire flap
- > Cooling system: eCoolCon from FEV
- > MORPHEE® Asy: control of up to 4 packs

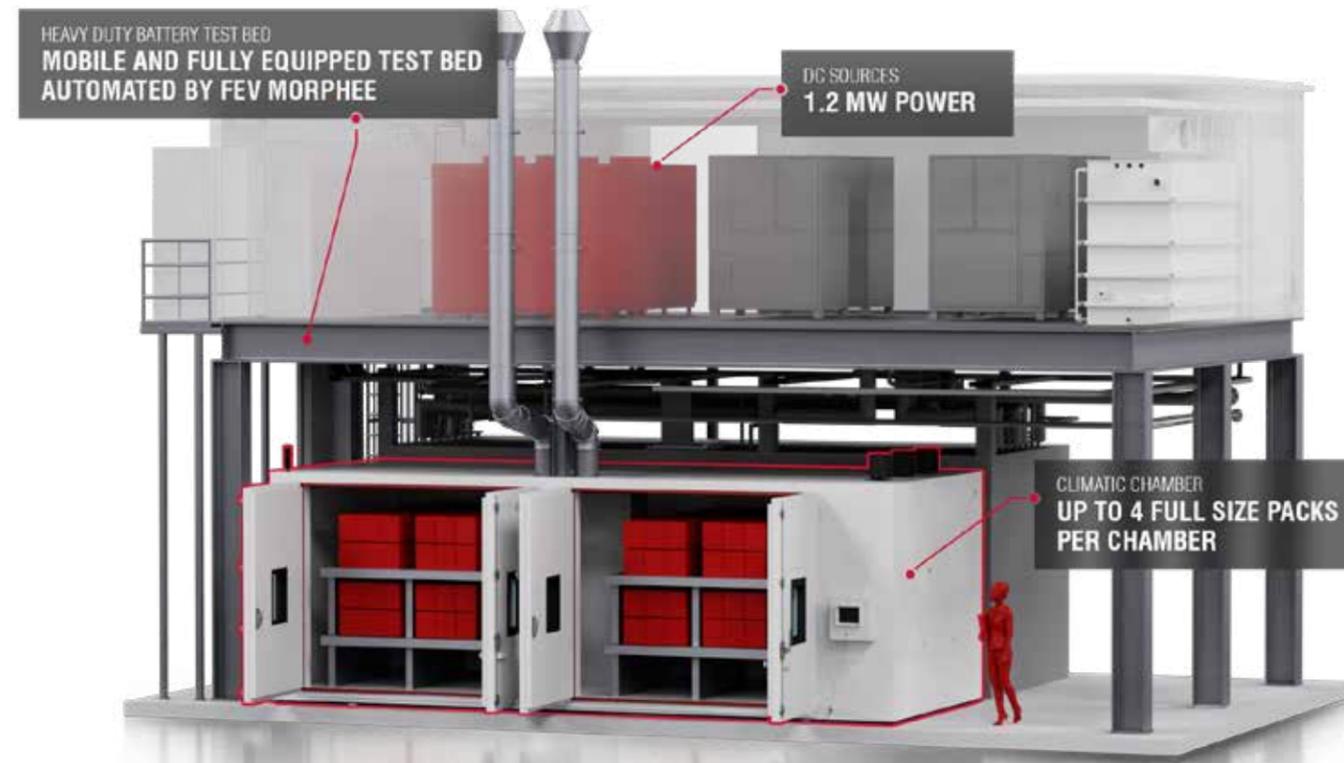


## BATTERY TEST BENCHES

### BATTERY

#### HEAVY DUTY: up to 8 HV battery equipped with 1,2 MW energy system

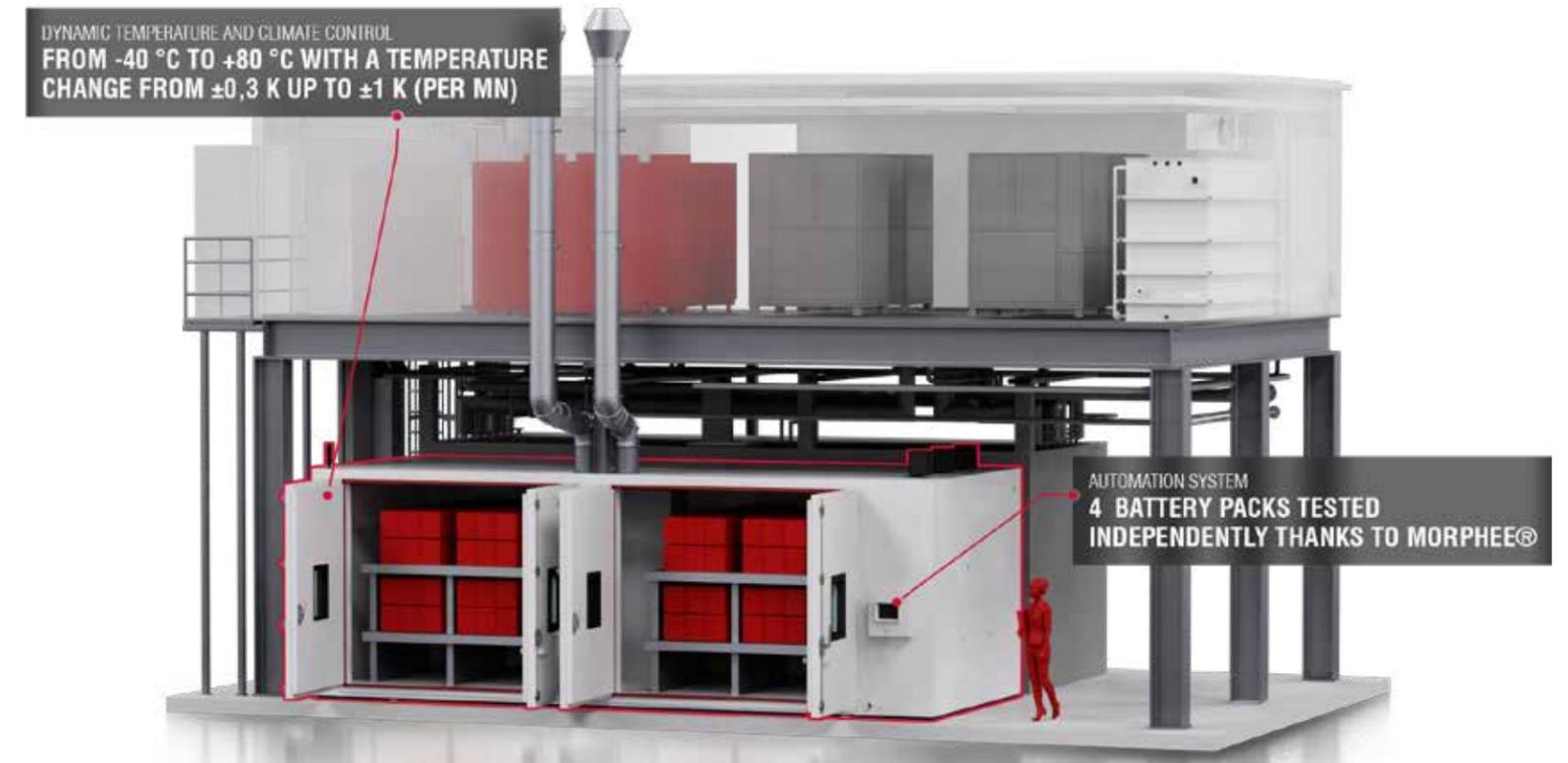
- > **High power energy systems:** Dynamic high power energy system up to 1,2 MW, flexible power profiles for up to 8 test specimens with a mass of 8T in continuous operation.
- > **Mobile free field system:** Mobile, modular test field. Designed for relocation on demand.



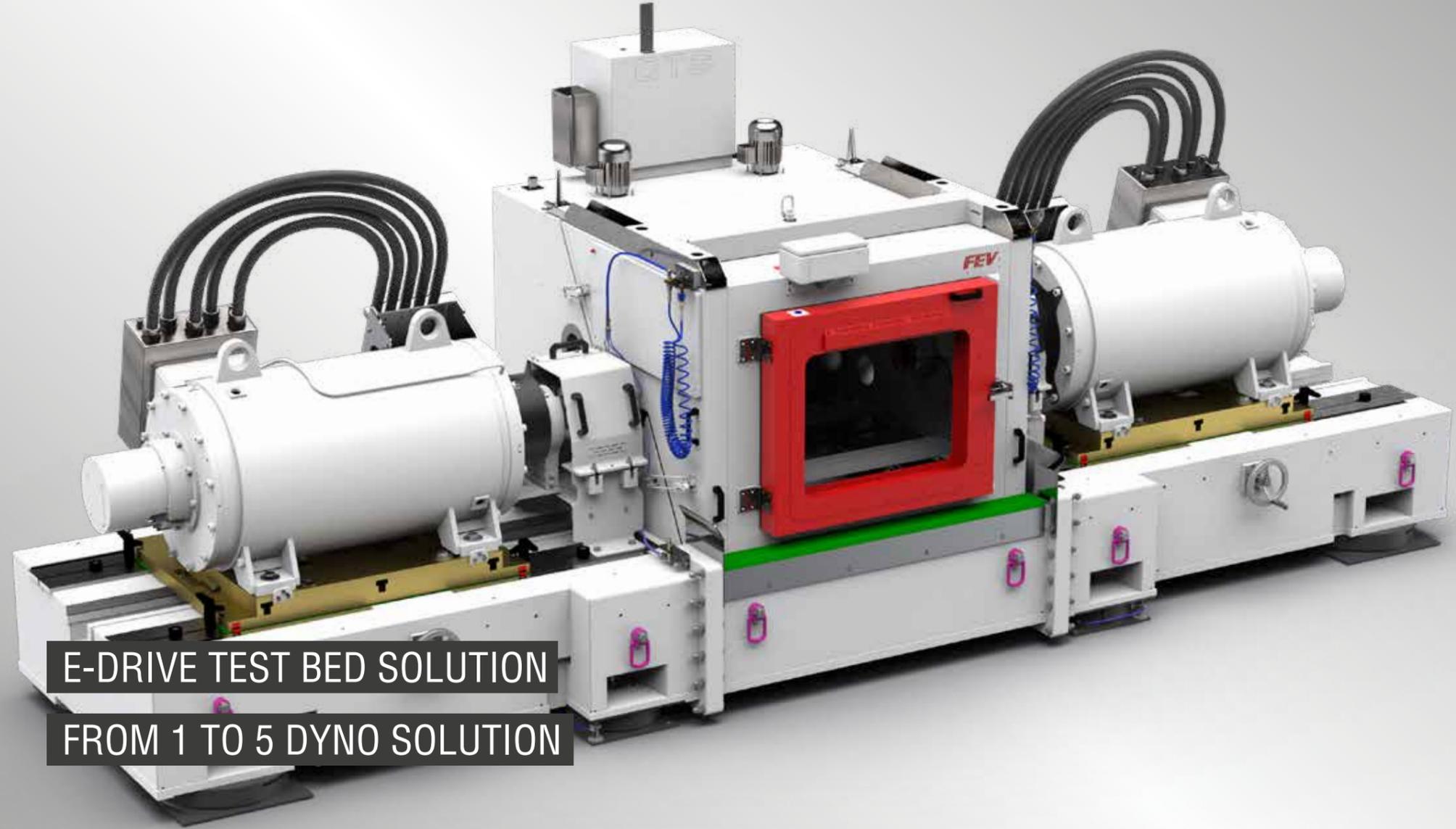
### BATTERY

#### HEAVY DUTY: multi-instance functionality thanks to MORPHEE® AUTOMATION SYSTEM

- > **Fully automated with MORPHEE®:**
  - In the same test bench, the 4 specimens tested independently thanks to the multi-instance functionality.
  - Expert test possible with access to the BMS and simulation mode.
- > **Dynamic temperature and climate control:** High-end temperature or climate chamber 1 for simulated environmental conditions from -40 °C to + 80 °C, with a temperature change from +/- 0,3 K up to +/- 1 K (per minute)



TEST CELLS - ELECTRIFICATION  
HYBRID POWERTRAIN



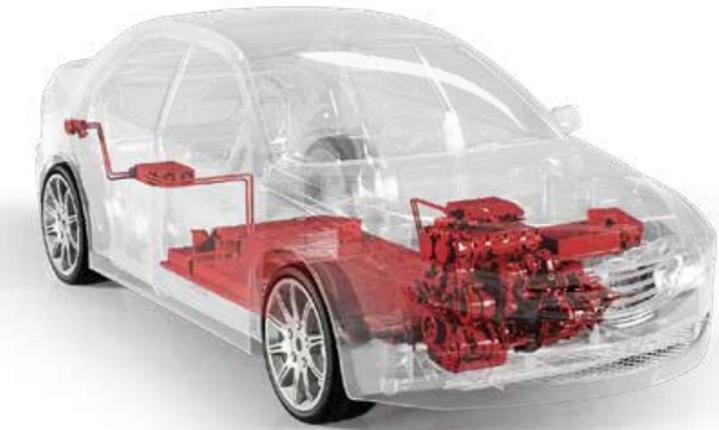
**E-DRIVE TEST BED SOLUTION  
FROM 1 TO 5 DYNO SOLUTION**

» 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 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.

## TEST CELLS - ELECTRIC DRIVE

### E-MOTOR

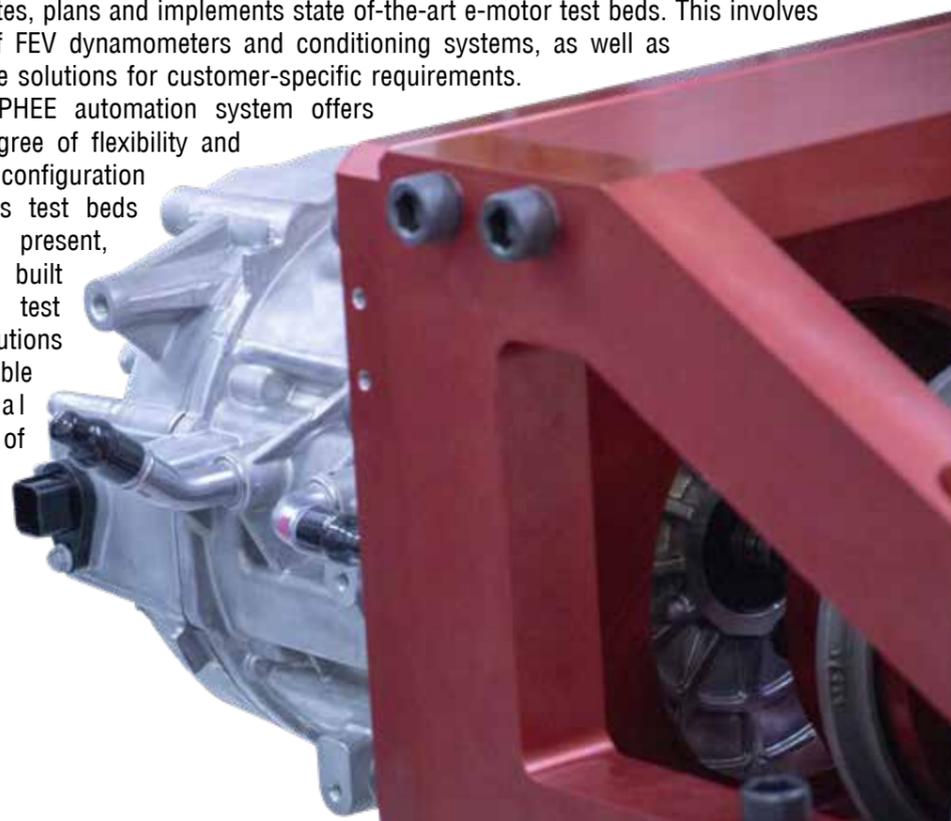
#### » E-MOTOR CHARACTERIZATION

##### > 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

## TEST CELLS - ELECTRIC DRIVE

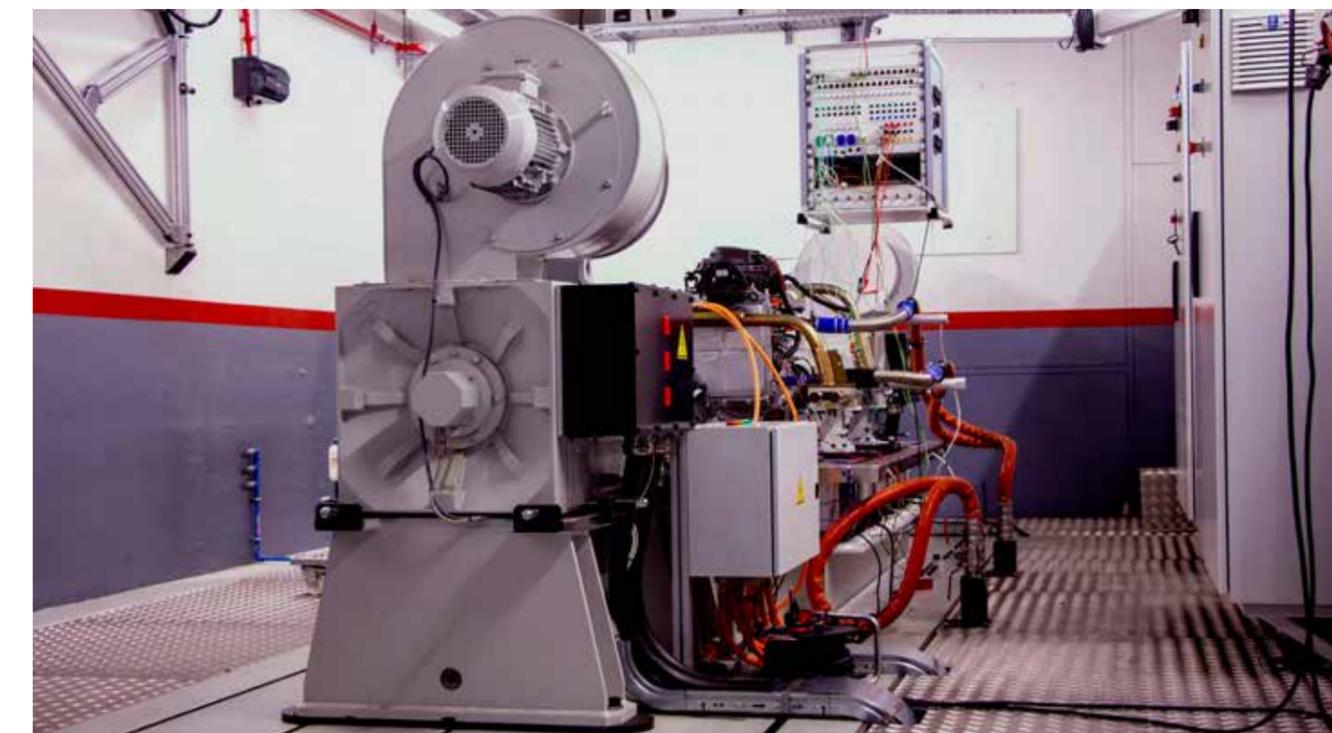
### E-AXLE

#### » 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
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- > Flexibility and scalability of MORPHEE: A test bed that follows changes in technologies

## TEST CELLS - FUEL CELL

## FUEL CELL

FEV helps you to plan, design and set up the right test cell following your individual needs in the field of fuel cell testing. Topics covered include fuel cell testing, stack testing and system tests. Thanks to our universal real-time automation system MORPHEE®, we take care about the overall safety of the test cell as well as the gas infrastructure and the storage of hydrogen in bundles or trailers. We interface the conditioning units filtering the gases and controlling pressure, temperature and humidity of hydrogen. LV and HV components are integrated in order to best analyze the fuel cells at highest

quality. From local definition or from a centralized server based FEVFLEX application, MORPHEE® manages all required experiments for fuel cell engine testing, such as startup characteristic tests, rated power tests, peak power tests, dynamic response experiments, steady-state characteristic tests, emergency-stop function tests, insulation tests, system mass tests, reliability durability test and system efficiency tests. With FEV, get ready for Hydrogen Fuel Cell testing!

- 1 HYDROGEN PEM SINGLE CELL TEST SOLUTION
- 2 HYDROGEN PEM FUEL CELL STACK TEST STATION
- 3 FUEL CELL SYSTEM TEST STATION
- 4 FUEL CELL BOP SYSTEM TEST STATION



ALL TYPES OF FUEL CELL TEST CELLS: CELL, SHORT STACK, STACK...

SYSTEM & SUBSYSTEM (ANODE, CATHODE, COOLING)



## TEST CELLS - HYDROGEN

### SINGLE CELL TESTING

#### » HYDROGEN PEM SINGLE CELL TEST SOLUTION

##### CHARACTERISTICS

- > Mostly for research purposes
- > From 100 to 2000 W
- > Analysis of processes in the cell
  - Aging of components (membrane, catalyst, etc.)
  - Accelerated stress tests
  - Contact pressure
  - Catalyst loading
  - Membrane thickness
- > Main customers: research institutes & MEA/Stack manufacturers
- > Operation possible with a local electrolyzer
- > Combination with electrochemical impedance spectroscopy



## TEST CELLS - HYDROGEN

### PEMFC STACK TESTING

#### » HYDROGEN PEM FUEL CELL STACK TEST STATION

##### CHARACTERISTICS

- > Cells' interaction in economic scale
- > Up to 10kW / 50kW / 100kW / 150kW / 200kW
- > Optional with climate chamber
- > Main features:
  - Anode conditioning system
  - Cathode conditioning system
  - Cooling supply system
  - Cell voltage monitoring up to 1000+ channels
  - Resistive or regenerative loads
  - Expandable with additional I/O
  - Humidification method with fast response



## TEST CELLS - HYDROGEN

### FUEL CELL TESTING SYSTEM

#### » STAND-ALONE HYDROGEN FUEL CELL TESTER

##### CHARACTERISTICS

- > Hydrogen flow measurement
- > Liquid coolant module
- > Electronic load bank, back-to-grid
- > Data acquisition
- > CANBUS Integration with FCE controller
- > Auxiliary power supply system
- > Optional integrated environmental chambers
- > CE certification
- > Complete integration with facility safety systems
- > Optional support with facility design / integration



## TEST CELLS - HYDROGEN

### SUBSYSTEM (ANODE, CATHODE, COLLOINF SYSTEM)

#### » FUEL CELL BOP SYSTEM TEST STATION

##### CHARACTERISTICS

- Testing of the auxiliary components in the system (includes pumps, sensors, heat exchanger, gaskets, compressors, recirculation blowers or humidifier)
- Three types of subsystem test bed are provided:
  - Anode system test bed
  - Cathode system test bed
  - Cooling system test bed
- Test single component as well as the whole subsystem
- Main customers are fuel cell system integrators and Auto Makers





HARDWARE IN THE LOOP

REDUCED DEVELOPMENT AND TESTING COSTS



FROM OFFICE

TO TEST BED

TEST CELLS - HiL

XiL solutions

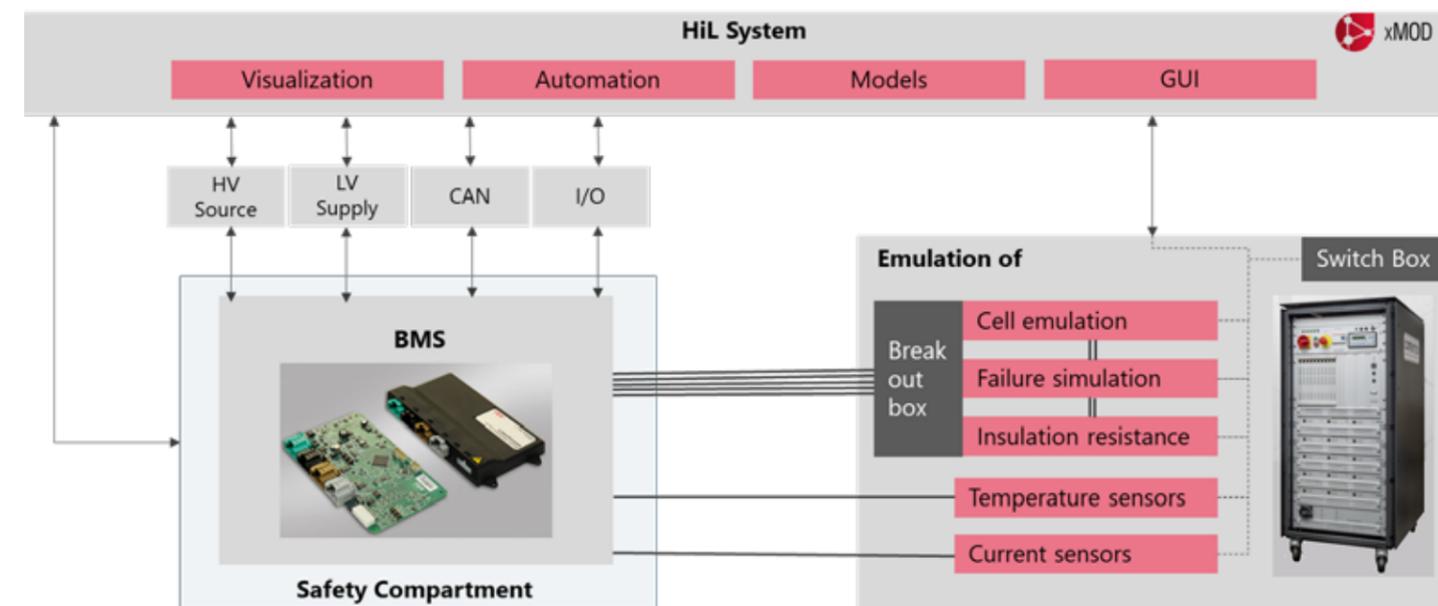
» TEST BMS WITHOUT BATTERY: IS IT POSSIBLE ?

The testing of Battery Management Systems (BMS) with real Li-ion batteries can be costly and time consuming. The Solution ?

Using a system such as BMS Hardware-in-the-Loop (HiL) will help shorten the development cycle of a BMS system and reduce costs. So the solution is to simulate the battery at a cell level with cells voltage, temperature sensors, current sensors, fault injection, and insulation resistance.

With the real time system xMOD® to integrate models, manage hardware, automate testing procedures, and generate visualizations.

For more information on FEV Battery test beds solutions, please refer to pages 49-55.



TEST CELLS - HiL

On-board Charger

» HOW TO DEVELOP AN OBC WITH SO MANY TYPES OF ELECTRIC VEHICLE SUPPLY EQUIPMENT ?



On-board-charger has a challenge : multiple standards and communication interfaces of charging stations !

How to develop an on-board-charger with so many types of stations ?

We, at FEV, have a solution, based on MORPHEE®.

Yes MORPHEE® again. The real time automation software is able to do so many tasks.

MORPHEE® manage the EVSE emulation, the battery emulation, the smart charging, while monitoring power ranges and the safety of your test cell.

Using one single interface and few clicks, you can start validation sequences, switch charging communication standard, inject default and test your OBC across the wide range of EVSE.

## TEST CELLS - HIL

### HIL TEST BEDS WITH VIRTUAL POWERTRAIN

#### » A VIRTUAL TEST BED FOR RDE CYCLES: THE vCAP

FEV offers a unique simulation-based virtual test bed to perform a significant part of up to 30 percent of Engine Control Unit (ECU) calibration on virtual and Hardware in the Loop (HiL) test beds, without the need for an engine test bed. It allows the demanding requirements associated with new transient cycles (Worldwide harmonized Light vehicles Test Procedures (WLTP)) and environmental cycles (Real Driving Emissions (RDE) linked to new temperature and altitude conditions) to be met.

Up until now, calibration of the ECU by simulating the engine and its environment has encountered major technical problems:

- With 0D/1D physical or numerical simulation, it is possible to simulate the impact of the engine design on pollutant emissions and fuel consumption and thus define the most suitable concept to achieve the desired performance. However, the level of accuracy is low and not sufficient for ECU calibration.
- On the other hand, design of experiments (DOE) enables reliable statistical models to be created with a limited and reasonable amount of experimental data. As a result, a global DOE enables the modeling and prediction of pollutant emissions and fuel consumption on the whole engine map, taking into consideration specific steady-state operating points, as well as the air path and injection parameters. Accuracy for these operating points (5% to 10% on NOx) is at the requested level for calibration tasks. However, the development of more dynamic cycles with Euro

6/7, such as WLTP and RDE, reveals the limits of this method: Since the acceleration phases are much more present than on the previous NEDC cycle, air loop control errors are becoming more significant. These air loop differences can result in a loss of accuracy in the prediction of pollutant emissions of up to 25% of NOx emissions per cycle.

#### A powerful combination of technologies

To overcome these challenges, FEV offers an innovative and simple solution based on FEV products, in combination with well-known third-party products: xCAL™ \* DOE model for combustion and pollutant emissions and Gamma Technologies GT-SUITE or SIEMENS Amesim for physical modeling of the air path, all together coupled and integrated into MORPHEE integration and automation platforms, to optimize CPU performances, easily set-up automated procedures and even connect a real ECU (HiL). This innovative virtual test bed solution achieves good accuracy levels (5 to 10% on NOx) thanks to the excellent behaviour of the complete air path, thus making it an efficient and reliable virtual calibration platform.

With these virtual test beds, engine settings are tested using simulations and results for emissions and fuel consumption can be quickly and easily obtained on RDE and WLTC cycles for a wide range of applications.

## TEST CELLS - HIL

### HIL TEST BEDS WITH VIRTUAL POWERTRAIN



#### BENEFITS

- **Decrease of the share of physical tests** in an engine development: engine test beds, chassis dyno and vehicle, in standard and non-standard conditions (temperature, altitude...)
- **Shorter development time**, due to a model based collaborative framework: the simulation, control, calibration and testing teams share the same models, dashboards and variable configuration
- **Due to the unique performance of FEV systems**, the accuracy of the models remains the same from the MiL step to the validation at the test bed

TEST CELLS - HIL

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

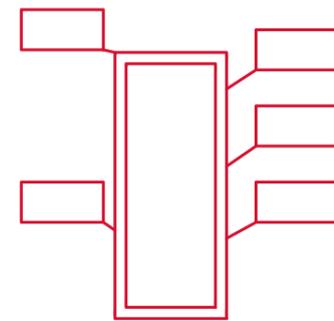
Specification of the needed tests to be performed from DOE to EATS tests to vehicle tests.

> MiL Stage Development

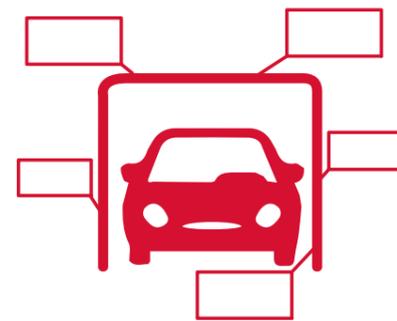
Analysis of existing customer plant models to be refurbished and integration of FEV models.

> HiL Stage Development

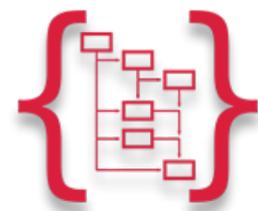
Integration of plant models, ECU and harness into vCAP hardware.



1- vCAP Definitions & specifications



2- Bench Test Specifications



3- MiL Stage Development



4- HiL Stage Development

TEST CELLS - HIL

HIL TEST BEDS WITH VIRTUAL POWERTRAIN

» 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.

TEST CELLS - HIL

HIL TEST BEDS WITH VIRTUAL POWERTRAIN

» 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.

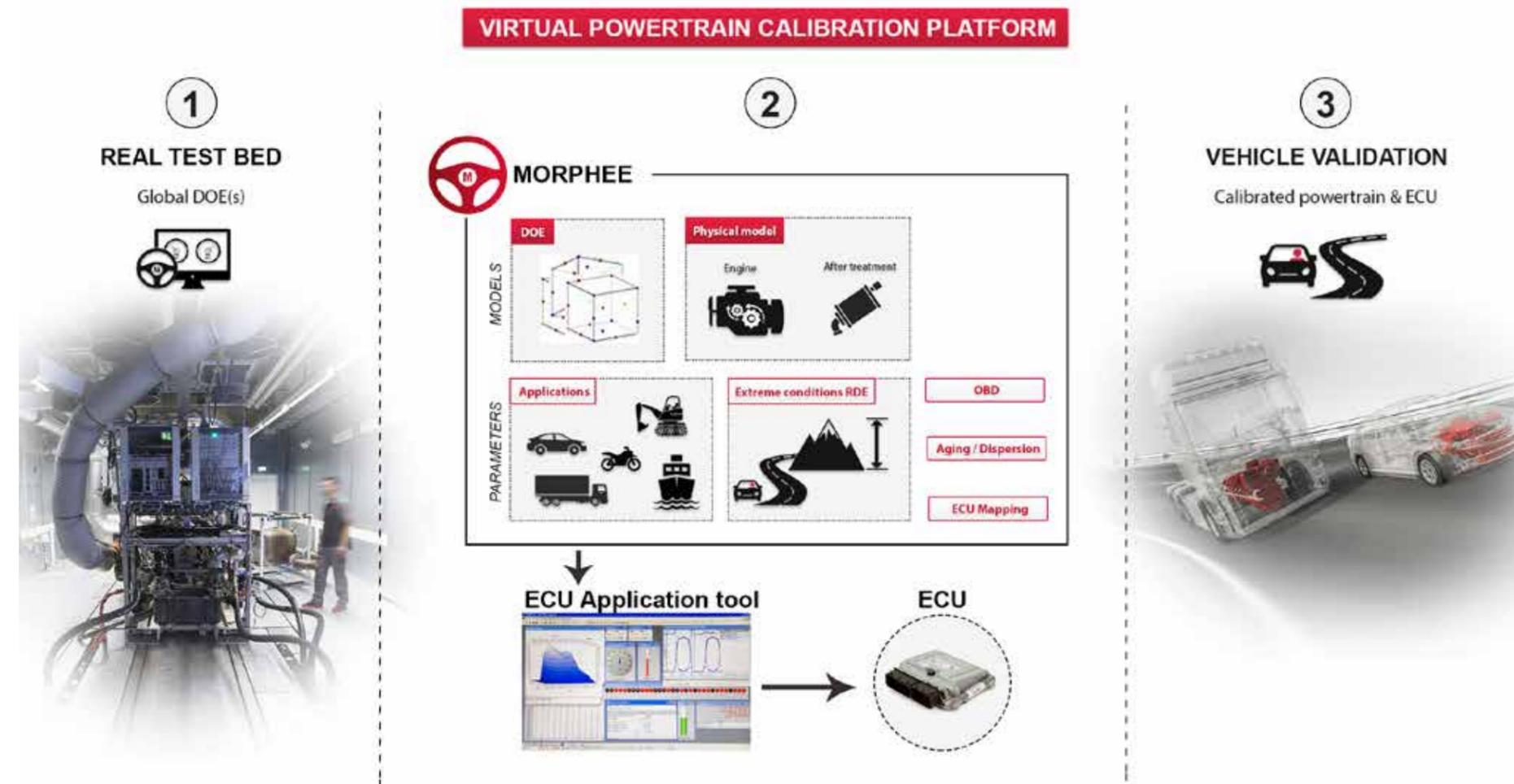
> Easy interfacing with 3rd party components

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.

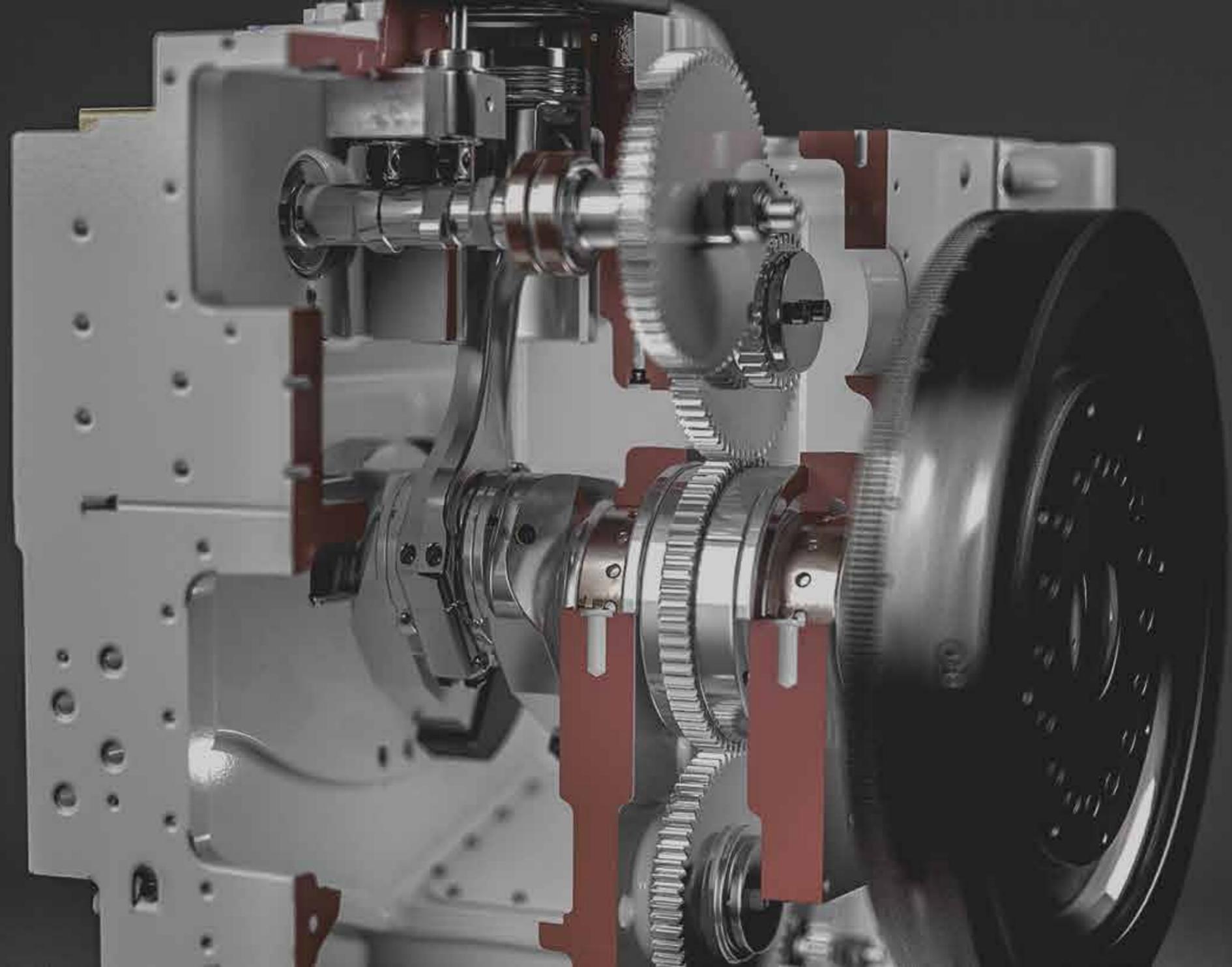
TEST CELLS - HIL

HIL TEST BEDS WITH VIRTUAL POWERTRAIN



COMBUSTION ENGINE TEST BENCHES

SINGLE CYLINDER, HEAVY DUTY, POWERTRAIN & TRANSMISSION



## TEST CELLS - ENGINE

### SINGLE CYLINDER

## » 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.

## TEST CELLS - ENGINE

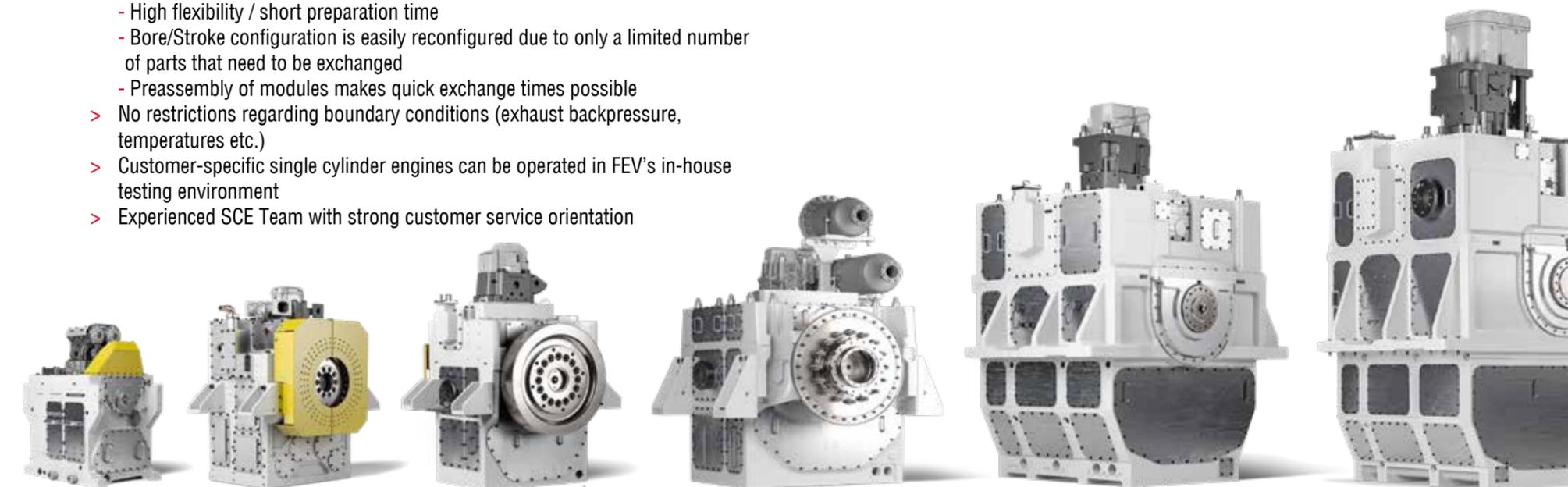
### SINGLE CYLINDER

## 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



TEST CELLS - ENGINE  
HEAVY DUTY

» 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...)
- > **Simulation friendly:** Very easy application of models on the engine test bed

TEST CELLS - ENGINE  
PASSENGER CARS

» 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)

## TEST CELLS - POWERTRAIN AND TRANSMISSION

### POWERTRAIN AND TRANSMISSION

#### » 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.

## TEST CELLS - POWERTRAIN AND TRANSMISSION

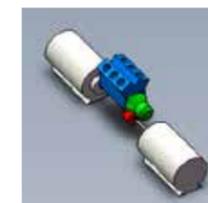
### POWERTRAIN AND TRANSMISSION

#### » ONE SOLUTION, MULTIPLE CONFIGURATIONS

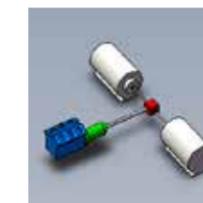
The FEV software solution for powertrain and transmission tests provides a powerful and highly flexible software tool for any customer to handle. It covers many possible test object layouts. The Graphical User Interface (GUI) comfortably allows all common layouts such as powerpack, FWD, RWD and AWD to be selected. Moreover, the GUI supports the detailed configuration of the equipment at the test bench. Herewith, all equipment

(dynamometers, gear-change robot, battery simulator etc.) can be easily adapted to the current testing programme, test object etc.

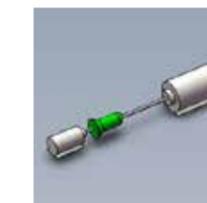
Building on its experience providing and controlling systems, FEV offers proven powertrain test bed solutions.



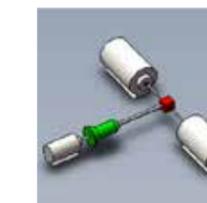
Front wheel drive



Rear wheel drive



Front wheel drive



Rear wheel drive



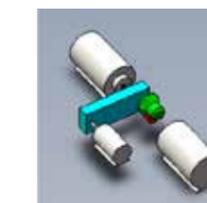
All wheel drive



Powerpack drive



All wheel drive



Powerpack drive

Powertrain test bench

Transmission test bench

## TEST CELLS - POWERTRAIN AND TRANSMISSION

### TRANSMISSION ETPS

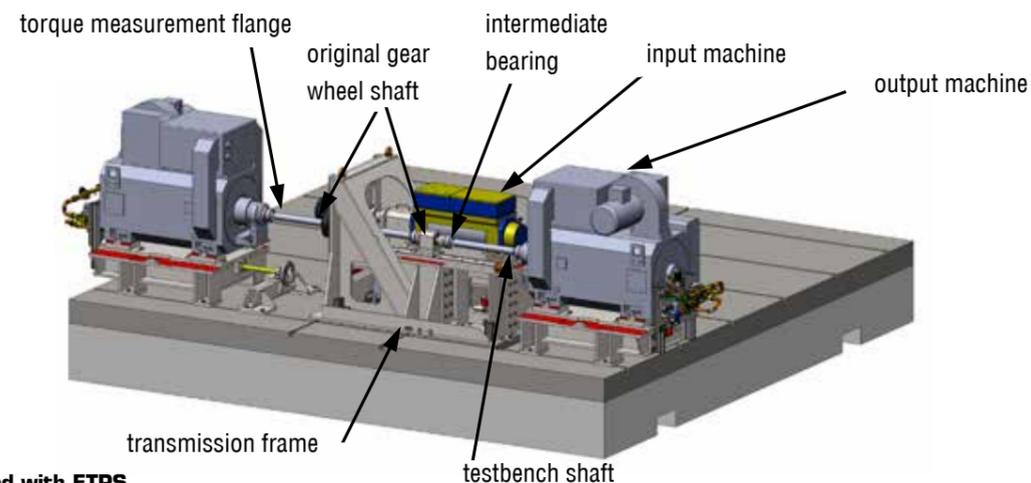
#### » ENGINE TORQUE PULSATION SIMULATION

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-cylinder 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 be designed with special care towards this use case.



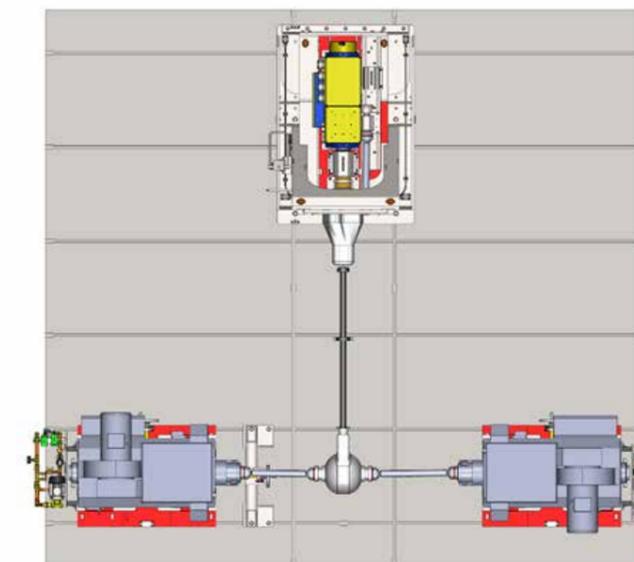
Transmission test bed with ETPS

## TEST CELLS - POWERTRAIN AND TRANSMISSION

### POWERTRAIN AND TRANSMISSION

#### » 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 m<sup>2</sup>, values between 0,3 kg m<sup>2</sup> and 9,6 kg m<sup>2</sup> 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

## TEST CELLS - COMPONENT

### 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

## TEST CELLS - COMPONENT

### FLOW TEST BENCH

#### » 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 turbocharged, 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-offline 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 m³/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)

TEST CELLS - COMPONENT  
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

TEST CELLS - COMPONENT  
FRICTION

» FEV METHODOLOGIES INSIDE

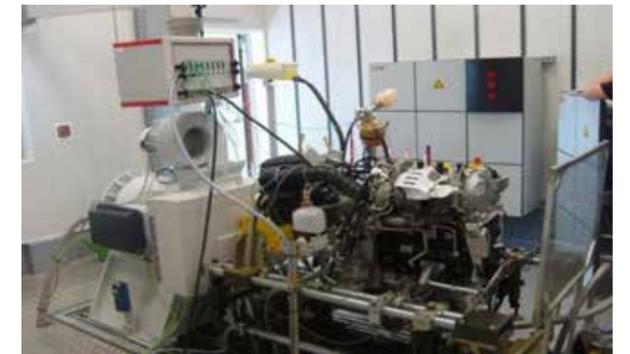
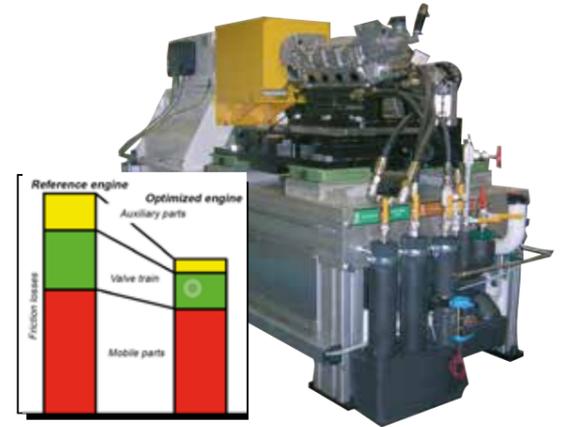
Friction investigations on combustion engines and their components are gaining increasing importance in terms of the fuel economy improvements required to reduce CO2 emissions. Friction test benches at FEV fulfill all of the requirements that must be met for precise investigation into friction. Depending 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  $\pm 0.5$  °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



TEST CELLS - VEHICLE  
CHASSIS

» 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)

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

TEST CELLS - ENGINE  
END OF LINE

» 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.



End of line hot calibration test beds

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

## TEST CELLS - CONTAINER CONTAINER

### » A SCALABLE 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

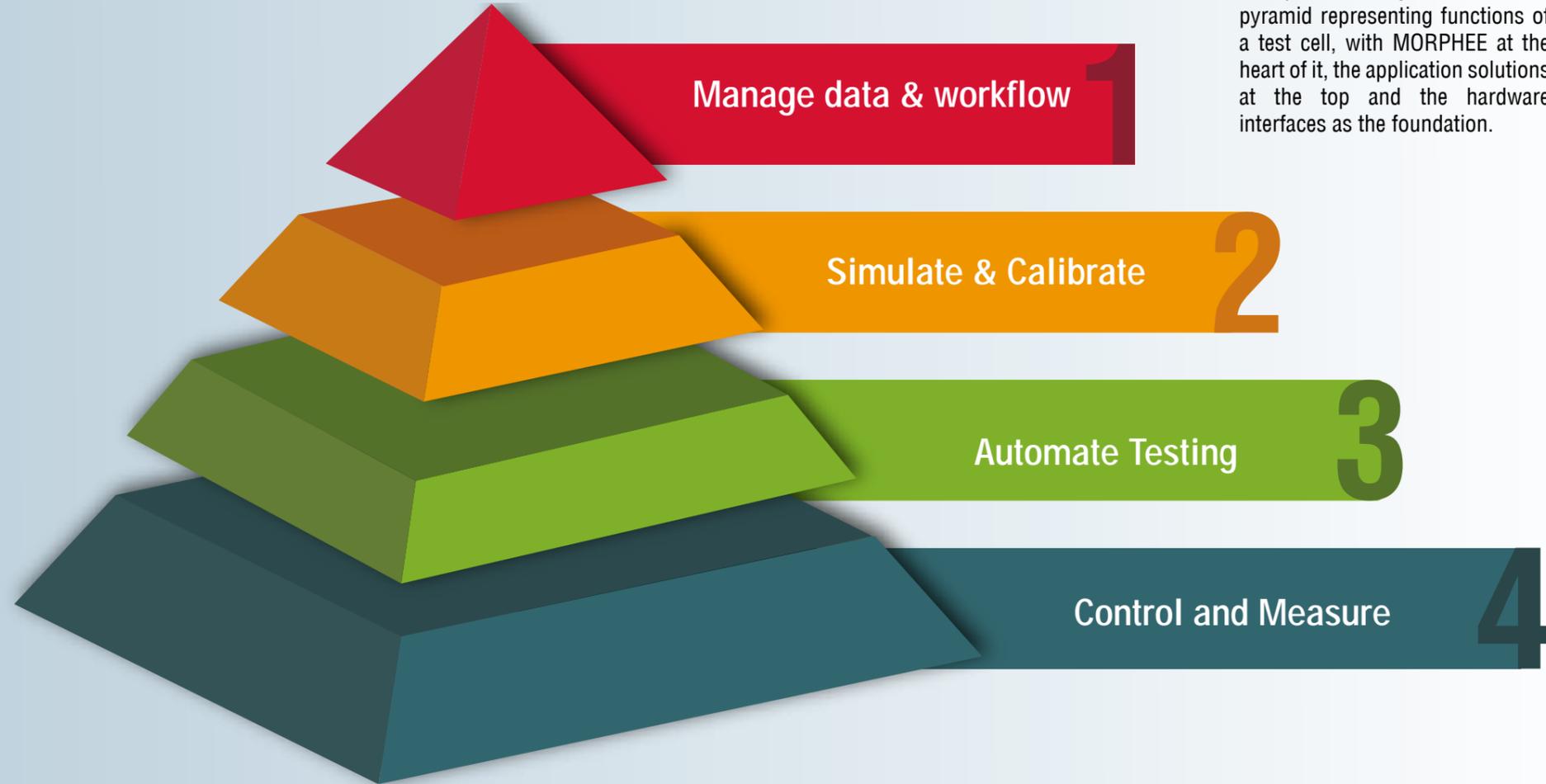
## TEST CELLS - CONTAINER CONTAINER



Container system for battery testing

# FEV SOFTWARE & TESTING SOLUTIONS

## PRODUCTS



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.

## PRODUCTS

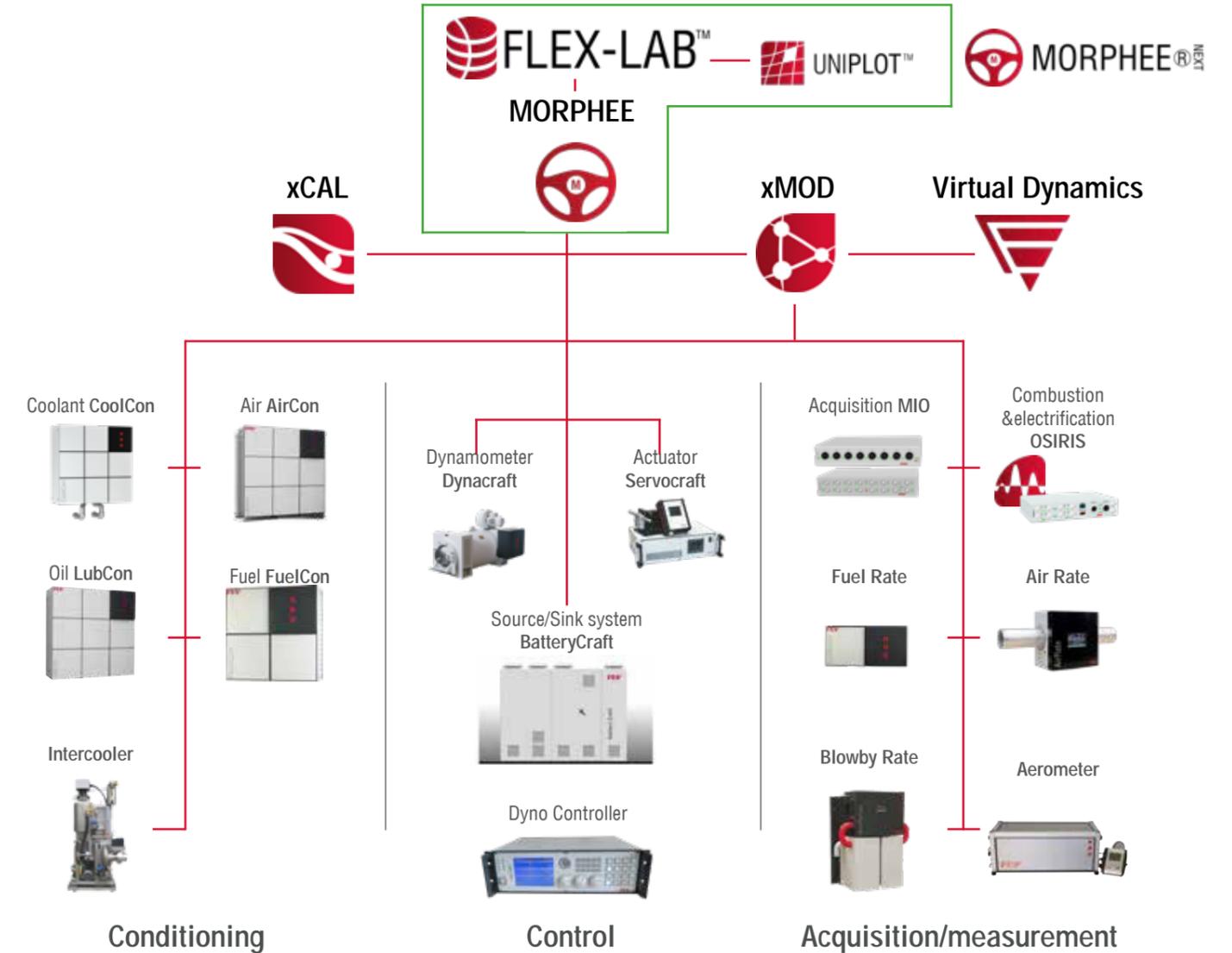
A RANGE OF PRODUCTS TO BUILD YOUR DEVELOPMENT CENTER

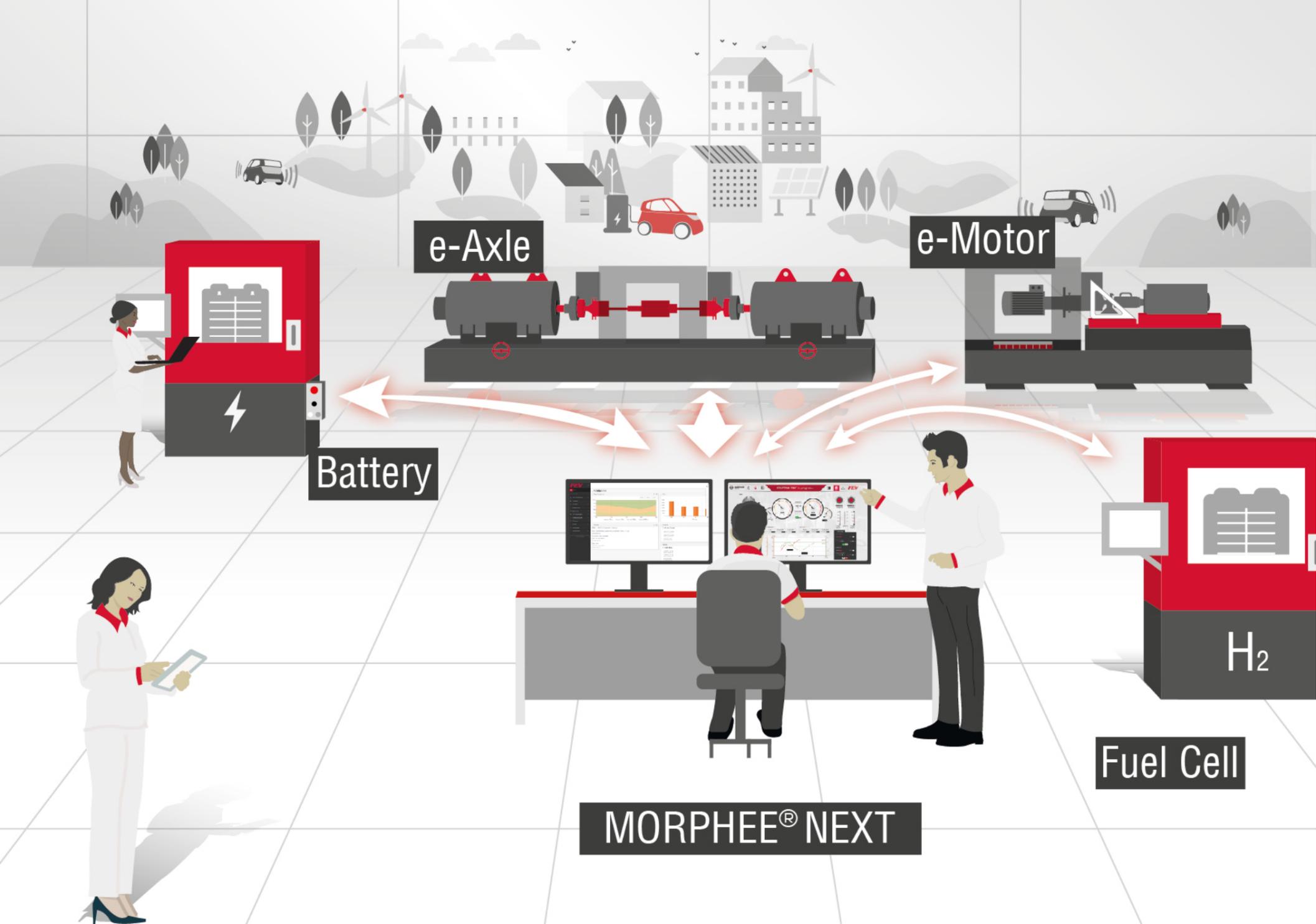
FEV offers a large selection of modular solutions which are easy to integrate and fully compliant with other equipment and software on the market.

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.



SOFTWARE AND TESTING SOLUTIONS





PRODUCTS

MORPHEE® NEXT



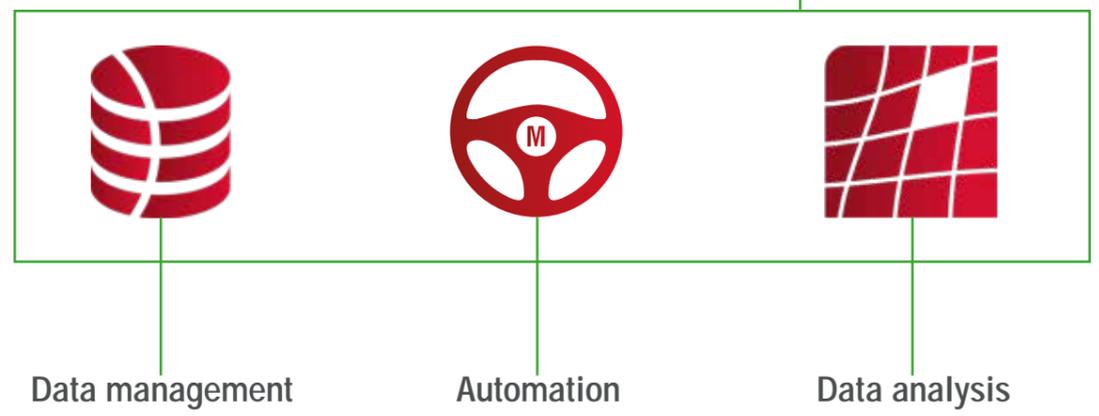
SOFTWARE AND TESTING SOLUTIONS

» WHAT IS MORPHEE® NEXT ?

**MORPHEE® NEXT**

A smart integration of our tools in unique software suite.

- > Cloud based and web technology
- > Secured customer data and processes
- > Dedicated and meaningful interfaces for each user
- > Efficient E-mobility test fields management



INTRODUCTION

TEST CENTERS

TEST CELLS

PRODUCTS

Manage data & workflow

Simulate & calibrate

Automate your tests

Control & measure

SERVICES

PRODUCTS - MANAGE DATA & WORKFLOW



**FEV**

SUITE

MANAGE YOUR TESTS

FROM THE CLOUD



## PRODUCTS - MANAGE DATA &amp; WORKFLOW

## FLEX-LAB™



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.

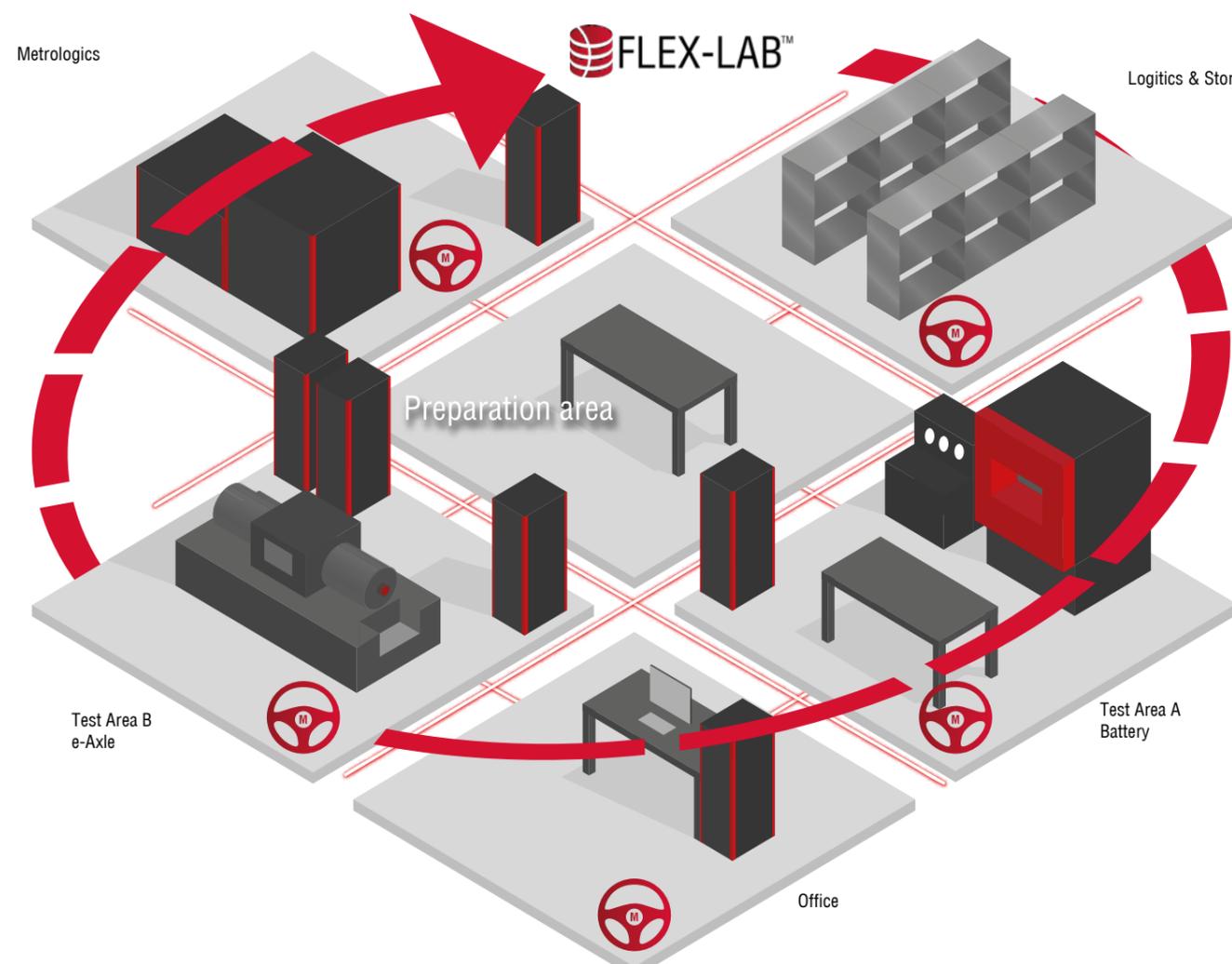
However, FLEX Lab™ goes further. It allows a total management of the test center or test bench thanks to a global view. This view is a live monitoring of any systems that allows the user to see all his test centers around the world, and more precisely to see his benches. The user thus sees the results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

- > 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.

## PRODUCTS - MANAGE DATA &amp; WORKFLOW

## FLEX-LAB™

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



## PRODUCTS -MANAGE DATA &amp; WORKFLOW

## UNIPILOT®

## » ANALYSIS AND VISUALIZATION



With UniPlot®, become more than an innovator !

Data is crucial in all organizations independent from the domain of activities. The amount of data produced today is more than ever and it even increases day by day. Analysis, visualization, efficient use and data driven decisions all require powerful software. UniPlot's interface helps navigate through your data and visualize it, its scripting module provides countless possibilities to analyze and transform it. Finally, its wide range of customization options let you produce professional reports with style !

UniPlot® was developed to visualize and analyze data. With only a few mouse clicks, you can transform your data into 3D surface maps with color zones, contour maps with color fill, or plot 2D data into diagrams with several axes. Text objects, scanned photos and other drawing and labeling elements can be easily inserted into the document.

Data can be processed interactively or automated for repetitive tasks or analysis.

UniPlot® offers an efficient and powerful programming language. It enables the user to add new functions to the user interface, to execute complex mathematical data analysis, to import specially formatted data files or to automatically produce complete documentations.

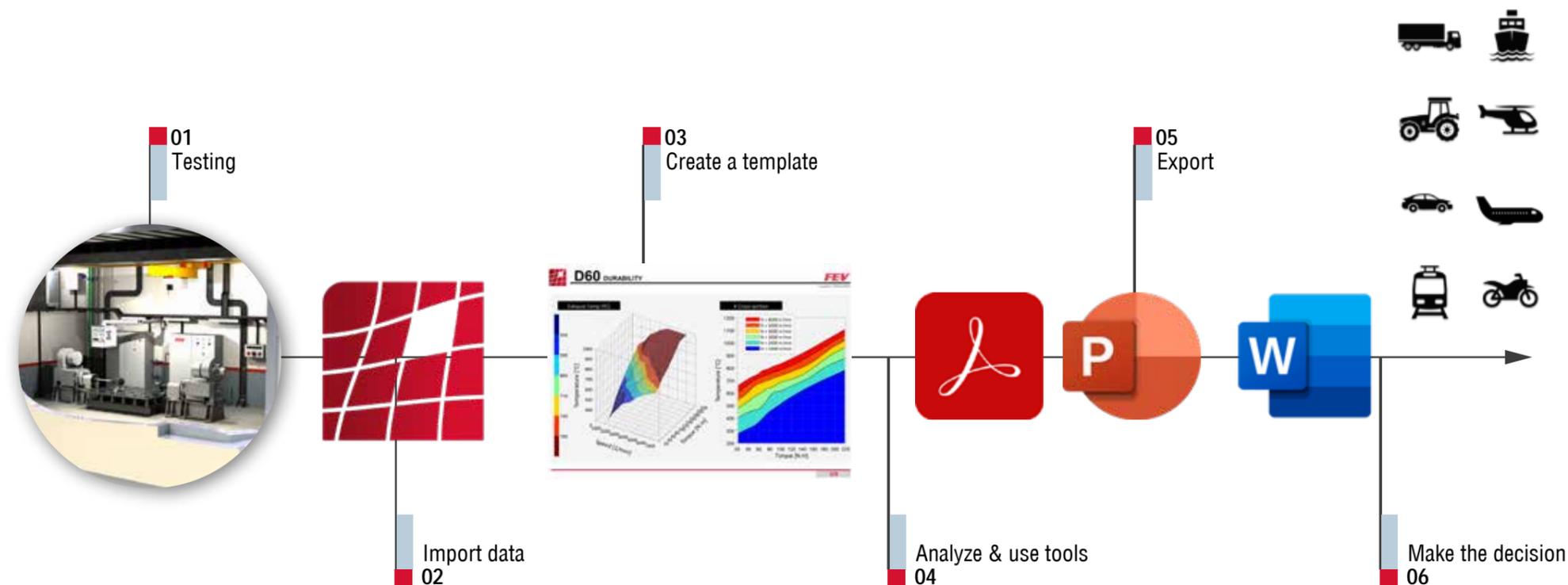
## HIGHLIGHTS

- > UniPlot® has a wide and evolutive range of import format.
- > Plot your data selecting from numerous options of plot designs (1D, 2D, 3D, waterfall, polar...).
- > Tune your graph changing colors, styles, markers and more.
- > Cursors, filters and tools help you make the most out of your data.
- > Create FFTs, integrals, 3D classification and much more. add conditional formatting to your reports to get meaningful information on your results.
- > The power of UniPlot® is its capacity to export customizable reports in multiple format, to facilitate the decision process.

## PRODUCTS - MANAGE DATA &amp; WORKFLOW

## UNIPILOT®

## » ANALYSIS WORKFLOW BY UNIPILOT®



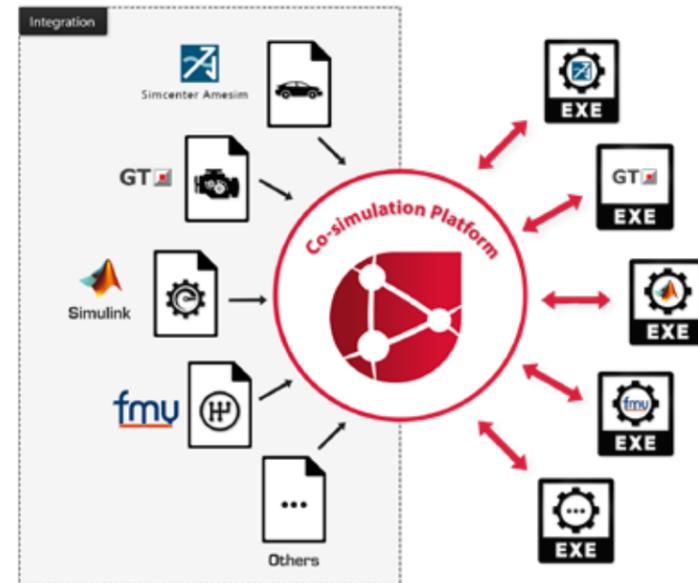
PRODUCTS - SIMULATION

xMOD®

» A MULTI-MODEL INTEGRATION & VIRTUAL EXPERIMENTATION PLATFORM



The xMOD® application software, based on MORPHEE technology, facilitates the integration of heterogeneous 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 simulation and control design teams, as well as test engineers, can work in a similar 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.



PRODUCTS - SIMULATION

xMOD®

» VIRTUAL EXPERIMENTATION

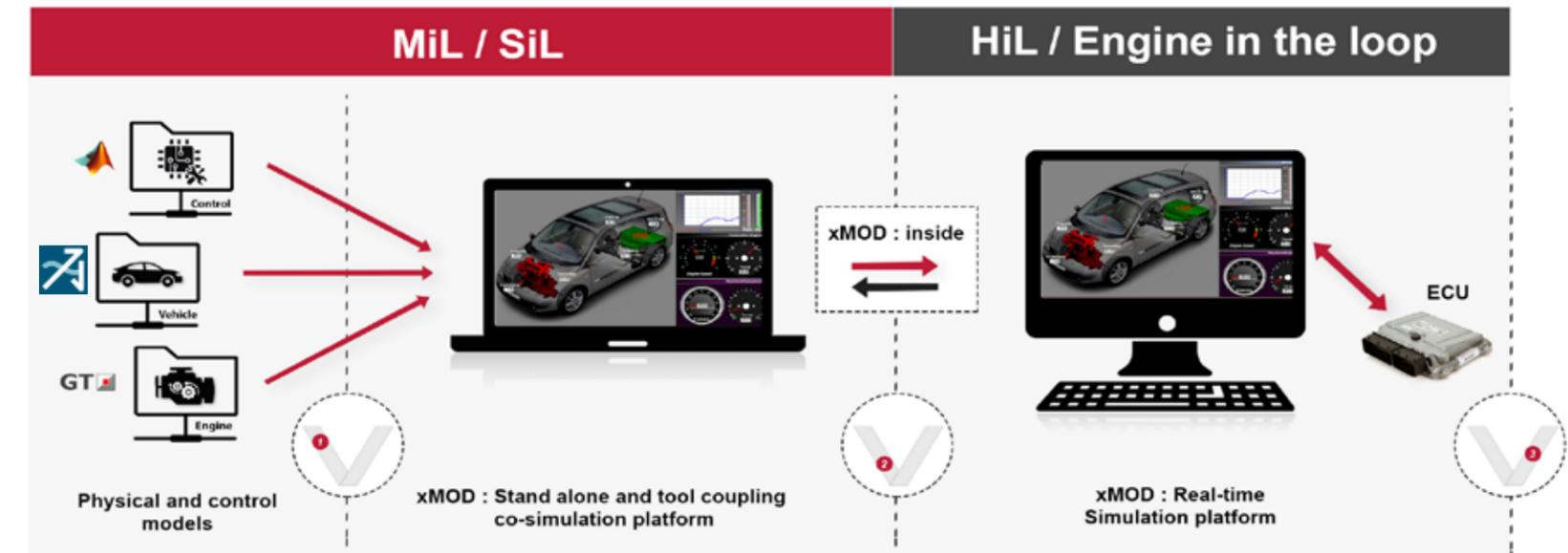
Models are becoming more and more complex and include a high level of detail.

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.



PRODUCTS - SIMULATION

VIRTUAL DYNAMICS™

» 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

PRODUCTS - SIMULATION

VIRTUAL DYNAMICS™

» INNOVATIVE KEY FEATURES

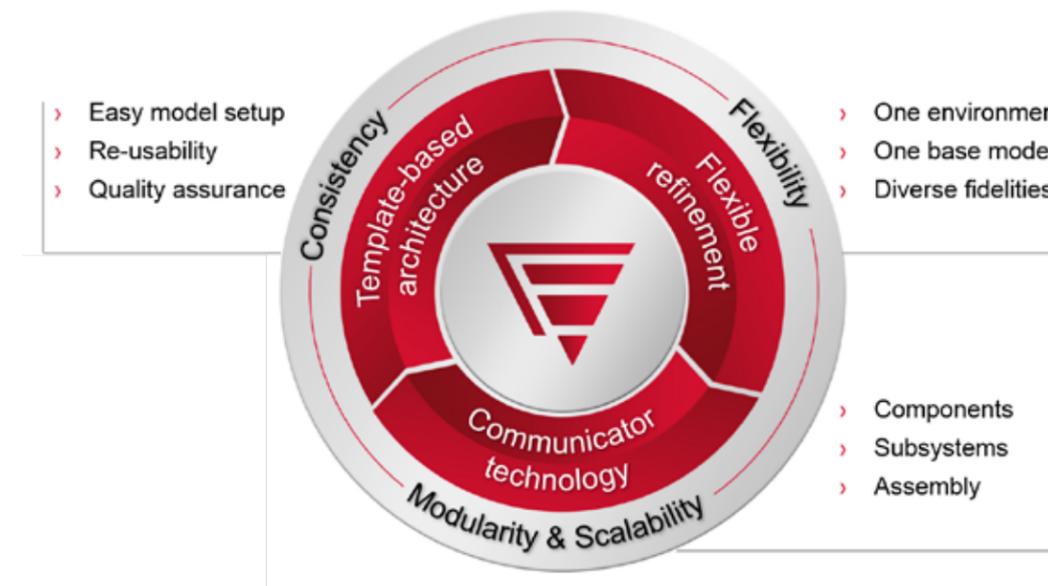
From powertrain engineers for powertrain engineers

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.

## PRODUCTS - SIMULATION

## VIRTUAL DYNAMICS™

## » 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 its 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.

## PRODUCTS - SIMULATION

## VIRTUAL DYNAMICS™

## » 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



Manage data & workflow

Simulate & calibrate

Automate your tests

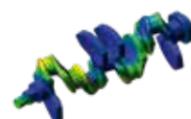
Control & measure

PRODUCTS - SIMULATION

VIRTUAL DYNAMICS™

» HIGH QUALITY SIMULATION

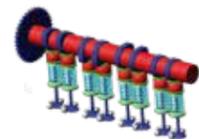
Cranktrain analysis



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

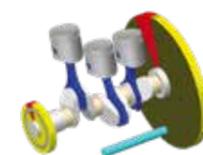
Valvetrain analysis



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

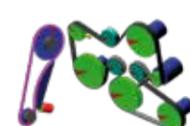
Piston and ringpack analysis



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

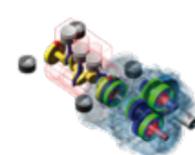
Timing and accessory drive



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

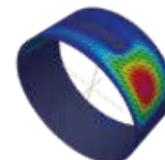
Geartrain and driveline



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.

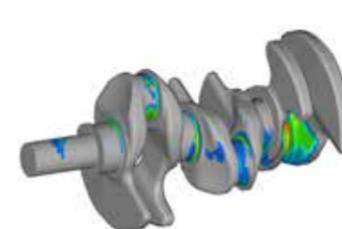
- > Minimum oil film thickness
- > Maximum oil and contact pressure
- > Displacements
- > Friction prediction
- > Wear prediction

PRODUCTS - SIMULATION

VIRTUAL DYNAMICS™

» REFERENCES

From optimized component to award winning engine



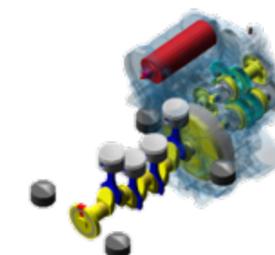
Friction optimized crankshaft  
> Design & CAE for Pre-XO



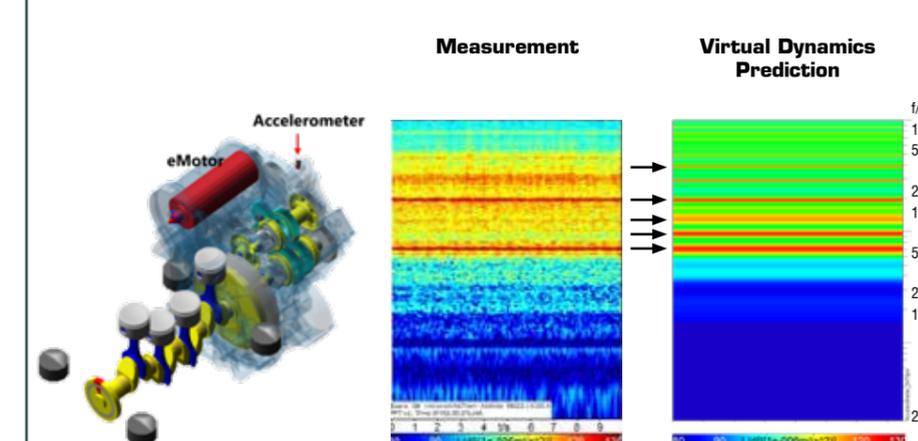
Friction optimized engine  
> 1.0 l Ford EcoBoost, max. 103 kW/l\*  
> CO2 Emissions: 99-129 g/km



Hybrid and electric powertrains



Hybrid Powertrain NVH Validation



HIGHLIGHT

- 3D eMotor-Generator Element
- > To analyze dynamics of hybrid and electric powertrains
  - > Parametric or Flexible components to study NVH and durability
  - > Drive options:
    - Shaft
    - Hub or wheel
  - > Periodical tangential and radial electromagnetic forces

PRODUCTS - CALIBRATION

ASM BOX™



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

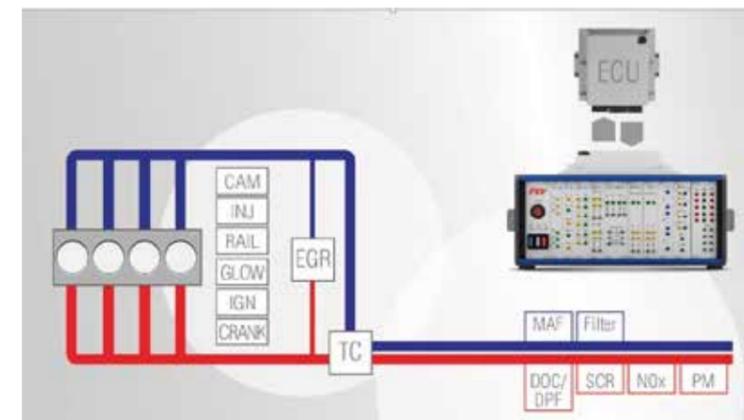
PRODUCTS - CALIBRATION

ASM BOX™

» OBD FAILURE SIMULATION

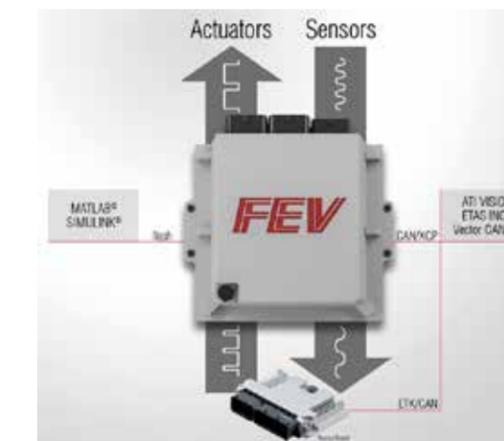
The system

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



PRODUCTS - CALIBRATION

ASM BOX™

» 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.



PRODUCTS - CALIBRATION

ASM BOX™



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 Motorcycle
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

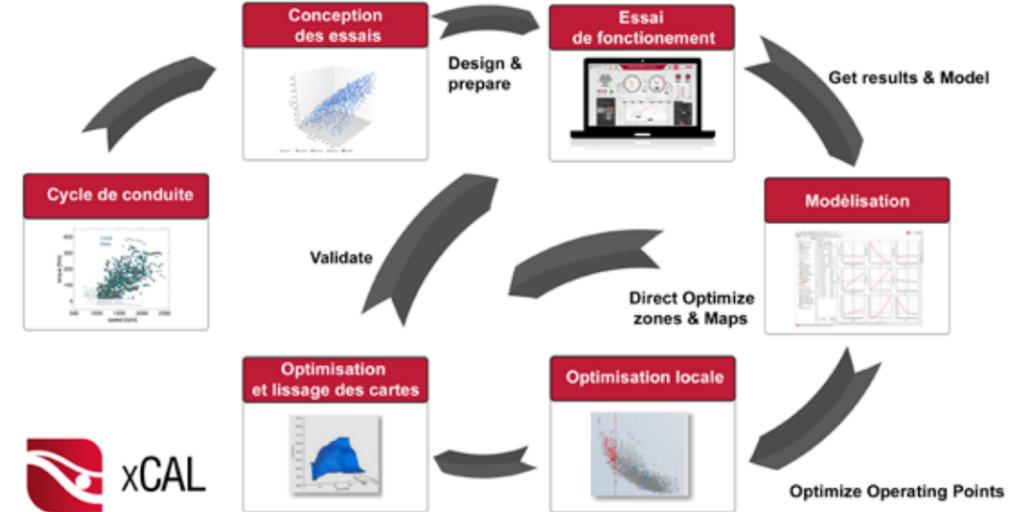
PRODUCTS - CALIBRATION

xCAL™

» CALIBRATION SOFTWARE



xCAL™ is a model-based calibration software that integrates the calibration knowledge of FEV into an easy-to-use tool. It makes the powerful DoE technique easily applicable and addresses the particular challenges of automotive development that require tailored adaptations of the generic DoE methodology. Special emphasis was placed on developing highly reliable and rapid modeling algorithms which are unique on the market. Today's state-of-the-art global modeling techniques based on Gaussian Processes have also been adapted to address the specific characteristics of engine and powertrain modeling. This approach, combined with intuitive visualization and user guidance, enables engineers to quickly investigate and optimize the engine's behavior, for example.



DOE SOFTWARE WITH GLOBAL MAP OPTIMIZATION

GAUSSIAN PROCESS MODEL

PRODUCTS - CALIBRATION

xCAL™

» xCAL™ SOLUTIONS

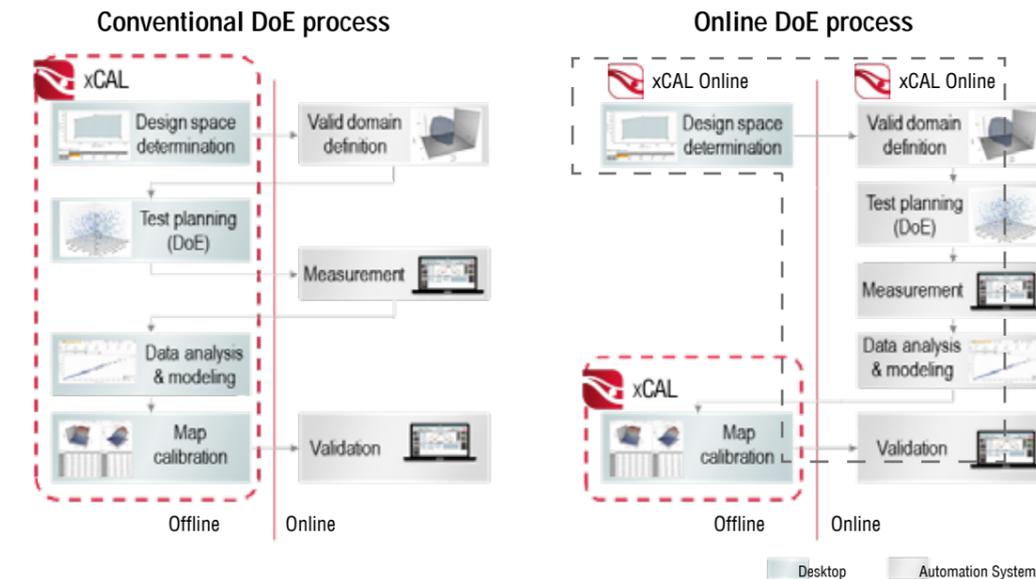
- > **Model-based calibration is mandatory with regards to the complexity of development tasks (Optimization, virtual calibration)**
  - State-of-the-art GP model with best-in-class Advanced GP Modeling.
  - Integrated map optimizer with possibility to implement global or cycle optimization.
- > **Complex design space**
  - Online DoE algorithms ensure the respect of any limits with screening approaches
  - Large choice of constraints, including convex hull gives the possibility to measure any design space
  - The upcoming limit prediction feature will be able to model any domain even the most complex thanks to the Gaussian Model\*
- > **Optimization of test time duration**
  - Online DoE techniques such as Active DoE and Online modeling or optimizing helps decreasing drastically the test time, while optimizing the modeling quality
  - The upcoming model-based design space definition will bring the efficiency of operation to the superior level thanks to the adaptive DoE feature\*
- > **Model-based optimization**
  - Optimization algorithms able to perform either local, global or cycle-based optimization (multi cycle also)
  - Large field of application, such as powertrain, conventional engine, eDrives
- > **High expertise required to run the DoE process**
  - The unique workflow approach of xCAL offers high efficiency in term of user guidance. Every action enables the next action required such that any junior user can easily go through all the process

PRODUCTS - CALIBRATION

xCAL™

» xCAL™ ONLINE

Additionally, xCAL™ Online enables online DoE to be efficiently monitored at the test bed, evaluates model quality, and finds optima parameters for a target, validating the optimum with no waiting time. Its active DoE technics enables the modeling in parallel of the test measurement process. The active DoE, as well as the screening capabilities avoiding to cross any limits, decreases the test duration by a 50% while optimizing the quality of the model generated.



xCAL Online decreases the test duration by ~50% while optimizing the quality of the model generated.

PRODUCTS - CALIBRATION

xCAL™ Online

» xCAL™ ONLINE



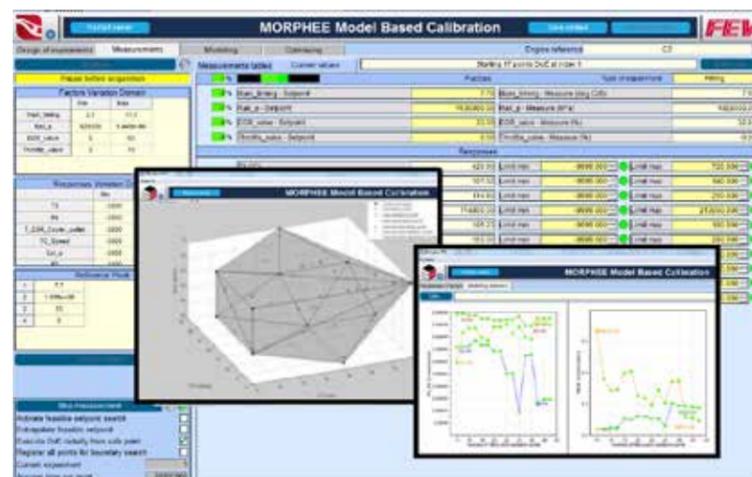
xCAL™ Online enables online DOE to be generated at the test bed, evaluates model quality, and finds optima parameters for a target, validating the optimum without waiting. It uses the design of experiment, modeling, and optimization tool in the same software.

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



PRODUCTS - CALIBRATION

xCAL™

BENEFITS

xCAL™

- > **State-of-the-art:** best in class algorithms and models (FEV patented Advanced Gaussian Process model)
- > **Structured:** the workflow leads the work according to the calibration process
- > **Flexible:** multiple calibration approaches available including cycle prediction capabilities
- > **User-friendly:** workflow based interface providing help to the calibration engineer
- > **Advanced:** providing best-in-class algorithms for fast and high accuracy modeling and optimization
- > **Independent:** operating efficiently all data and all results generated within the project
- > **Powerfull:** possibility to optimize calibrations for multiples criteria and driving cycles
- > **Open:** possibility to reuse the models and optimization results in other applications like Excel, Matlab or INCA

xCAL™ Online

- > **Cost effective:** xCAL Online allows to save test bed time and engineering hours
- > **Integrated:** uses MORPHEE® and already existing connection to ECU, indicating system and others devices
- > **Simple:** only need the AuSy PC at the test bed
- > **Safe :** investigate safely combustion settings possibilities in engine physical domain
- > **Precise :** model online, validate online directly in the process
- > **Efficient :** stop measurement process when enough measurement for a good modelling precision
- > **Flexible :** can execute any user-defined test plan within engine limits ( e.g. Global DoE test plan...)

And also:

- > Free update during the warranty year (new versions available on [www.fev-sts.com](http://www.fev-sts.com))
- > Free hotline access during the warranty year
- > Free blocking bugs correction

» 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).

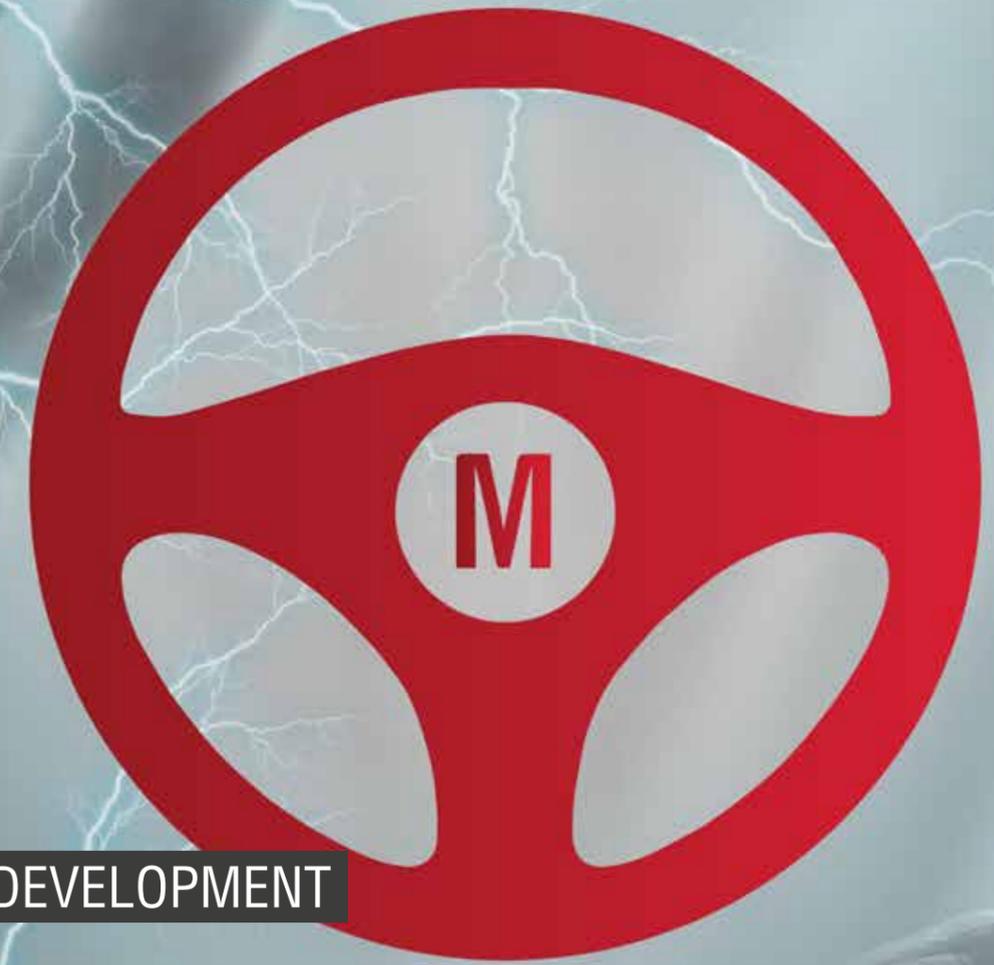
Where different software is often used on test cells, MORPHEE® adapts to any type of UUT (Unit Under Test): ECU (HIL test bed), component, engine, powertrain, vehicle, etc. Due to its versatility, it is currently used in a number of different markets, including the automotive, aerospace, marine and energy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

ENERGIZE  
YOUR E-MOBILITY DEVELOPMENT



## PRODUCTS - AUTOMATION

MORPHEE®

### » 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...

## PRODUCTS - AUTOMATION

MORPHEE®

### » 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 & equipment

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 modification: 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

## PRODUCTS - AUTOMATION

## MORPHEE® APPLICATIONS

## » SOFTWARE PACKAGES FOLLOWING TYPE OF TESTS AND TEST CELLS

MORPHEE applications are fully packaged solutions for different types of tests, test beds and devices, following their level of complexity and purpose.

## FIVE EDITIONS FOR ALL TYPES OF TEST CELL

**Desk**

Dedicated to application development purposes. It can also be used to run Test Cell Simulators or non-real time application, using mainly serial or Ethernet interfaces.

**Lab**

The entry level of simple automation, featuring all standard MORPHEE functions as well as most of interfaces and protocols (including EtherCat). This Edition is not real time (windows based).

**Lab-RT**

The entry level of hard real time automation, perfectly suitable for most of e-mobility applications, such as Fuel Cells and Battery testing. > 5,000 RT channels @ 2 kHz

**Bench**

Hard real time for all kind of Engine, Transmission or Powertrain test cells, including dedicated automotive protocols and interfaces. > 5,000 RT channels @ 2 kHz

**Bench-xCU**

Designed for cutting-edge R&D test cells, with most advanced features for managing parameters of complex units like xCUs and control them dynamically. > 5,000 RT channels @ 2 kHz

## PRODUCTS - AUTOMATION

## MORPHEE® APPLICATIONS

## SCALE: STANDARD AND CONFIGURABLE APPLICATION FOR LABORATORY ENVIRONMENT

SCALE is the condensed FEV knowledge integrated in a central State Flow, corresponding to the most adapted way to manage UUT at the test cell in a complete secure way. It also manages all links and acquisition from SCALE equipment, whatever they are.

SCALE is adapting MORPHEE to all types of test benches:

**SCALE BATTERY**

The essential element of new transportation area. In constant evolution, the battery testing has to be reactive!

**SCALE FUEL CELL**

The new trend for power generation in modern vehicles. Tomorrow's ideas have already a SCALE solution today.

**SCALE EMOTOR**

Adapt your test benches and working methods to new market trends. E-mobility is more than ever a reality!

**SCALE POWERTRAIN / EPOWERTRAIN**

Testing the complete powertrain in its conventional, hybrid or electrical configuration is now possible. From 2 to 4 outputs.

**SCALE VEHICLE**

Whatever the type of propulsion, the complete vehicle test is the last step in the validation process. Keep the benefit of the previous SCALE configuration used and easily cross-check your results.

**SCALE ENGINE**

The state of the art for all of your thermal and hybrid engine test benches. From End-Of-Line to Research & Development solution.

## 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

PRODUCTS - AUTOMATION

MORPHEE® APPLICATIONS

» 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.

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. 15 <sup>th</sup> 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 4 <sup>th</sup> 2013
WHTC	UN ECE R49 revision 6 from March 4 <sup>th</sup> 2013
WNTE	UN ECE R49 revision 6 from March 4 <sup>th</sup> 2013

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.

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

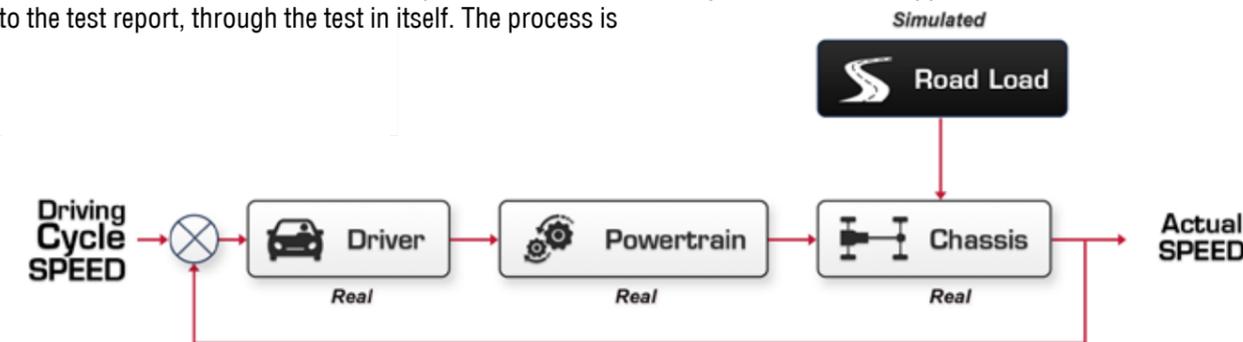
PRODUCTS - AUTOMATION

MORPHEE® APPLICATIONS

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

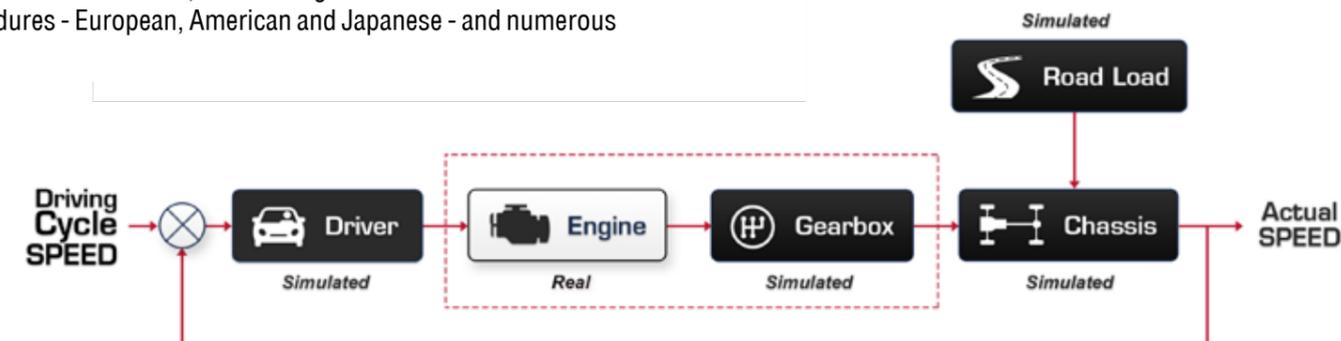
fully automated. The application follows the latest standards, including WLTP.

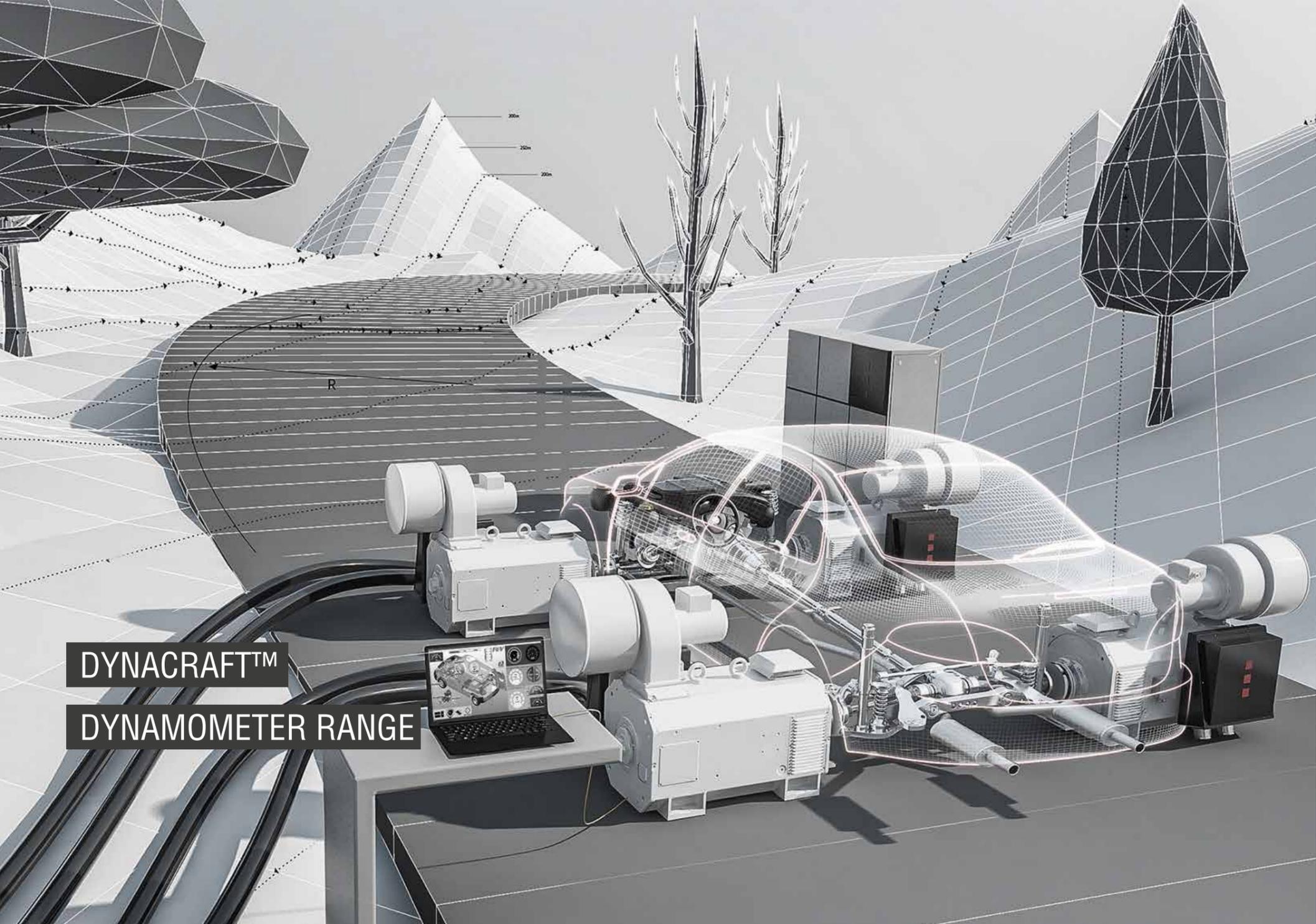


MORPHEE DYNAMIC SIMULATION

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.





DYNACRAFT™

DYNAMOMETER RANGE

PRODUCTS - CONTROL

DYNACRAFT™

» 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.

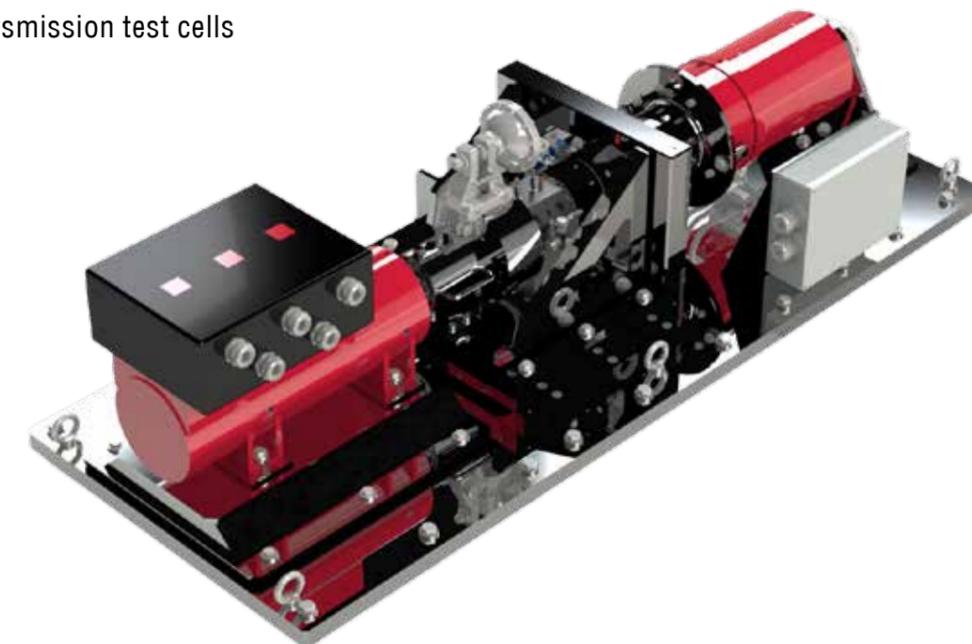
DYNAMOMETERS

A complete dynamometer range for every kind of test beds

- > DX series: E-motor dynamometers for e-motor test cells
- > DW Series: Wheel dynamometers for e-axle, powertrain and transmission test cells
- > DR, DS and DT series: AC dynamometers for engine test cells.
- > DE Series: Eddy Current dynamometers for engine test cells.

CONTROLLERS

- > Hardware units or embedded model based controllers
- > All possible control (speed/torque/current)
- > Adapted to a large range of frequency converters and machines
- > High performance thanks to EtherCAT link



PRODUCTS - CONTROL

DYNACRAFT™

» PACKAGED APPLICATIONS FOLLOWING TYPE OF TESTS AND TEST BEDS



DX SERIES: E-MOTOR DYNAMOMETERS FOR E-MOTOR TEST CELLS



DW SERIES: WHEEL DYNAMOMETERS FOR E-AXLE, POWERTRAIN AND TRANSMISSION TEST CELLS



DR, DS, AND DT SERIES: ICE DYNAMOMETERS FOR ENGINE TEST CELLS



DE SERIES: EDDY CURRENT DYNAMOMETERS FOR ENGINE TEST CELLS

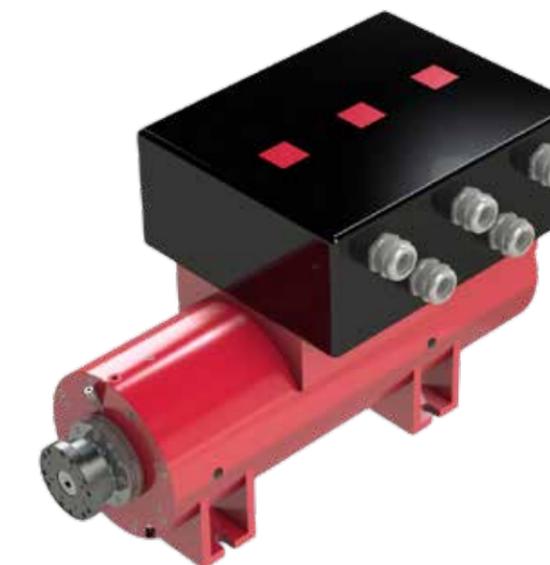
PRODUCTS - CONTROL

DYNACRAFT™ - eMOTOR

» DYNACRAFT - eMOTOR

	Rated power (kW)	Rated Torque (N.m)	Base Speed (rpm)	Max. Speed (rpm)	Inertia (kg.m <sup>2</sup> )	Voltage (V)	Current (A)
<b>DX250</b>	250	400	6,000	25,000	0.066	460	490
<b>DX300</b>	300	600	4,780	21,000	0.129	495	554
<b>DX400</b>	400	500	7,700	24,000	0.130	460	1,207
<b>DX500</b>	500	600	8,000	20,000	0.139	460	1,554

- > Excellent reliability
- > High quality of measurement
- > Integrated electrical and mechanical safety monitoring (motor winding and bearings)
- > Technology:
  - Permanent magnet
  - Water cooling
  - Torquemeter
  - Frequency converter

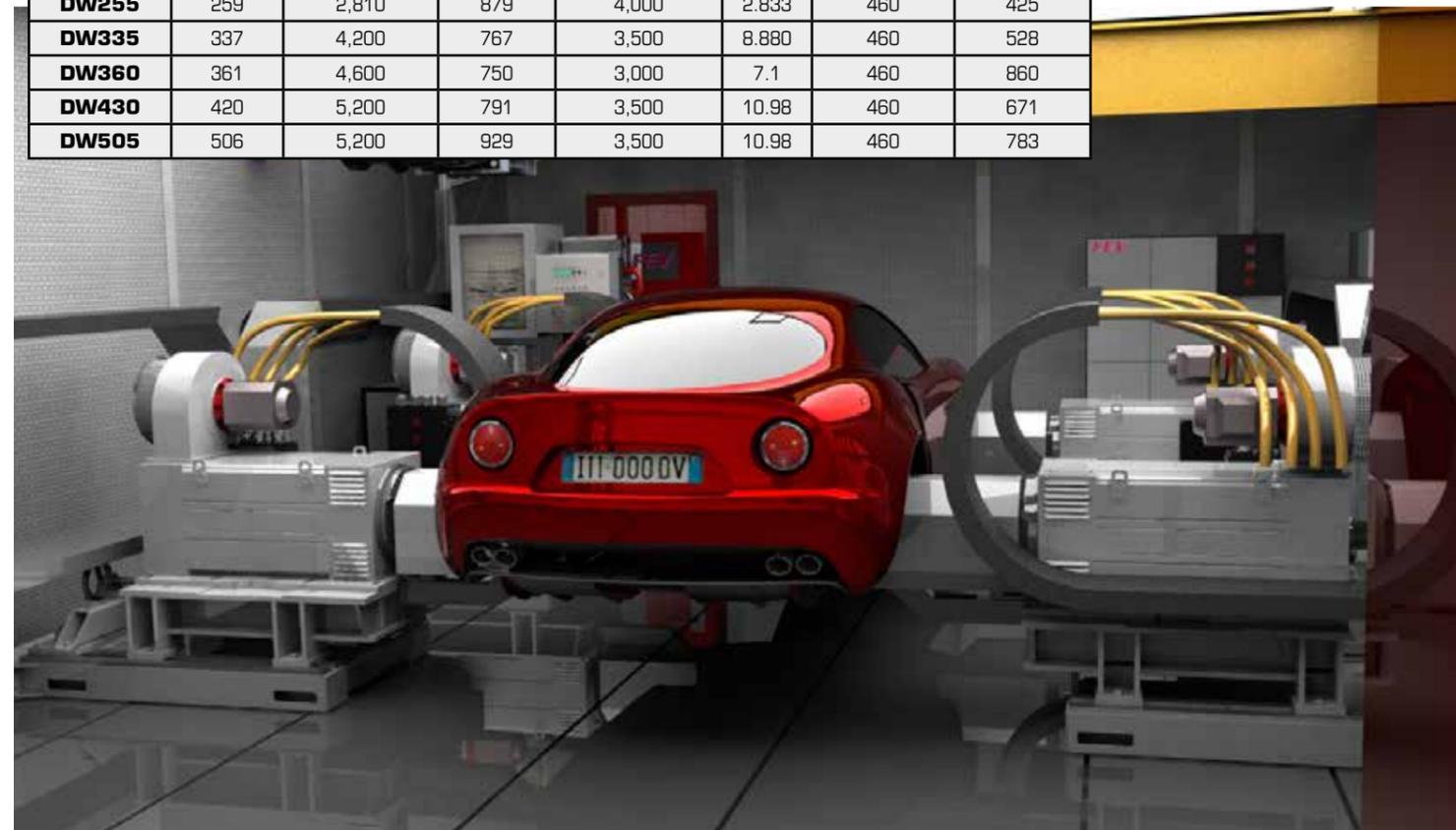


PRODUCTS - CONTROL

DYNACRAFT™ - Wheels

» DYNACRAFT WHEELS

	Rated power (kW)	Rated Torque (N.m)	Base Speed (rpm)	Max. Speed (rpm)	Inertia (kg.m <sup>2</sup> )	Voltage (V)	Current (A)
<b>DW200</b>	200	2,500	764	3,000	0.64	440	800
<b>DW255</b>	259	2,810	879	4,000	2.833	460	425
<b>DW335</b>	337	4,200	767	3,500	8.880	460	528
<b>DW360</b>	361	4,600	750	3,000	7.1	460	860
<b>DW430</b>	420	5,200	791	3,500	10.98	460	671
<b>DW505</b>	506	5,200	929	3,500	10.98	460	783



PRODUCTS - CONTROL

DYNACRAFT™ -DR Series- Asynchronous Dynamometers for ICE engines

» MEDIUM SPEED AND LOW INERTIA

	Rated Power (kW)	Rated Torque (Nm)	Base Speed (rpm)	Max. Speed (rpm)	Inertia (kgm <sup>2</sup> )	Voltage (V)	Current (A)
<b>DR160</b>	160	350	4,377	10,000	0.22	460	250
<b>DR250</b>	250	550	4,365	10,000	0.29	460	380
<b>DR300</b>	300	700	4,070	10,000	0.65	460	450
<b>DR380</b>	380	820	4,450	10,000	0.65	460	600
<b>DR500</b>	500	1,100	4,340	8,500	0.9	460	730
<b>DR600</b>	600	1,340	4,261	6,500	1.14	460	930



- > Excellent reliability
- > Suitable for transient emissions test cycles and vehicle simulation
- > High quality of measurement
- > Integrated electrical and mechanical safety monitoring (motor winding and bearings)
- > Technology:
  - Asynchronous motor
  - Air cooling
  - Torquemeter
  - Frequency converter

PRODUCTS - CONTROL

DYNACRAFT™ -DS Series- Asynchronous Dynamometers for ICE engines

» HIGH TORQUE

	Rated Power (kW)	Rated Torque (Nm)	Base Speed (rpm)	Max. Speed (rpm)	Inertia (kgm <sup>2</sup> )	Voltage (V)	Current (A)
DS250	250	1,110	2,155	8,500	0.9	460	390
DS300	300	1,400	2,046	8,500	1.85	480	450
DS380	380	1,800	2,014	8,000	2.25	460	580
DS470	470	2,200	2,043	7,500	2.85	460	770
DS530	530	3,060	1,691	7,500	3.1	460	840
DS590	590	3,450	1,631	4,500	3.7	480	1,080



- > Excellent reliability
- > Suitable for transient emissions test cycles and vehicle simulation
- > High quality of measurement
- > Integrated electrical and mechanical safety monitoring (motor winding and bearings)
- > Technology:
  - Asynchronous motor
  - Air cooling
  - Torquemeter
  - Frequency converter

PRODUCTS - CONTROL

DYNACRAFT™ -DT Series- Asynchronous Dynamometers for ICE engines

» LOW SPEED

	Rated Power (kW)	Rated Torque (Nm)	Base Speed (rpm)	Max. Speed (rpm)	Inertia (kgm <sup>2</sup> )	Voltage (V)	Current (A)
DT280	280	1,900	1,407	4,000	4.2	460	435
DT360	360	2,300	1,498	4,000	4.9	460	540
DT410	410	2,600	1,507	4,000	6	480	590
DT490	490	3,100	1,510	3,500	6.7	480	700
DT570	570	3,600	1,510	4,000	11	460	840
DT610	610	4,000	1,457	4,000	12.7	480	870
DT800	800	5,100	1,498	3,500	12.9	460	1,200



- > Excellent reliability
- > Suitable for transient emissions test cycles and vehicle simulation
- > High quality of measurement
- > Integrated electrical and mechanical safety monitoring (motor winding and bearings)
- > Technology:
  - Asynchronous motor
  - Air cooling
  - Torquemeter
  - Frequency converter

PRODUCTS - CONTROL

DYNACRAFT™ - DE SERIES - EDDY CURRENT DYNAMOMETERS - SYNCHRONOUS DYNAMOMETERS

» LOW INERTIA

	Rated Power (kW)	Rated Torque (N.m)	Base speed (rpm)	Max. speed (rpm)	Inertia (kg.m²)	Water flow rate (l/min)	Weight (kg)
<b>DE 80</b>	80	200	3,800	12,000	0.02	40	300
<b>DE 160</b>	160	400	3,500	10,000	0.09	135	520
<b>DE 300</b>	300	900	3,200	10,000	0.18	135	600
<b>DE 450</b>	450	2,000	2,150	8,000	0.95	290	1,300
<b>DE 450 HT</b>	450	2,500	1,500	8,000	1.06	290	1,300
<b>DE 500-2</b>	500	1,250	3,800	8,000	0.38	300	800
<b>DE 900</b>	900	5,500	1,600	4,000	4.05	500	3,000

- > Low Inertia
- > Excellent reliability and quality of torque measurement
- > Suitable for stabilized emissions test cycles: ESC, ELR, WHSC, ISO8178, Japan 6 & 13 modes...
- > Suitable for transient emissions test cycles like NRTC during engine development
- > Integrated electrical and mechanical alarm monitoring (coil and bearings)
- > Technology:
  - Asynchronous motor
  - Air cooling
  - Torquemeter
  - Frequency converter



PRODUCTS - CONTROL

CONTROLLERS

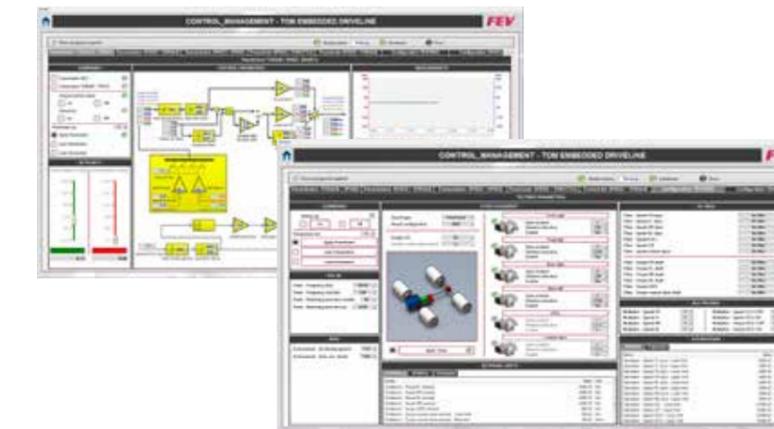
» MORPHEE® EMBEDDED MODEL BASED CONTROLLER

The scalable controller

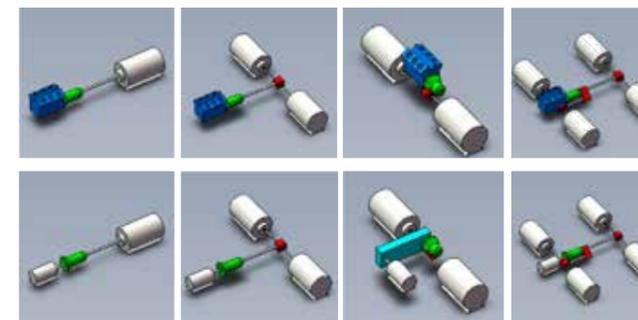
MORPHEE® embedded model based controller are universal controller that can handle all types of test beds, from single dynamometer setup to 5 dynos architectures.

They are seamlessly integrated into any testing environment and provides all established control modes which can be switched bumpless during operation.

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



SUITABLE FOR ALL KIND OF TEST CELLS ARCHITECTURE FROM STANDARD ICE TO EPOWERTRAINS



BENEFITS

- > Test control with high dynamic speed and torque control
- > High-speed performance in real-time
- > High dynamic simulations (wheel slip, RLS, Inertia, ETPS)
- > Simulink based control models
- > Control structures with decoupling and pre-control for UUT and loading unit
- > Linearization of loading unit setpoints
- > Integrated limit observation with selectable error reaction
- > Bumpless transfer between control modes
- > Online Tuning and easy setup

## PRODUCTS - CONTROL

## CONTROLLERS: DCU 3000™

## » 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



## PRODUCTS - CONTROL

## EPS 3000™

## » 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.

## 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



## PRODUCTS - CONTROL

### DYNABOX

#### » DYNABOX, A UNIVERSAL BOX FOR THE MONITORING OF ALL FEV DYNAMOMETERS

The DYNABOX is dedicated to the monitoring management of FEV DYNACRAFT dynamometers. This unit integrates a lot of channels for dedicated monitoring functions: Torque, Speed, PT100, PTC, Vibration measurements or digital inputs.

#### Inputs and Outputs

##### Inputs:

- > 4 x PT100
- > 2 x PTC / PT1000 / PT100
- > 4 x Digital input
- > 4 x Vibration 4-20mA
- > 1 x Speed (Incremental encoder)
- > 1 x Torque (Frequency signal)
- > 3 x Slots for optional input

##### Outputs:

- > 4 x Digital output (Dry contact)
- > 1 x Summary digital output (Relay)
- > 2 x Speed in Frequency (Input copy)
- > 1 x Torque in Frequency (Input copy)
- > 1 x Torque in Voltage (Measurement value)



## PRODUCTS - CONTROL

### BATTERYCRAFT™

#### » BATTERYCRAFT™, THE SOURCE/SINK SYSTEM

The source/sink system – „BatteryCraft™“ – is a highly dynamic, regenerative DC voltage source for various test bench applications.

The power unit consists of a power inverter and DC/DC converters designed in state of the art IGBT technology. The device is characterized by a wide operating range and high control and measurement accuracies for both the voltage and current values. Combined with the fast current rise times, the device is ideal for use in test benches. The isolation monitoring can be switch on /off as well during operation.

The BatteryCraft™ device includes its own safety PLC which takes care that the system will be switched off according to performance level „D“. In order to integrate our device into the external safety concept the relevant signals are available on terminal strips in the cabinet. The voltage drop on the supply line will be compensated over a separate sense line (by measurement of the voltage on the connection point).

#### BATTERYCRAFT™ BENEFITS

- > High measuring & control accuracy
- > High current dynamics
- > Performance level “D” by default
- > Compact mechanical design
- > Service worldwide
- > Isolation monitoring switchable



# CONDITIONING AND MEASUREMENT

## PRODUCT RANGE



### PRODUCTS - CONDITIONING



SOFTWARE AND TESTING SOLUTIONS

### » WHERE TO USE CONDITIONING UNITS



	AirCon	CoolCon	CoolCon Basic	LubCon	FuelCon	E-CoolCon
<b>EU6 / EU7 test bench</b>	✓ Required	✓ Required		✓ Required	✓ Required	
<b>Durability test bench</b>		👍 Recommended	✓ Required		✓ Required	
<b>Single cylinder test bench</b>	✓ Required	✓ Required		✓ Required	✓ Required	
<b>Hybrid test bench</b>		👍 Recommended	✓ Required		✓ Required	
<b>End of Line test bench</b>		👍 Recommended	✓ Required		✓ Required	
<b>Friction test bench</b>		✓ Required		✓ Required	✓ Required	
<b>Power train test bench</b>		✓ Required		✓ Required	✓ Required	
<b>E-axle test bench</b>						✓ Required
<b>Hybrid drive trains test bench</b>						✓ Required
<b>Battery test bench</b>						✓ Required

PRODUCTS - **CONDITIONING**

E-COOLCON

» E-MOBILITY COOLCON™

Use of FEV E-Mobility 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 have 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.



PRODUCTS - **CONDITIONING**

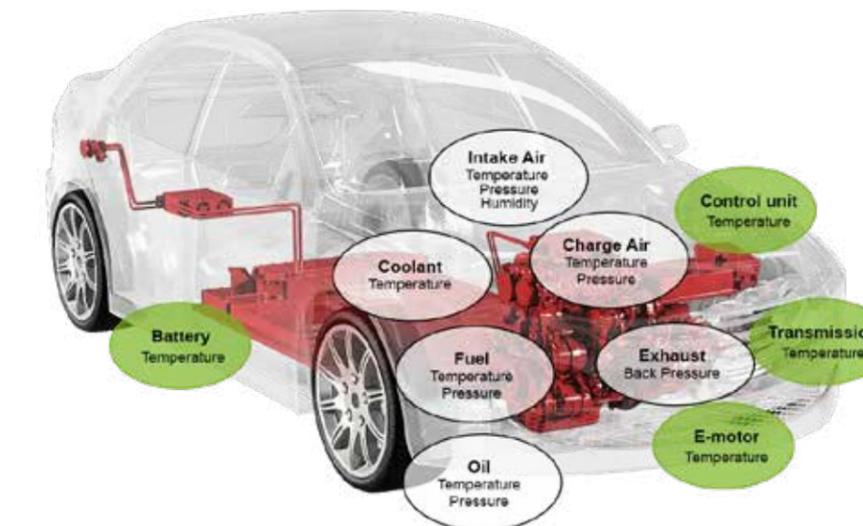
E-COOLCON™

» 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

PRODUCTS - **CONDITIONING**

AIRCON™

» 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.

Special machinery, available only on request



**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

PRODUCTS - **CONDITIONING**

COOLCON™

» 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.

Special machinery, available only on request



**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

PRODUCTS - **CONDITIONING**

## INTERCOOLER™

» 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.

Special machinery, available  
only on request

**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

PRODUCTS - **CONDITIONING**

## RACECON™

» 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.

Special machinery, available  
only on request

**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

PRODUCTS - **CONDITIONING**

CHARGECON™

» 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.

Special machinery, available only on request



**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

PRODUCTS - **CONDITIONING**

LUBCON™

» 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.

Special machinery, available only on request



**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

PRODUCTS - **CONDITIONING**

## HIGH ALTITUDE SIMULATION SYSTEM

## » 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.

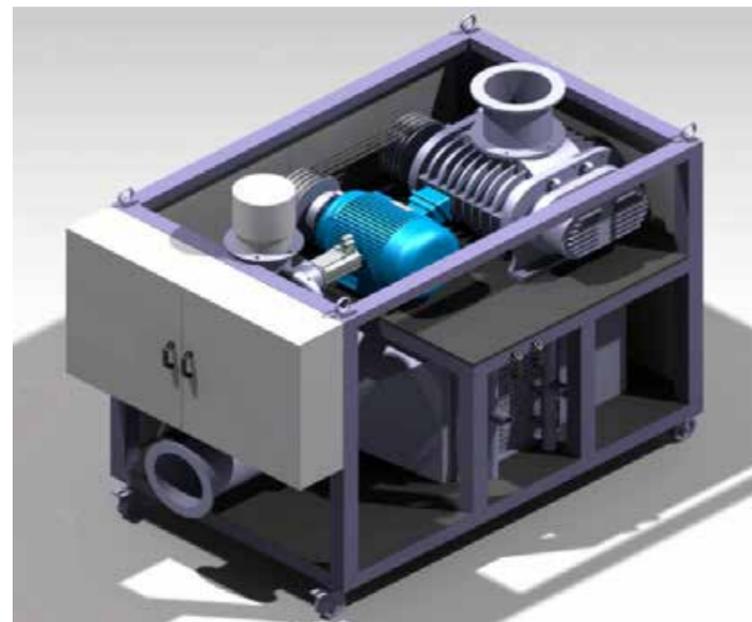
To meet this requirement, FEV has developed a system for altitude variation in order to simulate the effect of different altitudes on the engine by varying the pressure on the engine exhaust and air intake. The control and regulation of the system are done by an on-board controller mounted in the control 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

Special machinery, available only on request

**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

PRODUCTS - **CONDITIONING/MEASURING**

## FUELCON / RATE™

## » 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

Special machinery, available only on request

**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



## PRODUCTS - MEASURING

## AEROMETER™ - DEVICE FOR OIL DETERMINATION

## » 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

Special machinery, available only on request

## 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

## PRODUCTS - MEASURING

## AEROMETER™ - DEVICE FOR OIL DETERMINATION

## » 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

Special machinery, available only on request

## 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

AIRRATE™

## AIR MASS FLOW MEASURING SYSTEM



### PRODUCTS - MEASURING

AIRRATE™ XT AND AIRATE™ DN200



SOFTWARE AND TESTING SOLUTIONS

### » 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 extremely 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 developed 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.

Special machinery, available only on request



MIO™ ACQUISITION

SMART SOLUTION FOR TESTING MEASUREMENTS



SOFTWARE AND TESTING SOLUTIONS

PRODUCTS - MEASURING

MIO™

» 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.

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.

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.

» BENEFITS

QUALITY

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

FLEXIBLE

- > Simplified connectivity
- > Extension possibility through dedicated connectors

MODULAR & COMPACT

- > 19" or semi 19" housing
- > Infinity cascable

RELIABLE

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

MIO MORPHEE APPLICATIONS

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



OSIRIS®

POWERMETER AND COMBUSTION

PRODUCTS - MEASURING

OSIRIS®

» FAST DATA ACQUISITION



**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.

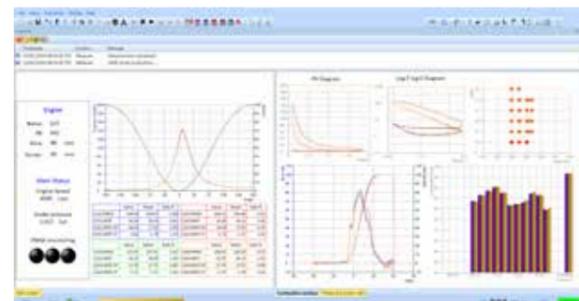
OSIRIS® as POWERMETER

- > 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



OSIRIS® as COMBUSTION ANALYZER

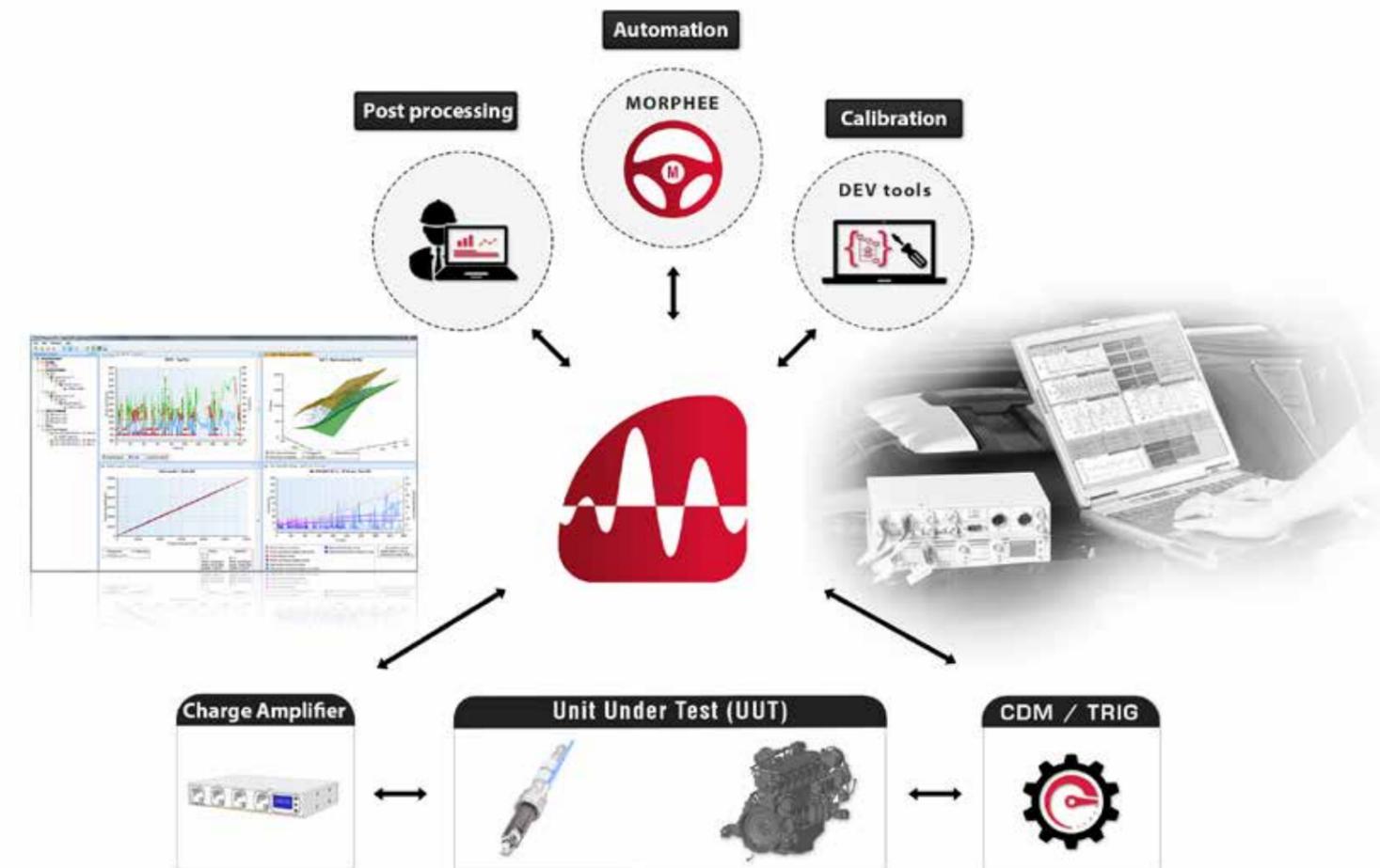
- > Combustion analysis system (indicating system or combustion analyzer)
- > Acquires engine signals (cylinder pressure, injector commands, engine revolution)
- > Is based on time or crank angle
- > Calculates engine-specific values (IMEP, CA50, Pmax, Knock, etc.)
- > Can be remotely controlled by other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



PRODUCTS - MEASURING

OSIRIS®

» INTEGRATION INTO EXISTING ENVIRONMENTS



PRODUCTS - MEASURING

OSIRIS® POWERMETER

» 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 performance 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 current signals, the system uses independent probes and current clamps. It allows fitting with the level of voltage and current 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

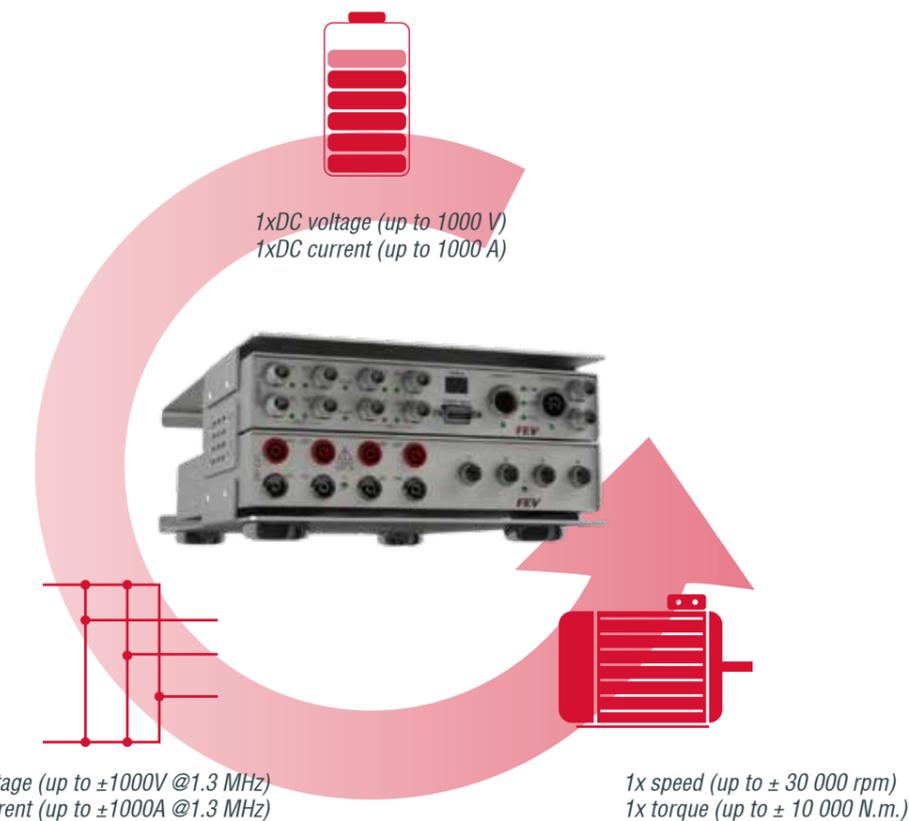
**BENEFITS**

- > Real time dynamic calculation and transfer 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

PRODUCTS - MEASURING

OSIRIS® POWERMETER

» OSIRIS® FOR ELECTRIC APPLICATIONS



Manage data &amp; workflow

Simulate &amp; calibrate

Automate your tests

Control &amp; measure

## PRODUCTS - MEASURING

## OSIRIS® COMBUSTION

## » 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

## PRODUCTS - MEASURING

## OSIRIS® COMBUSTION

## » 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



PRODUCTS - MEASURING

CHARGE AMPLIFIER

» 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...)

PRODUCTS - MEASURING

FREQUENCY MODULE

» 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 at test cell (from dynamometer to engine), gear boxes analysis, clutch analysis, acyclism measurement
- > Provides engine synchronization signals like CDM and TRIG to combustion analysis systems

SERVICES

» ALL SERVICES

Resident Services



Service Contracts



Repair Services



Spare Parts and Renting Services



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:

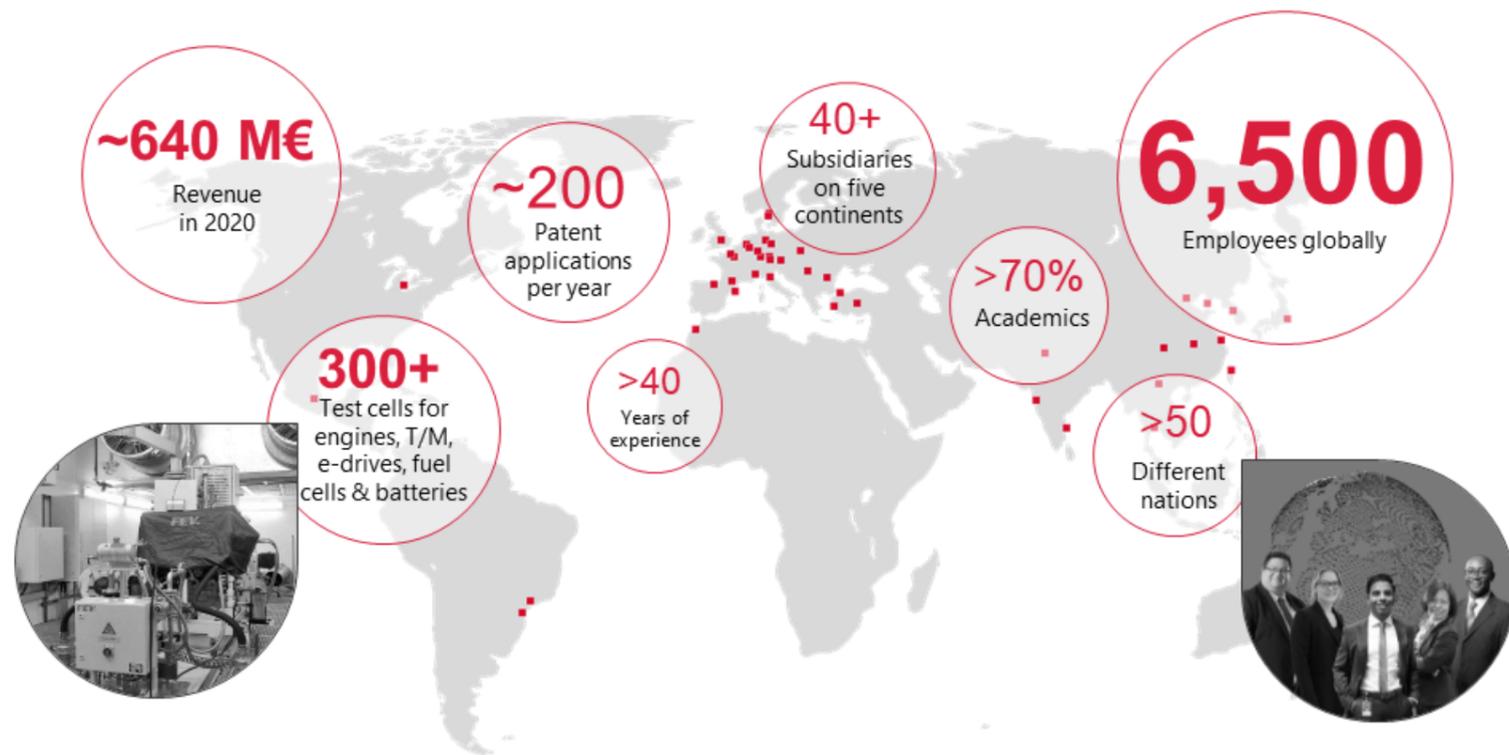
- Measurement equipment
- Dynamometer
- Conditioning unit
- Data acquisition and communication boards

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.

SERVICES

» FEV WORLDWIDE



SOFTWARE AND TESTING SOLUTIONS

SERVICES

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