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The future for dynamicists

From autonomous cars to flying cars, and regulations to liabilities... Experts consider the road ahead to 2030

Interview: Ford

Scott Lindstrom, Ford's tire development and ADAS technologies manager, discusses the effect of electronic systems on dynamics

Simulation technology

What could and should the future hold for dynamics simulation technology? Experts from across the sector share their predictions

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Looking ahead to 2030, dynamicists have some major new industry influences to consider. From flying cars to regulations, experts consider the major changes the future of transportation will bring for engineers

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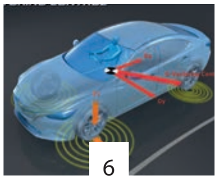
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"The greatest area that we need to make progress is bridging the gap between vehicle dynamics modeling and testing

Mehdi Ahmadian, director of the Center for Vehicle Systems and Safety, Virginia Tech, p12

A note from the editor

Dynamic disruption

There is no doubt that vehicle dynamicists have a disruptive time ahead of them. In the short term, the automotive industry is progressing rapidly through the stages of autonomous driving – indeed rather faster than many expected, especially with Ford rumored to be bypassing the tricky middle ground of Level 3 and progressing direct to Level 4, and Elon Musk announcing that Tesla's upcoming models will be equipped with all the hardware necessary for full-blown Level 5 autonomy. Of course, the greater the level of autonomy, the greater the level of passenger comfort that will be demanded – but for the tricky stages in between now and full autonomy, driver involvement and enjoyment still have to be considered in the vehicle's dynamic setup. And as dynamics engineers know, compromise is the hardest thing to achieve well.

The tools that dynamicists have to work with will also evolve, with active safety systems requiring further development to offer vehicle-to-vehicle and vehicle-to-infrastructure communication capability. This aspect is a systems engineering challenge that Amir Soltani, an active chassis control specialist at the UK's Cranfield University, describes as "a seismic shift" on p37.

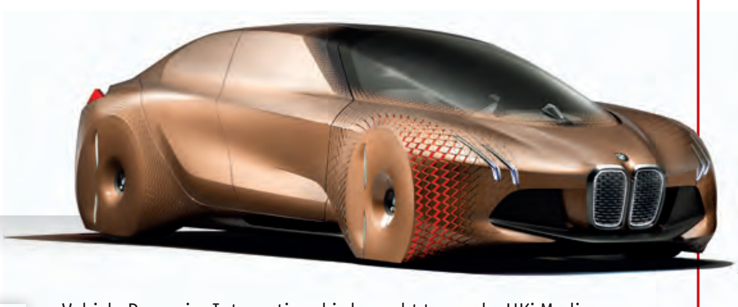
Further disruption includes decision and control algorithms for Level 4 autonomy, with what Daron Gifford, a partner at automotive consultancy Plante Moran, predicts on p38 to be "a headache" for OEMs and regulators in creating stringent certification that conforms to universal safety standards.

Looking even beyond Level 5 autonomy, Dr Mike Jump from the UK's University of Liverpool expects turbulent times for dynamicists as they have to reconcile the diametrically opposed engineering principles of achieving lift and drag in the same vehicle. Yes, he's referring to flying cars – what was once the childhood daydream of many a dynamicist could become a reality. A joy to behold but a potential nightmare to engineer, as you can find out on p40.

The future of vehicle dynamics looks set to be fascinating, as you will discover in this issue. You can discover even more at the Future of Transportation World Conference 2017, taking place on July 5 and 6 in Cologne, Germany. The focus begins with the short-range issues and opportunities of 2020, and proceeds to 2030 and beyond, with top-flight international experts – including Soltani, Gifford, Jump and many more – sharing their ideas and expertise. For full details, visit www.thefutureoftransport.com.

Back to present-day excitement, the results of the 2017 Vehicle Dynamics International Awards are announced in this issue (p26). The winners are impressive, from individual and team achievements, to the finest development technologies and a dynamically excellent car – all decided by our international panel of expert jurors. It was particularly heartening to see how tough and close the competition was across all categories – something of which the whole dynamics industry can feel proud.

Adam Gavine Editor



Vehicle Dynamics International is brought to you by UKi Media & Events, publisher of Engine Technology International, Automotive Testing Technology International, Automotive Interiors World, Electric & Hybrid Vehicle Technology International, Tire Technology International and Professional Motorsport World, and organizer of Automotive Testing Expo Europe, Automotive Testing Expo North America, Automotive Testing Expo China, Automotive Testing Expo India, Automotive Testing Expo Korea, Professional MotorSport World Expo and Vehicle Dynamics Expo.

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Annual subscription £80/US$104

published by
Published by UKi Media & Events, a division of UKIP Media & Events Ltd

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ISSN 1479-7747 (Print)
ISSN 2397-6403 (Online)
Vehicle Dynamics International

Average net circulation per issue for the period January 1, 2016 to December 31, 2016: 6,917

Printed by William Gibbons, Willenhall, West Midlands, WV13 3XT, UK

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Subaru Impreza

The 2017 Impreza is the first car to feature Subaru's new Global Platform. Graham Heeps explores how the new architecture benefits ride and handling

In its centenary year, newly renamed Subaru (goodbye, FHI) has become the latest car maker to introduce a flexible, cost-saving platform architecture. In this Japanese company's case it's the Subaru Global Platform (SGP), which makes its debut in the 2017 Impreza and will underpin several more new models going forward, including the 2018 Crosstrek XV first shown at Geneva in March.

Subaru is proud of its safety ratings in North America, its biggest market, and the all-new body structure is designed to better distribute crash loads. Increased use of high-strength steel lightens the body-in-white before new convenience features are added, increasing the Impreza's curb weight by 2-30kg over the 2016 model, depending on the version. However, the considerably stiffer structure also provides a much better base for suspension tuning.

"When you hit a big bump in the old car, you felt it through the structure," says Todd Hill, line manager for Subaru of America. "With the new car, because of the improved damping and the stiffer structure, you feel less of a vibration, and that vibration event is over more quickly. It's an area where the Impreza was a little behind some competitors; I think we've now moved past them."

Geometry lessons

At the front, a plate-metal, K-type cross-member increases the lateral bending stiffness of the body, as well as the rigidity of the members for the engine and gearbox mounts. A key structural enhancement is to the join behind the front wheel, between the A-pillar, firewall and frame rail. According to Hill, the area around the shock towers and where the front suspension bolts up to the body moves much less than on the previous model.

The front suspension itself retains its basic configuration – MacPherson strut with steel lower L-arm – but there are numerous detail revisions to reduce friction and slop. To improve handling stability and ride quality, and reduce NVH, the geometry has been completely overhauled and an input-separating front strut mount adopted. A load-axis-control coil spring reduces suspension friction, while the front stabilizer link is connected direct to the strut for greater efficiency and the front housing is now aluminum to reduce weight.

ABOVE: The mass offset for the front wheels has been lowered to reduce the vibrations transmitted from the wheels to the steering wheel

A similar approach was applied to the double-wishbone rear suspension. An input-separating rear damper mount and modified rear subframe bushings benefit NVH, stability and ride, while the stabilizer is now attached direct to the vehicle body instead of to the subframe, for the same reason.

"Again, that takes some looseness out of the system," Hill explains. "It also contributes to 50% lower body roll compared with the outgoing car." A 5mm lower center of gravity also contributes to flatter cornering.

"It's very relaxing to drive, it tracks straight, and it's fun"

The Impreza's EPS has undergone a major overhaul. The steering rack architecture incorporates the control unit into the rack assembly instead of mounting it on the bulkhead, making the system more compact, reducing harness/connection points and lowering the center of gravity. A similar approach was taken on the 2015 Legacy/Outback.

"Each of the components was designed from the ground up to reduce the delay from when you turn the wheel to when the car reacts," says Hill. "It's more precise and the feel is better than in the last car. By reducing the number of small corrections you need to make, we were able to fit a quicker steering rack to the car, so when you do turn the wheel, the car reacts much more intuitively, but without feeling darty. Even though you have a quick steering rack – at 13.0:1, it's the same ratio as the BRZ, down from 14.5:1 before – it's very relaxing to drive. It tracks straight and it's fun."

More bite during braking

The same kind of linear, intuitive feel was the goal for brake development, too.

"The team re-engineered the master cylinder and other components to reduce the delay between when you press the pedal to when the car starts braking," says Hill. "That distance has been shortened. Several competitors were identified as being best in class, and they were targeted and bettered. Once the brakes bite, they have a linear feel. They feel like sports-car brakes."

New for this generation of Impreza is a Sport model, which boasts 18in wheels, Yokohama tires and revised dampers. According to Hill, "You get a lot more handling and grip, with a similar ride. It's a lot sportier than any Impreza we had in the past that didn't say WRX on it."

RIGHT: Around 95% of parts are new on the 2017 Impreza, from the wheels to the steering wheel

Tech spec

2017 Subaru Impreza

Track: 1,540mm (F), 1,545mm (R)

Length: 4,460mm

Width: 1,480mm

Height: 1,775mm

Wheelbase: 2,670mm

Suspension: Front MacPherson strut, kingpin angle 14°14'; rear double-wishbone

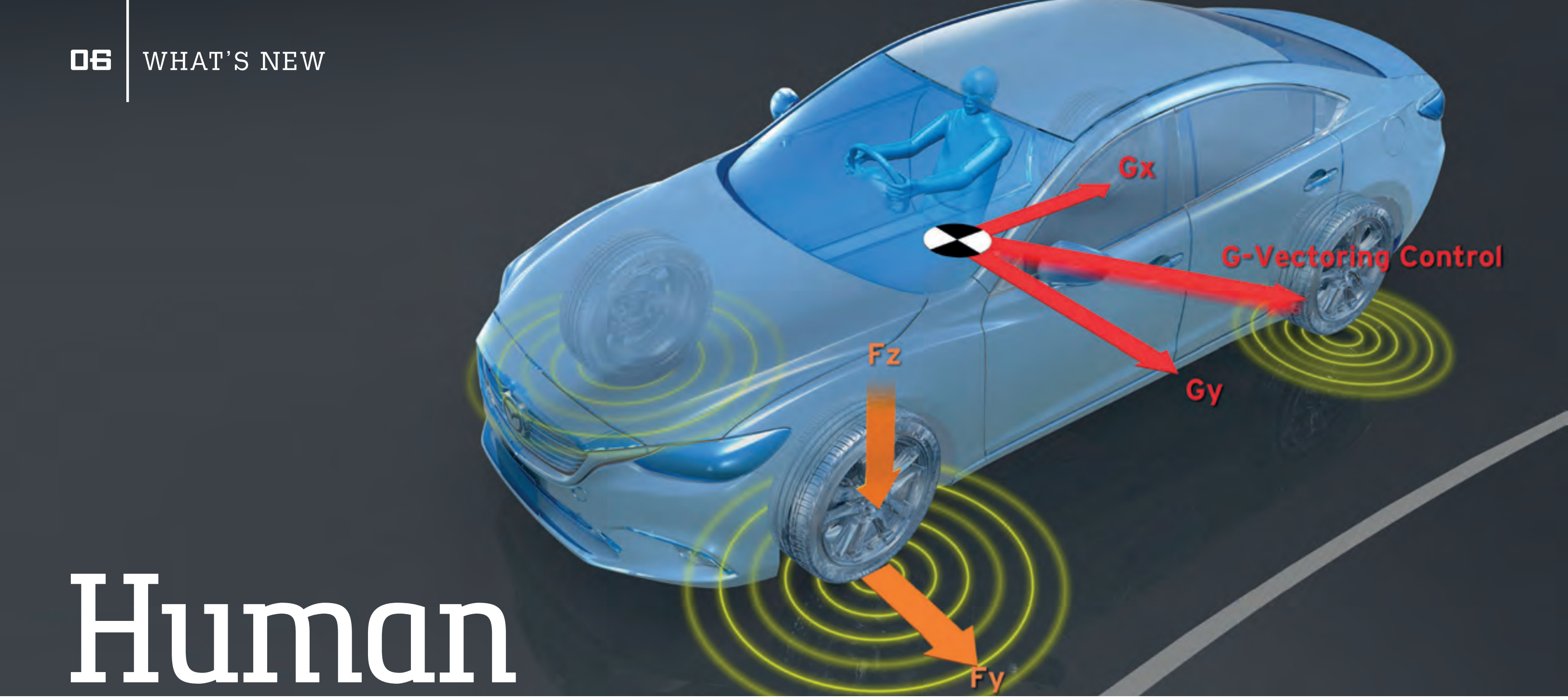
Geometry: Camber: front – 30', rear – 1°20'. Toe: front in 0mm ±3mm, rear in 3mm ±3mm. Castor: 5°55'

Steering: Rack-and-pinion EPS, ratio 13.0:1, 5.4m turning radius, 2.5 turns lock-to-lock

Brakes: Front – ventilated discs, 277x24mm (standard) or 294x24mm (Sport). Rear – solid discs, 274x10mm. Manual parking brake

Wheels: 16x6.5J, 17x7.0J or 18x7.5J

Tires: All-season tires: Continental ProContact TX 205/55 R16, Firestone FT140 205/50 R17 or Yokohama Avid S34 225/40 R18



Human interest

The 2017 Mazda3 heralds the beginning of a series of human-centric handling technologies being introduced across the Mazda range: SkyActiv-Vehicle Dynamics

Dynamics are key to the enjoyment of a vehicle, so why not consider them in every aspect of vehicle design and engineering? This is the approach Mazda has adopted with SkyActiv-Vehicle Dynamics, a series of vehicle motion control technologies that integrate dynamics with every key element of the driving experience, from engine and transmission, to chassis and body.

The inspiration comes from *yabasume*, the Japanese sport of mounted archery which dates back to the 12th century. Accurately firing an arrow from a cantering horse is quite a challenge, and to ensure stability and accuracy, horse and rider must work as one. The term for this sense of connectedness is *Jinba-ittai* and Mazda is applying it in its dynamics work to make drivers feel more connected with their cars.

The first stage of the SkyActiv-Vehicle Dynamics technologies is G-Vectoring Control (GVC), which is being introduced with the updated Mazda3 (known as Axela in Japan) before being rolled out across all its new-generation models.

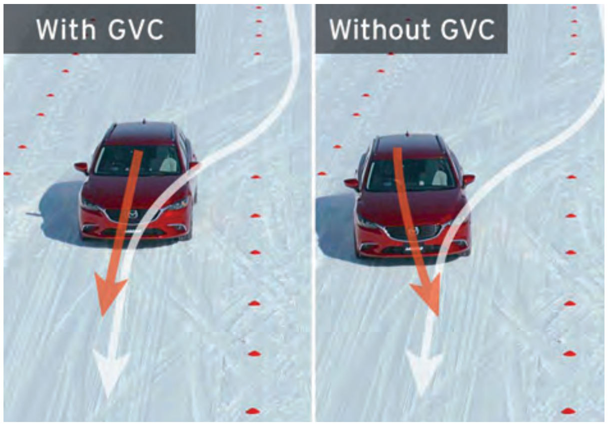
Turning the steering wheel in a GVC-equipped car does not just rotate the wheels: steering inputs also vary engine torque – torque that is available the moment the driver asks for and expects it, due to optimized boost control and precise fuel injection – and together they provide integrated control of lateral and longitudinal acceleration forces, optimizing the vertical load on each wheel. Better still, as GVC is a software system, it has no weight penalty.

When the steering wheel is turned, GVC adjusts engine drive torque to generate a deceleration *g*-force (usually 0.01*g* or less), thereby shifting load to the front wheels to increase front-wheel tire grip and turn-in responsiveness.

When a constant steering angle is maintained, GVC recovers engine drive torque, which transfers load to the rear wheels for vehicle stability.

As well as improving responsiveness and stability, the effect of the system is to make vehicle motion smoother, and for that motion to feel more natural and more in tune with what the body feels, thus keeping the driver – and passengers – comfortably and confidently in the saddle. An added bonus is that the control – and feeling of control – the technology provides improves everything from everyday driving to collision avoidance maneuvers, to handling on slippery or loose surfaces.

Customers that select the SkyActiv-D 2.2 engine can also opt for i-Activ AWD, an all-wheel-drive system that provides optimal distribution of torque to the front and rear wheels by anticipating road conditions, weather and the driver's intentions.



In addition to enhancing handling and safety, the G-Vectoring Control (GVC) system also improves comfort for all occupants by reducing torso sway

Smooth sounds

The 2017 Mazda3 also features Natural Sound Frequency Control technology, which reduces diesel knock in the SkyActiv-D clean diesel engine for a more pleasant engine sound.

What does this have to do with dynamics, you ask? Well, Mazda's engineers have found that engine knock increases at around 1.3kHz, 1.7kHz and 2.5kHz because peak engine vibration and peak structural vibration coincide. By controlling fuel injection timing to within 0.1ms, engine vibration can be used to cancel out structural vibration, thereby reducing knock.

By reducing pressure waves (vibrations) resulting from engine combustion and the structural resonance of parts, the ride becomes quieter and smoother, especially in the louder frequency bands.

Miles

Following the sad passing of Roger Becker, **John Miles** recalls his relationship with this remarkable dynamicist, and his legacy

From the early 1970s Roger Becker was the prime development specialist responsible for Lotus road car vehicle dynamics, and much more, because when Lotus Vehicle Engineering was formed, the strongest emphasis was on chassis development, based on sign-off criteria from the recently deceased Colin Chapman.

I was at *Autocar* magazine at the time, still reeling from my dismissal from the Lotus F1 team when Jochen Rindt was killed. Quality automotive journalism seemed to be in decline. It was vehicle engineering, specifically chassis design and development, that was calling me. Roger and I had talked several times about this, and we got to know each other really well on a shared trip to the Goodyear Technical Center Luxembourg and the Nürburgring in the newly launched Esprit Turbo. I now look back wondering if this journey was in fact a two-day job interview, because it was not long before CEO Mike Kimberley found some money in the cash-strapped coffers at Hethel to give me the chance of a lifetime.

Back in harness at Hethel, it was clear to me that Roger had inherited some of Chapman's work ethic and determination. Becker's calmness (quiet humor) and optimism under stress were reassuring. Also clear was his expertise with dampers and tire development, and his committed driving style. He would go off to "ask the car some questions", getting most of the answers on a trip around the Lotus ride route. Some say that when tire testing an Elan +2 in the early days on the Lotus track, a very severe double lane-change resulted in the car vaulting into a full 360° rollover, luckily landing back on its wheels, only for the terrified Michelin engineer to be calmly told "Oh they all do that…!"

In the early 1980s Lotus was more or less broke and being kept alive by shareholders Toyota and AMEX. On the plus side the Lotus Sunbeam, Toyota Supra and GM Cavalier development successes began to bear fruit, as more projects were signed up to a department consisting of myself, Roger Becker, Alistair McQueen and Tony Shute – who suddenly announced in the middle of a winter test that GM had bought Lotus Cars! Within a few months there were 20 people working for Roger and projects for all of us, as well as Lotus platform updates, the three-year US-based Esprit race program, and of course the FWD Lotus Elan. Roger had also formed strong personal links with Japanese and Korean car manufacturers.

Roger was also the one who backed the carbon-framed, super-aerodynamic, Mike Burrows-inspired, crouched-riding-position Lotus bicycle that Chris Boardman rode to gold in the 4km pursuit event at the 1992 Barcelona Olympics. This project earned Roger the sobriquet 'Mr Lotus', no less.

During the GM years there was an incredible feeling of camaraderie within his department, and at Lotus Engineering in general under Peter Wright. In truth Roger changed the lives of almost all the people who worked for him. The longer-term effects are clear, with the likes of Steve Swift, George Howard Chappell, Murray White, Graham Sutherland, Gavan Kershaw, John Croxford, Craig Croot, Jeff Walsh, Clive Roberts, Matt Becker and many others from Lotus – plus all the Toyota engineers and managers – now in key positions working the Becker way. Several Kia and Hyundai engineers were personally coached by him, convincing me of his directly beneficial influence on their more recent products.

As the political pressures built up during Bugatti and especially Proton ownership, it was often difficult to get Roger into cars for assessment. But after several caretaker CEOs, and false starts on an Esprit replacement, somebody at Proton finally had the wit to get Mike Kimberley back in the hot seat. It was the old alliance of Kimberley and Becker that produced the Evora, which only got its Toyota powertrain thanks to Roger's links with the by now senior Toyota personnel we had trained all those years ago. Evora done, Kimberley and Becker found their positions untenable, so they left the company, which seemed to be in irreversible decline. Perhaps if he had given up work at this point he might still be with us, but with chassis development running through his veins, Roger carried on as a consultant for the Koreans until he finally retired, only to engage in a third, and this time unsuccessful, battle with cancer.

Of course the Becker name will not die. Having run out of chassis to tune at Lotus, Roger's son Matt carries the name forward at Aston Martin with his similarly impressive driving ability and chassis development experience. Roger will be sorely missed worldwide for his unique abilities, but most of all for his total commitment to and passion for Lotus.

Technical editor John Miles is a major industry figure, known initially for motor racing in the 1960s, including F3, F2 and GT racing at Team Lotus, and F1 racing in the 1970s. He has vast experience, having spent 18 years at Lotus Engineering, three years at Aston Martin, and 13 years at Multimatic Chassis Engineering.

> "He would go off to 'ask the car some questions', getting most of the answers on a trip around the Lotus ride route"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Heider

The key to successful prototype testing for dynamics is a well-engineered prototype vehicle, says John Heider

Driving a fully camouflaged prototype of a future vehicle can create many issues, from causing a rolling roadblock on the freeway as people slow down to gawp, to being chased by spy photographers, to your friends and neighbors thinking you're the next Batman. Despite the continuing transition from less physical hardware development to more detailed analytical simulations, prototype vehicles still provide irreplaceable value in the vehicle development cycle.

Depending on the level of change for a new vehicle program, major OEMs typically build one to three levels of prototypes prior to the start of mass production. The planning, specification and construction of a vehicle dynamics prototype dictates the effectiveness, efficiency and ultimate success of the development work. Having your picture snapped by wannabe spy photographers with cell phones may seem glamorous, but the reality of driving and developing early prototypes can be quite the opposite.

The most valuable component an early vehicle dynamics prototype can have is a reliable powertrain. This may seem counterintuitive, but dealing with powertrain problems that render the vehicle unreliable, difficult to drive or simply immovable is a large, ongoing headache on top of the already challenging development task. Many OEMs insist on building 'kitchen sink' prototypes with every new system on every vehicle – new body, new powertrain, new chassis components, new interior systems, etc – which no doubt looks very efficient on paper. When the infotainment system doesn't work, it is a minor annoyance; when the powertrain won't run, development stops while the responsible engineer is located and coerced to come and fix the vehicle. For early program development work, a prototype with a reasonable body structure, representative chassis components and a carryover powertrain is a very useful and reliable tool.

Representative chassis components are assumed to be included in all levels of vehicle dynamics prototypes, but early prototypes usually include some surrogate parts. Components machined from billet aluminum are often substituted for stamped, cast or forged pieces; composite or non-metallic components are often replaced by fabricated steel or aluminum parts, and electronic control systems are normally functional but immature at this time. Accurate kinematic geometry must be confirmed; surrogate or prototype elastomer components should have nominal rates close to design-intent rates as a starting point for development work.

Body structure tends to be an all-or-nothing proposition: early prototypes built from a current production vehicle will often have different global and local structural properties from the future vehicle; later prototypes with an accurate body-in-white tend to be very representative, save for the late changes that improve the structure or reduce overall cost.

Overall weight, weight distribution, center of gravity height and vehicle inertias are always a challenge on early-level prototypes built from current production vehicles. The challenge is actually twofold: predicting the mass and inertia properties of the future vehicle and determining how best to simulate it. In general, if the prototype is lighter than the future vehicle there is usually a small opportunity to improve the representativeness of the vehicle; if it is heavier there is minimal opportunity to achieve the desired combination of mass and inertia properties. Once the later prototypes arrive, the accuracy of the predictions immediately becomes clear.

The functionality of other vehicle systems separates the well thought-out, high-quality prototypes from lesser ones. Functional HVAC systems not only aid driver comfort and improve vehicle safety in colder climates, but also enable ride comfort and NVH evaluations to be conducted in a quieter interior environment with the windows rolled up. Ensuring adequate body sealing and paying attention to squeak and rattle performance yields dividends for both vehicle dynamics and NVH development work, allowing engineers to focus on the components being evaluated without distraction.

Camouflage is not well-liked as it tends to inhibit outward vision and reduce safety, but front and rear seatbelts, a fire extinguisher, properly mounted seats and functional windshield wipers are desirable. Unfortunately, non-functional airbags are standard in most prototype vehicles.

The development cycle of prototype vehicles is an iterative process with few shortcuts. More often than not, the better your initial prototype, the better the result for the final production vehicle.

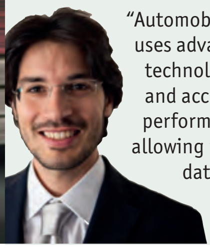
John Heider spent 21 years at Ford in all areas of vehicle dynamics and is now principal at Cayman Dynamics, providing vehicle dynamics expertise

"Being snapped by wannabe spy photographers may seem glamorous, but the reality of driving and developing early prototypes can be quite the opposite"

The imitation game

What will the future hold for simulation technology in the vehicle dynamics industry? We asked 10 experts from across the sector about the ways they would like to see dynamics development technology progress

Machine learning for Lamborghini



"Automobili Lamborghini uses advanced simulation technologies for quick and accurate vehicle performance tuning, allowing provisional data and accurate information to be provided against tight timescales," says Giuseppe Di Rosa, vehicle dynamics engineer at Lamborghini.

"For the future, higher fidelity for perception reproduction will probably lead to different methods of motion simulation. This will be linked to new visualization devices: augmented and virtual reality will become more than an option.

"Currently, data logged during sessions is analyzed live, but in the future this will likely be fully addressed by machine learning methods, to produce additional parameterization 'on-the-go'.

"Future mobility (ADAS, fully automated driving, etc) is a game-changer in the simulation world too, and a major part in developing simulations could be played by universities, even if their development projects aren't strictly related to vehicle dynamics."

Aerodynamic aims

"Riding in a car, you can feel the vehicle move due to the bumps in the road, the wind, acceleration and braking. When this happens, the suspension moves, changing the shape that is pushed through the air. These deformations change the drag, usually for the worse, and in a very non-linear way. Even when the vehicle is cruising, the airflow over the vehicle causes the posture to change due to the aerodynamic forces lifting or pushing the vehicle down," explains Ed Tate, senior director at Exa.

"These seemingly tiny changes can have a huge impact on drag and fuel economy. The ability to predict this effect early in design process, when no physical prototypes are available, is critical for enabling improvement of real-world fuel economy and easing the certification process. This will be possible in the short term digitally by combining detailed flow simulations with system models for vehicle dynamics."

RIGHT: The development department at Mercedes-Benz uses powerful simulation and computation programs, with real-time capacity being introduced

Next-generation ride and handling simulation for Mercedes-Benz

"From a historical point of view, two different tools have been used at Mercedes-Benz for ride and for handling simulations," states Prof. Dr Ludger Dragon, senior manager for ride comfort at Mercedes-Benz. "In order to gain more efficiency in the parameterization, validation and simulation process, a 'one tool strategy' has been developed, based on the mbs-tool virtual.lab.motion from Siemens running on a Linux operating system. If real-time capability is needed, a quad core Intel 6.Gen E7 will be used."

This new approach will integrate the advantages from the two historical tools, namely validated simulations up to 30Hz and real-time capability for hardware-in-the-loop applications, handling simulators and ride simulators, and simulations with flexible bodies.

"So it is mandatory to use a fast multibody simulation tool with a stable, fixed step-size solver including flexible bodies," adds Dragon. "Once established, these ride and handling prototypes can also be used for additional application fields such as the digital development of assistance systems."

One man's wish for software and hardware tools

"We have come a long way in the past two decades in our ability to simulate and test the vehicle dynamics performance of road vehicles before the rubber meets the road at the test track. Many of the software tools that we have at our disposal allow us to include detailed suspension, chassis, tire and other performance-critical elements such as bushings," says Mehdi Ahmadian, director of the Center for Vehicle Systems and Safety at Virginia Tech.

"Determining the parameters for the components included in the model, however, is an entirely different challenge that is often difficult to meet unless one has access to elaborate test equipment such as a kinematics and compliance (K&C) rig. Often the lack of reliable and accurate parameters leaves the modeler frustrated and having to make broad guesses, or entirely ignore some of the details that can be included in the model. Worse still, one may be forced to resort to canned vehicle models that are often included in dynamic simulation packages, without having a good appreciation for what is included in the vehicle model. In such a situation, the modeler is forced to model the vehicle without knowing what is under the hood, so to speak.

"The greatest area that we need to make progress in is bridging the gap between vehicle dynamics modeling and testing. This includes both laboratory setups in the form of hardware-in-the-loop and human-in-the-loop systems. It also includes the ability to bring the track testing data to the model to use machine learning and data analytics approaches to make the model match the track data. Getting the models to match the testing reality remains an elusive task for most."

Nic Fasci will be discussing 'A skeptic's view of validation processes' at the Autonomous Vehicle Test & Development Symposium 2017, taking place on June 20-22

Who programs the programmer, asks Tata

Nic Fasci, lead engineer for homologation at Tata Motors European Technical Centre, warns that programmers should not be blindly trusted when developing vehicles.

"Although the world is focused and committed to the deployment of automated vehicles, are the 'clever people' with the 1s and 0s the right people to be developing and evolving the algorithms for the vehicles? How can we be sure that the standard of driver training is adequate so that no gremlins or bad habits are installed from the outset during the test and development phase? Although the end goal is Level 5, humans are still key to the success of automated vehicles and if we get this wrong, the whole concept could be set back years."

Tire model simulation has potential

MTS's director of motorsport technology, Mark Gillan, highlights the usefulness of simulators in developing tire models: "Certainly in motorsport ,with a high-fidelity DIL simulator, your ability to develop the tire model is significantly enhanced. Most F1 teams have very detailed thermal models that can predict, for example, thermal degradation and various other transient performance parameters, and that's come from tight integration with the track and simulator.

"From an OEM perspective thermal modeling may be overkill, but tire models are still the weak point of any vehicle model," he says. "There's still a way to go to develop optimal OEM tire models and I think that's where a DIL simulator can help in giving feedback to the OEM, or the tire maker, to help accelerate the tuning and optimization of their tire models."

BMW seeks new approaches for HAD testing

Future advanced driver assistance and highly automated driving (HAD) systems are aiming to support various driving tasks.

"To guarantee fault-free operation of the HAD function under various traffic scenarios and conditions, new approaches for evaluating the system robustness and effectiveness are required," states Reiner Friedrich, vice president of ADAS development at BMW.

"Current approaches are supporting field tests with software- or hardware-in-the-loop tests. For a complete evaluation, these test instances need to be improved and cross-validated to guarantee a safety assessment of the function in the scenario space, including critical corner cases."

Reiner Friedrich will be discussing 'Challenges for verification and validation of highly automated driving' at the Autonomous Vehicle Test & Development Symposium 2017, taking place on June 20-22

PSA aims to expand CAE work

CAE currently accounts for around 60% of vehicle development work at PSA. The auto maker is working to change that, with ambitious aims to develop all of its vehicles entirely using CAE by 2025, starting by unifying its software models. PSA's answer is to use a single computer model for each aspect of CAE. The company is also looking to share more of its CAE information with suppliers of both software and components, as well as university laboratories.

In 2016, PSA met with 140 experts from different fields and identified 50 roadblocks, or scientific challenges, to achieving its digital transformation goal of developing vehicles entirely using CAE by 2025. The meeting also identified 22 'quick wins', which the OEM is currently applying to its CAE processes.

PSA has stressed its openness to working with any company with useful knowledge, even rival car makers, in its goal to increase simulation and improve profitability.

Laurent Declerck, PSA's senior vice president for vehicle architecture and performance, states, "We are really open to other companies, to laboratories, to suppliers, because we think we cannot make such a huge step with a standalone approach – so join us."

Volvo predicts detailed tuning

"The technologies of today, especially in real-time driver-in-the-loop simulation, already allow for in-depth development and decision making in concept phases," says Carl Sandberg, concept engineer at Volvo Car Group. "However, improvements to computing power and model efficiency would also enable detailed tuning work in later phases using real-time CFD models for advanced dampers, rubber bushings and flexible bodies."

"Furthermore, ADAS and vehicle dynamics are becoming increasingly interdependent. As the human driver and passenger will always be our focus, this means that future CAE needs to be able to handle high-fidelity vehicle dynamics with full ADAS functionality in a real-time DIL environment."

A wider frame for testing

The recent and ongoing proliferation of vehicle test protocols is an area where vehicle dynamics DIL can help. "Future steps will surely see vehicles no longer assessed in isolation, but in relation to their interaction with the environment – other vehicles, pedestrians, unexpected interactions or autonomous scenarios wherein vehicles communicate with each other and the surrounding infrastructure," says Phil Morse, technical liaison at Ansible Motion.

"Such complex test scenarios will be more easily and cost-effectively assessed in DIL simulator labs than they could ever be in real [prototype] driving tests, particularly in the early stages of a development program. In key safety areas, such DIL labs will benefit from being 'vehicle dynamics and engineering ready', rather than elying on legacy human factors-centric simulator technologies."

Balancing act

Scott Lindstrom, Ford's driver assist technologies and tire development manager, discusses the impact of electronic systems on dynamics development

WORDS BY **GRAHAM HEEPS**

Ford has been the standard bearer for mainstream dynamics excellence for a generation. Nowadays however, buyers care more about connectivity options for their personal electronics than their bottom's connection with the road. Looming large on the horizon are driverless systems, and Ford itself has committed to producing an autonomous ride-share EV by 2021. Do dynamics still matter? Does anyone still care whether a car feels great in the first 50m, as per Jackie Stewart's and Richard Parry-Jones's famous test?

"We very much still care about that stuff," assures Scott Lindstrom, Ford's Dearborn-based driver assist, active safety and tire development manager. "Developing vehicles that are fun and exciting to drive is something we're going to continue to do. We have a lot of people here who are passionate about vehicle dynamics, who want a car to feel good and be responsive. That joy of driving on a country road is still very important, even with all this technology on board."

As a manager of driver assist technologies, Lindstrom is well placed to assess the impact of new technology on vehicle dynamics.

"Developing vehicles that are fun and exciting to drive is something we're going to continue to do. We have a lot of people here who are passionate about vehicle dynamics"

"In some respects it's easier now with the technology; in others it's harder," he assesses. "In many ways it's the same work we've always done. When I first started, shocks and tires were all you had; when you'd turned those knobs as much as you could, you were done. Now you can do all sorts of things with EPS, electronic shocks and AWD systems, trying to optimize the algorithms, make them work together, make them smarter. There is more opportunity to screw it up if you're not good at it, but a lot more opportunity to optimize it [if you get it right]."

How has the dynamicist's skill set changed?
"You still have to have a good feel for a car, and being able to evaluate a car is still very important to the way we develop vehicles," Lindstrom continues. "The skill that's different is that you have to be comfortable with algorithms and understand how to calibrate software. You're not taking a shock off and replacing metal parts as much; it's more about hooking up your laptop, looking at the algorithm, trying to figure out what it did, and then tweaking it, or deciding whether you need a new algorithm because the current one isn't sophisticated enough for what you're trying to do.

"You have to be comfortable with algorithms and understand how to calibrate software. You're not taking a shock off and replacing metal parts"

"That last 10% still seems to need the old-fashioned way of evaluating"

ABOVE: An adaptive steering system was introduced on the 2015 S-Max and 2016 Edge. It continually changes the steering ratio with vehicle speed, optimizing the response in all conditions

RIGHT: Ford's latest Fusion Hybrid autonomous development vehicle has increased processing power with new computer hardware. Electric controls are closer to production-ready, and adjustments to the sensor technology, including placement, allow the car to better see what's around it. New lidar sensors have a sleeker design and more targeted field of vision, and enable the car to use just two sensors rather than four, while getting just as much data

BELOW: Ford Pre-Collision Assist with Pedestrian Detection Technology debuted on the 2015 Mondeo in Europe. The system provides a collision warning to the driver and, if the driver doesn't respond in time, can automatically apply the vehicle brakes

"The core skills of being a good evaluator, of knowing what you want to achieve, trying different things out and iterating your way to success, hasn't changed all that much. We'd struggle to find a young engineer who can do a hydraulic steering boost curve, because we don't do that anymore, but we still have a lot of cars with conventional shocks, and we still change a lot of springs and bushings."

Developments in analytical tools mean that Ford engineers are closer than ever to the goal, even before physical tuning begins. That doesn't necessarily mean the number of physical iterations is reduced, however.

"You always want to make it better and we get really close with a lot of the tools, but there's more fine tuning than in the old days and that last 10% still seems to need the old-fashioned way of evaluating," Lindstrom says.

Objective not subjective
So where does this approach fit in with the development of ADAS, where an objective decision based on sensor data replaces the subjective evaluation of a human?

"I came up doing vehicle dynamics and love that stuff," says Lindstrom. "I've been building up my driver assist portfolio, growing the team over the past five years

LEFT: Evasive Steering Assist uses radar and a camera to detect slower moving and stationary vehicles ahead, and provides steering support to enable drivers to avoid a vehicle if a collision is imminent

Testing electronics

Alongside the simulation programs, traditional tracks and VDAs are as important as ever, with the additions of HIL or SIL to test electronic systems. As Lindstrom observes, "A shock dyno by itself doesn't tell you as much as it used to."

In the future, DIL simulation could become part of the evaluation mix for cars more mainstream than the GT. Ford Performance already has an Ansible Motion driving simulator at its technical center in Concord, North Carolina. "One of the reasons we're in racing is that we want to develop technology and transfer people back and forth," he says. "It's definitely something we're looking at."

RIGHT: Driver-in-the-loop simulator at the Ford Performance Technical Center in Concord, North Carolina. The simulator was a crucial building block in the Ford GT drivers' preparations for the 2016 Le Mans 24 Hours win

"There's still the question of how easy it is for the computer controller to steer the car. It still needs a reasonably responsive chassis as the algorithm will work better if the chassis is more precise"

LEFT: Engineers for the Shelby GT350 found that having springs spin in different directions on each side of the car provided more rear-end stability. A counter-spun spring necessitated a new lower control arm design

because of the new technologies and vehicle applications, and it's been interesting.

"It's a delicate balance as we don't want to take away the pleasure for a customer who wants to go for a country drive on a Sunday afternoon, but there are opportunities. If I'm on my regular commute, in traffic, then steering feel may not be that important at that moment. I just want to get there. I turn on adaptive cruise control and let the car do some of the work, and it's good. We want to provide a car that, when you want to drive it, is fun and exhilarating, but when you want it to help you, it does."

There are plenty of intersections between the two worlds, with Lindstrom citing steering as one. Ford is hugely proud of the feel of its EPS systems, having committed wholesale to the technology earlier than many rivals. He says that by ensuring that the dynamicists are close to the ADAS specialists, there's no reason why Ford's high standards can't be maintained.

"You want to make sure that when you're steering on-center under normal conditions it's fine, but that the corrective steering works well for lane-keeping assist if you need it. If your steering-feel engineer and lane-keeping engineer aren't the same person, you at least want them in the same building, not continents apart, because of the interaction between the systems. We also need to share prototypes, and you're better off sharing with the steering engineer than a radio engineer!"

ADAS development at Ford is handled in a similar way to vehicle dynamics development. "My engineers are out there calibrating ADAS, tuning it, making sure it satisfies the customer and meets its requirements," Lindstrom says – but there are some unique challenges when it comes to testing the systems.

"One of the hardest things to test on a proving ground is the infrastructure and all the different road signs," he explains. "You have to go out and collect data. When we worked on Pre-Collision Assist [an autonomous braking system] for the Fusion [and which will appear on the 2018 F-150], we ended up doing 150,000 miles in Europe, China and North America, collecting camera and radar data to try to understand what the infrastructure was doing to us. We ended up with 240TB of data! It's a huge treasure trove that we can analyze and use to try different calibrations of the algorithm, but it's tied to those sensors. If we change to different sensors, then we'll have to go out and get it all over again..."

Taking the technology one step further, even the advent of driverless systems won't spell the death of good dynamics, in Lindstrom's view. "I think ride quality and good isolation will be of major importance, though on-center feel maybe not as much. But there's still the question of how easy it is for the computer controller to steer the car. It still needs a reasonably responsive chassis as the algorithm will work better if the chassis is more precise. There will still be suspension, tires and bushings, still a lot of work. I don't think dynamics is going away. We'll still be busy."

Over 300 delegates attended the event in 2016!

Budii © Rinspeed

Topics under discussion:

- Public road testing
- Virtual testing
- Simulation
- Traffic scenario testing
- Embedded software testing
- Safety and crash testing
- Fail-safe testing
- Cyberthreat testing
- Validation and verification
- Autonomy software
- VeHIL
- V2V and V2X testing
- Robotics
- Testing legislation
- Safety standards and legislation
- Case studies
- Possibilities
- Best practices
- Reliability testing of software and hardware systems

For more information about the Autonomous Vehicle Test & Development Symposium 2017,
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Vehicle Dynamics International Awards 2017

With an inspiring shortlist and a world-renowned international jury, 2017 is another great year for the Vehicle Dynamics International Awards. These are the vehicle dynamics innovations, professionals and technologies that have won this year's honors...

Nicol Louw, technical editor, *Car*, South Africa: "The new 5 Series achieves the perfect balance between comfort, refinement and sportiness for the segment. This is arguably a greater achievement than the outright dynamic ability of a sportscar"

Car of the Year:

BMW 5 Series

Dynamics have been a key focus for the 2017 model 5 Series, for which the dynamics team has designed a new chassis, lowered the center of gravity, increased torsional stiffness, and reduced body weight through the increased use of aluminum, magnesium and high-strength steels – indeed the new model is 100kg lighter than its predecessor.

Separating the construction of the double-wishbone front suspension into an upper and a lower control arm level gave the engineers freedom to fine-tune the balance between dynamics and comfort. As the spring struts are not required to perform wheel position functions, they only have to handle minimal transverse forces.

The new five-link rear suspension features specially calibrated elastokinematics, with the large axle subframe mounting and supporting system, the compression strut connecting the suspension and body, and the high structural stiffness, all combining to create an excellent balance between agility and comfort. The 2017 model also marks the first time that BMW's xDrive intelligent all-wheel-drive system can be combined with Integral Active Steering.

Highly commended:

Alfa Romeo Giulia

Runners up:

Honda Civic
Land Rover Discovery
Aston Martin DB11

Vehicle Dynamicist of the Year:

Leonardo Pascali, McLaren Automotive

Leonardo Pascali came close to victory in last year's awards, but some sterling work over the past 12 months has seen him win much-deserved recognition for 2017. His success is impressive since he is still a relatively new face at McLaren, having only joined in early 2015 as head of chassis and vehicle technology, but his strong background in dynamics, with previous experience as chassis dynamics manager at Porsche and head of vehicle dynamics at Centro Ricerche Fiat, has given him the talent to do some great work.

Pascali is helping to bring the brand into new customer territory through vehicles such as the 'baby' 570S and 540C models, with other current and recent projects underway including the 570GT, 675LT Spider, 720S, and the forthcoming BP23 – a highly anticipated three-seat successor to the iconic F1.

Pascali helped develop the carbon-fiber MonoCell II chassis, which weighs just 75kg and provides immense rigidity and stiffness that translates into outstanding dynamics. The next stage is the MonoCage II carbon-fiber body structure for the second-generation McLaren Super Series, which will help the new Super Series achieve a lightest dry weight of just 1,283kg – 18kg lighter than the already featherweight McLaren 650S – with the claim it will offer "the widest breadth of dynamic ability of any McLaren".

Pascali's recent work also includes Proactive Chassis Control II (an advanced new generation of the company's multi-mode chassis control system), which uses 12 more sensors than on previous Super Series models – including an accelerometer on each wheel hub – to 'read' inputs from the road and measure the tire contact patches. The information is then analyzed in milliseconds by the Optimal Controller algorithm at the core of the system, and the suspension damping is immediately optimized accordingly.

Another new project under Pascali's watch is McLaren Variable Drift Control, which provides greater involvement for drivers who want to fully explore the dynamic ability of the car, enabling the level of electronic stability control intensity to be varied with a swipe of the central infotainment screen.

Amazing work from an amazing dynamicist!

Highly commended:

Roberto Fedeli, CTO, Alfa Romeo

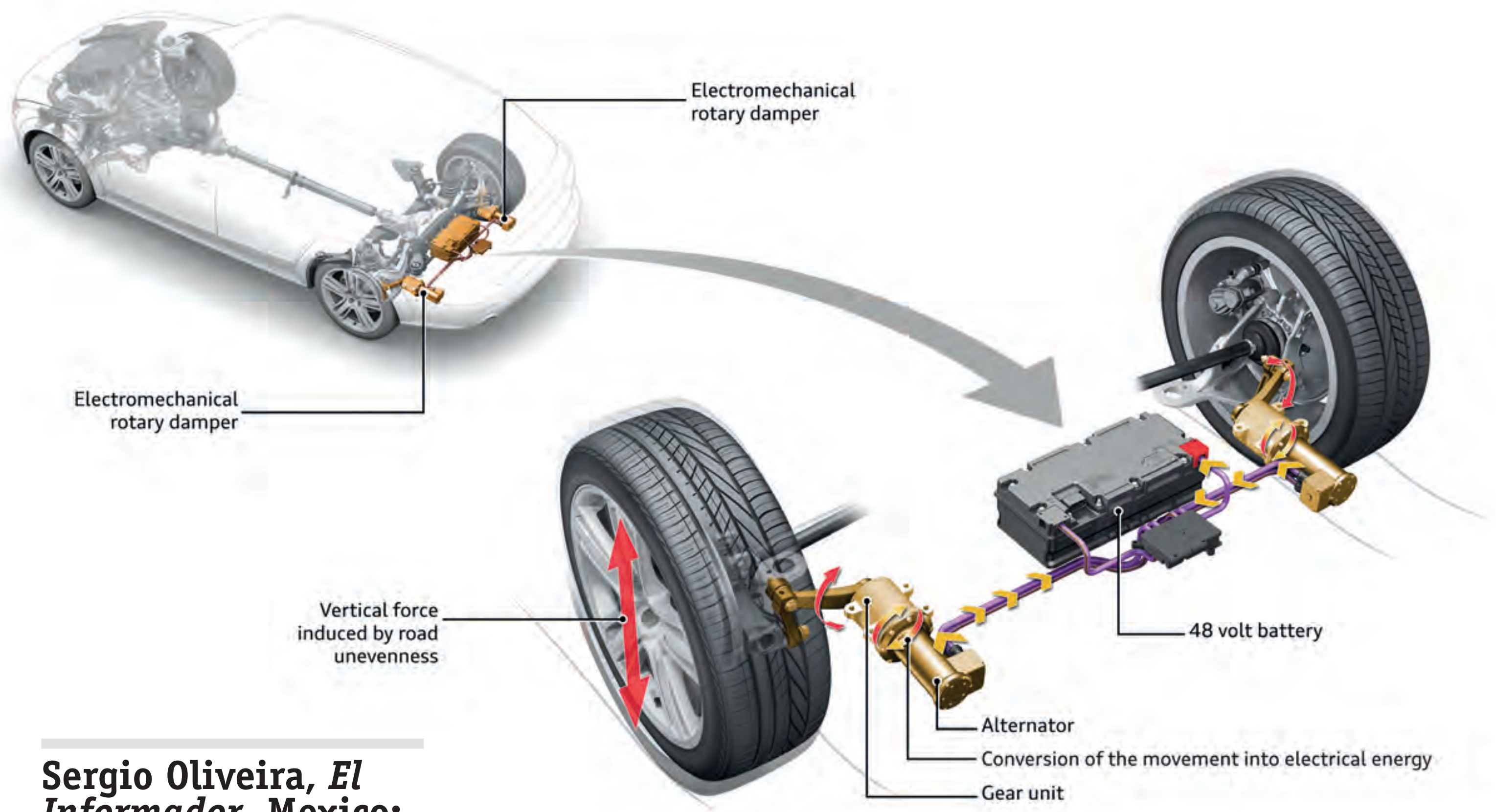
Runners up:

Victor Underberg, director of vehicle dynamics, Audi

Mitsuru Kariya, chief engineer, Honda

Matt Becker, chief engineer – vehicle attribute engineering, Aston Martin Lagonda

Hormazd Sorabjee, *Autocar India*: "Leonardo Pascali's depth of experience and nuanced understanding of chassis engineering allows him to deliver a finely judged balance of ride and handling"



Sergio Oliveira, *El Informador*, Mexico: "Audi eROT paves the way for the next logical phase of electrification (mild hybrids), enabling the development of innovative solutions for energy recovery systems"

Highly commended:

NSK wheel hub motor

Runners up:

- Eaton IntelliTrac
- BWI adaptive powertrain mount
- ContiTech spring strut mount
- Tata XPF800
- Nexteer Quiet Wheel Steering

Innovation of the Year:

Audi eROT

According to Audi, energy recuperation will play an increasingly important role in future mobility, including vehicle suspension systems. With this in mind, the company's engineers are developing eROT, a prototype system in which electromechanical rotary dampers replace the hydraulic dampers used today for a more comfortable ride.

The basic principle behind eROT is that every pothole, every bump, every curve of the road induces kinetic energy in the car. Today's dampers absorb this energy, which is lost in the form of heat. With the new electromechanical damper system in the 48V electrical system, this energy can be put to good use and presents new possibilities in terms of adjusting the suspension.

The eROT system is intended to respond quickly and with minimal inertia. As an actively controlled suspension, it adapts to irregularities in the road surface and the driver's driving style, with a damper characteristic that is virtually freely definable via the software systems.

According to Audi, the damper design would eliminate the mutual dependence of the rebound and compression strokes that limit conventional hydraulic dampers. With eROT, Audi configures the compression stroke to be comfortably soft without any compromise to the taut damping quality of the rebound stroke.

Another advantage of the system is its geometry, with the horizontally arranged electric motors in the rear axle area replacing the upright telescopic shock absorbers, which allows for additional space in the luggage compartment.

To convert the kinetic energy generated during compression and rebound into electricity, a lever arm absorbs the motion of the wheel carrier and transmits this force via a series of gears to an electric motor, which converts it into electricity.

The recuperation output is claimed to be 100-150W on average, measured during testing on German roads – from 3W on a freshly paved freeway to 613W on a rough secondary road. Under customer driving conditions, this would correspond to a CO_2 saving of up to 3g/km (4.8g/mile).

According to Audi, initial test results for the eROT technology have been promising, and its use in future Audi production models is certainly a plausible expectation. A prerequisite for this is the 48V electrical system, which is a central component of Audi's electrification strategy.

In the next version planned for release later this year, the 48V system will serve as the primary electrical system in a new Audi model and feed a high-performance mild hybrid drive, offering potential fuel consumption figures as low as 0.7 liters per 100km (336mpg).

Dynamics Team of the Year:

Audi

While Audi's dynamics team has been busy developing the award-winning eROT system (see left), they have also found time to develop new models – several new models, in fact.

The all-new Q7 SUV features a compact five-link suspension layout that allows for optimized steering rack placement, with handling and comfort enhancements generated through the reduced unsprung weight of lightweight aluminum control arm components and revised elastokinematic attributes. The sportier 429bhp SQ7 version adds in active anti-roll bars to stiffen the car for greater stability.

On a smaller scale, the Q2 features Progressive steering as standard in all versions, which varies the steering gear ratio as a function of the steering input. Installed at the rear on the front-wheel-drive versions is a semi-independent suspension, while the Quattro models have a four-link suspension.

The new A3 has a revised chassis with a McPherson construction with wishbones at the front axle, and a multi-link rear suspension, while the new A5 coupe has an entirely newly developed chassis, a new electromechanical power steering system, and the option of a dynamic steering system.

Other recent projects include new models and revisions, such as the S1 (complete with torque vectoring, a thoroughly revised chassis and specially developed electromechanical power steering), and performance variants such as the S4, S5, SQ5, RS3, RS5 and RS7, with work on the Q8 SUV coupe underway.

Highly commended:

BMW

Runners up:

Mazda

Honda

GM

Christophe Congrega, *L'Automobile Magazine*, France: "Audi really made a lot of good products over this last year, with very well calibrated steering systems and adaptive suspensions. Good handling means good products..."

Gábor Szécsényi, *Az Autó* and *Retro Mobil*, Hungary: "A brave and important step toward the future of cooperative 'open platform' car development"

Development Tool of the Year:

Cruden Panthera Free

Cruden has made an unprecedented move to make its Panthera Free professional driving simulator software available to the market for free, as a download. This unusual decision was made in order to allow automotive engineers to experiment freely, either professionally or personally, with driver-in-the-loop simulator software, without workplace and university license restrictions – and also for Cruden to launch itself as a provider of standalone, open architecture simulator software.

The product has seen many new users introduced to professional-level DIL simulation, who can now drive, modify and expand their vehicle models, run simulations, add interfaces to hardware, and use custom cars and tracks.

This approach by Cruden shows a real passion for the vehicle dynamics community, which we are pleased to reward.

Highly commended:

Altair HyperWorks

Runners up:

Genesys ADMA-Speed
MSC Software: Adams Real Time
rFpro DIL motorcycle simulation

List of jurors

- Choi Joo-sik, editor-in-chief, *Autocar Korea*, *iautocar*
- Nicol Louw, technical editor, *Car South Africa*
- Frank Markus, technical director, *Motor Trend*, USA
- Robert Bielecki, *Oponeo, Samar*, Poland
- Christophe Congrega, new technology editor, *L'Automobile Magazine*, France
- Carl Cunanan, editor-in-chief, *C!*, Philippines
- Padraic Deane, managing editor, Automotive Publications, Ireland
- Tarcisio Dias de Araujo, content manager, *Mecânica Online*, Brazil
- Jim Kenzie, *Toronto Star*, Canada
- Nikos Kounitis, *4Wheels*, *Auto Bild Hellas*, Greece
- Jürgen Zöllter – freelance, Germany
- Marco Marelli, freelance, Italy
- Roberto Nasser, *O Globo*, Brazil
- Marc Noordeloos, freelance, USA
- Tomaz Porekar, *Avto Magazin*, Slovenia
- Hormazd Sorabjee, editor, *Autocar India*
- Gábor Szécsényi, editor-in-chief, *Az Autó* and *Retro Mobil*, Hungary
- Mohamad Sheta, *Al-Masry Al-Youm*, *Auto Arabia*, *Middle East Auto News*
- Sergio Oliveira de Melo, *El Informador*, *La Cochera TV*, *Autoestereo Radio*, Mexico
- Brian Cowan, freelance, New Zealand
- Graham Johnson, managing director, UKI Media & Events, UK
- Oleg Vasilevsky, *Auto Bild*, Ukraine
- Alvaro Sauras Alonso, technical editor, *Evo Espana*, *Autofacil* and *CAR&Tecno*, Spain

How the judging process for the Vehicle Dynamics International Awards works

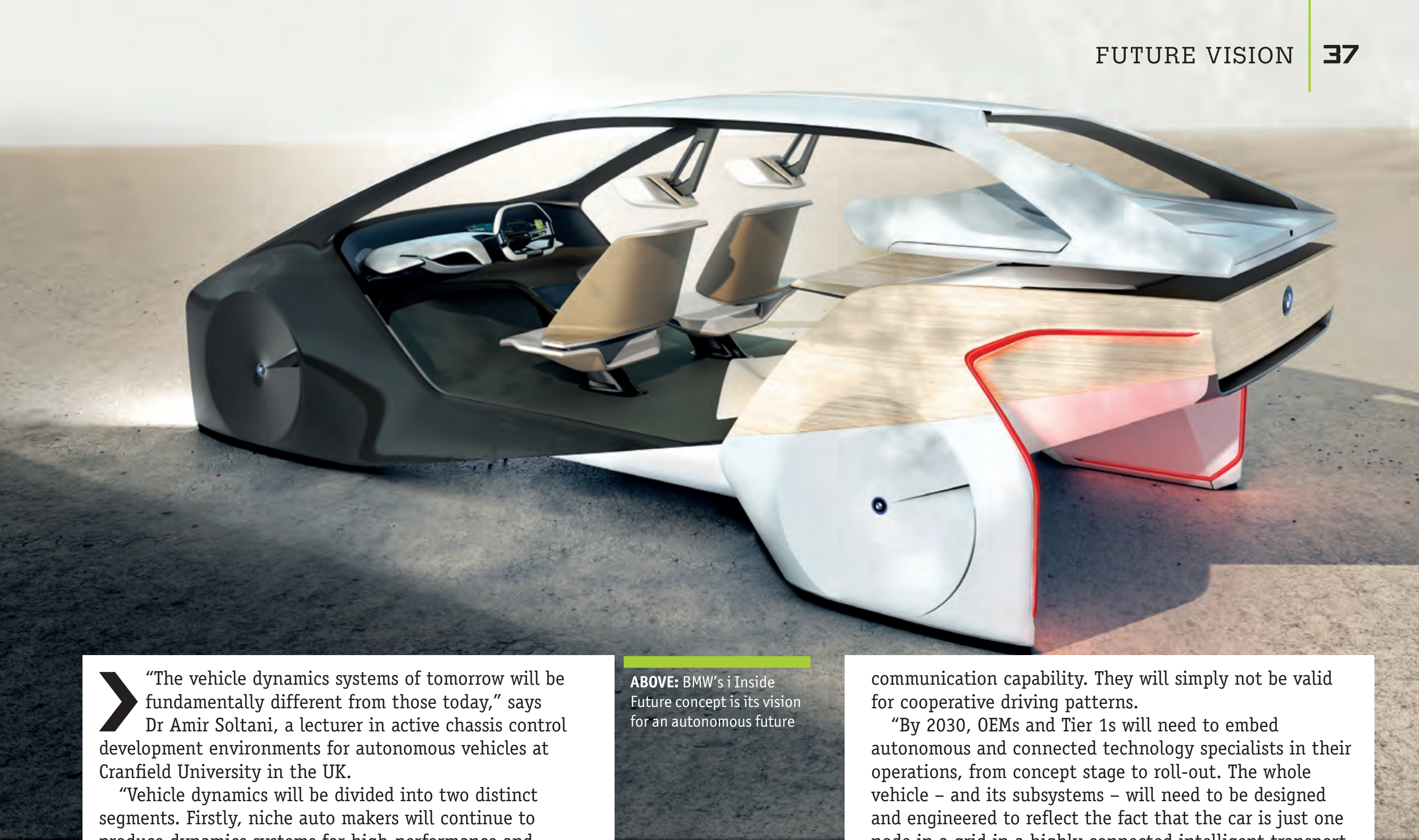
Nominations are received from *VDI*'s expert readership of chassis and dynamics professionals, and from the editorial team. From that list of entries, between four and six finalists are shortlisted for each category, and this shortlist is evaluated by our international, independent judging panel of automotive journalists, to decide the winners.

The future of dynamics

From autonomous vehicles to flying cars, from regulations to turbulence, the future holds some major changes for the vehicle dynamics sector. Let's look at the challenges and opportunities for dynamicists in 2030...

WORDS BY **JAMES GORDON**

"There will be a seismic shift over the next few years in terms of the engineering of active safety systems"



"The vehicle dynamics systems of tomorrow will be fundamentally different from those today," says Dr Amir Soltani, a lecturer in active chassis control development environments for autonomous vehicles at Cranfield University in the UK.

"Vehicle dynamics will be divided into two distinct segments. Firstly, niche auto makers will continue to produce dynamics systems for high-performance and highly personalized cars, which will have the capability to be self-learned and self-customized based on each driver's preference to maximize driving pleasure," says Soltani, who works in the university's Advanced Vehicle Engineering Centre. "Also, a second section of engineering design will emerge, which will fit around the need for efficient, eco-friendly, shared patterns of transportation."

So how exactly will the first category of dynamics manifest itself in the car segment?

"The main actuators for steering, braking, suspension and traction will be intelligent, by-wire mechatronics systems with machine learning capabilities that will largely replace the systems of today," predicts Soltani.

"For example, most cars will benefit from steering torque enhancements in their electric power steering system. Currently, EPS control systems and their boost curves are pre-tuned at the factory, and there is no way of understanding how much steer assist to provide to a driver based on their individual preferences. Machine learning technology, however, will equip the EPS with the ability to learn the highly nuanced behaviors and preferences of the person driving the vehicle, which will transform the driving experience and feel."

And with SAE Level 4 and 5 self-driving vehicles set to be rolled-out on the world's roads in the next two decades, how will vehicle dynamics systems adapt to this trailblazing autonomous technology?

Soltani says, "I believe that there will be a seismic shift over the next few years in terms of the engineering of active safety systems. The vast majority of active safety systems today, such as brake assist, electronic speed control and traction control systems, or even ADAS, are oriented around the vehicle itself and do not have the V2V [vehicle to vehicle] and V2I [vehicle to infrastructure] real-time communication capability. They will simply not be valid for cooperative driving patterns.

ABOVE: BMW's i Inside Future concept is its vision for an autonomous future

Amir Soltani will be discussing 'A paradigm shift toward the zero accident vision' at the Future of Transportation World Conference

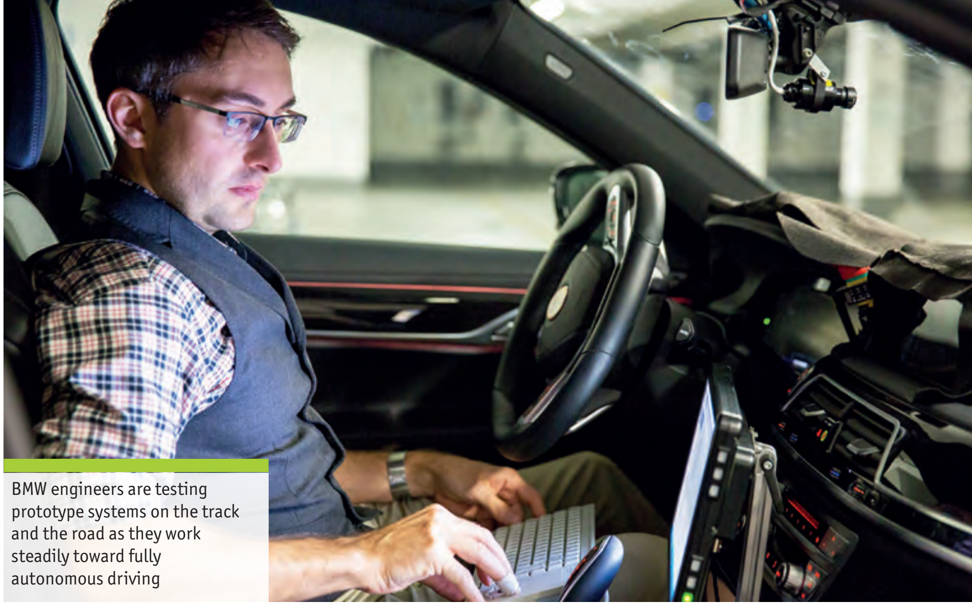
"By 2030, OEMs and Tier 1s will need to embed autonomous and connected technology specialists in their operations, from concept stage to roll-out. The whole vehicle – and its subsystems – will need to be designed and engineered to reflect the fact that the car is just one node in a grid in a highly connected intelligent transport system. We need smart real-time sensors, which will be able to communicate with cars and the wider – intelligent – environment at a very high bandwidth and speed, to be developed and deployed in vehicle dynamics systems. Artificial intelligence [AI] will also be heavily integrated into vehicle dynamics so that the car can learn and adapt to the many different conditions, driving behaviors, traffic patterns and weather that it will encounter."

With Mercedes-Benz, Audi, Bosch and ZF currently working closely with technology specialist NVIDIA to develop AI technology, and the University of California Riverside experimenting with AI as a way of eliminating range anxiety, the starter pistol has already been fired. But why are these next-generation dynamics systems so needed in the transportation landscapes of tomorrow?

Says Soltani, "Because AI systems will monitor the way we drive, and communicate with other cars, and have instant access to the driving conditions and the environment around the car, they can make real-time adjustments to the active safety systems. They will be able to adjust the traction, suspension, steering and braking, which will help conserve battery life and make vehicles much safer and more eco-friendly.

"Secondly, if we anticipate that connected and autonomous fleets will increase exponentially by 2030, then real-time sensors will not only enhance safety and performance but will transform car servicing. For example, sensors will notify the driver – and fleet operator, if applicable – about the remaining life of the systems and when components need to be replaced. This will make repairs quicker, easier and less expensive. Finally, in our increasingly connected and data-driven world, actuators with real-time detectors can update their software at a fleet or global level in a split second."

"The main actuators for steering, braking, suspension and traction will be intelligent, by-wire mechatronics systems with machine learning capabilities"



BMW engineers are testing prototype systems on the track and the road as they work steadily toward fully autonomous driving

Dr Wolfgang Bernhart will be discussing 'Understanding the automotive disruption ahead' at the Future of Transportation World Conference

THE LEGAL LANDSCAPE

With SAE Level 3 self-driving cars set to roll off global assembly lines in the next five years or so, to what extent is the legal landscape keeping pace?

Dr Wolfgang Bernhart, a senior partner at the Roland Berger consultancy's automotive competence center in Stuttgart, believes there needs to be "more clarity around the regulatory frameworks governing the use of self-driving vehicles", which he says "affect vehicle dynamics".

Says Bernhart, "The German government is clear on SAE Levels 1 and 2, but national, EU and global regulations do not appear to adequately cover SAE level 3, where the car is largely autonomous, but a driver must be present and ready to take over in extreme circumstances."

Explains Bernhart, "If, for example, the driver and car encounter an unforeseen and unavoidable object, the driver may not be able to assume control of the car until the collision has occurred. Therefore, the decision as to when the active safety systems should be deployed is being made by the powerful algorithms and neural networks in the car – not the motorist. But if the automated system decides to relinquish control of the vehicle some time before the crash, to what extent will the driver be given adequate time to avert disaster by using the brake assist and traction control systems? And, in law who is responsible for the vehicle dynamics systems in this scenario? This is a gray area that urgently needs to be addressed."

Daron Gifford will be discussing 'Disruptive change facing the mobility supplier' at the Future of Transportation World Conference

ABOVE: Volvo and Uber have joined forces to develop next-generation autonomous cars. The base vehicle for research is being developed on Volvo's modular Scalable Product Architecture

LEFT: Tesla's forthcoming entry-level Model 3 will introduce autonomous driving features to a wider spectrum of car buyers

THE HUMAN ELEMENT

Daron Gifford, a leading US automotive industry strategy consultant, agrees that the time it takes for these autonomous vehicles to transition back to a manual setting "is wrestling with confusion and uncertainty".

"The difficulty for a camera sensor to recognize a white truck trailer against a bright sky in Tesla's Model S Autopilot system apparently led to a fatality last May, demonstrating the depth of challenge faced by auto makers. For example, there are no legal standards around the transition time for the Tesla Autopilot technology, which is currently claimed to be at SAE Level 3 autonomous capability. In the case of the Model S accident, US safety regulators determined that the driver should have had at least seven seconds to notice the truck trailer before the collision, but did not react. Insurance companies remain puzzled and behind the curve on the potential underwriting risks, while Ford was so concerned by the lack of legal guidance that it has decided to bypass SAE Level 3 altogether, and instead is focusing on introducing a Level 4 vehicle by 2021, where the legal requirements governing self-driving vehicles would be far less ambiguous."

Gifford, who is a partner at Michigan-based automotive consultancy Plante Moran, believes that dedicated driving lanes on the road, similar to today's high-occupancy lanes, would separate self-driving cars from ordinary vehicles and offer a transitional solution for today's mixed environment.

"In the case of SAE Level 3 and 4 vehicles, connected cars operating in connected geo-fenced areas or designated lanes would give drivers precious seconds to operate active safety systems, which could help prevent accidents in the future."

But both Gifford and Bernhart believe that the role of vehicle dynamics systems controlled by human drivers will be greatly diminished by 2030, as more drivers turn to Level 4 and 5 automation.

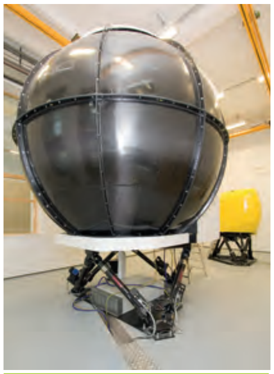
Says Bernhart, "SAE Level 4 vehicles may still require a steering wheel, but SAE Level 5 cars definitely won't need one. Already for Level 4 vehicles the challenges for OEMs will really be centered on ensuring powerful decision and control algorithms, which are based on the fusion of sensor, object and map data, to deliver close to 100% accuracy in terms of hazard awareness. To get this system on the road, the headache for OEMs and regulators will be how to create stringent certification that conforms to universal safety standards."

Whether vehicle dynamics will still have a role to play in this new world remains unclear.

USA-based Terrafuglia is developing Transition – a folding-wing, two-seat, roadable aircraft that drives like a typical car when on the ground

"The challenge will be to reconcile the systems, which are diametrically opposed from an engineering perspective"

Dr Mike Jump will be discussing 'Handling qualities and training requirements for personal aerial vehicles' at the Future of Transportation World Conference



The University of Liverpool has useful resources such as this 6DOF high-fidelity dynamic interface simulator

FLYING VEHICLE DYNAMICS

Flying cars may sound like the preserve of Hollywood movies, but they are coming, and the engineering is well underway. But with on-road performance to consider, as well as flying safety, what will this mean for vehicle dynamicists working on such projects?

One academic who has many of the answers is Dr Mike Jump, a senior lecturer in aerospace and engineering at the UK's University of Liverpool.

"Over the next few decades, the fledgling startups at the heart of this pioneering technology will develop both fixed-wing – like a twin-prop airplane – and rotary-wing technology – imagine helicopter blades mounted on wings – which will impact vehicle dynamics systems in different ways. However, even with two parallel models in place there will still be universal vehicle engineering dynamics challenges to overcome," he states.

Dr Jump, who has some personal interest in this area as he holds a private pilot's license, continues, "One of the chief challenges faced by engineers is how best to marry the engineering systems of a car with those of an airplane. This could prove both a highly complex and a circuitous process because the design requirements for a car entirely contradict those of an airplane.

"In terms of vehicle dynamics, a car's shape and design, coupled with the electronic stability control and traction control systems, have been especially engineered to keep it on the ground. Take the 'wings' for example, on an F1 car, which are positioned upside down to ensure that it almost magnetically grips the track beneath its wheels.

"However, the mechanical blueprint for a fixed-wing car-plane, at least when in the air, is focused on achieving and maintaining lift. While on take-off or landing, a streamlined fuselage and narrow-rack chassis with small wheels, reduces drag. The challenge will be to reconcile these systems, which are diametrically opposed from an engineering perspective."

TURBULENT TIMES

Jump believes that the wing design will be crucial in maintaining safety.

"If flying cars are to flourish, they will need to be able to take off and land over short distances. From an aerodynamic perspective, this requires constructing a car-plane with a low wing load. But an airplane showcasing these capabilities is much more vulnerable to gusts and turbulence, affecting the aerial ride quality. Airplanes that operate at more than 10,000ft employ gust-alleviation systems to reduce the effects of turbulence, but whether these advanced systems could be integrated into the design of a flying car remains to be seen."

But there have been breakthroughs too. Jump, who contributed to the myCopter project, an EU-funded project investigating the potential of personal aerial vehicles, believes that rotary-powered flying cars could be operated by drivers with very little flying experience.

"We created a simulation program for a rotary wing personal aerial vehicle with vertical take-off and landing capability," he says. We then invited drivers with little to no aviation skills to try the simulator. We asked all participants to perform a vertical lift-off, to accelerate into a cruise, descend, decelerate and then hover. Astonishingly, we found that the vast majority of trialists were comfortable with conventional helicopter controls – a control column, collective lever and rudder pedals – which enable forward, upward and sideways flight."

Further studies revealed that, in future rotary-wing flying car designs, there might be scope to eliminate the conventional controls altogether and replace them with a steering wheel, or in a fixed-wing design, deploy dual-purpose pedals, which allow the driver to seamlessly switch between a rudder pedal function in the air, and brake and accelerator controls for ground-based travel. Some startups today, such as Carplane in Germany, have two sets of controls – one for flying the airplane, the other for driving the car. The future is probably an amalgamation of these two systems.

Network RTK for vehicle testing

Real-time kinematic operation by **Racelogic** can enable increasingly precise tracking of the exact locations of vehicles, which benefits test programs for advanced vehicle systems

A good deal of vehicle testing requires the use of precise positioning via GPS. When developing systems such as lane departure warning, AEB or adaptive cruise control, it is generally necessary to track a vehicle's exact location, either geographically and/or in relation to other cars or trucks. Validating the methods we will use to achieve a truly autonomous transport infrastructure has made exact positioning a necessity.

Racelogic has been supplying differential base station units as part of its VBOX range for many years, even before manufacturers had really started to implement ADAS technology. To begin with it enabled positional accuracy up to ±20cm, but then with the advent of the Russian GLONASS satellite constellation, which brought additional signals, and the incorporation of RTK (real-time kinematic) measurement, this has been improved to <2cm – good enough for high-quality validation of critical safety systems that are now largely taken for granted in the automotive world.

What is RTK?

Standard GPS signals, even when processed by a high-quality, multi-constellation receiver, give a positional accuracy of approximately 3m. As the signals travel through the earth's ionosphere they are delayed by ±16ns, and then through the troposphere a further ±1.5ns, which is sufficient to create this error on the ground.

RTK operation uses GPS satellite carrier wave transmission rather than the actual signal itself. The civilian L1 GPS signal carrier wave is transmitted at 1,575.42MHz as opposed to 1.023MHz, and this thousand-fold increase in phase change means the standard time error that exists between the satellite and receiver is greatly improved.

Once this time alignment has been achieved, the distance to the satellite is much more accurately known. Consequently absolute positional accuracy is dramatically enhanced – a full RTK lock enables it to be as good as within 2cm.

Using RTK

A 100Hz VBOX 3i SL RTK datalogger, when connected via radio modem to an RTK base station, will receive not just standard satellite signals from the sky, but also a set of corrections from the base station that allow it to adjust the measured distance between itself and every satellite it can lock onto.

Because the base station has been placed in a known geographic location (or left to survey it for some time

Open-road ADAS testing

The use of NTRIP in ADAS testing enables a number of applications to be developed without the need to deploy a single static RTK base station.

Applications include adaptive cruise control, AEB, park assist, blind-spot detection, lane-keep assist and lane departure warning. And with new advances in autonomous technology such traffic sign recognition now appearing in normal passenger cars, real-world validation of all these systems requires extensive on-road testing.

Unlike within a proving ground, testing in varied, open-road environments requires vehicles to pass under bridges and trees, which interrupts the GPS reception, sometimes causing GPS dropouts and noisy data. This problem is solved by using VBOX IMU integration, which combines data from an inertial measurement unit and standard GPS input to smooth out the velocity signal.

This combination of network RTK correction messages, 100Hz VBOX datalogging and IMU integration enables resilient real-world ADAS development.

RIGHT: The VBOX NTRIP modem, pictured connected to a VBOX 3i SL RTK, receives GPS correction messages from an RTK network, making the use of a DGPS base station unnecessary

– either method results in a highly accurate position) it is able to transmit the ionospheric error corrections to the moving VBOX. The VBOX and base station are close to each other, so the signals are subjected to the same time delay; corrections for each can therefore be applied and a position solution – accurate to 2cm – is the result.

Using a base station and a VBOX to get this level of positional accuracy limits the range at which the roving logger can operate. Even in perfect conditions where there is no infrastructure or topography to interrupt the connection, RTK lock typically only reaches to 4km.

For some applications this is fine, as it is possible to test and validate a lane-keep assist system, for instance, within a 2km radius of the base station in a proving ground. Testing for such things as rear cross-path detection, or automatic parking control, is also possible within these limitations.

Operational range can be extended by using more powerful, licensed, radio communication up to a service area between 10km and 20km. However the further away from the static unit the VBOX gets, the less accurate the corrections become, as ionospheric errors are slightly different for the roving unit and the base station.

ABOVE: By using NTRIP, applications such as park assist can be developed without needing to deploy a single static RTK base station

Networked RTK

As the scope of autonomous vehicle systems continues to broaden, it is increasingly necessary for engineers to conduct test and development on the open road and cover many times the distance that precise positioning has, until now, allowed.

To overcome this issue, the use of RTK networks that have become operational in many areas of Western Europe, the USA, South America, southern Africa, Australia, China and Japan is becoming more prevalent, and Racelogic's VBOX equipment can now take advantage of this technology.

An RTK solution is constantly present within the network range of several permanently sited reference stations, all situated a similar distance from one another to provide consistent signal strength. Most such systems use internet protocol via cell phone coverage, known as NTRIP (network transport of RTCM via internet protocol) or CORS (continuously operating reference station) and incorporate a two-way communication link that enables the roving VBOX unit to send its position to the stations within the network – just as it would to a single base station. The NTRIP service provider will then calculate the appropriate corrections for the VBOX's location based on the data from nearby reference stations. This correction information is then returned to the VBOX in the same RTCM format as used for a single fixed-base station.

RTK correction via NTRIP is becoming more robust as the cellular mobile network continues to grow. The minimum requirement for it to be effective is 3G, but the prevalence of 3G across much of the area that has network RTK deployed means that a much greater geographical area is available for open-road testing.

A subscription to providers such Topnet in the UK and Germany, Swepos in Sweden and Unavco in the USA, for example, enables evaluation of new vehicle systems that require precise positioning to be conducted over far greater areas than is possible with a static base station.

For those looking to use differential GPS for the first time, network RTK enables entry into this testing sphere without the purchase of a DGPS base station, the VBOX cellular modem that replaces it being much more cost effective.

When using a VBOX 3i SL RTK and NTRIP modem, the system can be set up to receive corrections from specific individual reference stations or from a virtual point. For instance, in the UK Racelogic uses Topnet as its service provider, which provides a network solution based on the nearest nine reference stations, creating a virtual base near the rover's position. As the vehicle travels, the location of this virtual base is automatically updated, thereby keeping the correction range low so that the positional accuracy remains consistently high.

Correction messages received via the GSM network can also be an advantage compared with using a base station and RF radio signals, which can suffer if testing is conducted over large changes in elevation or with topographical obstacles getting in the way. Indeed, this is the case at some very large proving grounds, with one notable example in France that has a group of trees at its center that affects traditional RTK solutions that have to be broadcast from one side of the facility to the other.

Variable spring absorber

An innovative vibration damping system from **BorgWarner** facilitates cylinder deactivation as well as extreme downspeeding and downsizing by efficiently absorbing torsional vibration on the fly

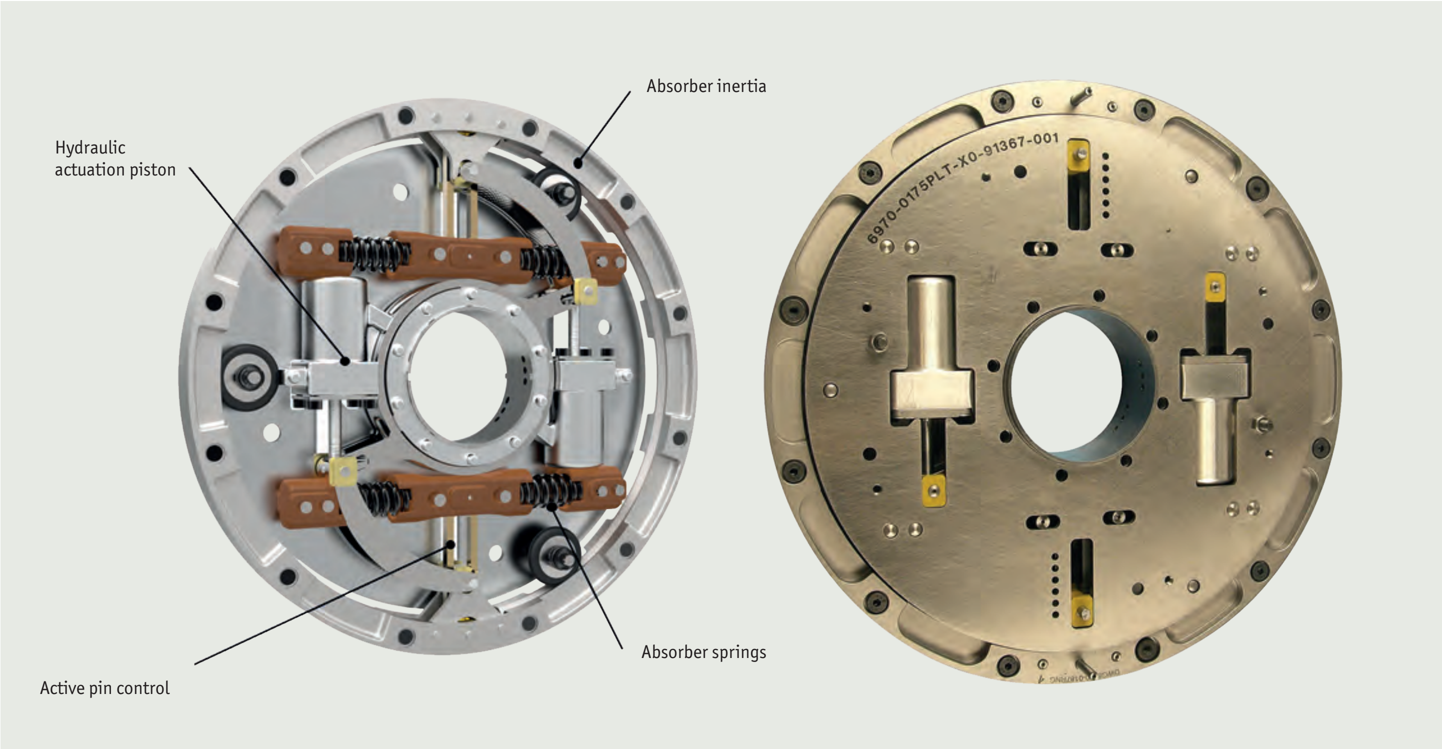


FIGURE 1: BorgWarner's variable spring absorber design for automatic transmissions

Engineered to follow the trends of downsizing and downspeeding in combination with highly turbocharged engines and a reduced number of cylinders, the powertrains in modern vehicles have very complex designs. Although the above measures improve the engines' fuel efficiency and reduce their emissions, they pose a considerable challenge for the capabilities of current torsional vibration damping systems.

The introduction of cylinder deactivation adds yet more complexity as the damping systems now need to deal with changing levels of torque fluctuation and thus torsional vibration in the same drivetrain.

To tackle these challenges and to help auto makers construct the increasingly powerful, clean and fuel-efficient cars that are being demanded for the future, engineers at BorgWarner are developing a highly innovative active torsional vibration absorber solution. Driveline simulations and component tests have shown excellent damping performance for the system, which features a variable torsional stiffness that can be actively changed to offer maximum isolation. In addition, the technology further reduces damper noises caused by engine cranking, which is a key benefit for engines featuring start-stop systems.

Absorbing vibrations for greater comfort and efficiency

Dual mass flywheels positioned between the engine and the transmission have reached their damping limits for modern engines with high specific torques and reduced cylinder counts.

Even at low rotational speeds, these engines have sufficient torque for most driving conditions. However, driving at high torque in higher gears at low engine speeds results in high torsional vibrations in the drivetrain. An efficient way to reduce these vibrations is to use a spring-mass or pendulum absorber system in addition to the dual mass flywheel, which uses the torque fluctuations to produce an opposing torque. The resonance frequency of the absorber system is tuned to match the torque fluctuation frequency and the absorber vibrates in opposite phase to the engine torque fluctuations, efficiently reducing torsional vibrations in the drivetrain (Figure 1).

Innovative design for greater vehicle refinement

BorgWarner's variable spring absorber is mounted on the secondary side of the dual mass flywheel, i.e. before the transmission input shaft. The newly developed system consists of an absorber inertia ring connected to coil springs on the secondary side of the dual mass flywheel, with a tilt lever. Additionally, the actuation system, which is designed to operate with hydraulic oil pressure, is enclosed inside the ring (Figure 2).

The springs and the inertia ring form a rotational spring-mass system. The fulcrum of the tilt lever is variable and can be positioned to change the effective spring stiffness acting on the absorber ring to alter the resonance frequency of the spring-mass system. During operation, the absorber system frequency is set to that of the torsional vibrational frequency of the powertrain. As a result, the absorber vibrates with the same frequency but in the opposite phase, thus canceling out vibrations on the secondary side.

The main advantages enabled by the system's design

A major advantage of using mechanical coil springs to store the vibrational energy is the fact that a large amount of energy can be stored in a small space with no great influence of temperature and rotational speed, resulting in an absorber that is equally effective at high and low engine speeds. By allowing active changes to be made to the absorber frequency independent of the engine speed, the same absorber can be used for various applications with different cylinder counts, as well as for engines with cylinder deactivation.

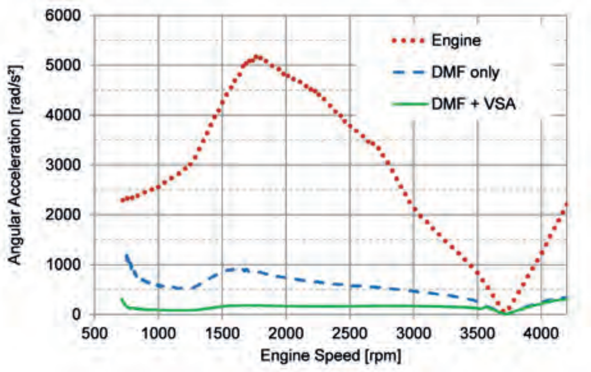
During start-stop maneuvers, absorber systems are susceptible to 'clonking' noises as the absorber masses hit their end positions when subjected to high torque peaks. To avoid unnecessary noise generation, BorgWarner's variable spring absorber system remains mechanically blocked as long as the engine speed is below idle. Once the engine starts and runs at idle or higher speeds, the absorber system is unblocked and the correct absorber frequency set.

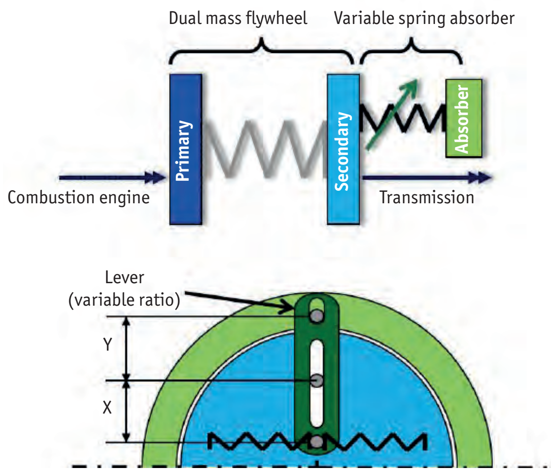
Fuel savings potential

The main motivation behind the development of a new torsional vibrational damping system is to enable vehicle manufacturers to develop fuel-efficient vehicles while maintaining or even improving driving performance and comfort. As a key enabler, the variable spring absorber supports this aim in different ways.

One fuel-efficient technology, cylinder deactivation, is facilitated by the absorber's adaptability to different resonance frequencies. By improving the vibration isolation for a wide range of cylinder counts on the fly, BorgWarner's solution helps reduce the lowest engine speed at which cylinder deactivation is viable. This results in fuel savings of 3-7%, depending on the deactivation strategy and the drive cycle.

In addition, the variable spring absorber allows extreme downspeeding, which is currently restricted by comfort requirements. High degrees of downspeeding can yield fuel savings of up to 3%. Moreover, the absorber would enable the use of two- and three-cylinder engines with an acceptable torsional vibration performance – a key factor for their use in premium vehicles, where four cylinders are currently the lower limit.





TOP: FIGURE 3. In combination with a dual mass flywheel, BorgWarner's variable spring absorber greatly reduces torsional vibration

ABOVE: FIGURE 2. Installed behind the dual mass flywheel, the variable spring absorber's vibration frequency can be changed on the fly

Performance evaluation

To evaluate the system's isolation performance, BorgWarner performed simulations for drivetrains that included the variable spring absorber. Typically, turbocharged diesel engines are more susceptible to torsional vibrations. Accordingly, a four-cylinder turbocharged diesel engine under full-load conditions in high gear was chosen for the simulations and equipped with a suitable dual mass flywheel, as well as the variable spring absorber.

Showing maximum torsional amplitudes of 180rad/s^2 for engine speeds between 800rpm and 3,500rpm, the simulation results verify the technology's immense potential to enable much slower engine operating speeds than are possible with today's systems. It thus contributes to major reductions in fuel consumption and CO_2 emissions.

Numerous tests conducted on a torsional vibrational test bench confirmed and reinforced the outstanding simulation results. Here, torsional vibration was introduced into a four-cylinder engine's drivetrain, with the absorber system active and in blocked mode. It was observed that an active absorber system provides vibration reduction of around 75-80% after the damper (Figure 3). Working in combination, the variable spring absorber and the dual mass flywheel potentially achieve a total isolation performance of over 95%.

Conclusion

BorgWarner's variable spring absorber is a promising solution for reducing torsional vibrations in future combustion powertrains. Simulations and tests show the potential of this concept as an enabler for extreme downspeeding and cylinder deactivation. In parallel with the further development of this advanced solution, BorgWarner will investigate the benefits of its implementation in electrified powertrains such as those used in hybrids and electric vehicles with range extenders.

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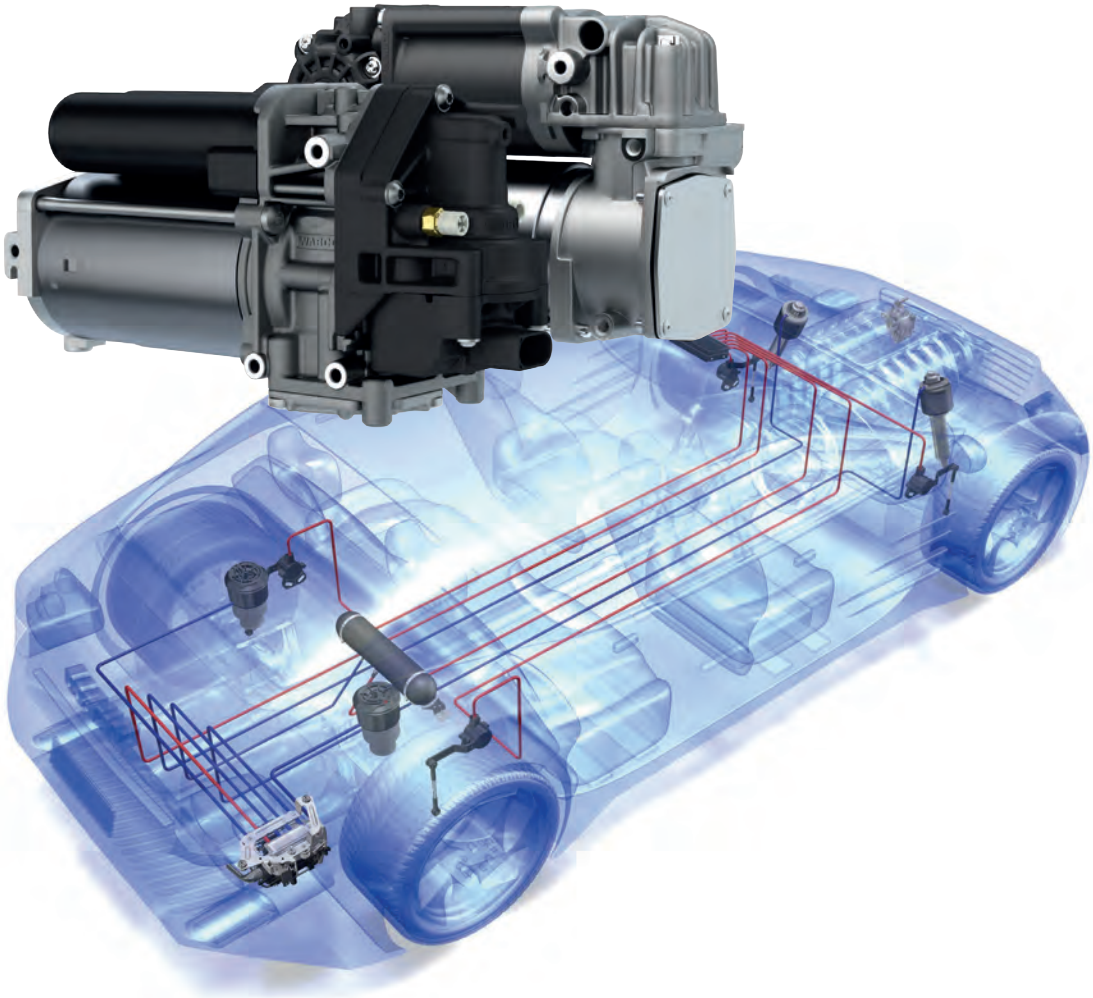
A boost for air suspension

WABCO's TWIN compressor can pressurize the most advanced air suspension systems. Higher reservoir pressures combined with a boost function increase air supply performance

Air suspension systems have become an increasingly popular technology for premium passenger cars around the world. The basic technology has been around for decades, however the industry saw a real breakthrough around 2000, with improved air spring technology ensuring a comfortable ride while electronic controls enabled efficient and precise system operation. Premium European car makers such as Mercedes-Benz, BMW and Audi began to introduce air suspensions on their luxury passenger vehicles at that time, with SUVs following soon after. Now almost two million vehicles with air suspension are produced globally each year.

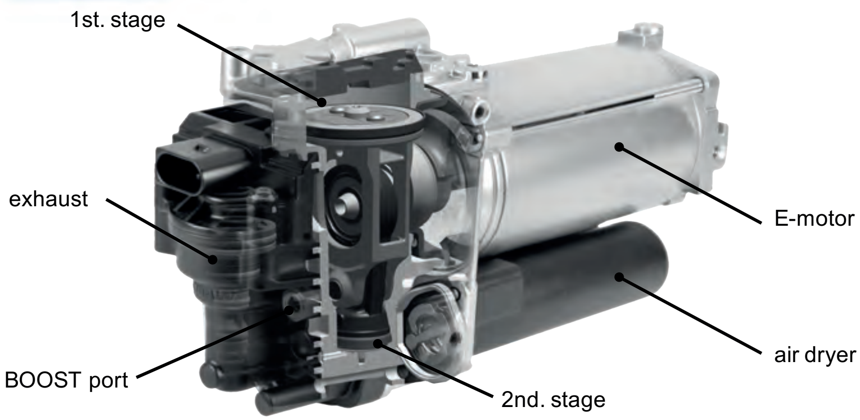
Today almost every premium car maker offers four-corner air suspension systems on their E-segment vehicles, and their adoption has started to trickle down into the D-segment. Key features of the technology include improved comfort, optimum ride height regardless of the load situation, increased ground clearance on demand, and speed-related lowering to reduce aerodynamic drag. The latest systems even offer adaptable air spring rates, which in combination with active damping, achieve the top level of performance for vehicle dynamics.



The heart of the system

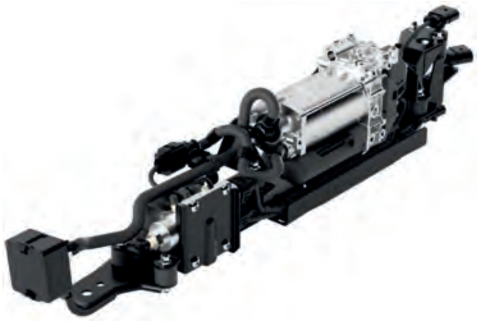
The compressor is at the heart of the air suspension system, providing a reliable flow of pressurized air into the air springs under all conditions. Key challenges are high output pressures of up to 20 bar under typical automotive conditions from -40°C up to 80°C and relative humidity of up to 100%. The compressor operates without oil and is maintenance-free across the full life of a vehicle. An air dryer situated just behind the compressor cylinder collects the moisture of the compressed, superheated air to ensure that the pneumatic valves and airlines do not freeze during cold ambient conditions.

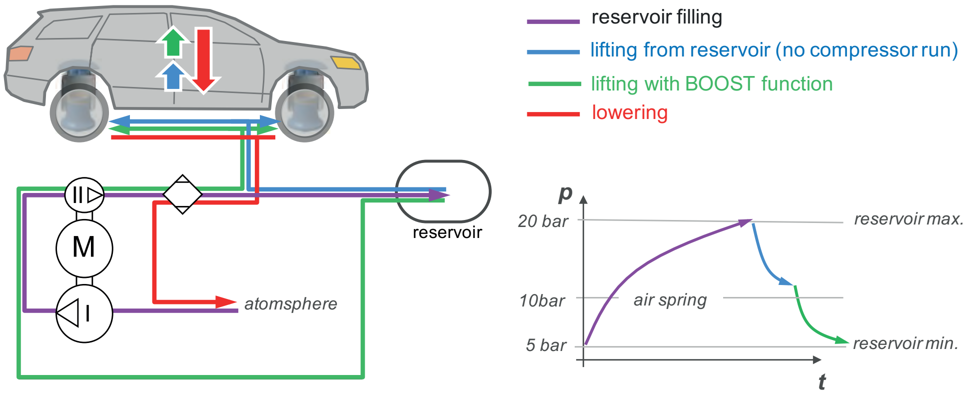
As a technology and market leader for automotive and commercial vehicle air supply systems, WABCO has focused



TOP: WABCO's two-stage TWIN compressor and single-stage compressor

RIGHT: WABCO's two-stage TWIN compressor





on the so-called 'open type system'. This approach pumps external air into the air springs or into a reservoir. The reservoir provides the advantage of quick lifting operations without requiring the compressor to run. The air flows from a typically 18 bar pressurized reservoir into the air springs, with a pressure rating of between 6 bar and 10 bar. In order to properly regenerate the air dryer, the air crosses a bed of desiccant in the counter-direction while exhausting air out of the system.

The alternative closed-type system pumps the air forward and backward between the reservoir and the air springs. The upside is smaller pressure differences; the downside is that the system is more prone to system leakages.

TWIN compressor with Boost function

WABCO's new-generation compressor – called TWIN – operates with two stages of compression. The result is a higher reservoir pressure of up to 20 bar, combined with a 40% improved flow rate, especially at higher pressure ratings, due to the improved volumetric efficiency. After lifting the vehicle two or three times in a row from the prefilled reservoir, the delta pressure between the reservoir and the air spring is reduced, which slows down the lifting speed.

To run further lifting operations, the all-new patented Boost function of the TWIN compressor kicks in. The Boost function connects the input of the compressor's second stage to the reservoir and boosts the remaining reservoir pressure into the air springs, thereby enabling lifting until the reservoir pressure falls to 5 bar. Consequently the number of lifts can be doubled compared with a conventional non-Boost system. Alternatively the vehicle manufacturer can decide to reduce the size of the reservoir by up to 50% to reduce costs and the packaging space required for the reservoir.

This value proposition has convinced several customers around the globe for their passenger car and SUV applications. In addition several EV models have been equipped with the TWIN compressor, such as Tesla's model S and X. Various other model launches are planned for 2018 and 2019.

TOP: The pneumatic arrangement of the TWIN compressor with Boost function

ABOVE RIGHT: The air supply unit with TWIN compressor as used in the Lamborghini Huracán

BELOW: Compressor valve tank from AccuAir Suspension with built-in WABCO TWIN compressor

Design features of TWIN

WABCO launched its first single-stage dry-running compressor in 1986. Since then the design has been improved over four generations, focusing on flow-rate performance, weight, packaging space and cost. A key differentiator of the TWIN compressor is the short packaging height in the direction of the cylinder axis. A patented arrangement of two swinging pistons realizes a high stroke at a minimum swinging angle. As a result the height has been reduced by almost 20% compared with the single-stage compressors previously used.

To maintain this advantage across the complete length of the compressor, WABCO has patented a new air dryer design. Instead of having one tube with a diameter of 60mm, the air dryer has two smaller tubes with a diameter of 30mm, which follow a U-shape.

In addition to the advantage of having a much better fit above the motor, because of the longer desiccant bed the air comes in contact with more desiccant particles, making the dryer even more efficient.

A further improvement arises from the thermal management of the device. The thermal duty cycle of the previous generation of single-stage compressors was usually limited by two hot spots – the piston seal and the motor brush card. The two-stage approach of the TWIN compressor reduces the heat of compression by dividing the heat generation into two cylinders. In addition the TWIN compressor air intake lets the air pass through the motor to cool its brush card before it enters the first stage of compression. Hence both typical hot spot temperatures are reduced, resulting in a higher duty cycle.

As another example the company AccuAir Suspension, a technology leader in the high-performance retrofit air suspension systems market, has developed a whole new product line of reservoirs with a built-in TWIN compressor. AccuAir Suspension realized the small packaging envelope of the TWIN compressor and installed it into the compressor valve tank (CVT). The benefits of this setup include ultra-low noise emission and very simple plug-and-play installation of the air supply module, which are key points of differentiation in the tuner market.

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Electric power drives the future

Advances in bearing technology will help to deliver the electric drivetrain of the future, says **Anthony Simonin**, EV & HEV competence center manager at **SKF**

Electric vehicles (EV) and hybrid cars are moving into the fast lane. While 'conventional' cars will continue to dominate the market, the need to reduce carbon dioxide and particle emissions will fuel the acceleration of these types of 'alternative' vehicles.

Whereas once they were little more than a sideshow, they are now undergoing a boom: industry analyst Frost & Sullivan recently estimated that EVs and hybrids could account for 10% of global car sales within five years. This means that further electrification of the drivetrain is inevitable. However, achieving this is no simple task. The drivetrain of a hybrid car, for instance, is far more complex than that of a conventional car because of the need to switch between electric and conventional engines, or to use both at once.

There are many ways to achieve this further electrification, and they are increasing all the time. The simplest way is to integrate the electric motor into existing configurations, but in the next 5-10 years we could see more than 30 designs of EV and hybrid drivetrains hit the market.

Designers of all these variants will be striving to make them as compact as possible, while seeking robustness, ease of assembly and – most importantly – greater energy efficiency. Their designs will be critical, as will the components they choose to specify. Bearings are often a hidden component, but using them selectively will help to solve some of the problems affecting e-drivetrain design.

Energy recovery

A critical component in the powertrain of a hybrid car is the belt-driven starter generator (BSG), which recovers braking energy and feeds it back into the engine to boost torque and engine performance.

SKF recently helped a Tier 1 supplier to improve the design of its BSG system, which formed part of a 48V powertrain system. For the latest version of the BSG, SKF developed a new design of rotor positioning bearing, which can be used either with synchronous or induction traction motors, used in electric and hybrid vehicles.

MAIN IMAGE: eDrive ball bearings are designed for use in electric and hybrid drivetrains

RIGHT: A rotor positioning bearing

# of cars

Compact and light enough for use in this type of drivetrain, the rotor positioning bearing has been designed to have enhanced resistance to extreme conditions. It can withstand continuous temperatures up to 150°C, is unaffected by severe magnetic field disturbances or high levels of vibration, and can reduce torque ripple and electric noise.

Overall, the higher accuracy delivered by the device allows the electric motor to run more quietly, which delivers a smoother ride and higher efficiency. As an added benefit, it is easy to incorporate into the BSG assembly.

Cutting friction

Despite the huge variations in design architectures, the challenges that underlie them remain the same. One of the most important is the automotive industry's oldest enemy: friction.

The fight against friction takes place in just about every part of the car, from the tires to the pistons. However, specific elements of electric and hybrid vehicles, most notably the higher power density and higher speed, accentuate the effects of friction.

A way around this problem is to design-in components that can reduce friction. In a recent customer collaboration, SKF helped a Tier 1 supplier maintain the compactness of a 48V belt alternator starter (BAS) while achieving increased speed, load and temperature.

This was achieved by fitting its eDrive ball bearings – in this case, deep-groove ball bearings – which exhibit very low friction and are specifically designed for use in electric and hybrid drivetrains.

ABOVE: Electric and hybrid vehicles are becoming increasingly popular, and the use of well-engineered bearings can help ensure they are refined in operation

BELOW: SKF produces a wide range of bearings for environmentally friendly vehicles

They use a polymer bearing cage, as well as an optimized bearing raceway geometry and specially formulated grease, to cut friction by up to 30%.

However, the process actually started earlier when SKF modeled the design of the part using its simulation software and tested it at a component level. Modeling components is usually the key starting point for getting them specified. In this example, the customer had originally been using standard bearings, but they were not up to the job.

Testing is also critical. In fact, SKF is already building a series of high-speed test rigs that go beyond the current needs of the market, as it is likely that those needs will change in the future.

Solving new problems

New technology can often be both a blessing and a curse. For every advantage it brings, there can also be a downside. A good example is electric inverters. For all their benefits – such as increased energy efficiency – their high-speed switching increases the signal frequency, causing them to leak current. This can harm components such as bearings and reduce their working life.

A way around this issue is to use alternative parts such as hybrid bearings. These combine a stainless steel ring with a ceramic rolling element, which helps to isolate current leakage and protect components from stray current. The technology can cope with the high speed of electric drivetrains, as well as instances of poor lubrication.

Electric and hybrid cars are also far quieter than most conventional cars. However, a slightly annoying consequence of this is that you can now hear all the squeaks and rattles that were once masked by engine noise.

Electric and hybrid cars are undoubtedly the way ahead for the automotive industry, with every major manufacturer working on its own range of vehicles. Design optimization will be critical, and it seems that the humble bearing could, in many cases, have a massive effect on performance.

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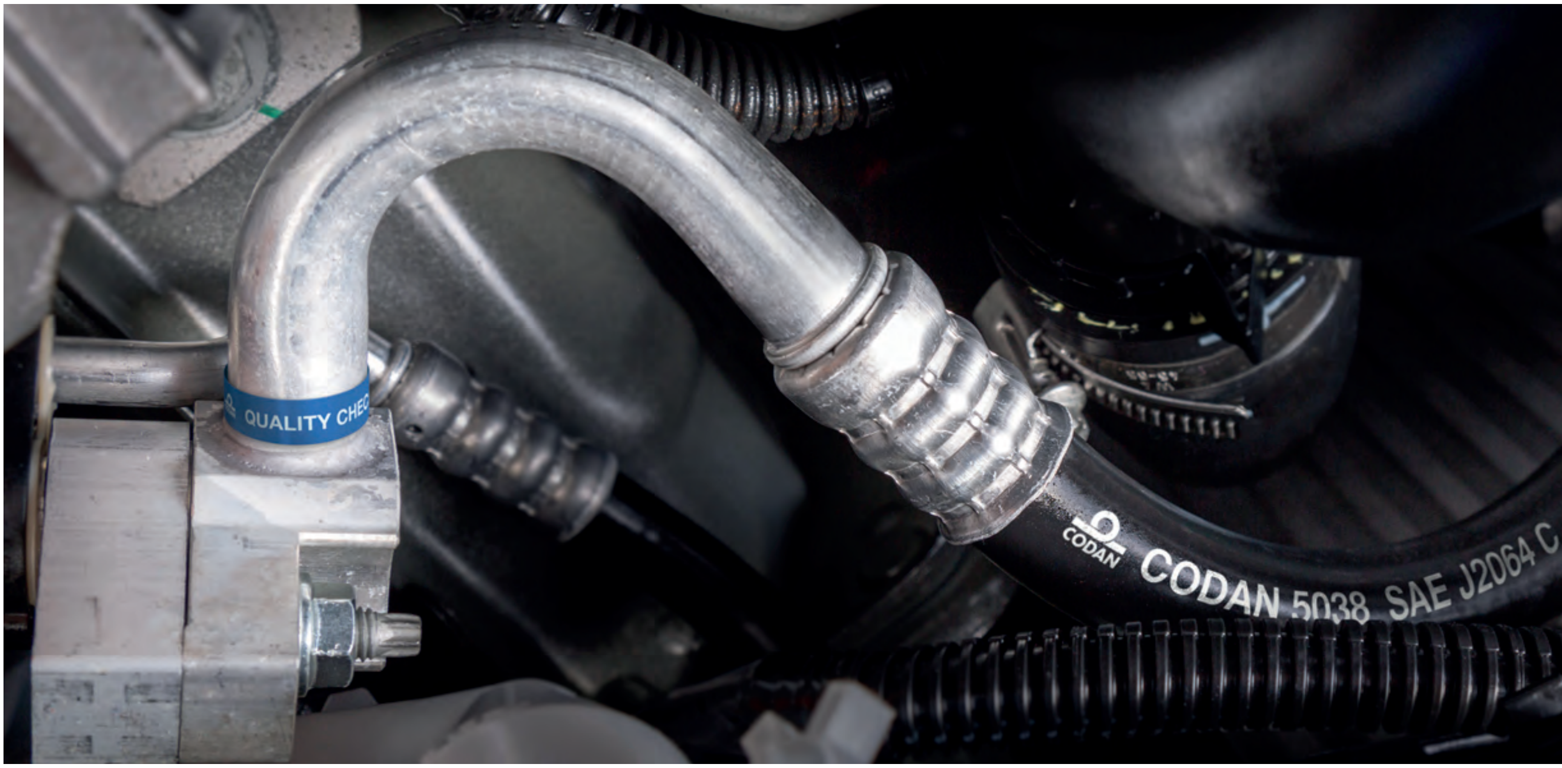
Modern hoses for modern cars

To ensure that hoses perform to the required specifications, OEM standards and legislation – especially with regard to the environment – it is essential that hose manufacturers adopt an innovative approach, like **Codan** has



ABOVE: There is an ever-increasing demand for high-performance automotive hoses

A hose is not just a flexible connection from point A to point B in a generic car; today hoses are manufactured for special applications and are required to perform to very high standards in extreme environments.

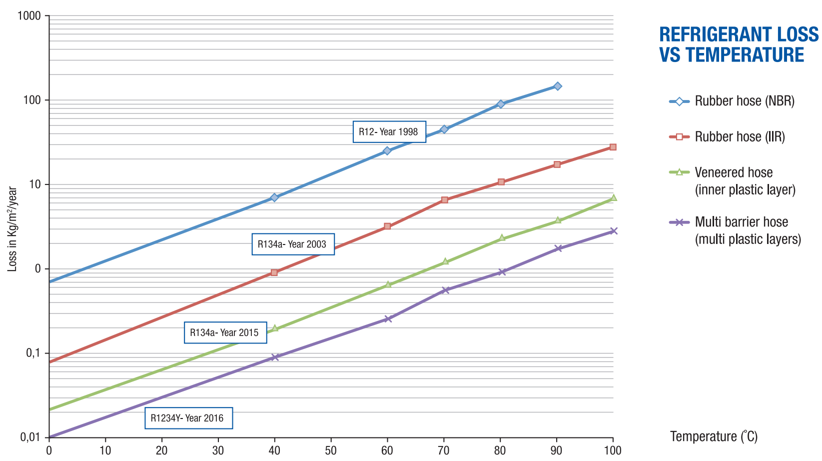
Examples of the demands made of hoses include low permeability of gas and liquids; chemical resistance to media; resistance to cold climate as well as high temperatures; resistance to both static and dynamic pressures in the system; and vibration and noise damping.

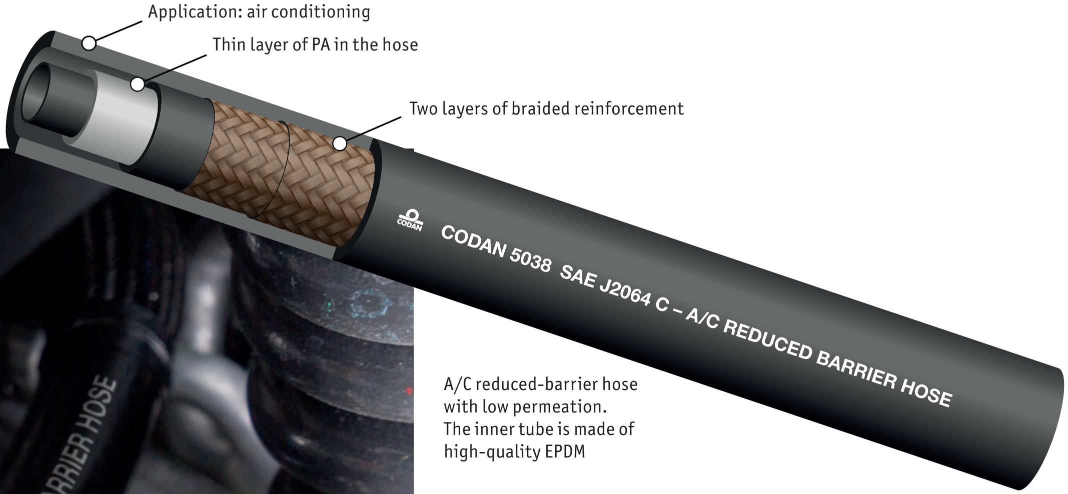
There is an increasing demand for hoses to perform to an ever-higher standard, and an innovative approach to new materials and designs is essential in order to be able to meet those new requirements.

To illustrate the point, here is an example: Before 2000, hoses used in vehicle air-conditioning (AC) systems were made from pure rubber, such as nitrile-butadiene rubber (NBR) on the inside and chloroprene (CR) on the outside. At this time, the refrigerant in the AC system was typically R-12 (dichlorodifluoromethane), the temperature requirement was -29°C to +120°C, and permeability was not an issue as demand was a maximum of 97-150kg/m^2/year. However, the issue of the degradation of the ozone layer resulted in new legislation on hose permeability as well as other restrictions.

Thus, the R12 was abandoned and changed to R134a (1,1,1,2-tetrafluoroethane). Because there was no chlorine present in the new refrigerant,

FIGURE 1 (RIGHT): Loss of refrigerant in relation to temperature





A/C reduced-barrier hose with low permeation. The inner tube is made of high-quality EPDM

FIGURE 2 (ABOVE): Permeability is as important as the working temperature

it had no impact on the degradation of the ozone layer (ODP=0), and at the same time the global warming potential (GWP) was reduced from R12=7100 to R134a=1200. And because the hose was developed even further, having previously being manufactured from pure rubber, with the introduction of hybrid hose technology (hoses based on rubber with plastic barrier layers), the permeability was reduced from 97-150kg/m^2/year to <5kg/m^2/year. This resulted in a further reduction of the impact on the environment. Today, the restrictions on permeability are in some cases even less than 2kg/m^2/year.

Performance improvements

As a result of recent investments in new production facilities and the development of more efficient processes using multibarrier technology, Codan produces hoses with permeability levels less than 1kg/m^2/year. To reduce the permeability further, new multibarrier designs are being developed and used in new products.

The demand for better performance has resulted in the temperature specifications being changed to -40°C to +160°C, which is more than a 30% increase in performance. This, of course, makes it necessary to use much more sophisticated materials compared with previously.

To lower the GWP even further, car manufacturers are currently changing from R134a to the new refrigerant: R1234YF. The change is fueling the pressure on hose manufacturers to ensure compatibility not only with this new refrigerant, but also with the oils that are being used to lubricate the compressor in the system.

It has been predicted that the ideal cooling gas for air-conditioning is CO_2, and hose manufacturers, compressor manufacturers, as well as system designers have worked hard toward developing new products for this gas, which has no negative impact on the ozone layer and global warming. But because the optimal solution has not yet been found, R1234YF will be used as a compromise until that day arrives.

Greater OEM demands

Permeability is important, as is working temperature, but revisions of other characteristics of hoses have also been necessary to accommodate the increasing demand for better performance from car manufacturers. Furthermore, as cars become more efficient and the ride quieter, there is a growing pressure for noise damping. Thus, the issue of noise has driven the development of softer and more flexible hoses to secure better NVH performance.

Codan has developed a new hose, which is claimed to have excellent noise-damping properties and compatibility with R1234YF and the new compressor oils, as well as very low permeability.

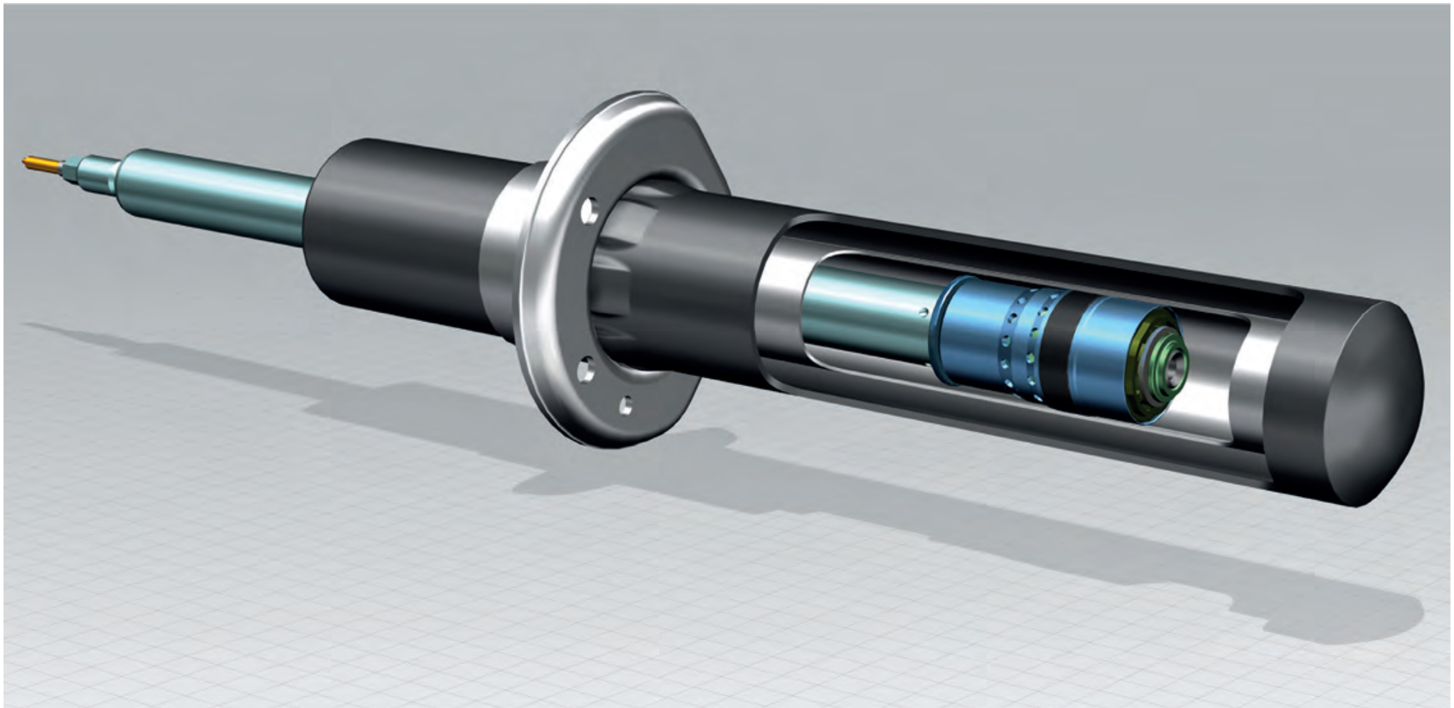
There have been extensive developments in hose technology over the past 20 years, and it will not stop here as the demand for more environmentally friendly components is the impetus that will continue the evolution of high-performance automotive hoses.

The next generations of hybrid, combustion and electric cars are also going to require special hoses with unique characteristics, which Codan already has in the pipeline.

RIGHT: Rigorous testing ensures very high quality standards

Ride quality

Luxury or uncompromising performance: **BWI Group** reduces the cost of switchable suspension options



ABOVE: DualRide dampers can bring dynamics benefits to entry-level models

Consumers expect all new vehicles to be bursting with technology, safety and refinement, including lower-cost models with entry-level specifications. The rapid advance of affordable technologies that empower advanced driver assistance systems and connectivity have helped create a feeling of cocooned safety for drivers – and also enable car makers to offer new models with an array of technology that doesn't compromise production cost or sale price. But what of refinement, and that worryingly old-fashioned term, 'ride comfort'?

A 'sporty' feel, with large wheels and low-profile tires is in vogue, often at the expense of a traditional feeling of comfort. But advanced chassis technology supplier BWI Group believes it has come up with an answer.

"BWI DualRide dampers provide a high-quality, affordable, switchable suspension that gives drivers a choice between comfort and sport, without compromising either mode," explains Marla Hughes, BWI Group's controlled suspension product team manager. "DualRide is a two-position, electrically switchable damper system that provides a smooth, comfortable ride in 'comfort' mode and a dynamic, fun-to-drive setting in 'sport' mode.

"The new dampers are perfect for B and C segment vehicles, where manufacturers still want to provide a feeling of luxury, driver-selectability and premium comfort at a 'reasonable' cost, but DualRide could also be applied on higher segment vehicles."

BWI Group has developed a two-position actuator that is contained within the damper piston-rod assembly. Designed for twin-tube damper configurations of 32mm or 36mm bore diameter, this actuator provides a manually switchable function. Damping level changes between comfort and sport modes can occur in less than 200ms. The use of a physical switch or screen-operated selector reduces system complexity and reduces cost over conventional adaptive or semi-active damping systems, while also offering driver-selectable adjustability.

DualRide enjoys a key advantage: comfort mode on the hydraulic circuit employs the same components that are used in BWI Group's tunable passive dampers.

"The aim was to offer as much comfort-mode tunability as possible while also offering a very good and very different sport mode, with minimal compromise between the two," adds Hughes. "DualRide provides two clearly defined damping modes that do not compromise each other. We have aimed to provide manufacturers with an option to enhance entry-level models with a feeling of refinement, sportiness and technology without encroaching on premium model specifications and also offering car-buyers affordable and meaningful suspension technology."

DualRide retains the capacity for further adaptation in the future, meaning that BWI would be able to offer a third, fully automatic mode. When coupled with an ECU, the dampers could respond to driving style and chassis inputs to provide a reduced cost, fully adaptable suspension system.

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To learn more from BWI Group, visit ukimediaevents.com/info/vdm ref. 006

GPS tracking technology

Introducing **GeneSys**'s high-precision GNSS receiver for enhancing driver-assistance systems

GeneSys has developed a new turnkey solution intended to help with the development of driver-assistance systems, with a particular focus on the localization of fixed objects and on vulnerable road users (VRU) participating in road tests.

The solution, named the SP80, has a position accuracy of ±2cm. A key feature of the technology is Spectra Precision's SP80, which was greatly enhanced in terms of functionality and exclusively adapted to the application in a joint development with GeneSys.

The high-precision, compact and portable GNSS receiver is therefore perfectly suited for motion tracking of slowly moving objects such as VRUs, for example pedestrians and cyclists, as well as for gauging the test environment, such as parking spaces, vehicle dimensions and road markings.

A joint development program between GeneSys Elektronik and PPM Precise Positioning Management greatly enhanced the functionality of the SP80 and saw it become adapted exclusively to the application.

The unique technology installed in the SP80 uses all four GNSS systems: GPS, GLONASS, BeiDou and Galileo.

A powerful GNSS antenna receives data from GPS and GLONASS satellites. The SP80 receives the DGPS correction data via a cellular modem (3.5G GSM, UMTS), which dials into a correction data service such as AXIO-NET or SAPOS. The system is alternatively available with an integrated wireless modem, which enables the smooth reception of correction data from a GeneSys GPS base station.

The position data can be logged to an SD card in the SP80, and real-time data output can be transmitted simultaneously via wi-fi. The Dewesoft datalogging software has a plug-in for synchronous data recording in combination with the GPS-augmented inertial automotive dynamic motion analyzer (ADMA) system. The data output rate is up to 20Hz.

The SP80 can be operated wirelessly, and both batteries can be replaced during operation with one hand, thus ensuring interruption-free measurement.

ABOVE: The SP80 is a compact and portable GPS-based tracking system that is ideal for vehicle-to-pedestrian tracking and gauging of the test environment

RIGHT: The SP80 is well-suited to the accurate determination of position and speed, for example while calibrating a parking space or vehicle dimensions

The high-precision GNSS receiver is also equipped with a status display that provides all important information and is highly legible, even in sunlight. Thanks to the fiberglass-reinforced housing, the SP80 is shockproof and waterproof as per IP67 and can also be operated in ambient conditions of -40°C to +65°C.

The SP80 supplements the ADMA system and is suited for both vehicle-to-pedestrian tracking and gauging fixed objects. Like all GeneSys measuring systems, the SP80 can be quickly installed, and after configuration further intervention by the user will not be necessary.

Another technology coming soon is the VRU-Tracker, a handheld GPS receiver developed by GeneSys. This wireless and lightweight receiver is equipped with a separate small antenna, dedicated to the precise localization of VRUs.

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To learn more from GeneSys, visit ukimediaevents.com/info/vdm **ref. 007**

Simulators for motorcycles

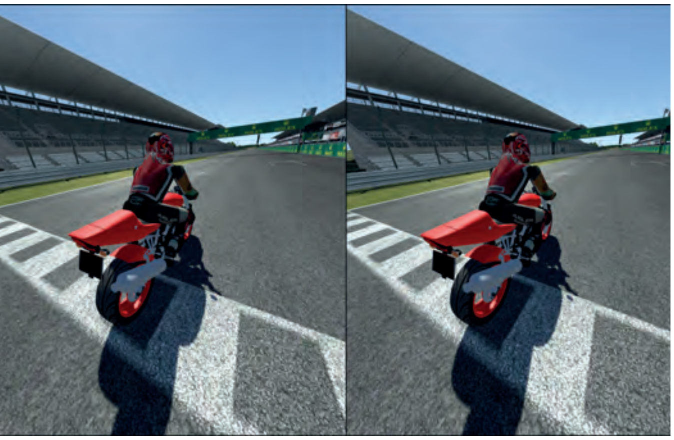
rFpro believes it has developed the world's first dynamics-grade DIL simulator for motorcycle applications

The dynamics of single-track vehicles, such as motorcycles, are very different from those of their four-wheeled counterparts, but the benefits offered by effective driver-in-the-loop (DIL) simulation are exactly the same for both in terms of confirming the vehicle's behavior in a virtual environment.

These benefits can include the safe and repeatable exploration of limit handling; the controlled evaluation of alternative chassis configurations using riders with different styles and ability levels; and the facility to compare the machine's behavior around existing test tracks and circuits without shipping physical prototypes and personnel to various locations.

Unfortunately the challenges of creating a truly immersive experience for a rider who may be hanging off the bike in a corner, or looking at anything from the ground beneath to the sky above, have severely constrained the realism of simulators – until now.

RIGHT: Ansible Motion adapted its R&D center for motorcycle dynamics



ABOVE: Left and right eye virtual reality output from rFpro

In what is believed to be the world's first development of a vehicle dynamics-grade DIL simulator for a motorcycle application, system integrator Ansible Motion is using rFpro software in conjunction with VR headsets or projectors to create a riding experience realistic enough for the evaluation of motorcycle dynamics. rFpro's simulator software has previously been used on everything from F1 cars to commercial vehicles, but the motorcycle application raised new challenges, according to the company's technical director, Chris Hoyle.

"Major differences arise between motorcycle applications and other vehicles, because of the difference in steering dynamics and the mobility of the rider," he states. "In a car, the steering angle is an input from the driver and the steer torque is fed back as a system output. On a motorcycle the opposite happens. The rider applies a steering torque to the handlebars and the vehicle model calculates the appropriate steering angle for the front wheel."

Hoyle also explains how the greater field of vision available to a motorcyclist influenced the method used to deliver the graphics. "A car driver is restricted by the windows, hood and roofline. They can look around freely, but only through a range of 20-30° upward and downward. The motorcycle rider can look anywhere, even down at the road surface, and once banked into a turn, because the rider is still upright on the motion platform, the horizon must be banked over to provide the correct visual cues."

The choice of a VR headset provides sufficient fidelity to give good immersion to riders, however far they bank over from the upright plane, by seamlessly adjusting the horizon presented to the rider's eye. An alternative would be to use a spherical projection system that wraps around both the rider and the platform. At the start of motion, the platform provides 'onset' cues, with the graphics then supporting the steady-state illusion, so the physical sensations of movement are triggered not by acceleration, but by changes in the rate of acceleration.

The rider's weight acts vertically downward through the seat of the motorcycle simulator at all times, which mimics cornering on a real motorcycle because, as bike and rider bank over, the resultant force through the tires remains in the plane of the machine.

As part of the software package, rFpro also supplies a number of digital test track models to enable direct comparison with physical data.

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To learn more from rFpro, visit ukimediaevents.com/info/vdm ref. 008

Helping hand

Driver-in-the-loop testing technologies from **Mechanical Simulation** enable accurate and effective ADAS validation

Advanced driver assistance systems (ADAS) play a pivotal role in the future of vehicle development. It is important to develop, test and deliver these systems in an efficient, robust manner. One effective way to achieve this is to have human drivers test these systems throughout the development process, especially before hardware hits the road.

This proactive approach was taken with the development of OnGuardACTIVE, a radar-based active safety system by Meritor Wabco that offers collision mitigation and adaptive cruise control (ACC). The system detects moving, stopped and stationary objects and vehicles ahead, and measures the vehicle's position in relation to those obstacles to warn the driver of a possible collision by providing audible, visual and haptic warnings.

When appropriate, the system will apply the brakes to help avoid an impending collision or lessen the severity of an unavoidable one.

The radar component of the system registers vehicles and classifies them in one of three ways. The first category is Moving, as in a vehicle that is currently and continuously in motion in the same direction as the ego vehicle. The second is Stopped, meaning a vehicle the radar has registered as moving but is now at a stop, for example at a traffic light. The third classification is Stationary, meaning a vehicle the radar is picking up but has never seen move, such as a broken-down car.

OnGuardACTIVE provides audible and visual warnings, a haptic warning and active braking for all three classifications of object that the radar registers, even when cruise control is not enabled. The system employs haptic warnings in the form of brake pulses, which cause the driver to respond faster. Additionally, the active braking system applies the vehicle's brakes to help avoid a collision or, failing that, to lessen its severity.

The ACC maintains the set speed in cruise control mode when the lane ahead is clear, and will automatically adjust the vehicle's speed to maintain a set following distance when a vehicle ahead is detected. The system provides early warning feedback for improved safety and collision mitigation.

The 'always on' feature means that feedback is provided to the driver even when ACC is not enabled. These features make cruise control a more useful tool in various traffic conditions, leaving drivers feeling more relaxed in heavy traffic and creating an improved driving experience. Furthermore, this technology reduces driver fatigue in congested traffic In today's fast-paced development environment, it is imperative that engineers test these systems early and often during development to tune the systems for the complex human-machine interaction that occurs in the real world.

The aforementioned complex human-machine interactions can be studied using realistic driving simulators. Mechanical Simulation's QuadDS driving simulator runs CarSim and TruckSim, which can to be used to test and develop ADAS by putting the driver in the loop for a variety of vehicle architectures and applications.

A wide range of driving styles and behaviors can be tested, which results in more thorough validation and higher confidence in the ultimate calibration for production. This includes a variety of road and weather conditions.

"QuadDS helped us understand how drivers respond to our OnGuardACTIVE system without having to equip a vehicle. Also, OEMs can get a complete understanding of our technology quickly and easily. It is great to see people's eyes light up when they get it," says Michael Lambie, marketing manager at Meritor Wabco Vehicle Control Systems.

Accurate vehicle dynamics software and a realistic driving simulator environment are the cornerstones of demonstrating and testing ADAS technologies, thereby enabling engineers to get their product to market faster with the desired quality and robustness.

CarSim and TruckSim vehicle dynamics software packages reduce the effort and cost associated with ADAS engineers creating realistic testing environments and events, and ensure high confidence going into final hardware validation. Coupling this software with the QuadDS driving simulator allows driver-in-the-loop testing for that real-world validation before hitting the road.

This testing improves productivity, ensures quality and lowers costs – a winning value proposition for organizations developing ADAS.

BELOW: Mechanical Simulation's QuadDS driving simulator simulates dangerous scenarios that are difficult to create using real vehicles. This ADAS application includes environmental conditions such as fog and rain

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To contact Mechanical Simulation, visit ukimediaevents.com/info/vdm ref. 009

Add motion to simulation

How far can motion technology take the automotive simulation industry? **D-Box** is pushing the limits with an authentic driving experience that takes simulation to a new level

When companies need to train a fleet of drivers, test a new vehicle in R&D, or give a test drive to a potential customer, using a real car or truck isn't always feasible. Maintenance and soaring fuel costs can make it economically prohibitive. And training for dangerous road conditions can put drivers at risk.

The solution for many is driving simulators. Their versatility, cost effectiveness and ability to safely test drivers in critical events make them an all-round intelligent option. However, driving simulators are not without their limitations. In fact, they are widely regarded among experts as some of the most challenging simulators to build because they require very accurate and precise feedback – more so than flight simulators. The vibration and accuracy of high-frequency movement needed by driving simulators can be challenging for traditional motion-based solutions.

To give all simulators the ability to leverage motion, a team of designers at D-Box has developed an affordable option that is easy to integrate. This Montreal-based company started turning heads in the entertainment industry back in 2009 with its innovative, high-fidelity motion technology that synced the action on screen with the movement in the seat, giving movie-goers an immersive experience that has no equal, even today. Over the years, the company has been successfully applying that same technology to simulation and training in the military, air force and automobile industries to become a world leader in immersive motion technology.

For driving simulators, D-Box allows users to quickly and affordably integrate an out-of-the-box motion system into their simulation engine and deliver a true-to-life physical experience from a wide variety of driving scenarios.

Nicolas Akarsu is head of export sales and international business development at Ediser, a leader in driver training and simulations. His company utilizes D-Box-enabled simulators to give trainees motion-based feedback on their driving performance.

"The D-Box Platform reproduces the real-time movements and driving sensations of a vehicle in its environment according to the actions performed," declares Akarsu. "Various movements during acceleration or deceleration, or actions such as pitch or roll, are all faithfully simulated. Irregularities such as road vibrations and jolts (curbs, potholes, speed changes, skids, etc) can also be simulated, providing more realism."

POSITION: D-Box's out-of-the-box motion systems are accomplished yet affordable

ABOVE: Ediser claims to have the most comprehensive simulation system for driver training in Europe, thanks in part to its D-Box Motion Systems

The experience is so true to life that the French Ministry of Transportation recognizes one hour of training in Ediser's simulator as one hour of in-car training. Instructors have noted that training in the simulator is much more efficient, especially when it comes to training students for specific situations. The fact is, it's much safer and easier to create such situations in simulation than it is to drive around searching for different scenarios and conditions.

Robert Mcginnis, senior account manager at Mechanical Simulation's CarSim division, is a proponent of D-Box. "I have nothing but good things to say about D-Box. The failure rate is non-existent. Everything works first time and we have never had a failure in the field. This is important because our QuadDS system from D-Box is used at trade shows, high-visibility marketing events and other technical demonstrations where downtime is not acceptable."

For D-Box, these testaments are proof that their motion technology is able to tackle the challenges of the automotive industry head on.

In fact, creating an authentic driving experience in a cost-effective way is, by all accounts, an advantage unique to D-Box that can't be simulated.

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To learn more from D-Box, visit ukimediaevents.com/info/vdm ref. 010

Rapid digital measurements

Make testing faster and more efficient with DTI technology from **Kistler**

ABOVE: Kistler's DTI Logger: from analog to digital, with one cable for all connections

Vehicle dynamics and durability testing can be made faster and simpler. To this end Kistler, a leading provider of test solutions in the automotive development market, delivers integrated measuring solutions that feature its Digital Transducer Interface (DTI) technology.

Reliable tests are the essential basis for optimum vehicle development and engineering. The objective is to capture the exact measurements of a vast number of physical variables, and that's why many hours are often needed for each test setup. So is there a way to reduce the enormous time and expense needed to obtain precise measurements from vehicle dynamics, tire and durability tests? Many customers ask this question and Kistler, an expert in dynamic measurement technology, has come up with the answer.

One cable for everything

When you opt for Kistler's DTI technology, you can be sure that your test setup will be fast and efficient. Only one cable is needed to configure the sensors, transmit and synchronize the measurement data, and supply power. TEDS-assisted automatic sensor detection makes configuration even simpler. Installed position, calibration values and relevant physical parameters are detected automatically by the KiCenter (Kistler's measurement software), where they can be configured. All this results in guaranteed maximum process reliability and efficient use of engineers' time.

End-to-end, from sensor to software

DTI technology makes use of an end-to-end bus system for the entire application. Signals are digitized as required, and converted into a DTI signal. This takes place either directly in the Kistler DTI sensors, or via suitable Kistler DTI converters if sensors are already present. The sensor data is fed into the central Kistler DTI logger – with no risk of interference – and is then transmitted via Ethernet to the computer for recording.

Braking distance measurements

For brake path measurement with straightforward ABS braking to DIN 70028, Kistler offers a holistic measurement solution based on its DTI technology. Components include Kistler sensors and triggers, the DTIlogger and the KiCenter. Test setup couldn't be simpler, thanks to the 'one cable for everything' concept. KiCenter enables end-to-end configuration of all connected sensors, guiding users through the entire test with three sequential measurement data displays: before, during and after the measurement task. Among the benefits, users can focus fully on their work, and valuable time is gained on the test track.

A proven track record in safety testing

Several years have passed since Kistler successfully launched its DTI technology for vehicle safety testing, and more than 40,000 DTI channels are currently in use for crash tests. Based on the know-how gained from this experience, Kistler has consistently developed its proprietary DTI technology at its competence center in Wetzlar, Germany, matching it to the demanding requirements for vehicle dynamics and durability tests. Kistler is the first and only provider to deploy this advanced technology in this segment, to boost efficiency and enhance process reliability.

Set the bar

MVO has discovered that warm-forging creates many benefits for the manufacture of rack bars, including wider teeth and increased bending strength

In the past 15 years, enormous advances have been made in the area of electric power steering (EPS). Problems such as noise, reliability and lack of steering feel that dominated the first EPS applications have largely been overcome. The solutions have involved simultaneous developments in both software and hardware; in the case of the latter it includes changing the component design to reflect new loading and performance requirements.

At the rack bar level, there has been a focus on new steel grades, increased tooth size and lower – or at least more consistent – friction characteristics. Notably, steering gear mass has also tended to increase, which is not in line with the general downsizing in the market. Putting the different motor and drive systems aside, the rack bar has also contributed considerably to increased weight.

The only way to increase tooth size in conventional broached or milled rack bars with a set steering gear geometry is to increase the rack bar diameter, thereby making the teeth wider. Although the increase in tooth width is roughly proportional to the increase in diameter, mass increases with the square of the diameter. This increase in bar diameter therefore leads directly to an increase in mass as well as in housing size, which will also lead to greater mass. The extent of this weight increase is dependent on the size and type of steering gear; however, weight penalties in rack bars alone are in the order of 0.4-1.0kg. Accordingly, strategies for rack bar weight reduction that were fashionable 10 years ago for hydraulic power steering (HPS) are being considered once again.

Broadly speaking, there are three strategies for reducing mass in rack bars. The first is deep hole drilling of the shaft, a process that is very well established for HPS. Depending on the size of the rack bar, mass reduction of 300-600g is typical, although the hole diameter tends to be limited by the internal tie-rod thread diameter. It is also a slow process, taking 3-5 minutes.

The second strategy is to use composite, or two-piece, racks. The use of two-piece racks where the shaft is made of tube and welded to the solid tooth section leads to greater mass reduction than that achievable by deep hole drilling, but carries the cost penalty of a welding operation. The risk associated with a welded joint on a safety-critical part also has varying acceptance in the market.

ABOVE: The precision warm-forged rack bar (on the right) has forged teeth, giving a wider, deeper cross-section

The third option is a precision warm-forged rack bar. The classical steering rack bar has the majority of its mass in the shaft, where stresses are lower. The smallest cross-section is in the area of the teeth and the maximum stresses are typically found there, so with respect to mass and stress loading, the rack bar is inherently unbalanced.

Precision warm-forging allows the process to start with a smaller shaft. By forging the teeth rather than machining them, material can be moved to make a wider and perhaps deeper cross-section, leading to the desired wider teeth as well as increasing bending resistance.

Should weight reduction be of paramount importance, the shaft of a precision warm-forged rack bar can also be deep hole drilled, thereby achieving weight targets that are comparable to rack bars made purely from tube.

A distinguishing aspect of the forged rack bar technology is that the measures used lead to a fall in manufacturing costs in terms of reduced material purchase, process steps and waste.

MVO is a specialized rack bar manufacturer that has been producing warm-forged racks since 2012 and launched the lightweight forged rack technology in 2014. Keeping pace with demand has been challenging, and a second forging line with a 30% reduction in cycle time was commissioned at the end of 2016. As customers accumulate more experience with forged rack bars, they are also prepared to do some of the general machining and processing themselves as they are likely to have these processes in-house.

Offering semi-finished rack bars into the market allows for better use of existing resources and enables MVO to focus its investment on key processes with lower cost and higher output, again leading to a fall in costs, demonstrating that reduced weight and reduced cost do not have to be mutually exclusive.

Lamborghini Countach

The 1985 Lamborghini Countach 5000 Quattrovalvole couldn't possibly drive as well as it looked – or could it? By Adam Gavine

The angular bodywork and the promise of the exotic-sounding (in name and in roar) Quattrovalvole engine in the 1985 Countach 5000 were enough to earn it a prime spot on many a dynamicist's bedroom wall. While the 5000 is not the purists' choice compared with the more reserved original, which dropped jaws at the 1971 Geneva Motor Show, it was my favorite, largely due to its widened arches, huge rear wing and engine bored out past the magical 5-liter mark. For me, 'less is more' does not apply to a beast like the Countach.

Without doubt, the car had all the show, and indeed plenty of go with 455bhp, but the slim multi-tubular space frame chassis beneath the Countach's outrageous aluminum-alloy bodywork was also impressive. That mid-mounted V12 formed a major part of the Countach experience – and its 1,446kg unladen weight – but the engineers at Sant'Agata succeeded in achieving a weight balance of 41.5% front/58.5% rear.

Tubular steel double wishbones of unequal-length were mounted at the front on single-spring damper units, with a similar geometry applied at the rear with wider wishbones and double-spring dampers, all complemented by front and rear torsion anti-roll bars. The result was a surprisingly supple ride.

The trend toward larger wheels is nothing new, with the fronts growing from the 7in of the launch car to 8.5in by the time the 5000 was released, and the rears from 9in to 12in. Those Campagnolo wheels were shod with 225/VR15 and 345/VR15 Pirellis, and with non-assisted rack-and-pinion steering (3.2 turns lock to lock), they took some muscle to move from rest. Further hampering urban posing was the 13.64m turning circle, not to mention the 2m width and the rather minimal view through the letterbox-sized rear window.

While the styling of the Countach courted attention in town, it was happiest on the open road, where as the speed increased the steering changed from heavy and cumbersome to lighter, more alive, and more communicative – although reportedly perhaps a little too light at high speeds, suggesting some front-end lift.

An adoring public would have forgiven so-so handling just because the Bertone-styled body was so daring and beautiful, but the skill of Lamborghini's engineers ensured that the beauty of the car went more than skin deep. As amazing as Lamborghini's more recent cars are, none of them have quite managed to surpass the Countach's pin-up credentials.

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