R&D CHALLENGES: ADVANCED VEHICLE CONCEPTS 2020+

POSITION

Four major trends will change mobility (on & off road vehicles) in the next five to ten years - in addition to the electrification of the drive train (see the positions on "Battery Electric Vehicle" and "Fuel Cell Electric Vehicle") - and thus change the environmental footprint reduce the entire life cycle:

- **New lightweight materials** (including composites) and joining technologies
- Innovative **production** technologies and **digitalization** of processes
- **Digitalization & Automation** of vehicles and infrastructure
- **Emission reduction** of vehicle components and systems without a direct / indirect connection to the internal combustion engine and its operation

TREND 1: LIGHTWEIGHT MATERIALS – TRENDS AND DEVELOPMENTS

The energy balance of future “climate neutral vehicles” will depend to a large extent on effective weight reduction and consequently on lightweight construction. The demanding requirements regarding CO_2/GHG emissions and safety make integrative vehicle concepts a major driver of innovation, in which **functional**, **material engineering** and **connection technology** lightweight construction are systematically linked. The use of fiber-reinforced plastics as well as aluminum and magnesium, hybrid lightweight construction and mixed construction (composites) will become increasingly important.

Lightweight construction will be essential for the further development of electromobility in order to compensate for the challenge that new electric cars are between 10 and 30 percent heavier than conventional vehicles due to the additional battery weight.

So far, the design and the modular building block systems as well as the materials of the vehicles are still based on the conventional series, as higher quantities result in lower costs. Therefore, cost-effective solutions are essential for a complete switch to lightweight construction concepts.

TREND 2: INNOVATIVE PRODUCTION TECHNOLOGIES AND DIGITALIZATION OF THE PROCESSES

DIGITALIZATION: Due to the possibilities offered by new data processing and communication technologies in competition, companies are required not only to increase the efficiency of classic production technology, but also to **improve and convert business processes**, to **link them with data processing** and to **integrate** them appropriately.

This applies in particular to digitalization from development to production to the service area and its networking along the value chain ("Industry 4.0") as well as the integration of digital technologies in all areas of the company (e.g. use of online elements in design and development as well as in the entire procurement and logistics and distribution system). The digitalization of security mechanisms, test and approval procedures and the use of simulation, artificial intelligence and machine learning in production will determine competitiveness.

Artificial intelligence (AI) and machine learning algorithms offer enormous potential to increase efficiency in production processes and to master the complexities that come with greater individualization. Automated systems in verification and validation and in production must work together with people with the highest level of security.

DEVELOPMENT PROCESSES: The seamless introduction of networked development backbones, which provide the information across the different technology areas and lifecycle levels, in order to be able to develop the increasingly complex vehicles in always shorter times, is necessary to remain successful in the global market. A particular challenge is the seamless integration of information from field tests into development and production processes.

PRODUCTION PROCESSES: With regard to the increasing emergence of e-mobility with a large variety of models and still relatively small quantities, the manufacturing industry is confronted with small and zero series (prototyping) for new vehicle concepts and their innovative components (e.g. smart components, smart materials). At the same time, it is important to create individualized products with "high volume" processes (mass customization).

Additive manufacturing has great potential, especially in lightweight construction, energy efficiency (flow channels, cooling) and functional integration. To do this, the processes have to work even faster, cheaper and with higher throughput, for which great efforts have to be made in research. For individual manufacturing and small series, it must be ensured that the "additive processes" used for the first test components also allow conclusions to be drawn about the later large-series solution.

Likewise, the optimization of the "classic" technologies with a high degree of maturity (pressure die casting, metal forming, machining, joining, etc.) should not be forgotten.

TREND 3: DIGITALIZATION AND AUTOMATIZATION

Information and communication technologies open up new opportunities in the area of transport and mobility. ICT-based assistance systems and automated vehicles are increasingly going to be used in vehicle technology. These systems will network with each other in the future. Assistance systems for vehicles enhance road safety, enable mobility for a wide range of people, reduce emissions and lead to more comfort for vehicle drivers.

We consider the following measures (excerpt from the digitization roadmap) necessary to be able to pursue the revolutionary approach of autonomous vehicles and traffic systems parallel to evolutionary automation:

- Establishment of the approved test environments for automated driving (Alp.Lab and DigiTrans) for the next 5 years and beyond.
- Definition of validation methods / techniques for automated and semi-automated vehicles that can minimize and quantify remaining risk in operation in different operating areas. To do this, tools must be developed that make these validation methods efficiently applicable.
- Implementation of clear framework conditions, norms and standards for automated driving (legal, ethical and safety-related) as well as for data use in intelligent and learning traffic management systems in order to be able to develop and validate automation systems inside and outside of test environments.
- Application of Austria's high level of ICT competence in vehicle electronics and control of vehicle systems to enable synergies between the automation of vehicles and the reduction in emissions in hybrid and electric vehicles.
- Implementation of the C-ITS strategy in public and private transport to connect road users, individual vehicles with traffic management and traffic infrastructure and among themselves for more safety, efficiency and sustainability.

There is great potential for Austrian companies, research institutions and universities to further develop their existing know-how in a cooperative manner, in order to take a relevant position in European and international competition, or to make themselves capable of international cooperation. With the approval of two complementary test regions for automated driving test environments (Alp.Lab for passenger car applications and DigiTrans for commercial vehicle applications) and specific lighthouse and cooperation projects, a good basis has already been created. In general, the cooperation of different industries or the demonstration of synergies as a positive funding criterion should also be included in the evaluation of research projects in future funding programs.

We recommend targeted funding of pilot projects on fully automated driving in order to enable the Austrian automotive industry to gain its own experience and thus prepare for the implementation of fully automated mobility concepts and the transformation of their own business model. To this end, projects in the field of tool development for the validation of automated vehicles are to be funded in order to secure the top position of many Austrian companies in this field.

TREND 4: EMISSION REDUCTION OF VEHICLE COMPONENTS AND SYSTEMS, THAT ARE NOT PART OF AN ICE

Based on published measurements in the context of the diesel exhaust gas discussion, it is assumed that the traffic-related real pollution, in particular fine particles, is not only emitted by internal combustion engines. Brakes, tires and clutches and other systems have been identified as possible sources of emissions. A specific quantification of the emission per system, the contribution per driving cycle and over the lifespan is only available to a limited extent.

Particularly with regard to the continuous electrification of drive systems, right up to fully electric vehicles, it is important to identify further potential systems at an early stage and to make a thorough assessment.

The current data situation with regard to emission type and quantity, as well as the definition of test cycles with regard to the pollutant emission of components and systems that are not internal combustion engines, can at most be rated as fragmented. Therefore, future research should address the systematic identification of all possible contributors and the objective measurement and evaluation of the real pollutant emissions. This need not only applies to cars, but can also be expanded to include all means of transport (e.g. single-track and multi-track individual transport, rail vehicles, etc.)

For this analyzations, further research and development with regard to measurement methods, test cycles, equipment and test infrastructure in order to develop a standardized and secure data situation is required.

Only on the basis of validated measurement results is it possible to derive the need for development in order to reduce the emission of means of transport in a holistic manner.

ESSENTIAL LEGAL FRAMEWORK

Currently, there are no preconditions or legal framework conditions on how an autonomous vehicle can be operated on public roads in Austria in the medium or long term without a driver.

It is therefore necessary, to determine in a roadmap when this is possible and which legal framework conditions have to be met. This can certainly take place in a step-wise approach in order to advance the research and development of such technologies and the establishment of an Austrian supplier base in Austria. A relatively short-term and practical solution is required here, since otherwise these use cases would have to be set up elsewhere where there is already a legal possibility (e.g. Spain, USA, China, etc.).

LIFE CYCLE ASSESSMENT

Key factors in Life Cycle Assessment (LCA) of autonomous driving passenger cars compared to non-autonomous vehicles are the changes in energy demand and efficiency during operation. Additional weight for the specific components, increased number of trips due to rebound effects and empty miles can increase energy demand, whereas increased productivity, increased driving efficiency due to vehicle platooning, ecodriving and lightweight construction can decrease energy demand. LCA of lightweight vehicle design depends on the environmental impacts of lightweight material production as well as on end-of-life treatment options of the materials.

RESEARCH REQUIREMENTS

LIGHTWEIGHT DESIGN

CONSTRUCTION BASED LIGHTWEIGHT DESIGN

- Function integration
- Weight management concepts for electric vehicles
- Multi-material design
- Crash management systems with functional integration made of die-cast aluminum
- Novel shape optimization approaches especially for flow-through components (pumps, paddle wheels, pipes, heating systems, energy exchangers, ...) for energy efficiency optimization and the resulting material savings in components (such as numeric/bionic optimizations)
- Lightweight design through the use of multi-scale, multi-physical numerical model approaches (use model approaches with and without nets)

MATERIAL BASED LIGHTWEIGHT DESIGN

- Application of fiber-reinforced plastics, light metals (Al, Mg, Ti) and light metal alloys with mechanically and thermally optimized properties (e.g. fire-resistant magnesium alloys)
- Use of high-tensile steels (TRIP, bake hardening, multi-phase steels)
- Hybrid use of light metal / steel / glass fiber / carbon fiber
- Use of metal foams
- Hard coatings
- Increase in recycling proportions in aluminum alloys
- Development of battery technologies with high energy and power density (e.g. based on Li-Air or Mg-Air)

PRODUCTION BASED LIGHTWEIGHT DESIGN

- New joining technologies (CMT welding, electron beam welding, gluing, etc.)
- Development of new welding consumables and solders for special metal mixing combinations
- Development of resources for efficient manufacturing processes for hybrid materials
- Development of joining processes for high-strength and low-ductile lightweight materials or mixed connections made of metal-plastic fiber composites
- Forming techniques (internal high pressure forming)

INNOVATIVE PRODUCTION TECHNOLOGIES & DIGITALIZATION OF PROCESSES

With "Production of the Future", "Energy Research" and similar program lines, a good basis has already been provided for funding programs in the past. In the future, too, subsidies will only be efficient if they address both the development of materials (development of new materials) and the processing side (further development and mastery of the production process).

DIGITALIZATION OF PROCESSES

- Development of valid simulation models and algorithms for production processes, "virtual product development"
- Simulation-supported life cycle assessments for technology scouting and decision-making processes
- Development and application of digital twins (for system optimization, variant handling, etc.)
- Methods for "Big Data" - use in technology and product development
- Combination of production technologies, process data, big data mining, material data and material data for numerical simulations
- Development of software for the "virtual homologation" of new vehicles

- Use of artificial intelligence and machine learning in the entire supply chain: self-optimizing production and machines, quality assurance (e.g. visual inspection), preventive maintenance, autonomous (intra-) logistics
- Wireless data transmission in harsh environments
- Paperless factory

INNOVATIVE PRODUCTION PROCESSES AND PRODUCTION PROCESSES

- Development of modular, scalable production lines (in terms of size and production volume) that can also be combined across companies to increase profitability
- Development of Industry 4.0 compatible control systems for the "networked, island-based factory", including suitable technologies and strategies for securing against unauthorized access to factory data systems and cloud-based communication systems, as well as techniques to support safety & security-based systems in edge computing Area
- Additive Manufacturing (AM)
  - Additive manufacturing techniques with order outputs greater than 10-15 kg / h
  - Wire-based additive manufacturing processes for variation of cast components
  - Faster development processes by using AM technologies in combination with special materials
- **Novel casting and forming processes** (e.g. cryoforming, electroforming, cryo-IHU) for optimized material utilization (e.g. uniform thinning) or for increased mechanical properties
- Development of **magnesium extrusion technologies** for applications in EVs
- Consistent "cradle to cradle" approach (re-use, recycling) in product design and production planning (e.g. for battery systems)
- Manufacturing of smart products (intelligent components, smart materials) with integrated sensor functionality in parts, components and materials
- Research program for pilot line of large-scale production of fuel cells

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DIGITALIZATION & AUTOMATIZATION OF VEHICLES AND INFRASTRUCTURE

TECHNOLOGY

- Development and testing of new vehicle concepts for highly and fully automated or autonomous driving including their networking technologies, which preferably allow the simultaneous transport of people and goods of all kinds, or are designed so that a quick change of different mobility needs is possible
- Development of controls and testing of innovative sensors including object and environment recognition for automated driving functions
- Development of decision and control algorithms with appropriate software and middleware for highly and fully automated / autonomous driving with or without artificial intelligence and their integration into Domain-Domain computer architecture structures
- Human-machine interaction (HMI): e.g. the retransfer of the driving task to the driver, driving skills with continuous use of the driver assistance system, aggregation and consolidation of existing research results in the areas of driver status detection and transfer times.
- Early development of innovative room concepts (alternative seat configurations, ergonomics, operating concept, adapted air conditioning, and adapted occupant protection) for vehicles that have automated driving functions at level 4 and level 5. (Note: Especially the scope of occupant protection requires a very long lead time and must therefore be developed in advance of level 4 and 5.)
- Methods, tools and test systems for the development and optimization of highly and fully automated driving functions or sensors, including securing them on the road, on the test site or under laboratory conditions (MiL, SiL, HiL)
- Evaluation methods for large amounts of measurement data from, for example, fleet tests or driving tests with comprehensive or high-resolution sensors. In particular, the automatic generation of scenarios, auto-tagging (object description), automatic measurement data evaluation and correlation to ground truth data

- Research into the **potential of fully automated mobility systems**, in particular interfaces between public transport and MIV using fully automated vehicles
- Definition of methods and specifications for the safe import and checking of software updates for automation functions
- Further development of **IT security methods** (encryption techniques, penetration tests, etc.) and definition of methods and specifications for ensuring IT security and data protection (also for over-the-air updates of automation functions)
- (Highly) automated vehicles: Development of methods for efficient verification and validation (V&V) of HAF in different test environments (from simulation in MIL / SIL to road tests)
- Research into possibilities for determining a test coverage or a residual risk for different V&V methods
- Development of **test and approval procedures for HAF**, in particular early clarification of the scope of requirements or AI algorithms (artificial intelligence)

TEST ENVIRONMENTS AND CONDITIONS

- Establishment of a transparent and nationally standardized **faster approval process for testing** highly and fully automated vehicles on public roads
- Establishment of test routes with communication-capable infrastructure (funding is already available)
- Definition and further development of the technical equipment and the use cases to be tested as part of the conception and the implementation of the test fields with the involvement of all actors involved in industry (including SME) and research
- **Implementation of urban test scenarios** with test options both on dedicated test fields and in field tests in public spaces (the dialogue with city representatives has to start!)
- Long-term funding of specially created entities ("**operating company**"), which coordinates the technical and organizational test operation and ensures equal access for all interested parties
- **Invitation of foreign manufacturers** to test in Austrian test environments, which may involve relocating these manufacturers to Austria
- **Creation of an insurance pool** in order to be able to cover possible damage claims / product liability claims when new technologies are introduced

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EMISSION REDUCTION OF VEHICLE COMPONENTS AND SYSTEMS THAT ARE NOT PART OF THE ICE

SYSTEMATIC ANALYZIS OF EMISSIONS OF EXISTING SYSTEMS

- **Identification** of all possible contributors (components and systems) across all vehicle classes.
- Classification of pollutant emissions and **quantification** of the possible emission potential.
- Evaluation of the **contribution performance**, per emitting system in test cycles and real environment.
- Categorizing the main contributors and derive the primary development needs.

MEASUREMENT METHODS

- **Checking** the suitability of available measurement methods.
- **Development of new measurement methods** and tools, if necessary.
- Development of **suitable test bench infrastructure** and “real life” measurement procedures.

DEVELOPMENT

- Development of technical solutions and operating strategies to reduce emissions, especially in real operation.
- Research on zero-emission concepts for the fundamental new components and systems that offer the same range of functions and the same functional safety.