virtual vehicle

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Context-Embedded Vehicle Technologies

Talking with
Jan Becker

Stanford

Automated Driving ■ Safety & Security ■ Efficiency & Comfort ■ Efficient Development ■ Living Innovation Lab

Presenting Projects with
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EDITORIAL

Automotive and digital industry: Moving closer together

More than ever, the vehicle industry is facing huge challenges and is undergoing a radical transformation. The shift towards connected vehicles and digital value chains raises not only new business models, but also bring unprecedented challenges and demands for vehicle developers.

VIRTUAL VEHICLE has positioned itself to support the automotive and rail industry during its change process – disruptive digitalisation, human-centred design, and context-embedded vehicle technologies are the core elements of the upcoming research activities. In our centre, more than 200 experts investigate and develop forward-looking concepts and methods, connecting the automotive and digital industry.

COMET K2 funding confirmed

Since 2008, VIRTUAL VEHICLE is part of the Austrian COMET K2 Programme and successfully received a confirmation for the next four years with an option for eight years. The new research programme will focus on „Digital Mobility - Context Embedded Vehicle Technologies" (read more on page 61).

Enjoy reading about some of our latest research topics!

DR. JOST BERNASCH

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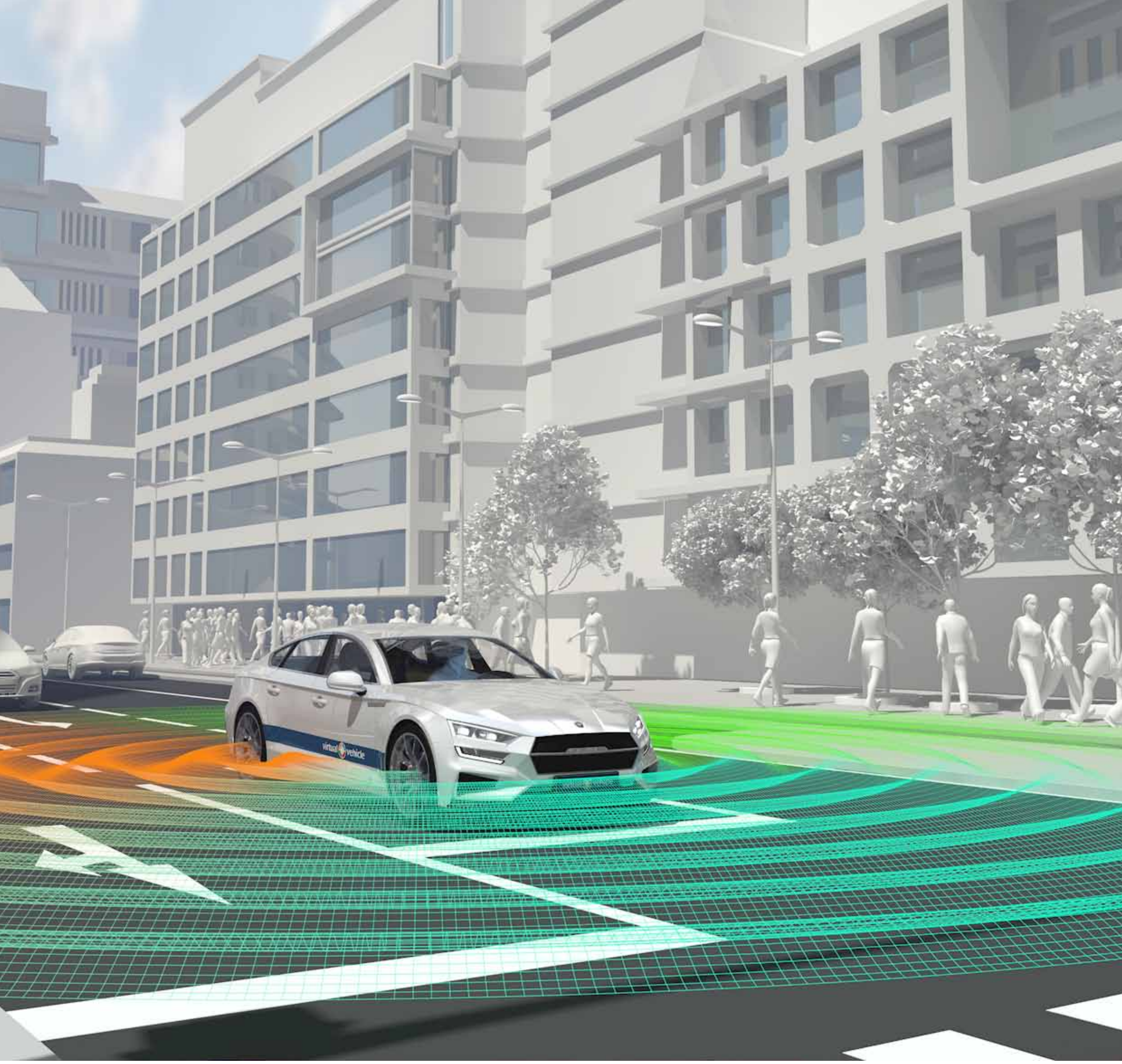
Graz University of Technology

Scientific Director
VIRTUAL VEHICLE



READY FOR THE FUTURE OF THE AUTOMOTIVE INDUSTRY

The automotive industry plays an important role in Europe, employing about 13 million people, and 500,000 in Austria alone. In the future, the automotive industry will undergo a significant change due to emerging context-embedded technologies driven by connectivity, automation, and electrification. Highly connected vehicle functions, including cooperative integrated safety, cloud-based comprehensive energy management, automated driving and assistance systems, will drive next-generation mobility. All of these functions must perform correctly, reliably, fail-operationally, and safely in any situation. More than 200 experts at VIRTUAL VEHICLE Research Center investigate and develop forward-looking concepts, methods and tools to meet the upcoming challenges.

The global automotive industry is undergoing a radical transformation. In contrast to the incremental developments of past decades, far-reaching and even disruptive changes are now apparent. The importance of digitalisation in the industry has grown significantly within the last ten years and will continue to increase. The shift towards a connected vehicle and a digital vehicle value chain with new business models has consequently given rise to new demands in development technologies.

Key messages from leading OEMs, summarised at the leading Wiener Motorensymposium in lectures from 2016 and 2017: *"The vehicle of the future will be equipped with artificial intelligence; it will collect information about its surroundings using sensors and cameras, store data in data clouds, and exchange its knowledge online with other vehicles, infrastructure and data bases in real time. Strategic fields of innovation include connectivity, digitalisation, efficiency and sustainability."* (Lectures at Wiener Motorensymposium I 2016, 2017 Members of the Board of Audi, BMW, GM and Toyota)

Strong expertise

Since 2008, VIRTUAL VEHICLE has provided exceptional proof that Graz offers an ideal setting for conducting high-quality research and devising industrial-strength solutions. Together with important players in Graz, such as AVL List GmbH, Magna Steyr and the Graz University of Technology, the Center makes a valuable contribution to the Austrian economy. Long-term project activities, in the form of the COMET K2 Mobility Research Programme, European Projects and Services, have built a strong network of leading European OEMs, suppliers, software vendors, semiconductor companies, and renowned research institutes. Hence, moving forward, VIRTUAL VEHICLE will emphasize a closer cooperation between the vehicle and digital industries, in order to face the emerging challenges of digital mobility together.

VIRTUAL VEHICLE has positioned itself to support the automotive and rail industry during its change process – disruptive digitalisation, human-centred design, and context-embedded vehicle technologies are the core elements of the Center's upcoming research activities.

Driving Forces: Four mega-trends

Current state-of-the-art processes, methods, and tools in vehicle development will have to evolve significantly in order to meet the demands for reliability and acceptance that come along with the four megatrends that will drive the automotive industry in the coming decades:

- ADAS, active safety, and automated driving – driven by safety ("zero road fatalities") and comfort
- Electrification (xEV and eMobility) – driven by mandated CO2 reductions
- Connectivity – driven by the need to integrate the car into the Internet (Internet of Things)
- Advanced security – driven by the required trust necessary for an increasingly connected and software-driven world

ABOUT VIRTUAL VEHICLE

VIRTUAL VEHICLE is an internationally established research and development center working on methods and concepts for the vehicles of the future. The center addresses the vehicles of tomorrow, which should be safe, environmentally friendly and more and more connected with its environment.

Advanced simulation technology is a key for the future. Methods to link numerical simulation and real testing are a USP at VIRTUAL VEHICLE. This will lead to virtual validation and virtual homologation of complex systems like ADAS/Automated Driving or integrated safety.

VIRTUAL VEHICLE is part of the Austrian COMET K2 Programme and is actively engaged in numerous EU funded projects (more than 30 ongoing). The center offers a broad portfolio of commissioned research and services as well as a broad range of testing facilities.

IN A NUTSHELL

Founded:	**2002**
Headquarters:	**Graz / Austria**
Employees:	**200+**
Turnover:	**19.2 Mio EUR (2016)**
Website:	**www.v2c2.at**
Shareholders:	Graz University of Technology (40%) AVL List GmbH (19%) MAGNA STEYR Fahrzeugtechnik AG & Co KG (19%) Siemens AG Österreich (12%) Joanneum Research Forschungs-GmbH (10%)

OUR WORLDWIDE NETWORK

International network of more than 150 partners

Innovation in an Industrial Network

The close cooperation with industry is not only a tradition at VIRTUAL VEHICLE, but is also the basis for success in innovative research activities. It is the close integration into industrial processes and the building of sustainable, strategic partnerships that guarantees success in cooperation projects.

Industrial Partners (Extract)

Scientific Basis

The cooperation with scientific partners and the integration into university networks is of great importance to VIRTUAL VEHICLE. Together with the Graz University of Technology, as a key research partner, and further 40 international institutions, VIRTUAL VEHICLE enables the interplay of scientific expertise and technical competence.

Scientific Partners (Extract)

Exchange and Cooperation – The Success Factors

- Medium to long-term perspective in the cooperation
- Building up mutual trust (e.g. through realistic result expectation, professional project management, confidentiality)
- Quality of results and cooperation
- Fair rights that guarantee a win-win situation for the use of project results

Highly connected vehicle functions, such as advanced driver assistance, cooperative integrated safety systems, cloud-based comprehensive energy management, intuitive and safe HMI, visualization enhancement and automated driving functions, are driving next-generation mobility. VIRTUAL VEHICLE will address these megatrends and the related major necessary technological elements in its **fields of research**:

Disruptive Digitalisation

Highly connected vehicle functions (e.g. ADAS&AD) and integrated safety systems give rise to comprehensive demands for validation and verification techniques that far exceed the current state of the art. Radically new development and test approaches are needed in order to significantly reduce current efforts. As a prerequisite, validated, high-fidelity models must mimic real systems and environments in order to predict and manage relevant challenges in system development and in-vehicle operation. Real-world data must be incorporated into virtual environments, with virtual validation and homologation representing the ultimate goal.

Automated Driving

Research projects at VIRTUAL VEHICLE cover the development, validation, test, operation, and continuous self-diagnosis of fail-operational automated driving architectures. Both industry and consumers expect numerous benefits from new automated driving technologies, including improved vehicle and road safety, reduced congestion, lower stress for car occupants, social inclusion, lower emissions, and better road utilisation via the optimal integration of private and public transport.

Safety and Security

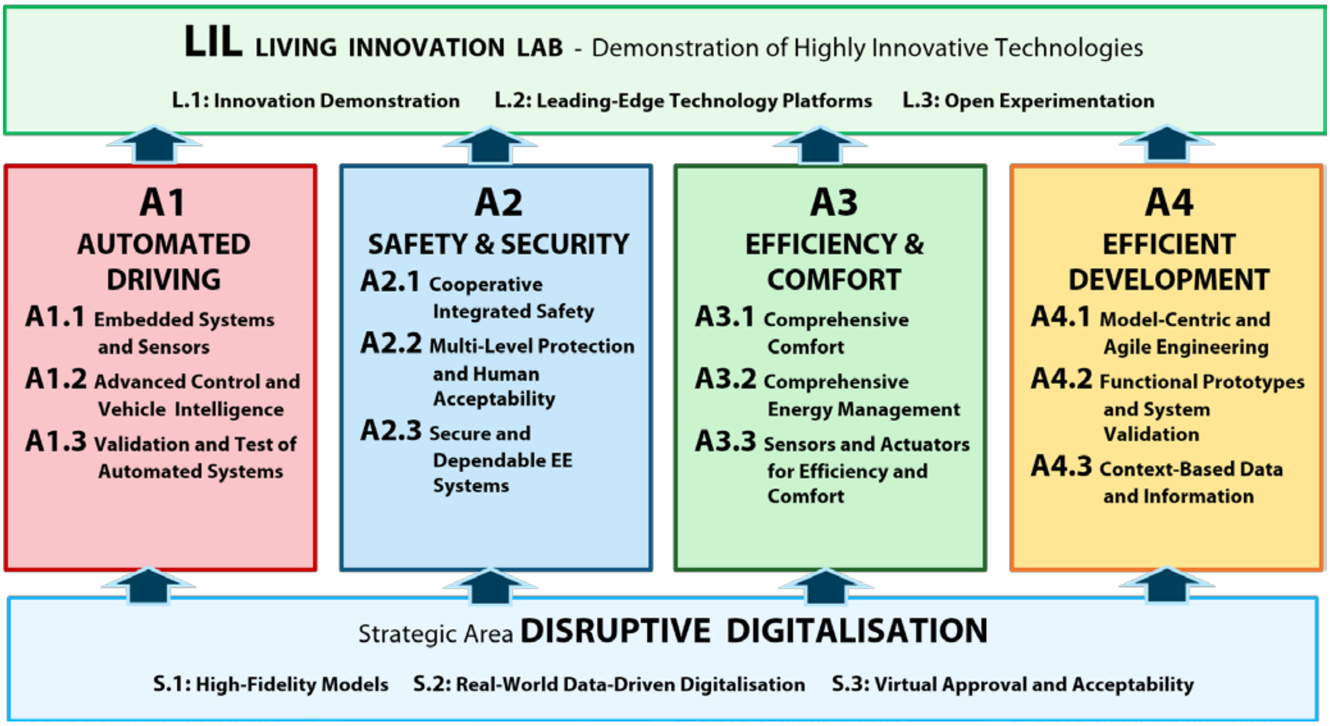
A further reduction of fatal accidents and fulfilling the EU´s Vision Zero will require a further enhancement of overall traffic safety, as well as reducing or preventing harm to vehicle occupants and vulnerable road users (VRUs), such as pedestrians and motorcyclists. Safety systems and automated driving functions are very demanding in terms of the dependability of the electric/electronic (EE) system. This requires new EE architectures that meet all the requirements related to availability, reliability, integrity, and maintainability, as well as functional safety and security.

Efficiency and Comfort

As a consequence of increasing mobility and the trend towards automated driving, passenger comfort has become an important market differentiator and will be even more important in the future. Furthermore, the need for CO_2 reduction has led to increasing electrification, lightweight design, and advanced, predictive energy and thermal control strategies that take the planned trip into account. Research at VIRTUAL VEHICLE is seeking to establish the future of vehicle comfort and energy efficiency.

Efficient Development

Automotive and rail vehicles are undergoing a radical change. Software is becoming a central driver and enabler for new functions and possibilities. Vehicles will look completely different in the future. In addition, current vehicle develop-



Overview of VIRTUAL VEHICLE's fields of research

ment inherently involves multi-site, multi-domain and cross-company teams. This is directly associated with a partitioning of the overall vehicle system into different subsystems and related different technological domains, with separate design activities being conducted at the OEM and supplier companies. The researchers at VIRTUAL VEHICLE are focussing on the model-centric, consistent system development approach in order to provide solutions for efficient system development and design management.

Living Innovation Lab

Within its Living Innovation Lab, VIRTUAL VEHICLE develops highly innovative technologies for demonstration purposes that cover Technology Readiness Levels (TRL) 3 to 7. By serving as a centre for interaction, the lab focuses on unleashing cross-discipline synergy effects and generating innovations that will create and extend leading-edge technology platforms. The resulting R&D infrastructure will then be made available for demonstrations, which will bridge the "chasm" between showing innovative concepts and early technology adopters.

Positioning of VIRTUAL VEHICLE

VIRTUAL VEHICLE Research Center is a holding company of the Austrian COMET K2 research programme – an international institution in the field of application-oriented vehicle development. The current COMET K2 programme, "K2 – Mobility", will provide the basis for funded research activities until the end of 2017. The continuing research programme, "K2-Digital Mobility – Context-embedded vehicle technologies", will strengthen this successful partnership until the end of 2025 and support research with a long-term perspective.

COMET is an internationally oriented research programme which fosters applied research in the field of automotive and rail research and brings companies and research partners together in joint projects. Projects are financed with a maximum of 50% funding and are conducted under the leadership of VIRTUAL VEHICLE.

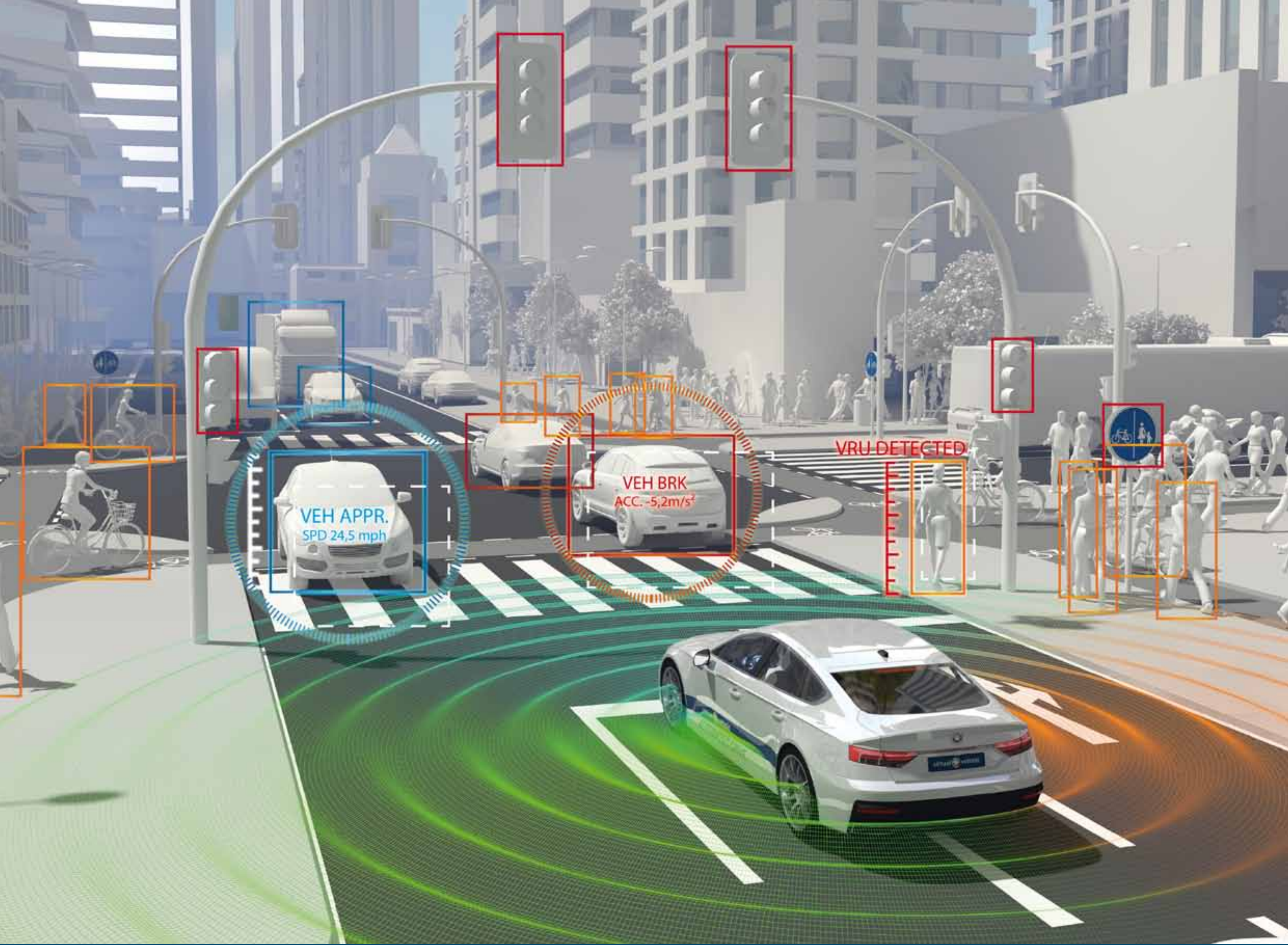
With the COMET K2 programme as a strong and long-term backbone, the Center is also known as an active influencer in the European research arena. Proactive engagement in numerous EU research projects and initiatives has catapulted VIRTUAL VEHICLE to the top of the EU research community. The Center is currently participating in 30+ European research projects and leading eight of them (read more on page 56).

Beyond the COMET K2 and European funding programmes, a broad portfolio of commissioned research and services rounds out the activities of the Center. VIRTUAL VEHICLE provides a number of Testing & Validation Facilities in the fields of Thermo & Fluid Dynamics, Engine & NVH Testing, Friction Testing and Battery Testing.

Outline

Drawing on its outstanding international network of industrial and research partners, VIRTUAL VEHICLE will address the digital transformation in the automotive industry by transferring the latest results from research into new products and industrial applications, thereby accelerating the implementation of the autonomous, connected, safe and efficient mobility of the future.

This edition of the VIRTUAL VEHICLE Magazine explores a wide range of upcoming challenges for the automotive industry, gathering them all under the title for the ambitious new 2025 research programme: "Digital Mobility: Context-Embedded Vehicle Technologies". ■



AUTOMATED DRIVING

SHIFTING TO A HIGHER READINESS

Automated vehicle technology has the potential to be a game changer in mobility, altering the face of driving as we experience it today. Although the basic technologies for fully automated vehicles are already well developed, numerous research questions related to feasibility are still open. Research projects at VIRTUAL VEHICLE cover the development, validation, test, operation, and continuous self-diagnosis of fail-operational automated driving architectures.

Both industry and consumers expect numerous benefits from new automated driving technologies, including improved vehicle and road safety, reduced congestion, lower stress for car occupants, social inclusion, lower emissions, and better road utilisation due to optimal integration of private and public transport.

Although the basic technologies for fully automated vehicles are already well developed, until the vision of automated and accident-free traffic becomes a reality, R&D engineers must address some fundamental challenges. How can the car continuously scan its surrounding environment in real-time? Can we ensure that there are reconfigurable and adaptive Electric/Electronic architectures, which guarantee 24/7 availability and ensure 360° collision avoidance? How can the vehicle react to changes in the environment and adapt itself to evolving scenarios? Within several research projects, the experts at VIRTUAL VEHICLE are working on answers to these and many more questions that are relevant for today's automotive industry.

Context-embedded & context-aware

VIRTUAL VEHICLE is deeply engaged with context-embedded and context-aware vehicle automation technology along the different evolution steps, from connected to cooperative (V2V) and ultimately automated operation. The centre's field of research covers self-aware and fail-operational conditional, highly and fully automated vehicle architectures (sense, control, act, monitor), seamless driver integration, 360° environmental awareness, and 24/7 system availability in any situation and at any ambient condition.

Fail-operational automated driving architectures

The automated driving experts at VIRTUAL VEHICLE concentrate on three main topics:

- Embedded systems & sensors
- Advanced control & computational intelligence
- Validation & test of automated systems

The overall goal is to cover the development, validation, test, operation, and continuous self-diagnosis, as well as the performance monitoring of future fail-operational automated driving architectures. Along with a comprehensive testing environment for sensors and automated driving functions, VIRTUAL VEHICLE seeks to advance embedded intelligence, sensor fusion, and fault-tolerant embedded control systems, thereby guaranteeing safe and predictable behaviour in any weather at any time in any scenario. ■

Context-embedded and context-aware automated vehicle architecture advanced by intelligent driver and system monitoring and fail-operational behaviour (redundancy in hard- and software)

A DISRUPTIVE, TECHNOLOGY-DRIVEN TREND

Automated driving is gradually becoming a reality. The VIRTUAL VEHICLE Research Center is well aware that the development and validation of automated driving functions require multidisciplinary and cross-sectoral expertise. Therefore, the Center is collaborating with national and international partners along the emerging digital value chain in numerous research projects, in order to ensure a safe, reliable, acceptable, and secure automated vehicle performance in the near future. Furthermore, VIRTUAL VEHICLE and Graz University of Technology are core partners in the recently established ALP.Lab – a national project to establish and operate a public testing ground for automated vehicles in Austria.

Over the last three years, public authorities from many countries have presented action and innovation plans to facilitate the development and stepwise introduction of automated vehicles. Those plans cover actions related to a multitude of technical and non-technical aspects that need to be taken into account. New sensor technologies, mapping and high-performance computers for data analytics, data fusion, artificial intelligence, and safe path planning are the key enablers to improve the current state of practice.

WANTED: The ultimate safety test

In particular, substantially improved vehicle and road safety is one of the major achievements expected. However, the ultimate safety test for automated vehicles will have to determine how well they can replicate the crash-free performance of human drivers, especially at the level of partial and conditional automation within mixed traffic. In order to be accepted by drivers and other stakeholders, automated vehicles must be reliable and significantly safer than today's driving baseline.

Sensing, planning, reasoning and acting

Automated vehicles by nature rely on sensing, planning, reasoning, and acting (or re-acting). A suite of vehicle sensors based on different sensing modalities (such as radar, lidar and camera), along with external sources (V2X) and detailed digital HD maps, gather raw data about the vehicle's environment, driving situation, and ambient conditions. Sophisticated algorithms interpret the data, process it, and convert it to commands for the actuators (e.g. steering, braking). Most of the state-of-practice vehicles and prototypes rely on in-vehicle sensors and require little digital infrastructure communication, although a greater connectivity between vehicles and their infrastructure is known to be beneficial. This entails the development of common communication protocols and security standards, as well as investment in new types of infrastructure or the upgrade of existing types. Reproducible testing of such highly connected, cooperative, bi-directionally interacting, automated systems of systems has become one of the biggest challenges.

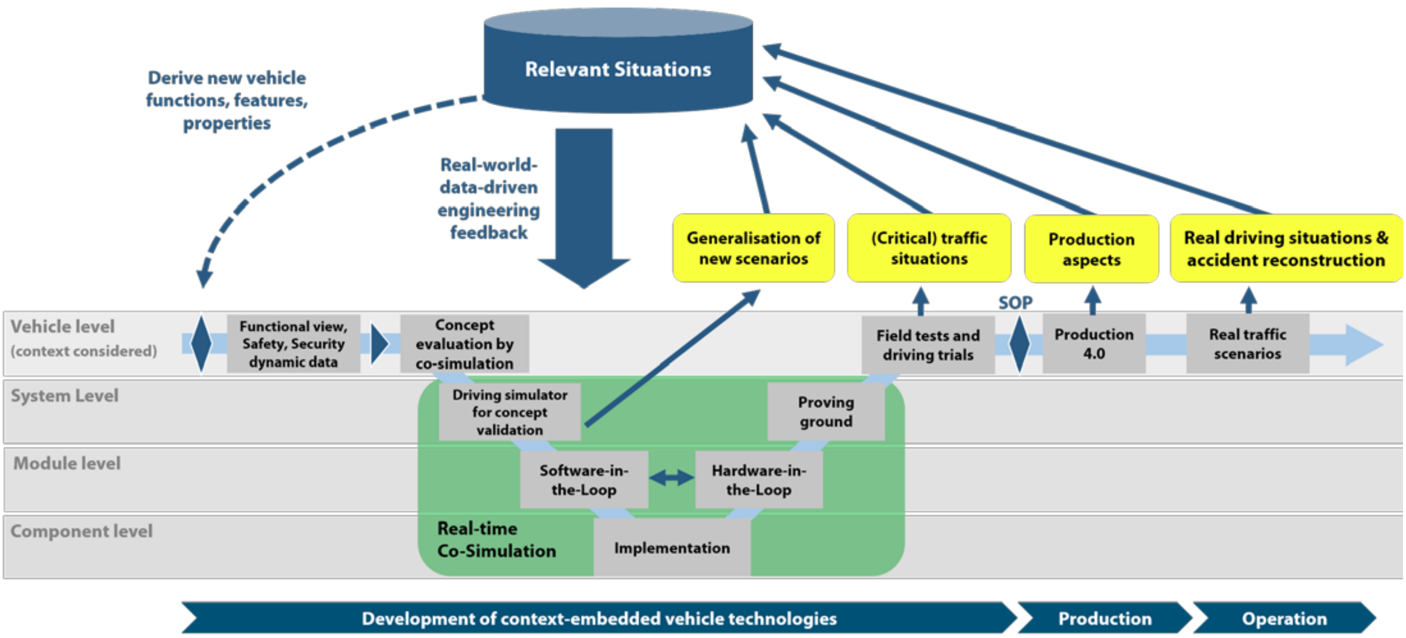


Figure 1: The use of real-world data to develop and test safety-critical automated driving functions

Remaining challenges

Despite tremendous improvements in recent years the areas of sensor technology, pattern-recognition techniques, robust signal processing, control system design, computational power (multi-core and many-core technology), V2X, and other system technology areas, market introduction of a fully automated vehicle that is capable of unsupervised driving in an unstructured environment remains a long-term goal. Even for structured environments, further research is needed to realise the full potential of road transport automation.

One of the keys to success will be the close harmonisation of experimentation and virtual development methods in order to devise new vehicle functions and features or improve existing ones, as well as enhancing or devising methods, processes, and tools for development and validation. Figure 1 highlights the 'closed engineering loop' needed to improve methods, tools, and processes for virtual approval.

ALP.Lab: Austria as a public testing ground for automated vehicles

Seamlessly connecting models, data, and processes with openness to a certain extent along the entire vehicle life-cycle will significantly decrease the number of road driving test kilometres, lower development costs, and ultimately improve reliability and safety. Austria has already acted to strengthen its position within Europe. The Austrian Federal Ministry for Transport, Innovation, and Technology (BMVIT) supports the establishment and operation of a public test region for automated vehicles. All of the relevant industrial and academic partners from the automotive and infrastructure domains have joined forces and are in the process of establishing the Austrian Light-vehicle Proving Ground (ALP.Lab) as of 2017, which will include motorways, federal highways, urban areas, and border crossings to Slovenia.

All of the abovementioned areas need to be further investigated in order to ensure a safe, reliable, acceptable, and secure performance of automated vehicles embedded in their intelligent environment at all times. Along with the technological advances, progress is urgently needed in legislation, liability, and insurance. ■

EUROPEAN RESEARCH PROJECTS

on Automated Driving recently launched at VIRTUAL VEHICLE

ENABLE-S3

European Initiative to Enable Validation for Highly Automated Safe and Secure Systems

68 m EUR · 05/2016 – 04/2019
72 partners
AVL, Philips, TU Graz, RENAULT, TNO, etc.
ECSEL JU

TrustVehicle

Improved Trustworthiness and Weather-Independence of Conditional Automated Vehicles in Mixed Traffic Scenarios

5 m EUR · 06/2017 – 05/2020
12 partners
VIRTUAL VEHICLE, Volvo, Ford, AVL, Infineon, CISC, University of Surrey, etc.
Horizon 2020

AutoDrive

Advancing Fail-aware, Fail-safe and Fail-operational electronic Components and Systems for Automated Driving

82.2 m EUR · 05/2017 – 04/2020
57 partners
Infineon, Daimler, Bosch, NXP, Magneti Marelli, JAC, CRF, TU Graz, etc.
ECSEL JU

Inframix

Road Infrastructure ready for Mixed Vehicle Traffic Flows

4.9 m EUR · 07/2017 – 06/2020
11 partners
AUSTRIATECH, BMW, TomTom, Fraunhofer, etc.
Horizon 2020

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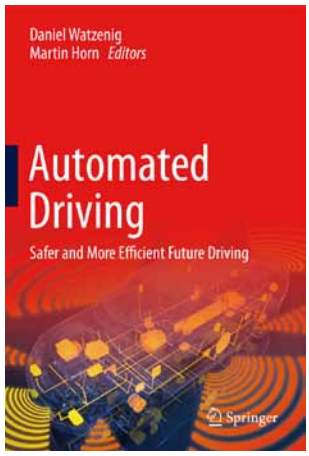
Daniel Watzenig, Martin Horn (Editors)

AUTOMATED DRIVING:
Safer and More Efficient Future Driving

- Advanced control
- Cognitive data processing
- High performance computing
- Functional safety
- Comprehensive validation

Springer; 1st ed. 2016



by Dr. Jan Becker | Stanford University

THE HISTORY OF THE FUTURE

The idea of automated vehicles is already over 100 years old but was initially explored only in fiction. The first technical experiments started in the 1950s but research with environment sensors did not start until the 1980s. Advanced driver assistance systems finally entered production vehicles in the late 1990s. Then, the DARPA Grand and Urban Challenges sparked the transition to technical development of fully autonomous vehicles, which was originally spearheaded by Google. Recent years now saw the formation of a whole industry around automated vehicles, made up of traditional automotive players as well as new ones, including many startups. In the last few months, the landscape has changed even more dramatically with many partnerships forming and acquisitions in the multibillion dollar range, all betting on the unprecedented success of automated vehicles in the next few years.

The dream of self-driving vehicles was already approached in fiction not long after the development of the automobile itself in 1886. In 1915, a magazine depicted a self-driving street car, "a motorist's dream: a car that is controlled by a set of push buttons". The 1950s saw a range of vehicle automation in fiction, leading to Herbie in the 1960s and KITT from the 1980s TV series Knight Rider, which was able to drive itself and to "see" the environment with the help of a scanner.

Early research

The late 1950s marked the starting point for research on self-driving or robotic vehicles. GM and the Radio Corporation of America (RCA) co-tested automated highway prototypes in 1958, using radio control for velocity and steering. Vehicles were equipped with magnets, thus, were able to track a steel cable buried in the road, while the overall traffic flow was managed by control towers. In 1979, Stanford University's Cart marked a milestone: initially remote controlled, it successfully crossed a room full of chairs in five hours, without any human intervention. Carnegie Mellon University's (CMU) Rover followed soon after, as did Shakey from the Stanford Research Institute, the first general-purpose mobile robot that was able to reason about its own actions.

The Tsukuba Mechanical Engineering Lab in Japan developed the first automated street vehicle with environment perception in 1977, it was capable of following lane markings for up to 50 m, with velocities reaching 30 km/h. The worldwide first actual robotic street vehicles were built at the Bundeswehr University Munich in Germany by Prof. Ernst Dickmanns and his research group in the 1980s. Operating with computer vision and probabilistic algorithms, they drove 20 km on an empty highway at speeds of up to 96 km/h. In 1995, Prof. Dickmanns' team drove from Munich to Denmark and back, traveling a distance of 1758 km. Both longitudinal and lateral guidance were achieved by computer vision, reaching velocities as high as 175 km/h. The longest part driven autonomously on that trip was 158 km. That same year, CMU conducted the "No hands across America" drive. Their research vehicle covered the entire distance from Washington, D.C., to San Diego, California, with automated steering while longitude was controlled manually. San Diego was also the venue for a technology demonstration of the U.S. Department of Transportation's National Automated Highway System Research Program (NAHS) in 1997. Automated cars, buses, and trucks drove on the I-15 with lateral lane keeping enabled by computer vision and magnets embedded in the road, and longitudinal distance by radar or lidar sensors.

The DARPA Challenges set the stage

DARPA, the Defense Advanced Research Projects Agency, funded a series of autonomous vehicle competitions. 15 teams qualified for the final competition of the first event in 2004. Their unmanned self-driving vehicles had to attempt a 150-mile course in Nevada's Mojave Desert across dirt roads, flats, and mountain passes. A set of GPS waypoints was distributed to the teams only 24 hours before the event. Not a single robot vehicle was able to finish the race, the best team completed only seven miles. The following year, DARPA repeated the event; five teams completed the 132-mile course, providing evidence of the remarkable progress in this field in a very short time span. First one to cross the finish line after six hours and 54 minutes was the robot car Stanley, which was developed by Stanford University's Sebastian Thrun and his team. The 2007 DARPA Urban Challenge then moved the competition to an urban scenario at an abandoned military base. The teams had to negotiate fourway intersections, blocked roads, or parking lots with other self-driving as well as human-driven vehicles. The first autonomous vehicle traffic jam occurred at this event as did the first minor collision of two robot cars. The 60-mile race was won by CMU's vehicle "Boss"; Stanford's "Junior" came in second. For the first time, researchers heavily relied on high-resolution lidar sensors and maps.

Industrial development starts

The Urban Challenge also marked the transition from academic research to industrial development; in 2008, Google started working on self-driving cars and announced its self-driving car programme two years later. The programme was directed by Sebastian Thrun. Several car manufacturers announced similar projects, such as Daimler, BMW, Audi, Volkswagen, GM, Nissan, Honda, Toyota, Volvo, Ford, Tesla, Hyundai, Jaguar Land Rover, and Faraday Future. Automotive suppliers like Bosch, Delphi, Continental, and Mobileye followed suit. Also, ride share companies, e.g., Uber, IT companies, e.g., Baidu, and

DARPA Challenge 2007: Stanford Racing and Victor Tango together at an intersection

chip manufacturers, e.g., Nvidia or Intel joined the field with their own self-driving car projects as did startup companies like Zoox, Cruise Automation, drive.ai, comma.ai, nutonomy, or Nauto. In 2013, a Vis-Lab research vehicle drove autonomously for 13 km in public traffic of Parma, Italy, partially without a safety driver in the driver seat. That same year, Daimler and the Karlsruhe Institute of Technology built the autonomous research vehicle "Bertha" which drove the 100 km long Bertha Benz Memorial Route from Mannheim to Pforzheim, Germany, in public traffic. In 2014, Google presented a car that was specifically designed for self-driving and by 2016, Google's fleet had completed over 1.5 million miles. Significant advances in machine learning over recent years enhanced an enormous progress in the area of environment understanding for automated driving, one of the key enablers for developing driverless cars driving in real traffic.

Automated trucks are potential beneficiaries

Lately, also automated trucks have gained attention. In 2015, Daimler Trucks North America demonstrated a self-driving truck in Nevada. Volvo and other truck manufacturers have also held autonomous freeway driving demonstrations in Europe. The Silicon Valley startup Otto started working on autopilot retrofit kits for trucks in 2016. Another Silicon Valley startup, Peloton Technology, has already been working on truck convoys for fuel efficiency since 2011.

The industry changes

In the last years, specifically in the past few months, unprecedented partnerships have formed in the industry. E.g., the competitors Audi, BMW, and Mercedes allied to buy the mapping company here in 2015 for over €2.8 billion. In 2016, GM bought the small startup Cruise for supposedly $1b; BMW, Intel, and Mobileye teamed up; Delphi and Mobileye announced a partnership, Uber acquired Otto for reportedly $680m; Delphi, Mobileye, and Intel partnered; Google spun out Waymo. In 2017, Intel invested in here and then bought Mobileye for over $15b. The automotive industry has realised that the technical challenges of automated driving are tremendous and require significant investments. At the same time, new and more agile players enter the field with new technologies and, as a consequence, development speed has increased. As a result, new partnerships form in areas that do not contribute to product differentiation, such as maps, sensors or perception.

Seven key challenges remain

In over a century, autonomous driving has developed from fiction to research to industrial development and first partially automated production systems. Several challenges remain though:

(1) TECHNOLOGY AND FUNCTIONAL SAFETY: Algorithms are still under development and being optimised. Suppliers are working on new and better sensors, and companies are testing various different sensor sets. Remaining challenges are, for example, how to deal with unforeseen weather and road conditions? Or with objects the sensors have never seen before? Or temporary construction zones or changes to a prerecorded map. Automated vehicle technology has made tremendous advances in the past years, but how reliable and safe does the technology need to be in order to be ready for introduction?

(2) CYBER SECURITY: Automated vehicles will likely also be connected vehicles in order to download map and traffic updates, and connecting to other vehicles or infrastructure, such as traffic lights and highway signage. However, connected vehicles have recently become targets for attacks. Cyber security may never be perfect. How can manufacturers build vehicles that are safe, nevertheless?

(3) HUMAN FACTORS: What is the role of the human inside partially, highly, and fully automated vehicles, respectively? Who is in charge and responsible? How does the handoff transition of responsibility from driver to vehicle and back work? And how will traffic participants and persons outside of the automated vehicle react to it?

(4) LEGALITY, REGULATIONS, LIABILITY: The 1949 Geneva and 1968 Vienna United Nations Conventions on Road Traffic require a driver who is "at all times [...] able to control" the vehicle. However, the interpretation of this requirement differs from country to country. Whereas the predominant opinion in the United States is that automated vehicles are legal, for example, the German interpretation is that highly automated vehicles are not [yet legal]. In 2016, the United Nations approved amendments to the Vienna Convention as well as to UN Regulation No. 79, explicitly allowing automated driving technologies transferring driving tasks to the vehicle, provided that these technologies are in conformity with the United Nations vehicle regulations or can be overridden or switched off by the driver. In the meantime, several US states have introduced, passed, or rejected various non-uniform state bills and regulations. Uncertainty also remains in the area of liability: Who will be liable when an automated vehicle is involved in an accident? Will liability shift from driver to manufacturer or even supplier as vehicle control shifts from the human operator to the automated vehicle?

(5) ETHICS: Should automated vehicles be as safe or safer than human drivers? How safe is safe enough? What if automated vehicles reduce fatalities significantly, but at the same time cause new, different types of accidents? Arguably, there may never be concrete answers to many ethical questions pointed out by philosophers dealing with the matter.

(6) INFRASTRUCTURE: Traffic depends on road infrastructure, and automated vehicles depend on digital and analog infrastructure as well. But how much infrastructure in the form of digital maps, infrastructure based communication systems, dedicated lanes is really required? Can, should, or must automated vehicles rely on the infrastructure? And how often do maps need to be updated?

(7) URBAN PLANNING AND ROAD PLANNING: Automated vehicles will have a huge effect on mobility demand and traffic but the concrete changes on the amount of traffic, future traffic patterns, and urbanisation are highly uncertain. Will there be more total vehicle miles travelled? But will automated vehicles need less road space than today? And will there be fewer vehicles overall that need less parking?

Significant challenges towards vehicles that can drive themselves in all locations and under all conditions still lie ahead of us. Given the tremendous progress in the field over the past ten years, the next ten years shall be even more exciting. ■

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Waymo's fully self-driving reference vehicle, Firefly 1

FUNCTIONAL SAFETY: TODAY AND IN THE FUTURE

Vehicle safety is among the most in-demand properties of vehicles and automated driving functions. Although autonomous driving functions have to manage unforseen driving situations while maintaining functional safety, the current functional safety standard (ISO 26262) does not cover the related challenges. Therefore, the "ISO PAS 21448 – Safety of the Intended Functionality" has been devised, where VIRTUAL VEHICLE is collaborating with OEMs and suppliers from all over the world to find solutions.

The main goal of functional safety is to prevent harm to vehicle passengers and other traffic participants caused by the electric/ electronic system of cars.

Achieving functional safety

This is achieved by conforming to the ISO 26262 standard, first released in 2011, which defines a set of system development tools and methods for systematically detecting and avoiding design and implementation errors. During system development, potential hazards are identified and analysed in terms of their severity, probability of occurrence and their controllability by the driver. The analysis results are used to assign Automotive Safety Integrity Levels (ASILs) to the desired vehicle functions that reflect their importance regarding functional safety. Based on the importance of each function, appropriate technical measures are incorporated to achieve functional safety.

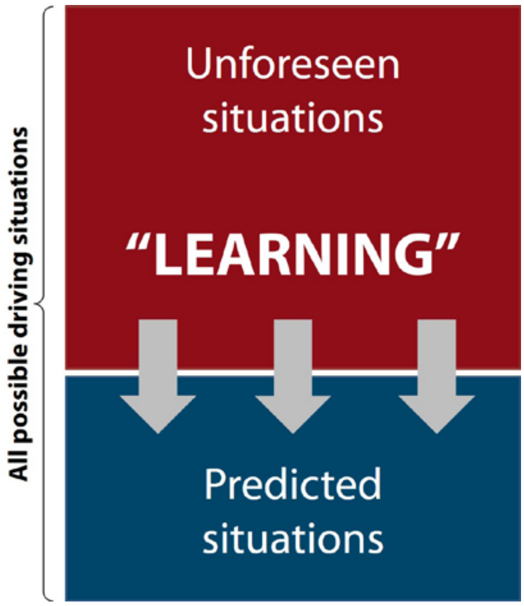
Expertise

Although the basic concept seems simple, both implementing an ISO 26262-compliant safety process and conducting the stipulated analysis requires specially trained personnel. Therefore, VIRTUAL VEHICLE has trained 12 TÜV Süd-certified functional safety professionals to support industry in these challenging tasks.

Shaping the future

ISO 26262-based approaches cannot handle highly or fully automated driving functions because they do not consider unforeseen situations. A situation is unforeseen if it was unknown and consequently not considered during development. Figure 1 shows that a situation becomes expected after its existence has been "learned", for example during field operation, and that all possible driving situations can be classified as either unforeseen or expected.

Since automated driving is still in its initial phase, the number of unforeseen scenarios is very large compared to the number of expected scenarios. This is due to the wide variety of environmental conditions that need to be considered, including different kinds of weather, streets, and traffic situations.



Handling of un-predicted situations needed for safety of the intended functionality (ISO PAS 21448), which is not covered by ISO 26262.

Summary

Automated driving functions present difficult new challenges, which have to be met before a vehicle can drive safely without human interaction. Since these challenges cannot be met using classic safety approaches, VIRTUAL VEHICLE has joined the ISO PAS 21448 committee to help further new technologies. ■

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THE ROLE OF HUMANS

The role of humans in automated systems is shifting as advances in machine learning and cognitive computing lead to increasing levels of automation. In such systems, human operators often take the role of monitoring or supervisory controlling, rather than active controlling. This shift can result in difficulties when it is necessary to make quick control actions. To accommodate the changed roles, new types of human-computer interactions are in demand that allow for intuitive, fluid coordination between humans and automated systems. VIRTUAL VEHICLE is developing the methods and computational tools that will allow designers and engineers to create the necessary advanced automation interfaces in the automotive and industrial domains.

Recent advances in artificial intelligence and cognitive computing allow for automation that alters the traditional boundaries between humans and computers. The highest levels of automation are often referred to as "autonomous system". The scope of automation differs in terms of how much of an operation is automated, ranging, for example, from automated self-parking to a start-to-finish driving operation. Full end-to-end automation includes highly adaptive task aspects, such as planning, initiating, terminating, and transitioning an operation. Such tasks are often complex and costly to automate. Instead, automated tasks usually exhibit sufficient regularities, such as maintaining a constant distance or even steering a vehicle in certain environments. However, most end-to-end operations, especially in complex environments, require human involvement.

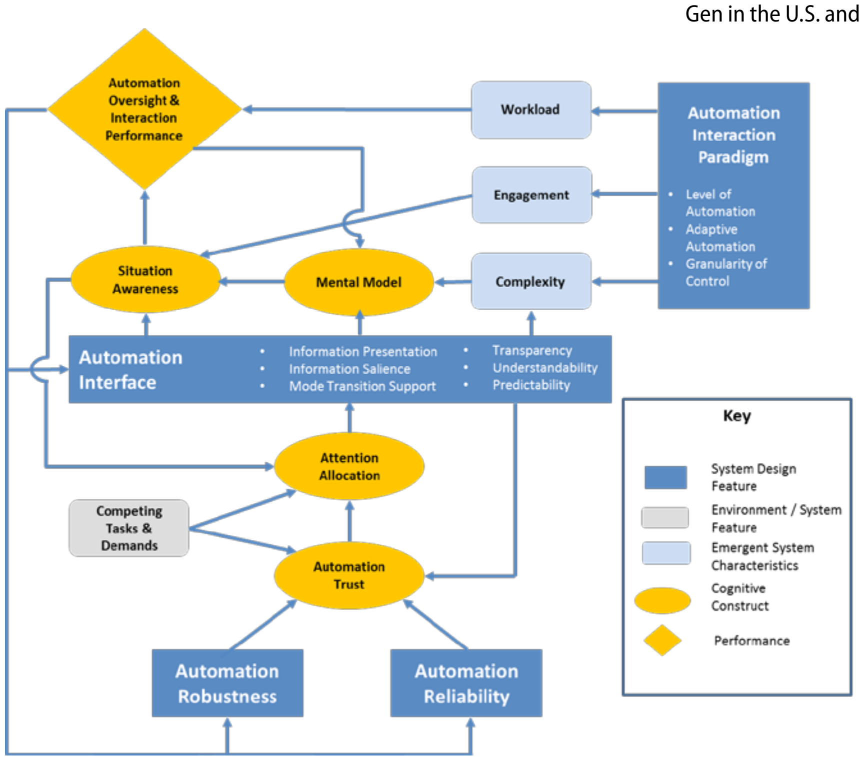

Figure 1: Model of interconnetion between human and automation (adapted from [2])

Humans in automated systems

One reason why humans remain essential, even in highly automated systems, is their relative flexibility to adapt to new and unplanned situations and to find creative solutions. Although the powerful intelligent learning algorithms that designers and engineers utilise today can extract increasingly complex behavioural patterns, predicting the future state in a dynamic environment such as a city or public airspace remains extremely difficult. While overly complex environments such as vehicle or air traffic could theoretically be simplified through new radical standards that reduce complexity (e.g. making air traffic more similar to rail traffic), this is rarely feasible due to the significant amount of necessary national and international harmonisation efforts and costs, which are often not compatible with the commercial need for product differentiation (the aviation innovation programmes NextGen in the U.S. and SESAR in the E.U. represent examples). Instead, the allocation of highly adaptive functionality to the 'intelligent' human is often more practical, less costly, and easier to certify. However, when the allocation of functions is primarily driven by technological capabilities and economic interests rather than by human constraints and abilities, the resulting systems are often difficult to use and can lead to unsafe operations or even remain unsold.

Current research is thoroughly investigating the human role in automated systems. The results indicate that supervisory control can lead to boredom and difficulties in maintaining sufficient situation awareness. In addition, humans respond slower when they are 'out-of-the-loop'. Aviation automation has shown that the increased use of flight-automation can lead to a loss of manual piloting skill and increased pilot confusion concerning what automation is actually doing. This leads to the "automation conundrum": the more and the better automation works, the less likely it is that human operators will be able to effectively intervene and take over manually

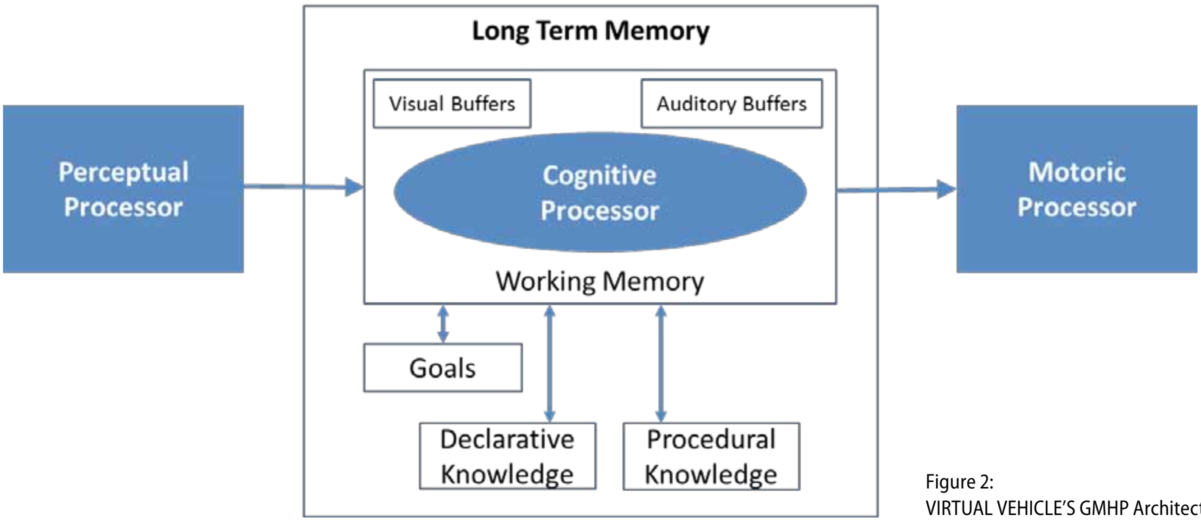

Figure 2:
VIRTUAL VEHICLE'S GMHP Architecture

when necessary. This multifaceted interconnection between human and automation has been well explained, such as in Endsley's HASO model[2] (see Figure 1). In essence, basic automation performance and human interaction performance are mutually dependent.

Human-system integration

As a result, human-automation interaction has become a critical enabler for the successful adoption of automation. The challenge is that the interface must provide sufficient information to the human who is less aware of what is transpiring, and at the same time enable a quick response. Information overload and the inability to effectively respond can be the result, such as in the accidents of Air France flight 447 in 2009 or Asiana Flight 214 in 2013.

The guiding principle for developing effective human-automation interaction has been well recognised for many decades: technological and human research should collaborate from early design phases to jointly optimise the allocation of functions to automation and humans. This helps prevent problems, such as the need for human operators to fix what automation cannot do or the creation of systems that fail because of the unrealistic expectations of the human operator. While the principle is straightforward, the implementation is more difficult because it requires collaboration between rather diverse team members (e.g. technical engineers and human-social researchers), who possess different knowledge, backgrounds, and goals. This requires shared language, methods, and tools to mutually contextualise technical and human characteristics.

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Methods and tools to integrate humans & automation

Connecting human and technological research to design effective automation requires methods and tools to collaborate, to exchange or share critical information, and to iterate designs. To support this process, VIRTUAL VEHICLE is developing methods and tools that centre around a new cognitive modelling architecture, the Grazer Model Human Processor (GMHP), see Figure 2. The GHMHP enables the simulation of the cognitive processes that underlie human performance and the subsequent integration of such processes into system simulations. As part of an ongoing internal strategic project, the GMHP architecture allows to model processes such as visual scanning, response selection, and distraction and leads to quantifications of human performance for large numbers of simulation scenarios. In addition, the GMHP will be used to design and implement adaptive user interfaces that learn from observing human behavior. The GMHP is based on more than 30 years of cognitive modelling research and is being developed in collaboration with the Computer Science department of the University of Illinois at Urbana-Champaign.

The GMHP will soon be available to enable the development of effective automation and adaptive computer interfaces in research projects and commercial applications. ■

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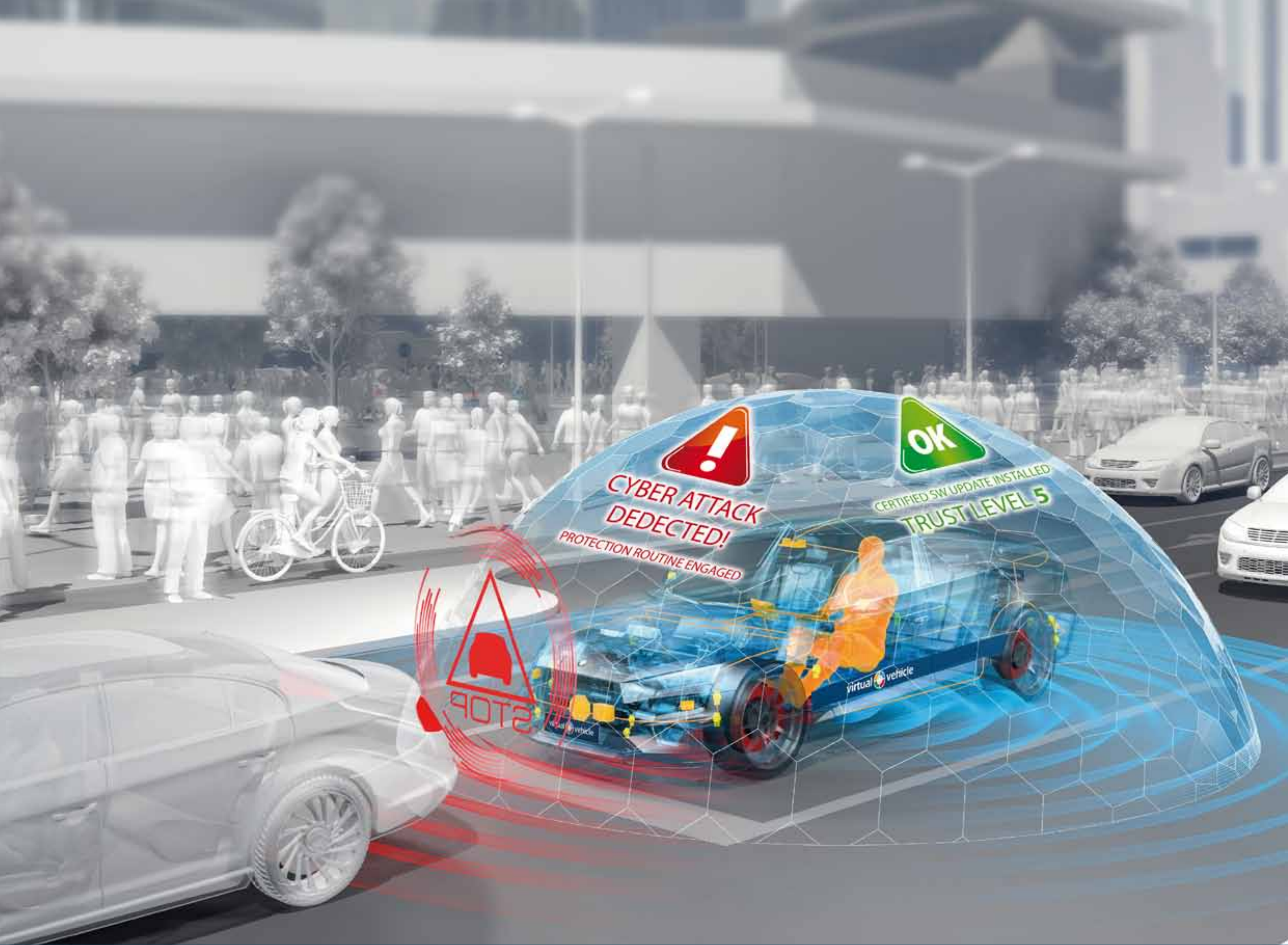
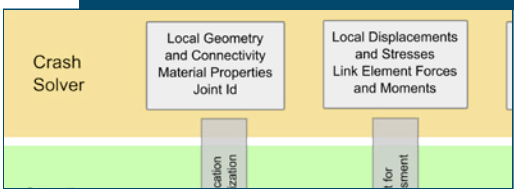
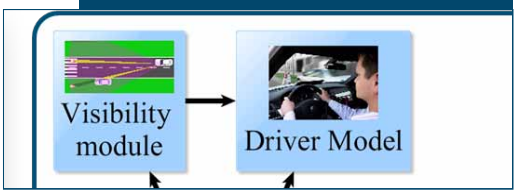
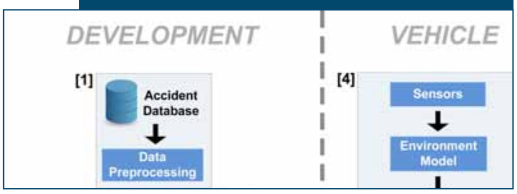


SAFETY & SECURITY







CREATING A SAFE, SECURE AND TRUSTABLE FUTURE

The EU "Vision Zero" defines the goal of nearly eliminating all fatal road accidents in the European traffic system by the year 2050. However, at the moment, the automotive industry is facing new challenges due to unprecedented technological advancements: automated driving, connected cars and the Internet of Things are giving rise to new demands for safety and security. The researchers at VIRTUAL VEHICLE are working on novel solutions to meet such challenges, particularly by taking into account both trustability and social acceptance in order to maximise market uptake.

When dealing with future road safety and security, numerous questions arise: What will be the relevant future scenarios? What is necessary to perfectly coordinate and align all safety and security measures? How can cooperative safety systems exchange environmental information and build common situation awareness? How can we deal with increasing system complexity, and how can we foster user acceptance?

Challenges & trends

The ambitious goal of zero fatalities requires developing cooperative safety systems and incorporating information from all traffic participants (vehicles, occupants, vulnerable road users/VRUs), as well as infrastructure. However, in addition to new technologies (e.g. ADAS, automated driving functions, and new materials) and the resulting increase in system complexity, new safety and security challenges (e.g. novel accident scenarios, new attack scenarios) will also arise, which will call for new design methodologies, products and services.

Future connected cars and the related infrastructure will require secure and rigorously verified communication channels that provide suitable mechanisms for authentication and encryption. Their fail-operational EE (electric and electronic) systems will need new hardware and software architectures, which must be able to explicitly consider failures and implement corresponding mitigation strategies. Moreover, system security has to be guaranteed over the whole vehicle lifecycle. Therefore, new online security update mechanisms are needed to maintain functional safety.

Fields of activity

Bearing in mind these challenges and trends, the Safety & Security department at VIRTUAL VEHICLE focuses its research activities on three key issues:

1. **"Cooperative Integrated Safety"**, where we investigate future accident scenarios that include new driving systems and functions, develop cooperative integrated safety systems using in-vehicle environment-sensing data and information received from other traffic participants and infrastructure, (virtually) assess the field effectiveness of such systems, optimise these systems, and then determine the associated impact on vehicle design.

2. **"Multi-level Protection and Human Acceptability"**, where experts investigate personalized perceptions of hazardous situations and associated design requirements for future scenarios; develop human behaviour and cognition models; create a trusted system development framework to promote user acceptance and trust in future safety and security solutions; and they carry out the joint CAE-driven development of new vehicle and production designs.

3. **"Secure and Dependable EE Systems"**, where the main emphasis is on developing design principles for safe, secure and dependable EE architectures ("safety by design", "security by design" ...) that will fulfil the requirements for active safety systems and automated driving. Additionally, experts are investigating secure communication schemes for data exchange. ■

Fostering both user and societal acceptance and trust will be a crucial competitive advantage for all such solutions on future markets. This will require improvements in terms of safety, security, privacy and dependability (e.g. availability, reliability, and maintainability), the use of a comprehensive human-centred approach, which can take into account human behaviour and cognition, as well as human-system interaction in the early development process. Appropriate system design and intervention strategies have to be devised to eventually create broad societal acceptance.

Interactions of future safe and secure vehicles

SECURITY FOR TRUSTABLE CYBER-PHYSICAL SYSTEMS

Whether a car is turned off or driving, owners want to protect the vehicle and themselves from theft or misuse. However, this is no longer straightforward when using a connected car. With today's connected cars, someone outside the car could theoretically take over control of the car, leaving the driver suddenly out of the loop. So what can be done to ensure operator trust in a connected car and - as a result - in automated driving in general? Security is one of the main factors.

In recent years, automobile security has been largely limited to preventing vehicle manipulation (e.g. obtaining more driving power) and securing keyless entry systems. Potential attackers required either direct contact or close proximity to the car (e.g. radio jammers). Trust in vehicles has been a minor issue because the close proximity also involved direct contact with the driver.

This changes radically when vehicles are connected to the outside, such as via internet access. By 2020, there will be a quarter billion connected vehicles on the road, enabling new in-vehicle services and automated driving capabilities. Any new service can potentially interact with vehicle functions and therefore pose significant security, privacy and trust challenges. With the increasing use of connected cars, it is evident that the need for security in cars will also increase.

Connected cars are just one example out of many: suitable security is important for all kinds of cyber-physical systems (CPS). Thus, nobody wants to be trapped in a hijacked metro controlled by an unauthorised external entity due to security flaws in its wireless systems, or connected to an insulin pump subject to the same security vulnerabilities. The question is: what needs to be done to create "trustable" systems?

Security as a key enabler for trustable CPS

At VIRTUAL VEHICLE, we have identified various factors that contribute to trustable CPS. This article focusses on security. Other factors include safety, reliability and reputation.

Adding a wireless interface to a CPS enables a wide variety of different new services, but also leads to an interface vulnerable to external attack. Thus, a wireless interface is a critical component with respect to security and, as a consequence, safety. Different attacks exploiting the infotainment system of a vehicle are already well known, and adding wireless interfaces will lead to more potential threats. Therefore, suitable measures (e.g. security processes and security metrics) must be developed and integrated into the development lifecycle of CPS. In two ECSEL[1] projects (DEWI, SCOTT), each conducted with almost 60 partners from across Europe and coordinated by VIRTUAL VEHICLE, CPS that interact wirelessly with the outside world are the main focus to enable their secure and safe usage and thereby create trustable CPS.

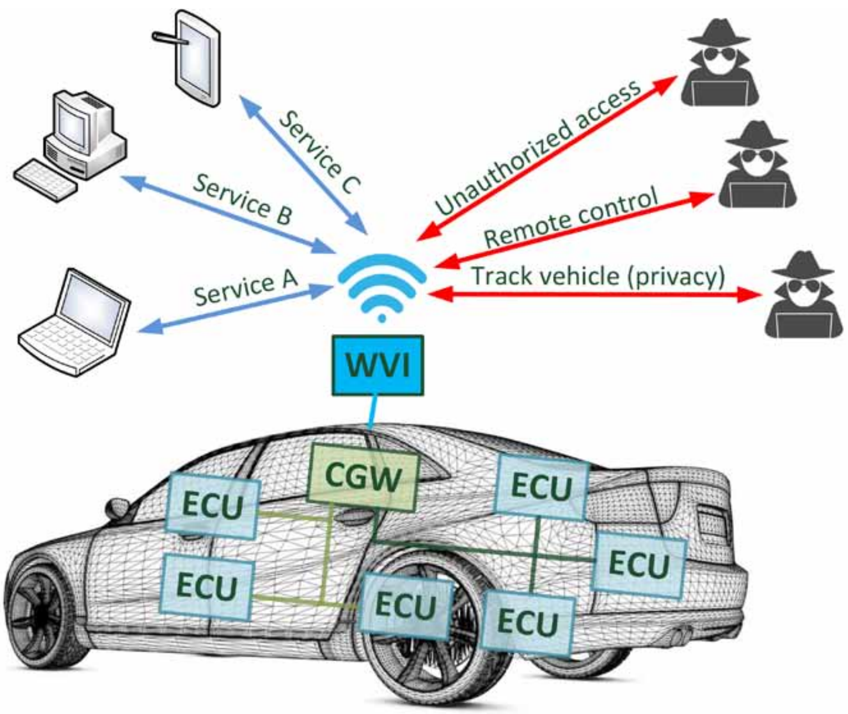


Figure 1: Connected cars – trustable?

DEWI

In the DEWI project, the partners provide key solutions for seamless wireless connectivity and interoperability concerning everyday physical environments in buildings, cars, trains and aircrafts. DEWI targets Technology Readiness Levels (TRL) 2-5, thereby demonstrating the basic applicability of the methodologies and use cases developed. Several of the more than 20 industry-driven use cases are already closely related to the topic of security (e.g. a demonstrator for secure wireless vehicle software update developed by VIRTUAL VEHICLE). Furthermore, VIRTUAL VEHICLE has developed and demonstrated a methodology for the structured security analysis of CPS.

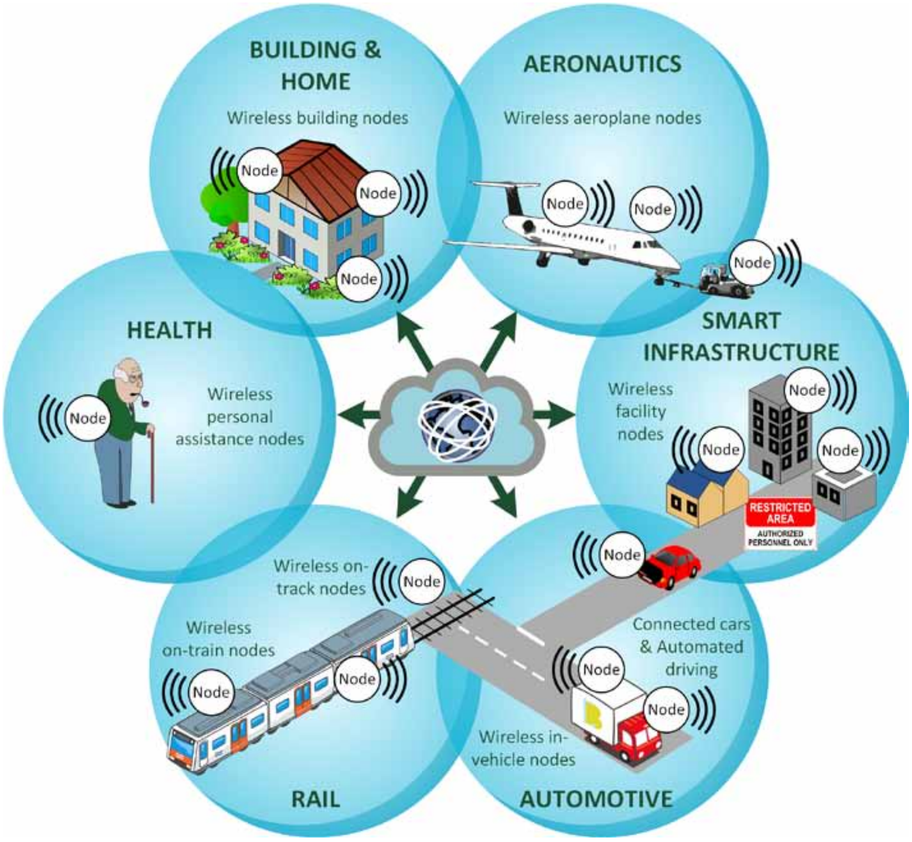


Figure 2: SCOTT - Creating and connecting trustable things in different domains

DEWI

Dependable Embedded Wireless Infrastructure

39.5 m EUR · 03/2014 – 04/2017
58 partners
VIRTUAL VEHICLE, Airbus, AVL, NXP, Philips, Volvo, Indra, GUT, ISEP, Thales, Valeo, Acciona, Siemens, etc.
ARTEMIS
www.dewiproject.eu

SCOTT

Secure Connected Trustable Things

42.7 m EUR · 05/2017 – 04/2020
57 partners
VIRTUAL VEHICLE, Bosch, Embraer, Siemens, Nokia, Ericsson, Telenor, AVL, Philips, etc.
ECSEL
www.scottproject.eu

Structured security analysis of CPS

The DEWI security metric can be utilised to analyse CPS in a structured way. Its application leads to a secure system configuration with comparable and reusable results. Additionally, the security metric can be used to support the conceptual phase of CPS development as specified in the SAE J3061 security standard (Cybersecurity Guidebook for Vehicular CPS). The steps required to achieve a secure system concept for a CPS are as follows:

1. Security analysis of the system (based on the DEWI security metric), resulting in a secure system configuration
2. Extraction of the security requirements from the secure system configuration
3. Definition of a security concept based on the security requirements and the specific characteristics of the application scenario
4. Evaluation of the defined security concept using the STRIDE[2] threat model

From basic research to industrial application: SCOTT

While DEWI is more focused on research, its successor project, SCOTT (launched in May 2017), targets higher TRLs (6-7) and is thus closer to market readiness. SCOTT is a pan-European effort with 57 partners from 12 countries (EU and Brazil). It will provide comprehensive, cost-efficient solutions for wireless, end-to-end secure, trustable connectivity and interoperability in the automotive, aeronautics, health, building & smart infrastructure and rail domains, in order to bridge the last mile to market implementation. SCOTT follows a user-centred design to significantly foster acceptance of Internet of Things (IoT) solutions on the market. SCOTT will deal not only with 'things that are connected', but with 'trustable things that communicate securely'. ■

[1] ECSEL – Electronic Components and Systems for European Leadership is Europe's largest R&D public-private partnership for technology development in the area of electronics.

[2] A methodology for identifying and categorising security threats

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FROM THE CRACK INITIATION AT JOINTS TO FAILURE OF STRUCTURAL PARTS

The prediction of structural failure under crash load is still a significant challenge in the virtual product development process. In particular, the increased use of modern lightweight materials and innovative joining techniques have spurred demand for innovative numerical methods that can meet the high requirements for passive safety. Together with Audi and Magna Steyr Engineering, VIRTUAL VEHICLE has developed a new modular failure assessment system, which can describe the relevant failure phenomena under crash loads.

Material failure and joint failure exert significant influence on the behaviour of car bodies under crash conditions. In particular, the load-bearing capacity of the whole car body depends on joints that occasionally fail prematurely and cracks that may occur. In particular, the increased usage of of modern lightweight materials (e.g. advanced high strength steels (AHSS), aluminium (ALU), carbon fibre reinforced plastics (CFRP)) presents new challenges for joining techniques. Beyond traditional resistance spot welds (RSW), self piercing rivets (SPR), flow drill screws (FDS), friction stir spot welds (FSSW), welded seems (WS) and many other techniques are used to join these different types of materials (Fig. 1). Besides the failure of joint elements themselves, current development efforts are focused on the initiation and propagation of cracks due to notch and softening effects.

The considerable variety of geometric shapes (point-, line-, or area-shaped), the diversity of joining technologies and the variety of materials to be joined are the main challenges in the simulation of crack initiation. In full-vehicle crash simulations using FEM, an additional challenge arises due to the fact that crack initiation at joints and the subsequent crack propagation are caused by the onset of localised stress concentrations in the vicinity of the joints. Strictly speaking, the related stress gradients that occur require a local mesh refinement (e.g. the method of Shell-to-Solid Re-meshing, SSR). However, such a local mesh refinement for all joints in full-vehicle crash simulations is not yet practical for two main reasons: the sheer number of additional Finite Elements required, and the fact that the calculation time step size correlates with the smallest element size in the entire FE-model (Courant-Friedrichs-Lewy condition), which leading to an unreasonably high increase in computation time.

Surrogate models

One possible way to overcome this limitation is to use surrogate models to assess regions with high local stress concentrations. The developed models for joint failure, crack initiation and crack propagation in the sheet structure are based on a combination of experiments, results from detailed, high-resolution FE simulations and selected concepts used in special-purpose finite elements. Since they are simplifying mathematical models defined within a suitable chosen parameter space without the need for local mesh refinement, they offer high computational performance.

Crack initiation and crack propagation

The essential factor which determines the tendency of crack initiation due to a notch effect is obviously the current state of the local in-plane strain- (stress-) field. Besides the purely homogeneous (averaged) local strain field, knowledge about the possible inhomogeneous part of strain-loading is required. To acquire this knowledge, it is necessary to monitor a sufficiently large shell patch around the joint in order to get access to the inhomogeneous part of the local strain field (see Fig. 1). The surrogate model for crack initiation automatically queries all required model parameters during solver run time, assesses the risk of failure, and occasionally initiates cracking by selectively triggering shell element elimination. Once a crack has been initiated, the displacements and stresses at the boundary of the deleted elements are analysed, and another surrogate model is used to predict further crack

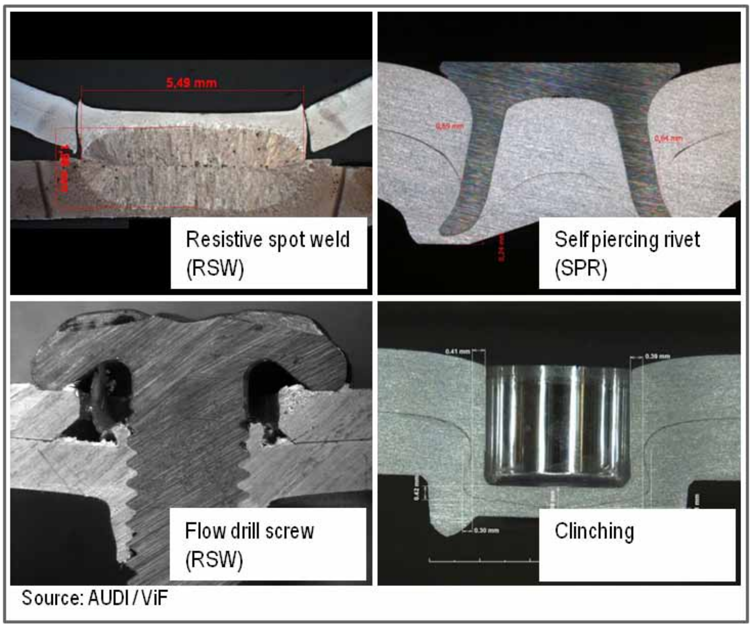

Figure 1: Micrographs of various point-shaped joints. The diversity of material properties, material inhomogeneities due to the joining process and geometric shapes require the development of various surrogate models for failure assessment of the specific joining techniques.

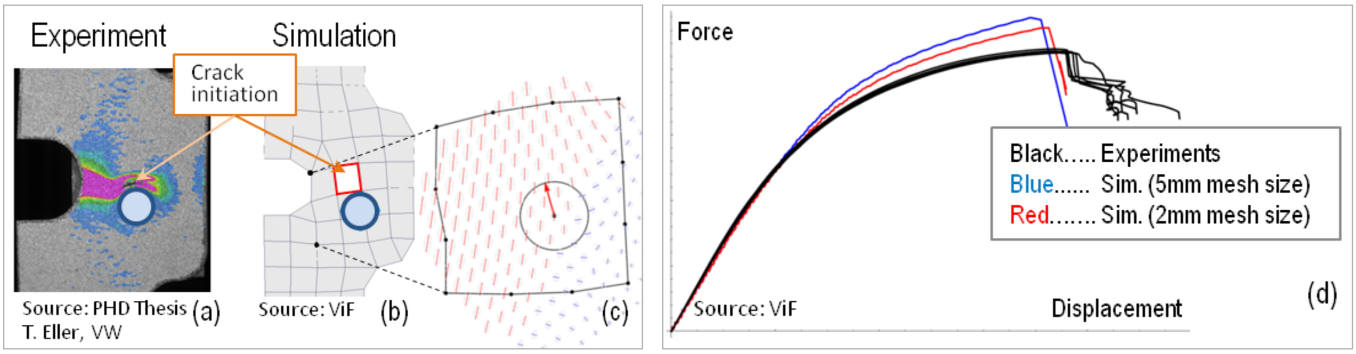

Figure 2: Crack initiation at the softened Heat-Affected Zone (HAZ) of a spotweld in ultra-high-strength steel (22MnB5) (a,b,d). The tension of a s-shaped specimen results in an inhomogeneous strain field around the spotweld. The current strain state is automatically detected (c) and assessed, which occasionally leads to selective shell element elimination (b). The predicted positions of the force drops in the load versus displacement curves due to crack initiation agree well with experimental results (d). The nearly identical position of the curve maxima of the blue and red curves shows the required mesh-independent behaviour.

propagation by means of a proper fracture criterion. All surrogate models for different types of joints, materials and failure modes are part of the Integrated Failure Assessment System.

Integrated Failure Assessment System

The Integrated Failure Assessment System (IFAS), developed by VIRTUAL VEHICLE together with AUDI and MAGNA, provides an add-on to existing crash solvers that provides access to the local deformations at critical points of the structure at runtime. It consists of two layers. A coupling layer organises the data flow for the parameterisation at the start of computation, as well as the input and output data at runtime (see Fig. 3), while the module layer includes the different surrogate models for the failure assessment in solver-independent modules. This architecture provides an efficient and flexible system which is highly open for future extensions to include additional failure models. It can be used for Symmetric Multi Processing (SMP) and Massively Parallel Processing (MPP). Currently, it has been implemented for Pam Crash and LS Dyna, but it would also be possible to develop versions for additional crash solvers.

IFAS is an essential element of the CAE environment for the virtual product development process. It plays an important role in overcoming current and future challenges that may arise from ever-increasing crashworthiness requirements, as well as the growing variety and higher strictness of crash testing scenarios (e.g. Euro NCAP). ■

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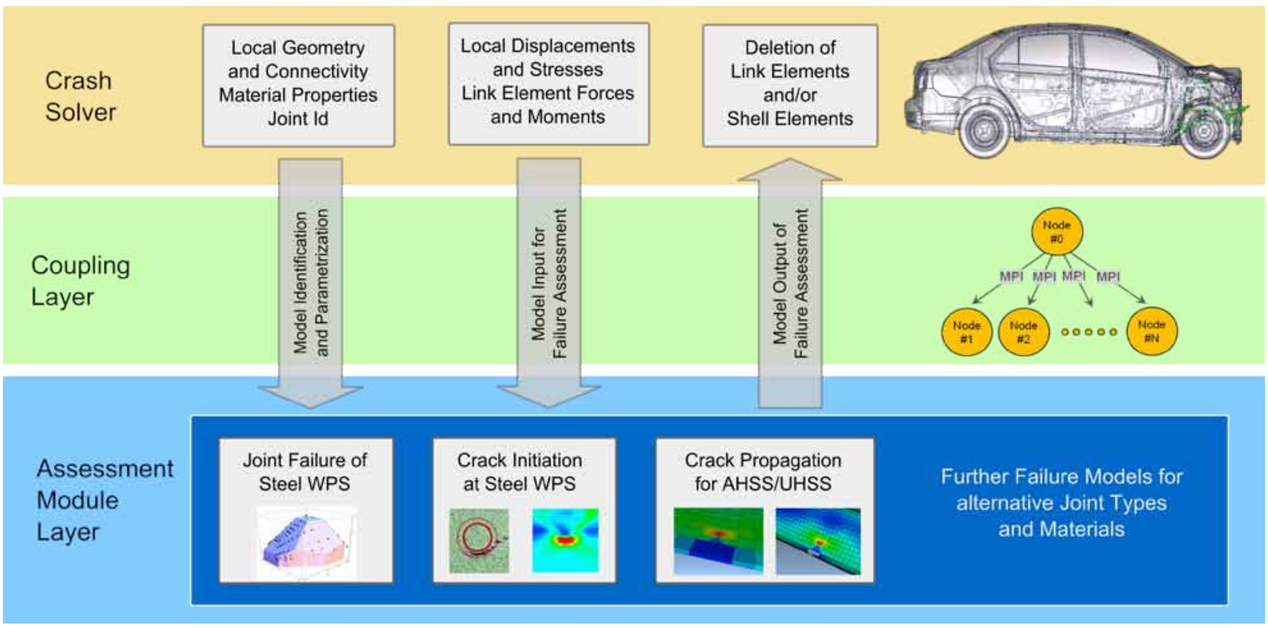

Figure 3: Structure of the Integrated Failure Assessment System, developed by VIRTUAL VEHICLE, Audi and MAGNA.

EFFECTIVENESS ASSESSMENT OF VRU PROTECTION SYSTEMS

Vulnerable road user (VRU) protection is one of the main research topics in vehicle safety. To assess the potential of different types of VRU protection systems for reducing injury severity under real-world conditions, VIRTUAL VEHICLE, in cooperation with BMW, has developed a unique simulation method. It provides detailed, vehicle-specific results across a broad range of critical situations while still being fast enough to be used in a standard vehicle development process.

When designing the VRU protection system configuration in a new car, one main question arises: What is the best system or combination of systems to minimize VRU injury severity under real-world conditions? Only limited testing is possible in this case, due to the large number of possibilities and the need to provide results already in early product development phases. Simulation can overcome these shortcomings and deliver results on time. However, setting up an adequate simulation method and providing suitable solutions poses enormous challenges.

Significant challenges

To compare the effectiveness of different types of protection systems (active, passive, and integrated), a continuous tool chain covering all aspects from ordinary driving to in-crash is required. This is the first challenge when attempting to assess effectiveness.

Many situations have to be considered to be close to real-world effectiveness. These situations should cover the whole range of different accident constellations. This ensures that the system performance is checked under both unusual and common conditions. Stochastic generation of critical situations based on real-world accidents addresses this challenge.

Simulating thousands of situations means the method has to be fast enough to provide results within a reasonable time. One approach would be to skip the slow simulation of the in-crash phase and replace it with general injury risk curves. However, this approach is unable to provide results for specific passive and integrated protection systems. Finding a way to reduce calculation time while still obtaining system-specific results is the third challenge.

Key factor 1: Continuous tool chain

The first main element is an automated, continuous tool chain, which covers the whole accident situation from ordinary driving to in-crash. This is accomplished by using co-simulation to couple models of all relevant elements (vehicle, driver, sensors, safety systems, and environment) and a method for seamless exchange of tools for different accident phases during simulation (e.g. driving dynamics during pre-crash and finite element method (FEM) during in-crash phase to simulate the vehicle's mechanical behaviour).

Key factor 2: Stochastic generation of critical situations

The number of documented real-world accidents is limited and will not cover the whole range of possible accident situations. Therefore, a

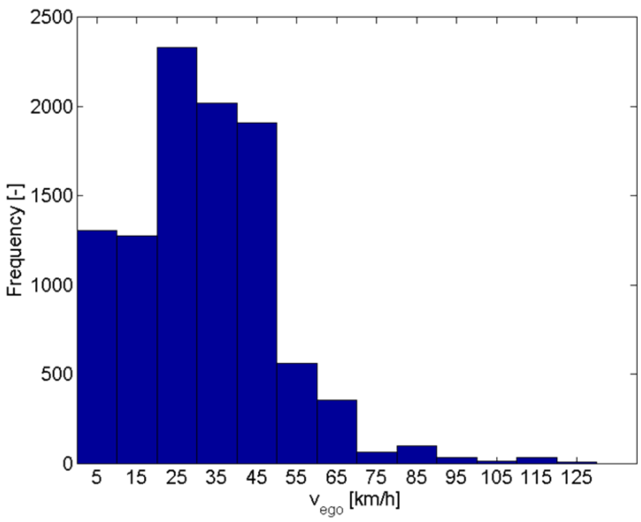

Figure 2: Sample result of the stochastic scenario generation: Distribution of vehicle initial velocities for 10,000 vehicle-pedestrian accident scenarios.

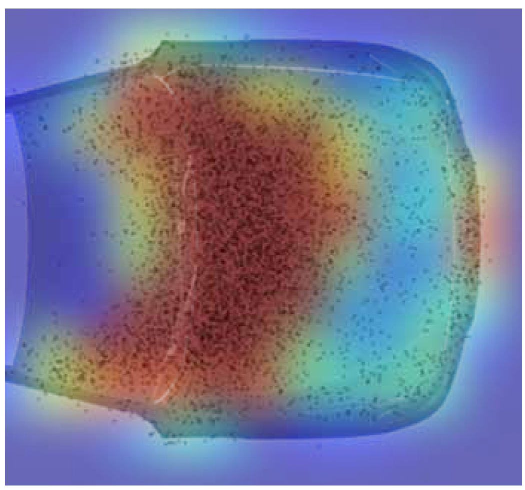

Figure 3: Head impact locations for about 7,000 typical vehicle-pedestrian collisions. This is an intermediate result of the overall assessment method and part of the input for the surrogate model for head impact injury.

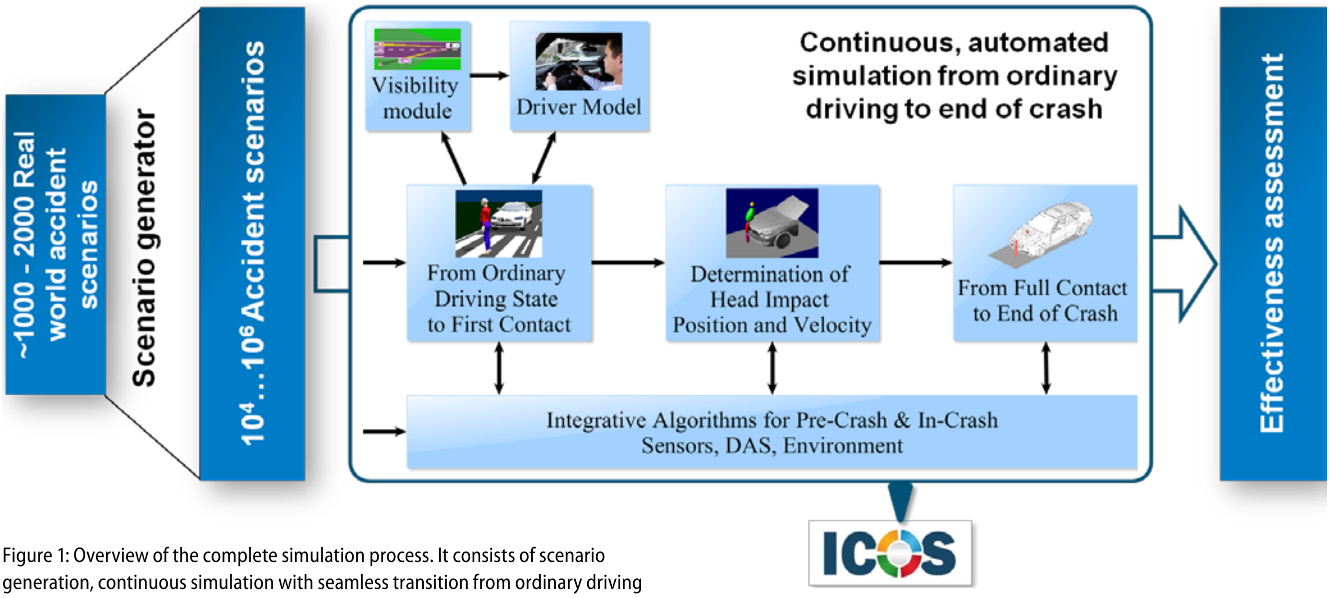

Figure 1: Overview of the complete simulation process. It consists of scenario generation, continuous simulation with seamless transition from ordinary driving to in-crash, and injury-criteria-based effectiveness assessment.

method to create an arbitrary number of critical situations is needed. At the beginning, we start with real-world accident data and use this basis to generate new situations via a stochastic approach. This method ensures that the overall distributions of the generated accident parameters are similar to the distributions in the accident databases. Fig. 2 shows a representative result.

Key factor 3: Reduction of calculation time

Key factor 1 is needed to obtain detailed, vehicle-specific results. This approach includes complex FEM models which need hours to days for one run. These models are the bottleneck for the overall simulation and are too slow to allow for a large number of simulations. Therefore, an alternative is needed to obtain equally detailed results within an acceptable time. The problem has been solved by replacing the FEM models with non-physical black-box models. The great advantage of the black-box models is that, once they have been trained, they are very fast and provide a good approximation of the FEM models. These surrogate models need less than a minute to calculate the 10,000 cases used in the application example, which is described below.

Application example

As an example, the method is used to determine the effectiveness of three protection system configurations: an autonomous emergency braking (AEB) pedestrian system, an active bonnet (the bonnet pops up in the case of a vehicle-pedestrian collision to increase the deformation zone during impact), and a configuration that integrates both systems. The use-case is defined by 10,000 critical scenarios of pedestrians crossing the road from both sides which lead to an accident if there is no intervention by the driver or the AEB system. The AEB system reduces the accident rate by about 50%. In the remaining accidents, the speed reduction due to AEB intervention has more impact on reducing head injury severity than the active hood. Another benefit of the AEB system is that it also reduces leg injury, whereas the active hood only helps to reduce the head injury. Fig. 4 shows an overview of the results of this example.

Reduction by	Injury Criterion/ Injury Risk (AIS2+)
Active Bonnet	
AEB Pedestrian	
Combination	

Figure 4: Results for the study of an active, passive and integrated VRU protection system

Summary

The method developed by VIRTUAL VEHICLE allows for an effectiveness assessment of active, passive and integrated VRU protection systems under real-world conditions when using identical injury criteria. It includes a continuous tool chain for simulating an arbitrary number of accident scenarios from ordinary driving to in-crash without user interaction. It is sensitive to specific vehicle geometry, mechanical properties and the protection system configuration. The method is also easy to adapt, due to the modular co-simulation approach. It is perfectly suited to finding an optimal configuration of VRU protection systems, thereby making the roads safer for the most vulnerable traffic participants as well. ■

THE AUTHOR

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INDEPENDENT CO-SIMULATION WITH MODEL.CONNECT™

THE SOLUTION

Model.CONNECT™ is AVL's open model integration and co-simulation platform. It helps you to connect your existing simulation models - created with different simulation tools - to a consistent virtual prototype. Also the connection of virtual and real components is possible.

THE EXECUTION ENGINE ICOS

One key technology behind Model.CONNECT™ is the execution engine ICOS, that was developed at the VIRTUAL VEHICLE. It is an innovative and independent co-simulation engine for the dynamic integration of CAE modeling tools from various domains.

THE BENEFITS

- Customized wrappers for leading simulation tools (Matlab/Simulink, AVL CRUISE, Dymola, AMESim, GT-Suite, Adams, etc.)
- Full support for interface standards (FMI)
- Industry-leading co-simulation and coupling error minimization
- Local and distributed, OS-independent co-simulation
- Connecting virtual and real components

USE CASE

Example: Integrated Safety ("Tool Chain") & ADAS

- Investigating the effectiveness of integral safety systems
- Considering issues such as driving dynamics, sensors, safety controller, safety structure and crash (including FEM)
- Connecting real-accident database with assessment of ADAS

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MACHINE LEARNING FOR ACTIVE SAFETY SYSTEMS

Future vehicles will be equipped with additional sensors and communication technologies. Detailed information about an accident or critical situations can be recorded. If enough recorded data from critical situations are available, such data could be used to improve Active Safety Systems. This project explores a methodology whereby accident data is directly used to develop a braking strategy for an autonomous emergency braking system using machine learning.

Available Active Safety Systems already address the most common accidents, such as rear-end collisions or accidents with crossing pedestrians. Therefore, in the development process such accidents are analysed, and the necessary strategies are derived. This approach works very well and achieves a high coverage of the most common accidents. In fact, a detailed analysis of accident data by the German Insurers Accident Research has shown that the 26 most common combinations of types and causes of accidents account for 50% of all accidents.. However, the remaining 50% of accidents are caused by about 5,300 combinations of types and causes of accidents. Significantly increasing the coverage of accidents requires too much effort in the development of individual Active Safety Systems. A manageable system requires new approaches that can address a larger variation of critical situations.

Learn from recorded accidents

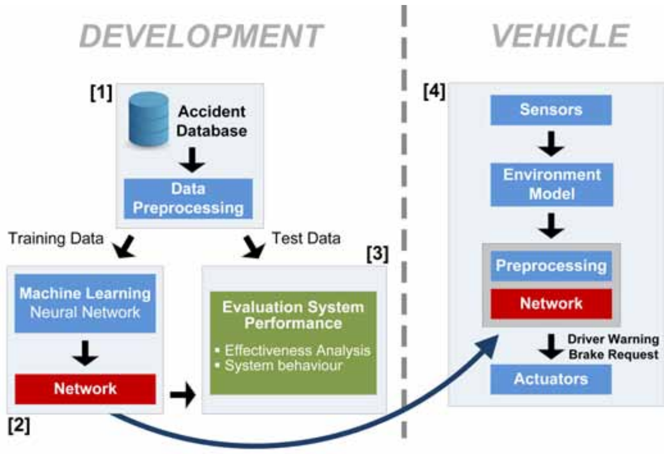
Using the technology built into Highly Automated Driving vehicles, the vehicle itself can record the accident sequence. Based on this recorded data, we investigated how this data can be used to learn the behaviour needed for an active pedestrian protection system. Thereby, we use machine learning to predict the request for a brake intervention. Machine learning in general has the capability to handle uncertainties and to define complex system behaviours, such as pedestrian movement or driver reaction. To this end, a neural network trained on a large amount of pedestrian accidents. The figure to the right provides a schematic representation of the process from the accident data to the transfer of the machine learning algorithm into the vehicle, via the training task for the neural network and the evaluation of the system behaviour.

Performance evaluation

Until now, there were not available recorded accidents that were accurate enough for this purpose. Therefore, we use traffic scenarios generated from an effectiveness analysis to evaluate the methodology. The machine learned algorithm is compared to a reference system, which corresponds to the AEB Pedestrian system in series production.

Summary

The proof-of-concept showed that Machine Learning offers the potential to improve Active Safety. It is possible to reach the desired system behaviour for the traffic scenarios considered. The machine learning algorithm achieves a higher collision speed reduction and does not trigger more false system reactions. However, the verification of the system behaviour presents new challenges. Active Safety Systems, in particular, must also feature deterministic and comprehensible system behaviour. To continue the investigation, we need more accurate traffic data with a higher variation in accident types. Additional generated traffic data can be used to continue investigating our approach for a higher scenario variation. However, ultimately a machine-learned Active Safety System for a production car can only be developed based on real-world data. Therefore, we first need Highly Automated Driving vehicles on the road. ■



Development Process: From the accident data to the function design in the vehicle

THE AUTHORS

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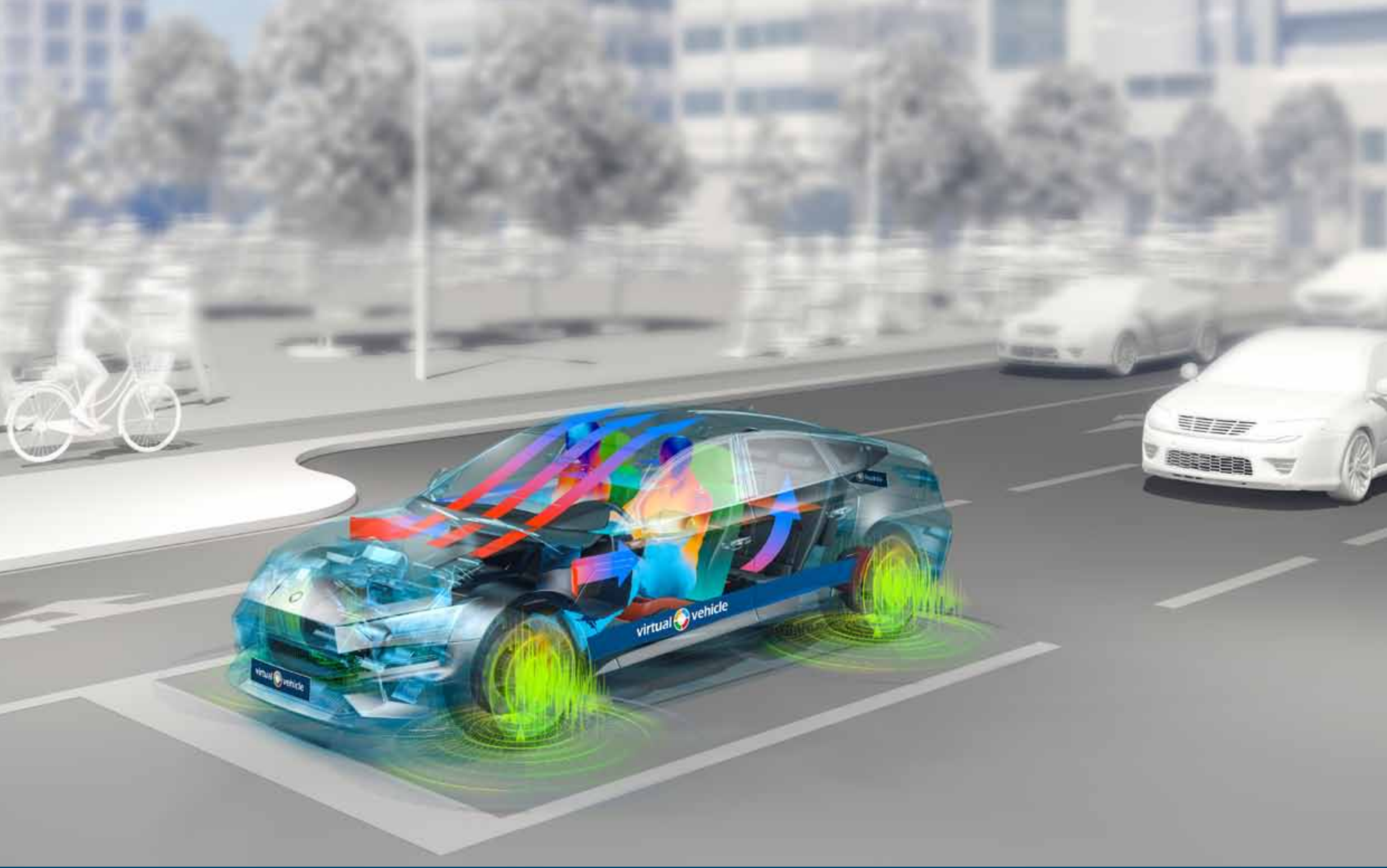


EFFICIENCY & COMFORT

COMPREHENSIVE ENERGY MANAGEMENT & VEHICLE COMFORT

How do electrification, lightweight design and energy management affect the passenger perception of vehicle comfort? To what extent do innovative technologies influence a vehicle's energy consumption? And how can efficiency be maximised while taking into account factors that affect comfort levels both within the vehicle and in the surrounding environment? VIRTUAL VEHICLE's experts in the field of "Efficiency & Comfort" are devising innovative answers to these questions and many more.

The key aspects for comfortable mobility in passenger cars comprise temperature, air quality, noise, vibration, light, ergonomics and the usability of assistance systems. However, the need to reduce CO2 emissions forces the automotive industry to focus on factors such as electrification, lightweight design, advanced and predictive energy management or thermal control strategies, and these factors often have a direct impact on passenger comfort. For example, lightweight design generally increases the noise level in the vehicle, and efficient thermal control strategies have a significant influence on thermal comfort in the cabin.

Wanted: Reliable comfort models

In light of current trends in the automotive industry, several challenges arise in the area of Efficiency & Comfort. For example, many new components that have appeared in recent years (e.g. thermal storages, kinetic storages, active shock absorbers, e-brake systems) have a strong effect on the vehicle's energy consumption). However, there is a lack of reliable comfort models for dealing with these new technologies.

"Efficiency & Comfort" at VIRTUAL VEHICLE

Bearing the aforementioned issues in mind, the researchers in the field of "Efficiency & Comfort" at VIRTUAL VEHICLE focus on three fields of research:

Comprehensive comfort

- Developing models that combine all aspects of comfort
- Examining comfort aspects in the vehicle's surrounding environment (e.g. noise and noxious emissions)
- Developing adaptive and individualised HMI to increase efficiency
- Gauging driver and passenger trust in new technologies, which is closely related to comfort or discomfort

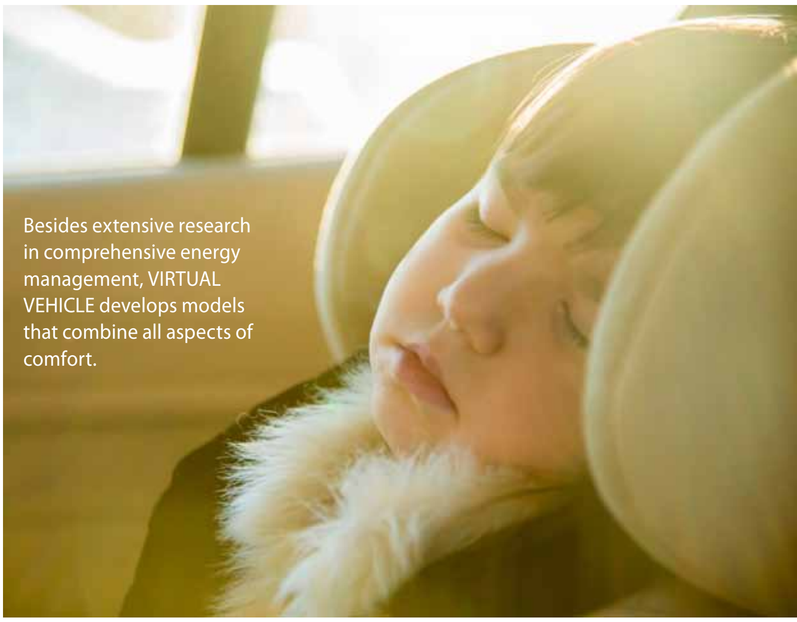
Comprehensive energy management

- Maximising efficiency in real driving situations, taking into account comfort aspects related to the vehicle interior and surrounding environment
- Developing advanced and predictive control strategies (with multi-core architectures) for advanced powertrain concepts, including electrochemical energy storages and thermal conditioning technologies
- Devising methods for reliable range prediction, taking into account environmental issues and the use of infrastructure (e.g. charging stations) by other traffic participants

Sensors and actuators for efficiency and comfort

- Developing reliable methods to assess noise and noxious emissions (environmental aspect)
- Developing reliable methods to assess noxious emissions onboard for SW/HW updates (self-certification)
- Developing actuator technologies to actively control noise and vibrations (in-vehicle comfort aspect)

To sum up, the "Efficiency & Comfort" team at VIRTUAL VEHICLE focuses on developing reliable validated models that can be implemented in a full-vehicle digital context in order to assess use in real driving conditions. These models are related to components and systems, as well as to human behaviour and comfort. Of course, the issue of safety is addressed as well, as increased comfort brings an improvement in the occupants' ability to concentrate and manage complex driving situations. ■



Besides extensive research in comprehensive energy management, VIRTUAL VEHICLE develops models that combine all aspects of comfort.

PREDICTIVE ENERGY MANAGEMENT IN MULTI-CORE SYSTEMS

Currently, the driving range of fully electric vehicles is very limited compared to vehicles driven by internal combustion engines. To help increase the driving range, a comprehensive energy management and enhanced control algorithms are introduced, such as the Model Predictive Controller (MPC). The MPC presented here is a first approach to solving a reference speed tracking problem on a multi-core platform in real-time.

Fully Electric Vehicles (FEVs) are considered a key solution for ensuring sustainable mobility. Among other properties, successful FEVs must provide an adequate driving range. Reducing energy usage is one way to extend range, which can be achieved by an energy-efficient integration of vehicle components and functions. To manage the rapidly growing amount of information and number of communication technology functions in the FEV, a completely revised information and communications technology reference architecture is required. This can be handled by developing and demonstrating an integrated Comprehensive Energy Management (iCEM) system within the Integrated Control of Multiple-Motor and Multiple-Storage Fully Electric Vehicles (iCOMPOSE) project, which is funded by the European Union within the Seventh Framework Programme (FP7) Grant №608897.

The integration of the energy, thermal management and vehicle dynamics controller into a single supervisory controller based on control allocation and MPC techniques yields significant performance benefits in energy efficiency, active safety, driveability and comfort. The iCEM system is implemented on the multi-core control hardware platform (TriCore™ AURIX™) developed by Infineon for high-performance automotive control applications.

The controller benefits from the integration of 'cloud-sourced' information (e.g. from satellite navigation systems, weather conditions, traffic information and mapping information) for the enhanced estimation and prediction of the vehicle states. It enables energy management based on predictive control techniques, for example to determine the optimal torque demand profile and the motor actuation in the case of autonomous driving, including consideration of cornering conditions.

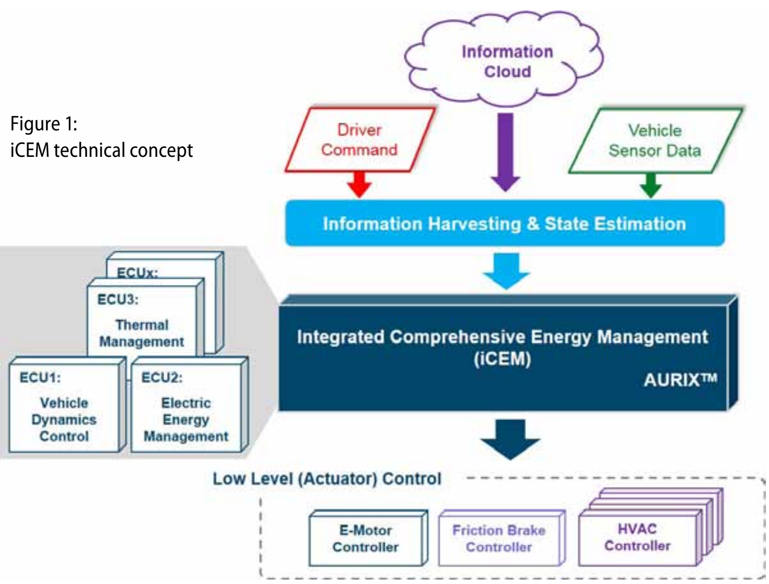


Figure 1:
iCEM technical concept

Approach

To show the flexibility of the control architecture, a semi-autonomous driving mode is implemented in the scope of iCOMPOSE. In this mode, the driver controls the steering wheel angle, but the Central Computing Unit (CCU) controls the wheel torque demand. A high-performance off-board system computes an energy efficient/time optimal reference vehicle speed profile for the journey in advance, which represents the solution of a global optimisation problem that takes all speed limits into account. The reference profile is followed by a predictive controller, which runs on the on-board system within the vehicle. The controller solves a reference tracking problem using a nonlinear, real-time MPC approach and current cloud-sourced data. Fig. 1 shows the technical concept of iCEM and the predictive controller. In this context, data sources and networks within the vehicle are part of the on-board system. Data obtained from sources outside the vehicle are defined as off-board data.

The MPC provides the speed and torque demand to the energy management system. One important requirement is that the predictive controller must be real-time capable in order to run on the AURIX™ platform. This involves the performance of the optimisation algorithm, the structure of the control problem and the size of the MPC horizon.

Central Computing Unit

The iCOMPOSE project requires a CCU that can function as an extension to the established concept of single-domain controllers, such as motor control, battery management or HVAC control. Fig. 2 shows the concept for such an integrated control structure.

Equipping the iCEM CCU with one TC299TX prototype of the Infineon AURIX™ multicore microcontroller family has been shown to meet the needs of the iCEM (i.e. 3 cores running at 300MHz, 2776kB RAM and various powerful communication interfaces, such as CAN-FD, FlexRay and Ethernet).

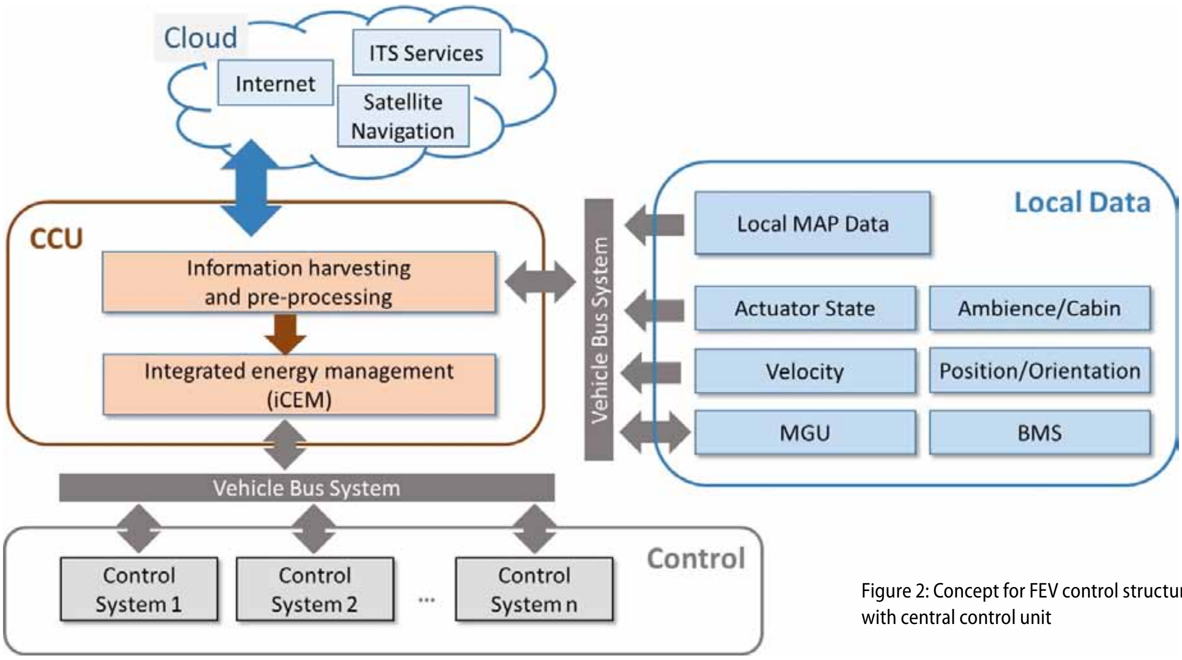


Figure 2: Concept for FEV control structure with central control unit

Software implementation

For the MPC implementation, the ACADO Toolkit[1] and the embedded-qpOASES[2] algorithm are used to solve the optimisation problem. After some adaptations in the code, the MPC is usable on the AURIX™ platform.

For testing, a simplified vehicle model was generated in MATLAB® SIMULINK and subsequently coupled with the MPC running on the AURIX™ via the Independent CO-Simulation (ICOS) framework. CAN communication was established for sending packets between the two models. Fig. 3 shows the remarkable results of this setup.

Summary

The new architecture provides the basis for a real-time-capable MPC. One remarkable result is that the Model Predictive Controller (MPC) approach can be run on the AURIX™ platform. This work gives an insight into an initial implementation of a (nonlinear) MPC using the aforementioned packages on an automotive–qualified, multi-core platform. The results show good potential for further research in this direction and give positive feedback for platforms similar to AURIX™. ■

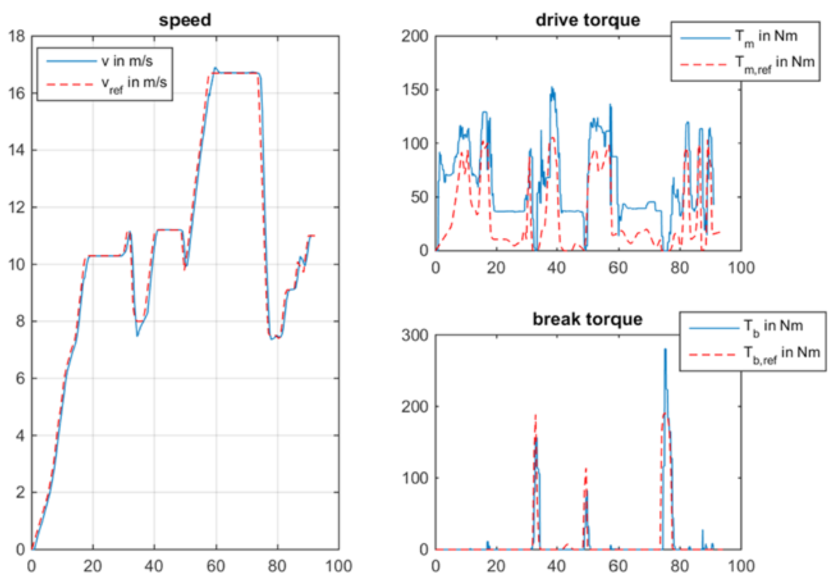


Figure 3: Co-simulation results including MATLAB model and AURIX™ platform coupled over CAN

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ANNOYING BELT RETRACTOR NOISE: A REAL CHALLENGE!

In a joint project, the VIRTUAL VEHICLE Research Center, the BMW Group and the two system suppliers Autoliv and ZF TRW are developing methods to prevent annoying noise from seatbelt retractors during early vehicle development. The developed simulation methodology and the extended acoustic test procedure represent a promising solution in vehicle acoustics.

Belt retractor noise, which can be described as a rattle, chatter, buzz or knocking sounds, is a disturbing noise that occurs in the vehicle interior. It is mainly caused by road excitation, especially on rough roads made of paving stone. Passengers can perceive such disturbing noises from retractor components as annoying or distracting, especially in quiet vehicles with little acoustic masking from driving noise. The retractor noise is excited by impacts between internal parts of the retractor, which are connected via clearances that are necessary for operation.

Vehicle integration and NVH issues

The noise mechanisms of retractors mounted in the car are very complex. Many different mounting positions and orientations, as well as the wide variety of vehicles and derivatives, present a real challenge for component integration because even small deviations can cause critical noise issues. Drawing on the in-depth knowledge of the involved partners and deploying an optimal combination of experimental und simulation-based approaches, an improved understanding of retractor noise phenomena has been generated, which focusses on the following two considerations:

- Apart from proper positioning of the retractor in the vehicle, the deployment of a stiff connection between retractor and vehicle is a fundamental requirement for a low vibration level at the position of the retractor.
- There is a demand for a neutral, generally valid and accepted test facility and procedure for the objective and reproducible noise evaluation of retractors close to real driving operation in the laboratory. This would support vehicle manufacturer efforts to determine the specifications for the supplier and selecting the most suitable retractor type for the vehicle from a NVH perspective.

Supporting an NVH-optimised component integration

Based on the analysis of the contact between vehicle structure and belt retractor, as well as the experimentally evaluated eigenmodes, modelling guidelines are derived for the calculation of the eigenmodes of a reduced Finite Element submodel, which consists of the retractor, the mounting bracket and the local vehicle periphery. Comparisons between the full-vehicle and sub-model levels confirm equal eigenfrequencies (figure 1) and mode shapes.

For a reliable prediction of the retractor vibration behaviour, it is necessary to calculate the nonlinear contact, including the elastic behaviour and the pre-tensioning of the bolting (Figure 2). The calculation of the contact makes it possible to identify an insufficient contact situation, which would reduce the local eigenfrequencies and thereby negatively affect the noise emission of the retractor.

Improved acoustic testing

Based on measurements of the operational vibration and acoustic behaviour in test vehicles under characteristic road excitation, the requirements for the component test rig and the test procedure were derived. Figure 3 shows the vibration levels for a retractor mounted in the back of the car . Each vehicle has its own vibration spectrum.. Besides the low-frequency road excitation (<15 Hz), the highest amplitudes can be found at the retractor's eigenfrequencies (45 to 90 Hz). The excitation of the ball sensor (ball rattling), a very significant noise issue in the car, is mainly excited in the frequency range up to about 50 Hz. Comprehensive investigations for the development of the test rig and the procedure yielded the conclusions described below.

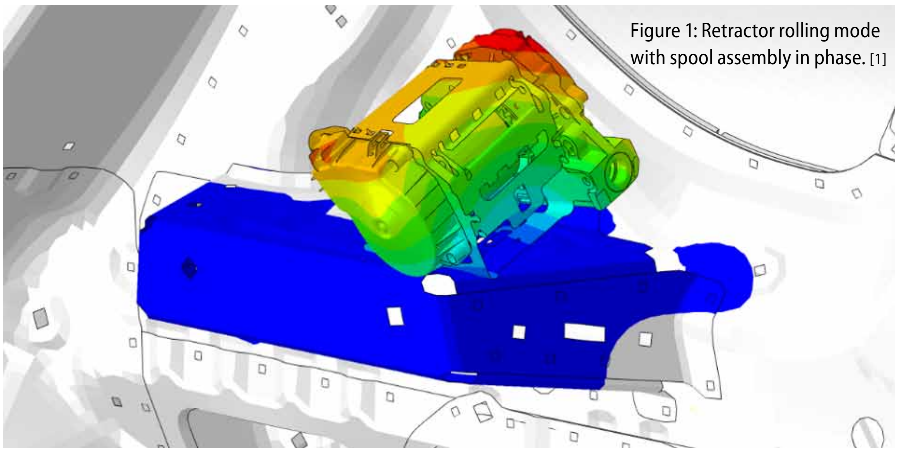

Figure 1: Retractor rolling mode with spool assembly in phase. [1]

So far it has not been possible to reproduce the 3D vibration excitation of the retractor mounted in the car on a component test rig due to the combination of the complex motion in and extremely low noise levels. In addition, the acoustic boundary conditions are different in the car and in the laboratory. Therefore, a uniaxial excitation of the retractor under well-defined, reproducible conditions in an acoustic room is proposed, in order to analyse the acoustic behaviour.

For the component test rig, a stiff connec-

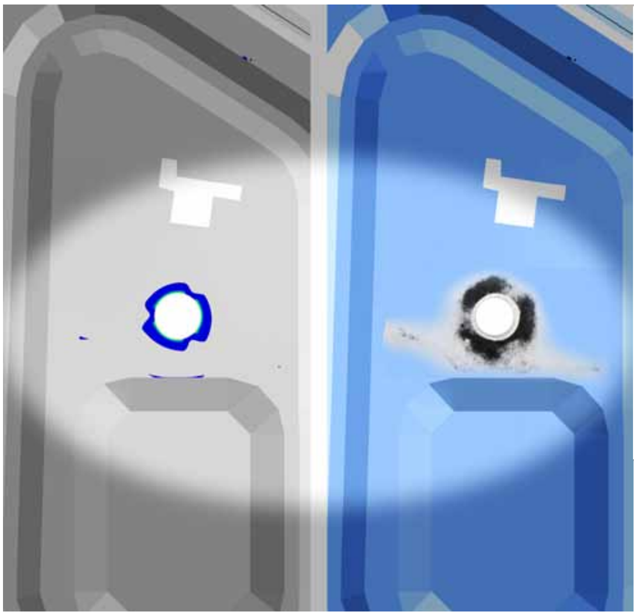

Figure 2: Comparison of the simulated (left) and experimentally evaluated (right) contact pattern [1]

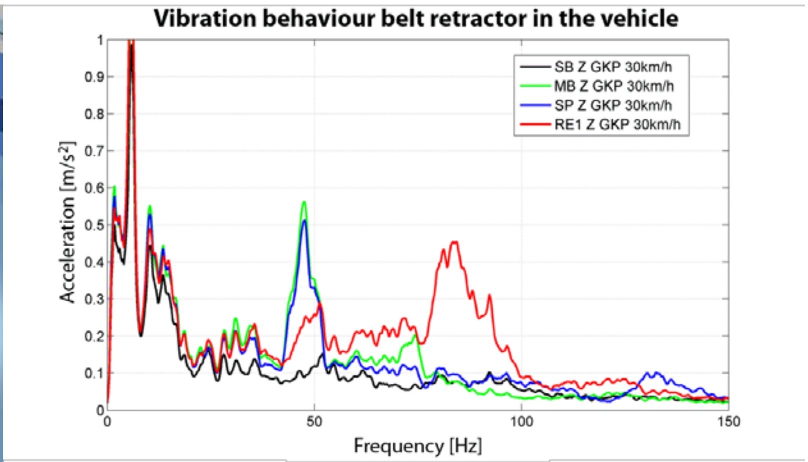

Figure 3: Retractor vibrations measured in a car during paving stone excitation (SB: rear suspension body side, MB: mounting bracket, SP: screw point retractor, RE1: measurement point 1 on retractor) [1]

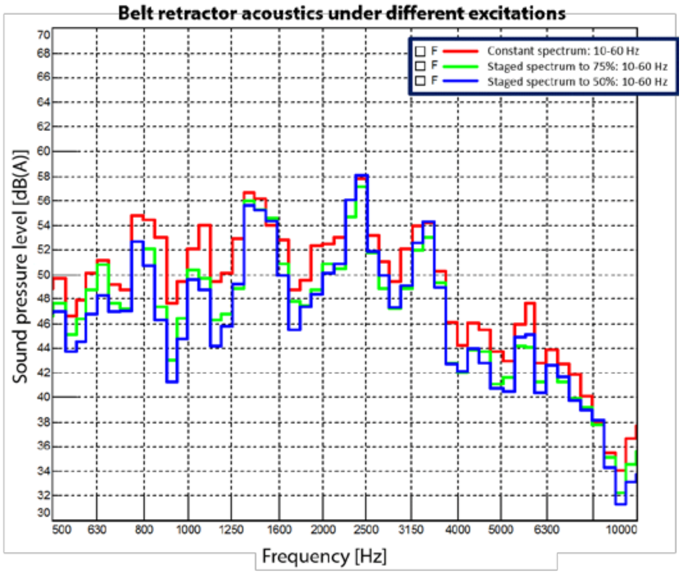

Figure 4: Spectrum of sound pressure level for one retractor under different uniaxial excitation signals in the y-direction (red: constant spectrum 10-60 Hz, green: staged spectrum 10-60 Hz, blue: staged spectrum 10-60 Hz) [1]

tion between the mounting plate and the retractor is needed to shift the eigenfrequencies of the retractor up and to obtain a well-defined vibration excitation without any disturbance caused by the dynamic behaviour. Furthermore, a low disturbance for the non-excited directions is required in order to keep all disturbances low and decrease the variability of results.

Round Robin

To analyse the reproducibility of the test procedure, acoustic testing was performed on different retractors in three different laboratories. In general, the results show a good agreement between the labs and low variance at each lab. The dynamic equivalent continuous sound power level can characterise the differences between the retractors considering the noise emission very well. It includes both the sound intensity and the duration and occurrence of the retractor noise. Nevertheless, due to the alignment towards an equivalent continuous sound power level, an evaluation of the rattling noise remains difficult.

Therefore, a preliminary psychoacoustic analysis was performed. The stationary loudness N10 is a psychoacoustic parameter which describes the perceived loudness of a sound event. The assessment of short pulsed sound events is more sensitive for the typical characteristic of rattling noise and is better suited for the results evaluation. Currently, the close investigation of the psychoacoustic analysis is an ongoing research issue for the project partners.

Summary

Disturbance noises from belt retractors are a real challenge for vehicle manufacturers due to the high complexity of the problem, strict cost and weight requirements and, in particular, due to the need for decisionmaking at early development stages. The partners Autoliv, BMW Group, VIRTUAL VEHICLE Research Center and ZF TRW have developed specific, demand-oriented virtual and experimental methods to improve the vehicle body design in the regions of interest in order to support the target setting in the specification process and in monitoring the product quality. ■

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[1] J. Girstmair, K.-U. Machens, F. Ober, E. Witfeld: „Störgeräusche von Gurtaufrollern – eine Herausforderung!". Automobiltechniche Zeitschrift 7-8/2017.

FEVs IN THE CONTEXT OF FLEET OPERATION

The European Project IMPROVE, coordinated by VIRTUAL VEHICLE, pioneered methods that are key to increasing the number of commercial fully electric vehicles (FEVs). IMPROVE's main achievements are addressing the energy demand in the vehicle comprehensively and predictively, including all components as well as driver behaviour. The route and velocity are optimised by exploiting traffic and weather information via the cloud.

IMPROVE addressed in-vehicle ICT innovations for commercial (fleet-operated) vehicles, which are in some aspects different from private passenger vehicles. They involve different use cases, different trade-offs between comfort, driving dynamics and cost efficiency, and they are embedded in a fleet of several vehicles.

Within this focus, IMPROVE leveraged a set of hardware and software innovations which, in sum, increase the range for the same battery capacity by 20%, increase battery life, reduce the cost of key components and use deeply integrated interconnections between subsystems inside the vehicle and between the vehicle and the outside world (cloud, grid, work, office).

All of these performance increases are achieved while maintaining safety and increasing comfort and wellbeing for the driver(s) of the vehicle.

Objectives, methods and achievements

To take a significant step forward towards increasing the number of FEVs in fleet-operating companies, the IMPROVE consortium identified two major targets: reducing costs (for acquisition and operation) and increasing acceptance.

(1) Reduce cost of components and the overall FEV (acquisition cost target 1)

IMPROVE uses novel hardware platforms to increase performance and, hence, to reduce costs. In this project, an externally excited synchronous machine with enhanced power density was developed . By using special installation features, drive mass, volume and overall system cost are reduced. The installation space for the electrical machine, inverter and charger is the same as for a conventional internal combustion engine, in order to allow for the use of the same production line at OEM site.

(2) Improve energy efficiency and extend mileage (operation cost target)

IMPROVE integrated model embedded predictive control into advanced algorithms to optimise energy efficiency and recovery. It leveraged data obtained from the cloud, grid and (back)-office applications of the driver for in-vehicle control optimisation. An advanced and predictively controlled thermal management system (including heat pump functionality for cabin heating) plays a central role in reducing the energy demand. For energy recovery, an e-brake system was implemented. All these elements were prototyped and installed

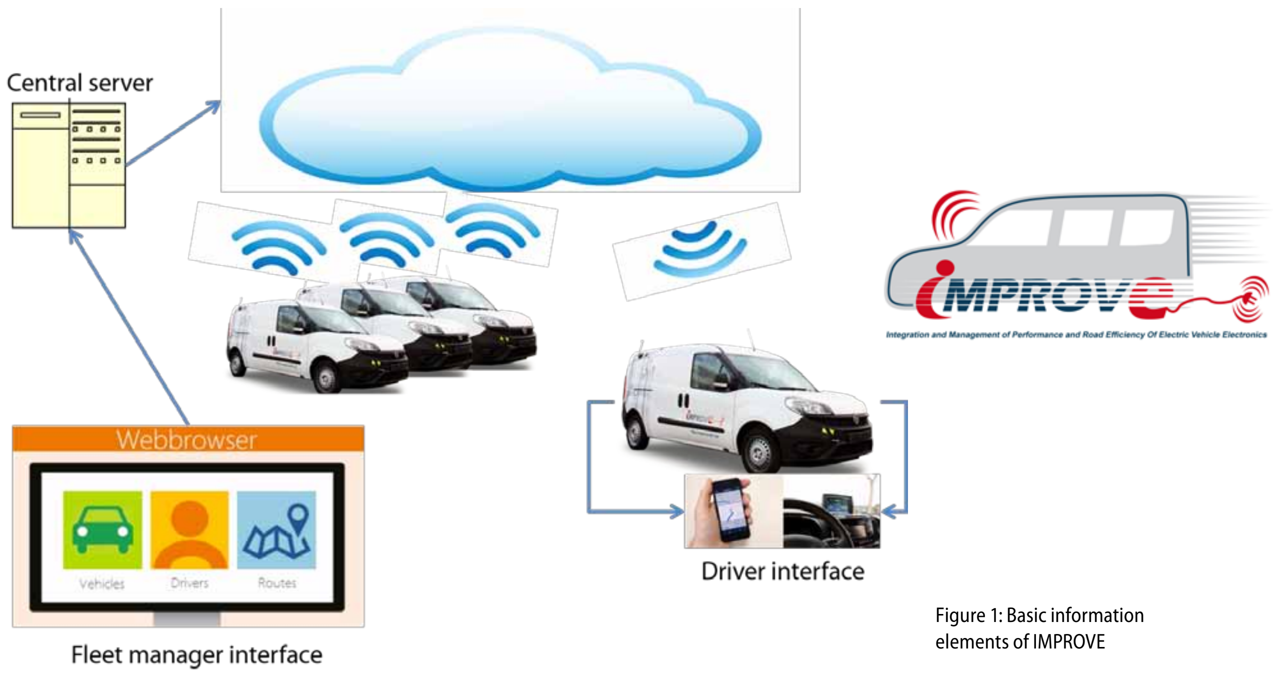

Figure 1: Basic information elements of IMPROVE

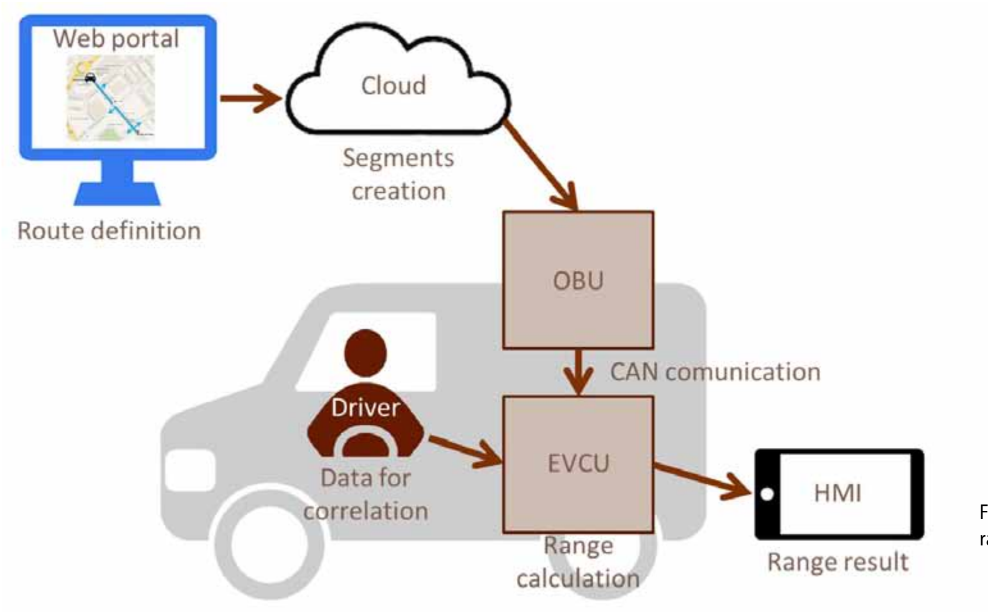

Figure 2: Information flow for range prediction

in a drivable test vehicle, which was subjected to extensive tests under real-world conditions.

Since different driving styles may lead to a difference of up to 30% in energy consumption, gamification features were developed to train the drivers in the vehicle fleet (information is provided in an anonymous form).

By using a holistic approach to the drivetrain, HVAC and thermal management, an optimal management of the energy fluxes within the FEV has been achieved. Including cloud-based data (e.g. global navigation satellite system (Galileo), weather forecasts, traffic data) further improved the energy efficiency of the FEV (Fig. 1). The fleet manager assigns vehicles in the fleet and drivers for a specific route. In a central server, initial optimisations are performed and sent via the cloud (where data from other vehicles are collected as well) to the vehicle. The optimum velocity profile is displayed to the driver by means of HMI or a smartphone app.

(3) Comfort & safety
(acceptance target)

The stable and predictive behaviour of vehicles in the fleet over a wider operating range has been ensured by exploiting information harvesting.

For increased safety, the use of an externally excited synchronous motor makes it possible to shut off the electricity in the rotor immediately in the case of an emergency – thus, no voltage is induced in the stator winding.

A highly efficient 22 kW charger supports fast charging, thereby reducing range anxiety and idle periods.

A reliable range prediction is necessary for increased driver and fleet manager acceptance of electric vehicles. Fig. 2 depicts the information flow for range prediction. A defined route is subdivided into segments, which can be estimated more easily. This information is passed to the vehicle and augmented with a model of the respective driver, and it then provides the basis for an improved range estimation that can be obtained via mobile app or via the cloud.

Outlook

The novel control strategies enable the production of high-performance electric vehicles that are attractive to customers around the world. The experimental evaluation and demonstration of the IMPROVE results at the full-system level advances not only the research related to comprehensive energy management, but also the understanding of power electronics and energy storage technology.

Since fleet operators will benefit directly from the IMPROVE findings in terms of cost and reliability, and additional financial benefits can be expected in several cities and regions due to government funding, it is assumed that the EV increase will be driven to a large extent by the sector of light-duty commercial vehicles.

Partner organisations of IMPROVE

The IMPROVE consortium combined the strengths of very large, large, mid-sized and small companies with the academic/technological excellence of established academic and research centres, thereby enabling it to optimally apply the project results in future vehicles and services with substantial impact on Europe's Green Car objectives.

Besides project management, VIRTUAL VEHICLE contributed its experience in vehicle functional safety, power and signal distribution, can communication and co-simulation-supported control integration. ■

All partners and further information:
improve-fp7.eu

SEVENTH FRAMEWORK PROGRAMME

The project is co-funded by the 7th Framework Programme of the European Commission.

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ENERGY-EFFICIENT DRIVING IN A DYNAMIC ENVIRONMENT

Although researchers and engineers have been investigating the topic of energy-efficient driving for more than a decade, they have not yet paid significant attention to surrounding traffic participants as a constraint and overtaking possibility. Neglecting these constraints when generating an energy-optimised speed trajectory may lead to trajectories which are unattainable in real driving situations, and may eventually result in greater energy consumption and lower driver acceptance. VIRTUAL VEHICLE has developed a method for planning energy-efficient driving of (semi)autonomous electric vehicles operating in a dynamic environment while also taking other traffic participants into account.

Energy efficiency in transportation systems is a long-standing goal. Optimisation approaches are related to vehicle design optimisation, the use of alternative propulsion systems and driving behaviour optimisation.

For many years, engineers have been working on optimising vehicles, but ultimately one limitation for achieving high energy efficiency is driver behaviour. Studies have shown that energy consumption may vary by around 30% depending on the driving behaviour. Increased automation in series production vehicles enables precise control, predictive planning and optimisation of driving behaviour and is a key for achieving the best energy efficiency.

Driving-behaviour-related approaches for improving energy efficiency can be grouped into:

- "eco routing" – for finding energy-optimised routes,
- "using road slope information" – for generating energy-efficient velocity trajectories,
- "traffic light assist" – for planning approaching and passing traffic lights in an energy-efficient way,
- "platooning" – for following other vehicles to decrease air drag resistance, and
- "overtaking" – for overtaking slower vehicles in order to continue driving on an energy-efficient trajectory.

Our current research focuses on an approach to overtaking. Up to now, this topic has not been well covered by the literature. One existing approach considers other traffic participants and optimises the overtaking problem by modifying a previously generated optimal trajectory in order to satisfy the constraints imposed by surrounding traffic. In contrast, the method developed at VIRTUAL VEHICLE incorporates a leading vehicle's motion as a constraint in the original optimal control problem. In this way, the generated trajectory is globally optimal. In addition, the overtaking decision-making itself is part of the optimisation, which allows for the possibility of not overtaking at all.

Optimal control problem

From a mathematical point of view, this problem can be addressed as an optimal control problem with an appropriate cost function to evaluate speed trajectories. The cost function has to reflect the initial requirement of minimal energy consumption. This includes energy used for propulsion and energy used on-board (e.g. infotainment, air conditioning, component temperature management). A vehicle dynamics

Figure 1: Approaches to increase driving energy efficiency

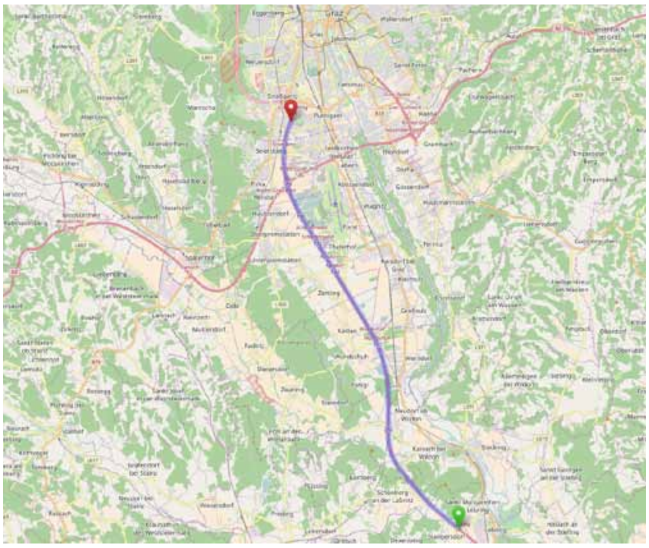

Figure 2: Segment of a A9 highway in vicinity of Graz used in simulation. ©OpenStreetMap

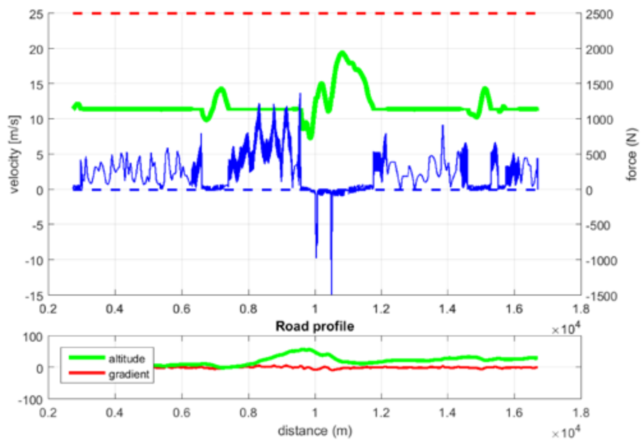

Figure 3: Optimal speed trajectory generated by using road slope information for predictive planning

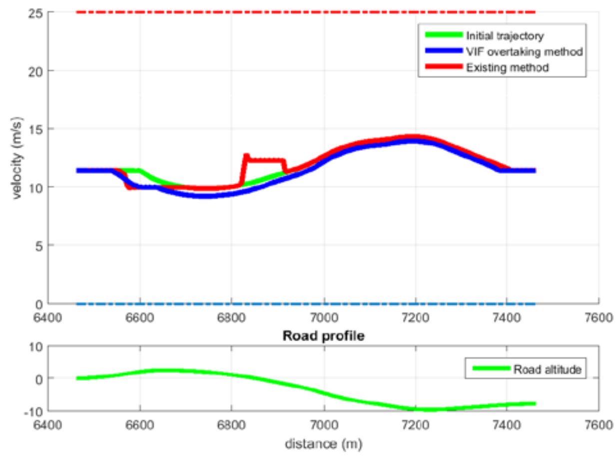

Figure 4: Comparision of VIRTUAL-VEHICLE-developed overtaking approach vs. existing approach

model is used to estimate the propulsion force needed to compensate for resistance forces (gravity, air drag, roll resistance) and to provide the required acceleration. When considering only this aspect, energy-efficient behaviour would result in smooth, low-speed driving (almost zero). However, as on-board energy usage is proportional to driving time, slow driving increases overall consumption. The optimal speed trajectory is therefore a balance between these two perspectives.

In addition, an optimal speed trajectory has to satisfy several constraints. Constraints can be internal and external. Internal constraints arise from system limitations (e.g. maximum acceleration, velocity, torque), while external constraints are caused by the environment (e.g. traffic signs, other traffic participants). The integration of constraints such as collision avoidance is not straightforward, as these constraints depend on the driving trajectory of the controlled vehicle itself.

Optimal motion planner

To solve this (generally) nonlinear problem under consideration of the time-varying constraints, we developed a motion-planning framework based on dynamic programming (DP). Utilising the advantages of forward and backward DP enables the consideration of constraints on internal states as well as constraints arising from the external environment. Beyond time/space invariant constraints, the approach allows for the consideration of time and space varying constraints as well. Using the predicted movement of other traffic participants, an optimal trajectory without collision is generated. This is used for decision making on possible overtaking manoeuvres.

Results

Initial simulation results show that considering other traffic participants is important when planning energy optimal driving. Even on a simple setup, the proposed driving strategy uses 2.5% less energy compared to existing optimal overtaking approaches.

Simulation results from different scenarios are used to make preliminary conclusions on overtaking decision-making. The results obtained support some the preliminary conclusion that in many cases it may be more energy efficient to overtake on horizontal road segments than on a road segments with a slope. The results also support the conclusion that it is not always best to overtake other vehicles, even though the desired velocity in the unconstrained problem is higher than that of the leading vehicle. Depending on the speed difference between the ego vehicle and the other vehicles, in some cases it is better to slow down and follow. ■

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PASSENGER COMFORT

The "Comfortable Vehicle" includes a wide range of topics and domains, from Noise, Vibration and Harshness (NVH) and thermal comfort to driver assistance systems, and requires innovative ideas from different perspectives. Passenger cars with a high degree of electrification must manage the trade-off between comfort and driving range. In this context, the air conditioning system plays an important role, as it has a significant impact on the passenger comfort and the energy demand. Investigations within different projects at Virtual Vehicle have shown that with only small changes in the system architecture, a preconditioned traction battery integrated in the heat pump circuit can be used as heat storage, which considerably improves energy efficiency. In addition, advanced CFD simulation methods for aero-acoustics can increase comfort in the passenger compartment.

The current trend towards green mobility forces car manufactures to adopt novel strategies to lower both fuel consumption and exhaust emission levels. Lightweight design, downsizing and drivetrain electrification are among the common strategies for meeting this demand. Unfortunately, these measures also imply conflicting design targets with respect to passenger comfort:

- Thermal passenger comfort versus driving range
- Deterioration of noise, vibration and harshness (NVH) functional performance attributes due to lightweight design
- Heating, Ventilation and Air Conditioning (HVAC) noise vs. miles/KWh in electrified vehicles

In this context, the challenge is to find optimal solutions for both environmental impact as well as passenger comfort. At VIRTUAL VEHICLE, advanced simulation and experimental techniques are being applied to address this issue in national and international research projects.

Thermal comfort and driving range

As there is a trade-off between driving range and thermal passenger comfort in electric vehicles, these issues have to be considered jointly. New solutions and approaches for air conditioning systems are necessary. In this context, Virtual Vehicle investigated the potential of using a thermally preconditioned battery for heat storage. This small change in the system architecture considerably improves the energy efficiency, while keeping comfort at an acceptable level.

The impact upon the overall system efficiency of a battery that is integrated into a refrigeration circuit and thermally preconditioned can be best illustrated by means of an annual energy demand analysis. Since this cannot be accomplished on a test bench, a validated refrigerant cycle model within the simulation environment Dymola was coupled with a cabin model. Using target specifications for conditioning the virtual cabin (based on DIN 1946-3) and a vast spectrum of ambient conditions that covers all operation modes, maps for power and efficiency of the considered system were derived from the simulation. These maps, together with climate data (e.g. ambient temperature, relative humidity, solar radiation) were processed within the existing annual energy demand calculation. In order to compare annual energy demands, the energy demand of the system was calculated once with the use of the battery as a heat source and once without. In addition, the analysis was carried out for three different geographic locations: Graz (Austria, moderate climate), Athens (Greece, warm climate) and Helsinki (Finland, cold climate). The results in Figure 1 show that the energy saving potential in heat-pump heating mode can be significantly increased by using an alternative heat source.

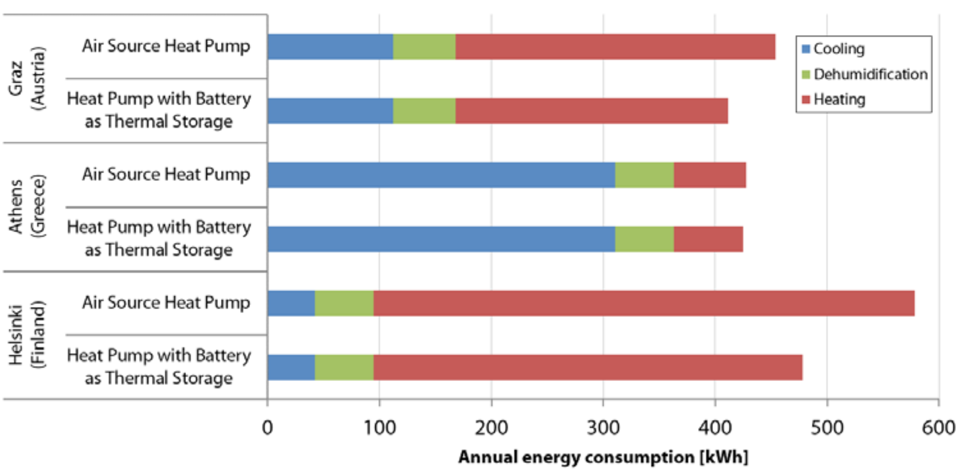


Figure 1: Comparison of the annual energy demand of the presented air conditioning system with and without the use of a thermal preconditioned traction battery [1]

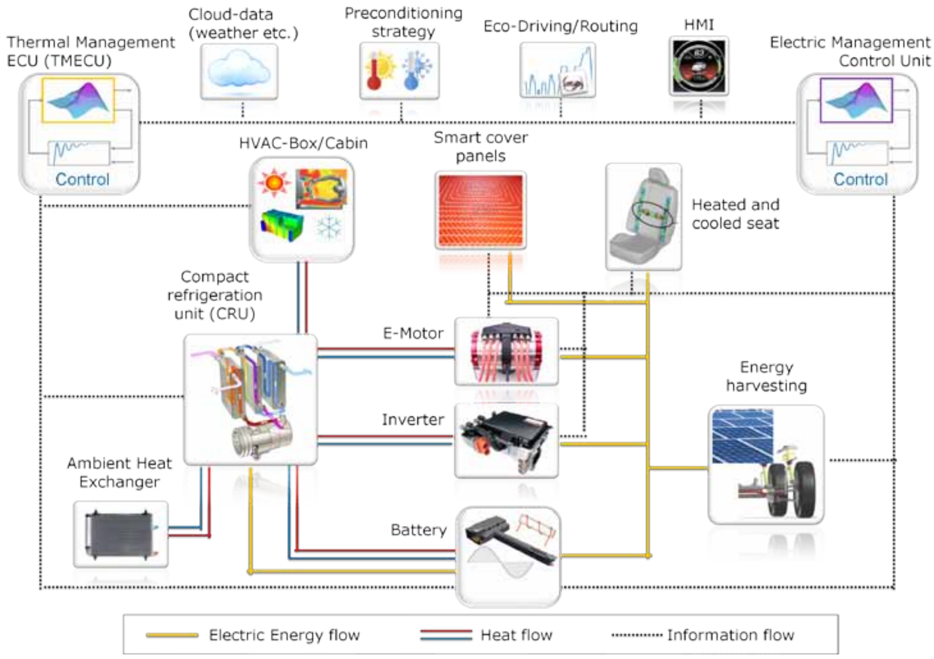


Figure 2: Schematic overview of the main technologies and dependencies in the OPTEMUS project

For geographic locations with a high heating demand (e.g. Helsinki), using the battery as a heat storage and source reduces the overall energy demand for cabin conditioning by 17 %.. Similar results can be seen for the prevailing climatic conditions in Graz. The calculated and measured results of the test bench run show that a higher Coefficient of Performance (COP) can be achieved by utilising the battery as a heat source for cabin heating during an operation time of 10 min. The implementation of the battery as a heat source into the heat pump system shows a remarkable increase of the driving range from 101 to 105 km (+4 %), which can be further enhanced by increasing either the battery mass or the temperature level at which the battery is thermally conditioned. Detailed information on this topic can be found in [1].

A much broader overall approach is being used in the EU-project OPTEMUS, which is led by the Virtual Vehicle (Horizon 2020 grant agreement No. 653288) to increase the driving range while maintaining thermal comfort for the passengers of E-Vehicles. This topic is tackled by leveraging low-energy consumption and energy harvesting through a holistic vehicle-occupant-centred approach, considering space, cost and complexity requirements. Specifically, OPTEMUS intends to develop a number of innovative core technologies (e.g. integrated thermal management system comprising the compact refrigeration unit and the compact HVAC unit, battery housing and insulation as thermal and electric energy storage, thermal energy management control unit, regenerative shock absorbers) and complementary technologies (e.g. localised conditioning comprising the smart seat and the smart cover panels, photovoltaic panels) combined with intelligent controls (e.g. eco-driving and eco-routing strategies, predictive cabin preconditioning strategy with minimum energy consumption, electric management strategy). Figure 2 provides a schematic overview of these technologies.

Aerodynamic noise and lightweight design

Particularly at high driving speeds, aerodynamic noise is of major importance for passenger comfort. Moreover, large structural subsystems of a car body (e.g. doors, panels and windows) are likely to couple well with the exterior flow field, in particular when a lightweight approach is adopted. Numerical prediction of flow-resonant, low-frequency noise in the early development phase is therefore becoming a key point in the design of modern vehicles.

To account for this noise generation mechanism in a numerical simulation, we developed a forward-coupling strategy, which integrates transient computational fluid dynamics (CFD) analysis with a vibro-acoustic finite element method (FEM) model into one seamless workflow. The numerical workflow developed accounts for both (i) the direct flow-resonant noise generation phenomena via openings and leakages, and (ii) the indirect transfer paths via flexible structures (see Figure 3). As a mutual phase relationship becomes important at lower frequencies, both noise transfer mechanisms must be correctly represented in the vibro-acoustic FE model to preserve the phase information.

In order to validate the numerical results, simulation work has been complemented by experimental tests conducted in an aero-acoustic wind tunnel (see Figure 4). During these measurements, both airborne and structure-borne data noise have been acquired to better understand the aerodynamic excitation mechanisms and complex transfer paths that occur on a real car.

HVAC noise and vehicle electrification

The HVAC system must provide suitably high air mass flows to ensure a comfortable environment for the driver, as well as to satisfy certain

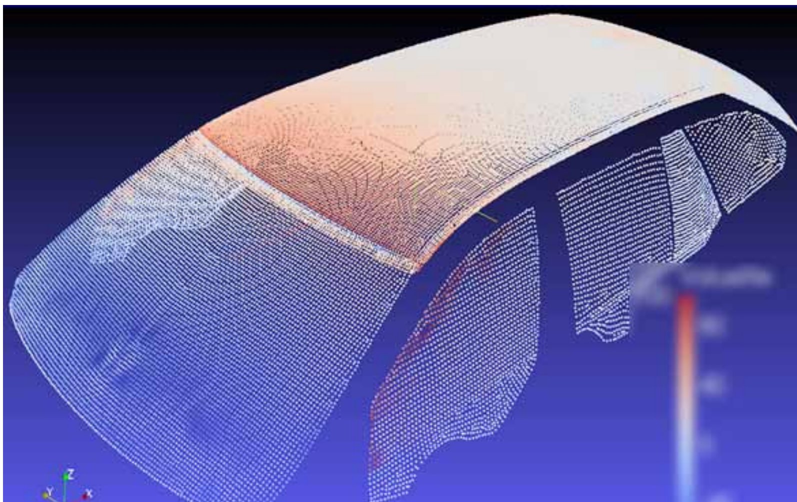
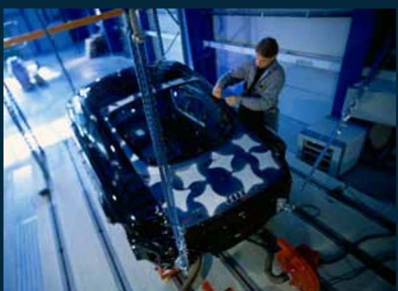


Figure 3: Coupling between CFD and FEM - pressures from CFD simulation mapped onto FE mesh

virtual vehicle

NVH & Friction Testing & Validation



Leading-edge Testing

- Structural dynamics and airborne sound
- Modal analysis, (operational) transfer path analysis
- Detailed friction analysis of engine and powertrain
- Trim characterisation
- Psychoacoustic investigations

Acoustic Engine Test Rig

- Fully Anechoic acc. DIN 45635
- Lower Limitation Freq. 100 Hz
- max Power: 400/440 kW motored/brake
- max. Input Speed: 7000 rpm
- max. Input Torque: 4000/1870 Nm
- Dimensions: 7.2 x 5 x 4.5 m

Acoustic Powertrain Test Rig

- Semi Anechoic acc. DIN 45635
- Lower Limitation Frequency: 100 Hz
- max. Power: 400 kW
- max. Input Speed/Torque: 7000 rpm / 1000 Nm
- max Output speed/Torque: 2500 rpm / 3200 Nm
- Dimensions: 8 x 4 x 4.5 m

Modal Analysis Test Rig

- Payload: max. 4000 kg
- Modal Shakers
- Impact Hammers
- Laser/Accelerometers
- Dimensions: 4 x 6 m

Friction Dynamometer (FRIDA)

- max. Input Speed: 10000 rpm
- max. Cylinder Pressure: above 200 bar
- Externally stabilized supply of coolant and lubricant
- High-Precision Friction Mapping

safety aspects (e.g. windscreen de-icing). At these operating conditions, the HVAC unit is likely to become a dominant noise source in the passenger compartment. This is especially the case in electric vehicles, which lack the masking noise provided by the conventional internal combustion engine.

Numerical modelling of these aeroacoustic phenomena typically relies on a so-called hybrid approach to reduce the complexity of the problem [2]. Combining incompressible CFD with a Computational Aero Acoustics (CAA) solver eliminates the need for a complex separation of dynamic pressure into acoustic and hydrodynamic components. These pressures usually differ by magnitudes (disparity of scales [3]), which makes a one-step solution by complete compressible CFD solution very difficult. Moreover, each sub-problem can be solved by the most suitable numerical scheme. Thus, the flow field is modelled by a finite volume discretisation of the incompressible Navier-Stokes equations in the time domain. For this type of problem, well-established solvers exist in commercial and open source software packages. On the other hand, the acoustic field is treated in the framework of the finite element method, which is well-suited to prevent any artificial sound refraction within the ducts, as well as in the acoustic far field.

The related workflow (cf. Figure 5) is also applicable to rotating parts. Therefore, any type of blower (axial or radial) can be investigated with respect to tonal components (blade pass frequency), as well as broadband noise. The cut-off frequency and high-frequency damping of the broad band noise is limited by the time and space resolution of the different solvers. The numerical results have been experimentally validated for blower acoustics, as well as for entire HVAC units.

Conclusion

Numerical prediction techniques have become an indispensable tool to support the vehicle design process in its very early stage and hence to ensure that the comfort targets set will be met. This article presented some of the current vehicle design challenges emerging due to the conflicting design objectives, which require a multi-disciplinary approach.

In recent years, Virtual Vehicle has been active in this research field, which is evident from the numerous examples of both completed and ongoing research projects. The future trend is to combine the best-in-class numerical methodologies into one integrated workflow based on their relative merits and to adopt experimental techniques where appropriate. ■

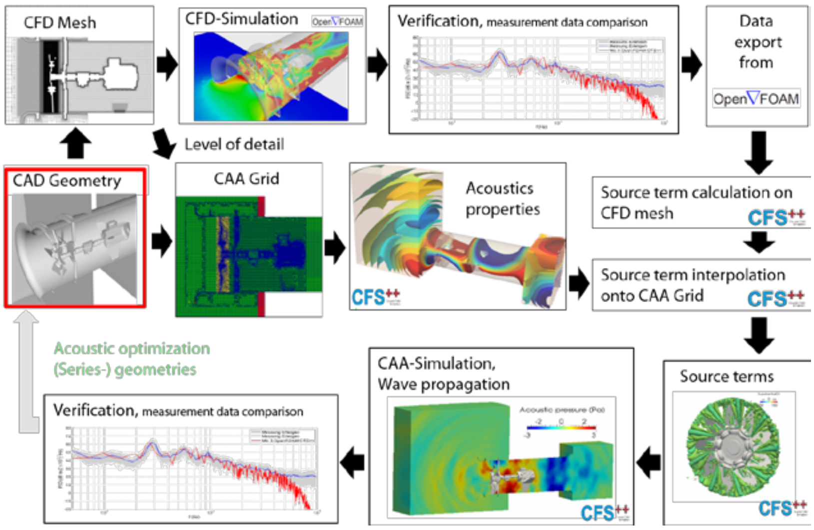


Figure 5: Workflow for aero-acoustic simulation of HVAC system within framework of hybrid approach

Figure 4: Experimental testing in aero-acoustic wind tunnel

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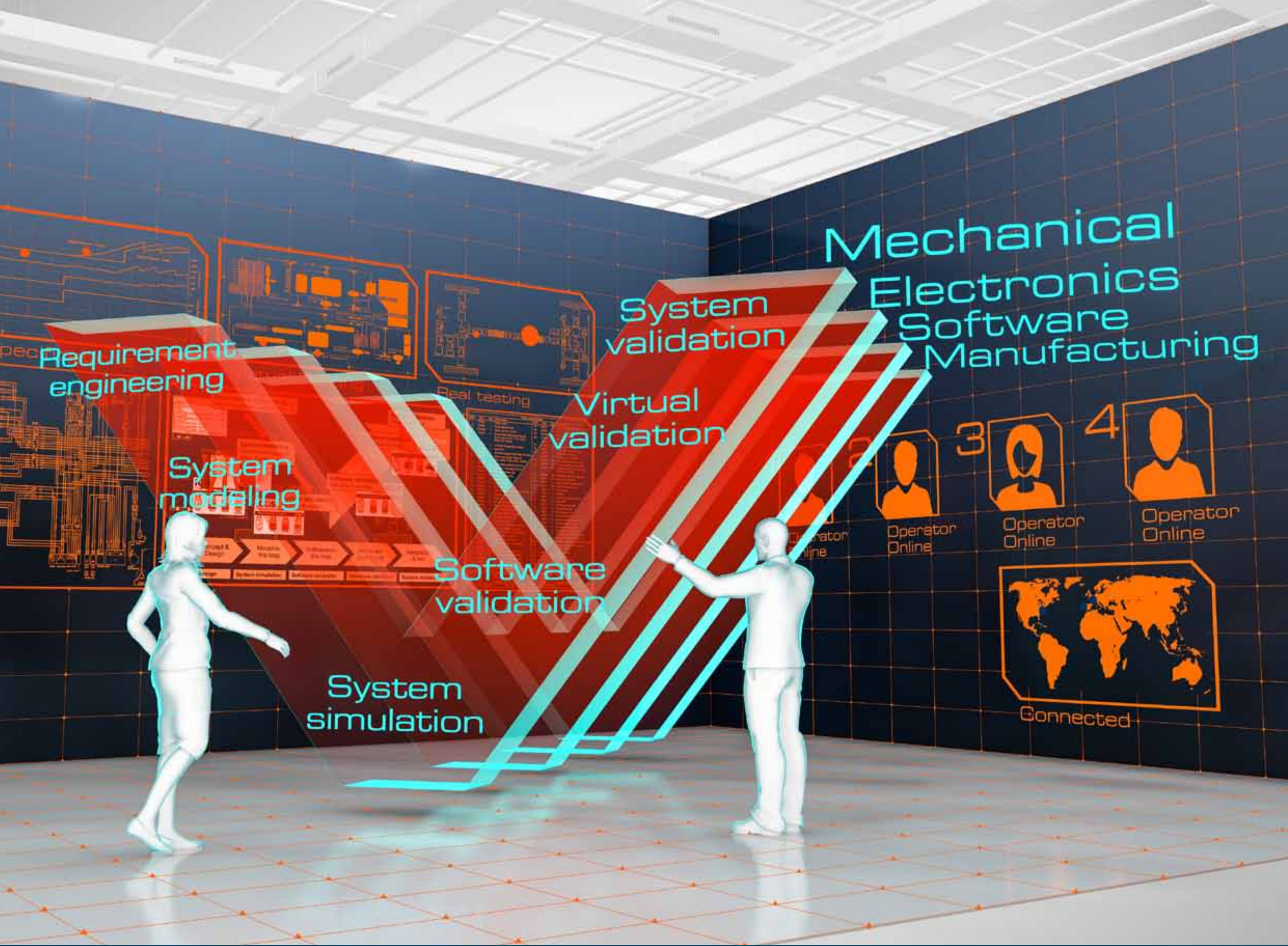


EFFICIENT DEVELOPMENT

HOW TO IMPROVE EFFICIENCY IN SYSTEM DEVELOPMENT

The partitioning of the overall vehicle system into different subsystems is common practice in the automotive industry. Technological domains and separate design activities are carried out at OEM and supplier sites, which leads to an enormous challenge in terms of efficient system development and design management. One promising possibility to meet this challenge is the model-centric, consistent system development approach – a distinct focus of the researchers at VIRTUAL VEHICLE.

In the coming years, the automotive industry will face a radical change. Software will be a central driver and enabler for new functions and innovative technologies. Moreover, the development of vehicles will inherently involve multi-site, multi-domain and cross-company teams.

These current trends are directly associated with a strict partitioning of the overall vehicle system into different subsystems: related technological domains and separate design activities are carried out at OEM and suppliers sites. As a matter of course, this massive partitioning lends itself to a beneficial parallelization of development activities, which is necessary for the required development speed and timely delivery.

Challenges

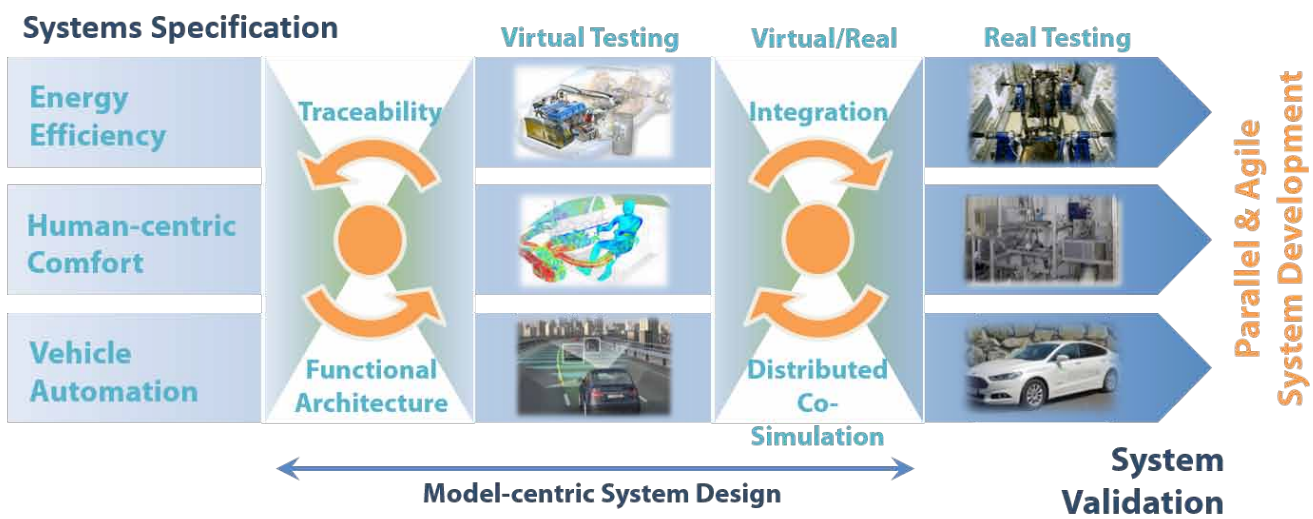
Although there are well-defined and well-enforced process models (e.g. V-model), a multitude of disturbances (e.g. late requirements, incorrect assumptions, supply chain disruptions) can lead to inefficient implementations and errors. Long redesign cycles, cost overruns and unacceptable delays are the results. Toyota's infamous recall of approximately 9 million vehicles due to a sticky accelerator and Boeing's 787 delay (which resulted in a cost of about $3.3 billion) are just two examples of the devastating effects that design problems may cause.

Developers agree that bold steps have to be taken to bridge the gap between Systems Engineering (high level) and System Science (low level). One promising possibility for coping with this current situation are model-centric, consistent system development approaches.

The model-centric approach

The model-centric approach enables consistent system development. Based on common functional system descriptions and architectures, systems are generated virtually and analysed at a scalable level of detail, while appropriate tests are automatically derived for V&V evaluation purposes. Mandatory functional safety aspects (such as ISO26262) and the design for safety-critical systems are straightforward extensions. The challenge is now to augment these approaches for highly distributed, parallel and agile systems engineering, which will help to "deverticalize" industries and to reduce development time and costs.

The researchers at VIRTUAL VEHICLE take model-centric approaches as a core research topic. Outstanding advances are expected in safety-critical systems, flexible scalability in design or the back-traceability of faults detected during system validation. One major target of the research center is to investigate and define approaches for massively parallel, distributed and collaborative engineering of vehicle systems, from requirements, through design, right up to realisation in hardware and software. ■



Bottlenecks in consistent system design

BUILDING THE FUNCTIONAL "DIGITAL TWIN" IN A SMART FACTORY

Digital Twin concepts aim to mirror real processes in the factory in order to get direct control. While current concepts primarily reflect the plant's resource situation, new concepts which cover the individual characteristics of each production part open up many more opportunities.

During the production preparation phase, the state-of-the-art is to simulate the process considering the most relevant parameters. Although statistical analyses are commonly used to test the robustness of a single production process, the tolerance ranges across multi-stage production processes are widely ignored. This is because, in practice, a combinatorial analyses is far too complex and would likely show that a worst-case combination simply will not work. The way to solve this problem is to narrow the tolerances on the parameters to maintain functional requirements under all conditions. Unfortunately, this is the crucial driver of manufacturing cost.

Vision

A possible way out of this dilemma would be to assure already during the production process the conformity to the functional requirements for each individual component being produced rather than meeting (indirect) tolerance and process requirements. This approach requires analysing the function (via a simulation) for each component being produced with its relevant and individual specific characteristics in parallel to the running process and preferably within the real cycle time. To implement such an approach, it is crucial to know the individual characteristics of the component. Assuming that not every relevant parameter can be measured directly via sensors, it is required to run the production preparation simulations for each individual process in parallel to the actual running production process, using the actual parameters instead of predefined nominal. As a result, each component being produced is linked to its production parameters and hence has its unique fingerprint characteristics. In a smart factory, it is understood to handle this data linked to the component (e.g. in the PLM or ERP system).

Linking process and function simulation

Consequently, it makes sense to tackle situations where the production process has a strong influence on the characteristics and performance of the produced component – and it is not easy to stay within the tolerances in order to maintain the quality.

Choosing a reference process as a use-case

The production process "hot stamping" serves as a reference process for the prototypical implementation of a function-oriented process

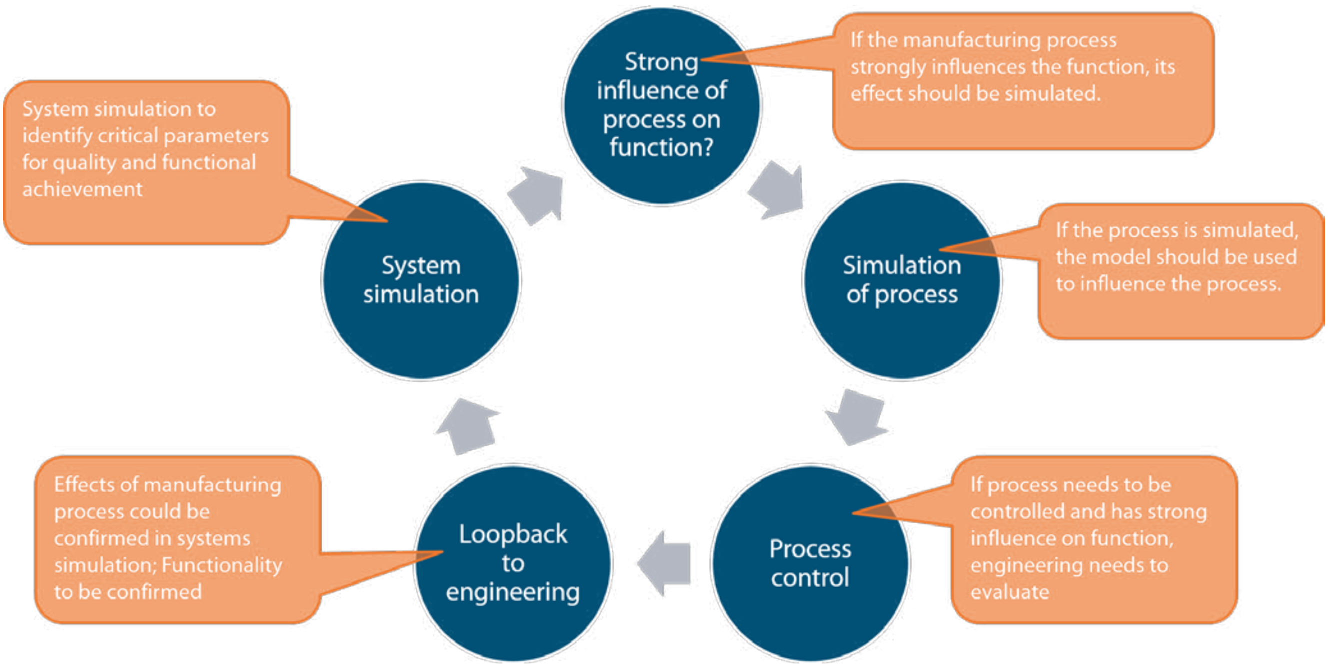


Figure 1: Twin Factory connects processes and function

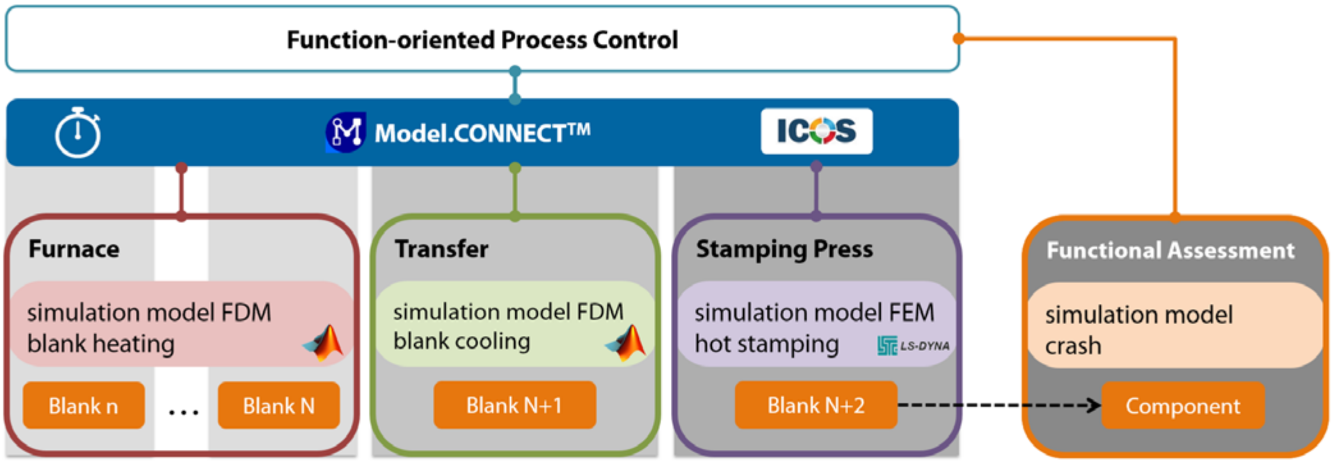


Figure 2: Process simulation models are embedded in real-time framework

control. This industrially established process is used to produce crash-relevant car body components (e.g. B-pillars) and is implemented as a three-stage process: (i) heating the blank in the furnace; (ii) transferring the blank from the furnace to the stamping press; and (iii) hot stamping and quenching the blank in the press. These steps are virtually represented in two different simulation environments; however, in other cases it could be any (often proprietary) vendor simulation model:

1. Finite Difference Model (FDM) of the spatial and temporal temperature development across the cross-section of a blank, implemented in Matlab®
2. Finite Element Model (FEM) of the forming and quenching process of the blank to simulate the microstructural transformations of the blank's material and the final properties of the component

The three processes are clocked by Model.CONNECT™ as a central interface, which enables the time-synchronous control of the data stream to the virtual process. To enable an active control of the press-kinematics based on the previous process steps, simulation results and measurements in the stamping simulation, co-simulation (ICOS) is used to control the stamping force at the upper die with respect to the temperature during the blank's quenching process.

To perform the functional assessment, the resulting characteristics of the now individually described component from the stamping simulation are transferred to a crash model (e.g. of a component test), and a crash simulation is performed. The functionally assessed results (e.g. impact force and component displacement) are translated into control parameters for the overall production process and are transferred to the single production stages again, in order to maintain functional conformity.

In a further development stage, the Function- Oriented Process Control will also be connected to the real production environment. This will allow for an efficient validation of the now online simulation models during the running production process and a continuous adaption of the Function Oriented Process Control model by using real and complementary virtual data in a kind of hybrid function-oriented process control system.

Outlook

Individualisation of (mass) production components with their specific characteristics may have a wide range of possible applications. First, trend analysis of the production parameters can predict the Conformity of Production (CoP), and countermeasures for critical parameters can be analysed in real time, parallel and during the actual build. Furthermore, one of most critical bottlenecks in a production preparation phase is the lack of production-like components, first-offs from production tooling that include their tolerance variations in order to test all equipment conditions (commissioning). With the help of realistic virtual components that can also represent deviations and simulation models capable of coping with these variations, virtual commissioning can be conducted much earlier at the equipment manufacturer's site, which makes it possible to fine tune the equipment before it is shipped to the component producer. ■

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VIRTUALISATION AS KEY ENABLER FOR EFFICIENT VEHICLE DEVELOPMENT

In many automotive companies, physical testing is still the primary method for precise development. However, numerical simulation is gradually changing from providing pure analysis support in emergency cases towards offering tremendous design and validation capability. The maturity level of virtualisation is often not determined by the technology but rather by attitudes and corporate culture. Efficient development must incorporate and benefit from the advantages of both worlds. A new development approach is needed to tap the potential of virtuality.

Automotive and rail vehicles are undergoing a radical change, as software is becoming a central driver and enabler for new functions, capabiliies and potential uses. Future vehicles will look completely different. Therefore, the development process must also change. The impressive speed of electronic and software development is forcing the industry to rethink methods for development and production. Competition and the market dynamic require a significant reduction of time-to-market, as well as an increase in cost efficiency.

Handling increasing product complexity

Companies are facing vast challenges due to increased complexity of the vehicle, new technologies, and expanded product portfolios. The main challenge thereby is to maintain the ability to design and validate every product function carefully within acceptable development time and with limited effort. Validation performed mainly by physical testing leads to an exponential increase in the number of prototypes, testing facilities, and tests. Moreover, advanced functionality requires not only single validation testing. Rather, system robustness and the interdependencies of the functions and variants have to be investigated to ensure customer satisfaction and safety.

The potential of virtualisation

Increasing the use of virtual, numerical validation to supplement or replace physical testing is seen as the primary approach to meet the challenge. Virtualisation features a balanced mix of virtual and physical approaches. The maturity of different methods – either for numerical simulation or for physical testing – must be highly transparent in order to determine the optimum validation mix for specific projects.

Virtualisation can: increase development agility by reducing the time required for analysis cycles and variants; enhance product quality by enabling early concept validation and investigation into variants and robustness; and decrease time-to-market drastically.

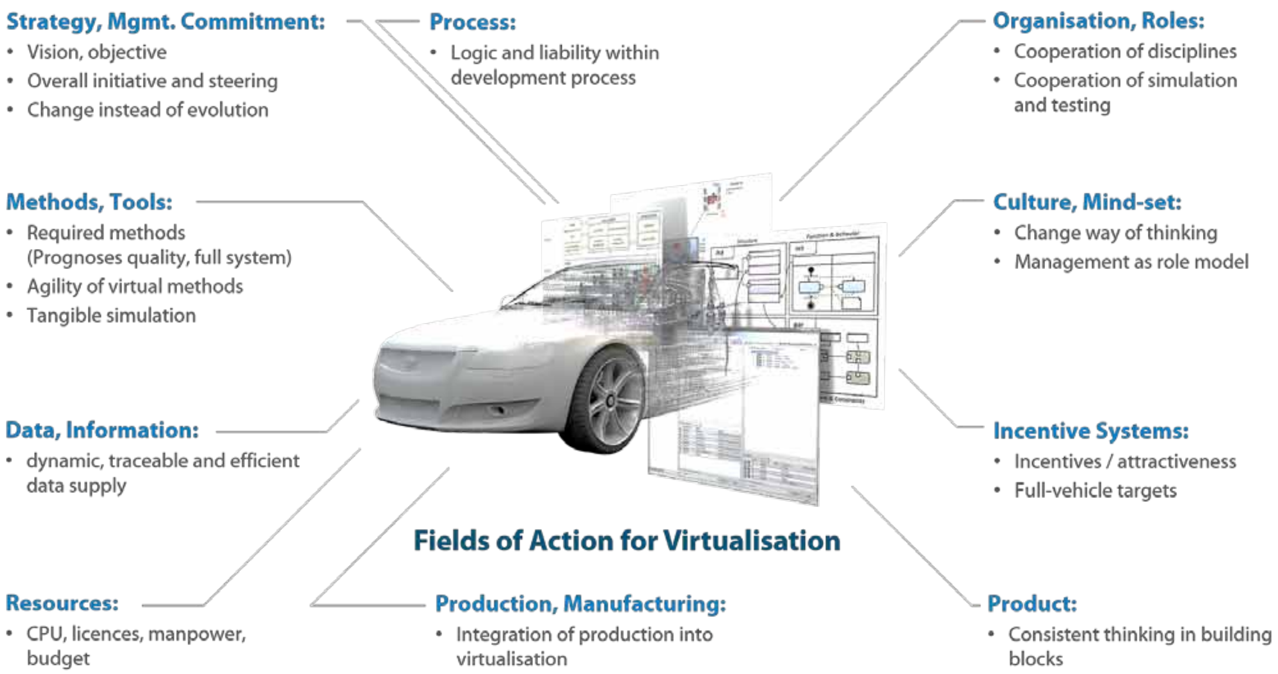

Figure 1: Fields of activity for virtualisation cover methods and technology, process, organisation and cultural aspects

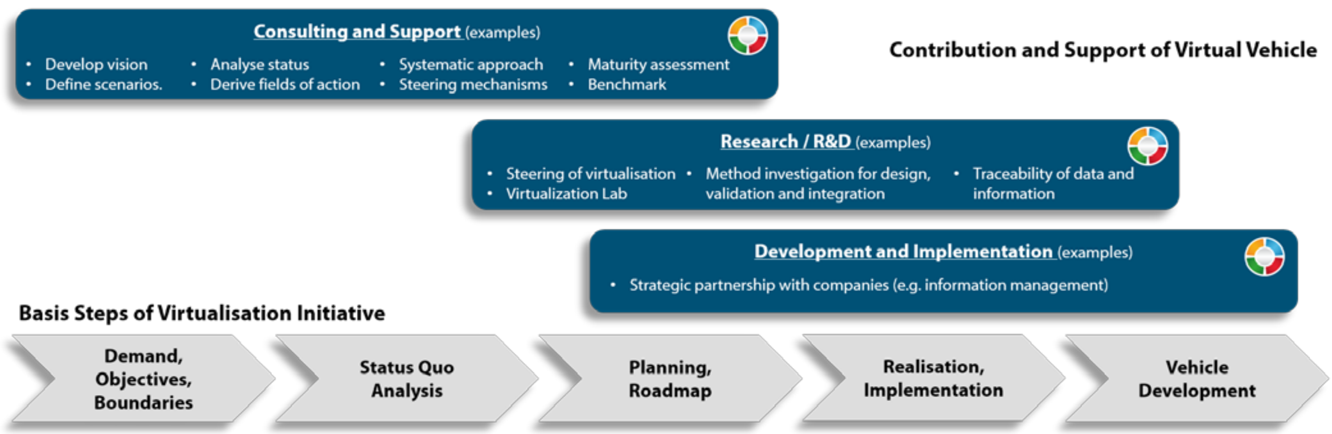

Figure 2: VIRTUAL VEHICLE supports industry on the way towards consequent virtualisation on different levels

Although this approach is no longer new, most companies have not yet successfully established consistent virtualisation.

Fields of activity for virtualisation

Analysis of the status quo at OEMs and system suppliers by VIRTUAL VEHICLE, in cooperation with consulting partners, has provided a detailed understanding of the wide variety of challenges and potential areas of deployment (see picture 1).

The major aspects that are hindering the progress towards virtualisation include:

- a lack of vision regarding future vehicle development
- a long established mindset that has to be changed carefully
- the testing-based logic of the development process
- limited transparency in the maturity of numerical methods
- an insufficient number of tangible simulation results for decisions
- binary thinking either in pure physical testing or pure simulation

Clearly, numerical methods offer a high prognosis quality. However, the best method is useless if the attitude and culture of a company cause them to reject decisions based on virtual results.

From virtualisation to efficient development

Highly efficient vehicle development can be characterised by

- high agility and short-time-to-market
- first-time-right for functional design and verification
- ability to product, product design and validation complexity
- highly economical product design and validation
- close integration and cooperation between development partners

Virtualisation has the high potential to provide several of these characteristic aspects. One key enabler for this potential is the level of consequence and the fact that virtualisation involves much more than the substitution of a physical test by an identical numerical simulation. It seems infeasible (both technologically and economically) to reach an absolute prognosis quality by numerical models. However, even a physical test is just a simulation with defined boundary conditions and a limited ability to precisely interpret the result, especially if no robustness analysis is available.

Gaining agility and speed for a broad variant analysis by exploiting the potential of many methods requires a new way of thinking about development.

Contribution of VIRTUAL VEHICLE Research Center

VIRTUAL VEHICLE Research Center is following a holistic approach. Fields of activity can be shown in 3 areas:

- Consulting and analysis: drive vision, strategy or roadmap towards virtualisation and identify possible applications for OEMs (e.g. BMW, Audi) and system suppliers (e.g. Brose); based on broad experience from industry and research, provide a neutral overview of praxis and the state-of-the-art in industry; cooperate with consulting partners (e.g. 3DSE, iCONDU)
- Research activities (strongest field): method- and product-related research and investigation with more than 80 industrial partners and 50 scientific partners (e.g. validation methods, system simulation and validation, systems engineering, process and information management)
- Development and implementation: service-oriented tasks to implement research results of partner-specific objectives at customer sites, cooperation with relevant strategic partner companies

Picture 2 provides an overview of the fields of activity related to a generic virtualisation initiative. ■

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EXPLOITING VEHICLE USAGE DATA TO ESTABLISH DATA-DRIVEN SERVICES

The collection of vehicle usage data facilitates the generation of new digital services. In analogy to the Quantified Self movement, the American-dominated Internet industry has already spawned a plethora of startup companies backed by enormous amounts of risk capital, thereby demonstrating the high market value of vehicle usage data. A growing community of drivers expects to gain more driving insights and (better) access to their vehicle data, and a growing number of industries want to exploit the potential of vehicle usage data for other purposes as well.

The rise of the quantified self

Quantified self refers to willingly collecting data about oneself, including biological, physical, behavioural, or environmental data. While some users are just curious, others want to be able to act based on this data in order to improve their quality of life.

The quantified self has already become a major value generator through mobile applications available for Android and iOS. One successful Austrian quantified-self startup is Runtastic, which was acquired by Adidas in 2015 for about 220 million EUR. The sports performance data collected from Runtastic's users delivers actionable knowledge for Adidas to facilitate product design and product marketing.

Similarly, the data collected by modern vehicles holds a huge potential for further exploitation and value creation. However, the automotive industry is still in the early stage of leveraging this potential.

The potential of quantified vehicles

The potential to exploit vehicle usage data for purposes other than driving currently remains relatively untapped by car manufacturers. According to the EU project AutoMat (coordinated by Volkswagen research), the automotive industry has not yet been able to successfully establish an ecosystem for apps and services equivalent to that of smartphone manufacturers.

The AutoMat project mentions three reasons why OEMs are currently struggling. First, brand-specific business approaches dominate, which results in a lack of brand-independent vehicle data. Second, current proprietary vehicle services focus on the individual customer, which leads to privacy concerns, and there are few ideas for making anonymous vehicle data available for other services. And finally, the implied or required collaboration between OEMs on vehicle data and services is considered risky in terms of competition.

Figure 1: Showcasing Apps developed by the US start-ups Automatic, Mojio and Zubie

Tech startups to challenge car manufacturers

Digital innovation in the Quantified Vehicle domain is currently being driven by a steadily growing number of innovation-friendly startups, the majority of which are located outside Europe. They demonstrate the potential of current Web technology by launching novel platforms, providing application programming interfaces to access novel services, or offering apps and services for curious and tech-friendly drivers.

The dominant IT industry in the USA has already backed a few Quantified Vehicle startups with risk capital, reaching more than 20 million USD in some cases. Examples of highly funded startups include zubie.com, automatic.com and moj.io, all of which provide smartphone-powered analytics and services for vehicle drivers and other stakeholders.

Most of these require a basic and sometimes even branded hardware adaptor that is connected to the standardised vehicle On-Board Diagnostic (OBD) interface. The adaptor captures vehicle data and transfers it directly via embedded 3G/4G modem or indirectly via a connected smartphone to a cloud platform for analysis and service provision. Some startups allow third-party apps to be built on top of collected vehicle data, which is gathered not by a single vehicle but rather by a plethora of vehicles. In all cases, the receipt of valuable services motivates drivers to share their driving data.

Market approaches and offers

Beneficiaries of apps and services include vehicle drivers, road maintenance authorities, transportation companies, online content providers, public traffic authorities, vehicle engineers, insurance providers, and, of course car, manufacturers, to name but a few. For example, individual drivers may be empowered to assess their personal driving style on their smartphone and receive suggestions for improving this style in order to drive more safely or more cheaply; organisational customers, such as insurance companies, can provide new kinds of insurance contracts; and city planners can be empowered to make informed decisions based on the knowledge gained about traffic patterns.

To increase the customer value of such services, vehicle usage data could even be enriched with data from other sources, including weather data, traffic data, environmental data or map data, to name but a few.

Towards a Quantified Vehicle ecosystem

In order to ensure that the concept of Quantified Vehicles achieves its full potential, at least four different types of stakeholders must be considered:

- The primary end users (individual service consumers) are vehicle drivers who directly benefit from innovative products, visualisations, statistics, gamification aspects, and recommendations based on the assessment of their shared vehicle lifecycle data. Value generated on the individual level is an incentive to share personal driving data.
- Secondary end users (organisational service consumers) are organisations which indirectly benefit from collected and assessed vehicle lifecycle data from multiple vehicles by consuming special services (e.g. engineering, city planning, and advertising).
- Service providers are organisations which provide Quantified Vehicle services for primary and secondary end users, thereby generating revenues (e.g. by providing fleet management services, traffic-style-dependent insurance services, vehicle maintenance prediction services).
- The cloud service provider (platform provider) operates the required infrastructure for the Quantified Vehicle ecosystem and enables service providers to establish services based on vehicle lifecycle data, as well as allowing primary and secondary end users to consume these services and share their vehicle lifecycle data in return.

Privacy and data protection as major obstacles

However, Quantified Vehicle ecosystems can only be successful if a critical mass of drivers shares their driving data. Hence, privacy concerns have to be addressed to support the emergence of third-party services with sufficient data in order to create representative statistics and knowledge for which a third party would pay.

Raising awareness about the kind of data a vehicle generates, processes, stores, and potentially transmits to a third party is an important task. The 'My Car My Data' campaign, launched by Federation Internationale de l'Automobile (FIA), educates car drivers about the potentials and pitfalls of connectivity. One strategy is to let the drivers decide what data to share with whom, as well as how it should be used and in what kind of third-party service. ■

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LITERATURE

Stocker, A., Kaiser, C. & Fellmann, M. (2017): Quantified Vehicles. Novel Services for Vehicle Lifecycle Data, Business & Information Systems Engineering. doi:10.1007/s12599-017-0465-5

AKNOWLEDGEMENT

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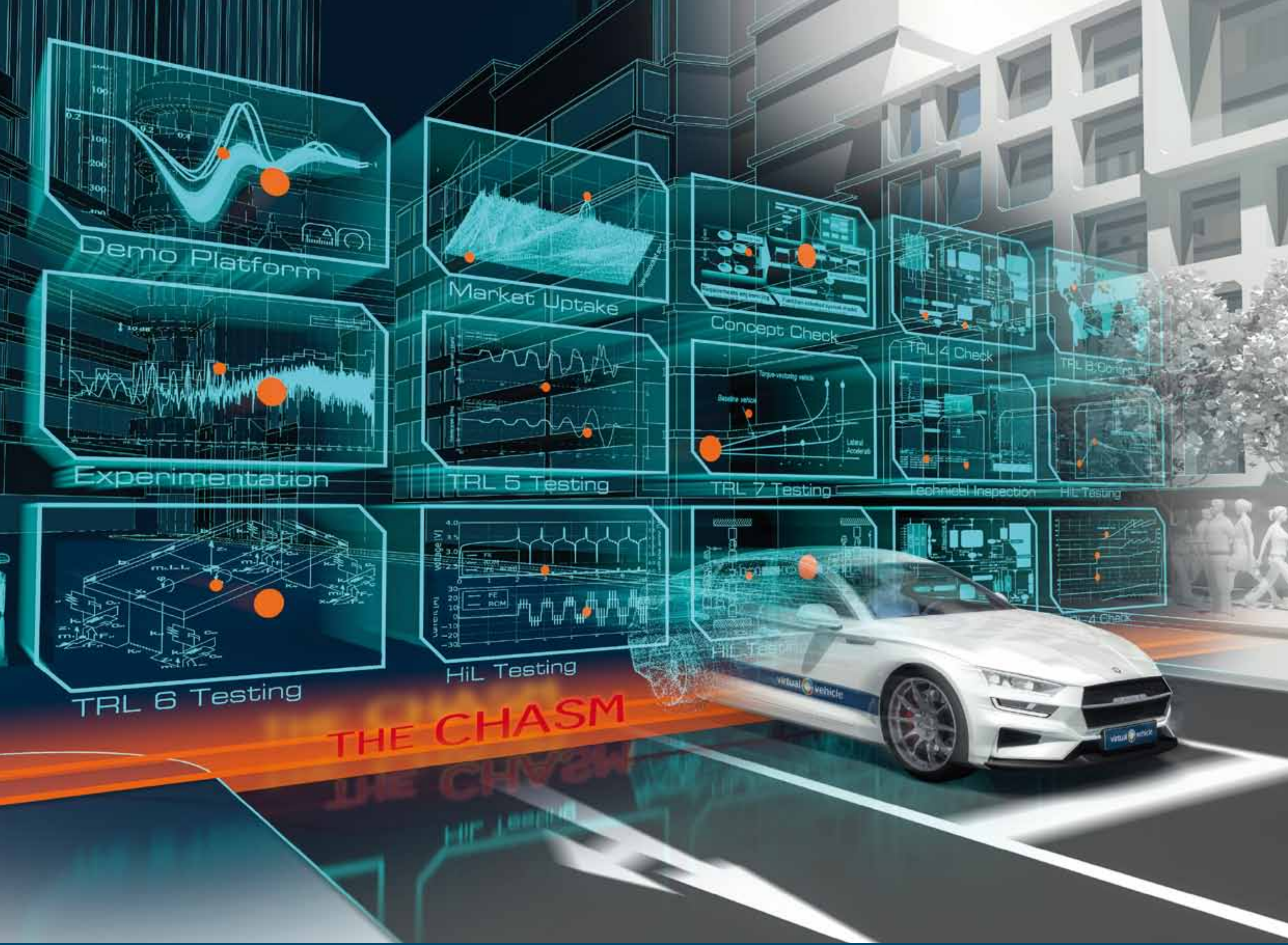


LIVING INNOVATION LAB

52 OPEN.CONNECTED.TESTBED

54 Open research platform for AD

INNOVATION DEMONSTRATION FOR MARKET UPTAKE

Fostering scientific exchange, examining new software and hardware functions, improving the innovation capabilities of small business: These are only a few of the many motivations of VIRTUAL VEHICLE's "Living Innovation Lab". As a centre for interaction, the overall goal is to unleash cross-discipline synergy effects as well as to build and extend leading-edge technology platforms.

Validated simulation models are now seen as a prerequisite for efficient system design. For small businesses, however, the technologies and large sets of measurement data required are typically not available due to the significant managerial and contractual efforts involved. In particular, research organizations, SMEs and mid-caps face this problem. They have very limited access to industrial standards, platforms and tools, which has a negative influence on their research and innovation possibilities in general.

Furthermore, modern technologies, such as autonomous, self-adapting and safety-critical systems, need to be evaluated during development within real scenarios using real-world data. This requires suitable proving grounds for real-life experimentation. In particular, human-centric design aspects will dominate upcoming research with respect to safety and product individualization and will require an appropriate R&D infrastructure for dedicated Human-in-the-Loop investigations.

These challenging circumstances in the development sector, as well as the desire to transfer precious knowledge from academia to industry, led the VIRTUAL VEHICLE Research Center to found its "Living Innovation Lab".

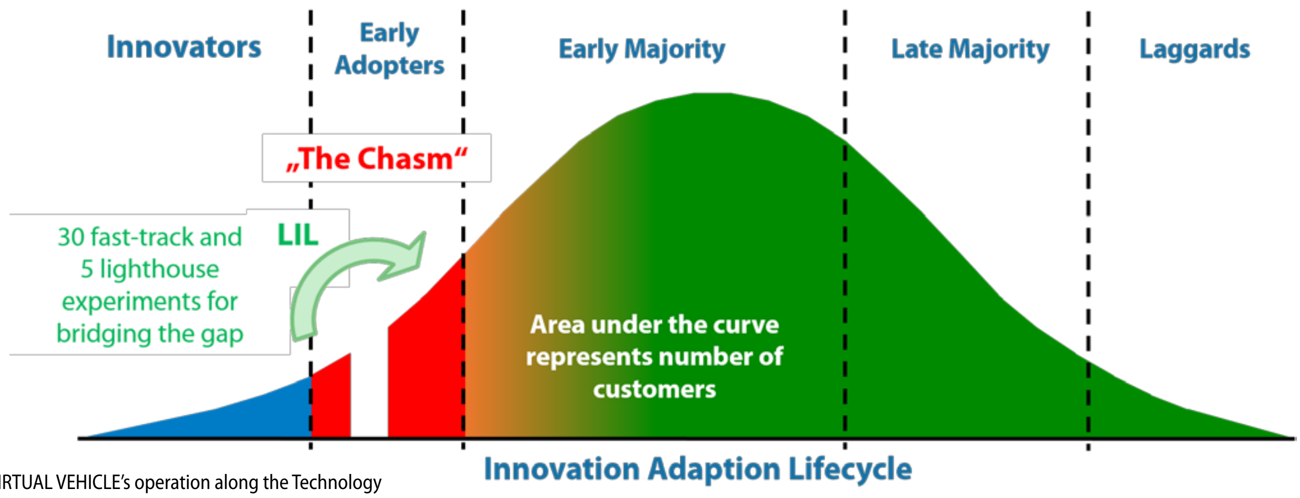
Unleashing cross-discipline synergy effects

Within its Living Innovation Lab, VIRTUAL VEHICLE develops highly innovative technologies for demonstration purposes that cover Technology Readiness Levels (TRL) 3 to 7. By serving as a centre for interaction, the lab focuses on unleashing cross-discipline synergy effects and generating innovations to build and extend leading-edge technology platforms. The resulting R&D infrastructure will then be made available for demonstrations during the acquisition process and follow-up R&D activities.

The goals of VIRTUAL VEHICLE's Living Innovation Lab are:

- to strengthen the knowledge transfer from academia to industry, thereby fostering scientific exchange and educational value
- to investigate innovations, platforms, software-functions and hardware for extending knowledge and identifying new research topics
- to improve innovation and development capacities for third parties, especially for SMEs and mid-caps.

The following pages present two selected projects from VIRTUAL VEHICLE's Living Innovation Lab: the Open Connected Test-bed for Human-centric Systems Design and an open vehicle platform in the form of a computer-controlled car, which can be used for various research projects in the field of automated driving. ■



VIRTUAL VEHICLE's operation along the Technology and Innovation Adoption Life Cycle

OPEN.CONNECTED.TESTBED

As the main goal of the automotive industry is to develop safe, efficient and affordable mobility concepts, a number of innovative concepts are being validated in virtual or real testing environments. However, the upcoming challenges related to automated driving will involve a significant shift to strongly context-embedded vehicle technologies. Broad modular and virtual/real development approaches are a key to managing the resulting complexity in system design. The unique OPEN.CONNECTED.TESTBED concept, a R&D infrastructure representing a suitable framework for open experimentation with highly innovative solutions, is currently under investigation.

Current market trends show a significant shift to strongly context-embedded vehicle technologies, which require more holistic system consideration for adequate investigation of vehicle, driver (human), environment (infrastructure) and data (cloud) interactions. An all-encompassing engineering framework is generally not available today, and the human factor, in particular, is not currently covered with the required depth, which significantly limits future innovation capacity.

Envisioned R&D infrastructure

The OPEN.CONNECTED.TESTBED approach seeks to bridge this gaps between individual stand-alone simulations (real and virtual), thereby providing an open R&D infrastructure that combines real testing with virtual design in real-time. Research plans include the installation of a high-performant driving simulator, which shall be connected to existing testbeds (e.g. an unique powertrain testbed in an anechoic chamber (DIN45635), existing HVAC test cells, and existing ADAS/AD equipment) in a modular and distributed manner, by using the recently developed real-time co-simulation approach (see Figure 1). Furthermore, gathered measurement data is panned to be made available for cross-domain system investigations. This will enable massive interdisciplinary research and provide significantly increased innovation capacity.

VIRTUAL VEHICLE has been exploring the modular, interdisciplinary engineering of complex systems since its founding in 2002. With its early research focus on co-simulation, simulation models and real-time systems (e.g. testbeds) were integrated via patented coupling algorithms, which have enabled outstanding virtual and real subsystem integration possibilities. These prominent research results were fed into the commercial co-simulation Platform AVL Model.CONNECT™, thereby creating a solid foundation for subsystem integration and the operation of the envisioned OPEN.CONNECTED.TESTBED. This will ensure a precise simultaneous interoperation of real test beds and various virtual testbeds (simulation tools), right up to the real-time-capable "Hardware-in-the Loop" systems.

Enhanced engineering

Classical automotive engineering domains include powertrain development, thermal management (including HVAC) and driver assistance systems (ADAS). As vehicles are becoming more and more intelligent and specialized, system design and validation approaches must also be extended. Instead of covering purely virtual or real domains, the OPEN.CONNECTED.TESTBED enables flexible and virtual/real analysis. The human role is to integrate the different engineering domains, which are typically handled separately, which will significantly enhance the development of future mobility concepts. Figure

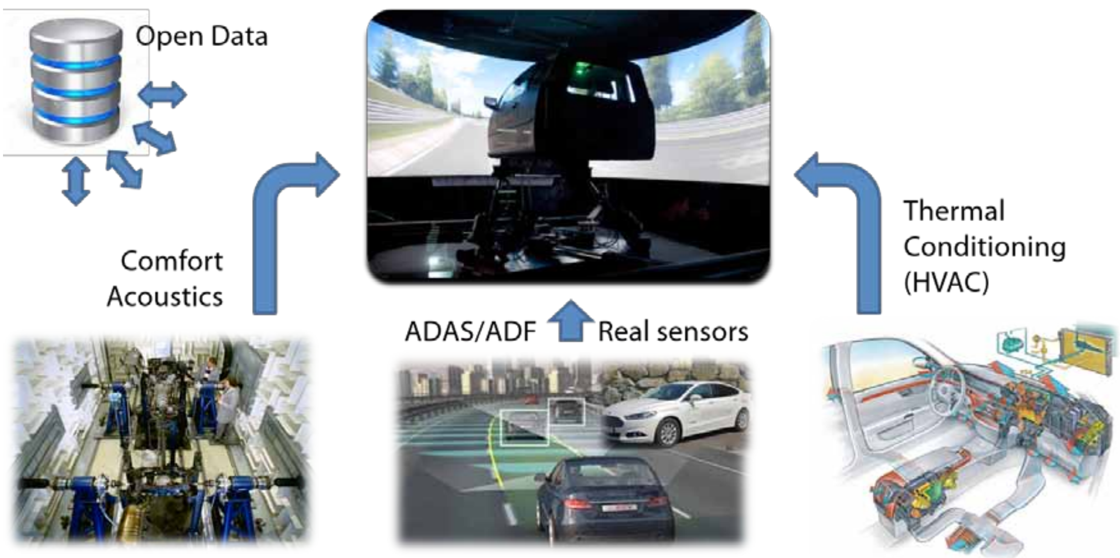


Figure 1: Cross-domain experimentation platform

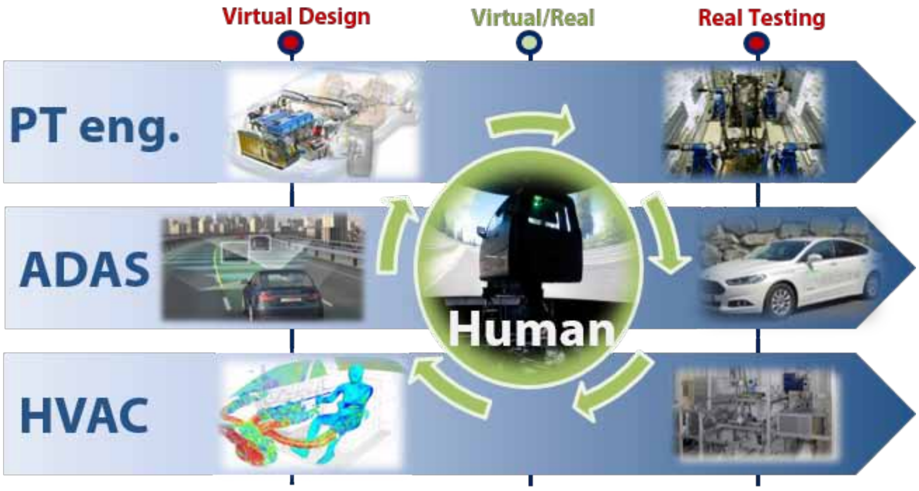


Figure 2: Integration of typically separate engineering domains

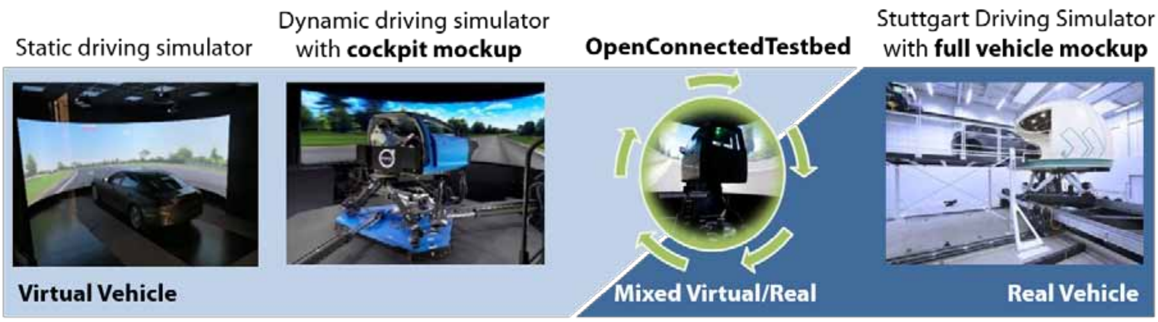


Figure 3: State-of-the-Art and positioning of the OPEN.CONNECTED.TESTBED

2 depicts this approach, whereby design meets real testing to provide an efficient, human-centric development at all stages of the product development cycle.

Technical framework

The core element of the OPEN.CONNECTED.TESTBED concept will be a high-performant (e.g. 9 Degrees of Freedom) driving simulator. This simulator is then planned to be connected to existing testing facilities (e.g. an engine testbed, powertrain testbed, HVAC cells, ADAS-Ford Mondeo 2.0) utilizing VIRTUAL VEHICLE's modular co-simulation platform approach. Due to its flexible integration possibilities, the testbed will offer significant (open) extension possibilities for 3rd-party components or testing environments. A data management system featuring an Open Data Service shall extend the novel R&D testing infrastructure to make anonymized and approved measurement data available for 3rd parties. In the long term, the OPEN.CONNECTED.TESTBED will serve educational purposes, as well as the dedicated training of personnel in the use of highly innovative technologies.

Currently, there is no comparable comprehensive R&D infrastructure in Europe. Most existing driving simulators are used for design decisions and some functional testing. Thus, static or dynamic simulators (up to a full-vehicle mockup) are deployed. In contrast, as shown in Figure 3, the OPEN.CONNECTED.TESTBED enables a smooth transition from pure virtual to real testing, covering human-centric aspects during all system development stages. Due to this novel cross-domain system engineering possibilities from virtual design to real testing, significant improvements human-centric system design, Automated Driving and Data Analytics are expected on short term.

Conclusion and outlook

The OPEN.CONNECTED.TESTBED will represent a unique R&D infrastructure that bridges system design and validation. Prominent, highly-innovative research outcomes can be achieved in interdisciplinary and virtual/real environments, thereby fostering technology awareness and thus rapid market uptakes. Furthermore, the OPEN.CONNECTED.TESTBED will serve as a centre for collaboration by bringing together academic and industrial partners. The primary use is within funded national and pan-European research projects in the form of fast-track (up to 5 month) and lighthouse experiments (up to 3 years). Beyond the non-funded and co-financing partners, more than 14 potential users have already expressed a strong interest in the unique OPEN.CONNECTED.TESTBED R&D Infrastructure, which highlights the strong demand and potential innovation capacity. ■

THE AUTHOR

DR. MARTIN BENEDIKT leads the Co-Simulation & Software group at VIRTUAL VEHICLE.

OPEN RESEARCH PLATFORM

Several researchers at the VIRTUAL VEHICLE are currently working on an open vehicle platform. The goal is to provide a computer controllable car that can be used for various research projects in the field automated driving. Unlike other comparable robot-cars, our car will not be confined to our testing facilities, but it will be made available to our national and international partners. Its open and well-defined interfaces allow for the integration and evaluation of new sensor technologies and artificial intelligence algorithms.

The starting point for our platform was a commercial Ford Mondeo HY 2.0 hybrid car. Several additions to the existing vehicle electronics have been made that enable an electronic control of the car. For safety reasons, the vehicle can revert to its original condition at any time. This can be triggered by manually overriding the steering wheel or the brake pedal, or by pressing an emergency button. Thus, the test-driver always has full control over the vehicle and its autonomous functions.

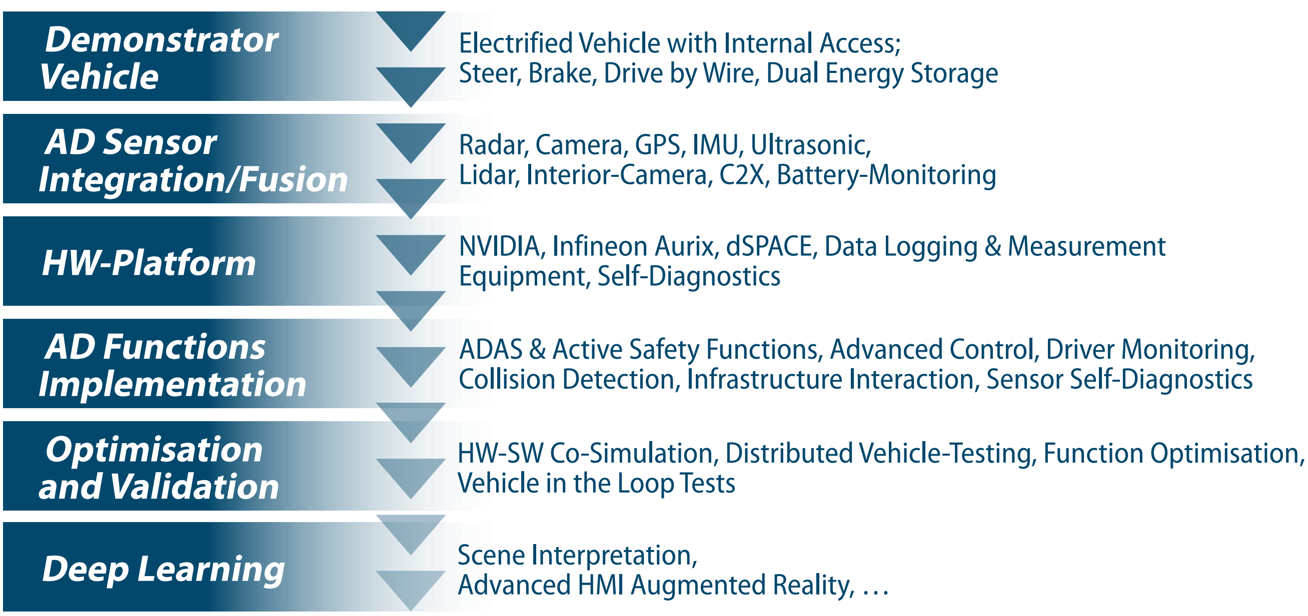
Roadmap

The development of the open vehicle platform is a strategic long-term undertaking that started approximately one year ago. Figure 1 depicts a roadmap with all major milestones and extension stages.

Currently, the ADAS sensor integration is nearing its completion, while the HW-Platform is being built up. In parallel, ADAS functions are already being tested on simulated scenarios. Simultaneously, strategic scientific partnerships are being formed to master the upcoming tasks, such as scene interpretation and deep learning.

Interface

Currently, it is possible to control the longitudinal and lateral guidance using predefined CAN messages. Simultaneously, the CAN interface provides a variety of vehicle information (e.g. speed, yaw rate, GPS position) and onboard sensor signals.



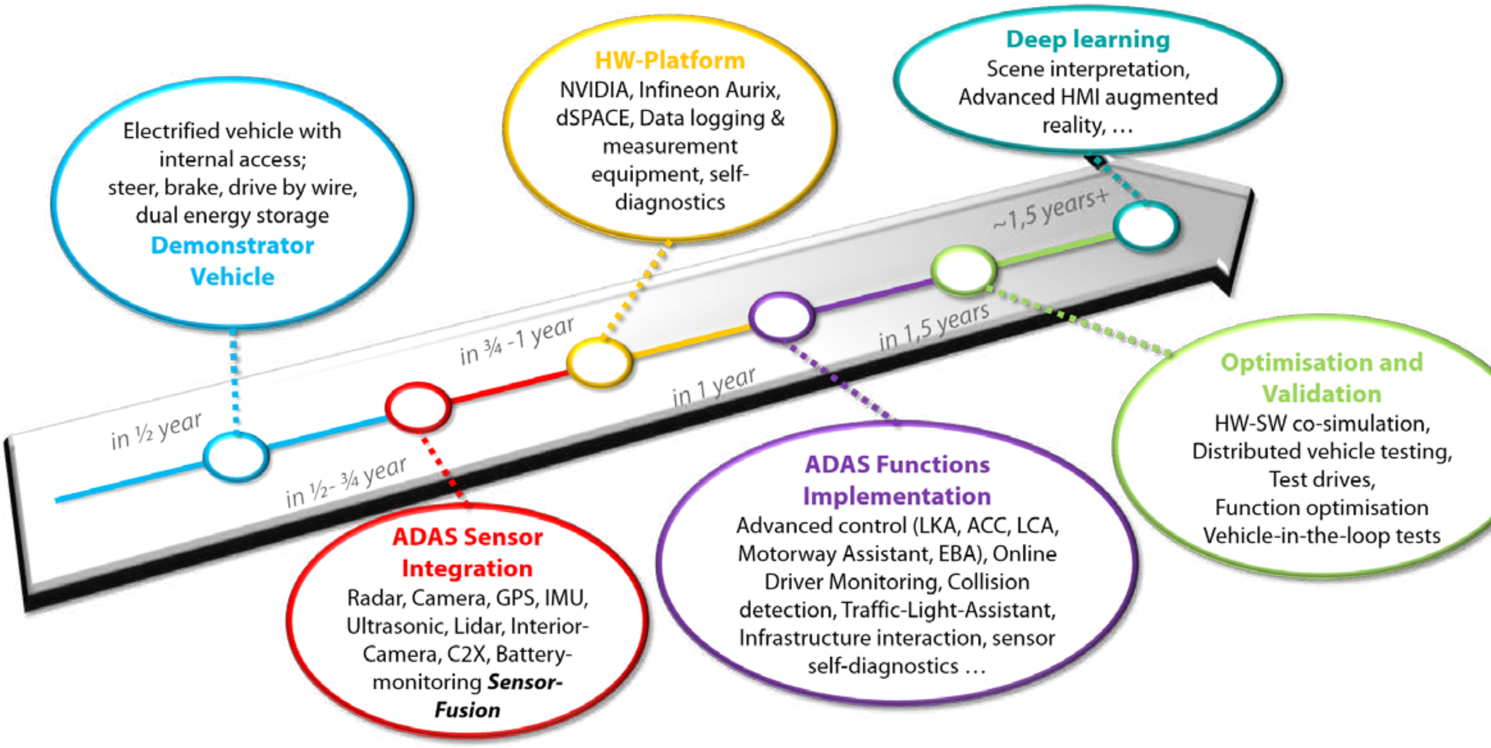


Figure 1: Roadmap for the open vehicle platform.

By using the Robot Operating System (ROS), we provide a flexible integration platform and data exchange within the vehicle. Moreover it enables collaboration between research projects and partners. Thus, a modular development of various driving functions and sensors is possible.

Sensors

Besides the ultrasonic sensors provided by the series-production vehicle, several additional sensors are available to monitor the vehicles surroundings.

A Mobile Eye camera provides information about the road and traffic ahead. Since the Mobile Eye can only be used straight on, six additional cameras provide a complete 360° view around the vehicle. Six radar sensors distributed around the car complement the cameras and provide information about distances and relative speeds between the car and other traffic participants.

In the next expansion stage, the platform will be augmented with several Lidar sensors. These will improve free space detection. In addition, affordable thermal cameras are currently being considered to handle difficult light conditions (e.g. darkness, fog).

High-performance computing

As these sophisticated sensors require significant computation power, a Drive PX2 platform from NVIDIA is integrated in the trunk of the vehicle. This platform consists of several multicore-processors and graphic processing units providing 8 Tera-Flops. For safety critical applications, an AurixTM processor is available as well.

Field of application

In the K2 project TECAHAD (Technology Concepts for Advanced Highly Automated Driving), a motorway chauffeur capable of handling common driving situations is implemented on this platform, together with our partners AVL, Magna and TU Graz. Within the EU project IoSense, a prototype of a Time-of-Flight camera is implemented – in collaboration with Infineon – into the platform and evaluated for reverse parking manoeuvres.

Moreover, VIRTUAL VEHICLE and its open vehicle platform is partner in "ALP.Lab" - Europe's most diverse test environment for self-driving cars (read more on page 63). ■

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VIRTUAL VEHICLE'S EU PROJECT ACTIVITIES

Conducting leading edge research and acting as a hub between industry and science - this is the strategy VIRTUAL VEHICLE has managed all the way up into the champion's league of European research. Currently, VIRTUAL VEHICLE cooperates in more than 30 EU projects with a total of 200 partners coming from more than 20 countries.

"We are actively involved in an increasing number of EU projects. This shows us that we are on the right track at the European level and have the necessary expertise for future topics", says Jost Bernasch, CEO of VIRTUAL VEHICLE. The centre works on research projects initiated by the European Union in cooperation with Graz University of Technology and 200 European partners.

A balanced portfolio

Addressing a broad portfolio of research topics relevant for the future automotive industry is a clear goal of VIRTUAL VEHICLE. Thus, the experts are working on a variety of projects with international partners within six different European programmes for research and innovation. The subjects of the projects are manifold, mainly arising from the following areas:

- Vehicle Technology
- Production
- Infrastructure
- Education

With the current 34 EU projects, the experts at VIRTUAL VEHICLE have a total budget of more than €21 million. Based on data, published by the European Commission, VIRTUAL VEHICLE already counts to the top ten project partners in Europe in the area of Surface Transport. ■

34 EU PROJECTS CURRENTLY UNDERWAY AND UNDER NEGOTIATION

7 OF 34 PROJECTS COORDINATED BY VIRTUAL VEHICLE

21 MILLION PROJECT VOLUME AT VIRTUAL VEHICLE

25 EU PROJECTS SUCCESSFULLY COMPLETED

SEVENTH FRAMEWORK PROGRAMME ARTEMIS Shift2Rail ECSEL Joint Undertaking MARIE CURIE ACTIONS HORIZON 2020

EU PROJECTS AT VIRTUAL VEHICLE

HORIZON 2020 | FP 7

ADVICE

AEGIS
Advanced Bid Data Value Chain for Public Safety and Personal Security

3.6 m EUR · 01/2017 - 06/2019
9 partners
Fraunhofer, EPFL, GFT Italia, HYPERTECH, KTH Stockholm, NTUA, SUITE5, UBITECH, etc.

ASSURED

CPSE Labs Experiment

DOMUS
Design optimisation for efficient electric vehicles based on a user-centric approach

9 m EUR · 10/2017 - 03/2021
16 partners
Idiada, Centro Ricerche Fiat, Volvo Cars, Fraunhofer, RWTH Aachen, etc.

DiePeR

ECOCHAMPS

EU-LIVE*

FACTS4WORKERS*

FiveVB

HD-GAS

Inframix
Road Infrastructure ready for Mixed Vehicle Traffic Flows

4.9 m EUR · 07/2017 – 06/2020
11 partners
AUSTRIATECH, BMW, TomTom, Fraunhofer, etc.

In2Rail

MeBeSafe

OBELICS

OPTEMUS*

REWARD

Roll2Rail

Science2Society

TRANSFORMERS

TrustVehicle*

SHIFT²RAIL* virtual vehicle austria consortium+

01/2016 - 12/2021
13 partners
VIRTUAL VEHICLE, Plasser & Theurer, Tatravagonka, voestalpine, etc.

MARIE CURIE ACTIONS

BATWOMAN*

ITEAM
Establishing an interdisciplinary training network in the field of multi-actuated ground vehicles

3.8 m EUR · 01/2016 - 12/2019
11 partners
TU Ilmenau, Infineon, KU Leuven, Volvo, etc.

PBNv2

ARTEMIS | ECSEL JU

3CCar

AMASS

AutoDrive
Advancing fail-aware, fail-safe and fail-operational electronic components and systems for automated driving

82.2 m EUR · 05/2017 – 04/2020
57 partners
Infineon, Daimler, Bosch, NXP, CRF, TU Graz, etc.

EMC²

ENABLE-SE3

IoSENSE

Productive 4.0

SEMI40
Main goal: "smart production" and "cyber-physical production systems"; one of the largest Industry 4.0 projects in Europe

62 m EUR · 05/2016 - 04/2019
37 partners
Infineon, AIT, AT&S, Bosch, Fraunhofer, MCL, etc.

SCOTT*

*) Project coordinated by VIRTUAL VEHICLE

HOW TO DEVELOP VEHICLES OF THE FUTURE

The Graz Symposium VIRTUAL VEHICLE connects people from science and industry to identify new approaches, methods and tools for the efficient development of the vehicle of the future. Pushing technology and discussing trends of tomorrow are and always have been essential topics of the GSVF. This year, the symposium is celebrating its 10th anniversary. The organisers, VIRTUAL VEHICLE and Graz University of Technology, take a moment to look back, while recognising that the most exciting times for the automotive industry are yet to come.

How to manage multi-disciplinary design. How to gain a consistent view of the product and its wide variety of functions. How to connect simulation models from all the different tools. And how to merge simulation and real hardware for one system. These and many more issues were discussed in 2008, when the Graz research centre launched the Graz Symposium VIRTUAL VEHICLE. Now, 10 years later, the GSVF focuses on the fact that vehicles are more and more connected with and embedded in their environment, which gives rise to completely new challenges in terms of vehicle development. Under the headline "Context-embedded Vehicle Technologies", the 10th-anniversary conference will shift the focus from vehicle-centred to vehicle-embedded development, which means a system-oriented approach.

The 2008 premiere: A surprising success

After the COMET K2 programme "K2-Mobility – Sustainable Vehicle Technologies" was approved and launched in 2008, VIRTUAL VEHICLE's management decided to host the first GSVF. At that time, the organising team had no idea that they were about to establish a long-lasting, successful event series. After more than 100 experts accepted their invitation to Graz, they realised that the event's programme accurately pinpointed future-relevant topics for both the vehicle industry and the research community. Since then, the conference has been organised annually by the research centre VIRTUAL VEHICLE and the Graz University of Technology.

Answers for a fast-developing industry

"Multi-disciplinary integration", "Interaction of mechanical engineering, electronics and software", "The interplay of simulation and testing", "Systems engineering", "Cyber-physical systems": in the ensuing years, the symposium's key topics developed as much as the


M. Eigner (University of Technology Kaiserslautern), 2013


M. Holzner (AUDI AG), 2010


T. Kriegel (AUDI AG), 2012


S. Rosenplänter (Adam Opel AG), 2013


B. Göschel (Magna International), 2009

GRAZ SYMPOSIUM VIRTUAL VEHICLE www.gsvf.at


Evening reception at the Graz Schlossberg, 2015


Ch. Gümbel (Porsche), 2011

B. Fachbach, GSVF Chairman 2009 - 2015

automotive industry itself. In these times of change, VIRTUAL VEHICLE was honoured to welcome top-level keynote speakers from both industry and science.

All the networking activities surrounding the GSVF solidified and strengthened the profile of both the research centre and the business location of Graz. We are looking forward to the next 10 years, and we are confident it will remain exciting! ■

Opening of the 7th GSVF in 2014: Prof. Helmut List (AVL List GmbH)

The speakers of the first GSVF 2008 (f.l.t.r.): M. Eigner (TU Kaiserslautern), Ch. Gümbel (Porsche), Dr. Jost Bernasch (VIRTUAL VEHICLE), C. Chucholowski (TESIS DYNAware), G. Lang (VIRTUAL VEHICLE), M. Holzner (AUDI AG), H. Wenzel (Engineous GmbH), M. Schilke (ILC PROSTEP GmbH), A. Eichberger (TU Graz), M. Wifling (MAGNA STEYR Fahrzeugtechnik), W. Hirschberg (TU Graz)

Talking about...

10 YEARS OF GRAZ SYMPOSIUM VIRTUAL VEHICLE

Ten years ago, Jost Bernasch initiated the Graz Symposium VIRTUAL VEHICLE (GSVF). Since then, he has served as the General Chair of the conference.

What motivated you to organise the first GSVF in 2008?

2008 was generally a very forward-looking year for us. In January, the COMET K2 programme "K2-Mobility – Sustainable Vehicle Technologies" was launched at our centre with a total project volume of more than 60 million euros. Furthermore, our merger with the Graz Acoustic Competence Centre also took place. These essential milestones greatly encouraged us to advance our research activities and to join forces with like-minded people. At this point, however, we realised that there was no scientific event or other platform that addressed our main focus: development methods and tools for the virtual development process. So we simply decided to organise a conference on our own to meet the right people with the same interests and visions as ours.

And so it happened… In this first year, we managed to organise a whole conference from scratch within three months. More than 100 experts accepted our invitation to Graz. To be honest, this is something I'm still proud of!

What were the key topics at the very beginning? Have the topics changed over the last 10 years?

At the first GSVFs, we were discussing virtual development on a rather general, or even visionary basis. What will be the roadmap for virtual development? How can we combine individual disciplines, such as mechanical engineering, electrics and electronics? What is the right path to multidisciplinary optimisation?

But particularly in the last few years, the automotive industry has been undergoin tremendous changes. Today, our conference is strongly inspired and influenced by the shift towards digitalisation. Context-embedded vehicle technologies, real-world data, adaptability and software updatability are some of the key terms. We have to create a vehicle development process that fully combines and integrates hardware- and software-based development. In other words: the different elements of real-world and virtual development will exist as digital twins.

"Today, our conference is strongly influenced by the shift towards digitalisation."

Dr. Jost Bernasch (CEO, VIRTUAL VEHICLE) is General Chair of the Graz Symposium VIRTUAL VEHICLE.

In order to achieve this, we are concentrating on topics such as virtual integration, requirements, semi-formal system specification or automatic derivation of virtual test cases. Also, co-simulation and real-time co-simulation with a high-quality integration engine will be relevant.

Thinking back on the last 10 years of GSVF, what was your personal highlight?

Off the top of my head, I recall Christoph Gümbel's keynote (Head of the Virtual Product Development department at Porsche) in 2010. At that time, he was already speaking very confidently about the huge potential of virtual development… and it turned out that he was right! Some years later, I discussed this with experts from BMW, Audi and Porsche at our evening reception at the Schlossberg. Besides enjoying the phenomenal view over Graz, we talked about the big challenges the automotive industry is facing and the massive changes it is currently undergoing, especially in light of new virtual development methods for connected, electrified and automated driving. At that moment, I had the feeling that Graz, and our GSVF in particular, play a crucial role in shaping the future roadmap for automotive industry.

K2 DIGITAL MOBILITY CONFIRMED

VIRTUAL VEHICLE is proud to announce that its project proposal "K2 Digital Mobility - Context-Embedded Vehicle Technologies" was successfully approved by the Austrian Federal Ministry for Transport, Innovation and Technology, the Federal Ministry of Science, Research and Economy and the Austrian funding agency FFG. The new COMET K2 Excellence Research Programme integrated in the VIRTUAL VEHICLE Research Center will start in January 2018. A total project volume of € 48 million until 2021 is expected.

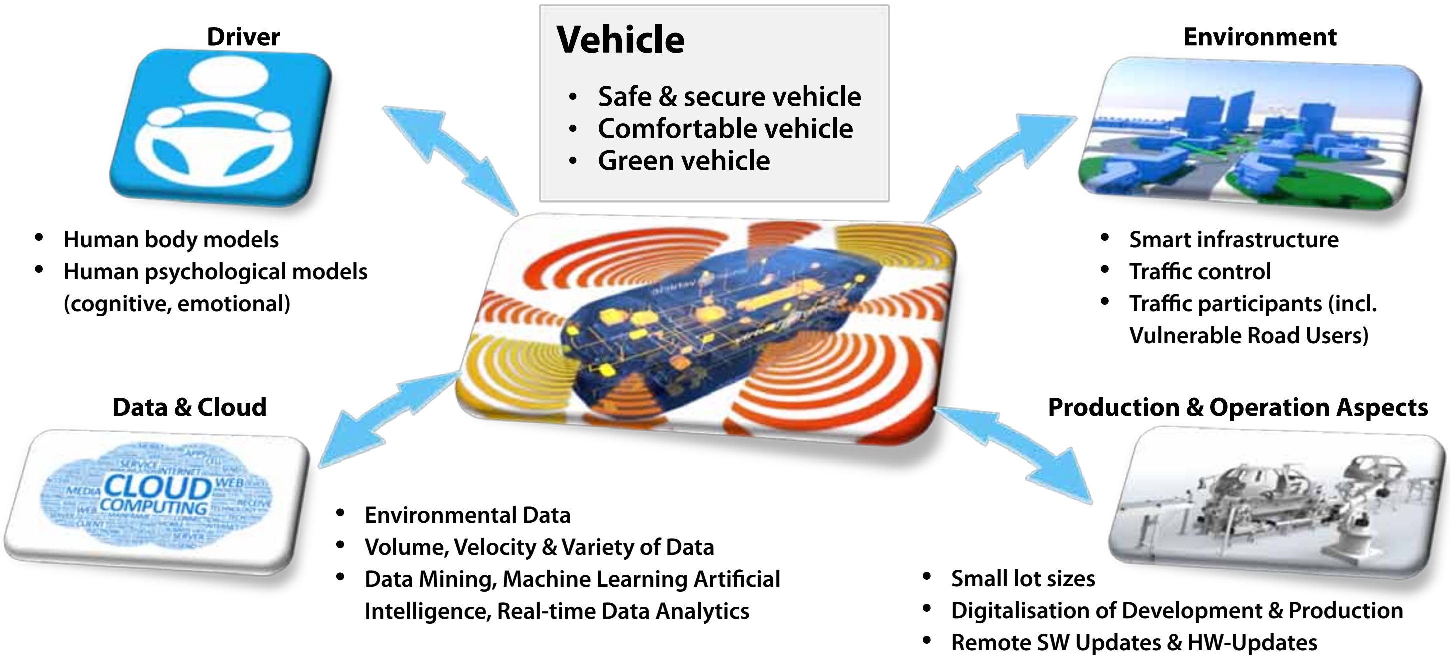
Hermann Steffan & Jost Bernasch with
Franz Wressnigg, Chairman of VIRTUAL VEHICLE's Strategy Board

The importance of digitalisation in the vehicle industry has grown significantly within the last ten years. The shift towards a connected vehicle and a digital value chain with new business models raises unprecedented challenges and demands for vehicle developers.

Linkage of the vehicle and digital industry

The recently approved COMET K2 project at VIRTUAL VEHICLE emphasise a closer cooperation between the vehicle and the digital industry, in order to mutually face the emerging challenges of digital mobility. Disruptive digitalisation, human-centered design, and context-embedded vehicle technologies will be the core elements of the Center's upcoming research activities within K2.

"We put great efforts in and worked very hard for our innovative and forward-looking concept. Now, we are highly motivated and look forward to starting a new era of vehicle development in 2018.", says Jost Bernasch, CEO of VIRTUAL VEHICLE. ■



Context-embedded view in K2 Digital Mobility and digital vehicle value chain:
Context awareness and context-embedding, as well as the ability to handle uncertain information, are crucial for reliable new functions and systems

K2 Digital Mobility supported by

Comprehensive Energy Management

READ THIS...

Daniel Watzenig, Bernhard Brandstätter (Editors)

COMPREHENSIVE ENERGY MANAGEMENT

Eco Routing & Velocity Profiles (Vol. 1)

Safe Adaptation, Predictive Control & Thermal Management (Vol. 2)

In its two volumes, the book discusses the emerging topic of comprehensive energy management in electric vehicles from the viewpoint of academia and from the industrial perspective.

It provides a seamless coverage of all relevant systems and control algorithms for comprehensive energy management, their integration on a multi-core system and their reliability assurance (validation and test).

Springer; 1st ed. 2017/2018

Secure Connected Trustable Things

KICK-OFF SCOTT

SCOTT, a pan-European, €40-million research project, focuses on building trust in the “Internet of Things” (IoT). The project will provide comprehensive, cost-efficient solutions for wireless, end-to-end secure, trustable connectivity, with a focus on applications in intelligent, integrated mobility for road, rail and air, as well as building technology, smart homes and infrastructure, and even health.

In SCOTT, 57 partners from 12 countries (incl. Brazil) are working together. The project consortium is led by VIRTUAL VEHICLE.

www.scottproject.eu

SCOTT Kick-off: J. Bernasch (CEO VIRTUAL VEHICLE), W. Rom (SCOTT Project Coordinator, VIRTUAL VEHICLE), P. Priller (AVL), B. Giptner (Siemens), H. Kainz (Rector Graz University of Technology)

Cross Innovation

WOOD MEETS VEHICLE TECHNOLOGY

Did you know that wood is a light-weight material that has outstanding strength, stiffness and stability with excellent damping behavior and low raw material costs? As part of the recently launched "WoodC.A.R." project, VIRTUAL VEHICLE will take a completely new approach together with 16 partner companies from business and science: wood materials should be digitally calculable and used in future vehicle technologies.

Modified framework conditions and strategic objectives in the area of mobility (such as carbon footprint, e-mobility or weight reduction) require new vehicle concepts. Wood materials, if used properly, are high-performance materials and have the potential to be a valuable material extension for the mobility sector. Low raw material costs, excellent availability and ecological aspects are only three of many strengths, which clearly help to take more account of the material wood in the development of future vehicles.

WoodC.A.R. creates new synergies

Since March 2017, representatives from the automotive industry (such as MAGNA or MAN Truck & Bus AG) and the timber sector (such as Weizerparkett or Holzcluster Steiermark) are working side by side with scientific institutions such as BOKU Wien (scientific management of wood technology), the Graz University of Technology and the VIRTUAL VEHICLE (scientific management of vehicle technology). ■

WoodC.A.R.
COMPUTER AIDED RESEARCH

www.woodcar.eu

Photo: MAGNA

EUROPE'S MOST DIVERSE TEST ENVIRONMENT

In Styria, Europe's most diverse test environment for self-driving cars is being created. Under the title "ALP.Lab" (Austrian Light Vehicle Proving Region for Automated Driving), research facilities and industrial operators from the Styrian automotive cluster bundle their competencies in the development and testing of automated driving systems on a large scale. It offers customer test tracks and road tests on both highways and in city traffic.

The range of possibilities is unique: In addition to tests on private routes, test drives on highways and in the city centre of Graz are also possible. In addition, modern simulators and measuring stations are available. VIRTUAL VEHICLE is a major contributor to this project, with other partners including AVL List, Magna Steyr, Joanneum Research and Graz University of Technology. The Ministry of Infrastructure supports the ALP.Lab test environment and two research projects with a total of 5.6 million euros.

Highway, tunnel and city traffic

ALP.Lab bundles the whole test chain in one location, from initial simulations to tests on test beds and, ultimately, tests on private and public test tracks. The testing is conducted on the ASFINAG test track, which is located on the A2 between Graz-West and Laßnitzhöhe and between St. Michael and the border to Slovenia. Next year, the Graz city centre will also be part of the test drives. In the research facility "Zentrum am Berg" (center on the mountain), behaviour in a highway tunnel can be tested. The Formula 1 Red Bull Ring will also be available for testing during the winter months.

Two new research projects in their initial phases

Within the framework of ALP.Lab, the Ministry of Infrastructure is supporting two research projects. In "Dynamic Ground Truth", VIRTUAL VEHICLE is developing a highly accurate measuring and reference system for the reliable detection of the environment, in coordination with AVL List, Joanneum Research, TTTech and Vexcel. The research center is also involved in the LiDcAR project, where the center is working with Infineon and the Vienna University of Technology on sensors for measuring distance and speed in self-propelled cars. ■

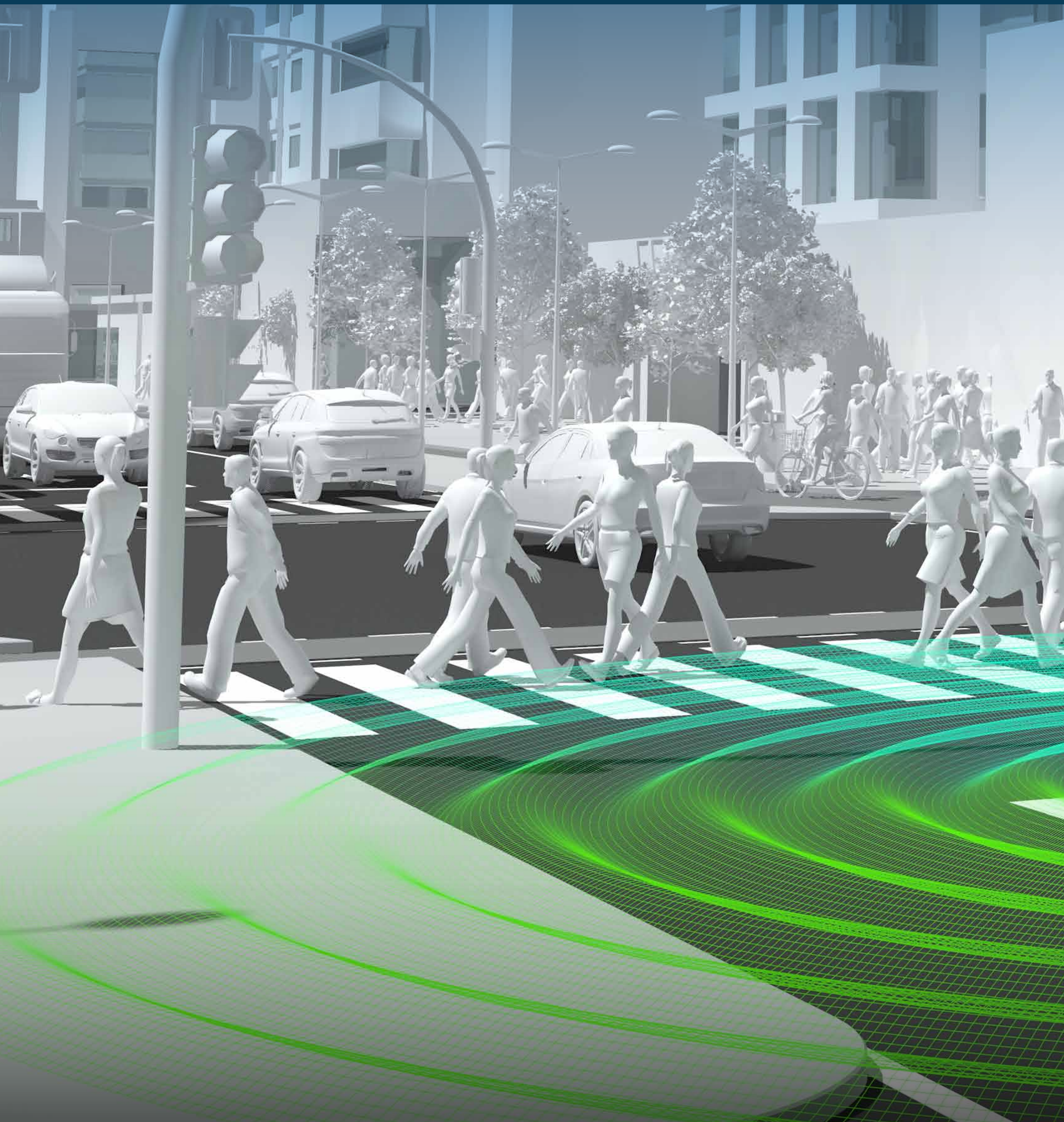
AVL MAGNA JOANNEUM RESEARCH DIGITAL TU Graz virtual vehicle

The ALP.Lab team with the Austrian Infrastructure Minister Jörg Leichtfried

(Horst Bischof (Vice-President of the Graz University of Technology), Infrastructure Minister Jörg Leichtfried, AVL CEO Helmut List, VIRTUAL VEHICLE CEO Jost Bernasch, Heinz Mayer (Joanneum Research), Dieter Althaus (Magna Europe)

virtual vehicle

Context-Embedded
Vehicle Technologies



virtual vehicle

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