focus

THE AVL MOBILITY TREND MAGAZINE

FEATURING
**SPECIAL
SOFTWARE
SECTION**

▶▶▶ p. 36 – 60

NOBODY CAN ACHIEVE NET-ZERO ALONE

Tore Enger
Group CEO of TECO 2030

Index

Prof. Helmut List,
Chairman and CEO AVL

Customizing cars to suit the needs and tastes of the end user has long been a key driver in the automotive industry. In an era when powertrains are converting to more electrified and autonomous mobility, and as everything becomes more connected, overcoming complexity is the new challenge. The risks that come alongside must be analyzed and managed cautiously though: Cybersecurity has become a major issue for OEMs.

AVL offers a diverse range of solutions for this new age, from simulation and testing solutions to embedded software development tools and services. They are based on four principles: delivering software that grows with you, reducing the burden of complexity to find the fastest solution that works for you, answering today's challenges and uncovering tomorrow's solutions. Together, we are defining the safe key for the "car quartet" of the 21st century. It calls for new perspectives on everything from how we manage our carbon footprint around the world, to how we simulate and test an infinite number of scenarios to be ready for the road.

Diversity is not only manifested in our holistic technology portfolio, or the way we manage our own operations around the world, but also in our workforce. Once a male-dominated industry, engineering is increasingly benefitting from the skills and perspectives of a growing female contingent. Women are playing a decisive role, in our labs, and in the office, where our creative minds shape future mobility solutions.

Helmut List

"NOBODY CAN ACHIEVE NET-ZERO ALONE"

INTERVIEW with Tore Enger, Group CEO of TECO 2030

Images: © TECO 2030 ASA

Focus magazine speaks to Tore Enger about TECO 2030's collaboration with AVL, and the future of the fuel cell in global heavy-duty transportation.

— focus: Thank you for speaking with us. Tell us about TECO 2030, what the company does and how it came to be.

Enger: TECO 2030 is a Norway-based clean tech company developing zero emission technology for maritime and heavy industries. We are developing PEM hydrogen fuel cell stacks and PEM hydrogen fuel cell modules, that enable ships and other heavy-duty applications to become emissions-free. TECO 2030 will industrialize the PEM fuel cells in Narvik, Norway where it is building up Europe's first gigafactory for fuel cells.

TECO 2030 was founded in 2019 in Lysaker, Norway. It is a spinoff from TECO Maritime Group, a group that has provided technology and services to the global shipping industry since 1994.

I have worked in the shipping industry for over 30 years, and dreamed for a long time about being part of the green transition in the maritime industry. Many years ago, it was clear to me that something had to be done to reduce greenhouse gas emissions. After a few years of travelling, researching and investigating which technology would be the winner, we finally met AVL in late 2019 and decided to kick off a project on exhaust gas cleaning systems for ships. Together with AVL we completed the project in a record time-to-market and decided to start another exciting project – the development of the first purpose-made marine and heavy-duty hydrogen fuel cells. There is no doubt that an industry like shipping needs to reduce emissions while trade volumes are increasing. If the industry does nothing, it will be one of the largest polluters in 2030. This is why TECO 2030 is accelerating the green transition in the maritime and heavy-duty industry with its leading PEM hydrogen fuel cells.

"THE RACE TOWARDS CARBON-NEUTRALITY HAS JUST STARTED… THE FUTURE IS NOT FAR AWAY."

Tore Enger
Group CEO of TECO 2030

Mr. Tore Enger founded TECO Group in 1994. Tore is a true entrepreneur and has created many products and services for the maritime industry over the last 28 years. He has an extensive network in the industry which is crucial for TECO 2030's access to shipowners. Mr. Enger was also the Chairman and major share-holder of Scanship Holding ASA (now Vow ASA), which has been listed on the Oslo Stock Exchange, for approximately 10 years (2008 – 2017).

focus: What roles can hydrogen and fuel cells play in the marine sector, and what are the challenges that you see in this respect?

Enger: International shipping is an important enabler of world trade, but also causes greenhouse gas emissions and pollution. The industry is facing increasingly stringent environmental restrictions and this regulatory back-ground is key to TECO 2030's strategy. The International Maritime Orga-nization (IMO) aims to reduce carbon intensity in international shipping by 40 % by 2030, and to cut the total annual greenhouse gas emissions from the sector by at least 50 % by 2050 compared to 2008.

There are several challenges with creating a bunkering network that will achieve this, however I am confident that by the time fuel cells are widely on board commercial vessels there will be hydrogen fueling stations. This is why large corporations have pledged to become carbon neutral over the next few decades, and this will only increase.

focus: Please tell us more about the TECO Marine Fuel Cell – and how it can overcome these challenges?

Enger: The first TECO 2030 400 kW fuel cell module will be ready soon and will go immediately onto the testbed at AVL's headquarters in Graz. It will be exciting to see how well it performs in the testing environment. The purpose-made marine fuel cell has been developed in collaboration with AVL as a design and simulation partner. Using sophisticated, indus-try-leading simulation software we simulated real life scenarios to devel-op a modular and scalable design with 400 kW as the building block. This makes it the most footprint-efficient fuel cell solution on the market. In a standard 6 meter ISO container, we can fit 3.2 MW of fuel cells. This is an attractive solution for shipowners wishing to retrofit zero emission solu-tions onboard marine vessels, as space is limited on a ship.

We are also aiming to automate the production of the systems with cost-effective production equipment delivered by thyssenkrupp, to reduce pro-duction risk. This will allow for steady supply of fuel cells to our customers who want to upgrade full heavy-duty fleets.

focus: Are you based solely in Norway, or do you have a growing foot-print in hydrogen technology around the world?

Enger: TECO 2030 is headquartered at Lysaker, Norway, with a 15,000 square meter production facility in Narvik, in the north of the country. In Narvik, we will automate fuel cell production over the coming years and in 2024, our fuel cell production output will grow to 120 MW, 400 MW in 2025 and 1.6 GW in 2030. Our strategic sales offices are located in Miami, USA and Singapore and our sales network covers a global footprint to meet an increasing demand globally. Our production facility in Narvik will pro-vide the world with leading energy efficient marine and heavy-duty fuel cells. Our projects involve several segments ranging from trucks to ships, ferries and construction sites, and is well suited for mining, data centers, trains, and emergency generators among other applications.

focus: What's the next big milestone for TECO 2030?

Enger: The next big milestone for TECO 2030 is to see our first FCM400 fuel cell module on the testbed at AVL, and of course seeing the AVL Hy-Truck commercial hydrogen demonstrator vehicle on the road in Summer 2023. And we are also planning to commission a gigafactory to begin auto-mated fuel cell production in the first quarter of 2024.

The FCC 3200™ fuel cell container

focus: How is the gigafactory positioned in the global competitive land-scape? And do you expect other companies to position themselves in the same way?

Enger: The gigafactory will be Europe's first state-of-the-art production fa-cility for PEM fuel cells. It will kick-start the establishment of gigafacto-ries around the world. TECO 2030 expects to position itself as the leading supplier for fuel cell stacks and modules, as well as a partner in large scale hydrogen projects. I assume we will see more announcements of fuel cell factories all over the world over the next decade as hydrogen infrastruc-ture concepts mature.

focus: What were the key aspects of the collaboration with AVL that con-tributed to the market introduction of the TECO fuel cell?

Enger: TECO 2030 values collaboration for achieving the green transition. Nobody can achieve net-zero alone. We are living in a time where global warming and climate change are global buzzwords and our largest chal-lenge. A close and successful collaboration between stakeholders through the entire hydrogen value chain will be the key to the market introduction of our fuel cells. Working together with partners on a project to realize lead-ing environmentally friendly projects is what we strive for every day. Who doesn't want generations to come to have a fantastic place to live as well?

Through our collaboration with AVL, we achieved complete fuel cell in-dustrialization at our Innovation Center in Narvik. The quick production ramp up is possible thanks to the consistent planning from the TECO 2030 and AVL teams working together. Our collaboration enables rapid expan-sion within the development and industrialization of our hydrogen fuel cell stack and system. It will be among the highest quality and most energy efficient fuel cells on the market for heavy-duty applications.

focus: If we look beyond 2030, which global endeavors will be required to accelerate the race towards carbon-neutrality?

Enger: The race towards carbon-neutrality has just started, and I believe our partnership with AVL is an important contributor to implementing a hydro-gen economy and infrastructure. As things accelerate, I believe we will have a solid growth of hydrogen hubs and infrastructure for refueling and con-suming hydrogen. Complete infrastructure networks will have been tested and validated. The future is not far away, and together with partners such as AVL I believe we are seeing the beginning of the implementation of fuel cells in the Nordics and beyond.

TECO 2030's fuel cell stack

INTERVIEW

Female Powered Innovation

The importance and value of increasing gender diversity in the tech-industry is a well-known topic, yet women are still underrepresented in tech-focused roles

— AVL managers Maria Segura Carrasco and Andrea Leitner discuss how to awaken an interest in tech among young girls, how to assert oneself as an expert in meetings, and why women need to be involved in innovation and engineering.

focus: Which career moment shaped you the most? What are you most proud of?

Segura Carrasco: A turning point in my career was my first project as a project manager at AVL, and I saw how satisfied the customer was at the final meeting. Later, I was responsible for the Fuel Injection Systems team; there, too, I really enjoyed working with the technical team. Since 2019 I have been Product Manager for High-Power Systems – a challenging but amazing task.

Leitner: While I worked in the AVL research section, a European research project coordinated by AVL began, focusing on safeguarding and testing automated driver functions. My boss asked me to take on the overall project coordination. At first, I thought I knew too little about the subject, and besides, I was very young and had never led a research project before. But then I thought, let me try! I had to coordinate 70 partners from diverse fields and was invited to conferences to introduce the project. In the end, it was a huge success.

ANDREA LEITNER studied at the Graz University of Technology. After completing her doctorate in Information and Communication Engineering, she started working in the research section of The Virtual Vehicle Competence Centre nine years ago and shortly afterwards joined AVL as a Project Manager and Research Engineer. Since May 2022, she has been Head of Development ADAS/AD Testing Solutions, which mainly involves test systems for the safety around autonomous driving.

MARIA SEGURA CARRASCO studied Mechanical Engineering in Spain, majoring in internal combustion engines. She completed her Master's degree in renewable energies, and started as a Development Engineer at AVL more than 22 years ago. Here she led the team for Fuel Injection Systems and has been the Product Manager and Key Account Manager for High-Power Systems since 2020. She is responsible for business development, market evaluation and R&D planning in the field.

occur. I was always supported by my parents and loved physics and chemistry experiments at school!

Leitner: In my case, my computer science teachers said: "You are a girl, you will never use this knowledge." That is when I thought: "Now more than ever!" However, this negativity was demotivating for most of the other learners. Nearly no one chose a career in technology.

focus: What challenges did you face, especially in male-dominated environments?

Leitner: In meetings, sometimes people assume you are someone's assistant. You have to establish yourself, especially when you are young.

Segura Carrasco: By the time you get to the first introductory round, it becomes clear what one is responsible for. But Andrea is right, at the beginning of your career, colleagues look at you like: "What is this woman doing here?"

focus: What do you think is the biggest obstacle to success for women? Or is the female definition of success different to men's?

Segura Carrasco: I think, if someone goes to work and is happy, that is success – no matter whether it is a woman or a man. And as far as building a career is concerned: It is difficult for women to have a strong

focus: How do we encourage more girls into technical careers?

Segura Carrasco: We need to start early in kindergarten or primary school. Very young girls are often interested in technology, especially when it comes to experiments. But in secondary school or even earlier, they lose interest. Later, when companies look for talent in high schools, it is too late for most girls who were once tech-savvy. Had they been supported through the years, this disjuncture would not

network and a good mentor because there are not many women in higher positions. Female networks are, unfortunately, not as influential as male networks – and that is exactly where you need someone to support you.

focus: Why do you think more women are needed in the technological industry?

Leitner: It is extremely important that women get involved in innovation and engineering topics as they convey other aspects and think differently. This generates a lot of creativity, which is very enriching.

focus: What advice do you wish you had received at the beginning of your career?

Segura Carrasco: At the beginning of my career, what I needed most was encouragement: "Believe in yourself! Be daring!" It is important that somebody supports you and believes in you.

Leitner: "Dare to ask questions," is what comes to mind. In my early days, I often had to deal with eloquent colleagues, and I would think to myself, that sounds right, but it makes no sense to me. Back then I did not dare to ask questions: Okay, why is it like this? Or: How can you make an argument for that? It would have helped if somebody had encouraged me to express my thoughts. ⎯⎯⎯⎯⎯

Launch of a Female Engineer Program

AVL RACETECH champions female talent in motorsport

Female engineers are still underrepresented in motorsport. To rectify this, AVL RACETECH has launched a Female Engineer Program for AVL employees. The initiative puts AVL's women in pole position for a career in motor racing.

The program combines two objectives: supporting women in tech, and diversity. AVL RACETECH already supports female racing drivers through its ambassador program: Tatiana Calderón and the "Dakar Sistaz" Aliyyah and Yasmeen Koloc, three strong women that represent the AVL colors on the international motorsport stage. Tatiana is the woman who has progressed furthest in motorsport and currently races in Formula 2 – the second highest class, after Formula 1. Aliyyah recently claimed the title in the FIA Middle East Cup for Cross Country as the first women ever.

The Female Engineer Program offers participants the opportunity to receive training within AVL's motorsport division while still working in their departments and projects. From getting involved in various racing fields to first-hand experience at the racetrack, over the course of the year they gain a deep insight into the world of professional motorsport. In practical workshops on the topics of race engineering, simulation, testbeds and driving simulators, the engineers acquire expertise to work in the industry.

The engineers also get to spend a longer duration working in racing teams, with which AVL RACETECH maintains cooperations. In return, female technicians from the respective teams will learn from AVL's motorsport expertise. The program starts in the first quarter of 2023. Initially, two places are available for female AVL engineers. Depending on the success of the program, it will be extended in years to come.

Ellen Lohr, Director Motorsport AVL, says: "The time is right for a program like this, as motorsport has no longer been a male-only domain for a while. However, we need more female role models. The more female engineers play a visible role in motor racing, the more women will identify with them, which can only be positive for the sport and also for AVL."

◄ AVL RACETECH ambassador Tatiana Calderón

Photos: © Dutch Photo Agency

Tatiana Calderón
AVL RACETECH Ambassador

Marie-Alice Lahaye
Race Engineer

REGISTER NOW!

START YOUR CAREER IN MOTORSPORT WITH US

AVL RACETECH FEMALE ENGINEER PROGRAM

"Female engineers are still underrepresented in motorsport, however more and more are getting into decision-making positions. Grab your chance now!"
Ellen Lohr, Director Motorsport at AVL

Within the Female Engineer Program, the selected participants will experience a motorsport scholarship at AVL RACETECH. From working at different motorsport departments to getting on track experience in collaboration with AVL RACETECH's technical partners. Our goal is to support your path into motorsport.

To get more information, please send us your application letter to avlracetech@avl.com until 01.03.2023

www.avlracetech.com

PUSHING FORWARD ENERGY REDUCTION AND ENVIRONMENTAL PROTECTION

Our vision of CO$_2$ neutrality across our global operations starts with our Austrian headquarters

— Climate change and environmental impact have been, and will continue to be, the biggest drivers of change within the automotive industry. It is something we take very seriously at AVL, as we work with our partners and customers to achieve climate-neutral mobility. But it is also something that we have always been and of course still are passionate about at AVL, and we're taking steps to reduce our own environmental impact across our business, starting with our head office in Graz, Austria.

GLOBAL PATHWAY TOWARDS A GREENER AND MORE SUSTAINABLE FUTURE

Making AVL climate-neutral is not a single task, but a series of activities with the aim of continuously optimizing, improving and monitoring our CO$_2$ footprint. Our employees are the changemakers, innovators and pioneers towards sustainability – not only with their work but also, for example, on their way to work. As a company, we encourage people to cycle to work and we subsidize the increased use of public transportation. Furthermore, more than half of our internal carpool is either electric or hybrid. We charge these vehicles on-site using renewable power, and when they are out on the road, we use the 100 % renewable Shell Recharge network.

We are already using 100 % renewable electricity at our headquarters in Graz, and heat produced by our own solar thermal plant, measuring more than 3,300 m², is fed into our internal heating network. The system offers an energy generation capacity of 2,424 kW, and boasts a cooling capacity of 650 kW using the high temperatures of summer for process cooling via an absorption chiller. This makes it one of Europe's largest process cooling systems.

Built in collaboration with SOL-ID Solar Energy Systems and solar.nahwaerme.at, the plant can save 320 tons of CO$_2$ every year and offers a practical example of how any industry can reduce CO$_2$ emissions. We have also installed a waste heat recovery infrastructure throughout our Graz facility to supply our internal heating system.

HOW WE ENSURE THAT OUR ACTIVITIES MEET OUR GOALS

The basis for our sustainable actions is the ISO 14001 certificate, which the headquarters has held since 2002 and we are working to roll it out at all locations worldwide. Furthermore, we have been part of the ECOPROFIT® initiative of the city of Graz for decades, which aims to conserve natural resources and reduce waste and emissions.

We already have global energy and CO$_2$ measurement and monitoring practices in place. For this purpose, we have developed our own in-house energy monitoring tool that provides the energy consumption and CO$_2$ emissions data of AVL globally to determine the most efficient measures to achieve our environmental targets, taking into account local conditions.

Together we move towards our vision of carbon neutrality at our head office and across our global business – creating a more sustainable world for future generations.

Leading in Digital Transformation

AVL's Jens Poggenburg joins influential industry body to shape the future of digitalization

— AVL's Executive Vice President, Jens Poggenburg, has been elected as the AVL board's new representative of suppliers at the prostep ivip Association. The association brings together members from a variety of industries to tackle the big issues around digitalization. Founded in 1993 with a focus on the STEP data format, then expanded to integrated virtual product creation, the association has now strategically realigned itself towards digital transformation.

"Since there is a huge overlap in the strategy of prostep ivip with the mid- and long-term objectives of AVL, I am happy to contribute as a board member of the association to its future success," says Poggenburg. "We are all facing the same challenge: How to ensure seamless collaboration in cross-organizational networks. Digitized processes, well-defined interfaces, appropriate skills, and global interaction are essential success factors which I would like to move forward. I am very optimistic to create relevant impact for the member group of suppliers in the association."

AVL has been an active member of the association since 2008. ——————

FIND OUT MORE: **www.prostep.org**

DESIGNING THE DRIVING EXPERIENCE

Examining hundreds of different characteristics and technologies, including innovations such as torque vectoring for electric all-wheel drive systems, and vehicle dynamic control, we are able to create a roadmap for different driving experiences. These are then functionally defined, developed, calibrated, and considered collectively in a way that meets the demands of vehicle makers and the end user.

By transforming our knowledge of market trends, system performance and technology into KPIs for target setting, we can then support our customers in creating a functional vehicle development approach to realize products that compete in specific market segments, with specific performance goals. This is especially vital for the development of new electrified vehicles, whose geometry and driveability are heavily impacted by systems such as the battery and its influence on the vehicle's center of gravity and aerodynamics. Similarly, e-axles and e-motors impact driving dynamics and comfort features, which in turn impacts development methodologies, timescales, and cost. Thanks to our experience, we can help you manage, and optimize, all of these many different factors.

SIMULATING A SUCCESSFUL PROJECT

At AVL one of the keystones of our business is our simulation know-how. The various software tools in our portfolio enable us to build a vehicle – from individual components and systems right up to the whole product – fully virtual. We use tools such as AVL-DRIVE™ and data from our benchmarking program to assess and model the performance characteristics of different systems in relation to each other. This means that we can ensure a vehicle will meet its driveability targets right from the start of development.

Other products in our software toolkit include AVL VSM™ for simulation, and AVL CAMEO™ for calibration, both of which contribute real value when designing and developing vehicles with particular user experience traits.

Ultimately, the goal is to create a driving experience that is competitive in a specific market segment. And as vehicles and their systems are becoming increasingly complex, to achieve this requires specialist functional development methodologies, know-how and expertise. And at AVL that is just what we are able to provide to our industry partners.

With our expertise in functional vehicle development, and our diverse portfolio of tools and services, we can help you create the ideal experience for your target market
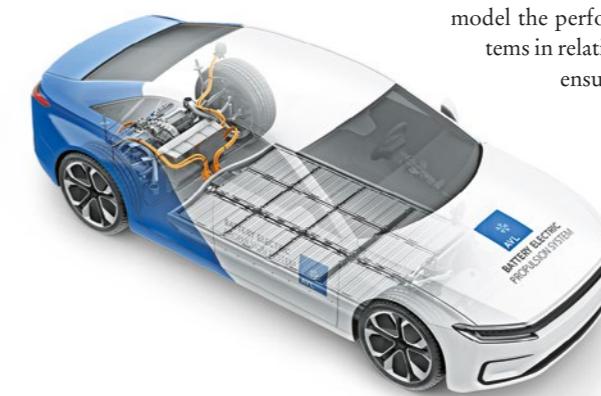
— The market position of a vehicle and the driving experience are influenced by tangible driving characteristics. Chassis attributes, braking and traction control, and comfort factors for example, all influence the driving feel and are created by the behaviors of different systems, functions and parameters.

But the vehicle is growing in complexity, as the automotive industry responds to customer demands for an increase in functions provided by systems such as electrified powertrains, ADAS and Automated Driving. These result in more systems – both physical and software – impacting the driving experience, and call for an intelligent design approach at both the system and complete vehicle levels.

To tackle this complexity, at AVL, we use a systems engineering approach that considers each system in relation to the complete vehicle, to optimize the end-user experience. The result is a product that meets user expectations for the market segment that it is in, while reinforcing the brand identity of the manufacturer, and aligning with their goals.

BENCHMARKING FOR TARGET SETTING

Understanding the type of driving experience – and therefore the types of vehicle systems – that are expected throughout the automotive market requires a deep understanding of the vehicle itself. Thanks to our AVL Global Benchmarking Program we can analyze the performance and system characteristics of vehicles across the market, with special attention to the premium segment which often sets the standard for other market segments to follow.

Main components of the AVL system for measuring brake abrasion particles.

One Step Ahead of Future Brake Emission Legislation

AVL is leading the world in brake emission measurement systems

Continuous improvements in combustion-based mobility, driven by increasingly stringent exhaust gas regulations, have led to a significant reduction in particulate matter pollution. Today, the majority of vehicular particulate matter no longer originates from exhaust gases, but from other sources such as tire, road and brake abrasion. Of these, brake abrasion is considered to have the greatest potential for reduction.

Under the Particle Measurement Program (PMP) of the United Nations Working Group on Pollution and Energy (UN-GRPE), a methodology has been developed to describe the procedure and conditions for measuring brake particulates and which metrics should be used. Subsequently, this methodology, known as the United Nations Global Technical Regulation (UN GTR) will become the foundation for futur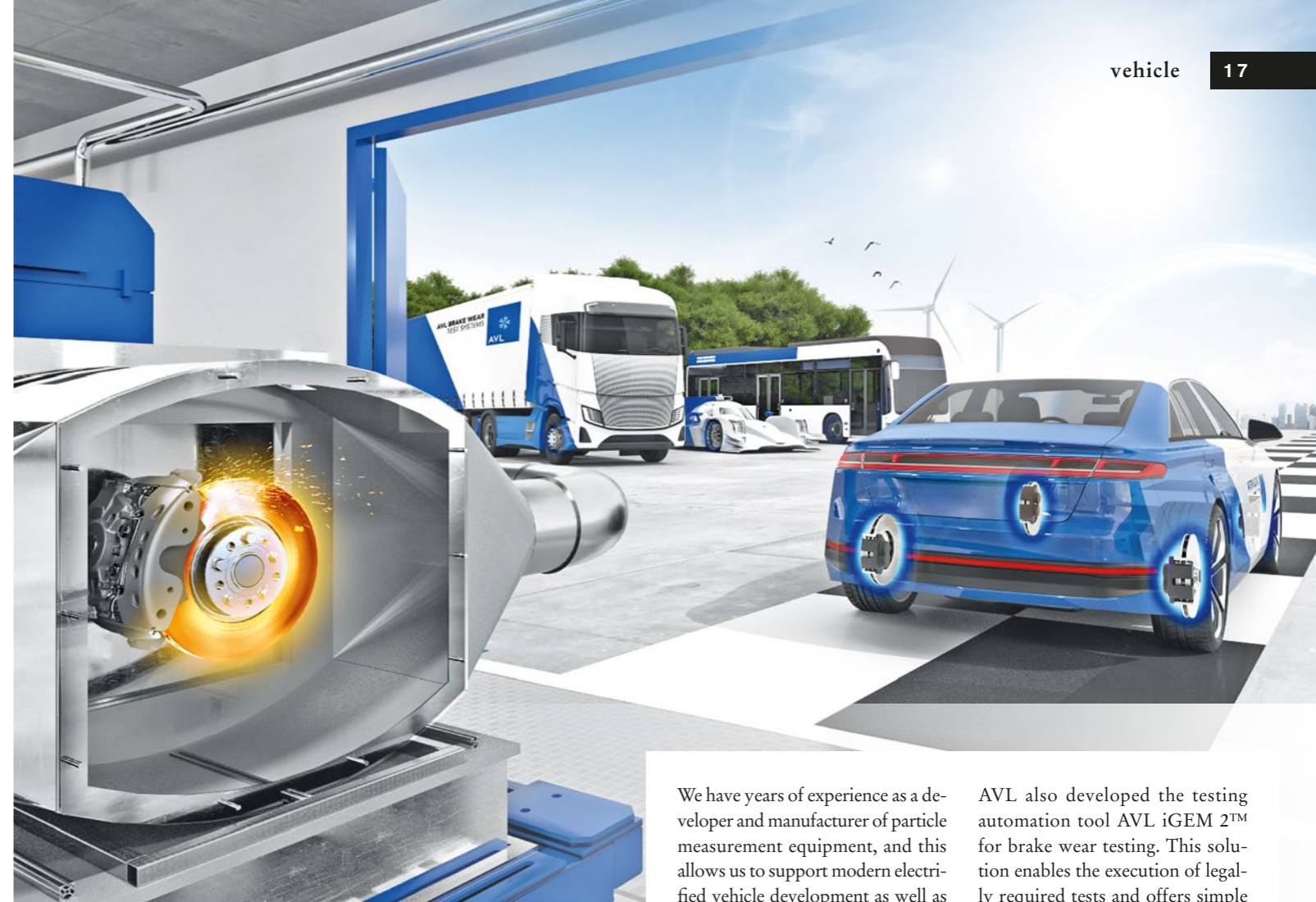e legislation with which vehicle and brake component manufacturers will have to comply, in addition to already existing requirements for brake development like braking performance, noise and driving stability. To support this compliance, there is a need for suitable testing solutions.

AVL EXPERTISE SETTING THE STANDARD

As an industry leader, AVL played a role in the definition of this UN-GTR and we have developed a solution – AVL Brake Emission Test Systems – that delivers repeatable and comparable measurement results through comprehensive optimization of the entire measurement chain. This starts with flywheel-free loading machines, air conditioning systems, volume flow generation, and the enclosure of the brake systems to be measured. It also includes suitable sampling systems with appropriate sampling probes, measuring devices for particulate mass, particle number and flow measurement up to test run automation and evaluation. All of which meet the requirements of the GTR. Modular in design and consisting of self-contained subsystems, it can be tailored to your precise requirements.

DEEP KNOW-HOW FOR ACCURATE RESULTS

The success of our solution is based on a deep understanding of the physical behavior of the particles generated during braking processes. In addition to cooling the braking system, the solution's enclosure is designed to dissipate the emissions generated during braking as completely as possible, without major particle losses. The transfer lines of the measuring equipment are built to minimize particulate losses and support efficient test rig operation. Air mass measurement as well as air conditioning with temperature and humidity control complete the system.

The iGEM 2 test automation system guides you through the entire brake test procedure, including pre-test dialog, test preparation and the test run itself. The test cycle is run automatically in an unmanned mode.

We have years of experience as a developer and manufacturer of particle measurement equipment, and this allows us to support modern electrified vehicle development as well as conventional combustion-powered vehicles. Brake systems in modern, electrified powertrains must be considered as a whole due to their interfaces and interactions with the vehicle. The focus here is on the ability to recover braking energy through suitable recuperation strategies. The consideration of vehicle operating strategies for optimized emission behavior requires the use of appropriate simulation tools. Regarding these simulation tools for vehicle co-simulation on the test bench, AVL can draw on many years of experience and mature functionalities that enable it to cover current requirements in development.

Our solutions cover all current development requirements. Additionally, we also developed a solution to convert your existing testbed infrastructure for brake emission tests. This could help to gain utilization of existing testbeds with minimum investment.

AVL also developed the testing automation tool AVL iGEM 2™ for brake wear testing. This solution enables the execution of legally required tests and offers simple modification options for customer-specific development tasks. The application's associated test evaluation and automatic test reporting round off this lean, optimized package. In addition we have developed a solution to convert your existing testbed infrastructure for brake emission tests. This could help to gain utilization of existing testbeds with minimum investment.

In analogy to exhaust gas legislation, it can be assumed that in the medium-term braking emissions will be examined not only on the basis of component tests on the testbed, but also in real driving operation. Here, too, we are already taking the first development steps, and will build on our success in exhaust emission reduction.

AVL Test Systems for Electromagnetic Conformity (EMC)

Ensuring electromagnetic compatibility in driving systems, vehicle control units, and ADAS systems

— An increasing number of electrical and electronic (EE) subsystems are being integrated into vehicles. Operating high-performance electric propulsion under all conditions and in close proximity to sensitive communication systems is one of the most significant hurdles the automotive industry must overcome. EMC measurement should therefore be considered early in development.

At AVL we have continuously expanded our portfolio of EMC test systems from component level to the complete vehicle, and always compliant with EMC standards. The three major test areas are e-motor, e-axle and vehicle.

EMC E-MOTOR TEST SYSTEMS

The AVL E-Motor TS™ EMC – fixed provides the highest performance and EMC capabilities. Customers do not have to compromise between the mechanical and the EMC performance of the test facility.

The AVL E-Motor TS™ EMC – mobile solution performs high-speed EMC testing under load in existing EMC chambers without major modifications. The mobility of the system allows complete pre-setup outside and transfer into the chamber, resulting in high efficiency.

EMC E-AXLE TEST SYSTEMS

The AVL E-Axle TS™ EMC is an extension of the fixed E-Motor EMC test system. This scalable solution can be extended to all performance classes of AVL's dyno portfolio, reaching up to 5,000 Nm and 3,500 rpm.

EMC VEHICLE TEST SYSTEMS

Integrable into both anechoic and shielded EMC chambers, AVL ROADSIM EMC™ is a chassis dynamometer that supports EMC testing for everything from passenger cars to heavy trucks. It complies with most international regulations (CISPR 12 and 25, ISO 11452, GBT 18387-2008 and ECE-R10).
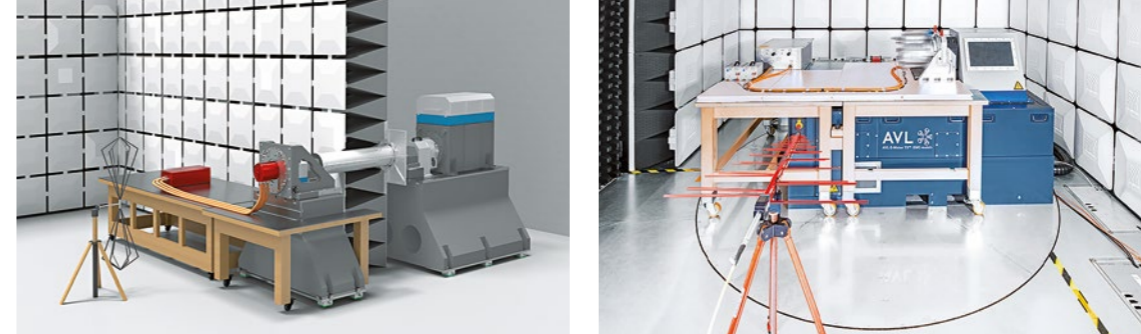
AVL E-Motor TS™ EMC – fixed (left) and mobile (right)

Analysis of EMC results under real-driving-conditions with an advanced Software Interface between AVL PUMA 2™ and R&S® ELEKTRA EMC TEST Software (right). Data post-processing in AVL CONCERTO™

ANALYSIS OF EMC RESULTS UNDER REAL-DRIVING-CONDITIONS

The behavior of components such as the e-drive changes depending on different uses. This forces the testing operator to dodge steady state measurements for real driving conditions. And EMC measurements with fixed operating points, as in conventional internal combustion engine vehicles, do not show the same effects as in the electrified vehicle.
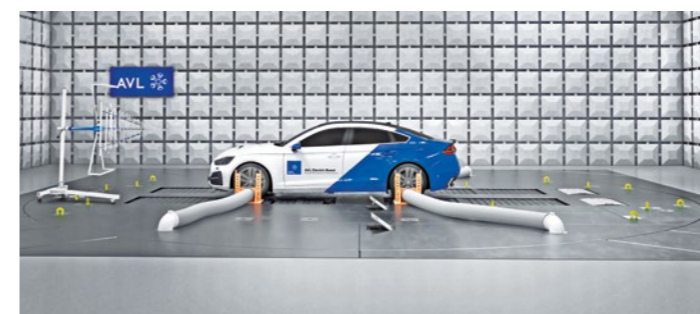
Additionally, the EMC test setup comprises of the device under test (DUT), the load simulation, conditioning systems and the EMC measurement hardware and chamber. All these components have separate automation and/or control systems for their operation, and must be interconnected to measure their dependency to each other.

To tackle this we have collaborated with Rohde & Schwarz, a provider of measuring and testing systems, on an exclusive solution for automated EMC data analysis. The system works under real operating conditions of an electric vehicle or any of its components.

AVL PUMA 2™ automation drives the test cycle and stores the measured data, in sync with the R&S®ELEKTRA test software, which exchanges information between the testbed and the EMC measurement equipment.

AVL CONCERTO™ post-processes the measured data automatically, delivering a full test report according to pre-defined pass and fail criteria. It supports automated testing with simulation of real driving conditions while covering typical automotive standards. The benefits include:

- Complete EMC results under real driving conditions
- Reduced complexity of EMC measurement procedure for components and vehicles
- All test specifications and examinations can be carried out depending on the different DUT and EMC parameters
- Synchronization of EMC measurement and DUT operating-data, which shows the dependency of the operating state and EMC data, and the behavior of EMC parameters depending on the operating variables of the DUT
- Repetitive and deterministic test procedures allow for fast comparisons between testing cycles and their visualizations
- Individual monitoring criteria can be defined for any channels. Deviations and violations of tolerance bands are evaluated automatically

Our EMC test solutions guarantee that the DUT is the only focus of each EMC measurement. They also reduce test setup complexity to ensure that testing is safe, precise and as time efficient as possible. This empowers our customers in their e-mission. —

AVL E-Axle TS™ EMC – fixed

AVL ROADSIM EMC™

— Electrified propulsion system development is accelerating and, along with it, the search for innovations to optimize cost, efficiency, performance, and integration space. The rising demand for e-drive solutions also requires high development capacity and expertise. Qualitative new requirements fill the specification sheets of car makers and suppliers: not only do engineers need new techniques, but also in-depth understanding of the different driving cycles, interactions between the components, and the constructional challenges of EVs.

Putting the power where it's needed most. Onto the road.

Electric Driveline – the Core of E-Mobility
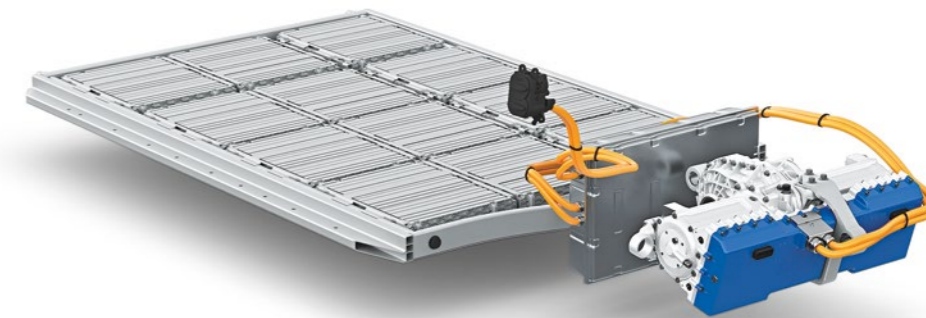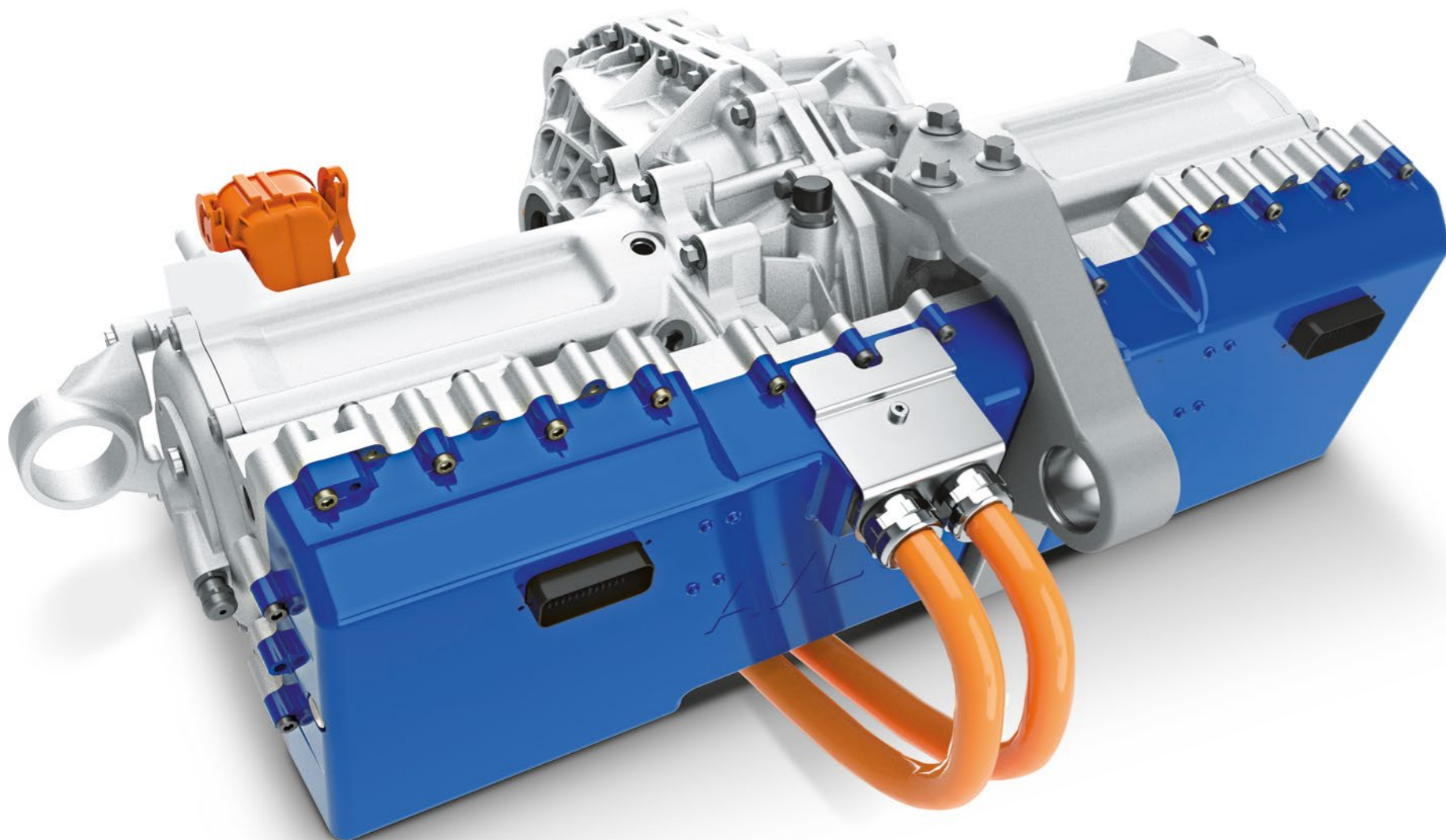
While every component must meet the highest demands, it is integrated solutions that deliver the biggest ROI. They do this by reducing costs, development time and effort, and delivering the highest efficiency, performance and integrability. Other advantages are smaller dimensions, lower weight, reduced interfaces, and improvements regarding electromagnetic radiation.

At AVL we are leading this new era of mobility, thanks to our decades of experience and our close relationships with the academic institutions driving knowledge in this area. But it is our product and solution portfolio that delivers real results. Whether it's the e-motor, the transmission, the e-axle, or the power electronics and software, we turn knowledge into motion.

E-AXLES – A MODULAR, LOW-COST APPROACH TO E-MOBILITY

Our e-axles integrate the necessary e-drive components – e-motor, transmission, and power electronics – and leave maximum space for the battery. As an out-of-the-box solution for passenger cars and commercial vehicles their compact design has additional advantages: optimal integration into the available space, and weight reduction – a bonus for improving driving range.

Our e-motor technology offers options for any application, including up to 800 V applications. Our port-

folio includes axial flux motors, motors with direct oil cooling of the stator, permanent magnet motors, asynchronous motors, or auxiliary units without traction tasks.

Two-speed transmissions and various configurations of single-stage reduction gear boxes are included in our comprehensive product range of transmissions. Light, efficient, powerful, comfortable and economical, they help to deliver the power where and when it's needed the most.

None of this would be possible without the appropriate electrical, electronic and software framework. We choose the best way to deliver the appropriate power densities, such as our new developments into semiconductors, including silicon carbide (SiC) or gallium nitride (GaN). These technologies offer increased efficiency and longer driving range.

Our modular and adaptable control software offers features like NVH-optimized control, torque vectoring for e-axles and predictive driving functions. Performance characteristics, alongside capacity, charging time and cost, are optimized by our modular power electronics systems. They get the best from every subcomponent and system, and include inverters for traction and auxiliary drives (including dual inverters) and DC/DC converters.

DELIVERING SUCCESS FOR ALL MARKETS

Our second generation high-performance high-speed e-axle for passenger car has one of the highest power densities on the market, using solely standard materials. It works with an 800 V characteristics, system and is characterized by a maximum rotation speed of 30,000 rpm. The unit produces a total top performance of 500 kW and an axle torque of up to 6,000 Nm, made possible by innovations such as silicon carbide semiconductors and direct-oil-cooled e-motors.

And it's not all about passenger cars. Our reinvestment into R&D has enabled us to develop a compact but powerful high-density e-axle for commercial applications. With flexible in-vehicle packaging that can be adjusted to suit use cases for both battery electric and fuel cell electric applications, from light to heavy-duty vehicles. To prove the feasibility of this system, we are fitting it into our fuel cell demonstrator truck, which will be available to our customers soon.

Master the Heartbeat of the Battery

The new generation of AVL CELL TESTER™

▶ Unrivalled accuracy

Current Measurement Accuracy graph: Current Measurement Uncertainty [mA] vs Current Output [A], also showing Percentage of Full Scale [%]. Points noted: 25 A, 2.5 mA.

— The battery cell is the most important component in the electric powertrain, both in terms of cost and performance. To ensure affordable and durable battery packs, it is vital to master the electrochemical processes within the cell. It is therefore crucial to conduct precise, reliable and accelerated cell testing while minimizing the operation of your testbed.

To improve and accelerate electric vehicle development, AVL has developed a series of battery cell testers. These are bi-directional, multi-channel DC power supplies that test, diagnose, characterize and validate battery cells. They can achieve an output current that ranges from ±2 A to ± 2,400 A thanks to their multiple variants and the parallelization of their channels.

HIGHEST QUALITY AND ACCURACY OF TESTING RESULTS

The AVL CELL TESTER™ 600A uses a unique current measurement technique providing the best accuracy (0.01 % of actual value) among high current cell testers while using only one current measurement range. This provides the following benefits:

- Reduced test programming complexity by avoiding range switching
- Accuracy is proportional to the output, enabling testing capacity with always the same proportional error
- Such high accuracy provides more reliable results and reduces test time by enabling accurate coulombic efficiency analysis

Another feature is real-world replication thanks to high dynamic control. With the fastest rise time on the market (0.5 ms) together with 1 ms control and acquisition frequency, this cell tester can apply realistic current or power profiles and adapt testing cycles based on real time models.

The CELL TESTER 600A is fully integrated and compatible with the AVL automation software AVL PUMA 2™ Battery and AVL LYNX 2™. It uses a real-time EtherCAT interface with a setting and measurement update rate of 1 kHz.

DESIGNED TO OPTIMIZE TOTAL COST OF OWNERSHIP

With the highest regenerative efficiency and high-power density, it reduces energy consumption and requires the smallest installation space. Reduced preparation time (easy programming with single range) accelerates testing and increases results quality (high accuracy and realistic profiles). So, you get your results faster.

These benefits accelerate Li-Ion cell development and/or validation while significantly enhancing quality control and reducing operating costs.
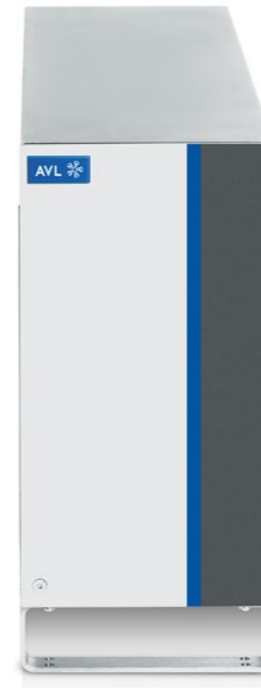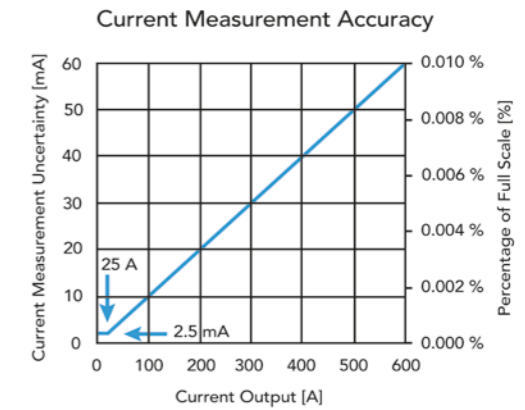
AVL CELL TESTER USE CASES

- **Application use case for cell development:**
  The CELL TESTER supports cell R&D. High accuracy and dynamic control enable tests in very precise conditions and accurate results. Its 1 kHz setting and acquisition rate, enables quick test program reaction as well as recording at rate to observe specific electro-chemical reactions. When used with AVL's automation software, you can flexibly program any test including dynamic profiles in current, voltage and power. This enables the creation of different tests for future needs. In addition, the CELL TESTER contains several advanced diagnostics features such as EIS
- **Applications use case cell validation and system development:**
  With CELL TESTER you can perform any cell validation test with high repeatability while minimizing laboratory space and energy consumption

OTHER POSSIBLE USES OF THE AVL CELL TESTER ARE:

- Capacity test: CC (constant current) or CCCV (constant current, constant voltage)
- Life cycle and dynamic profile (current or power) test with 1, 10, 100 and 1,000 Hz update rate
- Pulses test such as HPPC (hybrid pulse power characterization), DCIR (direct current internal resistance) and power test with 0.5 ms rise time and 1 ms time resolution voltage response
- Fast charging profile try-out and test with high dynamic control
- SOC OCV (state of charge, open circuit voltage) mapping with 0.01 % accuracy in current and voltage
- Coulombic efficiency thanks to 0.01 % accuracy in current and voltage
- Differential capacity analysis thanks to low ripple and unrivalled accuracies
- Electrochemical impedance spectroscopy from 1 mHz to 10 kHz

FIND OUT MORE:
www.avl.com/-/avl-cell-tester-

▲ AVL CELL TESTER™ 600A

▲ AVL CELL TESTER™ 50A

INTRODUCING AI FOR BATTERY DESIGN CONFIDENCE

— As the complexity and popularity of e-mobility increases, the demands placed on the battery are greater than ever. This crucial system must therefore perform and behave with utmost reliability. Even though today's batteries deliver more than ever before, their development and production are subject to uncertainties and unpredictable issues such as production tolerances. This can lead to a high level of costly production scrap.

Battery development is a vibrating space of captivating topics, such as cell characterization, cell aging, fleet battery modelling, and optimization of cell material and geometry. When optimizing cell material and geometry, there are risks of deviations in terms of capacity, aging, lifetime, or performance that can affect the battery's target values, but which are difficult to manage.

At AVL we're using AI to tackle this problem.

DESIGNING THE BEST CELL IN THE WORLD

Cell design comes with myriad considerations, from choosing the right chemical composition for the best performance, to the exact anode thickness and layout, all to achieve the desired KPIs. Input uncertainties (such as tolerances, environmental or usage factors) that are often difficult to consider, make optimizing the cell composition complex and time consuming. That is why we have developed the Robustness Optimizer, as part of AVL CAMEO 5™ for Battery.

This AI algorithm takes any difficult or uncertain values – such as tolerances, environmental or usage factors – and integrates them into the optimization workflow. The result is increased certainty in areas such as:

- Optimal trade-offs between battery KPIs such as cell capacity, fast charging capability and losses

- Production tolerance consideration and identification in cell composition design
- Strongly reduce production scrap and save money

With the Robustness Optimizer, we are leading the charge for optimal cell design. Turning uncertainty on its head, the unpredictable can now be added to the equation. ———

▼ The new AVL CAMEO 5™ for Battery tackles high cell production scrap.

Taking to the Skies with Fuel Cells

What does the future of zero emission flight propulsion look like, and how do we get there?

INTERVIEW

with David Diarra, DLR and Helmut Iancu, AVL

— The aviation industry has set ambitious CO_2 targets for 2050. Focus speaks to AVL's Helmut Iancu (Global Business Segment Manager Fuel Cell Testing Technology) and David Diarra (R&D Management, PL BALIS) from DLR, the German Aerospace Center, about the roadmap to sustainable flight propulsion.

focus: What does the development roadmap look like for the next generation of flight propulsion?

Diarra: Beside sustainable aviation fuels, the combination of hydrogen and fuel cells (FC) is a promising option for small and medium range aircraft. The feasibility of fuel cell-based electric aircraft has been demonstrated with small aircraft already.

focus: What type of electric architecture do you see as the most promising?

Diarra: For higher power ranges fuel cell (FC)/liquid hydrogen (LH_2) energy systems offer a higher specific energy density than battery systems to date. However, hybridization with a battery is inevitable in many cases. Combining the benefits of the fuel cell and the high specific power of a battery enables optimization of system efficiency and weight. Such an approach can offer advantages such as redundancy, system stability and dynamic behavior.

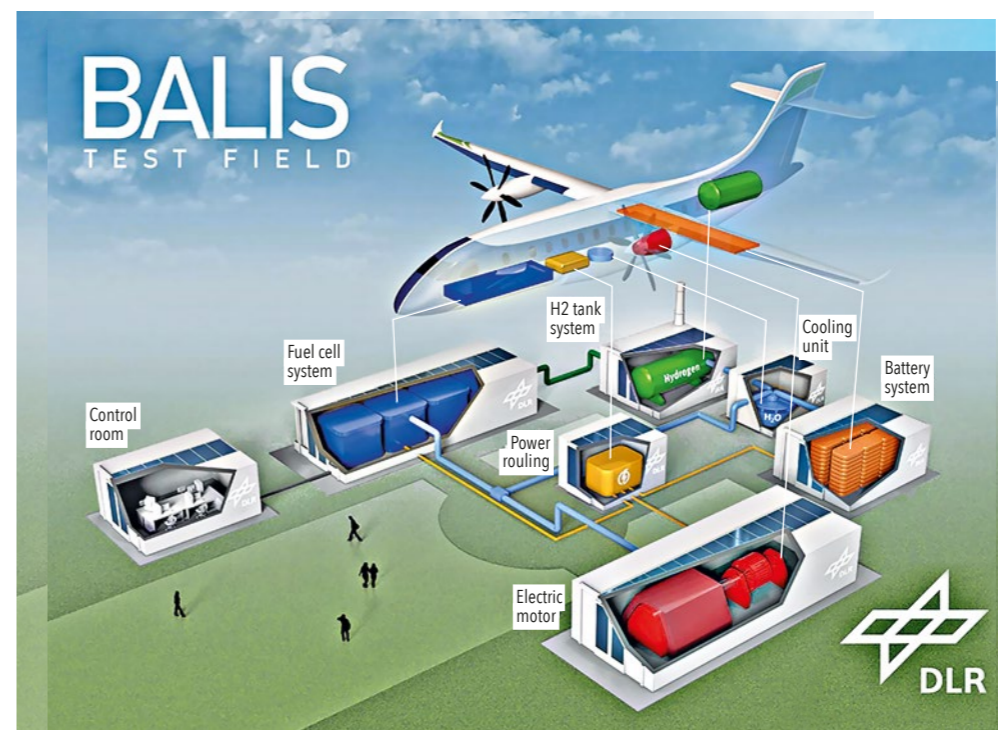**focus:** What will be the big challenges in transitioning to these technologies?

Diarra: Balancing the individual components of fuel cell-based powertrains requires new approaches for both testing infrastructures and R&D processes, to make the right engineering decisions early in development. In the BALIS project AVL and DLR are developing a first of its kind testing environment to cope with future challenges which address an increase of the power density and the high demands in reliability and technical/economic efficiency of powertrains in aviation.

Iancu: BALIS is a test environment built to upscale fuel cell powertrains to the megawatt range. It has several testbeds for different systems – fuel cell, battery and electric motor. It offers single component as well as coupling tests by procedural or electrical connection of the test fields following the multi-integration test environment approach.

Diarra: In addition to that, BALIS will be the first testing environment which implements a test field for LH_2 aviation tanks and a capable LH_2 infrastructure.

focus: This sounds like a very complex test field, where the seamless integration of simulation is key. Could this approach be used in other industries?

Iancu: Many industries are shifting to a simulation-centric approach. Virtual prototypes and models shorten development times and support an agile simulation approach. At AVL we have the expertise and solutions to change the way new propulsion systems are developed across industries. And with DLR as partner, we are shaping the future of sustainable propulsion. ———

BALIS TEST FIELD

Control room
Fuel cell system
H2 tank system
Power rouling
Cooling unit
Battery system
Electric motor

DLR

◄ BALIS test environment for the development of fuel cell propulsion systems in aviation
© German Aerospace Center (DLR)

Ribbon cutting at the official opening ceremony in September 2022.

Leading the World in

Hydrogen and Fuel Cell Testing

The opening of our latest hydrogen and fuel cell test center outlines AVL's commitment to clean mobility

— With its main emission being water, hydrogen is a viable clean energy source for mobility in both combustion and fuel cell applications. To support this we have opened the AVL Hydrogen and Fuel Cell Test Center at our head office in Graz. As one of the largest, most powerful facilities in the world, it can accommodate testing

activities for light, medium, and heavy-duty vehicle applications, as well as stationary power generation systems. It is futureproof and adaptable to tomorrow's demands.

The facility has a control and service area, with automated, remotely controlled testbeds. These run on the AVL PUMA 2™ automation system, ensuring accurate testing, safety, reliability, and repeatability. The facility covers all development-related test procedures, from performance characterization and model validation to durability tests, and controls optimization. This is managed with AVL CAMEO™.

COMMITTING TO THE FUTURE

With this center we are committing to the application of these new technologies for many sectors, including marine, rail, aviation, stationary power generation, and efficient hydrogen production. With its large hydrogen infrastructure, it will also be used to advance hydrogen supply techniques and technologies.

While this facility represents one of our most ambitious construction projects, it is just the latest development of this kind in our global network. We also run a newly built fuel cell test center in Canada, and another fuel cell test center is under construction in Hungary. —

AVL Hydrogen and Fuel Cell Test Center facts:

- 600 m² facility with a maximum allocation of 20 testbeds
- Total capacity of up to 2 MW
- Testing of polymer electrolyte membrane (PEM) systems with an output of up to 400 kilowatts
- System, subsystem, and component testing for solid oxide fuel cells (SOFC), solid oxide electrolysis cells (SOEC) and PEM electrolysis

© Hydrogen Europe

INTERVIEW

with Jorgo Chatzimarkakis, CEO of Hydrogen Europe

— **focus: What role will hydrogen play in Europe's 2050 net-zero emissions targets and where do you see its biggest potential?**

Chatzimarkakis: Renewable and low-carbon hydrogen is on track to play a significant role in meeting Europe's 2050 net-zero targets. The REPowerEU plan aims for 10 Mt of domestically produced green hydrogen and 10 Mt of imported green hydrogen by 2030. This will safeguard and diversify Europe's energy supply by replacing fossil fuels as well as rare raw materials.

Hydrogen's most important applications are in the power sector, in decarbonizing industrial sectors such as steel and cement, and in heavy-duty transport by road, rail, sea, and air. And there are other ways hydrogen can contribute to net-zero, too.

focus: What is your perspective on current and future developments of the hydrogen market and what is Hydrogen Europe's role?

Chatzimarkakis: Our role is to promote policies and initiatives that strengthen the development of European and global hydrogen technologies and clean hydrogen markets, and to coordinate the advancement of research, development, and innovation in hydrogen technology.

Europe could be the birthplace of the global hydrogen economy, where hydrogen is traded across borders and seas via pipelines and ships. The EU is a global leader in hydrogen technology and European companies are driving innovation.

That said, if Europe wants to remain at the forefront of the global hydrogen sector, it must act to finalize regulation and provide certainty to investors. Proactive and timely action will ensure our competitive edge over countries like China or the US, the latter having passed incentive schemes for hydrogen under its Inflation Reduction Act.

focus: What impact will the AVL Hydrogen and Fuel Cell Test Center have on the industrialization of hydrogen and fuel cell technology?

Chatzimarkakis: The new AVL center is one of the largest and most advanced test sites for fuel cells and electrolysis systems in the world. It can test a number of components along the hydrogen value chain and can therefore provide urgently needed test capacity to the whole industry. —

Tackling PEM Fuel Cell Freeze Start Challenges with System Simulation
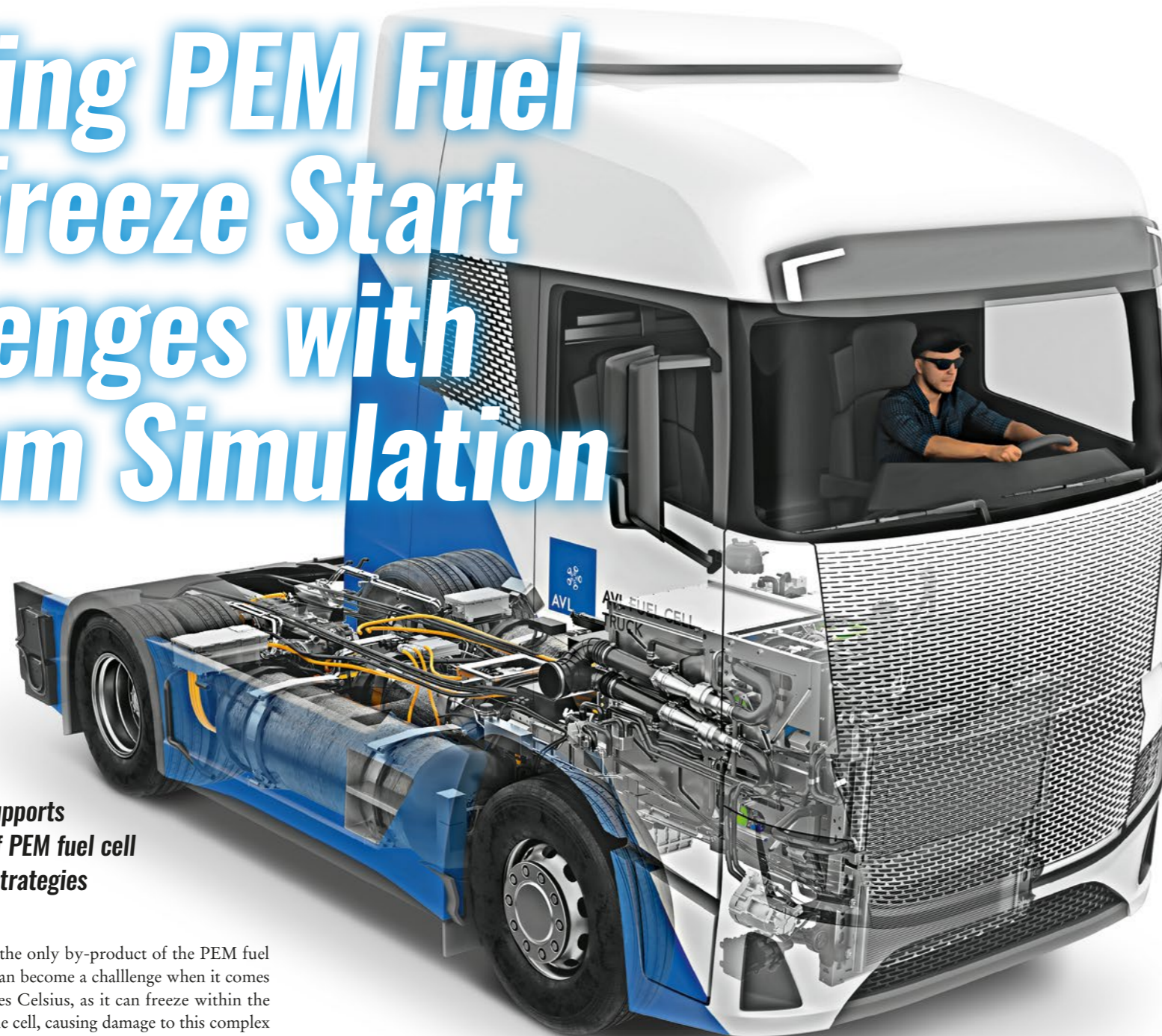
AVL CRUISE™ M supports the development of PEM fuel cell system cold start strategies

— Alongside electricity and heat, the only by-product of the PEM fuel cell is water. However, this water can become a challlenge when it comes to temperatures below zero degrees Celsius, as it can freeze within the membrane and reaction layers of the cell, causing damage to this complex and delicate system.

To tackle this challenge, any new PEM fuel cell integration will require a cold-start strategy that is appropriate to the design of the system, in order to avoid ice formation during system start-up. Generally, the heat produced by the processes within the fuel cell can be sufficient to melt any ice, but cell stacks and components don't warm up in a uniform way. So, if the system doesn't warm up fast enough or evenly enough, there may be a need for additional heating or another method to prevent damage caused by the freezing of liquid water.

▶ Start up of a PEM fuel cell stack from sub-freezing conditions (a) Cell voltage, (b) Solid temperature passing melting point from 120 to 140 s, (c) Dissolved and frozen membrane water content, (d) Liquid and frozen water saturation in cathode catalyst layer

Choosing the best strategy to tackle this issue – whether that's variation of current density or active voltage control to warm the stack, external heating, or a dry purge of water during shutdown – requires a deep understanding of the thermal and physical processes and interactions of the entire system. Fortunately, at AVL we have years of experience building tools to optimize the entire development process at both individual component and entire system level. This includes a wide variety of simulation tools. Among these, our multidisciplinary system simulation tool, AVL CRUISE™ M, now offers the possibility to analyse and optimize on a fully virtual basis PEM fuel cell defrosting strategies on stack level or in the context of the fuel cell system or even the entire powertrain.

GAINING A CLEAR PICTURE OF THE SYSTEM

To enable the simulation of the fuel cell under cold-start conditions, CRUISE M's fuel cell stack component was updated to allow for the modelling of the state change from gas to liquid to ice, as well as transport and storage. Our solution describes the transfer of water between different layers within the system due to diffusive transport and capillary action. It also models the way water interacts with different surfaces in terms of characteristics such as conductivity, diffusion resistance and the reactive surface area.

Delivering detailed insight into technical issues such as membrane humidification, electro-osmotic drag, and the impact of moisture in the ionomer, gives a realistic understanding of the influence of water in its various state on the performance of the system. Providing this data in real time also allows for Virtual Twin modelling of the entire fuel cell system.

DEVELOPING THE PERFECT STRATEGY

Ultimately, what all of this means is that you can now build a virtual copy of your PEM fuel cell system, and get a clear understanding of how it works under different thermal and moisture conditions. Seeing the pathway of water through the system at different temperatures and how the warming of components affects its behavior aids the development of strategies to protect the system's performance and lifetime.

Thanks to CRUISE M's versatility, you can now also model different integration configurations of hardware on the testbed, allowing you to optimize the fuel cell in relation to the entire powertrain while it is still in the design stage. Such simulation-based development saves time, reduces error and effort, and ensures the best performance of the electrified powertrain under all operating conditions.
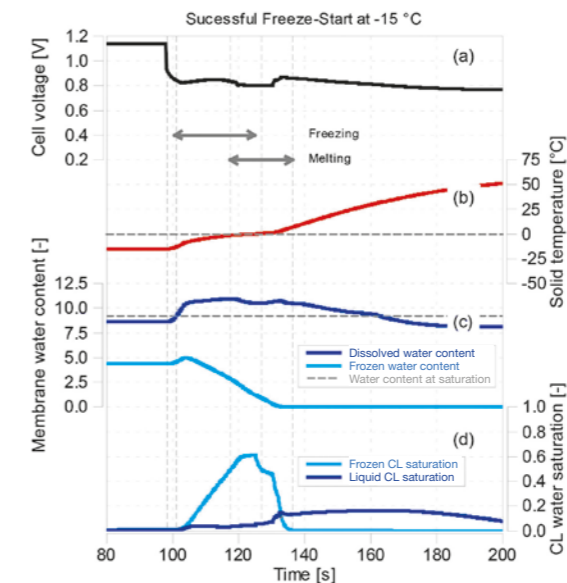
AVL RACETECH
BUILDS HYDROGEN COMBUSTION ENGINE PROTOTYPE FOR MOTORSPORT
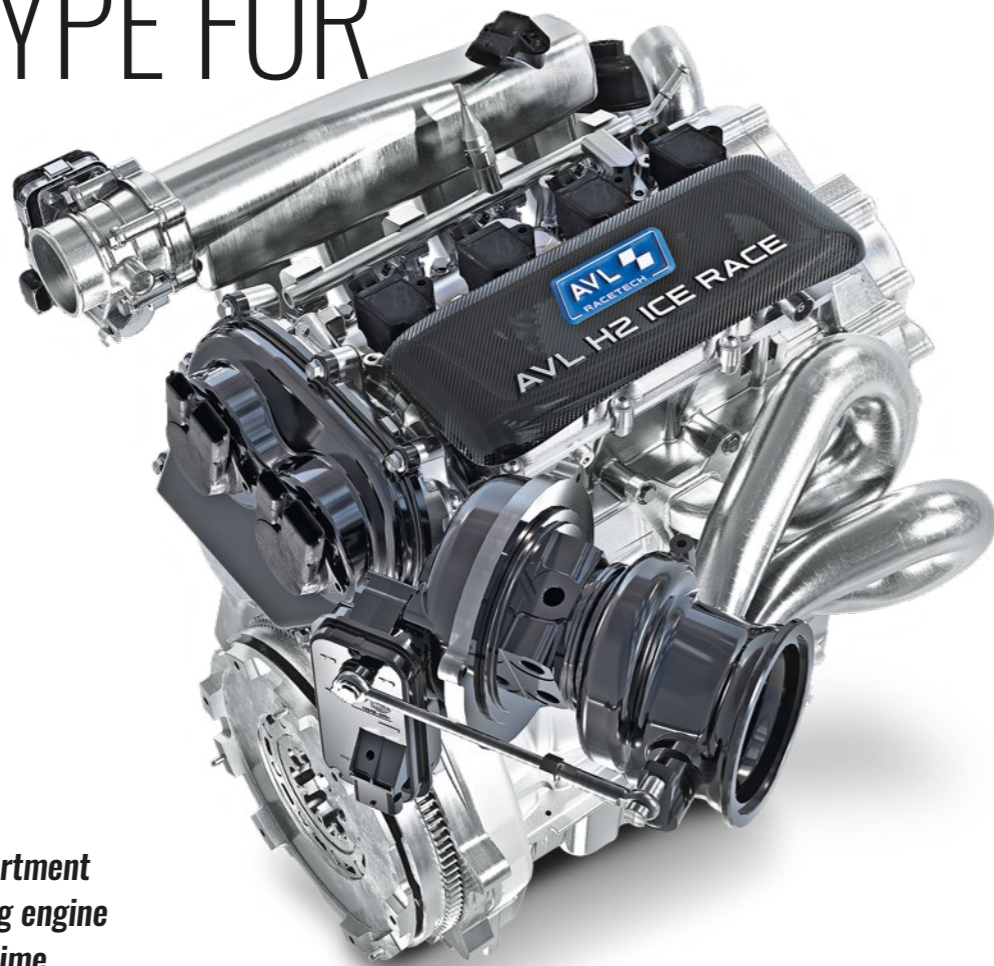
AVL's motorsport department develops its own racing engine in-house for the first time

— Hydrogen (H_2) is becoming an increasingly important energy source for the inevitable energy revolution. Propulsion concepts based on hydrogen are also becoming more widely accepted. When it comes to hydrogen innovation AVL is leading the way by realizing its first hydrogen racing engine developed in-house at AVL RACETECH. A hydrogen combustion engine is CO_2-free and typically has a lower power density than a gasoline engine. At least that used to be the case, but now AVL RACETECH is preparing to prove the opposite with their hydrogen racing engine.

THE CHALLENGE OF HYDROGEN COMBUSTION

Combining hydrogen and an internal combustion engine poses a number of challenges. Paul Kapus, Manager Development Spark Ignited Engine and Concept Cars, explains: "Hydrogen is gaseous, and its incredibly low density means it takes up a lot of space in the air/fuel mixture," he says. "In a naturally aspirated engine with hydrogen port fuel injection, this greatly limits the amount of air that can be transported to the combustion chambers, which results in massive performance losses. Additionally, hydrogen is also much more reactive than gasoline in its ignition and combustion behavior, which can cause undesirable combustion anomalies to occur more frequently, such as pre-ignition or backfire, which

strain the material of the engine. In addition, the engine is exposed to extreme stresses in racing operation. On top of this, there are higher safety requirements for refueling and crash safety."

THE GOAL: AIMING FOR HIGH SPECIFIC PERFORMANCE

However, the key challenge for racing applications is to increase power density. Hydrogen combustion engines usually use high excess air (known as lean-burn operation) which helps to reduce the combustion anomalies mentioned above, and also significantly reduces the amount of nitrogen oxide emissions as the only relevant exhaust pollutant. Realizing performance values at motorsport level under these conditions requires more air than a conventional turbocharger can provide. With a hydrogen-powered 2-liter turbo engine with water injection, AVL RACETECH is now aiming to prove that high specific performance values can still be achieved.

"Our engine will generate approximately 130–150 kW per liter with a moderately lean combustion – this puts it in the same range as the close-to-production classes of today," explains Kapus. "Since the basic technology of a gasoline engine and an H_2 combustion engine are very similar, the adaptations would be absolutely manageable in comparison to fuel cells, for example. And it also offers a cost-effective approach for sports applications."

MAXIMUM PERFORMANCE THROUGH WATER INJECTION

To meet the increased need for combustion air, and thus the need for high boost pressure, with available supercharging units, AVL RACETECH has transferred the principle of water injection to the hydrogen engine, and geared it towards increasing power output. An injector shoots additional water into the intake port of each cylinder, which reduces the temperature in the combustion chamber. The evaporating liquid has a strong cooling effect. Designing the necessary in-

jectors and valves requires precise knowledge of the overall system behavior with all air, fuel, and exhaust gas flows – for which AVL uses its wealth of experience and comprehensive toolkit for generating simulation models and 3D flow calculations. This also ensures that the mechanical limits of the engine are not exceeded.

Ellen Lohr, Director Motorsport, adds: "We are forerunners in many aspects of motorsport with AVL RACETECH, and have now made the decision to become leaders in the area of hydrogen combustion engines as well. Which is why we are building our own racing engine for the first time in the more than 20-year history of the AVL motorsport department. We expect to be able to present this hydrogen engine in spring 2023 and are extremely confident that hydrogen combustion technology will be decisive in achieving a CO_2-free future in motorsport." —

> "SINCE THE BASIC TECHNOLOGY OF A GASOLINE ENGINE AND AN H_2 COMBUSTION ENGINE ARE VERY SIMILAR, THE ADAPTATIONS WOULD BE ABSOLUTELY MANAGEABLE IN COMPARISON TO FUEL CELLS, FOR EXAMPLE."

Paul Kapus
Manager Development Spark Ignited Engine and Concept Cars

> "WE EXPECT TO BE ABLE TO PRESENT THIS HYDROGEN ENGINE IN SPRING 2023."

Ellen Lohr
Director Motorsport

Taking Autonomous System Testing to the Next Level

A new facility in Roding and the completion of the AVL Hungary Vehicle Engineering Center outline AVL's commitment to ADAS/AD and vehicle testing

The AVL Vehicle Engineering Center offers space for more than 50 test vehicles and prototypes.

Guests of honor, including AVL CEO Helmut List (second from left) cut the ribbon at the opening of the AVL Engineering Center.

Innovative spray systems simulate varying rain and fog situations (left) at the sensor testing facility in Roding.

Building an automated vehicle is not simply about equipping a car to drive itself down the road. It needs to function reliably in a near-infinite number of different scenarios, many of which pose a danger to humans in and around the vehicle. Testing and validation must therefore be exhaustive and comprehensive, and AVL offers its industry partners a wide range of solutions to this challenge, including two unique new facilities to support the development effort.

AVL – THE WEATHERMAKER FOR TESTING SUCCESS

Many road accidents happen in adverse weather and lighting conditions. So, it is very important that ADAS and AD systems can perform reliably in any conceivable weather. Since it is not possible to carry out testing in every type of weather on the open road, an alternative must be sought. That is the solution provided by our new test center in Roding, Germany.

The unique sensor testing facility can recreate a wide range of environmental scenarios to measure vehicle system performance. Almost any weather condition can be recreated, and the different variables and outcomes are recorded accurately thanks to a ground truth calibration chamber next door.

As well as providing you with highly realistic road conditions in both static and dynamic vehicle movement scenarios, the facility crucially also offers complete reproducibility. Full documentation ensures confidence in the outcome of any testing activities, and accurate sensor recording allows further investigations to be conducted in the simulation with digital twins.

IN THE ZONE WITH VEHICLE ENGINEERING

AVL ZalaZONE proving ground has already set the standard for ADAS/AD system testing, offering a wide range of road environments, including rural and highway roads, a smart city, an ADAS platform and different road surfaces. Since 2019 the proving ground in Zalaegerszeg, Hungary, has offered our customers a range of facilities for conducting tests as well as the expertise of local engineers who are familiar with all modules and requirements. The facility just got even more comprehensive with the completion, last November, of the nearby AVL Vehicle Engineering Center Hungary.

Facts about the AVL Mobility and Sensor Test Center

- 1,600 m² testing area incl. 1,000 m² of rainfall and fog facility
- Indoor asphalt street with variable road boundary lines and road layout
- Integrated control station for end-to-end monitoring and parameter documentation
- Realistic rain intensity, drop size distribution and falling velocity
- Fog facility: visibility < 10 m
- Maximum day illuminance derived from NCAP: 2.000 lux (10 cm above asphalt)
- Simulation of critical light conditions like dusk and dawn

You can now access 1,340 m² of workshop space, with room to accommodate more than 50 test vehicles and prototypes, and support for all types of powertrains, as well as assisted, connected and automated vehicles. A high level of information security ensures innovation and IP is protected, and direct access to the AVL ZalaZONE proving ground provides convenience and additional security. With a cold chamber for environmental testing and a modern office with space for 150 employees, all your engineering needs are met. Topics around all types of powertrains up to assisted, connected and automated vehicles can be covered.

The completion of the vehicle engineering center marks a milestone in the ZalaZONE collaboration between AVL and the Hungarian government. It now ensures that the location will play a major role in the realization of the current and next generation vehicles.

AVL in Zalaegerszeg now offers a single facility for crucial development activities, such as:

- ADAS/AD verification and validation (e.g., GSR, NCAP, ALKS testing, OEM-specific test programs, etc.)
- NVH and pass-by noise testing
- Durability testing and data collection
- Vehicle dynamics testing
- Benchmarking
- BEV and HEV testing
- Powertrain, ADAS, chassis calibration

At AVL we are committed to helping our partners realize their automotive visions in a rapidly evolving technological marketplace. With the addition of the new Roding and Zalaegerszeg facilities we are ensuring that none of our customers are left behind.

Ground Truth Calibration for the Validation of ADAS/AD-Sensor Systems

AVL's Ground Truth System and its calibration process are leading the way for real-world ADAS and AD validation

— For the validation of ADAS/AD systems in real-world driving situations, a highly precise Ground Truth (GT) reference dataset is requested. To create an accurate image of the environment around the vehicle, the sensors of this GT system have to be calibrated properly. Apart from calibration accuracy, "reproducibility" and "expenditure of time" for calibration data recording are important characteristics of the calibration process, too. At the Mobility and Sensor Test Center in Roding, a sensor calibration facility provides a highly automated calibration routine for the AVL Ground Truth System™, achieving high calibration accuracy within shortest calibration data recording time.
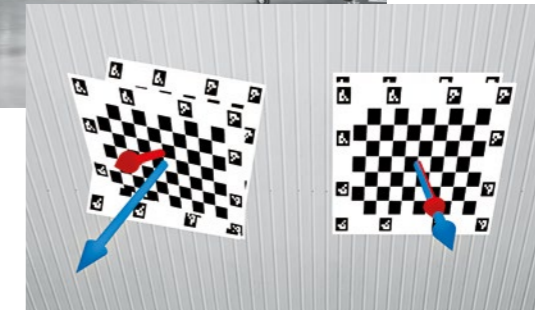
THE PROCESS FOR GROUND TRUTH SENSOR CALIBRATION

Three process steps are necessary for calibrating a GT reference system consisting of cameras, LiDARs and GNSS (Global Navigation Satellite System):
1.) Intrinsic camera calibration: Removes the distortion in the camera picture resulting from the specific "lens – aperture" combination of the camera
2.) Extrinsic calibration of all sensors of the reference system: This calibration step defines the orientation and the position of each sensor in the GT reference system with regard to one reference coordinate system (in our case the central LiDAR).
3.) Extrinsic calibration of the reference system with respect to the vehicle coordinate system: As the AVL GT system is exchangeable between arbitrary vehicles in the shortest time (thanks to plug-and-play functionality), a calibration routine is requested that matches the reference coordinate system of the GT system to that of the vehicle.

THE AVL SENSOR CALIBRATION FACILITY

For achieving the requirements and process steps mentioned above, the decision for a calibration bench (factory calibration) with defined target objects has been taken in an early stage of development. In comparison to online and self-calibration routines the achievable accuracy is higher and more revisable due to the well-known target objects and their defined positions. Additionally, a monitoring algorithm supervises the validity of the sensor calibration during vehicle fleet operation. For intrinsic camera calibration and extrinsic sensor calibration (step 1 and 2) the GT system (rooftop box) is mounted on a turntable and turned through a defined scenery of target objects (checkerboards).

▲ Extrinsic calibration routine: Numerical optimization algorithm aligns the two normal vectors (e.g. red from central lidar, blue from front camera)

Intrinsic camera calibration is carried out with respect to the known literature based on checkerboards with 7 rows and 10 lines. As quality criteria for the intrinsic calibration routine a reprojection error of < 0.4 pixel at a target object coverage rate between 70 % – 80 % is defined.

The "indirect" extrinsic calibration of the sensors using target objects is necessary, as sensor production tolerances have to be considered. Thus a "direct" measurement of the sensor position and orientation using a coordinate measuring machine (CMM) is not feasible. For a pairwise matching of the sensor's coordinate systems (= extrinsic calibration) to the central LiDAR (= reference coordinate system) the normal vectors for each detected checkerboard are being calculated. A numerical optimization algorithm aligns these normal vectors for each sensor pair and computes rotation and translation matrix accordingly. In this way the extrinsic sensor calibration of the four cameras as well as the two side LiDAR to the central lidar are carried out.

GT SYSTEM PLUS ACCURATE CALIBRATION ENABLES PLUG-AND-PLAY ADAS/AD VALIDATION AND HOMOLOGATION

AVL's Ground Truth reference system provides a highly precise 360° view of the environment around the vehicle. The sensor system comes with accurate sensor calibration. This offers a great advantage compared to chassis-mounted reference sensors and also provides plug-and-play functionality to our customers. Together with AVL's worldwide on-site presence and network of experts our customers receive the best support in their global data recording and sensor validation campaigns.

SPECIAL:
SOFTWARE

Solutions for a
New Age of Driving

Tackling tomorrow's challenges today

— A popular card game among youngsters is Car Quartet. Created in the late 1970s, the player whose card featured the car with the most powerful engine, the best acceleration or the highest top speed won the game.

In the 2020s, however, the key characteristics of a winning car are not so easy to categorize. Performance is no longer defined simply by what is under the hood, but is also about functions such as connectivity, ADAS and security. Drivers expect vehicles to behave in a similar way to smartphones, with new functions and apps available over the air, and seamless integration with other devices such as mobile phones and entertainment systems.

Welcome to the age of the software-defined vehicle. While this does not mean that mechanics and hardware are no longer of vital importance, attention is increasingly shifting to electrical and electronic components and software. With an average of over 200 million lines of code, a modern car has more software inside it than a Boeing 787.

With 80 to 100 control units, from engine management and gears, to seat adjustment, air conditioning, infotainment and ADAS, telematics, and third-party applications, managing these systems in the car and in the cloud is a complex affair. All these mini-computers need to be consolidated into fewer units with higher performance. This shift is the industry's next challenge and is expected to bring much more customer-relevant functionality and intelligence.

Some OEMs are heavily investing in their own software units and building their own operating systems, while some are pursuing more collaborative approaches. This offers a lot of space for independent players and, as the huge transformation of the automotive industry that has so often been predicted finally becomes a reality, AVL is in the middle of it.

AVL Facts in a Nutshell

- 40+ Software Product Titles
- 100+ Data Engineers and Scientists
- 3,000 Software Experts and Engineers
- 6,500 Testbed Automation Systems
- 20+ Software Development and Support Centers

"The vehicle has long become software on four wheels," says Georg List, AVL Head of Corporate Strategy. And it's not just the vehicle that is becoming software-oriented. The traditional sales model is also being disrupted by software. Over-the-air-updates make it possible for additional driver assistance systems and functions to be purchased or new performance characteristics to be made available without a visit to the mechanics. The car and the driver experience are constantly changing, even after it has been sold.

But there are dangers too. As everything becomes connected, the associated risks must be analyzed and managed cautiously. Cybersecurity has become a major issue for car makers. And functional safety in the electrified and connected car is an equally big issue today as it was in the era of the internal combustion engine.

At AVL we offer a wide range of solutions for this new age, covering everything from simulation and testing tools to embedded software development services. These are based on four guiding principles: delivering software that grows with you, reducing the burden of complexity, finding the fastest solutions and answering tomorrow's problems with today's innovations. Join us as we redefine key characteristics for the Car Quartet of the 21st century. ————

"The software is so powerful, it's almost paramount…

It's not just the breadth, it's the variety that makes AVL List unique as an automotive software company."

INTERVIEW

with Georg List, Head of Corporate Strategy

---

focus: Software is transforming car capabilities, but also creating development challenges for automotive players. What is AVL's role as a mobility technology provider in the new era of automotive software?

List: Nowadays, all OEMs have large software development organizations. However, they all operate differently: Some OEMs, such as Tesla, prefer to do everything in-house, while others selectively outsource or partner with different software providers. As software becomes more pervasive, in some cases more strategic, and overall a bigger part of value creation, OEMs are redefining their collaboration models with development partners like AVL. That was already the case with the engine. Many manufacturers saw the engine as being the heart of the vehicle, and that's why external developers hardly ever came into play. That stance has changed over the last decades and will also be the case with the software.

focus: Software has penetrated all functions of the car. Can a company like AVL, which comes from engine development, succeed in this field?

List: Definitely, and we have already been well on our way over the past two decades. We have always applied our know-how to emerging technologies. It is our strategy and our modus operandi. AVL has many years of experience in the development of drive systems and their integration into vehicles. With this we have continuously developed flexible and modular software for mature system architectures.

For example, the powertrain controllers used to be – and still are – an important part of the car software. They ensure comfort and energy efficiency while driving or provide some safety features such as torque vectoring. By understanding the overall vehicle software architecture, we have been able to extend our expertise to other systems. ADAS is a good example of such an important step. But we also play a role in other areas like chassis, thermal management, etc.

focus: To what extent have you made progress?

List: To the extent that we already employ around 3,000 software experts and operate more than twenty Software Development and Support Centers worldwide. Our software engineers work on the software in the car, the so-called embedded software, as well as software solutions which help to reduce complexity within the development process. Simulation and virtualization form an important part of this. As a side note: Simulation in automotive product development has already deeply penetrated the processes to make them fast and efficient. But this is about to go a step further in becoming the "automotive metaverse".

focus: What does this mean? Are there any examples?

List: Mixed reality is already a fact. We were able to demonstrate this recently with a racing driver who was sitting in a simulator in Graz but was maneuvering an electric E-DTM car 100 km away at the "Österreichring" in real time. Why

then shouldn't mixed reality also be able to enrich the consumer experience? It makes intuitive sense. We will drive with augmented reality to reach higher safety or comfort. We as AVL – in this new space – will certainly not deliver media content, but will remain in the background as a facilitator with innovative technology solutions. In this sense, software has a different value.

focus: Why should I, as a software talent, go to AVL and not to Google or Tesla?

List: At AVL, you gain a range of experiences since our portfolio is broad, which allows our employees to explore different technology topics. So, it is the variety of endless opportunities: One project may be for a Chinese manufacturer, while the next one will be with a sports car producer or a start-up. At the end of the day, we provide our employees a unique space for innovation. With a strong pioneering spirit, our employees help shape the technologies of the future every day. _____

INTERVIEW *with Johannes Deichmann, software expert at McKinsey Stuttgart, Germany*

"Significant Progress"

Deichmann talks to Focus about the drivers of the automotive software revolution

Automotive software market expected to grow by +9.2 % p.a.

Total automotive software[1] market
USD billions

CAGR 2019-2030

	CAGR 2019-2030
Total	+9.2%
Powertrain & Chassis	+0.8%
Body & Energy	+9.5%
ADAS & Highly automated driving	+11.1%
Infotainment, Connectivity, Security, Connected services	+8.9%
Operating system & Middleware	+11.6%

[1] Software incl. function development, integration and verification/validation
Source: McKinsey Center for Future Mobility

---

are at a point where the complexity is not manageable. That's where OTA updates come in, which help to reduce the number of hardware variants when I sell the car. The customer decides which function he wants to unlock and pays for it. In addition, the more software you have in the car, the more complexity there is. If I want to avoid repair shops getting stuffed, OEMs need OTA-updates to get them fixed.
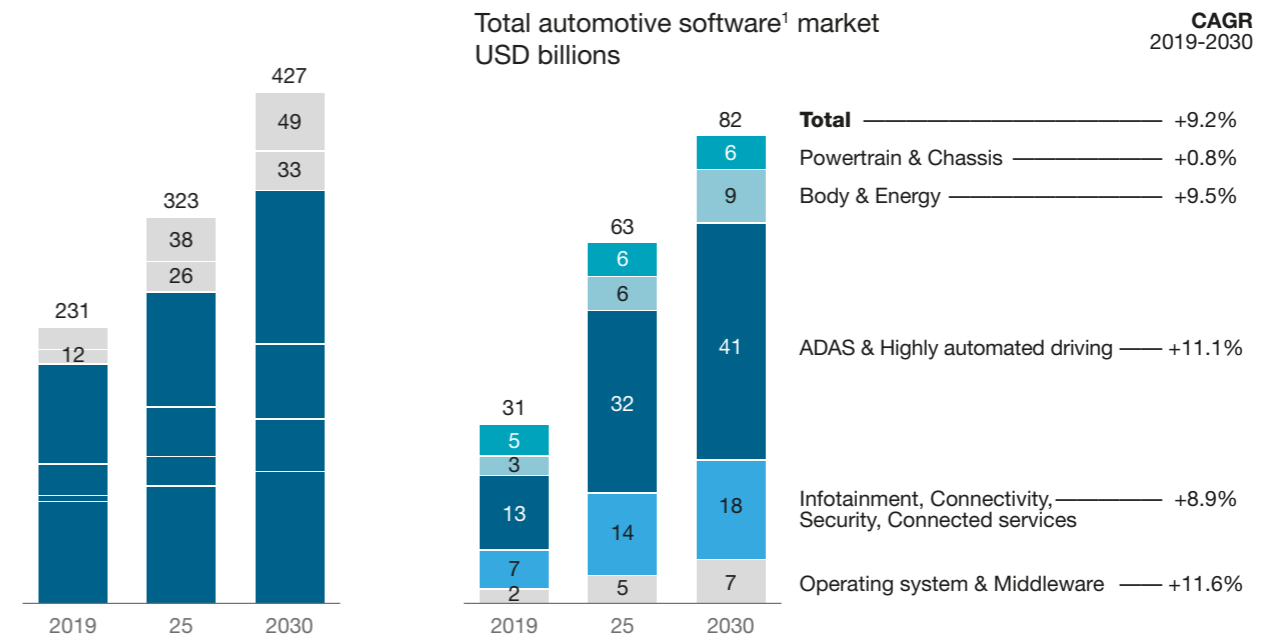
focus: Tesla has established the over-the-air (OTA) update model for cars, signaling the car is somehow work in progress. Will that be the lead model when it comes to business?

Deichmann: There are no alternatives to software-defined functions. European manufacturers were very successful in the past because of their configuration policy, where margins for extras, such as infotainment systems with big screens and premium seats, were particularly high. In the software age the number of variants is so big that we

focus: How big is the global market for automotive software?

Deichmann: Our studies show it will grow to 82 billion dollars by 2030, that's an average 9 % growth annually – three to four times faster than the overall automotive market. But the real question is: How does software create value? For example, there are direct services such as paying a monthly fee for traffic data. This area was a big hope five years ago, now we see that many people tend to get their data from their smartphones where this service isn't monetized directly. But software is also about sales and customers expect to "feel" the software. If a car feels like a tin box, he won't buy it. In China this is accelerated due to customer needs: There are OEMs who don't get this right and therefore leave a lot of space for new attackers.

focus: Doesn't this require a huge mentality shift in the perfection-driven German car industry?

Deichmann: Yes, but the industry has made significant progress in the past two or three years.

focus: What about testing and simulation?

Deichmann: That's a huge driver and stands for roughly 40 % of the market. The paradox: the better the car industry manages – by testing, simulating and validating in advance to create good products before they are integrated into the car – the smaller the overall market for automotive software.

focus: Is ADAS/AD still a major driver? After the big projections a couple of years ago it seems quieter now.

Deichmann: Yes, ADAS and AD together with OTA updates are a crucial driver, when it comes to centralization of control units, separation of hardware and software etc. Though infotainment and user experience are more visible to the

customer, they are not that complicated from a technology point of view. And there is safety and security, the "mean brother" of ADAS, OTA and co., which requires a lot of attention and innovation. The most secure vehicle in recent years was probably the VW Golf 1, because it had hardly any code inside.

focus: We talk about cars as smartphones on wheels. But how many operating systems for cars will be left at the end of the transformation?

Deichmann: I would distinguish between three types. With In-Vehicle-Infotainment (IVI) domains, there is a clear trend to Android platforms – except in China. Second, in the field of so-called high-performance operating systems where you got a lot of AI, high-speed combination of sensors, etc.

I think that we will have two or three dominant operating systems. And the third type is classical automotive: control units, powertrain and much more, where we will have four or five platforms that partially already exist today.

focus: What is the relationship between OEMs, automotive suppliers and genuine software firms in this development? Will there be a "winning model" that everyone else tries to copy?

Deichmann: There will not be "one" model, it will be a variety of models. A volume car maker whose customer wants user experience, but is not very much into ADAS, needs a completely different strategy than a premium car maker who claims to be at the forefront of technology.

THE FUTURE COMES EMBEDDED

> "OEMS THAT USED TO THINK ABOUT THEIR HARDWARE AND ENGINE AT THE BEGINNING OF THE DEVELOPMENT PROCESS ARE NOW FOCUSING ON SOFTWARE AND FEATURES FROM THE START."

Georg Schwab
Managing Director at AVL Software
and Functions in Regensburg

— You don't start your car, you log in. You voice-activate your settings from seat to mirror, from temperature to music. Your navigation system guides you in real time, suggests the best route and informs you of free parking spaces when needed. Moreover, your smartphone communicates directly with the computer and vice versa, enabling a seamless digital atmosphere turning the user experience to a cruiser experience.

This is the experience in a software-centric car. New electrified platforms and feature requirements create a new complexity of integration. Embedded software controls the interaction of high-performance components, while classic domain structures dissolve as components merge with software functions.
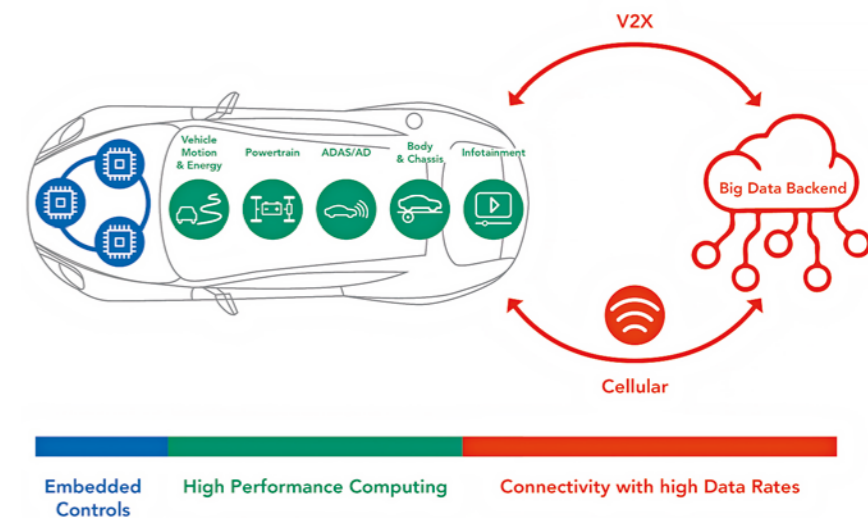
Georg Schwab, Managing Director at AVL Software and Functions in Regensburg, knows what he is talking about. He and his team are working on the vehicle functions and features of the present and future. He says: "OEMs that used to think about their hardware and engine at the beginning of the development process are now focusing on software and features from the start." With its competence in series

development, software integration with hardware, and testing, AVL is unique, he reckons. "There are few companies in the world with this combined expertise."

Validation and testing software is a valuable instrument for AVL developers. "We are also able to test software with simulated drivers, but a lot is still hybrid testing", explains Harald Petschnik, Business Innovation Manager. While infotainment requires less testing in the complete vehicle, safety and security-relevant functions in particular need to be tested in combination with hardware. Independent developers from the mechanical automotive world who also demonstrate expertise in embedded software and simulation have the biggest advantage: they know how to combine the two worlds.

To stay one step ahead, AVL invests heavily in research and development to remain the ideal technology partner in the coming decades.

▼
From Embedded Controls to Connectivity

V2X

Big Data Backend

Vehicle Motion & Energy   Powertrain   ADAS/AD   Body & Chassis   Infotainment

Cellular

Embedded Controls   High Performance Computing   Connectivity with high Data Rates

One of the key drivers is Autonomous Driving, which is still underestimated. Once Level 3 or Level 4 features are on the road, users will have more time to consume apps. Schwab therefore predicts a "revolution by small steps".

As revolutions are inevitable, collaboration is unavoidable – an essential basis for success in this fast-changing world. In AVL, we work not only with OEMs and Tier1s, but also with major US software companies and cybersecurity specialists. This work sets things in motion and allows developments to be multi-perspective. You will feel the difference the next time you log in.

New Car, New Architecture

BMW recently introduced its model of a heated seat subscription, for 17 Euros per month. You do not have to be a prophet to predict that it will show strong seasonal fluctuations. However, as new on-demand services will change their business models, OEMs are struggling to understand how the software inside has to be designed and set up.

The centerpiece of embedded software progress is the EE (electrical/electronic) architecture. As electronics hardware, network communications, software applications and wiring converge into one integrated system that controls an ever-increasing number of vehicle functions, OEMs and suppliers are looking to outside expertise.

AVL's major advantage is its knowledge of mechanics, but also its experience in developing e-mobility solutions and software functions, which goes back decades. Compared to newcomers, AVL's know-how of the entire system architecture – and its elements – is incomparable.

That's crucial to reliability, as the transformation inside the vehicle is enormous: An average car today has up to 200 million lines of code, which are expected to grow to 300 million lines by the end of the decade. Centralization is key: What used to be up to 130 ECUs in a car is now centralized on 3–5 in-vehicle servers, according to expert Dirk Geyer, AVL Software and Functions. The permanent change requires constant updating and testing, traditional fields of competence of AVL.

"EE is nothing completely new, having come into the vehicle with the turn signal and radio decades ago," says Stefan Schmid, Managing Director of AVL Software and Functions, but is now in a vital role as high-performance computing and Big Data have proven to be gamechangers. "We're going to have a pretty dynamic future," he says.

" WE'RE GOING TO HAVE A PRETTY DYNAMIC FUTURE."

Stefan Schmid
Managing Director of AVL Software and Functions

Controlling the Future Autonomously

▲
Truck with Dynamic Ground Truth System

▶
Driving Cube

Andrea Conti grew up in Rome and knows all about the hectic traffic in the Italian capital. That's why he's keen to see Advanced Driver Assistance Systems (ADAS) or Autonomous Driving (AD) work perfectly, not only on test routes or in countries with particularly orderly traffic, but also in traffic situations that tend to be more complex. "Countries like India would be a good example," he says.

As Vice President, Conti leads the global business development of the ADAS/AD area, which, according to McKinsey, is a key driver in automotive software. With around 450 ADAS/AD specialists worldwide, AVL advises not only established OEMs on special issues, but also the new players in the vehicle market who aim to integrate their product into an automotive environment or who require specific concepts for the safety or quality of their vehicle systems.

Whether overtaking, braking, accelerating, or changing lanes, the semi-autonomous or autonomous functions are considered at AVL

"according to a holistic model," explains Conti. AVL develops, simulates, and tests new ADAS/AD solutions, drawing on unique expertise in the interaction of sensors, actuators, and vehicles. This is not just about theoretical input, but mainly about getting the solutions on the road – the spectrum ranges from interface management with other components to preparation for official certification. Conti explains: "We don't just provide the knowledge of our engineering staff but work according to a holistic approach."

But why do customers specifically look for solutions from a company that historically comes from the combustion engine area? This is where AVL scores with its excellent engineering know-how built up over decades and its global presence in the automotive industry. After all, software that supports a driving function is very rarely developed for just one market. "Through our worldwide locations, we know about the nature of many markets and can offer targeted assistance here," explains Conti.

Our customers benefit from the synergies of our engineering, simulation and testing business units. Particularly when making the leap up to Level 3, Level 4 and Level 5 functions (see box), this is a decisive competitive advantage. "Automotive manufacturers want to sleep with a clear conscience regarding liability for autonomous driving systems," he says.

In addition, cybersecurity also plays a key role in the further development of ADAS/AD functions. The driving functions, previously distributed among many control units,

are increasingly being centralized on a few high-performance computers in a so-called "zone architecture" – via a central computer as an interface to the outside world.

This requires security precautions. AVL offers solutions – in some cases in cooperation with partners – for evaluating the potential vulnerabilities, for example, in the transmission of data via cV2X.

"As an independent company, we are often contracted to professionally look for vulnerabilities." Conti adds, "these are, of course, sensitive issues. An undiscovered loophole can lead to high-risk damage. Despite all the new risks the overarching goal of automated and autonomous systems remains to reduce accidents on the roads. And the faster these gain ground, the more necessary it is to work together with partners like AVL," Conti emphasizes.

Personally, he is looking forward to the rise of autonomous transport vehicles with Level 4 functions for inner-city areas, which can be ordered via an app. "When I'm 70 or 80, I want to use the new mobility service to comfortably visit my grandchildren." ——————

" WE DON'T JUST PROVIDE THE KNOWLEDGE OF OUR ENGINEERING STAFF BUT WORK ACCORDING TO A HOLISTIC APPROACH."

Andrea Conti
Vice President ADAS/AD at AVL

GREAT LEAPS FORWARD

Vehicles on today's market generally offer Level 2 or Level 2+ ADAS systems. Since 2022, Mercedes has been the first automobile manufacturer to provide an approved Level 3 offering in which the driver is allowed to turn away from traffic. However, the driver must be able to take over immediately at any time based on a system request.

A key point: From Level 3, the manufacturer and not the driver is now liable if the vehicle veers off the right path while the system is still activated. This is a significant leap toward fully autonomous driving (Level 5). The GSR2 (General Safety Regulation) directive, which has been in effect since July, has brought a "strong industry boost," says ADAS/AD expert Andrea Conti. More use cases for Level 3 are expected soon, once the legal framework is in place. OEMs are feverishly preparing for it with tests. In the truck sector, Level 4 functions are already within reach, which could allow entire fleets to drive autonomously 24/7 on highways.

DETECT, ANALYZE AND COMMAND!

As more cameras, LiDARS or radars in the vehicle deliver a continuous stream of data about the environment to the vehicle interior, software is crucial for processing and interpreting all this information. Therefore, Dominique Louarn-Pioch and Mathias Scheytt, department managers for ADAS/AD at AVL Software and Functions, are avidly working together with their teams of software engineers in Regensburg on the heartbeat of future mobility.

"Proper interpretation requires specific know-how," explains Louarn-Pioch. Machine learning and image processing skills are becoming increasingly important. In addition, of course, reliability and compliance with international standards are mandatory from the first line of code. "We fully understand the entire process chain," adds Scheytt, referring to AVL's vast experience in the testing and software sector.

The modular software and control architecture enables the reuse of tailored software and its integration from different suppliers (see picture). After the detection of the environment ("perception"), the next important steps are maneuver planning and decision making. Then longitudinal or lateral controllers come into play: The longitudinal controller is responsible for controlling the vehicle's speed, while the lateral controller steers the vehicle's wheels for trajectory tracking. This gives actuators, such

as steering or brakes, the signals to spring into action.

Validation and testing are the constant companions of every development activity at AVL. Using simulation models for the development of control functions and virtual calibration ensures greater efficiency. "This methodology can be applied at all levels, from the software components to system level," says Louarn-Pioch. Ultimately, everyone on the ADAS/AD engineering team is working toward a goal: To make driving safer and more comfortable.

▼
The modular approach enables integration and reuse of software from different suppliers (AVL, customer or 3rd party).

OUR MODULAR SOFTWARE & CONTROLS ARCHITECTURE
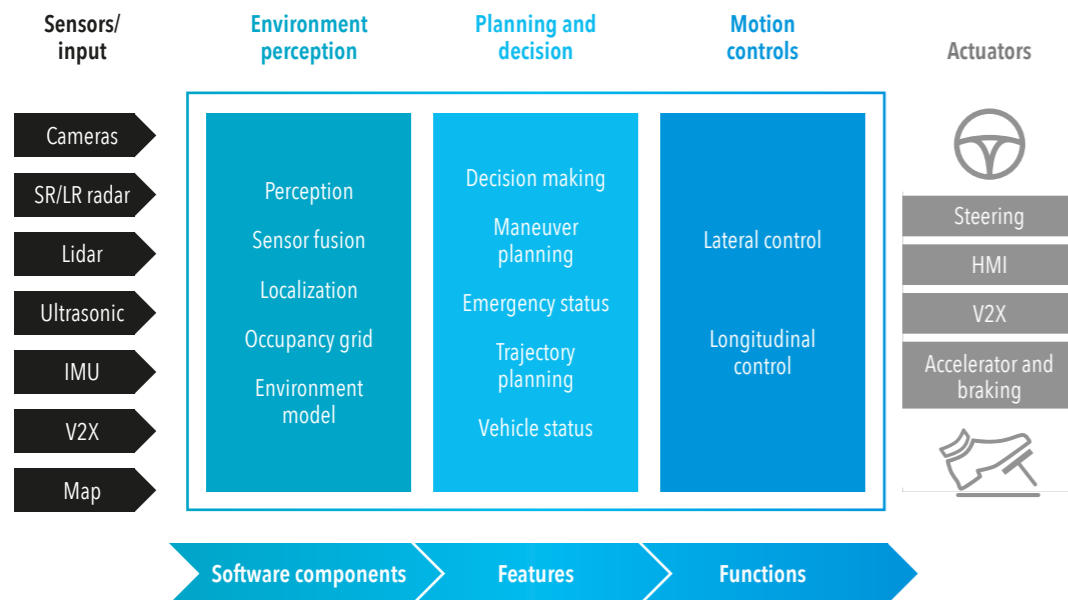
Compliance by Experience

AVL leads the way with ASPICE compliance

— The implementation of standards is the supreme discipline in the software world. Safety standards for control software are therefore at the heart of AVL's projects with customers. "This gives us a competitive advantage over start-ups," explains Stefan Schmid from AVL Software and Functions, referring to the company's impressive track record.

Automotive Spice, or ASPICE®, is the established quality framework for embedded software development in the automotive industry. It stands for Automotive Software Process Improvement and Capability Determination and was created to evaluate the performance of OEM suppliers' development processes. It helps teams to establish and maintain their process approach to ensure quality, reliability, and deliverables.
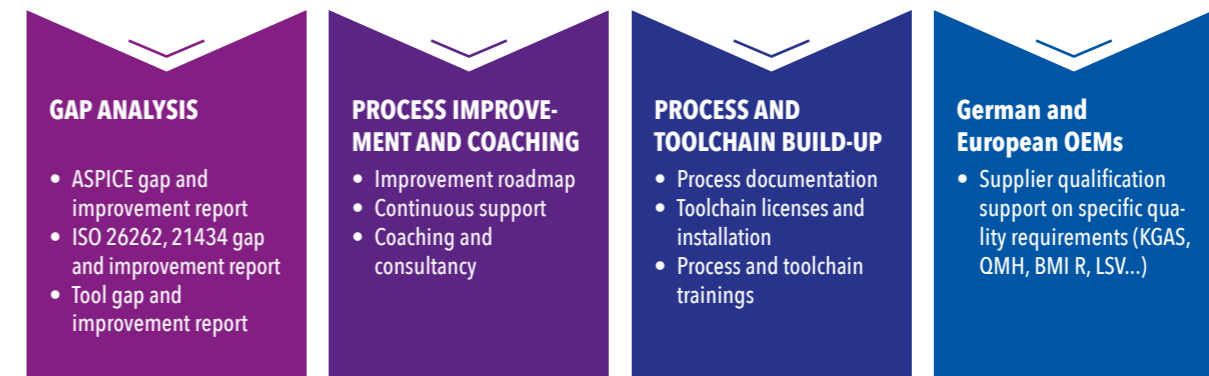
With more than 20 years of experience in the successful development of series-proven software products, AVL can competently accompany its customers in the implementation and application of rule-compliant processes, methods and tools.

"We ensure ASPICE compliance right from the very first line of code written", says Georg Schwab, Managing Director at AVL Software and Functions. This becomes even more important the more complex the vehicle software requirements are. "If there is an accident, you are lost without accurate documentation," he adds.

For AVL, dealing with ASPICE is also a matter of differentiation. We have developed a unique PMT (Processes, Methods and Tools) approach to ensure that the best possible software product meets every aspect of our customers' requirements and regulatory standards.

PMT by AVL

P ... We define the **Process** based on the standards (ASPICE, ISO26262, ISO21434)
M ... We create a comprehensive **Methodology** to each step of the process
T ... We develop appropriate **Tools** for efficient application of the process according to the defined methodology

GAP ANALYSIS

- ASPICE gap and improvement report
- ISO 26262, 21434 gap and improvement report
- Tool gap and improvement report

PROCESS IMPROVEMENT AND COACHING

- Improvement roadmap
- Continuous support
- Coaching and consultancy

PROCESS AND TOOLCHAIN BUILD-UP

- Process documentation
- Toolchain licenses and installation
- Process and toolchain trainings

German and European OEMs

- Supplier qualification support on specific quality requirements (KGAS, QMH, BMI R, LSV...)

▲
AVL PMT offers support along all process development phases.

" *CYBER ATTACKS ARE MORE COMMON THAN WE THINK.*"

Dirk Geyer
Head of Segment Safety and Security at AVL
Software and Functions in Regensburg, Germany

"We simply have to stay at least one step ahead of our opponents," says Geyer, explaining what he together with 90 colleagues in Regensburg focus their energy on.
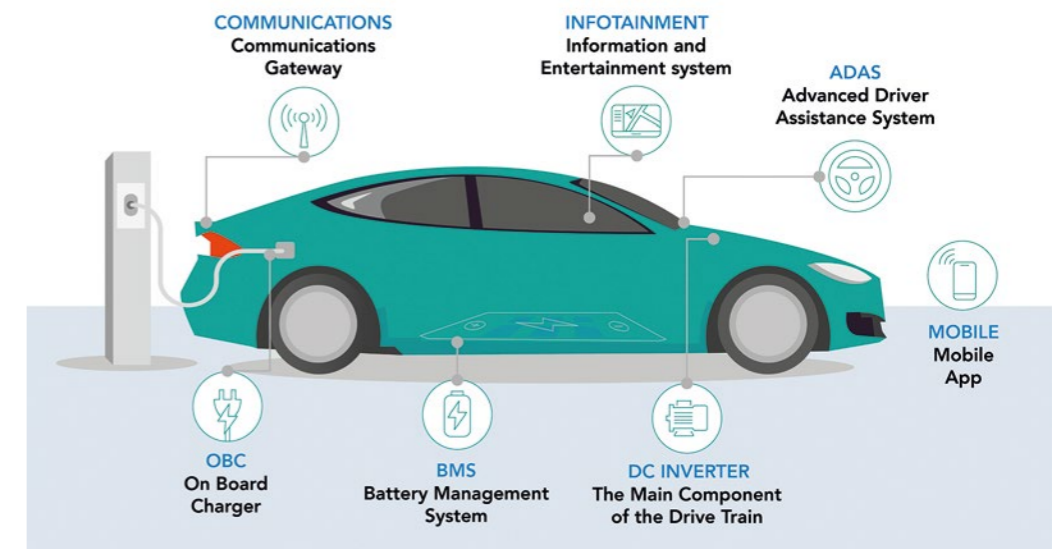
At AVL our Functional Safety and Cybersecurity portfolio aims to support OEMs, Tier1s and other suppliers – as well as certification bodies – throughout the complete development process. In recent years, the automotive industry has experienced the emergence of cybersecurity regulations. Besides the engineering standard ISO21434, the two most prominent are UNECE regulation UN R155, which applies to the UNECE member states, and GB/T, which applies to China. Automotive cybersecurity legislation establishes a set of requirements, practices, and principles to protect connected vehicles from misuse by malicious hackers. Binding standards such as ISO 26262 ensure that evolving mobility technologies meet the requirements for rigorous functional integrity and safety. We support compliance with these standards and continually keep up to date with regulatory requirements.

At AVL, we help our customers with our comprehensive engineering services from the development to the in-use phase. Furthermore, we offer a powerful software and testing tool suite to support and optimize process automation and efficiency.

As object detection for automated driving and rapidly changing attacker models for cybersecurity mechanisms have come on the scene, deterministic observers alone cannot be the answer. The power of cross-domain-servers (CDS) enables the implementation of appropriate machine learning algorithms.

Existing systems will be further developed under appliance of Cyber Security Management Systems (CSMS) and Software Update Management Systems (SUMS). One of our strongest responses to the additional effort and complexity to secure vehicles is the AVL Cyber Security Tool Suite. It is designed to streamline, automate and connect continuous tasks in the process such as lifecycle management, threat analysis/risk assessment, vulnerability management, testing and much more.

Fighting the enemy within

— It is a nightmare for drivers and car makers alike: A vehicle being hacked whilst driving, losing control over steering, braking or acceleration to somebody with a laptop miles away from the scene. Even if the nightmare can be stopped by paying a sum to the extortionist hacker, the damage remains.

"Cyber attacks are more common than we think", says Dirk Geyer, Head of Segment Safety and Security at AVL Software and Functions. This is a logical consequence of higher software complexity and increased connectivity: Formerly, electronic domains that were mainly independent, such as infotain-

ment, ADAS and powertrain, are now interconnected inside the vehicle and communicating with IT systems outside of the car.

This leap in complexity of distributed functionalities creates new security risks. It is estimated that there will be more than 400 million connected vehicles on the road worldwide by 2025. Most of them will be equipped with next generation vehicle technologies such as cooperative Automated Driving (AD), biometric systems for central locking, and so on. More than 100 million lines of code will attract legions of hackers.

The usual use case is theft: Perpetrators not only attempt to unlock cars, but also want to activate embedded software functions free of charge – for example, the rain sensor for the sunroof, which they would have to otherwise buy. The result is financial damage for the consumer and/or the OEM. The misuse of confidential data is another posed threat, as is the manipulation of ADAS functions. Since vulnerability typically increases with the number of functions and interfaces in a car, there is a high risk that they will become the target of larger-scale attacks by, for example, terrorist groups.

DISCOVER THE CYBERPOWER OF DISRUPTIVE TOOLS AND TECHNOLOGIES

COMMUNICATIONS
Communications Gateway

INFOTAINMENT
Information and Entertainment system

ADAS
Advanced Driver Assistance System

MOBILE
Mobile App

OBC
On Board Charger

BMS
Battery Management System

DC INVERTER
The Main Component of the Drive Train

the customers can be guided through the process and manage all cybersecurity development projects. It is the only process and project management solution that combines cybersecurity with safety, in just one tool.

We can support customers with the complex tasks of continuous vulnerability management across various software versions. For this purpose, we are cooperating with several strong cybersecurity and cybercompliance partners. Once vulnerabilities are detected it is relevant to see if the security mechanism in the vehicle is working or the vulnerability could be really exploited. To find it out, we offer automated toolchains for functional security testing and penetration testing.

"Our goal is to offer solutions to achieve higher process automation that can be increasingly integrated into the customer's IT landscape," explains Harald Petschnik, AVL Business Innovation Manager. With the support of AVL FUSE™

The focus is clear: It's not just about reacting to potential risks, but about building agile cyber resilience across the entire lifecycle of a vehicle. There will probably always be attackers – but effective and highly resilient cybersecurity will reduce the chance of these nightmares occurring. ────────

AVL CYBERSECURITY TOOL SUITE

Attack Simulation & Threat Analysis
and Risk Assessment (TARA)

Ensure standard compliance
to achieve type-approval

AVL FUSE

Test Case Generation
& Execution

AVL ThreatGet

AVL Cyber Testing

Automated Vulnerability Management
of embedded Vehicle Software

Efficient Variant Management
of embedded Vehicle Software

Cyber Digital Twin Platform - Cybellum

AVL CRETA
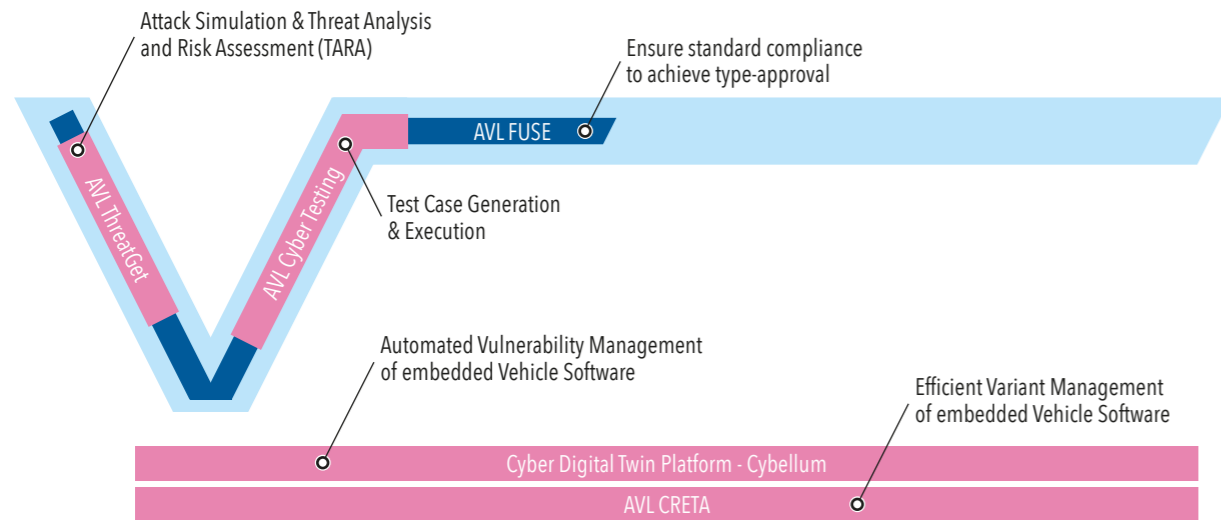
Simulation: From Sidelines to Center Field

── *The journey of automotive software begins long before the passengers take their seats. Speed, efficiency and cost pressures define the fast-changing world of vehicle development. Achieving these goals requires the right tools, such as innovative simulation models, the right development environments, data and automation.*

By providing simulation and testing software, AVL supports its customers throughout the entire development process. In particular, simulation solutions provide high-definition models and insights into the behavior and interactions of components, systems and entire vehicles. Additionally, virtualization enables system validation tests in early development stages, significantly reducing customers' needs for vehicle prototypes, while ensuring highly repeatable test conditions.

One of the most crucial data sources for modeling are those from vehicles in motion. The high volume of data generated and exchanged by increasingly complex systems can be a valuable treasure if properly evaluated. Engineers are therefore taking a systemic approach to development and no longer just looking at the individual components in isolation. This requires them to have both the knowledge and the tool landscape to work across disciplines.

The best case is to connect the real and virtual worlds, which is supported by AVL's global Integrated and Open Development Platform (IODP) business unit. For example, not all components of a powertrain need to be connected to the engine in order to be tested. "You can put a real engine on the testbed and then simulate different models of batteries, e-motors and vehicles to test their behavior," says Wolfgang Puntigam, Global Business Unit Manager, IODP.

The heart of IODP is so-called "connected software". Simulation supports the connection of single components of a vehicle to real conditions. "Open" means that not everything is necessarily developed by AVL. "We analyze the status quo, define development tasks and virtualize them together with our customers", explains Puntigam. In this hybrid world, his credo is crystal clear: As the industry is moving to a software-defined eco-system, "we continue combining our existing global software forces with our automotive domain applications know-how to serve our customers within this transformation."

THE TWIN THAT BEATS THE ORIGINAL

The enforcement of simulation to avoid high testing effort and cost is a general trend in the industry. With e-mobility on the rise, there are new car makers on the market who aim to have their models ready for the market in less than 18 months. Historically, this requirement would have been an illusion. The key to accelerating complex vehicle development is therefore virtualization. With the high quality of the Virtual Twin, more and more engineers are realizing the potential to replace time-consuming and costly testing of physical prototypes in development. It is the digital replication of a single cell, a component, the entire system and/or of a vehicle which enables it to interact with all other objects in the system, with the software and control functions, and above all with its environment.

AVL offers a centralized methodology with a fully integrated and automated workflow. This is where Roland Wanker and his 500 employees in AVL's Advanced Simulation Technologies come in. "We used to be the nerds whose job was to support the development process," Wanker says with some pride. "Now we're on the front lines."

▼
The Virtual Twin

"WE USED TO BE THE NERDS WHOSE JOB IT WAS TO SUPPORT THE DEVELOPMENT PROCESS. NOW WE'RE ON THE FRONT LINES."

Roland Wanker
Vice President Advanced Simulation Technologies at AVL

In this case, the technology shift is playing into the hands of his area of responsibility: "The transformation is helping us immensely," explains Wanker: "The traditional combustion engine was much more complex to simulate than today's battery and other components of the electric engine."

Today, AVL's simulation solutions cover a wide range of future mobility: How does the cooling liquid behave when the battery in the e-car overheats? 3D simulations are just one of many capabilities AVL is offering. In general, the new world will be very much about safety: "The battery may appear simpler than the combustion engine," says Wanker, "but in terms of safety it is more complex." Fast charging and thermal management today are core fields for AVL's simulation experts, as is ADAS/AD. When you need hundreds of millions of kilometers to measure everything around the car, you need to rely on simulation.

Thus, the virtual twin today is indispensable in supporting our customers in analysis, simulation, optimization and decision-making.

AVL VIRTUAL INTERNATIONAL SIMULATION CONFERENCE 2023, 28-30 MARCH

Don't miss this opportunity – sign up now to be part of the growing AVL Simulation Community!

Function Beats Performance

**AVL functional testing expertise delivers a competitive advantage**

— The combustion engine is complex, but not from the driver's point of view. They just step on the gas and go. In the electric and autonomous car, it is the other way round: The mechanical hardware is less complex, "but the overall functional complexity is higher," says Gianluca Vitale, Business Segment Manager Functional Testing and Virtualization at AVL.

Many new functions come with systems such as ADAS/AD, connectivity, cybersecurity, and thermal management. Control units need to communicate as more data flows in from sensors. OEMs tend to deploy frequent software updates, requiring additional functionality and performance testing. And for BEVs, environmental dependencies such as charging and networked powertrain functions, are very challenging.

Thus, the question for functional testing is not what performance the tested item delivers, but if it works. If you open the car door while driving, will the gearbox go into P-position? Where is it locked? That question requires interaction between subsystems: the door, the safety belt, and the gearbox. There are thousands of similar questions in development, requiring thousands of tests. Functional tests are simpler than, for example, performance tests, but the quantity and the software release cadence cause new complexity.

In the next decade the automotive sector will undergo a profound change and will focus on the software ecosystem rather than only on the vehicle as a hardware product. In this environment, in addition to process efficiency, speed is an issue, and at AVL we support our customers in accelerating their processes.

Expertise in virtual testing and test pipeline automation is an advantage in this situation. "We can simulate the entire system on the testbed," says Vitale. "Interaction with hardware remains indispensable" to fulfill safety and security system validation.

For us it is not just about providing tools, like software variant management, automated testing, or virtualization, but rather end-to-end toolchain integration. Vitale: "At AVL we define ourselves as integrators – that makes the difference." —

▼
Seamless testing, independent of environment
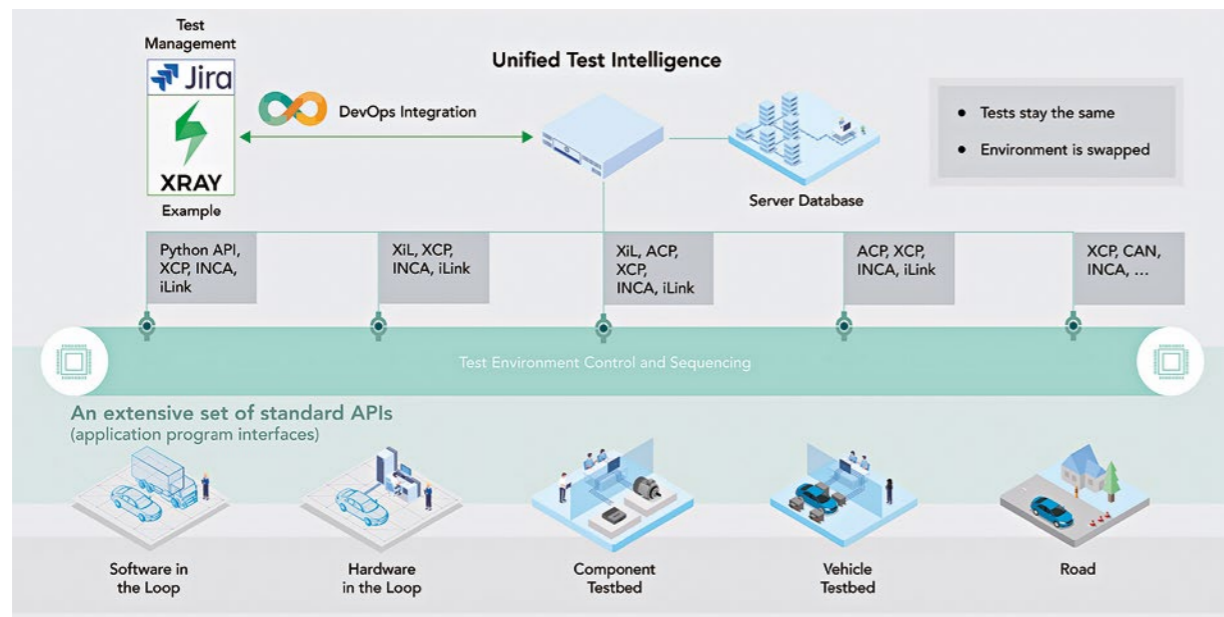
TEST EFFECTIVENESS AS A GUIDING PRINCIPLE

LAB AND PROCESS MANAGEMENT IS ESSENTIAL TO GET THE BEST OUT OF THE TEST FIELD

— Testing is critical in development. Effective and efficient operation of test fields, and their integration into the development process, is important for the success of our customers. Making this possible is not purely a technological issue. Rather, the key is the intelligent combination of proven methods and technology.

"Lab Management is not just another piece of software. It is a competence," explains Roland Strixner, AVL Global Business Segment Lab Management.

At AVL, up to 250 experts work in this area, including the Strategy Engineers consulting unit. Typically, companies with many global locations, as well as those who are extremely speed-driven, need organizational units to collaborate closely to remain competitive with a shortened time-to-market. Therefore, the primary concern is the efficiency of the test environment. Ideally, OEMs even want to keep these companies running 24/7.

This is where our expertise comes in, providing world-class workflow and data management. One relevant KPI is Operational Equipment Effectiveness (OEE), which delivers information on testing productivity. Software must be scalable and responsive to the systems of different hardware vendors.

In addition to the classical test environment and solutions for propulsion development, requirements are changing rapidly in the electrified automotive world. "It is important to understand how effectively and efficiently existing equipment is being used and how it matches up to current and future customer needs," says Michael Conrad, who works with Strixner in the battery business field. In battery development, test engineers deal with a variety of standards and test specifications, as well as short innovation cycles. The result: Up to 50,000 test channels operating in parallel for cell, module and pack development. Handling the growing number effectively is AVL's guiding principle. "Process digitalization and automation is not an option but a must to handle these challenges," says Conrad.

— Crisis makes you inventive. This was one of the few positive side effects of the pandemic since travel and movement possibilities were generally restricted. As a result, many systems had to be operated, maintained, and updated remotely – including vehicle testbeds.

"LIKE THE MODERN WORKPLACE, TESTING IS BECOMING INCREASINGLY HYBRID."

Werner Fuchs
Head of Software Product Management and Operations at AVL

Interlinking Virtual and Real Testing

Machine Learning is key for intelligent automation

"We really had to break new ground to develop real remote solutions," says Werner Fuchs, Head of Software Product Management and Operations at AVL. In parallel, we were facing strong pressure to adapt since testing plays a major role within the development process.

As the complexity of systems increases, such as ADAS/AD functions, the more testing effort is required. But not all conceivable combinations of all potential parameters – from weather conditions to vehicle distance, from lane changes to speed rules – can be tested on a testbed or even on the road. This makes simulation indispensable.

After all, OEMs who assume liability for accidents from Level 3 onwards should be capable of ensuring the safety and security of their ADAS/AD systems. Contingencies should be ruled out through simulated testing. While 30 percent of

tests in this field are simulated today, the ratio to real tests will decrease in the future, Andrea Conti, Vice President ADAS/AD at AVL believes, "since up to 80 percent can be virtualized."

As a leader in testing solutions and technologies, we operate around 7,000 testbeds worldwide. Originally designed for the world of combustion engines, the expertise has also been systematically built up for electrification in the areas of batteries, e-motors, inverters, and fuel cells. It is no longer just temperature, pressure, fuel consumption or emissions that are measured, but also, for example, the durability of a battery and its charging cycles.

To achieve testing efficiency in these labs, it is critical to employ automated processes. This is where Werner Fuchs's division comes in. His team is responsible for the leading testbed automation software

AVL PUMA 2™, the only system suitable for validating conventional and electrified powertrains.

"State-of-the-art test environments must be able to handle the increasing complexity arising from the different units under test. Therefore, virtual development and test execution on the testbed are necessary. Real-world testing will not be dispensable, but the number of physical test scenarios will decrease," states Fuchs. "Like the modern workplace, testing is becoming increasingly hybrid. Virtual and real testing must be better interlinked. Artificial intelligence can provide assistance with this."

NEXT LEVEL INTELLIGENT AUTOMATION

Historically, data has often been analyzed weeks after testing and possible inconsistencies were discovered too late. "It is critical to anticipate problems earlier to avoid costly damage to the unit under test and prevent delays in the project time scale. We have developed a tool that takes full advantage of machine learning algorithms," states Werner Fuchs about the latest software solution, AVL PUMA 2™ Machine Learning. This solution was specially tailored to the needs of AVL's customers and is very easy to use. "You don't need to be a Data Scientist for this," says Fuchs.

The process is relatively simple: Users can easily create models out of previously recorded data from the testbed. With the help of these models it is possible to compare predicted and measured values during runtime. "With this method, it becomes immediately apparent whether there are any deviations," says Fuchs. Week-long tests, such as endurance tests of batteries, which consume significant resources, can thus be stopped at an early stage, saving time, costs and nerves.

A brand-new study by McKinsey, "Industrialized Machine Learning," which precisely proposes this approach, fully confirms Fuchs's view. As with humans, one speaks of a "state of health" in batteries, fuel cells, and any other unit under test. The state of health is highly important to manufacturers who want to quickly understand whether their development is going in the right direction. Fuchs also finds his customers focused on fuel cell aging behavior share this interest. After all, hydrogen is too precious a resource to waste in test idle runs.

In the past, a testbed was purchased and then operated essentially unchanged for ten years. Nowadays, customers need to update in much shorter cycles as they are also confronted with constantly changing IT environments and an increasing number of security breaches. Both have put additional pressure on IT systems and environments in testing facilities. With the software maintenance approach, we ensure the value and stability of AVL software for the customer throughout the entire product life cycle. ───────

AVL Fuel Cell Production Test Solutions

Customized and innovative solutions to support fuel cell production

— As the development environment evolves to meet the demands of the electrified drivetrain, there is a clear need for optimization in industrialization, especially in the field of fuel cells. At AVL we look back on decades of experience in solutions for the production environment and have expanded our portfolio to include fuel cells.

Our production test solutions for fuel cell stack and system cover cold and hot tests, considering legal and customer-specific requirements. Through our virtual reality solutions, we can additionally make the integration, ergonomics and workflow investigations for the new production facility tangible for our customers even before the implementation phase. This ensures potential conflicts are resolved at an early stage.

Validation of the high-quality demands on the manufactured product is supported by our real-time automation system AVL PUMA 2™ Production. Based on a robust and fail-safe design, it covers the requirements of the production environment, like unmanned 24/7 operation, data management and statistical data evaluation of the measurement results. Similarly, to support your production tasks, AVL PUMA 2™ Machine Learning helps you create regression models using intelligent algorithms that enable the continuous monitoring of test signals.

Thanks to the modular approach, our production test solutions can be easily integrated into your environment and tailored to the planned production scenario and the required level of automation. ——

FIND OUT MORE:
www.avl.com/fuel-cell-test-system

▲ AVL fuel cell stack test station
▶ AVL fuel cell system test station

AVL vSUITE™

Complete vehicle system simulation

— Conventionally, vehicle systems have mainly been developed and optimized separately. This meant that cross-effects between different systems and their impact on the functional attributes of the vehicle – such as energy management, fuel economy, thermal comfort and driving dynamics – could only be optimized after integration into the vehicle.

But as vehicles have become more complex, particularly with new electrified powertrains, autonomous driving, and centralized control architectures, mutual dependencies of vehicle systems must be considered at a complete vehicle level right from the concept phase. This is vital to manage the complexity, reduce development time and achieve demanding vehicle targets.

To help you make this a reality, we have brought together a selection of our simulation tools to comprehensively view and optimize the vehicle, including all systems and functions, in a single solution. AVL vSUITE™ is a package that allows the creation of detailed real-time capable models that can be further used for calibration and testing in MiL, SiL and HiL environments.

Including a database of best practice examples, detailed documentation and even validated models of different vehicle types, vSUITE lets you adapt your processes and reach your toughest development goals. From vehicle system specification to control development and testing, it is a complete solution for modern vehicle development. ——

FIND OUT MORE:
www.avl.com/avl-vsuite

Reimagining Motion

For a greener, safer, better world of mobility.

We are driven by a passion to examine the science, mechanics and philosophy of movement. By using all our imagination, creativity and pioneering spirit, we create a world that is climate neutral and one that makes safe, comfortable, green mobility a reality for everyone.

Some will call it a distant dream.
We call it **Reimagining Motion.**

www.avl.com