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ETAS

RealTimes

2015/2016

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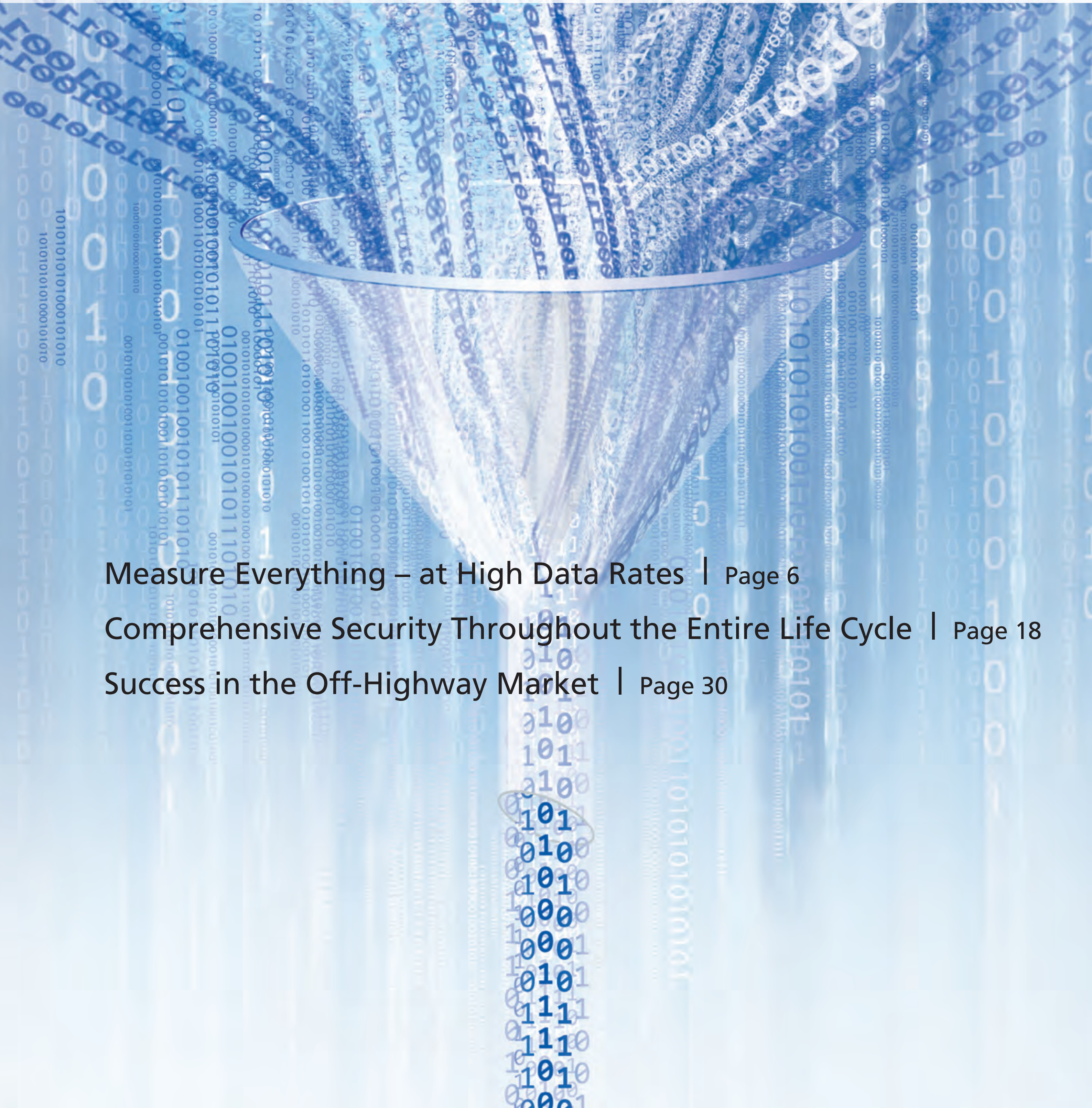


Dear Reader,

We're thrilled to present you with the latest issue of RealTimes, packed with fascinating articles about the world of embedded systems. In addition to news about the innovative solutions we're deploying to increase the efficiency of your development processes, you will discover exciting customer projects and how our solutions are being applied in a variety of market segments.

One area where new tools and methods are needed is the validation and calibration of advanced, powerful, and connected systems for new generations of vehicles. Conducting a series of isolated tests on the test bench and in the vehicle is no longer enough to optimize and safeguard the behavior of complex systems in all operating states. What's more, maintaining these as the sole method of validation and calibration isn't worth the effort and the money involved. In this issue, we'd like to tell you about the range of innovative tools ETAS provides to complement and make the most of these tests:

ETAS ASCMO offers an extremely effective way of using measurement data to model and optimize the behavior of complex systems. This makes it possible for instance to optimize and accurately predict fuel consumption and emission values for complex combustion engines according to engine speed, load, or any controlled engine variable.
ETAS INCA-FLOW gives calibration engineers all they need to graphically model complex calibration processes in the form of flow charts, which they can then use to guide other users through the complex stages of particular calibration cases.
ETAS EHANDBOOK is an efficient tool for documenting complex systems. It offers calibration engineers who are working on a vehicle a shortcut to understanding how the various ECU functions work and how signals flow through multiple functions. With just one click, they can jump straight to the relevant content, while the graphical representation makes it much easier to understand how things link together. Conventional ECU documentation, which typically fills between 10,000 and 20,000 PDF pages, is now a thing of the past.
Together, the ES800 solution and the FETK ECU interface make it possible to record measurement data from ECUs and from the system environment – simultaneously, at high rates, and with minimum strain on ECU resources. This solution brings us closer to fulfilling the goal of being able to record all vehicle measurements without interruption over a full day of testing.

Friedhelm Pickhard
President

Bernd Hergert
Executive Vice President
Operations

Christopher White
Executive Vice President
Sales

(left to right)

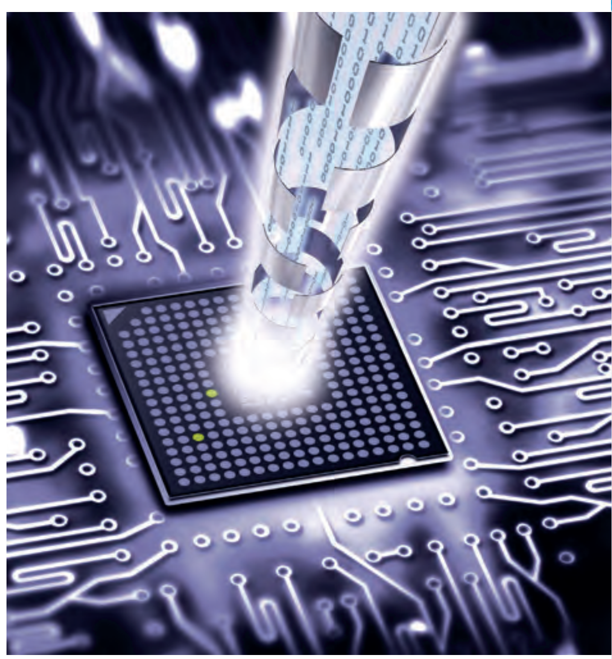
In connection with Big Data processing methods, the aim of this new ETAS measurement technology is to improve quality and raise efficiency when validating vehicles, systems, and ECUs. Engineers working on development, testing, calibration, and quality assurance can use the available measurement data for the specific task in hand. Existing data can be carried over into subsequent projects, which significantly reduces both test phase times and the number of test candidates. Share in our enthusiasm for innovative, efficient methods and solutions and get to know our latest tools starting on page 6.

Highly connected, electronically controlled systems present a big target to manipulators and it is time to reassess the risks. Growing connectivity is increasing the chances of malfunctions and breakdowns. Minimizing risk involves dovetailing safety and security disciplines over the entire product life cycle – especially when it comes to design and development. Read more about this topic in our feature on safety and security starting on page 18 and discover how ETAS is offering more of both with its modular solutions for the future connectivity market.

Closely connected with the automotive industry is the off-highway market segment. ETAS has many years of extensive expertise in embedded systems, especially in the powertrain area. Starting on page 32, we've included some customer projects that demonstrate how we are applying our highly specialized know-how to the off-highway market.

Dear Reader, we hope that you enjoy reading this latest issue of RealTimes and that it provides you with some inspiring ideas.

Friedhelm Pickhard   Bernd Hergert   Christopher White




ALSTOM


ETAS

New Tools for Vehicle Electronics

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High data transfer rates allow universal use

With the market launch of the new FETK high-speed ECU interface and the ES89x ECU and Bus Interface Modules, ETAS is introducing a new solution for validating and calibrating electronic systems, as well as for prototyping new electronic control unit functions. Thanks to data transmission rates that are 20 times faster, the new tools meet the needs of increasingly sophisticated testing in vehicles and on test benches.

A great many factors are making calibrating and validating electronically controlled systems in vehicles increasingly complex. In addition to emissions and safety standards, the key drivers are electromobility, advances in driver assistance systems and automated driving, and the growing number of vehicle models available worldwide.
To ensure that increasingly powerful electronics and extensive software in vehicles function properly, developers and calibration engineers need efficient tools for calibrating and acquiring large amounts of ECU data. ETAS has developed two new products that represent a great advance in efficiency – the FETK high-speed ECU interface device and the ES89x ECU and Bus Interface Modules (Figure 2).

ECU interface for high data rates with low latency

In contrast to serial interfaces such as CAN, the new FETK interface requires virtually no ECU computing power for external communication. It acquires data from the ECU via a dedicated microcontroller interface and transmits it to an ES89x module, which then reroutes the data to a PC or laptop together with data from other sources.
Maximum speed is provided by Gigabit-Ethernet and it is possible to achieve rates of up to 120 MB/s – the maximum data transfer rate for the Ethernet connection. ECU data acquisition rates of 17 MB/s are already being achieved via a single FETK. In the future, it is expected that data rates acquired by an ES89x interface module to which two FETKs can be connected in parallel will exceed 50 MB/s via the new ES89x + FETK system.

The ECU interface data is processed live in real time from a PC or laptop using ETAS INCA – the ETAS environment for measurement, ECU calibration, and diagnostics. This setup also allows users to change parameters in the ECU or have them automatically modified by INCA.

The FETK interface is compact and electrically and thermally designed for use in the vehicle. Since the interface has its own power supply, tests can be performed regardless of ECU operation. The ECU interface hardware acquires data even from control functions with cycle times shorter than 10 µs with chronological precision. Furthermore, the FETK interface can be used to efficiently program ECU flash memories as securely as with a debugger.

In addition to performing measurement and calibration functions, the FETK solution is also ideal for handling fast, time-critical control interventions (also known as function bypass). Low latencies are critical here since developers tend to rely on the bypass method – following a model-based approach. It is common to develop new control functions with ETAS ASCET or MATLAB®/Simulink® and then execute the functions on prototyping hardware.

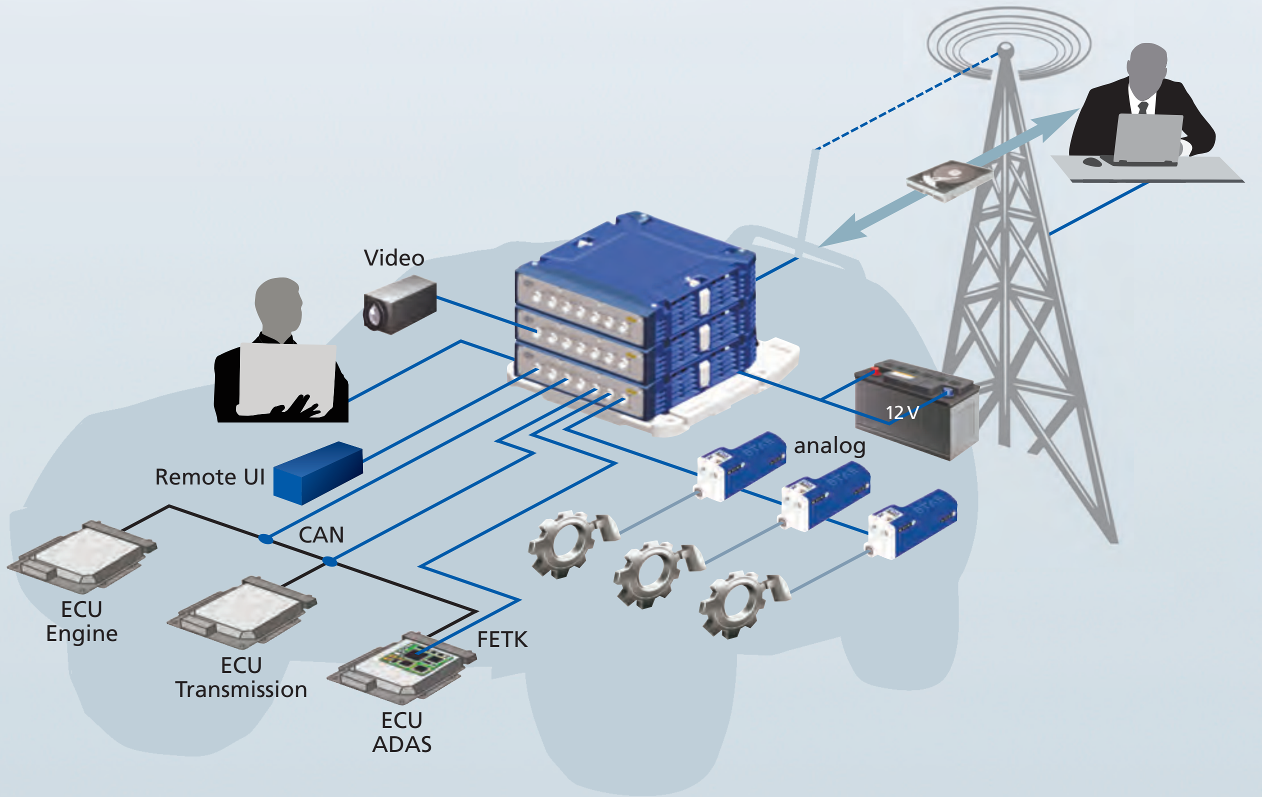
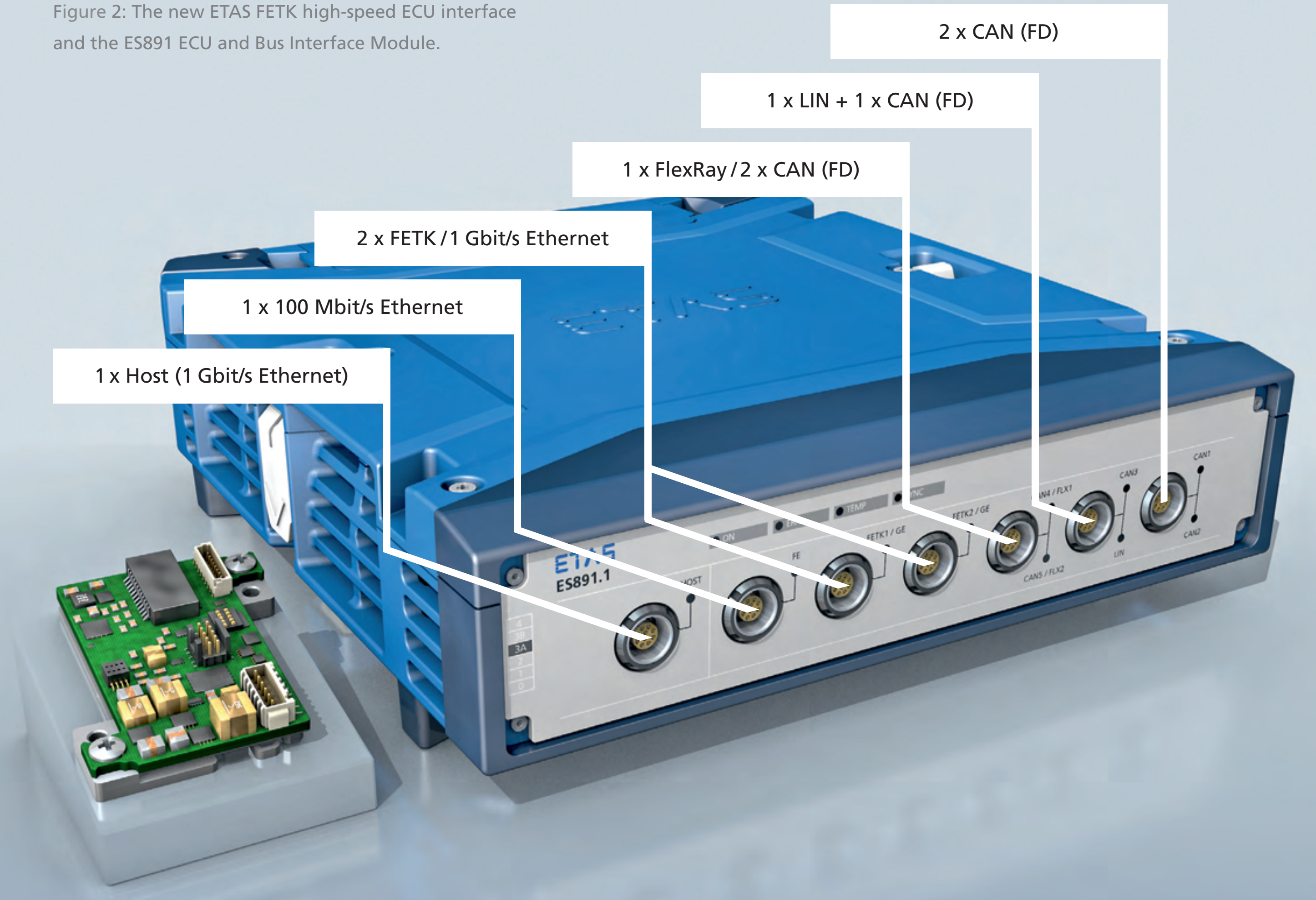


Figure 1: A test vehicle equipped with the ETAS measurement, calibration, and prototyping system of the future. The ES800 system communicates with the ECUs via FETK or serial ECU interfaces and acquires measurement data from the vehicle buses and other digital or analog signal sources in the vehicle. In the example shown, the entire measurement is recorded by a data logger. The experts in development get the data for evaluation at the end of the driving test via mobile communications.

Figure 2: The new ETAS FETK high-speed ECU interface and the ES891 ECU and Bus Interface Module.



The ES89x ECU and Bus Interface Modules – open and standards-compliant

- The new ES89x modules are compatible with the existing ETAS product families of the ES400/ES600 measurement modules, the XETK ECU interfaces, the ECU and bus interface modules of the ES51x/ES52x/ES59x series, and the prototyping and interface modules of the ES9xx series. On the basis of Ethernet, custom hardware can also be easily integrated with the new modules.
- The ES89x modules offer native support for the XCP-on-Ethernet protocol enabling both ETAS and third-party software applications to communicate via the standardized protocol with electronic control units with FETK or XETK interfaces.
- Time synchronization that conforms to the IEEE1588 standard simplifies the integration of the ES89x modules in heterogeneous test setups and automation solutions by means of a centralized clock.
- ETAS provides libraries for the integration of the ES89x modules' bus interfaces into other tools, such as CANape or VISION.

The prototyping hardware communicates with an ECU with FETK interface in real time via an ES89x module. This enables modifications to new software control functions and allows for immediate validation of these functions in the vehicle or on the test bench. Time-critical control functions require that bypass signals flow between the prototyping hardware and the ECU with the smallest possible latency. The FETK interface with the ES89x ensures the exchange of a 128-byte signal circulating from the prototyping hardware to the ECU and back with a latency of less than 100 µs.

Next generation ECU and bus interface

Thanks to the winning combination of a high data transfer rate, low latency, and easy integration into new ECUs, the FETK interface can be used almost anywhere. Excellent cooperation between ETAS and chip manufacturers, such as Freescale, Infineon, and Renesas, also makes it possible to adapt the interface to new microcontrollers. The FETK hardware offers users the utmost in operating convenience: since the Gigabit-Ethernet connection to the ES89x modules is generic, the latter can be seamlessly integrated in all FETK ECU projects without requiring any further configuration. The new ES89x ECU and Bus Interface Modules acquire measurement data from ECUs and vehicle buses to support the calibration, diagnostics, flash programming of ECUs, and prototyping of new ECU functions.

The ES89x enables the user to directly connect two FETK interfaces for these purposes. What is more, the ES891 and ES892 modules support XETK and the Ethernet, FlexRay (ES891), CAN, CAN-FD, and LIN vehicle buses. They synchronously acquire all incoming measurement signals with one microsecond precision.

The ES89x modules are designed to be mechanically stackable, enabling a robust mechanical and electrical connection between modules. If a vehicle has more than two ECUs equipped with FETK interfaces, multiple ES89x modules may be combined to synchronize the data from all connected FETK or serial interfaces automatically. Additionally, expansion is not only possible with ES89x modules but also with prototyping hardware, and data loggers that are currently under development at ETAS. All members of the new ES800 product family will help to secure the functioning of future electronic vehicle systems (Figure 1).

Outlook

ETAS' FETK provides powerful ECU access, making it a solution that is equally suitable validating and calibrating ECUs as it is for developing prototypes of time-critical functions of electronic vehicle systems. Based on this unique combination, a development ECU featuring an FETK interface pays off twofold: in calibration and in prototyping.

In addition, the ES800 product family will be augmented in the coming months by powerful and flexible prototyping hardware and a comprehensive data logger solution. The latter will make it possible to record ECU software variables and serial data bus signals for an entire day of testing without interruption.

Efficient Calibration

ETAS INCA-FLOW helps users standardize calibration tasks

Calibrating gasoline and diesel engine management systems is a challenging task that is largely repetitive with regard to specific customer projects. Using INCA-FLOW, the calibration process can be set up for one ECU variant and then reused for others, which can significantly increase calibration efficiency. In addition, measurements can be easily reproduced, leading to clear improvements in calibration quality.

AUTHORS

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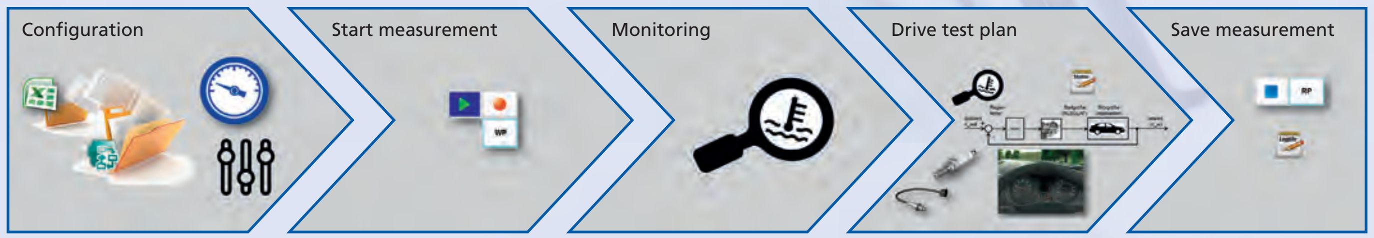
Bosch base calibration with INCA-FLOW

In the course of the base calibration of engine management systems at Robert Bosch GmbH, a Design of Experiment (DoE) plan is automatically carried out in the vehicle using INCA-FLOW.
This is analogous to the procedure used in engine test beds. The first step, which is done on a computer, involves creation of the DoE plan and measurement configuration in the tool. In the vehicle, the plan is then automatically put through its paces using INCA-FLOW and INCA. To do this, the user first imports the files containing the DoE plan and measurement configurations, which define parameters such as the limits for operation and monitoring. During testing, the values of the observed loads and other relevant calibration parameters are then set automatically. At the same time, INCA-FLOW monitors system limit values using specific methods. In this way, each operating point of the DoE plan is set, stabilized, and then measured.
Automation is used to check the calibration quality of the volumetric analysis, fuel pre-control, and torque



- Connection to Excel
  - Read the parameters
  - Read DoE test plan

- Save path
- Full control of INCA
  - Start recording
  - Switch to working page

- Global monitoring of
  - Exhaust gas temp.
  - Oil temp.
  - Cooling water temp.

- Governing of
  - Load
  - Engine speed
  - Ignition timing
- Local temperature monitoring

- Stop recording data
- Save measurement
- Write a logfile
- Switch to reference page

Sample INCA-FLOW sequence.

Automated base calibration with INCA-FLOW.

model in the vehicle. The same process is used for calibrating the exhaust-gas temperature model and component protection.

For the last two work packages, automatic calibration of the ignition angle is carried out based on each operating point in the DoE plan. The same calibration process can be used for different ECU variants once the DoE plan and the measurement configuration have been adapted using the INCA-FLOW standalone configurator.

INCA-FLOW standalone configurator for adapting calibration processes to different ECU variants

INCA-FLOW's runtime license allows scripts generated using INCA-FLOW Developer to be executed on a standalone basis, in other words without the developer license. The standalone configurator enables users to configure independently executable INCA-FLOW scripts for user-specific INCA environments.

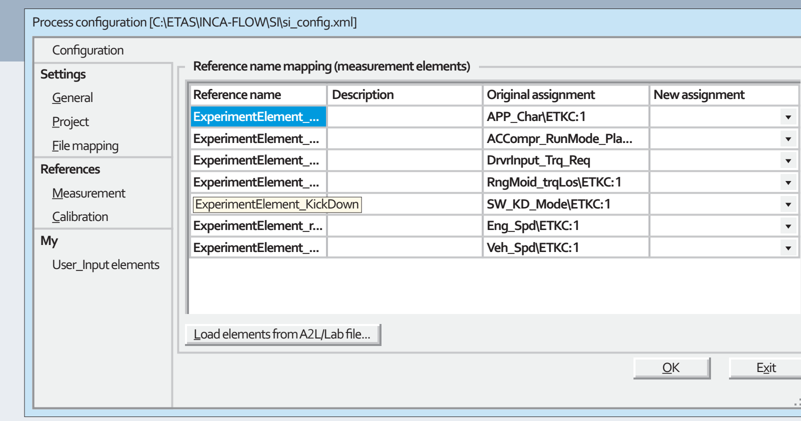
At the same time, calibration, measurement, and user-defined variables can be assigned according to user-specific application cases. In this way, the calibration process algorithm can be retained independently of specific boundary conditions, such as different names for calibration and measurement variables and/or other values for specific variables.

Users of the INCA-FLOW standalone configurator are able to configure general information such as project name, process name, comments, soft and hard bounds, etc. The "project" uses as default the data that was defined in the project configuration of the executed process. Configurator users can adapt these settings to their specific INCA environment.

In addition, interfaces can be assigned for the individual measurement and calibration variables of the calibration process. A mapping function allows users to change interface assignments and the names of variables.

Outlook

In the future, INCA-FLOW will also be used for other calibration tasks such as knock control, engine warm-up, lambda closed-loop control, oxygen probe heating, dew point threshold, fuel tank ventilation, transient compensation, driving behavior, idle control, and camshaft control.



In the "References" view, users can define "global references" for their calibration process based on existing measurement and calibration variables. The view shows the name of the global reference and, if available, a definition of the variable. The "Original Assignment" column shows the name of the measurement and calibration variable based on the existing process, while the "New Assignment" column allows users to reassign measurement and calibration variables. An existing A2L file or an existing LAB file can be used for the assignment. The "My" view permits users to define different values for certain user-defined variables.
With the standalone tool, existing configurations can be loaded and modified configurations can be saved or reset to the old values. The tool allows users to use the same process for the calibration of several ECU variants. In this way, INCA-FLOW facilitates major improvements in the efficiency and quality of calibration.

Better Understanding of ECU Software

New interactive documentation helps calibration engineers to quickly handle ECU software

As engineers develop ECU functions using ETAS ASCET, Simulink®, or C code and then translate these functions into software, a huge amount of documentation is generated. This documentation can quickly fill up 10,000-20,000 pages – and until now, calibration engineers have had to handle all this data in PDF format.

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Engineers often have to refer back to this documentation during the process of calibration, when they are fine-tuning the functions. But leafing through enormous PDF files is a tedious process that consumes valuable time – adding more to the workload of calibration engineers in the already very limited time available to them in the test vehicle. Now ETAS has developed EHANDBOOK – an interactive tool that offers an intelligent search functionality in place of tiresome manual searches and automatically generates interactive graphics and models from ASCET, Simulink®, or C code. These graphical representations give calibration engineers an immediate overview of the ECU's functions and signal flows. It breathes life into all the knowledge buried in those thousands of pages, giving everyone involved efficient access to the information.

ETAS EHANDBOOK makes knowledge transparent and optimizes workflow

The EHANDBOOK solution is made up of three components. Flexible transfer of source data into documentation with interactive graphics and models is handled by the EHANDBOOK CONTAINER-BUILD tool. ETAS offers services to support this where necessary. The resulting handbook is then stored in EHANDBOOK CONTAINER, putting the data files generated during the development work just a mouse click away for calibration engineers. This is where the third component comes in: EHANDBOOK NAVIGATOR.

The NAVIGATOR is the physical interactive tool that helps calibration engineers quickly and efficiently find their way around all the documentation that function developers generate. Alongside a search function, there is the option to get an overview of the system through graphics and models or to zoom in on the details. In addition, the tool can connect to calibration tools such as ETAS INCA. Users who set up experiments in INCA can use the NAVIGATOR to locate relevant measurement and calibration variables in the documentation and automatically transfer them to their experiment.

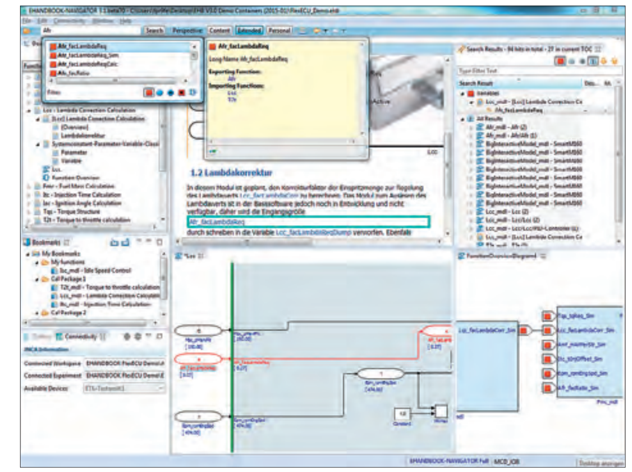
A navigation system beats poring over paper maps

Switching from PDF documentation to EHANDBOOK is just like making the move from a road atlas to a navigation system. Instead of having to laboriously follow, say, the signal flows in a particular model over several pages of PDF documentation, this tool lets developers zoom seamlessly in and out of whatever models they choose. This graphical representation of information makes signal flows much easier to understand. If necessary, users can generate what is known as "function wallpaper" with just one click, giving them a single view that seamlessly stitches together the relevant excerpts of a model.

EHANDBOOK helps calibration engineers to manage information quickly and work efficiently, offering them a deep understanding of the ECU functions their colleagues in function development have produced in their models. This interaction serves both to improve quality in the development process and share knowledge throughout the organization. But above all it saves valuable time, enabling calibration engineers to concentrate on their actual job – calibrating ECU functions – instead of wasting time looking for information and measurement data.

Pilot customer Bosch puts EHANDBOOK to productive use

In refining its interactive EHANDBOOK documentation solution, ETAS is working closely with pilot customer Robert Bosch GmbH, where the tool has already been rolled out internally for ECU projects. Upon request, Bosch can also provide interested parties with interactive handbooks for their ECU software. What's more, a number of automakers have already evaluated the new ETAS solution and have recognized how useful it is. They too are now using EHANDBOOK – and it is helping them to optimize the knowledge transfer between suppliers and vehicle manufacturers in software development.



EHANDBOOK-NAVIGATOR – a navigation system instead of scrolling through pages.

Model-based Development Methods

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A key to calibrating modern internal combustion engines

Design of Experiments and model-based parameter optimization are the keys to mastering complex engine management systems. In the following report, Hyundai and ETAS show how model-based development methods can sensibly support the calibration of modern internal combustion engines.

With CO_2 and exhaust gas emissions limits getting tougher all the time, engine management systems are becoming increasingly complex in response. The result is a constant increase in the calibration parameters that need to be optimized in the overall system. At the same time, strong competition is forcing manufacturers to shorten development cycles and cut development costs. To be able to carry out engine calibrations that ensure maximum ride comfort, high dynamics, and low emissions under these circumstances, there is a need for new computer-assisted calibration methods to complement conventional ones[1].

Engineers at the Hyundai Motor Europe Technical Center GmbH (HMETC) in Rüsselsheim, Germany, were quick to recognize this need: in powertrain development, they have been making greater use of Design of Experiment (DoE) and model-based optimization methods on top of increased automation levels since 2005. Acceptance of the initial solutions was severely hampered by their lack of user-friendliness and the fact that they did not cover all engine development process steps.

However, the introduction of the ETAS ASCMO[2] software resolved this situation: in addition to a program structure and user interface tailored to model-based ECU calibration, the software provides helpful functions to support inexperienced users. As an example, the following sections describe the use of this new solution in a preproduction engine project at the HMETC Powertrain Division.

Project scenario

The test candidate was a 2.0-l, four-cylinder diesel engine with preproduction engine hardware and ECU software. At the beginning of the tests, the existing calibration already complied with the Euro 5 emissions standard. The objective was to use the DoE software to further reduce the engine's fuel consumption.

To do this, it was important to find the optimal balance for the following calibration parameters:

- air mass/EGR rate
- start of injection
- swirl flap position
- exhaust back pressure flap position for low-pressure EGR control
- boost pressure
- rail pressure

The relevant target variables are listed below:

- fuel consumption (CO_2)
- particulate mass (soot)
- nitrous oxides (NO_x)
- hydrocarbons (HC)
- carbon monoxide (CO)
- combustion acoustics (dBA)

All tests were conducted on the engine test bench, with subsequent in-vehicle verification on the emissions chassis dynamometer. During the basic measurement run, the CO_2 value was determined as a reference for the optimization. As shown in Figure 1, the relevant operating points for optimization were supplied by the dwell times of rpm and load in the NEDC.

Planning data acquisition on the test bench

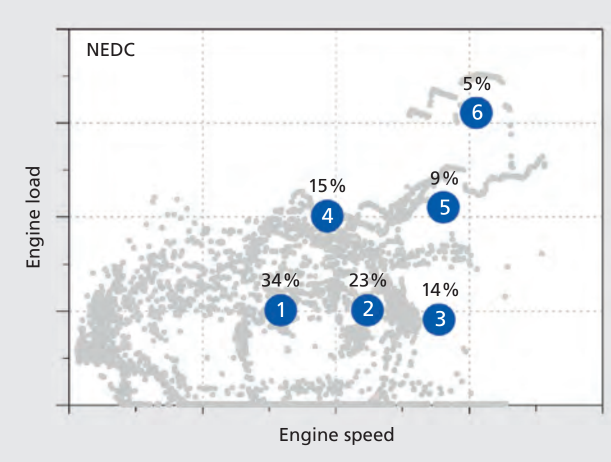
The DoE module used for test planning divides the workflow into eight user-friendly steps. A useful function facilitates the compression of measuring points via selected input variables, Figure 2. In the case at hand, the measuring points were compressed in the vicinity of small air masses, because in addition to greater measuring inaccuracy, less smooth physical dependency was also expected in this area due to high EGR rates.

Another function allows users to divide the test plan into a variable number of sections ("blocks"). Given a sufficient number of measuring points, each individual block offers optimum distribution for modeling. During live measurement on the test bench, it is therefore possible to quickly determine after each block has been run whether the requisite model quality has been achieved and the test run can be completed early. This can significantly reduce the amount of time and effort required for measuring. As an example, Figure 3 plots modeling accuracy for the smoke number as a function of the number of measuring points used for model generation.

Key element: Raw data analysis

Once the measurement data has been gathered, the next phase is raw data analysis. This often proves to be the most important data evaluation step. As well as identifying faulty measurements and drifts, it also provides insight into optimization potential.

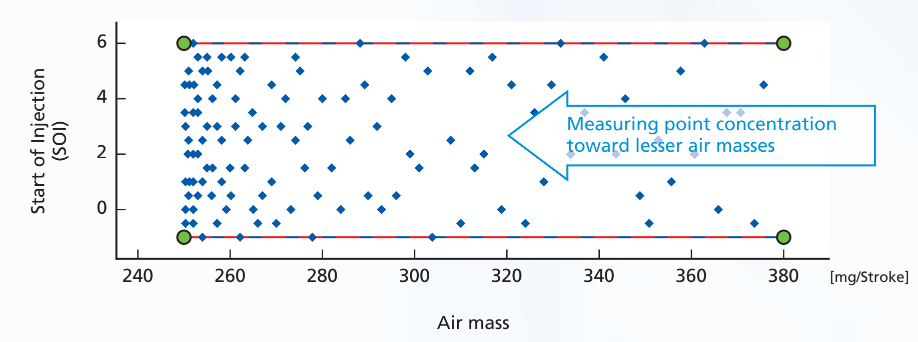
The DoE software supports this process very efficiently: interactive diagrams allow users to display

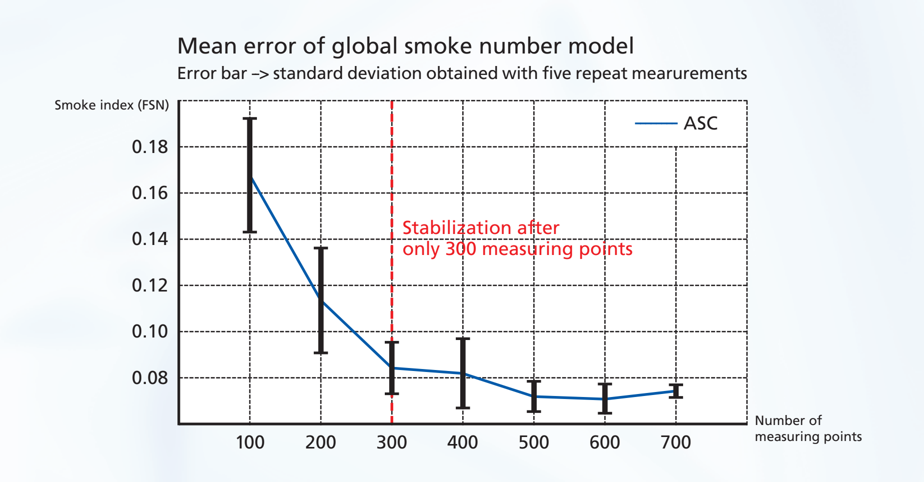


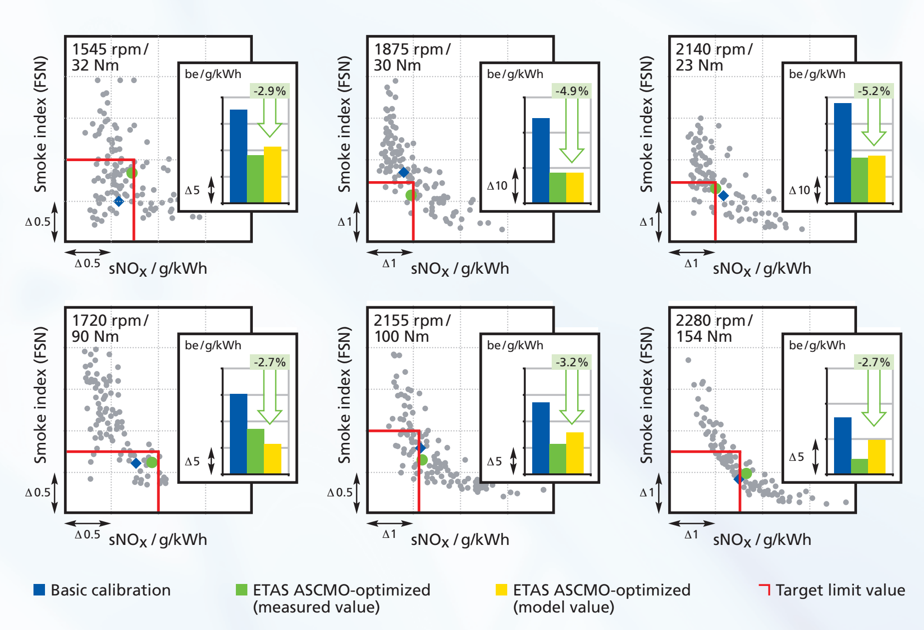
No.	Engine speed RPM	Load Nm
1	1545	32
2	1875	30
3	2140	23
4	1720	90
5	2155	100
6	2280	154

Figure 1: Distribution and weighting of operating points in the NEDC test.

Figure 2: Experiment planning using local measuring point concentration.





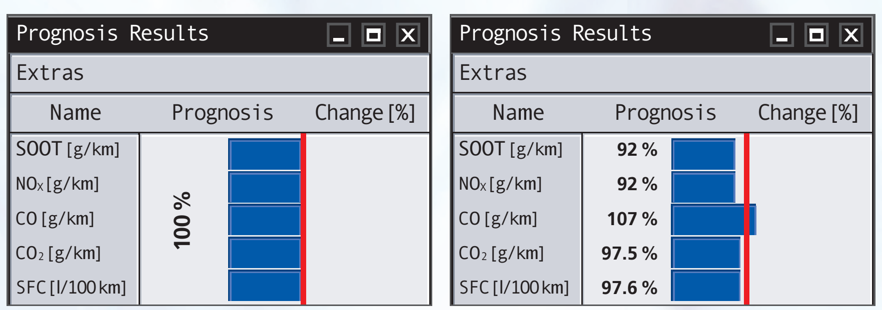


Pre-optimization Prognosis

Values adjusted as per results of dynamometer pre-testing

Post-optimization Prognosis

Forecast based on applied weightings and adjustment factors



	NO_x/g/km	CO/g/km	Soot/g/km	CO_2/g/km	FC/l/100 km
Deviation ETAS ASCMO vs. in-vehicle meas.	-3.7 %	-4.0 %	-12.5 %	+0.2 %	+0.3 %
Tendency	+	+	-	++	++

calibration parameters and/or target variables in relation to each other and, for example, to isolate the areas in which target variables display their optimal values. This facilitates the effective visual evaluation of measurement data and the identification of good parameter combinations.

Automated modeling

The core of ETAS ASCMO is its user-friendly modeling function, which is largely automated. Unlike the model-based calibration tools available on the market until now, users are not required to select a specific type of model from a large number of options. Instead, the tool suggests a single, particularly flexible and powerful model type for them based on Gaussian processes (GP). This approach makes it possible to model even highly nonlinear behavior by very complex systems to a high degree of accuracy without overfitting. To do this, users do not have to parameterize the model. A critical issue for GP models is often the computing times and memory capacities required for processing large measuring ranges. However, the efficient GP implementation allows to generate models from tens of thousands of measuring points even on a standard PC in an acceptable time.

The high flexibility of the GP models also enables users to create global engine models with rpm and load as additional input variables. In order to assess the maximum attainable quality in our sample project, the measurement data of the six operating points was used to create a global model in addition to local models. In both instances, the quality of the models was satisfactory and the modeling of physical dependencies was largely correct. In some cases, the global model provided even better characteristics than its local counterparts. Only the modeling of CO emissions, with a value range of up to 16 g/kWh and a standard deviation of 0.57 g/kWh, remains somewhat too inaccurate. The table shows the statistical quality levels of the global models based on verification measurements.

Figure 3 (top): Model accuracy of ETAS ASCMO model (ASC) versus data record size: mean error of global smoke number model (determined by means of verification measurements, error bar = standard deviation obtained with five repeat measurements).

Figure 4 (center): Optimization results based on measurements taken at six operating points on the engine test bench.

Figure 5 (bottom): Prognosis based on cycle extrapolations before and after optimization (partly screenshot).

Optimization results

While ETAS ASCMO's range of functions for local optimization is comparable with that of other commercial tools, its strength lies in its global modeling and evaluation capabilities, which enable it to automatically optimize entire engine maps with respect to drive cycles. Then, based on a list of weighted operating points, a current cycle prognosis is calculated online for each change of the characteristic maps. This means that a powerful optimizer can be used to automatically generate calibration data, which achieves minimal fuel consumption while staying within the cycle's limit values and respecting local limit values and map smoothness. The optimization results achieved in this way based on the analyses are summarized in Figure 4. During verification on the dynamometer, the vehicle with optimized calibration achieved a 2.5 percent reduction in fuel consumption compared to the base data, accompanied by slightly reduced smoke and NO_x emissions. When we consider that the base data version was mature to start with, we can see these increases for the impressive achievement that they are. Moreover, the value measured is very close to the DoE model forecast. Figure 5 shows the results of pre- and post-optimization cycle extrapolations.

Summary

Overall, the evaluation of ETAS ASCMO had a very positive outcome. Particularly in the area of engine calibration, the tool quickly achieved a high degree of acceptance among calibration engineers on account of its advanced task-centered functionality and its user-friendliness. Whereas many publications on model-based optimization have tended to emphasize the time and cost savings it delivers, the focus for HMETC was more on the measurable increase in quality and the improved documentation of calibration results.

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[1]) Klar, H.; Klages, B.; Gundel, D.; Kruse, T.; Huber, T.; Ulmer, H.: Neue Verfahren zur effizienten modellbasierten Motorapplikation (New methods for efficient model-based engine calibration). 5th International Symposium for Development Methodology, Wiesbaden, 2013

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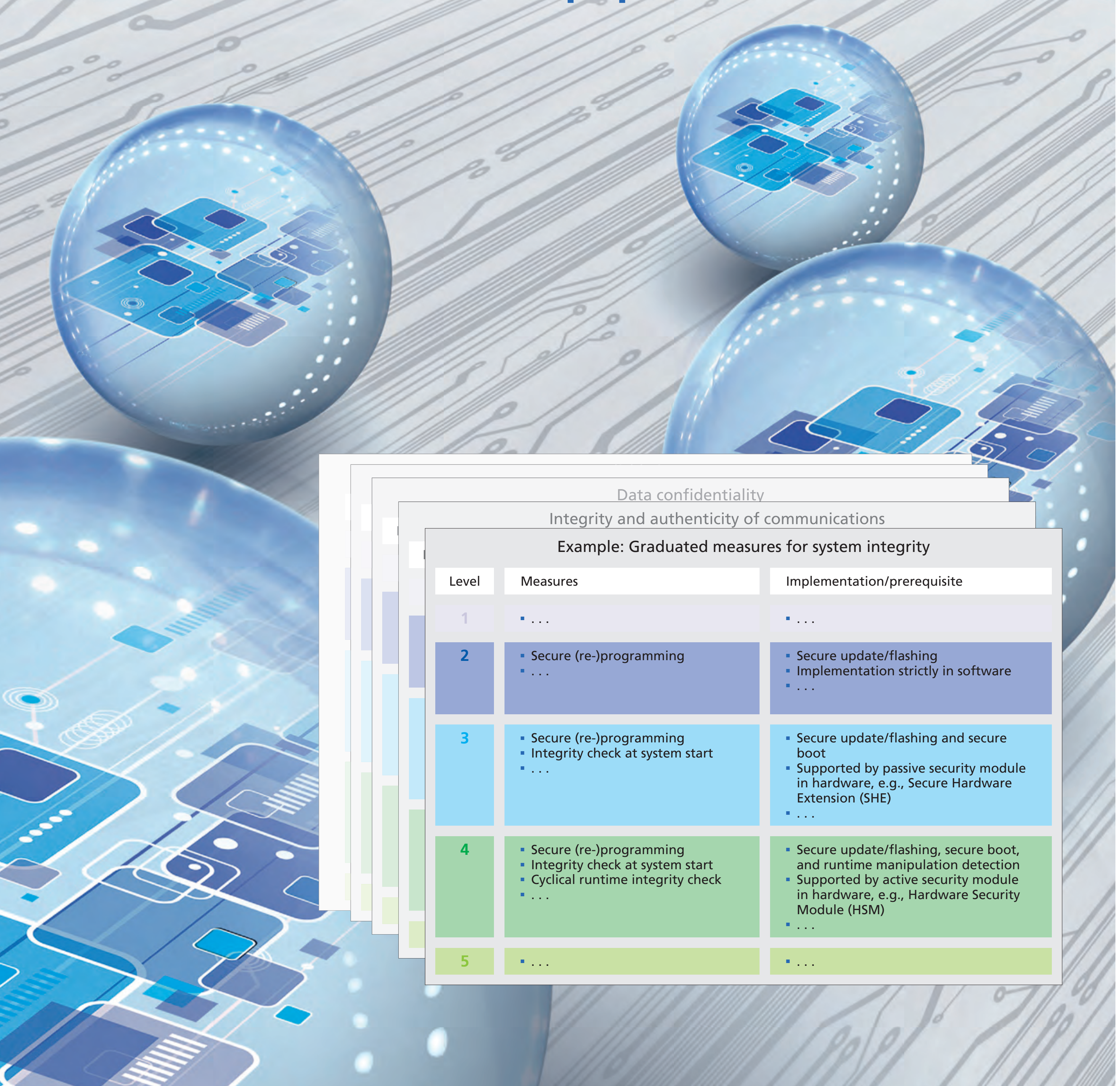
Quality of global model within the limits of definition range established by verification measurements.

	sNO_x/g/kWh	sCO/g/kWh	Smoke/FSN	CO_2/FSN	Combustion noise/ dBA	be/g/kWh
Model range	0.4 - 2.5	0.7 - 16	0 - 6	4 - 13	75 - 95	210 - 460
RMSE	0.058	0.57	0.089	0.059	0.23	5.32
R^2	0.97	0.98	0.97	0.99	0.98	0.99

Safety and Security – A Holistic Approach



Example: Graduated measures for system integrity

Level	Measures	Implementation/prerequisite
1	▪ . . .	▪ . . .
2	▪ Secure (re-)programming ▪ . . .	▪ Secure update/flashing ▪ Implementation strictly in software ▪ . . .
3	▪ Secure (re-)programming ▪ Integrity check at system start ▪ . . .	▪ Secure update/flashing and secure boot ▪ Supported by passive security module in hardware, e.g., Secure Hardware Extension (SHE) ▪ . . .
4	▪ Secure (re-)programming ▪ Integrity check at system start ▪ Cyclical runtime integrity check ▪ . . .	▪ Secure update/flashing, secure boot, and runtime manipulation detection ▪ Supported by active security module in hardware, e.g., Hardware Security Module (HSM) ▪ . . .
5	▪ . . .	▪ . . .

In a networked world,
secure systems require comprehensive protection.

Connected vehicles require new risk awareness

IT systems in the vehicle are becoming more accessible to the outside world. This brings new opportunities, but also new risks, which calls for a fundamental reevaluation of risk assessment and security architecture. Safety and security will have to mesh more tightly in the future. What is needed is a holistic approach that encompasses all components of the vehicle throughout its entire life cycle.

A sonorous voice points out tourist attractions, provides historical background information, and occasionally mentions current offers from local bars and shops. You're taking an online city tour in your own car, using an advertising-funded program based on connected technologies. Sensors monitor the surroundings and transmit this data to ECUs and the communications unit in the vehicle, which maintains contact with the traffic control center and other vehicles in the vicinity.

Thanks to this ongoing exchange of data, traffic keeps moving. Accidents and jams are a rare occurrence. Traffic lights use incoming vehicle data to adjust their cycles to the traffic volume in real time, which reduces the level of CO_2 emissions from road traffic. Vehicles searching for a parking space no longer disrupt the flow of traffic. Drivers and passengers get out of their cars in designated stopping zones, and web-based systems proceed to guide their vehicles to the next available parking space. The automatic parking assistant can calculate the parking maneuver required in advance by evaluating the data of the car that was parked there previously.

Vulnerabilities have no place in a successful network

This vision of the future only suggests the potential of connected transport. No one knows what business model options will open up when vehicle IT systems that used to be closed off to the outside world are connected as parts of larger networks. Upgraded engine performance, navigation and assistance systems are just as conceivable in the "internet on wheels" as reduced insurance rates based on voluntarily submitted driving data. However, opening up data channels for apps, upgrades, and any mobile devices from various occupants of the vehicle or Car-to-X data traffic brings new and, in part, unknown risks in the development stage. Minimizing these risks requires a fundamental reevaluation of risk assessment and security architecture.

Despite opening up more to the outside world, intrinsic security remains the goal. Under no circumstances should hackers or viruses smuggled in via mobile devices affect the safety of the vehicle and its occupants. The vehicle should also be automatically protected against the unwarranted installation of untested software by unauthorized providers without the driver having to do anything. Protection must therefore be integral to the vehicle's IT architecture.

Risk analysis and assessment throughout the entire life cycle

Clearly, a technological shift is called for: Security, defending against external attacks, and safety, ensuring that system functions don't fail in the event of an emergency, will have to mesh more tightly in networked vehicles than has been the case up to now. Security and safety experts should put their heads together before software and hardware development has even begun in order to identify and evaluate potential risks.
They could then formulate risk objectives using assessment procedures that rate the probabilities and consequences of potential disturbances in line with the ASIL scale in the ISO 26262. This fundamental analysis follows a holistic approach, and should take into account permanently installed components as well as intermittently connected smartphones, service diagnostics devices, servers, and vehicles exchanging data over-the-air (OTA).

Once the risks within the system have been assessed and the safety and security requirements identified, the software architecture can be designed. Even at this early stage, the engineers must clarify

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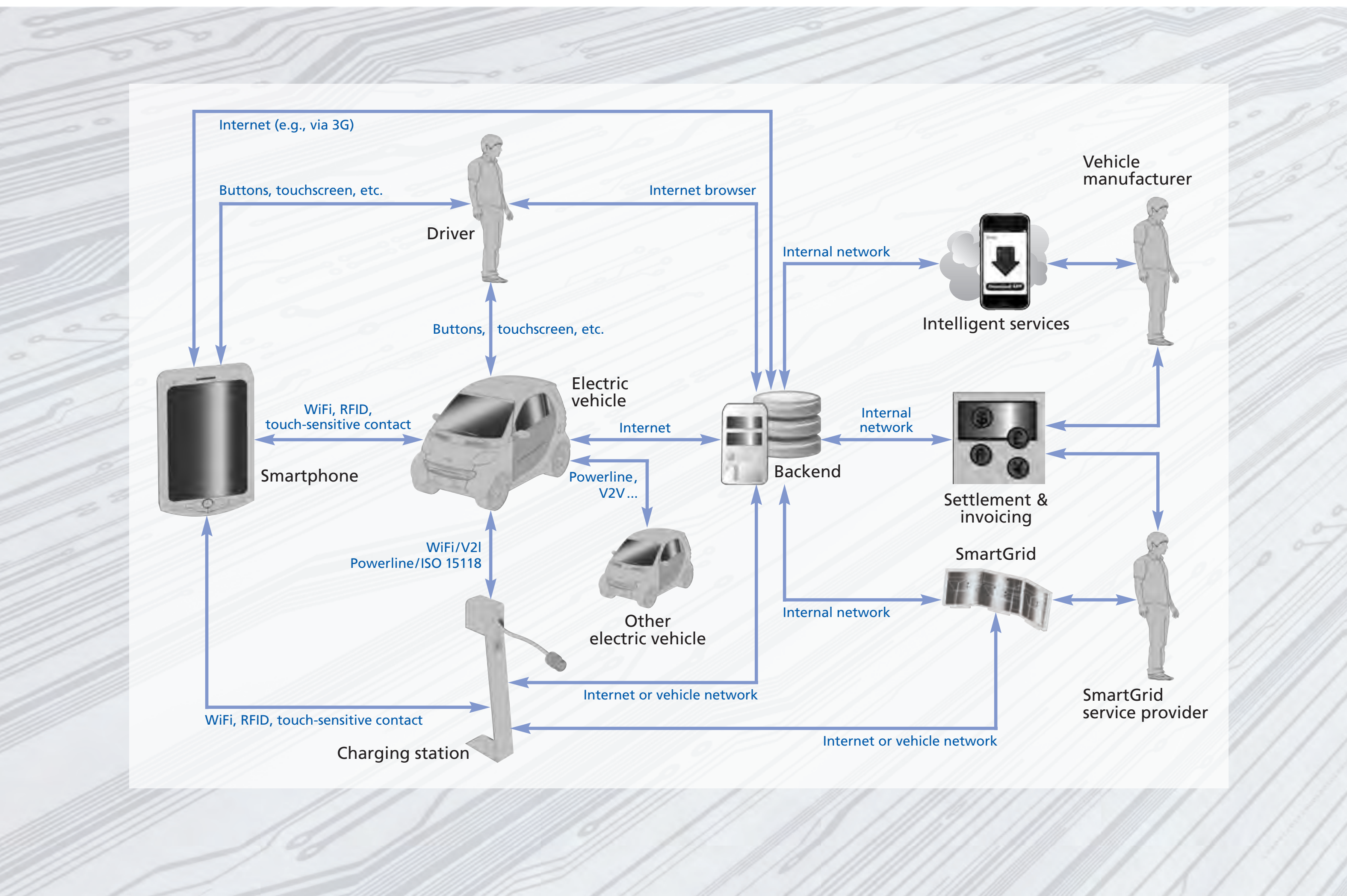
which data will go in the ECUs and how they will get there, who is allowed to read and/or change specific data, and which specifications subsequent functions and tests will follow. As connectivity increases, the deciding factor is that, once they have been delivered, vehicle systems are open to interaction with the complex outside world.
Remote access privileges for service workshops must be clarified, and senders of incoming data authenticated. Cryptographic data must also be protected against unauthorized access – from the start of development right through to their disposal. When no longer required, the vehicle's unique cryptographic keys must be reliably deleted to prevent security-relevant information getting into the wrong hands.

An overview of all components

Other sources of risk include over-the-air firmware and software upgrades (FOTA/SOTA) and apps that intervene in the vehicle software. Their intensified interaction with controllers, sensors, and actuators poses a threat to the overall network. The magnitude of this threat has been shown in experiments in which developers were commissioned to hack their way into vehicle functions from the outside. In 2015, for instance, a team in the United States succeeded in actuating the brakes and stopping the engine in a moving test vehicle, albeit with great effort. Manufacturers must take precautions against such attacks; for example, by protecting each vehicle with firewalls, gateways, and secured communication with unique cryptographic keys. Secure key management has a threefold effect: If every vehicle is protected by unique cryptographic keys, hacker attacks become much more difficult and, in the worst case, only affect a single vehicle. Moreover, the requirement to authenticate fulfills a gatekeeper function against unknown software and their senders.

The connected vehicle networks of the future provide numerous interfaces.



Data exchange only with authenticated partners

In the future, professionally installed security solutions backed by secure data centers staffed by appropriately qualified associates will determine participation in Vehicle-to-X communication. Data will only be delivered to the recipient if the sender can provide a trusted signature. Cross-manufacturer and cross-sector key management solutions also help vehicles to filter out relevant information from the flood of data.

Establishing security solutions will therefore become mandatory for all stakeholders in connected traffic. In the event of an emergency, however, safety solutions must also take effect. Systematic engineering geared towards standards such as the ISO 26262 ensures that all important vehicle functions remain operational even in the case of attack or negligent viral contamination.
Consequently, it is important that security-relevant areas are reliably safeguarded against the effects of software installed at a later date. Commercially available solutions include ETAS' Hypervisor RTA-HVR, which partitions a single ECU into multiple virtual ECUs that are strictly separated from each other, thereby completely shielded the ECU's functions from outside influences. This method requires core functions in need of protection to be defined in advance. Given the intense interaction that takes place between ECUs in the vehicle, this requires a great deal of experience, a tried-and-tested methodology, and efficient tools. These might include Software- and Hardware-in-the-Loop testing facilities, functional security protocols, or the equipment required to carry out real-time monitoring of memory accesses, computing times, and transfer rates. Last but not least, the process calls for skilled associates who are comfortable working in this development environment, and who are familiar with the required norms and industry standards such as AUTOSAR.

Utilizing existing knowledge

Customers will find all of this at ETAS. Our modular product and service portfolio starts with expertise and many years of experience in the planning, implementation and testing of secure embedded software, and continues with AUTOSAR-compliant operating systems and protocols for secure communication, and goes beyond tools such as our Hardware Security Module (HSM) or the Hypervisor RTA-HVR mentioned above.
Manufacturers will soon be able to use the latter to reserve selected areas of ECUs for their own updates and upgrades. This is yet another way to guarantee a bit more safety and security in the future connectivity market. Also available are the modular security solutions provided by ETAS subsidiary ESCRYPT, which extend across the entire life cycle of all new vehicles and cover cryptography software licenses through to complete key management, inclusive of processing in top-security data centers.

Applying know-how for affordable risk minimization

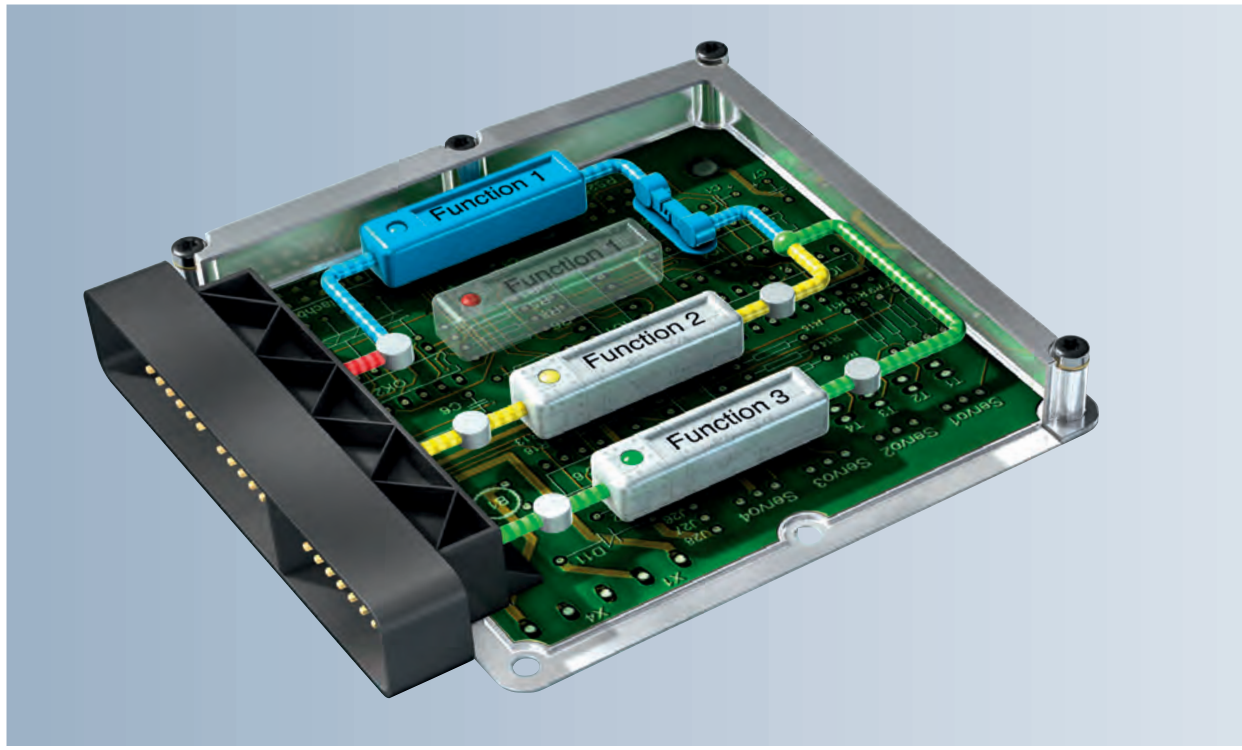
Cost reasons alone render the complete compartmentalization of every ECU in connected vehicles impossible. Compromises are necessary that can only be made on the basis of risk analysis and assessment, which makes an all-encompassing view of the safety concept for all vehicle systems essential. Should, in the worst case the security and safety of a function be particularly threathened, routines can be implemented to react accordingly, all the way up to a coordinated shutdown of the system.

Systematically interlinking security and safety approaches is crucial, because future threats are not yet known. The only effective means of equipping connected vehicles to face these unknown risks is to combine suitable key management with secure vehicle system design. It is not enough simply to respond to threats as they materialize. Fundamental flaws in security architecture cannot be fixed via an update, and, given the limitations of restricted data transfer rates, annoying security updates should be kept to an absolute minimum in any case.

Summary:
Adjust risk awareness – assemble a package of measures

Networks of connected vehicles require new risk awareness. The huge number of vehicles, the frequency with which they are used, and their connection to external data streams increases the likelihood of disturbances. To minimize the resultant damage, safety and security solutions that usually operated in isolation must now become much more interlinked. A holistic overall assessment of the risks prior to development is an essential prerequisite to reliably safeguard connected vehicles against current and future risks. "Safe and secure by design" should be the motto throughout the entire product life cycle.

360° Safety



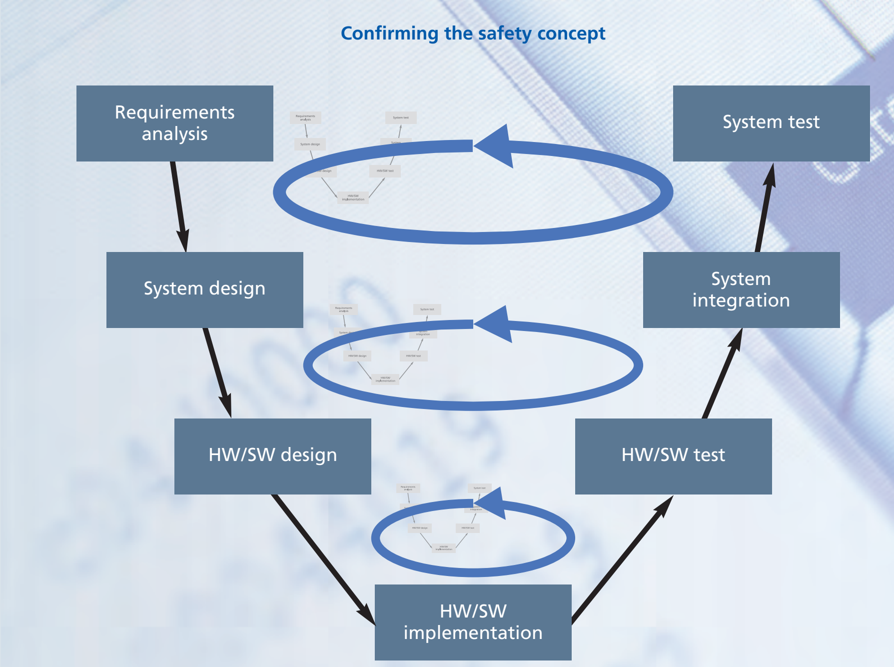


Figure 1:
With bypass hook tools, such as ETAS EHOOKS, errors can be deliberately introduced to test a system's robustness.

Figure 2 (diagram):
The safety concept must be examined throughout the entire development cycle – testing alone is not enough.

Rigorous development process for functional, safe ECUs

When distributed developer teams from several companies work on the same control unit, then functional safety also becomes a question of organization. This requires merging methodological know-how, proven development tools, and technical expertise into one rigorous process.

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More and more functions in cars are being executed by software in electronic control units (ECUs). Software functions that are connected across ECUs are on the rise, too. Some high-end models feature more than one hundred ECUs that are connected over data buses and communicate with sensors distributed throughout the vehicle. Connectivity between cars and their surroundings is also rapidly expanding, meaning that cars are becoming network nodes in the complex, connected world of mobility.

Although this connectivity promises safer, more efficient driving, it is not without risks. This is partly due to an increasingly complex development process for connected ECUs, often involving internationally distributed teams. Not only are an ECU manufacturer's developers and calibration engineers involved in developing ECU software and pre-calibration, but so are its suppliers and the automaker's developers. Different teams working on engine ECUs deal with fuel injection, air supply, ignition, and many other parameters. Furthermore, the entire process could take place several times, because OEMs often order identical ECUs from several suppliers to assure delivery, although of course car buyers must not notice any difference. Independent of their source, these ECUs and their software must function reliably, functional safety must be guaranteed.

Safety in the collaborative development process

How can functional safety be ensured under these conditions, especially when specific software functions are distributed over multiple ECUs and only a portion of the software is to be replaced? One key to success is to use innovative methods and tools, such as virtualization, which make it possible to validate software in realistic plant, environment, and driver models at an early stage of development. A tool such as ETAS' ISOLAR-EVE software, combined with PC simulation, allows developers to start testing like this long before an ECU prototype exists. Errors or faulty assumptions are discovered before any damage occurs. Developers can also sound out borderline areas in a virtual environment without any danger, which is particularly helpful when it comes to designing safety-critical assistance systems.

But virtualization is just one building block in a more complete, total architecture. The entire development process must be structured in advance (Figure 2) and include clearly defined software architecture and how each team will contribute. Furthermore, close process monitoring is crucial. Regular assessments and audits should be performed to confirm that teams have internalized the agreed upon safety philosophy, and that all participants share the same interpretation. Standards such as ISO 26262 provide the basis for this.

Established rules for software and development processes

The first step in preparing software development is to define the scope of the item under development. A top-down approach begins by considering the overall system and context and setting the limits for the functional scope of the interfaces and of interactions with other systems. Once this has been done, a structured hazard and risk analysis is conducted in which the likelihood and controllability of possible errors are weighted equally against the threatened extent of damage. The aim of the analysis is to define binding safety objectives. From this point on, these objectives are the guiding principle for development – and must first be broken down into specific work packages for the work groups.

Programming must be supported by clear rules and tried-and-tested methods, such as a focus on best practice, compliance with style guides, structured documentation, as well as dedicated regular reviews and code analyses. A testing plan is necessary as well. When and how will the software be tested, and in which contexts? Fault injection tests, which check the software's response against deliberately introduced errors, are indispensable. To conduct these, developers feed in faulty data using a bypass hook tool such as ETAS' EHOOKS. In contrast to earlier tests with ISOLAR-EVE, this is performed on real hardware (Figure 1). Using EHOOKS, test engineers can manipulate ECUs by replacing their internal signals with the planted errors or faulty data, with the ECU's calibration and diagnostic interface functioning as an access point. The faulty data is then generated with the ETAS INCA measurement, calibration, and diagnostics software.

Safely limit functions with AUTOSAR

It is by provoking these exceptional circumstances that developers can tell whether safety objectives and concepts really hold up. Robust software must recognize faults and either keep the ECU operational or bring it into a safe state. Precautions can also be taken to ensure that errors don't spread. This is where the AUTOSAR standard with memory protection helps: Developers can use hardware support to prevent software from accessing the memory of other software features. This ensures that errors remain locally contained and cannot compromise any safety-relevant software applications.

However, to integrate the AUTOSAR memory protection or timing protection mechanisms, all project participants must make their software components' source or object code public. Since this degree of transparency is often lacking or not desired, ETAS developed the RTA-HVR Hypervisor. This partitions the ECU into several strictly divided virtual ECUs and thus completely shields safety-relevant functions from each other. Communication between the partitions works in the same way as between various ECUs using defined interfaces and predetermined rules.

Technical and organizational partitioning

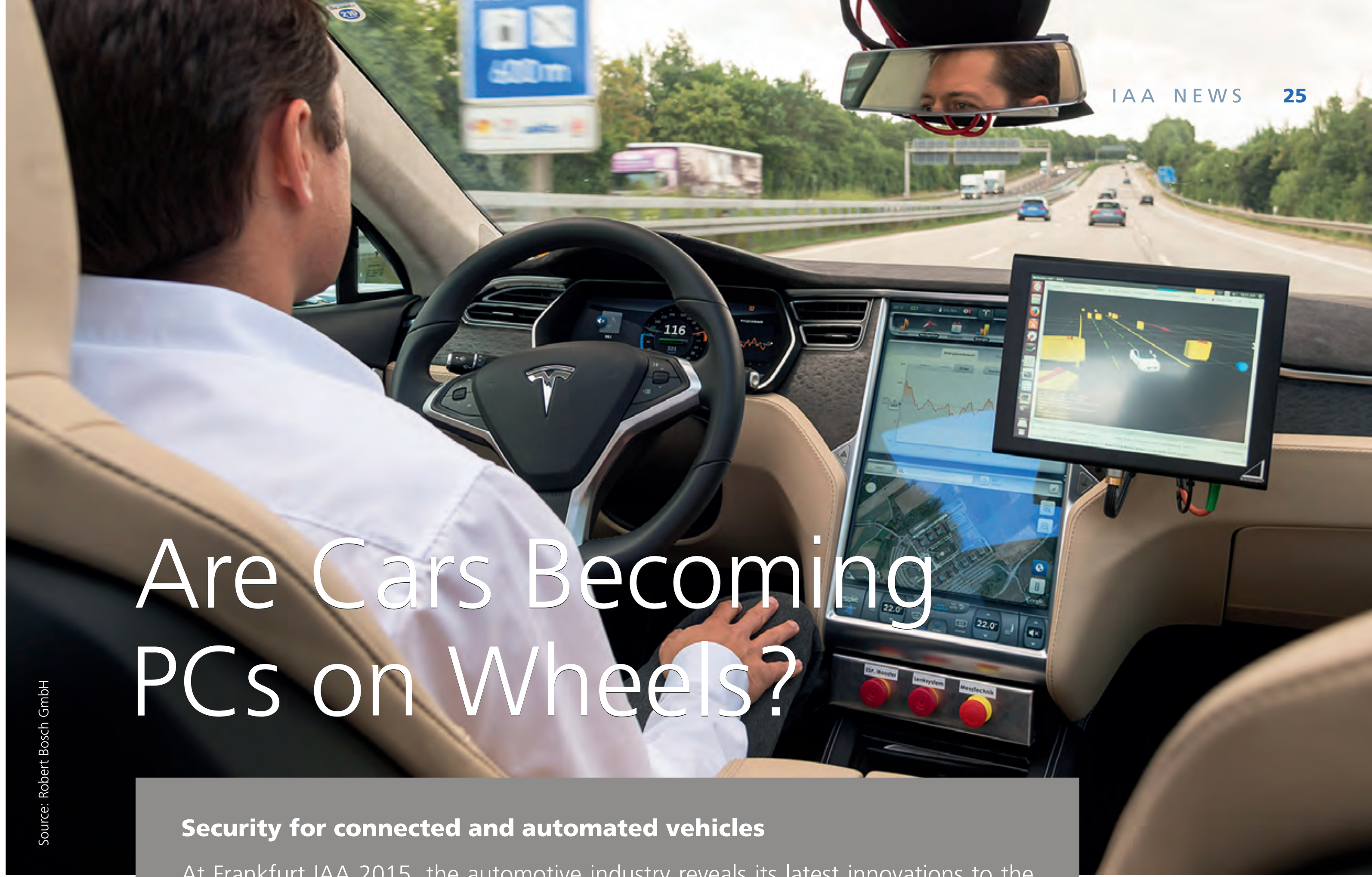
Partitioning offers another significant advantage: Teams from different companies can develop software independently from each other that will run within their own isolated, shielded partitions later. This means reciprocal access to the code is not necessary in the early stages of software development. Even so, parallel development requires the ECU manufacturer to coordinate and guide the process. Out of self-interest, all participants must commit to the same safety objectives and a binding schedule. This outlines when development partners must provide proof of functional safety, and in what form. The ECU manufacturer remains responsible for integration – merging the tested software components and their documentation from its suppliers and furnishing complete proof of the ECU's safety.

Prudent project management

Constantly validating, justifying, and – where necessary – readjusting assumptions are part and parcel of project management. Partners also need to be kept up to date. But the effort pays off: in instances in which a collective safety philosophy guides development, testing effort is decreased and expensive, nerve-racking corrections are eliminated in the final development stage. Less strict project management is often plagued by problems. Audits and assessments often bring to light different interpretations of safety objectives, presuppositions, and norms; without targeted countermeasures, these could soon give rise to expensive error chains. That is precisely why these checks are firmly anchored in the ISO 26262 safety standard.

Summary

It is possible to ensure the functional safety of ECU software, even in complex collaborative development processes. This requires more than just expertise in ECU development, however. It has far more to do with thoroughly embedding standardized development and modern methods, such as validation in a virtual environment, into a carefully controlled development process. With tools, services, and consulting, ETAS offers the right solution for every project phase.



Source: Robert Bosch GmbH

Are Cars Becoming PCs on Wheels?

Security for connected and automated vehicles

At Frankfurt IAA 2015, the automotive industry reveals its latest innovations to the general public for the 66th time. The trend towards more electronics in vehicles continues unabated, but who will manage the extra complexity? And what about security? At this year's exhibition, the experts at ESCRYPT discussed these topics with customers.

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Semiautomated vehicles, connectivity, and new powertrain systems were among the key topics at IAA 2015. These trends provide a number of benefits to road users. Our automobiles are becoming safer, cleaner, and more economical while offering a host of new features. It will soon be possible, for instance, to download and install the latest vehicle system service updates over-the-air via the internet. So are our cars becoming PCs on wheels? Absolutely not! But we will be seeing a lot more information technology in our cars and along with this trend there is much to consider, particularly when talking about information systems security. With automotive information systems, the requirements are far more extensive than those considered sufficient for other IT applications. The braking systems, lane assistants, and distance warning systems in our vehicles are just a few examples. They must always work properly in all situations, even if a sensor fails, a cable snaps, or when the latest in a long line of updates is installed.

But what is needed to achieve this? Our experts discussed these issues with customers at the Bosch booth during the IAA exhibition. They all agreed that there is no single measure which by itself is sufficient – a holistic solution is needed. Intelligent tools, a well-designed E/E architecture, secure basic software, seamless processes, and of course technical expertise are all required to ensure that our cars are truly safe and secure.

ETAS and ESCRYPT have a lot to contribute in these discussions. Our expert consulting services, early development phase virtualization tools, and secure software development are playing an ever greater role. When it comes to protecting against unauthorized access to automotive computer systems, ESCRYPT offers solutions to provide multiple levels of security for vehicle electronic systems.

Personally, I believe in our abilities and I prove it every day when I get in my car, trusting my life to the skills and expertise of my colleagues and customers.

Protection against Unauthorized Access

Intelligent interaction between software and hardware safeguards ECUs
Connected vehicle systems require protection against unauthorized access. Hardware Security Modules (HSMs) provide this, but have always been unsuitable for automotive applications. This is no longer the case, thanks to Bosch's HSM and its derivatives implemented by various semiconductor manufacturers. Timed to coincide with the growing popularity of these products, ESCRYPT has brought out CycurHSM – a matching firmware solution that makes an HSM a viable security solution for automotive ECUs.

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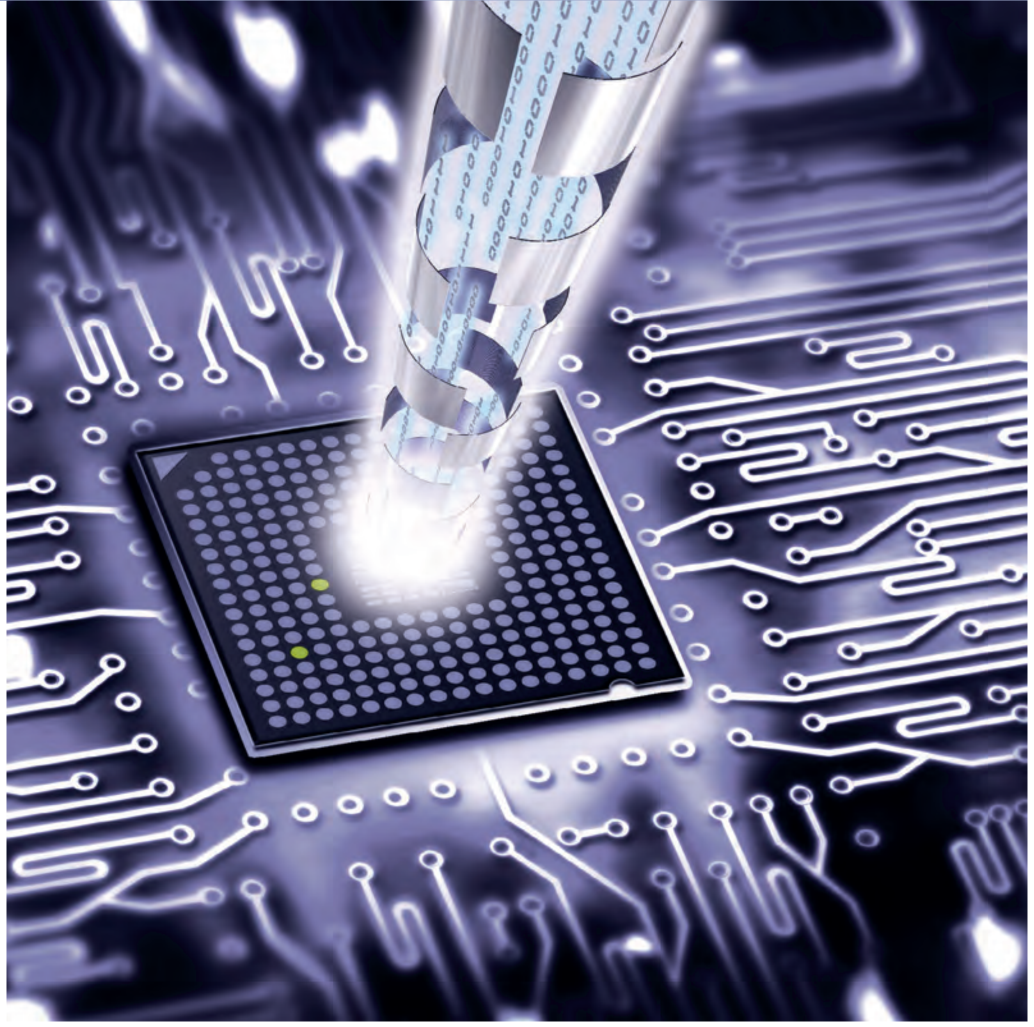


A side window has been smashed; the airbags and satnav are gone. Extremely annoying, yes – but at least the damage is obvious. Not so when the vehicle's IT systems have been tampered with. Unauthorized interventions of this kind pose an invisible threat, and the potential risks are growing as vehicles and ECUs become increasingly connected.

What is needed are strategies to defend against hackers and their potential attacks, virus contamination, and unauthorized uploads. Bosch recognized this several years ago, and identified Hardware Security Modules (HSMs) as a suitable protective technology. HSMs have their own processor core, their own RAM, ROM, and flash memory, and come with specific security features. However, the HSMs available at the time were too expensive, too sensitive, and too limited in terms of their functionality. This led Bosch to develop specifications for an automotive-compatible HSM and shared these with semiconductor manufacturers in a bid to speed up market penetration. A strategy that is paying off, as various manufacturers have now implemented derivatives of the Bosch HSM and are pushing these onto the market.

Standardized software stack for Bosch HSM and its derivatives

In July 2015, ESCRYPT released a compatible firmware solution: CycurHSM. By interacting intelligently with the hardware, CycurHSM protects vehicle systems against unauthorized access during all operating phases including initial boot, normal operation, and software updates or upgrades.

Hardware and software work hand in hand to offer this comprehensive protection. Each Bosch HSM contains a processor, sufficient memory, and a true random number generator (TRNG). In addition, it has accelerator hardware that enables it to calculate cryptographic message authentication codes in accordance with the Advanced Encryption Standard (AES) at lightning speed. It was on the basis of this hardware that ESCRYPT was able to realize functions such as secure boot, runtime tuning detection, and secure flashing in its CycurHSM. The software also relies on ETAS' RTA-OS, which was developed as a real-time operating system for automotive applications.

Maximum flexibility when choosing hardware

ESCRPYT began to brainstorm CycurHSM in mid-2013, and the vision was to develop a standardized software stack for the Bosch HSM and all its derivatives. This objective has been achieved. By standardizing processes at software level, customers can opt for whichever controller they like, regardless of their hardware setup.
In accordance with the open philosophy behind CycurHSM, the software's CSAI interface (Client Server Architecture Interface) makes it compatible not only with AUTOSAR, but also with all other applications beyond this standard.

Comprehensive protection

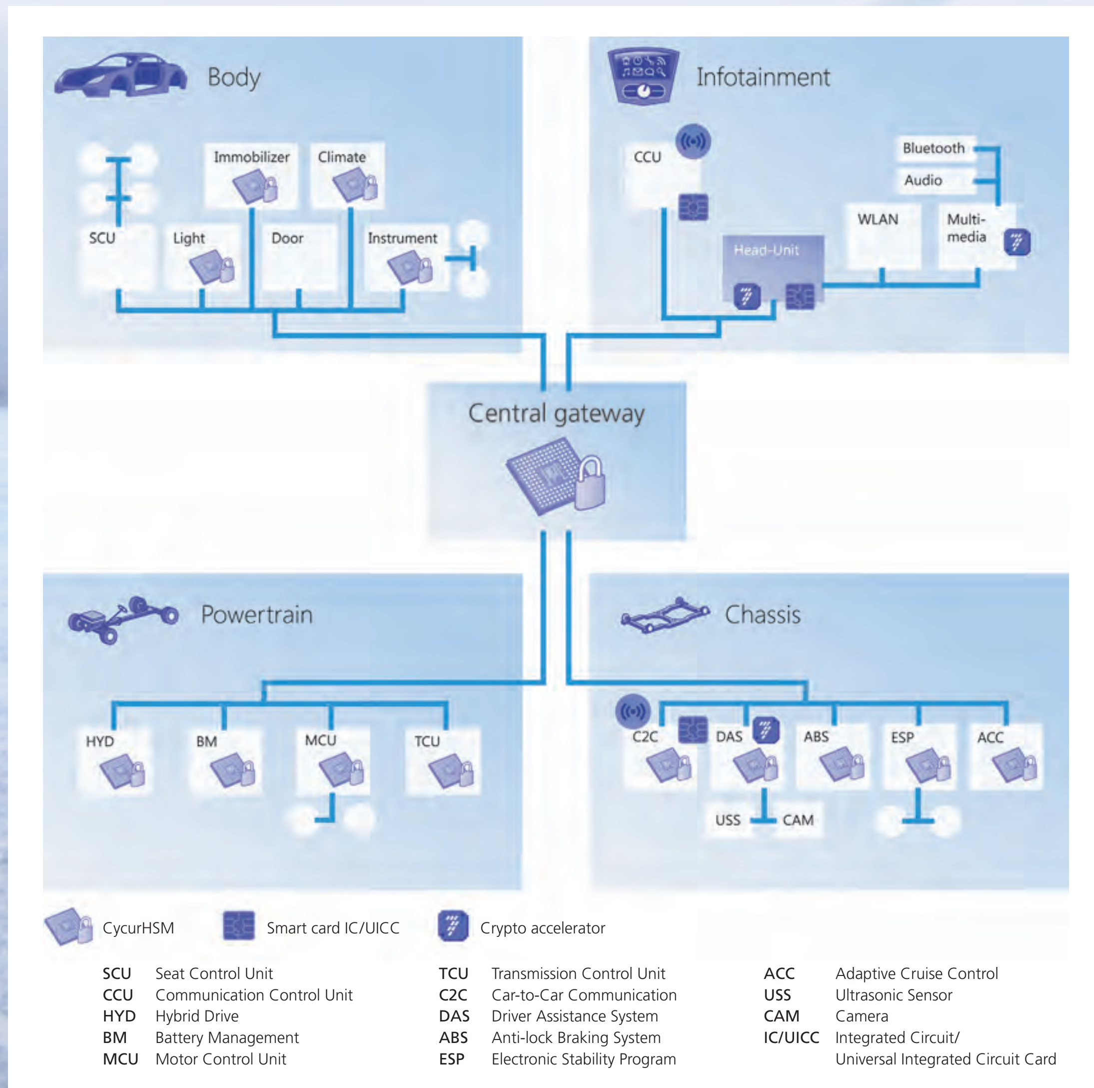
CycurHSM is embedded in ESCRYPT's modular product portfolio, as is the firmware's secure flashing function, which verifies sender authenticity for updates and upgrades. The secret keys required for this process are generated in the backend of the vehicle manufacturer or specialized service provider, and are shared only with trustworthy partners. As well as providing key management services and processing of this kind in high-security data centers, ESCRYPT also issues licenses for software that can generate such cryptographic keys. Gatekeeper functions such as secure flashing are prerequisites for vehicles using Car-to-X communication and over-the-air updates. If the source attempting to connect with the vehicle is unable to provide the required digital signatures, the HSM prohibits the data transfer. Encryption technology also lies at the heart of the CycurHSM secure boot function, which uses secret keys during the booting process to unequivocally determine whether ECU software is still authentic.
The process is sequential: As the system powers up, each component launched as part of the ECU boot chain verifies the integrity of the next. This ensures that malware is detected, at the very latest, the next time the system starts up – even if the entry route was via a trustworthy source such as through a diagnostic device in the workshop. Since the HSM records every single change, manipulation can still be detected even when the ECU software has been restored to its original state. In this way, CycurHSM brings the almost incidental added bonus of creating legal certainty within the notoriously gray area of chip tuning.
During operation, the CycurHSM's runtime tuning detection performs cyclical checks to establish the con-

tinued authenticity of ECU data. Accelerator hardware makes this testing, which is based on symmetric AES signatures, a very efficient process.
With its secure on-board communication function, CycurHSM provides a fourth method of protecting data passing from ECU to ECU in the vehicle. It protects the data traffic running through the vehicle bus against threats attempting to gain entry through gateways such as wireless interfaces. For this, the CycurHSM issues data on its way from ECU to ECU with AES-based message authentication codes, generating and verifying these codes so the relevant ECUs don't have to. It handles all cryptographic calculations and keeps the keys secure, thereby acting as an integrated security service provider for the ECUs.

Outlook

ESCRYPT is convinced that HSM technology will evolve over the next ten years to become a standard feature of new vehicles. The standardized CycurHSM software represents an important building block that will help this technology to break through. In conjunction with the HSM hardware, it protects safety-related IT systems in the vehicle against unauthorized access. Considering the pace at which connected technologies are advancing, CycurHSM can certainly be considered a future-ready solution.

Vehicle board network in 202x.



Happy Hacking!

First ETAS hackathon took place at headquarters

According to Wikipedia "A hackathon (also known as a hack day, hackfest, or codefest) is an event in which computer programmers and others involved in software and hardware development … collaborate intensively on software projects." It goes on to explain that "some hackathons are intended simply for educational or social purposes, although in many cases the goal is to create usable software."

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Such an event took place recently, when the software development department at ETAS hosted the first hackathon at its headquarters in Stuttgart-Feuerbach. Associates desired an opportunity for creativity beyond the daily grind and to think outside the box. This desire is something ETAS management took seriously. So topics were gathered and discussed, and teams formed in preparation for the one-day hackathon, which was attended by 25 colleagues.
"I'm enthusiastic about the variety of topics and the quality of the achievements," said Dr. Alexander Burst, head of software development at ETAS. "Moreover, I'm impressed by how well the teams organized themselves and joined forces with other groups. The hackathon was planned as an experiment – and it's certainly one that we'll be carrying forward, after all the positive feedback we've received from colleagues," Dr. Burst continued.

The winning team – as nominated by the other participants – extended ETAS ASCET, the leading product for model-based development of embedded software for electronic control units in the automotive area, so it can work with two new platforms, Arduino and Lego Mindstorms, both of them particularly popular at universities and amongst nerds and inventors. The team demonstrated its results by bringing two model cars to life using simple autonomous driving functions.
"Based on our demonstrator, we're now able to put together an out-of-the-box-solution that will give young engineers an understanding of ASCET and the ETAS brand. This is going to pay dividends in the long run," said the initiators of the project, Abhik Dey and Timon Reich. And this isn't the only topic they'll be working on in the near future. On this note: Happy hacking!


The winning team: Holger Ruf, Frank Beckmann, Patrick Engel, Abhik Dey, and Timon Reich.

AUTOSAR Goes Off-road

Automotive standard expanding to include agricultural and construction vehicles

A decade after its introduction, the AUTOSAR standard is finding its way into agricultural and construction vehicles. For cost and quality reasons, this makes sense – but equipment manufacturers should plan carefully.

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AUTOSAR is writing history. Only twelve years after it was introduced, AUTOSAR (Automotive Open System Architecture)[1] has become one of the most influential standards in the automotive industry. And with good reason: AUTOSAR-compliant software functions are interchangeable, independent of software and hardware providers, and reusable. Now, the most recent release has hit the unpaved road and has off-highway vehicles in its sights. While the first agricultural and construction vehicle OEMs are already using the standard, others are deliberating about what advantages AUTOSAR might bring them.

A successful standard

Nearly 180 companies worldwide have joined the AUTOSAR development partnership to further refine and use the standard for software architecture, application interfaces, and methodologies for configuring and generating ECU software. At the core is the AUTOSAR layer model (diagram), which makes it possible to implement software components from various providers spanning many product generations, independent of the underlying hardware.

Key challenges for agricultural and construction vehicles

A number of factors need to be considered before AUTOSAR can be used in the off-highway vehicle sector. In principle, ECUs for cars, agricultural equipment, and construction vehicles are similar, since they use the same microcontroller families. But there are some differences, too:

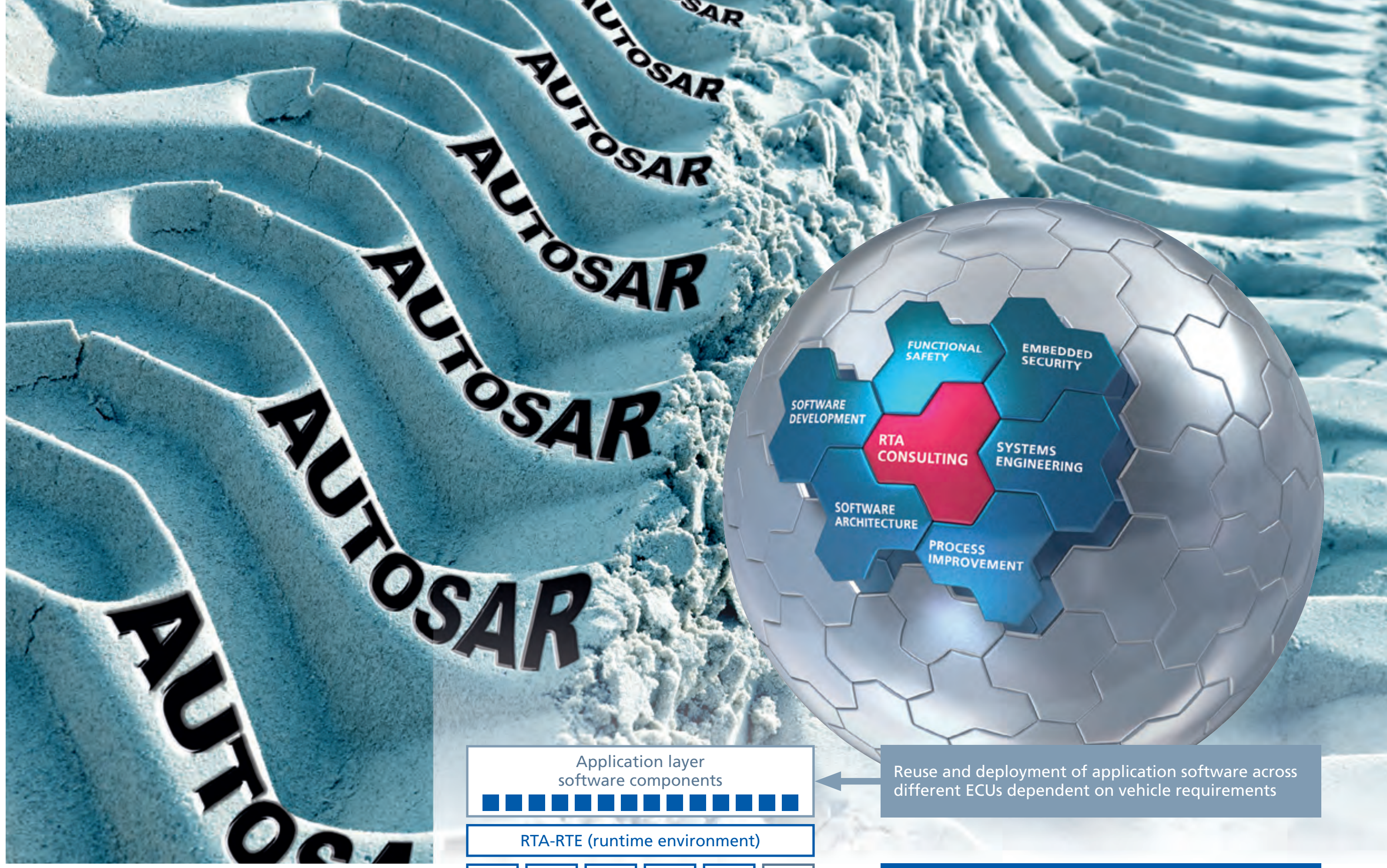
- Due to the lower number of units produced, the development costs per ECU are higher in the off-highway vehicle sector; this is often compensated for by the reuse of hardware and software designs based on "generic" ECUs.
- Vehicle manufacturers primarily develop software in-house. Only the board support packages come from Tier 1 suppliers.
- The wide range of implements that can be attached to these vehicles makes them even more varied – and increases the number of different variants of software functions. So a flexible software architecture and system configuration is required.
- Solutions must adhere to industry-specific standards such as J1939, ISOBUS, Profibus, and CANOpen communication protocols, as well as ISO 25119 "Functional Safety for Tractors and Machinery for Agriculture and Forestry[2]".

Although there are differences, automakers and agricultural and construction vehicle manufacturers do share one key requirement: in the interest of quality and efficiency, they all want to reuse as many software components as possible. AUTOSAR software architecture offers the perfect framework for this because it fulfills both application-specific tasks. For example control of individual devices, and system services such as network management. This allows OEMs to concentrate on the development of system and software functions that add value for end customers while sourcing and implementing commercially available standard software.

Requirements for functional safety

This modularity presents risks to functional safety. Faults in sourced modules could disrupt safety-related functions; this is something that must be ruled out before software modules from different sources are integrated. This is where ISO standard 25119 is helpful. It defines a set of measures that ensure faults remain isolated locally, for instance through software partitioning. Meanwhile multi-core systems, scheduling, and watchdog mechanisms safeguard communication between ECUs and software components.

AUTOSAR supports the ISO 25119 measures through its own software partitioning mechanism. Its use is particularly recommended for universal ECUs, which as a rule have been developed by a variety of partners and must fulfill the highest safety requirements. The standard provides the guiding principle, encourages an orientation on best practice during software development, and helps to detect faults at the hardware level.



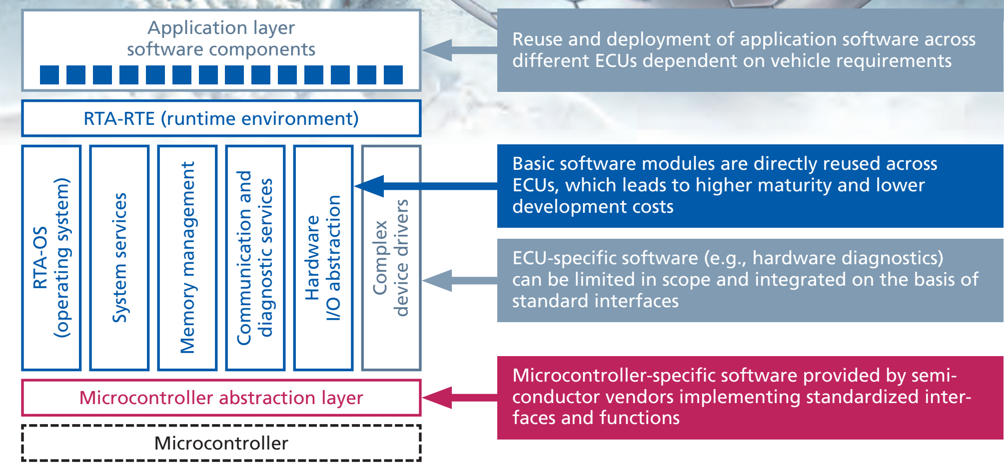


Diagram:
Layer model of AUTOSAR's software architecture.

Tools and processes as success factors

To make a success of applying AUTOSAR's safety measures, a well-thought-out development process is recommended that also considers available resources and budgets. In instances where these are limited and experience is lacking, expert advice is needed. The ETAS RTA (Real Time Architect) Solutions[3] business area for developing customer-specific embedded software has experience in numerous off-highway and heavy-duty projects and offers comprehensive support for the migration to AUTOSAR.

Agricultural and construction vehicle manufacturers' plans to make use of standardized AUTOSAR software components and a corresponding development environment are justified on cost and quality grounds. Another reason is the COMASSO association[4], which has several commercial vehicle OEMs – including Caterpillar, CNH Industrial, MAN, and Bosch Rexroth – as members, with high-quality series products as well as license-free reference implementations of many standard AUTOSAR components. This initiative is of increasing interest in the off-highway vehicle segment.

Conclusion

AUTOSAR offers manufacturers of agricultural and construction vehicles great potential to flexibly develop high-quality embedded software. They can achieve tangible cost savings by reusing and acquiring mature software components. However, it is important to plan aspects of functional safety and organize the process chain in detail. ETAS can offer support for this in various ways.

Sources:
1) www.autosar.org
2) ISO 25119, Functional Safety for Tractors and Machinery for Agriculture and Forestry – Safety-related parts of control systems, First edition 2010-06-01
3) www.etas.com/en/products/solutions_real_time_applications.php
4) www.comasso.org

LABCAR on Track

To reduce the risk of cost overruns and potential adjustments, early validation during the simulation process is a must. It is also important to have the right tool to perform this validation. With the increasing number of control units in train subsystems, Alstom Transport began looking for several tools able to validate the subsystem before its first integration in the train takes place. Alstom Transport selected ETAS LABCAR Hardware-in-the-Loop system to validate an auxiliary train subsystem, knowing ETAS is a global leader in providing tools and solutions for the development of embedded software in the automotive industry.

Train Subsystem Control Unit

The control unit is seen as a modular electronic control unit (ECU) able to control several different devices (such as genset, powertrain, and air conditioning). This means a dedicated HiL is mandatory for validating device behavior in advance and for checking communication networks – currently SAE J1939 as well as Common Industrial Protocol (CIP) and Multifunction Vehicle Bus (MVB).

Project challenges

Alstom is developing the application software for the TSSCU ECU. The first challenge was to create a tool for carrying out Model-in-the-Loop (MiL) tests. This was possible by integrating a model of the ECU software and a Dymola plant model using the experiment environment ETAS LABCAR-OPERATOR and the RTPC (Real-Time PC) real-time simulation target from ETAS. Alstom's second challenge was then to perform Hardware-in-the-Loop (HiL) testing on the complete LABCAR bench with the real TSSCU hardware as a unit under test.

An extremely stable and reliable VME architecture with high-end I/O boards has been designed for this purpose. ETAS has developed a specific and flexible load box concept for the project, including a wiring harness. The final setup was performed together with the

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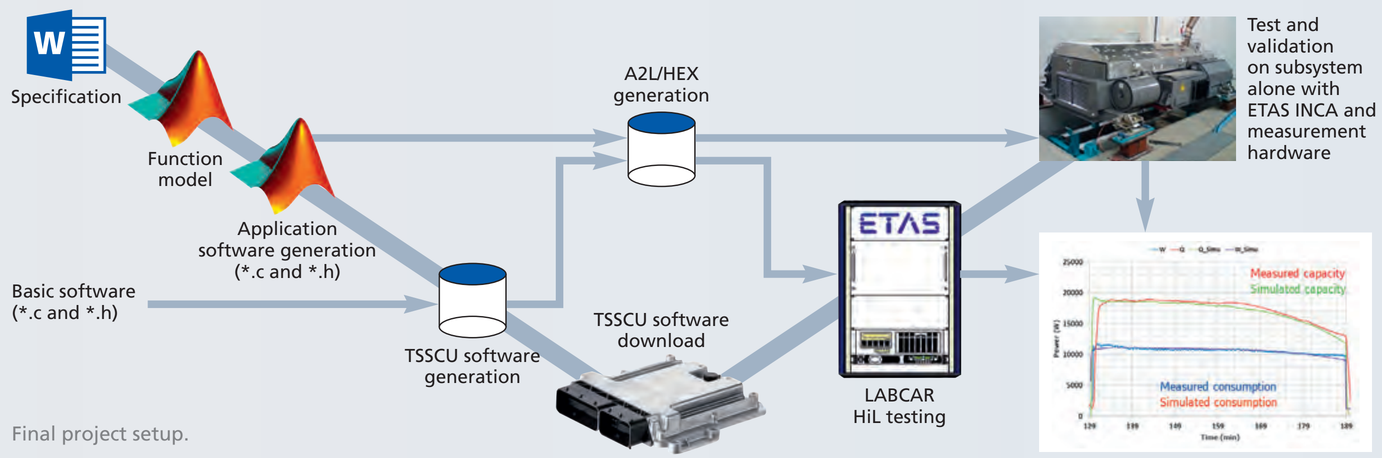
ETAS Hardware-in-the-Loop system validates train subsystem

In the railway industry, simulation is the key to developing and validating new products because the possibility to validate a train subsystem exists only during the period when the first production train is being built. Indeed, although all hardware components can be validated on the supplier bench, the validation of the subsystem control can only be performed on the train. Once the first train has been completed, any modifications or additional sensors or actuators may have a negative impact on the time to market and may result in a significant retrofit.



Final project setup.

In addition to LABCAR, Alstom Transport required a robust measurement tool chain. Parts of data acquisition and calibration are now performed using INCA and measurement hardware such as ES592, ES720, ES411 from ETAS.

About Alstom Transport

Alstom Transport develops and markets a complete range of rolling stock (train) systems, signaling systems, and services for the railway industry. Notable products include series production of the TGV (high-speed trains), with over 650 train sets sold in the last 25 years, as well as the AGV (Automotrice à grande vitesse), unveiled in February 2008 and in service with NTV in Italy since 2012. Alstom products also include trams (1,900 Citadis low-floor trams in more than 50 cities around the world), metro and regional trains (1,200 Coradia commuter trains operating in nine countries), and suburban trains (4,600 X'Trapolis single deck electric trains operating in countries such as Australia, Spain, and South Africa).

customer at the customer's site in coaching mode. Thanks to the support offered by ETAS France, Alstom has now received the necessary know-how to manage and maintain both the current and further configurations on its own.

Summary

- Tests were performed to compare HiL test system results against the real subsystem results. These indicated that Alstom Transport has reached its target since simulations predicted the real behavior of the subsystem.
- Thanks to active coaching of Alstom Transport associates during the project development phase, users can now handle the system on their own. The next HiL upgrade has been fully managed by Alstom with minimum interaction with ETAS help desk support.
- During the specification phase and HiL setup, ETAS and Alstom collaborated to create a modular and scalable architecture.
- Alstom's investment in ETAS technology is guaranteed for future ECU generations, such as Multifunction Vehicle Bus (MVB) and Common Industrial Protocol (CIP) due to ETAS' openness to third-party hardware and protocols.

ABS on the Rails

Knorr-Bremse relies on ETAS ASCET

High-speed trains are an essential part of efficient transport infrastructure in any modern industrialized country. But the trains' travel speeds – of up to 250 km/h and more – place enormous demands on brake system mechanical components and control electronics. For the last 15 years, ETAS tools have helped Knorr-Bremse AG to develop the software for managing and controlling these crucial safety-related systems.

Wheel-rail system:
The brake system's anti-skid/anti-slip protection prevents braking-induced flat spots.

For high-speed trains, the brake concept is a key element of the safety plan. It encompasses brake force management, comprising the optimum distribution of the brake force over the various brake systems throughout the entire train, specific actuation of the friction brakes, anti-skid/anti-slip protection, and rolling monitoring, as well as the recovery of electrical energy during braking.

The current generation of ICE trains has three complementary braking systems. Actuation of just the disk brakes suffices at lower speeds; at higher speeds the electrodynamic brakes also engage. These in turn are backed up by the eddy current brakes when traveling certain stretches. One thing is clear: no intelligent braking concept can be implemented without electronics.

Electronics instead of mechanical components

Rail vehicle brakes were constructed and actuated almost exclusively on a mechanical and pneumatic basis well into the 1970s. The impetus to introduce electronically controlled antilock braking systems (ABS) stemmed from the desire to reliably prevent annoying and dangerous vibrations or operational instability caused by braking-induced flat spots on the wheelsets. Today's anti-skid/anti-slip protection, comparable with automotive ABS, also controls axle slippage in order to optimize the stiction between wheels and rails when braking and consequently reduce the braking distance.

ASCET software – safe, proven, and automatically generated

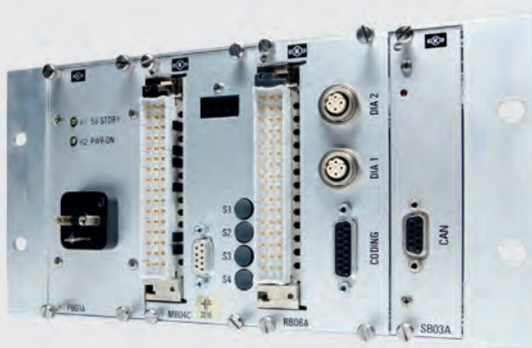
To develop open-loop and closed-loop algorithms requires reliable and professional tools. Engineers at Knorr-Bremse have relied on ASCET for model-based software development since 1999.

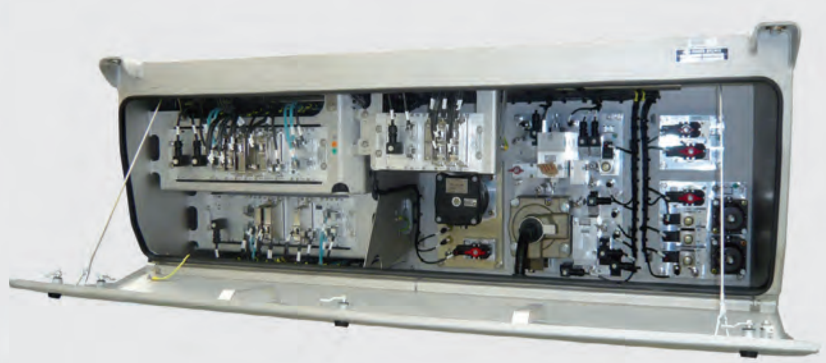
Previously, the engineers had to laboriously specify the system functions, which were then programmed in the computer language C by software developers. Back then, block diagrams of open-loop/closed-loop control systems were drafted on the computer with the help of MicroGrafX Designer, the first graphics program available for Windows PCs. When ASCET was introduced, its key advantage was how production-ready C code could be automatically generated from block diagrams

Knorr-Bremse

is the world's leading manufacturer of braking systems for rail and commercial vehicles. Founded in Berlin in 1905, the company is now incorporated as an AG (Aktiengesellschaft; publicly traded corporation) and headquartered in Munich, Germany. The first important milestones in the company's history were the K1 pneumatic brake for passenger trains, and more importantly the Kunze-Knorr compressed-air brake – introduced in 1918 for freight trains – which made it possible to increase the top speed for freight from 30 km/h to 65 km/h.

In 1972 Knorr-Bremse caused a sensation with the first ABS for commercial vehicles. Twenty years later the Munich-based company presented the first pneumatically operated disk brake for commercial vehicles. Today, in addition to braking systems, the corporation – with more than 20,000 associates – offers a variety of other technical systems for rail vehicles: from air conditioning and door systems to torsional vibration dampers for diesel engines.





The flagship of Deutsche Bahn – ICE 3.

Left:
Electronic brake control system (ESRA).

Right:
Brake module containing the control system.

that had been created in ASCET. In fact, using certified versions of the tool meant it was no longer even necessary to check the generated C code. But that's not all: ASCET fulfills DIN EN 50128 requirements and is therefore suitable for use in developing safety-critical SIL2 applications.

Given that braking systems are designed for a service life of between 30 and 40 years, are regularly overhauled, and are continually improved while still in operation, what truly matters to Knorr-Bremse – in addition to ASCET's special product features – is the fact that ETAS performs long-term maintenance support on this development tool.

Complex systems

Current brake control devices feature an extremely complex design. They have 19" ESRA plug-in boards with a CAN bus interface. The backplanes of the control unit hardware are a proprietary development by Knorr and have been specifically adapted to CAN.

A Freescale PowerPC MPC5554 microcontroller, with a 132 MHz clock rate and a PC104 interface, serves as a CPU. In operational deployment, a system consists of one or more mainboards plus additional boards with I/O expansion modules and bus coupler boards.

Application software with high safety margins

The development and specification of the modules, tasks, and processes of the current application software for the control units is carried out exclusively with ASCET. It is easy to integrate and call up any existing manually coded standard functions. The software architecture is supported by templates. These establish both the definition of the input and output signals of individual functions as well as their treatment for further processing. When creating variants, individual open-loop and closed-loop functions can be configured out of the ASCET model during code generation.

Part of an elaborate safety concept

After the calibration parameter values have been determined through comprehensive simulations and tests, the software is then "hardwired". Furthermore, the control unit is exactly monitored during runtime: the relative amount of diagnostic and safety functions in the various systems lies between 50 and 80 percent.

At the moment, Knorr-Bremse engineers are working with ASCET version 6.2. For software configuration management they use ASCET-SCM together with the JIRA tool, which tracks errors and requirements.

European urban centers are growing closer together – thanks to ASCET: Paris, Brussels, and Amsterdam are connected at speeds of up to 320 km/h by ICE 3, the flagship of Deutsche Bahn (Germany's national railway). Based on Siemens' "Velaro D" platform, ICE 3 employs state-of-the-art Knorr eddy current brakes, the software for which was developed with ASCET.

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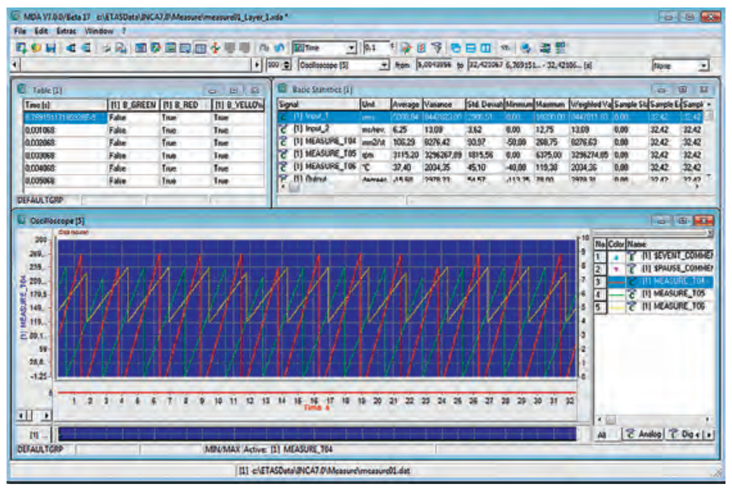
Extended Functions

AUTOSAR authoring users can enjoy the substantial improvements offered by the new **ISOLAR-A basic package**.
It comes with new editors, importers (DBC, FIBEX, LDF, and ODX), automatic features, validations, and exporters (system-based, ECU Extract, RTE Configurations). The BCT add-on helps users configure the basic AUTOSAR software with importers (e.g., ECU Extract), editors, and validations, as well as with C code generation for COMASSO* basic software modules. Both packages support single and multi-core electronic control units and can also be operated using command lines.

*) COMASSO e. V. is a registered association that supports the common implementation and use of the AUTOSAR standard (http://www.comasso.org)

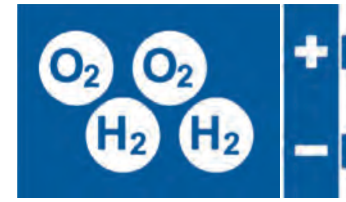


Comprehensive Analysis

With **MDA 8**, the new **software for analyzing measurement data**, users can efficiently analyze measurements with extremely high data volumes. A preliminary version of MDA 8 (MDA 8 preview) has been available since September 2015. It exhibits the tool's high processing speeds and makes it possible to test the new operating concepts that ETAS has developed together with users. MDA 8 preview can be installed in parallel to MDA V7.x and used for free. Further use cases will be supported as part of the planned quarterly service packs. In particular, Service Pack 1 (December 2015) will include conversion of MDF4 measurement files into MDF3.

Powerful Addition

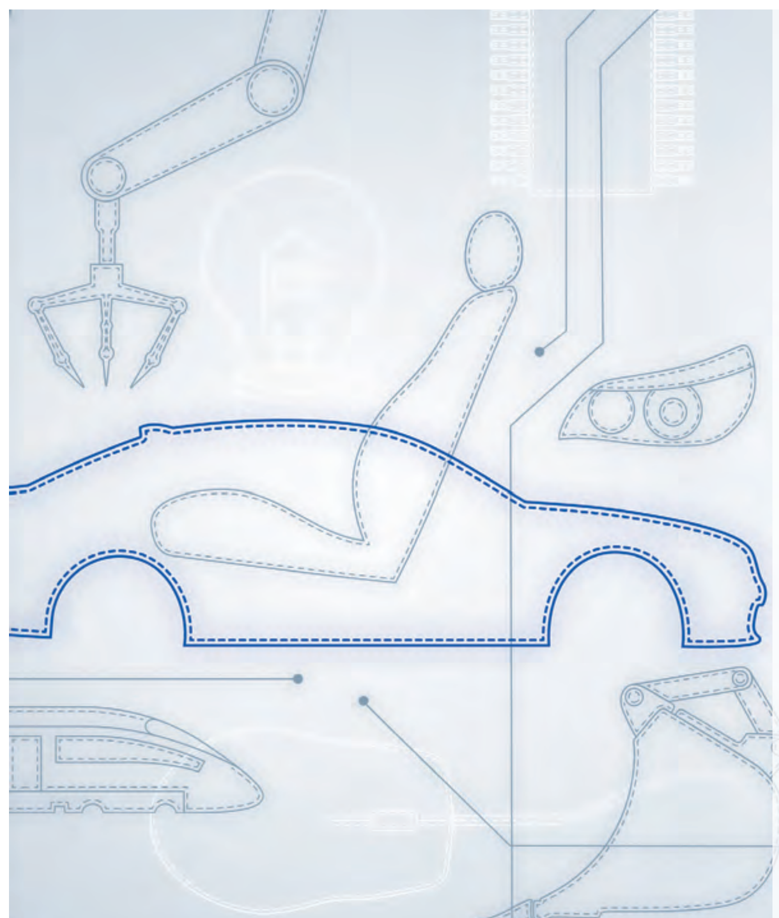
Powerful new features have been added to the flexible and open ETAS LABCAR test system: the **ES5321 PWM I/O Board** and the **ES5338 Wheel Speed Sensor Simulation Board** are scheduled for market launch in December 2015. These fast PCI Express-based boards are characterized by high accuracy and signal quality.
They can be used in the chassis, powertrain, body electronics, and electrical drives (ES5321) domains.



New Simulation Model

The **Polymer Electrolyte Membrane Fuel Cell (PEM-FC) model** for the ETAS LABCAR test system simulates a complete fuel cell system for automotive applications. From the transport of water/nitrogen through the membrane to the influence of low ambient temperatures, this model takes relevant physical phenomena into account and makes it possible to test numerous ECU tasks such as flushing the anode coils, water management of the fuel cell stack, or cold-starting the system. Thanks to the model's modular design, customer-specific adaptations are easily implemented. Its high accuracy makes the validated model ideally suited for end-to-end use – from function development to precalibration on HiL systems.

Available Modules



The **GM Standardized Utility Modules (GM SUM)** are part of the GM Global-B software platform. They are based on the AUTOSAR architecture and allow the complete separation of the software functions from the software infrastructure.
The GM SUM will be deployed in all ECUs within the GM Global-B platform. The ETAS modules were developed in accordance with the ISO 26262 and MISRA-C standards. Because ETAS works proactively with GM on refining the specifications of the modules, it ensures the conformity of all updates with GM.
Backed by ten years of experience with AUTOSAR, ETAS offers all ten GM SUM as part of an integrated basic software and tools portfolio and supports GM suppliers during on-site integration and testing.

INCA for Off-Highway

New features have been integrated for deploying INCA in chassis, body control, and off-highway applications: a polling mode for **measurement data acquisition** plus the **monitoring** of SAE J1939 messages on the CAN bus.
The new polling mode enables the use of INCA for measurements on ECUs that do not provide sampling mechanisms for data acquisition, such as the DAQ lists of the XCP protocols. In this case, the new INCA polling engine cyclically polls for the transmission of measurement data to the ECU in the CCP and XCP formats.
The polling mode can also be used in parallel with DAQ measurements to increase the number of variables that are to be recorded simultaneously.
The second new INCA feature is the monitoring of SAE J1939 messages on the CAN bus.
The SAE J1939 protocol is frequently used in the drivetrain as well as in the communication between the tractor vehicle and trailer for commercial vehicles and mobile machinery.
All of the new features described are already available in INCA.

Advanced Engine Control Algorithms

ETAS provides a flexible and portable prototyping solution

ETAS rapid prototyping and calibration tools have been simultaneously deployed at Clemson University's research engine dynamometer and within Fiat Chrysler Automobiles' (FCA) powertrain controls development team. Advanced engine control algorithms are able to be developed with high quality and short development times.

AUTHOR

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Advanced powertrain control algorithms are a critical part of the solution to meet future emissions and fuel economy regulations as well as to reduce development time and cost. Modern engine technologies utilize multiple actuators, many of which either directly or indirectly affect the same operating parameters such as engine airflow, residual mass, and in-cylinder turbulence.

This high degree-of-freedom situation presents significant challenges for the engine control algorithms. Traditional empirically derived algorithms are not well suited to these high degree-of-freedom engines when the actuators are operating in combinations that the system was not originally designed for. Algorithms designed around the physical principle of the engine and its actuators are being developed which can determine the optimal control parameters for any combination of actuator positions, thereby improving efficiency.

FCA is utilizing multiple university partnerships to perform research in this vital area. One such partnership is with the Clemson University International Center for Automotive Research (CU-ICAR) in Greenville, South Carolina.

The Campbell Graduate Engineering Center, located at CU-ICAR in Greenville, South Carolina.

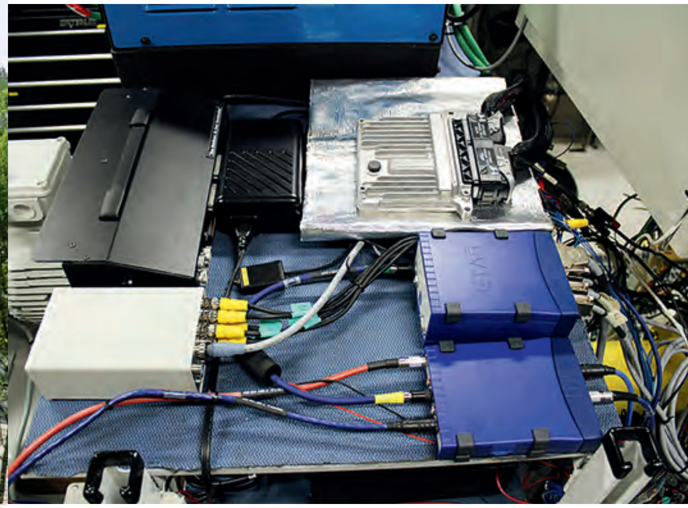
FCA leverages external partnership

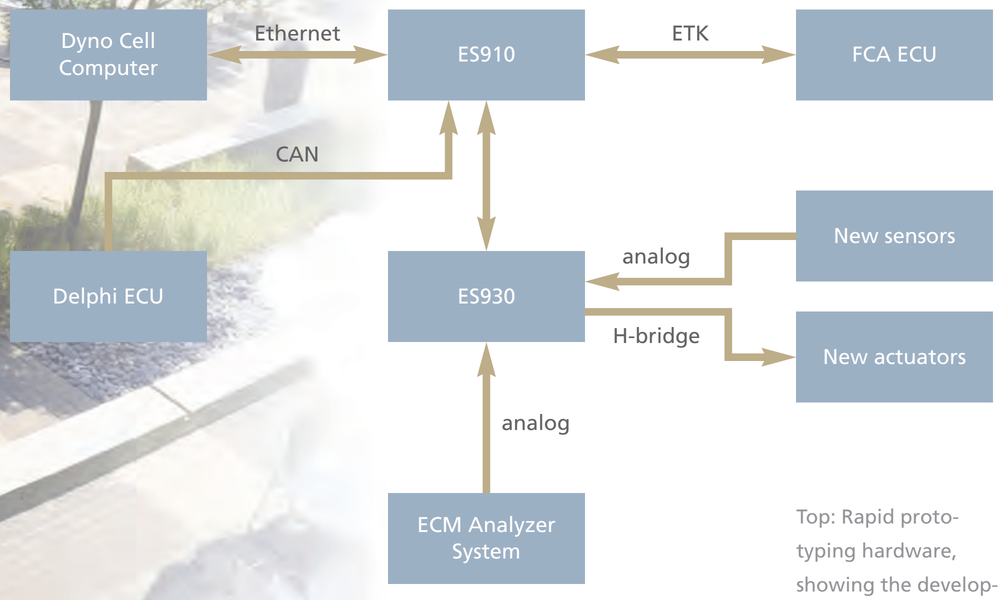
FCA and CU-ICAR entered into a partnership to create advanced engine control algorithms with the goal of improving engine operation efficiency under all operating conditions by utilizing physics-based solutions. FCA supplied CU-ICAR with a 3.6-l Pentastar engine to install in a dynamometer test cell for use in developing and validating the algorithms. Additionally, the project includes additional ECUs, sensors, and actuators that require dedicated I/O to sample and control.

These physics-based algorithms are being developed at the Chrysler Technology Center (CTC) and at CU-ICAR. Therefore, the algorithms need to be shared between both locations for testing in vehicles at CTC and in CU-ICAR's test cell. Due to the physical distance between CTC and CU-ICAR, a flexible and portable development environment was needed.

Project components

The electronic engine-related hardware in the CU-ICAR dyno cell includes:





Top: Rapid prototyping hardware, showing the development ECU connected to the ETAS ES910.3 Prototyping and Interface Module and the ES930 Multi-I/O Module.

A combination of ETAS ES910 and ES930 modules was chosen to facilitate communication between the various devices (diagram).

- FCA ECU
- Delphi ECU
- Dyno Cell Computer
- ECM (Engine Control and Monitoring) Analyzer System
- New sensors
- New actuators

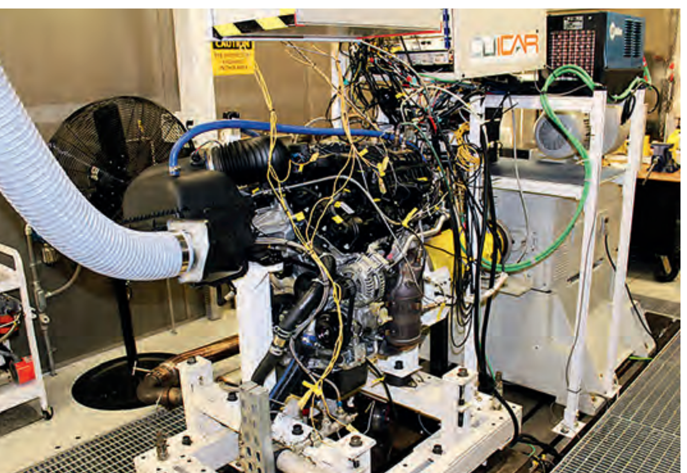
A combination of the ETAS ES910 and ES930 was chosen to facilitate communication between the various devices. As shown in the diagram on the previous page, the ES910 communicates with the FCA ECU via an ETK11 and to the Delphi ECU via CAN.

The ES930 is used to sample the new sensors utilizing traditional 0-5 V analog to digital sampling as well as PWM sampling as appropriate. The ES930 also powers new actuators with its on-board H-bridge drivers. The ECM Analyzer System is configured to send its information as analog outputs which are sampled and converted by the ES930.

The algorithm development is performed in the MathWorks MATLAB®/Simulink® environment. ETAS INTECRIO was chosen as the tool to convert the models into real-time capable code to run on the ES910. The interfacing to the model and ECU parameters is done on the dyno cell computer through ETAS INCA with the INCA-EIP add-on. This allows for a single interface to all measurement and calibration values and allows time-aligned data collection of algorithms running on each module.

The same system configuration exists in a test vehicle at FCA to allow validation of the algorithms as they are delivered. By utilizing the same environment in both locations the teams are able to share algorithms and software packages.

Engine test cell setup in the laboratory at CU-ICAR.



The ETAS Solution

Collaborative development of advanced engine control algorithms between FCA and its university partners requires a flexible and portable prototyping solution. ETAS rapid prototyping and calibration tools have been simultaneously deployed at Clemson University's research engine dynamometer and within FCA's powertrain controls development team. Advanced engine control algorithms, collaboratively developed between FCA and Clemson University, are able to be developed with high quality and short development times.

Efficiency and quality increase

This development environment has allowed FCA and CU-ICAR to work in a highly efficient collaborative manner. FCA is able to develop and test prototype engine code at CTC prior to sending it to CU-ICAR for usage in the dyno cell. CU-ICAR can quickly develop algorithms in Simulink® and test them on the engine in the ETAS environment.

The system allows for rapid model iteration to resolve issues and optimize the control system on the dyno engine. The resulting Simulink® and/or INTECRIO models can be sent to FCA for system validation directly in the development vehicle. FCA is then able to modify the model, if required, and send the resultant algorithm back to CU-ICAR for further development. This model of operation has significantly increased the quality of the algorithms delivered to FCA and has reduced travel costs typically associated with projects such as these.

Conclusion

FCA is committed to developing cutting edge powertrain control technologies. Collaborative development environments require a flexible tool chain to enable sharing between locations and platforms. The ETAS tool chain is being utilized to facilitate this effort and to allow algorithm portability between FCA and CU-ICAR, resulting in faster development cycles with increased quality.

reddot award 2015
honourable mention

Compact, Scalable, Open

ETAS brings professional real-time testing to your desk

ETAS DESK-LABCAR is a compact, scalable Hardware-in-the-Loop (HiL) test system that enables cost-efficient testing of electronic control units (ECUs) in the early stages of development – with award-winning design and usability.

DESK-LABCAR is the compact version of ETAS' proven LABCAR HiL system. Its unique housing includes an integrated breakout box (BOB), real-time PC simulation target, as well as expansion slots for interface boards. The system opens up a broad range of applications from economical open-loop tests of simple control functions to sophisticated closed-loop tests of complex algorithms. Thanks to its compact design, the system enables HiL testing even in confined environments.

Recently, DESK-LABCAR earned kudos from the Red Dot Award for Product Design in the Measuring and Testing Technology category, picking up an "Honourable Mention" in the areas of design and usability.

DESK-LABCAR is the latest product in the industry-established LABCAR product family. The DESK-LABCAR entry bundle provides a broad set of functionalities at an affordable price. It, therefore, fits either for customers hesitating to invest in full-scale HiL systems, or those that would like to reserve the utilization of their full-scale HiL systems for comprehensive system tests by moving less complex tests to the DESK-LABCAR.

Scalability in hardware and software doesn't mean a compromise in quality. DESK-LABCAR enables the testing of small and medium size ECUs without the necessity to use a complete HiL system. On the other hand, a switch-over to a full-scale LABCAR system is straightforward if required by the complexity of the tests or the unit under test. Compatibility with the other HiL platforms in the LABCAR family ensures the reuse of test artifacts from desktop testing later on full-scale systems.

DESK-LABCAR is available in four different bundles. Each combines the ES5100 housing with an ES5340 Multi-I/O Interface Board and either an open-loop simulation target or the real-time simulation target LABCAR-RTPC and the experiment environment LABCAR-OPERATOR. The closed-loop version is configurable. All bundles can be flexibly expanded with other ETAS software and hardware products.

As an off-the-shelf solution, DESK-LABCAR only requires that the customer connects an additional wiring harness to the DESK-LABCAR interfaces, breakout box, and ECU to be ready for use. In addition, it can be combined with other products and services. ETAS Engineering Services supports further customer-specific modifications.

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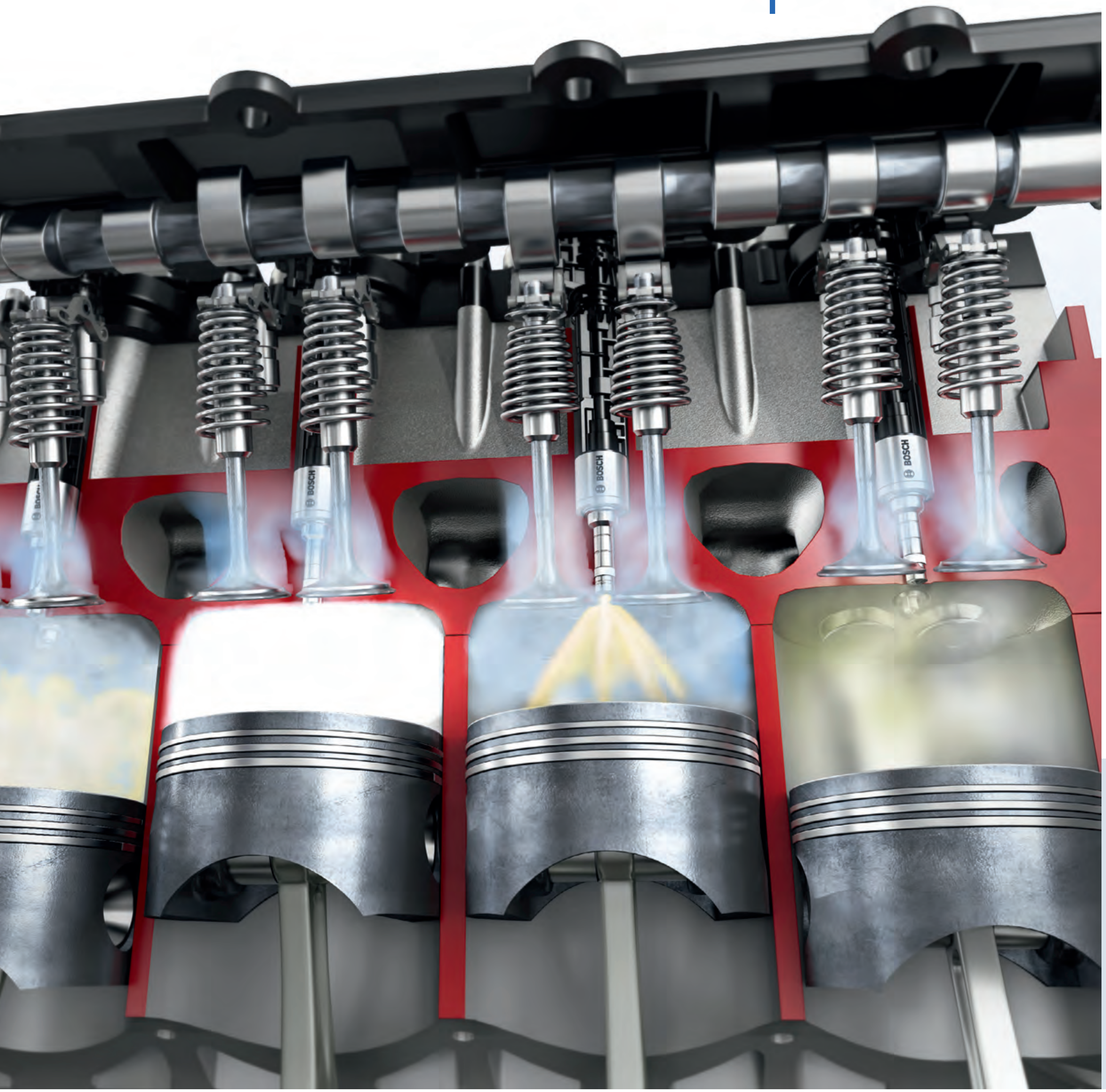
Precision-in-the-Loop



New development tools for clean engines

In modern injection systems, preset injection intervals are being replaced by mechatronic realtime control systems, whereby the engine control unit (ECU) determines the opening and closing of each injector needle and immediately corrects any deviations from the target values. With new high-precision development tools paving the way to series production, ETAS has brought its own Hardware-in-the-Loop solution onto the market. It can simulate the charging and discharging curves of the injectors' solenoid valve with unprecedented accuracy.

Today's downsizing engines combine remarkably low fuel consumption with surprising agility. The key lies in their modern injection systems, which feature injectors that provide a highly sophisticated millisecond-staccato of pre-, main, and post-injection to deliver milligram-precise dosages of fuel into the combustion chambers. The volumes of fuel are so accurately controlled that, under ideal conditions, they burn leaving almost no residue. However, the effects of aging and manufacturing tolerances on the injectors can nullify this precision. Preset injection intervals perform less effectively when the opening and closing times of the injectors vary. That's why developers are now designing ECUs that can interpret the characteristic current and voltage signals produced when the electromagnetically controlled injectors open and close. Knowing exactly when the injector needle opens and closes enables the system to calculate the amount of fuel that is injected as well as the precise moment of injection for each individual injector. Should the results deviate from the target values, the control system can immediately make adjustments, meaning the system can compensate for changes in the injectors' behavior. In view of future on-board emissions monitoring, this will also help to permanently stabilize fuel consumption and exhaust emission levels.

Precision development tools are a must for precise injection requirements

Fuel injectors rely on electromagnetic mechanisms. To raise the needle, a current flows through a coil in the injector and generates a magnetic field that lifts the needle against the pressure of a closing spring (Figure 1). This allows pressurized fuel in the rail to then flow into the combustion chamber. Fuel injection ceases as soon as the electrical current is interrupted and the closing spring presses the needle back down.

Yet what exactly is the time difference between applying the voltage to the coil and the valve opening? And how quickly does it close again after the current has stopped? The necessary answers can be found in the characteristics of the voltage and current curves. These depend on the inductance and ohmic resistance in the injector, which are expressed in charging and discharging curves. The ECU can use this information to redefine the preset intervals in response to each injector's

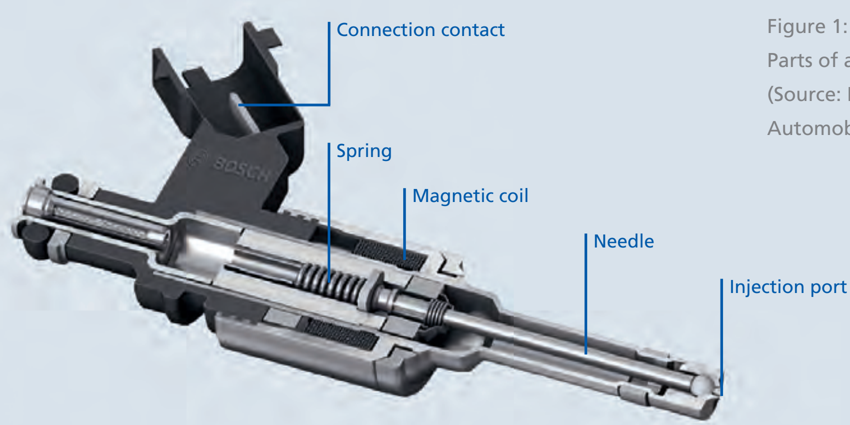


Figure 1:
Parts of an injector
(Source: Bosch Fachinformation Automobil).

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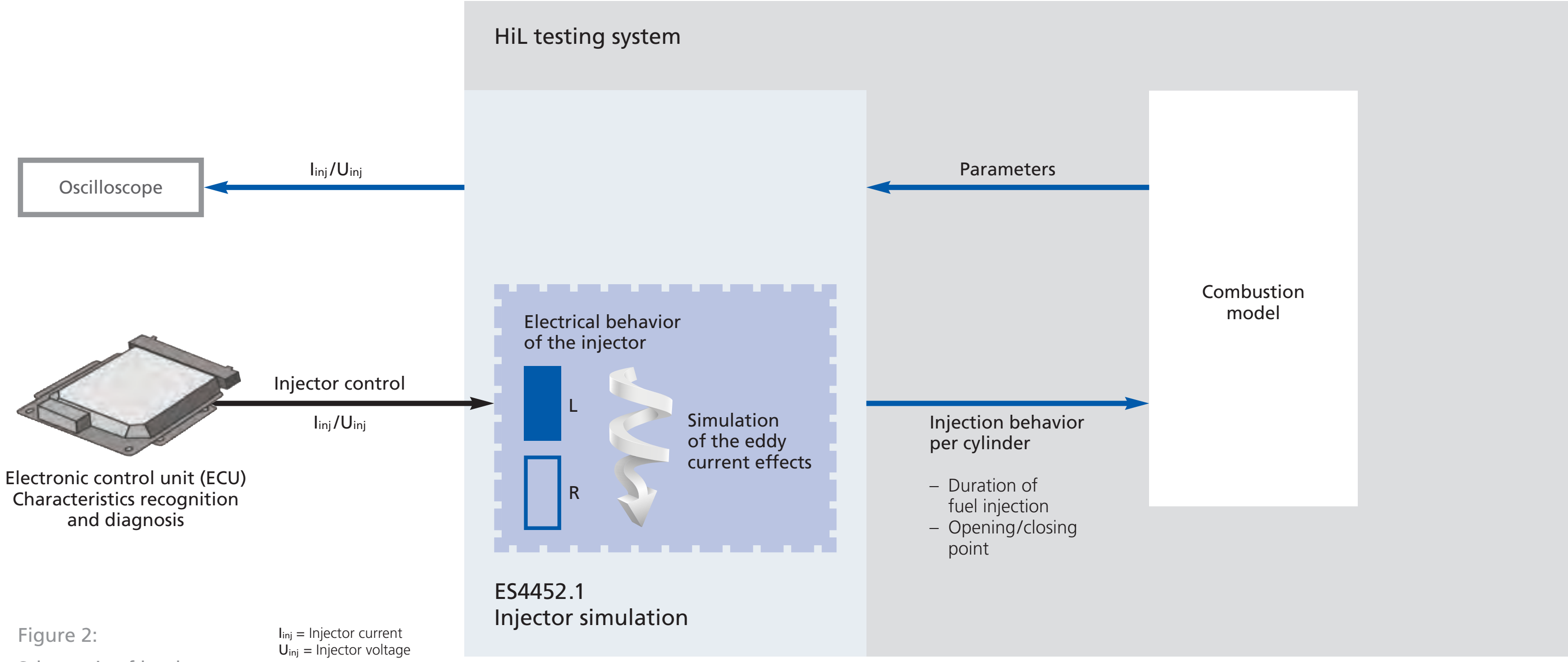

Figure 2: Schematic of load simulation in the HiL system.

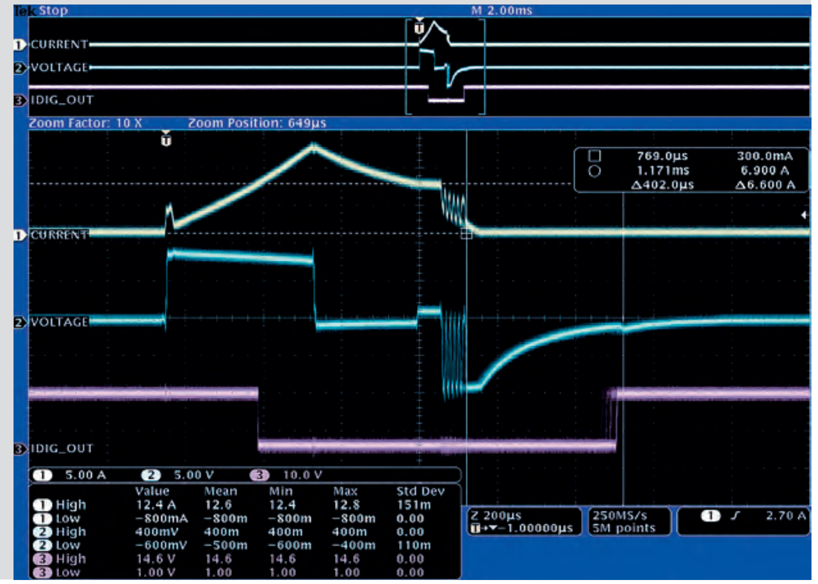

Figure 3: Signal trace of an injection.

changing reaction times. This process follows established software routines.

To be successfully deployed in series production, this part of the control unit software has to be tested and tried out in all possible operating states. Conducting tests using simulated or emulated components is ideal for a number of reasons, such as the fact that software testing usually starts long before the engine and its control unit and injectors are physically available. What's more, testing the most significant factor, the aging of the injectors, on an engine test bench would require a major investment of time and money. It's just as unrealistic to use test bench trials to investigate how software behaves when the injection system malfunctions. Last but not least, testing the injectors would require them to be operated around the clock in a fluid medium and at realistic pressure levels, as otherwise they would stall and their opening and closing behavior change.

Software tests in a virtual environment avoid these problems. Hardware-in-the-Loop (HiL) setups allow developers to test the operating strategy of a control unit while taking into account all conceivable parameter permutations, be it the aging of the simulated injectors or artificially created malfunctions. However, until now, no HiL solution on the market was able to reproduce the injectors' behavior precisely enough for the new control strategy to be tested in the closed loop of control unit and injection system. The most important aspect for any such HiL testing environment is that it must be able to precisely reproduce the charging and discharging curves of the injectors.

New HiL solution accurately reproduces injector behavior

For developers to test the control strategy on an in-the-loop test bench, the system has to supply the control unit with realistic voltage, electricity, inductance, and resistance values while the unit is in various states of operation. The unit needs to use these values to infer the opening and closing times of each virtual injector and in the end the amount of fuel that is injected. This requires that the charging and discharging curves be simulated so consistently that the control unit can recognize the simulated spikes.

The major challenge for simulation lies in hardware, more precisely in managing the discontinuities in the supply of voltage and electricity that are normally triggered every time active electronics intervene. Developers of the test system have to limit these breaks in supply enough to ensure the control unit doesn't misinterpret them as a movement of the needle or as an injector malfunction. Another challenge is simulating the eddy current effects in the injector coil accurately and at the right time, since they too can affect the discharging curve.

ETAS has now developed a HiL solution that overcomes these challenges. It simulates the individual fuel injectors through resistance and inductance and also incorporates eddy current effects – without generating malfunctions and discontinuities in the charging and discharging curves. No HiL system has been able to do this before.

Tests carried out in cooperation with a Tier 1 supplier over several months indicated that the solution could realistically reproduce injector behavior in both hardware- and software-based modeling even with variable boundary conditions, meaning injector aging could also be simulated. The core component of the solution is the ES4452.1 plug-in board for the ETAS LABCAR platform with a Field-Programmable Gate Array (FPGA).

Fast reaction times

The new control strategies require the opening and closing of the injector needles to be determined down to the last microsecond. Hence ETAS has ensured that its new solution features delays of no more than two to three microseconds – some 50 times shorter than the shortest injection times. This is achieved by providing a digital output signal that simulates the points at which the virtual injector opens and closes. These signals are synchronized with each other in the crankshaft angle for up to four different injector simulations. The command set for the board is openly accessible. Standardized interfaces, 100 Mbit/s Ethernet; SCPI (Standard Commands for Programmable Instruments), ensure the HiL solution integrates smoothly into existing development environments. The solution also features precise, dynamic analog output that can depict the voltage and current for each simulated injector via an oscilloscope or another measuring instrument, thereby making changes in the configuration directly visible without the need for expensive, high-precision current clamps.

Configuration settings, such as those dependent on rail pressure, changes in opening times, fuel temperature, or the threshold values of voltage and electricity, can be set – and changed – prior to and during the simulation by means of the SCPI protocol. The first version of the ES4452.1, which has been commercially available since mid 2015, is tailored for gasoline direct injection. The solution for diesel systems, the ES4457.1, was recently published.

Outlook

As part of efforts to improve combustion efficiency and reduce emissions, modern injection systems can regulate the amount of fuel they dispense down to the milligram. Now, the ability to compare the active injectors' actual condition with the target values enables new control strategies to be developed that can compensate for aging-related changes in injector behavior by adjusting system parameters. For mechatronic injection control systems to be successfully deployed in series production, they too have to pass various functional tests. ETAS developed the highly precise LABCAR HiL system with the ES4452.1 and ES4457.1 plug-in boards to allow these components to be tested in virtual form in Hardware-in-the-Loop testing environments. It is the first HiL system able to simulate injector activity with sufficient accuracy to allow control unit software to be geared to the new control strategies. The software is able to learn the future behavior of the injectors without having to integrate actual injectors into the loop.

ETAS China celebrated its 10th anniversary.

ETAS at the CENEX Low Carbon Vehicle Event held at Millbrook, U.K.

Automotive Testing Expo North America – ETAS participated with a new booth concept.

ETAS Impressions in 2015

"Big Data" was a key topic at the ETAS booth at the 2015 Automotive Testing Expo in Stuttgart, Germany.

ETAS in the midst of the melting pot for embedded systems – at the embedded world in Nuremberg, Germany.

ETAS India at the "Symposium on International Automotive Technology (SIAT)" in Pune, India.

The ETAS exhibition team at the embedded world.

Exclusive Solutions for Colleges and Universities

Students can familiarize themselves with ETAS tools early on thanks to special higher-education packages

With its comprehensive portfolio of products and solutions, ETAS offers active support to higher education and research institutes worldwide in the area of embedded systems. As a result, all work processes in areas ranging from software development to measurement, calibration, and diagnostics can be supported in accordance with the highest standards and using products with a proven track record in the automotive industry. In this way, ETAS is helping to optimize research and training at higher education and research institutes, as well as train qualified junior engineers.

AUTHOR

Klaus Fronius is University Liaison Manager at **ETAS GmbH**.

For years, ETAS has worked successfully with higher education and research institutes, based on a higher-education model tailored to their needs. In addition to providing well-established products and solutions which have been used in the automotive industry for many years, ETAS offers packages specific for higher-education. Such higher-education packages address a particular use case, usually drawn from the daily work of an engineer. The packages consist of the appropriate hardware and software, backed by support for the technical implementation. One such use case is the simulation of a vehicle CAN in the institute's own computer lab.

Students use the open source software BUSMASTER with the associated ES581 USB CAN Bus Interface Module. The use case presents complex topics in simplified form and establishes their relevance to the real world. What's more, the open source tool offers users the opportunity to experiment and include their own ideas. Professors can additionally obtain various documents produced by ETAS for their academic lectures, such as the reference book "Automotive Software Engineering". Based on what is known as the V model, the book's aim is to illustrate the respective phases of the software development process as well as the corresponding ETAS tools.

The ETAS University Liaison Manager is available to provide local support to higher education and research institutes at all times and jointly find custom solutions. Higher education and research institutes in countries where ETAS has a local office, such as India, China, or the United States, receive support directly from local associates.

More than 150 colleges, universities, and research institutes worldwide rely on ETAS, including: University of Stuttgart, RWTH Aachen University, ETH Zurich, TU Vienna, University of Bochum, TU Braunschweig, TU Darmstadt, Esslingen University of Applied Sciences, TU Munich, KIT Karlsruhe, Dayananda Sagar University (Bangalore), University of Applied Sciences Landshut, Jiaotong University (Shanghai), Universidade Estadual de Campinas (São Paulo), Politecnico di Torino (Turin), and Fraunhofer Institutes.

The Formula Student teams sponsored by ETAS achieved excellent results at the Hockenheim competition.

Formula Student – a recipe for success

Formula Student has established itself as an exciting project for applying the theoretical knowledge gained academically to real-world situations on and alongside the racetrack. Formula Student provides students with the opportunity to further their technical education and specialize in a preferred area, while also enhancing their soft skills. Since 2008, ETAS has been one of Formula Student Germany's main sponsors.

A win-win situation

In 2015, ETAS sponsored 25 teams with products and product training. ETAS supports teams with the entire product portfolio and gives participants a chance to get to know the products in practical applications. Not only do the students further expand the specialized knowledge they can directly apply later in their careers, they are already using ETAS products to take the lead in the racing series. Since 2010, over 1,800 students have become acquainted with ETAS and ETAS products in this way. Two teams have already used ETAS products to break the world record for acceleration to 100 km/h.

ETAS uses this platform to establish contact with students at an early stage. As Germany is one of the key centers of automotive development, it is important for ETAS to continue to attract highly motivated engineers who will help the automotive industry advance – because today's students are tomorrow's engineers.

Early Software Validation on the PC

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Validation of ECU software in virtual test drives with AUTOSAR and FMI

Hardware-independent validation of ECU software with virtual electronic control units and virtual test drives offers many advantages. ETAS and IPG Automotive GmbH make the most of them with a new solution.

The complexity of vehicle development is continually increasing. The driving forces are shorter development cycles, more model versions, cost pressure, cooperation between regionally distributed teams of car manufacturers and suppliers, as well as trends such as "semi-automatic or autonomous driving". These are compelling reasons to integrate an increasing number of ECUs and software functions into vehicles – and of course to validate in advance. The sooner manufacturers and suppliers can test ECU controller software, and the earlier they can detect possible software errors, the more cost-efficient development can be. A general rule of thumb applies: for every development stage in which a fault remains undetected, the resolution costs increase by a factor 10. Making corrections early on also saves valuable time in the tightly scheduled development process and early software testing helps to master the growing complexity.

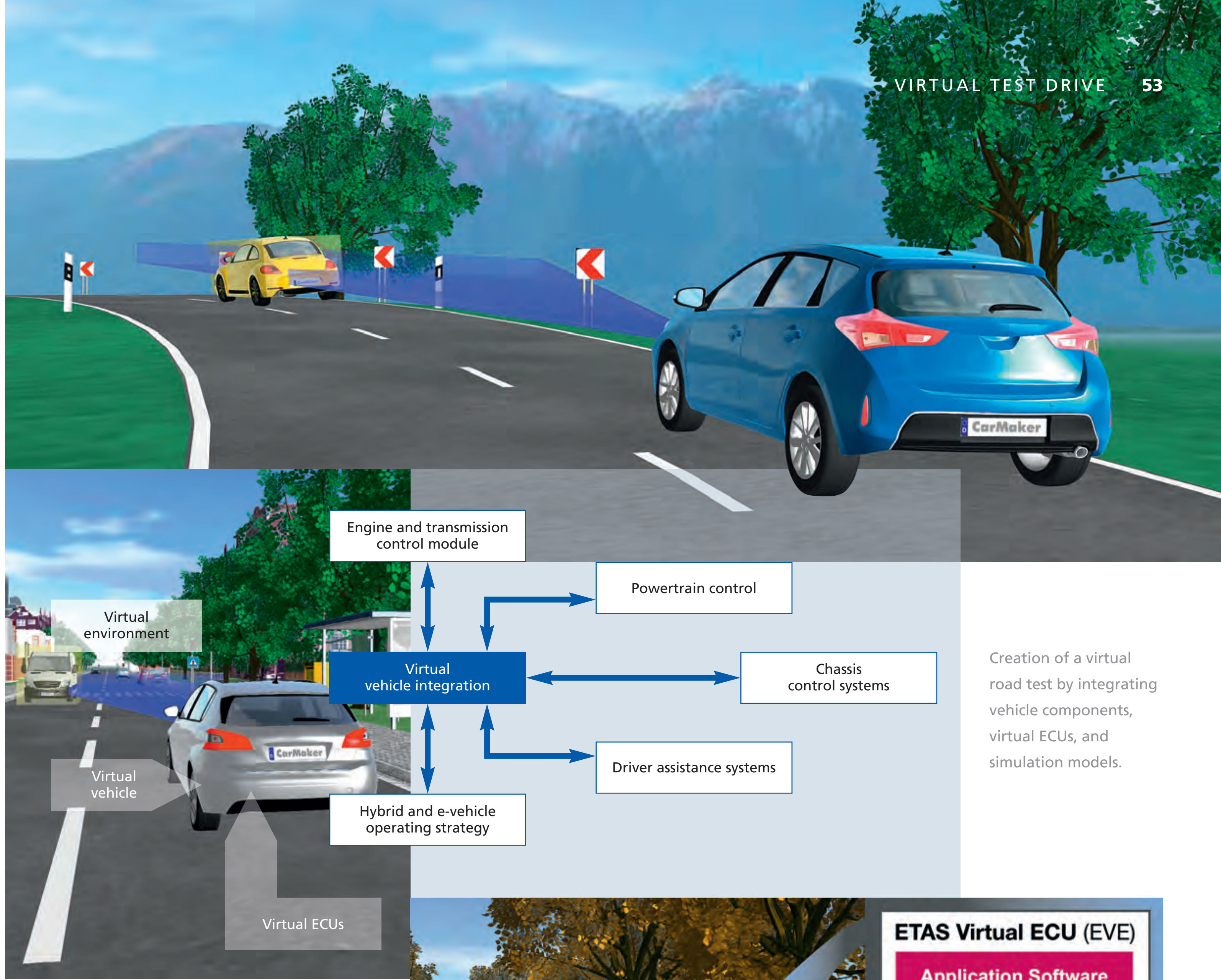
Limited test options with hardware prototypes

Up to now, prototypes of the electronic control unit and the vehicle were required for realistic testing of ECU software. For the most part, however, they are only available in later development stages – and are limited in number due to cost reasons. Result: in around 60 percent of the development time, no prototype is available and barely 10 percent of the engineers get the chance to perform tests in a real vehicle. The limited hardware availability makes software testing more difficult, and even more so if distributed teams in different locations need to have access. Costly and time-consuming transport, fraught with uncertainties, such as customs delays, are par for the course. Despite all the effort, a crucial disadvantage remains: dangerous situations and complex environmental conditions can hardly be simulated with hardware – and are even harder to reproduce. But testing in critical situations is exactly what is needed to assess the operability of driver assistance systems.

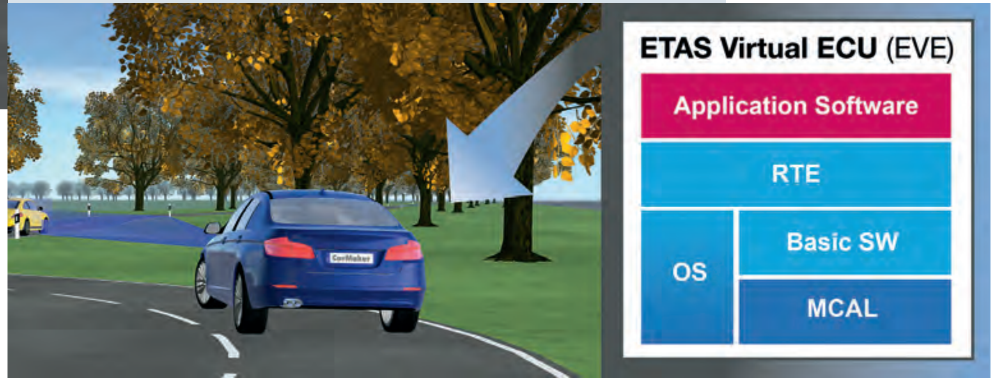
Requirements for efficient software validation

It is clear in order to make early ECU software validation possible, the current hardware dependency must be overcome. On top of time and cost savings, there are also convincing organizational reasons. If ECU software is validated in advance without hardware prototypes, this relieves the demand for using scarce resources in further development processes – such as Hardware-in-the-Loop systems or test vehicles. Furthermore, hardware-independent tests can be performed and reproduced in parallel at different locations. A prerequisite for this, however, is that the solution for software validation has been prepared for the heterogeneous toolscapes of the stakeholders involved in the distributed development process.

Models and components created with different domain-specific tools must be taken into account, just as well as the easy integration of the solution into the existing tool chain. For an efficient end-to-end development process, it is also important that existing models, test cases, and test data are reusable. Individual driving maneuvers or existing test catalogs should also be easy to integrate, so that potentially dangerous situations can be run through without any risk to the driver or vehicle. And, last but not least, the performing of realistic tests requires that the application software can be observed in interoperation with the operating system or basic software.



Creation of a virtual road test by integrating vehicle components, virtual ECUs, and simulation models.



Realistic software validation on a PC by using EVE, the virtual ECU from ETAS, and the open integration and test platform CarMaker from IPG Automotive.

Main components of potential solutions

To sum it up, we can deduce two main elements of potential solutions:

1. Use of virtual ECUs in virtual test drives

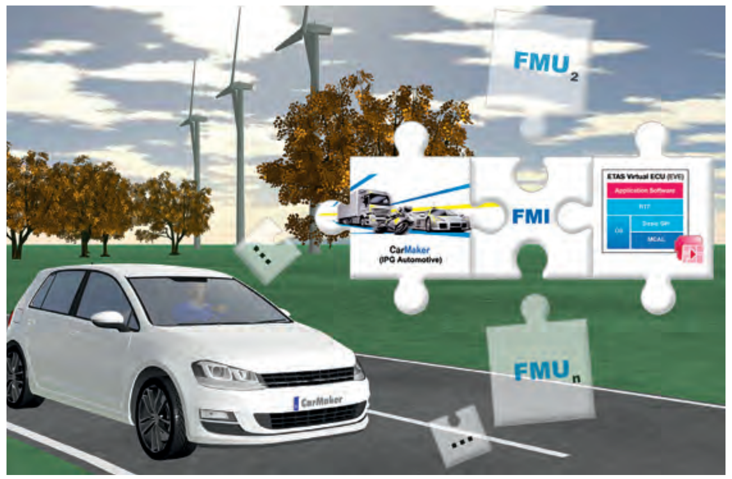
Virtual electronic control units can be created at an early stage of development, independent of the hardware. Compared to prototypes, virtual ECUs are inexpensive and easy to reproduce. They can be seamlessly integrated into existing development processes and enable the reuse of existing methods and artifacts. The ECU software can also be tested in the system context and validated in interoperation with environment and component models, long before hardware prototypes are available. This way ECU software achieves a high level of maturity earlier on, which provides developers with time to develop new functions. Trials in virtual test drives are possible; the virtual vehicle – as with its real counterpart – has all the components such as the engine, powertrain, driver assistance systems, etc. Nearly every one of these components has one or several integral ECUs. Validation is possible in virtual traffic scenarios in the virtual system.

2. Taking standards into account

If vehicle manufacturers and suppliers work together in teams, standards are the basis for efficient software validation. They allow the exchange of artifacts and lay the foundation for end-to-end processes, despite heterogeneous toolscapes. The automotive software standard AUTOSAR facilitates the exchange of software on different ECUs and ensures that software components can be reused, replaced, and integrated by defining methods to describe software in vehicles. Of similarly high relevance is the Functional Mock-up Interface (FMI) standard. As a tool-independent standard, it supports the exchange of models and the co-simulation of dynamic models, making virtual validation much easier.

Shared problem-solving approach of ETAS and IPG Automotive

Together with IPG Automotive GmbH, ETAS has developed a specific solution that overcomes the described challenges. It is based on the virtual electronic control unit EVE (ETAS Virtual ECU) and the open integration and test platform CarMaker from IPG Automotive. The EVE platform for virtual software integration and validation on the PC allows you to virtualize individual ECUs or an entire ECU network. In contrast to previous solutions, it allows for the integration of functional models, application software components, and basic software modules from various sources in virtual electronic control units. On the PC, the application software is integrated with the embedded operating system RTA-OS, with the AUTOSAR Runtime



Connection of the virtual ECU (EVE) to the integration and test platform CarMaker via the "Functional Mock-up Interface" (FMI) standard.

Environment (RTE), and with the basic software to be used. Independent of the ECU hardware, you are able to validate and calibrate, in real-time and non-real-time, under realistic conditions, and in a wide variety of use cases.

CarMaker is used as a simulation environment for virtual test drives. The integration and test platform is open to models of different modeling tools. Precise non-linear vehicle and trailer models form the basis for high-quality simulations, in which complex driving maneuvers can be easily set up and reproducibly performed – including the behavior of driver assistance systems in situations with many road users. CarMaker covers a wide range of application areas and allows for ensuring features through Model-, Software-, Hardware- and Vehicle-in-the-Loop testing.

To start with, the software to be tested is integrated in EVE, the virtual ECU. It can be exported as a Functional Mock-up Unit (FMU) and then integrated in CarMaker via the standardized FMI interface. In CarMaker the software is tested and released following virtual test drives. For the interactive operation, the solution from ETAS and IPG Automotive also allows for the debugging of the software code during testing.

This shared problem-solving approach clears the way for early software validation on the PC and a more efficient development of ECUs for vehicle manufacturers and suppliers. Thanks to its open design and standardization, developers can work using familiar tools and access existing artifacts at any time.

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