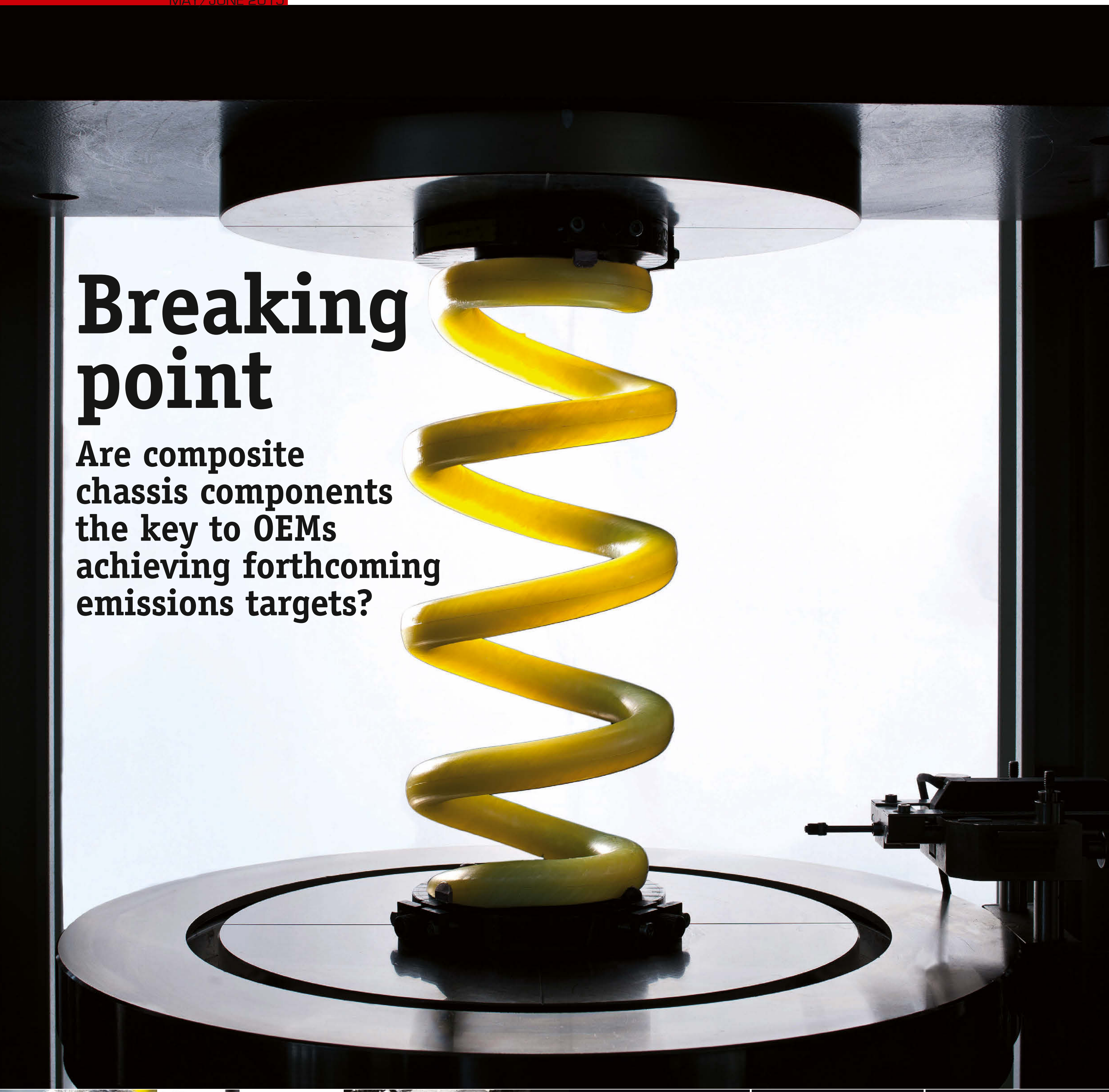
VEHICLE DYNAMICS INTERNATIONAL
www.VehicleDynamicsInternational.com
MAY/JUNE 2015



Breaking point

Are composite chassis components the key to OEMs achieving forthcoming emissions targets?

Vehicle Dynamics International Awards 2015

The results are in! We honor the best and most brilliant in the industry

Next-generation EPAS

An in-depth look at the development of electric power-assisted steering systems

Case study: TRE's new 7-post rig

How TRE's latest acquisition is helping motorsport and OEMs alike

COVER STORY

Lightweight components
26 Are composite chassis components the key to achieving EU emissions targets? And if so, what are the implications for vehicle dynamics?

What's new?
4 Cadillac CTS-V
With 648PS, CTS-V is the most powerful car in Cadillac's 113 years – and its most dynamic

8 Ford Focus RS
Developed under the One Ford program, the latest RS is the first to gain an AWD chassis

10 Honda NSX
Perhaps the most famous nameplate from Honda's history returns, with AWD and hybrid power

Columns
12 Home truths: John Heider
How true is the idea that you get what you pay for?

14 On the job: John Miles
The influences of rear-wheel steer

Awards 2015
22 The Vehicle Dynamics International Awards 2015 winners
Rewards for the year's finest technologies, vehicles and achievements in the dynamics arena

Features
17 Case study: TRE
Full details of Team Rosberg Engineering's latest addition: A seven-post chassis development rig

21 Case study: Ford's steering direction
Ford has created the world's first method of changing the steering ratio

38 Electric power steering
The latest advances in EPAS systems, and how they will influence car development

72 Dynamic legends
As Honda's NSX returns, we look at another iconic model from the Japanese OEM: the Integra Type-R

Interview
32 Frank van Meel, BMW M Division
Marc Noordeloos caught up with the former Audi man to discuss the future of BMW M models

Product & service profiles
44 Driver in the loop
46 Well prepared
48 Driving simulators
50 Volume control
52 CAE in motorsport
54 CFRP dampers
56 Combined sensors
59 Triaxal vibration recorder
61 Speedy dynamic testing
62 In-car measurement
64 Braking benefits
66 Mobile testing
69 High-quality bearings
70 Products & services roundup

Vehicle Dynamics International
Abinger House, Church Street,
Dorking, Surrey, RH4 1DF, UK
editorial tel: +44 (0)1306 743744
editorial fax: +44 (0)1306 875824
sales tel: +44 (0)1306 741200
sales fax: +44 (0)1306 743755
email: vehicledynamics@ukipme.com

Annual subscription £65/US$104

published by
UKIP Media & Events Ltd

EDITORIAL
Editor **John O'Brien**
Editor-in-chief **Adam Gavine**
Production editor **Alex Bradley**
Chief sub editor **Andrew Pickering**
Deputy production editor **Nick Shepherd**
Senior sub editor **Christine Velarde**
Sub editor **Alasdair Morton**
Contributors this issue
Graham Heeps, John Heider, John Miles, Andrew Noakes, Marc Noordeloos

ADVERTISING
Sales director
Mike Robinson
Publication director
Aboobaker Tayub
Publication manager
Paul Adam

DESIGN AND PRODUCTION
Art director **Craig Marshall**
Design team **Louise Adams, Andy Bass, Anna Davie, Andrew Locke, James Sutcliffe, Nicola Turner, Julie Welby, Ben White**

Head of production and logistics
Ian Donovan
Deputy production manager
Lewis Hopkins
Production team
Carole Doran, Cassie Inns, Frank Millard, Robyn Skalsky

CIRCULATION
contact **Adam Frost**
adam.frost@ukipme.com

CEO
Tony Robinson
Managing director
Graham Johnson
Editorial director
Anthony James

ISSN 1479-7747 *Vehicle Dynamics International*

Average net circulation per issue for the period January 1, 2014 to December 31, 2014: 7,917

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

A NOTE FROM THE EDITOR

When I was compiling the shortlist for this year's Vehicle Dynamics International Awards, the nominations from the industry in the Development Tool of the Year category took me aback. Two years ago, the nominations submitted were an even mixture of software and hardware. To a lesser extent, that applied to 2014's awards ceremony, too. This year, however, the submissions were mainly software-based, but in such a technological age, this shouldn't be particularly surprising.

At a couple of recent car launches, I've asked engineers about the percentage team split in terms of software engineers and engineers in the traditional sense. The response so far has been that there's a sizeable shift in weighting toward software engineers. This has its perks – one engineer told me that when he asked whether it was possible for the steering system to do 'X', the response he got was, "Not yet, but give me two minutes and the code will be there..."

This is probably akin to me waxing lyrical over the advent of the light bulb to most engineers reading this, but it did make me smile and ponder the possibilities of various components within a vehicle. I'm not a fan of electronics in cars – if I'm going to trash a car through over-driving it, I'd rather it be on my terms, not 500m further round the circuit after I've been lulled into that false sense of 'I've got this... No. No I haven't...!', brought on by the ESC/electronic diff/traction throwing a collective tantrum, braking and unbraking all manner of wheels in a vain attempt to recapture my 'heroics'.

My long-standing suspicion regarding the increased use of chassis electronics is these systems are simply there to mask basic faults with the car. Or to sound impressive on a spec list. Does a three-cylinder, one-liter car really need traction control or electronic stability control?

But the possibilities of tuning through electronics are endless, and have already set a precedent to an extent. ECUs have been looking after engines for years – and few have bemoaned the demise of the carburetor since. Maybe it's time for me to embrace electronic devices on vehicles, to stop being a Luddite and enjoy their function. Or, failing that, perhaps I should find myself a nice, mid-1960s Mini Cooper to commute in and truly return to the good old days.

John O'Brien

Vehicle Dynamics International is brought to you by UKIP Media & Events Ltd, publisher of *Engine Technology International*, *Automotive Testing Technology International*, *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 India, Automotive Testing Expo Korea, Professional MotorSport World Expo, Vehicle Dynamics Expo, Automotive Interiors Expo and Global Automotive Components and Suppliers Expo. To find out more, go to www.ukipme.com.

tedrive
Steering

TEDRIVE iHSA® ACTIVATES STEERING SYSTEMS

tedrive Steering has further developed the award-winning and patented iHSA® technology (intelligent Hydraulic Steering Assist) specifically for the commercial vehicle sector. The innovative iHSA® system facilitates a wide range of driver assistance functions, including active lane keeping, crosswind compensation, city mode, trailer stabilization, nibble compensation and joystick maneuvering. Integrated as a module into tedrive rack-and-pinion and tedrive recirculating ball steering systems, iHSA® technology offers commercial vehicle and bus manufacturers a high degree of design and functional flexibility for all hydraulic steering systems.

iHSA® – THE INTELLIGENT SAFETY ENHANCEMENT FOR ALL VEHICLE CLASSES

tedrive Steering Systems GmbH I Henry-Ford II-Straße 15 I 42489 Wülfrath, Germany
Phone: +49 (0) 2058 905-0 I sales@td-steering.com

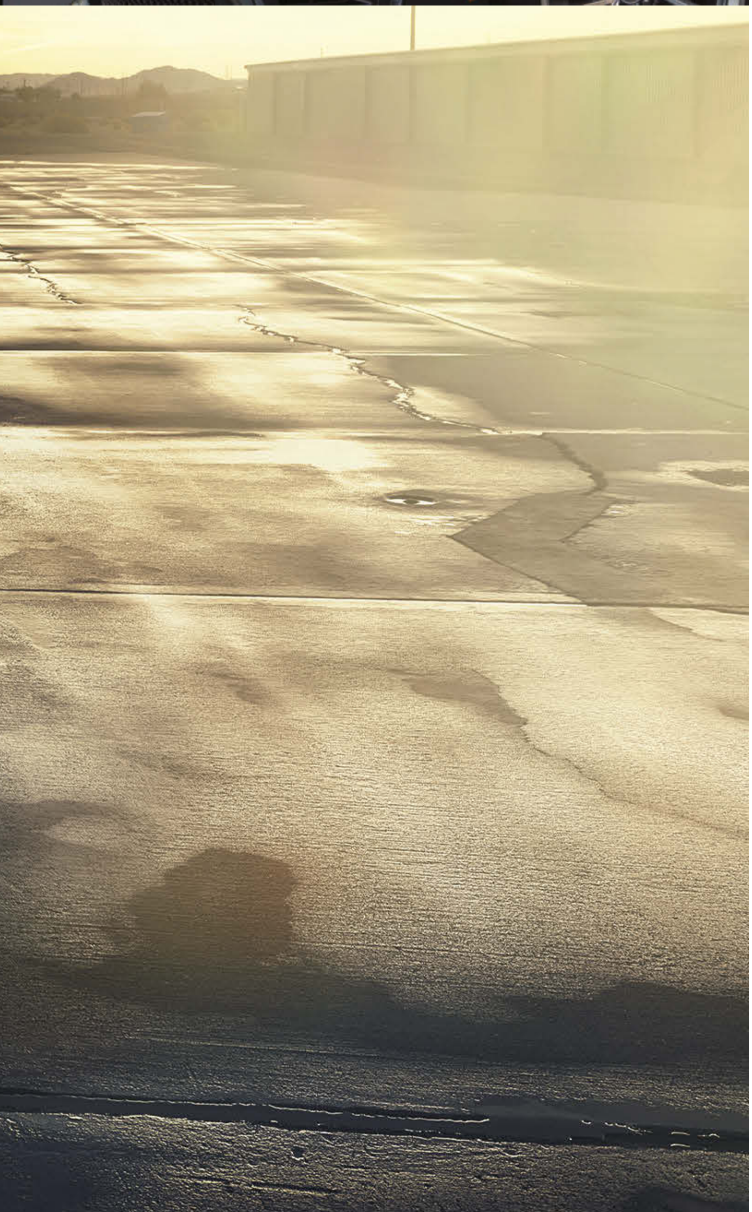
www.td-steering.com

American

"We've really paid attention to mass on the Alpha architecture, so everything about the car is as thin and small and purposeful as it can be"
Tony Roma, chief engineer, CTS-V program

dream

THE FIRST 200MPH CADILLAC IN HISTORY WILL TAKE TO THE ROADS AND RACETRACKS THIS SUMMER, PACKING 648PS AND A CHASSIS TO MATCH. BY **JIM McCRAW**



Cadillac recently introduced the 2016 CTS-V, the most powerful car in its 113-year history. With a supercharged 6.2-liter V8 closely related to that used in the Corvette Z06, the CTS-V will be rated at 648PS, 855Nm of torque and a top speed of 200mph.

The engine will be backed by a new paddleshifted 8-speed automatic transmission, featuring launch control and performance algorithm shifting that gives the new CTS-V a 0-60 performance of 3.7 seconds. Unique and revised body and chassis elements include a strut tower-to-tower brace, a strut tower-to-plenum brace, V-braces for the engine compartment, a strengthened rocker bulkhead, a stronger rear cradle-to-rocker brace, a Y-shaped aluminum shear panel at the front of the chassis, and upper tie bar-to-bumper braces. Taken together, these enhancements increase structural stiffness by 25% over standard models.

Chief engineer Tony Roma says, "We've really paid attention to mass on the Alpha architecture, so everything about the car is as thin and small and purposeful as it can be, so that we are the lightest in the segment. But when you make the car able to do the kinds of things that this car can do, it needs higher chassis stiffness for the car to feel right and do its job. We are trying to make the linear-range handling [envelope] as large as possible, pushing it out as far as possible. We have to have chassis stiffness to make that happen."

The CTS-V shares the same 2,910mm wheelbase as the CTS base models, but has wider front and rear footprints, 18mm front and 13mm rear, to enhance grip, reduce body motion and generate more direct steering.

For best bite, the CTS-V uses 9.5 x 19in alloy front wheels, 10 x 19in rear wheels and Michelin Pilot Super Sport 265/35ZR-19 front and 295/30ZR19 rear tires to give the CTS-V nearly 1*g* in lateral acceleration. The aluminum wheels are made of a low-mass forging 45% stiffer than previous CTS-V wheels, while the Michelin tires feature a tri-compound tread designed for the best combination of grip and wear.

A revised multilink double-pivot MacPherson strut front suspension delivers a quicker response and increased lateral control, incorporating hydraulic bushings, where traditional elastomeric bushings are replaced with zero-compliance cross-axis ball joints, higher-rate springs and a stiffer stabilizer bar for 20% greater roll stiffness.

The ZF Servotronic II variable-ratio electric power steering gear, with 14% greater system stiffness yields an improved feeling of precision and greater driver feedback. Roma says, "It's a belt-driven, rack-mounted electric power steering that has a unique ratio spread, much more aggressive, with fewer turns lock to lock."

Cadillac's five-link rear suspension features reduced roll center migration, stronger lateral control and anti-squat geometry, complementing the front suspension with greater body motion control. Contributing components include stiffer bushings, new cradle mounts, higher-rate springs and a stiffer stabilizer bar.

A standard electronic limited-slip differential supports optimal traction and enables maximum corner exit acceleration.

Roma says, "The geometry is basically the same, but the front tire is spaced out further with a larger spindle length than the base car.

We couldn't grow it in toward the strut, so we had to grow it out. That changes the kinematics of the front suspension. The same thing happens in the rear suspension. By moving it outboard, you get slightly different kinematics. We've taken compliance out. Even though we've retained the compliant bushings, we've made them as aggressive as possible to give the car that bimodal performance."

Larger prop shafts and greater half-shaft asymmetry (a stiffer, shorter driver's side shaft) are used to mitigate power hop during acceleration, with the larger shaft more than twice as rigid as the smaller shaft. "We purposely drive them to get out of phase with each another when they would otherwise want to hop," says Roma. "We have electronic controls that will come in and mitigate if the car does get into that mode. By having asymmetry and getting the tires out of phase with each other, we can then use the clutch in the limited-slip differential to help dissipate that energy. You force the tires to work against each other and use the clutch in the differential to remove the energy."

The Brembo brake system on the CTS-V includes two-piece 390mm front rotors with staggered six-piston calipers and 365mm rear rotors with four-piston calipers.

Importantly, the CTS-V features third-generation magnetic ride control and performance traction management. Four driver-selectable settings – Tour, Sport, Track and Snow – electronically optimize the car for driving conditions. Performance traction management is offered in Track mode and features five settings of torque reduction and brake intervention for track driving, including a 'completely off' mode that retains ABS braking.

The latest GM magnetic ride control reads the road a thousand times per second, sending data to magnetorheological fluid-filled dampers that can independently control the damping characteristics on all four corners, enabling 40% faster damping response. At 60mph, the third-generation system calculates optimal damping force once every inch.

The third-generation MRC system, says Roma, uses two wires going to each damper instead of one, "so we can move current in both directions. We can actively build up the magnetic field or actively tear it down. On previous versions, we only had one wire and one magnet, so we would drive current into the magnet, build up a large magnetic field with one large magnet, and not drive current, letting the magnetic field collapse on its own. With the new system, we have two smaller magnets, two smaller magnetic fields, and we control the current flow. It's three and a half times faster going from full jounce to full rebound. We are monitoring 130 different parameters every inch." He says that the system automatically prevents any serious brake dive because the ABS system communicates directly with the MRC system.

Roma says that the final Cd, aero lift and aero drag numbers of the CTS-V haven't been worked out yet. "The drag number definitely won't be an improvement over the standard CTS and that's because of the front-end airflow required for cooling. On the base cars, we have grille shutters, but on the V series, even a small amount of loss couldn't be tolerated. The wider tires add to the drag problem. We also pay a premium for lift because of the speed capability of the car. With the optional carbon fiber package, the car is close to neutral in terms of lift. We will have our final lift and drag numbers after we take the car to the Windshear rolling-road wind tunnel."

The Performance Data Recorder in the CTS-V, custom-made for the car by the Pi Instruments division of Cosworth, enables drivers to record high-definition track video, with a wide range of on-screen data overlays of their driving experiences, a system shared only with its cousin, the C7 Corvette Stingray.

SPECIFICATIONS

Cadillac CTS-V
Dimensions: 5,021mm (L) x 1,833mm (W) x 1,454mm (H). Wheelbase: 2,910mm. Track width: 1,577mm (F), 1,554mm (R)
Curb weight: 1,880kg (52.7/47.3 F/R split).
Powertrain: 6,162cc supercharged V8. 648PS @ 6,400rpm, 855Nm @ 3,600rpm
Steering: ZF rack-mounted electric, power-assisted with variable assist. Ratio 15.5 (on center) to 11.2 (full lock). 2.37 turns, lock to lock
Brakes: Brembo six-piston calipers (F) four-piston calipers (R). 390mm two-piece discs (F), 365mm two-piece discs (R)
Wheels: 19 x 9.5J (F), 19 x 10J (R)
Tires: Michelin Pilot Super Sport. 265/35 ZR19 (F), 295/30 ZR19 (R)
Performance: 200mph (321km/h) top speed. Acceleration 0-62mph (0-100km/h) 3.7 seconds

***VDI* SAYS**

The super-sedan segment has really come alive over the past few years. Once the sole reserve of the German 'big three', Cadillac is showing that fast sedans don't have to carry AMG, M, or RS badges to be credible...

Focused attention

ABOVE: **GKN DRIVELINE'S POWER TRANSFER UNIT FORMS PART OF THE FOCUS RS's DRIVETRAIN**

THE NEW-GENERATION FORD FOCUS RS IS THE FIRST TO GAIN AN ALL-WHEEL-DRIVE PLATFORM, AND THE FIRST TO BE BUILT UNDER THE 'ONE FORD' PROGRAM

Ford has been on a roll lately, introducing several high-performance models to much applause. The restructuring of its performance divisions around the globe also means that engineers from all corners of the world now have input into Ford's new car development programs.

The first performance model to be unveiled from this One Ford program is the Focus RS, which marks a significant departure from previous RS models, by adopting an all-wheel-drive (AWD) layout, rather than front-wheel drive.

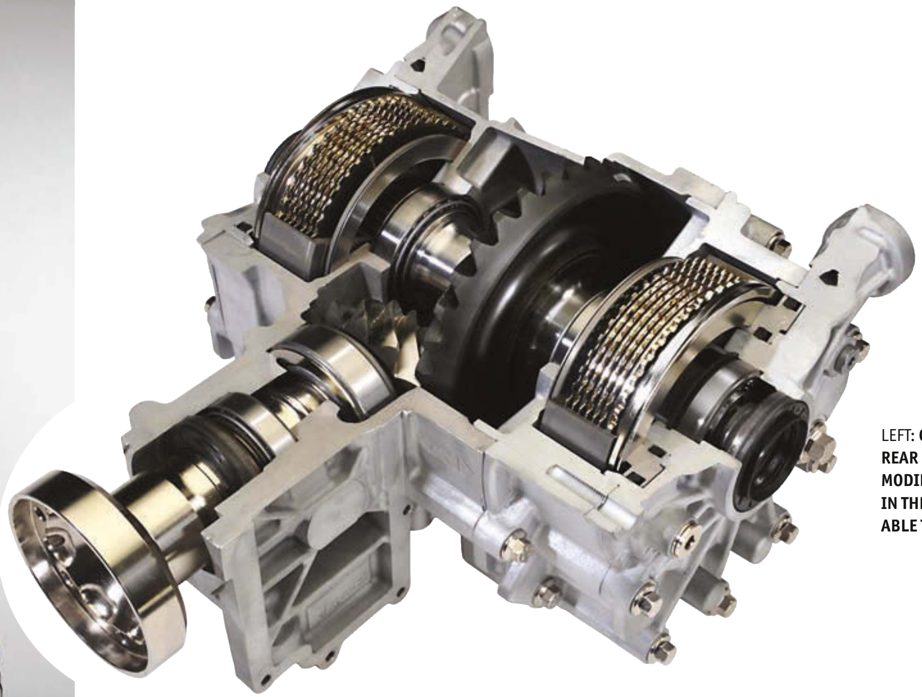
"When I got this job, two and half years ago, I began with discussions and meetings about what the Focus RS should be," explains Tyrone Johnson, vehicle and engineering manager at Ford Performance, a new division that brings together the old Team RS, Ford SVT, and Ford Racing operations. "Originally, it was set in the Ford cycle program as a FWD program. After a couple of months of discussions, convincing arguments, and late night presentations to Raj Nair [Ford's group vice president and CTO], we managed to convince everyone that AWD was the way to go."

The AWD system selected for use in the Focus RS is an evolution of GKN Driveline's Twinster system, as found in the Range Rover Evoque. "The first prototype that we built, we took one of GKN's prototype systems, installed it in our car, and that is the thing that convinced us we needed to go AWD," continues Johnson. "But, we soon failed that part as it just wasn't strong enough. We were asking a lot of things from this part that Land Rover simply wasn't at the time, in terms of torque transfer."

The revised AWD system implemented in the Focus RS allows up to 70% of torque to be distributed to the rear wheels, with up to 100% of that figure being diverted to either of the rear wheels, depending on circumstance.

"It's a very simple system," explains Johnson. "The rear drive unit is not a differential in the traditional sense, because it simply has a drive shaft coming in, and through the use of a worm gear, it transfers the torque right or left. But between that transfer, there is a clutch pack on both sides, and that clutch pack decides whether the torque is transferred or not."

Modifications to the car, made in order to accept the AWD platform, were surprisingly limited, thanks to the bloodline of the chassis. "The car is on the C1 platform, which is what is under the Kuga, C-Max, etc," states Johnson. "It was created 15 years ago when Volvo and Mazda were both part of the Ford Group. It was the platform for the Mazda 3, and the



LEFT: **GKN DRIVELINE'S TWINSTER REAR DRIVE UNIT (RDU) HAS BEEN MODIFIED BY FORD FOR APPLICATION IN THE RS, ALLOWING THE CAR TO BE ABLE TO 'DRIFT' AROUND CORNERS**

Volvo S40 and V50, which were all created in Cologne. Volvo insisted that the platform had AWD capability at that time, although there was no interest from Ford for an AWD application, but that has really benefitted us now.

"The rear subframe on this car is something we created for Volvo too, back when we were together," he adds. "We never used it, but Volvo did on some applications. We took that as it slotted right into the C1 platform, and we made some modifications to it so it will accept the RS's anti-roll bar and the GKN system. Fundamentally it allowed us to start at a point that wasn't 'absolute zero'.

"There's a certain beauty in that, as a new subframe would cost in the region of US$6-7m worth of investment," he continues. "We didn't have that money, and we had to look at other solutions."

The car's steering system is also a marked departure over previous models, in that this is the first RS to gain fully electric power steering. "The previous generation was electrohydraulic," explains Johnson. "The RS system does differ from the standard car's EPAS, as that has a variable assist. For the RS, we've removed that variability as we felt it detracts from the car. We have a linear rack on the car now."

Ford worked with Michelin to develop a choice of high-performance 235/35R 19 tires. As a result, the car will be offered with Pilot Super Sport tires as standard, with the option of Pilot Sport Cup 2s for owners who have track time in mind. These tire choices are wrapped around 19in lightweight, forged alloy wheels.

Behind the lightweight wheels is an all-new brake system by Brembo. In comparison with the previous generation car, the ventilated front brake discs are marginally bigger in diameter, now measuring 13.78in, up from 13.23in. These discs are specified in combination with aluminum four-piston calipers.

With track use being identified as a distinct possibility for many potential RS owners, Ford has ensured that the brake system is properly cooled. Two 'jet tunnel' stylized ducts in the front bumper direct cool air on to the brakes. This effect is enhanced through the use of dedicated airflow guides mounted to the lower suspension arms.

The front suspension setup for the car is largely new. "Because we've had to install the power transfer unit, the front suspension location has changed, and so we had to make a new knuckle to get the steering curve we wanted," states Johnson. "We've also fitted new, shorter steering link arms."

As with the previous RS, this third-generation car's dampers are supplied by Tenneco. Unlike previous versions, however, the new car makes use of Tenneco's dual-mode dampers, offering a dedicated track setting. Ford states that the system is 'marginally' more comfortable than the previous car, while the 'sport' mode is significantly harder.

When it came to benchmarking cars for the Focus RS, Ford turned its attention to two cars that helped redefine what a fast car should be. "We looked at the Subaru Impreza and Mitsubishi Evo," says Johnson. "We also looked at the modern versions of those ex-rally type cars, such as the Golf R and the Mercedes-Benz A45 AMG."

Johnson believes that the next RS entertains more than it's modern counterparts, which he feels fall a bit flat in terms of dynamic ability. "We bought a Mercedes-Benz A45 AMG," he concludes. "As when it was being announced we all thought 'Hmm… 360bhp, that'll be the thing to have…' But, it's boring. Very boring. The engine's good, but that's about it."

***VDI* SAYS**

Widening the Focus RS's appeal, and availability, may be a smart move for Ford. With many performance car owners looking to downsize, the RS may deliver the 'bang-per-buck' ratio that many seek...

ABOVE: **THE ONE FORD PROGRAM HAS SOFTENED THE RS's APPEARANCE, BUT IT HAS GAINED EFFECTIVE AERODYNAMIC DEVICES**

Welcome return

HONDA HAS LONG PROMISED A REPLACEMENT NSX AND, 25 YEARS AFTER THE DEBUT OF THE ORIGINAL, THE NEXT-GENERATION JAPANESE SUPERCAR IS FINALLY HERE

ABOVE: **HONDA'S ADVANCED SPORTS PACKAGE PLACES KEY HYBRID COMPONENTS LOW WITHIN THE CHASSIS SO THEY DO NOT IMPEDE ON THE CAR'S CENTER OF GRAVITY**

While on the face of it there is little more than a nameplate to link the all-new Honda NSX to the previous 1990s iteration, the new car has actually been heavily influenced by the original 'everyday supercar'.

The first big difference between the two generations is that the all-new car has been developed principally in North America, rather than Japan.

The second big difference is far more noticeable though, as the NSX is now a hybrid supercar. Unlike other Honda hybrids such as the Insight, Accord and Jazz, this hybrid system has been exploited for performance gains, and has been designed in what Honda refers to as an 'Advanced Sports Package'.

Honda's engineers have placed key hybrid components low within the chassis, to keep the car's mass as low as possible. Honda is slowly releasing information on the NSX, but does state that this principle has helped the NSX achieve the "lowest center of gravity in its class", and one that is "more than one inch" lower than the original NSX.

In terms of dimensions, despite the switch to a longitudinally mounted internal combustion engine, the new NSX is just 1.8in longer overall, while its wheelbase has increased by 3.9in to 103.5in.

The original car's all-aluminum chassis has been replaced with a multi-material space frame, which mixes high-tensile steel with composites and aluminum. The chassis' internal frame is constructed of aluminum, and is anchored to a carbon fiber floorpan.

The original NSX achieved its performance through its lightweight, rigid structure, so the NSX team started with that principle again as the foundation for the car.

Ted Klaus, chief engineer on the NSX project, saw the key consideration as, "How can we take mass out of any component, but keep the long-term rigidity and robustness?"

As a result, Honda has used ultra-high-strength steel in a continuous three-dimensional shape that comes from the base of the front suspension, all the way up to where it meets the B-pillar.

"The idea of a carbon tub was available to us, but the aluminum-intensive approach, especially when we considered it from a price point, had several advantages," he continues. "We knew we could meet our development target, in terms of torsional rigidity with the multimaterial spaceframe, and there were some concerns with regard to carbon fiber's long-term robustness."

Honda wouldn't give exact figures for the NSX's torsional rigidity, other than stating that it surpasses that of the Audi R8, Ferrari 458 Italia, and Porsche 911 that it was benchmarked against. "I do worry when I mention benchmarking, as there's always the assumption that you are driving those cars simply to copy them," says Klaus. "Much like the original NSX against the Ferrari 355, there's a distinctively different character in the driving experiences. And, much like the original, our intention is to make it accessible. So the performance should be accessible and exploitable."

That accessibility has been achieved through the use of electronics, and by using the hybrid

powertrain to bolster performance. The 2015 NSX uses an evolution of its 'super-handling all-wheel drive' (SH-AWD) in which two electric motors, mounted in either wheel on the front axle, are used instead of the usual combustion engine powered mechanical driveshaft and clutchpacks. This system is used in conjunction with Honda's agile handling assist (AHA) system, which applies brake torque to the inside wheels when turning.

While the second-generation NSX is all-new, several design ideas have been carried over from the previous-generation car. The use of independent, all-aluminum double wishbone suspension all-round is one familiar feature, as is the use of staggered wheel sizes.

Honda wouldn't elaborate on the suspension setup, beyond that it is a conventional multilink arrangement, which utilizes magnetorheological dampers. The staggered wheel sizes see the NSX fitted with 19 x 8.5in (front) and 20 x 11in (rear) lightweight, aluminum alloy wheels, wrapped in 245/35Z19 and 295/30R20 Continental ContiSportContact tires, respectively. Much like the original NSX, the 2015 model also debuts several new manufacturing techniques. Honda states it has created technology that combines the design and manufacturing flexibility of casting, with the strength and elongation properties of forging.

"What we've done is bring together the best properties of those two processes," concludes Klaus. "We are now able to create a casting that is very thin-walled, but also strong. It enables us to then place that casting within the vehicle, and properly model it to take on forces that could cause stretching or elongation, without the concern of a brittle fracture."

ABOVE: **THE NSX'S STYLING ACCENTUATES THE WIDE AND LOW DESIGN OF THE CHASSIS**

***VDI* SAYS**

Honda's intention with this all-new NSX is to deliver dynamic performance similar to the 458 Italia, but at a price point closer to the 911. If Honda achieves that, another icon could be born.

Technology gaps

THE 'PAY FOR/ASK FOR' RELATIONSHIP IS ALIVE AND WELL IN VEHICLE DYNAMICS, SAYS JOHN HEIDER

The commonly used colloquialism "you get what you pay for" when invoked by vehicle dynamics development engineers is usually uttered in disdain when realizing the component at which he or she is staring is either broken or not functioning as intended. The reason for the under-performance of the component may indeed be ultimately traced back to cost, but it also may be traced back to the closely related corollary "you get what you ask for". The two may be related, but many times this relationship is not as close as one would expect.

> The 'pay for/ask for' relationship generally holds true for EPAS systems; don't expect best-in-class performance if you select the cheapest system

Working with vehicle manufacturers both large and small, mature and startup, experienced and inexperienced, has demonstrated that large gaps exist in technologies that are made available to manufacturers by suppliers. These gaps exist for three main reasons: highly capable suppliers choose not to offer certain technologies to a manufacturer for any number of reasons; less capable suppliers only offer what they can to a manufacturer; or a manufacturer is not experienced or aggressive enough in its specifications to either type of supplier. Regardless of the reason, the end result is a vehicle that is not optimized for either the manufacturer or the customer.

Tire development programs are conducted in similar fashion at most major manufacturers: tire functional targets for vehicle dynamics and NVH are established versus an existing control tire; wear, rolling resistance, weight, cost, uniformity and other targets are established; and the tire supplier progresses through a series of prototype tire submissions to the manufacturer until all targets are met. This is a well-established process, with the major tire suppliers and major vehicle manufacturers having a good understanding of the expectations of each other. This is not to say contentious issues don't arise, but solutions are normally worked through jointly until both parties agree the final solution is acceptable. This process has recently gone awry a number of times as new or quickly growing manufacturers have engaged less experienced tire suppliers. Case in point on a recent program: limited targets were established at the beginning of the vehicle program by the manufacturer, limited choices were available for rubber compound and mold design, coupled with little experience developing the internal construction details at the tire supplier, resulting in a predictable outcome: cost and weight targets for the tire were met – and that was about it! Similar blind-leading-the-blind examples can occur on virtually any chassis component. If you are not a major vehicle manufacturer who has the internal supplier relations capability to develop a new, inexperienced supplier, you will get much further ahead by engaging experienced suppliers whose own internal standards will protect you from impending doom on your future vehicle.

Engaging highly experienced and capable suppliers is certainly a step toward the success of a vehicle, but this positive step can be undermined by setting poor functional and cost targets. Electric power assisted steering (EPAS) has become the norm in virtually all vehicle classes in mature markets across the world. With similar or more mechanical complexity than a hydraulic system, coupled with complex control algorithms including virtually an infinite number of combinations of two- or three-dimensional calibratable parameters, the specification and development of an EPAS system can be daunting. With most major EPAS suppliers on their fourth or fifth generation system, vehicle manufacturers need to ensure the specifications created for the system for a particular vehicle match the expected functional performance. Maximum tie rod force required? Should be a straightforward question, sometimes is not. Catch-up specification? Calibration capability for small or large angle returnability, damping, torque hysteresis, drift/pull compensation, nibble compensation, other? All these items need to be taken into consideration when specifying a system. Additionally, if you are specifying a column-assist system, the manual gear specifications cannot be ignored. The 'pay for/ask for' relationship generally holds true for EPAS systems. Don't expect best-in-class performance if you select the cheapest system.

Vehicle manufacturers are obviously providing the path-to-market for suppliers and their products. Unfortunately there are sometimes large gaps in the technical capability between manufacturer and supplier, and the leader/follower relationship is not always readily apparent. Bridging these gaps is accomplished by each party being honest about their own internal capabilities, setting targets that are achievable for all attributes, and working together to jointly develop systems and components that are optimized for the vehicle.

LMS solutions for driving dynamics

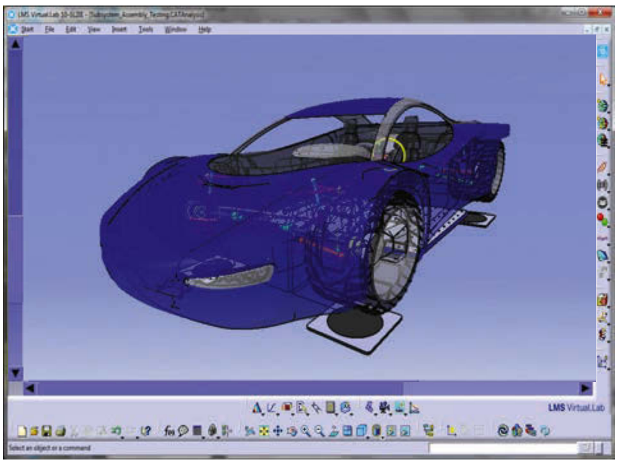
Balancing vehicle handling and ride comfort using real-time modeling technologies

LMS driving dynamics solutions offer an integrated approach to chassis and suspension engineering – one where vehicle handling, durability and NVH are optimized in parallel.

Thanks to the uniqueness of the LMS real-time simulation technologies using the exact same high-fidelity model able to maintain the complexity of the suspensions and subsystems (steering, brake, shock-absorber, etc.), LMS solutions support engineers in the development of design and validation of the complete real-time vehicle models chain, starting with model-in-the-loop, then moving to software-in-the-loop, up to hardware-in-the-loop.

We can guide you in all steps of the process of vehicle design, including preprogram benchmarking, target setting, concept development, detailed chassis development and prototype refinement of suspensions and steering system characteristics as well as controls integration.

For more information, please visit **siemens.com/plm/lms**



Using LMS Imagine.Lab Amesim and LMS Virtual.Lab Motion, engineers can quickly and accurately model and simulate vehicle dynamic behavior in real-time.

Realize innovation.

On the job

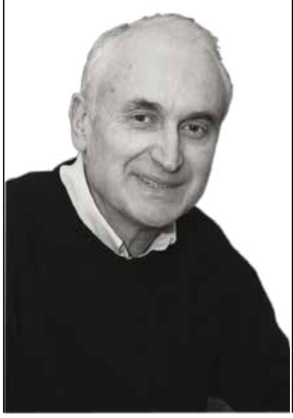
WITH MODERN STEERING AND SUSPENSION SYSTEMS IN A PRETTY WELL-POLISHED STANDARD TUNE, **JOHN MILES** EXPLAINS THE SIZEABLE INFLUENCE THAT YAW BEHAVIOR HAS ON STEERING FEEL

Most of the deficiencies inherent in early EPAS systems have now been designed out, leaving a Pandora's box of realistic steering tunability, and feedback control available at the touch of a button. Meanwhile on the car side, K&C rig measurement of pretty much every suspension stiffness and kinematic parameter is now considered run-of-the-mill stuff. So apart from the mysterious workings of damping, Ackermann angles, and the dramatic effect that tires can have on steering, we are left with the rear suspension as the highly influential, yet less well-understood element of the steering feel/response conundrum.

My view is that if a car is excessively restrained in yaw by virtue of heavily understeering (toeing in) rear-axle steer characteristics, a response 'dead band' will be felt through the steering wheel, because it will require an increased slip angle on the front tires (felt only as steering wheel torque gain and not response) before the car will change direction. Increased rear-axle kinematic and compliance toe-in can be driven by the need to counter the harshness effects of ultra-low profile tires. The reasoning goes like this: more compliance for comfort = less response = a requirement for more understeer (toe-in steer) and perhaps camber, to gain back response = worse steering feel. Yes, 17in and 18in wheels may look good on a family car, but are they worth the reduced aligning torque, increased tread wear, suspect hydroplaning resistance, much greater cost, susceptibility to rim damage, and greater sensitivity to suspension set up? Not to me.

Modern family cars seem little more refined than those of 10 years ago unless fitted with the base model tires. My base model Ford Focus 1.6 Edge is a case in point. It's certainly quieter than the previous model, but its mid-range handling finds me running wide in corners and countering a peculiar high-speed mild wandering, plus the very clear steering dead band around center. The same rear-axle steer effects often cause a sharp (but lagging) lateral acceleration build-up at the rear axle in transients, when occupants' heads get thrown hard sideways – a nervous characteristic that Lotus engineers struggle to mitigate so often on Far Eastern prototypes. All these effects relate strongly to steering delay, lane change overshoot, and consequent out of phase corrective action – a 'tank slapper'.

"We are left with the rear suspension as the highly influential, yet less well-understood element of the steering feel/response conundrum"



There are no easy answers. The battle remains between road noise attenuation and steering/handling at all speeds. Good low- to middle-speed maneuverability (high yaw gain) is coincident with good steering feel, but will require minimal, if any, rear-axle understeer, while at high speed, stability demands require increasingly fast rear axle response, hence the push for active rear steer on high-performance cars.

During my time at Lotus, particularly during GM ownership, we did quite a lot of work with active rear steer (using Lotus's suspension 4x4 Esprit look-alike research vehicle, SID) where rear steer could be programmed to modify all aspects of yaw behavior at any chosen speed. Of course it became blindingly obvious that miniscule adjustments in rear steer had major effects on chassis dynamics, only confirming what we know already from tuning the FWD Elan, Esprit S4S, Esprit Sport 300, Lotus Carlton and others. And herein lies the problem. We are talking about maximum adjustability of say ±7', almost within the setup tolerance of the suspension in the first place, nevermind the dramatic effects of switching rear (or front) wheel steer signs from toe-in to toe-out. To me, this says that active rear steer can only be thought about on suspension with extremely solid or almost solidly jointed links throughout, eliminating most, if not all, everyday cars. So for hypercars, I end up asking, "Why not make all the suspension links ball-jointed, i.e. just stick road legal tires on a race car suspension?" Active rear steer also raises searching questions concerning failure modes when a more practical solution to modifying yaw behavior might be an e-diff, as used on the Ferrari 458 and even some VW family cars.

Steering system suppliers deal with their systems, and are not equipped to dig this deep. It's not their job to test tires! Steering feel/absence of response delay is inexorably linked to transient handling and thus yaw behavior, and, in turn, rear-axle behavior. Ultimately it comes down to the quality of the design, and development engineers who understand the myriad subsidiary elements that affect steering attributes and transient stability. That's the brilliant thing about chassis development: measure and analyze all you like, but there will always be room for us ancient chaps who just might know something the youngsters don't.

ActivRak™ – Variable Ratio Steering Rack

for Cost Efficient Active Steering Feel

- LARGEST FLEXIBILITY IN STEERING RATIO DESIGN
- SUITABLE FOR WIDEST RANGE OF STEERING APPLICATIONS
- PIONEERED VARIABLE RATIO RACK & PINION TECHNOLOGY
- LARGEST INDEPENDENT EUROPEAN STEERING RACK SUPPLIER
- ACTIVE STEERING FEEL FOR STANDARD STEERING COST

Winner of:

VEHICLE DYNAMICS INTERNATIONAL WINNER Innovation of the Year 2008

and Winner of the 2008 "BorgWarner Louis Schwitzer Award" for use of this technology in IndyCar® Series

MVO GmbH
Metallverarbeitung Ostalb
BISHOP TECHNOLOGY INSIDE

www.mvo-g.de

ABOVE: **A FORMULA 3 CAR ON THE NEWLY OPENED RIG. THE WHEEL ACTUATORS OFFER 36KN OF DYNAMIC FORCE, THE AERO ACTUATORS 29KN**

Super Seven

TEAM ROSBERG ENGINEERING (TRE) IS EXPANDING ITS DYNAMIC TESTING ABILITY WITH THE ADDITION OF A NEW 7-POST CHASSIS TEST RIG. BY **GRAHAM HEEPS**

A new 7-post chassis test rig has just opened to customers at TRE in Neustadt an der Weinstraße, Germany. Together with a new damper dynamometer, the rig fills a gap in TRE's suite of tools for chassis development.

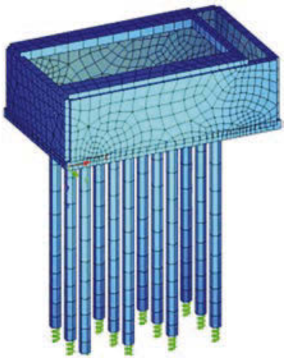
TRE began in 1997 as TR-Engineering, an offshoot of Team Rosberg. This race team had been set up three years previously by Keke Rosberg, the 1982 F1 World Champion and father of current Mercedes F1 racer Nico; it still competes in DTM and GT racing. Since 2008, TRE has been a joint venture with IAV, which now owns 51% of TRE and is itself 50% owned by the Volkswagen Group.

Vehicle dynamics is a particular area of expertise for TRE, but until now its test activities were confined to the road, track or computer screen. The company says that its Servotest-supplied 7-poster and damper dyno complete the loop for its OEM and motorsport customers.

"We can already design suspension layouts and do multibody simulation of dynamics and ride comfort in-house using Adams/Car," explains Eckardt Döhrer, TRE's managing director. "We also have a large prototyping workshop in which we can build up complete chassis, and we have a testing department that does in-car testing and has three AB Dynamics steering robots. We do a lot of homologation testing for the big car manufacturers – FMVSS and ECE tests, for example. The next step is this completely new building for rig testing."

Careful analysis of the terrain led to the use of a 200 metric ton seismic mass to ensure a stable rig and proper isolation from the surroundings. The mass consists of 12 concrete piles, each 8m long with a diameter of 65cm. The extensive groundworks were largely complete by November 2014. Calibration and commissioning of the

BELOW: **THE SEISMIC MASS FOR THE RIG CONSISTS OF 12 CONCRETE PILES, EACH 8M LONG WITH A DIAMETER OF 65CM**



ABOVE: **THE FOUNDATIONS TAKE SHAPE NEXT DOOR TO TRE'S EXISTING FACILITY IN NEUSTADT**

hydraulic 7-post rig were underway by mid-January, with the first customer through the doors in mid-February.

Döhrer expects the new facilities to appeal to OEMs – who make up around 80% of TRE's business – and racers alike, including Formula 1, touring car and sportscar teams. "We work for all OEMs, not only Volkswagen," he stresses. "We are integrated into IAV and completely independent of car manufacturers, as well as of suppliers such as damper manufacturers, which is important for this project."

Former KW automotive 7-post engineer Martin Malinowski has been hired by TRE to run the rig, which can measure everything from a formula race car to a Sprinter-sized van thanks to variable wheelbase and track width. There is also enough actuator travel to measure SUVs and rally cars: "Most rigs have 75mm amplitude but our wheel actuators have 125mm (for a total displacement of 250mm)," says Malinowski.

The rig also boasts a built-in MAHA lift and an integrated leveling system for geometrical alignment of the vehicle before measurements are taken.

And at 300mm, the chassis and aero actuators offer even greater displacement than the wheel actuators. Meanwhile, the neighboring servohydraulic damper dynamometer takes advantage of the high-power circuits installed for the 7-poster to offer a maximum velocity of 6m/s.

"We have a lot of experience with vehicle dynamics," Döhrer concludes. "For a long time we've been setting up cars for the track and running simulations. Now we can validate our models on the test rig. It enables us to close the loop on the development process."

"We are integrated into IAV and completely independent of car manufacturers, as well as of suppliers such as damper manufacturers, which is important for this project."

Kistler MSW Sensors – The Next Generation of Measurement Steering Wheels.

Get Better. With Kistler.

960-207e-03.15

The introduction of new driving assistance systems calls for testing equipment that performs even better. Kistler MSW sensors meet the growing demands of modern automotive engineering perfectly.
Reduced in size and weight, they offer higher dynamics and increased resolution without impairing steering wheel functions (airbag) and control elements.

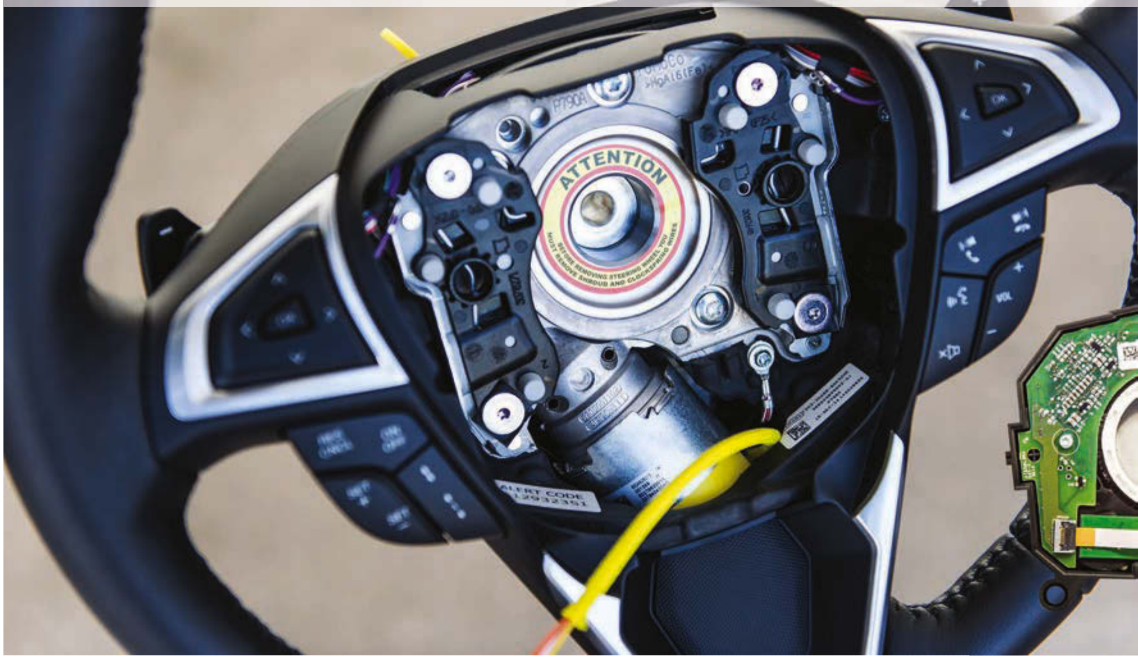
KISTLER

measure. analyze. innovate.

www.kistler.com

To the MAX

A UNIQUE ADAPTIVE STEERING TECHNOLOGY WILL DEBUT LATER THIS YEAR IN THE FORD S-MAX, EDGE AND OTHER MODELS. **GRAHAM HEEPS** GETS THE LOWDOWN



MAIN: **SYSTEM PACKAGING WITHIN THE S-MAX STEERING WHEEL**

INSET: **THE SETUP INCORPORATES A PRECISE STEERING ANGLE SENSOR**

BELOW: **FAS IS INDEPENDENT OF THE STEERING RACK. S-MAX HAS A BOSCH (EX-ZF LENKSYSTEME) SINGLE-MOTOR, BELT-DRIVE EPS**

BOTTOM: **LODEWIJK WIJFFELS, FORD'S ADAPTIVE STEERING SYSTEMS EXPERT**

Ford has been investigating adaptive steering technologies for some time. With its EPS tuning at a high level of maturity, it was keen to further improve steering performance and remove the compromise between low-speed agility and high-speed stability inherent in a mechanical ratio.

According to Lodewijk Wijffels, Ford's technical specialist for adaptive steering, the rack- or column-based solutions such as those employed by Audi and BMW were rejected and the search continued for something more affordable, more modular and applicable to different vehicles with minimal changes.

The solution is a Takata-supplied system that fits in its entirety inside the steering wheel. After a couple of years of intensive development, it will enter production later this year on some of Ford's CD cars: Edge, Galaxy, S-MAX and the Lincoln MKX.

"We put an electric motor, gearbox and ECU within a normal-sized steering wheel," Wijffels explains. "We use that to provide an overlay. With the motor, we can add or subtract a steering angle to what the driver is doing, thereby changing the ratio between the steering wheel and the road wheels."

Inside the steering wheel, an ECU carries all the software for the system (Ford has taken out around 15 patents in the software strategy, although the Takata hardware will not be exclusive to Ford). A clock spring with eight tapes takes care of power to the motor and ECU.

"On top of that, and because the primary input to the system is the steering wheel input from the driver, we have a very precise steering wheel angle sensor integrated into the system," he says. "Normally there might be an angle sensor on the rack, but we need to know precisely what the driver's doing."

A vacuum-folded airbag sits on top of this compact package, which fits within the center volume of a regular steering wheel. Only the filled-in bottom spoke of the wheel gives away the presence of what has been branded Ford Adaptive Steering (FAS).

At low speed, the ratio (just under 15:1 as standard) is much more direct, offering around two turns lock-to-lock instead of the normal three. The system is always on and Wijffels says that as the vehicle speed rises, care has been taken to create a very distinct on-center position. "If you then steer further at higher speeds, we make the vehicle's response to the driver's input smoother. It's fully blended in at all speeds and we have tried to optimize the ratio for all conditions."

There's also a tie-in with the optional Hitachi adaptive damping system. The three personalization settings of sport, normal and comfort now change the dampers, steering ratio and EPS power assistance. Six different calibrations of FAS are stored in its ECU to tie in with standard or sport suspension, with the appropriate three activated on the production line depending on the vehicle's spec.

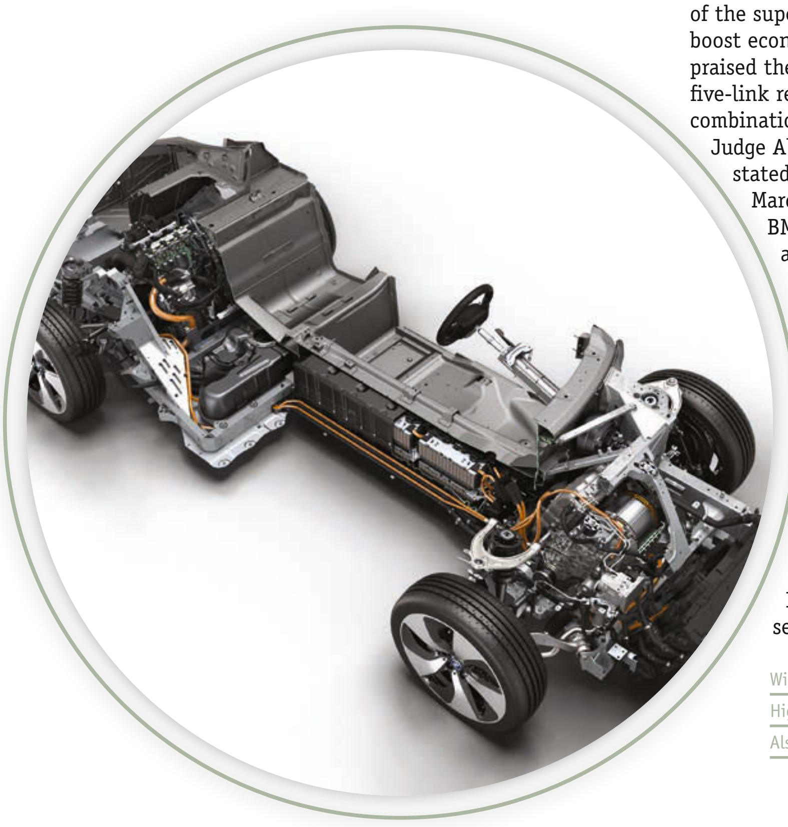
The three elements to the chassis setting are always linked, with no option to individually adjust one or the other. "It's difficult to separate them, because if you change the damper setting by itself, you get different on-center behavior," Wijffels argues.

"We've taken care in the tuning that the three systems are blended together very well. During the development it was important to us to provide a very natural feel, not to give the driver the feeling that a system was working in the background. Good steering feel is very important to Ford. We wanted to improve on it without introducing additional error states, so during the development with Takata, we set high requirements for steering feel and precision."

"With the motor, we can add or subtract a steering angle to what the driver is doing, thereby changing the ratio between the steering wheel and the road wheels"

Vehicle Dynamics International Awards 2015

IT'S TIME ONCE AGAIN FOR *VEHICLE DYNAMICS INTERNATIONAL* AND ITS JURY OF INTERNATIONAL JOURNALISTS TO SEEK OUT THE FINEST AND BEST INNOVATIONS, DEVELOPMENTS AND TECHNOLOGIES IN THE INDUSTRY



CAR OF THE YEAR: BMW I8

BMW's i8 was a runaway winner this year. The car made waves at its unveiling by breaking from the norm in its high-end sector. The self-proclaimed 'future of the supercar' uses a CFRP passenger safety cell mated to a GKN eAxle to boost economy by a claimed 50%. As a result, jurors from across the globe praised the i8 for its drive and the introduction of new technologies alike. Its five-link rear suspension setup and double-wishbone front arrangement, in combination with the stiff yet light passenger cell deliver an impressive drive.

Judge Alvaro Sauras Alonso, technical chief at *Autofácil* and *CAR&Tecno* stated: 'The i8 shows an astonishing dynamic behavior – it feels so light!" Marc Noordeloos from *Automobile Magazine* agreed, commenting: "The BMW i8 blends impressive efficiency and staggering performance into a groundbreaking, aspirational design."

In second place was Mazda's all new MX-5. The Japanese OEM's decision not to add more weight to the previous generation MX-5 was a move respected by the vast majority of jurors, with Carl Cunanan, editor in chief of *C!* magazine, commenting: "The little sports car that saved Mazda in the 1990s never had a replacement that captured hearts in the same way – something that's hard to do with modern demands, be they safety, environmental or financial. This latest model, however, manages to be the first true successor to the feeling of the original."

Still, it was not enough to best the BMW. Praise for the i8 continued, with Alex Kersten, editor of *CarThrottle*, stating that the i8 delivers "a driving experience that is first class. It's fast, comfortable, and finally proves that hybrids can be sexy and desirable."

Winner: BMW i8

Highly commended: Mazda MX-5

Also shortlisted: Ford Mustang, Volkswagen Passat, Volvo XC90

VEHICLE DYNAMICS INTERNATIONAL AWARDS 2015

DYNAMICIST OF THE YEAR: NOBUHIRO YAMAMOTO

Taking top spot as this year's Dynamicist of the Year is Mazda's Nobuhiro Yamamoto. The lead on the MX-5 program has a CV firmly rooted in some of Mazda's most illustrious programs, including the iconic 787B project of 1992. Sticking to the MX-5s legendary 'horse and rider as one' philosophy, the new car is smaller in every dimension than the previous generation, but reviews prove that it delivers a benchmark dynamic performance.

Praise for Yamamoto came from nearly all the jurors, with Sergio Oliveira of *El Informador* in Mexico stating: "It is very tempting to put a lot of power into a car like the MX-5, but thankfully they didn't." Juror Yves Maroselli of *Le Figaro* in France added: "Yamamoto has instilled his racing culture into the MX-5 chassis to make it as predictable and enjoyable as possible." Frank Markus, technical director of Motor Trend brands, added: "Nearly every production vehicle Yamamoto has been involved with is memorable for its dynamic brilliance."

Highly commended in this category was Volkswagen's Jürgen Pützschler, for his involvement in the all-new Volkswagen Passat. The latest iteration of the MQB modular platform drew wide praise, mainly in regard to the continual development of the technology and how it is now delivering a variety of platforms, each with its own distinctive handling characteristics and traits.

Ford's David Pericak was also nominated for his involvement with the all-new global Mustang, while BMW's Jos van As and Klaus Huber were also nominated for their work on the FWD architecture that underpins the 2-Series Active Tourer. Volvo's Stefan Karlsson also scored highly on the shortlist, praised for his work on the all-new XC90.

Winner: Nobuhiro Yamamoto, Mazda

Highly commended: Jürgen Pützschler, Volkswagen

Also shortlisted: David Pericak, Ford; Jos van As/Klaus Huber, BMW; Stefan Karlsson, Volvo

SUPPLIER OF THE YEAR: ZF FRIEDRICHSHAFEN AG

As with previous years, the Supplier of the Year category proved to be hotly contested. The eventual winner was ZF Friedrichshafen AG, for its impressive work on several new cars introduced over the past 12 months. Its OEM tie-ins have seen it supply Porsche with the Active Kinematics System, as well as Honda with its new CDC 1XL adaptive rear damper. "ZF Friedrichshafen AG is a company that has always produced systems of the highest quality," explained Lorenzo Facchinetti from *Auto* in Italy. William Wang Kun, chief editor of *Xcar.com* also praised ZF's work, highlighting the sizeable market share it has in his home market of China as reason for his vote.

It was fellow Porsche supplier GKN Driveline that ran ZF close throughout the judging process. Praise for GKN centered on its US$1,045m of new business won over the past 12 months, as well as its all-new two-speed eAxle and the world's smallest disconnecting all-wheel drive system. Nexteer won praise for its expanded portfolio of EPAS systems, while TrelleborgVibracoustic and BorgWarner also scored well.

Winner: ZF Friedrichshafen AG

Highly commended: GKN Driveline

Also shortlisted: BorgWarner, Nexteer, TrelleborgVibracoustic

DYNAMICS TEAM OF THE YEAR: BMW

The past 12 months have been a busy time for BMW. Launching a number of diverse models, in addition to refreshing existing platforms, saw the model range swell to over 50 in total. Standing out among a list that includes the i8 supercar, M3/M4, X5 and new 3-Series, is the 2-Series Active Tourer. BMW's first foray into a true FWD chassis has been welcomed positively since the launch.

The German manufacturer was run close by Mazda, however, with the Japanese firm's equally impressive new models receiving praise for their dynamic prowess. Praise for Mazda was equally forthcoming with juror Leonid Golovanov from *Autoreview*'s comments being typical: "While BMW and VW do fantastic work on their products, only Mazda's small team, acting as a small group of 'car nuts', has the ability to make me smile when I'm driving one of their products."

Praise for BMW was just as forthcoming, with juror Carl Cunanan, editor in chief of *C!* magazine, stating that "Trying to change the way a historic brand moves is challenging at any time. To do so in two directions – with the i8 and the Active Tourer – and produce end results that are well received is close to amazing." Fellow juror Sergio Oliveira of *El Informador* in Mexico simply concluded that "BMW consistently shows other manufacturers the way to build fun cars."

Also shortlisted were Jaguar Land Rover, for the impressive all-new Range Rover Sport, Land Rover Discovery Sport, Jaguar F-Type Coupe and Jaguar XE sedan. Joining JLR was the Renault-Smart collaboration that spawned the all-new Smart and Renault Twingo. Volkswagen rounded out the final five, thanks to the continued refinement of the MQB modular tool-kit, which continues to yield quality variants.

Winner: BMW

Highly commended: Mazda

Also shortlisted: Jaguar Land Rover, Renault-Smart, Volkswagen

VEHICLE DYNAMICS INTERNATIONAL AWARDS 2015

INNOVATION OF THE YEAR: ZF ACTIVE KINEMATICTS CONTROL SYSTEM

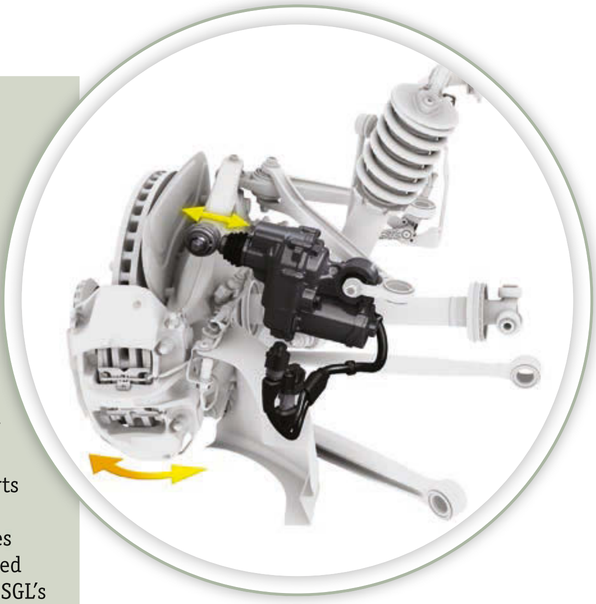
Innovation of the Year is often one of the closest fought categories, and this year it was ZF's Active Kinematics Control system that emerged victorious. Supplied to Porsche for its 911 Turbo and 911 GT3 models, the system is built around a length-adjustable toe link. Moved by electromechanical actuators, toe angle can be altered by up to three degrees while the vehicle is in motion, for improved stability and turn-in. The judges were impressed with the implications of ZF's system, with Gabor Szecsenyi, editor in chief of *Az Auto* and *Retro Mobil* stating that ZF's system is a "complicated, but very clever solution that, while showcased in a high-performance sports car, has real advantages for all cars in everyday motoring".

As predicted, however, this was a close contest. Advances in polymers and composites meant that two highly advanced developments, Sogefi Group's polymer spring and Benteler-SGL's composite leaf spring, featured in the shortlist and scored well, as did Trelleborg Vibracoustic's DualRubber mount, which consists of two elastomer compounds for both spatial directions. American Axle & Manufacturing's disconnecting all-wheel drive system, EcoTrac, rounded out the final five.

Winner: ZF Active Kinematics System

Highly commended: Sogefi Polymer spring

Also shortlisted: Trelleborg Vibracoustic DualRubber mount, Benteler-SGL composite leaf spring, American Axle & Manufacturing EcoTrac



DEVELOPMENT TOOL OF THE YEAR: RFPRO

A unanimous winner, rFpro's road modeling service, uses new surface-scanning technology to produce ultra-accurate digital road models. The software has modeled the entire track surface of the Nürburgring Nordschleife in 3D with an accuracy better than 1mm vertically and 1cm horizontally.

As juror Yogendra Pratap, editor of *AutoBild India*, explained: "While simulations on the other side of the table have moved forward rapidly, it was about time that external factors, such as advanced and precise road conditions, could also be input with accuracy, and this is the best modeler yet." Fellow judge Lorenzo Facchinetti, editor of *Auto.it*, simply added that "rFpro is the perfect example of how a tool created for other purposes is able to assist in the development of a new car."

On winning the award, rFpro's technical director, Chris Hoyle commented, "rFpro is thrilled to have won *Vehicle Dynamics International*'s prestigious Development Tool of the Year award. Digital road models are a critical part of the transition from physical prototypes to a representative virtual world. This award recognizes the substantial contribution of our team in helping vehicle manufacturers test their autonomous and active assistance systems. It is fantastic to have our contribution honored by industry specialists and we are delighted to have won."

This year we believed it would be a close call, with the shortlist consisting of five impressive nominations direct from the industry. Altair's bushing model enables accurate simulation of a car's bushings and hydromounts, through the application of a 'family of empirical bushing models'. Anthony Best Dynamics' ABD SPMM5000 has been designed to cater to current vehicle design trends, whilst MSC's ADAMS/Car high-fidelity vehicle simulation is a further example of advancing software. This year's final shortlist entry was CaeMax's all-new WFT-CX, a wheel force transducer that is claimed to offer new levels of measurement accuracy.

Winner: rFpro Road Modeling Service

Highly commended: Altair bushing model

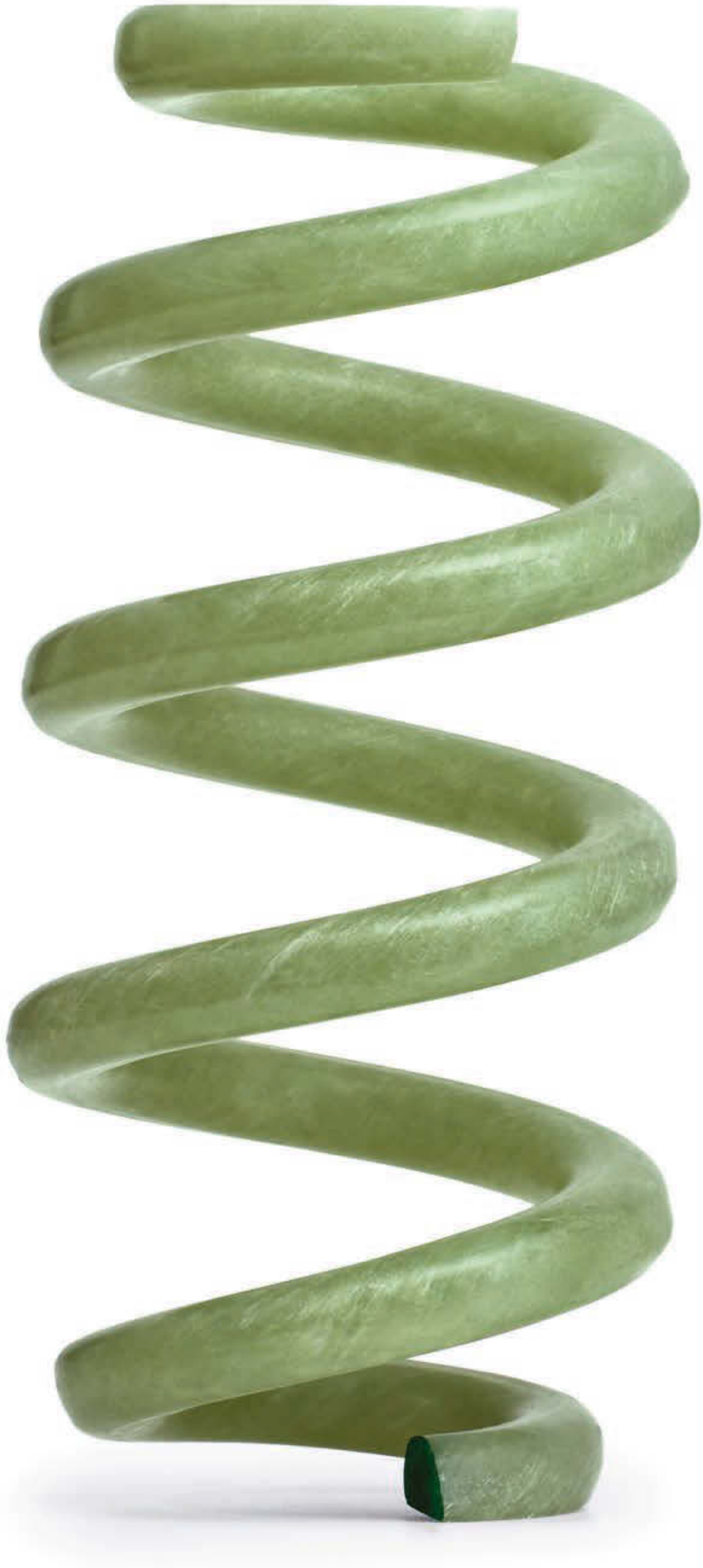
Also shortlisted: MSC ADAMS/Car, Anthony Best Dynamics ABD SPMM5000, CaeMax WFT-CX

LIST OF JURORS

Robert Bielecki, Oponeo, Poland
John Simister, freelance, UK
Marco Marelli, freelance, Italy
Richard Russell, freelance, Canada
Kun Wang, Automotive Weekly
Michael Taylor, AutoCar worldwide
Yogendra Pratap, Autobild India
Choi Joo-sik, Autocar Korea
Leonid Golovanov, Autoreview, Russia
Hormazd Sorabjee, Autocar India
Gabor Szecsenyi - Az Auto and Retro Mobil, Hungary
Jürgen Zöllter – freelance, Germany
Tomaz Porekar, Avto Magazin, Slovenia
Lorenzo Facchinetti, Auto, Italy
Markus Franklin, Motor Trend, USA
Jim Kenzie, Toronto Star, Canada
Carl Cunanan: C! Magazine, Philippines
Yves Maroselli, Le Figaro, France
Sergio Oliveira de Melo, El Informador, Mexico
Oleg Vasilevsky, Auto Bild Ukraine
Alvaro Sauras Alonso – Autofacil and CAR&Tecno, Spain
Tarcisio Dias de Araujo – Mecânica Online, Brazil
Marc Noordeloos – freelance, USA
John O'Brien – Vehicle Dynamics International, UK
Alex Kersten – Carthrottle, UK
Phil Morse – dynamicist and automotive writer, UK
Dean Slavnich - Engine Technology International, UK

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.

Lightest **touch**



With European Union law requiring a fleet CO_2 average of 95g/km by 2021, OEMs are being faced with a tough challenge. Although this may sound mainly like a powertrain issue, another area that can be applied to all aspects of a car's design and development to boost economy and cut emissions is weight reduction.

One idea that is quickly gaining credibility is the use of composites within the chassis to shave both sprung, and unsprung, mass. The use of polymer composites within the automotive industry is far from a new idea, however. Chevrolet's Corvette made the first use of a composite leaf spring in the early 1950s. Since then, advances in production techniques, raw materials and quality control have allowed polymers and other composites to become a legitimate way of saving weight in vehicles.

An extreme example of this is the 2013 Peugeot 208 Hybrid FE concept. Designed to show what is achievable in terms of lightweight vehicles, the concept made use of glass-fiber resin composites in its front and rear suspension as part of drastic weight-saving measures.

Replacing the front and rear wishbones, anti-roll bars and suspension springs are two 'blades'. Effectively two transversely mounted leaf springs, the lightweight epoxy matrix composite elements were designed to incorporate the three replaced components' functions, and were created in conjunction with composite specialist Hutchinson – a subsidiary of Peugeot's technical partner, Total SA.

"The project's target was to achieve a vehicle weight of less than 800kg, from a starting point of 1,025kg," explains Philippe Girard, direction scientifique, Total SA. "In total,

EU LAW WILL CALL FOR EMISSIONS TO BE SLASHED FROM THEIR CURRENT LEVELS BY 2020. **JOHN O'BRIEN** ASKS, ARE COMPOSITE COMPONENTS THE KEY TO MEETING THOSE TARGETS?

MAIN: **SOGEFI GROUP'S POLYMER COMPOSITE SPRING** (LEFT) **AGAINST A TRADITIONAL STEEL SPRING** (RIGHT)

Sogefi has introduced the world's first mass-produced glass-fiber reinforced polymer spring, with claims that it offers a weight saving of 40-70%

we saved over 260kg by replacing some steel parts with composite components, and introducing new concepts such as those in the suspension."

Peugeot and Hutchinson refer to the composite suspension as a 'pseudo-MacPherson' arrangement. The resin blade is fitted with ball joints as well as metal and rubber filtration components, and represents a saving of over 20kg compared with the standard 208's steel components.

According to Girard, the front and rear leaf springs are produced from the same mold, but have different characteristics thanks to a slight variation earlier in the production process. The front 'blade' has been designed non-uniformly along its length so that different sections have different elastic properties. The central section has high flexibility to mimic the motions of a traditional spring, while the outer edges of the blade are much stiffer to accommodate lateral loadings and support the car when undertaking braking maneuvers.

"The flexibility depends on the adhesion of the resin to the fibers," explains Girard. "Depending on the spacing between the composite strands, you can introduce flexibility on a composite part. It's a mechanical part with elastic behavior, which does mean if you push past the stress limit, it can and will crack, but you can modify the flexibility of the blade quite easily. It all depends on the tolerances required. We can play around with that parameter, and have developed some specific modeling software to help us in that area."

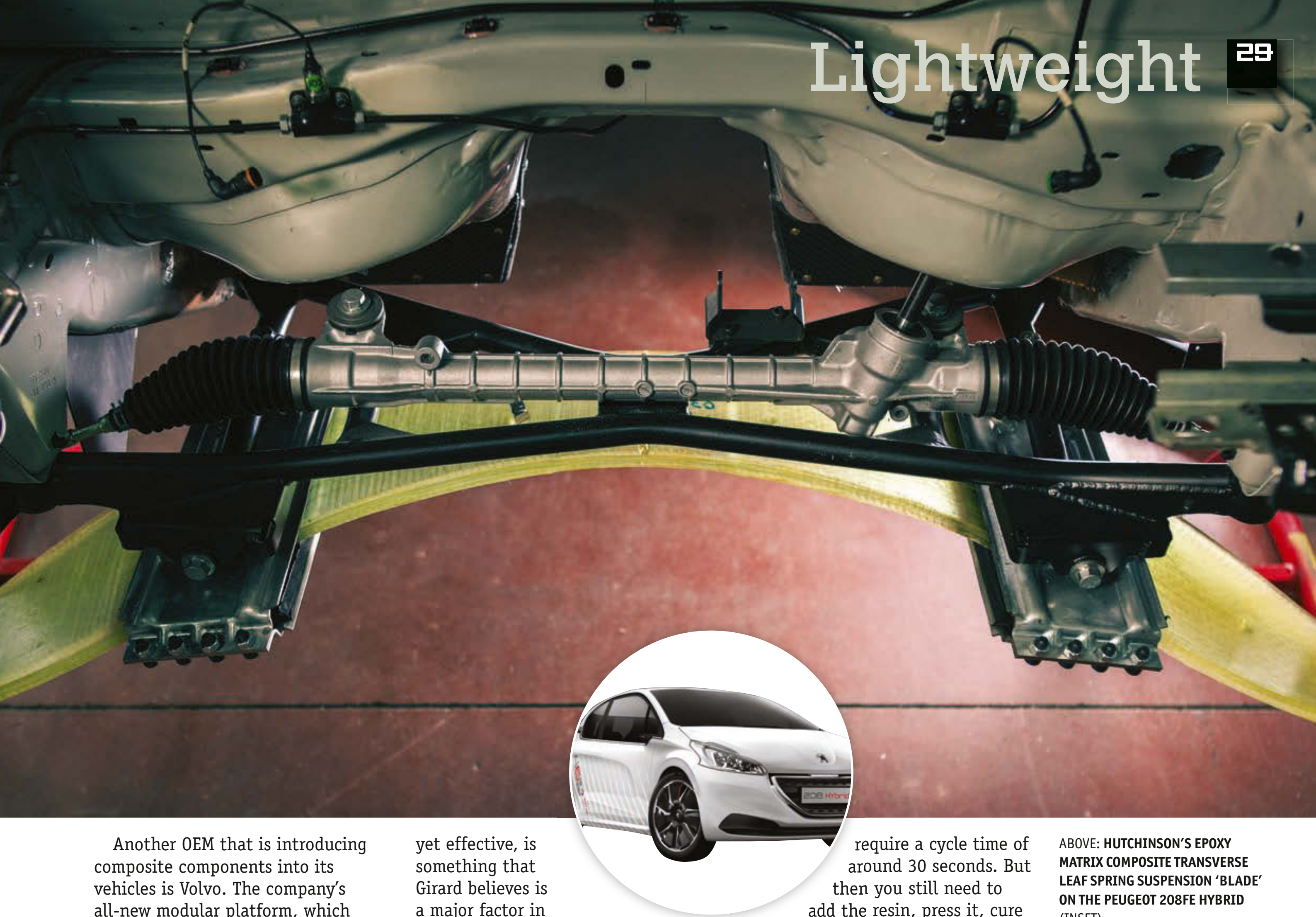
While highly conceptual, the 208FE Hybrid is what Girard refers to as 'middle of the river', and he says that 80% of the proposed solutions on the car could be introduced to the mainstream over the next five years.

ThyssenKrupp Bilstein

Your partner for adjustable damping solutions

- ADS: Million-seller technology with two independently working valves
- DampTronic® I: Best balance between soft ride comfort and dynamic agile driving
- DampTronic® select: Closing the gap between continuously adjustable and conventional dampers
- DampTronic® sky: Benchmark regarding ride comfort

ThyssenKrupp Bilstein



Another OEM that is introducing composite components into its vehicles is Volvo. The company's all-new modular platform, which underpins the new XC90, uses a transverse composite leaf spring in its rear integral axle. This isn't the first time that the Swedish manufacturer has used composites in a suspension system, though, with the 900-Series of the early-1990s using a fiberglass rear leaf spring arrangement. The new item, however, has been developed by supplier Benteler-SGL, a joint collaboration between Benteler Automobiltechnik and SGL Group, and is said to offer a 65% weight reduction in comparison with a traditional leaf spring.

Benteler-SGL worked with adhesive specialist Henkel to ensure that the new leaf spring could meet the demands of mass production (see sidebar, *A sum of parts*). According to Henkel, the company's past experience in resin transfer molding ensured that the XC90's rear suspension could be produced in an appropriate cycle. The proposed solution was to use a modified version of its low-viscosity polyurethane matrix resin, Loctite Max 2.

Henkel states that its Loctite Max 2 has been used in the production of leaf springs since 2013, but for its application in the XC90 a revised additive was used to help speed up the curing process.

The need to ensure that a manufacturing process is quick, yet effective, is something that Girard believes is a major factor in composites not being commonly used in the industry, and that advances in machinery could be what unlocks this potential.

"Increased automation, especially when preparing the parts, could help speed up the overall process," he states. "If you need to add the liner to the mold, then using a robot will be quicker than doing it by hand. Introducing the liner automatically and finishing by hand is something that does occur, but I'd say something like that would still require a cycle time of around 30 seconds. But then you still need to add the resin, press it, cure it, and de-mold in the remaining 30 to 60 seconds, depending on what the OEM's production line requires. It's very, very difficult to achieve."

While composite leaf springs have evolved gradually over the past 60 years, Sogefi Group, working in close collaboration with Audi, has taken the concept of a composite chassis component one step further.

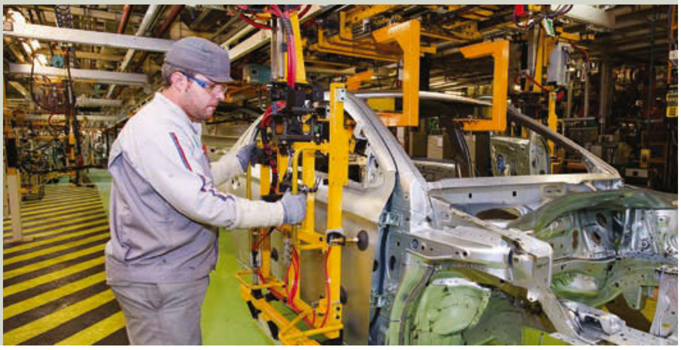
For use on Audi's highly efficient A6 Avant Ultra, Sogefi has introduced the world's first mass-produced glass-fiber reinforced polymer spring.

ABOVE: **HUTCHINSON'S EPOXY MATRIX COMPOSITE TRANSVERSE LEAF SPRING SUSPENSION 'BLADE' ON THE PEUGEOT 208FE HYBRID** (INSET)

A SUM OF PARTS

Traditionally, the creation of a composite component has been a labor-intensive process, but is there any one critical step in producing a composite part? "It's a combination of many things," explains Total SA's Girard. "You have to work on the fibers, the adhesion of the resin to the fibers, and the manufacturing process itself. You need to control all those chemical processes to optimize the process, and to be able to prove to OEMs that you are capable of short-cycle production. Today, some OEMs are producing over 1,000 cars per day in some facilities and you need to guarantee that your cycle is compatible with the OEMs' frequency of production. You need to be able to produce parts in around 60-90 seconds.

"It's something that you need to take into account at the very beginning of a project," he continues. "An existing production line is very difficult to modify, as it is usually optimized to its output already. If you slow the production line by introducing a new part, you are handicapping your partner, as you are directly affecting the number of cars they are producing."



ABOVE: **PART OF VOLVO'S ALL-NEW MODULAR ARCHITECTURE IS A REAR AXLE UNIT, FITTED WITH A TRANSVERSE COMPOSITE LEAF SPRING**

INSET: **THE ALL-NEW VOLVO XC90 WILL BE THE FIRST CAR TO USE THE TECHNOLOGY**

Sogefi claims that its new spring offers a weight saving of 40-70%. In application on the A6 Ultra, it has saved Audi 4.4kg in comparison with a traditional, steel coil spring.

Sogefi explains that the polymer item is made using a process that involves the twisting of long glass fibers into a central 'core'. The structure is then impregnated with an epoxy resin, before further fibers are mechanically wrapped around the twisted glass core. The outer layer of fibers is laid out at alternating angles of ±45° to the longitudinal axis, to counteract any stresses that may act on the spring. The completed assembly is then cured at over 100°C.

The finished spring is easily distinguished from its steel counterpart. The cross-section diameter of the spring is increased, as is the overall diameter, while the spring carries fewer coils than a traditional unit.

While the benefits of using composites can be extended beyond weight saving (almost all of a composite can be recycled and reused), there is one perception of composites that manufacturers are still battling against – their perceived strength.

"I'd say one of the biggest difficulties with composites is that you are proposing a solution that people simply don't, and won't, have in mind," explains Girard. "I think the biggest disadvantage that composites have is in trying to convince the public that they are just as robust as steel components. Both resins and composites are often seen by the general public as somewhat of a 'dark art', as it is chemistry, not mechanics in the traditional sense."

But in terms of a comparative lifetime, what can be expected of a composite chassis component?

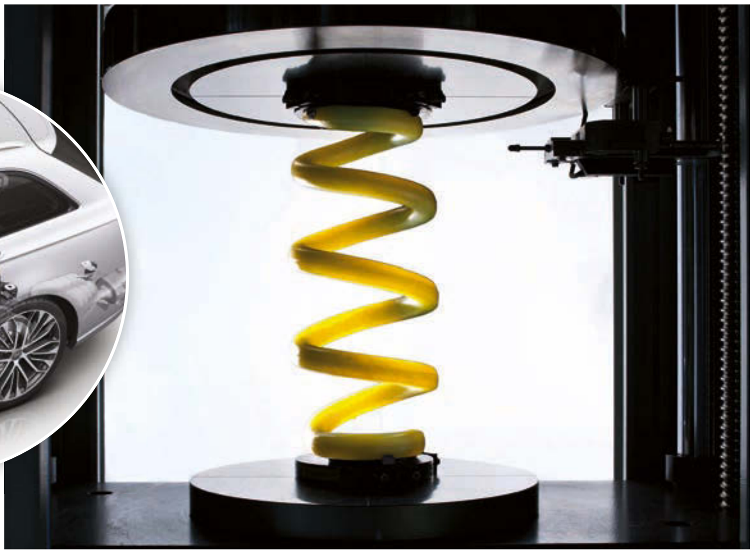
"If there is no major shock to the blade, it will be a very good mechanical part for at least 30 years," explains Girard. "If the part is subjected to such shocks repeatedly, I wouldn't be able to answer, as a severe impact on the blade could destroy it – much like repeated major shocks can damage traditional components. That said, we are working hard to improve longevity."

Overcoming public preconceptions of composites could be a critical step in this process. With EU law requiring the fleet average CO_2 emission figure to be slashed by 2020, lightweight architectures are going to be of equal importance to drivetrains over the next five years. With a large number of manufacturers rumored to be concerned about the reality of hitting this and future targets, composites are likely to be a key contributing factor in meeting the EU's demands.

"When you save 10kg on a car, you save 1g/km in emissions," says Girard. "Today, car manufacturers are ready to pay a few euros per kilogram, if you are able to propose a solution that reduces pollution. But as time goes on, each gram of CO_2 will get more expensive after 2020. It will be difficult to achieve 95g/km if you don't have an EV in your fleet. After that, the target will then be 75g/km. But we are entering a new era of weight saving. Today, there are around 200kg of plastics and composites on a car. Tomorrow that will be 300-350kg."

RIGHT: **SOGEFI'S COMPOSITE SPRING UNDERGOING TESTING**

INSET: **THE COMPONENT IS INSTALLED ON THE REAR AXLE OF AUDI'S A6 AVANT ULTRA**



Balance of power

BMW'S M DIVISION IS UNDER NEW MANAGEMENT, AND EX-AUDI MAN FRANK VAN MEEL IS AT THE HELM. **MARC NOORDELOOS** MET WITH HIM TO DISCUSS EVERYTHING FROM DRIVEN WHEELS TO SOME NEW HARDCORE MODELS

From 1978 until 2010, BMW offered a maximum of three M models at any time. Today that figure has doubled to six, with the M3, M4, M5, M6, X5 M and X6 M. Add in derivatives (convertible versions, etc) and there are now nine BMW M models, not including the seven less-extreme BMW M Performance models such as the M550d xDrive and M235i. That's some serious growth in only five years.

During this progression at BMW, Franciscus (Frank) van Meel was at Audi, where he started in 1996 and became managing director of the company's sporting division, quattro GmbH, in 2012. Van Meel joined BMW in October of 2014 and was appointed chairman of the board of management at BMW M GmbH on January 1, 2015. Less than two weeks into his new job, we met up with van Meel at the 2015 North American International Auto Show (NAIAS) in Detroit.

All-wheel drive is a core component of Audi's performance brand. The traction-aiding technology is referenced in the division's name (quattro GmbH) and the division has never produced a front or rear-wheel-drive road car. Meanwhile, BMW M stays loyal to rear-wheel drive with its core range of performance cars (not counting the X5 M and X6 M). "Our philosophy is to make performance cars that are very agile, perform very well on race tracks and have a high degree of precision," says van Meel. "For that, rear-wheel drive is important. That is also what has made BMW M so successful over the past 40 years and built the M image. That is something that will continue in the future and we will even enhance those properties. That is our main differentiator from the other high-performance cars in the segment, especially German ones – the driving feel."

Push, or pull?

We pressed van Meel on the subject of driven wheels, especially given the growth of all-wheel-drive Mercedes-Benz AMG models. "If we were to make a four-wheel-drive car," notes van Meel, "it would have a rear-wheel-drive feel but with added traction. It would need to drive like an M car. If it was possible to get those vehicle dynamics with four-wheel drive, then it would be suitable for us."

With BMW moving to front-wheel drive on models such as the 2-Series Active Tourer, we naturally asked for van Meel's thoughts on that driveline setup for BMW M. "I think a pure M with front-wheel drive is impossible to make. We cannot put so much torque and horsepower through the front axle. We wouldn't fulfill the M philosophy with that."

As the BMW M brand has grown, certain customers and journalists have complained about the cars getting softer and losing focus. "You don't think the new M3/M4 is a purists' car?" asks van Meel. "Last year I was looking at the BMW stand with another focus [while working at Audi] and I saw the M3/M4 and I was really impressed. For me, the M3/M4 is a very pure, very precise car, and it's very edgy. The M5 and M6 are set at a higher price and we have to take into account that there are some different expectations from those customers."

Some of the complaints about BMW M are due to the brand's recent commitment to turbocharging and automatic transmissions. Historically BMW M meant naturally aspirated engines and manual transmissions. "Regarding emissions and performance, turbocharging is the way to go, especially if you look toward downsizing," says van Meel. "Lighter engines with more performance – that's what we want.

"I think a pure M with front-wheel drive is impossible to make. We cannot put so much torque and horsepower through the front axle. We wouldn't fulfill the M philosophy with that"

"Potential for growth is already there in the segment. If you look at the sales numbers from last year compared with two years ago, we've had an increase of 44%"

We want to have the best power-to-weight ratio, so there is no way around turbocharged engines."

He then adds his thoughts on manual transmission. "The technical answer is that you're slower with a manual gearbox and you have higher fuel consumption. The emotional part is that if there is a market for it, we will stick with the manual gearbox. Currently we see a decreasing market for manual. It's already quite small and it's falling."

Mercedes has done an excellent job keeping the hardcore enthusiast buyer happy with its extreme Black Series models. These cars have very limited production runs and a focus on maximum performance, with understandable sacrifices in the area of on-road comfort and refinement. Should BMW M build cars to compete directly? "I think it's a good idea to do something like that, to do limited edition models like the Black Series, but in a BMW M way," says van Meel. "We are actively looking into that."

BMW M executives told *Vehicle Dynamics International* the same thing at the 2013 NAIAS, but now van Meel quickly responds, "Let's just say you won't have to wait another two years to see something."

The future

Speaking of higher-end models, BMW's top-spec halo car is the i8 hybrid. Van Meel feels it would be too crowded to have a BMW M halo car at the same time as the i8. But what about an electric BMW M model? "The BMW i team uses the carbon fiber technology from BMW M. And of course, we are looking into what BMW i does regarding drivetrain technology, vehicle dynamics control systems and enhanced lightweight technology. Without trying to make an 'M i' model, maybe there could be a BMW M inspired by BMW i, or a BMW i inspired by BMW M."

He adds that BMW M is more inspired by the race track than the laboratory, but is impressed that "BMW i is conquering new boundaries in technology and mobility".

"The good thing is that we are one company, so we can use each other's technologies across boundaries. However, I don't think combining BMW M and BMW i would work."

Diesel is also off the table for a pure BMW M model. "It works for the M Performance models. The diesel market is still Europe, not the USA and not China. That doesn't matter if it's M Performance or pure M. If we look only at the pure BMW M market, the biggest sales are in the USA, so we always have to take that market into account when we look into new technologies or ideas. Last year 40% of BMW M cars were sold in the USA."

Developing all the technology to the highest level is a key focus for van Meel. "An interesting part is our engine development setup, with all the features, test benches, design department and testing department," says van Meel. "It's very impressive. What's also impressive is that at the BMW headquarters we have the ability to show customers individual models, as well as the personalization of cars. That way people can see what is already possible today.

"Also, at the 2015 Consumer Electronics Show in Las Vegas, we showed our organic LED (OLED) technology, which we will bring into a BMW M in the near future. For testing our cars, the Nürburgring (Nordschleife) is still a key place. We now have two test centers there. The one in the center of Nürburg was getting too small for us, so we opened a second in the industrial park outside town last year. Every car we develop has to perform at the Nürburgring for 1,000km (620 miles) for the final sign-off."

What about the future of BMW M? "Potential for growth is already there in the segment," says van Meel. "If you look at the sales numbers from last year compared with two years ago, we've had an increase of 44%. We're currently at 45,000 in sales for BMW M and M Performance automobiles. For the future, we are looking into other segments; there's a possibility for more BMW M automobiles. But, as always, if we bring such a car to the market it must be the best in its segment. With that perspective, we see more possibilities for the future, which we are currently working on. We see more possibilities and more segments where we can go for M Performance. That is what our future looks like and it seems very strong and growing."

BMW'S RANGE OF M CARS IS NOW PRETTY ECLECTIC. THE I8 (INSET LEFT) **HOWEVER, IS SOMETHING THAT WILL NOT WEAR THE M BADGE**

Book your delegate pass now!
www.autonomousvehiclesymposium.com


© Rinspeed


© Continental


© Bosch

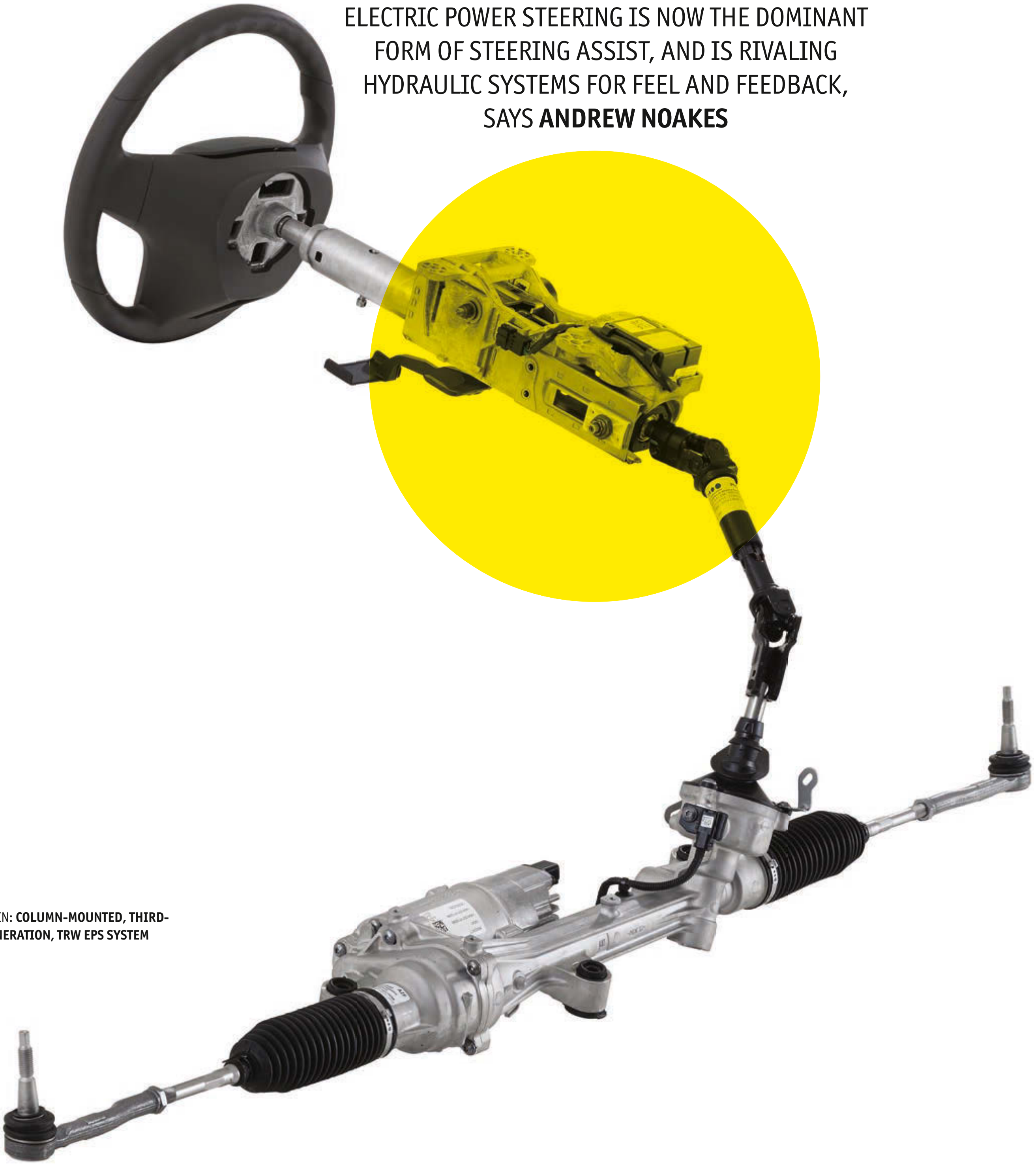
Topics under discussion:

- Public road testing
- Virtual testing
- Simulation
- Traffic scenario testing
- Embedded software testing
- Safety and crash testing
- Fail-safe testing
- Cyber threat 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 2015, **please contact Mike Robinson,** conference director: mike.robinson@ukipme.com
Tel: +44 1306 743744 | www.autonomousvehiclesymposium.com

Critical feedback

ELECTRIC POWER STEERING IS NOW THE DOMINANT FORM OF STEERING ASSIST, AND IS RIVALING HYDRAULIC SYSTEMS FOR FEEL AND FEEDBACK, SAYS **ANDREW NOAKES**



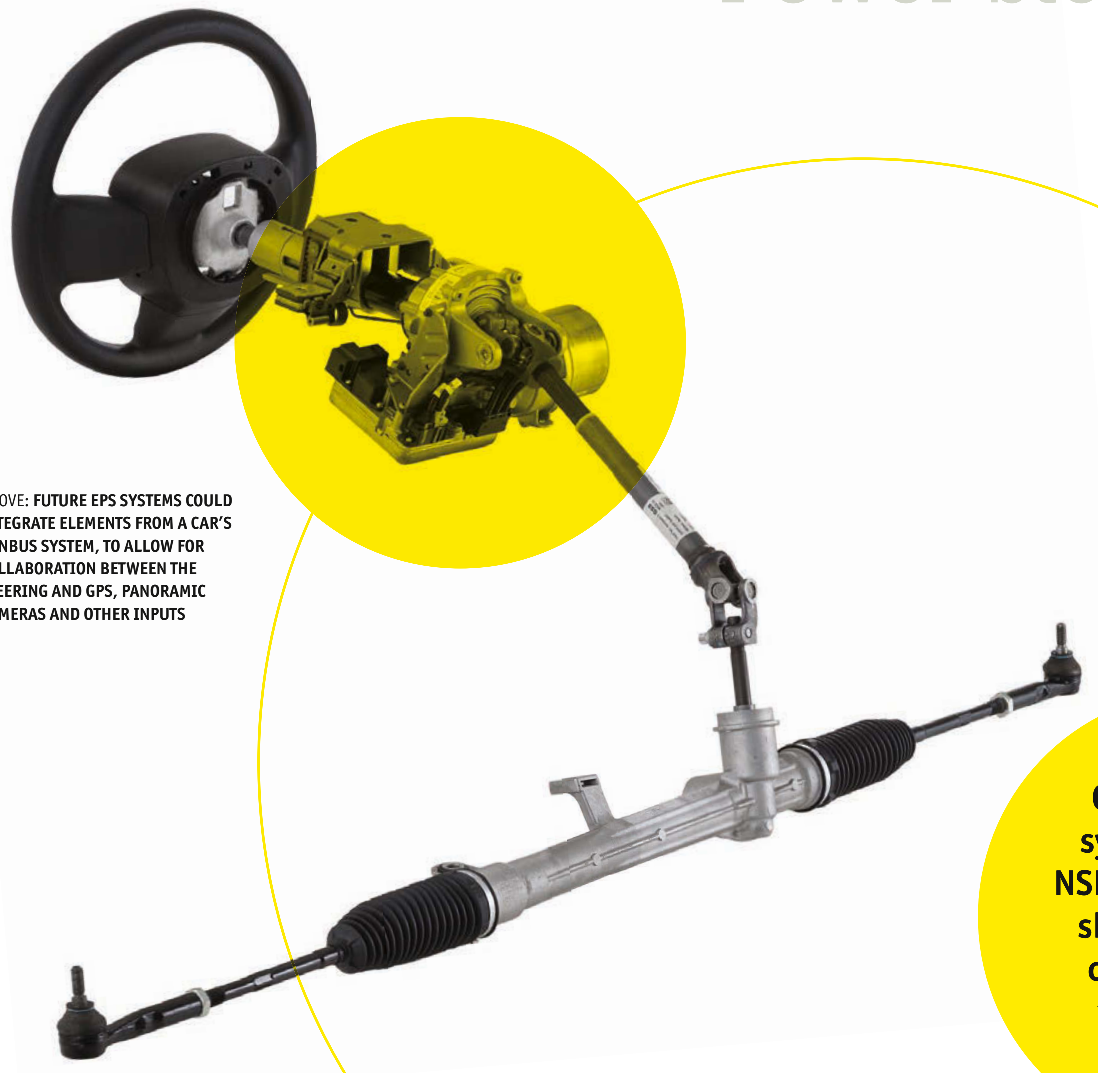
MAIN: **COLUMN-MOUNTED, THIRD-GENERATION, TRW EPS SYSTEM**

Jaguar launched its F-type sports car with hydraulic steering assistance in 2013, but 2016 models switch to electric power steering (EPS). When a company that spends as much time and effort on driver satisfaction as Jaguar adopts EPS on its most driver-focused product, it's time to accept that electric assistance is no longer the feedback-free zone it once was.

Enthusiast drivers' complaints about EPS steering feel were largely reactions to setup and calibration, rather than fundamental issues surrounding the technology. One of the first applications of EPS, back in the 1990s, was the Honda/Acura NSX, and a more recent one is the C7 Chevrolet Corvette – neither of them regarded as lacking in steering quality. The US magazine *Car and Driver* carried out a blind back-to-back test between EPS and hydraulic steering, and ended up voting EPS the winner. BMW switched to EPS for the latest M3 and M4, with a design that has minimal electric assistance returning the steering to the straight-ahead position, which the company says improves steering feel.

Every generation of EPS has offered improvements in steering feel, says Ananth Parameswaran, TRW's product planning director for steering engineering. "This is really achieved through software tuning, and it's possible to optimize that for each OEM's preferences. Each OEM has a particular driving feel that they look at as being part of their DNA, and that's something which over time you can learn to do very well with EPS." Although some aspects of the response and feedback of the steering can be quantified, much of the process is still subjective. "It's an art as much as a science," Parameswaran says.

Jaguar launched its F-type sports car with hydraulic steering assistance in 2013, but 2016 will see a switch to EPS



ABOVE: **FUTURE EPS SYSTEMS COULD INTEGRATE ELEMENTS FROM A CAR'S CANBUS SYSTEM, TO ALLOW FOR COLLABORATION BETWEEN THE STEERING AND GPS, PANORAMIC CAMERAS AND OTHER INPUTS**

Global steering systems supplier NSK predicts market share for EPS will climb to 80% of passenger cars by 2018

For the majority of users, EPS offers nothing but benefits. Chief among them is an improvement in fuel economy of around 0.3-0.4 liters/100km (about 1-3mpg) with a concomitant saving of up to 8g/km in CO_2 output. A further environmental benefit is the elimination of hydraulic fluid from the system, and there is a reduction in whole-life costs through lower servicing requirements. EPS requires no pump drive or hoses so it is more compact, which can yield a packaging or crash performance benefit, and can easily offer variable assistance or user-selectable assistance curves. Development is quicker because steering characteristics can be changed by modifying a software control map rather than necessitating a rebuild of the steering system, and characteristics can be tuned for different models without the need for a redesign. Driver assist systems are enabled, or at least facilitated, by EPS. With safety, comfort, convenience and efficiency benefits all delivered by one technology, it is easy to see why EPS has quickly become the dominant form of steering assist and is set to grow still further: global steering systems supplier NSK predicts market share for EPS will climb to 80% of passenger cars by 2018. Analyst Frost & Sullivan says that by 2021 most OEMs will be EPS-only.

That's in spite of the recent arrival of even more advanced steering systems, in the form of steer-by-wire. Infiniti introduced a steer-by-wire system, called Direct Adaptive Steering (DAS), on its Q50 midsize saloon. It provides a notable lack of kickback on poor roads, and is said to improve steering precision and the operation of the lane-departure warning system. Infiniti has retained a conventional steering column as a back-up, disengaging it using a clutch that can be closed in the event of a malfunction in the three ECUs controlling the steering. Once the technology is proven, the steering column could be removed, freeing up more space in the engine bay and making the production of left- and right-hand-drive vehicles much simpler and cheaper.

But there are arguments against full steer-by-wire systems. NSK says most of the advantages of steer-by-wire can be obtained using EPS at much lower cost. Steer-by-wire must build in redundancy more commonly seen in aircraft control systems, but without the benefit of the rigorous maintenance regimes and highly-trained users that apply in aircraft operation. Retaining a back-up mechanical connection to the wheels, as Infiniti has done, limits the benefits the system provides and adds further expense.

Failure in any power-assisted steering system generally results in a sudden removal of steering assist, which could be dangerous if it occurred mid-corner and is certainly inconvenient. The increase in steering effort following a failure can be greater with EPS than with a conventional hydraulic boost because the driver has to turn the electric assist motor as well as the now unassisted steering gear. One fault tolerance strategy is the use of a motor with two separate three-phase circuits, so even if one circuit fails, some steering boost remains, providing enough assistance for the driver to retain control. The challenge then is to ensure that when both circuits are operating they each provide the same steering boost,

HEAVY-DUTY EPAS

Bigger vehicles need more power to assist steering, which has left commercial vehicle steering as the reserve of purely hydraulic systems until very recently. But since 2013, Volvo Trucks has been offering Dynamic Steering, a hybrid between hydraulic and electric – but not the kind of electrohydraulic system that has been used in cars.

The Volvo system is a conventional powered hydraulic rack with an additional electric motor. At low speeds, the motor provides supplementary assistance that enables the steering to be turned with one finger. The input torque required is so low that Volvo was even able to set up a demonstration where a truck was steered out of a quarry by a hamster in a wheel fixed to the steering wheel. At higher speeds, the motor, which is computer-controlled 2,000 times per second, counteracts kickback and corrects for drift caused by side-winds and road cambers. Volvo says the system improves control and reduces driver fatigue.

As demand grows for car-like driver assist systems in commercial vehicles, on safety grounds, electronic control of steering assist will become more common. In commercial vehicles, in the medium term, combined electric/hydraulic systems such as Volvo's are likely to be the most common solution.

"EPS will continue to penetrate higher vehicle segments, so increasingly you will see EPS in premium sedans, SUVs and even light commercial vehicles"

Ananth Parameswaran, product planning director for steering engineering, TRW

ABOVE: **A TRW EPS SYSTEM UNDERGOING TESTING AND CALIBRATION ON A SPECIALLY DESIGNED RIG**
RIGHT: **ELECTROHYDRAULIC SYSTEMS HAVE HELPED USHER IN FULL EPS SYSTEMS, BY OFFERING INCREASED PERFORMANCE AND A REDUCED PRICE POINT**

to avoid inconsistent response of the whole system, and this places an extra burden on the system's motor control electronics.

TRW's Parameswaran sees integration of EPS with other electronic control units via the CANbus as a great opportunity for data sharing to improve automated driving functionalities. But there is no clear trend regarding centralization or distribution of the functions. "Different OEMs are going to choose different solutions depending on the vehicle architecture, and their perspective on it," he says. "From a technical feasibility standpoint, both are very much open roads for us."

Future EPS will improve steering feel still further by reductions in weight and inertia of the electric assist motor, for example moving from the common die-cast alloy casing to a molded polymer. To maintain dimensional stability of the case, this requires low heat dissipation from the motor and the control electronics, and will be a further impetus to increasing the system's efficiency. Innovative approaches to other steering components – such as ThyssenKrupp's lightweight, hollow steering rack fabricated from sheet steel, will enable lighter, smaller-output motors to be specified.

On larger and premium vehicles, rack-mount EPS is preferred, as this offers finer control of steering assistance resulting in improved steering feel. It also enables the use of a larger motor providing the higher boost necessary for light steering on a more heavily-loaded axle. On B- and some C-segment vehicles, pinion EPS provides a more cost-effective alternative. Meanwhile, lighter cars will continue to use column-mounted motors as these are generally the lightest and cheapest option, and provide packaging advantages that are particularly important for small, front-wheel drive cars. Column-mount solutions are growing in popularity in Asian markets, where there is increasing demand for compact cars, opening the door to growth in driver assist systems in those markets.

Bosch is integrating driver assist functions into the steering system as a means for improving functions such as µ-split braking, oversteer/understeer compensation, crosswind compensation, and rollover prevention. GPS navigation data and traffic information could also be fed in so that the steering system could take into account corners and traffic conditions beyond the view of on-vehicle cameras. The next addition to the roster of assist strategies will be emergency steering assist, which will support a driver's efforts to take evasive action for collision avoidance.

"EPS will continue to penetrate higher vehicle segments, so you will see EPS in premium sedans, SUVs and even light commercial vehicles," says Parameswaran. "You will continue to see EPS delivering more power. You will see increased functionality and support for automated driving features, and then you'll have increased levels of fault tolerance and redundancy."

Driver in the loop

rFpro'S DIL SIMULATION SOFTWARE FOR VEHICLE DYNAMICS IS HELPING MAKE FERRARIS FASTER AND TRUCKS SAFER

ABOVE: **THE LATEST UPDATE TO THE SYSTEM IS AN ACCURATELY MAPPED SIMULATION OF THE NORDSCHLEIFE CIRCUIT**

Business is booming at UK software company rFpro, specialists in low-latency software for vehicle simulators, now working with Ferrari on Formula 1 car development and at the same time supporting commercial vehicle projects with IDIADA and The Swedish National Road and Transport Research Institute (VTI). The upsurge in demand can be linked to the increased functionality available from a new generation of DIL simulators that respond quickly enough to enable the realistic simulation of vehicle dynamics.

Simulators have historically been limited by the latency of the feedback loop – typically up to a quarter of a second delay – that has restricted their use to ergonomics, human factors and human-machine interface applications, where the delayed response was not an issue. To create a simulator with sufficient physical accuracy and the necessary visual and aural realism, rFpro developed new software that provides video signals up to 10 times faster and audio signals 20 times faster than established systems.

Ferrari's Giacomo Tortora, responsible for vehicle dynamics, says, "Video bandwidth is very important to us because we run multichannel stereo projection and also wanted the fastest possible refresh rate," he said. "rFpro is able to deliver the maximum video bandwidth, in stereo, at very high refresh rates with just a single frame of latency between our vehicle model and the projectors. This is the fastest solution on the market; video bandwidth is probably an order of magnitude greater than a traditional OpenGL-based solution."

The second area of breakthrough is the 3D mapping process employing lidar laser-imaging technology, used by rFpro to capture road and track surface data with an unprecedented level of detail. Every bump, curb, ripple and camber from the actual surface is faithfully reproduced, allowing real chassis engineering development in a virtual environment. The most recent addition to the extensive library of roads and tracks in rFpro's TerrainServer software is the famous Nordschleife circuit at the Nürburgring, captured in 3D with an accuracy better than 1mm in z and 10mm in x and y, representing a tenfold improvement over the resolution previously available.

Ferrari's Tortora was clear about the benefits. "TerrainServer impressed us with its ability to run complete contact patches for all four tires in real time on a road surface built and validated over the original point-cloud," he said. "The way in which TerrainServer captures every lidar-scanned datapoint within the tire contact patch, and integrates them all to provide our vehicle model with accurate road input, improves correlation with our measured data and also feels more realistic for the driver."

Ferrari's mid-season move to rFpro software underlines the compelling benefits available. Simulator downtime in Formula 1 is expensive in terms of interruption to the engineering development schedule, and Ferrari already had a well-developed DIL software solution in which it had invested substantially, but the leap in performance was too great to ignore. "The trial of rFpro was so promising that we immediately put it to use in production-intent applications in our Formula 1 team," explains Tortora.

In a very different market sector, the safety and handling of heavy trucks and commercial vehicles can be improved through better DIL simulation. VTI has pioneered the use of simulators and been at the forefront of their development for over 40 years. The implementation of rFpro at VTI on its Sim IV platform during summer 2014 means that customers requiring a suitable cabin arrangement and driving position for a commercial vehicle have access to a simulator that is coupled with all the benefits of rFpro software.

One of the first customer projects at VTI that benefitted immediately from the use of rFpro technology was led by a team from Applus IDIADA, the state-of-the-art vehicle testing organization in Spain. The project fitted the rFpro business model perfectly as it enabled IDIADA to develop its customer's vehicle model remotely on a workstation and then, when it was sufficiently developed, take it to VTI to conduct commercial vehicle testing with a professional driver on the simulator.

Jonathan Webb, IDIADA's head of vehicle dynamics simulation, says, "rFpro offered us the possibility of the offline integration of our CarSim vehicle model, which could then be seamlessly integrated with the dynamic motion platform at VTI. We used rFpro's own virtual Vehicle Dynamics Proving Ground for our customer's project, which enables subjective and objective testing to take place just as it is done in real-world track testing."

AVL, the world's largest independent developer of automotive powertrain systems, is also using DIL simulation with rFpro software. By front loading the engineering activity on a DIL simulator with subjective feedback, AVL estimates that over 30% of costs incurred in developing driving attributes could be saved.

"Early in the development of new powertrain concepts, decisions are made regarding fundamental architecture, which have far-reaching consequences," explains AVL's Erik Bogner, manager for driveability and simulation. "Many of those decisions influence the subjective feel of the vehicle and require driver feedback to supplement objective data and ensure that the best choices are made. Simulation software from rFpro not only provides graphical realism for the driver, but also the ability to 'feel' events such as gear shifts and vehicle movements, and experience them in ways that are not possible with offline desktop simulation.

"AVL chose rFpro software because it provides seamless integration of the vehicle model and the best level of immersive experience for the driver conducting the assessment testing," Bogner continued. "rFpro's inherent strengths, low latency and high bandwidth make it the only viable solution for conducting DIL vehicle dynamics studies."

BELOW: **SO ACCURATE IS THE NORDSCHLEIFE MAPPING THAT EVEN THE FAMOUS GRAFFITI HAS BEEN CAPTURED**

Well prepared

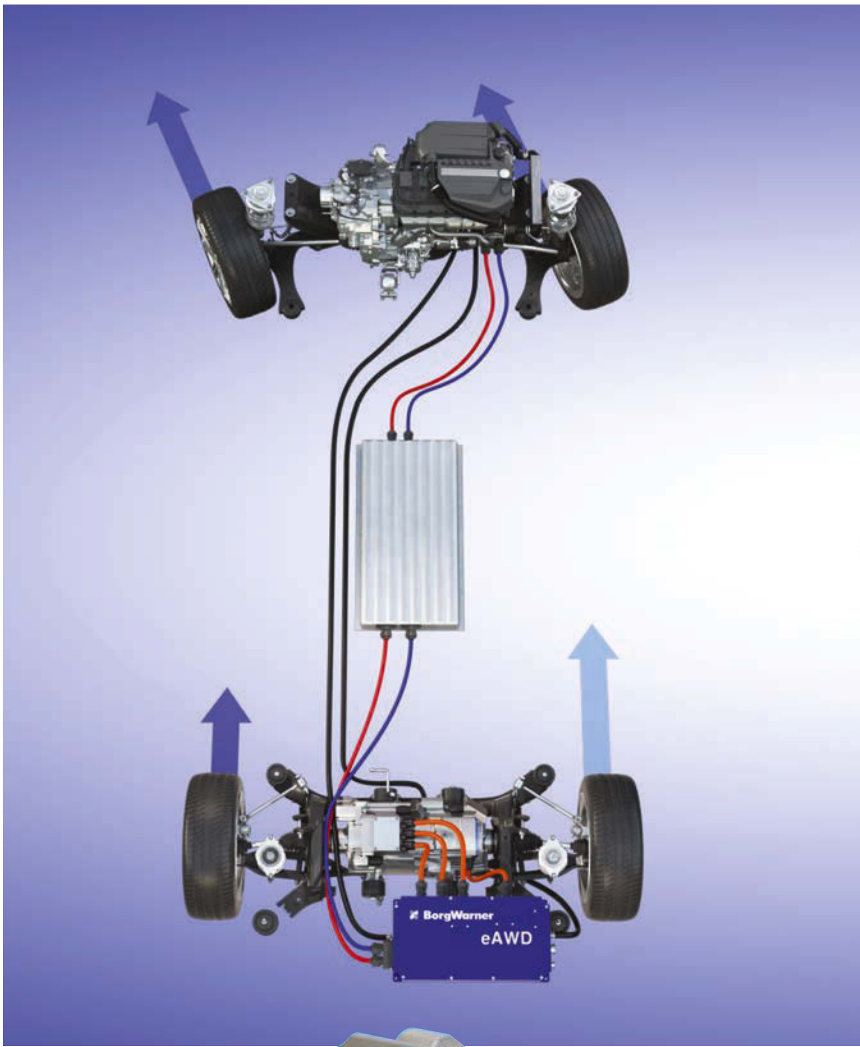
BORGWARNER'S PRODUCT PORTFOLIO MEETS CURRENT AND FUTURE DEMAND FOR DRIVEABILITY-ENHANCING TECHNOLOGIES

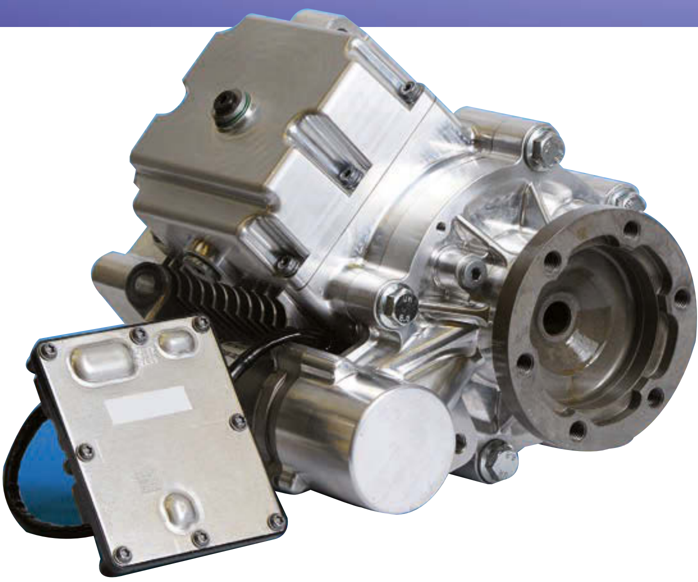
MAIN: **THE EAWD SYSTEM ENABLES ON-DEMAND ALL-WHEEL DRIVE**
FAR RIGHT: **THE GEN V AWD COUPLING OFFERS IMMEDIATE RESPONSE TO THE DRIVER**
BOTTOM: **BORGWARNER'S FXD ELECTRONIC LIMITED-SLIP DIFFERENTIAL**

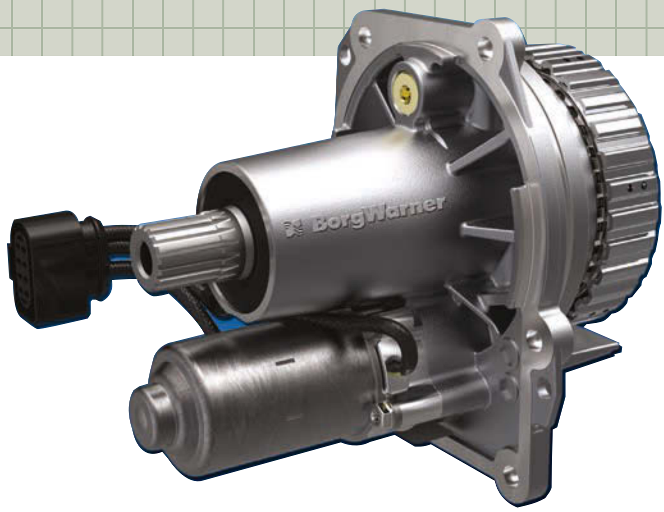
All-wheel drive (AWD) and advanced drivetrain technologies, which provide improved handling and dynamics, are hugely popular at present. With its complete line of transfer cases, AWD couplings, electronic limited-slip differentials, torque vectoring technology and hybrid/electric vehicle driveline systems, BorgWarner has the right technology for virtually any circumstance.

The story of BorgWarner's TorqTransfer division commences in the early 20th century in Muncie, Indiana, USA. There, Tom and Harry Warner designed a differential gear for automobile transmissions that allowed a vehicle's two drive wheels to turn at different speeds during cornering. The Warner Gear Company was established in 1901. In 1919, it had great success with the first standard transmission for all makes of cars. The Borg-Warner Corporation was founded in 1928 by merging Warner Gear with Borg & Beck and two other companies. Twelve years later, BorgWarner's Warner Gear division expanded its portfolio by adding innovative transfer cases. While customer expectations of high quality and high performance have never changed, the technologies themselves have advanced considerably. Since 1990 in particular, the automotive industry has witnessed tremendous growth in the demand for vehicles with AWD systems. Besides the established markets of North America, Western Europe, Japan and South Korea, the main drivers of this growth are the so-called BRIC countries – Brazil, Russia, India and China.

AWD applications, originally reserved for SUVs because of their advantages off the road, are now in great demand across all vehicle segments. Global demand of AWD applications is expected to grow by a further 3.1% by 2019. In particular, drivers value the improved handling, dynamics and stability resulting from these technologies. The dominant AWD architecture continues to be active on-demand AWD, in which one axle is the primary driven axle and torque is transferred to the







secondary axle when needed. In this connection, BorgWarner offers the GenV electronically controlled AWD coupling. The state-of-the-art technology automatically distributes power between the front and rear wheels. To accomplish this, a new lightweight and compact design for reduced vehicle complexity and easier integration into the drivetrain is used. BorgWarner's GenV AWD coupling delivers an immediate pre-emptive response with a high torque accuracy. Calculation is carried out by the integrated ECU based on data provided by the onboard electronics. If required, and depending on road conditions and vehicle load distribution, full locking torque is available at any time and any speed.

The widely respected GenV AWD coupling was the first major product launch after BorgWarner acquired the Sweden-based Traction Systems division of Haldex AB in 2011. Originally patented by Sigvard Johansson in 1998, it is based on a unique differential pump that creates a hydraulic flow, proportional to the difference in velocity, over the coupling. Using a linear throttle valve that is activated by a stepper motor, the stiffness can be varied, and the torque transfer controlled.

Another future-oriented technology from BorgWarner TorqTransfer Systems is the industry-first electronic limited-slip differential system for front-wheel-drive (FWD) vehicles, commonly known as the front cross-differential (FXD). It was launched on the Volkswagen Golf GTI, in the optional Performance Pack. The system constantly communicates with onboard electronics as well as vehicle sensors, using data such as steering angle, engine torque or yaw rate to adapt the torque to most driving situations. By controlling the locking torque between the front wheels and directing power to the wheel with the best traction, FXD prevents wheel slip before it occurs. During cornering, it delivers a torque-vectoring effect to prevent understeer. To reduce oversteer, FXD provides a yaw-damping effect. The result in both cases is enhanced vehicle stability.

Finally, BorgWarner's Disconnect Coupling enables the secondary axle to be disconnected from the driveline, and a synchronization function in conjunction with a power transfer unit (PTU) provides mechanical disconnection for improved fuel economy. It features the rationally designed centrifugal electrohydraulic (CEH) actuator. With its long-established competencies resulting from more than 100 years of experience, BorgWarner TorqTransfer Systems' product portfolio is in an excellent position to meet the constantly growing demand for enhanced driveline technology. Following current major trends such as all-wheel drive and driveline disconnect technologies, the GenV, FXD, eAWD and the Disconnect Coupling provide a fun to drive, highly efficient experience across all vehicle segments and under practically all driving conditions.

Driving Simulators

MECHANICAL SIMULATION EXPANDS ITS RANGE OF DRIVING SIMULATORS TO INCLUDE PLATFORMS SPECIFICALLY FOR ENGINEERS

Motion-based flight simulators were invented in the mid-1950s as a means to train military and commercial pilots in a safe and cost-effective manner. Since that time, automotive engineers have spent thousands of hours writing proposals to convince management to invest in simulators for ground vehicles. In most cases, their proposals were rejected based on return on investment, performance limitations, and operating cost concerns. Aviation simulators easily trumped these objections since the cost of a flight simulator facility is minimal compared to the cost to train a few hundred pilots. Preventing a single plane crash easily justifies the cost of a comprehensive, simulation based flight training program. It is also worth stating that hexapods – the most common 6DOF platform used in motion-based simulators – are well suited to simulate the yaw, pitch and roll motions of airplanes.

Driving simulators have now reached a level of refinement and sophistication where they are powerful, economical and necessary tools to meet the challenges faced by a rapidly changing automotive industry. New driving simulators, such as Mechanical Simulation's QuadDS, feature high-fidelity vehicle dynamics, interfaces to standard engineering tools including MATLAB/Simulink, high-quality visualization systems, and motion platforms optimized for development driving. The engineering driving simulator is designed for medium-sized labs with a small team of engineers – ideal for rapid prototyping and A-B comparisons early in the development process.

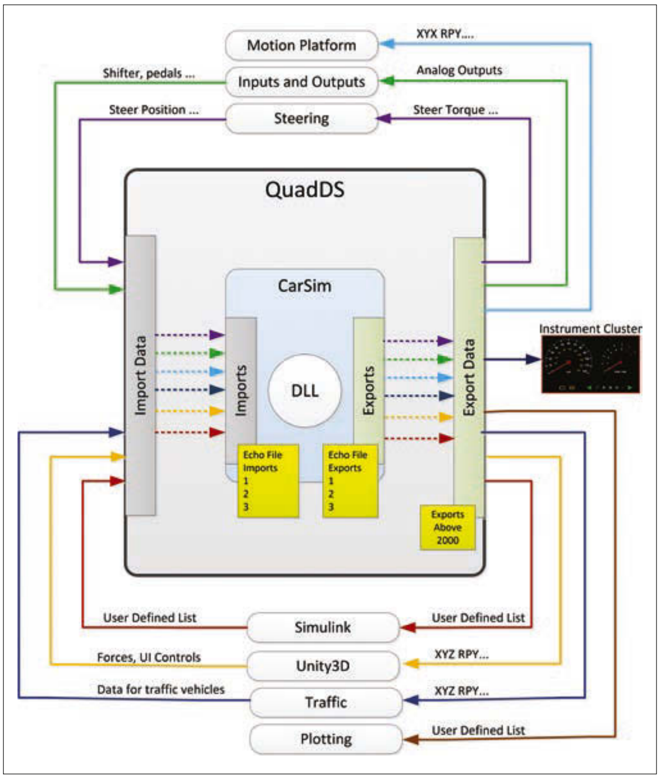
"The QuadDS platform," explains Len Johnson, senior driving simulator engineer at Mechanical Simulation, "provides another dimension to engineers. CarSim and TruckSim models can be driven and evaluated in virtual environments well before hardware is available. This allows early confirmation of targets and assessment of vehicle model quality. Since engineers now perform first-cut tuning tasks and evaluate hardware tuning kits on driving simulators, they are able to quickly and efficiently complete final tuning tasks once production ready hardware becomes available. Engineering driving simulators have now reached a price point where every engineer can experience a representation of their designs early in the product development process."

The idea of automotive driving simulators gained momentum in the late 1990s as the cost of industrial automation, computer, and visualization technologies plummeted and performance escalated. As soon as the first large facilities were commissioned, the industry realized that simulating automobiles is much more challenging than simulating airplanes. Early attempts at automotive driving simulators left drivers underwhelmed and often victims of simulator sickness. From the complex interaction at the tire/road interface, to the high visual flow rate drivers experience compared to pilots, to the relatively unrestrained seating position of passenger cars, every aspect of applying hexapods as the motion platform for engineering driving simulators required new and innovative thinking.

The fundamental differences between driving and flying drove automotive simulators to an "all or nothing" approach that permeated the driving simulator industry for several decades. At the high end, this thinking led to the construction of a handful of multimillion dollar driving simulators housed in massive facilities and staffed by dozens of engineers and technicians. Financial realities made these simulators suitable for two major applications: (1) large government-funded human factor and driver behavior studies with drivers selected from a pool of volunteers, and (2) high-budget motorsports simulators optimized for a select number of professional test drivers. At the same time, the low end of the market produced fixed-based driving simulators targeted at the driver training market. As these devices focused on teaching basic vehicle operation, they lacked the fidelity and flexibility required for use in engineering applications.

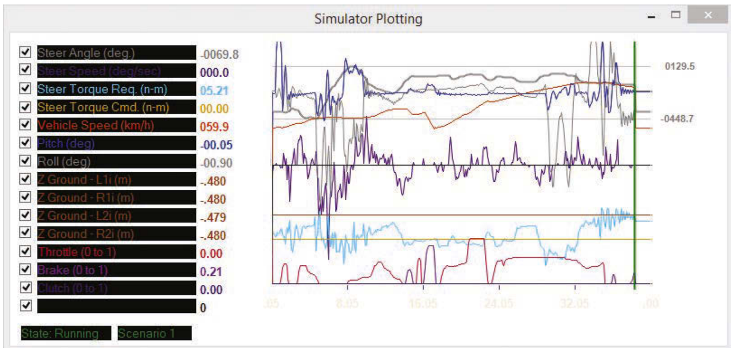
Fast forward to 2015, we find that industry trends are converging to bring engineering driving simulators within reach of most development organizations. The most important trend, initiated by high-end motorsports organizations, is that simulation platforms must only produce the most important motions for the driving situation while minimizing or ignoring motions that do not feel natural to the driver. This thinking minimizes the use of hexapods in favor of motion platforms designed for specific applications. For motorsports applications, this refinement translates into rotary platforms capable of generating high yaw rates. For engineering, the focus is on small motion cues and precision steering/pedal systems that communicate how subtle driver inputs are translated through the road/tire interface. The next trend is the intense pressure created by economics of the automotive industry and the rapid deployment of ADAS and autonomous

BELOW: **DIAGRAM SHOWING THE ARCHITECTURE OF THE QUAD DS VEHICLE DRIVING SIMULATOR**



driving technologies. OEMs looking to optimize and streamline their investment in simulation technologies continually seek tools and techniques that allow them to use the same set of simulation models throughout their entire engineering development process.

The QuadDS is the first driving simulator to put all of these pieces together in a package feasible for medium-sized engineering labs. Instead of focusing on large facilities for a few anointed drivers, the simulator is designed for engineers who need to combine their vehicle simulation models and associated active controllers – brakes, suspension, powertrain – in a virtual environment. The simulator features CarSim as the vehicle dynamics platform, a MATLAB/Simulink interface, CAN ports to interface with HIL systems and vehicle controllers, and an open architecture that lets engineers integrate their own driver controls and I/O systems. Other interfaces allow engineers to integrate traffic simulation programs and high-end visualization systems that can simulate advanced sensors such as radar and lidar. "Many of our OEM and Tier 1 customers have eliminated weeks of proving ground testing because they were able to complete multiple calibration rounds using Mechanical Simulation's driving simulator technologies. Engineers are able to evaluate multiple



ABOVE: **INSIDE THE REALISTIC QUAD DS ENVIRONMENT**
LEFT: **PLOTTED FEEDBACK ALLOWS USERS TO TRACK PROGRESS**

configurations quickly and optimize their time at the test track," explains Robert McGinnis, senior account manager at Mechanical Simulation. "The surprise to us is that the simulator has become more than an engineering tool – it is a communications tool that helps engineers fully investigate the nuances and limitations of their vehicle systems and share this information with their management early in the product development process."

The future for engineering driving simulators is promising as ADAS and autonomous driving technologies are pushing the traditional test plans and automotive proving ground protocols to their breaking point. These advancements are also causing great concerns with proving ground staff tasked with performing high-speed, close quarter maneuvers to fully test a vehicle's sensor capabilities. "When you combine high-fidelity vehicle dynamics, accurate sensor models, and virtual/augmented reality technologies, you have an ideal platform to evaluate technologies that require multiple cars to operate in close proximity to each other. By networking real and virtual vehicles in the same environment you get the best of both worlds – realistic scenarios and safe driving." As sensor technologies becomes more demanding, the QuadDS is keeping pace by providing photo-realistic driving environments featuring realistic lighting, dynamic weather, kinematic pedestrians and bicycles, and advanced driver assistance displays.

Volume control

SKF'S NEW LOW-NOISE STEERING COLUMN BEARING HELPS TO BOOST CUSTOMER CONFIDENCE IN AN AGE OF QUIETER CARS

Quieter engines are one of the many improvements found in modern cars. This, coupled with enhanced noise abatement technologies, makes the car interior a much quieter place than ever before.

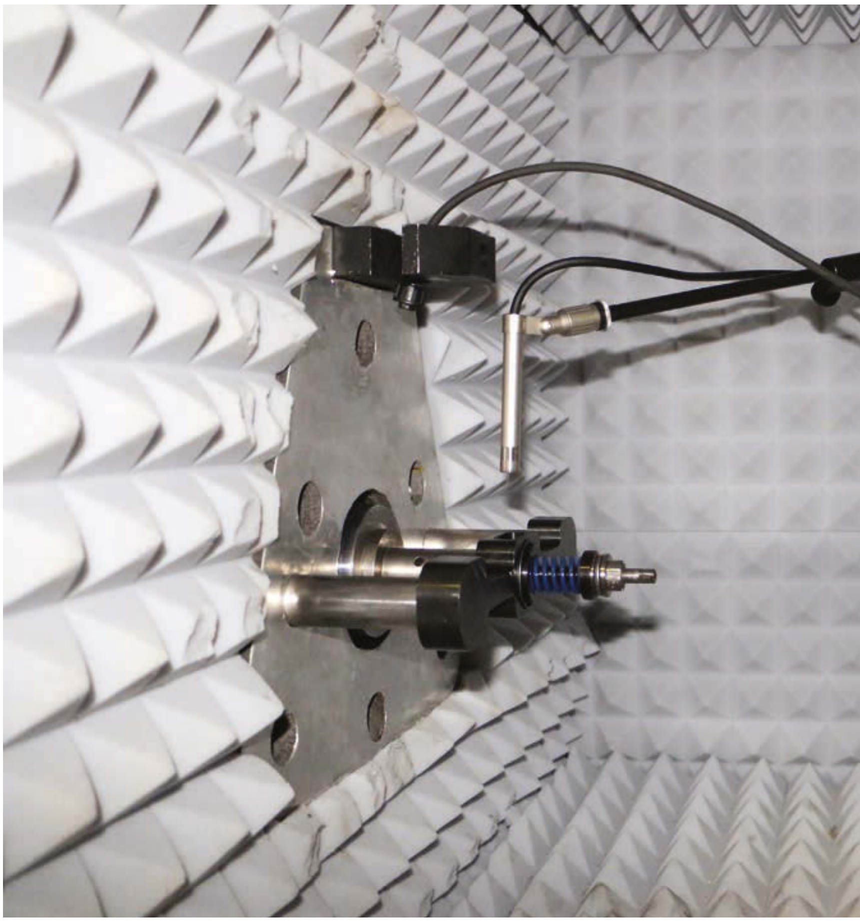
But this effect – which is particularly noticeable in electric or hybrid cars – means that sounds from subsystems such as steering, transmission and suspension are now far more noticeable. For this reason, noise reduction of vehicle subsystems is currently a major trend for automotive manufacturers.

SKF has helped to address this by developing a new customized bearing for steering columns, which exhibits significantly reduced noise levels. The pre-loaded wire steering column bearing (P-WSCB) is aimed at Tier 1 automotive manufacturers, and will help them to meet the low-noise specifications of OEMs.

Excess noise is often perceived as a failure by customers and end users, while low noise is a sign of quality and comfort. Tier 1s and OEMs are likely to have more confidence in the durability and overall performance of bearings that run more quietly.

Customer perception is also a critical factor. Internal noise, no matter how quiet, can cause customers to question the quality and safety of the steering, the car's overall reliability – such as its ability to maintain performance over its lifetime – and ultimately the perception of the brand itself.

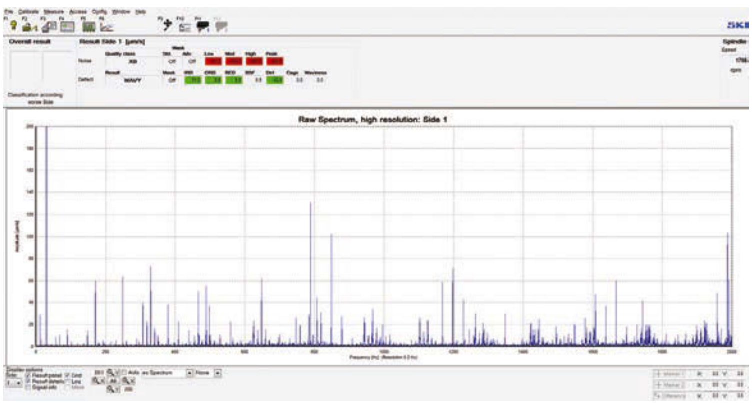
SKF's new low-noise bearing reduces noise levels by around 4dB(A) compared with standard SKF bearings – and even more in comparison with competitor products – while maintaining existing high performance characteristics.



RIGHT: **LOW-NOISE STEERING COLUMN UNDERGOING TESTING**

The low-noise P-WSCB has a noise level of 37-38dB(A), compared with the 41-42dB(A) of its standard P-WSCB. This is the same amount of noise reduction as it achieved between the standard and low-noise versions of its angular steering column bearing. While the reduction appears to be minor, a drop of 3dB(A) is equivalent to half the audible noise.

A number of design changes contributed to the performance – and noise reduction – of the new P-WSCB. Gaps in the wire raceway give flexibility to the bearing's outer ring, which allows for press fit mounting into the housing. The wire gap produces internal bearing excitation as the ball passes. Careful design of the gap helps to reduce bearing noise. Other important design features that reduce noise include: reduced roughness of the inner ring, a change of ball quality grade, and optimization of grease quantity.



RIGHT: **GRAPH SHOWS THE AMPLITUDE AND FREQUENCY OF VIBRATIONS THROUGH THE BEARING**

The new bearing offers a better driving feel, in terms of friction torque and steering column stiffness, and helps to mitigate vibrations that are transferred from the road to the driver. It supports axial and radial loads well, and provides electrical conductivity – which helps toward the smooth functioning of airbags and other electrical components.

Steering systems – which are connected to both active and passive safety systems – are likely to play a huge part in solving future technical challenges of the automotive industry. Electric steering, for example, has so far only been used to replace traditional hydraulic steering, but will be the first step in creating automotive primary control systems in future.

Electric steering will be a fundamental part of active safety technologies, connecting the wheel, brake and suspension areas in order to improve overall vehicle performance. Sensorized components, such as bearings, will enable communication between the separate systems – so that mechanical components can be replaced with steer-by-wire technology.

SKF's P-WSCB range for steering columns is available in nine options – all of which are available as low-noise variants. Internal diameters vary from 22-30mm, with outside diameters of 40-44mm. They weigh between 28-43g, and the series is designated BAQ by SKF.

Benefits across the range are extensive and include excellent vibration absorption, and allow for the correction of angular deviation and misalignment. The low-torque items also offer high axial retention, while their design means that no machining is needed on either the shaft or the housing.

Further benefits include the inclusion of a dumping function, a high misalignment tolerance, and a good compromise between stiffness and friction torque.

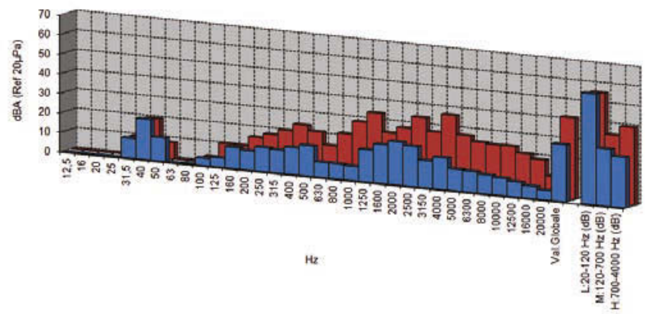
SKF has created a new rig to test the bearings, using a new specification. It aims to develop a standard measurement method for its full range of steering column bearings, creating a baseline for its products versus those of competitors.

The new bearings are expected to find use in electric and hybrid vehicles, and a range of higher specification cars – such as the C, D and E segments of luxury brands like Audi and BMW, as well as high-class premium brand cars such as Volkswagen and Volvo. This will be achieved through supplying the leading Tier 1s, such as ZF Lenksysteme, Fuji Autotech, ThyssenKrupp Presta, Nexteer, Mando and TRW.

Electric power-assisted steering (EPS/EPAS) is also becoming more commonplace in modern cars, and is the basis for enhanced functions such as emergency steering assistance, lane holding, torque steer compensation, and parking assistance. In the future, it will underpin advances such as autonomous driving, active collision avoidance, and active stability control.

SKF already supplies other bearings – including low-noise versions – for EPAS systems. Its four-point contact ball bearings for rack EPAS are available in five bore diameters, from 40-50mm. All offer low noise, low torque, high stiffness, high load-carrying capacity, and low axial clearance. At the same time, its deep groove ball bearings for column and dual-pinion EPAS are available in nine different bore diameters – ranging from 6-25mm. Benefits include a very thin section, flexibility, low torque and low noise.

The company's car steering and suspension product development is managed by its Global Center of Excellence in Saint-Cyr-sur-Loire, France. Bearings for steering systems are manufactured in five locations – three in Europe, plus the USA and India – and are supported by several regional technical centers.



TOP: **MEMBERS OF THE SKF TEAM DISCUSSING THE APPLICATION OF LOW-NOISE BEARINGS**

ABOVE: **GRAPH PLOTS NOISE LEVELS FROM THE BEARING AT VARIOUS FREQUENCIES**

CAE in motorsport

ALTAIR'S RANGE OF COMPUTER-AIDED ENGINEERING SOFTWARE IS MAKING A COMPETITIVE DIFFERENCE FOR OEMs AND MOTORSPORT TEAMS ALIKE

Developing light but strong structures has always been a major goal for engineers. For the automotive racing community, though speed is paramount, there is the additional objective of driver safety, often conflicting with the 'light' mandate. Achieving cutting-edge performance as well as safety, given the complexity of vehicle models and diversity of materials, is a daunting task indeed. Lighter, stronger, faster – every manufacturer and racing franchise pushes the technology envelope to analyze, refine, iterate and test to gain a meaningful advantage on race day.

Race cars must be optimized for weight, performance, reliability and efficiency. This process involves a multitude of CAE tasks, including the meshing of parts and full vehicles, FEA of components, crash test simulation, optimization and CFD analysis. In the design of a complete vehicle, engineers design and optimize every single part, simulate crash tests, simulate the aerodynamic performance of the car, and fulfill the rigorous testing requirements for FIA homologation before a physical prototype is even built.

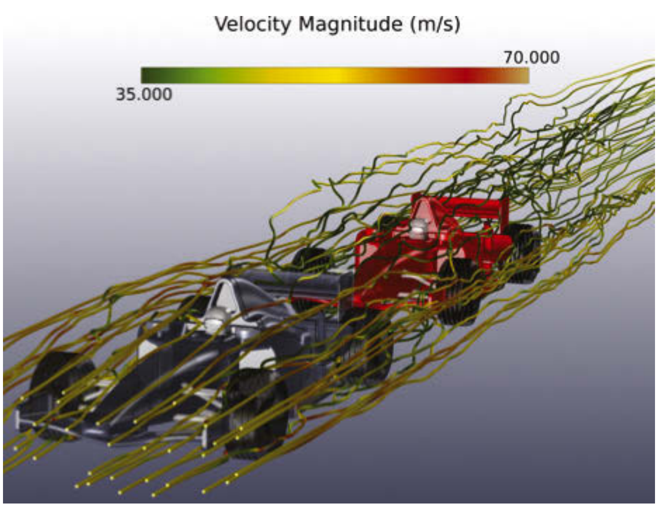
Use of innovative materials represents a major variable in the weight and strength equation. Options include high-strength steel, stainless steel, aluminum alloy and composite structures. Composites introduce a high level of complexity for CAE analysis, particularly for crash simulation. Various shapes and types of composites (woven and unidirectional, for example) must be modeled and manufactured differently. Behaviors are difficult to predict as the physical phenomena are very complex. A large amount of data is necessary to perform the analysis, and specialized expertise and software is required.

Dallara Automobili is an Italian chassis manufacturer that designs with safety in mind. Several prominent drivers have gone on record to attribute their survival after potentially fatal crashes to the company's design innovation. The company is committed to pushing the boundaries of what can be done to protect the driver, from an engineering perspective. To that end it uses Altair HyperWorks, a comprehensive open-architecture CAE suite containing pre- and post-processing tools, multiple solvers and optimization capability.

"Race cars must be fast and safe," says Luca Pignacca, Dallara's chief designer and EM racing business leader. "They must be light to be competitive, and to be safe, they must be well designed. Software helps us get the best out of the structures we design."

For Beta Epsilon, a design company offering high-performance full-vehicle design and engineering services to automotive manufacturers as well as racing teams, CAE tools are indispensable. The company has expertise in light composite structures, including their manufacture, particularly those subject to dynamic stress and a high level of vibration. In-house prototyping, crash testing, homologation services and aerodynamics simulation represent additional competencies. With

BELOW: **ALTAIR'S SOFTWARE CAN BE USED TO SIMULATE A VARIETY OF SCENARIOS, SUCH AS FOLLOWING IN THE WAKE OF ANOTHER CAR**



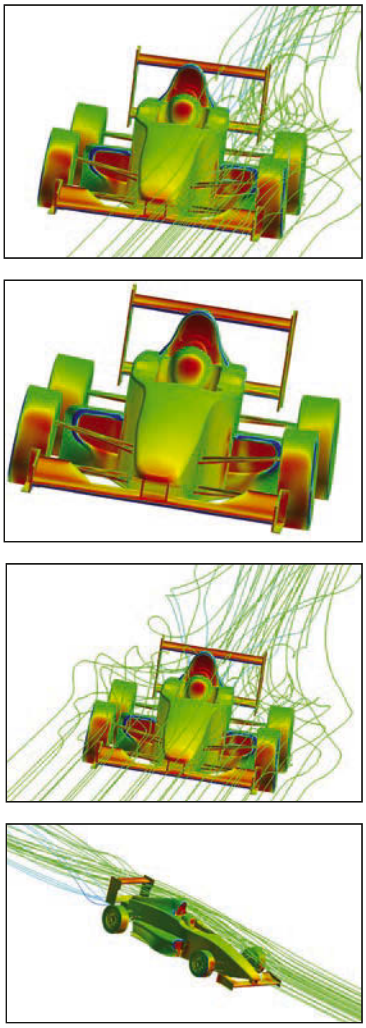
Altair HyperWorks, Beta Epsilon has access to almost all the CAE tools required in its development process, including pre- and post-processing, topology optimization, crash and impact analysis, CFD and wind tunnel simulation.

For aerodynamic simulation in particular, Beta Epsilon relies on CFD analysis to understand the physical phenomena occurring as a consequence of a particular design. HyperWorks' Virtual Wind Tunnel enables the study of downforce, drag, cooling airflow and flow structures for increased safety and elite performance. The solution offers advanced meshing capability, high-fidelity CFD simulation, powerful reporting features and a simulation-driven design workflow.

Multiphysics such as fluid-structure interaction (FSI) may be studied: for example the deflection of a spoiler due to aerodynamic loads and the effect on the downforce of the vehicle. Race engineers need to understand the flow structures along the entire vehicle length to maximize downforce. Without sufficient downforce, safety and engine power could be compromised.

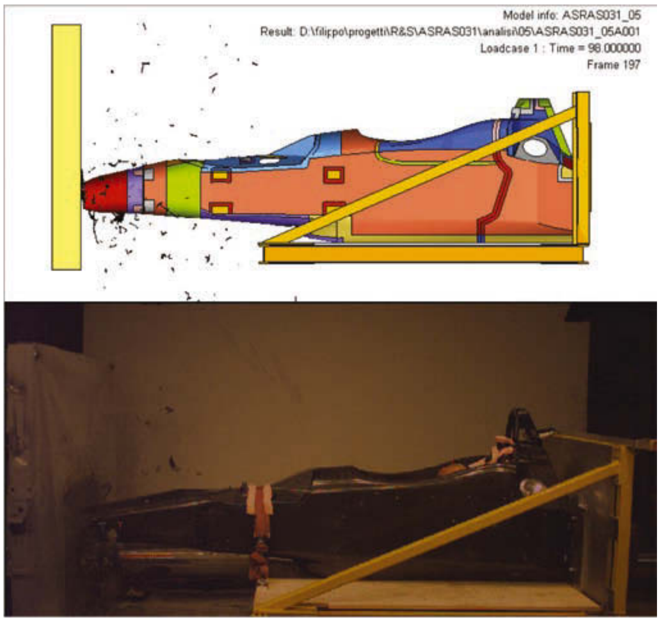
Central to the HyperWorks Virtual Wind Tunnel solution is AcuSolve, Altair's general-purpose flow solver, which is differentiated by its speed, scalability, robustness and accuracy. Its advanced turbulence modeling technology enables HyperWorks Virtual Wind Tunnel to predict flow field and flow separation using steady-state and transient simulation for faster and more accurate results. AcuSolve's FSI facilitates realistic and comprehensive automotive virtual wind tunnel simulation by considering the flexibility of structures and flow-induced vibration.

Of particular note, AcuSolve is highly tolerant of varying element qualities, efficiently handling unstructured meshes with high aspect ratios and badly distorted elements. These mesh characteristics are unavoidable with complex geometries. Accurate external aerodynamics results are achieved for both steady-state and transient simulation. In addition, thermal characteristics such as engine and brake cooling may be studied.



This level of analysis would not be possible without powerful computing resources. For additional scalability, an engineer may easily tap into high-performance computing (HPC) by submitting the job to a computing cluster. This often occurs, and is very convenient for computing- and memory-intensive tasks such as volume meshing, solving and post-processing. For a one billion element model, excellent parallel solver run efficiency (over 90%) has been demonstrated with up to 1,600 processing cores, and very good parallel efficiency (80%) with 3,200 cores. Intelligent automation for problem setup, mesh statistics and results makes the process even easier when using HyperWorks' Virtual Wind Tunnel.

The use of CAE and virtual wind tunnel simulation has added flexibility and agility to the product development process at Beta Epsilon, Dallara Automobili and many other Altair customers in motorsport. Efficient, robust, accurate physics-based simulation, including multiphysics capability along with the ability to seamlessly leverage the power of HPC, enables engineers to investigate phenomena occurring as they design, rather than after the fact. Design changes may be explored interactively, for rapid iteration and shorter development cycles. This ability is revolutionary in that a better design may be reached and higher performance achieved than would otherwise be possible.



ABOVE: **COMPARISON BETWEEN REAL-LIFE TEST AND SIMULATION ON A DALLARA CHASSIS**

LEFT: **CFD STREAMLINES SHOWING AIR PRESSURE AND FLOW OVER A SINGLE-SEATER COMPETITION CAR**

CFRP dampers

THYSSENKRUPP BILSTEIN HAS DEVELOPED THE WORLD'S FIRST AUTOMOTIVE MONOTUBE DAMPER TO FEATURE A FULL CARBON FIBER REINFORCED PLASTIC TUBE

ThyssenKrupp Bilstein has a long, and rich, heritage of introducing technical innovations. Since its introduction into the automotive sector in 1928, the company has striven for technological advances, both on the circuit and on the road.

With the aim of reducing the weight of existing aluminum tube solutions as much as possible without compromising the resistance and endurance of these highly stressed components, ThyssenKrupp Bilstein has developed the first automotive monotube damper to feature a full carbon fiber reinforced plastic (CFRP) tube. This innovative damper design does not have a metal liner on the inner surface.

Layout and technical requirements

Most monotube damper designs consist of a working piston attached to the lower end of a piston rod, which is guided inside the damper tube. The gas chamber is located in the lower part of the damper tube, which is separated from the oil chamber by a piston. As common assembly technologies such as welding and crimping cannot be used in the manufacture of CFRP tubes, the design of the CFRP damper is unique, especially when it comes to its joins and seals.

Focusing on the working conditions, the technical requirements of the CFRP tube structure are that it should be able to withstand a system pressure of up to 200 bar, a working temperature range of -40°C to 160°C (and as high as 200°C for short periods), while covering dynamic loads of +/-30kN. These loads are introduced into the tube structure via load input elements at the lower and upper ends of the tube.

Reference part

The reference part (see 'Aluminum tube' opposite) for the development is a 46mm aluminum damper tube with a wall thickness of 3mm and a total weight of 557g. It features an aluminum eye ring that is friction-welded to the tube. The seal pack is fixed into the tube via a crimping process or snap-ring closure.

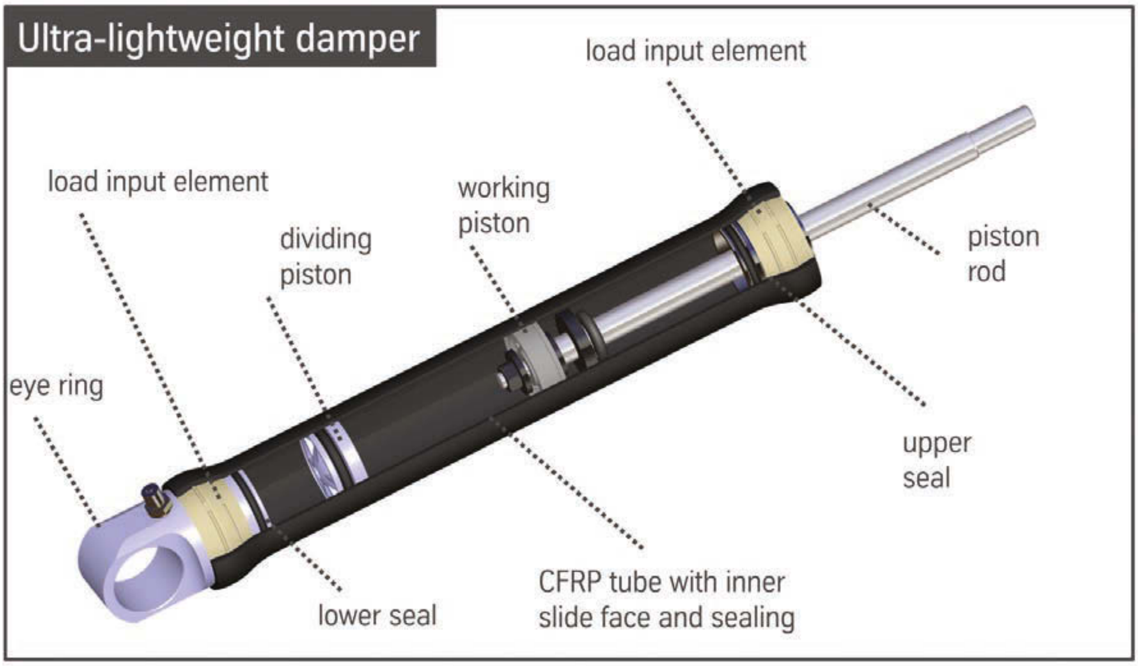
The unique and patented feature of the CFRP damper tube is that it does not have a metallic inner liner or metallic inner surface, which is also a key factor in the component's light weight, which is claimed to be up to 33% less than that of aluminum damper tubes.

The tightness and the high load requirements, together with the high temperature demands, play an important role in material selection. It is also necessary to look at the thermal expansion factors of the different materials to be combined. The CFRP tube has extremely small differences in thermal expansion coefficient, and the metallic load input elements have a much bigger coefficient. As temperature increases, the extension of the load input elements inside the CFRP tube help to increase the compression stress between the two components – and thus the strength of the connection.

As the working principle of every shock absorber is to turn kinetic energy into heat, when CFRP is used, the heat transition through the tube's inner surface suddenly becomes a major challenge.

However, that challenge is offset by the benefits that the material

RIGHT: **CUTAWAY IMAGE OF THE CFRP DAMPER SHOWS THE UNIQUE DESIGN**



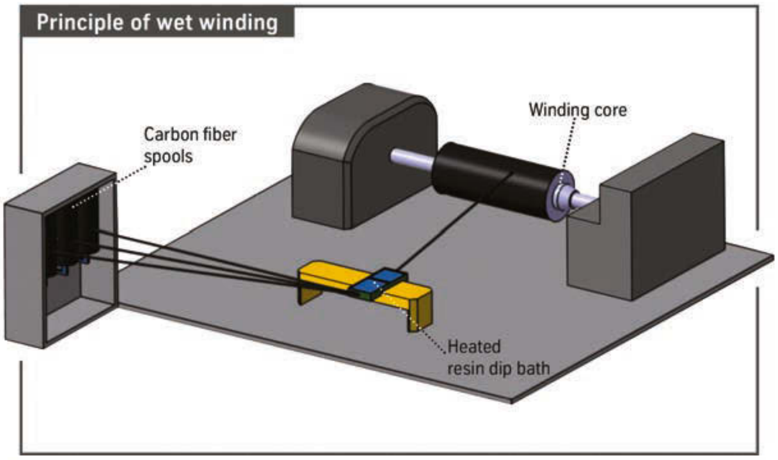
provides, such as low material density, reduced wall thickness, a larger outer surface to support free convection, and stability in the manufacturing process. All these factors help CFRP tubes to achieve an impressively low temperature delta between the inside and outside of the CFRP wall.

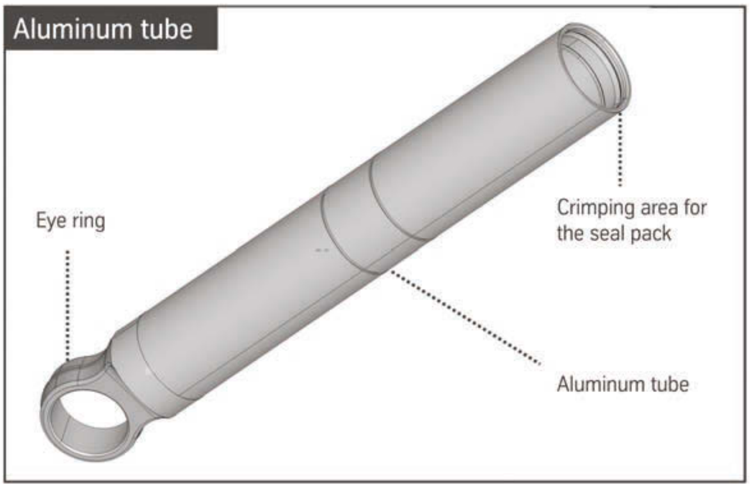
Manufacturing process

The tubes are manufactured using the wet filament winding process (see 'Principle of wet winding', right). Without an intermediate step for the manufacturing of semi-finished parts, the fibers and the matrices are directly fed into the component. Other advantages of this process are that a high fiber volume is obtainable, and that no autoclave or other compaction process is necessary.

First the load input elements are positioned on the mandrel. The fibers are unwound and passed through a heated resin bath. The impregnated fibers are then laid on the mandrel at a predefined tension. The mandrel and the positioned load input elements are then encased in the laminate. Finally, after curing and tempering of the matrix, the damper tubes can be removed from the mandrel.

Using this special process, the inner surface of the tubes can be improved to such high quality that a suitable sliding and sealing surface is achieved.





LEFT: **DIAGRAM SHOWING THE MANUFACTURING PROCESS FOR THE CFRP DAMPER TUBE**

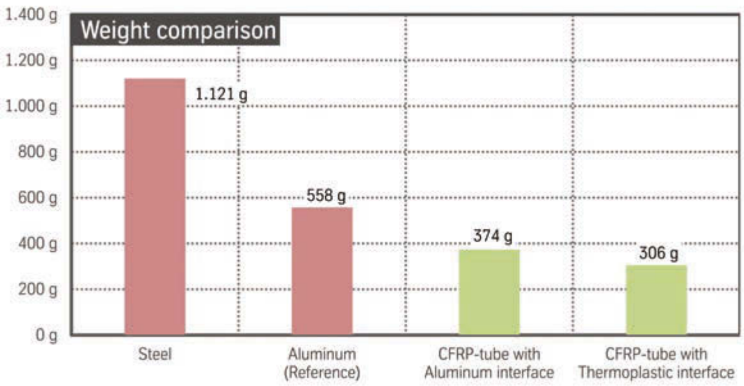
BELOW: **TRADITIONAL ALUMINUM DAMPER TUBE, PRODUCED USING CURRENT METHODS**

The future

Following completion of a full damper design verification on the test bench under tough conditions, the first dampers have been on trial with OEMs since 2013 and have already covered over 60,000 miles (100,000km).

The results have been promising, leading to further development projects with the clear goal of serial implementation.

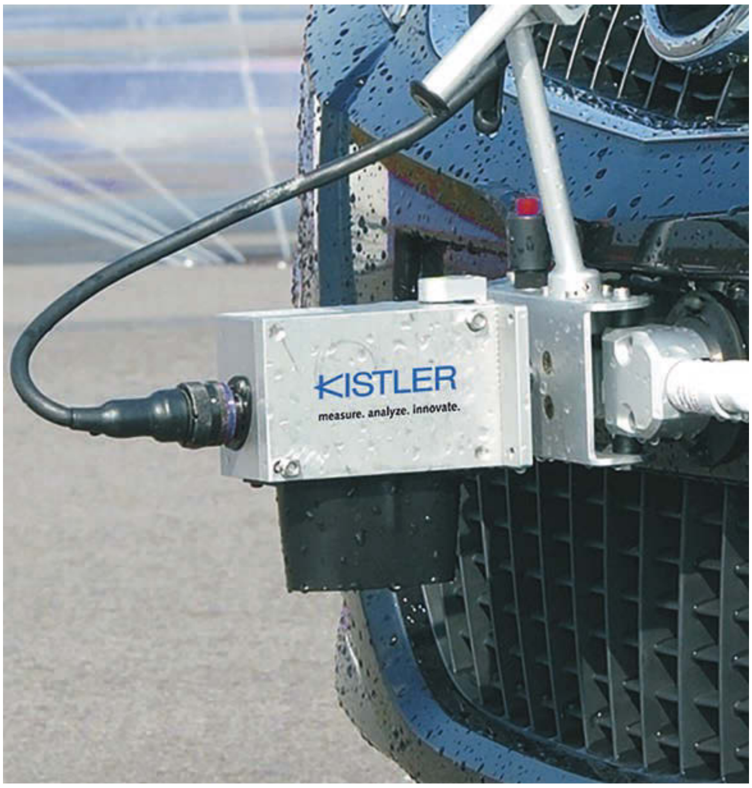
The weight advantages of CFRP dampers will be enhanced even further in the future. Through design alterations such as replacing the lower aluminum interface with a glass fiber-reinforced plastic interface, weight can be reduced further compared with the reference component without compromising any functional requirements.



ABOVE: **GRAPH HIGHLIGHTS THE POTENTIAL WEIGHT SAVINGS CFRP OFFERS**

Combined sensors

BY USING A MOTION SENSOR AND A MEASUREMENT STEERING WHEEL, DYNAMICS TESTS CAN BE QUICKER, SIMPLER AND MORE RELIABLE



RIGHT: **KISTLER'S CORREVIT L-350 AQUA SENSOR IN SITU DURING AN AEB TEST**

Driving dynamics tests often involve highly complex motion sequences and therefore require proven test methods and equipment. Standardized tests are especially important when it comes to the assessment of vehicle driving behavior.

A typical example of such a standard test is the open-loop test 'braking in a turn', as specified by ISO 7975. During this test, a vehicle's directional behavior is determined when it moves from a steady state (i.e. the steady-state circular course drive) into a non-steady state following a braking action. Vehicle engineers must know the exact effects of directional behavior to enable them to develop safe and comfortable vehicles.

Typical measurands of this test method are steering angle, brake system pressure, longitudinal and transverse acceleration and speed, yaw velocity, slip angle, and pitch and roll angles.

The test procedure begins with the steady-state circular course drive, performed on a specified radius. The driving speed is then increased until the stipulated transverse acceleration is reached. These steer angle and speed values serve as reference values for the evaluation of the next in the series of tests. Fixing the steering angle facilitates the execution of the test, as it enables the steering angle to be constant, even when the braking action induces deceleration.

Often an accelerometer is aligned to the vehicle's y-axis to measure transverse acceleration. However, the accelerometer only measures the lateral acceleration and it must be corrected by applying the roll angle to determine transverse acceleration. If you apply an analog accelerometer to measure longitudinal acceleration, it must be corrected by the pitch angle. After determination of these reference values, the braking action during the steady-state circular course drive will be performed.

When the transverse acceleration given by the standard is reached, braking is initiated at a constant steering angle. The test is performed with various longitudinal decelerations. For future evaluation, it is necessary to determine the rise time of the brake pressure.

Figure 1 shows the course of a braking maneuver performed during the steady-state circular course drive. When braking commences, the vehicle rolls around its y-axis for a short time, due to the decreasing transverse acceleration. As a consequence, the decreasingly active lateral force springs back to its original position.

The determined reference values of the steady-state circular course drive, as well as the measurement values from the braking action, are used to evaluate the parameters for the steerability and the yaw behavior as a function of the braking characteristics.

Another test procedure for the assessment of driving characteristics is the ISO 7401 lateral transient response test, for determination of the transverse dynamic behavior of a vehicle.

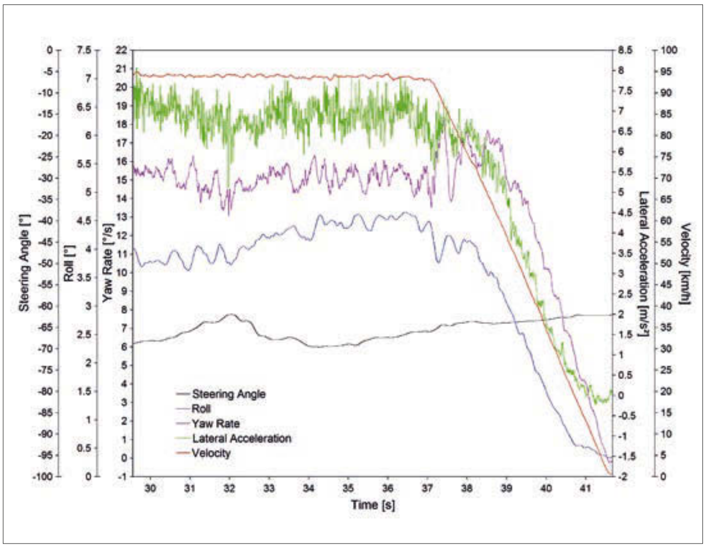
Different test methods, such as step-steering input, sinusoidal input (one or more periods), random input and pulse input, enable characterization in the time range as well as in the frequency range.

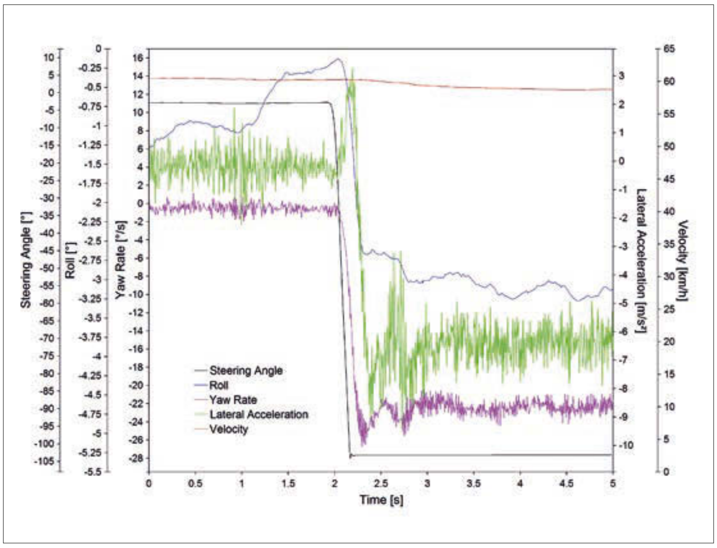
Important parameters in the time range are: time shift between steering wheel angle, transverse acceleration, yaw velocity and the magnification ratio of the yaw velocity.

Important parameters in the frequency range are: transverse acceleration related to the steering wheel angle, and yaw velocity related to the steering speed.

To determine these correlations it is necessary to measure the following parameters: steering angle, steering moment, longitudinal acceleration, yaw velocity, slip angle, longitudinal and transverse speed, and roll angle.

For the determination of time behavior, step steering or sinusoidal input over a certain period may be applied. Step steering input means a quick turn-in of the steering wheel when driving straight ahead, applying a steering angle that has been determined in a pre-test, and





which must be held constant for some seconds. In the pre-test (the steady-state circular course drive), a steering angle for a transverse acceleration of 4m/s² was determined. The sinusoidal input, on the other hand, requires a steering input over a period with a steering frequency of 0.5Hz.

Figure 2 shows the course of yaw rate, roll rate, longitudinal acceleration and longitudinal speed as a response to the step steering input.

Random input provides measurement values for evaluation in the frequency domain; it means an arbitrary input of the steering angle for a longer time period to gain enough measuring points per frequency. Another test option is pulse input, which requires a steering input of a triangular pulse followed by a steering movement toward straight-ahead driving. A third possibility is a steering input of several sinusoidal steering movements, with a frequency starting at 0.2Hz and rising to 2Hz at constant steering angle maxima.

With the help of this test procedure it is possible to characterize part of the transverse dynamic behavior of the vehicle. The required measurands can be determined with the recently developed Correvit S-Motion sensor and the Kistler MSW (measurement steering wheel) sensor.

A Correvit S-Motion sensor is capable of delivering all measurands that are relevant for vehicle dynamics testing: longitudinal and transverse speed, angles (slip angle, pitch and roll angle), acceleration in three directions, direction detection and position data via GPS.

The high measurement frequency of 500Hz and a novel algorithm help to reduce signal noise substantially and enable a constant signal delay of 6ms. The sensor can be easily installed on the vehicle using the included mounting equipment (suction or magnet holders). A considerable advantage is the built-in inertial measurement unit, which makes the use of external acceleration and yaw rate sensors redundant and saves the user considerable setup time as it is not necessary to mount, adjust and configure these additional sensors.

The S-Motion sensor electronics can be configured to perform various calculations to the point of interest, which means that no post-processing of the measurement data is needed. Most interesting is the fact that no laborious running-in procedure is required. Just align the S-Motion sensor to the vehicle's longitudinal axis and the complete adjustment of speed sensors, yaw rate sensors and acceleration sensors is done.

Kistler's measurement steering wheel (MSW sensor) is a good tool for measuring steering moment, steering angle and steering speed. It is installed in the vehicle between the steering shaft and the steering wheel. To enable universal application, MSW sensors can be equipped with an exchangeable adapter for connection to the steering shaft. The wheel does not impair the airbag function, and a universal mount enables quick mounting of the MSW sensor to the original steering wheel.

Furthermore, the MSW sensor may be combined with a special steering angle stop, which enables the user to fix the steering angle to a set point and to perform steering movements between freely adjustable limits. Locking levers fix the steering angle. Releasing the levers immediately unblocks the steering wheel, allowing normal driving.

A multitude of driving dynamics measurands must be determined to perform standardized test procedures, which often means that the test vehicle must be equipped with a lot of measurement instrumentation. The more instruments that are required, the more error sources will be present, and the longer the setup time.

Especially these days, quick and easy mounting, reproducibility, plausibility of measuring results, high accuracy and comfortable operation of the measurement instrumentations, play a decisive role in dynamics tests. The combination of the Correvit S-Motion sensor and the Kistler MSW sensor provides exactly this.

FIGURE 1 (ABOVE LEFT): **THE COURSE OF A BRAKING MANEUVER PERFORMED DURING THE STEADY-STATE CIRCULAR COURSE DRIVE**

FIGURE 2 (ABOVE RIGHT): **THE COURSE OF YAW RATE, ROLL RATE, LONGITUDINAL ACCELERATION AND LONGITUDINAL SPEED AS A RESPONSE TO THE STEP STEER INPUT**

Triaxal vibration recorder

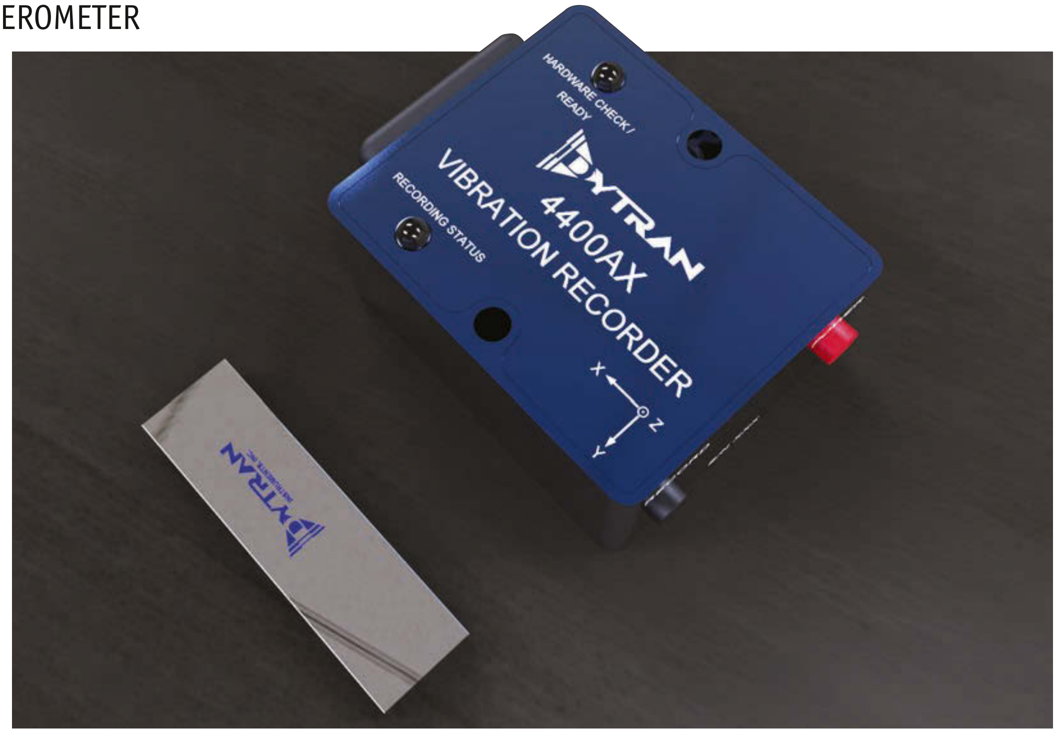
DYTRAN HAS INTRODUCED VIBRACORDER: A TRIAXIAL VIBRATION RECORDER WITH BUILT-IN MEMS ACCELEROMETER

Dytran Instruments Inc is an industry-leading designer and manufacturer of piezoelectric and DC MEMS sensors to support a variety of automotive testing applications, including noise, vibration and harshness (NVH); component durability; modal and structural analysis; squeak and rattle evaluation; road load data acquisition; transmission, powertrain and exhaust manifold testing; ride quality and durability; whole-body and hand-arm vibration measurements; and other vehicle dynamics testing.

Since its founding in 1980, Dytran has engaged in the successful design and manufacture of piezoelectric sensing technologies, including dynamic accelerometers, pressure transducers and force sensors, to support a variety of demanding customer applications and program requirements. In response to a growing number of customer requests for expanded offerings to support low-frequency vibration applications, Dytran is continuously updating its sensor portfolio to include new ranges of DC MEMS single and triaxial accelerometer models.

Included among the new DC MEMS sensors now available from Dytran is the VibraCorder, a vibration recorder with a built-in triaxial MEMS accelerometer capable of recording acceleration in three orthogonal directions and writing data on an SD memory card.

Dytran's 4400A series VibraCorder goes anywhere and everywhere to capture critical vibration data, solve problems and move product development forward. Compact, lightweight and battery operated, the 4400A series features an environmentally sealed package that fits into small spaces. Units include easily installed, user-configurable software that optimizes data collection, an internal accelerometer that eliminates the need for external cable runs and complex signal conditioning, and a removable memory card that plugs directly into your laptop or PC. The VibraCorder is easily mounted with screws or magnets.



THE ROBUST HOUSING ALLOWS THE UNITS TO BE USED IN HARSH ENVIRONMENTS, FROM TEST TRACKS TO FIELD MONITORING

Device features of the VibraCorder include multiple recording regimes (free run, triggered free run, auto stop, etc); several sampling rates available up to 3,200 samples/sec; environmentally sealed with IP64 rating; magnet mount or screw mount; battery operated (9V); up to 24 hours of recording time; low-battery indicator with emergency file save feature; and available in ranges of +/-16*g* (4400A1) and +/-200*g* (4400A2).

Software features of the VibraCorder include immediate data retrieval from the SD card to the computer screen; easy cursor operation for data selection, zoom and cursor alignment; one press of a button snapshot; data overlay; filtering; oversampling; time synchronous averaging; FFT analysis; and data export.

The VibraCorder can operate in a variety of environments, including automotive, vibration testing, remote vibration measurements, rotating machine diagnostics, impact testing, ride quality and handling, sports, safety equipment, playground testing, motorcycles, development of ATVs, suspension testing, power sports and bicycles.

In addition to the VibraCorder, Dytran has designed a unique portable data acquisition system that combines a triaxial MEMS accelerometer, triaxial gyroscope and onboard temperature sensor. Named the VibraScout 6D, units plug directly into a laptop or PC for instant acquisition of triaxial or 6DOF data; no external power supply or signal conditioning is required.

The VibraScout is a unique and innovative solution for fast, portable and cost-effective surveys and data acquisition in a myriad of automotive testing applications, including ride quality, component testing, impact testing and end-of-line testing. Units are offered as either the 3D (5340B series, triaxial) or 6D (5346A series, 6DOF). The VibraScout 3D is available in ranges of +/-16*g* and +/-200*g*, while the VibraScout 6D is available in ranges of +/-14*g* and +/-200*g*. Both accelerometer models contain a variable capacitance MEMS chip with USB interface. Sensors are hermetically sealed in a titanium housing weighing 13g.

Speedy dynamic testing

RACELOGIC HAS COMBINED ITS HIGH-GRADE GPS WITH INERTIAL MEASUREMENT UNITS TO CREATE AN OFF-THE-SHELF TESTING SOLUTION

Combining survey-grade GPS and high-quality inertial systems to provide outputs of vehicle speed, heading and body angle is now well established as an accurate and robust method of carrying out vehicle dynamics testing. In individual terms, GPS is perfect for measuring speed, distance and acceleration, and an IMU provides highly accurate measurements of pitch, roll and yaw. In addition, if the two signals are integrated, the data improves dynamic response, reduces signal noise, and consequently GPS dropouts can be eliminated when the vehicle passes under a bridge or through an area with poor satellite visibility.

Racelogic has been manufacturing GPS and inertial products for the vehicle testing industry for more than a decade, and in that time the demands for accuracy and ease of use have risen substantially. As passenger vehicles become ever more complex, pressure on engineers to successfully develop and then test a new model means that time spent on the test track becomes increasingly precious.

GPS datalogging has the advantage of being quick and easy to set up. Racelogic has recognized, however, that when using a GPS with an integrated IMU, the crucial aspect of accurately measuring the distance from the antenna (on the roof) to the IMU (normally located on the vehicle floorpan) increases setup time and can be difficult to get right. Maximum Kalman filter performance and best application of lever arm correction requires configuration derived from accurate measurement between the IMU and antenna. If the equipment is being moved from car to car, the issue is exacerbated.

The way to get around this is to co-locate the GPS antenna and the IMU. By putting the two together and mounting them on the vehicle's roof, there is no requirement to measure the distance between them as you do in a standard setup, and it is easier to install. With the GPS and inertial data sources coming from the same point, this critical measurement is eliminated, leaving only the required translation to – typically – the vehicle's center of gravity. This method is far easier, isn't prone to human error, and doesn't require quite the same level of accuracy.

TOP: **RACELOGIC'S CO-LOCATED IMU AND GPS ANTENNA IN SITU**
INSET LEFT: **THE VBOX 100HZ TWIN ANTENNA SPEED SENSOR WITH INTEGRATED IMU**
INSET RIGHT: **REVERSE SIDE OF THE ROOF-MOUNTED IMU AND ANTENNA**

Having been developed using a tactical grade iMAR unit as a reference, the VBOX IMU04 achieves 0.06° accuracy (RMS) for pitch and roll. Combined with a twin antenna VBOX 3i SL RTK 100Hz datalogger, the roof-mounted IMU/antenna allows for high-dynamic testing to be conducted very quickly with the minimum of setup time.

For applications where logging is not needed, but where a high-grade speed and inertial signal is required as a component of a wider test or control system, Racelogic has also now introduced a new speed sensor with integrated IMU. This uses the same Kalman filter as the VBOX 3i to integrate the inertial data, leading to smoother velocity and heading channels for feeding into a data acquisition setup or for applications that require high-quality and accurate speed and heading data, such as controlling autonomous testing robots.

The VBOX speed sensor plus IMU provides the output for steering robot path-following, throttle and brake robots, or for guided soft target platforms put to use in ADAS testing. Under normal circumstances, this would come from Racelogic's top-of-the-range VBOX 3i SL RTK, but the speed sensor supplies the same output at a significantly reduced cost, and with more straightforward installation.

In-car measurement

DEWETRON HAS TEAMED UP WITH OTHER SPECIALISTS TO PROVIDE A COMPLETE TESTING SOLUTION FOR AUTONOMOUS EMERGENCY BRAKE SYSTEMS

RIGHT: **PERFORMING AN AEB TEST, WITH THE DEWE2-A4 MEASUREMENT INSTRUMENT**
BELOW: **COMPLETE IN-CAR SYSTEM FITTED TO A TEST VEHICLE**

Now that passive safety systems are becoming standard fitment on most new vehicles, manufacturers are continuously developing driver assistance systems aimed toward Vision Zero, and ultimately the autonomous vehicle. With the rising number of safety and assistance systems and the interaction between them, however, effort and testing complexity increases exponentially.

Whether it is testing in the development phase, following tests in the integration phase, acceptance tests, or even assessment tests such as Euro NCAP, they all have in common the complexity of the overall measurement. But what has been missing so far is a standardized measurement system.

To provide the market with such a solution, Dewetron has teamed up with other experts from the automotive testing world: GeneSys Elektronik, a specialist in gyroscopic and GPS-based sensors; Stähle, a manufacturer of high-end robotic systems; and the Technical University of Dresden's faculty of transportation science and technology, an experienced insider in vehicle testing programs.

Usually the DEWE2-A4 data acquisition instrument is at the core of a complete testing solution; the compact instrument fits all mobile applications and can be mounted in the vehicle. It synchronizes and records analog signals, multiple streams of CANbus data, and GPS position and speed. TRION modules are available for voltage, accelerometers, strain gauges, voltage, current, IEPE and more, with 16- or 24-bit resolution and sample rates up to 2MS/s. These units can easily be exchanged by the user, which enables the reconfiguration of the system: in terms of channel count, by simply adding modules to the system; and in terms of functionality, by plugging modules with different functionality. For very complex testing, the DEWE2 hardware is provided with an open system driver so it can be used in third-party software such as DASYLab, LabVIEW or DIAdem.

The system is provided with an internal buffer battery that bridges power outages for up to five minutes. Furthermore, the use of battery packs allows for a virtually endless power supply, by using hot-swappable batteries, and being completely independent from the vehicle's power grid.

The ability to acquire input signals from all synchronized sources is essential for the accuracy and the comparability of the data. The online synchronization and visualization of data from different vehicles enables calculation of relative values such as distance, velocity and heading between multiple vehicles during the ongoing measurement.

In examples of autonomous emergency brake (AEB) testing, the DEWE2 unit uses the internal GPS receiver of the GeneSys ADMA as the time source for the synchronization. Additionally, the ADMA is the sensor for all channels needed to calculate relative position, altitude, speed and direction. This information is then used as input for control loops of actuators, such as Stähle's driving robots.

Stähle robot systems complete the solution in order to provide a full testing package for AEB testing. They offer a short installation time, an unmatched build quality and exceptional performance.

Additionally, airbag functionality is retained, as the steering robot is designed to not impede the device, when mounted on the standard wheel.

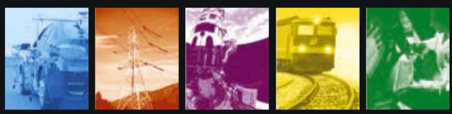
This complete measurement solution offers a huge benefit for end users; it enables them to focus on the measurement task in hand, instead of dealing with compatibility issues.

FREE READER INQUIRY SERVICE
To learn more about this advertiser, visit www.ukipme.com/info/vdm ref. 010

worldwide DEWETRON

Evaluation of AEB systems

also for ACC, LDW, FCW, Park assist, and more ...



Test & Measurement Solutions

Real time monitoring of test requirements

Online overview of the whole test situation via 3d display

Supports robot systems as required by Euro NCAP

Braking benefits

TRW'S RANGE OF BRAKING ASSISTANCE SYSTEMS IS HELPING IMPROVE CO_2 AND FUEL EFFICIENCY, AS WELL AS DRIVER ASSIST FUNCTIONS

ABOVE: **TRW'S MANFRED MEYER, VICE PRESIDENT OF TRW BRAKING ENGINEERING**

TRW's braking advances are having a positive impact in the areas of safety and driver assist functions, as well as CO_2 and fuel efficiency, according to a company brake engineering expert.

One of the major drivers for brake systems today is NCAP requirements for pedestrian and vehicle automatic emergency braking (AEB). Higher-performance brake systems are critical to driver assist systems; autonomous braking will also be required for future driving functions such as electronically controlled deceleration for adaptive cruise control (ACC) up to AEB and auto hold electric park brakes.

AEB requirements are driving TRW's work on brake and sensor systems – especially in terms of stopping time and object recognition. "We're having discussions with customers about improved braking systems that can automatically bring a car to a stop in less than 300-400 milliseconds," explains Manfred Meyer, vice president of TRW Braking Engineering. "The speed of the brake system's response determines how much time the sensors have to analyze a potential emergency situation. Everything has to be optimized, from the brake control unit, to the calipers, to the system's fluid dynamics. We have very clear development plans in place to achieve very fast pressure-apply with conventional electronic stability control [ESC]."

Emission reduction targets are playing an important role in the uptake of fuel-efficient technologies and systems that allow recuperation of energy during braking.

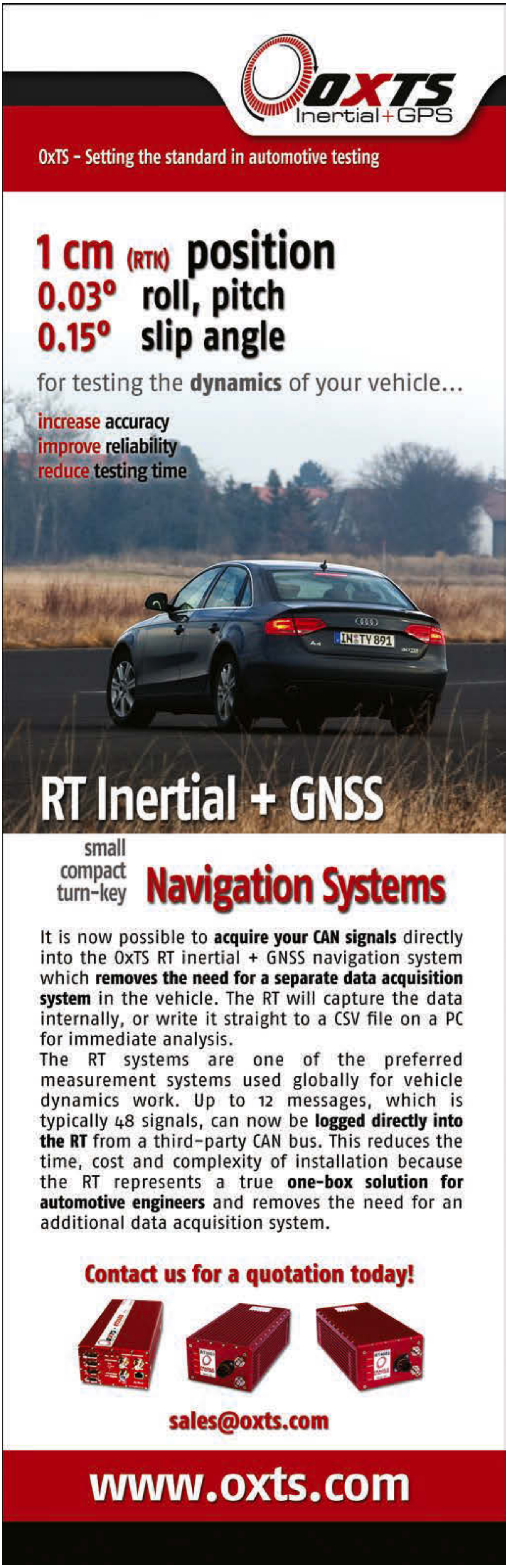
"With brakes, auto makers are looking for solutions that are smaller, lighter, faster, safer, more durable and more affordable, every year," Meyer says. "The reduction of residual drag and the growth of stop/start functionalities are driving TRW's braking development work."

In the past few years, fitment of stop/start has reached 30-40% of new cars. In the near future, this will rise to more than 50% globally.

"When vehicles with the stop/start feature halt at a traffic light, sometimes the engine stops, sometimes it doesn't," Meyer says. "That's because the decision to switch off the engine is safety related. The vehicle must have the power to stop and restart safely. For that, there needs to be enough pressure in the brake system, enough vacuum in the brake booster, and enough electrical power on board. The longer the vacuum lasts, the longer it is before the pump and engine need to restart. This translates into direct fuel and CO_2 savings." TRW's cooperation of hydraulic hold (also out of Auto Hold) and electric park brake is important.

TRW is also working to reduce residual drag without compromising other brake functionalities. Reducing residual drag by just 0.5Nm per caliper – 2Nm at vehicle level – can save 0.1 liters per 100km of fuel. Advances are possible even in TRW's standard cast iron Colette design. But when the next-generation TRW product enters production later this year, it will have an improved guiding system, pad abutment and spring arrangement to achieve the lowest-possible drag.

Finally, TRW's Integrated Brake Control (IBC) remains a key advanced technology. It replaces the ESC system, vacuum booster, pumps and cabling with a single integrated unit. The system's light weight and pressure dynamics are perfect for AEB and its suitability for driver assist functions is compelling. IBC is ideally suited for regenerative braking and full brake blending. TRW's core architecture enables high levels of component re-use, so the technology can be scaled to all requirements.


OXTS
Inertial+GPS
OxTS - Setting the standard in automotive testing
1 cm (RTK) position
0.03° roll, pitch
0.15° slip angle
for testing the dynamics of your vehicle...
increase accuracy
improve reliability
reduce testing time
RT Inertial + GNSS
small
compact
turn-key
Navigation Systems
It is now possible to acquire your CAN signals directly into the OxTS RT inertial + GNSS navigation system which removes the need for a separate data acquisition system in the vehicle. The RT will capture the data internally, or write it straight to a CSV file on a PC for immediate analysis.
The RT systems are one of the preferred measurement systems used globally for vehicle dynamics work. Up to 12 messages, which is typically 48 signals, can now be logged directly into the RT from a third-party CAN bus. This reduces the time, cost and complexity of installation because the RT represents a true one-box solution for automotive engineers and removes the need for an additional data acquisition system.
Contact us for a quotation today!
sales@oxts.com
www.oxts.com


www.vehicledynamicsinternational.com
Vehicle Dynamics International is available online, with news and exclusive-to-web content from the world of ride, handling, steering and braking
Log on now for...
Latest industry news
Recruitment | Blogs
Supply contracts
Photos & videos
Driving impressions
New car stories

Mobile testing

ONE OF THE UK'S LEADING PROVING GROUNDS IS EXPANDING ITS TESTING PORTFOLIO THROUGH THE ADDITION OF A MOBILE DAMPER TESTING RIG

RIGHT: **MILLBROOK'S NEW DAMPER TESTING RIG WILL AID THE DEVELOPMENT OF NEW SUSPENSION SYSTEMS, BOTH ON- AND OFF-SITE**

Millbrook, a leading provider of a comprehensive range of vehicle test, validation and engineering services to customers in the automotive, transport, petrochemical, defense and security industries, has added a mobile suspension tuning workshop to its vast range of capabilities.

Millbrook is engaged with a number of European clients who use its facilities and engineers to develop and tune their vehicles' functional attributes – including suspension, steering and braking characteristics and performance.

Gerry Baker, head of vehicle development at Millbrook, explains the advantages of this new facility and how it can benefit customers.

"Following the success that we at Millbrook have had in this area, and by liaising with our clients to ensure we are offering the most comprehensive service, we have now extended our capabilities to include a mobile element to our suspension tuning facilities," he states.

The mobile workshop includes an integrated damper rig, supplied by SPA Design, which exceeds industry standards for damper characterization and can be customized to any vehicle with dampers or springs of up to 100mm stroke. The 7.5KW damper dynamometer provides ride and handling tuning, comparative test, quality control and fault analysis.

"This investment will significantly reduce tuning cycles and therefore increase productivity in all of our vehicle development activities, particularly within the special projects and vehicle dynamics departments at Millbrook," continues Baker. "The added benefit of Millbrook's rig is that it is mobile, enabling us to provide tuning and measurement services not only on site at Millbrook, but anywhere else our customers require."

Millbrook states that the dynamometer rig will deliver turnkey damper tuning solutions, and will act as a dedicated workshop for technicians and engineers, where vehicles can now be tuned for and at specific sites and tracks, and in a variety of climates.

"This solution enables us to provide customers with impartial verification with no restrictions," continues Baker. "We are therefore able to independently manage and deliver standalone projects, resulting in highly refined products."

This new capability adds to Millbrook's extensive facilities and expertise, including over 70km of varied test tracks, such as hill routes, high-speed areas and challenging off-road courses, as well as a range of test laboratories for components and full vehicles. These include engine dynamometers, environmental chambers, a crash laboratory and advanced chassis dynamometers.

The mobile damper laboratory follows a number of other key investments at Millbrook so far this year, including the announcement of a state-of-the-art advanced vehicle emissions center, to be completed in early 2016, and a number of major upgrades to its crash test facilities.

The 283ha proving ground also secured additional investment in February 2015 to help fund its innovative Technology Park, which will create a high-quality center of excellence for automotive research, development and small-scale production. Millbrook Technology Park will enable more companies to be located on-site and create a significant number of highly skilled jobs within the automotive engineering and technology sector.

The vehicle development team plans to take the mobile damper rig on tour this summer, visiting both existing and prospective customers to showcase the new facility and its capabilities.

High-quality bearings

SAINT GOBAIN EXPLAINS HOW BEARINGS – SOME OF THE SMALLEST COMPONENTS IN A CAR – CAN AFFECT THE OVERALL DRIVING EXPERIENCE

A vehicle's quality is equal to the sum of its parts, even those so small that consumers may not be aware of them. Such is the case with bearings, tiny but necessary components in automotive design that are used in a range of applications throughout the vehicle, from the powertrain to the cockpit. The right component, wherever it is used, can make a big difference to performance, helping to ensure a smooth, comfortable ride – the trademark of any high-quality vehicle – and bearings are no exception. This smoothness of ride is dependent on automotive manufacturers and suppliers selecting the correct bearing solution for their application and technology.

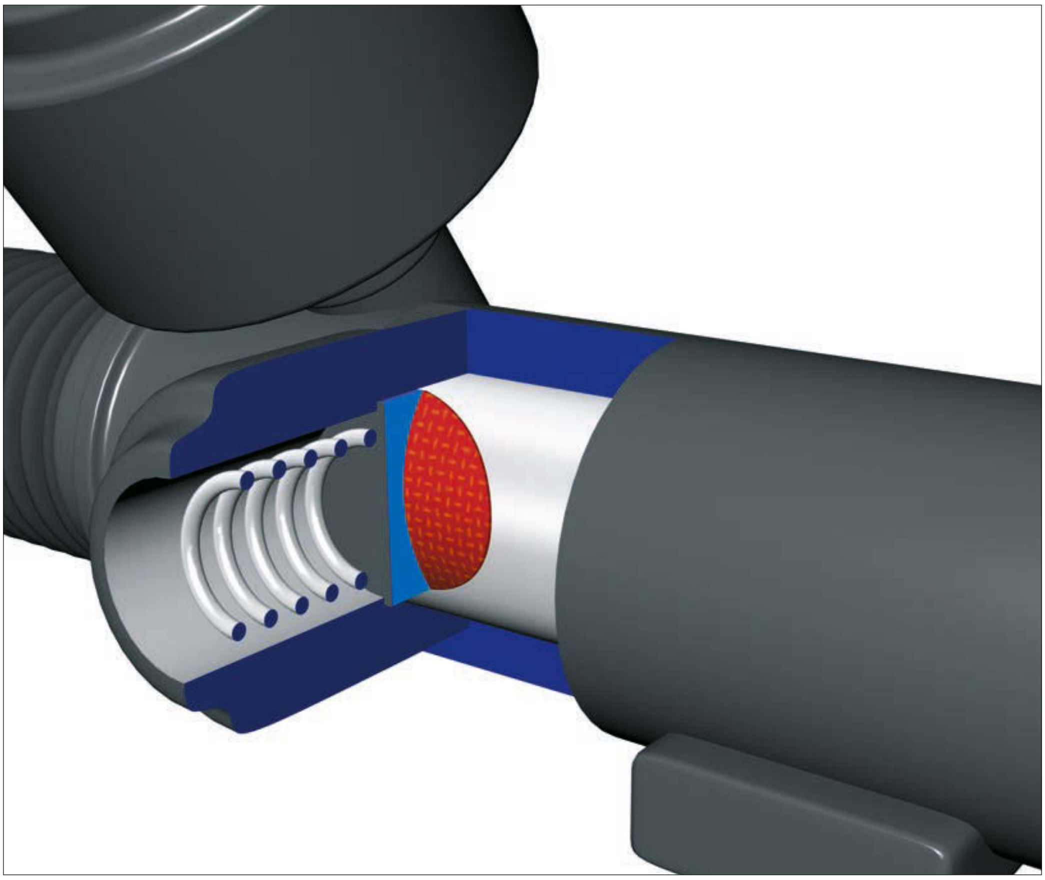
Bearings are used in seat mechanisms, enabling them to be adjusted for comfort. With a self-lubricating polytetrafluoroethylene (PTFE) liner, composite bearings offer consistent friction control for the mechanism's long life, with no need to replenish oil or grease. They can be fitted with different lightweight and/or high-strength materials, resulting in a slimmer, lighter component that contributes to both the smart design of the vehicle and overall weight reduction efforts. Manufacturers can also install such bearings quickly, thanks to the split-ring design, which means they can be compressed into place with no adhesives or extra tools required.

Composite bearings can be adapted when customization is needed. Those designed with a PTFE liner absorb excess vibration in the mechanism, eliminating rattling, for a noise-free driving experience at higher speeds and when encountering adverse road conditions. The PTFE liner also compensates for the manufacturing tolerances of the mating components, ensuring quality mechanism performance.

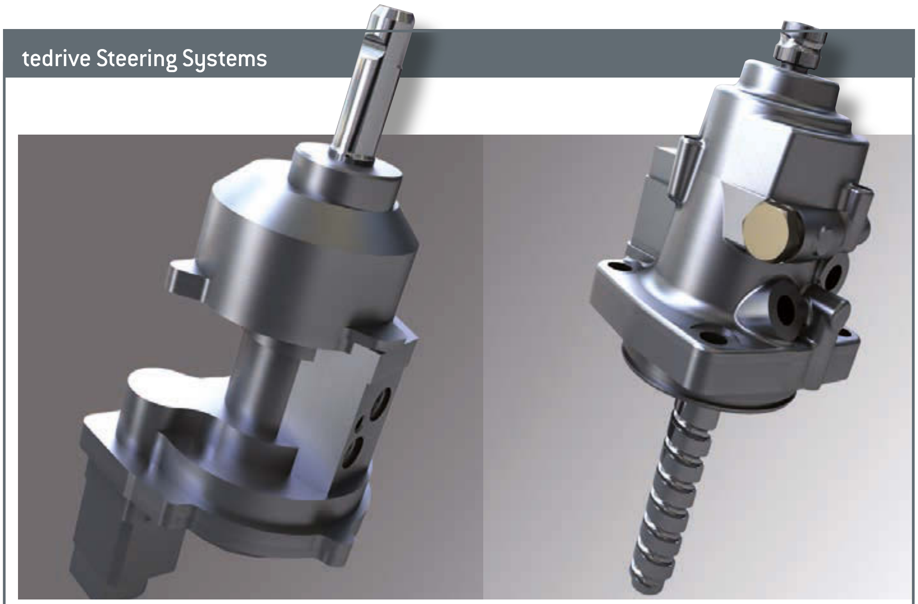
At the interface between the steering rack and the steering column sits the steering yoke. This component requires a bearing to ensure smooth movement of the steering rack for quick, responsive handling of the car. When used in the steering yoke, composite bearings offer consistent low friction, thereby enhancing steering response and feel for the motorist. The PTFE liner, in combination with the yoke contact pattern, enables the rack-shaft load to be spread over the widest possible area, allowing for consistent steering feel over the system's long life.

In doors, bearings sit between the hinge pin and housing to ensure smooth movement when the door is opened and closed. They also play an important role in the assembly process, when the hinge must hold the door open while the car body is painted. Automotive manufacturers have specific torque requirements on the production line to ensure that doors do not close while the car is painted. The PTFE composite bearings are sizable enough to ensure a sufficient torque level to hold the door ajar. In addition, the conductive properties of composite bearings enable the use of an electrostatic painting process on the automotive manufacturer's line. In this instance, the composite bearing allows the transfer of electricity through the hinge during the painting process so that the door can be properly painted.

Bearings are a vital component in automobiles, and they can boost both comfort and consumers' perception of quality. Though a small component, the bearing must be capable of withstanding projected stresses. It must interact well with other materials in the application, and be able to tolerate exposure to external conditions. These bearings must undergo rigorous testing to ensure that they enhance the performance of the mechanism and of the vehicle as a whole.



ABOVE: **SAINT GOBAIN'S HIGH-PERFORMANCE STEERING YOKE BEARING IN SITU** tedrive Steering Systems



Commercial comfort

The incorporation of active driver assistance systems has previously been the reserve of passenger cars with electromechanical power steering (EPS) systems. But the integration of the patented tedrive iHSA module (intelligent Hydraulic Steering Assist) into conventional recirculating ball steering systems has enabled the inclusion of active driver assistance systems for the first time. All safety and comfort features can now also be realized in heavy trucks and buses, thus reducing the risk of accidents. Functions such as active lane-keeping assistance, automatic crosswind compensation, trailer stabilization and maneuvering assistance via joystick can be incorporated using the iHSA plug-and-play system.

The iHSA can be modularly incorporated into hydraulic recirculating ball steering, as well as rack and pinion steering. In these systems, the power steering is executed by the integrated hydraulic cylinder, which is controlled by a hydraulic valve. In the iHSA system, this valve can be controlled independently of the driver. An additional torque sensor measures driver input and facilitates system regulation. An electronic control unit programmed with all the algorithms required for steering control gathers all the signals and also works as an interface to the vehicle communications systems via CANbus or similar. This setup enables hydraulic power assistance to be combined with assistance systems, thus facilitating all safety and comfort functions. The torque overlay described above can be used in heavy trucks and buses, for example for active lane-keeping, thus significantly reducing the risk of accidents. It can also be used to compensate for crosswinds. This considerably exceeds the capabilities of currently legislated lane departure warning systems.

The development of tedrive's iHSA module improves the performance parameters of hydraulic steering systems and thus represents a valid alternative to EPS technology. It has successfully transformed hydraulic steering into an active power steering system, offering all the functions of an electromechanical steering system. The active hydraulic solution is variable and independent of front-axle load.

FREE READER INQUIRY SERVICE
To learn more about this advertiser, visit www.ukipme.com/info/vdm ref. 014

INDEX TO ADVERTISERS

Altair Engineering...... Inside Front Cover
Automotive Testing Expo Europe 2015 ... 68
Autonomous Vehicle Test & Development Symposium 2015..... 36
BorgWarner GmbH 19
BWI Poland Technologies Sp z.o.o....... 25
Cayman Dynamics LLC 67
Dewetron GmbH................................ 63
Dytran Instruments Inc....................... 31
GeneSys Elektronik GmbH.................. 70
Kistler Automotive GmbH 20
LMS International 13
Mechanical Simulation Corporation.... 58
Millbrook Proving Ground................... 60
MSC Software Corp............................. 40
MTS Systems Corporation 7
MVO GmbH 16
Oxford Technical Solutions Ltd 65
Racelogic... 15
Saint Gobain Performance Plastics..... 58
SKF .... Outside Back Cover
tedrive Steering Systems GmbH 3, 43
Tenneco Europe ....Inside Back Cover
ThyssenKrupp Bilstein GmbH 28
TRW Automotive.................................. 31
Vehicle Dynamics International Online Reader Inquiry Service...........60, 68, 71
www.vehicledynamicsinternational.com 65

Honda Integra Type-R

HONDA'S TYPE-R DIVISION WAS LARGELY UNKNOWN OUTSIDE JAPAN FOR ITS FIRST THREE YEARS. THE INTRODUCTION OF THE INTEGRA IN 1995 CHANGED THAT

BY JOHN O'BRIEN

While Honda's latest generation NSX and Civic Type-R stole most of the headlines in the run-up to the 2015 Geneva motorshow, it was the now-defunct Integra that originally took the Type-R nomenclature from obscure JDM special edition to a global phenomenon.

Prior to the Integra, Honda had built just one Type-R model, which was based on the NSX. Borrowing the engineering principles and ethos of that car, the Integra lost weight, gained more power and was transformed from a mundane hatch into what has been hailed as one of the finest FWD chassis of all time by many journalists and pro drivers.

The Type-R's double-wishbone front suspension assembly consisted of an L-shaped lower control arm (with revised compliance bushings to impart a toe-out condition on the front wheels under braking), heavily revised dampers, an upgraded 24mm anti-roll bar and what Honda referred to as a 'performance rod'.

The front dampers used Honda's Progressive Valve (HPV) technology for more compliant damping under hard driving. The front spring rate was greatly increased by 22% to 4.4kgf/mm. The damping compression rate was also increased by 115%, while the rebound was increased by 70%, again in the anticipation of 'spirited' driving. Stiffer bushes throughout the front end rounded out the revisions.

The DC2's rear end also consisted of a double-wishbone setup. The standard Integra used straight-rate springs, but these were replaced with progressive-rate items on the Type-R. Much like the front end, damping rates for the rear suspension were also greatly increased, with compression damping settings in the progressive valve unit increasing by 66% and rebound damping going up by 31%. The diameter of the rear anti-roll bar was greatly increased from the standard car's 13mm to 22mm. To enhance rear wheel stability, the bearing span within the rear wheel hub was also increased by 10mm.

The DC2 Integra Type-R was, and is, an iconic Honda. From the hand-built engine to the extensive chassis modifications, it is one of the purest driving cars ever sold. However, the result of the bespoke additions to the car meant that Honda lost money on every one sold. The company also developed, to a high level, a supercharged all-wheel-drive version of the DC2. Road tests at the time placed it as far more capable than its contemporaries, such as the Toyota Celica GT4, Lancia Delta Integrale and Mitsubishi Lancer Evolution. Nevertheless the production, front-wheel-drive DC2 Type-R did more than enough to leave a lasting impression on the industry.

THE INTEGRA TYPE-R WAS BADGED AS AN ACURA IN THE USA. FOR A STORY ABOUT ANOTHER SPECIAL HONDA, READ ABOUT THE LATEST-GENERATION NSX ON PAGE 10

Silent driving with low noise bearings

SKF's new low noise steering column bearing to boost customer confidence in an age of quieter cars

Low noise
–3 to –4 dB(A) reduced noise level compared to our standard current solution.

Gentle guidance
The new bearing offers a better driving feel, in terms of friction torque and steering column stiffness, and helps to mitigate vibrations that are transferred from the road to the driver.

It also supports axial and radial loads well, and provides electrical conductivity, which helps towards the smooth functioning of airbags and other electrical components.

www.skf.com

The Power of Knowledge Engineering

SKF