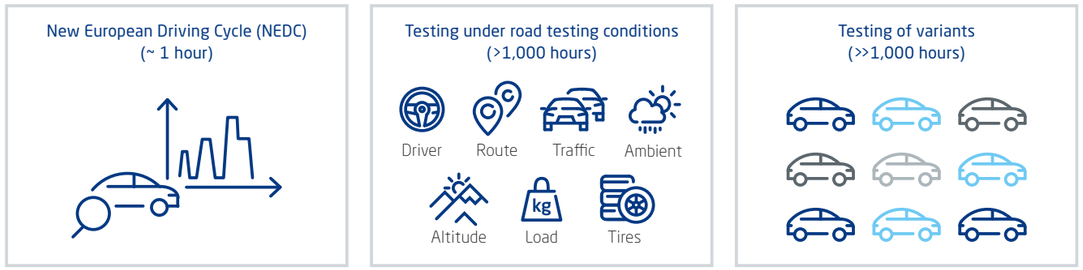
Developing low-emission powertrains with AI and in the cloud

Huge efficiency gains from cloud-based simulation

The adoption of real-world driving emissions in vehicle emissions legislation has introduced a new measure of complexity to powertrain development, which was already a costly and complex process. To prevent further escalation of the time and cost involved, ETAS is pushing ahead with the virtualization of road and bench testing. Combined with cloud-based simulation and artificial intelligence (AI), a new development landscape is opening up that will raise the legally compliant design of low-emission powertrains to a whole new level of efficiency.

The development of modern vehicles is a highly complex process, especially in powertrain development, where thousands of functions interact. With hundreds of developers working in parallel across departmental and company boundaries on engine components, ancillary components, and ECU functions, any change could potentially have an impact on everyone else's work. Test benches and road tests are used to detect and measure the impact on driving behavior, functional safety, and emissions, involving very expensive prototypes and costly measuring equipment. Yet this poses a problem: real-world test-drives are not reproducible because the traffic, weather conditions, driving behavior, and other parameters are constantly changing, and no two drives are identical. Therefore, studying the impact of system changes in real-world tests is unreliable and inefficient, especially with a limited supply of test vehicles and skilled personnel. What is more, tests in cold regions or at high altitudes often necessitate long journeys.
Virtualization is regarded as the key to reproducible test results, faster development cycles, and managing complexity in the development process. In the optimum case, the use of real-world tests and measurements can be limited to simply verifying simulations.

Figure 1: Time spent on vehicle validation – past and present.



Systematically driving ahead with virtualization

ETAS recognized the potential of virtualization early on and has spent years building up a portfolio of solutions for the simulation of individual components and entire vehicles. In the current situation, in which increasingly complex powertrains in a rising number of variants must be tailored to the Euro 6d-Temp and Euro 7 emissions standards, this groundwork is now proving to be a way out of this complexity dilemma. Emissions measurements must be carried out in real driving cycles. Real driving emissions (RDE) are measured using portable emission measurement systems (PEMS), and a statistical analysis of several measurements is performed to ensure compliance. The nature of this analysis threatens to increase the test and validation workload to unmanageable levels. This is where simulation can help! With realistic driver and plant models, vehicles can be simulated successfully – including the functions of the engine, ancillary components, chassis, tires, and even exhaust gas treatment, as well as the interaction between vehicle domains under a wide range of environmental conditions – and the testing workload decreases dramatically.

There are clear benefits to the availability of such a realistic simulation environment: the number of costly vehicle prototypes can be reduced, time-consuming preparatory steps – such as stabilizing the vehicle's temperature, calibrating measuring instruments, and resetting ECUs – are no longer necessary, and schedules can no longer be thrown off course by measurement errors or loose cables. This makes planning more reliable in the validation phase.

Cloud opens up new potential for efficiency and quality

As strange as it may sound, reality is actually the biggest hurdle in the transition to measuring real driving emissions. Reality prevents identically reproducible test-drives, poses the risk of measurement errors, and makes time-saving test parallelization almost impossible. This is compounded by the time and effort required for tests under different climatic and topographic conditions. In addition, financial and organizational factors place a limit on how many test-drivers can be

used for RDE measurements. Obtaining full test data coverage in the development process therefore depends on experienced experts designing precisely defined test-drives in advance. Yet, as the amount of testing increases, uncertainties and bottlenecks will also occur here.
In contrast, high-quality simulation, based on corresponding models, allows virtual test-drives to be performed in parallel hundreds of thousands of times and reproduced as often as required. To achieve optimum workflows, ETAS, Bosch, and ESCRYPT have joined forces to merge the available simulation platforms, tools, and models in the cloud. With the aid of artificial intelligence and cutting-edge IT security, they are creating a scalable and secure simulation environment.
Thanks to the computing power of the cloud, powertrain developers can run thousands of test-drives in parallel, monitoring and validating changes in the powertrain and ECU software through detailed, model-based analyses and regression testing. This improves quality as well as increases efficiency.

model of real-world driving is a new development that makes use of AI. This development is based on an extensive database of GPS data from real drives that has been enriched with map information. It also incorporates numerous drives used to record measurements – involving a variety of demonstrator vehicles, drivers, route profiles, weather conditions, and traffic conditions – which developers have used to derive a highly variable model of real driving with the help of AI. The realistic trajectories generated in this way – such as speed, gradient, and gearshift profiles – serve as a basis for the tests that can be performed in parallel using virtual vehicles in the cloud as often as required.

Making virtual vehicles available in the cloud

With the ETAS virtualization tool kit (see Fig. 3) ready for use, the next goal was to allow users to make productive use of the new all-in-one solution within the ETAS cloud services. The steps to achieve this included a thorough risk analysis

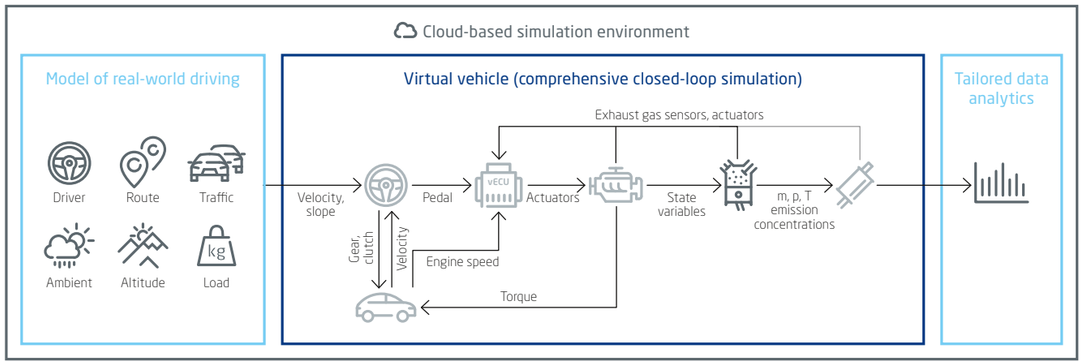


Figure 2: Cloud-based development environment.

Cloud-based platforms have the potential to take cross-departmental and cross-company collaboration between powertrain developers to a whole new level. However, there are still challenges ahead that now need to be tackled.

The challenges of real-world driving

To obtain realistic data from test-drives with virtual vehicles, the underlying scenarios need to provide a high variance of driving styles, route profiles, weather conditions, and traffic conditions. This task is performed by the model of real-world driving. While the vehicle model (virtual vehicle) is based on commercially available solutions in the ETAS portfolio, the by ESCRYPT, which produced a comprehensive security concept to protect the highly sensitive processed development data. ISO 27001 certification is now underway.
Much like the Software-in-the-Loop (SiL) method, the virtual ECU is incorporated in the virtual vehicle as a functional mock-up unit (FMU). It exchanges data via standard buses with the models incorporated in the respective simulation. In powertrain projects, the virtual vehicle offers precise reproduction of exhaust emissions from the tailpipe. To achieve this, the team incorporated sophisticated exhaust gas treatment models and a raw emissions model for the combustion engine, which were created using ETAS ASCMO.

With the ability to perform thousands of simulations in parallel in the cloud, powertrain developers gain access to a highly efficient solution that allows RDE tests to be performed with a much more comprehensive database than would be realistic or financially viable with real test-drives. This database enables developers to more easily prepare real-world tests to validate the virtual RDE measurements.
Obviously, this kind of solution stands and falls by its usability. Prior to running the full cloud simulation, developers can access the entire system on their local workstation to verify proper functionality of the model. In addition, tailored data analytics support efficient test evaluation. Thus, this new solution offers a fast, plannable route to obtaining the statistically relevant driving data that is required for the legally compliant and fully secure design of a powertrain control system.

Summary and outlook

With its cloud-based simulation based on realistic driving trajectories and vehicle models, ETAS provides an elegant and innovative solution to the increasing variety of drives and the RDE regulations. But that is not all: this new approach also promises significant improvements in quality. Instead of offering a small number of non-reproducible test-drives done by just a few drivers, this new method of powertrain design involves thousands of test-drives running in parallel in a virtual environment. Thanks to AI, these cover the full diversity of traffic conditions in statistically relevant trajectories.
This makes it possible to achieve the realistic testing required in the RDE cycle via the indirect route of virtualization.

ETAS is continuously improving the vehicle, plant, and driver models used in this new approach and developing them into a complete tool chain for cloud-based simulation. This fully virtualized development method is now available for customers to work with. The next step is to make the cloud-based solution available for more efficient collaborative processes and train AI algorithms to evaluate the virtualized tests. ETAS is already working on it!
At the end of the day, what is at stake is nothing less than a new state-of-the-art in powertrain development.

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Figure 3: Modular, freely scalable solution for the development of a virtual vehicle.