automotion

03 | 2021

SOFTWARE

Vehicle connectivity 2.0: IAV offers an end-to-end big data value chain, from collecting measurement data to validating the entire vehicle.

POWERTRAIN

Keeping things just the right temperature with the mobile climate box for conventional and battery-powered drives.

VEHICLE DEVELOPMENT

Today's rapid development cycles call for smart and efficient methods so manufacturers can put the pedal to the metal.

Breaking new ground

With HEAT, we've brought autonomous driving to life.
Our next goal: getting autonomous vehicles ready for series production.

Dear Reader,

Will we all be moving around in autonomous vehicles soon, or will we still have to take part in driving for a while to come?

DR. UWE HORN
President, CHRO
IAV GmbH

MATTHIAS KRATZSCH
President, CEO
IAV GmbH

KATJA ZIEGLER
President, CFO
IAV GmbH

It's a fact that cars are getting smarter and smarter. There is already a wealth of driver assistance systems, and more are being added with each new vehicle generation. What James Bond's cars could do some 20 years ago is increasingly a part of our day-to-day lives on the road, although the invisible Aston Martin Vanquish has yet to hit the streets – then again, it probably wouldn't be entirely legal anyway …

And speaking of legal, the German federal government has really stepped on the gas this year in terms of legislation. This past summer's adoption of the new Autonomous Driving Act makes Germany the first country worldwide to have established a legal framework for autonomous vehicles in public road traffic. For an inside look at the doors this has opened for technological development and testing and where further action is needed, turn to the interview with our expert Marko Gustke on page 18.

At the same time that the new law went into effect, the HEAT (Hamburg Electric Autonomous Transportation) autonomous minibus was entering the home stretch. After three years, IAV and its project partners successfully concluded the study at the ITS World Congress in Hamburg. Matthias Kratzsch, our CEO, met with Henrik Falk, Chairman of the Management Board of Hamburger Hochbahn, to talk about what role autonomous shuttles might play in local public transit in the future and what challenges lie ahead as we move toward readiness for series production (page 12).

And of course, this issue looks ahead eagerly to the greatest possible level of automation in the future, but that's not all. We also look at the highly automated projects that are already in the works. And when we say things are up in the air, we mean it literally. A drone helps our colleagues approach testing and validation of driver assistance systems much more effectively (page 23). But with or without a drone, one thing is currently true of all driving maneuvers piloted by AI: The right sensors are absolutely crucial (page 24). That makes it even more important to protect them from rain, mud, and snow when the vehicle is in motion so the AI keeps a clear view (page 50).

In this final issue for this year, we offer not just something for the eyes, but also for the nose: Air freshening systems have long been available as a feature in luxury vehicles, providing a premium driving experience. A mobile "sniff lab" developed by IAV now enables computer-based analysis of fragrances in air freshening applications (page 52). So what else is needed for a vehicle experience that really delights all the senses? That's right – the acoustics to go with it! Our experts turn to innovative development methods to illustrate how to get rid of unwanted noise in electric cars and optimize the sound inside (page 54).

In closing, a few words on our own behalf. In light of the massive changes taking shape in our industry, we at IAV are charting a new course so we can proactively use this change for our own growth and evolution. Our objective: IAV as a tech solution provider. In the future, we want to be more than "just" a reliable partner to our customers. Our goal is to offer answers to increasingly complex issues and questions in the form of holistic solutions – and, more and more, to take on full responsibility in the process. (CEO interview, page 8).

We wish you an inspiring read!

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A clear view for sensors: IAV has developed a simulation method that identifies which parts of the vehicle will be least affected by spray, snow, or dirt even before the first prototype is built – making these areas perfect for sensor placement.

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The HEAT autonomous shuttle started driving around Hamburg's HafenCity area this summer. Matthias Kratzsch, President and CEO of IAV, and Henrik Falk, Chairman of the Management Board of Hamburger Hochbahn AG, discuss how it could revolutionize the urban traffic of the future.

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IAV operates its very own testing facility to test driving functions. An airfield near the city of Chemnitz offers everything anyone might need for application, homologation, and extensive tests to assess active vehicle safety (NCAP).

Dr. Arnd Eden and Steffen Spies know their way around interactive data analysis. They and their team use innovative data analytics methods to help customers test electric and electronic components.

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A new home in Heimsheim

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IAV is significantly expanding its footprint in the south of Germany with a new development center. Joining the test center for electromagnetic compatibility (EMC) is a building complex that will be home to 370 jobs and an advanced high-voltage testing infrastructure, test fields, and workshops. “For electromobility to successfully ramp up, electric vehicles need to come onto the market in sufficient variety and at shorter intervals,” says Katja Ziegler, President and CFO of IAV. “With our development center, we are intensifying our close customer relationships with automakers and creating a node for development of new generations of vehicles.” These new vehicles will be put to the test using the high-voltage (HV) testing infrastructure consisting of pre-integration stations and testing units for intelligent charge functions along with DC rapid charging test fields. The idea is for suppliers of various components to be able to check right then and there whether their components are working together perfectly inside the vehicles. This will make the process of integrating high-voltage components into the vehicle faster and shorten the time to readiness for series production. “This way, we will be able to offer our customers the full breadth of our people’s expertise and the right testing infrastructure, which is essential to developing electric vehicles quickly and to connected mobility, all from a single source and all in one place,” says Matthias Kratzsch, President and CEO of IAV.

In a FLASH

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Photographer: Christian Hüller

An option for the last mile and more flexible mobility for rural areas – that’s exactly what the FLASH pilot project is all about. IAV is working with the Northern Saxony Rural District and other partners to retrofit a midibus as a fully automated shuttle and integrate it into regularly scheduled local public transit service. To get there, a team of engineers is equipping the vehicle with six laser scanners, eight radar systems, and six additional cameras. The heavily modified commercial vehicle features a hybrid steering concept that allows it to operate in either fully automatic mode or with a person at the wheel. FLASH will be plying the route between the Rackwitz train station and Schladitzer Bucht, where the shuttle will operate automatically. At the same time, though, the vehicle can also be used for regular bus service. IAV is contributing its valuable experience from the urban testing field to get the concept of an autonomous off the ground in rural areas as well. Specifically, the team headed by IAV project manager Tim Alscher is supplying the entire automated driving operation system, from the concept through to application on the road. “We’re delighted to be able to bring the expertise we’ve developed through years of research and advanced development work to life in an innovative application project with a transportation company,” Alscher says. FLASH entered test operation on this commuter route back in July. A pilot phase that includes passengers is planned for 2022.

Saxony and IAV know hydrogen

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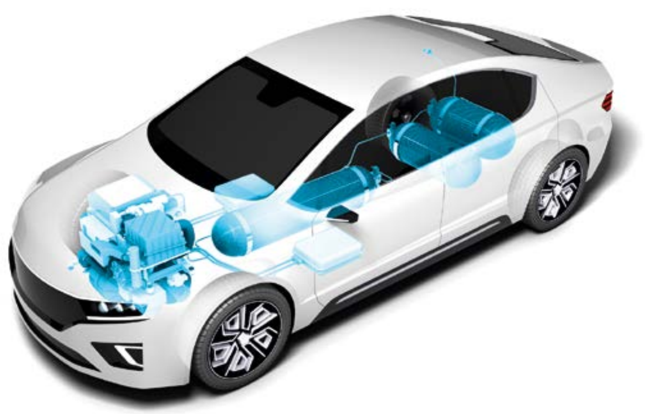
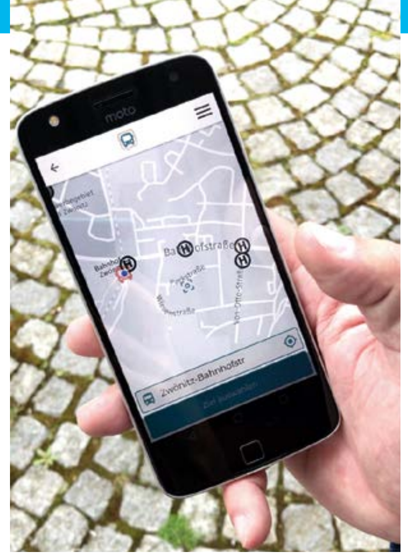
The subject of hydrogen as a versatile energy source is a field of development for future mobility and energy needs at IAV, as elsewhere. To further its network in the regional business sector in Saxony with an eye to R&D projects, IAV joined an innovation cluster called “HZwo – Antrieb für Sachsen” early this past summer.

The first few projects have arisen in the meantime, including through the cooperative initiative that has been in place with the Fraunhofer Institute for Machine Tools and Forming Technology (IWU) in Chemnitz since the start of the year. Fraunhofer IWU is currently developing a bipolar plate for fuel cell systems – with IAV contributing valuable computation expertise in the area of 3D fluid dynamics simulations and performance assessments. The simulation topics handled at IAV’s Stollberg development center range from the component level to thermal management and operating strategies involving the overall system. IAV also plans to develop and optimize aspects such as testing scenarios, infrastructure, and traffic concepts in the field of H_2 mobility.

The German federal government’s recent decision to award 60 million euros in funding for the hydrogen center project in Chemnitz has given fresh impetus to the H_2 offensive in Saxony, a major focus for the state.





A companion for the smart city

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The city of Zwönitz, Saxony, has a population of just under 12,000 and is located in a rural area. It is to receive a flexible, advanced local public transit option in the future. As in many small cities in Germany, there is a lot of room for improvement on the “last mile” issue here. While the city center of Zwönitz already has good service, the goal is for all of the other neighborhoods to be reachable flexibly in the future as well. The planners responsible for the future “smart city” concept aim to ensure that 80 percent of the city’s population has a transit stop within a 600-meter walk at the most, a goal they hope to realize by the end of 2021.

This will be made possible by the electrified “ERZ-mobil,” which will serve three additional lines in the lesser-served parts of Zwönitz on a rotating basis on demand in the first phase of the program. The technical basis for this is an adaptive mobility backend with two connected apps containing a booking service for passengers and an information system for the shuttle driver. “Our goal is to create an innovative service that acts as a hybrid version of regularly scheduled service, on-demand mobility, and ride pooling. This will let us cover a broad swath of the city while also achieving great flexibility for passengers, and we will also be able to adjust what we offer to better accommodate the local transit operator’s plans,” says IAV project manager Dr. Michael Gröschel, offering a summary of the group’s aims. IAV began partnering with the city of Zwönitz on this project in mid-July. With its mobility platform, the company is laying the groundwork for further activities aimed at making Zwönitz a smart city.

“Acting instead of reacting”

President and CEO Matthias Kratzsch explains IAV’s strategic alignment for the future and what it means to customers.

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automotion: Mr. Kratzsch, the automotive industry is experiencing great change in terms of both technologies and cooperation models. What challenges does this bring for your customers?

Matthias Kratzsch: The automotive industry is facing huge challenges. The shift from conventional to alternative drives, the growing importance of software, the adoption of new and digital technologies for vehicle development, and the rise of the automotive service world are in full swing. There have also been big advances in autonomous driving, with many new players entering the market from adjacent industries. These changes have brought a number of challenges for our customers in the automotive industry – and to meet those challenges, they need strong partners. In today’s highly competitive market environment, it’s no longer enough to offer support services according to spec.

automotion: How is IAV positioning itself for this future?

Kratzsch: I think of it as “acting instead of reacting.” We realize that our customers have new needs. They expect us to master complexity and processes, to contribute integration expertise, and to act with a focus on solutions – and to do it all at high speed, of course. They need partners who can shoulder some of the burden today, not tomorrow, and handle parts of the new challenges completely on their own. So we are consistently realigning ourselves to meet the increasingly stringent requirements. We are adopting digital technologies and automating our development methods, focusing on system requirements, and taking on responsibility for entire systems. And we are putting a lot of effort into building on our technology expertise, flexibility, and autonomy so we can add even more value for our customers. The product of all of this is a new strategic focus for us as a company: IAV as a tech solution provider.

automotion: What exactly do you mean by “tech solution provider”?

Kratzsch: “Tech” describes our focus on the latest technologies and development methods. “Solution” stands for our proven ability to take technologies into series production in full. And as a provider, we proactively anticipate our customers’ issues and offer our own solutions. This means IAV is no longer exclusively a development partner in the sense of fulfilling customer requirements. Instead, we are harnessing our understanding of systems and our integration expertise to proactively create solutions for our customers’ most important and most pressing issues while also placing our own solutions on the market – and doing all of it much faster than is currently the case. This is a shift in how we view ourselves, our range of services, and the value we provide. And this realignment will make it possible for us to continue to do what we do best as engineers and developers now and into the future: seeking out and realizing creative, innovative solutions.

“This realignment will make it possible for us to continue to do what we do best as engineers and developers now and into the future: seeking out and realizing creative, innovative solutions.”

MATTHIAS KRATZSCH,
President and CEO of IAV

Transformation front and center

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Globalization, the shift to digital, and climate change will all bring major changes for society and the modern working world. These changes are especially apparent in the automotive industry, which is facing the biggest upheaval in its history. It is up to companies and their employees to help shape this change and initiate the new developments it will bring at the right time.

“Right now, we at IAV have teamed up with our highly qualified employees to develop into a tech solution provider.”

DR. UWE HORN,
President and CHRO of IAV

At this year’s Engineering and IT Conference hosted by the Hans Böckler Foundation and trade union IG Metall in Chemnitz (29 September – 1 October), experts from companies, works councils, and the research sector discussed possible solutions for setting the necessary processes in motion together and shaping the transformation successfully and on a lasting basis. Dr. Uwe Horn, President and CHRO of IAV, and Mark Bäcker, Chairman of the Central Employee Council at IAV, delivered keynote addresses on both days of the conference.

In its role as an overall solution provider for the automotive industry, IAV is at the forefront of the massive changes sweeping the industry. This transformation is the essential lever for IAV to be able to successfully tackle the deep-seated change across the company. Training is a key aspect here. Under a new collective agreement between the company and the union, IAV and IG Metall agreed on a comprehensive budget for employee training back in the spring of this year. Going forward, it will be crucial to respond faster to changing market conditions and focus our training and recruiting activities on fields of the future. In addition to non-automotive business fields, IAV is shifting an increasing number of staff to software development in particular.

TRANSFORMATION AT IAV: SUCCESSFUL AND MULTIFACETED

This summer, IAV began managing the transformation process holistically through an agile “project office” made up of representatives of all the relevant stakeholders. “This is a great opportunity to move forward with a company like IAV amid these structural changes and help make sure that employees have a seat at the table in setting rules for training as part of this technological change,” says Johannes Katzan, IG Metall district manager for Lower Saxony and Saxony-Anhalt.

President and CHRO Horn is also confident: “Our partnership with IG Metall is one of the reasons IAV continues to do business with great stability, even in times of economic challenges. Right now, we at IAV have teamed up with our highly qualified employees to develop into a tech solution provider. Our goal is to strengthen each other to the point that we can all make a useful contribution to IAV as a technology provider.”

Says Mark Bäcker, Chairman of the Central Empoyee Council at IAV: “IAV is a special place. We’ve had a collective agreement with the union for about 30 years now. That doesn’t go without saying, and definitely not when you look at our competitors. Employees have more of a voice at IAV than they do elsewhere. That’s another reason this meeting in Chemnitz sends a good signal for eastern Germany, where this kind of co-determination isn’t as widespread yet.”

SUCCESSFUL TRANSFORMATION FOR OVER 200 IAV EMPLOYEES

IAV has already shifted more than 200 employees to future areas at the company since June 1 of this year. In addition, IAV is supporting the transformation through the CHANGE@IAV program, through which the company is supporting its strategic realignment as a tech solution provider effectively, with the participation of stakeholders and at all levels of the organization. Through these initiatives, IAV has created the stable and reliable work environment its employees require in order to do what the technical teams do best: develop the innovations our customers will need, from the initial concept through to the turnkey final product.

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“The fresh start we needed”

The HEAT autonomous shuttle started driving around Hamburg’s HafenCity area this summer. Matthias Kratzsch, President and CEO of IAV, and Henrik Falk, Chairman of the Management Board of Hamburger Hochbahn AG, discuss how it might revolutionize the urban traffic of the future.

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automotion: How will people get from point A to point B in cities like Hamburg in the future?

Henrik Falk: The mobility transformation isn’t necessarily the same as a shift in drives. We have a lot more individually used cars than we need in our cities. But people won’t move away from car ownership unless there is a reliable and convenient alternative. That’s why here in Hamburg, we are creating a new mobility system that is intended to wrap around to all modes of transportation between now and 2030. We call this the “Hamburg-Takt” initiative, and it is based on a simple promise: Everyone in the city should have the form of mobility that fits their living situation available to them within five minutes – 24 hours a day, seven days a week.

Matthias Kratzsch: It’s true, we have too many individually operated vehicles in our big cities. One possibility would be self-driving shuttles or robotaxis that pick people up, even from home, and take them to their destination or to the nearest U-Bahn or S-Bahn station. These solutions will carry a relatively small number of passengers. In addition, we also see a need for larger autonomous shuttles with more seats, which are more flexible as level 4 concepts than large buses providing regularly scheduled service. In outlying areas and at non-peak times, these kinds of shuttles are a good way to supplement existing public transit service, and in certain environments they could even replace traditional transit service entirely.

Falk: On heavily trafficked routes, traditional public transit service will continue to take passengers where they need to go. But then we also need small shuttles that can take people home as needed, with differences in pricing for dropping people off right in front of their door or cheaper service to a specific stop nearby. Our simulations show that we could need as many as 10,000 vehicles in Hamburg by 2030. But at the same time, demand for private vehicles could decline by as many as 100,000.

automotion: Might the traditional competition between public transit and cars even be replaced by a new kind of coexistence?

Falk: I have seen more humility from the automotive industry in recent years. But representatives of the transit sector have also realized that simply expanding on traditional offerings won’t be enough to transform mobility in full. If our research and pioneering work are rooted in this kind of humility, we will be laying the cornerstone for new business models to emerge in the future. All on-demand mobility services are burning money right now. They won’t start to make sense in business terms unless and until autonomous driving catches on. We expect to see that happen in city centers first and then gradually spread to outer areas of the cities.

Kratzsch: That was why it was important to us to develop HEAT, a concept that is significantly different from other pilot projects. In the city center application context, we initially set ourselves the goal of 50 km/h as the maximum speed. We designed all the hardware and software with that in mind. But the fact that we aren’t allowed to drive that fast yet for regulatory reasons doesn’t matter on the route we are currently serving in the HafenCity area. We can keep up with traffic there pretty well at 25 km/h.

automotion: What does this approach mean in terms of vehicle technology and transportation infrastructure in cities?

Kratzsch: We have focused from the start on combining sensors in the vehicle with infrastructure sensors along the way. The exciting question for us was, do we let the external infrastructure guide us, or is it there more for verification? In the course of the project, we learned that we need to place a large portion of the intelligence needed for safe driving inside the vehicle. With this approach, we’re to the point that the vehicle can automatically avoid obstacles on a two-lane street. Even on a one-lane

> **“In the course of the project, we learned that we need to place a large portion of the intelligence needed for safe driving inside the vehicle.”**

Matthias Kratzsch has held the position of President and CEO of IAV since early 2021. He is also responsible for the company’s technical areas. A mechanical engineer by training, Kratzsch has worked for the tech solution provider since 1997.

“Everyone in the city should have the form of mobility that fits their living situation available to them within five minutes.”

Henrik Falk is the Chairman of the Management Board of Hamburger Hochbahn AG, which transports more than 460 million passengers annually. Falk has a background in law and has worked since 2004 to improve local public transit, initially in Berlin and then, starting in 2016, in Hamburg.


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street, the vehicle can orient itself dynamically and avoid objects extending into the roadway, for example. Still, ongoing communication with the infrastructure does help us. For example, we use traffic lights to help us enter intersections faster and more dynamically. We have a lot of work ahead of us before this solution is ready for series production, though.

Falk: I think the project’s biggest success is that we’ve learned where we really stand. I have a clearer view now of where the challenges for autonomous driving lie. I don’t want to see solutions for dedicated routes or lanes, since after all, if these kinds of shuttles are truly supposed to contribute to mobility at some point, they will have to work in a bustling city – and we have our work cut out for us there. One piece of good news from the project is that we don’t need infrastructure support on the scale that we installed it in the HafenCity area. If cities had to fully overhaul their infrastructure, it would be the death of autonomous driving. In my view, having enough intelligence for secure self-driving on board the vehicle, combined with additional information to enhance performance, is the right approach under these circumstances.

automotion: How quickly could this kind of solution be ready for series production?

Kratzsch: First, the higher operating speed is a challenge for the regulatory side. That’s why we need to meet the authorities where they are and bring them along so the possibilities afforded by technology can in fact start moving around on our roads. In technical terms, we need to get all the hardware, some of which is still in prototype form, up to an automotive level. This means making sure the technology works securely and robustly – with performance significantly better than that of a human driver in order to get the necessary buy-in from society. That would send a signal to the government and the cities. The quality of the software needs to improve further, too. We have to find solutions for every situation where a safety driver still has to intervene these days because the vehicle system is not yet trained for them or another road user doesn’t follow the rules of the road. By the middle of the decade, we hope to have reached the point in the industry that shuttles can run without safety drivers at all.

automotion: HEAT has been in real-world operation since this past summer. What feedback have you gotten from passengers?

Falk: One of the big successes of the project is that even with the restrictions we faced due to the pandemic, we managed to develop the shuttle as a whole and set up test operations as well. Of course we wondered whether people would actually be willing to use the shuttle. The answer is a resounding yes. We have been flooded with registrations because everyone wants to try it. I think once people have learned that they can move around safely in an autonomous shuttle, they’ll be glad to keep coming back.

Kratzsch: Most of the passengers are curious about the technology and feel safe on the shuttle. But you can see that some of them are a little uncomfortable. So we need to counter those isolated instances of discomfort with optimized features and comfort-oriented applications and incorporate psychological research findings into our adaptive drive controls. There’s a lot of detailed work still to be done.

automotion: So what’s next for autonomous driving?

Kratzsch: Germany has taken the lead with the new legislation on highly automated vehicles. That’s why I expect we will see something similar to what we’ve realized in Hamburg in many other cities in the next few years.

Falk: Once it becomes possible to operate a system made up of traditional local public transit and autonomous shuttles cost-effectively and enable the same mobility as today, but with a lot fewer vehicles, that will be when it catches on. This will be an elementary step toward the transformation of mobility for all cities around the world.

Kratzsch: I think there will be providers or provider consortia that approach cities with exactly these kinds of solutions in a few years. At IAV, we see our role as not just supporting the development of autonomous vehicles, but also the process of adaptation to the individual national and local circumstances – including IT integration into operators’ backend systems.

Falk: These kinds of solutions should be market-ready by the middle of the decade so that we can roll them out on a large scale a few years later. Our task now is to make autonomous shuttles less of a niche option and give them a key role in the urban transportation of the future. The ITS World Congress was the fresh start we needed.

Interviewer: Johannes Winterhagen.


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To be continued

With passenger operation in the third stage of development and the unveiling of the shuttle at the ITS World Congress in Hamburg, IAV and partners brought the HEAT (Hamburg Electric Autonomous Transportation) research project to a successful close. Whether the autonomous minibus has a future, and if so what that future will look like, is still uncertain at this point. But one thing is definitely certain: that the many insights gleaned will be available for new projects.

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Use of autonomous minibuses on the last mile in suburban areas is viewed as a promising possible solution for establishing a flexible, forward-looking mobility model. The partners in the HEAT project – Hamburger Hochbahn, Siemens Mobility, IKEM, DLR, and IAV – deliberately selected a very busy area, Hamburg's HafenCity, to test the concept.

"We chose the toughest available setup so that we would face many different complex traffic situations in the HafenCity area," says Veit Lemke, HEAT project manager at IAV. The project partners' goal was to bring highly automated driving to life and prove that this kind of shuttle, equipped with a connection to the Hamburger Hochbahn transit control center, route sensors from Siemens, and one or more vehicle attendants, can transport passengers. "We reached our target," Lemke says. "We are sure that some of our takeaways will help with other setups, like outlying urban areas, and new business segments, like parcel delivery service."

A MIX OF SENSORS FOR PRECISION POSITION LOCATION

The shuttle itself features a setup of radar and lidar (light detection and ranging) sensors and cameras that allow it to operate independently, safely, and with high automation in this kind of complex environment. This is a key requirement if a solution is to be approved for operation on public roads. But the HEAT project was about more than just the primary goal, safety. It also aimed to achieve enhanced driving performance and recognize the many traffic lights accurately and automatically. These milestones were achieved through consistent addition of information on the surrounding area derived from infrastructure sensors, which were installed at intersections in particular, and through exchanges of data with the traffic lights. The external data were classified and supplemented with "health information" to enhance the reliability of the traffic light data in particular. This health information allows signals from traffic light systems to reach a high level of integrity. The data were analyzed, interpreted, and compiled inside the shuttle, using IAV's AD (Automated Driving) stack.

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With all these features on board, the shuttle moved around with enhanced safety, reliability, and performance in the highly complex traffic situations found in Hamburg's HafenCity area, running its route automatically and picking up passengers at different stops according to a fixed schedule.

"But now, when you see the shuttle driving smoothly through these narrow streets, it's clear that all the hard work everyone put in has really paid off."

VEIT LEMKE,
HEAT project manager at IAV

SUCCESS BUILT ON TEAMWORK

Groundbreaking optimizations were still being made to the shuttle and the route sensors in the third and final stage of development. At 1.8 kilometers, the test route in the port city is twice as long as last year's. Now, for the first time, HEAT can make a left turn at an intersection and automatically go around obstacles like double-parked cars. Thanks to the optimized sensor setup and improved component sealing, the shuttle was also able to operate even in the rain, another first. "With all the changes in weather we had this summer, we found out that not all rain is equal. We can't operate in heavy rain. But as long as the road isn't covered by a solid film of water, we can maintain passenger service," Lemke says.

This development would have been impossible as part of the approximately three-year project if not for the excellent teamwork among the various partners. The expertise needed for the pioneering project's overall system architecture wasn't built overnight. "Aside from that, there was no clear definition at the start of the project of who was to lead the consortium in terms of technology. It took time to clarify the responsibilities. But now, when you see the shuttle driving smoothly through these narrow streets, it's clear that all the hard work everyone put in has really paid off," Lemke says.

HEAT 2.0?

The ITS World Congress marks the conclusion of the HEAT pilot project. Discussions will show where things will go from here. "Within the consortium, people are talking about a HEAT 2.0 project. This collaboration could focus mainly on industrialization possibilities for the shuttle or on taking into account the new German federal law on autonomous vehicles," Lemke says. The AD system developed for the shuttle is also available for further refinement and development. Or IAV can also provide targeted support during the development of wraparound service offerings like on-demand services or help with integrating the technology into a control center or advice on approval procedures.

"A balancing act between being open to different technologies and clear specifications"

Germany's eagerly awaited new law on autonomous driving took effect this past summer. The move makes Germany the first country in the world to have created a legal framework for autonomous vehicles in public road traffic. But is the law alone enough, and what changes will it bring for the automotive industry? Marko Gustke offers his assessment. He worked at the German Association of the Automotive Industry, or VDA, when the first automated driving law was passed, in 2017. He joined IAV in the role of head of the Intelligent System Functions department in May 2020.

3 Questions for Marko Gustke

"The content and regulatory approaches can serve as a pilot for Europe and other countries."

automotion: Mr. Gustke, what do you think about the new law? Is it a step in the right direction, or is it all just for show?

Marko Gustke: The German federal government created a legal framework for automated driving back in 2017. The new law adopted in early summer 2021 marks a logical next step toward autonomous systems that no longer call for a human driver as a fallback in the vehicle. This has created a framework for the introduction of autonomous systems for specific applications on public roads, even beyond individual approvals for development. For the law to be a success, the content laid out in it will require further detail relatively soon. This is necessary in order to define a clear framework for implementing the technical and organizational requirements and make it possible for all stakeholders to act. That is true of the approval process, but that isn't all. It also applies how the technology on the vehicle interacts with the technical supervision at the control center. At the same time, the technical specifications need to be open to different technologies, opening up innovative solution spaces. Formulating those is a balancing act between being open to different technologies and clear specifications.

automotion: How will the law affect day-to-day work in the future and the processes used by OEMs and suppliers?

Gustke: To further improve traffic safety, the safety standards for introducing autonomous systems are very stringent, and rightly so. To ensure that the system behaves correctly in traffic on the road and prevent technical failures, autonomous vehicles themselves and the autonomous vehicle development process have very stringent requirements to meet. To master technical complexity, an increase in virtual scenario-based development approaches is needed alongside the tests in real-world environments. That's why relevant documentation and record-keeping during development will be part of the approval process. The component and system suppliers involved in a vehicle manufacturer's supply chain, along with development partners like IAV and the manufacturer itself, will have to use the right chains of tools and methods and demonstrate that they have done so either through certification or self-disclosure. IAV is very well prepared for this thanks to its experience with developing driver assistance systems and autonomous systems.

automotion: The legislature plans to take the law back up in 2024. Is the timeline too ambitious?

Gustke: An evaluation phase is a good thing because it gives people time to assess how effective the requirements are. Are they too broad, or too narrow? As everyone involved builds more and more experience, we will be able to respond and fine-tune things accordingly. In light of the fact that there is no timetable yet for the publication of these regulations and guidelines, it is questionable whether there is enough time between now and 2024 for these kinds of insights. But it's also important to consider the positive approaches set out in the law and our experiences with its application in the process of crafting the international regulations.

Autonomous vehicles can rely on these chassis functions

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Autonomous driving is bringing a whole new set of challenges for engineering teams in the area of functional safety of chassis functions. As soon as there is no longer a human driver, all of the safety related processes have to work completely independently at all times. Technical measures such as the heterogeneous redundancy already known from aircraft and continuous safety monitoring enable possibilities for disruption-free operation.

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Vehicles that reach level 4 or 5 automation on the autonomy scale recognized internationally (SAE levels) promise a whole new mobility experience. All vehicle occupants can put the time they spend on the road to good use, whether to work or relax. But what if there is a technical issue? Right now, a human still has to intervene at the wheel if any safety-critical system like the steering or brakes doesn't function perfectly. In an autonomous vehicle, however, there is no one at the steering wheel, and mechanical connections to central chassis components are replaced as well. Instead, the steering, brakes, and other components receive commands purely electronically, in an approach known as "drive by wire." If a problem occurs during transmission of these commands, a human can no longer intervene as the fallback. That means new approaches are needed in order to fulfill the specifications in the area of functional safety and enhance trust in autonomous vehicles.

HEAT: PRACTICAL EXPERIENCE IN A BIG CITY

The HEAT (Hamburg Electric Autonomous Transportation) project may offer these kinds of new approaches. In the project, IAV and partners teamed up to develop an autonomous shuttle for use in a major urban city. HEAT is currently operating with a vehicle attendant who monitors the shuttle's behavior, but it incorporates many level 4 functions, which already allows the shuttle to move around independently in traffic today. "This allowed us to gain valuable practical experience, but that wasn't all. We also developed an in-depth understanding of functional safety in systems like these," says Martin Gebhardt, head of the Steering department at IAV. "Working with our customers, we are already making the leap from level 2 to level 4 in the chassis segment, while also supplying detailed cost-benefit analyses on specific safety solutions."

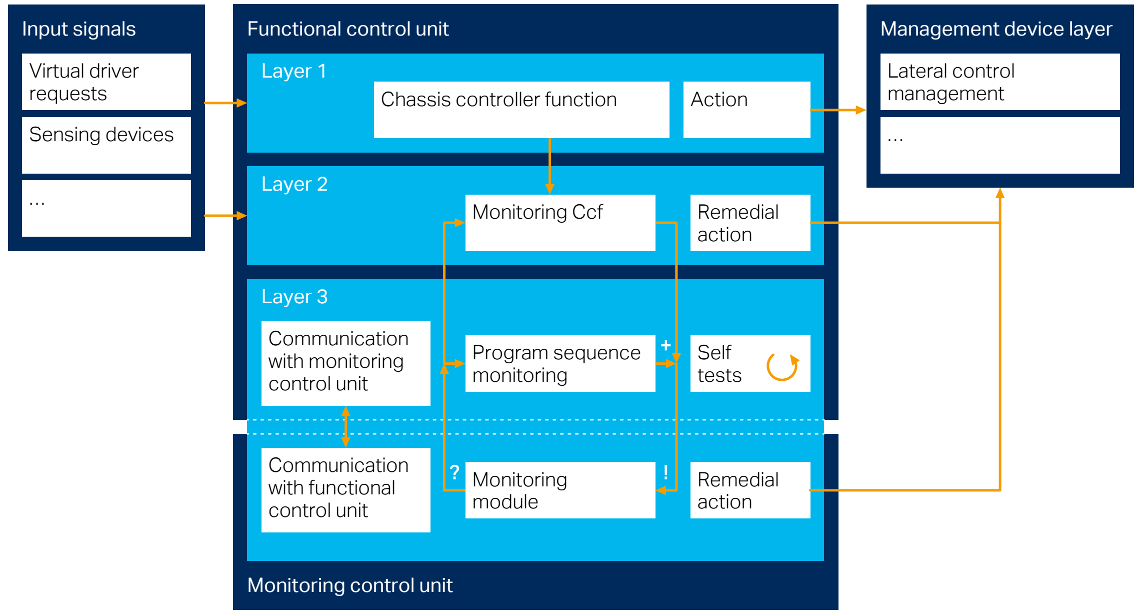
One reasonable possible solution to move toward automation level 4 is redundancy: If one controller fails due to a hardware fault, for example, then a different one steps in and takes over. "Safety-critical systems in aircraft have multiple redundancies, and if there is any discrepancy, the majority of the systems decides," explains Dr. Marcus Perner, technical consultant for Functional Safety at IAV.

However, that would be a very costly solution for mass-produced vehicles. Defining an optimized safety concept is essential. Diagnoses measures and safety mechanisms form the core here. A successive approach and identification of safety measures can help to pinpoint where redundancies are needed. "Heterogeneous redundancy" is a useful approach here – for example in the event that a sensor in the steering system no longer works correctly. The implausible sensor data could cause the steering actuator to behave uncontrollably, which could then lead to a dangerous driving situation. Diagnostics would identify the faulty data from the sensor. As a result, logic for further operation switches to the secondary sensor. The crucial point here is that the second sensor must be different from the primary one in technological terms to significantly lower the likelihood of the same malfunction occurring again. In this kind of scenario, the error cannot have the same effects.

A THREE-LEVEL CONCEPT FOR IMPROVING SAFETY

Another effective safety element is an adjusted three-level monitoring concept. It is based on the standardized E-Gas monitoring concept, from which the testing concept has been adopted. The actual function is found on the lowest level. The monitoring level is positioned above that, identifying errors at the functional level and initiating remedial action. The first and second levels run on the same functional control unit, but work independently of each other. The third level works on both the functional and monitoring control unit. One of its key functions is monitoring the correct functioning of the monitoring level.

Passengers in future level 4 vehicles will have nothing to worry about: "Studies show that statistically speaking, technology already makes far fewer errors than humans," Perner explains. "Nevertheless, the public has higher demands on technology – that is the reason why it is so important to ensure functional safety of chassis functions in all situations."



Change of perspective: Drones validate driving function

High-resolution cameras take videos of test scenarios for parking or emergency braking assistance functions – making validating these functions more effective. Further driving functions could also be developed faster and more effectively this way.

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Not everyone is good at parking. That's why a lot of drivers are happy to use driver assistance systems that handle the tedious maneuvering process for them. But how well do these electronic helpers do their job? That's the key question for Lukas Zehnpfennig and his colleagues on the System Integration Methods team at IAV. They recently began receiving aerial support in the process of validating automated driving functions like parking and emergency braking assistance features: Drones now use artificial intelligence (AI) to measure whether the technology meets all the requirements.

Photos from a height of 15 to 25 meters are useful for validating a parking assist feature. An AI places a box around each vehicle in the drone images, but that's not all. It also recognizes the vehicle's exact silhouette and alignment. Classic object recognition algorithms then determine the distances relative to other vehicles, in real time and with accuracy down to the centimeter range. This makes it possible to determine efficiently and automatically whether a parking assist feature is working properly and meets the necessary quality standards when a driver assistance system is being migrated to a new vehicle model.

COMPARISON WITH SENSORS IN THE VEHICLE

Drones can also be used to record video of the test scenario when validating emergency braking assistance features. Developers want to know how well the vehicle's onboard sensors determine its position and speed. To find out, they compare the data from these sensors against the values supplied by the drone. In this application as well, the AI segments the individual images in real time to determine things like the positions of vehicles and pedestrians. "Adding drones is a good way to supplement the existing GPS measurement technology," Zehnpfennig says. "The video material helps us achieve fast, reliable results."

METHODOLOGY HOLDS GREAT POTENTIAL FOR THE FUTURE

Unmanned aerial vehicle technology has advanced to the point that experts from IAV are equipping standard commercially available drones with 4K cameras these days. The engineering team believes the new method holds great potential for the future. "Other autonomous driving functions such as intersection or lane keeping assistance features are currently being evaluated and could be visualized this way in the future," says student trainee Ruwen Kohm. He was responsible for training the AI to recognize vehicles as part of writing his bachelor's thesis at IAV.

IAV customers benefit not only from more-efficient validation of new driving functions, but also from greater detail and scope in test reports, including aerial views of the tests. GPS-supported tests are still likely to be needed to some extent in the future, though, for things like final certification. But the path to get there will be a shorter one, as these "flying eyes" are set to significantly accelerate the development process.

All a question of sensors

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Automated driving functions require a wide range of sensors to accurately and continuously sense the surrounding environment. Lidar sensors will become increasingly common in vehicles as a result, especially at SAE level 3 and above. IAV already has extensive experience with this technology, which is increasingly catching on in the automotive environment, and supports its customers along the entire development process.

Automated driving functions and autonomous driving are inconceivable without sensors to sense the vehicle's surroundings. They are key to allowing the vehicle to perceive its surroundings accurately. This means good performance, redundancy, and safety are the most important requirements for the sensor setup. Vehicles already use various sensor technologies today, with the strengths of some types of sensors compensating for weaknesses in others. For example, cameras offer high resolution and the possibility of recognizing colors, but they have issues in extreme lighting and weather conditions, such as when emerging from a tunnel into bright sunshine. Radar does not rely on ambient light for active sensing, is not as heavily impacted by the weather, and also determines the relative speed of moving objects in the vehicle's surroundings due to the measurement principle (Doppler effect). Present-day sensor setups are typically supplemented by ultrasound sensors, which are primarily used for parking applications due to their specific characteristics, such as a small range.

Automated driving functions at SAE (Society of Automotive Engineers) level 3 and above in particular require greater redundancy so that the vehicle can create an accurate picture of its environment even in difficult conditions. Lidar (light detection and ranging) has properties that dovetail effectively with those of established sensors, so it will increasingly be found in mass-produced vehicles in the years to come. Lidar sensors are active optical sensors that transmit laser beams and detect the light that is reflected back.

HEAT SHUTTLE AS PLATFORM FOR NEW MOBILITY CONCEPTS

In the HEAT (Hamburg Electric Autonomous Transport) research project, IAV selected various lidar sensors and integrated them into the autonomous shuttle. The HEAT shuttle is equipped with one front camera and four surrounding cameras and with eight radar and ten lidar units. The shuttle also communicates with the surrounding infrastructure, which provides additional information on objects and traffic lights.

"This sensor configuration generates huge amounts of different data," says Dr. Philipp Materne, a development engineer for autonomous driving at IAV. "That's why we developed an innovative approach to data fusion for perception purposes. It is highly flexible and scalable, but at the same time, it doesn't take much processing power."

The product of this data fusion is detailed and comprehensive sensing of the vehicle's surroundings, providing a description of the static and dynamic characteristics of the shuttle's surroundings and forming the basis for further AD functions. The big advantage here is that the knowledge gleaned in the HEAT project can be transferred to other vehicles quickly. The software solution and the shuttle's AD system are modular in structure and can be integrated into cars, people movers, and both large and lightweight commercial vehicles via IAV's development platform.

LIDAR: ACTIVE SENSOR WITH A LONG RANGE

A lidar sensor is an active sensor with a range of more than 200 meters that uses targeted laser beams to sense the environment in three dimensions with great accuracy and achieves full performance even in the dark. "That's why we believe lidar will experience growth similar to that of camera or radar sensors in the near future," says Dr. Dominik Kufer, technical consultant in the AD Sensorsets & Vehicle Validation department at IAV. "The properties of lidar are used optimally in highly automated driving functions in particular, making them a perfect addition to the existing sensors that are in use."

But the use of lidar also brings new challenges. Since they actively emit laser beams, there can be unforeseen effects such as mirroring and multiple reflections. The quality of the signal detected also depends on the amount of light reflected back – so it varies according to the specific qualities of the surfaces of objects or obstacles and any disrupting factors in the optical path, such as precipitation or dirt on the sensors.

There are many lidar manufacturers working on solutions to these issues through various technologies and approaches. But that, too, makes the task more complex, as OEMs have to choose the system that is best suited to their specific use case from a broad selection. "While camera and radar technologies are mature, lidar technology is still in its infancy," says Sebastian Schau, head of the AD Sensorsets & Vehicle Validation department at IAV. The company has been working with lidar for years now and has already supported a large OEM in the areas of testing and validation during series development. "We are intimately familiar with the challenges that arise during integration and validation."

Research projects like HEAT and cooperative relationships with OEMs during series development have given IAV a good overview of the key lidar manufacturers and their sensor systems – expertise that benefits customers in the search for the solution that is perfect for them. "Lidar sensors are highly interesting to the majority of OEMs and tier 1 suppliers," Kufer says. "Since this is a relatively new system, there is a big need for consulting and support along the entire development process. We are ready and willing to work with our customers to take this new technology into series production."

Building bridges for connected roads

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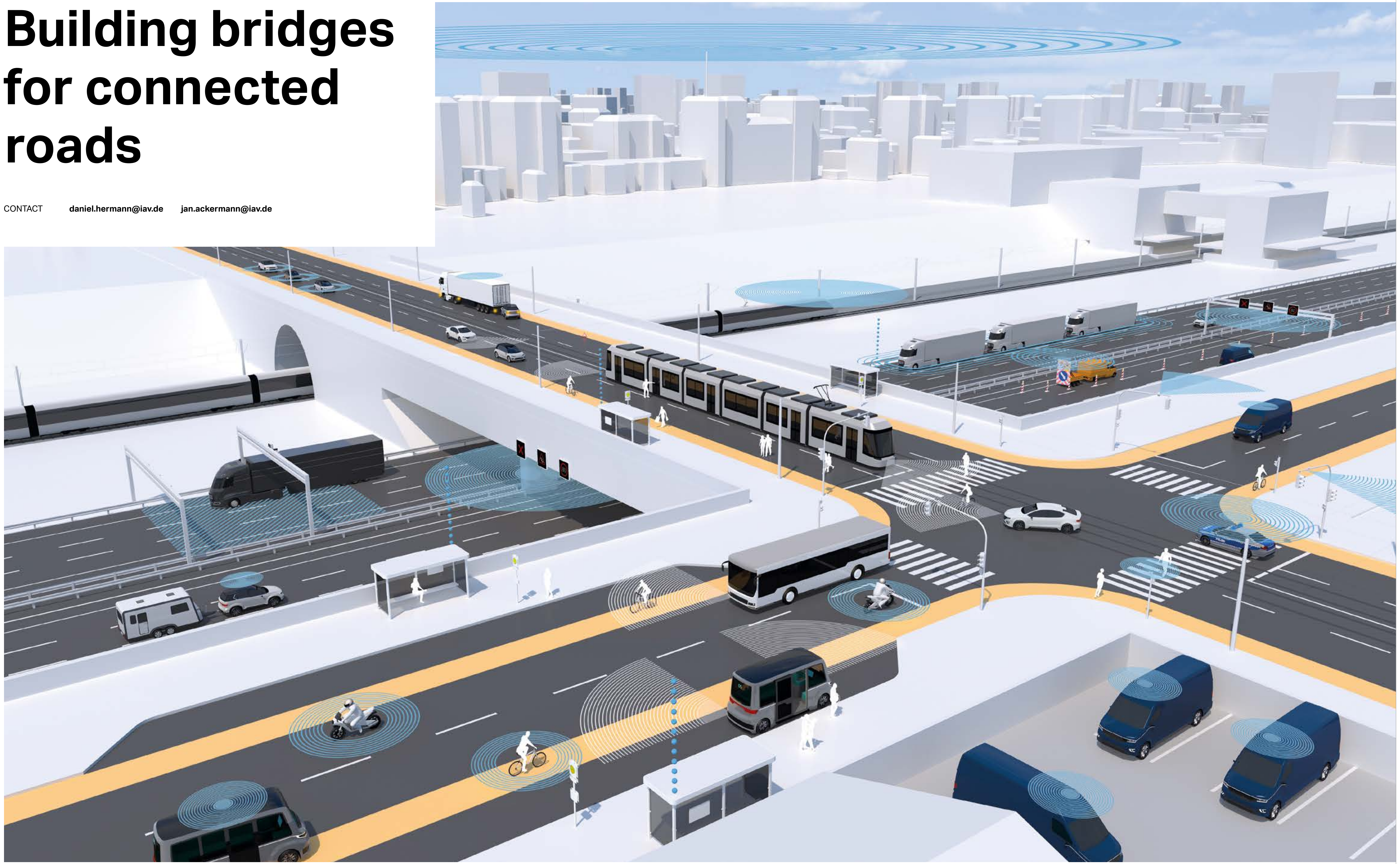


Road traffic needs to be safer and more efficient, with lower environmental impact. Getting there will require sensor-based cooperative intelligent transport system (C-ITS) technology. As part of the Europe-wide C-Roads Platform, IAV has taken on a key interface position in pilot projects and in standardization efforts, thereby helping to ensure that ITS communication on the road and in vehicles is compatible.

Eight EU countries teamed up to establish the C-Roads Platform (www.c-roads.eu) five years ago. Government agencies and road operators joined in to coordinate the introduction, testing, and harmonization of cooperative intelligent transport systems (C-ITSs) on Europe's roads. Their goal? To ensure the use of international C-ITS services in Europe.

A C-ITS encompasses a wide range of technologies and applications. Using ITS-G5 wireless communication technology (based on the IEEE 802.11p WiFi standard), these kinds of systems enable effective exchange of data between vehicles (V2V) or between vehicles and the infrastructure or other road users (V2X). ITS-G5 can additionally be supported by mobile communications, with the two technologies acting as a hybrid system. The benefit to passengers is that advanced, connected vehicles check the data that are transmitted right away to see if they are relevant and then display information via the instrument cluster.

"That means they get the right information at the right time, whether that means the end of a traffic jam, variable message signs (IVS) like temporary speed limits, or emergency vehicles that are nearby (EVW)," says Daniel Hermann, senior technical consultant for V2X Application Development & Standardization at IAV. This adds value, especially for users of highly automated vehicles whose onboard sensors do not sense all traffic situations clearly and rely on additional information from the infrastructure.

These intelligent systems are viewed as a possible avenue to future use of autonomous shuttles on roads. At the same time, a C-ITS can also be used to streamline traffic management. The C-ITS technology of the future will require roadside units at hotspots such as traffic lights, variable message signs, and "black spots" where accidents have historically been concentrated, with these units emitting signals and/or acting as repeaters to pass along information from vehicles. Thus far, about 2,300 of these units have been installed Europe-wide as part of C-Roads, and some 20,000 kilometers of road have been equipped with the ITS-G5 radio system.

IAV LINKS THE WORLDS OF INFRASTRUCTURE AND VEHICLES

IAV has been involved with the national arm of the EU project, C-Roads Germany, since 2016. Activities have included participating in a pilot project in Lower Saxony. Along a seven-kilometer stretch of the A2/A39 autobahn, three roadside units have been installed between the Braunschweig North junction and the Braunschweig Watenbüttel interchange, offering three services: MVW (Maintenance Vehicle Warning), IVS (In-Vehicle Signage), and PVD (Probe Vehicle Data). "In the project in Lower Saxony, we have implemented the IVS function in the vehicle to display information on variable message signs to occupants with sufficient lead time," Hermann says.

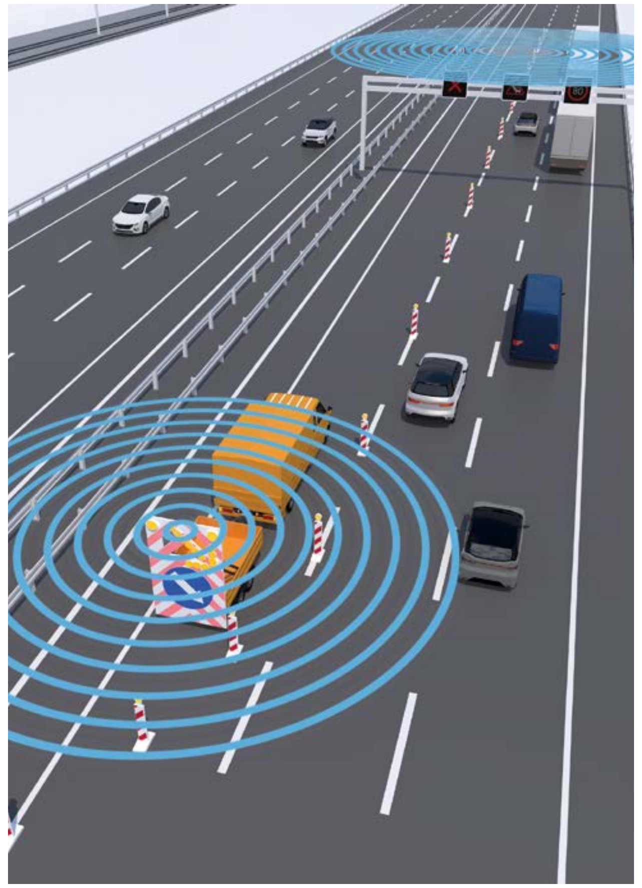
IAV also views itself as an intermediary between the infrastructure world of the C-Roads Platform and the European vehicle world represented by the Car2Car Communication Consortium (C2C-CC). A member of both bodies, IAV contributes the experience it has gained through various projects with OEMs and infrastructure operators such as Austria's ASFINAG and Autobahn GmbH in Germany.

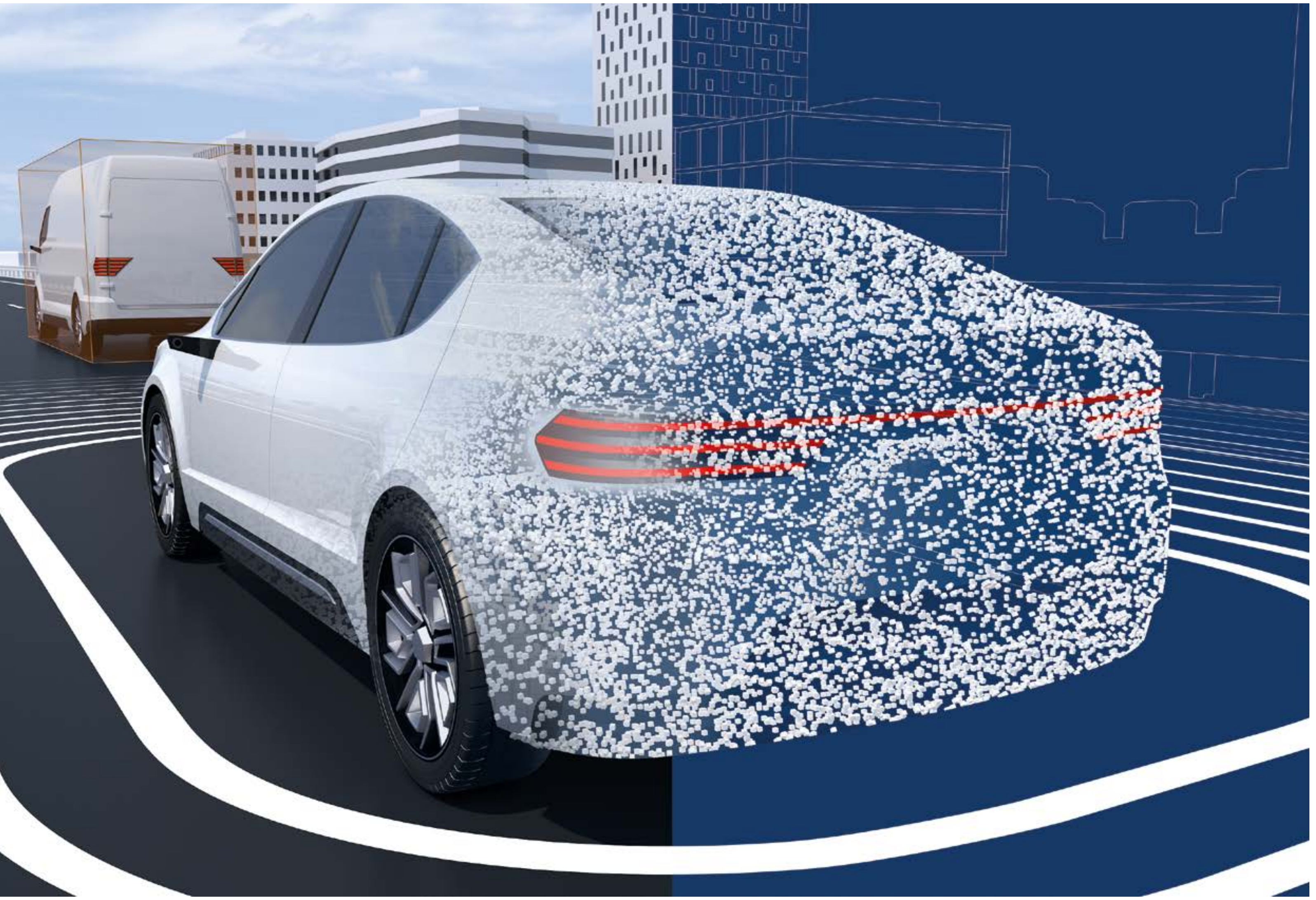
In both C-Roads and C2C-CC, IAV is working to harmonize C-ITS function and system specifications, specify test cases, and execute and analyze test drives. "We are helping to make sure everyone speaks the same language," Hermann says. "We know both sides, and we are using our expertise as a system integrator as a basis to ensure that the vehicle and infrastructure functions are compatible." Hermann and his team plan to use their findings to take C-ITS functions into series production reliably and efficiently throughout Europe.

Co-financed by the Connecting Europe Facility of the European Union

"We are helping to make sure everyone speaks the same language."

DANIEL HERMANN,
Senior Subject Matter Expert for V2X Application Development & Standardization at IAV





The digital prototype by your side

As the systems for automated driving functions grow increasingly complex, conventional development methods are pushing the limits of their capacity. Digital prototypes can help, unlocking possibilities for a highly efficient and rigorous development process. IAV uses digital prototypes across the entire process of developing automated driving functions – from concept validation through to approval.

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Development of automated driving functions is arguably the biggest challenge in automotive engineering right now. AD functions have to prove themselves in a complex, ever-changing environment while meeting a wide range of safety requirements and offering useful added value for customers. Processing large volumes of data is only one of the arising challenges – inside the vehicle, a wide array of components are also involved in executing automated driving functions. This inevitably leads to a need to rethink the development methods used in this segment.

VIRTUALIZATION ENABLES EARLY TESTING

Digital prototypes (DPs) are one tool for meeting the various challenges involved in the development process early on. The idea behind them is that DPs describe both: a vehicle's components and functions as well as its surroundings. The depth of abstraction is adjusted toward the specific development steps in each case. This digital representation in the form of numerical models, executable on a computer, is aligned with the basic idea behind model-based systems engineering (MBSE). This type of virtualization allows for early, low-cost testing of a system that is to be developed. The method can help identify areas in need of optimization and sources of error in these increasingly complex driving functions early in the development process, shortening development time. Especially in the AD context, this approach permits continuous, reproducible validation of specifications in a large number of complex environments before a design enters further refinement stages. Beyond that, using models helps to formalize function specifications. "Human communication often involves inadvertent ambiguities. By removing natural language as a factor, we are taking all the room for interpretation out of the specification process," says Dr. Nico Schertler, a development engineer for virtual function development in the AD unit at IAV. "This prevents errors in communication, for example in dialogue with suppliers, which in turn leads to greater effectiveness in the development process."

The interaction of DP and real-world driving functions is a key part of this approach. Along the path from concept to product, the digital prototype provides early support in implementing functional properties. In later phases of the process, findings from trial runs with physical prototypes are also used to improve the system model. AD functions benefit greatly from this combination, as real-world test runs often include unknown combinations of factors in the vehicle's surroundings. "This methodology adds the most value when these models are used as early as possible and throughout the development process," explains David Seidel, team manager for AD Functions & Simulations at IAV.

ESPECIALLY INTERESTING FOR DEVELOPERS WITH SYSTEM RESPONSIBILITY

Experts from IAV have already been able to gain experience with DPs through numerous projects, as they have been in use at the company for several years now. On top of that, they can always keep an eye on the entire development process during their work while striving to use these models as consistently as possible across the board. "A digital prototype is hugely important to all OEMs and suppliers that develop or integrate complex functions for automated driving systems," Seidel says. "Since the biggest added value comes from using this methodology consistently from the start, developers with holistic system responsibility can benefit in particular."

IAV uses DPs to develop entire systems and their components (such as sensors) and to test them in different environments, such as simulations or virtual reality systems. This makes it possible to experience and validate functions early on in the development process. Because all components are described in a machine-readable format, end-to-end traceability is guaranteed – so it is possible to demonstrate that a driving function fulfills the specifications that apply to it, such as standards and laws. Linking individual components and models together also makes it possible to propagate changes through the entire system with a high level of automation. The DP methodology also extends through the entire development process, right up to approval. "This shortens development times while improving product quality in that the systems are more robust," Schertler says. At the end of the development phase, the DP methodology can also serve as a basis for digital twins, which represent real-world vehicles virtually.

Cleared for takeoff: IAV tests driving functions of tomorrow on airfield

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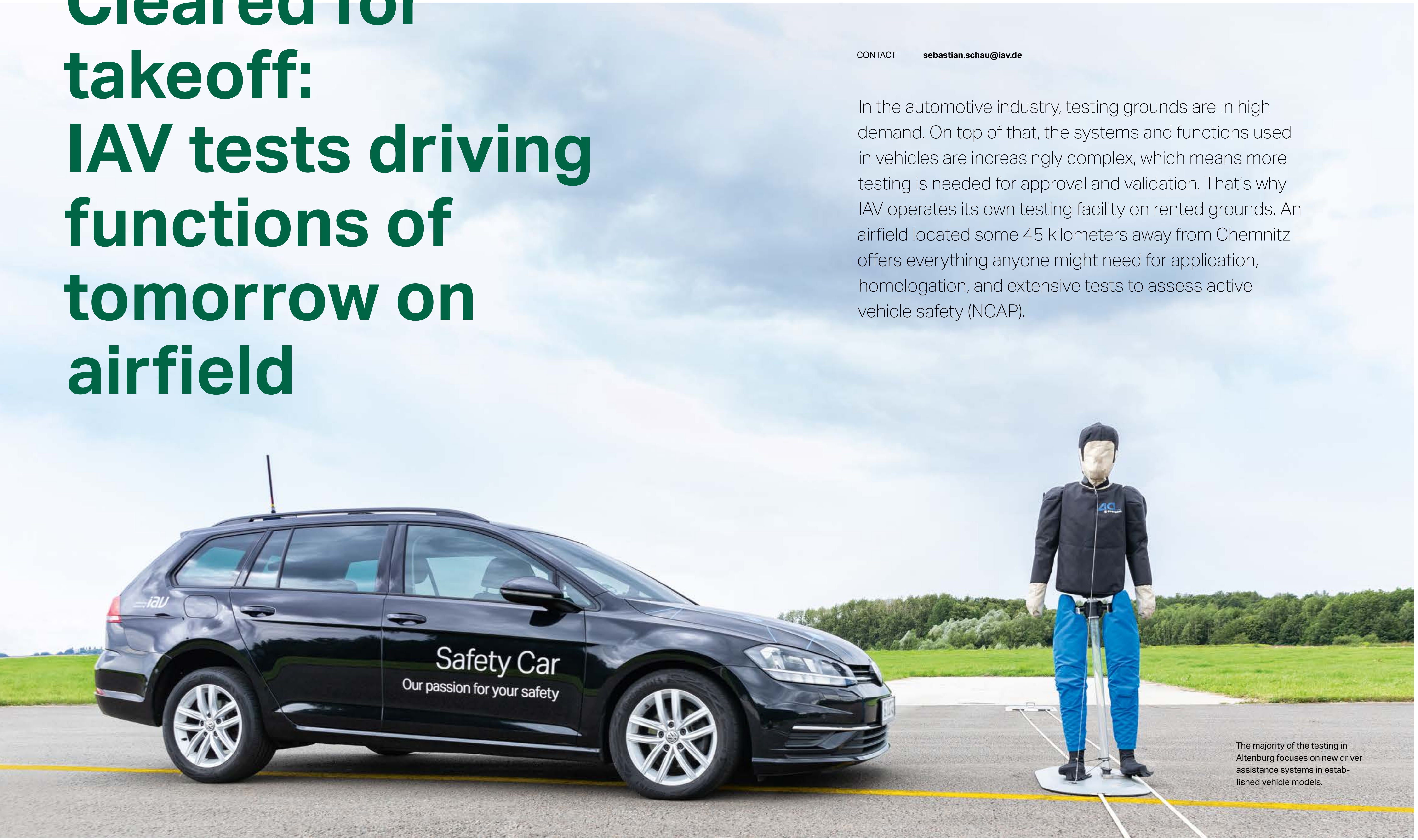
In the automotive industry, testing grounds are in high demand. On top of that, the systems and functions used in vehicles are increasingly complex, which means more testing is needed for approval and validation. That's why IAV operates its own testing facility on rented grounds. An airfield located some 45 kilometers away from Chemnitz offers everything anyone might need for application, homologation, and extensive tests to assess active vehicle safety (NCAP).



The majority of the testing in Altenburg focuses on new driver assistance systems in established vehicle models.

> **"We can work on a wide range of different topics in Altenburg, from homologation and NCAP to application in the project and beyond, to performing safety-critical test cases."**

SEBASTIAN SCHAU,
Head of the AD Sensorsets & Vehicle Validation department at IAV

When he talks to customers, Sebastian Schau hears the same thing time and again: "OEMs' testing grounds and equipment are generally booked solid, and people are urgently looking for alternatives," says Schau, the head of the AD Sensorsets & Vehicle Validation department. "That's why we decided to run a facility of our own. It's completely independent, and we can perform all tests according to the NCAP standards for 2020 there, for example."

As part of the New Car Assessment Programme (NCAP), active safety systems are tested in the vehicle. These include active passenger and pedestrian protection features. The test results offer guidance for buyers who are looking for quick, detailed information on how safe a car is.

The testing is possible on the former military airfield at Altenburg, between Leipzig and Chemnitz. The air strip was first opened in 1913, making it one of Germany's oldest. Now, over a century on, it is home to various concrete and asphalt roadways up to 2,400 meters in length for a wide range of tests. A protected area hidden from view also allows for tests on prototypes.

The local infrastructure includes safe places to park prototypes, a conference room, target and transportation vehicles, trailers for prototypes, charging stations for electric vehicles, pedestrian facilities, an Ultra-Flat Overrunable (UFO) robot platform to move crash targets at a speed of up to 100 kilometers per hour, various dummies (vehicles, pedestrians, bicyclists), steering, gas, and braking robots, and a Euro NCAP-compliant light system for nighttime testing. A dGPS system guarantees position accuracy down to two centimeters. There is also a fully automated tool chain that the experienced team of system developers and test engineers can use to perform and evaluate the tests highly efficiently in Altenburg.

"We can work on a wide range of different topics in Altenburg, from homologation and NCAP to application in the project and beyond, to performing safety-critical test cases – including using virtual methods," Schau notes. "We can also work 24/7 with our testing grounds and equipment, which means we can do more than just offer turnkey projects. We can also cover periods of peak demand at our customers' end." These days, the airfield where historical aircraft used to take off and land is home instead to the driving functions of tomorrow.

Hulk on the loose

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Many municipalities and operators of large properties have the same issue: Lawns need mowing, streets require care, and snow needs to be cleared. An autonomous commercial vehicle could handle these tasks reliably and efficiently. IAV's "Hulk" demonstrator is a retrofitted Multicar model. It proves that the necessary intelligence can be incorporated after the fact as well.

From mild-mannered nuclear physicist to the green-skinned muscle man known as "The Hulk" – protagonist Bruce Banner's spectacular transformation lay at the heart of the "Incredible Hulk" series first published by Marvel Comics in the 1960s. Now, a ten-year-old Multicar model has undergone a similar metamorphosis. After it spent years as a street sweeper in France, IAV developers have transformed the simple commercial vehicle into an innovative technology demonstrator, albeit one distinguished less by its sheer power than its unusual intelligence. IAV's Hulk is an autonomous municipal vehicle that mows lawns on its own, thanks to a retrofit solution that can also be adapted to other fields of use.

LOW-COST, PRACTICAL RETROFIT APPROACH

"When it comes to autonomous driving, vehicle manufacturers think first and foremost of solutions that can be mass-produced in large unit volumes, with relatively long development cycles," says Tom George, director business development for Commercial Vehicles at IAV. "At the same time, though, municipalities have high demand for autonomous commercial vehicles available on short notice, which no one can meet yet." That was the source of the idea to develop a retrofit solution that can be used to automate exactly these kinds of commercial vehicles after the fact. After all, they have a very long service life, so upgrading to autonomous driving is still worthwhile while they are in use.

In the Hulk's case, the engineers at IAV made changes in various places. The demonstrator was equipped with a GPS system that determines its position in open areas with accuracy down to two centimeters. New sensors (lidar and 3D and mono cameras) also scan the vehicle's surroundings and supply data to its "brain": an industrial PC with high-performance GPU that is responsible for autonomous driving (high-level layer). The graphics processor uses the sensor data and neural networks to classify objects such as molehills, rocks, bicycles, and pedestrians in order to avoid collisions.

One level down (low-level layer), a control unit receives the commands from the PC in autonomous driving operation or signals from the radio remote control system in RC mode, which can also trigger an emergency stop. Between this control unit and the normal vehicle control units is a switch box. Its task is to switch between manual driving and autonomous or remote-controlled mode. The Multicar has also been equipped with new features at the lowest level (the vehicle level), including a touch display and failsafe brake.

SOLUTION READY FOR CUSTOMER USE

Even with just the current features, the Hulk will already make a significant difference in mowing lawns. These days, city employees still drive a Multicar over the lawn to mow it, then park the vehicle and reach for a trimmer to handle the details. With an autonomous Multicar like the Hulk, the lawn almost mows itself while the employee can handle the finer points by hand at the same time – bringing major time savings for an industry where staffing shortages are the norm. This makes the system an appealing option for municipalities and a true win for others, such as soccer teams. Operators of airports or even race tracks would benefit from this kind of automation, too. Autonomous commercial vehicles could remove abraded rubber from the road surface, for example, or clear snow in the winter – without any human assistance.

"With the Hulk, we've shown what an autonomous municipal vehicle might look like," says Markus Robert of the Intelligent System Functions department at IAV. "Now we're ready to start offering this solution to customers as well, although the system will have to be adapted to the application and the base vehicle and then approved, of course." Potential customers include the operators of large properties and vehicle manufacturers themselves as well: IAV can imagine developing an OEM retrofit kit. Robert and George think it could also be a good option for underground mine systems. If everything goes according to plan, many commercial vehicles could soon undergo a metamorphosis of their own, copying the Hulk.

Climate zones in the testing facility

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Reproducible measurements obtained under extreme climate conditions are becoming increasingly important in drive development for both conventional and purely battery-powered cars. A new method from IAV makes it possible to transform almost any IAV test unit, from traditional engine test benches to those for batteries, into a full climate testing unit at low cost and with minimal mechanical effort.

Low outdoor temperatures and high humidity encourage the formation of deposits on components and can damage the engine when exhaust gas is recirculated in combustion engines. To investigate the effects of these kinds of environmental climate conditions, vehicle manufacturers typically use special testing facilities. But time slots are often hard to come by and very expensive, while test drives in road traffic are of limited utility when it comes to taking the relevant measurements.

The "variable IAV climate box" can be used to do things like set the temperature and humidity as control parameters for component tests involving engine test benches. This will unlock a greater depth of testing using conventional IAV test units in the future, supplying additional information for development and validation.

The IAV climate box measures 3000 x 3000 x 2500 mm. It is installed on an IAV test unit around the relevant test subject, such as a combustion engine, and conditioned using mobile cooling and climate control assemblies. This retrofit "climate test unit" is also integrated into the existing test unit automation. The IAV climate box (10 kW of cooling performance at minus 20 °C) has a performance range extending over temperatures from minus 20 °C to 15 °C and humidity from 10% to 90%.

"We wanted to generate a mobile application that lets us take a box like this from test unit A to test unit B," explains Jörg Jacob, team manager of Powertrain System Development at IAV. "This variable solution can be used in endurance runs or mechanical testing, for example, or it can be used in functional testing – whatever the customer wants to do."

ALSO USABLE FOR ELECTRICAL COMPONENTS

There is an ever-growing range of development topics relating to electronic powertrains, which is also driving increasing demand for test capacity in the electric mobility segment. The IAV climate box can be used here as well, says Ronny Mehnert, team manager of Energy & Thermal Management at IAV.

Batteries are also prone to condensation, because moist air enters the system through the ventilation unit's semipermeable membrane. As temperatures fluctuate, the condensate forms droplets and collects in the battery, for example when the drying unit storage capacity is exceeded. Alongside high-voltage batteries, fuel cells, power electronics, and inverters are all components that are sensitive to condensation.

"The variability this box allows is not limited to just combustion engines," Jacob says. "It can be used in various ways, including for electric car and battery test units where small, low-cost housings are needed."

The design has proven its effectiveness through extensive tests and simulations involving deposition and condensation. The virtual analyses also offer insight into increases and decreases in the amount of condensate in relation to ambient humidity. 3D calculations have also been used to identify where the water arises and how it is transported in the cooler and pipe system, and thanks to modern topology, optimization and remedial actions have been developed, for example by evenly distributing the flow within the cooler or water separator.

One thing is clear: Test facilities are critically important to quality assurance in the automotive industry. The more functional and flexible they are, the greater the competitive advantages they can yield. Thus far, IAV has used the climate box exclusively in customer projects with OEMs and suppliers at in-house locations, but the company is also considering a solution on a product basis.

IAV'S CLIMATE BOX – QUICKLY TRANSFORMING AN ENGINE TEST BENCH INTO A CLIMATE CELL

ADVANTAGES

- Use any test bench for assemblies as a conditioned test bench
- Short assembly time
- Different virtual vehicles as well as route and driving profiles
- No restrictions on the use of exhaust gas measurement
- Proven high comparability of results with a climate test bench

CLIMATE BOX FEATURES

- Insulated floor
- Access through one door
- Visual surveillance with camera system
- Actual values and fault messages are monitored in the test bench automation system

OPERATING OPTIONS

- Dynamic cycles (e.g., WLTC +20 °C / -7 °C or Shanghai cycle +35 °C, 90-95% humidity possible)
- Standard endurance test bench can be retrofitted with a mobile climate box (e.g., no need to change test bench for operating conditions close to the dew point)
- Conditioning of cooling water/oil circulation
- Conditioning of intake air
- Moisture regulation (stable) up to 95% humidity from 10 °C

Meeting the highest standards

The upcoming Euro 7 emission standards will set stricter rules for fuel supply systems. That means efficient fuel pumps and advanced tank systems are becoming even more important, including with an eye to limiting evaporative emissions. IAV has developed a new test bench to test components using real fuel at high temperatures and with changes in ambient pressure in an explosion-proof setting – with a lot of advantages for customers.

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Fuel and tank systems are subject to significantly tighter legal regulations these days than they were just a few years ago. Alongside increasingly stringent specifications for vehicle emissions, the rules on reducing emissions from evaporative processes are also being tightened.

The vapors emitted primarily by gasoline contain hydrocarbons, which are harmful to human health and the environment and are subject to legal limits. Key factors that influence evaporation include the temperature of the fuel, actuation of the fuel brought on by a dynamic driving style, and vapor pressure. Pressure tanks are one option for reducing the emissions evaporating out of tanks.

With increasingly stringent emission and pressure requirements to meet, functional testing facilities for components of the fuel supply system play a crucial role. A new component test bench at the IAV development center in Gifhorn is scheduled to begin operating in the fourth quarter of this year, focusing mainly on testing electronic fuel pumps, supply modules, suction jet pumps, or the entire pumping system, including the electronic control unit. Component validation tests for tanks, valves, lines, and filters can also be performed.

HIGHLIGHT: ALTITUDE SIMULATION WITH REAL FUEL USE

"This is an altitude and temperature test bench where development and testing activities involve real fuel," explains Walter Jakobi, a development engineer in the Tank & Fuel Supply department at IAV. "It lets us set the ambient temperature and fuel temperature, but that's not all. We can also lower the ambient pressure."

The pressure tank ranges from minus 500 mbar to 1,000 mbar of pressure at temperatures spanning from minus 40 °C to 140 °C. It has a volume of approximately one cubic meter.

The altitude simulation function can be used to set exterior pressures for an altitude of 5,000 meters, for example, and test components under those conditions. There is also the question of ventilation of highly flammable vapors in the tank – which, in a testing environment involving electrical components, use of real fuel, and temperatures near the boiling point for tests and endurance runs, requires the very highest safety standards.

INERT GAS BLANKETING PREVENTS EXPLOSIONS

To meet those standards, IAV turns to inert gas blanketing, in which the inside of the module, the working area, is flooded with nitrogen. A safety enclosure around the pressure vessel is also in the final assembly phase – here, too, the goal is to blanket the interior with inert gas in case there are any unexpected leaks in the pressure vessel. IAV takes great care to ensure that occupational safety and health regulations for employees and environmental protection guidelines are followed with equal rigor.

In the implementation of their testing specifications, customers benefit from the modular structure of this test bench, which was developed and produced by IAV in-house.

FLEXIBLE MEASUREMENTS, EFFICIENT DEVELOPMENT

"We can adapt and offer a high degree of flexibility, for example in the case of hardware measurement technology and evaluation," says Markus Weiss, head of the Tank & Fuel Supply department at IAV. "The same is true of test cycles and high-end specialty tests. Our customers value the specifications we offer."

The new unit offers a range of benefits. It saves customers valuable time and keeps them from having to perform costly and labor-intensive test drives in other countries. It also makes it possible to take measurements on components early in the prototype stage, when vehicles are not yet available – which yields valuable findings for concept development.

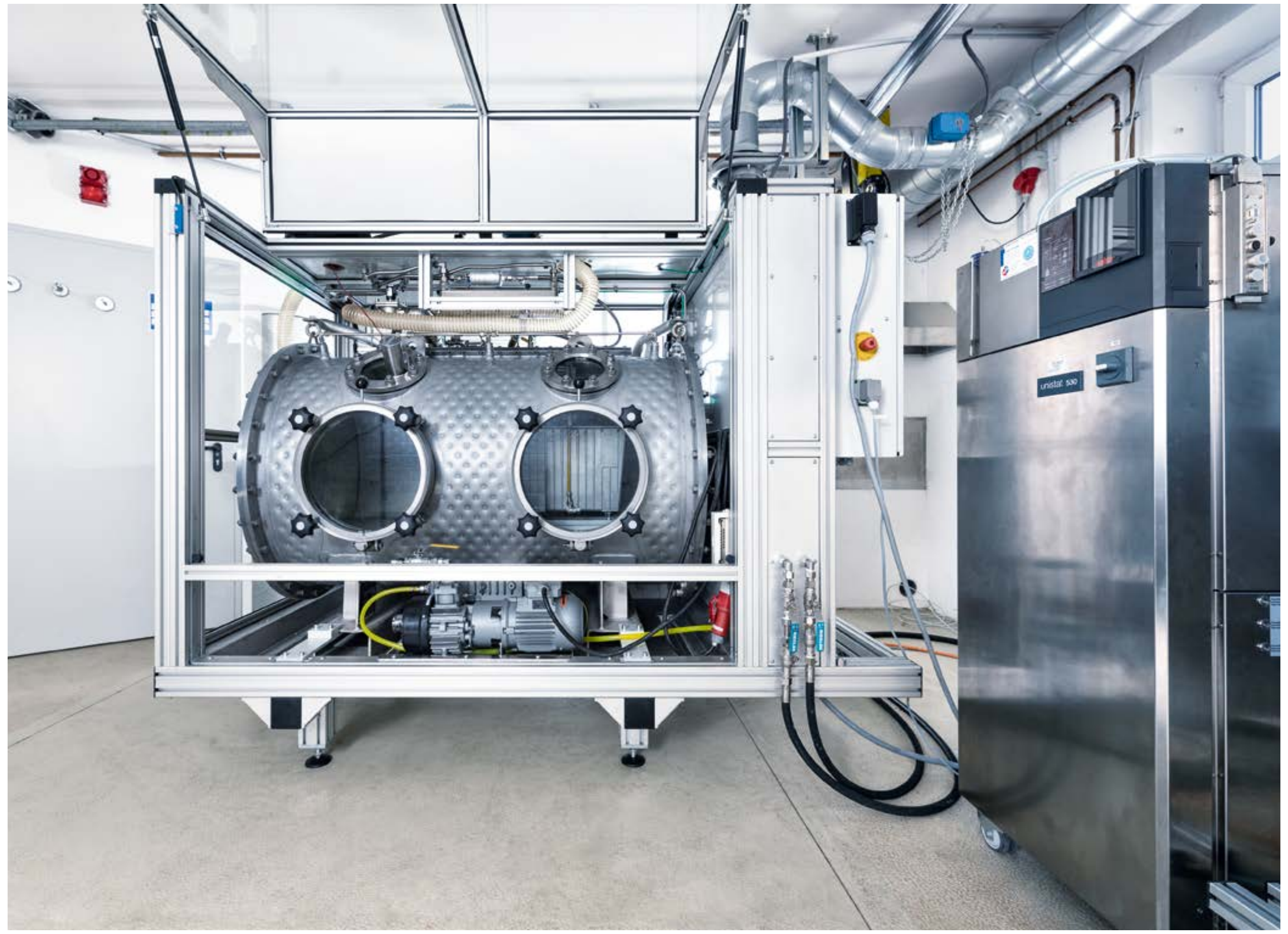
One thing is clear: The new IAV component test bench offers true leverage for added efficiency in development. And the system isn't designed exclusively for the fuel segment, either. It can also be used to test any kind of components for which ambient pressure simulation could be relevant.

"Wherever pressure differentials could arise in the system, or wherever systems are operated with ventilation or filters can become clogged," Weiss says. "There's a lot of potential."

ALTITUDE AND TEMPERATURE TEST BENCH

Performance

- Pressure range: –500 to 1,000 mbar rel.
- Temperature range: –40 to 140 °C
- Fuel resistance: diesel, gasoline, AdBlue
- Materials: stainless steel/FKM
- Tank volume: 957 liters
- Simulation of mountain driving up to 5,000 meters
- Pressure tank simulation



Connected Software

Tracking down errors

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Vehicle connectivity is in flux, shifting away from conventional systems and toward complex network architectures. This poses huge challenges for vehicle manufacturers with everything from data collection to validating the full vehicle. IAV offers a comprehensive big data value chain and provides support for testing all electrical and electronic components with innovative methods (data analytics) and proprietary systems.

From real-time traffic jam information to distance warning systems and automated search functions for parking spaces, today's vehicles have a variety of smart features that offer true value for occupants. At the same time, connectivity is on the rise: Complex assistance systems, mobile online services, and communication between vehicles and their surroundings creating a constant flow of information. For example, various functions and the communication involved in the Car2X segment or driver assistance systems and AR (augmented reality) applications are growing increasingly complex – especially when it comes to validation and testing. Huge volumes of data on a vehicle's movements, status, and surroundings arise. For vehicle manufacturers, these unstructured volumes of data – big data – offer tremendous advantages, but also several challenges. One of those challenges is the connectivity architecture used for vehicles. Similar to the network architecture found in the IT world, this architecture has to cope with large amounts of data.

So far, conventional systems such as Controller Area Network (CAN bus) have been used, which are designed for a low data transmission rate and a neat information structure. These systems are now replaced by the Automotive Ethernet communication standard and by network architectures based on high-performance computers. Thanks to their tremendous processing power, information can be requested from certain control units ad hoc, simultaneously and in parallel. All this makes for a complex network architecture waiting to be mastered.

NETWORK STRUCTURES AND DATA ANALYSIS

"OEMs are taking new approaches to meet the challenge," explains Richard Benedix, team manager for data analysis and reporting at IAV. "We help them to validate the new network structures and make them transparent using both proven and innovative analytical methods."

Automotive manufacturers require deep insight into the world of big data. IAV helps them visualize what computer scientists program and engineers develop. Interactive dashboards and structured reports allow OEMs to trace flows of data and network communications throughout the entire system.

To achieve this, IAV has created a holistic data analytics value chain that encompasses all of the services needed to analyze measurement data, from data recording to preparation and interpretation and to visualization. "Companies can use these data to track down errors and make solid decisions – we give them the tools to do it," Benedix says.

It starts right away with the documentation of the data in the vehicle. Modern measurement technology is used to determine which information should be recorded, when, and in what formats. Vehicle connectivity has changed a lot in this regard as well: Concepts for logging measurement data have been adjusted with an eye to performance and data recording so that the volumes of data generated – which are unusually large by past standards – can be processed efficiently. Data that used to take up just a few gigabytes (GB) of storage, can in some of todays test drives reach up to 200 GB each.

The data are stored in the measurement data platform, which gives OEMs a comprehensive management tool. The Web-based front end gives them a full overview of all vehicles, measurement devices, and analysis. Because the data are transmitted in real time, they can even perform analysis and troubleshooting while a test drive is in progress.

TROUBLESHOOTING AND REPORTING

The interactive data features allow even users with no programming skills to browse for certain events in their data, using simple search language. Machine learning algorithms support the process of searching for possible errors by identifying anomalies in the data patterns.

An automated measurement data analysis feature (AMeDA) shows customers complex contexts surrounding various errors. To this end, data scientists and data analysts from IAV generate reports in line with customer questions, programming templates that visualize certain matters in diagram form. After that, the customer can pull the report automatically from the measurement data platform. AMeDA and interactive data analysis are highly flexible, as these systems can be adapted individually to any data format or data logger. Both tools are also distinguished by their scalability and expandability, which makes the entire tool chain future-proof. Even if vehicles generate zettabytes of data, the interactive data analysis and AMeDA process the data quickly, without any issues. In this way, the IAV value chain harnesses rapid automated analysis and direct visualization on dashboards to unlock direct findings to resolve errors and provides the openness and flexibility needed for future-oriented engineering.

“Interactive data analysis: The Google of vehicle data”

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There are various analysis tools available on the market, but using them is highly complex in some cases, sometimes even requiring programming experience. With the interactive data analysis feature, Steffen Spies and Dr. Arnd Eden and their team have created a tool that customers can use to perform their own analysis easily. They sat down with us to offer a look at what they do.

Dr. Arnd Eden, technical consultant for data analysis at IAV, and Steffen Spies, head of the Vehicle IT department, can see through the important points in the jungle of data (from left).

automotion: How does interactive data analysis work?

Steffen Spies: The interactive data analysis feature gives our customers an easy way to access their measurement data. They can search for certain events using an intuitive search language and perform error analysis. They don’t need any programming skills to do this, and they don’t need detailed familiarity with the data and signals, either.

An interactive dashboard prepares the results in an understandable format and provides additional information – things like geographic details for where anomalies in the measurements occurred. It’s like a Google search function for vehicle data. Anyone can work with it, anytime, anywhere.

automotion: What is the structure of the tool?

Dr. Arnd Eden: The interactive data analysis feature is connected to our IAV measurement data platform, where all of the data from the vehicles are managed. These raw data measurements can be 200 gigabytes or more in size. To be able to analyze the data efficiently, they are converted into an appropriate format and cleaned up so unnecessary data and log overhead are removed. That way, the data can be searched very quickly, but still contain every single measurement point of the signals in question.

The processing of the data takes place using our in-house analysis engine, AMeDA, which we have integrated into Apache Spark for operation in a cluster. For resource management, we use Hadoop or Kubernetes, depending on the customer’s requirements. This makes the whole thing technology-independent, and we can adapt individually and flexibly to our customers’ software landscape. Hadoop is used in most cases if the customer has already implemented this kind of cluster at their company. Kubernetes is geared more towards cloud computing. It also offers greater flexibility, especially if a new system is being set up.

> **“That means the system offers the same internal flexibility for many different sectors. No matter what machine the data come from, they can be analyzed using interactive data analysis.”**
>
> STEFFEN SPIES,
> Head of Vehicle IT department

automotion: Compared to solutions from other providers, the interactive data analysis tool isn’t based on a database. Why has IAV chosen a different concept here?

Eden: A lot of systems that enable rapid search are based on a database containing a lot of tables. SQL (Structured Query Language) is the standard language that is usually used to search through these databases. In our case, the measurement data exist in MDF, or Measurement Data Format, so they don’t require as much pre-processing as they would with a database. That means we can store entire measurements, searching every signal and every measurement point at high speed. So we provide very large volumes of data very quickly – that’s what makes our form of interactive data analysis so special.

automotion: The interactive data analysis feature was designed for the automotive industry. Could it potentially be used in other areas as well?

Spies: Since the IAV measurement data platform stores all of the data, the interactive data analysis feature could also be used in other areas, such as wind power. That means the system offers the same internal flexibility for many different sectors. No matter what machine the data come from, they can be analyzed using interactive data analysis. We can always adapt the system individually to meet customers’ needs.

With the wrong key in our pocket …

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A commentary by Timm Kellermann, Managing Director, consulting4drive

Why we in the automotive industry mistakenly view car keys as customers' way of accessing their vehicles – and what kinds of opportunities they actually unlock for the automotive industry.

consulting4drive
powered by IAV

For more than a century now, users have received physical keys to their vehicle from the manufacturer as part of the delivery process. All of us view this as so routine that we seldom stop to ask why. In technological terms, physical car keys are definitely no longer needed. Digital keys stored on a smartphone are available from many automakers these days. But even though the add-on price is moderate, this option hasn't gained much traction. At the same time, tech companies like Apple and Amazon show what a key should be like in the digital age and how to get people on board. The key is the digital ID. It's free, but still valuable:

a) Without this ID, there is no access to devices or services, even on a trial basis.

b) As part of the profile process, the standard terms and conditions are used to map out certain basic agreements with every user: electronic data storage, access to personal data, permission to analyze use and movement patterns, and much more.

c) With the user's consent based on the "opt-ins" that form part of this process, Apple, Amazon, and others store all of the user's preferences and transaction histories across all touchpoints and devices on this ID.

Just like a user's ID enables access to a smartphone, the car key today serves as a manifestation of power over the vehicle, just as it has since cars were first invented.

But today, in the era of the digital platform economy, it isn't enough to try to give our vehicles a superficial digital upgrade; we need to rethink our perspective on every "key element" of value creation. A consistent shift would be highly worthwhile for manufacturers, though.

With the right key in the user's pocket, many present-day challenges could be resolved better, or even optimally: direct, lasting, GDPR-compliant customer dialogue. Detailed personal behavior and preference history as input for development, sales, and customer care. Loyalty programs and upselling across the entire customer lifecycle. Secure protection that meets and exceeds all the requirements for cars that operate automatically and their occupants in the field. Ongoing digital updates to all contract and license information. Intimate insight into people's mobility needs – not just in the vehicle, but in the entire mobility context as a whole.

HOW CAN THIS BE ACHIEVED?

HYPOTHESIS 1:
The requirement for access to the manufacturer's world must be a manufacturer ID in the future, in all cases without exception (for example, vehicle ownership, business use, short-term rentals via car sharing models, etc.).

HYPOTHESIS 2:
Profiling must satisfy the latest digital benchmarks, require practically no manual entries, and be complete in 90 to 180 seconds – including downloading the app.

HYPOTHESIS 3:
Manufacturers should respect users' wishes for data transmission from third-party provider IDs for profiling purposes (examples include profiling using a ShareNow ID, WeChat ID, etc.).

HYPOTHESIS 4:
All physical vehicle keys must go digital – as base features, with no extra charge. These will arise from the combination of a profile ID and vehicle authorization (car, truck: for all vehicles).

HYPOTHESIS 5:
Users who do not want a digital key can order a physical one for a substantial added fee.

HYPOTHESIS 6:
The digital master key is kept not on the device, but in the cloud. Following user authorization/authentication, digital keys and all other license authorizations are transferred to the user's desired devices, with use being monitored continuously across all devices to ensure plausibility.

HYPOTHESIS 7:
Technical implementation must be in keeping with the latest technologies used in the finance industry (!). From the perspective of the digital platform economy, the manufacturer ID is the equivalent of an account, and transferring a key right is equivalent to a funds transfer from the manufacturer to the user.

HYPOTHESIS 8:
Users fundamentally cannot share keys and licenses with others; they have to be delegated. If recipients do not yet have an ID, they go through the one-time profiling process (see above).

HYPOTHESIS 9:
There is no situation in which a profile ID can be used by a second person; this means users never have to log in manually – this occurs automatically in principle, via the initial identification of the personal device where the key is stored (smartphone, watch, wearable, etc.) and the subsequent biometric check inside the vehicle.

HYPOTHESIS 10:
The individualization of the vehicle (seat, climate control, ambient cocoon, infotainment, etc.) and the activation of free and paid licenses (mobile online services, assistance systems, etc.) take place automatically in principle whenever the user gets into any "rolling device." If a vehicle does not yet meet all of the hardware requirements to use the licenses acquired, the next best approximation is independently suggested in the background.

HYPOTHESIS 11:
There is only one cross-brand ID within a single group of companies. The cross-brand nature of this ID is essential to the successful establishment of the manufacturer ecosystem.

HYPOTHESIS 12:
Keys assigned temporarily in the context of short-term rentals via share models are fundamentally associated with the manufacturer ID for all brands across that corporate group, so users have full access to their preferences and the licenses they have acquired in other contexts even in a share model.

"With the right key in the user's pocket, many present-day challenges could be resolved better, or even optimally."

TIMM KELLERMANN,
Managing Director, consulting4drive

What you just read won't necessarily come to pass in exactly this form. After all, there are also good alternative solutions. After more than 20 years of cross-project, cross-industry expert dialogue on telematics, connected services, and mobile online services, we are very sure of one thing, though: Only the set of hypotheses sketched above will lead to maximally strong positioning for manufacturers in the context of globally established digital ecosystems. Discounting even a single one of these hypotheses significantly worsens manufacturers' positions.

Getting the right key into all vehicle users' pockets won't be simple. But this path is both customer-oriented and lucrative from a business standpoint – so it's really worth the effort.

Banishing dirt

From distance measurement sensors to radar and lidar, the higher the degree of automation in advanced vehicles, the more important the sensors involved are. They have to work at all times, whatever the weather conditions – but it doesn't take long for them to run into their limits if a film of dirt obscures the lens. IAV has developed a simulation method that identifies which parts of the vehicle will be least affected by spray, snow, or dirt even before the first prototype is built – making these areas perfect for sensor placement.

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An autonomous vehicle glides soundlessly along the autobahn. All the occupants hear is the rain pattering against the windows. Suddenly, the car slows. The occupants look up from their tablets and toward the instrument cluster, which is blinking madly and displaying error messages – finally, the vehicle comes to a complete stop. The sensors are dirty. The car can no longer recognize its surroundings correctly, so it places an automatic emergency call to the nearest towing company. The vehicle's occupants have nowhere to go but the shoulder of the road.

Admittedly, this is a worst-case scenario, but it isn't unrealistic. Mud, snow, and spray can cover the sensors, disrupting the functioning of the driver assistance systems. "If I'm on the road in a sleet shower, it doesn't take long before my vehicle tells me adaptive cruise control (ACC) is unavailable. It's annoying, but you can still continue to drive. But once vehicles are operating autonomously, the consequences are more bothersome," says Dr. Rico Baumgart, team manager of Simulation at IAV.

LOOKING FOR THE SWEET SPOT

This is why Baumgart and his team of engineers have developed their own modeling approaches that identify areas of the vehicle at high and low risk of accumulating dirt – even before the first prototypes are built. The basis for this is the MeshFree base tool, an innovative algorithm used to calculate the flow of liquids by the Fraunhofer Institute for Industrial Mathematics (ITWM). The IAV approach eliminates the need for OEMs to conduct costly and laborious testing series, saving time and money – a crucial advantage in light of the fact that development cycles are growing ever shorter.

"With our simulation approaches, we identify exactly how much dirt there is in the various spots around the car after driving in the rain. We extrapolate from that for placement of the sensors later on," Baumgart explains. Recommendations for minor geometric changes to the body to redirect flows of air – and water and dirt with them – are also possible. "Simulation tools are also used in body development to determine which areas of the vehicle could be affected by dirt. That's why we are currently refining this mathematical and physical approach to be able to make statements in this regard as well," explains Christopher Franzke, a development engineer on the simulation team at IAV.

Another advantage of IAV's method is that sensor cleaning systems can be evaluated and optimized with an eye to effectiveness. This reduces the need for cleaning agents, which also reduces environmental impact while eliminating the need for frequent refills.

THE CUSTOMER DETERMINES THE TEST CASE

In principle, the simulation model can be used for all vehicle types and component assemblies. To simulate a vehicle, all the engineers need is the relevant CAD data and detailed customer requests for the drive in the rain they are to simulate. "We can set test parameters like the vehicle's speed at will and visualize different weather scenarios," says Oliver Pettke of the simulation team at IAV. "The wind direction, the intensity of the rain, and the size of the raindrops can also be varied as desired." Whichever test combination a manufacturer chooses, the complex physical processes involved can be analyzed with much greater detail and reproducibility than in practical tests. This also benefits the development process and the optimization of components.

With its new modeling approaches, IAV offers added value in manufacturers' development process, but that isn't all. This method can also make automated and autonomous vehicles significantly safer through targeted sensor placement – so the occupants of vehicles with well-placed sensors won't be left standing out in the rain on their own.

The super nose

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Air freshening systems are an integral feature in luxury vehicles these days. But until now, the only tool available for developing unobtrusive fragrances for vehicles was the human nose. IAV's new mobile "sniff lab" now enables objective, reproducible measurements in real time. And faster application.

Scents have an immediate effect on the brain. The direct neural connection between olfactory cells and the memory center means that odors bring past events immediately to mind. They also release neurochemical substances such as endorphins or serotonin. All this means it's no wonder that medical professionals use fragrances for aromatherapy, or that some retailers use scents to boost sales or brand loyalty.

Vehicle manufacturers are also aware of the potent psychological effects of smells, which is why air freshening systems are already available as special features in luxury vehicles today. "These systems are supposed to enhance comfort, and the OEM can also use them to emphasize a vehicle's value," says Thomas Einzinger, who heads the Thermal Management department at IAV. He and his employees also work on the air inside the vehicle.

At Audi, for example, passengers can choose between "winter" and "summer" scents, with four levels of intensity: subtle, light, medium, and strong. The fragrances are located in two bottles under the steering wheel, and they are diffused in the vehicle's interior through the vents. They were composed by world-renowned perfume specialists in the small town of Grasse, in the south of France, where various French perfume makers are based.

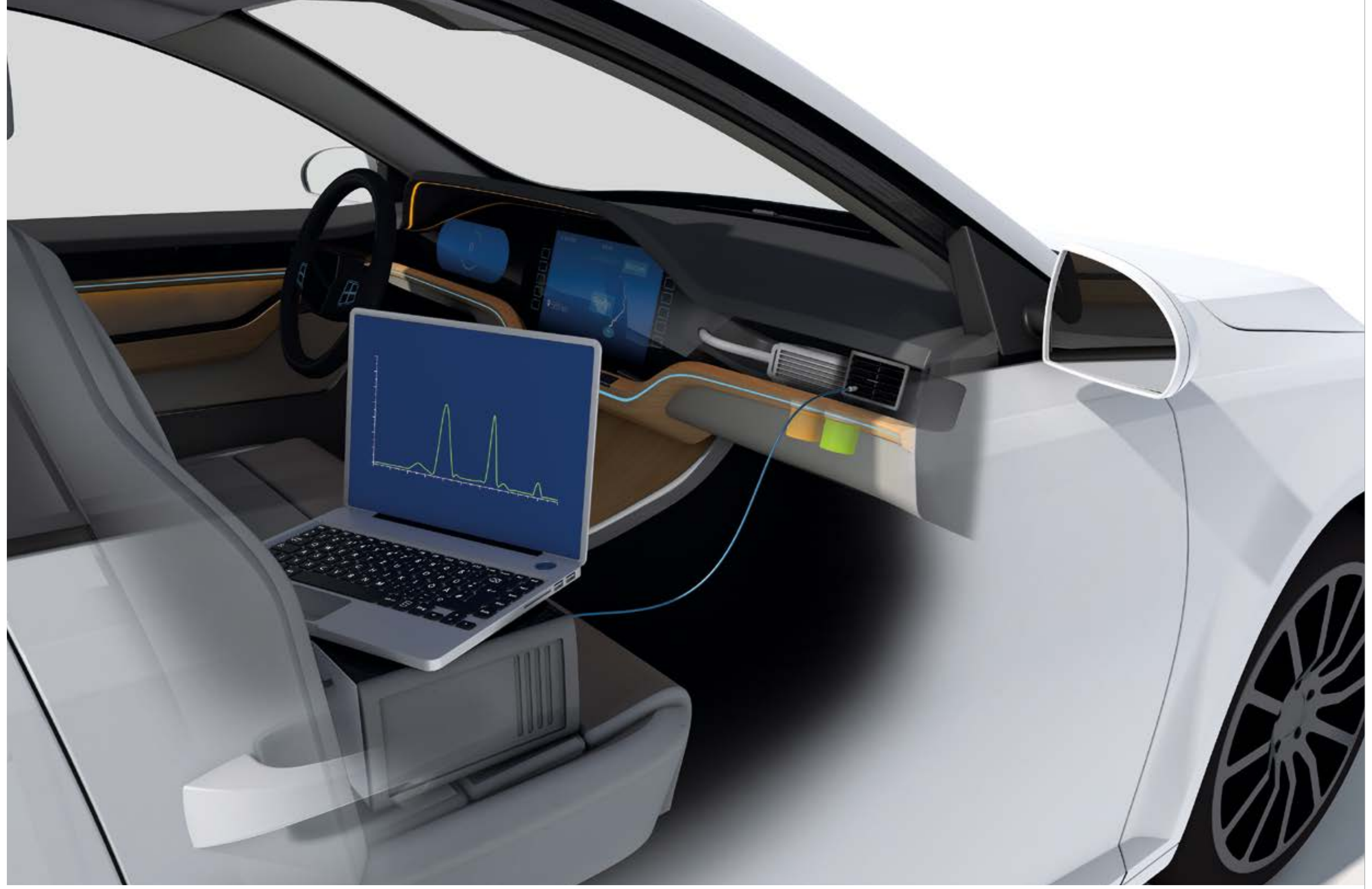
IAV has supported OEMs in developing these kinds of air freshening systems in the past. Before now, the only measurement instrument used in this application was engineers' noses. They were the benchmark used to decide when a certain dosage was still considered "light" and when it should be considered "medium" instead. But this method is rather subjective, and it does not provide objective measurement values.

PRECISION DOWN TO THE PPM RANGE

With this in mind, Einzinger and his team set about developing a new measurement method for the application of air freshening systems. IAV's mobile "sniff lab" is about the size of a desktop computer. It takes in air from the vent and sends its measurement results to a connected computer. In this way, the sensor inside can tell developers with pinpoint accuracy just how many fragrance molecules the interior air contains (expressed in ppm – parts per million).

"This makes the measurements quantifiable and reproducible," says Dominik Fellner, team manager of System Development in Einzinger's department. "Our new measurement system also supplies all values in real time, which noticeably accelerates the application." This means which fragrance concentration corresponds to the "light" or "medium" setting is no longer a matter for (just) the application engineers' noses.

The ultra-sensitive mobile sniff lab was created in-house at IAV and has been available to use since April 2021. Einzinger and Fellner are silent on the details of the measurement method. All they will say is that the sensor is an ultra-sensitive measurement device from chemical lab operation and was integrated into an overall measurement concept that is optimally adapted to the requirements of vehicle development. Aside from that, the experts use the Design of Experiments (DoE) method to minimize the number of measurements needed.



UNIVERSALLY USABLE IN ALL MODES OF TRANSPORTATION

In the future, air freshening systems could also be available as special features in vehicles below the premium class. And in combination with eye recognition, they could, for example, use fragrances deliberately to affect drivers' mood. "But we also see possible uses in other areas, such as buses, trains, ships, and airplanes," Einzinger says.

With an eye to the future, completely new approaches arise for autonomous driving in conjunction with ongoing position location and an AI methodology. A future system could be self-learning, adjusting the air freshening function automatically when there is a change of drivers or when the car enters an urban area with poor exterior air quality.

Appropriate natural scents could also be fed in during autonomous driving, for example through a forested area. It is also conceivable that a person will have the car drive them autonomously while watching a movie with the system adding appropriate scents for the action scenes, creating not a 2D or 3D experience, but a 4D driving experience.

"The USPs for the vehicles offered in the future will no longer be geared solely toward the quality and performance of the powertrain. Instead, they will focus on comfort or experience features during the time people spend in the vehicle," Einzinger says. "We want to contribute something there."

IAV's "super nose" is ready and waiting for new use cases, at any rate.

Electric vehicles – the sound of silence?

For passengers in electric cars, interior noises from actuation of the powertrain and auxiliary systems should be as non-disruptive as possible. By contrast, electric cars do need to make noise outside so others around them can hear them. Customized new development methods are allowing acoustics experts at IAV to resolve this conflict of goals.

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It's comparable to an orchestra: the overall vehicle acoustics. If even one element is out of tune, the whole ensemble sounds bad. The same is true of vehicles with combustion engines and electric cars alike – although there are also differences, of course: With diesel or gasoline engines, deep frequencies of up to two kilohertz (kHz) are more prominent, while electric cars have a sound profile centering on high-frequency noises at up to eight kHz.

And that in turn means electric mobility is changing the sound of the "orchestra," posing new challenges for developers. After all, although they have decades of familiarity with the acoustics of conventionally driven vehicles, the noises made by electric cars tend to be uncharted territory. In addition to the changed spectrum, there is another particularity: At speeds of up to 50 or 60 km/h, the drives are so quiet that they no longer cover other, more disruptive sounds. The sounds of rolling, tire contact, and airflow do not become dominant until the vehicle reaches higher speeds.

COMPENSATING FOR UNWANTED NOISES

This is where IAV's experts on noise, vibration, and harshness (NVH) come in. With their wide range of acoustics expertise and the experience they have gained through numerous series projects, they make sure an electric vehicle has just the right sound. Take the powertrain, for instance: They minimize bothersome noises right at the source, in the area of the air gap in the electric motor and the tooth contacts in the gear box, thereby noticeably reducing the noise by around three to five decibels. "To do this, we use FEA and MBS simulations early on in the development phase, working closely with the other areas involved," says Mario Schwalbe, team manager of NVH Simulation at IAV. "This approach means we need fewer prototypes, save on costs, and significantly reduce development time."

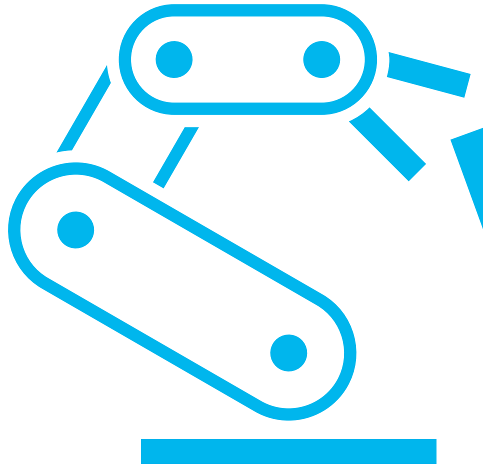
The quiet electric drive is a boon to passengers – but it also lets overly noisy ancillary systems take center stage. The electric compressor used in the air conditioning system can be a particular issue. The acoustic experts study it and other troublemakers on a special test bench where they can measure individual components separately from the rest of the system. "Together with the manufacturers, we optimize the components by doing things like changing the mounting or putting ribs on the enclosure," explains Oliver Olbrich, team manager of NVH Testing at IAV. "We also adjust insulation and damping components, such as the front wall damping, to the higher frequency range."

The experts at IAV also tackle bothersome interior noises. In most cases, these are dominated by lower frequencies of up to 600 Hz and can be suppressed using active noise control (ANC). To do this, a reference microphone records the annoying noise, and a controller generates a customized counter-signal and sends it out via the in-car entertainment system, so the two noises cancel each other out in the specified quiet zone. "We've developed our own algorithms to do this. They can suppress both static and dynamic noises," explains Dr. Samira Mohamady, technical consultant in the Communication & Audio Functions department at IAV.

> **"Together with the manufacturers, we optimize the components by doing things like changing the mounting or putting ribs on the enclosure."**
>
> OLIVER OLBRICH,
> Team manager of NVH Testing at IAV

SOUND DESIGN FOR ELECTRIC VEHICLES

But the IAV experts do more than just fight bothersome noises – they are also responsible for giving electric vehicles a defined sound. Acoustic vehicle alerting systems (AVASs) are tasked with making warning sounds and letting road users like pedestrians and cyclists know there is an electric car there. The law requires these vehicles to make continuous noise at a level of at least 50 decibels (up to 10 km/h) or 56 decibels (up to 20 km/h) within two meters. The sound also has to make it clear to those around the vehicle whether it is accelerating, braking, or reversing. "We generate these artificial vehicle noises using speakers or actuators," one expert says. "But they need not to be perceived as bothersome inside the vehicle, so we design the sound so the driver perceives it as acoustic feedback for speed or acceleration."



The Robotics toolbox

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The robotics industry is slowly recovering. The VDMA, the association of Germany's engineering industry, expects to see 3.5 billion euros in sales in the current fiscal year, representing double-digit growth over 2020. IAV has been developing intelligent robotics solutions suitable for real-world practice with the goal of readiness for series production for about seven years now. Experts see great potential in the area of advanced AI robotics in particular.

There is rising demand for robotic solutions across various industries, which presents an especially promising opportunity for Germany as a hub of industrial activity. With in-depth technical expertise and a highly developed vertical range of manufacture, the German industrial sector seems a perfect fit for a high-tech field like advanced AI robotics. At IAV, as elsewhere, numerous teams of engineers are dedicated to research and development on the necessary technologies.

BABY STEPS IN ROBOTICS

"Paul," a stair climber, is an initial project in the area of autonomous robot systems at IAV. Some seven years ago, the engineering team developed Paul as a helping hand for shopping. The robot moves on two wheels, fits inside a car trunk, and can climb stairs carrying shopping bags. Since then, IAV has been delving deeper and deeper into the subject of robotics with the goal of developing scalable and flexible hardware and software technology solutions.

Two important milestones along the way are the MiRo Base and EnerGlider research projects, which have been implemented together with universities and industrial partners under Dr. Manus Thiel as project manager. MiRo Base is a system platform for modular, remote-controlled underwater vehicles, while the EnerGlider is a high-altitude wind turbine, a low-maintenance and efficient alternative to classic wind turbines. "We are still relying on insights gleaned from our MiRo Base project today in terms of guidance, navigation, and control (GNC) topics. In that project, we successfully completed dives in the Baltic Sea. The test flights with the EnerGlider have also helped us make progress in this regard," says Dr. Thimo Oehlschlägel, team leader, Control Engineering Excellence Cluster, at IAV.

In the area of image recognition and perception of a device's surroundings (computer vision), the "Franka" concept has brought crucial advances. This concept represents an arm that can grasp tools and pass them along autonomously. "To be able to perform these actions, Franka has to recognize individual tools, tell them apart using AI, and calculate its own position and the distance between it and the tool. Then the arm reaches out, grasps the item, and pivots toward the person. The results of this early project are also found in our current robot projects, in modified and refined forms," says Dr. Dirk J. Lehmann, a university lecturer and technical consultant for computer vision and visual data analysis at IAV.

MODULAR ROBOTICS TOOLKIT AS PLATFORM FOR NEW INNOVATIONS

The development teams have a shared goal in the robotics segment: to develop base technologies and fundamental methods that can be carried forward optimally as building blocks for future projects that will further optimize them. This is the only way to scale developments and move with agility in the many fields of application for robotics solutions, such as agriculture, maintenance, and automated surveillance and monitoring. This is also why the experts are working on a robotics software framework that is undergoing further refinement and expansion on an ongoing basis. "We can integrate functions like object recognition, distance analysis, and image processing quickly into other projects, based on this framework," Lehmann says. He and his team believe the biggest challenges for the next few years lie in the areas of onboard computing, data fusion, and online training of AI. "If you meet the basic prerequisites in these areas, then you have faster access to high-level functions for highly automated systems, including – and especially – in relation to AI-controlled decision-making processes. With the right tools in our toolbox, we are able to address customer wishes within just a very short time", Lehmann says.

The modular robotics toolkit approach works well, as a look at beekeeping robot "TomBigBee" shows. It is a view that applies to the latest robot projects. "One thing these systems have in common is that they drive automatically on a rover. This means that in cases like these and many other highly automated mobile systems, our state-of-the-art navigation algorithms and path and route planning algorithms, which have also already been tested in flight applications, can be used with minimum time and effort involved in porting them over. Our beekeeping robot also has an image recognition feature to locate the queen bee and check beehives for mite infestation," Oehlschlägel says. That means the conditions are ripe for continuing the journey that officially started seven years ago, but is actually only just getting off the ground.

> **"With the right tools in our toolbox, we are able to address customer wishes within just a very short time."**

DR. DIRK J. LEHMANN,
University lecturer and technical consultant for computer vision and visual data analysis at IAV

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IAV customer magazine automotion
IAV GmbH
Ingenieurgesellschaft Auto und Verkehr

Publisher
IAV GmbH · Carnotstr. 1 · D-10587 Berlin, Germany
Tel. +49 30 3997-80
www.iav.com

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Collaboration
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fischerAppelt
Johannes Winterhagen

Post production
Highlevel

Design
publicgarden GmbH
Ligalux GmbH

Frequency of publication
Three times a year

Picture credits
Christian Bierwagen, Hamburger Hochbahn AG, Kathrin Heller/Pixel and Dot Photography, Mirko Hertel, Christian Hüller, istockphotos, Thorsten Jander, Max Lautenschläger, Sonja Hornung, Gérard Pleynet

Print
K+L PrintMedia GmbH

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