

Reimagining Motion

Foundation and Development of AVL

Our journey from an engineering office to one of the world's leading mobility technology companies for development, simulation, and testing in the automotive industry and other sectors.

75 YEARS AND BEYOND

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Dear Readers,

It is an extraordinary pleasure and honor for me to welcome you to this exclusive special edition marking the 75th anniversary of our company.

As we celebrate this milestone, we are in the midst of probably one of the most profound transformation processes in the world of mobility. The battery electric vehicle has already successfully made its way onto our roads. At the same time, fuel cells are also being used in commercial vehicles and non-road applications. In addition, the trend is moving towards alternative fuels such as hydrogen and other e-fuels. The concept of the software-defined vehicle has already become a reality.

For more than seven decades, we have strived to push progress in technology and innovation, always with the vision of making tomorrow's mobility sustainable, safe, and affordable.

This special edition of FOCUS is all about how we are shaping this transformation now, how we are supporting automotive manufacturers and suppliers in overcoming current challenges, which milestones we have already reached on the road to tomorrow's mobility, and which topics we are currently working on. Exciting articles and exclusive interviews with experts reveal more about the current state of propulsion technology and about new trends in the areas of engineering, simulation, and testing.

In addition, allow us to take a brief look back at our history. You'll find that a pioneering spirit and curiosity have been driving us since the very beginning. Our decades of experience and the creativity of our dedicated employees form the solid foundation for our success both today and in the future.

But all this would be impossible without you. Success is only possible in collaboration: Without you, the companions, the driving forces, the challengers and supporters, the customers and partners and, of course, our employees, we would not be able to celebrate this anniversary. Therefore, we would like to take this opportunity to thank you for your loyalty, for valuable momentum, for sharing your visions, for jointly developing ideas, methodologies, and vehicles, and for your continued trust in us.

I look forward to embarking on the path to the mobility of the future alongside you. May this magazine be a companion for our next steps.

Helmut List Chairman and CEO. AVL

Foundation and Development of AVL

We have come an extraordinary way in 75 years: from a robust industrial diesel engine in 1949 to one of the world's leading mobility technology companies for development, simulation, and testing.



Ingenious, Right into His Senior Years: Prof. Hans List

It is widely known that Hans List is the forefather of today's AVL. But did you know that he was already well on his way to becoming a hydrogen pioneer back in the 1940s? Or that at almost 100 years old, he is one of the oldest people in the world to have received a patent? But let's start at the beginning.

B orn on April 30, 1896, Hans List grew up around the turn of the century in an upper-class family in Graz. His grandfather, Eduard List, ran the renowned "Grand Hotel à l'Éléphant" until 1900 – one of the biggest hotels in the city, whose guests included members of the imperial house.

Hans List's father, Hugo List (1857–1932), studied at Grazer Handelsakademie (Graz commercial academy) before starting his professional career at Escompte Bank. After the stock market crash of 1873, he left the bank and developed an increasing interest in technology. He studied civil engineering at Graz University of Technology and went on to work as an engineer for the Styrian state rail authority, in the field of railway construction. From 1890 to 1906, he and his partners Brunetti and Radl ran the company "Brunetti, List & Radl", which built narrow-gauge railways in Lower Austria.

Inspired by his father, Hans List also developed a passion engines. for technology. He studied mechanical engineering at Graz University of Technology and completed his studies after six From 1932 to 1941, he held a teaching position as Professor semesters. In 1920, he got a job working in the diesel engine of Combustion Engines at Graz University of Technology. department at the Grazer Waggon- und Maschinenfabrik (Graz During this time, graduate engineer Egon Niedermayer was Wagon and Machine Factory). He was initially responsible for employed as his assistant and Dr. Anton Pischinger as his various detailed drawings of crankshafts but was gradually research assistant. Together, they continued their research work. In 1941, Hans List was called to Dresden and proposed entrusted with the design of more complex parts. He eventually designed a control mechanism for a reversible engine, that Dr. Pischinger should take over his teaching position in which was completely smokeless, and in which the fuel was Graz – a proposal that was approved. In Dresden, List forged atomized by compressed air. close connections with the industry, particularly the aircraft



Main teaching building of Tongji University in Woosung

In 1926, he was employed as a scientist at Tongji University in China. The turbulent trip took him by ship from Genoa, through the Suez Canal, to Colombo, Singapore, Borneo, and Hong Kong, before arriving in Shanghai. Once he had arrived, he set up an institute for important research to calculate vibrations during the charge exchange process in internal combustion engines.



Prof. Hans List

Honors and Accolades:

- **1952** Gold honorary coin from the Austrian Engineering and Architectural Association
- **1955** Ackroyd Stuart Prize from the Institution of Mechanical Engineers, England
- 1958 Gold medal of honor from the Republic of Austria
- **1959** Decorated with ring of honor from the city of Graz
- **1963** Honorary doctorate from the Graz University of Technology
- **1967** Large silver medal of honor for services to the Republic of Austria
- **1971** Prix de Promotion International Technique d'Institute International de Promotion et de Prestige, Paris
- **1976** Honorary citizen of the city of Graz
- **1976** Large gold medal of honor with the star of the state of Styria
- **1980** Schrödinger Prize from the Austrian Academy of Sciences
- **1981** Awarded the medal of honor for science and art by the Federal President
- **1981** Ring of honor from the state of Styria
- **1985** Honorary professor of Tongji University in China
- **1986** Large gold medal of honor with the star of the Republic of Austria
- **1989** Kaplan Medal from the Austrian Association of Patent Holders and Inventors
- **1989** Foreign Associate of the National Academy of Engineering (USA)
- **1989** Honorary member of the Austrian Association of Engineers and Architects
- **1990** Special 50th Anniversary Horning Memorial Award, awarded by SAE (USA)
- **1991** Honorary professor at Jiangsu University in China
- **1991** Soichiro Honda Medal of American Society of Mechanical Engineers

engine departments at Mercedes-Benz and BMW. He was commissioned to improve the efficiency of aircraft engines by performing tests on piston engines.

In the course of the German-Soviet War during World War II, politicians planned to use large parts of Russia to produce food, such as grain. Farms were to be set up in the colonized regions, with the energy required being provided by wind turbines. The intention was to store the electricity thus obtained in accumulators and to use some of it to produce hydrogen and oxygen. Hans List was given the task of creating the hydrogen engine and making contact with scientists. However, the project lost significance with the defeat of the German army in Russia.

After the war, aged 50, Hans List took the step into entrepreneurship and founded Ingenieurbüro List (IBL), the predecessor to AVL. His dedication to technical advancement and innovation continued to shape the many successes and technological breakthroughs experienced throughout the history of AVL. He was even immortalized in the Guinness Book of Records as the oldest patent holder in the world: at a proud age of 99 years, he received a European patent, which served to underline his sustained power of innovation. Hans List died on September 10, 1996. ■

During his career, Prof. Hans List registered more than 300 patents.



The 1940s

In 1946, graduate engineer and Prof. Dr. Dr. h. c. mult. Hans List founded the engineering firm "IBL", before renaming it to "Anstalt für Verbrennungsmotoren Prof. Hans List" in 1948. His goal was to develop modern engines, based on the latest findings from basic research while simultaneously taking into account the growing economic criteria within the industry.

The new company's first order was the development of a robust industrial diesel engine. This went into series production at the Jenbach plant in Tyrol and at the Andritz engineering works in Graz in 1949. Even then, the success of the company relied upon the pillars of development and construction expertise, rigorous testing, and income generated from patents.

focus SPECIAL EDITION

To this day, Hans List's publications remain among the most important scientific book series on internal combustion engines in the world.





First expansion of AVL in 1952



Further expansion in 1958

The 1950s

In 1951, the company now known as "Anstalt für Verbrennungskraftmaschinen List" (AVL for short) was formally established in Graz. Supported by investment from the Marshall Plan, the central test site was opened at Kleiststrasse 48 in 1952, boasting its own testbeds and a workshop. This enabled AVL to take on more orders for engine development, for example, for Jenbacher Werke, Steyr-Daimler-Puch, and numerous foreign companies. The corporate headquarters are still at this location today, alongside the head office for central research and development tasks. In 1955, AVL made the decision to develop engines for commercial vehicles. Market analysis determined a need for small diesel trucks with a load capacity of 800 to 1000 kg, and for light equipment carriers for smaller agricultural enterprises. AVL quickly came to an agreement with the steel industry in Rottenmann to construct and manufacture diesel-powered delivery vehicles. In 1958, AVL introduced the first four-stroke diesel engines with direct injection for trucks equipped with swirl ducts. These replaced the two-stroke engines and fourstroke prechamber engines.

The 1960s

In 1963, the intensive continuous development of diesel engine technology resulted in the construction of an 18-cylinder two-stroke diesel engine with 2,250 HP. Alongside engine development, AVL began to produce engine testing devices and started series production of quartz pressure transducers, gravimetric fuel consumption measurement equipment, flue gas measurement devices, and complete engine indication systems. Helmut List joined AVL in 1966, his initial role was to lead the production department for electronic and precision measuring instruments. In the same year, two further engine testbeds were built, including a system for acoustic inspections. These boasted an interior design that was revolutionary at the time, with anechoic furnishings for walls, ceiling, and floor to exclude all external interference.

Since the company had already gained experience with measurement devices and displayed a degree of affinity with medical devices, AVL started to develop innovative medical

<mark>1962</mark> Foundation of AVL Test Systems, Inc.

AVL Test Systems, Inc. was established in Plymouth, Michigan (USA) in 1962. The subsidiary has continued to grow ever since and has remained at the same location. It now offers a comprehensive portfolio that encompasses equipment for entire battery labs, component tests, and solutions for all e-mobility projects. The company's ADAS/AD solutions are ensuring the advent of a secure, autonomous mobile future.



focus SPECIAL EDITION



Austrian physician and university professor Dr. Karl Harnoncourt's achievements include blood gas analyzers, which AVL manufactured in the 1960s based on his research findings.

measurement devices. University professor Dr. Karl Harnoncourt's research results in the field of medical technology were significant here. The electronics in those first models were first developed by AVL with the Institute for Electromedicine at Graz University of Technology, and the AVL electronics department soon assumed responsibility for development as a whole.

In 1967, Helmut List completed his mechanical engineering studies at Graz University of Technology as a graduate engineer. In 1968, the son of the AVL founder added project lead responsibility for the medical measurement device Gas Check 935 to his role as head of production. The delivery of the first green devices to customers in 1969 heralded a period of intensive development, which generated regular product improvements. The first digital testbed was also installed at headquarters during this time.

Prof. Helmut List – His Personal Life and Achievements

It is nearly impossible to acknowledge the life and work of Prof. Helmut List in just a few words. For almost six decades, he has shaped AVL, and with his many achievements he is the embodiment of the spirit of our company.

fter attending elementary school, Helmut List attended the secondary school in Lichtenfelsgasse in Graz. At a young age he showed extraordinary talent for technology and started tinkering with radios, which led him to study mechanical and electrical engineering at the Graz University of Technology. During his studies he gained hands-on experience at engine factories in England, the USA, France, and Germany.

He joined AVL in 1966, where he started his career heading up the production department for electronic and precision measuring instruments. He also assumed the role of project manager for the development of a new medical blood gas analyzer based on a concept by and in collaboration with Prof. Dr. Karl Harnoncourt. Blood gas analysis was at the heart of what would become AVL Medizintechnik; In his role as managing director he was responsible for the technological aspects of this field – from the very beginning until it was sold to Roche Diagnostics in 2000.

In 1970, AVL set up a new, younger management board – and Helmut List took the chair for measurement technology, production, and sales, thus laying the foundation for continuous rapid growth. During this time he also started to set up the first AVL subsidiaries around the world.

In December 1975, Helmut List married his first wife Dagmar Grill, who gave birth to their daughter Katharina in 1979. During his travels he met his second wife – an American called Kathryn. They married in Dearborn, USA, in 1987. In 1989, she gave birth to their son Hans Gordon, named after his two grandfathers. Their daughter Olivia followed in 1991, with their daughter Clara Elizabeth arriving in 1996.

In 1979, Helmut List became CEO of AVL. Under his management, the pioneering findings and research activities in the area of diesel engine technology were expanded. Under his leadership, AVL expanded into a global company with a worldwide network of tech centers. Over the last two decades, he has placed a strong emphasis on shifting the primary focus from just the engine to the entire propulsion system. In pursuit of this goal, he has initiated various endeavors involving acquisitions and research programs dedicated to the advancement of electrified propulsion. Now, with 11,200 employees in more than 90 locations and with 45 tech and engineering centers, AVL is one of the world's leading mobility technology companies for development, simulation, and testing in the automotive industry and in other sectors.

One of the key priorities of Helmut List's work is the targeted application of research. This is reflected in the high R&D share across all strategic business areas and the many collaborations with university institutes both locally and internationally.

His initiatives have also revolutionized many R&D fields: For example, digitization at AVL, which Helmut List initiated in the 1970s with the introduction of digital testbed control systems; or the development of completely new unknown materials, such as the gallium phosphate crystal with the highest temperature resistance for pressure measurements. His idea to correlate drivers' subjective evaluations of the drivability of a car with the measurable factors in the vehicle and to gain an objective, reproducible benchmark from the multitude of such correlations was also revolutionary. Thus, the AVL drivability technology was born. He came up with pivotal initiatives in the field of the mathematical modeling of flow processes in 1980, which was the driving force behind the later establishment of the "Advanced Simulation Technologies" division. With the "Integrated and Open Development Platform" he united mathematical simulation and test results interactively in a cyber-physical development environment.

Over the years, Helmut List transformed AVL into the most innovative company in Austria, especially in terms of its

inventions. The corporation has topped the Austrian patent office rankings for many years.

Helmut List also advocates for excellent collaboration between universities and the industry, supporting, among other things, the establishment of Christian Doppler Laboratories and competence centers in Austria. He has held the position of university council chair at Graz University of Technology for ten years. Moreover, he was also actively involved in the foundation of the Styrian technical colleges in 1995 and the Styrian university conference.

Of particular importance in Helmut List's work is his strong commitment to Europe by actively shaping the areas of research, innovation, and economics. Since Austria's accession to the EU, he has shared his view of innovation with several committees on the topic of research and technology development. For example, he has been involved as Chairman of IRDAC, the European Commission's main advisory body for industrial research and technology development, as Vice Chairman of ERTRAC (European Road Transport Research Advisory Council), and Chairman of SSTAG (Sustainable Surface Transport Advisory Group). The focus of these and other committees is on linking technological topics with applicability to society and sustainability.

Helmut List built a bridge between science and art with the opening of Helmut List Halle in Graz in 2003. The acoustic brilliance of the hall was defined by the collaboration of AVL scientists and international artists (Nikolaus Harnoncourt, Beat Furrer, Bernhard Lang).

The AVL Cultural Foundation was founded by Helmut List and his wife Kathryn in 2007 – and she has been managing the foundation with great dedication and passion ever since. Following the guiding principle that technical innovation and artistic creativity have important things in common, art has now been connected with technology for many years and supports a wide variety of art and cultural projects, especially in the areas of the avant-garde and art and science.

In memory of his father, Helmut List also supports students of technical fields who are involved in scientific work in the field of vehicle propulsion systems and vehicle technology as well as related areas, through the Hans List Fund.

Prof. Helmut List

Honors and Accolades

1987	Honorary citizenship of the University of Graz
1992	Awarding of the title "Professor" by the Austrian Ministry of Science, on the recommendation of the Technical University of Vienna
1993	Honorary doctorate in engineering sciences at the Technical University of Dresden, Germany
1994	Honorary senator, University of Graz
1997	Honorary professor, University of Tongji, China
1997	Josef Krainer Award, governor of Styria
1999	Honorary professor, University of Jilin, China
2000	Rosthorn Medal, Austrian government
2002	Honorary Ring, city of Graz
2003	Exner Medal, Austrian Association for Small and Medium-Sized Enterprises (SME)
2005	Grand Decoration of Styria, Styrian provincial government
2007	Colin Trust Prize
2010	Grand Gold Decoration of Styria, Styrian provincial government
2012	Austrian Cross of Honor for Science and Art, 1st class
2013	Archduke Johann Ring of Honor, Graz University of Technology
2014	FISITA Medal
2015	Large gold medal of honor with the star of the state of Styria
2017	Archduke Johann Research Award, Styrian Economic Chamber
2017	Hermes Business Award, Federal Ministry of Science, Research, and Economy, Austrian Economic Chamber, leading Austrian companies
2022	Councilor of Commerce (professional title, awarded by the Federal President of Austria for services to the Republic)
2023	Honorary citizen of the city of Graz

The 1970s

The 1970s saw AVL initiate sales of its first fully automatic testbeds. Fifty medical devices were distributed at the same time. The importance of the technical support provided in Graz grew, guaranteeing operational stability for customers with as little downtime as possible. The aim was to analyze complaints quickly, make any necessary improvements to the devices, and then put these into production with top priority.

This was accompanied by the introduction of a younger executive management board, with Helmut List assuming the chair. He was also responsible for the Measurement Technology, Workshops (Production), and Sales areas at AVL. At this time, Hans List retained the top management role at the company. Further significant milestones were reached during the decade, with the introduction of capsule technology for acoustic insulation in engines and the initiation of development of DI diesel engines for passenger vehicles in 1974. AVL proudly presented the first prototype of a light diesel engine (LD) in 1975.

1979 saw Helmut List finally assume overall control of AVL from his father, having been actively involved in the company since 1966. The handover took place from September 9th to 24th with notarial authentication. At this time, AVL had around 500 employees.

1972 Foundation of AVL United Kingdom Ltd.

AVL United Kingdom Ltd. was established in Hartlebury (UK) in 1972. The subsidiary company now has centers of excellence in Coventry, Basildon, and Hartlebury. These can be used locally, thanks to the access to the international expertise network of the entire AVL Group.



Founded in 1976, AVL Deutschland GmbH started out as a pure sales company. Starting from the headquarters in Mainz-Kastel, more than ten locations were established in Germany, linked with the continuous expansion of the already extensive portfolio in the areas of engineering, instrumentation, test systems, and simulation.





The 1980s

In 1982, AVL introduced a procedure that enabled real-time insights into the combustion processes of diesel engines. In 1985, AVL commissioned a high-dynamic testbed, allowing a real engine to be tested in a virtual vehicle for the very first time. Testbeds of this type were developed for Italian carmaker Ferrari, for example.

In 1986, the first HSDI (High-Speed Direct Injection) diesel engine developed by AVL went into large-scale global production. This advanced engine was produced in large batches as a propulsion system for light commercial vehicles, marking a significant milestone in the development of diesel engine technology.

1980 Foundation of AVL Italia S.r.l.

Headquartered in Turin, AVL Italia S.r.L. was founded in 1980 with the aim of introducing AVL testing and instrumentation to the Italian market. In 2006, the subsidiary expanded its expertise in the areas of mechanics, fluidics and end-of-line cold testing systems. The area of end-of-line cold testing systems has been operating as a separate legal entity since 2017. A state-of-the art technology center opened in Cavriago in the same year, featuring a high-voltage laboratory with a prototype battery assembly area. This saw AVL establish a powerful presence in the Emilia Romagna region, known as the "Motor Valley" of Italy.

1984

Foundation of AVL India Private Ltd.

AVL India Private Ltd. was established in 1984 and has pioneered the provision of turnkey projects, encompassing testbed systems, end-of-line tests, and quality control for all types of mobility technology. The expansion of the technology center allowed for the provision of customer-specific services for the construction and development of propulsion systems for the Indian market.

1987

Foundation of AVL List Nordiska AB

AVL List Nordiska AB has been headquartered in Stockholm since its foundation in 1987. Scandinavia plays a significant global role in the automotive industry. This geographical relevance is reflected in the four AVL subsidiaries in Sweden.

The 1990s

In 1990, AVL introduced the tomographic combustion analysis (TCA). This enabled visual capture and analysis of the combustion phenomena displayed by a close-to-series Otto engine. In 1992, AVL developed a powertrain demonstration system for fully-hybrid propulsion, in conjunction with another manufacturer. The Universal Hybrid System (UHS) used planetary gearing to link an internal combustion engine with two electric motors. One year later, in 1993, AVL became the first company in the world to deliver specific motorsport testbeds that were able to simulate the dynamic requirements of race engines, such as those in Formula 1 or the IndyCar series.

In this decade, AVL also developed the first demonstration model for a GDI Turbo (Gasoline Direct Injection).

1990 Foundation of AVL Ibérica S.A.

AVL Ibérica S.A., established in Barcelona, Spain, in 1990 is responsible for the Spanish, Mexican, and Portuguese markets. AVL Ibérica focuses on delivering top-level services for the development, simulation, testing, and integration of propulsion systems – in conjunction with the entire AVL Group.

1990 Foundation of AVL France S.A.S.

Until 1990, the privately-owned company "Etablissement Urbah", located in the 8th arrondissement of Paris, represented the instrument and testbed department of AVL in France. To better meet the demands of globalization and the need for customer proximity in France, some employees joined AVL France in Chatou in 1990. In 1993, AVL France was the first AVL subsidiary to set up a simulation department, before the establishment of the Advanced Simulation Technologies (AST) business area.

1991 Foundation of AVL Korea Co. Ltd.

Since its foundation in 1991, AVL Korea Co. Ltd. has been a reliable partner for Korean customers in areas such as technical services, measurement systems, and test systems, as well as software and simulation. In addition, the opening of the Tech Center in Seoul in 2007 was an important further step that had a positive impact on the overall business development in Korea.



1995 Foundation of AVL Japan K.K.

Business activities began for AVL in Japan back in 1969 in the area of construction and development of engines for truck manufacturers. Since its foundation in 1995, AVL Japan K.K. has been offering the complete range of innovative AVL technologies. 2016 saw the opening of the Japan Technical Center, to implement customer requests with regard to propulsion technologies for automobiles, industrial machines, and ships.

1996 Foundation of AVL Moravia s.r.o

AVL Moravia, headquartered in Hranice, Czechia, was established in 1996 and produces electric motors, chassis dynos, and testing equipment. The expertise of this subsidiary is reflected in the close cooperation with development departments from major automotive concerns. AVL Moravia is a market leader in Czechia.

1996 Foundation of AVL AST d.o.o. Hrvatska

AVL AST d.o.o. was founded as a member of the AVL Group in 1996, with headquarters in Zagreb, Croatia. As a strategic partner, the company focuses primarily on software development, electrification, and creation and implementation of software solutions for the simulation, testing, and optimization of all types of propulsion systems for passenger and commercial vehicles. 2019 saw the opening of the AVL Powertrain Engineering Center in Zagreb, followed by the Power Electronics Center and Lab in 2021.

1996 Foundation of AVL-AST d.o.o. Slovenija

AVL-AST d.o.o., located in Maribor and Ljubljana, Slovenia, was established in 1996 and has since focused primarily on the Advanced Simulation Technologies and Engineering Services business areas.

1997 Foundation

Foundation of AVL MTC Motortestcenter AB

The AVL MTC Motortestcenter AB in Jordbro, Sweden, was established in 1997 and has since supported customers from the automotive industry with the development of engines and transmissions. It also enjoys the role of an intermediary with industry-specific expertise for research programs. For example, numerous international projects have contributed to optimized air quality.

1997

Foundation of AVL Mobility Technologies, Inc. (formerly AVL PEI North America)

Since its foundation in 1997, AVL Mobility Technologies, Inc. has offered solutions in the areas of e-mobility, fuel cells, batteries, ADAS/AD, data intelligence, and embedded systems for all types of vehicles. The global AVL network enables the company to deliver outstanding and sustainable mobility solutions for North America and the world. AVL Mobility Technologies Inc. thereby makes a significant contribution to improving vehicle safety and reducing emissions.

1998

Foundation of AVL South America Ltda.

AVL South America Ltda. is headquartered in São Paulo, Brazil. The company was founded in 1998 and operates in the field of clinical laboratories, focusing on technical analysis and testing. In 2012, AVL South America Ltda. expanded its portfolio to include simulation solutions. In 2014, the Engineering Tech Center, including two engine testbeds and a vehicle testbed, was opened.

1999

Foundation of AVL DITEST GmbH

Since 1999, AVL DITEST GmbH, based in Graz, Austria and Cadolzburg, Germany, has been successfully distributing intelligent device solutions for the automotive sector around the world. The wide range of products from AVL DITEST GmbH delivers perfectly coordinated devices to suit all needs in the area of vehicle diagnosis and instrumentation, guaranteeing precise exhaust analysis for petrol and diesel engines.

1999

Foundation of AVL SEA & Australia Co. Ltd

Since 1999, AVL SEA & Australia Co. Ltd has had its headquarters in Bangkok. This location – alongside the offices in Hanoi, Jakarta, Melbourne, Kuala Lumpur, and Taipei – serves customers with the technical expertise of AVL SEA & Australia Co. Ltd. In addition, AVL had an office in Australia for many years to provide local support to Australian customers from Sydney. This office was closed in 2019 after the international automotive industry left Australia.



The 2000s

In 2000, the business area for medical devices was sold to Roche Diagnostics. 2002 saw operations begin at the test track in Gratkorn, near Graz.

2003 saw the opening of the Helmut List Halle in Graz as an event center for up to 2400 visitors. After four months of planning and a ten-month construction phase, the event location officially opened on January 9, 2003 with the first staged performance of "Begehren" by Beat Furrer, which also heralded the start of Graz's year as Cultural Capital of Europe in 2003.

2001 AVL Schrick Performance Components GmbH

AVL Schrick Performance Components GmbH has been focusing on the production, processing, and distribution of mechanical components and systems made from a range of materials – for chassis, combustion, electric, and hydrogen motors and for the heavy-load sectors of the industry since 2001.

2002 Foundation of AVL Hungary Kft.

AVL List GmbH acquired the engine development department of the company known as AUTÓKUT at the time, integrating this into the AVL Group. AVL Hungary Kft. is involved in domestic and international projects, working with state-of-theart equipment and developing propulsion systems of the future for the automotive, heavy-load, construction, and shipping industry.

2002 AVL Schrick GmbH

2002 saw AVL take over the German engine developer Schrick, which was founded as Dr. Schrick GmbH in 1969, and integrate it into the company. Schrick had its roots in motorsport and specialized in manufacturing camshafts. AVL had been working on the development of new, alternative propulsion concepts since the early 2000s and started to integrate hybrid technologies into vehicles in 2003.

2004 Foundation of AVL Tippelmann GmbH

Tippelmann GmbH near Neuenstadt, Germany, was founded in 1976 and became part of the AVL Group in 2004. Now active on the global stage, the company develops measurement procedures that allow the capture of flow processes in internal combustion engine cylinders. The strict requirements in place for exhaust gas quality mean that the development testbeds and series test machines constructed for this purpose at AVL Tippelmann play an increasingly critical role.

2004 Foundation of AVL Zöllner GmbH

Headquartered in Kiel, Germany, AVL Zöllner GmbH was founded in 2004. The company specializes in the development, production, and distribution of mechanical engineering and electronic products, especially testbed equipment for the automotive industry.

2005 Foundation of AVL Test Systems Co. Ltd

AVL Test Systems Co. Ltd was established in 2005, with the aim of enabling RMB transactions for AVL in the Chinese market. Originally located in Pudong, Shanghai, the company has built up a number of branch offices in China and assumed economic control of the production and assembly workshops and warehouses in Beijing and Lingang. Now represented with locations in Shanghai, Tianjin, and Beijing, as well as a software center in Chengdu and offices in Wuhan, Chongqing, Jinan, and Guangzhou, AVL Test Systems Co. Ltd has developed into a significant and extremely profitable part of the AVL China organization.

2005 Foundation of AVL Powertrain UK Limited

AVL Powertrain UK Limited consists of an international team that develops state-of-the-art technologies in the areas of e-mobility, connected and autonomous driving, testing methodology, and software and simulation for all propulsion applications. In 2009, the company expanded to include the Engineering Centre Coventry, followed by the Technical Centre Coventry in 2017. In 2020, the Engineering Centre Basildon was opened for internal research and development in the area of fuel cell and battery development.

2005

Foundation of Piezocryst Advanced Sensorics GmbH

In the late 1980s and the 1990s, a research project for creating artificial crystals came to fruition in the Physics department. As a result, 2005 saw the foundation of Piezocryst Advanced Sensorics GmbH, focusing on pressure and acceleration sensors. The company focuses on the optimization of production and combustion processes. The use of these products reduces the rejection rate, lowers the consumption of complete engine and turbine generations, and improves the efficiency of large engines and turbines during operation. In addition, Piezocryst has its own crystal growing system to ensure the quality of the sensors.

2006

Foundation of AVL Analytical Technologies GmbH (formerly AVL Emission Test Systems GmbH)

2006 saw the foundation of AVL Emission Test Systems GmbH, the result of an amalgamation of Pierburg Instruments, Peus Systems, and the AVL emissions department. 2007 saw the AVL subsidiary bring the new, intelligent AVL-iGeneration family of products to the market, consisting of exhaust gas measurement systems, dilution systems, and particle samplers. 2017 saw AVL AMA SL[™] make its first appearance at the Automotive Testing Expo Europe in Stuttgart. The subsidiary was renamed AVL Analytical Technologies GmbH in 2022.

2007 AVL LMM S.A.S. (formerly AVL Le Moteur Moderne S.A.S.)

Further internationalization efforts saw the AVL Group take over the French propulsion system service provider Le Moteur Moderne in 2007 – this company had originally been established in Boulogne as an engineering firm in 1951. In light of the increasing significance of France in the global automotive market, the aim of this acquisition was to increase customer proximity and enable larger-scale series development programs. The company was renamed AVL LMM S.A.S. in 2014.

2007

Foundation of AVL Romania S.R.L.

AVL Romania S.R.L. was founded as a member of the AVL Group in 2007, with headquarters in Bucharest. The company's extensive portfolio covers all customer requests from the automotive industry – innovative testing solutions, optimization of propulsion systems for passenger and commercial vehicles, and software production and electrification.

2008

Foundation of AVL Software and Functions GmbH

2008 saw the foundation of the new subsidiary AVL Software and Functions GmbH, based in Regensburg, Germany. With a focus squarely on technologically advanced software and system solutions for intelligent, ecologically sound mobility, system integration, and electronics development, as well as safety and security applications. Employees of AVL Software and Functions GmbH are currently working on the mobility of the future at six locations.

2008

AVL Zöllner Marine GmbH

Headquartered in Kiel, Germany, AVL Zöllner Marine has been concentrating on the development, production, and distribution of machine engineering and electric/electronic products since 2008. The focus is on testbed equipment for propulsion systems.

2008

Foundation of AVL Research & Engineering Turkey

In 2008, AVL was the first international engineering services provider in the automotive segment to establish a subsidiary in Turkey. Since then, the organization in Istanbul has grown to nearly 400 engineers, working on global projects and serving local customers.



The 2010s

2010 saw AVL open a battery lab in China, the AVL List Technical Center (Shanghai) Co. Ltd. This was followed by the AVL List Technical Center (Tianjin) Co. Ltd. as a second Chinese center in 2016. The aim was to streamline the engine development process to match the increasing demands from the Chinese automotive industry for a shorter product development cycle. This also allowed Chinese and foreign suppliers to be included at an earlier stage of development. This was the first technical center for engine development run by a private company in China. To this day, the involvement of AVL strengthens the long-lasting relationship with China, which can be traced back to 1926, when AVL founder Hans List lived and worked at Tongji University.

In 2014, AVL acquired a majority stake in qpunkt, which was founded in 2008 and at the time employed 150 people in Hart near Graz and at four other locations. qpunkt was well-known for specializing in thermal management, flow technology, and acoustics. The company focused on the use of physical and virtual methods, as well as the corresponding instrumentation, to develop innovative solutions related to thermal management. The addition of the subsidiary Epzwo made it possible to cover the entire V-process, from thermal management development to SOP. In 2018, qpunkt was completely integrated into the AVL Group as the Thermal Management & HVAC product line and operates globally within AVL's worldwide network.

2010 Foundation of AVL Engineering & Test Systems Türkiye

The steep development curve in the Turkish automotive industry included the delivery of test systems in the 1980s and AVL Instrumentation and Test Systems therefore decided to become active in the region in 2010. The company has since grown steadily, with 50 engineers now providing engineering, after-sales, and project management services locally and globally.

2012 Foundation of AVL SET GmbH (formerly SET Power Systems GmbH)

2012 saw the company now known as AVL SET (then SET Power Systems GmbH) established as a "Member of the AVL Group", in a joint venture with AVL List GmbH. The company is located in Wangen im Allgäu, Germany. The aim was to provide customers in the development area of the automotive industry with power Hardware-in-the-Loop test systems. A completely new methodology was developed for the market, to test propulsion inverters using e-machine emulation technology. Continuous technological advances and the resulting need for innovation in the area of power electronics for electro propulsion systems continues to demand swift and agile growth from AVL SET. In 2016, AVL agreed to enter a partnership with Greenlight Innovation Corp., one of the world's leading providers of test and production systems for hydrogen fuel cells, electrolyzers, batteries, and energy storage devices. In May 2018, AVL announced the opening of a research and development center for fuel cell technology in Vancouver. The investment in this new R&D center was intended to strengthen the leading role of AVL in the provision of engineering solutions for next-generation propulsion systems.

On May 31, 2017, AVL opened the world-leading center of excellence for research and development of innovative propulsion systems, together with Graz University of Technology (TU Graz). The AVL-TU Graz Transmission Center is anchored in the Expertise Mobility & Production field, one of five strategic research areas at TU Graz.

In 2018, AVL opened an expanded battery lab in Graz after eleven months of reconstruction. The test center covers an area of around 700 square meters, featuring four testbeds that can cover battery developments up to 1200 V. It is regarded as one of the most modern centers for electric and thermal battery testing in Europe. It also allows test execution with larger batteries, from electric buses or trucks. The expansion of the center sees AVL continue to drive large-scale series production for batteries. Back in 2012, AVL developed and realized the first 800 V electric vehicle (BEV) "AVL CoupE", which was regarded as the concept car for battery technologies for largescale series BEV.

2019 saw AVL work with ZalaZONE to establish the joint venture "AVL ZalaZONE Proving Ground Ltd." Operated by AVL, the 250-hectare vehicle testing site to the west of Zalaegerszeg, Hungary, was conceived specially for the development and validation of autonomous and electric vehicles. It also enables the execution of dynamic and durability tests for conventional vehicles. AVL ZalaZONE provides complete testing solutions with engineering services, technical equipment, workshops and offices for testing staff, AB Dynamics EuroNCAP equipment for ADAS tests, HD mapping, and test drivers.

> "It is a long journey from the development of challenging system solutions to their industrial implementation, and one which we will be embarking on in the area of transmission system electrification in an even closer partnership with TU Graz. This allows us to ensure that AVL can continue to expand its leading international position in research and development of state-of-the-art propulsion solutions."

2012

Foundation of AVL Commercial Driveline & Tractor Engineering GmbH

AVL Commercial Driveline & Tractor Engineering GmbH was established in Steyr, Austria, in 2012. Comprehensive engineering experience, paired with the use of efficient development, simulation, and testing tools, form the basis for innovative solutions in tractor technology, for example.

2017 AVL End of Line Testing Systems S.r.l.

Located in Turin, Italy, AVL End of Line Testing Systems S.r.l. has been focusing on the production of measurement and control devices, drawing instruments, counters for electricity, gas, water, and other fluids, and analytical precision scales since 2017.

2018

Foundation of AVL Fuel Cell Canada Inc.

2018 saw the establishment of AVL Fuel Cell Canada Inc. Based in Vancouver, Canada, the company is a global center of expertise for state-of-the-art proton-exchange membrane fuel cell development and covers all applications, including automotive, heavy-load, and marine.

2019

Foundation of AVL Maroc SARL AU

In 2019, AVL LMM S.A.S. founded AVL Maroc SARL AU in Rabat, in order to establish a strong engineering center to look after customer projects jointly between France and Morocco. In total, roughly 500 employees are working to further develop the respective markets of AVL.



2022 AVL Hungary Kft - Zalaegerszeg

In November 2022, AVL opened a unique technical facility in Zalaegerszeg, Hungary, for testing current and future vehicles vehicles. The vehicle development center consists of a 1,340-square-meter hall with space for more than 50 test vehicles, as well as prototype garages. In the hall, full solutions are possible for testing ADAS/AD systems in real environments. It also has a direct link to the AVL ZalaZONE testing site, as well as the Smart City integrated in that facility.

The 2020s

2021 saw AVL start operations at the Battery Innovation Center (BIC) at the Graz headquarters. The 1,600-squaremeter center of excellence for batteries will provide the best possible support for the automotive industry as it transitions to e-mobility. Alongside the functional development of new, high-voltage batteries for electric vehicles, the focus is on establishing, implementing, and validating new, highly efficient production processes. A range of simulation tools allows these to be adjusted flexibly to new requirements and enables early customer implementation in large-scale series.

In order to support on-site mobility requirements as efficiently as possible, AVL opened a further office in San Sebastián, Spain, in addition to the existing three subsidiaries. The office in the Basque region began operations in July 2022 and is located in the technological and economical ecosystem of Gipuzkoa Science and Technology Park. The expertise of the AVL Group, combined with the Basque economic, technological, and innovation network, provides the ideal framework for future growth in the sector.

As well as the Battery Innovation Center, the AVL Hydrogen and Fuel Cell Test Center – one of the largest and most cutting-edge test sites for fuel cells and electrolysis systems in

> "The demand for electrical energy is growing continuously, while at the same time we are faced with the challenge of reducing CO₂ emissions. Hydrogen and fuel cell technology offers promising solutions. At AVL, we develop this technology and use our test capabilities to bring it to market maturity. We established ourselves as the leading company in this future technology a number of years ago, and we are now strengthening that position with our new test center." HELMUT LIST

the world – was also officially opened in September 2022. The new center at the headquarters in Graz has a maximum capacity of up to 20 high-performance testbeds and strengthens the pioneering role in the extensive development of fuel cells and innovative technologies for the production of hydrogen.

On October 27, 2022, AVL opened another competence center: the AVL Mobility and Sensor Test Center in Roding, Germany – a unique indoor laboratory for verifying and validating sensors for driver assistance systems. In the 1,600-square-meter test area, safety-related functions can be tested in adverse weather conditions, regardless of actual outdoor conditions, thus ensuring that the vehicles are safe in semi-autonomous mode.

In 2023, AVL Canada established two new research and development sites in Montreal and the Toronto-Windsor corridor. This expansion allows AVL to develop and provide stateof-the-art fuel cell technologies, and also boosts technical support and business expertise in Canada.

In the same year, AVL Schrick expanded to Mlada Boleslav (CZ) to support local development activities within their newly opened engineering center.

Always on the Pulse of the Times

AVL's brand evolution is a testament to our adaptability. It shows that we understand the market, anticipate future trends, and can change with the world. However, one thing has remained consistent throughout the decades – our commitment to innovation, excellence, and sustainability.

The Evolution of a Brand

AVL was founded at a time when vehicles were developing from a luxury item to an everyday object. The first ten years were marked by intensive research and development, strengthening the brand's commitment to scientific excellence. With the fuel crisis in the 1970s. AVL shifted its focus towards fuel-efficient technology. This era marked our transition from being purely research-oriented to becoming more solution-focused. In the 1980s and 1990s, we continued to extend our global presence. Through strategic partnerships with industry experts, we have been able to make our solutions accessible to a wider audience and establish ourselves as one of the global leading companies in automotive technology. At the turn of the millennium, AVL adjusted course once again and aligned itself even more closely with the new sustainability goals. Recognizing the rising trend of electric vehicles, we invested heavily in the development and testing of electric propulsion systems and battery technology.

Reimagining Motion

Today, AVL's brand identity is shaped by the legacy of 75 years of pioneering spirit, openness to technology, and adaptability. We crafted a new visual identity to reflect our vast product and service portfolio, multitudinous R&D activities, and our worldwide network of experts. Our new claim 'Reimagining Motion' is a good fit in today's world of constant change and innovation, signaling our commitment to shaping the future of mobility. A promise to push the boundaries of what's possible and to make mobility safer, cleaner, and more efficient. The word "motion" has been chosen since it represents the underlying principle behind all movement, regardless of propulsion system and fuel.



"Remain Curious and Open to All Possibilities That Lie Ahead!"

Interview with **Prof. Helmut List**

For 75 years, AVL has been forging an innovative path with its expanding range of technologies and services, ensuring that we always remain at the forefront of the industry and first choice for our customers. FOCUS interviewed the man behind this unique success story.

This year AVL celebrates its 75th anniversary. Prof. List, what do you consider to be the best aspect of managing the company?

The exchange with my colleagues. It is inspiring working with so many talented people who are passionate about technical topics and innovations. Every day I have the opportunity to learn from their perspectives while also contributing my own knowledge and ideas. There is also a deeper motivation for me. AVL is in the unique position of having a positive impact on the world. By developing innovative technologies and solutions for sustainable mobility, we help keep our planet a place worth living for people.

focus SPECIAL EDITION

Our headquarters is located in the green heart of Austria. What connects you to the city of Graz?

I have close ties with the beautiful city of Graz. I grew up here, went to school, and completed my academic career here. While I was studying at the Graz University of Technology, my father regularly accompanied me on my way to university. Our walks together not only provided an opportunity to exchange ideas about technology and AVL, but we also had lively discussions about possible solutions to current challenges. And my dear wife Kathryn and our children also have deep connections with Graz.

How have your own experiences and visions shaped AVL's direction and strategy over the years?

Visions and direction are always the result of many discussions and analysis. These lead to scenarios and thus also different approaches to solutions. I have always endeavored to incorporate every potential solution and to remain as flexible as possible in order to react quickly to new conditions.





What challenges were and are you faced with, and how have you overcome them?

The path towards being climate neutral is one of the greatest challenges of our time. Reducing CO₂ emissions must also be our primary goal in the mobility sector. At AVL, we are pushing forward the transition from fossil fuels to renewable energies. We are putting all our efforts into the research and development of sustainable technologies and, including ADAS, already generate 60% of our revenue in this sector. This also shows that climate protection and economic growth can go hand in hand.

Looking back at AVL's 75-year history, what are the most important milestones that are particularly close to your heart and why?

We combined simulation, testing, and validation relatively early on. Over the decades, this has resulted in major innovations that have led to a large number of patents, of which more than 2,000 are still in active use today. In the 1980s and 1990s, we deliberately focused on business growth – especially in Germany, but also in the USA and China. We have placed research at the center of our strategy and invested in R&D even in challenging times. We have also applied our expertise to the field of medical technology. Furthermore, we expanded our global presence early on, to be as close as possible to our customers, and we now have 90 locations in 26 countries. Furthermore, we were also one of the first companies to fully embrace new technologies. I am proud of all of these milestones.

How has AVL developed over the years?

AVL's great strength has always been being very well prepared for the future. It is important to always be one step ahead. For example, we already developed an e-drive 20 years ago. We are one of the most renowned companies in the world when it comes to battery development. We are heading in a new direction with our high-temperature electrolysis facility, which achieves an efficiency of over 80 percent in the production of hydrogen using electricity. And we are just as innovative when it comes to integrating the energy source into hybrid cars and fuel cell technology, for example. Software-defined vehicles and automated driving are also part of our main focus areas. This is how we shape the transition towards climate neutral mobility, both at our location in Graz and globally.

What role does innovation play in AVL's success, and how has the company fostered a culture of innovation throughout its history?

Together, we live a culture of openness. We listen and take the advice of our experts seriously. We create free spaces for exploiting full creative potential. We are not afraid of setbacks; we always try to learn from mistakes. This is how innovation is born.

How has AVL adapted to the rapidly changing automotive industry and the emerging technologies to remain at the forefront of mobility solutions?

We consistently invest in research and development to meet the complexity of today's mobility. In doing so, we remain open to new technologies. The important thing is to use the best solution where it contributes most efficiently to decarbonization. Sustainability and environmental awareness are becoming

increasingly important in the automotive industry. How has AVL taken up the challenge of sustainable mobility and what initiatives has the company introduced to contribute to a greener future?

AVL holds two thirds of its patents in the field of e-mobility. Together with our customers, the goal is to reduce and ultimately eliminate CO₂ emissions. We always approach each other here with openness and a clear understanding of the needs of both worlds. AVL is strongly committed to the Paris Climate Agreement and we are aware that we need to make our full contribution to decarbonization. Ultimately, what counts is the result that best helps the planet.

Cooperation is an important aspect in AVL's journey. Could you give some examples of successful partnerships that have contributed to the growth and innovations of AVL?

Our active partnerships with renowned universities and research institutes enable the development of innovative technologies, processes, and new and sustainable products. AVL is also represented in many committees, such as the European Road Transport Research Advisory Council and the Sustainable Surface Transport Advisory Group, and thus has an active role in helping to shape the European research, innovation, and economic space. The main focus is on linking technological matters with those of applicability for society, as well as on the importance of sustainability.

What future trends and challenges do you foresee in the mobility industry and how is AVL preparing to meet them?

In addition to e-mobility, the trend is moving towards alternative fuels such as hydrogen or e-fuels. Here, it is important to use the available resources in a particularly sustainable and efficient manner. Meaning where they have the greatest influence on minimizing the carbon footprint. But software-defined vehicles and cybersecurity – and thus automotated, inclusive, and safe mobility – will be topics becoming increasingly relevant. Digitization enables us to use generated data to further develop and optimize existing systems.

What is your message to AVL employees as they look to the future?

Remain curious and open to all possibilities that lie ahead! And stay passionate about working on new solutions!

Is longevity also sustainable per se? A company that lasts for generations?

Longevity is not a value per se. It's about constantly reinventing and redefining yourself, taking on new challenges but acting from experience.

Which of AVL's qualities can be described as enduring over the decades?

Our pioneering spirit and problem-solving competence. We have the ability to identify important trends and developments at an early stage and reach related goals ahead of the market. Only the courageous broaden their horizons and make discoveries that lead to outstanding innovations. At the same time, we take responsibility for our society and for humanity. We want to ensure that our world is a place worth living in – today and in the future. ■

"Only the courageous broaden their horizons and make discoveries that lead to outstanding innovations."

Pillars of Our Success

A company is like a house – the foundations are key. You can only build something that will endure if the groundwork is right. As has been the case at AVL for 75 years.

VL's success is built on five pillars that have remained unchanged since 1948: Pioneering Spirit, Customer Orientation, Problem-Solving Competence, Independence, and Responsibility. These core values are the driving force behind our daily work. They have shaped our corporate culture since the very beginning and are incorporated in all our business activities. However, the objective with which they are aligned has evolved over the past decades: Whereas initially the focus was on technical progress, these days it is on striving for climate-neutral mobility.

Pioneering Spirit

Turning visions of the future into reality with courage and expertise. We have cultivated the ability to recognize important trends and developments early on, and achieve the related targets ahead of the market. Only the courageous look beyond the horizon and make discoveries that lead to outstanding innovations.





Customer Orientation

Our success can only be measured by that of our customers. True understanding of a customer and their needs, combined with experience and a global view, allows us to create innovative solutions. Expertly conceived, uniquely tailored, and efficiently carried out – a shared success.



Responsibility

Modern mobility represents progress only when it can be implemented sustainably. Our work at AVL reflects a deep understanding of the responsibility we share for our society, for mankind, and for the world's achievements. We want to ensure that our world is one we can live in – now and in the future.



Problem-Solving Competence

It's a demanding world. A focus on research, cutting-edge technological developments, and clear product orientation are fundamental requirements for global competitiveness. With multi-disciplinary teams, we offer expertise, creativity, innovative thinking, and effective project management to support professional solutions.



Independence

AVL is a company with personality. Embodied in Helmut List and reflected in our work. A personality rooted in a life-long pursuit of knowledge, characterized by a deep sense of responsibility, and expressed in the company's independent status.

Our Values from an Artistic Perspective

In 2003, visual artist ILA created the installation The Brain – The Cloud, which is well-known to AVL employees and enjoys a prominent position at AVL headquarters.

In a recent project, ILA takes an artistic look at the five AVL values: Customer Orientation, Responsibility, Independence, Problem-Solving Competence, and Pioneering Spirit, visually re-interpreting them from his artistic perspective based on existing images by photographer Gerald Liebminger.

For ILA, an essential role of art is reminding oneself of the transcendental, altruistic meanings of life.

ILA (born in Leoben in 1969) studied Architecture, Philosophy, and Physics in Graz and graduated in Studies of Technical Geology. ■

Problem-Solving Competence, 2020, 70 x 70 cm Mixed technique on aluminum



"I can imagine a highly developed technological civilization with the deepest respect for life and for nature." ILA, artist

Pioneering Spirit, 2020, 70 x 70 cm Mixed technique on aluminum EVENTS HORIZON TRUE **PIONEER SPIRIT**

> Customer Orientation, 2020, 70 x 70 cm Mixed technique on aluminum



focus special edition

TEPONSIBILITY

Responsibility, 2020, 70 x 70 cm Mixed technique on aluminum

Independence, 2020, 70 x 70 cm Mixed technique on aluminum



Driving Innovation, Shaping the Future



VL's corporate strategy plays an important role in defining our portfolio and is just as significant in determining how we realize our sustainability objectives. It sets the directions that guide our decisions and our continuous transformation. These alignments also ensure that AVL remains at the forefront of technological progress, meets the evolving needs of our customers, motivates our employees and experts, and contributes to a more sustainable, more efficient future of mobility.

Innovation is in our DNA. At AVL, we recognized the potential of new technologies in the advancement of propulsion systems from the very beginning. We invested heavily in research and development, and in doing so constantly pushed the limits of what is possible. The result being efficient, powerful, and sustainable solutions. This innovative spirit has enabled us to grow with new ideas and in new areas, and to continuously develop our portfolio and our expertise.

> "Our strategy is the compass guiding us through the dynamic transition in the world of mobility."

Collaboration is the cornerstone of our success. We cultivate strong partnerships with leading global companies, academic institutions, and research organizations – a vibrant ecosystem for sharing knowledge and for cooperation. Together, we tackle complex challenges, accelerate technical progress, and shape the future of mobility across disciplines and borders.

Our corporate strategy will continue to be built on three pillars in the future: The targeted expansion of our products and services, combined with digitization and intelligence – all with the aim of developing sustainable solutions. Our portfolio of sophisticated technologies will facilitate the transition to green energy sources and the efficient integration into new energy systems. We are also exploiting the huge potential of digitization, intelligence, and connectivity. All this is revolutionizing the way the automotive industry develops and manufactures, and the way its products – vehicles and other mobility solutions – are used. By harnessing data and intelligent systems, we are taking efficiency, performance, safety, and user-friendliness to a whole new level and continuously improving even during the lifetime of a product.

Sustainability has always been at the core of our strategy. We are committed to developing environmentally friendly solutions that reduce emissions, conserve resources, and facilitate a more sustainable future.

With a clear course towards the future, AVL will be driving future mobility.

Looking back at AVL's 75-year history, what would you say were the key factors that contributed to the success of the company?

The key factors are innovation and a "steady hand" when pursuing good ideas. Another thing that makes us strong is our consistent customer focus – after all, our customers' success is our success. And lastly, our global outlook enables us to be a major player in every region.

AVL is celebrating 75 years. What role does corporate strategy play in the future direction?

Our strategy is the compass guiding us through the dynamic transition in the world of mobility – past, present, and future. It is also an important medium for letting all AVL employees, partners, and customers know where the journey is heading and what our priorities are.

What is AVL's strategy for taking advantage of the challenges and opportunities of digitization and connectivity in the automotive and industrial sectors?

This is where we have the edge. We started with digitization early on at AVL, accelerating virtualization and expanding our software portfolio. The more that digitization technologies evolve, the more we are harnessing intelligent systems and connectivity in our solutions, and the more this trend accelerates.

Sustainability is a key aspect of AVL's corporate strategy. How does the company drive environmentally friendly solutions and in doing so contribute to a sustainable future?

We see potential to further improve our own processes regarding resources, energy, and emissions. We are already well on our way here with many initiatives, and the results confirm we are heading in the right direction. But reducing the resource and energy intensity of our customers through our solutions is another important element. However, the biggest lever is the technologies we are working on to improve the sustainability of transportation and mobility – such as battery-electric or fuel-cell-electric vehicles. Interview with Georg List

"The results of our work are efficient, powerful and sustainable solutions."

It is also clear that sustainability is not something we can achieve alone. Collaboration in research, as well as intensive cooperation when planning investment projects and in operational activities are key factors here

Looking to the future, we are celebrating 75 years of AVL. What is particularly important to you personally?

For me, the anniversary is first and foremost a wonderful opportunity to say thank you: Thank you to all the employees, partners, and customers who have joined us on our journey. Together, we have achieved remarkable milestones and are now writing the next chapter in a story of innovation, growth, and collaboration.

Shaping the Future Responsibly and Sustainably

We take ESG (Environment, Social, and Governance) principles into account when making decisions and taking action – and have been doing so long before the term existed.

"At AVL, the correlation between sustainable actions and long-term economic success results in innovations created by committed employees."

DR. YORCK SCHMIDT, Chief Financial Officer and Member of the Management Board s an international company, we see it as our duty to contribute to solving social, cultural, and ecological issues – particularly with regard to environmental protection, sustainability, and the reduction of global emissions. Using resources sparingly and the ambitious targets for reducing greenhouse gas emissions will trigger a significant change in the transport sector; e-mobility and a balanced, efficient, and environmentally friendly mix of propulsion systems will be key here. AVL is taking on a pivotal role as a driving force.

Dr. Yorck Schmidt, Chief Financial Officer and Member of the Management Board AVL, summarizes: "At the core of our values and strategies, we placed the idea of responsibility and sustainability at the center of our business operations at a very early stage. And we will remain challenged in the area of ESG in the future since our customers' requirements will change significantly." In terms of the requirements of the ESG taxonomy, the EU-wide system for classifying sustainable economic activities, AVL is active in all three defined areas:



Environmental Protection: Innovation for Sustainable Mobility

AVL is driving innovative and cost-effective solutions for climate-neutral mobility – from traditional and hybrid technologies, to battery and fuel cell technologies. With a holistic approach ranging from brainstorming to series production, we have every architecture, platform, and energy source covered. As a result, we are making a significant contribution to the global reduction of CO₂. We are also reducing the emissions at our own infrastructure. For example, the AVL battery test center in Graz is powered by 100 % renewable electricity. Virtualization also reduces fuel consumption during testing. Ten AVL virtual testbeds save around 1,500 tons of CO₂ per year.

Social: From Company Kindergarten to Knowledge Transfer

People are at the heart of all creativity and innovation – this is one of our central guiding principles. We are striving to create a working atmosphere that both meets today's requirements for a modern workplace and promotes the spirit of invention. AVL was an early adopter of a flexible working model (teleworking) and supports young families by providing a company kindergarten. For example, we were awarded the "Family & Career" state prize in 2021 in recognition of our efforts and were voted one of the top 3 companies in Austria in the state prize the following year. In the rankings compiled by Randstad, we have consistently been among the top 3 employers in Austria in recent years – and were even number 1 in 2023.

AVL employees benefit from around five days of further training per year, while managers take an average of seven days – top values compared with the rest of Austria. Another key factor is safeguarding expertise: it is very easy to deploy expertise from traditional internal combustion engine areas in the new fields of mobility. Product-specific characteristics can be acquired quickly, and tools and methods as well as series production experience can be adopted or adapted. This helps accelerate the transformation toward sustainable mobility.

Corporate Governance: Responsible, Certified Leadership

Change only succeeds when employees are informed, when the measures are understood, and when there is an opportunity for active participation. AVL has already implemented essential requirements in the context of management structures and systems as well as reporting. We follow a proven approach with regard to quality, the environment, security, and occupational health and safety. We have certifications for our quality management system (ISO 9001), our environmental management system (ISO 14001), our information security management system – (ISO 27001 ISMS), and our management system for occupational health and safety (ISO 45001). ■

Initiatives and Collaborations in the ESG Environment

ÖKOPROFIT

ÖKOPROFIT is a program run by the Graz environmental office that benefits both the environment and the economy. It shares expertise with businesses in order to reduce and avoid waste and emissions, thereby saving money. This has a positive impact on the city's environment and ensures economic success in terms of sustainability. AVL has been participating in this program since 1999 and has been presented with the ÖKOPROFIT business award several times.

respACT

respACT is Austria's leading platform for corporate social responsibility (CSR) and sustainable development. The initiative mobilizes key stakeholders to make Austria a pioneer when it comes to a sustainable and responsible economy. AVL has been actively involved in respACT since 1999, making the company one of the longest-standing members ever.

"Carbon-Neutrality" Project in Cooperation with denkstatt & enertec GmbH

Energy consumption and greenhouse gas emissions have been monitored globally for some time. In cooperation with denkstatt & enertec GmbH, a project was launched in 2020 to decarbonize the AVL headquarters in Graz. The project will run until 2026.

Diversity Charter - No One Left Behind!

Launched by the Austrian Federal Economic Chamber in 2010, the charter promotes respect for all members of society. It is a voluntary, public commitment based on the recognition that diversity is an essential characteristic of Europe. By signing this charter back in spring 2020 – in addition to the inclusion management strategy launched in 2018 – AVL sent a clear signal in support of promoting diversity in the company.

Certified Quality: Our Integrated Management System

Global IMS responsibles of AVL List GmbH



AVL's progression from a small engineering office to a globally active corporation posed many challenges. Overcoming these challenges required an ever-increasing degree of structure and organization over the years. Binding standards, stringent processes along the entire value chain, and precise documentation have been our modus operandi ever since. They determine the quality of our work and are key factors for the continued growth of AVL. e took a huge step in our pursuit of excellence in 1992: This was when the Testing Solution business unit introduced a quality management system (QMS) with ISO 9001 certification. This measure was also adopted in the business units of Engineering and Simulation Solutions in 1997. From this point on, actively controlled, verified, and officially certified quality became embodied in corporate culture – and a significant part of the company's success.

In the years that followed, we systematically continued along the path we had started out on: In addition to quality management, we now focused more intensely on environmental management. To integrate an appropriate system into the operational work environment in a way that was strategically smart and beneficial, we decided to get involved in the ÖKOPROFIT program run by the city of Graz as early as the end of the 1990s.

It wasn't long before this commitment bore its first fruits: As a Q1 supplier to Ford, our environmental management system received ISO 14001 certification for the first time in 2002 – proof of our early commitment to taking sustainable and forward-looking action. Since then, we have been working on continuously reducing our environmental impact. In addition, we are striving to become carbon neutral in order to fulfill our responsibility towards people and the environment. Particularly in view of the ecological and economic parameters changing constantly, this has been and remains our guiding principle to this day.

Consequently, responsibility for the environment and climate was firmly embedded into the processes at the headquarters – and successively extended to the entire AVL family around the world. One of the first subsidiaries to receive ISO 9001 and 14001 certification was AVL Deutschland GmbH. Most recently, ISO 9001 was successfully introduced at AVL Maroc SARL AU.

The safety of our employees has always been a top priority for AVL: Reducing risks in the workplace and improving working conditions are of great importance to us. The management system with ISO 45001 certification (occupational health and safety) since 2021 will continue to support us with this in the future.

AVL also recognized the importance of the field of information security early on. As early as 2010, we obtained ISO 27001 certification (information security) for our management system. This proves to our customers that we protect information appropriately in line with the latest technology. Continuously adapting our security measures in response to current threats and risks enables us to ensure the confidentiality, integrity, and availability of information throughout the entire AVL Group. For specific requirements in the automotive sector, AVL also complies with standards such as TISAX and ISO/SAE 21434 to protect networked vehicles from cyberattacks.

Together, the five certifications currently held form the core of the Integrated Management System at AVL. Work on global compliance with these standards has been ongoing since their introduction.

In addition, our business unit Instrumentation and Test Systems decided to apply for accreditation as an ISO 17025 calibration laboratory in the field of flow measurement (fuel consumption) in 2010. We were granted initial accreditation in 2012. Several extensions with new calibration methods were added in the years that followed – e.g., gas concentration, particle count, etc. – and these were confirmed by

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ZERTIFIKAT

Initial ISO 9001 certification of the business unit Engine Research and Development: AVL List GmbH, Graz HQ and Steyr branch, November 1997

the "Akkreditierung Austria" office. A success story made possible by the commitment of our employees.

And the latest? AVL headquarters in Graz passed the TÜV SÜD recertification audit with flying colors in 2023, as in previous years. This means that we will hold the group certificate of the headquarters for a further three years. In order to be able to guarantee this status beyond that, internal audits are carried out on a regular basis at the headquarters and at our subsidiaries.

Here, special thanks go to Prof. Helmut List, who has driven all these activities from the very beginning on his own initiative, has committed himself personally to the further developments, and has supported them to the fullest extent. Companies like AVL will continue to face major challenges in the future: With the ISO certifications as a basis, we have the best prerequisites for overcoming all future hurdles. And for continuing to deliver the highest quality – for a better world of mobility.

AVL and Microsoft

Global Partners for Intelligent and **Sustainable Mobility**

Together, AVL and Microsoft are driving the digital transformation of vehicle development. The world's leading mobility solutions provider and the technology company are combining their expertise to help vehicle manufacturers bring their innovations to market faster than ever before. The key to accelerating development cycles lies in the power of data.

n August 2023, AVL and Microsoft entered an exclusive strategic partnership. Their common goal is to make vehicle development even more efficient and sustainable – thereby helping to shape the future of mobility. To this end, AVL uses the secure, AI-based cloud solutions provided by the American software leader. Together, the partners will also focus on overhauling software functions that currently define vehicle development.

The collaboration addresses Microsoft's primary goal of supporting customers to increase their business growth and drive digitalization-thus creating positive effects on people and economies.

Now, AVL is part of the world's largest partner ecosystem, with 400,000 partners in more than 225 countries. "The strategic partnership with Microsoft enables us to boost the digital transformation," says Jens Poggenburg, Executive Vice President AVL. "Pooling expertise allows us to refine the engineering and toolchain offering for our customers at top speed."

Today, around 3,000 software experts at AVL are already working on making the car of the future fit for real road traffic using virtual methods. All experts work independently of time and place within the digital space. The data collected from simulation and testing flows together into the cloud. This means

data is stored safely and securely- and can be evaluated with maximum efficiency using AVL's intelligent algorithms.

Cloud-Based Methodology: High Flexibility, Global Usage

A cloud-based approach to vehicle development allows a broad integration of AVL software. These tools are available to global development teams, including manufacturers, anytime and anywhere.

The key word here is: "Software as a Service." This model enables simultaneous access for all project stakeholders and encourages collaborative and innovative solutions as part of an open development process. Even with limited storage or computing power, there is no need to invest in new hardware – be it in engineering, simulation, or testing.

The integration of high-performance computing (HPC) complements this approach and takes it to the next level. HPC enables CPU-intensive tasks to be handled without the constraints of physical hardware capacity, which contributes to the scalability and efficiency of software testing.

Sebastian Jagsch, Global Head of Partner Management AVL, illustrates what this means on a higher level: "Revolutionary solutions are being created here, taking the development and validation of vehicle systems to the next level. This groundLeft to right: Hermann Erlach, General Manager Microsoft Österreich; Alex Flade, Director Strategic Partnerships EMEA Microsoft; Joacim Damgard, President of Western Europe Microsoft; Jens Poggenburg, Executive Vice President AVL; Sebastian Jagsch, Global Head of Partner Management AVL; Nikolai Rizzo, ATU Senior Sales Manager Cross-Industry Microsoft



breaking collaboration marks a significant step towards the future of mobility and opens up new opportunities for our customers around the world."

Sustainability as the Key Objective: Working Together for Greener Mobility

The partnership between AVL and Microsoft is a milestone on the road to greener and more sustainable mobility. It combines AVL's comprehensive expertise in vehicle development with Microsoft's innovative cloud and AI technology to create sustainable solutions.

The seamless integration of artificial intelligence not only results in accelerated development processes and optimized resource efficiency, but also makes a significant contribution to reducing the carbon footprint. Particularly in the area of Advanced Driver Assistance Systems and Autonomous Driving (ADAS/AD), artificial intelligence enables technologies that increase safety and comfort as well as optimized traffic flow and reduced fuel consumption.

Joacim Damgard, President of Western Europe at Microsoft, sums up the essence of this partnership vision: "We believe effect-and now so do AVL and its customers. that technology can be an instrument for global good. Which is why our collaboration with AVL is not just a synergy of tech-Microsoft's partnership model is based on three pillars: First and foremost, with the Microsoft Cloud, the company offers the most comprehensive solution for supporting digital transformation-in other words, true cloud innovation. The model also enables partners to scale guickly with the help of 35,000 global vendors and the Microsoft marketplace. Finally, Microsoft's technical extensibility and comprehensive business model facilitate the development of differentiated solutions for customers.

nology, but also a desire for greater sustainability. Together, we are using our resources and expertise to make fundamental changes to the way vehicles are developed and used, and to make significant further improvements to their sustainability." Generative AI Revolutionizes Autonomous Driving Systems The use of artificial intelligence focuses on what is known as generative AI. This uses existing information to generate

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entirely new content, data, and scenarios. Generative Al proves particularly impressive when creating highly realistic simulations and scenarios for autonomous driving. Here, real data and conditions converge in a smart way, creating realistic environments in which new driving technology can be tested and refined.

"For us, using artificial intelligence in vehicle development opens up a new chapter in mobility that is characterized by efficiency and sustainability. We are proud to be at the forefront of this transformation alongside AVL," emphasizes Hermann Erlach, General Manager at Microsoft Austria.

About the Microsoft Partner Ecosystem

With over 400,000 partners from more than 225 countries and regions, Microsoft's partner ecosystem creates a clear added value: useful and accessible cloud solutions and intelligent edge solutions, developed in collaboration with strong partners who can thereby generate new customer benefits by scaling and differentiating their solutions. Companies and local economies around the world benefit from this synergy



Our employees are the engine of our success. Nothing would work without them.

Employees – Value and **Appreciation**

AVL employs more than 11,000 people around the world. As an employer, the company has been performing well in independent rankings for many years now. In an interview, Chief Human Resources Officer Markus Tomaschitz reveals more about why this is.

Mr. Tomaschitz, you have been head of the HR department at AVL for nearly ten years now. What has changed during that time?

Like the industry as a whole, we are also facing major transformative challenges in HR. The system change in mobility has accelerated sharply. In addition to the conventional internal combustion engine, there are now also new alternative drive technologies, fuel cell development, battery technology, hybrid models, and driver assistance systems. This has also changed the job profiles at AVL. The traditional mechanical engineering profile is still in demand, but chemistry, electrical engineering, mechatronics, and IT are also gaining in importance as a result of the changes described. The classic job profiles remain, but more interdisciplinary expertise is in demand these days. For example, we need IT specialists to make cars safer and machinists for our affiliate company Piezocryst Advanced Sensorics GmbH. The power of IT may not always be visible, but it is essential for modern mobility. Fortunately, at AVL we already have many people who break the mold, creative lateral thinkers, personalities with rough edges. We need these types of characters because they are what make the difference. We

are looking for people who bring interdisciplinary talents and want to actively shape the future of mobility.

What are the biggest challenges facing HR policy currently?

The shortage of skilled workers is the central issue that we will no doubt be dealing with in the coming years and decades. The baby boomers are currently retiring from the workforce. In demographic terms, in Austria we now have more people aged 64 and above than people of working age between 15 and 64. Around 50,000 more people retire than new workers replace them each year, be that from schools, universities, or technical colleges. Of course, this is a real problem wherever very specific qualifications are required, like at AVL. Digitization will certainly make a difference here, but it cannot replace everything - we are already feeling and noticing that. Another problem for Austria as a location is that customers often take their orders to countries with an adequate workforce. The keyword here being migration - this is another area in which it is important to bring people with the appropriate qualifications to Austria.



Between digitization and an increased desire for a balance more in favor of "life" than "work": How is AVL responding to the changing needs and expectations of employees?

Many applicants really do have more definite expectations these days than they did in the past. How you react to this on a case-by-case basis very much depends on the current market opportunities and what you can implement. As a global company in a dynamic industry, we are well positioned here since we offer excellent internal development perspectives. Naturally, we also offer regular working hours and appropriate breaks, so work-life balance is not as much of an issue for us as we sometimes hear from other companies or as it is communicated in the media. Most people who come to AVL primarily want to prove what they are made of and what they can achieve.

Creative methods for recruiting and retaining employees are in demand right now. Do you feel that there are any projects/ programs that stand out?

Yes, we try to contact educational institutions as early as possible in order to find future employees through internships, pre-scientific work, bachelor's and master's theses. We also use AI in the recruiting process to find suitable applicants as efficiently as possible. Retention is becoming increasingly important – which is why we have learned a great deal from the employee surveys, and listened carefully to what is important to our colleagues. So we learned what we can and want to offer.

How does AVL's HR policy differ from what you might expect at a company of this size?

Undoubtedly, a key factor is our understanding of teamwork. This benefits both existing and future employees. We have a large international network of innovative teams and methods **focus** Special Edition

"Digitization cannot replace everything – we are already feeling and noticing that."

Interview with **Dr. Markus Tomaschitz**

that other companies can only dream of having. Flexibility and personal responsibility are particularly noteworthy: everyone who starts at AVL is immediately part of one or more teams. At the same time, you are quickly given responsibility. We foster a culture in which personal opinions matter. This boosts self-confidence and satisfaction. Fundamentally, I am convinced that companies that have a good corporate culture, i.e., a balance between give and take, perform better in the long term. Those who see employees merely as a cost on two legs will have problems because people won't stay at or join companies like that.

One of the ways AVL is looking to recruit new employees is through current AVL employees. How important are these kinds of initiatives?

Our employees are AVL's most important ambassadors. No one can speak more credibly about our company and our brand. And no one – no customer, no partner – can provide better insights than someone who currently works at the company. To support this, we have launched a program: Employees Recruit Employees (MwM), and we also have the initiative "#AVLuencer – inspiring people for AVL together". This is a targeted call to our employees to present AVL as an employer – and to do so at every opportunity and via all channels. At events as well as on social media or in private circles – after all, potential applicants are everywhere. ■

AVL Cultural Foundation Where Art and Science Meet

Founded by Kathryn and Helmut List

AVL has always supported a culturally rich and diverse environment. Whether by sponsoring existing art institutions and festivals, or by actively engaging artists, musicians, dancers, or other performers to enrich and enliven the AVL community including our partners and clients.

he creation of the AVL Cultural Foundation by Kathryn and Helmut List in fall 2007 has intensified and focused these activities in pursuit of a platform that creatively intermingles artistic endeavors with science and technology. Since then, a dynamic mix of programs, disciplines, and participating persons provides a context that aims to inspire innovation and dialog.

Why does the AVL Cultural Foundation focus on the dialog between art and technology?

The AVL Cultural Foundation encourages the dialog between artists and AVL engineers and technology experts. Often, we have managed to make AVL technology available to artists, and they use this technology to create new works of art. This also gives us an opportunity to see AVL's work through different eyes, since art uses and values the technology in a completely different way. I think that is very empowering for both sides.

What value can be derived from that?

The technologies and innovations that AVL offers the industry always include the end users as a vital part of the vision. The user point of view is always subjective, reflecting their current condition. The perceived value of technology as environmentally friendly or safe (as in ADAS) is always critical to user experience. Insight into and respect for the people who will be using or be affected by new developments are at the center of decision-making. And this is where art comes into play, since interaction with art is always subjective. The artists give us new perspectives on our technologies and thereby raise our awareness of the responsibility we have as a company.

Both art and innovation thrive on creativity. What is the significance of creativity for you personally?

For me, creativity means the freedom to reflect on our lives and imagine a more beautiful world. In doing so we also confront the difficult aspects of living in an imperfect world. It is a courageous undertaking. But it is a necessary part of our efforts to shape a better future.

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Interview with Kathryn List

"Imagination, flexibility, and the expression of profound human creativity are what innovation is all about. The exchange with art facilitates a broad perspective of the world and our society in a design language that is very different from technology. This strengthens the openness to engage with the unknown, to explore emotions, and to translate this back into technology's own sphere of life and application. New solutions are always the result of exchange and dialog."

PROF. HELMUT LIST, Co-Founder and Advisory Board Member of the AVL Cultural Foundation



The sound of technology: Gallium phosphate crystals developed by AVL used as part of a musical experiment.





The Art in Technology. Technology in the Arts.

The AVL Cultural Foundation provides opportunities for artists to interact with AVL through its Art&Science program and to use unique technologies for their art. It also plays an important role in finding a common language between art and technology. As a discipline that has no clear goal, art dares to experiment with open-ended outcomes. Living with this openness and drawing strength from it is an intrinsic part of the artistic process. The AVL Cultural Foundation is not simply concerned with the collaborative process and the end result – our primary concern is using the synergies from this creative collaboration and supporting the spirit of innovation.

Living Diversity. Changing Perspectives.

Changing your point of view triggers inner creative processes. In AVL Cultural Foundation projects, challenges lead to new solutions and to a new way of looking at things. We also hope that the interaction between art, science, and technology is a constant source of inspiration.

The diversity of project topics reflects the multifaceted essence and vibrancy of human nature and the complexity of the world: from musical experiences paired with new sensor solutions and the experimental application of AVL's own gallium phosphate crystals to generate music, to creative projects for and with our employees. **focus** SPECIAL EDITION

"A single fantasy can transform a million realities."



Every keystroke expresses a new emotion – art and technology as creators of new ideas.

A Global AVL Art Community.

Art is way more than a basic need. Art and culture play an important role in addressing social challenges.

The AVL Cultural Foundation strives to engage the global AVL community through the world of art and to promote understanding across disciplines and cultures. The various initiatives invite both AVL headquarters in Graz and the global AVL community to participate in art projects. In doing so, we are opening doors for active engagement and a lively exchange.

lt's clear: art connects. ■



"The Helmut List Halle is not only pioneering in artistic terms. As the operator, we have invested in sustainable and efficient technologies from the very beginning, to give artists more space while also acting in a way that is conscious of the environment."

GÜNTHER REICHER, Managing Director HLH

A Place of Encounters, Creativity, and Innovation

The **Helmut List** Halle

ne Helmut List Halle (HLH) is a unique project in the heart of Graz's cultural scene. It was opened in January 2003 as part of the "Graz 2003" Cultural Capital of Europe. The grand opening of the former factory building took place with the first staged production of the work "Begehren" (Desire) by Beat Furrer and the stage design of Zaha Hadid. Subsequently, the HLH quickly established itself as a major performance venue for a wide variety of art forms in Graz.

The impetus for the construction of the Helmut List Halle was the urgent need for a new, very specific venue for the "steirischer herbst" and Styriarte festivals. It was brought into being through the creative collaboration of engineers and artists in a construction period of just ten months.

The project combined the expertise and passion of conductors, composers, artists, and engineers like Nikolaus Harnoncourt, Beat Furrer, Gerd Kühr, Bernhard Land, Prof. Karlheinz Müller, Mathis Huber, and AVL CEO Prof. Helmut List. The unique interplay of technology and art created a symbiotic art and science project that remains pioneering to this day.

What really makes the concert hall stand out is its flexibility. It provides the basis, shell, and technology for what art wants to show – and with as few spatial restrictions as possible, and only those that are most necessary. This inspires and has, not least thanks to continuous development, made the Helmut List Halle a cultural hotspot for 20 years - one that you can't imagine Graz without.

With the Helmut List Halle, architect Markus Pernthaler created a new standard for contemporary performance spaces. Whether avant-garde or classical, the Helmut List Halle offers optimal conditions for artistic performances of all kinds while also meeting the strict criteria of opera houses around the world.

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The new management team of the Helmut List Halle: Günther Reicher and Christoph Baloch. We would like to express our sincere thanks to Erwin Hauser for his many years of successful commitment to this extraordinary venue.

However, it is not only the building that is appreciated, but also the fundamental idea that has been resonating ever since its realization: Daring to try new things and knowing about the importance of meeting places that facilitate exchange and creativity. The development of the Smart City district surrounding the Helmut List Halle in recent years has also underlined the importance of the Helmut List Halle as an artistic center and meeting place. From the very beginning, the venue has been constantly reinventing itself and adapting to the increasing demands for events such as the Styriarte, the PSALM festival, or the "steirischer herbst" festival

The vision of the Helmut List Halle, to form the basis for creative encounters and to produce something new in collaboration with art, has clearly been fulfilled. Under the motto "Art Meets Science", the Helmut List Halle has evolved into a unique meeting zone where creativity, inspiration, passion for art, and innovation come together. Its contribution to the promotion of art and artistic creativity is indispensable, and it will continue to be a driving force for the development of culture in the future.

In order to provide even more space for art and artists in the future, an annex to the HLH opened in fall of 2023.



Transforming technology requires inventiveness. AVL has been innovating for 75 years – and is driving dynamically into the future.

We have always played a key role in shaping mobility trends – be that in vehicle development, simulation, or measurement technology. And our numerous patents are just one piece of evidence for this. How many do you think we have at the moment?

Research, Develop, Protect

With 2,200 active patents, AVL is one of the industry's pioneers – not least thanks to our innovation strategy of investing around 11 % of our turnover in research and development each year.

nnovation is firmly embedded in our DNA. With our experts we push the boundaries of technology around the world. To ensure we remain at the forefront of innovation, we invest around 11 % of our turnover in research and development each year. We also collaborate across industries with more than 100 universities. With 189 patent applications – two thirds of which were in the field of electrification – we topped the rankings of the Austrian Patent Office for the eleventh year in a row in 2022. Our primary objective is to offer our customers the latest technology solutions at all times and in doing so to create sustainable, safe mobility for everyone.

More Than 200 EU Projects in Research and Technological Development

The EU started to fund research and development activities through various programs almost 40 years ago. Within this framework we have successfully participated in more than 200 projects as partner or coordinator since 1992. An important function of our activities is networking with the leading European R&D players with regard to coordination and funding measures. Application-oriented research is also important for transferring basic research to appropriate innovations. In this area we have access to a strong network of more than 100 universities. In addition to the continuous contact and collaboration, we conduct and coordinate special projects and studies for the European Commission. Parallel to the activities at EU level, AVL is actively involved with all relevant research-oriented institutions and associations in many EU member states.

Research Projects for Future Mobility – from Sustainable Batteries to Automated Traffic

When planning these research projects, AVL collaborates with a large number of European research-focused institutions and associations, such as ERTRAC (European Road Transport Research Advisory Council), Hydrogen Europe (fuel cells and hydrogen), EARPA (European Automobile Research Partner Association), EGVIA (zero-emissions traffic), BEPA (battery development). The projects are realized within the framework of the European research program "Horizon Europe", research partnerships such as BATT4EU, 2Zero, and Clean Hydrogen Europe, and various IPCEIs (Important Projects of Common European Interest). The research projects span a wide range of topics. In the field of electrification these cover, for example, sustainable batteries and future-proof, efficient fuel cell and hydrogen propulsion systems. Here, we also fully consider the cycle of the raw materials used and the sustainable use of these materials - from concepts for various raw material compositions of batteries and e-motors to recycling and reuse. In energy production we are researching highly efficient electrolysis systems for producing green hydrogen. Fields such as automated driving, artificial intelligence, and digital key technologies are further drivers of innovation for future mobility. Last but not least, carbon neutrality is also the focus of many research projects.

New Multi-Fuel Propulsion System Supports Decarbonization of Heavy Goods Traffic

Successfully decarbonizing the mobility sector requires different propulsion concepts and energy sources. The limited availability of green electric energy means that existing



technologies need to be developed in a way that allows them to also be run with new fuels such as e-fuels. In addition to efficiency, other important factors when selecting an energy source for applications are availability, use of resources, and reliability. The most recent example of our innovative ability: Together with Jülich research institution, the CMT institute of the Universitat Politècnica de València, and the Institute of Chemical Technology (CSIC-ITQ), AVL is currently working on a highly efficient integrated propulsion system based on carbon-neutral fuels as well as hydrogen for applications in heavy-duty traffic. The system will make it easier for users to deploy clean, hydrogen-based technologies.

High-Tech Test Systems for E-Mobility

We have worked on research and development projects in the field of testing and measurement systems as well; these projects take account of the major transition towards electrification. The activities implemented in collaboration with Austrian and other European research organizations recently resulted in the successful launch of an entire product range of high-performance testbeds with the latest SiC (silicon carbide) power electronics. For example, high-speed e-motors with up to 25,000 rpm can be tested here. In terms of battery testing, this new technology enables packs of up to 1,200 V and 1,000 A, as well as cells of up to 600 A, to be tested. ■

Further Selection of Relevant Research and Cooperation Partners and Organizations

ACStyria Styria's mobility cluster A3PS Austrian Association for Advanced Propulsion Systems

CCAM European Partnership on Connected, Cooperative and Automated Mobility

Chips Act Development program in the field of electronic components and systems

ECH2A European Clean Hydrogen Partnership

EPoSS European association for the development and integration of intelligent and environmentally friendly technologies and solutions

ESBS Austria The Austrian association for electronics and software-based systems

FAT-VDA the research association of the German automotive industry

FKG Vehicle Component Group, Sweden

FVA Deutsche Forschungsvereinigung für Antriebstechnik (German research association for propulsion technology) **FVV** Deutsche Forschungsvereinigung für nachhaltige Fahrzeugantriebe (German research association for sustainable vehicle propulsion)

HyPA Hydrogen Partnership Austria of the BMK and BMWA **INSIDE** European association for intelligent systems and embedded software

Mov'eo the French center of excellence for mobility and automotive research

SafeTRANS a cluster for embedded systems in transportation

Silicon Alps a cluster for the development and networking of companies in the field of electronics and microelectronics **ViF** Virtual Vehicle Competence Center Graz

Patents at the Core of AVL – from Day One to Today

From the very beginning, it was extremely important to Hans List to patent company inventions. He filed the patent application entitled "Evaporation Cooling for Horizontally Opposed Piston Engines" on April 7, 1948. Helmut List has also been an active inventor since 1972 and filed a patent application for the invention "Digital Control Layout for a Pressure Medium Actuated Work Cylinder of a Screw Casting Machine" on December 5, 1972. On July 6, 1983, Hans and Helmut List filed

the joint patent application "Diesel Engine with Direct Fuel Injection".



AVL Engineering – Innovative, Production-Ready Solutions for All Types of Mobility

With expertise in driving functions, subsystems, and components, we are perfectly set to help you integrate systems into vehicles for production. We also focus on Advanced Driver Assistance Systems and fully automated driving, as well as offer technology consulting and stationary energy application development.

Engineering in the Technology Transformation

AVL is leading the way in the development of innovative mobility systems – from hydrogen engines to fuel cells. With our engineering portfolio, we help our customers overcome the challenges currently posed by the technology transformation. In an interview, our members of the board with responsibility for engineering – Mario Brunner, Gustav Tuschen, and Uwe Grebe – discuss this and their personal backgrounds.

AVL is proud of its values. With which value do you have the strongest connection?

Brunner: With our enthusiasm in working together. It is impressive what we can achieve together at AVL. When we bundle our strengths in research, acquisition, and project execution, we are capable of developments that are extremely demanding, not only from a technical perspective. Cooperation is a great strength of AVL – and it is fun to achieve new things and enjoy success together.

Tuschen: With the pioneering spirit and passion for innovation, the global presence and intercultural setting, and the respect for colleagues and customers, AVL is a perfect reflection of the values that are important to me personally. It is an exciting, inspiring, and dynamic environment, in which I can support AVL with my experience. This cooperation gives us the chance to be successful and have fun.

Grebe: We are the leading company in our industry. What inspires me is the opportunity to use our global network to work with all of our customers. Establishing the connection between customer requirements and the outstanding capabilities of AVL, that is what drives me and motivates me with regard to our business strategies. For me, giving our sites greater responsibility and mutual trust is very important. Our competitors envy our global positioning.

Could you share a personal story from your time at AVL?

Tuschen: After 33 years of professional experience with an OEM, I decided to switch to AVL in December 2022. I have fond memories of working with AVL when I was the CTO at the Mitsubishi Fuso Truck & Bus Corporation in Japan between 2011 and 2013. During this period, AVL and my engineering team at the time established a strong and trusting partnership. We developed many products together: e.g., the first light-duty hybrid truck (Fuso Canter Hybrid). When I joined AVL last year, I was pleased to see that this successful cooperation is still ongoing.

Grebe: My first contact with AVL dates right back to my time studying at TU Darmstadt. Back then, Prof. Hans and Prof. Helmut List visited the institute regularly. Those events were prepared with the greatest of professionalism: the students and assistants even had to paint the testbeds in the AVL colors. So, I actually knew the RAL color code for AVL long before I joined the company.

Brunner: When the Austrian Chancellor Nehammer spoke to us about energy and mobility in the future, Prof. List was able to report back on over 20 years of investment in fuel cells, hydrogen, and electrolysis. You could sense the huge admiration among those involved in the dialog and the great deal of pride felt by everyone from AVL – for the vision and the consistency in the way we have driven technology. This



determination to push technology to the limits of physics and the related pioneering spirit is something you can feel throughout the whole company and has been driving me personally at AVL for 19 years.

Mobility is changing. What do you feel is the greatest challenge facing the engineering sector? Where can AVL exploit its strengths in the future?

Grebe: Society and the mobility systems are changing all over the world. We are in the midst of a transformation that goes way beyond propulsion systems. Sustainability with regard to the energy and materials used as well as the digital networking are setting the course for technologies. The expansion of the markets relevant to us determines our options. Our strengths are our technical understanding of systems and their interaction, as well as our innovative solutions to problems. This helps us to push forward in areas like the entire vehicle, driver assistance systems, and multi-modal mobility systems.

Brunner: The greatest challenge is to be open to the full range of technology. Our significant investments in research and development are focused on these areas. We are therefore well prepared for future challenges. As such, the industry is faced with the challenge of converting a significantly higher amount of engineering data into information. This allows us to achieve multipliers and solutions that go beyond what is standard. **Tuschen:** To master the technological transformation driven by decarbonization, automation, and digitalization, and the uncertainties that come with it, all market players need to adapt their strategies. It is important to enforce technology openness and to intensify entrepreneurial spirit, so that we can scale up innovative technologies and make our strengths a reality. It is crucial to remain flexible, leverage synergies, and open up new areas of business. My vision for AVL is to be the benchmark for commitment, synergy effects, and flexibility. ■



Leading Through Change

"Our goal is sustainability through cutting-edge technology, fundamentally transforming every facet from concept to finished vehicle. With exact Virtual Twins, we are accelerating innovation cycles while reducing dependence on physical testing."

DR. ROLAND WANKER

Democratizing Simulation

From punch cards to Virtual Twins and beyond – there is a long tradition of Advanced Simulation Technologies at AVL. What started out more than 40 years ago is now a dedicated business unit and an important pillar of the company – with high added value and a great appearance.

"We have always differentiated ourselves from our competitors through high-precision simulation software."

DR. GOTTHARD RAINER

Opting for an Independent Business Unit

The business unit Advanced Simulation Technologies was founded in 1996 as part of the reorganization of the engine technology division. Prof. Helmut List recognized the potential of the simulation software that had been developed in the various departments. He had the vision to unite all AVL simulation products in one business unit comprising development, sales, and service, and to build a profitable business model. The goal was to offer the simulation software products that had primarily been used internally up to that point externally, to further advance the already very precise physical models. Based on customer feedback, the software was optimized and the user-friendliness increased. This set the strategic focus for the independent business unit - led by Dr. Gotthard Rainer until 2018. The foundation has been an investment in the future, with Prof. Helmut List as the driving force providing crucially important assistance.

The Foundations Were Laid

Computer-aided simulation in AVL's engine development dates back to the early 1970s, with Dr. Gotthard Rainer – who joined AVL in 1978 – playing an important part. "At that time, AVL was already using CAE calculations and the first applications of finite element methods (FEM)," says Dr. Rainer, recalling a time when creating input data was still a tedious process involving punch cards. Interactive computing was introduced in the early 1980s. The installation of a TEKTRONIX 4014



graphics workstation, connected to the UNIVAC computer at the Graz University of Technology, and the installation of a VAX-11/780 computer are representative of this era. Instead of spending an inordinate amount of time punching punch cards, there were now terminals with small alphanumeric screens available for operating the new computer generation. "This was the beginning of the democratization of the use of sophisticated simulation software," describes Dr. Rainer. New generations of supercomputers such as CONVEX or CRAY saw the possibilities grow. The simulation models became more sophisticated. Important driving forces were fluid mechanics calculations (using AVL FIRE™) and engine dynamics calculations (using AVL EXCITE[™]), which only became economically viable with the new generation of computers. In particular, the software for simulating combustion processes - which was initially developed for internal use - was very well received.

The Beginning of Accelerated Development

The start of the new business unit was challenging, because "apart from FIRE, we didn't really have any marketable software in 1996," admits Dr. Rainer. That soon changed: the mechanics, flow, thermodynamics, and injection system software were merged; at the start of the new millennium, the CRUISE development project for driving performance and consumption calculations was also ready to be launched. AVL EXCITE[™] became the market leader for engine dynamics simulation. The entry into real-time-enabled system simulation from around 2008 extended the application into the testbed area.

Parallel to the development of the products, the necessary sales and service structures were put in place: Starting in 1996, offices for Advanced Simulation Technologies were established in Slovenia, Croatia, Japan, Korea, the USA, China, Germany, India, and Russia within a few years. According to Gotthard Rainer, the growth of the Asian business in particular is key to the success: "Japan was very simulation-oriented right from the beginning and therefore quickly became one of our strongest markets. We sold the first license for the flow software there to a big Japanese car manufacturer back in 1987." This car manufacturer remains an important customer



to this day and uses AVL simulation software widely, which is based on two important factors for our success: long-standing customer relationships and experienced employees – explains Roland Wanker, who joined the business unit in 2000 and has headed it since 2019.

Comprehensive Simulation Offering

The simulation portfolio has expanded significantly over the last 20 years with the change in mobility. Entire vehicle simulation, e-mobility, ADAS/AD, Simulation as a Service – these days the business unit has an extensive offering for an increasingly broad portfolio of use cases. In this context, Roland Wanker notes a continuation of the aforementioned "democratization": "In the past, customers had experts who delved deeply into the structure of a piece of software. Whereas these days, software products must become increasingly user-friendly and intuitive to operate. A quantum leap in the direction of integration and user-friendliness was achieved through the complete integration of all products into a common user interface."

Armed for Upcoming Challenges

- For the future, Roland Wanker predicts an even more fundamental change than with the appearance of the Internet. Development in the automotive industry is under enormous time and cost pressure. In view of these drivers, simulations are gaining in importance. The Virtual Twin is becoming the central element in all development phases. Artificial intelligence (AI) will also play an increasingly important role. Complex simulations (e.g., in multibody dynamics) could soon be set up and evaluated with AI support – with corresponding recommendations for design improvements. One of the central challenges of the future will be taking a leading role in the context of AI as well, to ensure the offering remains attractive in the market.
- Roland Wanker: "We must also continue to drive the democratization of simulation internally. To do this, we have to unite accuracy in the simulation results with simplicity, efficiency, and robustness in their application at the customer. That is our brand essence, our DNA."

AVL Testing Solutions – Advanced Tools and Methodologies for Development, Testing, and Validation

focus special edition

technologies for the entire propulsion development process, from the first concept study all the way through to series production. Our great variety of application solutions connects differthe virtual to the real world.

Measuring and Testing for Tomorrow's World

Knowledge is based on testing - and there is no better proof of this than AVL. Measurement technology and test systems have been part of our core business for decades. The history of AVL Instrumentation and Test Systems is characterized by dynamic processes and innovative solutions for the future.

etween the first quartz pressure transducers of the 1960s and the turnkey test systems for the mobility requirements of the future lay an exciting journey. And it began rather by chance: "When our development engineers found themselves stuck with the usage of current equipment or tools, they innovated new solutions and methods," explains Matthias Dank. This led to the creation of products and systems that are still successfully in use today in an advanced form

The Beginnings of Testing Solutions

Early milestones include gravimetric fuel consumption measurement systems and flue gas measurement equipment. These were followed by the first digital testbed at the Graz headquarters in 1969. One year later, Prof. Helmut List – who was still in charge of the measurement technology division at that time - decided to establish global sales for fully automatic testbeds. In 1982, AVL's test experts created a groundbreaking procedure that allowed them to look inside a diesel engine in real time, causing a significant sensation.

Furthermore, during the 1990s, AVL pioneered the development of its initial testbeds for hybrid propulsion systems, a cutting-edge technology at that time. AVL also showcased its expertise through lighthouse projects: In 1993, AVL conducted the first-ever tests of high-performance Formula 1 racing cars on its testbeds, a capability that continues to this day.

Large-Scale Turnkey Solutions

With the new millennium, the strategic business unit AVL Instrumentation and Test Systems established itself as a turnkey provider. Containerized solutions were an important step in this process: This modular concept enables flexible scaling of engine testbeds. The proof of concept was provided by Motorenhaus III (MH3), which AVL built for DaimlerChrysler in Stuttgart-Untertürkheim starting in 2002. "MH3 was the first testing factory on several floors - this technology has become the standard today," says Urs Gerspach.

Growth Through Acquisition and Collaboration

Over the past 20 years, the growth strategy has also been accelerated by targeted company acquisitions, for example, in the area of emission measurement technology with the takeover of Pierburg Instruments, or the expansion of the chassis dynamometer business with AVL Zöllner. This resulted in a steady stream of pioneering projects – for example, most recently with the California Air Resources Board (CARB).

Our collaboration with Microsoft and various investments also stimulate our steady growth. One example of investment is AVL SET, which offers power Hardware-in-the-Loop test systems to customers in the field of automotive development – a completely new methodology for using e-machine emulation technology to test propulsion inverters.

Another example is the partnership with Greenlight Innovation Corp. The company is based in Vancouver, Canada and is a global provider of test and production facilities for hydrogen



fuel cells, electrolyzers, batteries, and energy storage systems. This strengthens AVL's leading position in providing advanced engineering solutions for next-generation propulsion systems, particularly through its research and development center dedicated to fuel cell technology.

Not to forget the acquisition of MOOG's (formerly VUES) large rotating machine business. With this acquisition, AVL has extended its capabilities in designing and manufacturing dynamometers, e-motors, generators, exciters, and other customized e-motor solutions with high growth potential. This enables AVL to realize high-performance, reliable, and costoptimized solutions in a power range from 80 kW to 1,000 kW.

Customer Focus for Maximum Satisfaction

"The continuous growth of AVL's testing solutions resulted in a strategic decision to establish the Customer Service business unit in 2002," explains Jens Poggenburg, who adds:" We consistently embrace the AVL philosophy: Stay close to the customer at all times."

The strategic business unit Instrumentation and Test Systems currently employs approximately 6,000 professionals worldwide; just over half of the total workforce. The transformation of new business areas has led to a shift and broadening of job profiles. In addition to conventional measurement technology Today, AVL has more than 30 service locations and sales offices, making AVL measurement and test systems available on skills (such as physics, chemistry, engineering, etc.), there is every continent. The fast and competent on-site support is still an increasing demand for profiles with expertise in software, a unique selling point. Customer satisfaction is generally the electronics, and service-oriented roles. At AVL, topics like artop priority, emphasizes Matthias Dank: "Our customers trust tificial intelligence (AI) are viewed as additional opportunities. that we will successfully oversee the entire project, and deliver Jens Poggenburg explains: "We have a deep understanding results that meet their precise requirements." of how to harness artificial intelligence and machine learning effectively, utilizing these new technologies to enhance **Pioneers in the Fields of Electrification** efficiency, expand our operations, and ultimately create new employment perspectives."

Helmut List identified the potential of electrification at a very early stage and founded a dedicated segment for it in 2007. Urs Gerspach elaborates, "We were pioneers in this arena with our measurement technology. Testing batteries, e-axles, and electrified propulsion systems is now one of our key strengths. Our portfolio ranges from our own e-storage products to complete test labs."

Expanded Specialized Units for Software, Hydrogen, and ADAS/AD

AVL Instrumentation and Test Systems has earned a long-standing reputation in the market for its software offerings. Products like the validation and verification

software AVL CAMEO 5[™], the data processing platform AVL CONCERTO 5[™], and the automation system AVL PUMA 2[™] are now global industry standards. Building upon this expertise, the portfolio is being progressively adapted to cover all key applications of sustainable mobility. The Fuel Cell business is a separate segment. This business area was significantly advanced by the close cooperation with Greenlight Innovation Corp.

One of the relatively young segments covers ADAS/AD, which specializes in advanced driver assistance systems and automated driving. In this area, AVL is consolidating all of its engineering and testing capabilities with the goal of discovering innovative offerings and developing value-added solutions to drive sustainable growth in the future.

Best Prospects for Employees

Shaping Future Mobility and Beyond

AVL's approach to supporting the fast-paced industry transformation centers on delivering the right solutions. Embracing innovative thinking and uncovering new business potential is essential. This also applies to sectors beyond automotive, like marine, rail, etc. and stationary applications. Amidst the vast opportunities presented by electrification, maintaining technological adaptability is paramount to ensuring the continued role as a reliable and forward-thinking partner for our customers in the years to come. ■



Energy and Sustainability

AVL Sets Trends

The automotive industry is introducing greener energy sources, raw materials, and production methods. AVL helps companies around the world as they reduce CO₂ efficiently.

ur planet is undergoing a transformation towards a sustainable future. Companies all over the world are tackling the manifold challenges of reducing CO₂ emissions and achieving net zero targets. The automotive industry is also working tirelessly to find solutions.

Reliable Partner Wanted?

This is where AVL comes in. Driven by our vision of a better, safer, and greener world of mobility, we work at the intersection of renewable energy generation, innovative technologies, and tailored sustainability strategies. We help our customers make processes more efficient and ensure that every part of a product is manufactured or sourced in a sustainable way. Together, we define reasonable goals and help manage the supply chain.

Making It Easier to Imagine the Future

When we talk about a sustainable future, we're talking about things we often can't even imagine. And yet companies like AVL are already working on them. In doing so, we rely on sophisticated tests and simulations to explore the unknown accurately and more guickly. We usually develop the necessary methods and tools ourselves, which is how we ensure

that the results meet our high expectations. With our unique combination of CO2 engineering, simulation, and measurement, we accelerate development processes immensely and make it easier to imagine the future.

Less CO₂ Throughout the Life Cycle

Concept and development – this is the key for ending up with a closed, CO2 lean system and is why the circular economy must be considered from the outset. Hybrid as well as alternative solutions such as battery electric and fuel cell electric vehicles also still need to improve CO2 efficiency. AVL is conducting extensive R&D in this area to reduce the carbon footprint and use environmentally friendly raw materials.

Regarding the end of life: second-life battery storage is slowly starting to establish itself, but research is still needed to reach industrial market maturity. This is also true of battery recycling and the related business models. Other powertrain components will follow accordingly.

Each country has its own climate targets. Therefore, AVL is also working with governments and cities to make the idea of sustainability a local and regional reality.

Automotive Sustainability

The Seven Main Trends

Martin Rothbart has been responsible for business development in the areas of energy, hydrogen, and alternative and synthetic fuels, as well as sustainability in the product life cycle at AVL for more than four years. He summarizes the main trends.

Trend **01**

Managing the Conflict Between Climate Neutrality and Energy Security

The world must rise to the challenge of radical decarbonization. Many countries and regions have already announced their goal to become carbon neutral. However, achieving carbon neutrality comes with many challenges. On the downside, the COVID-19 pandemic and armed conflicts have shown just how fragile the global energy supply system is. Additionally, renewable energy sources like solar and wind power are associated with lower availability - due to daily and seasonal intermittency – compared to their fossil counterparts. On the upside, Environmental Social Governance (ESG) regulations as well as carbon taxation and carbon trading systems are driving sustainability by establishing stricter rules. The Carbon Border Adjustment Mechanism (CBAM) of the European Union, for example, regulates carbon taxation on imported raw materials, promoting a global green material trading system.



Trend **02**

Future Global Trade with Green Chemical Energy Sources

The EU imports 57 % of its primary energy from outside Europe but plans to shift to renewable energy in the future. Renewable energy projects are being developed in regions such as North Africa and South America, with electricity being transferred to Europe. Long-distance transport routes rely on hydrogen and e-fuels. Synthetic energy sources will be prioritized for sectors where replacing fossil fuels is challenging, such as in aviation and shipping. Initial pilot projects in South America, North Africa, and Australia show the urgent need for molecular-based energy carriers in the future global energy trading system. Hydrogen-based energy sources will be crucial for long-distance energy distribution, despite conversion losses. They enable transportation with ships or pipelines, like in the fossil distribution and storage structure of today.





Trend **03**

Automotive OEMs Target Net Zero CO₂ Between 2030 and 2040 To meet legislative targets, the automotive industry usually improves vehicle emissions and propulsion system technology. This approach might change with the life cycle CO₂e (CO₂ equivalent) application. Automotive suppliers are committing to the automotive OEMs' CO₂e targets and measures much earlier than legislation requires. CO₂e labeling of products, including reporting the CO₂e value at product level and the application of maximum footprint thresholds, is set to become mandatory in 2025. In the long term, manufacturers will require CO₂e data exchange using energy measurement and encrypted data transfer.

The increased reporting requirements come with CO₂e reduction plans and roadmaps for each component supplied.

Trend 04

Need for Detailed Assessment of Carbon Footprint for All Technology Options and Steps in the Life Cycle

To limit greenhouse gas (GHG) emissions in the transport sector, we need to address all aspects of the life cycle, including production, in-use, and recycling. Battery electric vehicles (BEV) have significant GHG emission benefits during the in-use phase compared to conventional vehicles. The greatest potential for improvement in CO₂e reduction for the battery lies in the area of raw materials and manufacturing. Nevertheless, other components such as the electrical drive unit (EDU) also have sustainability aspects that can contribute to the CO₂e reduction in the life cycle. A 5 % increase in EDU efficiency for a base BEV can save nearly a ton of CO₂e over a distance of 250,000 km. A future proven EDU concept needs to comply with a sustainable design to reduce the CO₂e footprint. Proper methodologies and guidelines are needed for design-to-multi-life-cycle approaches.



Trend 05

Virtualization and Simulation

A virtual prototype can be used to optimize CO_2e emissions in the development phase: If an avatar, a digital twin of the vehicle, is deployed onto the virtual test track, emissions can be reduced by up to 30 %. With the help of virtualization and simulation, the carbon footprint of entire fleets can also be reproduced and predicted. In turn, as part of data analytics, in-use data of vehicle fleets can feed into the developments, precisely in the early stages where simulation and virtualization come into play. This means fewer real-world tests and thus fewer CO_2 emissions.

AVL is particularly innovative in this area and supports OEMs in determining the optimal propulsion system configuration to meet CO₂ fleet targets. To this end, we look at the entire ecosystem, including the framework conditions such as infrastructure and available energy for the production of sustainable fuels.

Trend 07

Designing Products with a Smaller CO₂e Footprint and Designing Them for Additional Life Cycles Where Applicable

The key question that needs to be answered is: How can we maximize our impact to reduce CO₂e in the life cycle as quickly as possible?

"Design-to- CO_2e " as a holistic approach in the course of systems engineering means a transition from the original focus on Design-to-function" and "Design-to-cost" to include

Product Life Cycle Model With Qualitative Patterns for CO₂e Influenceability, Determination, and Occurrence



Trend 06

Measurement and Central, Transparent Monitoring of CO2e Will Become Mandatory in the Long Term

The CO₂e assessment methodology will evolve in the future. ESG and the Corporate Sustainability Reporting Directive (CSRD) regulations enable reporting of measured CO₂e in Scope 3 upstream emissions. Energy consumption measurements will be implemented in all production steps to calculate CO₂e in real time. Digital twins and real-world data combined with simulations optimize CO₂e reduction in production.

The AVL Battery Innovation Center (BIC) is a small-scale battery production facility for pilot manufacturing and small series manufacturing of battery packs. All production steps are equipped with energy meters. The energy consumption data is used to calculate the carbon footprint of each manufacturing step and to optimize CO₂e. The information obtained is fed back to future development projects at earlier stages for CO₂e improvements.

the additional dimension of CO_2 equivalent throughout the life cycle. Existing methods and tools from total cost of ownership and life cycle costing can be taken as a basis and supplemented by the dimension or currency CO_2e .

In the various development and validation phases, engineering service providers such as AVL can achieve decisive competitive advantages together with the OEM and its value-added partners. ■



Speed and Affordability Are Central for E-Mobility

E-mobility plays a key role on the road to an emission-free future. AVL has been making an important contribution to this for more than 20 years. Gerhard Meister, Business Field Leader for Electrification, Luigi Giordano, Director Electrification Application, and Jürgen Rechberger, Business Field Leader for Hydrogen and Fuel Cells, discuss, what we have achieved, what we are working on, and how we can help shape the future of mobility.

Interview with

Gerhard Meister Luigi Giordano Jürgen Rechberger

E-mobility is a broad field. Where do you see the applications for various technologies?

Luigi Giordano: We need to make a distinction between passenger cars, commercial vehicles, SUVs, and all the non-automotive applications. With passenger cars, we see more pure electric propulsion, whereas in the commercial vehicle sector there is also potential for propulsion systems based on fuel cells and hydrogen.

Jürgen Rechberger: Yes, absolutely. The key to these applications is energy storage. With a battery, we can currently only store a relatively limited amount of energy. Hydrogen can do much more – it will play an important role wherever large vehicles and long distances are involved: i.e., in aircraft, ships, and trucks. For cars, most requirements can be covered using battery electric propulsion.

Gerhard Meister: There are various ways to achieve sustainable mobility; at AVL we are working on solutions for several energy carriers. If you can use electrical energy directly, BEVs (battery electric vehicles) are the perfect solution – being five times more efficient than vehicles that are powered by synthetic fuels. The bottleneck to becoming carbon neutral is in producing electricity from renewable sources and in storing the electric energy. The more efficient you are, the easier it is to manage the transformation. It is important to bear in mind that we are aiming for climate neutrality overall, not just in the transport sector.

The new energy mix for sustainable mobility raises the question: How do we get new technologies to function optimally – as well as make them affordable for the industry?

Giordano: The optimization of new technologies for sustainability and consideration of their affordability starts during the development phase. Costs can be reduced through smaller batteries, faster charging times, and more efficient electric motors. In addition, our testing facilities, through the extensive use of virtualization, enable our customers to test the propulsion system components in the widest range of operating conditions, which saves significant costs and accelerates development times.

Meister: In electromobility, cost and charging infrastructure are among the key challenges in terms of a broad roll-out. The huge need for battery storage is keeping battery prices high. To alleviate the pressure on supply chains, new battery cells need to come to market. Sodium-ion batteries, for example, are on the rise for certain applications. They are cheaper to manufacture and could lighten the high pressure on demand for lithium-ion batteries, thus helping to reduce the price of batteries in



the medium term. Generally, in view of cost sensitivity, scarce raw materials need to be used as sparingly as possible and recycling needs to be set up in a way that uses as little energy as possible. To this end, AVL has just implemented an innovative battery cooling solution that doesn't need heat-conducting paste. This makes it much easier to separate the different materials from one another in terms of the substances during recycling. So, you need to use less energy to return to raw materials that are suitable for batteries. This is a good example of how we are driving sustainability.

Could you tell us a bit more about hydrogen and its potential impacts on the world of mobility?

Rechberger: Hydrogen will be needed primarily for the decarbonization of energy-intensive industries and the energy system. Industrial processes such as steel production currently require a lot of energy in the form of coal and natural gas. Hydrogen is the only option for extensive decarbonization in this sector. The second key role of hydrogen is in energy import. Even with massive expansion of local renewable energy, countries like Austria and Germany will have immense energy deficits. In the future, a carbon-neutral energy carrier will have to be imported and that will be renewable hydrogen or a hydrogen derivative such as ammonia or methanol. In this sense, hydrogen is even crucial for our electric vehicles, as it will help to secure the energy supply for them.

How do you see the future development of e-mobility?

Meister: The most important thing when it comes to e-mobility is that anyone who hasn't tried an electric car out yet should if they can, the driving experience is fantastic. It's silent and the acceleration is amazing. The technology has reached a high level of maturity and is ready to be rolled out widely. The charging infrastructure is also very good in many countries these days.

- **Rechberger:** Yes, we are already very close to a good solution at vehicle level. My concern is more regarding the underlying energy supply and the corresponding infrastructure. We need to be much faster and must accelerate the development of local renewable production dramatically. Of course, we also need to focus on energy imports in the form of hydrogen and on the additional expansion of the infrastructure.
- Giordano: The further development of electric power grids and their linking between regions is essential for balancing the natural fluctuations in renewable energy sources. This is key to ensuring that cheaper power can be made available to end users when they are charging their vehicles. ■



AVL and Henkel

Working on More Efficient Battery Development Together

Henkel is the global leader in adhesives, sealants, and functional coatings. The company's portfolio includes a wide variety of solutions for the automotive industry. To accelerate innovation in the e-mobility sector, Henkel has now opened its first Battery Engineering Center inside its Inspiration Center in Düsseldorf – with the support of AVL. Our company contributes to the success of the center with the latest simulation solutions and testing technologies. We talked to George Kazantzis, corporate vice president, global head of automotive components at Henkel, about the features and objectives of the Battery **Engineering Center.**

Can you reveal details of the specific technologies, projects, and initiatives Henkel is currently working on in the area of e-mobility?

We have transitioned our long-standing expertise in adhesive technologies, which we have been developing for over 100 years for conventional vehicles, to formulate new solutions for battery electric vehicles. Now, we are not only leading in adhesives, sealants, and functional coatings, but also in thermal and electronic materials. Our technologies are designed to enable battery and automotive manufacturers to design and produce batteries efficiently, at a competitive cost, and at the required production rate, always prioritizing safety.

Moreover, sustainability and circular economy are at the forefront of our agenda. We're actively working towards enabling battery manufacturers to design batteries that can be efficiently dismantled and recycled at their end of life.

Henkel celebrated the inauguration of the Inspiration Center Düsseldorf (ICD) last year, a €130 million investment from the company. What is the vision behind it?

The Inspiration Center Düsseldorf (ICD) represents Henkel's dedication to pushing the boundaries in adhesive technologies. The facility gathers over 650 of our experts, creating a space where new solutions are developed in partnership with customers across more than 800 industry segments. The goal is to address the industry's pressing challenges swiftly and reliably by increasing the development speed and enhancing the customers' confidence in our solutions. The ICD offers not only the space, but also the collaborative environment needed for these endeavors, involving our customers, suppliers, and business partners. Central to our mission is addressing the industry's challenges with a pronounced focus on sustainability, from CO₂ reduction to championing a circular economy. Through the ICD, we aim to solidify our role as industry



pioneers, committed to sustainable action and innovative collaboration.

Part of the ICD is a new Battery Engineering Center, which was opened in September 2023. What are the objectives?

The main objective of the new Battery Engineering Center is to further accelerate innovation by seamlessly integrating product development, digital modeling and simulation, automated material application, and full-scale battery system testing – all under one roof. This allows us to significantly reduce development cycles and expedite time to market, which is critical in accelerating the transition towards electric mobility.

How do you foster collaboration among researchers, engineers, and other stakeholders at the Battery Engineering Center?

Firstly, we cultivate a strong partnership with our customers through close collaboration. We deploy our resident engineers the world to achieve genuine carbon neutrality, in line with the most recent standards. Year after year, we've been honored directly within our customers' design and development centers. This allows them to learn about the customers' challengwith awards that recognize our efforts towards sustainability. es hands-on, and address them with Henkel solutions. We In the transition to electric vehicles, we not only aid the reducfurther enhance this collaboration by inviting our customers' tion of the global carbon footprint, but also support a circular design and engineering teams to visit the Battery Engineering approach to battery use and reuse with our products. Center to test and validate solutions and work on prototypes A final thought: How would you personally describe the and next-generation batteries, for days or weeks at a time. In addition, we engage our raw material suppliers to work with us perfect mobility of the future? My primary wish is absolute road safety – zero casualties. in our labs and co-develop solutions alongside our chemists. Secondly, I envision a world in which mobility makes a positive And finally, there's a third group of experts we collaborate with: service providers, who offer equipment-related or engineering contribution to the global carbon footprint. And finally, I see services, for example. Importantly, our Battery Engineering vehicles becoming seamlessly integrated into our daily lives, Center in Düsseldorf is only the first in a network of global truly enhancing our overall quality of life. It's my hope that our children and our children's children can enjoy a safer and more Battery Engineering Centers that we are currently establishing around the world, giving us an enormous advantage in this sustainable mobility experience, one which is also fun. ■ globally interconnected industry.

What role does simulation play in the Battery Engineering Center?

Modeling and simulation enable us to accelerate our innovation process and deliver tailor-made solutions for our customers at an unprecedented speed. For example, by creating a digital twin of any battery system, we can virtually test and adjust our material solutions before applying them in-house to the actual batteries. These solutions then undergo various stress tests to validate that they perform as expected. With this streamlined approach, we are able to bring validated solutions to the market faster than ever, thus helping our customers significantly reduce their development cycles.

Interview with **George Kazantzis**

How does AVL enrich the Battery Engineering Center?

We chose to partner with AVL given its esteemed reputation as a leading global provider of testing and analysis solutions for the automotive industry, particularly in the field of e-mobility. It is the company that our customers trust. The underlying philosophy is to combine the expertise of the global market leader in simulation, modeling, and testing with the proficiency of the world-leading manufacturer of adhesives, sealants, functional coatings, and thermal and electrical materials. In doing so, we aim to unlock significant synergies and create added value for our customers. Together, we can make our shared ambition of leading green mobility a reality, and at the same time further expand our leadership positions.

In your opinion, how does Henkel contribute to more sustainable mobility globally?

Henkel will certainly be the first adhesives manufacturer in

Henkel and the Automotive Industry

- Active in the automotive industry for more than 100 years
- Currently more than 10,000 applications for the automotive industry
- Of the 150 cars produced each minute globally, 140 have at least one Henkel application
- World market leader in adhesives, functional coatings, and thermal and electronic materials for BEVs

From Research to a Business Segment and Beyond

Michael Paulweber

Senior Advisor AVL

"HIFAI was one of the most successful research projects for our Research and Technology segment. The project perfectly combined the expertise of AVL and HyCentA to build the world's first dynamic fuel cell system testbed and the prototype of a dynamic hydrogen measurement system. Both prototypes have since been successfully taken over by the AVL fuel cell product team and sold on an industrial scale to several customers. HyCentA also uses the high dynamic fuel cell system testbed in various research and sold to several customers on an industrial scale. This project has created a win-win situation for both partners."

Alexander Trattner, CEO HyCentA

"AVL and HyCentA have been working together for many years. We enjoy excellent cooperation in the field of measurement and testing technologies as well as fuel cell propulsion systems. With HIFAI, fuel cell development has for the first time reached a level comparable to internal combustion engines, which offers unique opportunities. Unprecedented among competitors, AVL's fuel cell system testbed at HyCentA enables fuel cell systems to be tested under realistic conditions, embedded in a virtual environment and developed using state-of-the-art test and measurement technology. This test system marks a turning point in fuel cell development." he completion of the BALIS project in the first quarter of 2024 is a major milestone for AVL. For the first time, AVL will deliver a Fuel Cell System (FCS) test system to the aviation industry. The origins of this project, which was acquired by the Fuel Cell and Hydrogen Systems segment, trace back to the HIFAI (Highly Integrated Fuel Cell Analysis Infrastructure) research project. At AVL, HIFAI was coordinated by Christoph Kügele, who at the time was working as a technology scout in the Technology and Research department, and Tomas Dehne, the chief engineer for Fuel Cell Testing Technology.

The history of fuel cell development at AVL dates back even further. The first steps were taken in the early 2000s with the planning of testbeds in the Engineering division division alongside fuel cell CFD simulations in the Advanced Simulations Technology division.

The HIFAI project was initiated in 2014 with the goal of establishing a testing infrastructure for fuel cell systems at the HyCentA site on the TU Graz campus. The official inauguration of the project was in October 2016. This was followed by more than 100 visitors to HyCentA, including OEMs, suppliers, universities, and many other organizations, to see AVL showcase the first fuel cell system testbed. This was a pivotal moment, as AVL expanded its product portfolio into the field of fuel cell testing, introducing successful products such as AVL HyTron[™] (winner of the AVL Instrumentation and Test Systems Innovation award 2019).

First Customer Projects

By the time the research project was completed in 2019, AVL had already been awarded customer projects. The number of business opportunities generated in the electrification department was a hundred times higher at that time. The obvious demand for more expertise led to the creation of the Fuel Cell and Hydrogen System segment. The initial team of six was soon doubled in Graz and an additional team of fuel cell experts was hired in Mainz-Kastel.



Fuel Cell and Hydrogen System Testbed Development

Since then, numerous product developments have emerged from this segment. The willingness to adapt and innovate further products and system lines for applications extending beyond the automotive sector, as exemplified by the BALIS project, drives not only the the Fuel Cell and Hydrogen System segment, but all of AVL, including Greenlight Innovation.

Industrial Green Energy

Continued advancements are required to meet the challenges in emerging fields, such as electrolyzer test systems. Being part of the Industrial Green Energy landscape calls for the development of highly innovative products and solutions, including the degradation diagnostics for fuel cells and electrolyzers. ■

focus SPECIAL EDITION

Christoph Kügele System Design at GLI

"Throughout my time at AVL I've witnessed the transformative power of technology, particularly through my involvement with the HIFAI project. This experience has not only shaped my career, but also allowed me to play a pivotal role in defining the direction of this cutting-edge topic within our organization. Together, we explored the full spectrum of possibilities and harnessed all available tools, making HIFAI the ultimate showcase of AVL's capabilities in the field of fuel cell testing."

Modern Propulsion Systems with Internal Combustion Engines

The internal combustion engine (ICE) remains a relevant option in the mix of propulsion systems. With low pollutant emissions and the use of sustainable fuels, it can even contribute to reducing climate-damaging greenhouse gases globally.

"Emissions legislation has been in place since the 1970s. Technology ensures that the environmental targets are met. This works so well that, in all statistically relevant driving conditions, modern vehicles now only emit 1% of the emissions of the past, or even less."

> KURT ENGELJEHRINGER Business Development Manager, Emission Testing

Internal Combustion Engines Are Still a Relevant Part of the Global Propulsion Mix of the Future

Looking at the expected technological developments in the various regions, significant differences regarding the long-term acceptance of internal combustion engines are evident alongside a strong global trend towards BEVs. While Europe remains fixated on a politically motivated dogmatic "BEV only" approach, China and Japan are pursuing legislation that is open to technology, pragmatic, and based on facts. China in particular continues to develop new internal combustion engines with the utmost efficiency as a relevant way to help reduce CO₂.

In the commercial vehicle and mobile machinery sector, hydrogen is one of the energy carriers currently establishing itself as a promising alternative to fossil fuels in the internal combustion engine.

The industry is therefore being challenged to offer advanced and cost-effective ICE solutions that cover every need.

Innovations in the Name of Efficiency

Efficient ICE technologies have always played a key role at AVL. The first AVL HSDI of 1976, the Universal Hybrid System of 1992, and the Otto DI of 1995 are just a few examples of our early innovations in the car sector. We have also been

"In a global environment, ICE-based drivetrains will continue to play an important role as part of the solution towards sustainable mobility. The crucial factor is a fact-based openness to technology."

> MICHAEL WEISSBÄCK, Business Field Leader, Passenger Car

focusing on hydrogen internal combustion engines as a zero-emission technology since 2019. In addition to extensive activities in the commercial vehicle sector, developments even include a hydrogen racing engine presented in 2023.

The Internal Combustion Engine Is Becoming Climate-Friendly

By making use of the synergies between the internal combustion engine and electrification, maximum efficiency levels of up to 45 % can be realized in the car sector. In China especially, AVL is strongly represented in the dedicated hybrid engine sec-

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tor. We also offer solutions for regenerative fuels, and in the commercial vehicle sector we are working on a hydrogen HPDI engine that combines the advantages of diesel engines and hydrogen. With this concept we were able to demonstrate an efficiency level of more than 50 % for the first time in 2023.

Our current developments for high-speed large engines include an innovative cylinder power unit with ignition pressures of up to 330 bar: It enables the use of alternative fuels and thereby contributes to the decarbonization of various high-power applications.

For marine engines, for example, we rely on ammonia and methanol produced regeneratively to meet the high range requirements.

From Concept to Practical Application

- AVL's systems support current and future zero-carbon mobility by means of simulation, test and measurement systems, software, data analysis, as well as lab and workflow management. Our testing solutions and virtual approaches – including the Digital Twin in an SiL environment – facilitate rapid and cost-effective development, testing, and measurement of new propulsion technologies and concepts. Thus, we offer modular, configurable, and extendable solutions for all types of
- propulsion system and for all energy carriers. ■

Next Generation Vehicles

What does the future of mobility look like? What will the cars of tomorrow be capable of? How will they be powered? What makes them stand out? Questions like these determine the daily activities at AVL. Finding the right answers is one of our crossdivisional core competencies. With the latest virtualization tools, comprehensive integration expertise, and function-based systems engineering we support our industry partners with the challenges of the next generation of vehicles.



New Vehicle Concepts, New Challenges

The wheel of automotive development is turning ever faster. Time and cost efficiency increasingly determine the way manufacturers and suppliers do business. New vehicle concepts - be that battery electric or hydrogen propulsion systems - also bring a whole new level of complexity. Instead of individual components, it is the system level that is more important. Previously, many projects at AVL involved mounting an existing internal combustion engine in various series or models of vehicles and making modifications and calibrations. These days, the focus is on the overall vehicle. With BEVs, for example, the battery determines the size of the vehicle, the wheelbase, and even seating comfort, since the seats are usually directly above the battery. The overall vehicle is developed around the battery, so to speak.

Meeting Customer Expectations Faster

The next generation of vehicles will be shaped more than ever by the rapidly changing expectations of end customers. Comparable to a smartphone, the connected and software-based car of the future will always be equipped with the latest functions. At the same time, the expectation will be for new functions to be available faster - for example in the ADAS/AD field. Meaning that time to market will be significantly shorter. And since customers do not want to

wait, solutions are needed to regularly bring updates and thus new functions to the vehicle throughout its life cycle.

More and More Virtual Vehicle Development

Virtualization is a key factor in overcoming the outlined challenges of future generations of vehicles. AVL is a global pioneer in this area. With advanced simulation methods, we ensure a rapid transition from component-oriented to function-oriented vehicle development. Instead of costly and time-consuming verification and validation using physical hardware prototypes, we utilize complex vehicle system simulations. This enables configurations to be defined precisely at an early stage, meaning that important decisions can be pushed forward (frontloading) and the entire development process accelerated.

Virtual Twin Replaces Physical Prototypes

Virtual Twins are pivotal in AVL's simulation approach. They are based on the mathematical, physical, and chemical relationships between the various vehicle components. They provide profound insights into the behavior and interaction of the components and systems of the overall vehicle - long before these actually exist. The Virtual Twin is an extension of the Digital Twin concept widely used in industry, which combines only certain aspects of data from tests with simulation models. With the Virtual Twin, AVL accelerates development,

saving time and money. Development is also more sustainable thanks to the reduced need to build physical prototypes.

Systems Engineering and Integration Capability

At AVL, we work according to the principle of model-based systems engineering (MBSE). This means that we approach to changing customer expectations throughout the vehicle's development goals holistically from the outset. For example, life cycle. the thermal system is a key factor in reducing energy consumption, but you can also lower the chassis and thus reduce At the Forefront of Global Development air resistance. Weight also reduces the energy required – in Our global Vehicle Benchmarking Program is one of the factors behind us at AVL having a very specific idea of what any case, the systems must interact harmoniously. In this context, integration capability also plays an increasingly important the vehicles of the next generation will look like. For years, the role: The industry demands solutions that are as flexible as program has been providing objective assessments for numerous vehicle characteristics of market-leading models. The possible and can ideally be adapted to other derivatives at a manageable investment cost. To this end, we are developing subjective impressions of end customers are thus translated innovative platform solutions for future vehicle architectures into comparable, objective metrics from which technical rewith a wide range of modular integration options (e.g., for proguirements for the entire vehicle development can be derived propulsion systems, E/E systems, chassis, thermal manage-- from product positioning, including the customer market ment, ADAS/AD, etc.). profile as well as the technical specifications of the individual components derived from this, through continuous review of the development status, to release testing. Focus on Functions

Closely related to AVL's cross-system approach is our focus on functions. For example, we don't just look at a brake as a component, but address the function of braking on several levels - from the chassis (friction brake) to the propulsion system (recuperation) and the exterior (aerodynamics). The

software area in particular offers great potential for integrating new functions. These can be implemented more easily via updates than by intervening in the hardware, for example, in the control units. We are developing appropriate solutions in this area, with which certain attributes can be repeatedly adapted



An Off-Road Innovation Package

Under the brand name "Grenadier", the automotive division of the global chemical company INEOS has developed a zero-emission off-road vehicle with hydrogen fuel cell propulsion. AVL was part of the complete vehicle development. Pamela Amann, Chief Engineer Fuel Cell at INEOS, revealed exciting details about the technology, the cooperation, and the future of mobility.

Why did INEOS decide to go down this path? What were the end customer needs?

Pamela Amann: The classic Grenadier customer expects their vehicle to be an uncompromising full off-roader and a "workhorse". The task was to make this uncompromising vehicle fit for the future: "no compromises – no emissions".

What influenced INEOS' decision?

In order to develop this uncompromising, zero-emissions vehicle, various technologies were considered. In addition to fuel cell, these included pure battery electric (BEV) and hydrogen combustion engine. We have a BEV coming to market in 2026, which will have high off-road capabilities and be slightly smaller than the Grenadier, but the technology has some limitations when it comes to payload and range. Since the Grenadier is just as much at home in the heat of the Sahara as it is in the cold of Iceland, we wanted a technology that would function reliably regardless of the ambient temperature. For us, a fuel cell propulsion system in the Grenadier is the best solution so as to not significantly restrict the "workhorse" in its payload and range, while completely maintaining the off-road capability and really achieving 100 % zero emissions.

What are the other framework conditions?

In my opinion, hydrogen is the primary energy carrier of the next century. In order to become independent of limited resources and to significantly reduce the consumption of fossil energy sources, we will have to switch to alternative energy sources. The INEOS Group produces 400,000 tons of hydrogen per year as a by-product of chlorine production, and with Inovyn[®] also has a large producer of electrolyzers that are necessary for the production of green hydrogen. This makes INEOS the largest hydrogen producer in Europe.

What were the technical goals and the specific technological
challenges?What approach did INEOS adopt? How was the project set up
and why?

We started with four focus topics: No restrictions in off-road Through calibrating the internal combustion engine propulsion capabilities, maintaining the payload of the basic vehicle, guarsystems in the basic Grenadier, AVL was already very familiar anteeing a minimum range of 550 km in all weather condiwith both the vehicle and INEOS Automotive. With BMW we tions, and maintaining the robustness of the "workhorse". For gained another partner with fuel cell system experience for the the show car, the goal was to show that the technology works, project. Combined with AVL's propulsion system and complete that the fuel cell is best suited to a zero-emissions Grenadier, vehicle expertise, we were excellently positioned in this triumand that the goals for potential series production are achievvirate for the development and construction of the Grenadier able. fuel cell

Why did INEOS choose AVL as its partner?

AVL, with its reputation as an innovative, reliable partner that has been working on the fuel cell for years, made an excellent choice as a development partner. In addition to the propulsion system topics, we were also able to fully cover the complete vehicle topics with AVL as our only partner, since AVL has also built up a fantastic, experienced complete vehicle development department in recent years.

Which innovations were implemented in this vehicle?

In addition to the fuel cell propulsion system in a full off-roader, intelligent off-road torque vectoring ("Gecko mode") and an electric all-wheel drive (eAWD) were integrated, and a creative workshop gave birth to many more innovations, which will give us great pleasure in the future and will set our engineers' pulses racing... what are they? Let us surprise you, we promise they won't be boring.

What was the biggest challenge?

That's easy: not compromising! Meaning uncompromisingly bringing together all the challenges involved in developing an innovative, new propulsion system that is unique in this class of vehicle.



How was the cooperation with AVL from INEOS' point of view?

In the words of Hans Rosenthal (German TV presenter): "That was ... great!". Unfortunately, I can't get the legendary air jump on paper now. The vehicle meets expectations and achieves the goals, and also shows that teams who are motivate, innovative, and peform excellently can create vehicles that even exceed all goals and expectations. Everyone was open to discussion and new ideas throughout the project; in the design phase, during building, or during testing. People listened, were interested, willing to learn, respectful, and had an extraordinary interest in creating an outstanding product. The partnership between AVL, BMW, and INEOS is based on trust, reliability. openness, helpfulness, and competence. It is one of the best teams I have experienced in my 23 years in the automotive industry! The team is motivated, innovative, and gets things done. The mixture of ambition, passion, thoroughness, open-minded thinking, and the necessary "craziness" enabled the team to develop this vehicle, which exceeds previously known limits!

How does INEOS see the market changing this decade?

In order to use hydrogen as an energy carrier, it is necessary for politicians to rethink the topics of energy production, energy storage, and energy supply in the sense of feeling responsible for their realization. With this new way of thinking, the implementation of a hydrogen infrastructure is definitely possible within this decade. With the establishment of the infrastructure for battery electric vehicles, we have seen how quickly charging stations can be provided if the right incentives are in place and the politicians want it to happen. Something comparable would be conceivable with a hydrogen infrastructure, with the difference being that a hydrogen infrastructure would be easier and cheaper to implement – as can be clearly seen in the examples of China, Germany, Switzerland, as well as Korea and Japan.

How will INEOS position itself for the future?

The right technology will continue to be needed for each area of application in the future. That's why it's important to remain open to different technologies at all times in order to meet customer needs. We also need to use resources as sparingly as possible as we work towards zero emissions; comprehensively from the beginning to the end of the product life cycle. The Grenadier fuel cell and INEOS are ready – now all that is needed is the infrastructure.

The Journey Towards Autonomous Vehicles



How far off is autonomous driving? What steps need to be taken to get there? How can the countless scenarios be tested reliably? These are the questions the automotive industry is currently focusing on regarding ADAS/AD. AVL has established itself as an expert in this field, at the latest since its large-scale europe-wide "enable S3" project.

Market Needs, Perceptions, Brand Strategies: The Challenges

Developing driver assistance systems and autonomous driving functions (ADAS/AD) is by no means trivial. And the key focus is always on the end consumer: How will the driver perceive the safety of the vehicle and how will the passengers perceive its comfort? The answers to these questions vary from market to market, sometimes even from person to person. In addition, the brand strategies of manufacturers determine the course.

To understand how great the discrepancies are in the perception of driving situations, a comparison between India and Europe is a good place to start: Narrow gaps in traffic, which Indian drivers don't even bat an eyelid at, set off all the alarm bells for European road users. This is also due to the average number of vehicles and the typical dynamic flows.

To enjoy success in various markets, vehicles need to fit naturally into the respective traffic situations. To this end, the processes in the environment and the behavior of other road users must be precisely recognized and implemented.

Virtualization of Reality

How can these different conditions be incorporated into ADAS/ AD development? Virtualization in the form of simulation plays a key role here, since it is only through simulation that a large number of scenarios is able to be depicted, which would require billions of miles to be driven on just the road. This calls for the collection of a large volume of meaningful and reliable data.

Converting Subjective Perception to Objective Data

To include the human factor in the analysis, AVL developed the AVL-DRIVE[™] software – a tool that translates subjective driving impressions into data that can be assessed objectively, in real time and independently of the test environment. Graphically prepared scatter band diagrams show the range of how positively the system is actually perceived by the respective occupants. This is a solid decision-making basis for the further development of virtually all ADAS/AD functions in different markets.

Legal Situation and Vehicle Safety as Guidelines

In Europe, the General Safety Regulation, Release 2, dated July 2022, defined a series of driving functions that must be

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installed in new car registrations as of 2024. There are also new rules from America, where automatic emergency braking (AEB) will be introduced in all vehicles. While in Asia, autonomous driving at level 3-4 is to be given a legal framework so that vehicles are allowed to drive on public roads in defined areas.

AVL addressed this issue at an early stage and set up a separate department to deal with standards and legislation years ago. On the one hand, this means that the company is always up to date internally, and on the other hand, it is a strong sparring partner for its customers who want to play it safe when it comes to regulations. In this context, AVL can also help design a legally compliant system.

The topic of cybersecurity is also of growing importance. Whereas vehicles have tended to be closed systems in the past, ADAS and AD are making them more and more open – after all, they have to be aware of their surroundings and react to them. This opens the door to criminal activity. AVL provides the right equipment for testing protection features.



The Future: From Valet Parking to People Mover

This leaves the exciting guestion of what the future of ADAS/ AD will look like. "We will see a greater penetration of driver assistance systems across further vehicle classes and brands," predicts Andrea Conti, Vice President Business Field ADAS/ AD at AVL. When it comes to autonomy in passenger cars, he sees numerous new use cases, such as valet parking.

In the truck sector, both platooning and hub-to-hub are hot topics to counter high driver costs or lack of driver availability. "Another important future trend that is already being widely developed is people mover applications," adds Andrea Leitner, Global Business Segment Manager ADAS/AD Tools & Solutions. "This involves setting up autonomous shuttle traffic in defined areas."

A carmaker wanting to be known as innovative in the coming years will not be able to avoid "features on demand". This means providing driving functions and specific features when the end customer needs them. According to our experts, making these available in a way that is targeted and profitable will determine success.

Impressive Figures

There is no doubt that AVL is well equipped for this megatrend. The company is broadly positioned, especially in the field of ADAS/AD: At 19 locations - with Graz as the headquarters - more than 450 experts around the world are working on ADAS and AD. In the last ten years alone, a total of around 350 projects have been completed in this field, from Europe and Asia to the USA. Andrea Conti and Andrea Leitner agree: "We are ready for more."

Automated and connected mobility has been an integral part of our corporate strategy for many years. We see ourselves as the link between IT and automotive development, as we have the knowledge required to bring applications into vehicles.

TNO **Driving Safety Forward Together**

AVL and TNO have teamed up for a safer future and share their insights on safety validation and risk quantification for automated vehicles.

Interview with

Sytze Kalisvaart, Product and Project Manager at TNO Heiko Scharke, Global Product Manager at AVL

What inspired AVL and TNO to join forces for "safety validation and risk quantification"?

Kalisvaart: Well, the automated driving community has made a huge step in AI and computing and sensor capabilities. But the system complexity and real-world variability still makes ensuring the safety of autonomous vehicles challenging.

Scharke: I agree. Another issue is navigating new regulations and standards. Traditionally, these provided clear guidance. Today, OEMs face two daunting tasks: demonstrating safe driving and ensuring compliance for homologation.

Scharke: We have an initial functional implementation What were the key questions that needed to be addressed? focused on Automated Lane Keeping System (ALKS) maneu-Scharke: Firstly, the solution had to be based on a sound vers. Our next step is improving user-friendliness. Our open methodology for use in various driving environments. Secondtoolchain already provides the basis for wider compatibility ly, it had to be data driven. Safety claims can only be substanwith simulation packages, seamless data management, and tiated with real world statistics customization.

Kalisvaart: So actually, three guestions came up: How to convert data into a computer-readable model of the world? How to quantify safety risks through simulation? And how to integrate this in an end-to-end software tool?

Can you outline some of the innovations you are proud of?

Kalisvaart: Sure. We found a scalable and modular framework to model the world using scenario probabilities. Scalability is important for customization. The probability and variability statistics are crucial for estimating safety risk.

Scharke: We also managed to combine the methodology and algorithms of TNO with the AVL data acquisition, simulation, and reporting pipeline. It provides a seamless data flow from driving data to a safety risk report.

Can you elaborate on the impact this will have on the automotive industry?

Scharke: It accelerates the release process. In our industry, where experienced automated driving safety experts are



scarce, this is crucial. Additionally, our solution attributes safety risks to specific scenario categories, giving guidance for prioritization and reaching the overall safety target.

Kalisvaart: And it helps authorities to accelerate the type approval process through built-in compliance with standards and regulations. Our approach uses the basic concepts from existing UNECE/ISO standards and translates them to the new regulation.

What can we expect in the near future?

Kalisvaart: Clients require evidence of safety claims as well as traceability to establish trust in the outcome. Our recent addition includes a safety risk uncertainty metric; a confidence indicator to measure the trustworthiness of the safety validation outcome and to verify that enough data has been collected.



Find out more about AVL's and TNO's coope

Software Solutions for a New Era of Mobility

A new vehicle contains around 200 million lines of code. Meaning it already has more software on board than a Boeing 787. And this is an upward trend: by the end of the decade, the average code volume will rise to more than 300 million lines. Software, however, is not only ubiquitous in modern vehicles, it is also revolutionizing traditional development processes, test methods, and sales models. We support the industry with the most technologically advanced software systems in all areas.

The Future Comes Embedded

Embedded software applications in the automotive sector are highly complex. Unlike with other technology products - such as the smartphone - they primarily involve real-time interactions that affect safety-relevant high-performance components like the propulsion system, brakes, chassis, and other vehicle systems. Real-time capability is also becoming increasingly important in development. It is necessary, for example, to achieve meaningful results with little physical test effort. In the vehicle itself, the trend is toward bundling: While component manufacturers often used to also provide the control unit (ECU) for the respective component, these days the software from several domains is combined in more powerful zone ECUs. Classic domain structures are increasingly dissolving, while the software ecosystem is gaining in importance as part of the overall E/E architecture. The electrification of the propulsion system and a sharp increase in the number of ADAS/AD functions (Advanced Driver Assistance Systems/ Autonomous Driving) are reinforcing this trend.

The Car of Tomorrow Is Software-Defined

While the customer experience in a car used to be primarily determined by the hardware, today it is the code that sets the tone in the software-defined vehicle. New functions for connectivity, automation, and personalization are predominantly realized through software applications. They have a significant impact on the driving experience and have thus become an important differentiator. Similar to smartphones, users expect their car to integrate into the digital world as seamlessly and as fully as possible, with intuitive interfaces.

Today's Challenges Are Tomorrow's Solutions

More software in the vehicle automatically increases the complexity. But software is also the key to making that complexity manageable. Part of this software-based approach is that even lines of code are increasingly being written automatically. The motto is "use software to develop software". In addition, the future of vehicle software will be influenced by many other factors; examples include open-source applications, increased



use of AI, a focus on end-to-end software development, as well as the growing importance of compliance and cybersecurity measures.

AVL with Software Expertise for the Development Process

We support the industry with cross-functional software expertise and many years of implementation experience. The engineering skills of our software developers are unique, making our solutions exceptionally application oriented. With our comprehensive software applications, engineers around the world can realize their own innovations. We help them meet industry standards and legal requirements, as well as tight cost and time-to-market schedules. The best example is our high-precision simulation and testing software, including the corresponding methodology for efficient in-the-loop testing of all kinds.

Like the modern workplace, testing is becoming increasingly hybrid. This means that virtual and real tests will be even more closely linked in the future – thanks to artificial intelligence, among other things. This is the only way that test environments will be able to cope with the increasing complexity arising from the various units under test in the future. Virtual development and test execution on the testbed does not make testing in the real world superfluous, but it does reduce the number of physical test scenarios required. At AVL, we have developed tools that enable users to take full advantage of machine learning algorithms, simulation, and virtualization in

their development process. This allows customers to identify problems early to avoid costly damage to units under test and prevent delays in the project schedule.

We operate more than 20 development and support centers worldwide, where around 3,000 software experts are working on the mobility solutions of the future. Beyond that, we work closely with automotive manufacturers and suppliers as well as major software companies and cybersecurity specialists to ensure the best possible solutions.

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It is the code that sets the tone in today's software-defined vehicle. We support the industry with cross-functional software expertise. AVL and Microsoft

Testing Software Faster

Why do software-defined vehicles need faster-paced software development? And how can this be achieved? Dr. Daniel Lueddecke, Senior Software-Defined Vehicle Ecosystem Manager at Microsoft, has the answers.

Interview with **Dr. Daniel Lueddecke**

How do software-defined vehicles affect the development and validation process?

In essence, it's about shifting the center of the customer experience from hardware to software. This also increases customer desire for regular software updates, which means that development and validation processes are needed that allow software to be developed much faster than before – without compromising on quality.

What are the challenges to be overcome?

The validation process is usually added on at the end instead of being thought of as an integral part of the development process. In addition, the established validation processes often rely on real hardware. All this leads to high development costs and SOP postponements. Now, we all need to succeed in moving the validation part forward significantly.

How important is open source?

The challenges can only be overcome through the interaction of many parties. In collaboration with other companies, we are pooling our contributions to software-defined vehicles in the "Eclipse Software Defined Vehicle Working Group". This gives us the opportunity not only to come up with solutions at specification level, but also to implement them directly together – we call this "code first". Based on these open-source components, commercial solutions can then be developed and marketed.

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Why are AVL and Microsoft working together in this area?

Hardware tests are very time-consuming and expensive. While they cannot be eliminated entirely, it is necessary to reduce them significantly, by shifting a large part of them to a virtual environment. These virtualized test environments scale much better. And it is even possible to test on virtualized hardware that does not yet exist in reality. AVL's expertise in testing and validation is an excellent starting point for addressing the challenges in these areas. Combined with our expertise in designing highly scalable and secure systems, we create immediate value for our mutual customers.

We are currently working with AVL on developing new, scalable DevOps solutions to perform and orchestrate software tests as early as possible and fully automatically in virtualized environments. Software versions, test cases, and Digital Twins of the hardware are combined into individual configurations and validated automatically in the cloud.

A look to the future ...

Software-defined vehicles are already a reality. Until now, however, there have usually been years between the deployment of new software versions in vehicles. This has meant lengthy validation cycles. We need to break this pattern. We need processes and tools that shift development and validation processes forward significantly. Shorter release cycles will allow us to have shorter validation cycles and streamline the entire process.

Most Profound Change in Ford's History

By revitalizing the Advanced Propulsion Laboratory (APL), Ford has significantly enhanced its testing capabilities in the UK. This modernization has taken the facility's functionality to a new level, aligning with global partners' methods, and pushing the boundaries of automotive innovation.

ord's propulsion test resources in the United Kingdom have undergone significant enhancements, bringing the facility up to date for the evaluation of electric and fourwheel drive technologies. A key aspect of this transformation involves the revitalization of the Advanced Propulsion Laboratory (APL) located at the Dunton Technical Centre in Essex. The primary objective is to facilitate testing for electrification and four-wheel drive systems. These newly upgraded areas became operational in the middle of 2022.

Prior to this development, the individual program teams were consulted about their forthcoming projects, allowing for a thorough assessment of the construction measures required to support future electrified endeavors. This process was crucial to align with the company's corporate engineering test procedures. Additionally, a comprehensive understanding of the testing methodologies employed by global partners was essential to identify areas for improvement and enhance the overall capabilities of the test facility. Updates include, for example, new two-wheel drive and fourwheel drive propulsion NVH test chambers, each with high voltage battery emulation up to 1,200 V In total, the APL has 15 test cells; everything from an e-axle to a single engine or full vehicle can be assessed.

The APL is spread across three floors, and the facilities can run 24 hours a day, seven days a week. The second floor is where all the testing happens. Ian Murray, supervisor of the Advanced Propulsion Laboratory, makes sure that all testing processes run smoothly.

"The AVL PUMA software is the heartbeat of the test room environment. The development process and facility output are directly affected by the efficiencies of the PUMA operating software. The testing facility is able to offer highly efficient lights out testing at an early stage of the development process, which grows our capability and efficiencies in the testing environment. Having a globally aligned way of interacting The AVL PUMA 2[™] software used in Ford's APL is the global industry standard for testbed automation. It is suitable for electrified testbed types as well as for conventional test environments.



with the PUMA automation system, particularly the PUMA 2 platform, makes the efficiencies even more valuable", Murray explains.

For Murray's projects it is essential to have a partner like AVL that can offer future solutions that integrate, which gives them the competitive edge. Combining ICE and EV test equipment and connectivity is the key in remaining flexible for Ford's future needs. High capability dynos, e-storage, fast charging, and cooling systems are critical equipment sets required for their footprint. Having these under one operating system means that Murray and his team can perform complicated test cycles encompassing multiple functions efficiently.

When asked about the future of automation and which further developments, e.g., in terms of artificial intelligence and the use of machine learning, he expects in his application area, Murray states, "Automation is woven into the fabric of most testing that we complete here. We have internal teams working on this and we are also now integrating iGEM software, particularly for testing where report generation is required. The facility demands lights out 24/7 operation and the automation gives us this efficiency. Artificial intelligence and machine learning are being studied, the wider team are looking into how this can be incorporated from a test and data analysis standpoint".

The transformation is ongoing as Ford plans to get more cells within the APL up to standard for EV testing. \blacksquare

The APL is spread across three floors, and the facilities can run 24 hours a day, seven days a week



AVL RACETECH engineers Filippo Guzzabocca and Thomas Amhofer at Le Mans

From AVL RACING to AVL RACETECH

Motorsport is an important development and testing platform for technical innovations - including for AVL. But our commitment goes far beyond that. At AVL RACETECH, cutting-edge technology meets diversity in action and a green future.



Peak Performance from the First Lap

ith a passion for innovation and the relentless pursuit In addition to this expertise and state-of-the-art technology, utof perfection, AVL's motorsport department has been most secrecy and consideration for the special characteristics working on improving the interaction between man of the drivers are important factors for success in motorsport. and machine for 25 years now, to meet the high demands and And it is not only in the pit lane that AVL RACETECH engineers fierce competition in various racing series. work closely with OEMs, teams, and drivers from 17 different racing series; AVL RACETECH's expertise in the field of testbed The course was set for a dedicated AVL motorsport departtechnology is also in demand away from the racetrack: more ment in 1997, when Graz received the first orders from racing than 180 projects have now been successfully implemented teams in a wide range of racing categories. AVL's reputation in around the world - and it all started with the first testbed for a racing team, which was supplied to Ford Racing in the USA in the area of optimizing drive systems and the test stands and 1997.

testbeds required for this had also spread to the global stage of motorsport.

From that point on, the AVL engineers provided active support in areas such as the new and further development of racing engines to achieve greater performance and faster lap times. The range of tasks quickly expanded to include analyzing and optimizing racing cars and components. Over the years, AVL has developed more and more sophisticated and racing-specific software solutions, which are integrated in the software toolchain offered today (AVL VSM[™] RACE, AVL-DRIVE[™] RACE, AVL Simbook[™] RACE, AVL Kinsolver[™] RACE).

With these software solutions. AVL RACETECH is Official Supplier of the FIA (Fédération Internationale de l'Automobile), the highest authority in motorsport. AVL RACETECH's expertise in vehicle dynamics simulation is used by the FIA in a number of championships, including the FIA Formula One World Championship, the ABB FIA Formula E World Championship, the FIA World Rally Championship, the FIA World Endurance Championship, the FIA World Rallycross Championship, and cross-country events.

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AVL RACETECH partner team Inter Europol Competition celebrates Le Mans 2023 victory in LMP2 class

Today, there is a wide-ranging portfolio of testbeds for motorsport customers, from individual test units to entire test centers. One of the most recent examples is the Red Bull Racing team's test facility in Milton Keynes (UK). Many years of experience and comprehensive expertise make it possible to handle projects of this magnitude professionally, and thereby play a part in the success story of racing teams.

Initially, services for motorsport were provided under the umbrella brand AVL. However, increasingly full order books soon meant that a separate corporate identity was necessary The sub-brand AVL RACING was established at the start of the new millennium and became more and more well-known. For a clearer positioning, rebranding with the current brand name AVL RACETECH finally followed at the start of 2022. And this name put a much clearer focus on the core competence than ever before: technology for motorsport. The offering continues to range from engineering through testing, testbed engineering and simulation, to production. The focus for the future is a significant expansion of activities in the field of electrification and the various hydrogen technologies.



IDrive Fast

Act Faster

The Motorsport of the Future is Green

AVL H2 ICE RACE engine, 2-liter turbo with an output of 300 kW.

Environmental protection and sustainability have long been of global significance and relevance. And motorsport is no exception – even though reconciliation often involves major challenges, there are numerous initiatives for a green future for the sport. AVL RACETECH is taking responsibility in this area and actively contributes to making motorsport more environmentally friendly and sustainable.

One of the pioneering projects is the development and production of a hydrogen combustion engine specifically for racing. This is a compact, hydrogen-powered 2-liter turbocharged engine, which achieves a completely new level of performance through intelligent water injection. The aim is to produce an environmentally friendly racing engine that with a total output of 300 kW is on a par with production-based motorsport classes. The brand- and team-independent development of the engine opens up a wide range of possible applications, such as equipping a carbon-neutral race series with the AVL H₂ ICE RACE engine.

In addition to alternative drive units, AVL is also working on solutions for the environmentally friendly production of hydrogen – if required, this can be done at the racetrack in the future. Modular solutions in transportable containers make this possible. For racetrack operators and race series, this opens up the possibility of cooperating with AVL RACETECH to hold race events that are completely carbon neutral.

While the goal of carbon-neutral motorsport is yet to be achieved, AVL RACETECH is already investing in more sustainable and climate-friendly motorsport according to the motto "Drive Fast, Act Faster". For the third year in a row, all CO₂ emissions generated by AVL RACETECH brand ambassadors will be offset. The entire carbon footprint produced during the racing season will be offset in cooperation with the Green Future Project, by purchasing rainforest areas in the Narupa Reserve (Ecuador). This not only permanently protects valuable forest areas, but also ensures the preservation of biodiversity.

AVL RACETECH Brand Ambassador Ferdinand Habsburg, who initiated the "Drive Fast, Act Faster" program together with the Green Future Project, wants to make use of the role model effect of such projects as well as the carbon offsetting. The idea is to promote sustainable developments and the positive environmental and social impact in the communities in which they are implemented.

> Offering a hydrogen racing engine makes us a pioneer in the field of sustainable motorsport.

The Road to Success Is Diverse

Diversity is valuable and facilitates better progress and innovation. For a long time, little attention was paid to this fact in motorsport, but by consciously promoting female engineers and developers, and focusing on diversity in the race teams and engineering teams, the AVL motorsport department is also working hard to utilize and expand existing competencies.

2023 sees the launch of a dedicated program within AVL that invites female engineers to participate in training and together. exchange programs. This Female Engineer Program has two goals: to promote female engineers in the field of motorsport and to act as a role model for future generations. The aim is to systematically remove hurdles and inhibition thresholds for talented young women. For an innovation-driven company like AVL, it is out of the question to leave the potential In general, the promotion of talent within AVL RACETECH of talented people untapped. The Female Engineer Program is of great importance. The development of the brand involves practical workshops on the topics of race technoloambassador portfolio shows that not only successful racing gy, simulation, testbeds, and driving simulators. Assignments drivers, such as Tatiana Calderon (Formula 2, among others) at the racetrack with teams with whom AVL RACETECH or Ferdinand Habsburg (Le Mans winner 2021) are signed, cooperates, as well as individual career coaching, round off but also talented youngsters from karting and motorcycle racing as an investment in the future. the program.

AVL RACETECH Brand Ambassadors: (from left to right) Lena Kemmer (AT), Laura Bubenova (SK), Luca Schlegl (AT), Yasmeen Koloc (CZ), Tatiana Calderon (CO), Liam Müller (DE), Ferdinand Habsburg (AT), Jonas Müller (DE), Finn Gehrsitz (DE), Aliyyah Koloc (CZ)



By embracing diversity, we are transforming the future of motorsport at all levels to benefit together.

From an engineering office in Graz to a global company for mobility technologies: This is an example worth copying. We have already made our footprint sustainable – from America to Japan.

Interview with Don Manvel, Chairman & CEO, AVL Americas; Joe Strelow, President, AVL Test Systems, Inc. and Stephan Tarnutzer, President, AVL Mobility Technologies, Inc.



AVL North America on the Rapid Shift to Electrification

The three of you first connected with AVL in various ways, but what led to your decision to join the company? Manvel: I was working for Chrysler while in Graz and eventually ended up being introduced to Helmut List. I got to know both him and AVL – very people-oriented and always at the cutting edge of technology.

Strelow: I heard really positive feedback. Not only was it a great place to work, but the products were good, and it was run with a moral compass.

Tarnutzer: Right, the opportunity to work for a company that values people - I think we do that well - and, as Don said, a company that wants to drive the future of mobility while valuing the people that help make that happen.

How did you think AVL was positioned in the industry - or what value did you think AVL brought to the automotive industrv?

Manvel: I've been with the company for over 20 years now. AVL was new to the American market at that time, particularly the engineering side. I really felt that US OEMs (especially) needed our advanced technology.

Strelow: When I started, AVL's main focus was on ground vehicles still. I love the auto industry - my father was an auto mechanic, I grew up around cars. And I saw there was a huge

opportunity to make cars more efficient and cleaner, and things were just beginning to happen with electric cars.

That was the early 2010s ... and then electrification really started to take off. Did you expect it to happen so quickly? Tarnutzer: Electrification came onto the scene faster than I had ever imagined it would in the US. When I joined, there was still a heavy emphasis on the traditional ICE, but it was clear for AVL and the future of mobility that we needed to think about more than just the propulsion system in the vehicle.

Manvel: The speed at which the industry changed direction really surprised me.

Strelow: And within about three years of me joining AVL, conversations with startups started happening, and then it became all about startups, particularly in the electric segment ... but not exclusively, there were also discussions about fuel cells. I thought I might see two or three new car companies during the remainder of my career. And then we had to laugh, because I think we alone had already been involved with FIVE.

How does this transition to the future? Where do you see AVL excelling in the next decade?

Manvel: I think electrification really helps drive the next generation of software-defined vehicles. We have the people and the expertise to continue leading the industry and keep pushing the boundaries for the future of mobility upwards.

AVL Expands Canadian Footprint

core R&D clusters of Montreal and the Toronto-Windsor corridor.

hese resources will complement the existing research **Future E-Car Conference** team that continues to develop and deliver cutting-edge The electrification team welcomed warmer weather in the fuel cell technologies. AVL has had a home base in spring by heading to Windsor, Ontario, where they presented at Burnaby, British Columbia, since 2018 – to advance fuel cell the Future E-Car Conference hosted by the University of Windresearch, testing, and development. This region is home to sor. The event featured a technical presentation, demonstration AVL Fuel Cell Canada, Inc., and hydrogen fuel cell test system areas, and a tour of the newly constructed Centre for Hybrid leader and AVL partner, Greenlight Innovation Corp. Automotive Research and Green Energy (CHARGE) Lab.

Joseph Strelow, President of AVL Test Systems, Inc., noted, Alongside other industry experts, the team showcased the "Our goal is to stay close to our customers to support their ef-AVL SPECTRA[™] Universal Inverter: this was followed by a techforts to develop sustainable mobility. AVL sees not only a rapnical presentation by AVL Global Product Manager, Andreas idly evolving Canadian mobility market, but also a rich source Ficsor, who illustrated how inverter switching frequency influences motor efficiency. They also collaborated with NOVONIX, of top-notch engineering talent from Canadian universities. It's now appropriate to make this investment in the market and in AVL's battery cell testing collaborator, to highlight the power of our growing customer base." ultra-high precision coulometry in a nimble R&D setting. It was a pleasure to explore the technologies driving the future of Historically, Canada's automotive industry has focused on battery and electric vehicle testing, development, and producvehicle production, with seven final assembly plants producing tion across Canada.

1.4 million vehicles annually. Canada is also home to several Tier 1 global automotive suppliers. In recent years, Canada's automotive focus has expanded to include multiple R&D centers for battery electric vehicle and electrified propulsion system development in industry and university settings. AVL predicts this trend will continue and is investing accordingly.

With this in mind, the AVL team set out to expand its network and showcase the testing technologies to help advance the next generation of mobility.



In February of 2023, AVL announced it is expanding its North American footprint by dedicating technical support and business development expertise to the Canadian market. These new resources will be based in Canada and near the two

Fuel Cell Tech Dav

In June, AVL collaborated with Greenlight Innovation to host an event to reach the alternative fuel community. The Fuel Cell Tech Day, which took place in Burnaby, served as the perfect forum to examine a hydrogen future and discuss how AVL's technology is an essential part of the energy transition to generate efficient and emission-free electricity for a wide range of applications.

Together, the collaborators led a facility tour and presented a series of tech talks centered around applied systems engineering methodology as a measure for risk mitigation on fuel cell system testbeds, stack development with three dimensional multiphase CFD modeling, as well as advanced diagnostic techniques for fuel cells and electrolyzers.

AVL is proud to continue to expand its Canadian presence and meet with the minds helping drive the future of the mobility industry.



n 2018, AVL was awarded several contracts to provide all relevant testing software and hardware for light-duty and heavy-duty vehicle, engine, and propulsion system testing at the California Air Resources Board's (CARB) new, net-zero energy lab in Riverside, California.

As the key supplier of testing and measurement hardware and software, AVL is helping move the world toward a more sustainable future. AVL's experts recognize that mobility systems are still evolving. Therefore, the team developed and delivered a seamless lab operating system coupled with hardware to to fully equip the CARB facility to achieve its goals for decades to come.

The USD 368 million facility houses one of the world's most advanced vehicle emissions testing and research centers. AVL delivered 18 dynamometers for chassis, engine, and propulsion system testing, more than 90 emission measurement devices and systems, fuel and air measurement instrumentation, and the associated control, simulation, and data acquisition I/O.

Every test cell features AVL iGEM 2[™], which supports the full range of electrification testing needs for vehicles, such as hybrid, battery electric vehicle (BEV), and fuel cell applications. CARB will also leverage AVL Lab Management[™] to ensure the smooth operation of the entire testing lab.

AVL's toolchain allows users to control all aspects of the testing process – from planning work orders and preparing and executing individual tests, to analyzing test result data. With AVL's configurable software, CARB will not only be able to create and run tests quickly, but also monitor and control their systems and data from anywhere in the world through wireless tracking via PCs and mobile devices.

In November 2021, the CARB lab was dedicated to Mary D. Nichols, to honor her legacy as a former CARB chairperson and figurehead in advancing the state of California's strides toward improved air quality and public health. The facility officially opened its doors for business in spring 2022 and has been fully operational ever-since. The AVL North American team is proud to provide AVL's technologies to CARB, which help advance California's vision for a more sustainable future.

California Technical Center (CTC) Provides Big Boost to EV and Mobility Startups

In 2009, AVL opened a state-of-the-art battery and e-mobility technical center in Lake Forest, California. Nearly 15 years later, the California Technical Center continues to lead the mobility industry with first-of-itskind projects and technologies. The facility located in the greater Los Angeles area provides a leading source of innovation for battery, fuel cell, power electronics, and more to an ever-expanding mobility industry in Southern California and on the West Coast of the US.

TC (as it is affectionately known) has built nearly 100 demo vehicles on site and completed numerous design and development projects, including passenger vehicle e-axles, commercial vehicle battery modules and packs, and battery management systems for prototype and series applications. In recent years, new technologies and capabilities developed by the team at CTC have allowed them to push the boundaries of "traditional mobility" and pioneer new products and designs in stationary power, aerospace, and even lunar mobility.

Earlier this year, the team completed work on a stationary fuel cell power plant for a large mobility OEM, which will be installed at one of their corporate locations to serve as a source of backup power generation. The generator was fully designed by the CTC team and all fabrication work was done in-house. In September 2022, the world's first all-electric passenger air-

- craft "Alice", from Eviation Aircraft, successfully took to the sky in its inaugural flight. Led by the California team, AVL contributed to the development of the aircraft's energy storage system, including development of the battery modules and pack design housed along the bottom of the aircraft's fuselage.
- The CTC team is also continuing its efforts in developing concepts for the next-generation lunar terrain vehicle (LTV). The LTV is part of the Artemis program, set forth by the National Aeronautics and Space Administration (NASA), which aims to bring robotic and human exploration back to the moon. AVL is part of a team developing and simulating concepts for lunar mobility.

AVL Germany

Collaborative **Research at AVL** Germany

VL Deutschland GmbH has been a research partner involved in numerous European, national, and regional research projects since 2004. These collaborative projects are usually funded for three years and provide AVL with an optimum framework for working on new and challenging topics in the fields of electrification and automation and the reguired development methods. Close collaboration with OEMs, Tier 1s, and universities in particular gives AVL employees new perspectives on relevant cutting-edge technologies. Another advantage is the intensive networking of the simulation, testing, and engineering division at the various locations.

Projects such as VVMethoden and KisSME provide new approaches for automatically detecting critical traffic scenarios and demonstrate them in practical use. In the TechReal and SmartLoad projects, new solutions for Vehicle-in-the-Loop and networked component testbeds for safeguarding electrified and highly automated vehicles were developed and tested in specific applications.

Such references enable AVL in Germany to get involved in new customer projects, like contracts for the series development of Level 4 Mobility-as-a-Service shuttles.





eVTOL from Lilium

with support from AVL

German aviation startup Lilium has caused something of a sensation with its electrically powered aircraft that takes off and lands vertically (eVTOL). To test the new battery developed for the high energy demand, the company turned to AVL's expertise.

he development of eVTOL for the urban air mobility of the future meant that Lilium needed to design an of Costs innovative battery system that meets the high technical The test facilities developed by AVL were implemented gradrequirements and certification specifications of the aviation inually, taking into account synergy effects for other projects dustry in terms of mechanical, electrical, and chemical design. and optimum operational usability of the equipment. This However, since there are no established testing requirements minimized the total cost of ownership (TCO) and maximized for batteries in the aviation industry at present, the company the transparency of costs. A dedicated testbed building with was faced with the task of developing its own product valia bunker for battery misuse tests was also planned. The condation methodology for its new battery design. The complex cepts and design specifications form the foundation for the challenge called for the best test environment available, which final implementation of the test facilities at the Lilium campus is why Lilium opted to collaborate with AVL. near Munich.

Gradual Implementation of the AVL Test Facility

AVL designed a comprehensive test facility to be implemented in several phases. The focus is on developing customized battery test equipment for cell, pack, and system tests that meet the specific requirements of these extraordinary components. This equipment has been specially adapted to the requirements of cellular chemistry and aircraft design, and facilitates extensive testing, which also goes beyond the limits of real-world use. Special attention is paid to the high current flows during eVTOL's take-off and landing procedures, as well as to handle complex redundancy methods of the pack units.

Minimizing Total Cost of Ownership, Maximizing Transparency

The Importance of Collaboration for the Success of the Project The collaboration between Lilium and AVL in developing a test environment for eVTOL was pivotal to the success of the project. The use case demonstrated that aircraft battery cells, packs, and systems can be validated using the AVL battery test systems (AVL E-STORAGE SiC[™] battery tester, AVL PUMA 2[™] battery automation system, AVL cell/battery pack/battery system test chambers, and AVL safety system). With the implemented operating modes, all jet-specific parameters can be tested in real-world and artificial conditions.

AVL United Kingdom

Making the Fuel Cell Concept a Reality

AVL and Ford Britain FCVGen1.0 team

AVL Powertrain UK teamed up with Ford of Britain to build a light-duty commercial hydrogen fuel cell electric demonstration vehicle.

VL Powertrain UK are working on a variety of projects designed to decarbonize and reduce emissions across the automotive sector. One such project was FCVGen1.0, a collaboration between AVL and Ford of Britain to create a fuel-cell-powered electric light-duty commercial vehicle. Undertaken as part of the Advanced Route to Market Demonstrator (ARMD) competition, the efforts were part-funded by the UK's Advanced Propulsion Centre (APC), a not-forprofit organization helping to accelerate the transition to a net-zero automotive industry through funding, support, and insights.

The idea behind FCVGen1.0 was to develop a fully functional fuel-cell-powered Ford Transit light-duty commercial vehicle, along with a validated digital twin of the fuel cell system (FCS) and vehicle, in under 12 months. A prototype Transit BEV donor van provided by Ford was converted to a fuel cell demonstration vehicle at the AVL Engineering Centre in Basildon. The project drew on AVL's experience in the development and integration of hydrogen propulsion and fuel cell technology, combined with Ford's knowledge of vehicle controls as well as the development of vehicle calibration and energy management systems.

Pooling Expertise

The project team comprised various disciplines, including component and system design, control system and functional safety development, simulation and system integration, as well as construction and commissioning. The team drew on their expertise to design, specify, and integrate the fuel cell balance of plant (BOP) and high-pressure hydrogen storage system including supplier selection and component procurement.



AVL CRUISE[™] M was used to simulate the fuel system and performance. A rapid prototype of the fuel cell stack and hydrogen tank control systems, including an infrared communications system for fast refilling, was also developed. This rapid refilling allows the vehicle to offer comparable fueling performance to a conventional commercial van, with the hydrogen tanks refilling in approximately five minutes - similar to a typical combustion-powered vehicle.

A vehicle drivability assessment was conducted using AVL-Drive[™], and the team developed and installed a humanmachine interface (HMI) in the vehicle, to allow the driver to monitor the status of all the systems.

Transforming Goals into Products

The outcome is a vehicle that proves the engineering feasibility of zero-emission hydrogen fuel cell propulsion in light-duty commercial vehicles, both in terms of performance and practicality.

"This collaborative project demonstrates that fuel cell electric vehicles (FCEV) can become an integral part of the solution to enable a net-zero future," says Dr Matthias Wellers, Managing Director, AVL Powertrain UK Limited. "I am very proud to have been part of a team that has delivered an exceptional FCEV demonstrator in a light-duty commercial vehicle and a Digital Twin model of the vehicle and fuel cell system in under 12 months. The collaboration between Ford of Britain and AVL supported the delivery and achievement of the project goals. It was a great project delivered by an extraordinary team."



AVL Ibérica

Driving an Electric, **Connected**, Autonomous, and Greener Future

AVL Ibérica, with its vision of a more sustainable and connected future, has decided to establish a new office in San Sebastián. The main objective is to provide local support to meet the growing demands in the field of mobility.

ith the new office, AVL is strengthening its presence in the Basque Country, a region recognized for its innovative approach in the industry and its close relationship with the automotive sector. In the Basque Country, the automotive industry and the vision of a more efficient and sustainable future have come together in a powerful alliance. The goal is to optimize the use of mobility and transportation services while reducing dependence on fossil fuels and increasing energy efficiency.

This technological shift is facilitated by the potential collaboration between AVL and the Basque Science, Technology and Innovation Network. Together, they can drive the development and validation of new mobility technologies in the region, offering efficient services and solutions that help shape a cleaner and more sustainable future.

The local administrations have also recognized the potential of smart and sustainable mobility as a strategic commitment and have created an advantageous ecosystem through MUBIL, a reference center and hub for smart and sustainable mobility in Gipuzkoa and the Basque Country. This project brings together

the efforts of public and private agents in the sector and seeks to position the Basque Country as an industry leader in smart and sustainable mobility at an international level. Its focus includes four main areas: knowledge management, entrepreneurship, technological infrastructure (energy storage, propulsion systems, and fuel cell testbeds), and Living lab.

One of the lighthouse projects of this initiative is the "E-Mobility & Hydrogen AVL to MUBIL Project", valued at 9.5 million euros. This project involves designing, implementing, and equipping new test facilities for high-speed e-motors for light-duty vehicles, e-motors, and e-axles for both light-duty and heavy-duty vehicles, and PEM fuel cells for stack and cell systems. The AVL team has been working hard and collaboratively since the end of 2021; the project officially kicked off in May 2023 and the installation phase is scheduled for mid-2024.

This undertaking in the Basque Country is proof of AVL's commitment to its quest for a more sustainable and efficient mobility of the future. Collaboration, innovation, and passion for a better world are laying the foundations for a future of electric, connected, and autonomous mobility.

AVL Italy - Battery Technology Center: **AVL Part of Stellantis' Journey to Redefine Mobility**

n Italy, the stories of Fiat Auto, then the FCA group, and AVL - with its local headquarters based in Turin – have been inextricably linked for decades, and both companies have witnessed the evolution of the automotive world as an active player.

The foundation of the Stellantis Group from the merger of FCA and Peugeot S.A. in 2021 further enriched this collaboration at a crucial time for the technology transition, and the targets the group has set itself are a confirmation of this: The Stellantis "Dare Forward 2030" program states that all new product launches in Europe from 2026 onward are to be battery electric (BEV) only.

To achieve this ambitious goal, Stellantis decided to build a complete test field dedicated to battery and component testing. AVL has been part of the project since the beginning to fulfill the customer's requirements. Stellantis' customer need was by no means trivial:

The challenge was to transform and adapt their current testing and engineering capabilities from ICE to e-mobility. AVL adopt-Our team of project managers, engineers, technicians, and ed a holistic approach, offering a complete turnkey solution international experts embarked on an incredible journey to able to vertically integrate the capabilities to develop and test support Stellantis in this remarkable achievement. This is not battery packs. only the success of a project, but a big step in collaboration with our customer towards the next generation of sustainable mobility.

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Photos: Stellantis N.V. - Mirafiori Battery Technology Cen (Turin, Italy)

Largest Battery Testing Facility in Italy

The result of more than two years of intense work was recently unveiled as Stellantis Battery Technology Center (BTC): the 8,000 m² area is the largest battery testing facility in Italy and one of the largest installations in Europe, featuring 32 climatic test islands - 24 of which are dedicated to packs and eight to cells – designed and installed by AVL.

The BTC can perform and oversee climatic stress tests (-40 to +140°C), lifespan durability testing, battery management system (BMS) software development, and calibration and tear downs of packs and cells for analysis and benchmarking.

The backbone is the new generation of AVL PUMA 2[™] systems. Combined with state-of-the-art equipment (e.g., AVL SiC Battery Testing Systems) and complemented by AVL Lab Management and Energy Management software suites, these systems empower Stellantis with intelligent testing planning features, enabling them to consider the charging and discharging cycles to optimize overall energy consumption.

AVL Japan

Supporting Japan's Automotive Industry

fter many years of working for Suzuki Motor Corporation, Prof. Dr. Takahiro Noyori joined AVL in 2014 to commit to advanced technologies and global knowledge, and now serves as Deputy General Manager of the engineering division.

Having dedicated his career to technology, he has extended his passion to the growth of the automotive industry and to talent management.

Prof. Noyori has made significant contributions to AVL's corporate success. For example, his dedication and leadership helped make Suzuki Motor Corporation one of the most steady customers of the engineering division in Japan. He also contributed to the first exhaust measurement system, AVL AMA SL[™], and an e-motor testbed delivery for Suzuki in the Instrumentation and Test System field in 2022, and was a key player in growing business for Maruti Suzuki India Limited in cooperation with AVL India.

While extending his professional experience and knowledge at AVL and connecting with intellectuals from around the world, Prof. Noyori moved into talent management, passing on his accumulated experience to the next generation.

Prof. Noyori has been teaching undergraduate and master's programs at his alma mater, Waseda University, since 2016, and has had more than 300 students. Notably, he acts as a bridge between Waseda University and the internship program at AVL Graz. Two of his students who participated in the internship program later joined AVL in Graz. In addition, in 2017 he launched the joint symposium between Waseda University and AVL with Prof. Kusaka, a key figure in Japan's automotive industry; the symposium attracts around 1,500 attendees. Prof. Noyori also works with Japanese associations and the government.



Prof. Dr. Takahiro Noyori

He has a leading role in many major Japanese associations, such as the Society of Automotive Engineers of Japan (JSAE) and the Research Association of Automotive Internal Combustion Engines (AICE), is linked with various government agencies such as the Ministry of Economy, Trade, and Industry (METI), the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT), and the Ministry of Environment (MOE), and often advises the government on important policies.

Prof. Noyori's wide-ranging activities in business, government, and academia are nothing short of amazing, and he attributes this to his strong passion as well as his belief in AVL and the automotive industry.

"I think AVL's technology is outstanding. It is very easy for me to keep up with global technical trends," he says, and continues, "I would like to share the knowledge I have gained at AVL with the Japanese government and academia. I believe this will enhance AVL's presence in Japan. I would also like to convey the attractiveness of the automotive industry to young people."

Prof. Dr. Takahiro Noyori continues to strengthen his profound knowledge of AVL and be a strong advocate of AVL.

Dr. Heywood, a well-known person in the world of engine development, visiting the KTC.



AVL Korea

The Story Behind the Growth of the AVL Korea Technical Center (KTC)

stablished in 2008 as a subsidiary of AVL Korea, Korea Technical Center (KTC) has served as a platform for providing engineering activities in the Korean market and exchanging experiences and knowledge via the global network.

KTC's journey has not been without challenges. When the diesel calibration market experienced a rapid decline, KTC focused on enhancing its capabilities in gasoline calibration, validation, and software, as well as electrification.

This strategic shift in focus has proven successful for KTC, firstly through resident business with OEMs and then through calibration work packages for OEMs and Tier 1s. KTC established a strong reputation with smaller sized advanced gasoline calibration projects and, since a pilot project in 2020, this has translated into multimillion-euro SOP calibration projects for vehicles launched in global markets. KTC has established itself as a prestigious industry partner, now actively participating in an average of 8 to 10 ongoing SOP projects for well-known Korean clients.

Recognizing the significance of electric propulsion system technology in the evolving automotive landscape, KTC took

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a proactive step in 2019 by establishing an Electrification Development Team. This new team contributes to benchmarking and validation projects conducted locally at KTC. The team also provides significant liaison support for projects running throughout the affiliate network to ensure the smooth and successful execution of projects in the domains of battery and power electronics.

The pandemic caused great volatility in 2020; KTC re-organized at the end of that year and adapted testing facilities to the changing demand, resulting in a more efficient operation. Additionally, in early 2021, KTC established a strong foundation for the Software and Controls team, which has continued to grow. The team's competencies are continuously developing through completing projects involving requirements engineering, process methodology & toolchain (PMT), and validation & verification (V&V). The team has supported significant projects, including ASPICE.

KTC has developed a position as a highly competent and reliable partner within the Korean market. KTC continues to strengthen its image and client relationship for the journey ahead through quality project delivery and continuous engagement with key players in the industry. ■

AVL India

The End Customer in Mind, the Future in Sight

Shashi Singh, Managing Director, AVL India, on his personal career, major milestones, key success factors, and future prospects for AVL in India.

Interview with Shashi Singh

What initially inspired you to join AVL, and how has that inspiration evolved over the years?

India had very limited options for automotive testing equipment in the 80s. My association with AVL, which started in 1983, enabled us to bridge that gap. AVL's growth in India is nothing short of spectacular – what started out as a trading company grew to a workforce of 900 plus people with 3 companies and offices across India.

As I reflect on my long and successful association, I am filled with a deep sense of gratitude and admiration for the journey I have been on with AVL. To sum up this journey, it is often the small consistent steps rather than the giant leaps that have brought us to where we are.

What have been some of the most memorable and challenging projects or experiences you've had during your time at AVL?

Setting up the factory, the India Tech Center, and the software divisions were organizational challenges. On the business front, the first engine development project with Mahindra (IDI to DI) in 1986 was groundbreaking. This revolutionized the tractor industry in India. The exceptional work done by AVL saw Mahindra's market share improve from number three to number one.

I have to add, all of this was only made possible because of the faith Prof. List placed in me and my team.

How has AVL evolved as a company since you first joined? What are some key changes or developments you have witnessed?

In my long association, I have personally witnessed AVL's transformation from an engine development company to a global leader in advanced automotive technologies. The company's global expansion, embracing of new technologies, digital transformation, commitment to sustainability, and strategic collaborations have been instrumental in shaping AVL's success and reputation in the industry.

Can you share a significant milestone or achievement that you have been particularly proud of during your tenure at AVL? My role has been to promote AVL and build contacts in the

industry, we have excelled in this area in India by becoming the most preferred partner in the industry.

As someone with extensive experience in the industry, what are some notable advancements or trends you have observed in the Indian or technological development field?

Over the past 40 years, the Indian automotive industry has portation. undergone significant advancements. Liberalization policies opened the market to foreign investments, leading to the If you could offer any advice to new employees or young entry of international car manufacturers. Production capaprofessionals starting out on their careers at AVL, what bilities expanded, technological upgrades improved vehicle would it be? Remember, you are part of an exciting industry that offers imperformance and safety features, and the industry embraced electric vehicles. Connectivity, infotainment, and vehicle design mense opportunities for growth and impact. Stay passionate, improved, while localization efforts reduced costs. Stricter be persistent, and never stop learning. Be resilient and as a emission standards were implemented and digitization result open to change, collaborate with others, and remember to prioritize your well-being and cultivate a healthy work-life brought innovations such as connected cars and autonomous driving. These developments have made the Indian automobalance. In technology, it's crucial to keep the end user in tive industry more competitive, technologically advanced, and mind. Strive to understand their needs and aspirations. Develaligned with global standards. op a deep empathy for the people who will ultimately use the

What role has teamwork played in your work at AVL? Can you share an example of a successful collaboration?

Looking back, it is evident that our shared vision and aligned values have been the driving force behind our accomplishments. We have consistently pushed each other to reach new heights, to challenge the status guo, and to exceed expectations. Our shared commitment to excellence has fueled our success and earned us a reputation as trusted partners in the industry.

The new Cummins technical center in Pune is a good example, it is a benchmark for global engine manufacturer Cummins. This would not have been possible without excellent collaboration between AVL Graz, AVL North America, and AVL India.

How do you think AVL's culture and values have contributed to the company's success and growth over the years?

AVL's culture has made a significant contribution to its longterm success. Through a strong sense of identity, commitment to long-term goals, trust, focus on relationships, and commitment to social responsibility, we created a unique competitive advantage that fosters sustained growth, customer loyalty, and employee engagement.

Also commendable is the groundbreaking work done by our cultural foundation to connect art and science. These initiatives make us more attractive to all stakeholders, including future employees who are looking for meaningful work and want to be associated with organizations that make a positive impact.

Looking ahead, what excites you the most about the future of AVL and the automotive industry as a whole?

The future of the automotive industry holds several exciting developments that have the potential to transform transportation as we know it.

From electric propulsion systems and battery technology, to artificial intelligence, sensor systems, and new materials, innovation is driving the industry forward. As you are aware, at AVL we invest more than 11 % of our revenue in research and development. With this focus on innovation, AVL will be at the forefront of these advancements, contributing to cutting-edge technologies and solutions that will shape the future of trans-

- products or services you create. By maintaining a user-centric mindset, you'll be better equipped to deliver innovative and
- meaningful solutions that truly make a difference.

"It is often the small consistent steps rather than the giant leaps that have brought us to where we are."

AVL China

The Bond Between AVL and China Is Older than AVL Itself

Michael Laske, Managing Director, AVL China, talks about his beginnings at AVL, key milestones, the rapidly changing Chinese market, and what all this means for the future of AVL and the industry.



Interview with **Michael Laske**

How did you join AVL and what was your original motivation? My background is rather atypical for AVL, as I don't come from the technical field, but from political science and economics. I studied at Columbia Graduate School and was already very involved with China there – with the language and the country. Then I have worked at a think tank in Taiwan for four years doing economic research. Back in the US, I had a lot to do with Chinese-American business relations and founded my own start-up in this area in 1989. In the mid-1990s, AVL approached me: the company wanted to further expand its China business and brought me on board. I came to Graz, met Professor List and decided to give it a try. In all these years, he has always supported me fully. I respect him very much – as a visionary and as a leader.

How has AVL China developed over the years?

When I started at AVL in China back in January 1995, we were just twelve people. First, we had to create the structures to be able to grow. I worked hard to build up the workforce. Those first ten years were very challenging, but then the conditions were right and the market in China was ready. Today, we are a valuable asset within AVL with over 750 employees and a significant share of the company's total sales. For instance, we are number one in emissions testing in China. We have installed more than 2,000 testbeds here over the years. That's enormous. Our goal has always been to be the market leader in our field. I don't believe in being second!

What milestones has AVL reached in China

Where to start? Important steps were certainly the various site openings: our first office in Shanghai in 1995, then our first Technical Center in Shanghai, which went into operation in 2003. From this point on we were able to work locally for our Chinese customers for the first time. In 2016, we opened a second technical Center in Tianjin. In 2018, in conjunction with Graz and Regensburg, we launched a very important and highly skilled software center in Chengdu. We have expanded into a new workshop in Lingang (Shanghai) for the production of instrumentation and test systems, and installed an inverter testbed for engineering projects related to the control units required by BEVs. The foundation for the future is in place and is fully aligned with our strategy of becoming the market leader in mobility solutions related to NEV applications. We began this journey twelve years ago and it is the shared vision of our entire staff in China.

What role does teamwork play in AVL's success in China?

Prof. Helmut List's leadership style is a role model for all of us in this respect. AVL is one big family. Chinese culture fits in very well with that. Loyalty is very important here. At AVL, employees have the opportunity to grow and contribute to a better world. When someone joins our company, we hope that they will spend their entire career with us, if possible. For sure, we support our people if they want to change. AVL is large and diverse enough that this is also possible within the company in most cases.

There is a special bond between AVL and China. Where does that come from?

The relationship with China is even older than AVL itself. From 1926 to 1932, AVL's founder Hans List was a professor at Tongji University. His memory is cherished here in China to this day. You can still visit a museum at Tongji University with many wonderful photos and even some old dynometers he used in his research while in China. His textbooks have been translated into Chinese. And everyone who studies automotive engineering here knows about the achievements of Prof. Hans List, as well as the contributions AVL has made to the Chinese automotive sector under the guidance of Prof. Helmut List.

As someone who has known the Chinese automotive industry for many years, what do you consider to be the most remarkable developments?

When I first came to China, there were very few cars on the streets. Everyone rode bicycles. Starting in 2000, that changed dramatically. The government had decided to build a competitive automotive industry. Many foreign companies came in and invested. The market took off and there was a lot of work for AVL. In 2010, the next paradigm shift followed: the political decision-makers in China realized that they were unable to quickly close the gap between them and the Europeans, Japanese, and Americans in terms of traditional internal combustion engines, so they focused their investment priorities and industrial policy on electrification, ADAS/ AD, and fuel cell applications. All activities in this direction are strongly supported by the Chinese government at national and local level. At AVL, we anticipated this and positioned ourselves accordingly through our global network of technology development centers – with testbeds for e-axles, battery development, fuel cell research capabilities, and so on.

What do you consider to be the biggest difference between China and other markets, and what do you derive from this for AVL?

The Chinese market is characterized by competition. If you are successful with a product or a solution, there are immediately ten other providers who want to do it better. The competition is endless, and the Chinese people work incredibly hard to be successful. Today, a great many technological innovations come from China and the country has taken over the market leadership in many areas – for example, BEVs and software-defined vehicles. For AVL, this means finding the right access points to make a difference. Fast and cost-effective solutions – from all our strategic business units. Our Chinese customers are always on the hunt for innovations.

How important are the values of AVL for its success?

Our values are a good basis for succeeding in any market. Pioneering spirit, innovative strength, passion, independence, and, above all, reliability: If we tell a customer that we can solve an important problem, we solve it. Where I think we can do even better is in the speed with which we complete tasks. Industry development cycles are getting shorter and shorter – especially here in China. We have to keep up with that.

What excites you most about the future of AVL and the automotive industry as a whole?

The acceleration of technological change has always fascinated me. Quantum computers and AI will continue to drive this trend. Our minds have to adapt to this pace. I am curious to see where we will be in autonomous driving in ten years' time. I am very confident that it won't be long before we are no longer driving our cars ourselves. From AVL's point of view, it is important to have the right people in house to face these new challenges and to manage the transformation. From the position of AVL China, where we have worked with hundreds of customers, it is always exciting to support new organizations and to interact with young entrepreneurs and engineers with new mindsets and visions for the future. And, of course, we continue to play an important role in resolving climate-change-related issues. What we do matters, and we can wake up energized each morning knowing that we are finding solutions and not creating new problems for mankind.

What advice do you have for young people just starting at AVL?

Be flexible and open to new challenges. Work hard, it will pay off. AVL is a great place to be employed, because we are an organization where individuals can build successful careers and make a difference. At AVL, talented people have a real and rare chance to create and realize their dreams and ambitions. This is one of the main reasons why young people join AVL and stay here for decades. ■

"The relationship with China is even older than AVL itself. From 1926 to 1932, AVL founder Hans List was a professor at Tongji University. His memory is cherished here in China to this day."



Shaping the Future Together

Welcome to Creators Expedition

Innovation only comes about through research? That used to be the case. Nowadays, people are innovating for all they're worth, especially in dynamic environments. Startups and dedicated innovation ecosystems are the ideal conditions in which to experiment.



utonomous vehicles, alternative drive systems, software-defined applications – the automotive industry is one big playground for creative minds. But the task is by no means child's play. Developing alternative propulsion systems requires expensive virtual simulations or complex hardware. Al and digital solutions from autonomous vehicles mean high computing power and huge volumes of data. This is simply too expensive for small or otherwise specialized companies.

Our Answer: Creators Expedition

Corporate partnerships can make an important contribution to overcoming the numerous challenges through sharing resources and test facilities and searching for market applications for innovations together. Therefore, in order to tap the full potential of co-creation, AVL launched Creators Expedition back in 2017. Here, AVL experts and business departments come together with innovative partners from the fields of electromobility and alternative fuels, automated and connected mobility, AI, and big data, with the goal of jointly pioneering the development of innovations. This first requires a clear shared vision and clear objectives to ensure that everyone is on the same page and sees a clear benefit for themselves. Then we can go on a joint "expedition" and reach out to new customers and markets.

1. Co-Creation With Startups

We primarily consider early-stage companies that have a strong team, a viable product, and some experience. With our expertise and resources, we give them the opportunity to focus fully on developing their product. If the new technology is mature but the market is not yet ready, we also help them find more immediate applications.

focus Special edition

AVL and Neural Concept Al as a Turbo Booster for Design, Simulation, and Prototyping

Objective: Substantial reduction of development times and budgets for early design and simulation variants, as well as lower project risk due to greater variance of possible design variants

 ${\rm Solution:}$ 3D deep learning approach to bypass classical FE simulation loops in early development phases

"Conventional approaches require several dozen FEM simulations to be run through for various design variants of components throughout the entire development process. This consumes a lot of resources and time and is difficult to reconcile with ever shorter development cycles. With our technology, efficient optimization is possible at an early stage, guaranteeing high performance and the reduction of expensive errors that occur later. For the chosen use case, the proof-of-concept project with AVL clearly demonstrated that our deep learning approach saves a massive amount of time even with relatively little training effort required for the models. At the same time, the expectations regarding the precision of the results are exceeded significantly. We can now build on these promising results in our collaboration with AVL in other fields." Kosmas Kritikos, Commercial Director, Neural Concept



AVL and Batemo **Concentrated Expertise in** Virtual Battery Development

Goal: Complementing AVL competencies at module, pack, and vehicle level to drive electromobility and develop customer-oriented solutions

Solution: Integrating Batemo's modeling and simulation technology into the system simulation solution ÁVL CRUISE™ M

"Collaboration is necessary to support customers throughout the battery system process. This includes electrode formulation, cell design, and pack development, as well as validation tests and operational solutions." Jan Richter, CEO Batemo



AVL gives startups the chance to make a name for themselves in international networks of suppliers, customers, and employees. And it is not only the startups who benefit from a partnership. Co-creation is also worthwhile for AVL in many respects:

- Access to new technologies and business models We can benefit from the expertise and technology of startups in areas that are not among our core topics but are relevant for the future. Together, we are able to bring new products and services to market more quickly.
- Agility and flexibility Since startups are usually very agile and flexible, together we can react to changing market conditions faster.
- Risk minimization Instead of investing in development ourselves, we can draw on the technologies and products of others and thus focus on joint market penetration.
- Culture of entrepreneurship Cooperation fosters a culture of entrepreneurship and innovation, and thus also the creativity and entrepreneurial spirit of our employees.

2. Co-Creation With Established Companies

In order to keep our finger on the pulse of the times and even more importantly – of our customers in an increasingly complex world, further cross-company and cross-sector initiatives are needed. In particular, large, established companies like ours with strong R&D capabilities are challenged to adapt to current conditions. Smart, strategic collaboration with other companies allows us to gain speed and creativity and use scarce resources more efficiently. Together, we have a better understanding of the market and can develop transformative innovations of a technical nature and business models that are closer to the needs of our customers.

This explains the second focus of Creators Expedition: collaboration with companies from adjacent industries that are striving for innovation to ensure their future business success. These include well-known global corporates in the IT sector, in the steel and metal industry, in logistics, and in mobility. The ultimate goal is always the customer-centric implementation of highly innovative and future-proof solutions for both existing and new target groups.

Our initial focus is on building networks. In discussions and workshops, we elicit common areas of interest, customer requirements, and visions. In doing so, we focus on problems that have relevant application fields in other industries and sectors besides the automotive industry and thus offer great scaling potential. Potential topics include the expansion of virtual development processes, the development of digital product passports, industrial hydrogen applications, and smart virtual sensor technology.

The primary role of Creators Expedition is to align with AVL's strategy, to build up the network, to bring together all the technical experts, and to provide methodological and process-related support. Both AVL's technical teams and those of the partner companies are responsible for developing prototype solutions and, in the future, specific products or services.

3. Other Initiatives

Creators Expedition also facilitates the regular exchange of experience regarding issues in the field of corporate innovation and organizes joint hackathons with universities and innovation camps. We act as a link between AVL and the (radical) innovation units of other large companies. We also actively shape innovation ecosystems, such as the Austrian industry network PIER 4 or Innovation Circle in Graz. We are



also involved in the national and international startup scene around universities and incubation or accelerator programs (for example, Gründungsgarage in Graz or TACC programs offered by UNIMORE in Modena).

4. Creators Lounge - Our Online Event Focusing on Innovation

At the start of 2022, we organized the online event "Creators Lounge" for the first time. Here, experts from various industries, startups, and academia discussed hot topics related to open and corporate innovation live with AVL employees. Since then, "Creators Lounge" has taken place twice a year. The event format has established itself as a good platform for open exchange, and there is great interest on all sides. In this way, our ecosystem continues to grow, and new exciting contacts are being made all the time.

Overcoming Tomorrow's Challenges Together

At Creators Expedition, we build strategic partnerships beyond the boundaries of AVL. In doing so, we discover not only outstanding ideas and novel technologies, but above all creative doers with whom we work on innovative solutions for the future: We collaborate to innovate. We invite anyone wanting to shape the future with us to follow our channels and events.

focus Special Edition

AVL and DeepScenario The Virtual World from a Drone Perspective

Goal: Providing a realistic, virtual test infrastructure in considerably less time and with significant cost savings

Solution: Combining the digital test environments with real scenarios captured by drones

"Using AI, we are making it possible to train, test, and validate autonomous systems on a large scale. Our platform provides unique insights for each scenario and enables new software features to be released rapidly. Together with AVL this allows us to resolve and identify specific scenarios much faster and derive relevant statistics for safety reasoning." Holger Banzhaf, Co-Founder of DeenScenario







Thank you!

With the future in sight, we proudly celebrate the 75th anniversary of AVL, a significant milestone in our company's history. This remarkable event allows us to embrace AVL's past, present, and future as we embark on a new era of sustainability and excellence in the automotive industry. We would like to thank all our customers, partners, and employees, who have played a pivotal role in AVL's success story.

The editorial team would also like to thank everyone who has contributed to this special edition of FOCUS – The AVL Mobility Trend Magazine.

We invite all readers of this special anniversary edition to engage in stories about technologies and the people behind them. Enjoy reading!



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