RealTimes

2021

Stronger together

ETAS

DRIVING EMBEDDED EXCELLENCE

Left to right:
Günter Gromeier
Executive Vice President Sales
Christoph Hartung
President
Götz Nigge
Executive Vice President Operations

Dear Readers,

Those of you familiar with ETAS will undoubtedly have spotted three new faces when you opened this issue of RealTimes. ETAS GmbH reorganized its Board of Management at the start of 2021, and we would like to use this opportunity to introduce ourselves. On page 55, you can find out more about us, our backgrounds, and how we intend to meet the new and exciting challenges that lie ahead.

Challenges are something that have dominated our lives since early last year. The pandemic has turned the world upside down, creating huge difficulties for healthcare systems. The automotive industry, too, has been hit by numerous challenges. ETAS has been affected along with many other companies in the sector, for example by the current parts shortages.

We were compelled to find new ways of working together. Physical distancing and working from home were important from the outset, but we also focused more than ever on the idea of being stronger together. Of course, the automotive industry is also facing many other challenges, from automated driving and e-mobility to connectivity and new business models. New methods are required to continuously improve automotive software and bring it to market much faster, all without compromising safety. Teamwork is essential here – just like it is in activities such as whitewater rafting. Successfully navigating a river is something that can only be done as a team. If the boat tips over, life jackets ensure that nobody goes down, so everyone can get back on board and keep moving forward.

We already offer an extensive portfolio of promising solutions to help you develop automotive software, and we have plenty of other sustainable approaches in the pipeline. Agile methods, cloud-based solutions, and perfectly harmonized development solutions are the key to success. To find out more, check out our articles on work methodologies of the future starting on page 6.

This issue also includes fascinating insights into exciting customer projects from around the world, such as model-based development at Nissan, the use of EHANDBOOK at Audi, and the use of ETAS ASCMO-MOCA at Hyundai Motors. We also reveal how measurement data can replace human senses and explain how to successfully master the testing and validation of fuel cell ECUs.

Perhaps you want to take a look behind the scenes at ETAS? This issue includes a report on how ETAS hardware is tested in production and how this contributes to the high quality of ETAS products. And we also invite you to join us on a brief journey through the history of INCA.

We hope you enjoy reading this year's issue of RealTimes. We look forward to working together with you, our customers and partners, to meet the new challenges. And we intend to continue to provide the very best support for your current and future projects. Many thanks for the trust you have placed in us. Stay healthy!

Christoph Hartung   Günter Gromeier   Götz Nigge

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Evolution, revolution, or out-of-the-box?

Is the automotive industry ready for its encounter with IT?

Automated driving, connectivity, and new business models pose a challenge to software developers. They need new methods that will allow them to continuously improve functions and bring them to market much faster, all without compromising safety. Are we up to meeting these challenges?

At the 1968 Summer Olympics in Mexico, US high jumper Dick Fosbury's new jumping technique was initially met with a skeptical reaction – yet he ended up winning gold and setting a new Olympic record. Instead of the front of his body facing the bar, Fosbury used a "back-first" technique. Now known as the "Fosbury Flop," this is the standard method used by today's high jumpers.
It has enabled top female athletes to jump almost 2.10 meters – and top male athletes to clear over 2.40 meters.

So what does this have to do with the future of automotive electronics? At ETAS, we believe that optimizing today's development methods will no longer be sufficient to achieve the required improvements in performance. The way in which the automotive industry develops automotive software is currently geared primarily toward safety and long-term releases. In light of such rapid increases in complexity, however, the software requirements of connected automated vehicles can only be met by fundamentally changing the methodology. Just like the high jumpers 50 years ago, the automotive software development needs to take a new approach.

We need to reinvent ourselves

Connected vehicle systems require continuous software development and delivery, both for security and other reasons. This continuous delivery process extends over the vehicle's entire life cycle, even after the vehicle and its ECUs have rolled off the assembly line. This is especially true in cases where new E/E architectures are taken on board. Developers using powerful, microprocessor-based vehicle computers can place functions anywhere they choose, even when different Automotive Safety Integrity Levels (ASILs) are involved. Increasing interaction between individual functions causes domains to merge. This means we must also consider functional safety, robustness, and security from an overall system perspective – and that requires a new management and corporate culture.

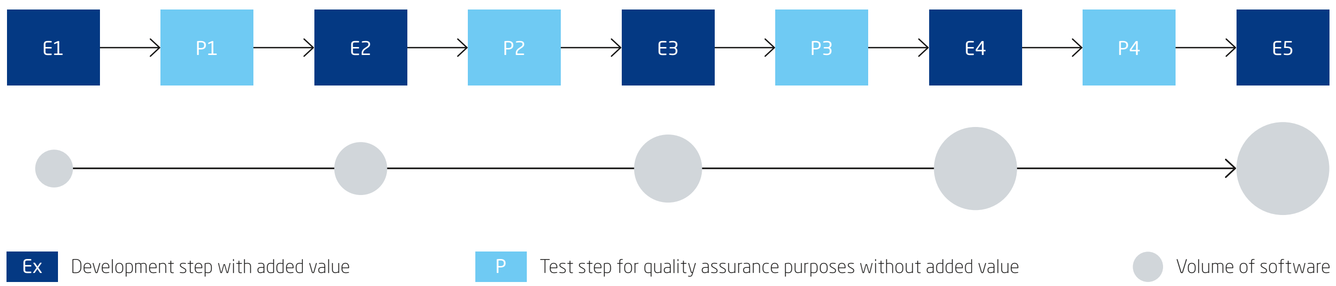
Virtualization and front-loading are important starting points. But the breakthrough we need cannot be achieved solely by shifting existing process steps into the virtual world. Only by combining this with parallelization, automation, and agile methods can we gain the traction we need to successfully develop automated and connected vehicles.

Validation is carried out in an automated, object-oriented approach (Fig. 2). This ContinuousX parallelization of development and testing makes the process faster – especially when it covers the entire chain from the Tiers to the OEMs and has an impact that extends far beyond the start of series production.

Collaboration should not stop at the company's boundaries. Instead, all the partners work together on an equal footing and are authorized to integrate and test their current version. Open source plays an important role, too, because speed and interactions are key priorities.

Access to the development platform and many of the development tools is provided through a hosted cloud platform. Teams work on this platform to develop solutions that reflect the selected business model and meet customers' needs. Consistency between the real and virtual world is essential to ensuring this approach works efficiently. The only question is whether this brave new agile world can withstand a reality in which people entrust their lives to our software.

Figure 1: Traditional development methods tie up resources during the transition to the next step.



Forging new paths

In projects that involve cooperation between multiple partners, traditional software development invests significant time and energy in validating previous steps in the development process. In many cases, a new step only begins once the previous step has been completed (Fig. 1). Mistrust in the results delivered by others costs money without adding value for end customers.

Continuous, end-to-end virtualization and integration take a different approach, with all the DevOps partners working with the latest model and software version along the entire value chain. Quickly and easily created Minimum Viable Products (MVPs) enable fast feedback. Customer and development teams recognize errors but also opportunities for improvement at an early stage and can immediately apply the findings to series development.

Our experience

At ETAS, we have spent several years implementing many of the approaches outlined above. We are gradually replacing traditional organizational structures with Scrum teams that use agile methods (see page 10). Development is shifting to the cloud, where our experts work together with suppliers and enjoy easy access to measurement and development data as well as the latest development tools. Their focus is entirely on the functionality of the software.

Immediate verification on delivery builds trust and reduces costs. Overall, the changes are having a very positive impact. Our customers confirm that we have become better and faster in the relevant areas of our business. They appreciate our ability to offer significantly more cross-functional solutions that provide them with real added value.

We are also gradually aligning our portfolio to the continuous development methodology. Our co-simulation and integration platform COSYM already allows engineers to take a continuous approach to working on MiL, SiL, and HiL platforms – even in the cloud. We are setting new standards for calibrating large volumes of data with the cloud integration of our systems for data logging and the ETAS Analytics Toolbox (EATB). And RTA-VRTE offers an AUTOSAR Adaptive platform software framework for future microprocessor-based vehicle computers that will run software from a wide variety of sources.

Raising the bar

Just like in the world of IT, success depends on continuous monitoring of robust key performance indicators (KPIs). It is important that the indicators measured are uniform and transparent for all those involved. The performance of the overall solution takes priority over that of individual components. This ensures that everyone involved is united in a common effort to prioritize the benefits for the customer. All the key stakeholders must be included for this approach to work.

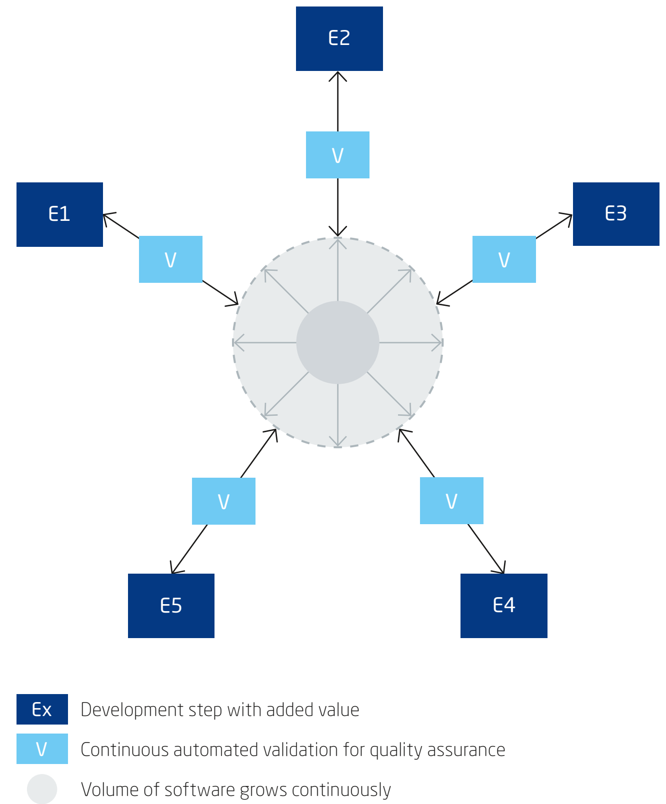
Vehicles are high-value purchases with a long service life. They will continue to be subject to restrictions in the future with regard to storage, performance, costs, environmental influences, and long operating lives. Security and IP must be guaranteed in the vehicle over long periods of time. For this reason, development approaches from the IT world cannot be transferred 1:1 to meeting our requirements, especially since there is also a need for legal clarification. It will therefore take some time to achieve the goal of continuously connected, virtualized, and agile development processes for automotive software. Yet our positive experiences so far show that we are on the right track.

Summary

There is an urgent need for action. The challenge we all face is how to apply the innovative power and performance of traditional IT methods to the development of vehicle software. New approaches are required that take into account vehicle safety requirements and service life as well as cost pressures in the automotive industry. This course is now being set.

Will this require evolution, revolution, or new out-of-the-box thinking? We believe that all three variants are necessary: evolution of our high safety requirements, a revolution in vehicle architectures, and systematic out-of-the-box thinking about development methodologies for automotive software that will control innovative connected and self-driving cars in the future.

Figure 2: In the case of a simultaneous development process in the cloud, automated validation and parallel development reduce lead times and increase added value.



Our portfolio already includes many promising solutions, and further sustainable approaches are in the pipeline. We look forward to achieving new levels of efficiency and performance in collaboration with our customers and partners. Our hope is to create the same kind of enthusiasm among our customers as Dick Fosbury did in 1968 with his new jumping technique.

Authors

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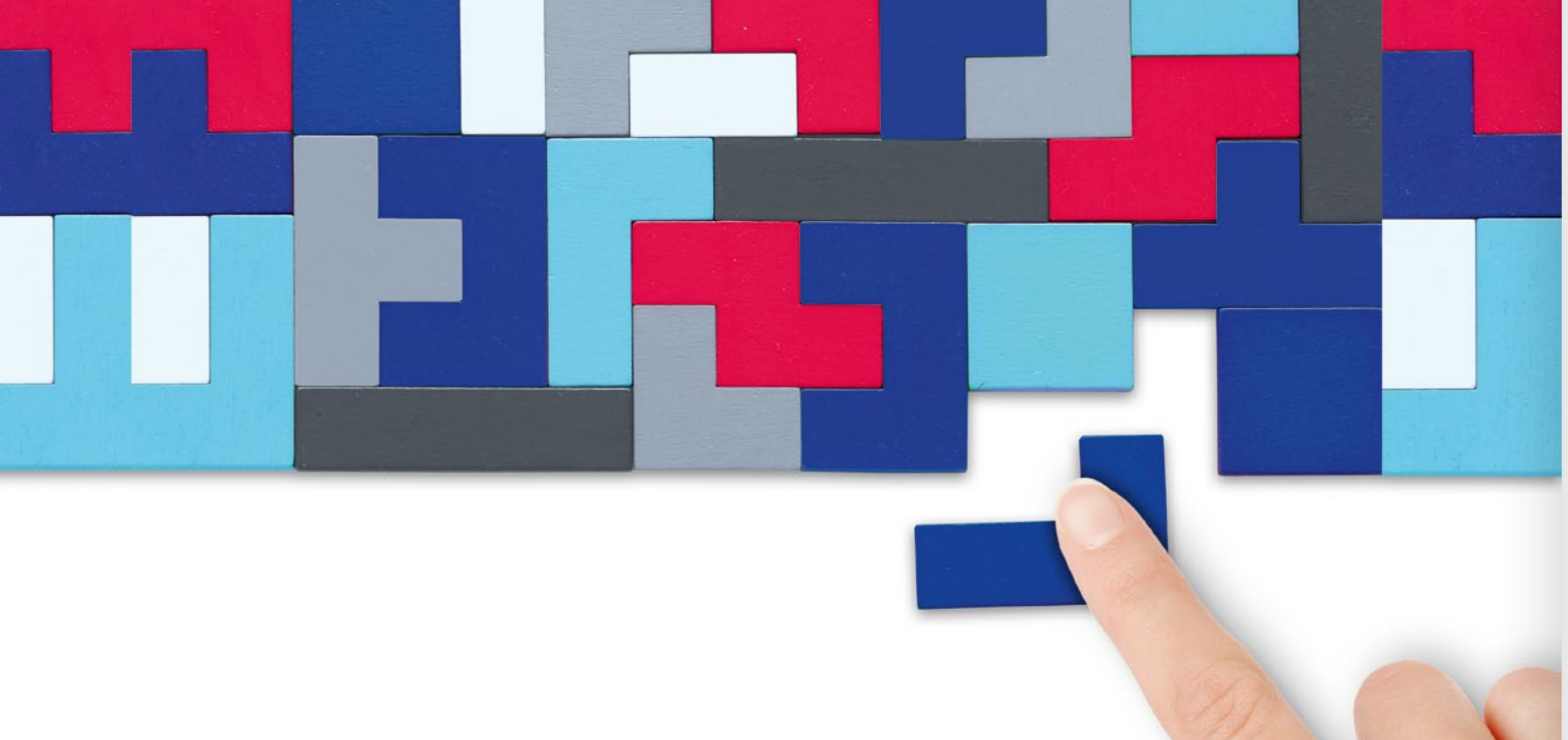


Embedded meets IT

Developing automotive embedded software using agile methodologies and SAFe

The traditional V-model development process has worked well for a long time. But projects based on this approach reach their limits when it comes to complex software systems for autonomous, connected driving. So is this approach completely wrong now? The answer is both yes and no.

Software for connected, autonomous vehicles is never finished. It is continuously updated over the air. This has consequences for the development. It is very difficult to assess project complexity in advance. Even creating a detailed specification of the development goal can be challenging in some fields. Development teams are essentially "driving by sight" and if they come up against technical difficulties or new aspects when using traditional methods, they often have to move a few steps back in the process – and that means taking their colleagues and suppliers back with them.

Faced with similar dilemmas, the world of IT resorts to agile methodologies: prototypes are created in short sprints and immediately reviewed and approved by the customer. The Scaled Agile Framework (SAFe) provides a methodology toolbox for scaling agile working methods across all levels of product development. The only question is whether this also works for the high safety requirements in the automotive sector.

The right tool

There is no one "right way" of doing things in software development. The less that is known about the requirements and technology at the start of a project, the more important it is to have flexible tools. Nobody would reach for a hammer if they were still unsure whether they would be dealing with nails or screws. The same applies to development methods: their usefulness only becomes clear once the task is known (Fig. 1).

Dave Snowden's Cynefin Framework (Fig. 2) helps project planners make an initial assessment. For simple tasks, where the relationship between cause and effect is obvious, planners can let themselves be guided by the "best practice" approach.
In contrast, complicated tasks require analyses of the principles of cause and effect or the application of expert knowledge in order to find a "good practice" approach. This good practice approach has become the standard method for automotive development projects based on the V-model.

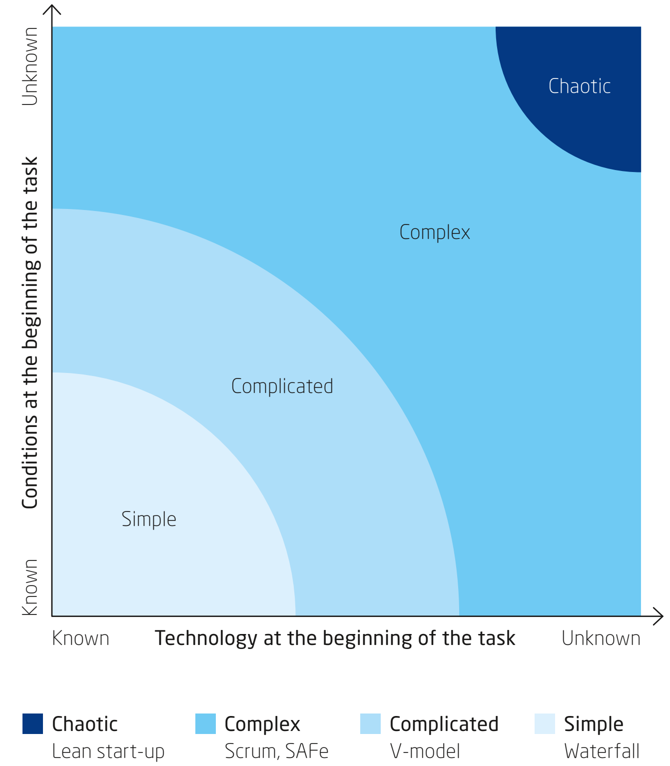
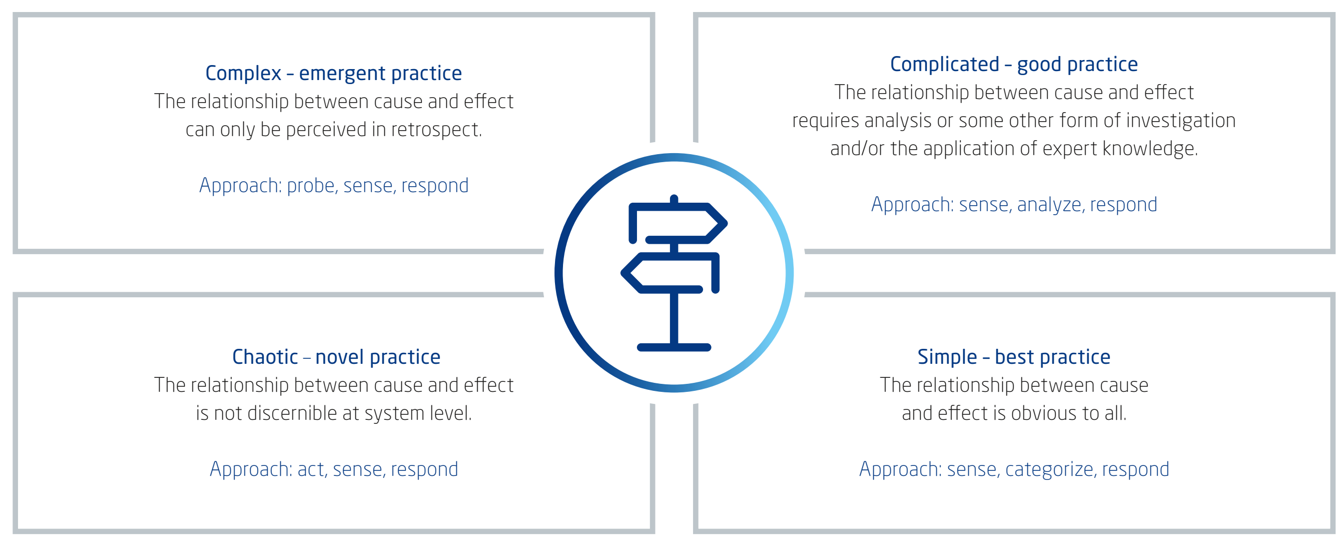


Figure 1: The Stacey Matrix created by Ralph Douglas Stacey classifies problems according to the complexity of the requirements and knowledge of the technology.

Figure 2: The Cynefin Framework shows how different problems require different approaches.



In the case of complex problems, the relationship between cause and effect can often only be understood in retrospect – it cannot be fully described at the start of the project. When introducing new technologies, developers therefore proceed experimentally in short cycles. This incremental approach with agile working methods and SAFe is becoming a popular choice in development projects for autonomous, connected vehicles. The final level in Snowden's framework is that of chaotic problems. If the relationship between cause and effect is not discernible, developers have to proceed by trial and error, continuously adjusting their methods to get the situation under control. This is the approach taken in a crisis.

Summing up this aspect, the question of which approach will achieve the goal fastest depends primarily on the type of problem. In the real world, tasks change and technological expertise increases steadily, so the chosen methods need to be flexible enough to ensure the focus remains on the goal.

Focus on the goal

When it comes to developing complex vehicle systems with unknown technologies, agile methodologies make it possible to work toward the development goal in incremental steps. Throughout this process, it is important not to lose sight of the overall goal and the planned milestones. The decisive factor at all stages is the added value for the customer.
The incremental approach and immediate review and approval of prototypes by the customer make it possible to change course whenever necessary. All decisions are made within the team, including the distribution and prioritization of all tasks. Maximum transparency and mutual trust are therefore essential in order to plan projects efficiently, prioritize tasks correctly and ultimately come up with the best technical solution.

The Scaled Agile Framework (SAFe) is a set of organization and workflow patterns that support agile development methodologies, including Kanban, DevOps, Scrum and customer/user-centricity as well as Big Room or Product Increment (PI) planning. This latter method offers everyone involved the opportunity to bring together all their ideas and visions in one (virtual) room in order to agree on a common route forward that best aligns with these ideas and visions. This approach serves to dovetail product management and development.

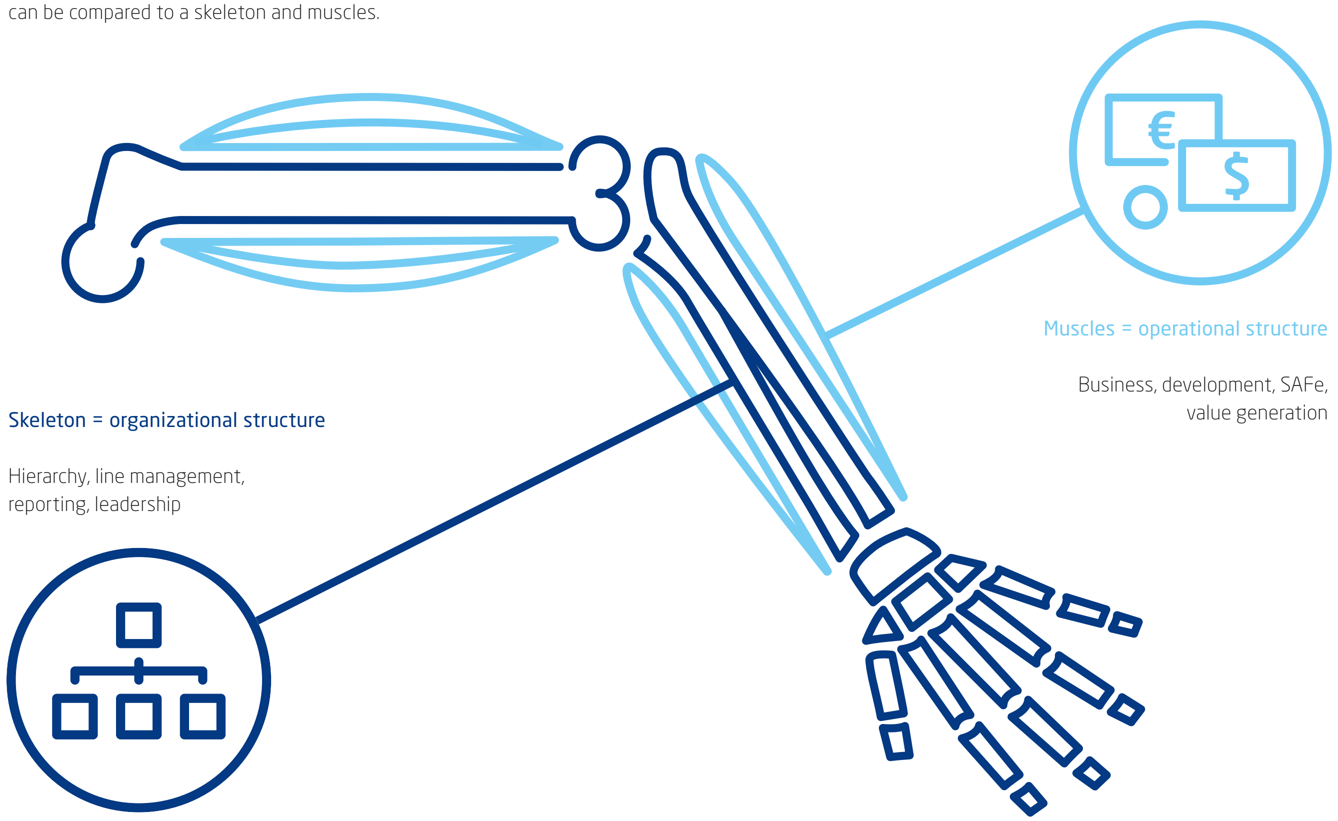
Experience gained during implementation

ETAS has been using agile methodologies of software development for almost a decade. Their gradual introduction was driven by the adoption of new technologies.
The first teams began working with the new approach in 2011 following an initial heatmap-based analysis of benefits. They quickly understood and adopted the agile methodologies and the number of successful projects steadily increased.
In 2014, agile methodologies were implemented by additional teams in the fields of embedded systems and hardware development.
Since 2017, ETAS has also been using SAFe for the step-by-step scaling of cross-team collaboration and the coordination of development work.

One of the keys to the new methodology's success was that the heads of the various groups and departments supported and actively promoted it right from the start. Yet there were also challenges. The pilot groups soon realized that there was no longer any intrinsically right or wrong approach. The most promising method for each specific problem had to be reassessed in each individual case. The Stacey Matrix and the Cynefin Framework provided useful assistance in this context, making it easier to classify the problems and reach a shared understanding. Heated discussions about the right method to choose belonged to the past.

Initially, the teams sought their own individual ways of creating and optimizing solutions, which led to redundancies in the portfolio: components with similar functionalities were developed and brought to market multiple times, which prompted confusion among customers, pushed up maintenance costs, and hindered product interoperability. To remedy this, ETAS developed the Solutions principle in 2014. ETAS defines Solutions as functionalities that are based on the interplay between multiple products and components. Each Solution solves at least one customer problem. Interoperability of the individual products is essential. PI planning meetings proved to be an indispensable part of implementing this principle, leading to a strong focus on common goals and prompting tangible changes in working methods and a significant boost in motivation.

Figure 3: The two basic structures in an organization can be compared to a skeleton and muscles.



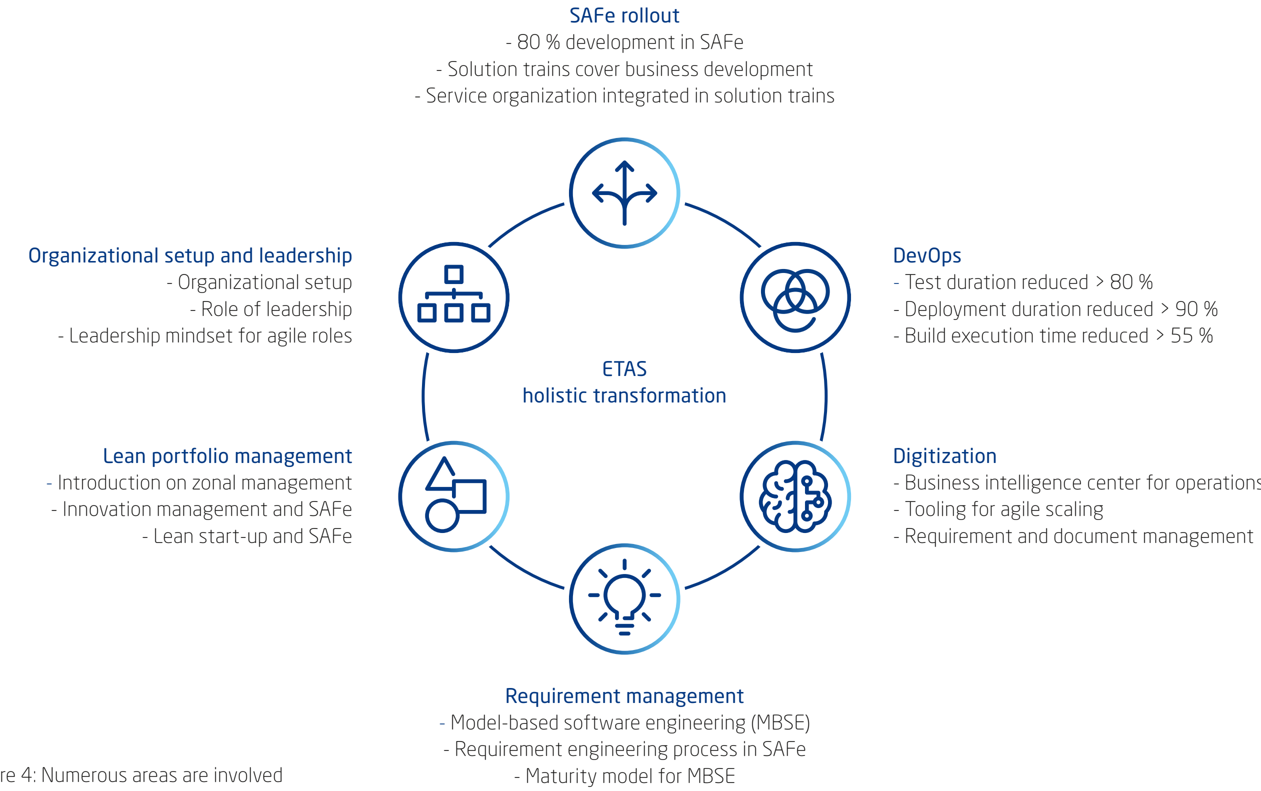


Figure 4: Numerous areas are involved in organizational development.

Further important findings

In addition to the technical complexity, there was a considerable need for coordination between the projects, which have to take into account a multitude of dependencies and interactions between products in the ETAS portfolio. Interoperability creates added value for customers, so the decision was taken to make these dependencies easier to manage and control. This requires optimum embedding of agile working methods within the organizational framework. The DevOps automation approach is ideally suited to achieve this: it uses shared incentives, processes, and development tools to facilitate more effective collaboration between the Development, IT Administration (Operation), and Quality Assurance (QA) teams.

Process optimization and process digitization are closely interlinked. The operational organization that creates value – including value for the customer – and the supporting organizational structure are inseparably linked, much like the muscles and bones that comprise the human musculoskeletal system (Fig. 3). The introduction of agile methodologies therefore sets in motion a holistic transformation (Fig. 4). This is by no means an automatic process. One tried-and-tested way to help counter frustration and doubts is by assigning well-connected associates as facilitators. A clear commitment from management and defining clear responsibilities are also essential prerequisites.

Summary: a positive outcome

Ten years after the introduction of agile working methods, the outcome has been positive. Planning reliability and customer satisfaction have noticeably improved. Using the new working model, we are continuing to meet essential safety requirements as required by ASPICE and ISO 26262. Increased productivity, higher associate satisfaction, and greater reliability confirm that we are on the right track. Our approach is seen as setting a pioneering course within the Bosch Group and in the world of SAFe. And the fact that we are putting our agile methodology into practice is additionally attractive in the highly competitive market for skilled workers. This benefit offers further encouragement to hold our course as we make our agile way into the connected future.

Authors

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Introduction of SAFe at ETAS

Interview with Günter Gromeier and Adrian Hanussek

ETAS recently launched the Scaled Agile Framework (SAFe) for the two application fields Measurement, Calibration, and Diagnostics (MCD) and Software Engineering (SE). RealTimes met with Günter Gromeier, Executive Vice President Sales, and Adrian Hanussek, Vice President Engineering, to take a look behind the scenes.

Is SAFe primarily a development topic?
Günter Gromeier: With SAFe, there is no fixed dividing line between product management and development and both areas were equally involved in the launch of this project. Our respective roles in portfolio management* and engineering management complement one another, and we're working together closely.

What are the key changes?
Adrian Hanussek: Our goal is to make ETAS fit for the future by systematically applying agile organizational principles. We asked ourselves how our organization should be structured to best grow our business. Prior to this project, our organizational structure had been a traditional one with associates assigned to groups and departments. We saw conflicts arise from overlapping responsibilities and roles, which was an unnecessary waste of our time and energy. We also found it difficult to adapt the size of the Scrum team organization which already existed in some areas.

We needed a new structure to strengthen our organizational alignment and improve responsiveness and efficiency by simplifying communication and synchronization. The structure should also enable associates to develop their skills in a modern, supportive environment.

What are the biggest changes that come from introducing SAFe?
Günter Gromeier: The most obvious change is the division of our organization into an operational structure (Trains) and an organizational structure (Chapters). We're also adapting our style of collaboration to take advantage of all the potential benefits of SAFe. Decisions will no longer be made by individuals within a hierarchy. Instead, responsibilities will be distributed across a range of different roles.

How do Chapters and Trains work together?
Adrian Hanussek: Chapters bring together all the people who possess similar skills and perform similar roles and tasks. The projects draw resources from this pool, organizing them into Agile Release Trains. They define the goals for projects and solutions and set priorities and budgets.
We hope this structure will enable us to achieve greater motivation and associate satisfaction as well as improving collaboration, planning, transparency, and organizational alignment with our corporate strategy.

How were associates prepared for these changes?
Günter Gromeier: We took a transparent approach to allocating the new roles and held various workshops and training courses. This gave us the solid foundations we needed to develop the new organizational structure. We also worked closely with management, human resources, and the works council right from the start.

Have we already reached our goal?
Adrian Hanussek: It takes time for such big changes to become established, but we're confident we will be successful on the path we've chosen. The feedback we've received from customers also shows we're heading in the right direction.

Thank you for these insights into the new ETAS world.

* At the time of the interview, Günter Gromeier was Vice President Marketing, Business Strategy, and Portfolio Management at ETAS GmbH.

Günter Gromeier (left) and Adrian Hanussek (right).

"We're confident we will be successful on the path we've chosen."
Adrian Hanussek

Successful together!

Coordinated development solutions are the key to success

Transition, change, transformation, and uncertainty are probably the best words to describe the current situation in the automotive industry. E-mobility, connectivity, (partially) automated driving, mobility services, automotive apps ... The list of technical challenges goes on and on. What will be launched onto the market – and how quickly? No one knows exactly. However, they have one thing in common: software plays the leading role in most innovations.

The pressure to change is enormous. Major players from the world of IT are forcing their way into the market. New mobility business models for vehicles in the field are growing in importance. Many software projects are developed separately from the hardware. In addition, the very highest safety and security requirements apply for automotive software – especially in the field of ADAS/AD. Therefore, the challenge is to launch innovative software quickly, safely, and economically onto the market before continuously updating it in the field. Agile development methods, virtual validation, and continuous integration and deployment (CI/CD) are all prerequisites for success.

If we take a closer look at the development process, we can identify four important areas (see picture). These include functional application software, middleware for microcontroller- and microprocessor-based hardware, holistic solutions for cybersecurity, and development tools for the secure and efficient development of complex systems with high data volumes that enable the fastest possible development cycles, whether in a traditional developer workspace or in the cloud.

While the application software offers great differentiation potential for the OEMs, middleware, security, and tools have great potential in terms of standardization and common development platforms. Alongside synergy effects, this also offers a higher degree of safety and security. After all, the effort involved in verifying functional safety and in the measures for consistent security increase disproportionately to the software's complexity, degree of connectivity, and update frequency. Only by acting together can this challenge be overcome.

This will enable OEMs and their suppliers to concentrate on the functionality of the application that actually sets it apart as a USP – and reach their objectives quickly. To ensure success, it is imperative that the middleware, security solutions, and development tools are coordinated with one another. This is the only way for development partners to add value to their solutions and achieve their goals.

We believe that ETAS is an important enabler for our customers' success in these very challenging market conditions, whether it is about development efficiency, software optimization, comprehensive middleware, or holistic cybersecurity.

The speed and scope of the changes in automotive software development have never been as significant as they are today. Positive, close cooperation and partnerships are more important than ever for this. The time for pure isolated solutions is definitely over. We are ready!

Authors

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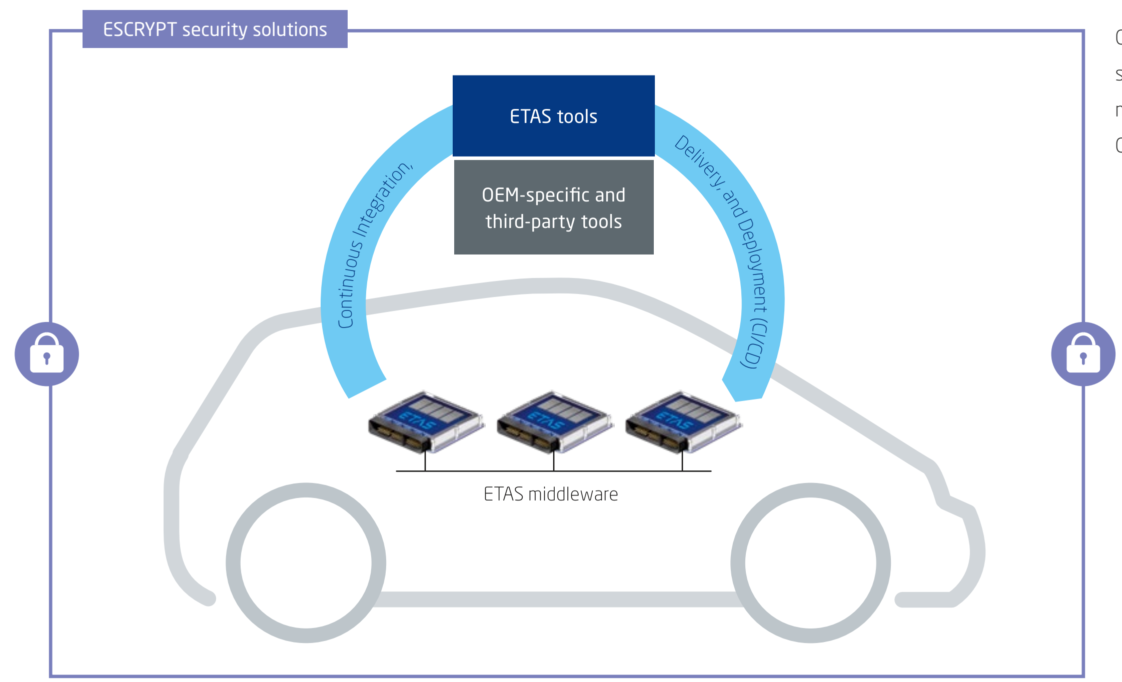
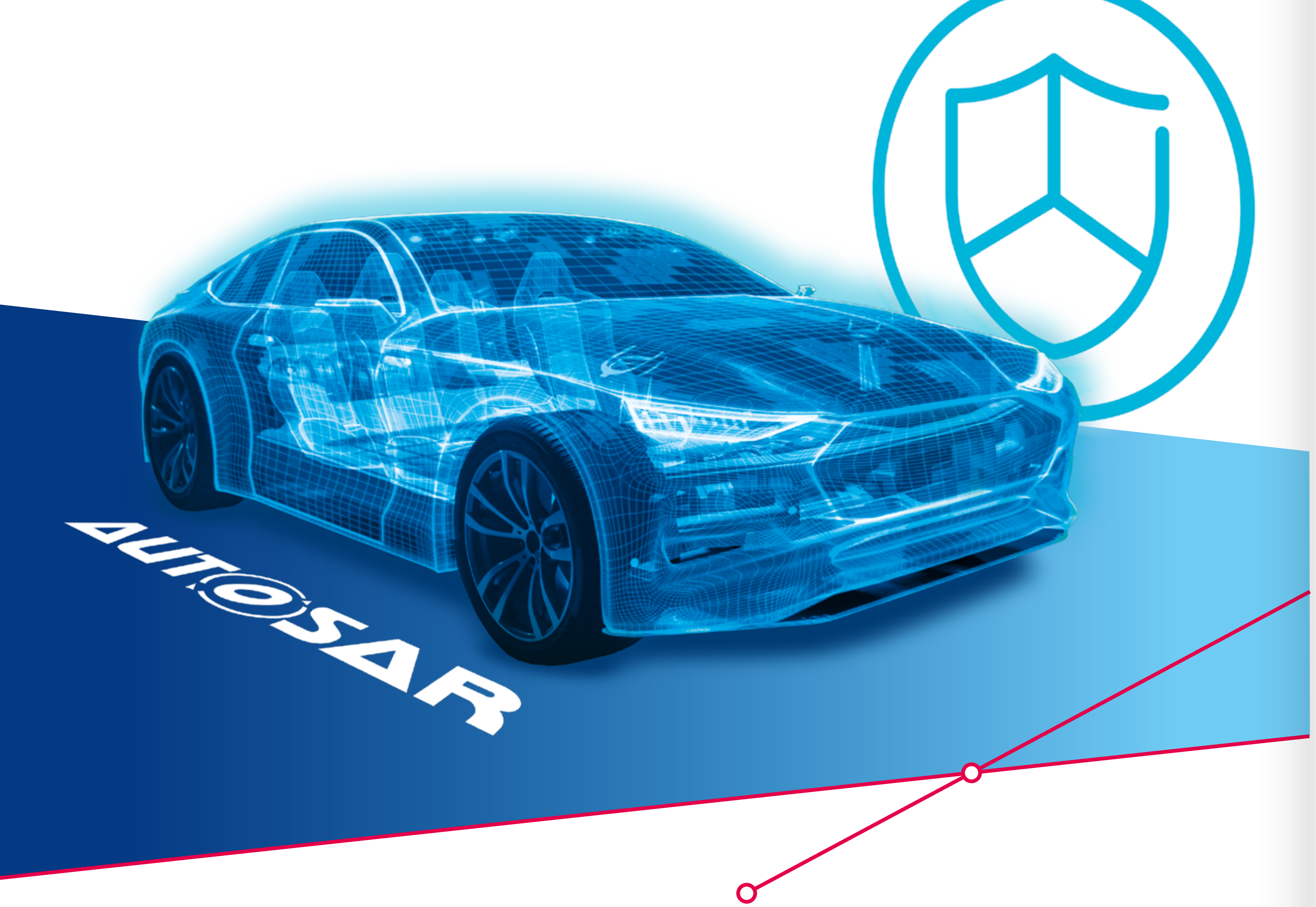


Coordinated middleware, security solutions, and development tools enable efficient CI/CD development processes.



Cybersecurity included

Security for AUTOSAR Adaptive architectures

AUTOSAR Adaptive paves the way to an intelligently connected vehicle. To provide reliable protection against cyber-attacks, this standard features security functions that can be integrated today into tomorrow's E/E architectures.

E/E architectures with signal-based connectivity and functionally partitioned ECUs are reaching their limits when it comes to connected and highly automated vehicles. Calls for autonomy and connectivity lead to centralized high-performance vehicle computers (VCs) and domain controllers (DCUs) making strategic decisions, and sensor and actuator ECUs simply executing the commands.

The AUTOSAR Adaptive platform provides the framework for these new E/E architectures. It makes it possible to dynamically adapt application software and uses the AUTOSAR Runtime for Adaptive Applications (ARA) interface to establish a connection with a POSIX-based operating system, such as Linux (Fig. 1). To ensure that software from different vendors and of different ASIL categories run safely on the VC, hypervisors are used to preconfigure partitioning.

Cybersecurity management

Smart connected vehicles cannot be secured with individual measures., but only with integrated concepts based on risk analyses of the entire vehicle architecture. These concepts must be broken down to the security requirements of individual components, ECUs, and their logical partitions. Accordingly, AUTOSAR Adaptive features an integrated basic set of security functions that developers can use to address the shifting quantitative and qualitative protection requirements of connected, automated vehicle systems. Given that distributed, software-based E/E architectures drive up data loads under real-time conditions, security measures must be designed to perform better. This is why the following security functions have been integrated into AUTOSAR Adaptive (Fig. 2).

Cryptography as a "key component"

Many security use cases rely on cryptographic primitives to, for example, encrypt confidential data or verify the signature of software updates. The cryptographic keys and certificates required to do so must be stored securely, managed by an authorized application, and sometimes even synchronized across several ECUs. In AUTOSAR Adaptive, these primitives are provided through the cryptography functional cluster (also called crypto API). It offers an abstraction of the interfaces provided and thus increases overall software portability.

To ensure secure data exchange, AUTOSAR Adaptive follows the latest standards, including TCP/IP communication via Ethernet. Using TLS and IPSec – the established protocols within the world of IT – it is possible to set up secure channels for communication within the vehicle and with external instances that are impervious to manipulation or eavesdropping.

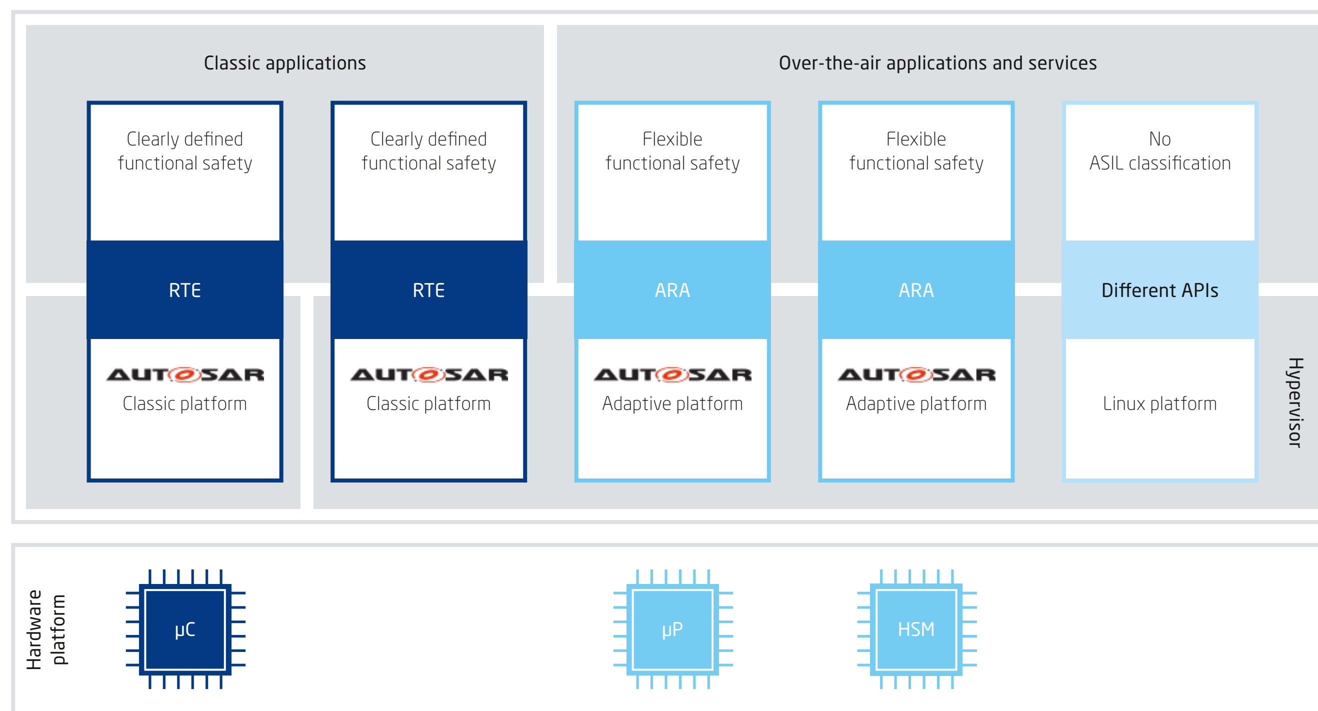
AUTOSAR Adaptive manages access to system resources such as persistent memory, communication channels, and cryptographic keys. The AUTOSAR Identity & Access Management module provides a gatekeeper that allows only explicitly authorized applications to access the respective resource. Access rights can be configured as required and updated at any time.

Secure update and trusted platform

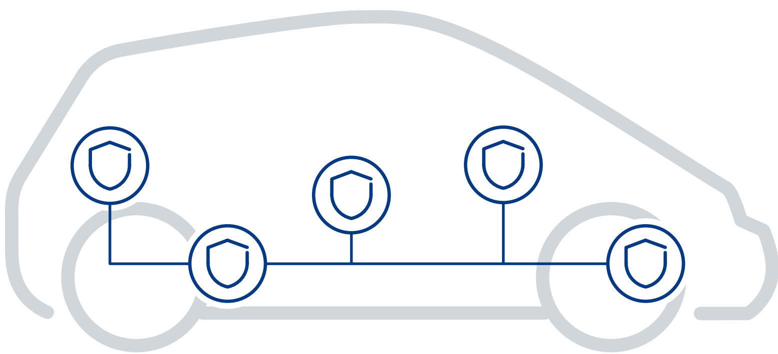
The secure update function in AUTOSAR Adaptive helps to fix detected vulnerabilities, for instance found by IDS (Intrusion Detection System). It receives and processes security updates for individual applications or even for the entire platform. The individual Update Blobs are signed by the back end so that only updates from a trusted source are executed.

In addition to updates, ECU and VC applications must also be verified at regular intervals. This calls for either secure boot or the trusted platform function in AUTOSAR Adaptive, which, as a trust anchor, verifies all applications as well as the platform itself. By maintaining the trust chain from boot to platform to application, only trusted software is executed.

Figure 1: While AUTOSAR Classic supports systems with fixed real-time requirements, AUTOSAR Adaptive distinguishes itself as the standard for dynamic applications.



RTE = Runtime Environment
µC = Microcontroller
ARA = AUTOSAR Runtime for Adaptive Applications
µP = Microprocessor
API = Application Programming Interface
HSM = Hardware Security Module



Security components in AUTOSAR Adaptive

- **Crypto stack** for managing key material and access to crypto primitives
- **Secure communication** via established protocols TLS and IPSec
- **Access protection** for sensitive resources (e.g., keys through the Identity and Access Management module
- **Secure updates** for everything from individual applications to the complete platform
- **Authentic software** thanks to continuing the secure-boot trust chain as part of the "trusted platform"

Figure 2: Central security components in AUTOSAR Adaptive.

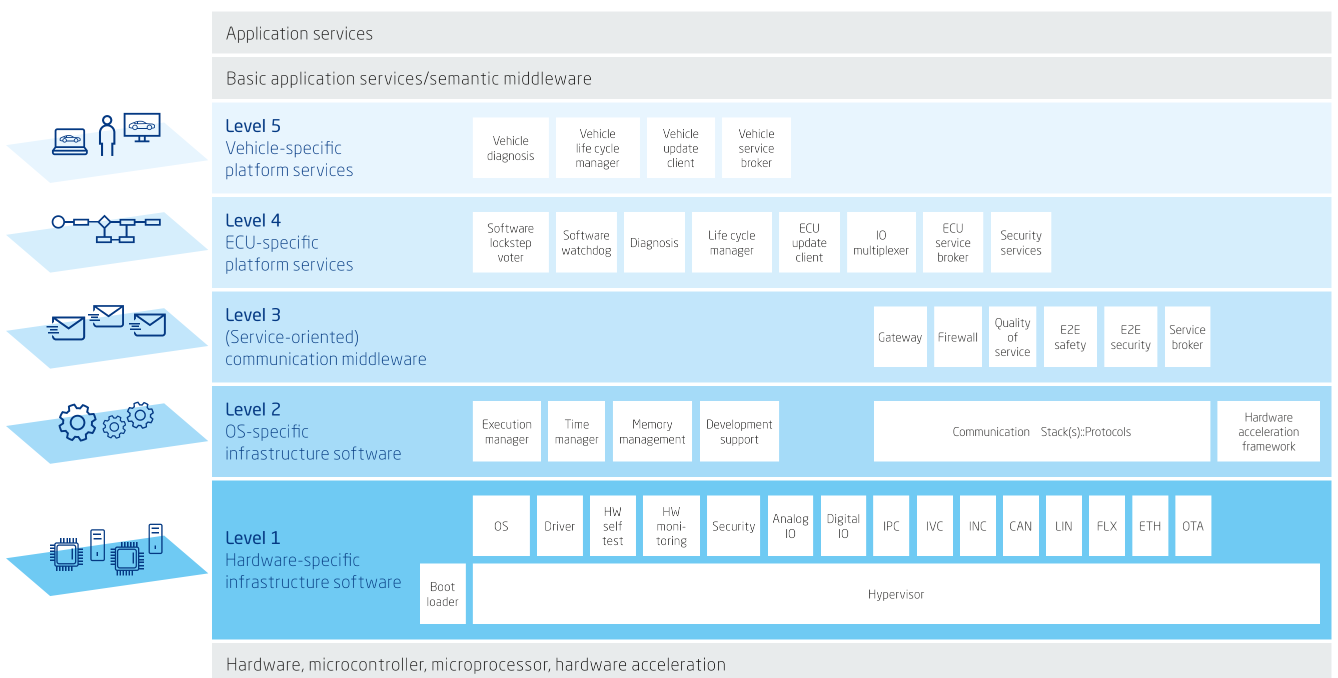
RTA-VRTE: platform software framework for AUTOSAR Adaptive

For future users of AUTOSAR Adaptive, it is crucial to become familiar with the new architecture today. The Vehicle Runtime Environment (RTA-VRTE) platform software framework is the ideal basis for integrating and implementing security functions as well as for all other AUTOSAR Adaptive-compliant processes.

RTA-VRTE contains all the important middleware elements for microprocessor-based vehicle computers. The platform software framework enables the function of virtual ECUs to be simulated on conventional desktop PCs and networked via Ethernet. RTA-VRTE creates a virtual machine consisting of four layers of basic software architecture, with the fifth layer then containing the vehicle-specific platform services (Fig. 3).

Levels 1 and 2 contain the infrastructure software for the hardware used (e.g., device drivers) and a POSIX-compliant operating system. Level 2 also provides platform-specific elements that derive from the AUTOSAR Adaptive specifications – first and foremost execution management. This manages the dynamically assigned applications, ensures that they are started and stopped correctly, and monitors adherence to the assigned resource and execution limits. Execution management is thus a key function in IT security, providing the trusted platform and verifying the integrity and authenticity of Adaptive applications. In this way, possible manipulation or damage is detected in advance.

Figure 3: The RTA-VRTE five-level model supports the important software functions and requirements for VCs.



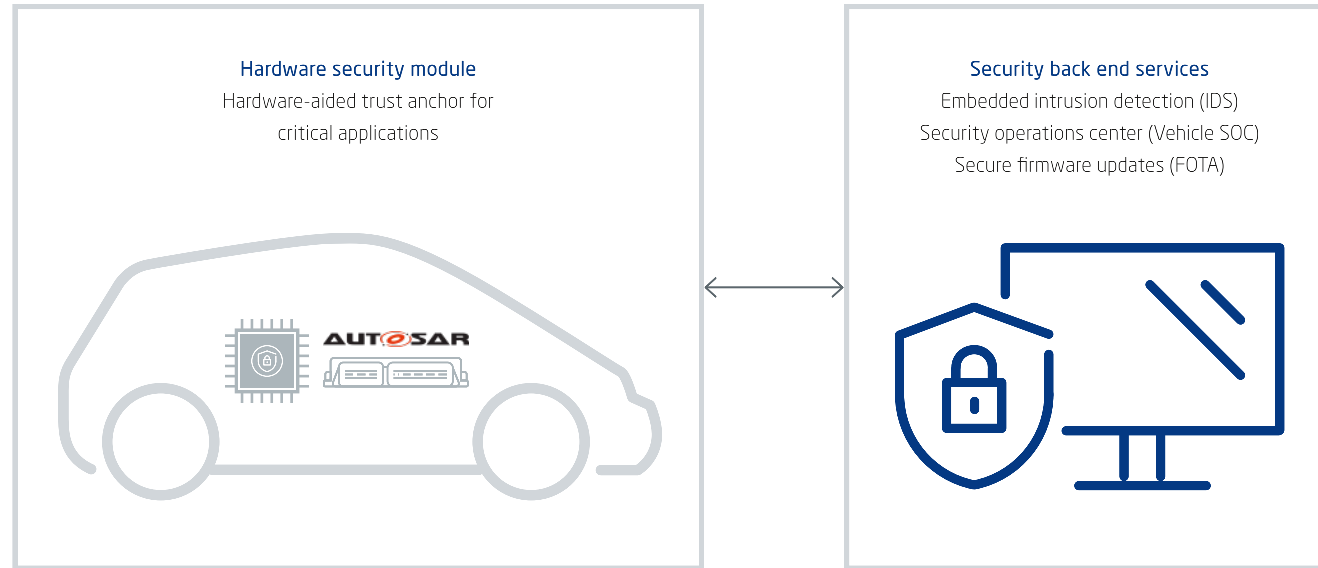


Figure 4: Integrated automotive cybersecurity with the hardware security module as a trust anchor in the microcontroller and vehicle security monitoring throughout the entire vehicle life cycle.

In addition, the level 3 communication middleware ensures that the dynamic, flexible Adaptive applications and the other software applications can be integrated into the system. As a core component in RTA-VRTE, communication management controls and regulates the interaction between the levels and guarantees the smooth operation of the encapsulated software including the ECU- and vehicle-dependent platform services on levels 4 and 5. In securing end-to-end communication between services offered by authenticated applications, this function is also highly relevant to cybersecurity.

RTA-VRTE communication management together with ECU-specific services on level 4 provides application developers with a versatile framework for automotive applications. To provide security, this level also features an update and configuration manager (UCM), which supports authenticated updates of individual applications and coordinates them across the entire platform. On level 5 of RTA-VRTE, the AUTOSAR++ aspect allows the integration of whole-vehicle and even fleet-wide functionality, providing robust over-the-air (OTA) updates of the RTA-VRTE AUTOSAR Adaptive application set.

Outlook: comprehensive security beyond AUTOSAR Adaptive

In 2020, RTA-VRTE began to be used around the world in projects aiming to bring AUTOSAR Adaptive vehicle platforms to production. In addition, ETAS and ESCRYPT offer an Early Access Program (EAP) that enables OEMs and suppliers to establish the development methodology of next-generation hybrid E/E architectures while implementing the security components already available through AUTOSAR Adaptive.

Beyond these security modules, what is required are truly comprehensive cybersecurity concepts for connected, automated vehicles. This starts with hardware security modules (HSMs) as trust anchors to physically encapsulate cryptographic key material in VC microcontrollers or in ECUs. And it extends to fleet-wide vehicle protection over the entire life cycle together with embedded in-vehicle attack detection, a vehicle security operation center (VSOC) in the back end, and firmware over-the-air (FOTA) security updates (Fig. 4).

The RTA-VRTE platform software framework enables developers to bring AUTOSAR Adaptive-based E/E architectures to life in a virtual setting today. In so doing, it expands the basis for comprehensive protection against cyberattacks, which in the vehicles of the future will have to extend from the microcontroller to the in-vehicle network and to lifelong, fleet-wide monitoring.

Authors

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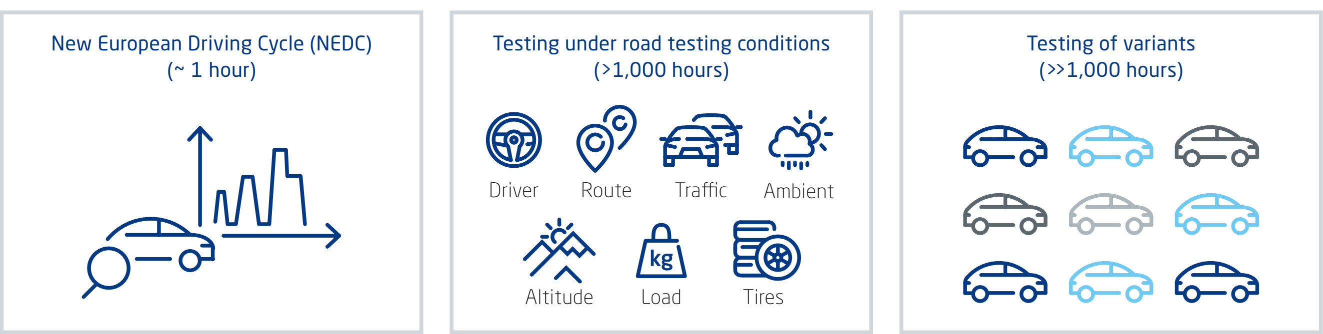
Developing low-emission powertrains with AI and in the cloud

Huge efficiency gains from cloud-based simulation

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

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

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



Systematically driving ahead with virtualization

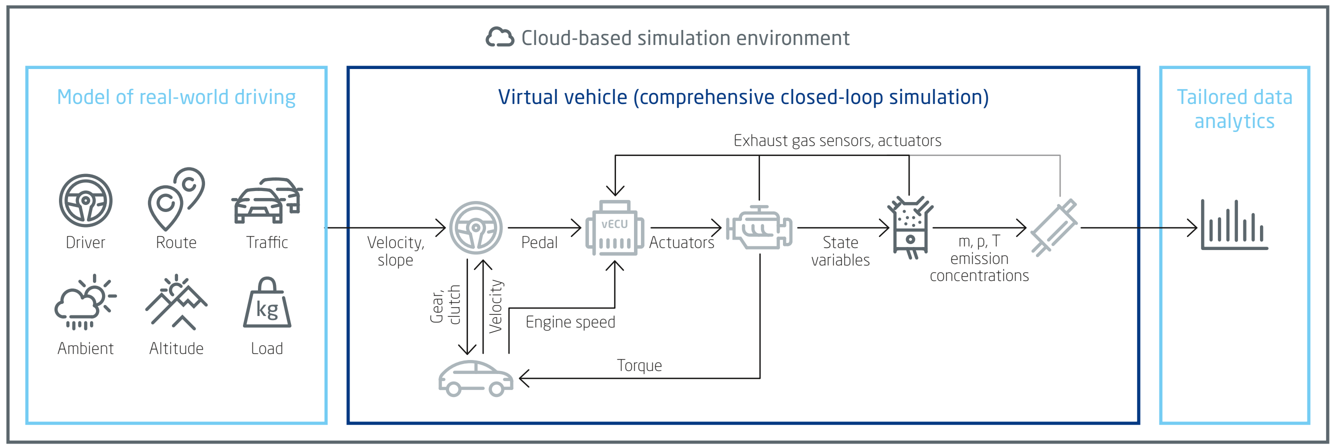
ETAS recognized the potential of virtualization early on and has spent years building up a portfolio of solutions for the simulation of individual components and entire vehicles. In the current situation, in which increasingly complex powertrains in a rising number of variants must be tailored to the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

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

Cloud opens up new potential for efficiency and quality

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

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



Virtualization services: Customized virtualization of emission-capable powertrain system models (virtual vehicle).

Software services by ETAS: Scaling cloud simulation to enable fast development iterations. AI-based generation of statistically representative drive cycles.

AI approach

Physical models

Figure 2: Cloud-based development environment.

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

The challenges of real-world driving

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

Making virtual vehicles available in the cloud

With the ETAS virtualization tool kit (see Fig. 3) ready for use, the next goal was to allow users to make productive use of the new all-in-one solution within the ETAS cloud services. The steps to achieve this included a thorough risk analysis by ESCRYPT, which produced a comprehensive security concept to protect the highly sensitive processed development data. ISO 27001 certification is now underway.
Much like the Software-in-the-Loop (SiL) method, the virtual ECU is incorporated in the virtual vehicle as a functional mock-up unit (FMU). It exchanges data via standard buses with the models incorporated in the respective simulation. In powertrain projects, the virtual vehicle offers precise reproduction of exhaust emissions from the tailpipe. To achieve this, the team incorporated sophisticated exhaust gas treatment models and a raw emissions model for the combustion engine, which were created using ETAS ASCMO.

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

Summary and outlook

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

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

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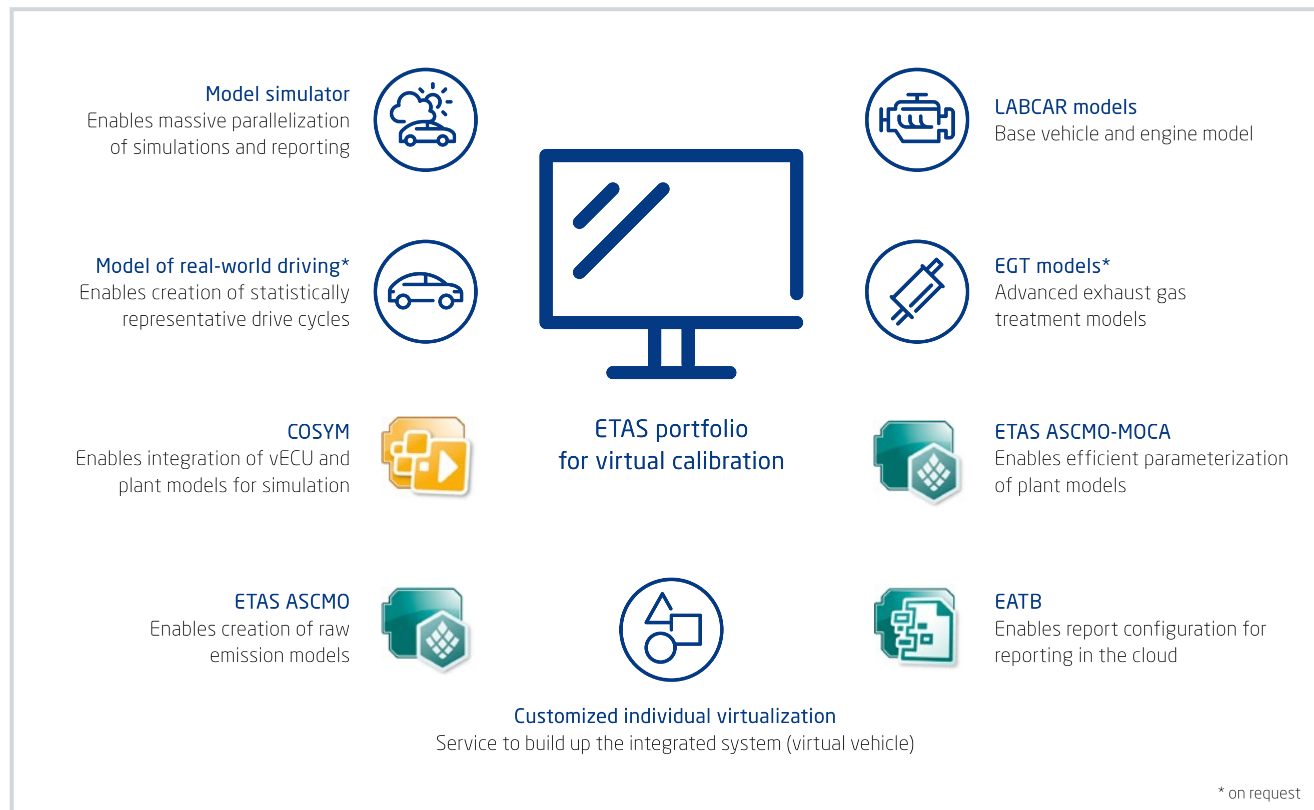
Figure 3: Modular, freely scalable solution for the development of a virtual vehicle.



Next generation large scale prototyping

ETAS comprehensively supports Nissan's model-based development

Model-based design/development (MBD) and Rapid Control Prototyping (RCP) are essential for developing high quality control software with higher efficiency. However, in the case of large scale software – such as engine control – up to now, RCP could only be used for some parts of the development process. Nissan Motor Corporation and ETAS took on the challenge of jointly developing an RCP environment for large scale control software models for series production projects.

Handling increasing scale and complexity

In order to comply with ever-increasing environmental regulations, engine control software has become larger and more complex than ever before. To master this challenge, Nissan started to introduce MBD in the 1990s with the aim of creating an environment in which software can be developed with higher quality and in a shorter period of time.
Since 2019, Nissan has been using its third-generation MBD process in about 85 percent of the company's projects.

Recently, Nissan has redesigned its engine control software, adopting a new architecture called Nissan Engine Management System (N-EMS). But N-EMS still had room for improvement, especially when it came to efficiencies across the entire alliance group. This alliance also includes Renault in France, where the software architecture is different.

In addition, the AUTOSAR standard is used comprehensively to further improve development efficiency and significantly reduce development costs. Nissan is currently working with alliance companies such as Renault to define an AUTOSAR-based Alliance Engine Management System (A-EMS), featuring a common global control software architecture and fourth-generation MBD process.

Double V-cycle enables sharing and effective use of models

Nissan has adopted the double V-cycle, a hierarchical development process that combines two MBD V-shaped cycles (Fig. 1).

In the first V-cycle, a model of reusable, validated software components (SWCs) is developed. This model is registered in a common database library and is shared in development projects within the company and among alliance companies.

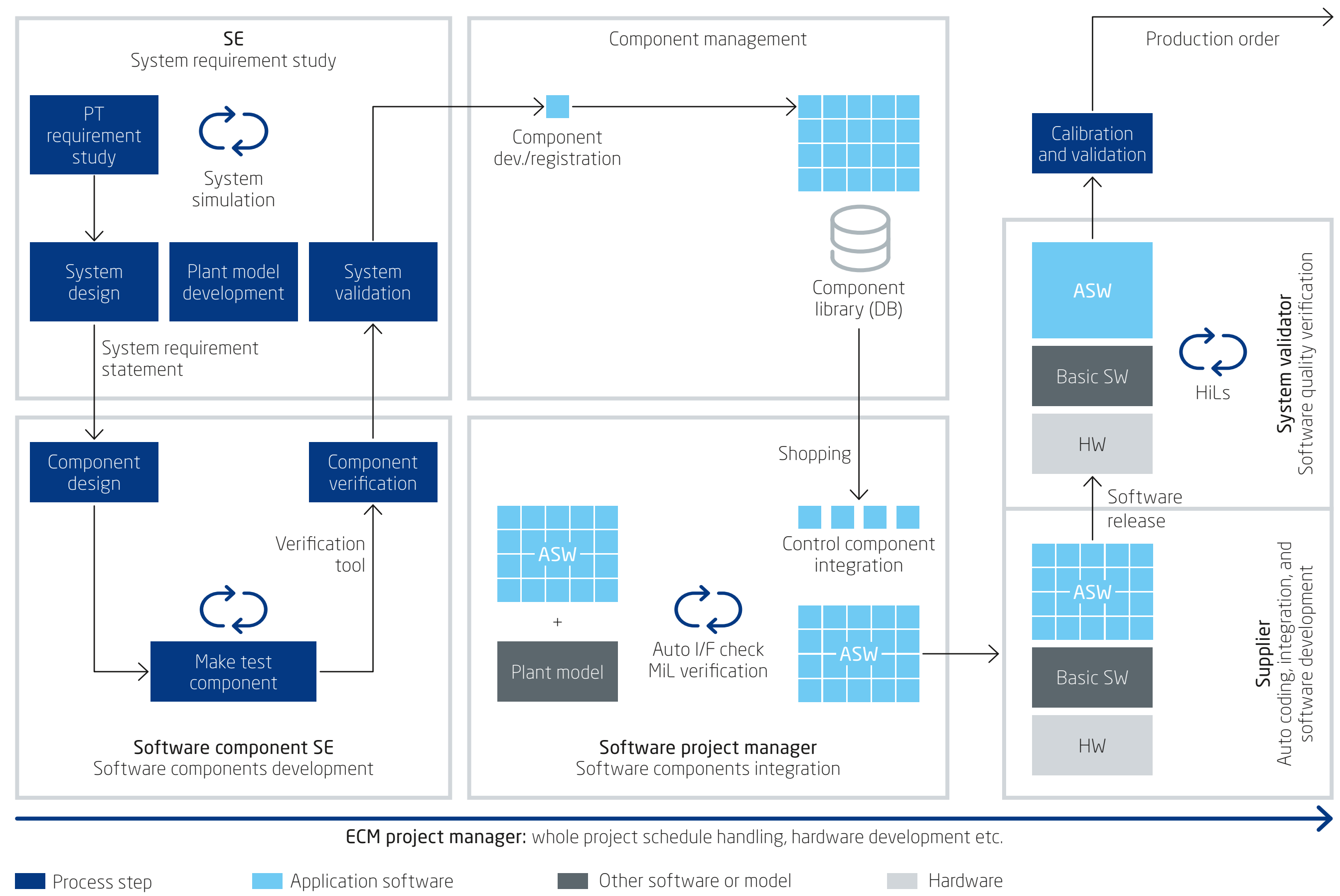
The second V-cycle assembles the control software according to N-EMS and A-EMS rules and processes. The application software (ASW), which greatly affects engine performance, is developed independently by each automaker.

The basic software (BSW) and OS which are not part of the immediate project scope are designed or selected by suppliers. The automaker then creates a model of the entire ASW, called a "template" by combining the parts in the library. The supplier incorporates this template model into the BSW and OS and automatically generates serial production code.

Develop an evaluation process

So far, there was no RCP environment for the complex entire ASW. Hiroshi Kato, senior manager of the EMS Control Technology Development Group, Nissan Motor Corporation, explains, "We decided to establish an evaluation process and toolchain to create an RCP-suitable engine control ASW, developing the fourth generation of MBD in parallel." If a bypass for the entire ASW, called "full bypass," could be realized, Hardware-in-the-Loop (HiL) tests or actual device evaluation for the entire ASW would be possible, resulting in a dramatic shortening of the evaluation period and reduction of development cost. Also, by seamlessly connecting to the "full Model-in-the-Loop (MiL)" environment for the entire ASW, consistent testing would become possible.

Figure 1: Nissan's double V-cycle powertrain control development process.



Harmonizing the toolchain, with INCA as an essential component

Nissan's previous partial bypass evaluation had problems with the connection of tools from different vendors. A unified toolchain with all tools from one vendor would create efficiencies by providing a consistent usage method for all users during calibration and validation.

"There are two tools in the MBD control development process that are hard to replace. The first is MATLAB®/Simulink® from MathWorks for model development. The other is INCA from ETAS, which has been the standard tool used by the powertrain industry for many years," says Kato. Using MATLAB®/Simulink® and INCA was also a requirement from Renault.

Keeping INCA was not the only reason for Nissan to choose ETAS as its co-development partner. Nissan also has a high regard for ETAS as a vendor who could fulfill all requirements. According to Kato, "Many vendors only bring proposals that include products they can offer themselves. However, ETAS set objective evaluation criteria that could be disadvantageous to their company, and if one recommendation didn't work, they would immediately suggest a second solution. So we had high expectations of them as a reliable partner."

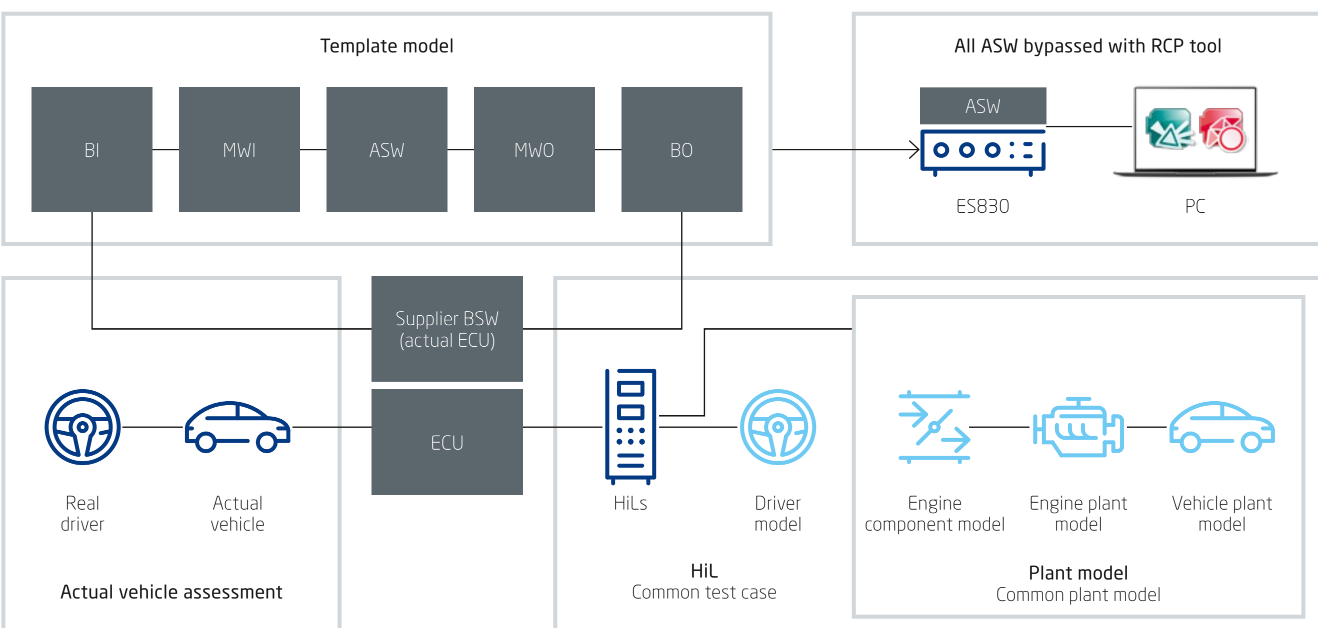
Figure 2: Full bypass RCP environment jointly developed by Nissan and ETAS.

The four key points for success

There were four key points to realize this full bypass RCP evaluation process and toolchain for a whole project, which contained more than 1,300 models (Fig. 2). The first point was the processing performance of the RCP tool. Among ETAS' RCP tools, the potential candidates were the ES910 and the more powerful ES830, which had only just been released at the time of the study. The second was the capabilities of the communication interface. Considering the amount of data to be transferred between the ASW and the BSW, the developers decided that ETK, XETK, and FETK would be the possible options for the ECU interface.

Looking back on the tool selection process, Kato says, "At that time, we were optimistic that we could run the model even without using very high-performance hardware. When we actually tested the ES910, we discovered that we needed much more processing than we had anticipated. So during the weekly meetings with ETAS we discussed alternatives and the pros and cons of using the more powerful ES830. ETAS was still in the final stages of developing the ES830, but we decided to use it as an early adopter and perfect its development together." We also decided to use the XETK interface for fast data transfer.

The third key point was improving the speed and efficiency when building the development environment. There were many things to do, such as global standardization of the architecture, and Nissan suffered from a lack of resources. "If it hadn't been for the quick and accurate support we received from ETAS, we wouldn't have been able to complete the project," says Kato (Fig. 3).



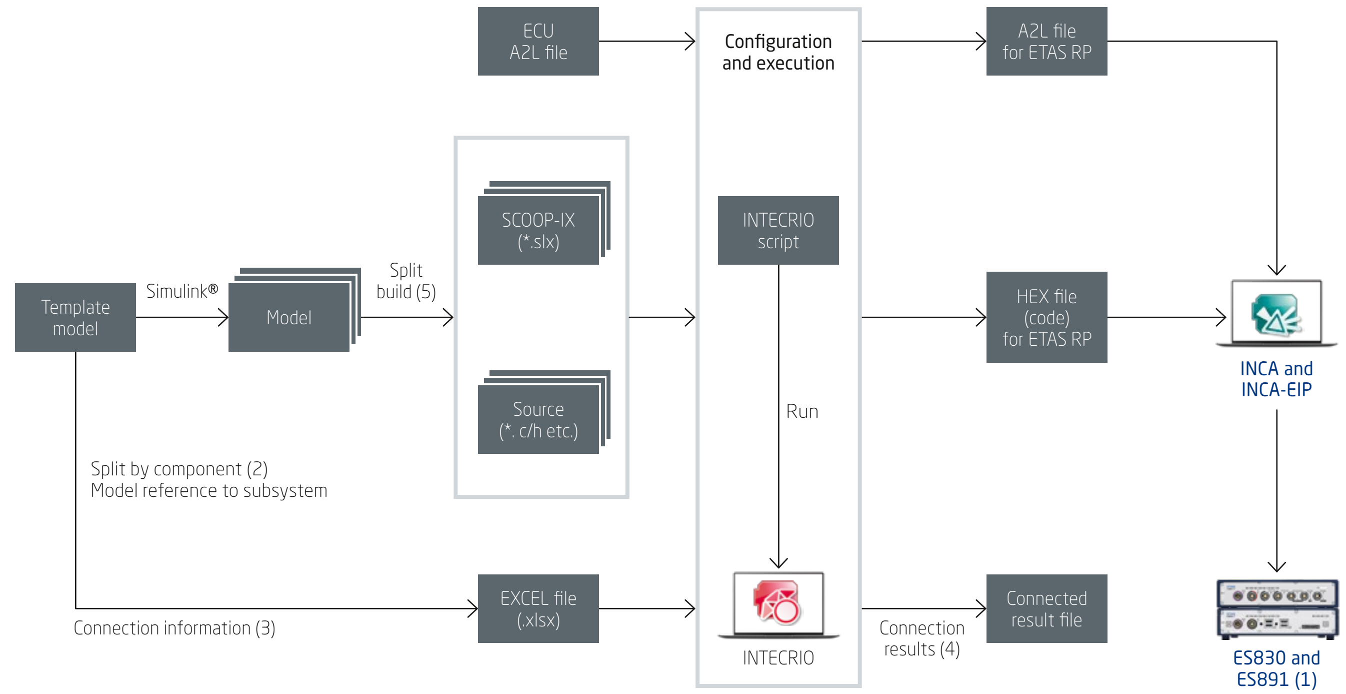


Figure 3: Contributing to improving the speed and efficiency of environment construction as a partner.

In order to further increase evaluation efficiency, the team jointly developed a number of features:

- A mechanism that would allow developers to build only the changed part when the model was changed (1 and 2)
- A mechanism to extract the connection information between models that was required for integration with INTECRIO from the template model (3)
- A function to check the connection result such as the presence of unconnected ports (4)
- A function to handle bypass-side calibration variables with only a label name in the same way as on the ECU side (5) and script automation for each process step

The fourth key point was compatibility with AUTOSAR. Using this standard, the bypass was implemented at a common level to ensure cooperation between automaker and supplier platforms for ASW and BSW. The non-volatile memory in the ES830 was used for RCP. The existing third-party interfaces were replaced by a simplified model for supplier diagnosis and data monitoring.

Evolving together as win-win partners

By coming together for this joint development, Nissan and ETAS were able to build an unprecedented RCP for large scale models that can handle the overall engine control application and can be applied to serial production projects.

Users can now perform simulations and bypasses in the same way that they collect measurement data, with the familiar INCA user interface. ETAS fully supported users, such as by providing a manual for the evaluation work procedures and tool operating methods. Kato says, "We have already begun applying the evaluation environment to our latest engine projects and we are beginning to see the effects of improved development speed, improved quality, and reduced development costs. Going forward, we intend to expand to e-POWER and EV development of Nissan original HEVs, so I expect that we will gain even more clear benefits when we fully utilize the technology."

The joint development of full bypass RCP with Nissan was also a big challenge for ETAS. Working to meet the cutting-edge technological requirements of this project, ETAS engineers and developers gained experience in the issues they will face in the future and were able to improve the ES830 and other RCP-related products. This win-win relationship between an automaker and ETAS will serve as a driving force to further evolve the development environment of automobiles.

Interviewee

Hiroshi Kato is Senior Manager of the EMS Control Technology Development Group, Powertrain/EV Control Development Department, Powertrain/EV Technology Development Division at Nissan Motor Corporation.

The challenge to develop the powertrain of the future

Successfully mastering the testing and validation of fuel cell ECUs

To make mobility more sustainable, automakers are turning to battery-electric and fuel cell-based powertrains. To enable the efficient development and testing of fuel cell ECUs, innovative test and validation methods are required. ETAS delivers these in the form of a comprehensive package combined with simulation models.

The development of fuel cell-based powertrains is gaining attention and gathering momentum not only in the automotive industry, but also in government, especially among environmental policymakers. Particularly in the commercial automotive engineering sector (goods transport, public transport, etc.), fuel cell technology offers major advantages over purely battery-electric technology in terms of energy density, charging/refueling time, and so on.

To realize these advantages, however, fuel cells must continue to improve on a chemical, mechanical, and electrical level. Moreover, their electronic control with ECUs continues to pose challenges. Overcoming these challenges requires efficient test and validation methodologies targeted specifically at fuel cells.

Virtualization supports efficient software development

The primary goal of the HiL system setup is to simulate the driver, the vehicle, its components, and the environment as realistically as possible and necessary. The accuracy of the simulation can be defined based on quality metrics, which are set in close collaboration with the development teams involved in each particular project. Virtualization improves software development efficiency and reduces its time and cost. It does this by making major contributions to the progress of software development from the early pilot phase. With the HiL approach, safety-critical functions of ECU software such as hydrogen leak detection, safety concepts, and the activation and pre-charge algorithms of electrical components can be tested early on at the function developer's desk. The resulting embedded controls software can be seamlessly transferred into the laboratory for parallel testing.

Fig. 1 shows the front view of a fuel cell HiL system. It provides analog and digital input/output hardware boards and bus communication interfaces (CAN, LIN, etc.) for configuration purposes. It also offers the option of incorporating real or simulated electronic loads for special functionalities. For example, a hydrogen-gas injector can be simulated with high accuracy using an electronic injector load module in the HiL system. The fuel cell model is designed for operation under strict real-time conditions on a real-time simulation computer. The software integration platform ETAS COSYM serves to connect the inputs and outputs of the physical fuel cell simulation model to the inputs and outputs of the HiL hardware. The fuel cell ECU calibration interface closes the loop between simulation, fuel cell software interaction, and the simulated fuel cell system.

Based on an exact physical simulation model

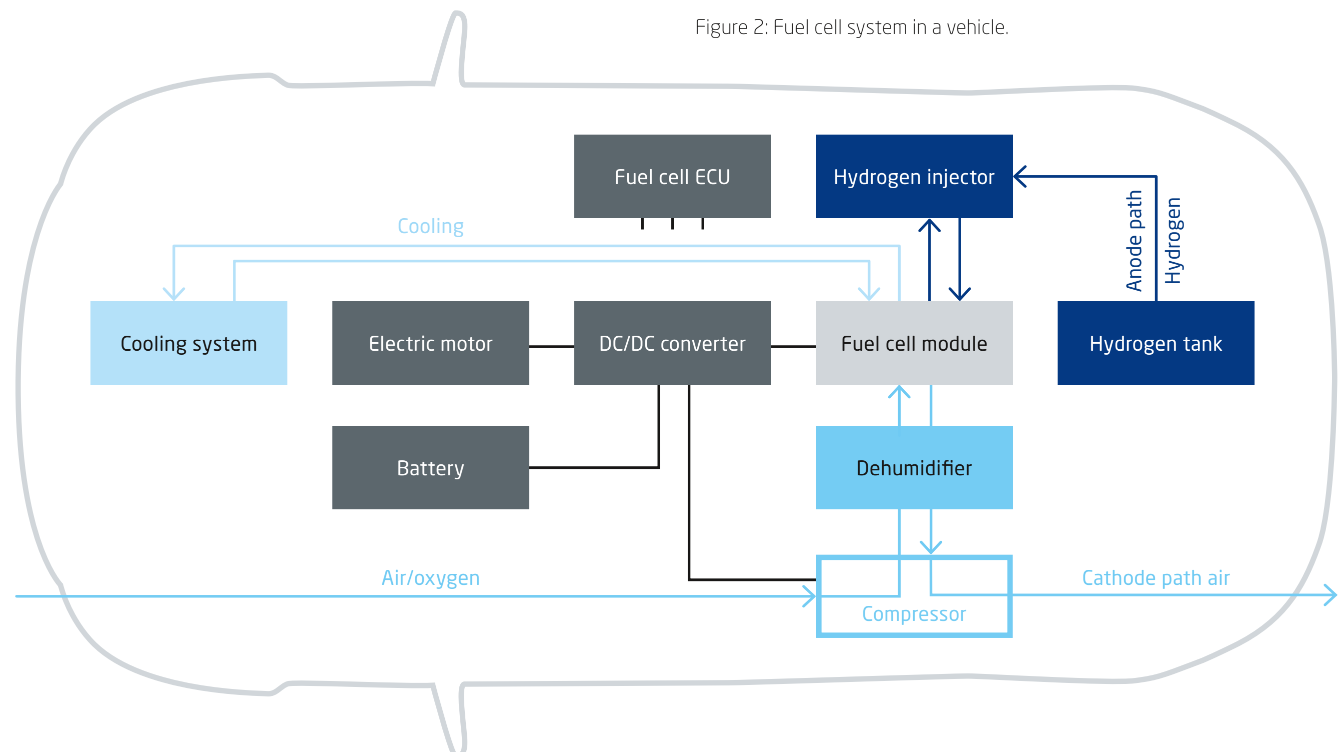
The core component of the HiL system is the physical simulation model of the fuel cell system ETAS LABCAR-MODEL-FC. This consists of five main parts (Fig. 2) that have a significant influence on the efficiency of the fuel cell system:

- Fuel cell module
- Anode path with hydrogen supply/tank
- Cathode path for the air supply
- Cooling for system temperature control
- Electrical high-voltage path for energy storage, voltage conversion, and electrical load (electric motor)

Figure 1: Front view of a fuel cell HiL system.

In order to run this simulation model on the HiL system, some important conditions must be met. For one, the software model must be executable in real time. Furthermore, the single-cell fuel cell model must be capable of precisely simulating physical laws, such as losses and other effects that influence electric current, temperature, and electrical resistance stoichiometry.

Figure 2: Fuel cell system in a vehicle.



A detailed water composition and a two-phase water model calculation are also required to represent the motion and states of aggregation of water in the gas channel. Equally important in this context is the ability to specify the individual gas composition of each electrode and describe pressure loss characteristics. A 1D multicomponent gas channel model can be used for this purpose. Moreover, support is required for a variety of flow field designs and the detailed calculation of internal cell humidity.

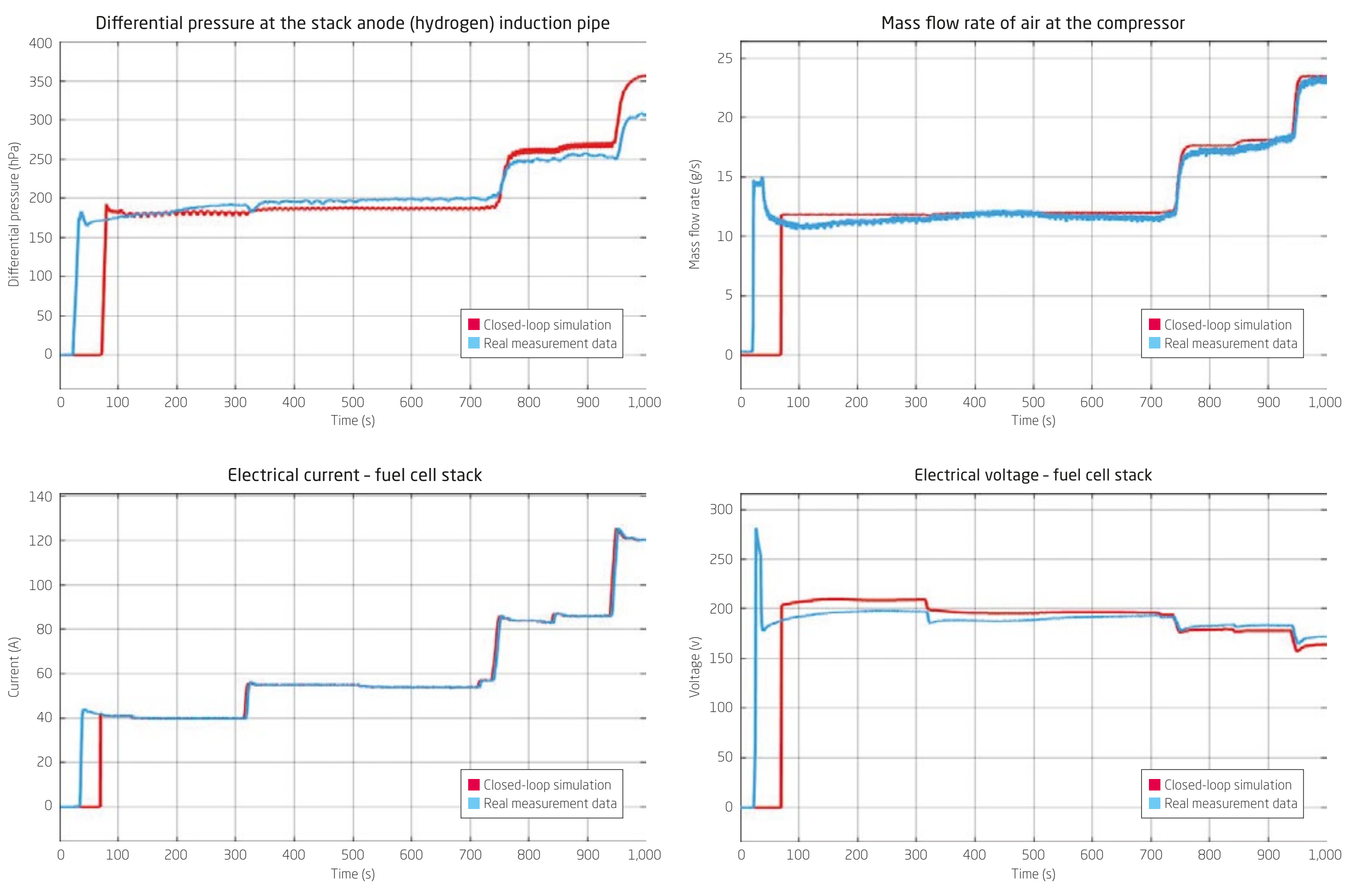
In addition to these basic functions, a highly accurate and precise simulation of cold start behavior in fuel cell operation is also necessary. This requires a membrane temperature model as well as the incorporation of non-linear dynamics of the cell water composition and temperature-dependent fluid properties. Ideally, a model library would also be implemented to enable use of the simulation model on a variety of fuel cell architectures.

Practical implementation

ETAS has systematically put these requirements into practice. As shown in Fig. 4, individual fuel cells can be separated into multiple segments along the gas channel. While the Z coordinate follows the gas flow, the X and Y coordinates are arranged perpendicular to the membrane and gas channel. Each segment addresses all the functional layers of the fuel cell, including bipolar plates, gas channels, gas diffusion, and membrane. The same system of equations can therefore be used for both individual segments and an entire cell. Mass and heat flows connect the segments and layers of the cell. Exchange between model segments only takes place via heat and mass exchange in the gas channel and bipolar plates.

By contrast, the membrane electrode arrangement (MEA) hardly contributes at all to the energy exchange with adjacent segments. Furthermore, its expansion in the X direction is in orders of magnitude smaller than in the Z/Y direction. Spatial pressure and concentration gradients – which drive proton and water transport through the cell – therefore occur primarily in the X direction. To model the spatial characteristics, it is sufficient to focus on the gas channel and bipolar plates. This kind of MEA model can be evaluated segment by segment and is not directly influenced by the 1D model.

Figure 3: Comparison between results of LABCAR HiL simulation (red) and vehicle test drive (blue).



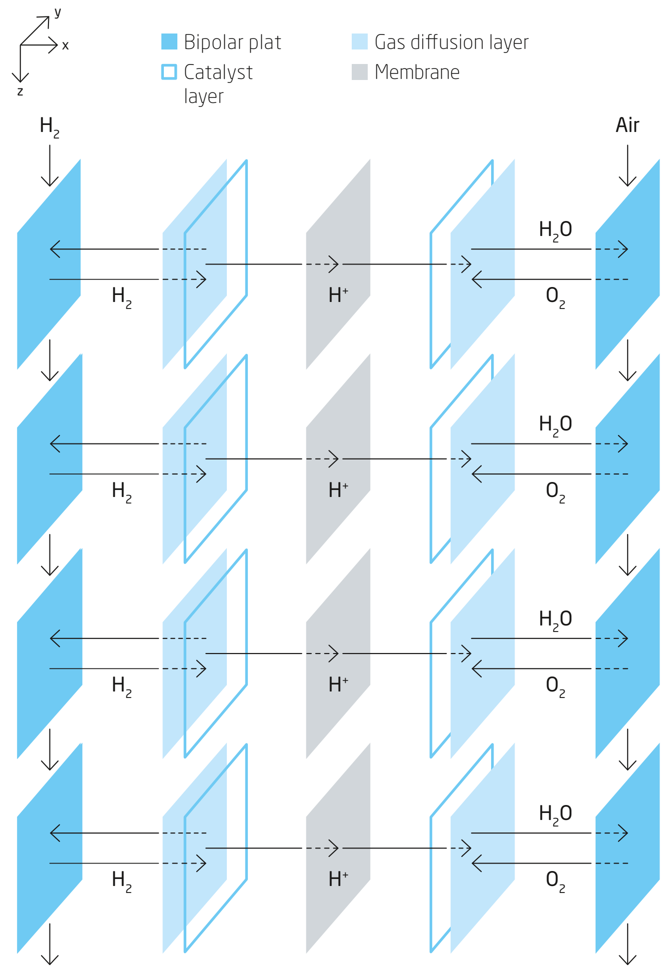


Figure 4: Separation of the fuel cell into individual segments.

The ETAS approach is rounded out with a library of components including the hydrogen gas injector, hydrogen recirculation blower, vent valve in the anode path, air compressor and humidifier in the cathode path, cooling pump, MCV valve in the cooling path, safety circuit, and DC-DC high-voltage input. The result is a complete fuel cell plant model for use in the HiL system.

Application

The performance and precision of the ETAS solution is illustrated by a comparison between the results of an uncalibrated real-time LABCAR HiL simulation platform (Figure 3, red line) and a vehicle test-drive (blue) using the same fuel cell ECU.

The anode (hydrogen) differential pressure follows much the same path as in the vehicle test-drive. The mass flow rate of "air" at the compressor also sees a largely equivalent trend between the test run and model. Moreover, the electric current and electrical voltage delivered by the fuel cell also exhibit close correspondence between the model and vehicle data.

Yet this solution offers still more potential. The accuracy of the simulation can be optimized further by calibrating the fuel cell model in advance using test bench measurements, for example with ETAS ASCMO-MOCA. Currently, the fuel cell model offers the ability to set some 350 parameters for this purpose, thereby giving developers the flexibility to cater to the requirements of a variety of ECU software projects. They can also improve the simulation results further by integrating additional simulations of the electric motor, battery, or vehicle dynamics.

The fuel cell model can be deployed not only for test and validation on the HiL system, but for example also for virtual test runs in the early phases of software development. The ETAS COSYM XiL test platform allows the software functions to be validated in a closed-loop experiment while also enabling the simulation model to be integrated into a higher-level vehicle model that is also simulated. By simulating all the vehicle buses – such as virtual CAN and Automotive Ethernet networks – developers can achieve a realistic analysis of network communication even at this early stage of development.

Summary

Safety, performance, and monitoring of powertrain components will continue to be important parameters for the development of electrified powertrain components in the future. For the development and refinement of fuel cell ECUs in particular, precise, real-time simulation of the fuel cell provides the basis for validation on the HiL test bench. Furthermore, the use of SiL test platforms enables concurrent tests to be performed even at an early stage of development. The XiL solution from ETAS presented here – together with the simulation models – provides the basis for highly efficient development of fuel cell ECUs in accordance with all safety requirements. It brings the fuel cell one step closer to being incorporated in the large scale series production of tomorrow's climate-friendly vehicles.

Authors

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Complex engine simulation using LABCAR-MODEL

Tata Motors' experience on how ETAS LABCAR-MODEL-VVTB and LABCAR-MODEL-ICE helped validate various features of an engine management system

To meet the government's requirements, the validation team of the Passenger Vehicle Business Unit of Tata Motors, decided to use ETAS LABCAR and associated LABCAR models. Using a closed-loop simulation, the team was able to verify the cases that do not require a real vehicle.

The government of India decided to skip an entire regime of emission standards when it announced its plans to shift directly from BS IV to BS VI in 2016. Moreover, this was to be done in four years, by 2020. This regulation not only imposed more stringent emission targets, but also called for next-level OBD (onboard diagnostics) and RDE (real driving emissions) readiness by 2023. Alas, the world's fourth largest automotive market is not considerate enough to let companies focus exclusively on the powertrain. The peer pressure to constantly roll out and upgrade chassis, body features, infotainment, safety standards (for example ABS: Anti-Lock Braking System is now compulsory for all vehicles), and other comfort features is tremendous.

Given all these demands to contend with, engineers are hard-pressed to validate the entire vehicle communication network and the various features of ECUs in the network. Testing in a real vehicle was the conventional approach for validating various vehicle functionalities. Given the limited availability of prototype and test vehicles, it is always a challenge to deliver test results, validate different scenarios, and execute automation in the available limited time. In order to address these various challenges, the validation team of the Passenger Vehicle Business Unit of Tata Motors decided to use a combination of a HiL system and compatible LABCAR models.

The HiL system enables the Hardware-in-the-Loop (HiL) tests. LABCAR-MODEL-VVTB (Virtual Vehicle Test Bench) simulates vehicles with highly accurate models, while the LABCAR-MODEL-ICE (internal combustion engine) simulates the IC engine. This test environment satisfies nearly 95 percent of the testing needs.

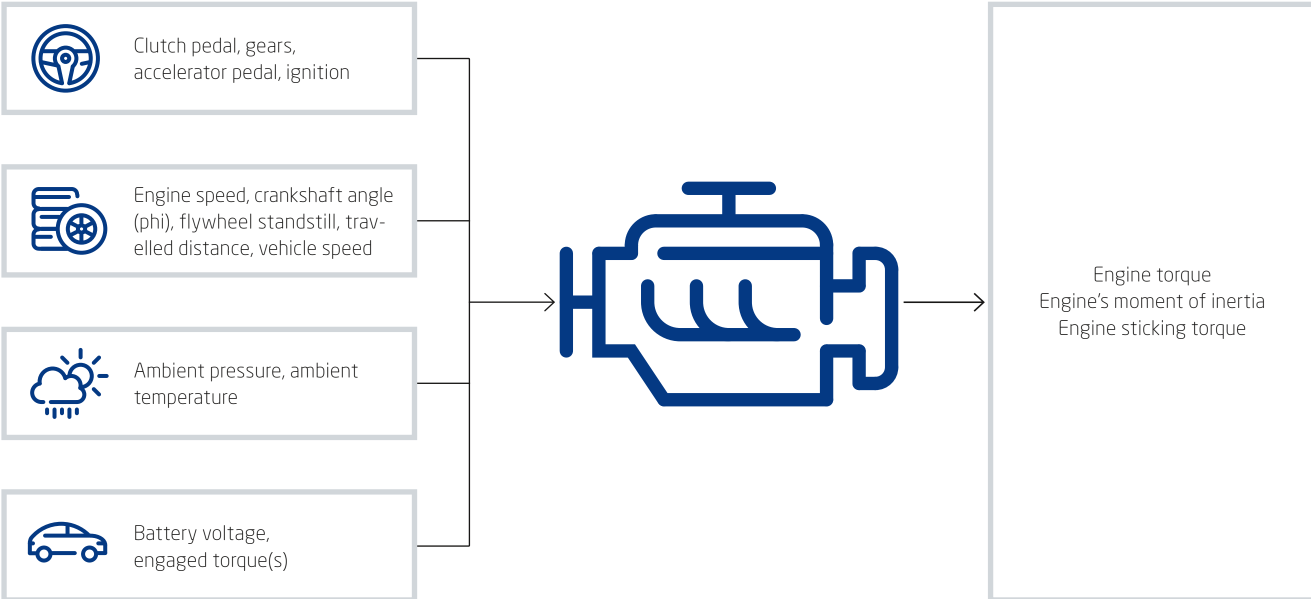
The test system

ECUs from the vehicle are connected to LABCAR. These ECUs are part of a network, much like that of a real vehicle. Along with the simulation models of engine, transmission, and drivetrain, a near-vehicle simulation environment can be achieved.

LABCAR-MODEL-VVTB and LABCAR-MODEL-ICE

Virtual Vehicle Test Bench furnishes the basic model architecture for simulating different components of a vehicle. It consists of a driver model, an environment model, and a vehicle model with engine, dynamics, drivetrain, and transmission. This flexible architecture allows components to be replaced with detailed models when needed.

As an example, the engine model can be replaced with the detailed and accurate internal combustion engine model LABCAR-MODEL-ICE. This in-house Bosch model for testing and pre-calibrating gasoline, diesel, and CNG engines includes the main subsystems of an ICE – that is, the intake/exhaust, fuel, combustion, and after-treatment systems. It provides variables at each sublevel for the customer to parameterize and to achieve the desired engine specifications. LABCAR-MODEL-ICE is a richly detailed mathematical and data-driven model that calculates engine parameters (see Fig. next page) such as torque, moment of inertia, RPM, and the like based on various vehicle input parameters and the ECU control logic.



LABCAR-MODEL-ICE calculates various engine parameters.

LABCAR VVTB-ICE models in action

Tata Motors is using the VVTB-ICE model pairs to simulate the vehicle and internal combustion engine environment in the test system. ETAS India and the RBEI (Robert Bosch Engineering and Business Solutions) Global Testing Team tapped its engine parameterization capabilities for the customer vehicle lines for both diesel and gasoline engines. The focus of parameterization was on error-free (nil DTCs) verification of functionalities required by the team. The gasoline engine was parameterized for the Bosch ECU. During the acceptance phase, the customer team randomly verified the various functionalities to ensure smooth operation. VVTB and ICE models proved highly stable during prolonged runs, yielding accurate and consistent results at every point of simulation.
ETAS Real-Time PC (RTPC) features a high-performance computation platform that enables highly complex models to be run at a higher resolution in order to obtain more accurate results.

With this real-time closed-loop simulation, the team was able to verify the majority of all functions for cases that do not require a real vehicle. The team was also able to conduct repetitive tests and multiple test runs, which is hardly feasible with an actual vehicle. Another benefit of an accurate closed-loop simulation is the option of running the vehicle at different conditions such as high speed, high RPM for longer periods, and so on. The team was also able to conduct several automated tests quickly in the test system that otherwise would have required protracted manual tests.

Outlook

Accurate, high-fidelity simulations are an important asset for all system testing requirements. LABCAR models are built to meet these market needs. Paired with advanced ETAS tools like ETAS ASCMO-MOCA and engineering services, LABCAR-MODEL-ICE and -VVTB can serve to pre-calibrate EMS software in a HiL system. The team is currently validating the various ECUs across the vehicle network for different platforms. It benefits from accelerated automated validation with increased accuracy. This will surely expedite testing and support rollout of new vehicles with more mature ECU software. With advanced solutions, the team is well prepared to handle the validation challenges of the future.

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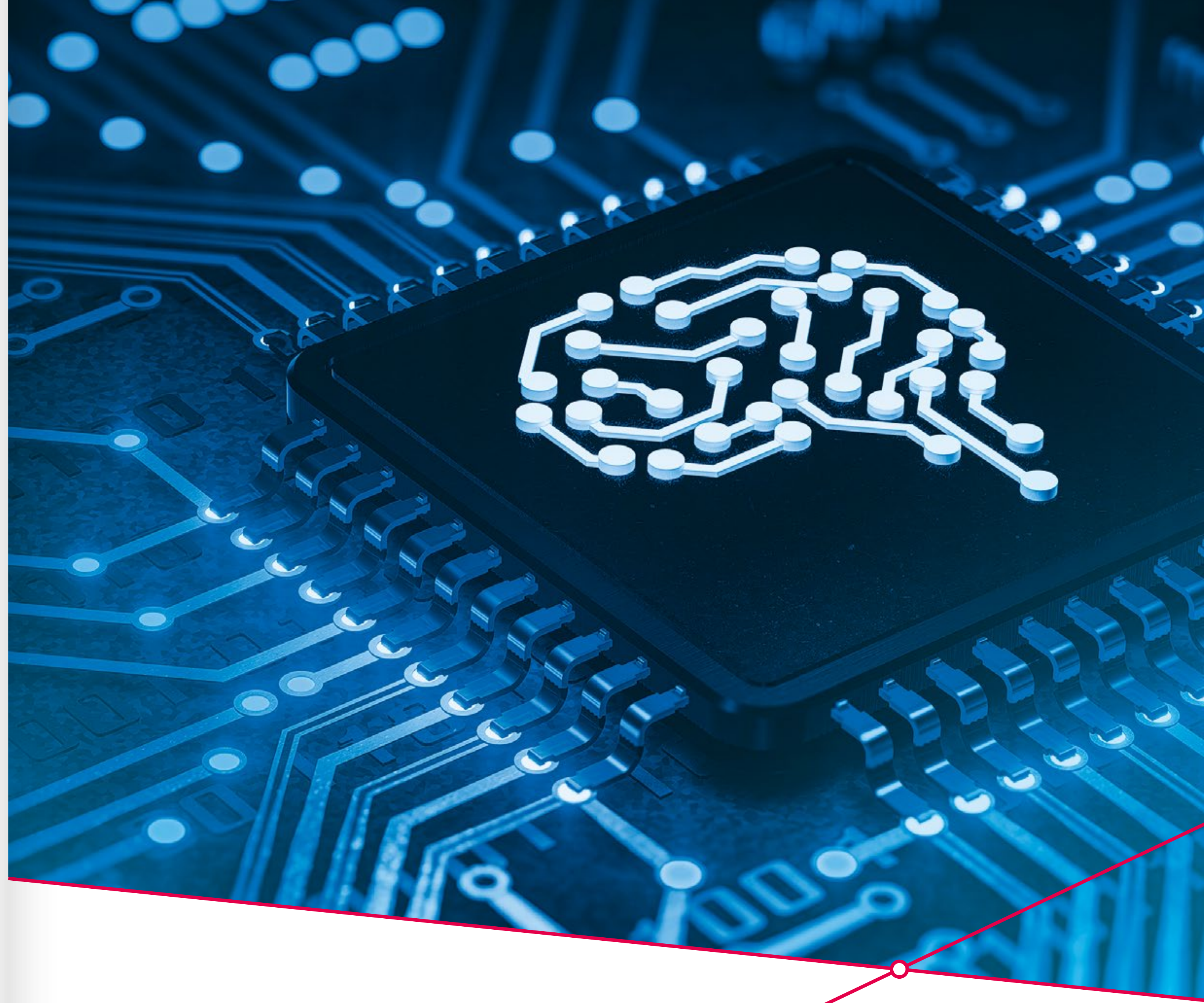


Embedded Artificial Intelligence

New capabilities in engine controls development

The latest engine control units (ECUs) come with a new generation of high-performance system-on-chips to increase available computational power. These devices have the ability to provide onboard resources to support unexpected feature growth and on-demand customer requirements. Infineon and ETAS worked together with Ford Research to demonstrate the use of data-driven modeling algorithms directly on the ECU as a remedy for the limitations of classical control strategies.

More stringent emissions legislation and the increasing complexity of recent technologies such as hybrid electric vehicles and autonomous driving are pushing the need for more advanced control functions in engine management systems. Traditional control strategies and virtual sensors introduced on ECUs have been limited to calibration maps of up to two input dimensions to deliver the desired engine behavior for various operating conditions. Higher-dimensional relationships are possible when combining a map's output with other calibrations. However, only two input parameters can be processed simultaneously on the ECU core. Considering the requirements of upcoming ECU controls and the necessary calibration effort within the development cycle, the map-based approach is only applicable to a limited extent. As a remedy, data-driven models have the potential to replace and outperform traditional map-based structures in cases where multidimensional and non-linear behaviors cannot be captured with sufficient accuracy.

Data-driven system identification ETAS ASCMO

Data-driven modeling refers to approximating the input/output behavior of a physical system through the aid of mathematical equations. A set of model parameters is inferred from a representative set of measurement samples collected under operating conditions. ETAS ASCMO uses Gaussian Processes, a Bayesian modeling approach, to generate high-fidelity data-driven models. The model creation is executed automatically and does not require any parameterization effort by the user. The tool may be used without any knowledge of the underlying principles and may deliver similar or even better model accuracies than comparable data-driven solutions. For the model's application in embedded environments, ETAS ASCMO provides a model compression feature to minimize the computational impact and to guarantee real-time execution.

Infineon's hardware accelerator Advanced Modeling Unit (AMU)

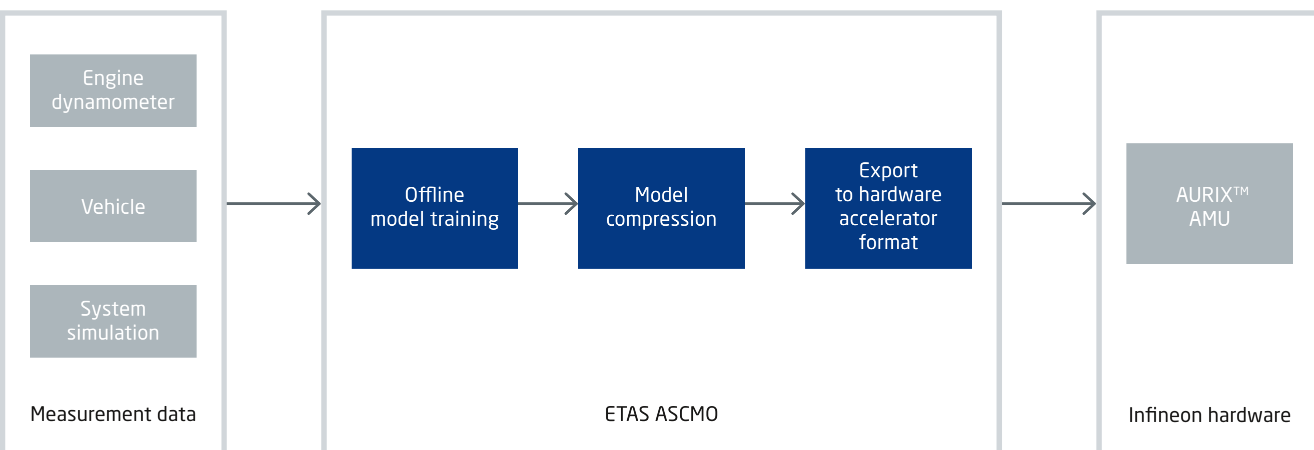
ECU function developers are faced with limitations when implementing complex data-driven modeling algorithms on microcontroller-based architectures. The new hardware accelerator Advanced Modeling Unit (AMU), which was developed with intellectual property from Bosch, is a floating-point coprocessor to increase performance of critical applications by off-loading the computation from the central processing unit (CPU). The AMU is available on Infineon TriCore™ AURIX™ TC3x microcontrollers and provides hardware logic to perform exponential function calculations (e.g., Radial Basis Function – RBF) necessary to run ETAS ASCMO models on chip without software and CPU resources. An example for a RBF-based use case can be a virtual sensor calculation, which, in comparison to a software implementation on the main TriCore™ CPU, achieved hardware acceleration by a factor of greater than 30 [1].

ETAS ASCMO and AMU within the application

In traditional development methods, models are developed based on system physics and fundamental engineering principles. These models are generally designed once per system type and then reused across many applications. A lot of data is collected in order to gain sufficient understanding of the system so it can be modeled as part of the development process. The intent is for the models to be identical across the various applications and differ only in the calibration for a specific application.

Software development with ETAS ASCMO and AMU is slightly different from traditional methods (Fig. 1). Only the inputs that may contribute to a particular output need to be identified during software development; the specific relationship between inputs and output is not needed. Required data for training and testing the model is collected from engine dynamometers or instrumented vehicles. Training and evaluating the models in ETAS ASCMO is done offline. The training data size and compression ratio in ETAS ASCMO have trade-offs that impact execution time, required memory size, and output precision. Validation of the model accuracy based on statistical measures is also done in ETAS ASCMO. If the output precision is sufficient, then the model is exported to the AMU data format, and subsequently deployed into ECU hardware.

Figure 1: Workflow of data-driven models and hardware accelerator.



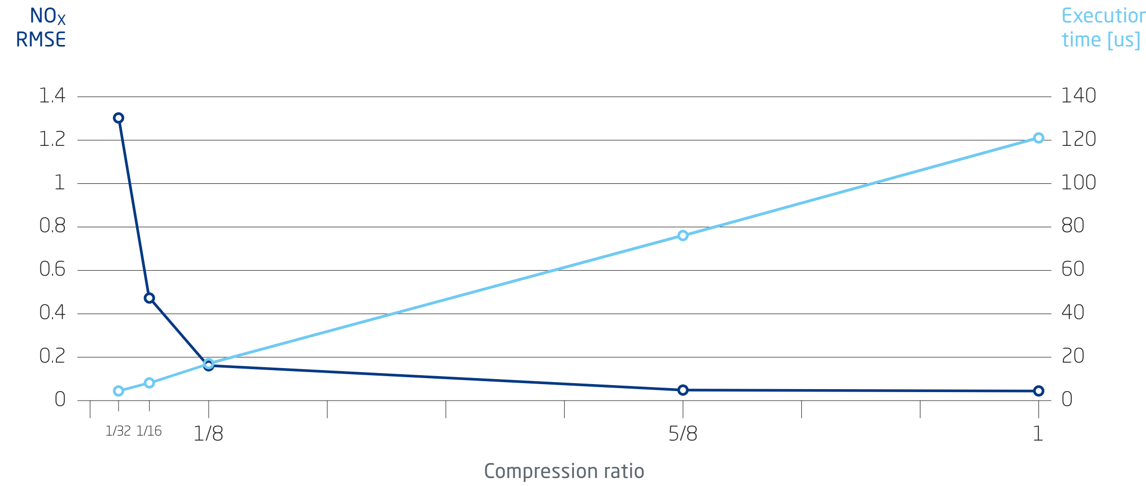


Figure 2: Results NO_X example.

Example and performance analysis

The results of a non-production intent example to calculate engine NO_X emissions are summarized in Fig. 2. The AMU execution time of the uncompressed model was about 120 µs. One conclusion from Fig. 2 is the linear relationship between compression ratio of the model and execution time.
The gradient of the skew line will depend on the number of inputs. Another take away is the non-linear trade-off between model compression and the model's root mean square error (RMSE). The RMSE will drastically increase for larger compression factors, in other words, less than 1/8 in this example. This reduction in model size will result in shorter execution times while maintaining the original model behavior without a significant loss in accuracy. The RMSE requirement of the particular application will be driving the compression ratio.

Other applications of ETAS ASCMO and Infineon's AMU are available in the literature, for example, for volumetric efficiency and exhaust gas recirculation modeling [2], which adds evidence demonstrating the benefits of this new approach in series production software development.

Summary

As ECU functions become increasingly complex, using data-driven modeling will considerably reduce the overall time and effort required while offering better quality and ensuring that the application is clearly understood. ETAS ASCMO gives the user the ability to generate highly accurate behavioral models with a simple click of a button. Infineon AURIX™ AMU is an enabler to execute ETAS ASCMO models in real time without having a significant impact on the ECU's main core. Hardware acceleration of the AMU and model compression in ETAS ASCMO are key to efficiently implementing data-driven models on the ECU.

Authors

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This article is a summary of the findings previously published in [1].

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Automated optimization of ECU function calibration

Hyundai Motor's successful approach to automating and optimizing calibrations

Hyundai Motor improves calibration efficiency through automated mapping optimization

As engines are increasingly equipped with various actuators for better performance, fuel efficiency, and tighter emissions regulations, the complexity and degrees of freedom of engine systems are also increasing. Accordingly, it takes more time and effort to calibrate numerous parameters in several operation points and various test environments. This article examines Hyundai Motor's successful approach to automating and optimizing calibrations to satisfy the demands of rapid development of vehicles tailored to customers' needs.

The automated optimization process

Simulink® models served to create the EMS control logic required to automate the optimization of mapping. EMS models were generated for each function such as fuel mass correction, throttle air flow, EGR gas flow, temperature modeling, and turbo pilot control. The actual data measurements in the vehicle were used as system inputs to ETAS ASCMO-MOCA. The optimization task was then to align the Simulink® models' virtual outputs to the physical measurements taken under all conditions (see Fig. 2).

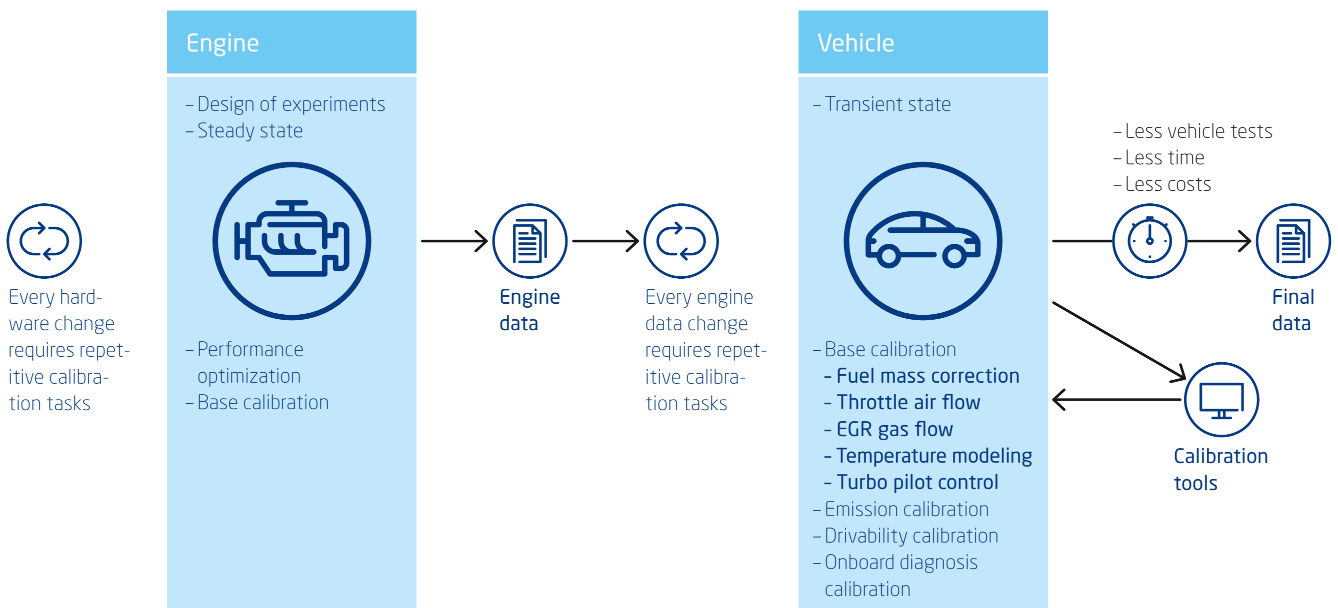

Figure 1: Automated mapping optimization.

Background and objective

The Hyundai Motor R&D Center's PT Performance Development Center introduced automated mapping optimization to improve the efficiency of calibration effort, a vehicle development task that takes a great deal of time. The idea was to save time and cut costs by reducing repetitive calibration tasks and the number of actual vehicle tests required caused by hardware changes during the development process (see Fig. 1). This project focused on the third generation of Kappa/Gamma engines, most of which featured in new vehicle projects in 2020.

Automated calibration (mapping optimization)

The optimization task was then fine-tuned in ETAS ASCMO-MOCA to ensure the best result for each project. This meant that, for example, limits and gradients for each parameter, the order of the optimization, or relevant subsets of the data could be configured in an easy way. Fig. 3 shows an example of the results of optimization runs for three channels.

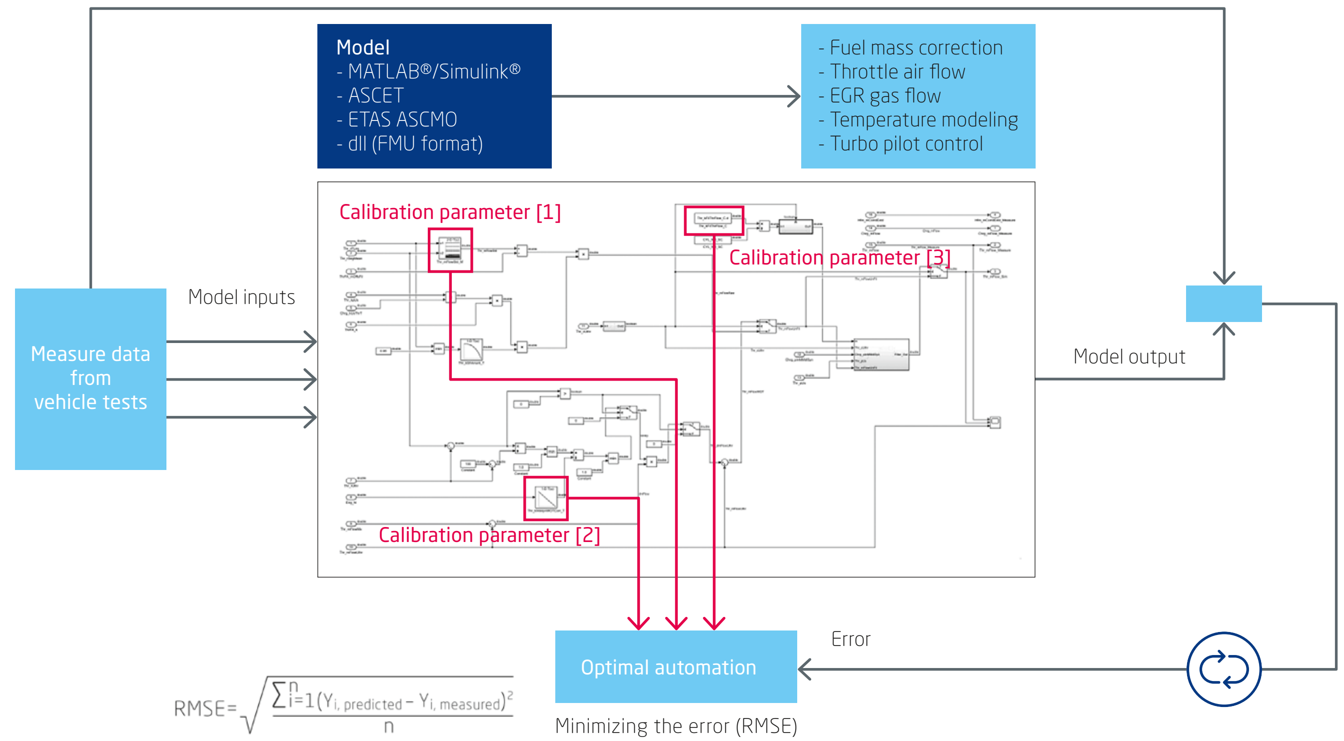

Figure 2: A look at how ETAS ASCMO-MOCA works.

Conclusion: calibration time reduced by more than 50 percent

Hyundai Motor utilized ETAS ASCMO-MOCA as part of the calibration process to perform offline calibration. It reduced calibration time by more than 50 percent and achieved higher accuracy for each function than the previous online calibration techniques. This mapping tool also delivered results that are more consistent by minimizing the human variable – the variance attributable to individual engineers' work – and could serve to standardize the process.

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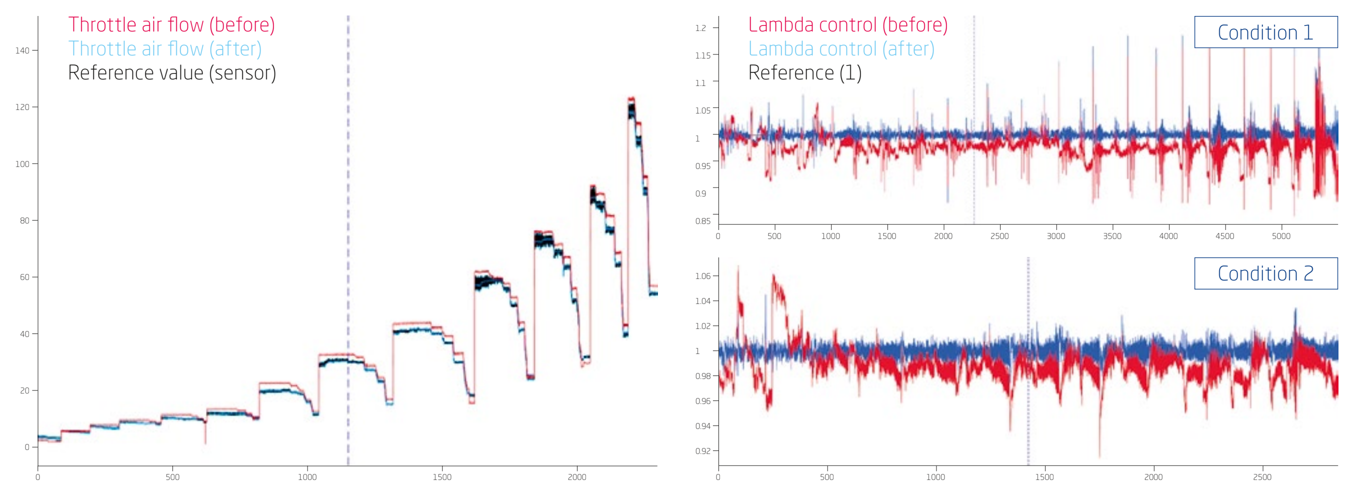
Figure 3: A look at the results of optimized mapping.

Throttle air flow function

RMSE		The time required	Remarks
Before	2.51	6~8 hrs	Measurement and calibration by human
After	0.56	3~4 hrs	Measurement and calibration by tools

Fuel mass correction (lambda control)

RMSE	Condition 1	Condition 2	Effort (1 person)	Remarks
Before	0.0315	0.0183	2~3 days	HOM1
After	0.0098	0.0046	Within a day	HOM1



Replacing human senses with measurement data

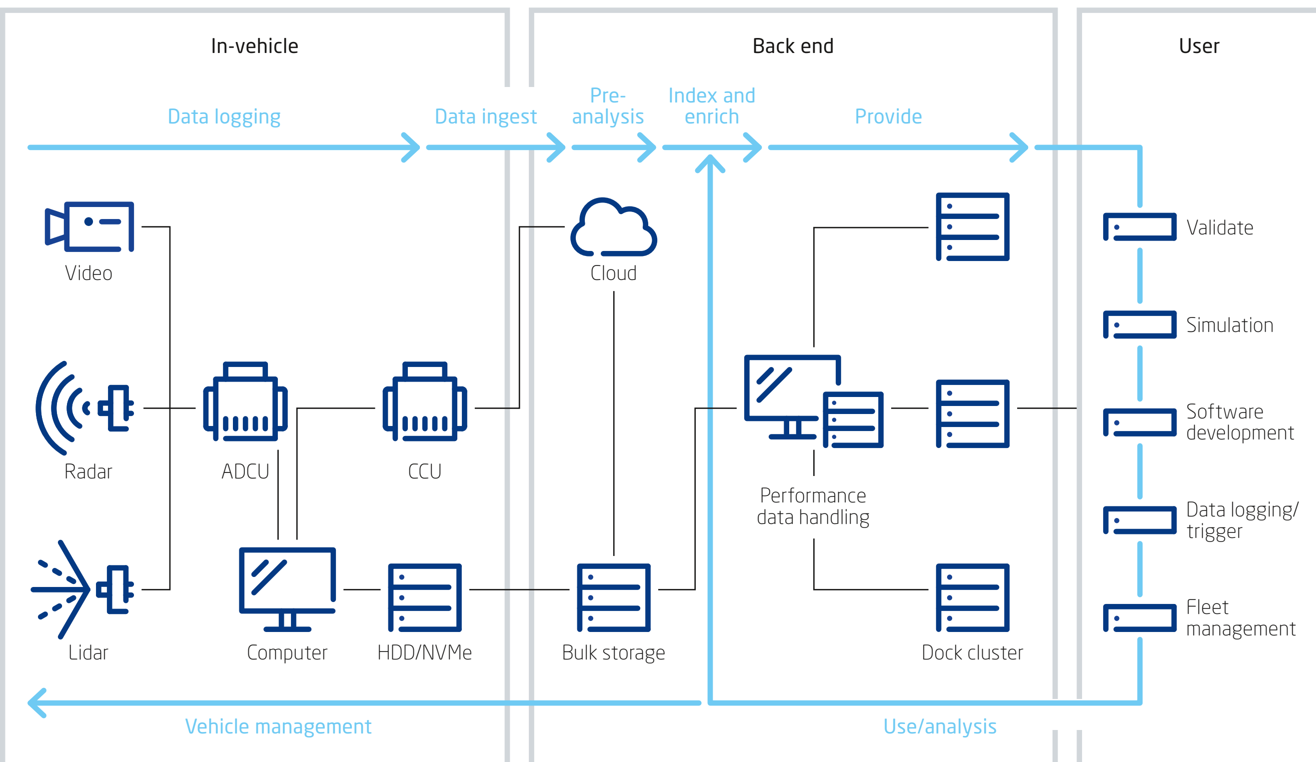
Scalable measurement data acquisition for ADAS development

To enable automated driving, sensor systems must replace human sensory perception. To design these systems and check their function at all stages of development, system developers need comprehensive access to measurement data. New modular measurement technology from ETAS is helping to acquire and deliver this data.

Eyes, ears, experience, and a healthy dose of intuition – that is all you currently need to drive a car. But, because people get tired and distracted and are sometimes slow to react, there is a growing move toward the use of advanced driver assistance systems (ADAS). The hope is that these systems will make automated driving possible within a few years. Instead of using our eyes and ears, the vehicle's surroundings will then be monitored by radar, lidar, video, and ultrasonic sensors.

Powerful electronic control units (ECUs) are used to coordinate the complex sensor networks. These must be capable of processing huge quantities of data and deriving driving strategies from this data within a matter of milliseconds. To develop these complicated control strategies efficiently, development of the software functions is shifting to the lab. Wherever possible, virtualization is replacing experiments based on real hardware. Yet this approach relies on adequate validation of the models with real environment data. This requires reliable, flexible tools for efficient data acquisition as well as the possibility of accessing data via a cloud or back end (Fig. 1).

Figure 1: Development chain from real data acquisition to the prepared data for system development.



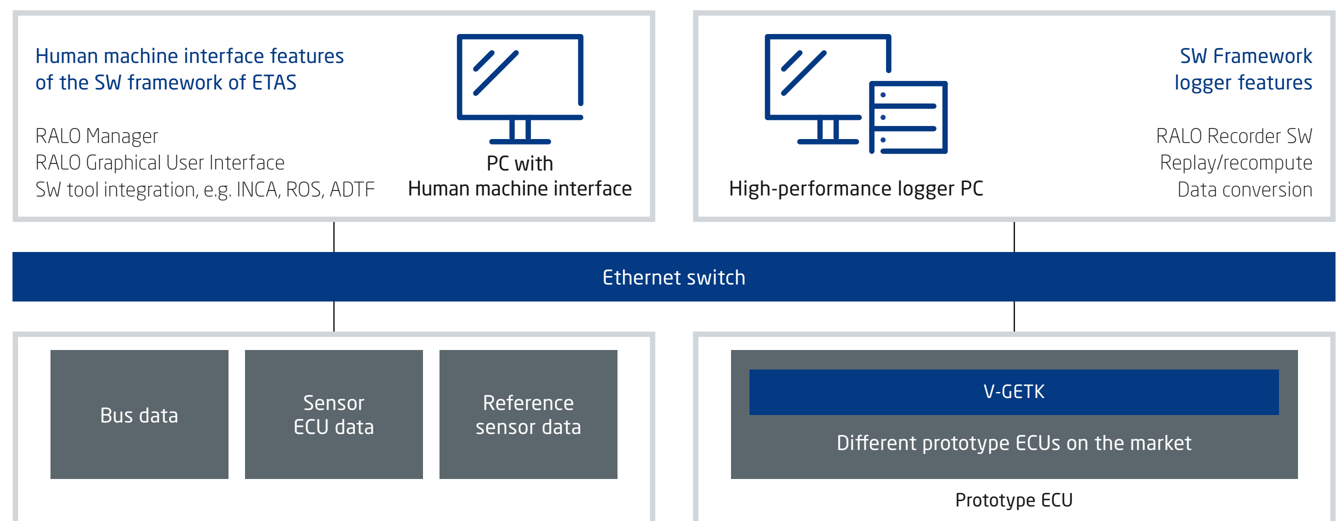
ADCU automated drive controller unit **CCU** connectivity control unit **ADAS** advance driver assistance systems **HAD** highly automated driving

Moreover, such a development environment must be capable of being integrated into the vehicle development processes that are split between OEMs and suppliers and supporting their various maturity levels – from prototyping and the various phases of development and function extensions right through to fleet management after start of production. Whatever the phase, developers need solutions for acquiring measurement data and accessing this data. It is important to note that configurations vary, so adequate data volumes may range from just a few megabytes (MB) to several gigabytes (GB) per second. ETAS offers a modular portfolio of scalable solutions specifically designed to meet these requirements. These solutions provide optimum support for in-vehicle data acquisition (DAQ) in every phase.

In-vehicle data acquisition from the prototyping phase

This in-vehicle DAQ is extremely important because it supplies the database that can be used to validate the virtualized development of automated driving functions. Yet, particularly in the prototyping phase, such data acquisition has previously been unsuccessful due to the fact that, as a rule, production-ready ECU and sensor hardware is not yet available. To allow earlier development work to proceed, simulated ECUs implemented on industrial PCs are typically utilized. These simulated ECUs provide different interfaces and properties than hardware intended for production, preventing the usage of legacy ETAS hardware-oriented measurement technology such as the emulator test probe (ETK). To fill this gap and enable data measurements to begin from the prototyping phase, ETAS has developed a virtual GETK, the V-GETK (Fig. 2).

Figure 2: V-GETK integration in a prototype ECU.



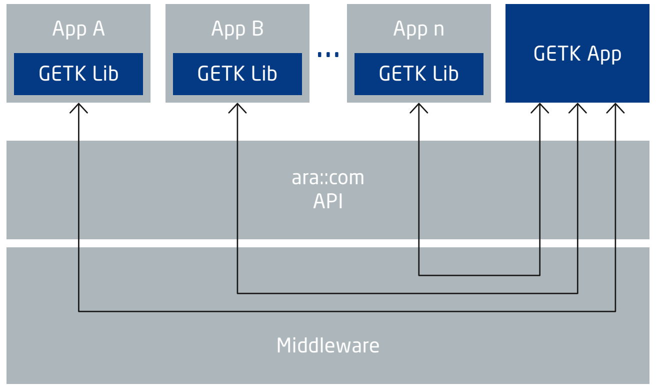
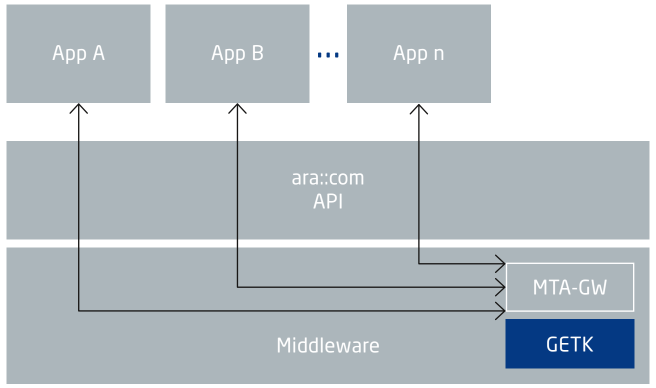


Figure 3: GETK integration in the middleware as a service.

Figure 4: GETK integration within the middleware.



By enabling measurement data acquisition at an early stage of development, the ETAS V-GETK helps minimize costs and save time in the software function development process. Performance is dependent on the PC hardware. The more cores and processing power are available, the more data can be recorded via the virtual GETK. The solution is flexible when it comes to embedding it in the software environment: users can choose to make it available as a service on the AUTOSAR Adaptive interface ara::com (Fig. 3) or as a protocol driver in customer-specific middleware (Fig. 4).

The V-GETK is integrated into the ECU prototypes as software. This offers the advantage of using the high-performance Ethernet interfaces of industrial PCs for data output. In this way, the measurement data reaches a data logger directly or via the Ethernet network. The virtual GETK is managed via the ETAS SW Framework, in which the measurement data can also be visualized.
Intuitive handling is supported by various modules for control and configuration such as the RALO (rapid logging) Manager and the RALO Recorder. Standard software tools and frameworks can also be connected – for example the robot operating system (ROS) and the automotive data and time-triggered framework (ADTF).

In-vehicle DAQ in the development phase

As soon as function developers have access to preproduction prototypes of the ECU and sensor hardware, they can make use of integrated measurement technology such as the ETAS ETK or GETK. This allows them to measure all the required data from the vehicle ECU in the course of test-drives or Hardware-in-the-Loop (HiL) tests. In ADAS projects, the focus is on raw data and internal data on the sensor level. Capabilities must be in place to handle data rates of 100 MB/s for radar sensors and up to 1 GB/s (for example for an 8-megapixel camera). It is also necessary to acquire data from traditional domains, ranging from powertrain, chassis, and infotainment through to connectivity. Reference data from ground-truth sensors and reference measurement systems (Fig. 5) are also required.

New measurement technology solutions are required to develop assistance functions into automated systems. In situations where dozens of sensors must seamlessly monitor their surroundings, the need for measurement data increases dramatically. Acquiring this data and transmitting it reliably requires a dedicated in-vehicle network architecture for the measurement technology, because data rates in the order of 6 to 15 GB/s can only be recorded cost-effectively using a scalable logger system that dynamically distributes the data streams to the available data sinks.

The ETAS portfolio includes a DAQ solution that is suitable for this purpose. It consists of the ETAS GETK family, the ETAS SW Framework, additional system components, and supplementary measurement modules. This scalable solution ensures a seamless development chain across all phases of the development of automated and semi-automated functions. The development results from the prototyping phase can be seamlessly transferred to subsequent phases. Integrated in the ECU hardware, the GETK is an excellent example of the consistently modular philosophy of the ETAS DAQ solution. In addition, data sources from microcontrollers (μC) with rates around 70 to 100 MB/s and from microprocessors (μP/SoC) with 2 to 8 GB/s per GETK can be integrated into the measurement network. Data is transmitted via the PCIe bus and accessed via direct memory access (DMA). The new measurement technology standard thus provides the basis for capturing enormous amounts of data in automation projects and reading them with high performance. The key to this is its scalability.

The ETAS SW Framework serves as the basis. It guarantees completely reliable and secure transfer of data from source to sink – and it efficiently distributes the data streams generated by the GETK to the available data loggers via 10-/40-/100-gigabit Ethernet. Data rates reach up to 8 GB/s per logger.

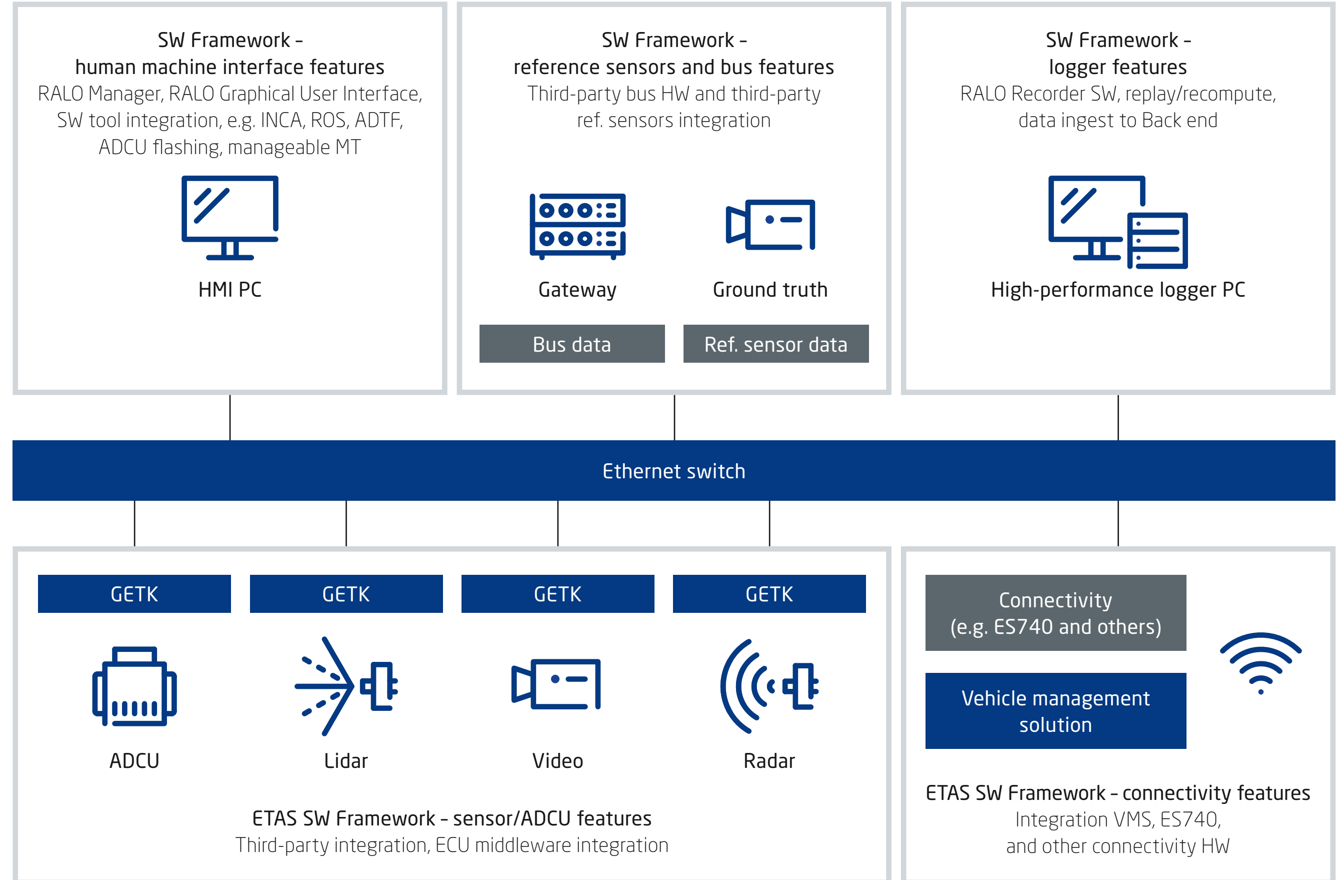


Figure 5: Schematic diagram of ETAS measurement data acquisition.

The system also enables the integration of standard software frameworks such as ROS and ADTF across all development phases. This allows function developers to continue working with their preferred tools.

In-vehicle data acquisition in the post-SoP phase

In the future, access to data from sensors and ECUs must also be guaranteed after start of production (SoP) – for example for ongoing fleet validation. The ETAS solution provides developers with fully validated access to the measurement data available from vehicles in the field and to supplementary background data. Developers can also interact with vehicles via a cloud infrastructure, which allows manufacturers to continue developing and testing the software functions of automated driving even after SoP in order to continuously sharpen the senses of sensor-based systems.

Summary

The ETAS DAQ solution is the answer to the increasing demand for measurement data for efficient function development. The consistently modular, scalable approach provides developers with access to measurement data at every phase of vehicle development and allows powerful measurement technology to be integrated into the vehicle. One of the most decisive factors for time- and cost-efficient development is seamless integration from the prototype phase to the post-SOP phase. This starts from the prototype stage with the virtualized ETAS V-GETK, continues with the integrated GETK as soon as production ECU hardware is available, and extends all the way through to cloud-based data exchange with vehicles in the field. This capability for comprehensive data acquisition from laboratory to production vehicle provides function developers with new scope for validating the highly complex functions of automated driving in a way that will allow sensor systems to effectively replace human sensory perception in the future.

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A journey of discovery through ECU software

How EHANDBOOK makes calibration more efficient

With the growing scale and complexity of ECU software in recent years, understanding signal flows and dependencies in ECU software has become an increasingly difficult and time-consuming task. In the field of ECU calibration, many automakers use ETAS EHANDBOOK as a form of interactive documentation that enables them to gain a better and faster understanding of how the ECU software works. In this article, two users from Audi, Christophe Fauqueux and Patrick Nohe, and ETAS expert Dr. Patrick Frey explain how EHANDBOOK can be used to make day-to-day work more efficient.

Background

Recent years have seen steady growth in both the scale and complexity of powertrain ECU software. This trend is driven not only by the increase in ECU functions, but also by ECU connectivity and the rising tide of electrification and hybridization. A plethora of vehicle models and variants has also led to a steady increase in the time and effort required for calibration. There is a wide range of use cases, each requiring detailed knowledge of how the ECU software works, hence the need for appropriate documentation. The knowledge required for this purpose is provided by function and software development units. Besides the documentation for ECU software developed in-house, Audi also requires corresponding documentation for purchased software components, which must be made available by the individual supplier in each case.

A step up from the standard PDF format

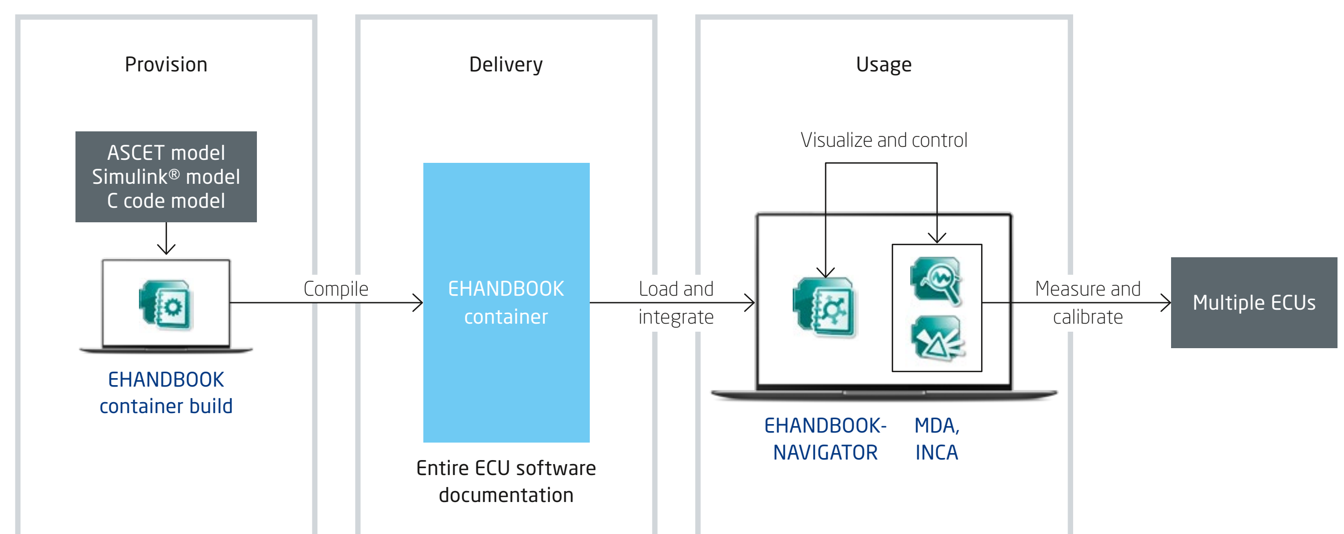
Over time, PDF documents became firmly established as the de facto format for ECU software documentation in the automotive sector. However, as the volume of documentation has continued to increase, this file format has become increasingly unmanageable. One of the biggest challenges is working with multiple PDF files at the same time, especially since the content of each document tends to be substantial, with files typically running to several thousand pages.

An added difficulty is the absence of interlinking between individual PDF documents, which makes overall navigation more difficult. The most important content – graphical representations of the ECU software in the form of screenshots of the ASCET or Simulink® models – is broken apart across multiple separate pages in A4 format. This makes the task of following signal paths difficult and time-consuming, with users having to constantly scroll from one page to the next.

EHANDBOOK at Audi: a standard tool in the making

ETAS' EHANDBOOK solution offers a new approach to ECU documentation (Fig. 1). Many users have quickly recognized EHANDBOOK's advantages and potential: by providing an integrated graphical visualization of all the ECU software functions in the form of interactive models, it helps users to comprehend dependencies much faster and simplifies the task of following signal paths. Thanks to its seamless interoperability with the ETAS measurement and calibration tools INCA and MDA 8, EHANDBOOK also supports standard workflows. In 2015, Audi tailored EHANDBOOK to its in-house ECU software. Since then, the solution has been used in numerous calibration projects and established itself as a standard tool.

Figure 1: EHANDBOOK enables systematic documentation of ECU software, providing targeted insight into its functionality.



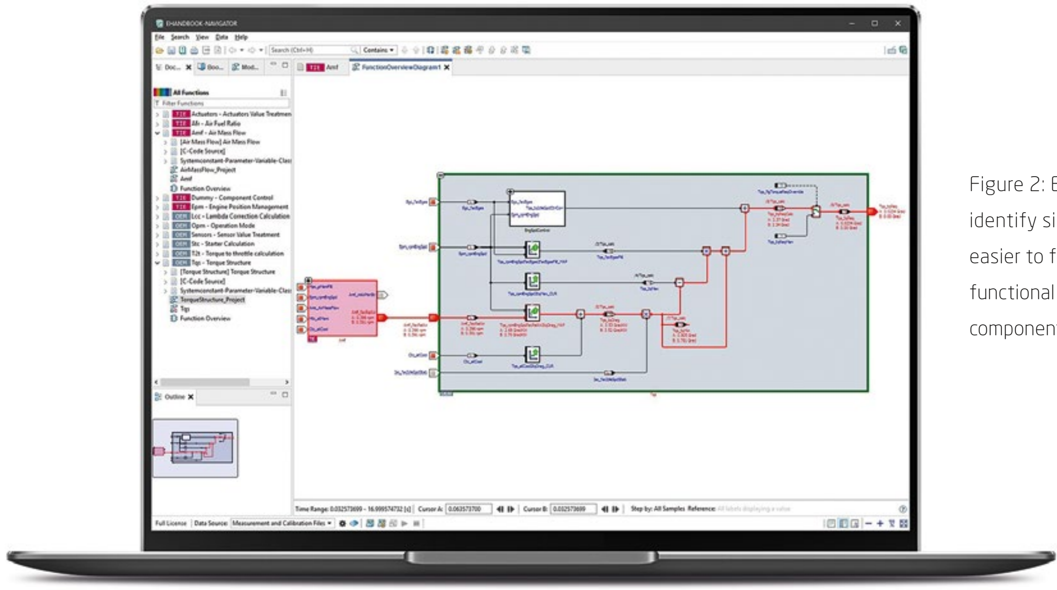


Figure 2: EHANDBOOK helps users identify signals quickly and makes it easier to follow signal paths. Its cross-functional approach works across all components of the ECU software.

Significant time savings in typical use cases

As long-time users, Christophe Fauqueux and Patrick Nohe from Audi's Neckarsulm plant have extensive experience in working with EHANDBOOK on a day-to-day basis. The two calibration experts have seen their work become more and more complex in recent years, especially with Audi's adoption of new powertrain solutions. Patrick Nohe works on a steady stream of new and modified hybrid drive functions and must familiarize himself with each new development. Christophe Fauqueux works on fuel cell development in collaboration with other experts. Their goal is to move this technology toward a production-ready solution. This requires the technology to be re-engineered and calibrated from scratch.

A much faster way to comprehend ECU functions

A fundamental understanding is key to familiarizing oneself with ECU functions. With its user-friendly interface and seamless graphical overviews of ECU software, EHANDBOOK provides the necessary clarity. Helpful features include a cross-functional display that shows individual ECU functions within an overall context. This makes it easier to identify the origin of specific signals and determine which functions they affect, even when searching across multiple software components prepared separately by in-house development departments or external suppliers (Fig. 2).
Compared to the previous method of working with PDF files, EHANDBOOK helps users familiarize themselves with ECU functions up to 50 percent faster and identify signal origins up to 75 percent faster.

A much faster way to locate measurement signals and calibration parameters

Engineers frequently have to look up information on the meaning of measurement signals and the values of calibration parameters. A major advantage of EHANDBOOK is the rapid access it provides to the relevant information. In a typical procedure where the INCA experiment has to be opened to display the data, EHANDBOOK saves users a great deal of time, allowing them to get the job done in just 25 percent of the time it would normally take.

A much faster way to identify the causes of errors

Often, ECU software does not behave as it should during the development process. The causes of errors are many and varied, and experts argues that attempting to identify the causes during calibration is an inherently difficult task. "You're stepping into unknown territory every time," says Christophe Fauqueux. To remedy this, EHANDBOOK-NAVIGATOR and MDA 8 have been specially designed to work together to enable seamless operation. Thanks to powerful measurement technology (FETK), engineers can measure very large numbers of signals on test-drives. The measurement data file is loaded in MDA 8 and the time stamp at which the error occurred is highlighted with the cursor. This time stamp is transferred directly to EHANDBOOK and the measured values along the signal path are annotated. Based on the signal for which the error was observed, the entire chain of calculations and decisions made by the software can then be traced. "You don't have to spend ages searching because the correlations between the calculations are immediately apparent," says Christophe Fauqueux. This reduces the time spent on troubleshooting by up to 75 percent.

A much faster way to understand interactions between functions

It is very often necessary to calibrate functions that stem from various in-house development departments as well as from external suppliers. In such cases, the documentation that corresponds to each function is provided separately. "Trying to comprehend the overall context from multiple PDF documents is a hugely laborious task. This is where we can benefit from EHANDBOOK's ability to load and consolidate multiple EHANDBOOK files," say the Audi experts. By linking all these files into a single, coherent overview, cross-functional dependencies can be displayed clearly and transparently. This leads to time savings of between 20 and 80 percent depending on the project phase and the quality of the content (Fig. 3).

Summary

EHANDBOOK users can benefit from considerable time savings. A better understanding of ECU software can also help to avoid errors, leading to corresponding improvements in the quality of calibration results.

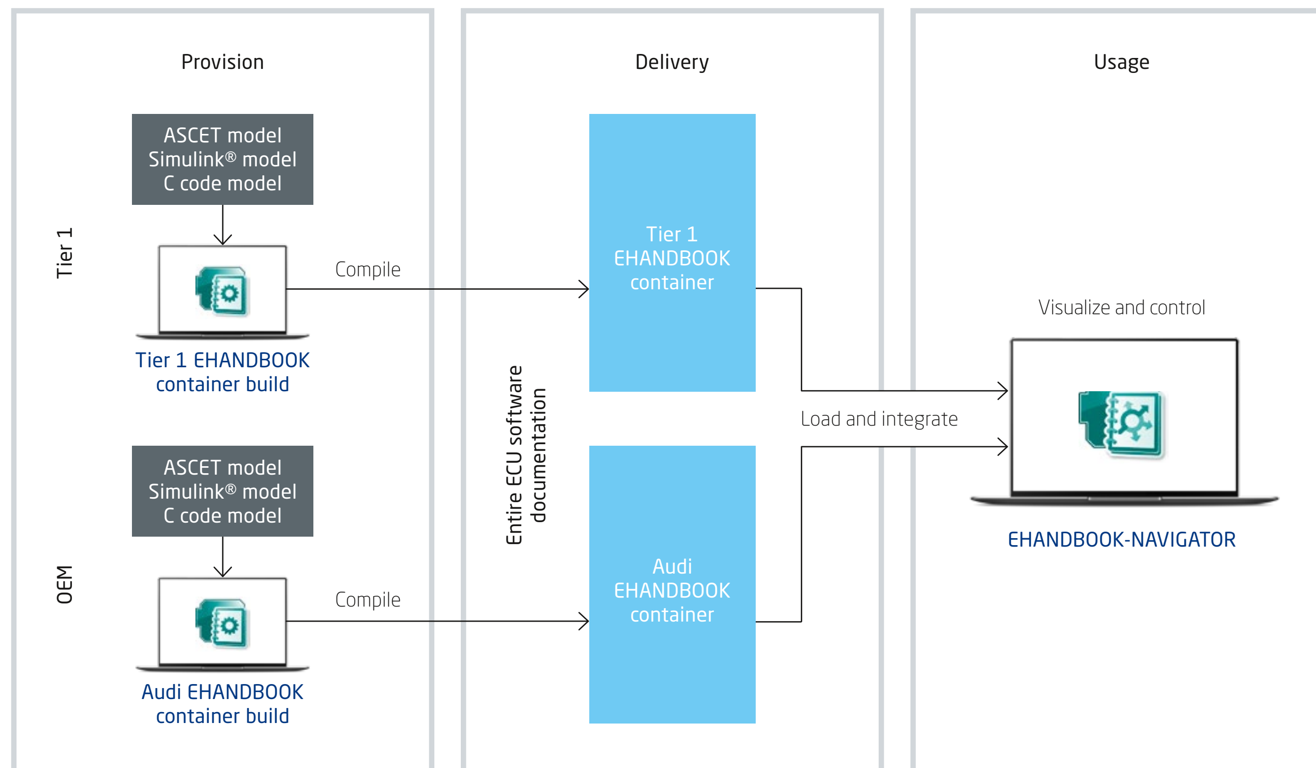
Audi experts help shape further development

For Patrick Nohe and Christophe Fauqueux, one of EHANDBOOK's most important features is the ability to represent the ECU software in a graphical form. The seamless display of signal paths across ECU functions makes interrelationships much easier to understand. EHANDBOOK offers even more potential for improvement in this area, for example in regard to saving and forwarding model views.
Experts will therefore continue to support the further development of EHANDBOOK in the future, contributing their expertise and feedback in the context of user research and concept validation. Besides applying EHANDBOOK to traditional powertrain ECUs, Audi has now also started using it in other domains. Other suppliers are also gradually making EHANDBOOK container files available.

Interviewees

Christophe Fauqueux is an expert in the development of calibration and fuel cell functions at Audi AG. **Patrick Nohe** is an expert in the calibration of driving behavior for V diesel engines at Audi AG. **Dr. Patrick Frey** is a Senior Product Manager at ETAS GmbH. He is responsible for the EHANDBOOK solution.

Figure 3: EHANDBOOK makes it possible to seamlessly combine ECU software documentation from OEMs and suppliers.



Defining new paradigms of collaboration

Realizing solutions with INCA and beyond for vehicle fleet management

For its fleet management, Mahindra was looking for a versatile solution that would meet unique requirements. The solution: an automotive-grade Windows tablet running INCA that acquires data via Ethernet over XETK at a high data bandwidth. Or in short: TOUGHIE.

Go to the office, boot the computer, check the vehicle fleet's status, investigate issues, rectify errors, and set the vehicles back in the fleet – all before the coffee gets cold. This wishful start to a fleet manager's day at Mahindra became reality when a crisis call came in from a test-driver reporting a Malfunction Indicator Light (MIL) error.

Time to pack a bag and hit the road again for a few days. With many vehicles scheduled to run across India, immense time pressure and the need to be omnipresent, this crisis was a smaller version of the storm to come. Krishnaraj P, responsible for fleet management at Mahindra Automotive, was worried.

Many products enable vehicle data acquisition, but Mahindra wanted more than just a data logger. The solution would have to be versatile enough to meet unique requirements. There was also the trade-off between costs and data acquisition bandwidth to consider. With delivery time pressure, experimenting or investing a lot of thought and effort into building a solution was hardly feasible. Engineers from ETAS worked with stakeholders at Mahindra to understand their concerns, detail the requirements, and create a solution that addressed all their needs, while boosting efficiency and enhancing convenience for multiple teams.

The solution

An automotive-grade Windows® tablet running INCA that acquires data via Ethernet over XETK at a high-data bandwidth. ETAS consulted with all stakeholders to identify their demands, pain points, concerns, and operating methodologies. ETAS also addressed potential pitfalls and then helped design an all-encompassing solution. Ideation and brainstorming was a joint effort with user teams, done with a keen eye to detail and executed on the actual fleet, mostly out in the field, followed by painstaking assessments and corrective actions. Custom features and pre-configured options now treat Mahindra users to a seamless experience.

This benefits everyone, from the test-driver, the solution's primary user, to the engineer evaluating vast quanta of data. User safety, data security, and a GUI meticulously configured to Mahindra's specifications make this a holistic solution. An onboard GPS and mobility module provides location information and delivers data at 4G speeds to a server for automated processing. Remote access to vehicles enables monitoring, investigation, and rectification of issues without having to go to vehicles located thousands of kilometers away.

"The INCA-based solution was an innovative approach. We were able to meet data acquisition requirements at an affordable cost. It exceeded our expectations and we could enhance the experience with additional features such as a dashboard for the driver, remote monitoring, etc., which made life easy for both fleet engineers and drivers. With this approach, we were able to eliminate the tedium of data transfer and the need for manual intervention and realize the full potential of data automation without compromising data security. The additional bandwidth gained by using XETK instead of CAN meant we could capture significantly more data per drive to avoid repetitive activities, which also helped us adhere to the timelines. The built-in GPS capability is an added feather in the cap", says Krishnaraj P.

Today, a crisis call from a test vehicle driver is no longer an issue and data-backed decisions have become a habit at Mahindra thanks to a cocreated solution nicknamed TOUGHIE. Leveraging on its consulting and engineering excellence, ETAS helped turn a dream into a reality that benefits Mahindra's business.

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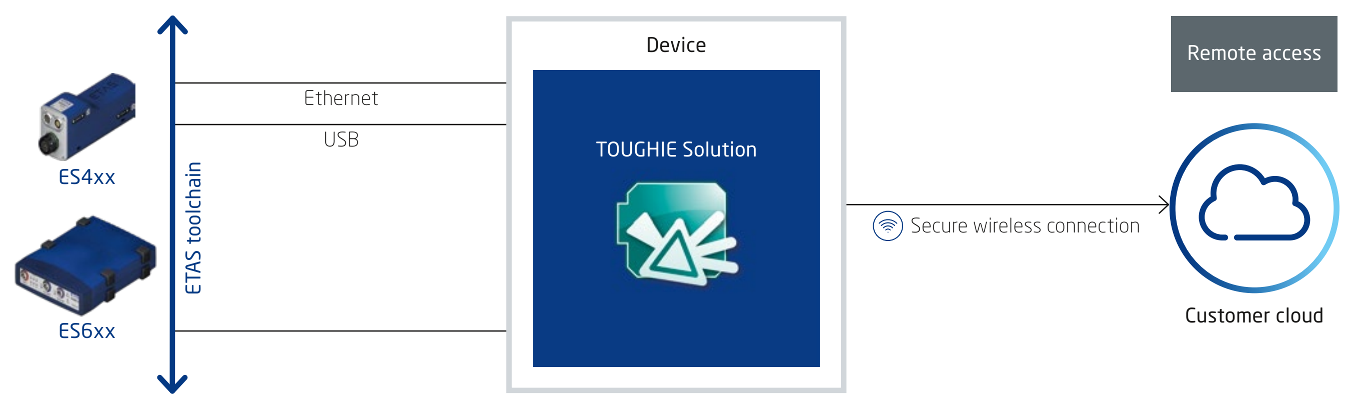

Functionality of TOUGHIE – the INCA-based tablet solution.

Transforming a vision into success

A journey through the history of INCA

Looking back at the features and changes introduced over the years illustrates how the focus has always been firmly on the user.

Data export and import features to simplify collaboration between colleagues were introduced in INCA V2.0. This version also included the database concept that enables users to store experiments and hardware configurations and then reuse them for a range of development tasks.

INCA V2.0

The workspace concept introduced in version 3.0, which was released in the year 2000, combined the experiment, hardware configuration, and ECU project into an INCA workspace element. This made it much easier for users to work with the artefacts and clearly track the dependencies between them. It also allowed newly created workspaces and experiments to be reused in other development tasks.

INCA V3.0

On April 17, 1997, ETAS launched a new product: INCA V1.0: The developers' vision – a tool for ECU calibration that could be used by any automaker in the world – must initially have seemed like an unattainable dream. Today, 24 years after the launch of INCA V1.0, this vision has been more than realized. Yet, there is still more to be done, with technical innovations and the future of the automobile posing new challenges for developers on a daily basis.

Calibrating ECUs was possible even before INCA V1.0 was introduced – but it certainly wasn't simple or efficient. From today's perspective, the operation of INCA's MS-DOS-based predecessor VS100 seems almost absurd. Performing measurement and calibration in parallel was impossible. This made the work very time-consuming. Graphics capabilities were also very limited.

But 1997 marked the start of a new era in ECU development with the launch of INCA V1.0. By taking full advantage of the computing power available at the time, INCA V1.0 finally enabled developers to perform this parallel operation. This significantly boosted the efficiency of ECU development. The software also offered numerous other benefits: INCA V1.0 allowed calibration engineers and developers to rapidly process much larger quantities of measurement data. They could focus their work on the exact parameters they chose.

What's more, the software was compatible with ECUs from many different vendors. This gave automakers greater flexibility in selecting components and considerably facilitated their collaboration with ECU manufacturers and other suppliers. INCA had established itself as a major force in ECU development – a position it continues to hold today.

Expanding INCA to meet new requirements

Stricter emission standards and steadily increasing complexity have always been the drivers behind ECU development. Nowadays, it is standard to have an ECU network with a multitude of function areas and mutually dependent parameters. Whenever one variable is changed, this has an impact across the whole network.

As the years have passed, this has placed significantly greater demands on INCA. Yet this steady increase in requirements has also led to INCA becoming increasingly powerful. INCA's success since 1997 in establishing itself as an industry standard tool for ECU calibration largely comes down to ETAS software developers. By putting themselves in the shoes of calibration engineers and developers and understanding their tasks in detail, they are able to offer them appropriate solutions.

Launched in 2002, version 4.0 was the first to offer the function of calculated signals based on available measured values – a major advantage for certain tasks, for example, helping to identify a specific ECU behavior and subsequently analyze it. This version also introduced Ethernet to replace the RS-232 and Centronics interface previously used for the measuring hardware. This allowed users to simultaneously operate several measuring instruments and calibrate ECUs on one and the same computer.

INCA V4.0

Released in 2004, version 5.0 achieved even bigger time savings for users. By linking the INCA experiment to the corresponding ECU documentation, the software enabled experts to skip from a measured value to the corresponding place in the relevant documentation at the press of a key. This allowed functions and relationships to be understood more quickly and tasks to be completed more rapidly.

INCA V5.0

Version 6.0 added even more benefits for users in the form of the Variable Selection Dialog and the MultiRecorder. The dialog simplifies configuration by enabling the targeted selection of variables and verifies whether the measurement is possible with the available hardware.

INCA V6.0

Forging the future of ECU development with INCA

INCA has been on the market for 24 years – a claim that very few software products can make. Today, this efficient ECU development tool is used by almost every OEM and supplier. More than 50,000 users all over the world use it in their day-to-day work. The INCA software interface is now available in German, English, French, Japanese, and Chinese.

A comprehensive set of tools based on INCA has long been available for measurement, ECU calibration, and diagnostics. Current development work focuses on meshing these products together to facilitate end-to-end data management and evaluation. This gives users huge benefits in terms of convenience and time savings.

One of the cornerstones of this approach was the decision in 2016 to make versions of the completely revamped Measure Data Analyzer (MDA) V8 available to users on a quarterly basis; the V8.4 version replaced its predecessor, MDA V7, at the end of 2019. An interface has already been established between INCA and the EHANDBOOK-NAVIGATOR, making it possible to easily link measurement data with the interactive ECU documentation. This interaction provides a much faster means of finding critical parameters and errors. It also allows measurement results to be verified and a report generated immediately after data acquisition in INCA. This is completely automated thanks to the link with the ETAS Analytics Toolbox EATB. The next major development step will be a new Calibration Data Manager.

INCA also has a vision for other challenges that will arise in the future. Examples include working with virtual ECUs and buses in scalable simulation environments, domain controllers with microprocessors in new AUTOSAR Adaptive software architectures, and cloud capabilities for applications. All these things are already being addressed and taken forward by INCA developers.

At the same time, ETAS will continue to focus closely on the needs of users to make sure that the INCA success story continues for decades to come.

Authors

Jörg Herrmann is an INCA Project Manager at ETAS GmbH.
Kilian Schnellbacher is the Lead Product Manager responsible for INCA at ETAS GmbH.

Version 7.0 introduced open hardware and software interfaces to make both INCA and ETAS measurement hardware compatible with products from other vendors. This gives users flexibility in choosing their working environment. Regular service packs were introduced from version 7.1. This allows ETAS to respond quickly to customer requirements and bring changes to market.

INCA V7.0

The revised Calibration Data Manager in version 7.2 includes an improved table view that now shows parameters of two or more data sets.

INCA V7.2

Version 7.3, the most recent release, is the first native 64-bit version of INCA and another major step forward. By making full use of the available RAM, it opens the door to more elaborative experiments, more project files (which can also be bigger), and a measuring rate of up to 40 MByte/s with parallel adjustment of the calibration parameters.

INCA V7.3

New Board of Management at ETAS

Interview with Christoph Hartung, Günter Gromeier and Götz Nigge

ETAS appointed a new Board of Management on January 1, 2021. RealTimes talked to Christoph Hartung, President and Chairman of the Board of Management, Günter Gromeier, Executive Vice President Sales, and Götz Nigge, Executive Vice President Operations, about their careers, the role ETAS plays in automotive software, and how to build a relationship with associates when the global pandemic makes it so difficult for people to meet.

Christoph, you took over as Chairman of the ETAS Board of Management on January 1, 2021. What were the previous stages in your career? And which one had the biggest impact on you?
Christoph Hartung: I started my career in 1999 and spent the next 20 years working for various automakers – Mercedes-Benz and Volkswagen. That whole period was very memorable. Eventually, in 2020, I joined the Connected Mobility Solutions division at Bosch. That's where I learned to see things from a Tier1 perspective for the first time. I find it helpful being able to tap into my many years of OEM experience to benefit the "other side" in my new role at ETAS. In other words, I have no difficulty seeing things from a customer's perspective.


Christoph Hartung President

Götz, your most recent role at Robert Bosch GmbH was also as Board Member of the Connected Mobility Solutions division, where you were in charge of commercial areas. How did your career lead to that point?
Götz Nigge: I began my career as an officer in the German Navy, which was a tremendously exciting time. I joined Robert Bosch GmbH in 1999 and worked in human resources, purchasing, and various other areas, running and managing a wide range of projects. While I was at Bosch, I spent more than six years working abroad. I have very happy memories of that time. In 2010, I was appointed Vice President Finance at an independent Bosch subsidiary in Italy with around 500 associates. That was a totally new experience for me; it taught me a lot, because the structure of a small company is obviously very different from a global organization the size of Bosch. I think my experience provides an excellent foundation for my new role at ETAS, and I look forward to working with ETAS' highly motivated associates to continue moving the company into the future.


Götz Nigge Executive Vice President Operations

Günter, ETAS was founded in 1994 and you joined shortly afterwards in 1995. What have been your most important milestones at ETAS?
Günter Gromeier: When I joined ETAS as a calibration engineer in Schwieberdingen, the company was still finding its feet. I've worked in many different areas over the course of the past 27 years, including sales, marketing, product management, and corporate development. I particularly enjoy working in intercultural environments, which is why the years I spent in France and China were definitely some of the most exciting of my career. But the last few years at ETAS have been equally remarkable. Developments such as e-mobility, connectivity, and autonomous and semi-autonomous driving are transforming the automotive industry. The market is in a constant state of flux, with new innovations appearing all the time. Software plays a key role in most of these innovations. As a member of the ETAS Board of Management, I'm looking forward to taking an active part in shaping how this field develops.


Günter Gromeier Executive Vice President Sales

Christoph, what role does ETAS play in the current state of automotive software development?
Christoph Hartung: We do supply tool and middleware solutions to enable the implementation of these applications and the ability to run them on the control unit. In this respect, our focus is on efficiency and safety in development processes: we have understood how processes, methods, and tools need to change to be able to implement complex systems in a vehicle, manage them and also support them over their entire life cycles. Development efficiency is a crucial factor in bringing new systems on the road. At the moment, the complexity of vehicle electronics is increasing rapidly. These systems can no longer be developed using classical methods. This is good news for us because mastering a high degree of complexity is our expertise.

You took up your new position in the middle of a global pandemic. Meeting up face-to-face is impossible and it is likely to remain that way for the foreseeable future. So how did you get to know your associates?
Christoph Hartung: Obviously, it would be great if we could have larger gatherings where I could meet associates in person and discuss our strategy, portfolio, and ideas for the future. But since that's not possible at the moment, we're mostly using video calls. I'm grateful we have that alternative, and we still have the possibility of meeting in person in exceptional cases as long as we comply with all coronavirus guidelines. But regardless of whether we meet in person or via video, openness and transparency are the key factors when it comes to communicating with associates.

> "I have no difficulty seeing things from a customer's perspective."
> Christoph Hartung

Do data-driven topics such as ADAS/AD pose new challenges?
Christoph Hartung: Absolutely. We are working on ADAS/AD in a large network of Tier1 suppliers and OEMs to determine what they need and how we can best support their development processes. These data-driven development flows have a clear basic framework: test vehicles drive as many test kilometers as possible and gather the data in the backend where it is simulated and validated, resulting in optimized algorithms being transferred back to the vehicle. Our tools and expertise in the areas of measurement, calibration, and tool chains are in demand to cover these development steps and to work together with the OEMs to implement them in their vehicles. What's different in automotive development compared to IT is that automotive tools are never only digital, they always need to provide a bridge to the hardware world, and they must also fulfill safety requirements.

Let's finish on a more personal note by asking all three of you: How do you unwind when things get stressful at work?
Götz Nigge: For me it has to be sports. I like running and martial arts.

Günter Gromeier: There are all sorts of outdoor activities that help me unwind. It depends on the time of year, but running and golf are good options for me.

Christoph Hartung: I find sports really helpful, too. I like running, and I even set up a small gym at home so I could work out with my sons during the pandemic.

Thanks for talking to us!

Nothing left to chance

Testing highly complex ETAS hardware during manufacturing

The combination of high circuit board packing density and complex product functionality requires state-of-the-art test methods and an integrated test management system to verify production.

The ongoing development of our hardware products is characterized by two simultaneous trends: rapidly increasing product complexity on the one hand, and the miniaturization of assembled circuit boards on the other. This situation requires the use of modern test methods as well as end-to-end design of the test infrastructure in the product engineering process.
One of ETAS' core competences is the development of high-performance hardware products that are designed for widely diverse driving conditions, from the extremely hot and dusty environment of a desert to the extreme cold of the far north. To meet these requirements, we rely on our experienced development departments, our specialized external manufacturing service providers for electronic products, and the departments that form the bridge between these different areas.

One of the key pillars of this bridge is the Technical Functions (TEF) department. TEF's responsibilities include development and maintenance of the test infrastructure as well as global management of test data in the manufacturing process for ETAS hardware products.

What distinguishes the test infrastructure used in the manufacturing of ETAS products?

The key to successful test infrastructure design lies in an integral test method approach. This involves weighing various state-of-the-art test methods for each specific product and applying them selectively.
A distinction is made between structural electrical, functional electrical, and structural optical test methods.

Each test method has its own strengths that can be harnessed for the verification of assembled circuit boards. We distinguish here according to different test coverage parameters polarity, component placement, value/functionality, and solder quality (see Fig. 1).

The structural electrical test

Conventional test methods are reaching their limits due to high packing density, the use of components with connections on the bottom, and extremely small components that appear no bigger than a dot to the human eye. These limits can be overcome by performing embedded board tests using the JTAG (Joint Test Action Group) test bus. This is the boundary-scan test (BST) according to IEEE1149 standard. This test method can be pictured as a kind of "testing worm" that diligently wriggles its way through the circuit board. On its way, it verifies the connections between the components and detects unsoldered connections and short circuits.

The functional electrical test

Two test methods are employed in this area of testing: an embedded functional test (EFT) uses the JTAG bus to access the intelligence of the components that are already assembled. EFTs make use of ChipVORX® and VarioTAP® test technologies as well as test functions programmed in-house in conjunction with the powerful CASCON® systems software from the company GÖPEL electronic GmbH. These high-performance tests detect errors in the dynamic range. This is a key test technology that makes it possible to pinpoint errors with outstanding diagnostics without requiring board-specific software. Functional tests (FTs) with product-specific software are used as a supplement to the EFT. A distinction is made here between cluster testing, which involves in-depth tests of certain areas of hardware, and product function testing, which checks product functionality at the interfaces.

Test areas/methods

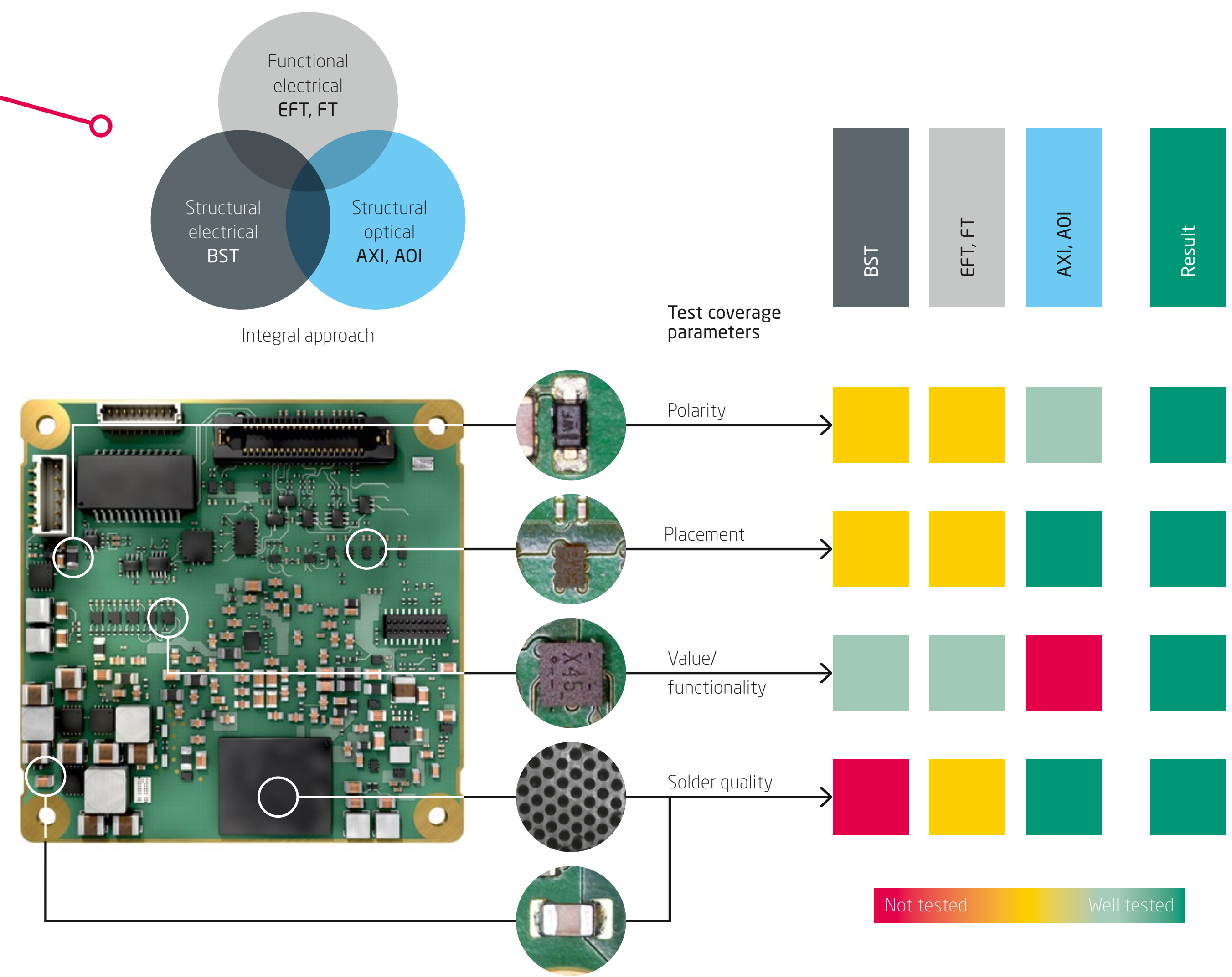

Figure 1: Test coverage parameters illustrated using the FETK-T3 product.

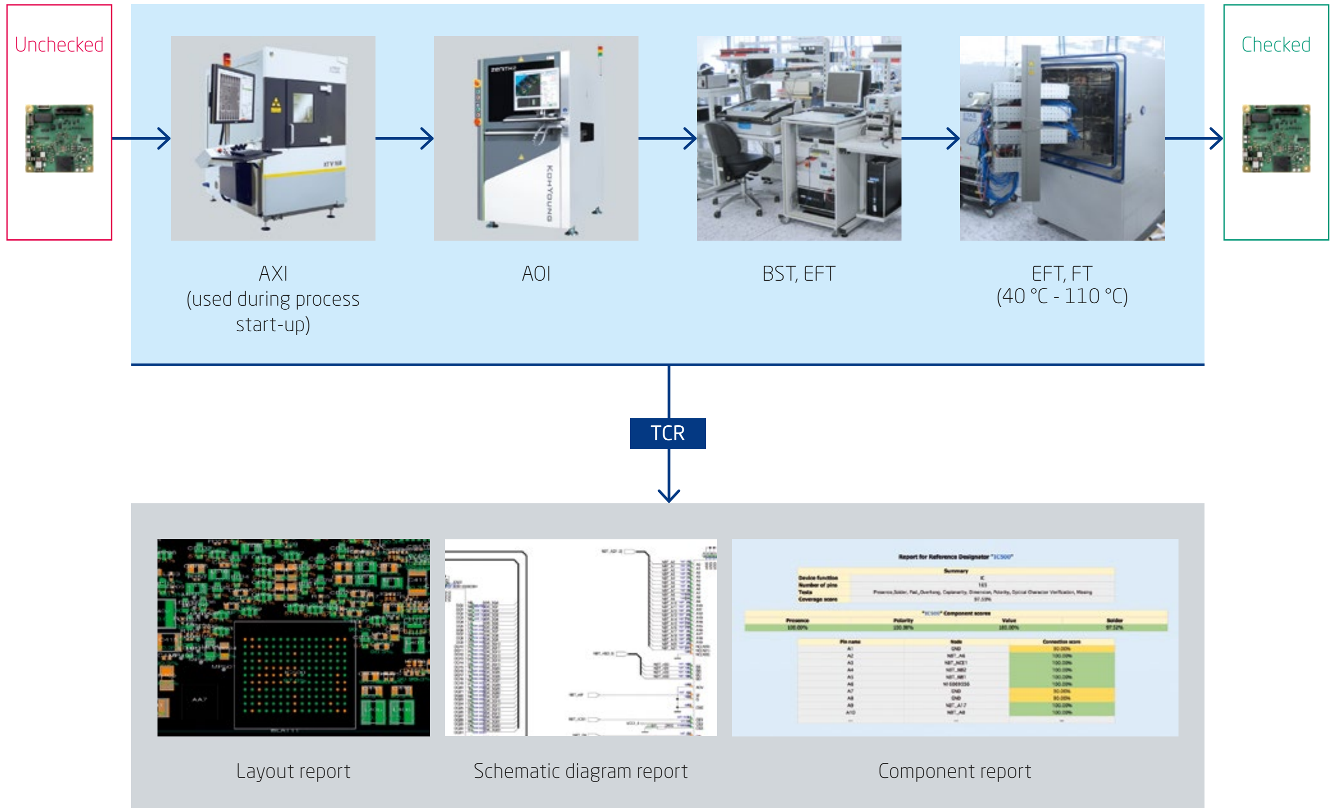

Figure 2: Test chain illustrated using the FETK-T3 product.

The structural optical test

The key strengths of optical testing lie in the evaluation of solder quality and component placement. It is performed with X-ray systems similar to those used in orthopedics and with state-of-the-art camera systems in 3D image quality.
The efficiency of the X-ray test systems (AXI – automated X-ray inspection) and optical test systems (AOI – automatic optical inspection) is therefore of the utmost importance. This area of testing is covered by test systems from our manufacturing service providers. When selecting suppliers, ETAS places great importance on ensuring that manufacturing service providers' test facilities are suitably well equipped.

The test chain

The test methods described above are used in highly complex test systems that are embedded in a test chain. Each test system makes an important contribution to product test quality (Fig. 2). Test quality is determined on the basis of test coverage. The test coverage of each individual test system is, in turn, indicated by Test Coverage Reports (TCRs). These reports contain the test coverage parameters of each individual component and component connection, and are used to analyze and optimize the test chain.

The fully integrated test coverage analysis tool TestWay Express® from ASTER Technologies is used to help maximize test coverage and optimize the use of test methods.

Summary

Nothing is left to chance. To accommodate the broad portfolio of ETAS hardware products during manufacturing, we use a modern test infrastructure that has been developed on the basis of state-of-the-art technology. The key to optimizing the testing of our hardware products lies in our many years of experience in developing manufacturing test systems, our use of high-performance, state-of-the-art tools, and our close cooperation with hardware manufacturing service providers. This is an important piece of the puzzle that contributes to the high quality of ETAS products.

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Italy	Turin
Japan	Nagoya, Utsunomiya, Yokohama
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