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COVER STORY


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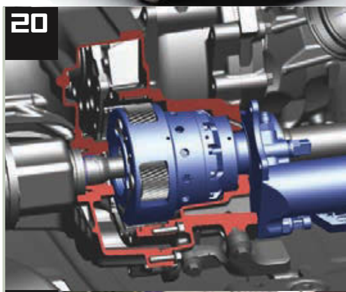
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A NOTE FROM THE (NEW) EDITOR

An engineer once told me that the marketing department is the engineering department's 'eyes to the outside world', allowing them to jointly develop a product with mass appeal.

But at a recent car launch I attended, when an engineer explained that it was a necessity for a 270bhp hot-hatch to have 19in wheels and ultra-low-profile tires because of its performance capabilities, I couldn't help but raise an eyebrow. Apparently, the oversized wheels were specified simply to facilitate the fitment of 340mm front discs – to a car weighing less than 1,350kg. The cynic in me wonders how far-reaching the marketing department's influence truly is, and how much the equipment selection is dictated by starting with a slab-sided car, with large wheel arches...

But a marketing department can provide valuable input. Its interaction with customers through traditional and social media means that it is simply reacting to what customers actually want. It also opens up ideas for new development programs, as witnessed in our personalized dynamics feature on page 26.

The interaction works the other way too: engineering feats often make for great marketing material. The aforementioned hot-hatch recently broke the Nürburgring lap record for its class, thanks in part to the latest generation electronic LSD. An amazing feat and an amazing technology, which we investigate further in our differentials feature on page 20.

With light weight becoming the latest design trend, and with components shedding weight and size in a bid to hit emissions targets, small wheel and tire combinations might even be the next big thing.

On the topic of change, after eight years as editor of *VDI* Graham Heeps is stepping aside to concentrate on sister titles *Automotive Testing Technology International* and *Tire Technology International*. However, Graham will continue to contribute his encyclopedic knowledge of all things automotive to *VDI*, starting with a look at the all-new Mustang on page 4, and Twingo on page 8.

Speaking of contributing automotive knowledge, this year the inaugural Vehicle Dynamics Conference takes place at Messe Stuttgart, on June 24, 25 and 26 (the full program can be found on page 44). I will be there in my new role as editor of *Vehicle Dynamics International*, and I hope to meet many of you during the event.

John O'Brien

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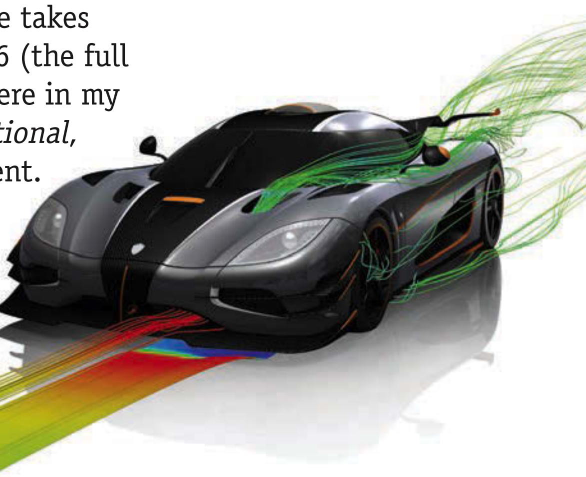

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Horse power

THE 2015 FORD MUSTANG IS THE MOST DYNAMICALLY SOPHISTICATED IN THE NAMEPLATE'S 50-YEAR HISTORY. **GRAHAM HEEPS** FINDS OUT WHAT MAKES IT SO SPECIAL

SOME OF THE DEVELOPMENT DRIVES WERE DONE IN COMPANY WITH A BMW M3, A PORSCHE 911 AND A NISSAN GT-R TO COMPARE DIFFERENT DEVELOPMENT AND TUNING APPROACHES, AND ENCOURAGE THE TEAM TO AIM HIGH

The Ford Mustang's illustrious history means that the engineers developing a new model feel a particular sense of responsibility. The desire to do a good job was intensified for a car being launched in this, the 50th anniversary year for the original 'pony car'. Add to the mix that this Mustang is to be sold worldwide under the 'One Ford' plan, and that the car is new from top to bottom, and the stage was set for a demanding development program.

The key chassis change on this new, unique-to-Mustang platform is the adoption of independent rear suspension in place of the traditional solid rear axle. A number of rear-suspension architectures were considered, including retaining the solid axle, a Watts-link setup, trailing blades and various multilink configurations. Instead, the adopted design is a bespoke version of Ford's integral link concept, which has already been seen on the latest Fusion (see *CD Changer*, Annual Showcase 2013, p18-23). The new rear setup's links are steel but the lower control arm is aluminum, as are the knuckles.

Naturally the switch to an independent rear gave the engineering team far more tuning flexibility to balance handling (the existing Boss 302 was the target for the V8 Performance Package) with a "controlled but comfortable" ride. Chief engineer Dave Pericak notes that the existing Mustang's solid rear is highly developed, but describes the "night and day" difference between it and the independently sprung 2015 model:

"The Boss 302 is one of the most balanced Mustangs we've ever done, but when you come out of a tight turn you have to take care with the throttle so that the back end doesn't step out," he says. "With the new car you can floor it out of a hairpin and it just puts all the power down – the traction is out of this world. The car is so capable that it will reward the novice driver, but if you do know how to drive, you'll be able to exploit the hell out of it.

"I'm really happy at where we ended up, from a performance perspective," he expands. "I'd take a well-done solid rear axle over a poorly done independent rear suspension any day, so we were very committed to doing it right. We spent a lot of time, effort and money to make sure that this was spot-on. This particular version of the integral link has been designed specifically for the Mustang's horsepower and torque, and all the pick-up points are different from what you'll see in any other car."

However, when the first prototype vehicles with the new rear axle hit the test track, it quickly became clear that the MacPherson front suspension would need a redesign to match its performance – something that hadn't been in the original plan. The resulting new front end features double-ball-joint MacPherson struts that permit the fitment of larger brakes without an excessive wheel offset that would hurt steering feel. A non-isolated subframe stiffens things up and replaces the previous crossmembers. Together with the changes at the

ESC IS SWITCHABLE VIA A DRIVING MODE TOGGLE SWITCH. THE LEVEL OF EPS ASSISTANCE IS SEPARATELY ADJUSTABLE. ADAPTIVE DAMPING WAS DISCUSSED BUT REJECTED ON COST GROUNDS

SPECIFICATIONS

Ford Mustang Fastback

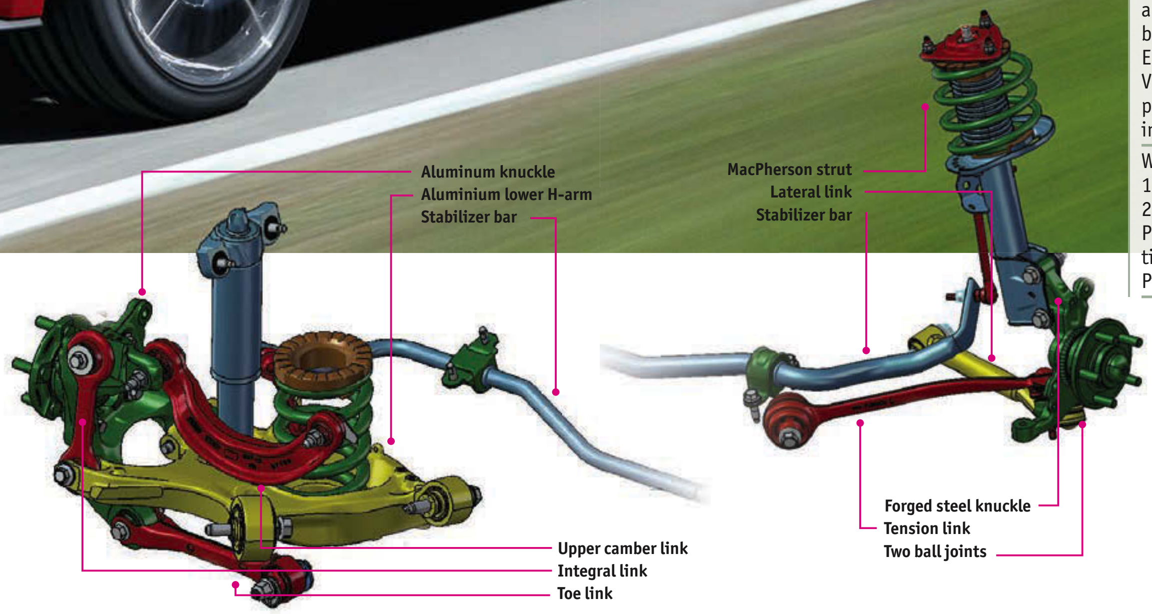
Dimensions: 4,783mm (L) x 1,915mm (W) x 1,382mm (H). Wheelbase: 2,720mm. Track width: 1,582mm (F), 1,648mm (R)

Suspension: MacPherson strut front, integral link rear. Tokico dampers

Steering: Nexteer EPS, ratio 16:1, turning circle curb-to-curb 11.5m (18in and 19in wheels)

Front brakes: Three specifications.
V6 and EcoBoost base – 320 x 30mm vented discs, twin-piston 43mm floating aluminum calipers;
V8 Performance Package and V8 base – 352 x 32mm vented discs, four-piston 46mm fixed aluminum calipers;
V8 Performance Package – 380 x 34mm vented discs, Brembo six-piston 36mm fixed aluminum calipers.
Rear Brakes: Two specifications.
V6 and EcoBoost base – 320 x 12mm solid discs, single-piston 45mm floating aluminum calipers, integral parking brake;
EcoBoost Performance Package and all V8s – 330 x 25mm vented discs, single-piston 45mm floating iron calipers, integral parking brake.

Wheels and tires: V6 and EcoBoost: 17x7.5J 235/55R17 H A/S. V8: 18x8J 235/50R18 W A/S. Performance Package cars get 19in rims and summer tires. Hankook (17in), Goodyear, and Pirelli (19in) are all-season suppliers



rear, the geometry of the new suspension offers twice the previous antidive, antilift and antisquat performance, keeping the car flatter and improving rear brake utilization.

Pericak emphasizes the role of subjective evaluation in the development of the Mustang – more so than on other Ford programs – and it was this that led to another unplanned hardware change.

"There's a handful of us that sign off at the milestones throughout development," he explains. "We all know Mustang and are very particular in what we're looking for from the car. When we thought we were nearly done with the V8 tuning we went out to Arizona to drive the final setup. We had the Boss 302 and others with us for comparison. As we drove the final tuning prototype, we came off the track and looked at each other, and there was that recognition that 'No, we're not there yet.'

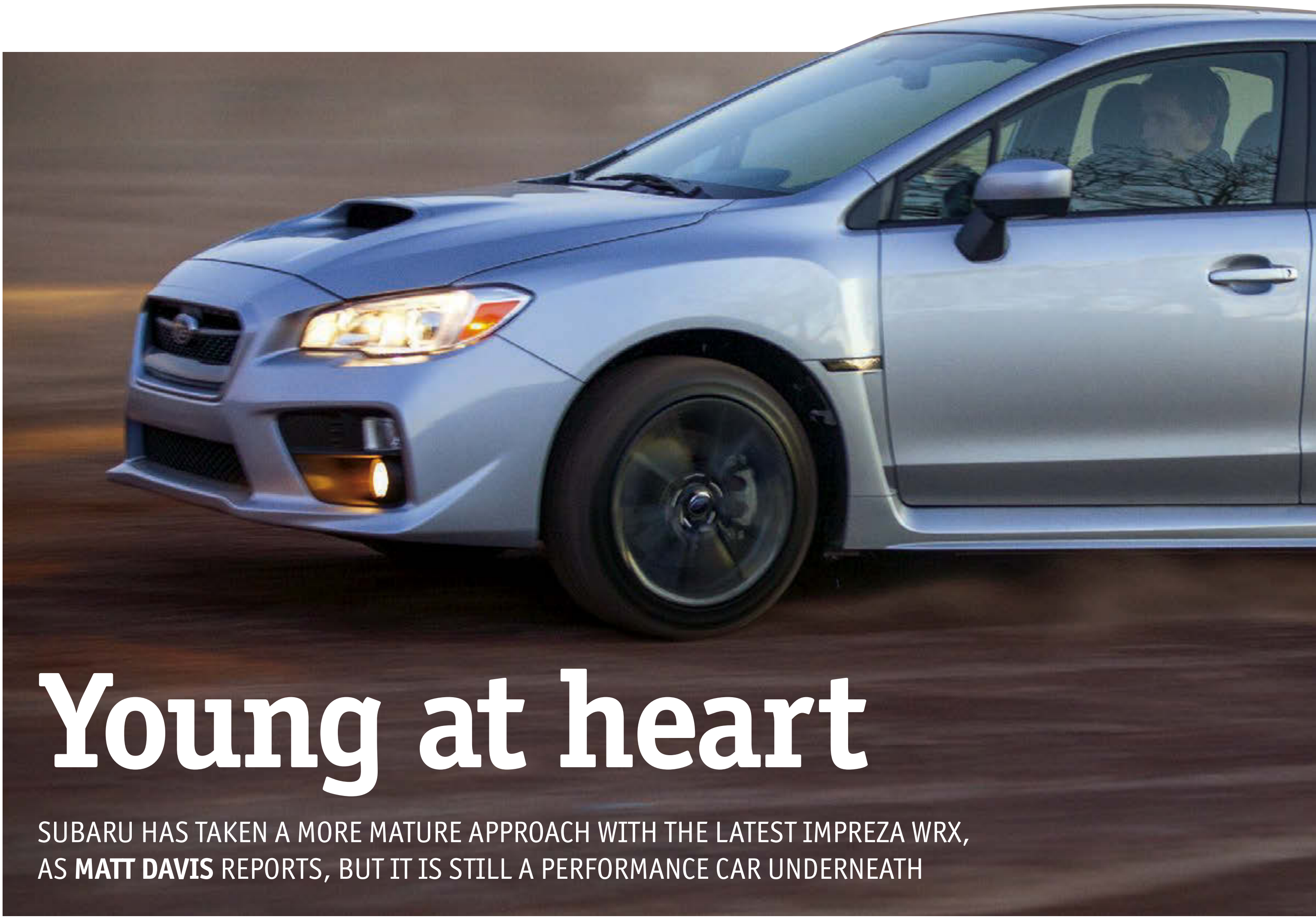
"We subsequently made some massive modifications to the Performance Package version of the car – we put monotube shocks in the back and cross-axis ball joints. We knew that we had to take a huge leap forward in hardware terms to get the car to where we needed it, but we knew that the feel of the car wasn't right. So yes, it's subjective, but we know the car, we know the customer, and we know when it's right.

"It's frustrating to do that stuff so late," he admits. "But one of the things we learned on Mustang, which is different from most programs, is that we will not stop until it's right, even if it does get late. As you start to get the real hardware through, where you thought you were might not be where you end up. For some cars that might be OK, but for the Mustang it has to be perfect. Ultimately it's very rewarding when we know we've got it right."

Changes to the car for international markets will be limited. The Performance Package versions of the 2.3-liter EcoBoost I4 and the 5-liter V8-powered GT will be the export cars. Both come with summer tires as standard, so any suspension tweaks for Europe are likely to be minor. With autobahn use in mind, a little more emphasis than usual has been placed on high-speed stability.

VDI SAYS

Ford seems to have pushed the boat out to give the Mustang dynamic credibility in international markets, for which it should be applauded. Will European customers take this US icon to their hearts?



Young at heart

SUBARU HAS TAKEN A MORE MATURE APPROACH WITH THE LATEST IMPREZA WRX, AS **MATT DAVIS** REPORTS, BUT IT IS STILL A PERFORMANCE CAR UNDERNEATH

For this fourth generation of the hallowed WRX model from Subaru, the Fuji Heavy Industries subsidiary has created a more capable and serious sedan. Versus the third-generation, four-door trim, this fourth WRX as a four-door adds a fairly modest 27kg. Actually, this time around, the WRX will come only in sedan form as Subaru uses this strategy to try to popularize the model worldwide.

I was able to sit and chat with WRX product general manager Masuo Takatsu at the recent thorough test drive over the California coastal range and some terrifically gnarly and sometimes slippery roads that at times were nearly as narrow as the 1,795mm width of the car. If dynamics testing of a smaller all-wheeler is on the menu, it won't get much better than doing it here.

Just by its very compactness, the WRX (based heavily on the Impreza series car) has always been a tossable yet controllable wonder. What it lacked really was refinement, real everyday utility, eagerness in the really tough stuff (STI trims aside), worthy brakes, and materials issues. I believe Subaru has answered most of these reservations in the new WRX, although it remains some distance from, say, the new Audi S3 quattro sedan. But then the WRX shouldn't ever get too fancy.

For this latest WRX, less is shared with the Impreza civilian car, which is why Subaru no longer just lumps the WRX into the Impreza line-up as a variant. It stands alone, sharing on the exterior just the roof, rear deck lid, and cabin glass with the Impreza. The additional 27kg come from increased standard equipment and those new refinement measures.

The words "responsive" and "stiffness" come up a lot here in discussions with Takatsu. The steering setup was crucial for this rally inspired car, especially since – like the rest of the car world – Subaru has changed the system from hydraulic to now electrically activated. The ratio drops from 15.0:1 to a quick 14.5:1 and the steering wheel itself is just 368mm in diameter. From what I felt out in these trying conditions, FHI has nailed it where many others are still in search of more precision.

Both castor and camber angles have been increased front and rear as well. At suspension points on the chassis, the knuckles on the front and rear structures' lower arms are lowered by 4/10 inch, which helps with steering response and the toe-in effect, the latter in the rear having increased by 3°. These rearrangements have also nicely minimized any dive or squat tendencies in the sedan while driving under pressure. The new dampers are supplied by KYB, while stiffer springs (62% stiffer in the rear) arrive from supplier Mitsubishi Seiko – two suppliers with much

SPECIFICATIONS

Subaru Impreza WRX STi

Dimensions: 4,595mm (L) x 1,795mm (W) x 1,475mm (H). Wheelbase: 2,650mm. Track width: 1,540mm (F), 1,540mm (R)

Weight: 1,502kg

Powertrain: 2,457cc turbocharged flat-four. 300PS @ 6,000rpm, 407Nm @ 4,000rpm

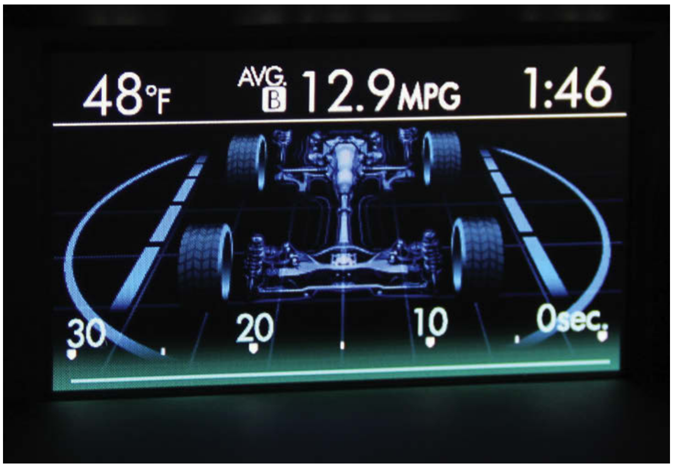
Steering: Rack and Pinion, electronic assistance

Brakes: Brembo performance system. 4 piston calipers and 326mm discs (F), 2 piston calipers and 316mm discs (R)

Wheels: 18 x 8.5J

Tires: Dunlop SportMaxx 245/35 ZR18

THE 2014 IMPREZA WRX HAS DISTANCED ITSELF FROM THE IMPREZA RANGE, MUCH LIKE THE HIGH-PERFORMANCE STI VARIANT. STRATEGIC APPLICATIONS OF HIGH-TENSILE STEEL CREATES A MUCH HIGHER TORSIONAL RIGIDITY FIGURE FOR THE SEDAN



Subaru experience. Front lateral stiffness is increased by 14%, rear lateral stiffness by 21%. Engine mounts beneath the modified 2.0-liter twin-scroll turbocharged 'FA' series variant engine are some 200% stiffer than before.

MASUO TAKATSU, WRX PRODUCT MANAGER

Takatsu went on with this list for me, stating that body roll – which felt clearly more contained than in the last generation WRX – is indeed effectively 20% less thanks to all of these modifications and the now lower center of gravity. With the new 6-speed manual transmission there remains a traditional viscous coupling center differential and thus a weight distribution of 50:50. Opt for the Subaru-engineered CVT transmission with six or eight programmed 'speeds' and the center action is via an electronically controlled hydraulic set (retaining the planetary mechanical rear differential), and weight distribution shifts to 45:55.

The engineering and testing team has used Nastran software for gauging WRX body rigidity for optimizing bend and twist motion Nm/d numbers, while the Adams suite of MSC software has been used to dial in vehicle dynamics and create all simulation scenarios. All of which helped the team decide definitively on, among other things, how to combine the particular Subaru/FHI all-wheel-drive systems with the WRX's first use of standard active torque vectoring via the braking system in conjunction with Vehicle Dynamic Control. The braking system itself has improved as well (this was needed, definitely) using Hitachi as supplier.

I had to ask what engineer Takatsu decided to use as the ultimate benchmark while concocting this new WRX sedan's exceptional dynamics. No hesitation: "The Porsche 911 Carrera 4." Well done.

VDI SAYS

When mentioning the Impreza, it's hard not to imagine it in mid-1990s' WRC guise. With this new model, Subaru has answered some criticism on overall ride comfort, interior quality, and other nuances expected by the European market. While Subaru has gone some way to appease its critics, it's good to see that rallying heritage remains.

Back for good?

AS PART OF A TIE-UP WITH DAIMLER, RENAULT HAS DEVELOPED A REAR-ENGINED, REAR-DRIVE TWINGO FOR LAUNCH LATER THIS YEAR. BY **GRAHAM HEEPS**

THE TWINGO RIDES ON 15 AND 16IN WHEELS. THE FORMER WILL BE THE VOLUME FITMENT AND WAS USED FOR THE BASE CHASSIS TUNE

In the late-1950s, two rival schools of thought emerged at UK car makers to challenge the small-car status quo. One was the transverse-front-engined, front-drive layout of the Mini, which has been widely copied ever since. The other was the rear-engined, rear-drive setup of the Hillman Imp (see also *VDI*, September/October 2004), which never gained such widespread acceptance.

The Smart Fortwo had been the only volume small car of recent years to plow this particular furrow, but in 2010, Daimler signed an agreement with Renault that paved the way for three new rear-engined, rear-drive city cars to emerge: the next Fortwo, a second-generation Smart Forfour, and the third-generation Renault Twingo.

Renault had been investigating the rear-engined option since 2008 and had conducted some simulation work, but had not yet built a running prototype.

"We wanted to make a breakthrough in packaging terms and bring something new to this segment of the market," says Christian Steyer, chief vehicle engineer for the Twingo. "Rear-wheel drive was one way to do it. There was a potential benefit for customers in terms of occupant space. We then combined our work with Daimler's input to build this vehicle."

With a finished product that's 100mm shorter than its predecessor but boasts 220mm of extra cabin length, Renault appears to have achieved its goal.

A common project team was set up in Renault's Technocentre in Guyancourt, France. Steyer was evasive about the precise details of the cooperation, although it has been reported that the Smarts will share up to 70% of their components with the Twingo. What he did want to talk about were the goals for the new Twingo's chassis: "We wanted a car that works for the customers in this segment. It's not a sporty car, it's well balanced and easy to drive."

'Stability' is a topic to which he returned several times. The new car is 3.59m long with a lengthy 2.49m wheelbase, up 130mm on the outgoing car. The inherent stability of that ratio is one reason why there was no reason to resort to Fortwo-style wider rear tires and track to keep the Twingo stable.

"We wanted to keep the previous model's ease-of-use and create a stable car that doesn't surprise you," he reiterated. "I think we've succeeded in that with the basics of the car and in the chassis tuning. Our tuning logic is always to have a sound base [chassis] without electronic aids."

The front suspension follows small-car convention with MacPherson struts; the tuning, like that of the rack-mounted EPS, was simplified by the reduced weight over the front axle and the absence of engine torque. With front/rear weight distribution of 45/55, maneuverability is said to be good, and at 8.65m, the turning circle is more than a meter less than that of the current Twingo.

At the rear, a U-shaped twistbeam winds around the front of the engine, which is itself canted over at 49° to free up trunk space. Says Steyer of the rear suspension setup, "It's an efficient way to go around the engine and still get good driving behavior. The geometry is well maintained – camber control is good."

VDI SAYS

After VW abandoned its rear-drive concept for the Up!, it's interesting to see that Renault has followed the idea through to production. Will it and the Forfour start a revolution, or remain a unique case?

Pure breed

MATT DAVIS MUSES MCLAREN'S CONTINUAL QUEST FOR PERFECTION

If something is just certifiably poor dynamically, I'll beg to not write about it any more than once. I have written volumes about the McLaren 12C and all subsequent modern-day McLarens. This is not necessarily because I believe them all to be at the peak of their dynamic potential. Most often, in fact, I have written tons of stuff on the Macca chassis strategy because it is so excellent, apart from just a couple of little things that would make it perfect at its job.

Among all this work, the extraordinarily fine RaceActive Chassis Control dynamics from Tenneco in the US$1.15m P1 hypercar stands apart, with its ride and handling system that works on two separate circuits for dive/roll and impact/rebound. Should I have to spend that much, however, to get hot handling and feedback from a McLaren? The US$240,000 for the 12C coupe gets me fascinating handling, although not quite the type of fascinating that best serves me out there on mountain roads or at the track. The car the 12C should have been all along, i.e. the 650S coupe and spider, gets nearly everything handled that, while by no means broken, needed some tending to.

The 650S is inspired much by the P1, and not only in looks. The more civilian ProActive Chassis Control – still from Tenneco – is rendered much more exhilarating than the initial version on the 12C. The 650S comes standard with specifically formulated harder Pirelli P Zero Corsa tires – 235/35 R19 (91Y) front and 305/30 R20 (99Y) rear – and Formula 1-worthy carbon ceramic brakes from Akebono, both features that are standard on the P1 and optional on the 12C. Besides the fancy Pirellis in place, the standard wheels are now lighter weight forged alloys, even further reducing the rolling unsprung weight at each corner.

Ground clearance is lower on the 650S versus the 12C, especially up front, where you find a much more aggressive splitter. At 150mph, the 'mass' of downforce is 40% greater than on the 12C, which thereby necessitated the harder Pirellis to be standard kit, along with higher spring rates. Between this newfound tremendous frontal downforce, the Akebonos (398mm diameter front and 380mm rear), the slightly more aggressive rear AirBrake, and the newly designed 'door blades' and larger side air intakes, the 650S is dramatically more sucked-down to the tarmac than any 12C I have driven. In addition, while the pedal action for the braking on the 12C has felt rather abrupt and non-linear for passengers, this has now completely changed to feel as progressive as it needed to.

"It's just fascinating to me to see how McLaren is able to limit itself to one chassis, essentially one set of dampers, and one powertrain for its entire line-up"

All of these important touches make the previously pretty numb and light steering much crisper, especially on aggressive turn-in moments. The actual Tenneco dampers themselves have larger diameter tubes with correspondingly larger pistons, a move which in itself improves the overall action of the adaptive dampers. The capper here, however, is that, akin to the P1 dampers, the units on the 650S all have a hydraulic accumulator attached directly to the upper tube, and this provides much tighter control of the suspension dynamics for all conditions. There is the needed comfort that I have come to really like on McLarens, but there is a much greater linearity for every calibration of the handling knob on the center stack, be it Normal, Sport, or Track.

It's just fascinating to me to see how McLaren is able to limit itself to one chassis, essentially one set of dampers, and one powertrain for its entire line-up. And they'll successfully manage to do this for an undisclosed number of years yet.

With the shockingly good P1, and now this 650S coupe and spider, the slight weirdness of that original version of the ProActive Chassis Control on the 12C has vanished. Things can still afford to be a little more tingly and enthralling for the less expensive McLarens, not quite so clinical and ultra-efficient. But progress is being made, seemingly daily, with the objective of rendering the 12C/650S part of a line-up as bristling as any Ferrari 458 or Porsche GT3 variants. This is not to say that these base McLarens don't have the speed, because they absolutely do. I simply want to feel more a part of the action, more moved, and the dynamics on the 650S come closer to making me feel involved.

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Push or pull?

WHILE REAR-WHEEL DRIVE IS OFTEN SEEN AS THE PURIST'S CHOICE OF DRIVETRAIN LAYOUT, JOHN MILES REMEMBERS THE REASONS WHY LOTUS CHOSE FRONT-WHEEL DRIVE FOR THE ELAN M100

Back in the late 1970s, I bemoaned the fact that rear-wheel drive family cars were getting rarer. Ford come out with the awful FWD Escort, unbelievably claiming it was competition for the Alfasud and Golf in terms of chassis dynamics. For me the eureka moment came when the backstreet tuning boys started doing turbo conversions for hot hatches. Yes the engines were often 'grenades', but the cars were phenomenally quick and, most importantly, foolproof to drive. Excessive wheel spin acted as a safety valve, not a tail slide. These cars made supercars of the period look poor in comparison in terms of A to B driving in all weather. Then I re-joined Lotus when there was much talk of the new Elan and what should it be? What was the point of rear-wheel drive? How much power could a FWD drive car take? Which was more effective, FWD or RWD? At the time, Toyota made both RWD and FWD Corollas of the same weight, same power, and with the same tires. Wet or dry, circuit or Alpine climb, the FWD car was faster everywhere, and with any driver, and by a big margin, especially in wintery conditions. Lotus might have overlooked the enthusiast's preference for a car that is a little bit of a challenge to control at the limit, but the cold performance facts said a lot at the time.

Added impetus to go FWD came from the availability of a new Isuzu 160bhp 1.6-liter turbocharged powertrain, which, after 25 years, has proved spectacularly reliable, and shoves the 1,050kg car along extremely well – and it provided a business case for making the car in the first place. Okay, so this was a car with no real competition potential, but instead there was the challenge to make a FWD car without the usual torque steer issues.

We soon found that the FWD stability theory was correct, and that the biggest disturbing forces in the steering system are top- and end-view driveshaft angles, and especially the hub height offset between tire center-line and the king pin axis, wherein the outer driveshaft UJs should reside. Different driveshaft angles mean different side-to-side secondary drive shaft couples (moments), which are then exaggerated by hub height offset as the car is hauled forward. Gosh we had fun shifting the engine around on the Toyota Corolla 'mule' and watching the unattended steering veer off to the left or right. Yes, all received wisdom was proven, including the desirability for equal length driveshafts, and that end-view driveshaft angles should run upward to the hub as this generates an outer shaft couple to partially resist the powerful toe-in steer moments as you accelerate. Even with the Elan's (by modern standards) moderate output, it proved essential to severely limit the rotation of the powertrain to prevent throttle on/off 'shunt', and the resulting long torque arm running rearward into a fixing within the backbone was one of the car's better mechanical features. In the end, you could slam the throttle on and off in a corner, or straight ahead, with hardly a quiver at the steering wheel.

> "Wet or dry, circuit or Alpine climb, the FWD car was faster everywhere, and with any driver, and by a big margin, especially in wintery conditions"

Until recently, FWD hot hatches were in the same place as we were back in the 1980s.

Audi 'solved' the critical hub height offset issue with its complicated Dopplegelenk front suspension, whose linkages allowed very low KPI. Unfortunately, the necessity for five ball joints (one very highly loaded) and a poor damper ratio, led to lack of steering feel and durability issues.

Then some bright spark came up with the much simpler way of reducing the hub height offsets, and in turn, more or less eliminated the dreaded torque steer. The end-view angle of a conventional strut fixes the hub height offset; but with a fixed strut, an old-style short king pin can be packaged close up to the brake disc, and within the wheel envelope, also resulting in much lower KPI and offset than with conventional rotating struts. The 'Revo' type knuckle, as Ford calls it, enables the recent crop of FWD hot hatches to deliver getting on for 300bhp to the road surface in a controlled manner.

The best FWD limited-slip unit I ever tried was a Torsen all-gear type made by Quaife, a design usually limited on life. Once again, digital control technology seems the way forward. The Ferrari 458 E-diff accounts for much of its highly rated dynamic behavior. With all the necessary sensors in place, the same opportunities are there with FWD, by precisely controlling torque transfer and wheel spin over the entire speed range without using one-wheel braking, as with the ESC. With systems like the electro hydraulic BorgWarner e-FXD (in production with VW/Audi), traction, and most importantly yaw behavior, can, at a cost, be beneficially adjusted to taste, without the typical trade-off of excessive understeer.

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Job description

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- On the basis of your results and your own judgment, you evaluate the tires' rides quality
- With organizational talent you ensure that all equipment, such as tires, wheels and cars, are always ready for use at the respective testing locations, both nationally and internationally
- You work closely with one of our development teams and consult our development specialists to achieve optimized tire specifications

Job requirements

- You hold a bachelor's degree in mechanical engineering (vehicle dynamics) or similar discipline
- You possess substantial professional experience in evaluating roadability and performing test drives
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Let’s not make it personal

FOR **JOHN HEIDER**, PERSONALIZATION OF A CAR IS A NICHE TOO FAR

My cell phone has a distinctive, calypso-style ringtone, selected as a thinly veiled reference to our company name. When booking hotel reservations, I gladly log onto the ‘My Account’ page at my preferred hotel chains to avoid always having to enter the same credit card information, and smoking or floor preferences. I am even vain and self-important enough to ask the Subway employee for all the veggies except black olives on my lunchtime submarine sandwich selection. Why, then, does it dismay me to see the proliferation of manufacturers offering ‘driver selectable’ suspension or steering system settings?

Simply put, allowing customers to select preferences from multiple choices, and giving them a very clear understanding of the trade-offs, and thus saving time, aggravation and money, is different from allowing them to make choices about the functional performance of an extremely complicated piece of mechanical equipment. For all the complex computer simulations and objective on-road and laboratory testing that make up the vehicle dynamics development process, the final suspension, steering and tire tuning decisions are made subjectively by the development engineer. Understandably, this person is 90% engineer and 10% artist, with the ability to take a step back and make these final selections with an eye toward delivering the best overall vehicle to the customer. Offering ‘driver selectable’ settings is akin to Vincent van Gogh including a few extra tubes of paint with each of his works and attaching a note reading: “If you didn’t like the shade of blue I used, try these instead.”

This is admittedly an exaggeration for effect, but the reality is this: from the earliest level prototype, thousands of decisions regarding the functional performance of a vehicle are made, with the end goal of achieving a target for ride, steering, handling, road/wind/powertrain NVH, and many other attributes. Throughout development, individual components are evaluated, as is the interaction of these components, to progress toward this goal. In the case of an attribute with a driver-selectable option, the target-intent function becomes the ‘normal’ setting. In our dynamics-centric world, tire characteristics, wheel rates, roll rates, damper and steering system tuning is all focused on delivering a fully optimized ‘normal’ setting for the vehicle. By default, optimized for normal means the components are not optimized for sport/comfort, heavy/light, high/low, or any other set of paired adjectives available for the driver to select.

“Offering ‘driver selectable’ settings is akin to Van Gogh including a few extra tubes of paint with each of his works”

Individual brands have spent years developing so-called DNA for their vehicles, which quickly becomes compromised when the decision is made to allow drivers to start selecting their own preferences for key, DNA-defining vehicle attributes. Luxury vehicles with sport modes, sports cars with comfort settings, and similar oxymorons, suggest that auto makers are willing to move away from using vehicle dynamics attributes to define their DNA. Two major factors have fueled this movement: marketing departments’ constant search for advertisable features, and quality departments’ belief that if you give customers more choice they are less likely to complain about steering effort, ride comfort or handling performance.

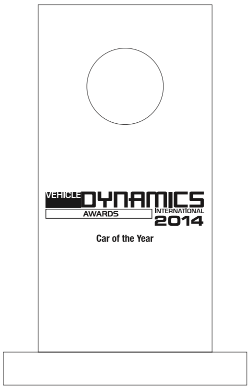
Perhaps my view is skewed, but I don’t think I am alone: customers may always be right, but I’m not sure they always know what they want. BMW has done an admirable job of convincing the world that it produces ‘The Ultimate Driving Machine’ and I applaud the company for this stroke of marketing genius. Having sampled a collection of its recent offerings, I would suggest that their marketing department and vehicle dynamics department are not on the same page when it comes to their driver-selectable settings. Why erode a sterling reputation by allowing customers to select ‘non-ultimate’ settings?

So where does this leave us? The development of new, advanced electronic features within the chassis of a vehicle is inevitable. The integration of those features with powertrain, active safety and other systems within the vehicle will continue to produce extremely safe and fun-to-drive vehicles. Manufacturers need to be confident in their ability to develop outstanding vehicle dynamics attributes tailored for their brand and not use the crutch of ‘driver selectable’ as a futile means to try and satisfy the individual desires of every customer.

John Heider is from Cayman Dynamics LLC, providing vehicle dynamics expertise to the transportation industry: www.caymandynamics.com

Vehicle Dynamics International Awards 2014

ONCE AGAIN, *VEHICLE DYNAMICS INTERNATIONAL* AND A JURY OF ESTEEMED, INTERNATIONAL AUTOMOTIVE JOURNALISTS, SEEK OUT THE FINEST AND BEST INNOVATIONS AND TECHNOLOGIES IN VEHICLE DYNAMICS DEVELOPMENT



CAR OF THE YEAR

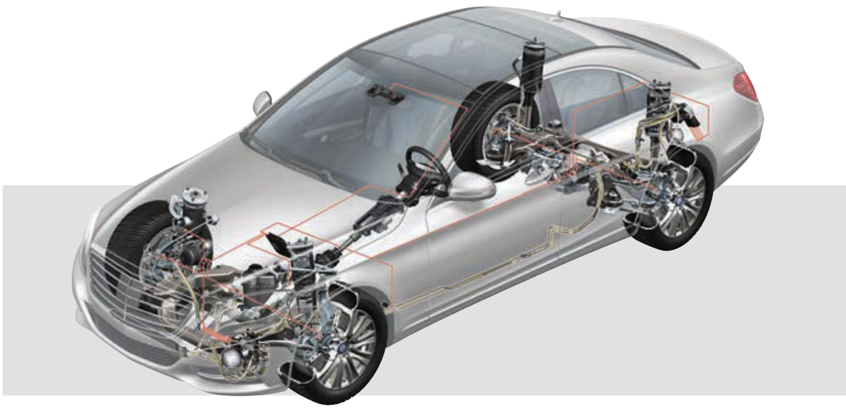
The all-new Mercedes-Benz S-Class has received high praise and acclaim in the motoring press since its introduction last year, so it came as no surprise to see the applause continue through to the Vehicle Dynamics International Awards.

The S-Class did have to fight off serious competition from the Chevrolet Corvette Stingray, with the two exchanging top-spot several times as the votes rolled in. The 2014 Corvette represents a major step-forward in terms of dynamic attributes for the car, and has gained the admiration of drivers from both sides of the Atlantic. Unfortunately, it wasn't enough to beat the S-Class, whose plethora of new technologies set it apart from the other nominations, as jury and Press Association member Matt Joy summarized: "In a sector where excellence is the minimum standard, the way in which the S-Class has raised the bar again is a testament to the work of Mercedes. It makes super-luxury rivals look ordinary, while being half the price."

Other jury members were equally forthcoming with praise for the flagship Mercedes-Benz. "The new S-Class, specified with all the goodies that can be added, could well be launched into deep space as a bold message showing what we humans have reached in our automotive technologies so far," proclaimed Gábor Szécsényi, editor-in-chief, *Az Auto* and *Retro Mobil*, in Hungary. Freelance journalist Jürgen Zöllter added, "Overall, the new S-Class is the most advanced passenger car in terms of safety and comfort. The combination of assist systems is setting standards in the automotive industry."

On accepting the award on behalf of Mercedes-Benz, S-Class chief engineer Dr Hermann Storp stated that the single aim when it came to tuning and refining the S-Class was to simply "make the best chassis in the world".

Winner: Mercedes-Benz S-Class
Highly Commended: Chevrolet Corvette Stingray
Also Shortlisted: Porsche Macan, MINI Cooper



INNOVATION OF THE YEAR

As one of the most cited reasons for the Mercedes-Benz S-Class being worthy of the Car of the Year accolade, its Magic Body Control suspension system was understandably awarded Innovation of the Year. A stereo camera scans the road, and is able to distinguish three-dimensional objects up to 15m ahead of the car before adjusting the dampers to absorb the impending impact, ensuring maximum comfort for the occupants inside.

The Innovation of the Year category proved to be another hotly contested one, with Magic Body Control facing tough challenges from Audi's Recuperating Electromechanical Rotary Damper and Nissan-Infiniti's Direct Adaptive Steering.

Ultimately, it was the adaptive technology from Mercedes-Benz that won the jury over, with the *Toronto Star*'s Wheels columnist Jim Kenzie stating: "The S-Class brings camera technology to suspension performance in an unprecedented fashion. In North America, where road infrastructure is rapidly deteriorating, we need all the help we can get."

Padraic Deane, of Automotive Publications, Ireland, added: "Magic Body Control is out there now, which is impressive in a car that gets closer examination for technical advancement than any other. It is a sophisticated suspension system that automatically flattens out any bumps that may lie ahead."

Chief engineer Dr Hermann Storp explains that, "MBC works on stereo data processing in real time, with an in-house developed algorithm that is based on statistical data analysis. You need the best, most ambitious, and sometimes "craziest" engineers on this topic, who never accept limits and always try to find the next step for better performance."

Storp also reveals that Magic Body Control is already being evolved. The 2014 Mercedes-Benz S-Class Coupe is set to feature the system with an additional 'curve-tilting' functionality, which will allow the large coupe to 'lean' in to corners.

Winner: Magic Body Control – Daimler AG
Highly Commended: Recuperating Electromechanical Rotary Damper – Audi
Also Shortlisted: Direct Adaptive Steering – Nissan/Infiniti, iDWS – Dunlop Tech, Compact Suspension – Benteler, Lightweight Damper – BWI

SUPPLIER OF THE YEAR

Supplier of the Year is often a closely fought category, but this year it was ThyssenKrupp that emerged victorious. Its victory was courtesy of the semi-active damping system Bilstein DampTronic.

As part of the larger ThyssenKrupp group supplying the automotive components supply chain, Bilstein is its dynamics subsidiary and has been developing its Ridecontrol range of adaptive dampers since 2007.

The dual-valve damper body enables continuous and independent adjustment of the rebound and compression stages. The German Tier One states that several series contracts have been obtained for the DampTronic sky damper, with the units having entered series production late last year.

ThyssenKrupp also states that it systematically addressed the design-to-cost aspects during development, and by employing a highly automated manufacturing process it has been able to produce a product with a "very attractive price to performance ratio".

Jury members were keen to praise the work of the German supplier, with *VDI* contributor and freelance journalist Marc Noordeloos stating: "ThyssenKrupp continues its magical work in the world of chassis dynamics."

"It is great to see such a big company offering so many different components at 'state-of-the-art' sophistication levels," agreed Alvaro Sauras, technical editor for *Autofacil* and *CAR&Tecno* magazines. While Halit Bolkan, of *auto motor & sport*, Turkey, simply said of ThyssenKrupp's output: "They are high-tech, high-quality and highly demanded products that deserve to be complimented."

"We are very proud to be awarded Supplier of the Year 2014. Granted by international automotive journalists, this award is a wonderful acknowledgement of our constant effort to develop first-class technology for our customers," commented Guido Grandi, CEO, ThyssenKrupp Bilstein. "Our teams always manage to succeed with new ideas and new products that increase customer benefits. In doing so, we always have the whole chassis in mind to optimize the safety, comfort and agility of the car. Our latest innovation the new DampTronic sky damper is the best example of that."

Winner: ThyssenKrupp Bilstein
Highly Commended: Nexteer
Also Shortlisted: SKF, Sumitomo Rubber, Anthony Best Dynamics

DYNAMICS TEAM OF THE YEAR

Continuing Mercedes-Benz's successes in 2014, the team at Stuttgart responsible for the S-Class, and all other new models, also collected the 'Dynamics Team of the Year' award, narrowly beating off a praiseworthy effort from BMW.

Mercedes-Benz is on a new model offensive, aggressively expanding its range to cover almost all bases, with several new models launched in the past 12 months.

This is also true of BMW, which is expanding its equally eclectic range through the development of the i3 and i8 sub-range of electric vehicles, as well as new 2-Series, FWD Active Tourer, MINI, M3, M4 and X5 models.

However, once again it was Mercedes-Benz that edged out the competition. "The S-Class chassis team comprises of around 30 chassis engineers," explains chief engineer Dr HermannStorp. "With about four to five specialists for the fine-tuning of the suspension in the S-Class. We have to be able to balance low-frequency body movements, like a real luxury limousine is expected to, with the dynamic attitude of a performance car."

Successfully developing this diverse range of new, accomplished vehicles is what the judges recognized and honored in 2014. "Investing in innovation, primarily in its models, but also in its production processes, shows the level of importance considered by Mercedes-Benz," stated *Mecânica Online*'s Tarcisio Dias, in Brazil. "This technology makes for safer and more comfortable driving."

Motor Trend's Frank Markus explained that he wasn't the only one impressed with what Mercedes-Benz is currently producing. "The S-Class moves the needle for high-end luxury vehicle dynamics, but our editorial staff has been equally impressed with the dynamics of the much more affordable new C-Class. Sindelfingen is on its game."

Winner: Mercedes-Benz
Highly Commended: BMW
Also Shortlisted: Nissan-Infiniti, Chrysler-Jeep

DEVELOPMENT TOOL OF THE YEAR

With simulation now central to a vehicle's development, advances in that area are continuing to help reduce development program times and reduce overall costs.

It is understandable then that the top three positions in this category were filled by simulation tools. Finishing as joint-runners-up were Ansible Motion's Series 2 Driver-in-the-Loop Simulator, AM-S2 and TRICK, a tire-modeling program developed by Flavio Farroni. The Tyre/Road Interaction Characterization & Knowledge (TRICK) software was developed in collaboration with the Ferrari F1 team, and aims to fully characterize tires by means of specific track test sessions, integrating results with grip/thermal models recently developed by Farroni.

Ansible Motion's AM-S2, a minimum latency vestibular cueing architecture, unifies motion control and real-time computing systems for engineering-class simulators, and both AM-S2 and TRICK were highly commended by the jury.

However the Development Tool of the Year 2014 title was claimed by the VI-grade and Saginomiya developed Driver in Motion (DiM). The innovative nine-degrees-of-freedom moving platform is currently operational at Ferrari, with a further installation taking place at Volvo and, according to VI-Grade, several other major automotive OEMs have also placed orders.

DiM's kinematic movements have been specifically tailored to extract the most from VI-grade's motion cueing technology. Despite the software having been available since 2008, VI-grade states that this is the first time such a tailoring has occurred.

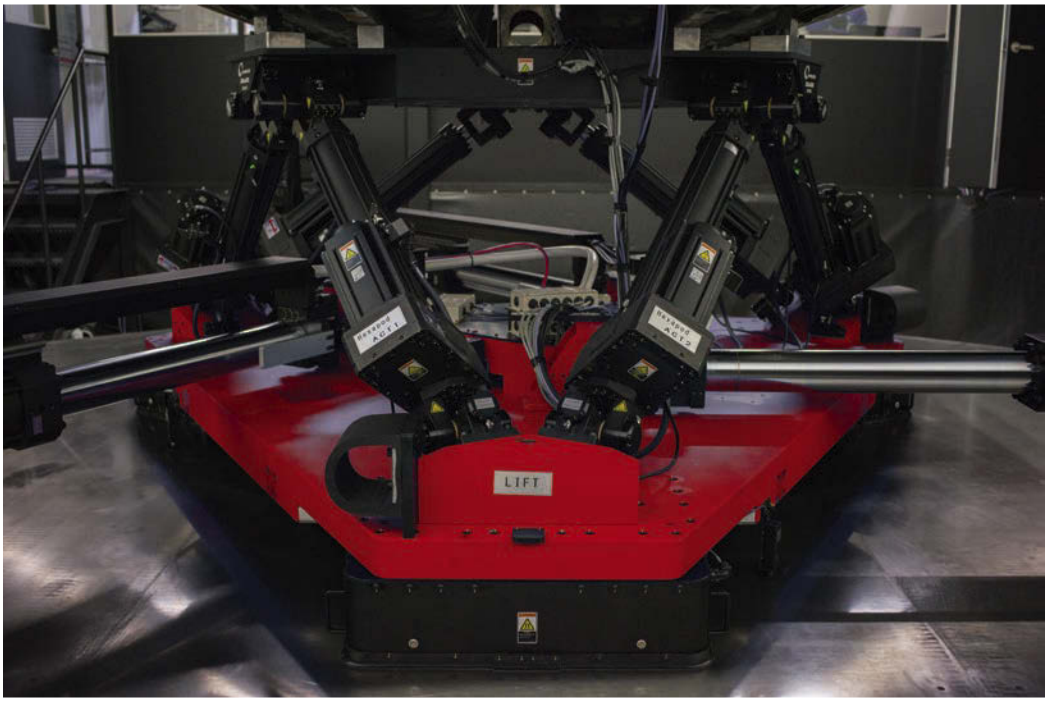
Boasting reduced overall dimensions, and having its basis in more compact and less expensive driving simulator architecture, DiM offers further savings to OEMs in terms of costs. Something the jury appreciated, with *MSN Autos*' contributing editor, Marc Lachapelle, stating: "It's a more efficient, more compact and less expensive simulator architecture, in perfect tune with the times."

"Adopted by small-volume prestige car makers as well as by more mainstream companies, this technology is proving to be reliable and cost-efficient as companies see the need for just such technologies to increase," added Carl Cunanan, editor-in-chief of *C!* Magazine.

On accepting the award, VI-Grade's technical director, Diego Minen, said: "Motion platforms architectures for driving simulators have been undergoing a very creative development phase in recent years. The new conceptual idea from VI-grade, which resulted in the final platform design, provided by Saginomiya, provides an ideal solution for low/high motion frequencies separation and enabled us to win the 2014 Development Tool of the Year award, which will introduce our new solution to a broader audience.

"DiM is an extremely efficient tool for implementing our new motion cueing strategy, which has been fine-tuned with the help of professional drivers in simulation centers over the past two years. The combination of DiM's mechanical architecture and performance, as well as VI-CarRealTime and VI-MotionCueing characteristics, is certainly unique in obtaining the best driver motion perception."

Winner: Driver In Motion - VI-Grade/ Saginomiya
Highly Commended: TRICK – Flavio Farroni, AM- S2 – Ansible Motion
Also Shortlisted: Steering System Test Bench – Munich University, SPMM 5000 – Anthony Best Dynamics



DYNAMICIST OF THE YEAR

As you may have gathered from its victories in three other categories, Mercedes-Benz has been highly praised in 2014. The man responsible for the S-Class program, Dr Hermann Storp, has also been honored in the Dynamicist of the Year category.

Storp was hotly pursued through the voting process by the Corvette Stingray's lead dynamicist, Jim Mero, But ultimately it was the Mercedes-Benz man who claimed top spot. Closely following the duo was Porsche's Manfred Harrer, responsible for the Macan's dynamic attributes.

"As the dynamicist responsible for the development of the S-Class' chassis, I wanted to make sure that the comfort enjoyed within, remains the benchmark in all luxury cars," stated Storp, in response to being awarded Dynamicist of the Year 2014. "My intention was always to have both ride comfort and dynamic handling. It was enjoyable to create a car with a relaxing drive and have reduced body movements, but yet be offered the chance to drive a limousine in a very sporty, agile way like a performance car."

Jury members were equally forthcoming with their praise for what Storp had achieved. "Improving the benchmark ride of the previous S-Class is a terrific task. Storp has managed to do just that with the introduction of Magic Body Control," stated Nicol Louw, *Car Magazine*, South Africa.

"It is no easy task to maintain classic vehicle dynamics refinements while pushing technology in the direction of sensible improvements," added Phil Morse, dynamicist and writer. "Yet Storp has gently waved his wand and the new S-Class has appeared."

Winner: Dr Hermann Storp – Mercedes-Benz
Highly Commended:
Jim Mero – Chevrolet
Also Shortlisted: Manfred Harrer – Porsche, Noboru Kaneko – Nismo

SIMPACK Realtime

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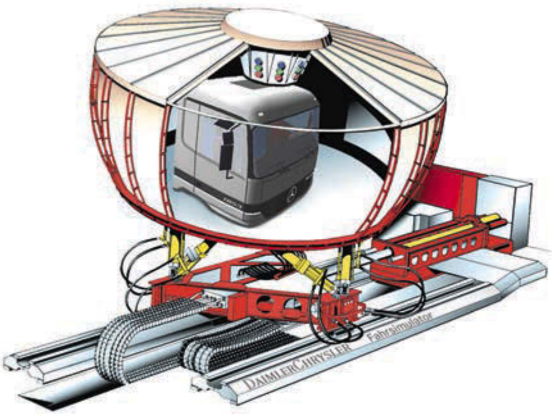

SIMPACK Multi-Body Simulation Software

SIMPACK is a general-purpose 3D multi-body simulation (MBS) software tool which is used to aid the development of any mechanical or mechatronic device, ranging from single components through to complete systems, e.g. passenger cars, high performance Formula 1 engines, railway vehicles and wind turbines. All SIMPACK products are 100% compatible.

SIMPACK Realtime is an add-on module which enables the use of detailed models for a wide range of realtime applications, e.g. Hardware-in-the-Loop (Hil) and Software-in-the-Loop (SiL). Pre-existing SIMPACK models can be used directly within realtime applications without the need for model reduction, compilation or pre-generation of look-up tables. Animating and logging results during realtime simulation is also possible.

Applications:

- HiL, SiL and MiL
- Driving simulators
- Test rigs, e.g. gearboxes, engines
- Active Safety and Advanced Driver Assistance System testing

Highlights:

- Direct realtime simulation; no code- or lookup table generation required
- Built-in multi-core support
- Use of full range of SIMPACK modeling elements
- Usable with fully parameterized dynamic models (already proven with models of >250 DOF and 40 Hz frequency content)
- Wide range of predefined targets, e.g. dSPACE, Concurrent

SIMPACK Realtime Setup:

- Standard realtime-enabled Linux operating systems
- Use of latest off-the-shelf hardware; no expensive realtime hardware required
- Communicates with realtime systems via a dedicated network, shared memory or a user-defined communication library

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United front

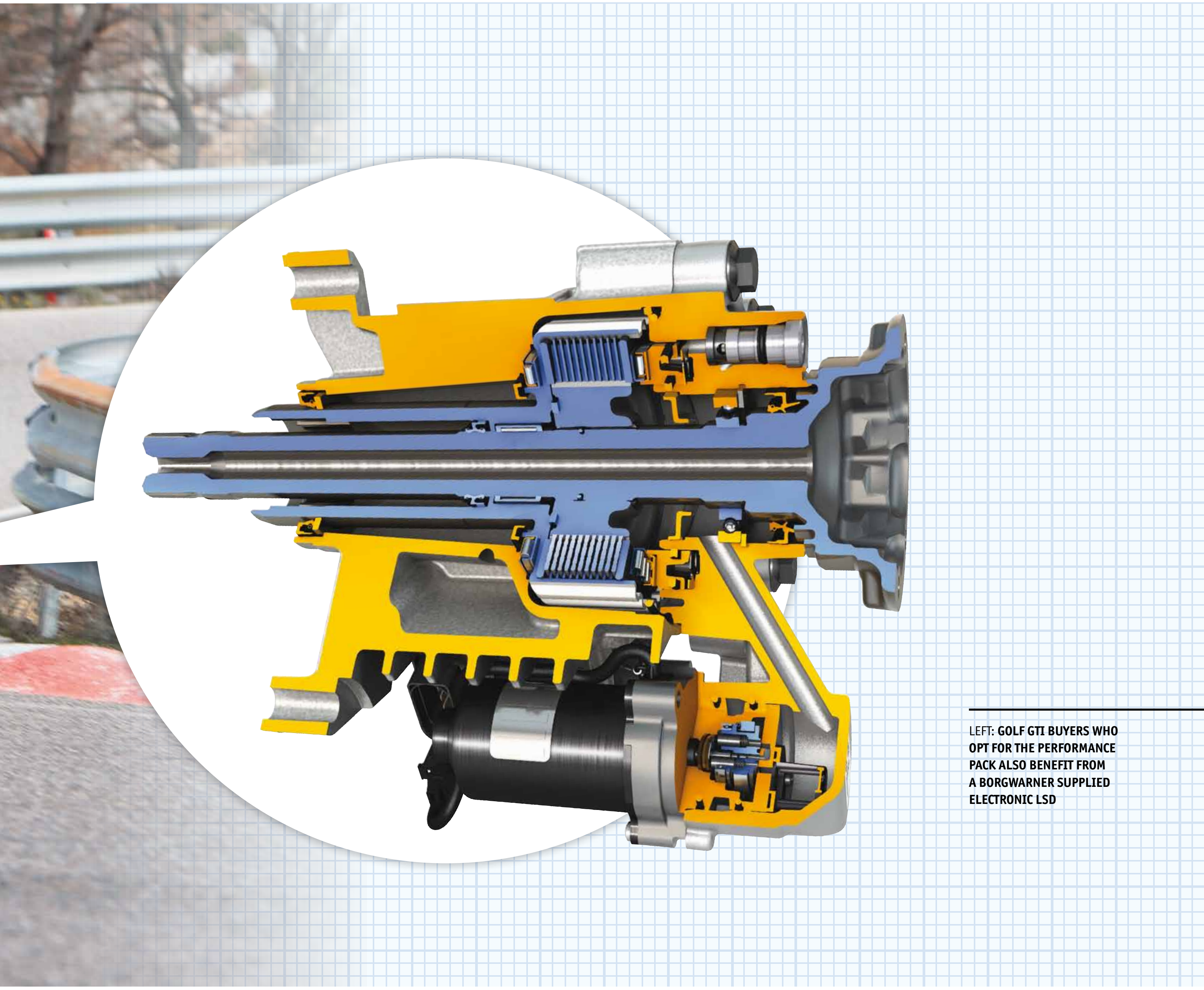
ALTHOUGH THEY MIGHT NOT HAVE HIT THE SAME HEIGHTS AS THEIR RWD COUNTERPARTS, ELECTRONIC LIMITED SLIP DIFFERENTIALS FOR FWD APPLICATIONS CONTINUE TO BE DEVELOPED. **JOHN CHALLEN** FINDS OUT THE LATEST NEWS

The goal of optimized dynamics, performance, traction and driver comfort is difficult to achieve, but automotive Tier 1 suppliers are determined to work on solutions that come close. However, issues such as cost, packaging and integration stand in the way of successfully engineering solutions into new products that meet the requirements of OEMs and their customers.

The likes of Eaton Automotive and GKN Driveline have been working on electronic – or active – limited-slip differentials (otherwise known as eLSDs) for many years, albeit with limited success in the mass market. Things are slowly changing, but still have a long way to go, believes Heinrich Huchtkoetter, GKN Driveline's manager, vehicle integration. "It is difficult to say if eLSDs for FWD applications will become mainstream, largely due to marketing pressures," he admits. "We have been working on them for the past 20 years and when we initially talk to vehicle engineering people at OEMs, they are enthusiastic but also believe it is an extra device that will cost money to put into the car."

Huchtkoetter says it is normally at this point in discussions that purchasing and programming departments get involved, and indicate they would prefer to spend money on something visible, such as leather seats. He adds, however, that if eLSDs do penetrate into the mass-market, drivers would really benefit. "It would lead to big advantages in reducing the king-pin inclination and toe-in elasticity, similar to what Ford achieved with the RevoKnuckle.

ABOVE: **E-LSDS COULD BE AS GOOD AS, BUT MORE COST-EFFICIENT THAN, THE FOCUS RS REVOKNUCKLE**



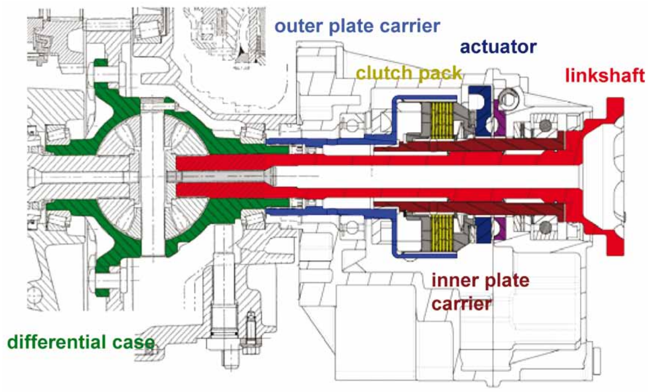
LEFT: **GOLF GTI BUYERS WHO OPT FOR THE PERFORMANCE PACK ALSO BENEFIT FROM A BORGWARNER SUPPLIED ELECTRONIC LSD**

Torque bias has always been limited – you use it to make a very nice racing car, but it is not always as good to drive as a standard car."

Rick Kukucka, product strategy manager at Eaton Automotive Controls, is more positive about the potential role that eLSDs could have in the next generation of FWD automotive applications. "They have the ability to help build on brand DNA when it comes to active driving dynamics, and they also make it possible for the driver to control the specific settings in the eLSD," he says. "This means they can personalize their driving experience from sporty to comfort, and induce some understeer in extreme conditions if they require it.

"We've seen luxury brands having selectable features, including electric assist, air springs and even changeable damper rates," adds Kukucka. "We think we could help augment that technology by changing the behavior of the electronic differential as well. We could have more active or aggressive intervention in sport mode and more predictable understeer behavior in comfort mode."

Huchtkoetter agrees with his Eaton counterpart, and highlights what effect his own company's developments could have on the dynamic setup in a vehicle. "With a passive LSD you have to make compromises, because from a dynamic point of view it would be



ABOVE: **THE BASIC INNER LAYOUT OF GKN'S E-LSD SYSTEM**

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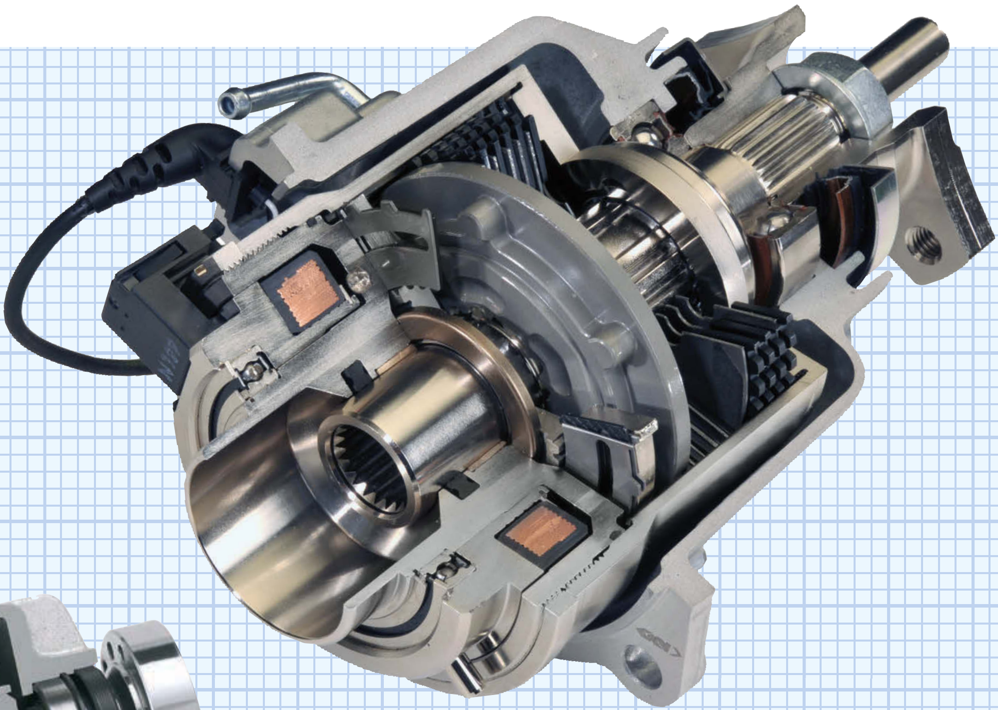
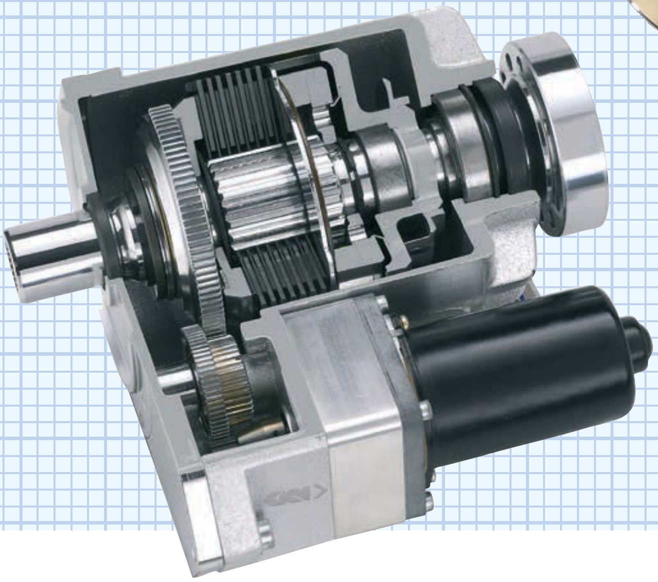
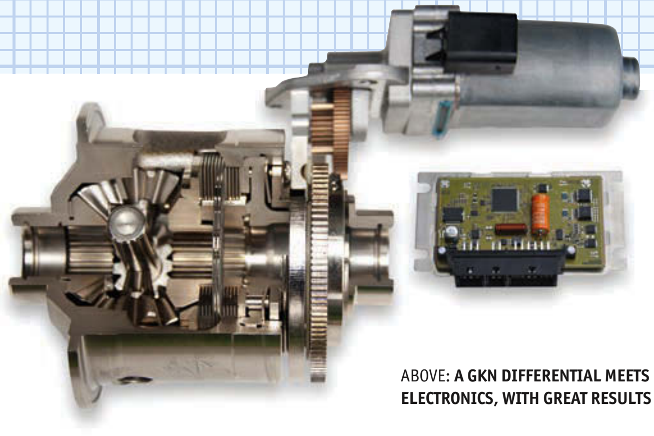
feel good about driving

"With an eLSD, you can use the full potential of the differential in specific situations when you need to"
Heinrich Huchtkoetter, manager, vehicle integration, GKN Driveline





ABOVE AND LEFT: **GKN HAS BEEN WORKING ON THE TECHNOLOGY FOR YEARS, BUT BELIEVES THAT MASS-MARKET ADOPTION IS STILL YEARS AWAY**



ABOVE: **A GKN DIFFERENTIAL MEETS ELECTRONICS, WITH GREAT RESULTS**

advantageous to have a high torque bias ratio, but this leads to torque steer," he says. "With an eLSD, you can use the full potential of the differential in specific situations when you need to, but if you are in a situation where a passive system suffices, you don't actuate the electronic system. For example, the viscous coupling of an LSD in an AWD application typically has some compatibility problems with ABS, so if you have an active system, and you see an ABS on the CANbus, you just open the LSD."

When *VDI* spoke to Eaton about eLSDs in 2009, the company was deep in the midst of developing a system that was packaged inside a transaxle, all destined for some of Fiat's Brazilian vehicles. That system is still in use, but now, Kukucka reveals that he and his colleagues are working on the next generation, set to launch in two to three years.

"What we've learned since 2009 is how to elevate the state-of-the-art when it comes to stability control," he reveals. "We've greatly increased the capability on dynamic control, and how you do that with other systems, as well as getting into adjustable damping rates and steering assist. It's much more sophisticated with total architecture integration."

Kukucka says that as well as luxury and performance vehicles, the technology is being developed at Eaton for other applications. "We can do the same with a crossover vehicle, and use off-road imagery to illustrate performance on sand and snow, as well as normal road conditions," he explains.

By integrating such a system with the existing stability control systems in today's automobiles, Eaton believes it can improve the performance of those systems, as well as the behavior of the differential. "By allowing the eLSD to work out how much brake or throttle intervention is needed, and at which point, you are scrubbing off a lot of momentum and speed," comments Kukucka. "By integrating the systems with a common control algorithm, instead of overlaying them, we can bring a whole new dimension to stability control."

However, he also points out that a range of options are open to automotive manufacturers. "OEMs could benefit from the maximum level of integration," says Kukucka. "For an FWD vehicle, we are internal to the transaxle occupying the differential space that a conventional

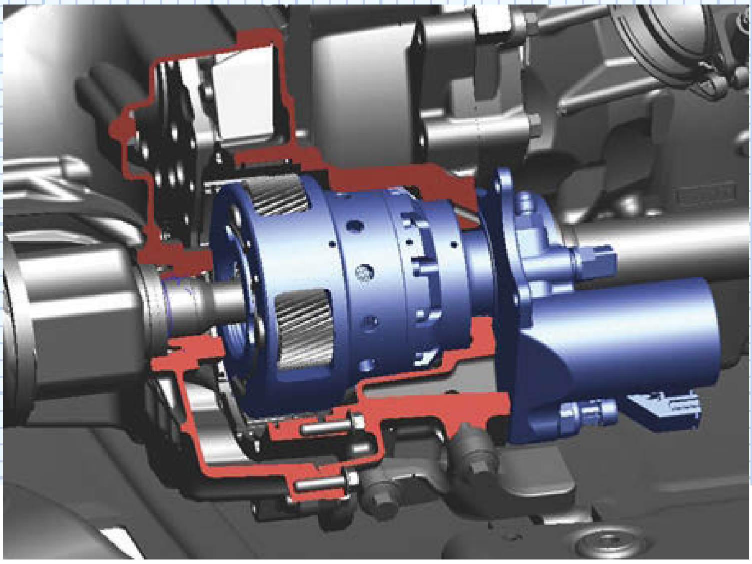
ECONOMY DRIVE

Away from dynamic performance, another area that will see the benefits of eLSDs in the future, according to Rick Kukucka, product strategy manager at Eaton Automotive Controls, is fuel economy. "We are at the point in the industry where CAFE standards – and other pieces of legislation – are driving decisions more than customer acceptance," says the Eaton man. "Many OEMs are more concerned about survival and selling vehicles, than customizing vehicles and optimizing performance.

"With the eLSD, we offer performance approaching an AWD without the weight penalty, which equates to an 8% fuel savings [AWD versus 2WD]. Couple that with a luxury vehicle market that has, in the past, been fueled by RWD platforms, but now the likes of Mercedes-Benz and BMW are adding FWD options to their portfolios.

"To retain the same DNA, these manufacturers can opt for the FWD eLSD because it not only gives them a more dynamic experience, but they also reduce fuel consumption, as well as around 70-80kg by not having an AWD architecture."

ABOVE RIGHT: **RICK KUKUCKA FROM EATON BELIEVES THE WEIGHT ADVANTAGES OF E-LSDS COULD BE A KEY SELLING POINT**
RIGHT: **RENDERING OF EATON'S E-LSD**



"For someone looking for a complete package from us, with minimal design involvement from them, the best option would be the bolt-on solution,"
Rick Kukucka, product strategy manager at Eaton Automotive Controls

open differential would occupy, but some OEMs want to keep the same transmission and not create separate ones for eLSD and non-eLSD applications." In such a case, Eaton can design a bolt-on solution where the clutching and actuation takes place outside the transaxle, occupying the space designed for an AWD power transfer unit (PTU), but actuates the differential inside the transaxle.

"For someone looking for a complete package from us, with minimal design involvement from them, the best option would be the bolt-on solution," says Kukucka. "We have a lot of interest from manufacturers in emerging markets, such as China, who might not have developed the necessary in-house integration capabilities. They look to suppliers such as us to deliver a total system that can be bolted on."

While Huchtkoetter admits that a passive LSD is a more suitable replacement for a standard differential in terms of packaging, he warns that there is a compromise in terms of more oversteer and other dynamic factors. "Using an eLSD is more like an add-on unit, or an external component to the differential," he explains. "For previous demonstrator models we have built, we chose an AWD vehicle with the standard gearbox, and just moved the PTU to the rear. In this space we integrated an external (to the differential) mounted eLSD, and I believe that is also what Volkswagen is doing." The impact on the overall weight of the car is an increase of around 10kg, reckons Huchtkoetter.

The role of electronics is becoming increasingly important in automotive applications and from a dynamics standpoint, optimization of the CANbus is vital. "We are using all the signals available to us on the CANbus – without them an eLSD would be a pure traction device and no one would integrate it into the car," says Huchtkoetter. "To realize the dynamics and stability improvements that OEMs are asking for on a vehicle, you need information from the CANbus if the car is equipped with ESP. If you accelerate out of a high-mu bend, as long as you avoid the outer wheel spinning, the eLSD will improve understeer, but you need to know the vehicle and wheel speeds. Without having that information, the eLSD wouldn't make sense because it could reduce the stability of the vehicle to a level that is unacceptable."

Huchtkoetter also believes that an eLSD could also counter torque steer. "Knowing the limitations of the LSD, it can be combined with an electric power steering (EPS) system," he believes. "Theoretically, if influenced by the ESP, the wheel would tend to steer into the corner but our system could control the EPS to compensate for that."

There's an **app** for that

ADAPTIVE DAMPERS ARE NOTHING NEW – BUT THE ADVENT OF THE SMARTPHONE APP HAS OPENED UP A WHOLE NEW WAY TO CONTROL THEM AND INTERACT WITH THEM. **JOHN O'BRIEN** CONSIDERS IF IS THIS A MARKETING GIMMICK, OR A WORTHWHILE ADDITION TO A SUSPENSION SYSTEM

Creating a car setup that will please every driver is the dream of most vehicle dynamics engineers. However, while achieving quantifiable targets – a 5% reduction in unsprung weight for example – is challenging, it is often possible through hard work. The real challenge lies in satisfying the individual tastes and preferences of drivers. Just as a car's exterior design can split opinion depending on reviewers' individual preferences, its dynamics are also open to criticism, applause or indifference.

The advent of dynamic chassis control systems, offering a choice of pre-defined settings to suit a range of road conditions or driving styles, has given dynamicists the means to empower – and delight – more drivers, by allowing them to select the settings that best suit their mood or situation.

However, the game is about to move on again. The timely rise of the smartphone application, or app, is introducing new ways for drivers to interact with and personalize their vehicle suspension settings.

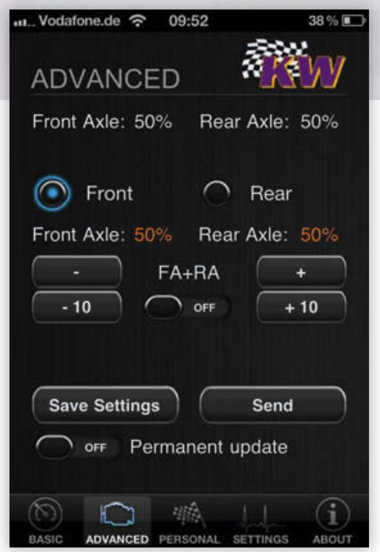
Suppliers are acting quickly in response to these new possibilities, and German suspension specialist ThyssenKrupp Bilstein has developed an app-based system. "This kind of product has a huge advantage from a marketing perspective," explains Klaus Lepenies, head of car integration, and head of the ride and handling department at Bilstein. "It's hip these days to have an app for a smartphone. But, when we sat down to discuss a new product, we came to the conclusion that we wanted to give something more to customers."

Bilstein chose to base the system on its Ridecontrol adaptive damper system. In standard form, the manually controlled passive damper system is adjusted via a knob, mounted within the car. But Bilstein has spotted a development opportunity in application-based adjustment to create iRC (intelligent Ridecontrol).

"We are trying to expand our knowledge in terms of electrical suspension and electrical devices, as we know it is the future," explains Lepenies. "The iRC is our development in this area. It is something which, on the one hand, has helped develop our understanding of electronics in suspension systems, but it is also something that can help customers from a marketing point of view. We came to the conclusion that a device

ABOVE: **THIS DEMONSTRATOR HAS RATHER MORE PHONE FEATURES THAN THE AVERAGE M3, THANKS TO BILSTEIN'S APP**

LEFT: **BILSTEIN'S RIDECONTROL DAMPER CAN NOW BE ADJUSTED VIA A SMARTPHONE APP**



that makes the passive Ridecontrol into an active suspension would be something that addressed both points. It was a nice introduction into this side of things, and it was really enjoyable to develop."

The manual Ridecontrol damper controller is replaced with an ISE module that automatically alternates between two pre-defined settings of comfort and sport. Additional components to the system include an ECU, with pre-programmed parameters, and a three-axis accelerometer.

"If a driver has a technical interest, it allows them to go really deep into the values and parameters of the suspension," explains Lepenies. "And the accelerometer recordings can be viewed on a smartphone in real time. The system allows the driver to change the parameters, and the suspension will automatically switch between them."

The aftermarket app-roach

Aftermarket supplier KW Automotive is also working on app-controlled dynamics settings, with initial work targeting track day and fast-road drivers. "Our DDC ECU kit is aimed at the enthusiast who wants to upgrade their vehicle visually and functionally with a high-end suspension kit," explains engineer Michael Rohn from the company. "It will give drivers the opportunity to make a car more comfortable or sporty within a few milliseconds."

The system also offers benefits beyond the obvious time savings for those customers who like to drive on circuit, but only sometimes get a chance to, continues Rohn. "This way, they can use their car on a daily basis in comfort, before individually adjusting the bump and rebound to their own driving styles, without the risk of burning their hands on hot vehicle components, unlike conventionally adjusted shock absorbers."

KW's approach to vehicle integration will see the DDC system supplied with an OE-specification, vehicle-specific wiring harness.

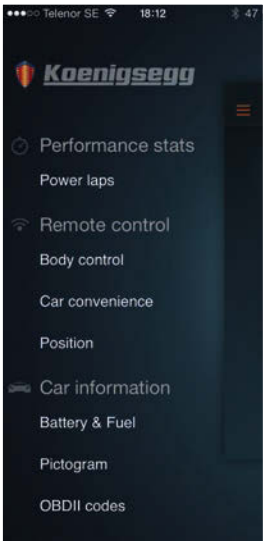
"The control unit and WLAN modules are both in-house developments, which have undergone stringent tests to withstand use on the vehicle," states Rohn. "The addition of the WLAN module allows the driver to further customize the vehicle's dynamic behavior, once a connection is made between a smartphone and the control unit. The KW DDC app allows different settings to be made via its different pages."

KW's semi-track-focused approach is evident in the adjustability range of the damper stiffness, with an operating range of 100%, and the ability to save individual tuning settings.

Safeguarding against settings that could severely compromise a vehicle's

ABOVE: **KW'S DDC SYSTEM HAS BEEN DESIGNED TO OFFER KEEN DRIVERS A PLUG-AND-PLAY CAPABILITY**

LEFT: **NO MORE OILY HANDS. USERS CAN ADJUST VEHICLE SETTINGS VIA KW'S SMARTPHONE APP**



ABOVE: **KOENIGSEGG'S ONE:1 DYNAMICS APP MUST BE THE MOST EXCITING APP EVER. IT'S JUST A SHAME SO FEW PEOPLE WILL EXPERIENCE IT**

ABOVE RIGHT: **KOENIGSEGG'S PREDICTIVE ACTIVE TRACK MODE SETUP SCREEN**

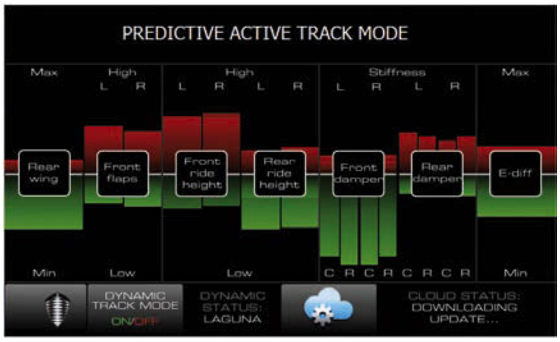
dynamic ability, the DCC's connection is protected by an individual password that prevents anyone from tampering with the app.

"On the grounds of safety, there is also a maximum offset of 30% allowed between the front and rear axle," explains Rohn. "The system also uses a minimum identifier, called KW Comfort, which is activated at certain vehicle speeds, and cannot be changed [automatically changing from comfort to sport mode at a predefined speed, for example]. With the possibilities for individual settings, the driver can exert a noticeable influence on the vertical dynamics of the car, including the pitch and roll movements, as well as steering response and ride comfort."

The future is now

With such systems offering the ability to combine comfort with dynamic ability, tied in to a customizable package, it is almost unsurprising that it is the supercar sector that is also experimenting in personalized dynamics. Koenigsegg's latest hypercar – or megacar, as it is being marketed – implements the idea of app-controlled dynamics on a higher level.

"The suspension on the One:1 is 3G controlled," explains Jon Gunner, technical director at Koenigsegg. "We can track the car's location, and adjust all four corners of the car remotely."



Building on Bilstein and KW's pre-defined settings, which are at the upper and lower limits of the damper, Koenigsegg has added a further element by utilizing the cloud's remote storage capabilities. "We are planning to set the car up perfectly for all local European tracks," explains Gunner. "So as the driver approaches whichever circuit they will be driving on, the car downloads the best settings for that circuit."

The One:1's suspension is the result of a collaboration between Koenigsegg and Öhlins, with the Triplex rear setup from Koenigsegg's other hypercar, the Agera R, being retained. The setup uses a third damper which links the rear wheels horizontally, and a Z-shaped anti-roll bar to control squat during acceleration, combined with active dampers, which can be controlled through the app.

Koenigsegg's app, however, is far further reaching than anything offered in the aftermarket at present. Integrated deep into the car's CANbus system, the app also has the ability to control the car's active aerodynamic devices, including the hydraulically activated rear wing, which has the ability to be almost stalled, in order to help the car achieve its claimed top speed of 440km/h (273mph).

However, the likelihood of such a far-reaching application being offered on the aftermarket soon, is slim.

"Right now, the project ends with the product we have," explains Bilstein's Lepenies. "Heading into the future, so much is possible. But to be honest, we are looking for a product we can sell on the market. We develop springs and dampers. To start introducing more elements, or to add more integration, would be to move away from our main market. And just adding more electronic features really isn't our main goal."

"These systems can continue to increase complexity," concludes KW's Rohn. "They essentially have to be expanded usefully, and to be further customer-oriented. Customers only want usable and meaningful features that will be useful for them long-term. Placebo features simply would not achieve this."

RIGHT: **INTEGRATED DEEP INTO THE CAR'S CANBUS SYSTEM, KOENIGSEGG'S APP ALSO HAS THE ABILITY TO CONTROL THE CAR'S ACTIVE AERODYNAMIC DEVICES, INCLUDING THE HYDRAULICALLY ACTIVATED REAR WING**

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GYROSCOPIC EFFECTS ARE A CRUCIAL CONSIDERATION FOR CANCELLING OUT DESTABILIZING CHARACTERISTICS IN A SUSPENSION SYSTEM, SAYS **JOHN MILES**

Recent discussions around technical papers by Magnus Roland (Saab/GM/Swedish automotive consultancy S2AB) have highlighted the hitherto little publicized effects of gyroscopic precession forces generated by wheel/tire assemblies, and how they can be used in conjunction with kinematic toe change to minimize, or even eliminate, destabilizing camber/toe-related tire thrust effects in response to the myriad vertical and roll inputs seen by the suspension.

Cycle and motorcycle dynamics perfectly demonstrate that an angular change in a spinning wheel generates an immediate and seamless reaction at 90° to the plane of rotation. In a typical 600mm diameter road wheel assembly, the reaction force can be considerable, and will certainly influence handling and ride behavior, according to Roland. He highlights that the kinematic camber gain present in almost all suspension systems results in a gyroscopically generated toe-in moment. This, added to the traditional kinematic toe-in at the rear axle, gives a gyroscopic precession moment toward positive camber, giving a decrease in apparent camber stiffness. By contrast, kinematic toe-out steer results in an instantaneous camber stiffness gain.

You can feel the power of gyroscopic precession yourself by 'angling' the spindle of a spinning bicycle wheel. Granted much of the resulting wheel steer is transient, and dependent on the stiffness of the wheel bearing pack and suspension compliance, but these effects certainly need to be thought about.

For example, calculations show that at 60mph, a 25kg/600mm diameter wheel/tire mass subjected to a 1m/sec vertical input on a suspension with a typical bump camber gain of 30°/m, generates a precession moment (torque) of around 53Nm, and double that at 120mph – significantly more than a typical wheel nut torque.

Every chassis engineer who has tuned a road car knows that virtually the only way to desensitize the response profile of the front axle is to individually tune bump/roll/compliance steer toward toe-out (4-10°/m is typical), as this automatically compensates for tire thrust spontaneously generated by camber change and track change over

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CLOCKWISE FROM ABOVE: **LOTUS OMEGA/CARLTON, SAAB 9000, CHEVROLET CORVETTE Z06, AND BMW 3-SERIES ALL HAVE SLIGHT KINEMATIC TOE-OUT WITH BUMP BUILT IN TO THE REAR-AXLE GEOMETRY**

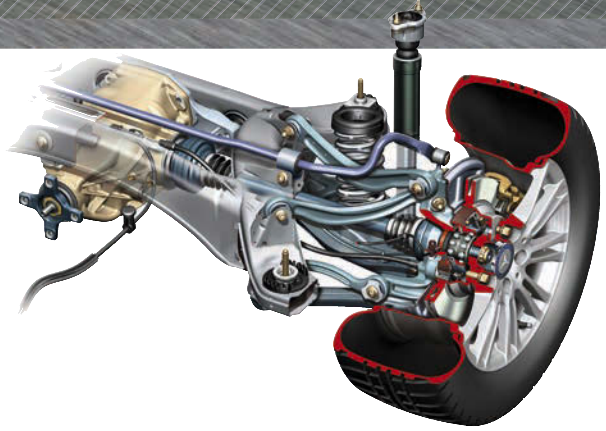
bumps, and on all vertical and roll inputs. The foregoing is an example of what Roland calls "destructive interference" – the built-in automatic and virtually instantaneous elimination of unwanted response gains due to the myriad individual (stochastic) vertical inputs, and related camber gain/gyro-related toe-in steer. There is also a reduction in potential over-response at the front axle due to rough steering input.

Ultimately, it is the rear axle that controls much of the overall yaw behavior, and therefore response phasing between front and rear axles. In turn, it largely influences steering center feel, yaw damping and controllability at the limit of adhesion. Rear-axle roll centers are usually higher than at the front, which means more kinematic camber gain on bump and, in turn, more camber thrust and a greater reaction toward gyroscopically generated toe-in.

Static toe-in is always specified to 'pre-tension' the rear tires, and this is typically coupled with kinematic toe-in on bump/roll and lateral force, and maybe compliance toe-in as well, linked in some cases to static negative camber as high as -2.0°, all of which can be attributed to the fear of any body yaw at high speed.

Paradoxically the result is often a kind of false stability feel, where the rear axle is so heavily restrained laterally that it causes excessive resistance to yaw, a woolly on-center steering feel, coupled with a side-to-side wriggling motion on single wheel bumps, and an odd low-frequency wander at high speed, due to spontaneous and unpredictable side-to-side tire thrust effects, especially on cambered long wave inputs – not to mention an unpleasant lateral acceleration 'jerk' and nervous – tire buckling – grip gain feel in response to quick steering inputs. Roland sees these effects as generating an "internal power struggle" between the left-hand and right-hand suspensions, whereby they are pushing against each other, so destabilizing the whole car on single wheel inputs – especially on low-grip surfaces. When operating at the other end of the performance envelope, the increasingly dramatic in-built rear tire slip-angle generation (toe-in gain) can finally give way to the flick oversteer that stability control systems have to sort out in their rather crude manner. In addition, such a serious amount of continuous tire scrub at the rear axle will cause excessive tread wear.

For years, Roland's design philosophy has been to devise suspension linkage systems (topology) that can automatically extract order from the disorder generated by the extraordinarily complex inputs seen by the wheel/tire assembly, and it is true that a very slight toe-out rear steer geometry is currently the only known way of automatically mitigating or eliminating the spurious thrusts – those "internal power struggles" again – generated by the suspension kinematics while retaining the intended primary characteristics. Furthermore, only gyroscopically



ABOVE: **MERCEDES-BENZ E-CLASS USES A CROSS-COUPLED LINK INDEPENDENT SUSPENSION LINKAGE TO CONTROL ALL 6DOF**

RIGHT: **STIFF TOE LINKS RESULT IN REDUCED CAMBER-GAIN, AND ULTIMATELY REDUCED WHEEL WOBBLE ACROSS POOR SURFACES**

generated initial toe-out steer has the effect of instantaneously stiffening the wheel in camber mode at the same time. Roland points out that the correct suspension topology is vital. Ill-considered spring, damper or link positions often result in conflicts within the system itself. This might result in a link having to push and pull simultaneously (more internal power losses), an example being the positioning of a damper mounting on the hub carrier in such a way as to put compression loads into the lower suspension link or trailing arm while it is simultaneously trying to permit the hub center to recess on bumps.

Roland believes, quite logically, that for the system to work properly, the toe link must be as stiff as possible to prevent negative camber-gain related gyroscopic toe-in steer increasing any tendency toward instability on bumps and wheel wobble where there is internal confusion between cross-coupled kinematic and gyroscopic outputs.

As I have said in previous *VDi* features, the philosophy of slight kinematic toe-out with bump at the rear axle is not new: witness the Lotus Esprit rear axle (although that was by accident rather than design); the uniquely stable-on-all-surfaces Saab 9000; the Lotus Omega/Carlton; the FWD Lotus Elan; the Corvette Z06; and judging by some rig test data I have seen, also the BMW 3 Series platforms. The joyous handling Alfasud had all the right Saab 9000-like rear suspension ingredients as well. Additionally most twist-beam rear axles, made since the Golf in 1972, managed with compliance toe-out – and many still do.

Applying the reversed kinematic rear steer philosophy to a side-view Watt linkage and Panhard rod located lightweight beam axle, as seen on the Saab 9000/Alfasud, or the solid toe control link/semi-trailing arm system on the Lotus Omega/Carlton is one thing, but there is a school of thought that it could be more of a challenge on Roland's new IP patent-protected Mercedes' E-Class-like cross-coupled link independent – the only type of system that can independently control all 6DOF and therefore simultaneously assure a toe-in trend under braking and acceleration.

For some suspension systems, especially those with plenty of spare rear-axle cornering capacity (larger tires or light loads), I have complete confidence that the concept can work robustly and perform very well indeed, but with bump toe-out steer values specified at around 1.0-1.5°/m, the 'reversed' kinematic steer philosophy (which originally came from extremely successful Saab rally car development) could raise questions about production tolerances where there is already lots of lateral compliance, such as with a rubber-to-body mounted subframe, or when bump steer tolerances are no better than ±2.0°/m in the first place. Hence the normal trend is for manufacturers to play safe, always retaining toe-in kinematics.

A Roland design feature also seen in the cycle/motorcycle world is fixing the spin axis of both driven and un-driven wheels forward of the steer axis (king pin axis), to counter wheel 'wobble', or high-speed gyroscopic oscillations, therefore out of balance sensitivity. With caster increased to give the same ground trail I have experienced the benefits in 'free steer' stability, and kick-back damping, attributable to this topology in the driven wheel case during the development of the FWD Lotus Elan. I can't comment on the multitude of inputs involved and their relative importance or Roland's explanation using quantum mechanics theory, but a simplistic view is that as the wheel steers with the spin axis ahead of the steering axis, the hub center rotates in the same direction as the steer action and is pulling on the king pin axis. As a result, an additional restoring moment to center is generated under drive torque, which in turn results in desirable negative feedback. In contrast, a rearward offset spin axis would generate positive feedback because the wheel center thrust generates an instantaneous torque in the opposite direction to steer (another internal power struggle), meaning that any camber-generated toe-in probably is more likely to encourage wheel/tire mass wobble, or shimmy.

BELOW: **THE MID-90S FWD LOTUS ELAN CAN REPLICATE THE FREE STEER STABILITY OF A RWD PLATFORM, THANKS TO INCREASED CASTER**

Smooth sailing

FOR 60 YEARS, CITROËN HAS BEEN REFINING ITS HYDROPNEUMATIC SUSPENSION SYSTEM. **JOHN O'BRIEN** MET WITH THOMAS D'HAUSSY TO FIND OUT WHAT'S NEXT

The 2014 Geneva Motor Show saw Citroën debut the latest iteration of its venerable hydropneumatic suspension system – Hydractive. While adding only a simple ride-height function to the existing platform, Hydractive III+ is symbolic of Citroën's approach to evolving its system. For six decades, the gas- and liquid-controlled setup has been refined and improved, culminating in its installation on the 2014 C5 CrossTourer.

Hydractive III has been in use since the launch of the C5 in 2001. The introduction of information from the vehicle's CANbus system – and the placement of sensors on the car's front and rear anti-roll bars – allowed ride height to become active, while the one additional sphere added to both axles could be isolated to vary overall ride stiffness from Comfort to Sport profiles. The CrossTourer's system takes the variable ride height to new extremes, offering a 10cm difference between its highest and lowest settings, in contrast to the standard system's difference of just 35mm.

"The extra height wasn't asking too much of the system," explains Thomas d'Haussy, head of product at Citroën. "It can stay at its highest setting up to 40km/h, and at that speed you don't feel any effect of vibration in the front axle's geometry. Because there is a constant height for the rear axle, it is always in a favorable position. And historically, the reason Citroëns have had solid handling is because the rear axle is not influenced by variables in the car's load."

While Hydractive has proved its worth in the family and premium car sectors, it is still absent from Citroën's A-, B- and C-segment cars, despite the introduction of the luxury-oriented DS subrange of cars.

"What you need to remember is that there is an issue with wheelbase length," says d'Haussy. "You need a relatively long wheelbase to support the system – a city car, by its very nature, wouldn't take to Hydractive well. The true issue is the frequency of movement. It is different from a traditional suspension configuration. It operates at around 1Hz, whereas conventional suspension will have a frequency of around 1.3Hz. This difference is quite acceptable on a car with a longer wheelbase, but on a short wheelbase this kind of movement can induce sickness in passengers!"

BELOW: **THE C5 CROSSTOURER DEBUTED THE LATEST VERSION OF HYDRACTIVE, WHICH FEATURES A 10CM RANGE OF OPERATION**

ABOVE: **C5 CROSSTOURER'S SYSTEM REMAINS REACTIVE; THE NEXT GENERATION IS SET TO BECOME ACTIVE, WITH THE ADDITION OF A RADAR CAMERA TO THE SETUP**

"It's easy to simulate things like body angle or acceleration forces. But simulating the way the driver and passenger feel in the car? That is very difficult to make a parameter for"

The cost of implementing such a system in a very competitive segment of the market is an issue that Citroën is painfully aware of. "We did have a C-segment car with Hydractive – the GS," begins d'Haussy. "With that, we witnessed first-hand the customer being reluctant to pay for that sort of technology. In attracting new customers it proved less than ideal, as they simply weren't prepared to pay for such technology."

Motion sickness, an unfortunate trait of earlier-generation Hydractive systems, has been eradicated, but it is still something that Citroën considers.

"The human parameter is the most difficult thing to simulate," explains d'Haussy. "It's easy to simulate things like body angle, acceleration forces, and so on. But simulating the way the driver and passenger feel in the car? That is very difficult to make a parameter for."

Hydractive remains a thoroughly Citroën product, with the system developed predominantly at PSA's facility in Vélizy, just west of Paris. D'Haussy states that the single development location, used before global climatic testing, has facilitated the refinement of the Hydractive system, as engineers know which areas of the facility's proving ground can highlight a poorly configured solution. It is this continuity, also present in the manufacturing of the system's components, which has led to improved reliability as each generation has passed.

"It used to be developed completely in-house," he explains. "Recently, however, some of the work has been tendered out. The production is still done in-house though. The only item we buy in is the neoprene membrane for the spheres. We used to make that in-house too, but we have since found a good solution from a third party. However, all the mechanics remain manufactured in-house."

Despite the apparent complexities of Hydractive, Citroën insists that the system is largely maintenance-free, with servicing schedules set at 200,000km.

"Long-term life is something that is a key focus, rather than purely reliability," states d'Haussy. "When you bring something different, it has to be reliable. If it's not, how can you sell it as being beneficial to the customer? We've been working a long time with this technology, and we have ironed out the imperfections. Reliability issues are something we simply don't hear about now."

Just as the fundamental principles of Hydractive haven't changed radically, neither has the construction of the system. The introduction of Hydractive III ushered in a more environmentally friendly mineral oil – named LHM – for the spheres, while the gas used remained nitrogen. But in a system that has seen elements repeatedly added, is there scope to shrink the packaging, or weight of Hydractive?

"The question is the volume of the gas," begins d'Haussy. "That, and the diameter of the damper body, which is always going to be fixed. We could work on different technologies for the sphere to make it lighter, but it is a completely different way of working from having a conventional spring and damper.

"Because all the energy and forces are contained in the sphere, it is very difficult to reduce the overall diameter. So at the moment it's not possible to reduce the weight of the system."

Despite this, Citroën is continuing to develop the system in other ways, and the next generation is set to see it move from a reactive system to an active one. "Currently, we monitor the movement of the front wheel, and can adapt the suspension for the trailing wheel accordingly," says d'Haussy. "The next step is to have the car target and identify an obstacle on the road, and set up the suspension before it arrives at it. So at present we are working on the car's 'vision', which will scan the road."

The introduction of a stereo camera to the system, similar to Mercedes-Benz's Magic Body Control, is just one option for the future of Hydractive, with d'Haussy stating that the possibility of integration into the car's GPS is another. "The second innovation that we are working on is tying the suspension in with the car's navigation system," he says. "That way, information about the road is fed to the car, meaning it can run in comfort mode 95% of the time, only stiffening up for cornering, or during moments of heavy braking or acceleration. This approach ensures passenger comfort for the longest periods of time."

Soft focus

KEITH REID SPEAKS WITH MSC SOFTWARE ON HOW ITS ADAMS PACKAGE CONTINUES TO ADAPT AND EVOLVE IN PARALLEL WITH THE AUTOMOTIVE INDUSTRY

A year ago, MSC Software calculated that current simulation could accommodate 80% of customers' demands, and predicted that integration of technologies would ensure coverage of the outstanding 20%. Today, with the launch of the company's 2014 releases, much of what had been 'blue sky' thinking is now – or soon will be – a reality.

MSC has introduced System Dynamics, a newly formed business unit responsible for Adams, its 3D multibody dynamics product, and its Easy5 code for advanced control and system simulation. Heading up System Dynamics is Peter Dodd, who joined MSC in early 2013 from an engineering service company, where he did a lot of physical testing. His career started in the automotive industry where he used products such as Adams. "Keeping current with technology developments, like the work we've done with tire modeling for instance, is keeping Adams ahead," he says.

"At any time one of our competitors could come out with a brand-new technology that could take the market by surprise and cause us some discomfort. We're not aware of any. But I think we're going to be in a very good position to defend our market if, and when, that happens. At the same time, we're not so much watching what the competition is doing as looking at market demands and making sure we're satisfying those demands. In some cases that's a question of listening to customer demands and responding to them. In other cases – certainly with our non-linear technology – it's a question of recognizing we have some key tools that other companies don't have.

"As well as being a multibody dynamics company, we are an FE company. We have Nastran, and we have Patran for pre- and post-processing… so if we can pool our resources, we believe that we can come up with some leading-edge tools that the competition is going to find hard to challenge."

System Dynamics product manager Chris Baker adds that the company has taken a three-tier approach to embracing the 20% of needs previously not met and to integrating non-linear technology within Adams.

"The first tier is FE Part, a wholly Adams-native modeling object that has distributed mass and is accurate for very large deformation cases – geometric non-linearity – of beam-like structures. It emulates an FE technology, the foundation for which is the Absolute Nodal Coordinate Formulation [ANCF], and provides the user with the ability to create an FE beam within the multibody dynamics environment. Our offering is geometrically exact, and is also very fast and improves fidelity.

"The second tier takes advantage of our MSC Nastran SOL400 non-linear FE technology. We're taking a component from Solution 400 and embedding it within Adams. This bridges the gap between ride and durability. Analysts in the Adams world will be able to evaluate stress and strain with high accuracy in full-vehicle simulation. They could look at a twist-beam axle and model it with a high fidelity non-linear part behaving within the context of a full vehicle driving through a pothole, for instance. And it can be done virtually, giving very accurate stresses and strains, and accounting for full geometric, material and contact non-linear behaviors.

"The third tier is a true co-simulation, coupling our Marc solution with Adams – two solvers working side-by-side, talking to each other at communication intervals, exchanging data and boundary conditions. The advantage of this scenario is that Marc provides the ability to do adaptive re-meshing of the component during run time, and it also has an extensive library of viscoelastic materials. So for non-linear parts that see large deflections in a simulation – and potentially require re-meshing during simulation – or for a part that sees plastic deformation that is significant enough to require re-meshing, the Adams-Marc co-simulation feature will be the preferred route. It also has some thermal capability."

Dodd says MSC is providing a way that analysts and designers can model from first principles some of the things that, previously, they've had to measure – such as bushings.

He reveals that one European OEM wants to look at the potential non-linear behavior of body structures: "As the car goes around a corner, or as it approaches the limits of handling, there are fine differences in the structural behavior and stiffness of components. Manufacturers want to model those extremes so that they can more accurately predict dynamic performance.

"I don't think we'll ever get to that isolation stage (relying completely on predictive methods) – nor should we. We want to be able to start producing useful models before there's any physical test data available, because at the beginning of a program you don't have any hardware to measure. But you do want to be able to characterize, approximately, what the behavior of that hardware should be. You need to zero in on a fairly narrow envelope of what characteristics that part should have. And that's what we can do in the first stage with a tool like Adams and come up with reasonable estimates of how that part should behave. And then you can go away and design it. But you're not designing in a vacuum."

PETER DODD, SYSTEM DYNAMICS CHIEF AT MSC, IS POOLING THE COMPANY'S TECHNOLOGIES TO ENSURE A COMPETITIVE EDGE

LEFT: **RECENT ADVANCES IN TIRE MODELING CAPABILITIES ARE HELPING TO KEEP THE ADAMS PACKAGE FRESH**

The main event!

THE INAUGURAL VEHICLE DYNAMICS CONFERENCE IS GOING TO CHALLENGE PERCEPTIONS WITHIN THE VEHICLE DYNAMICS INDUSTRY. WITH THE INDUSTRY'S TOP NAMES TRADING KNOWLEDGE AND HAVING NO-HOLDS-BARRED DYNAMICS DEBATES, THIS EVENT CANNOT BE MISSED!

June 24, 25 and 26 will see the launch of a unique new platform for the vehicle dynamics industry. Some of the biggest, most respected names in the industry will converge at Messe Stuttgart, Europe's automotive hub, and they are going to put the dynamics world to rights. Experts from some of the world's elite automotive names, including Porsche, Ferrari, Aston Martin, Lotus Engineering, Ford, Fiat, SAIC and Jaguar Land Rover, are planning to debate some of today's hottest topics including the influence of the marketing department on dynamics; satisfying the consumer motoring journalist, but at the same time producing fun and safe dynamics attributes; the best tuning techniques; and the application of new technology. The gloves will be off, frank discussions will be held, and knowledge exchanged. And you can be a part of it.

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VEHICLE DYNAMICS CONFERENCE 2014

Tuesday, June 24

The OEM forum

9:40am-10:05am

Integrated collision avoidance by active intervention for intelligent vehicles

Jitendra Shah, senior research engineer, Ford Forschungszentrum Aachen, Germany

A considerable proportion of road accidents are attributed to rear-end collisions, lane-change collisions, and run-off-road events. Shah from Ford believes that an integrated design of information, warning and intervention system might help reduce these types of accidents. During this presentation, Shah will present a new approach to how rear-end, lane-change and run-off-road collisions can potentially be prevented. He will also explain the required architecture and control concept, including a specially developed common dynamic path planner, and a controller that combines braking and steering intervention. The team at Ford have also implemented a safety shield concept for cascaded HMI, for longitudinal and lateral threat, and Shah will be sharing the winter test results with attendees.

10:05am-10:30am

918 Spyder – technologies for advanced vehicle concepts

Dr Peter Schaefer, director of chassis development, Porsche, Germany

The 918 Spyder defines new standards in the segment of super sports cars. It offers outstanding driving performance as well as optimal efficiency and driving comfort for everyday use. Dr Schaefer will discuss the objectives of the 918 Spyder's development program, and share details of the hybrid concept, which includes the electric Porsche Traction Management and the hybrid braking system. He will also introduce attendees to the car's rolling chassis and mechatronic chassis systems, which are key to precise handling, high driving performance and optimal ride comfort. The 918 Spyder displays a high level of innovation, and the incredible technologies developed for it will soon be found in more mainstream Porsche vehicles.

10:30am-10:55am

Active vehicle ride and handling development by using integrated SIL/HIL techniques in a high-performance driving simulator

Marco Fainello, vehicle dynamicist, Ferrari, Italy; Diego Minen, managing and technical director, VI-Grade, Italy

Dynamic driving simulators are becoming more and more popular in the automotive industry for developing equivalent-to-real full vehicle testing. As simulators embed detailed in-SW or in-HW descriptions of all the passive and active vehicle subsystems, for combined ride and handling maneuvers, this gives professional drivers access to an accurate reproduction of the real vehicle. Now, a revolutionary approach to vehicle engineering is seeing these drivers working with engineers to significantly influence the design of on-dev prototype vehicles. Key factors for the effectiveness of a dynamic driving simulator are vehicle and road model accuracy; graphics/sound/vibration quality; realism of human interface; effective motion cueing; and the ability to correlate parametric results between simulation and reality. Balancing all these factors is a real issue for dynamics professionals, and doing it properly within all the constraints of a simulated reality is one of the main challenges for the OEM and the simulator supplier. Thus Ferrari and VI-Grade have been, and are, working together to fine-tune Ferrari's new driving simulator in order to minimize the on-platform versus on-vehicle driver feeling difference. Want to learn more? During this presentation, Ferrari and VI-Grade will be sharing their experiences and learnings from the project, and how they will push it forward.

10:55am-11:15am Break

11:15am-11:40am

A wider setup vision for new developments

Dr Claudio Ricci, engineering specialist, Fiat Group Automobiles, Italy

This presentation will see Dr Ricci discuss several new, upcoming models that require wider methods and tools to build overall performance.

11:40am-12:05pm

Vehicle dynamics development of the Aston Martin V12 Vantage S

Wayne Doyle, project engineer – vehicle dynamics, Aston Martin Lagonda, UK

The V12 Vantage is renowned for being one of Aston Martin's greatest cars. With the V12 Vantage S, the remit was to broaden its appeal while maintaining the brutal character of the original. Through the application of adaptive technologies, and with thorough and measured chassis hardware tuning, a vehicle with bold but accessible dynamics performance has been created. Attend this presentation to see Doyle highlight some of the technical aspects that contributed to the success of this remarkable car. Fans of the marque will also enjoy Doyle's discussion of how Aston Martin's approach to vehicle dynamics development contributes to a well-resolved product.

WORKSHOP

The process for optimizing and studying the effects of suspension parameters – MSC.Adams

Day 1 Lunchtime workshop - 12:30, 24 June - MSC.Adams

The MSC.Software Vehicle Dynamics team will be presenting, with some live demonstrations, the process of validating suspension parameters, optimizing their characteristics while investigating their influences on full vehicle maneuvers. They will also take a deeper look into some of the capabilities that help make MSC.Adams the software of choice for loads extraction in durability analyses.

12:05pm-2:00pm
Lunch break, and a chance to visit the neighboring exhibitions

2:00pm-2:25pm
Grip and thermodynamics-sensitive tire/road interaction forces estimation and modeling
Dr Flavio Farroni, technical consultant and vehicle dynamics researcher, Ferrari and Naples University, Italy
The fundamental role that tires have played in motorsport and in the automotive industry in recent years, and the growing need to reproduce with a high level of detail the phenomena concerning vehicle dynamics, have given a strong impulse to research in the field of vehicle systems analysis and modeling. During his presentation, Dr Farroni will propose an innovative procedure, which he claims is able to estimate, analyze and model tire/road interaction characteristics based on the use of GrETA friction and TRT thermodynamics models.

2:25pm-2:50pm
Optimizing tire inflation pressures for vehicle performance
Maelle Dodu, advanced chassis engineering, Jaguar Land Rover, UK
The tire contact patch is the only link between the vehicle and the ground, and as such, plays a fundamental role in almost all vehicle attributes. During a new vehicle development program, the tire is designed and tuned to reach a specific balance between these different vehicle attributes. This balance of performances is defined to fit with the OEM brand aspirations and the vehicle market positioning. However, one parameter can dramatically alter this hard-to-achieve balance: the tire inflation pressure. During this presentation, JLR's Dodu will show how an OEM can make the best use of inflation pressures for improved vehicle performance.

15:00 Panel discussion

VEHICLE DYNAMICISTS: servants to the marketing department and journalists?

Key vehicle dynamicists to take part: Dr Ulrich Eichhorn, managing director, German Association of the Automotive Industry; Dr Peter Schäfer, director of chassis development, Porsche AG; Magnus Roland, founder and owner, SA2B; Damian Harty, senior staff engineer, CAE Group at Polaris Industries; John Heider, vehicle dynamics development, Cayman Dynamics; Tim Roebuck, function leader, vehicle dynamics R&D, Lotus Engineering; Craig Croot, manager, of vehicle dynamics, aerodynamics and durability, Aston Martin Lagonda; Chris Regan, senior project manager, Honda R&D; Andy Kitson, vice director of chassis, SAIC Motor UK Technical Centre; Karsten Schebsdat, manager of passenger car chassis tuning, Porsche; Jürgen Pützschler, senior engineer, Volkswagen AG; Simon Newton, chief engineer for driving dynamics, Williams Advanced Engineering; Ruediger Hiemenz, engineering director, Mando Corporation; Guy Mathot, head of dynamics development, Ford C Cars & Focus

Wednesday, June 25
Development and tuning

9:00am-9:25am
Advanced target setting for a front-loading development process with virtual tools
Alexandre Català, vehicle dynamics corporate manager, Applus+ IDIADA, Spain
The increasing pressure to deploy virtual tools in a wider spectrum of applications and development phases with high accuracy and efficiency demands precise target-setting processes. Applus+ IDIADA has been using advanced measurement techniques to characterize vehicle dynamics performance for over a decade, and this database information is now a key asset that permits identification of the descriptive parameters and set ranges linked with different types of performance styles, vehicle concepts and branding differentiation. Català will explain how advanced target setting is therefore possible by cross-matching subjective rates with the right combinations of metrics through an extensive number of vehicle results.

9:25am-9:50am
The latest developments in motion cueing provide a low-latency handling experience
Edwin de Vries, senior dynamics engineer, Cruden, the Netherlands
Cruden is well known in the field of motion simulators for vehicle dynamics, and its engineering team has now developed a versatile interface to define novel motion-cueing approaches. Imposing the vehicle side-slip angle on the platform's yaw angle avoids washout and cueing filters, and a dynamic varying yaw pole enriches the driver's perception of handling. By replaying race car driving, the platform's motion can be analyzed repeatedly and objectively. The latency of platform motion with respect to a simulated vehicle shows the benefit of providing acceleration next to position and velocity input. In this session, Edwin de Vries will discuss the new simulator handling experience and how it can provide the architecture for creative motion cueing.

9:50am-10:15am
Slippery road detection using only EPAS signals
Mariam Swetha George, product engineer, Nexteer Automotive, USA
The conventional method of estimating road surface friction uses wheel slip computed from non-EPAS sensor signals. However, flaws with this method can include it being either expensive, dependent on tire signals, or providing late detection.

VEHICLE DYNAMICS CONFERENCE 2014

Road friction feedback is of importance in itself to the driver, but friction information is also needed in other safety-related functions. This discussion will cover how to use only EPAS signals to determine tire-road friction. Detecting slip using EPAS signals can be potentially faster than using yaw rate and lateral acceleration, as these signals follow the steering signals. As a minimum, such a system can provide an inexpensive early warning to drivers.

10:15am-10:40am
A systems engineering approach to the conceptual design of vehicle handling dynamics
Mandar Hazare, doctoral research assistant, Clemson University International Center for Automotive Research, USA
It is important to have a systematic approach to the design of vehicle handling dynamics, in order to ensure that the final products meet customer expectations. At the same time, dynamics engineers need to reduce concept development times, balance other conflicting functions, and avoid late design changes and over-engineering with regard to cost and weight. Hazare, from this venerable South Carolina institution, will discuss his latest research, which is a simulation-based vehicle handling design methodology based on a systems engineering approach using decomposition-based target cascading principles (most applicable during the concept development phase). This systems engineering-based simulation framework connects customer requirements to vehicle-level targets, subsystem-level requirements and component-level design specifications using a multi-objective optimization scheme.

10:40am-11:00am
Break

11:00am-11:25am
Adaptation of vehicle dynamics simulation software to ADAS applications
Dr Thomas Gillespie, director of product planning, Mechanical Simulation Corporation, USA
In vehicle dynamic simulation programs, CAE software tools are used to develop ADAS systems. In conjunction with real or simulated sensors, the CarSim package can simulate the test vehicle, testing environment and driver, which gives ADAS engineers the capability to sense the surrounding environment, evaluate the situation, and determine what response is required for best safety performance. Dr Gillespie will explain how developers of vehicle dynamics simulation tools are adding more sensing capabilities to packages in order to improve vehicle dynamics models for future ADAS requirements. This presentation will also describe some of the sensing extensions available in CarSim.

11:25am-11:50am
Models and controls of vehicle dynamics designed directly from data
Prof. Mario Milanese, CEO, Modelway Srl, Italy
The development of mathematical models, control and virtual sensors for complex and non-linear systems requires great efforts in the design and calibration phases. In this presentation, new design technologies are described: NOSEM for model building, STC for controls and DVS for virtual sensing. They are based on a new systematic approach in which the real system measurements are directly used in the design process. Examples of NOSEM, STC and DVS applications to cutting-edge vehicle systems will be presented by Prof. Milanese, showing significant advantages in development time and costs, and algorithm robustness versus variability of system operating conditions.

11:50am-12:15pm
The interrelationship of suspension kinematic and compliance solutions
Gene Lukianov, principal, VRAD Engineering, USA
Suspension kinematics, the process of determining geometrical architectures, is determined early in a vehicle's design; suspension compliance engineering occurs later in the design sequence. Lukianov will share information as to how the early determination of kinematic (hard-

WORKSHOP

The process for optimizing and studying the effects of suspension parameters – MSC.Adams

Day 2 Lunchtime workshop - 12:30, 25 June - MSC.Adams
The MSC.Software Vehicle Dynamics team will be presenting, with some live demonstrations, the process of validating suspension parameters, optimizing their characteristics while investigating their influences on full vehicle maneuvers. They will also take a deeper look into some of the capabilities that help make MSC.Adams the software of choice for loads extraction in durability analyses.

VEHICLE DYNAMICS CONFERENCE 2014

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point) architecture actually sets the stage for achieving suspension compliance performance and provides a broad window of compliance instead of boxing the chassis design into mediocre design solutions. He promises that a methodology will be presented that can be used to understand and achieve ideal kinematic and compliance performance.

12:15pm-12:40pm
Pushing the boundaries of compliance modeling in vehicle dynamics simulations
Dr Alfred Boulos, strategic business development manager – EMEA, MSC Software, UK
The improvement of compliance behavior modeling during dynamic vehicle simulation is always a goal for developers, as it is often required for capturing more realistic vehicle ride and handling performance data. This is also a requirement for better extraction of the structural loads experienced on vehicle components. As these are connected mechanical systems, several factors need to be considered collectively to achieve this goal, including how tires interact with the road, the material and geometrical non-linear behavior of components, the representation of frequency-dependent stiffness and damping, and the closed-loop forces/torques driven by external control systems. This presentation will detail simulation developments by highlighting application case studies.

12:40pm-1:40pm
Lunch break, and a chance to visit the neighboring exhibitions

1:40pm-2:05pm
Tire and vehicle research – then and now
Prof. Saied Taheri, associate professor and director, Virginia Tech, USA
There has been vast renewed interest in the area of tire and vehicle research, so Prof. Taheri from the venerable Virginia Tech will discuss the future of tire and vehicle research. He will provide a brief outline of the history of tire and vehicle research, and will focus on what the future will bring. Topics such as intelligent tires, advanced chassis control, tire and vehicle dynamics modeling and simulation, and the role of the global economy on the transformation of these industries will be discussed and evaluated.

2:05pm-2:30pm
A novel vehicle motion recording platform for synchronized video/inertial playback
Dr Joost Venrooij, project leader, Max Planck Institute for Biological Cybernetics, Germany
Accurate measurements of vehicle maneuvers are of great value in research, development and simulation. To this end, a recording platform has been developed that can provide high-quality synchronized video/inertial data recordings of vehicle maneuvers. The system allows for capturing stereoscopic video footage from a driver's perspective, while simultaneously recording vehicle motion data using an inertial navigation system (INS) consisting of a FOG-based IMU and a GPS system. Find out how the institute has also developed software to accurately synchronize the recorded video with the inertial data, and used the recordings in perceptual experiments on an 8DOF motion simulator to realistically reproduce driving and flight scenarios.

2:30pm-2:55pm
Modeling, control and evaluation of semi-active suspensions
Dr Jorge de Jesús Lozoya-Santos, professor, Universidad de Monterrey, Mexico
Discover a new methodology for the modeling of passive and semi-active dampers using the characteristic diagrams. The model structure and the proposed functions are numerically tractable and easy to program and execute in embedded systems. In semi-active suspension systems, four controllers are compared using two validation approaches: hardware-in-the-loop and software-in-the-loop. Results indicate the best controller is not the same in the hardware-in-the-loop and software-in-the-loop approaches. Since the motion ratio of automotive suspensions influences the performance of the semi-active control systems, the inclusion of this geometric parameter in further analysis and synthesis of semi-active suspension systems is recommended.

15:00 Panel discussion

Is the vehicle dynamicist now simply a safety engineer?

Key vehicle dynamicists to take part: Dr Ulrich Eichhorn, managing director, German Association of the Automotive Industry; Dr Peter Schäfer, director of chassis development, Porsche AG; Magnus Roland, founder and owner, SA2B; Damian Harty, senior staff engineer, CAE Group at Polaris Industries; John Heider, vehicle dynamics development, Cayman Dynamics; Tim Roebuck, function leader, vehicle dynamics R&D, Lotus Engineering; Craig Croot, manager of vehicle dynamics, aerodynamics and durability, Aston Martin Lagonda; Chris Regan, senior project manager, Honda R&D; Andy Kitson, vice director of chassis, SAIC Motor UK Technical Centre; Karsten Schebsdat, manager of passenger car chassis tuning, Porsche; Jürgen Pützschler, senior engineer, Volkswagen AG; Simon Newton, chief engineer for driving dynamics, Williams Advanced Engineering; Ruediger Hiemenz, engineering director, Mando Corporation; Guy Mathot, head of dynamics development, Ford C Cars & Focus

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Thursday, June 26

The application of new technologies

9:30am-9:55am

Topological geometry dynamics as key words for future vehicle dynamics

Magnus Roland, president and CEO, Swedish Advanced Automotive Business, Sweden

Vehicle Systems Dynamics 2003, Vol. 39, states: "It is not completely clear what exactly makes vehicles 'easy to handle'. Vehicles are complex systems with human beings in the control loop… it is not yet quite clear which behavior determines 'good handling'." Vehicle dynamicists with capacities of visceral experiences of driving should guide the engineering development of vehicle control from the workings of two fundamentals: 'gravity' and 'mind and consciousness'. Vehicle dynamics in 2014 cannot build upon classic mechanics dating back to Newton in 1770, asserts Roland. Gyroscopic instantaneous action caused by spin and conservation of momentum are important prerequisites for good handling.

9:55am-10:20am

Unfinished business: the knowledge challenges in dynamics

Gene Lukianov, principal, VRAD Engineering, USA

Lukianov will begin proceedings with a review of the state of knowledge in vehicle dynamics and the opportunities/challenges that exist in advancing understanding of the physics and engineering within the field. He will go on to summarize the progress of current knowledge, starting with Maurice Olley, the 'father of vehicle dynamics', before progressing to later publications. He will also discuss how the characteristics of successful vehicle dynamics performance relies more on 'art and experience' than solid engineering, which implies that progress in understanding has stagnated and should be reignited. As a finale, Lukianov plans to address specific challenges involving tires, damping, frequency response, friction and suspension geometry.

10:20am-10:45am

Optimized parameter combinations of hydraulic damper modules

Dr Reinhard Sonnenburg, design engineer, ZF Friedrichshafen, Germany

Dr Sonnenburg's latest research is devoted to the problem of finding optimized parameter combinations of damper modules. Different cost functions using the amplitude spectrum of the excitation and the frequency response function of the car model will be investigated, and it will be shown that for three different arbitrary road excitations there exists a parameter combination of top mount stiffness, piston rod mass and damping constant that provides an optimum for the dynamic wheel load fluctuation. Attendees can also find out how the advantage of the optimized damper module in terms of the dynamic wheel load fluctuation, compared with a simple damper, can reach up to 20%.

Dr Flavio Farroni, technical consultant and vehicle dynamics researcher, **Ferrari and Naples University, Italy**

SPEAKER FOCUS!

Could you tell us a little about what we can expect to learn from your conference presentation?

I will present TRICK (Tire/Road Interaction Characterization and Knowledge), a tool developed within a research program in collaboration with a Formula 1 racing team, a sports car company, and with the tire production industry. The aim of the tool is to fully characterize tires by means of specific track test sessions, integrating results with grip/thermal models recently developed by our research group. We achieved the following features: analysis and modeling of actual grip/thermal phenomena involved in tire/road contact dynamics; identification of MF parameters set that are able to take into account the cited phenomena; and total independence from bench tests and data provided by tire makers.

Why is this an important topic for the industry?

Nowadays, every automotive company is looking for the optimal solution to modeling and for understanding tire behavior, both in experimental and simulation environments. The TRICK tool allows users to follow a totally new approach in tire characterization and vehicle simulation procedures, enabling the complete reproduction of the dynamic response of a tire, and of its frictional and thermodynamic behavior simply by means of a specific track session and a few laboratory measurements.

What will people gain by attending your presentation?

My presentation is an ideal opportunity to be updated about the state of tire modeling in vehicle simulations, paying particular attention to improvements in the traditional Magic Formula method, and with the further advantage of an overview on the main viscoelastic, thermodynamic, structural and performance tire characterization procedures.

What has been the biggest influence/driver of your presentation?

My activities are a result of the combined support of a very skilled and stimulating academic research environment (I've recently become a PhD) and of a company that can doubtless be considered as excellent in everything concerned with automotive research, development, production and performance seeking fields.

What would you say is the biggest challenge facing dynamicists today?

The challenge is in preserving the integrity of the discipline. My conception of vehicle dynamics is research and testing, and these activities need time and resources to be properly developed. In today's fast market, dynamics must be allowed to adapt to technological advances, like it has been in the past decades, without being compromised through selling rules and production times.

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10:45am-11:10am
Reinventing the traction controller – the radical approach
Dushyant Wadivkar, team leader, Robert Bosch, Germany
ESP algorithms, especially the traction controller, have been around for more than two decades. Once exclusive to the Mercedes S-Class, traction controllers are now even installed on almost all sub-compact cars. In the last 20 years, the algorithm has been exposed to a spectrum of OEM performance requirements, which has led to an unwanted increase of complexity in the algorithm. Today, in a time when ESP algorithms are being considered as commodities, Wadivkar will demonstrate how his team is going about reinventing the traction controller with a clear mission to reduce complexity and still meet performance expectations.

11:10am-11:30am
Break

11:30am-11:55am
Advanced robust control of vehicle steering systems
Dr Xiao-Dong Sun, technical specialist, TRW Conekt, UK
Join Dr Sun as he explores the challenges faced by dynamics engineers in vehicle steering system feel and control. He will introduce advanced modeling and robust control techniques to meet steering feel performance challenges, and demonstrate some application cases in the robust control of EPS, steer-by-wire (SBW) and advanced steering wheel systems (ASWS).

WORKSHOP

Short lecture – Virginia Tech, Prof. Saied Taheri – Tire-vehicle handling dynamics

Day 3 - Lunchtime Short Course - 1:35pm, 26 June
The handling performance of the vehicle greatly depends on the tires. Understanding the handling performance of the tires and their effects on vehicle performance requires understanding tire force and moment generation mechanisms and their variations with tire and vehicle parameters. In this lecture, an introduction to tire and vehicle handling performance is discussed and various tire parameters are analyzed. In addition, vehicle subjective and objective handling performances are discussed.

11:55am-12:20pm
Vehicle diagnostics and suspension control with smart air springs
Lutz Axel May, CEO, Torque And More GmbH, Germany
Almost every category of vehicle, whether a truck, coach, agricultural vehicle or passenger car, is now available with an air suspension system. The research and development activities for almost every vehicle category the have been expanded into smart air suspension systems. Better and actively controlled air suspension systems increase the performance of the vehicle and also offer new and exciting features. A standard air spring in the past (rubber, metal, air connectors) is now a high-tech device with integrated sensors, actuators and DSP processors. It includes the obvious features and functions we expect from a smart air-spring device, plus new developments that focus on integrated vehicle and road diagnostics.

12:20pm-12:45pm
Circumventing the compromise between agility and stability using the DSLD
Jonas Alfredson, managing director, DsenseD Technology, Sweden
DSLD technology enables the driveline to increase both the performance and the stability of a vehicle by redistributing the tire forces. The latter allows vehicle handling to be tuned in a more balanced way for better baseline agility, without sacrificing high-speed stability. The DSLD can be used in vehicles with only minor changes to existing hardware, which means that DSLD is a cost-effective and, packaging-wise, very clever device that can revolutionize the way the industry looks at differentials. In short, Alfredson proposes offering 'two vehicles in one', in the most cost-effective way possible.

12:45pm-1:10pm
Leaning vehicle suspension

systems – perpetually a future technology?
Edward Smith, technical director, TreMoto, USA
Leaning vehicle suspension systems have long been envisioned by OEMs, futurists and garage inventors, but have yet to achieve success in the market. Despite innovations in active and semi-active suspensions, fusing the elegant dynamics of motorcycles with the user-friendly stability of traditional automobiles has proved elusive. In his presentation, Smith will consider attempts by automotive and motorcycle OEMs to develop active roll-control systems (including the Nissan Land Glider and Harley-Davidson Penster), and steer-balanced multi-wheel vehicles such as the Piaggio MP3. In the near future, the marriage of leaning vehicle suspension systems with autonomous control systems could disrupt the current vehicle dynamics paradigm.

1:10pm-1:35pm
Vehicle dynamics safety technologies and tuning
Amit Kumar, deputy manager, Continental Automotive India, India
Kumar will discuss the many different safety functions on offer to stabilize a car, such as ABS, TCS, AYC and EBD, and will also look at how the physics of vehicle dynamics – including weight transfer, coefficient of friction, center of gravity, tire width and height – influence the stability of a vehicle. By controlling these parameters, the vehicle can be stabilized. He will also discuss how individual tire pressures can be controlled to achieve stability.

SPECIAL OFFER – FREE TRAVEL PASS!
The Stuttgart Convention Bureau is running a 'Mobile Extra' offer: guests who book accommodation through Stuttgart-Marketing in one of the 120 partner hotels will receive, along with their booking confirmation, a free local public transport pass for up to a maximum of eight days for the regional public transport network (valid until December 31, 2014).

Sister events

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GLOBAL AUTOMOTIVE COMPONENTS AND SUPPLIERS EXPO 14 EXHIBITOR

ROBOT CONTROLLER UPGRADE

Automotive Testing Expo exhibitor Anthony Best Dynamics has recently launched the latest version of its Robot Controller software, which includes a range of new features and improvements. The most significant is the inclusion of a special test group for performing the Euro NCAP AEB test procedure (city and inter-urban).

With just a couple of clicks, users can now create a test group that has all the required elements, including pre-test conditioning, brake characterization, and the all tests for FCW and AEB systems.

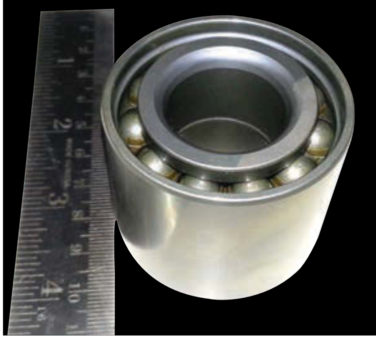
As with the existing special groups for sine-dwell and fishhook testing, this offers a significant time saving for test engineers.

Booth 1346

GLOBAL AUTOMOTIVE COMPONENTS AND SUPPLIERS EXPO 14 EXHIBITOR

SOLID LUBRICANT COATING

Booth 4410



NBC Bearings, India's largest bearing manufacturer, has developed a new range of wear-resistance coatings for bearings, which will be on display at Global Automotive Components and Suppliers Expo.

Various energy studies reveal that, in a vehicle, only about 12.6% of energy is used for its movements, while the remaining energy is wasted in the form of friction and other losses. Tungsten disulfide (WS2) coating has been implemented because it eliminates and reduces costly maintenance problems that cause breakdowns and expensive downtime by stopping galling, fretting, and friction caused by dissimilar metals and their different hardness factors.

WS2 coating is used to reduce wear in extremely severe environmental conditions (high or low temperature, high vacuum, high speeds, and high loads). It is compatible with, and enhances the performance of, all oils and greases.

ENGINEERING SERVICE PROVIDER

Visit Automotive Testing Expo to meet Lotus Engineering, one of the most dynamic automotive engineering consultancies. It has over 60 years of proven ability in motorsport, sports car production and engineering, developing products for hundreds of clients in the automotive industry and beyond. With offices in Europe, the USA and Asia, Lotus says that its engineering excellence, innovation and design flair are instilled in everything it does. The company uses its motorsport heritage to be nimble and quick when required, but it also ensures this is aligned with its production engineering experience to deliver the appropriate processes and engineering rigor for series production.

Lotus's expertise allows it to provide the following services in efficient powertrain systems: engine downsizing, engine optimization, alternative fuels, control systems and calibration, powertrain hybridization, powertrain electrification, power and energy management, engine testing, exciting vehicle dynamics, chassis concepts and chassis design, dynamics attributes development, advanced chassis systems, vehicle dynamics training, aluminum and composite structures, lightweight architectures, niche vehicle engineering and whole-vehicle testing.

Booth 1348

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Booth 1314

SIMULATION PLATFORM

Hydraulic drives are complex systems that need high-quality components, sophisticated mechanical systems, and an intelligent control system. In order to meet this demand, exhibitor Hagenbuch has assembled its own development department specializing in the areas of mechanical engineering, electrical engineering and control systems, along with the fabrication of components and aggregates.

One of its core competencies is testing with Hexamove. The Hexamove system is ideally suited for the development of testing machines. The highly dynamic system makes it possible to perform high-frequency shaking with large payloads, regulating the forces at any given reference point and precisely positioning test components. Force and position can be controlled in various degrees of freedom. The innovative software ensures that the system is easy to use. Find out more at Automotive Testing Expo.

Booth 1013

CONCEPT ELECTRIC SPORTS CAR

Applus+ and IDIADA will be presenting the Volar-e concept at Automotive Testing Expo, an innovative prototype electric car with high performance, comparable to conventionally powered sports cars.

The Volar-e features an 800kW electric powertrain assembly powered by high energy density batteries and controlled by the innovative iTorq system, which allows perfect traction and stability control, and substantially improves the dynamics behavior of the demonstrator.

The car benefits from a host of active safety systems (brakes, suspension, steering and electronic management), and a chassis with great torsional stiffness has been designed to protect occupants in the event of an accident.

Regenerative brakes save energy and allow for a greater driving range, and an ultra-fast charging system means the batteries can be recharged in 15 minutes. The Volar-e also has vehicle-to-vehicle and vehicle-to-infrastructure communications systems, as well as a user interface based on new applications designed for smartphones.

OVER 70 VEHICLE DYNAMICS-RELATED EXHIBITORS, INCLUDING:

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SERVOHYDRAULIC SOLUTIONS

Automotive Testing Expo exhibitor Inova Testing Systems is a leading supplier of servohydraulic and mechanical testing systems, for service load simulation and characterization of components. Inova is able to supply complete turnkey servohydraulic testing solutions, in addition to individual test rig components. Components such as hydraulic power packs, actuators, controllers and software are developed by Inova to ensure the best reliability and quality. Inova has more than 40 years of experience in the field of servohydraulic testing, and operates with a strong customer-orientated outlook. The company's multichannel digital control system, along with its modular software solutions for iterative generating of optimized drive signals, enable the setup of complex test rigs for real-time fatigue load simulation with recorded test-track signals.

Booth 1134

Multibody dynamics

ALTAIR'S CHRIS COKER EXPLAINS HOW THE FIRM IS TAKING MULTIBODY DYNAMICS TO THE 'NEXT LEVEL'

ABOVE: **CHRIS COKER, ENGINEERING MANAGER AT ALTAIR PRODUCTDESIGN INC**

Simulation has always played a role in the product-development process. Physical simulation, or testing, has been supplanted to a large degree by virtual computer-aided engineering (CAE) methods. The latter enable design engineers to simulate real-world performance scenarios to evaluate more design alternatives, especially during the concept phase, prior to the creation of expensive prototypes. One notable CAE focus area, multibody dynamics (MBD), enables engineers to study physical systems in motion. MBD is well established today in the automotive design process. We sat down with Chris Coker, engineering manager at Altair's global consulting practice, Altair ProductDesign Inc., to get his views on the current state of MBD simulation.

What do you consider to be the current challenges in getting the best use out of MBD in the automotive design process?

"Speed and accuracy remain the most important considerations for MBD simulation. An MBD model is only as good as the physics model upon which it is based. Being able to correlate with real-world data and accurately model the problem in a timely fashion are key to success in MBD. Better modeling techniques yield improved accuracy. At Altair ProductDesign, we draw on our experience across a broad range of automotive products, from passenger to commercial vehicles and beyond, to think creatively about innovative solutions to customers' problems. A close relationship with software development helps drive the creation of better engineering tools.

Are you talking about using applied engineering knowledge to improve CAE software?

Yes. Take the MacPherson strut as an example. Strut suspensions create a large bending moment in the strut itself, due to the nature of the design. Suspension kinematics and compliance (and therefore handling) are affected by the stiffness of the strut rod. Camber compliance is the main effect. Good correlation with physical testing requires modeling of this strut-bending phenomenon. Modeling the bending of the strut rod presents some unique challenges because rod stiffness changes as a function of strut length, and modeling approximations typically require component testing of the strut to determine rod stiffness.

Historically, some automotive OEMs have implemented this scenario using complex user sub-routines. MotionSolve, a solver within the Altair HyperWorks product suite, offers two unique modeling entities that, when combined, create a powerful method for modeling strut bending.

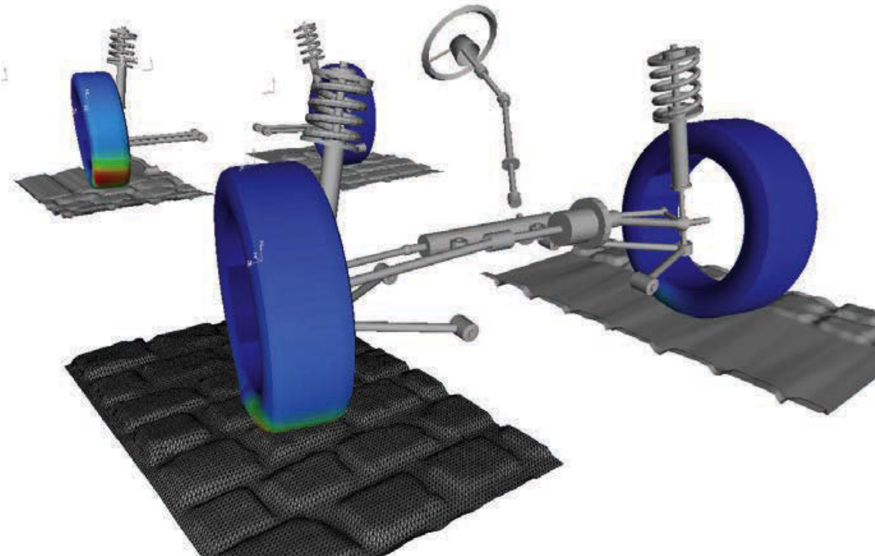
First, the Polybeam entity can easily model the stiffness of the rod. The user only needs to provide the overall length, diameter and material stiffness of the rod. Second, the Deformable Curve entity, when applied to the polybeam rod, enables a joint to be created between the rod and the tube so that the rod can bend, maintaining the correct location of loads at the top of the strut tube.

This approach accomplishes two goals. First, it provides a more realistic description of the strut-bending kinematic and compliance effects than previous approximations. Second, it accomplishes this with very simple inputs (rod length, rod diameter and rod material stiffness). Only minor modifications to the existing standard MotionView libraries are required, producing a slight increase in solve time. This is a very small price to pay for improved results.

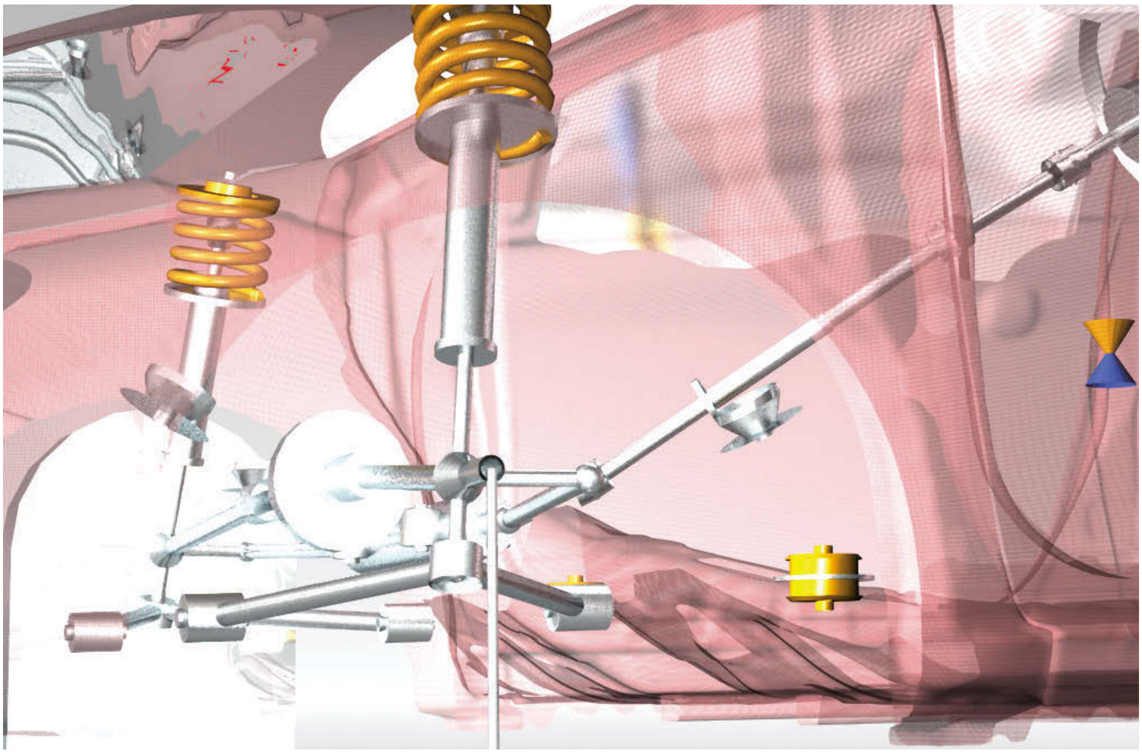
Could you elaborate more on Altair's MBD solution and what makes it unique?

Altair's MBD solution is MotionSolve, integrated with MotionView in the HyperWorks suite to analyze and optimize multibody system performance. Based on superior numerical methods and scalable formulations, MotionSolve offers powerful modeling, analysis, visualization and optimization capabilities for multidisciplinary simulations that include kinematics and dynamics, statics and quasi-statics, linear and vibration studies, stress and durability, load extraction, co-simulation, effort estimation and packaging synthesis.

The accuracy, speed and robustness of MotionSolve have been validated through extensive testing with customer models and test data. Compared with other commercially available tools, suspension and vehicle dynamics simulations can be created twice as quickly, and durability simulations up to eight-times faster. For suspension and vehicle dynamics simulation, MotionSolve has a built-in parametric vehicle library that is fully integrated with Altair's OptiStruct structural analysis and optimization solver



RIGHT: **MOTIONSOLVE ANALYZES THE DYNAMIC BEHAVIOR OF VEHICLE PLATFORMS**



LEFT: **A MACPHERSON STRUT, AS VIEWED THROUGH THE MOTIONVIEW SOFTWARE**

for flexbodies. Likewise, MotionSolve is integrated with Altair's HyperStudy product for design of experiments and optimization. The multibody system-level optimization in OptiStruct is unique in the MBD solution market.

Is Altair MotionSolve compatible with other MBD solutions?
Yes. MotionSolve offers unmatched compatibility with other MBD solver inputs. Considering the typical use cases for vehicle dynamics simulations, all the modeling entities used by other major commercial MBD solvers are supported by MotionSolve.

The real world is inherently multidisciplinary, and there is a pressing need to efficiently combine different technologies at the system level. How does Altair address this?
In order to accurately understand the behavior of such systems, there is a need to simultaneously combine hitherto separate physical disciplines in a logical manner to generate higher-level mathematical models that can accurately represent natural behavior. Simulation tools have traditionally focused on a single discipline, such as controls, fluid dynamics, structures or motion. There is a pressing need to efficiently combine these various representations, solve the resulting model and predict reality.

Due to its system-level focus, multibody simulation provides a natural impetus for meeting this need. MotionSolve is an industry-proven multibody simulation tool that provides a logical environment for integrating technologies and solving a combined problem. MotionSolve is integrated with Altair's OptiStruct structural analysis and optimization code. Bidirectional coupling with Altair's AcuSolve computational fluid dynamics solver is also being implemented, which confers the ability to solve multiphysics simulations involving rigid-body motion of complex mechanisms.

How would this work in practice?
MotionSolve is used to simulate the motion of the mechanism, while AcuSolve provides CFD loading on the components of the mechanical system. This enables simulation of single- or multibody dynamics models with complex physics that is not accurately modeled by a single, internal rigid-body solver. MotionSolve can also enable co-simulation between MotionSolve and Simulink via the Simulink Coder. You can make use of a script to compile your Simulink Coder model into a dynamic linked library.

This script automatically compiles and links the code generated by the Simulink Coder, making it ready to use with MotionSolve for co-simulation.

What big improvements do you envision in the near future?
The accuracy and speed of MBD models will continue to grow, for example through the use of non-linear finite elements within MBD to model leaf springs and twist beams, and through better models of frequency-dependent elements such as hydromounts and bushings. Multidisciplinary simulation will increase, focused on MBD models with their inherited system-based approach. In addition, the promise of quick and accurate design sensitivities from MBD models will finally be realized, allowing for full system optimization.

Finally, accurate component loads from MBD system simulations will begin to drive topology and weight optimization of vehicle components, such as control arms. The Altair Enlighten Award, an industry award created to acknowledge innovations in vehicle light-weighting, was created to recognize this type of achievement.

High-fidelity testing

MTS's FLAT-TRAC RIDE COMFORT ROADWAY IS AN EASY WAY TO BRING HIGH-FIDELITY TESTING IN TO THE TEST LAB

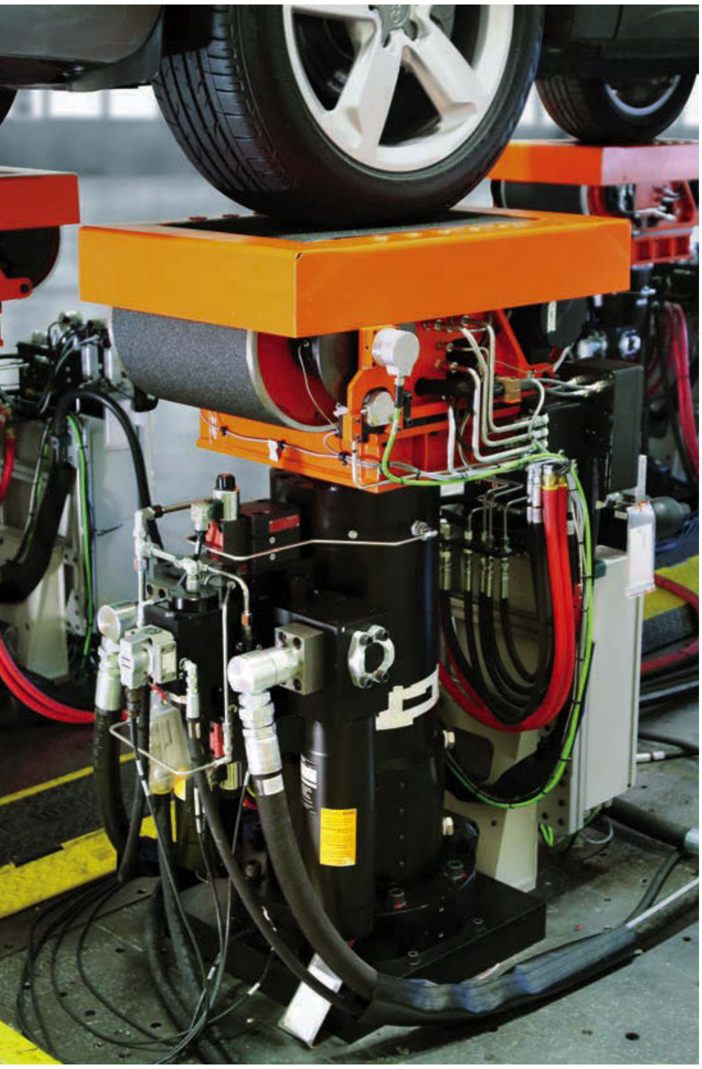
To help automobile manufacturers better address growing industry requirements for more demanding ride comfort evaluation, MTS is expanding its range of flat-belt roadways to include the new Flat-Trac Ride Comfort Roadway.

Today's emphasis on ride comfort is driven by several factors. The global focus on increased fuel efficiency and reduced emissions has led to quieter cabins, making noise and vibration much more noticeable to passengers. The increasing adoption of active and semi-active suspensions has made vehicle benchmarking and tuning more complex and time intensive. Also, an industry-wide trend toward platform consolidation means that each vehicle platform must be specifically tuned and optimized for many individual regional markets.

Conventional approaches to ride comfort evaluation are proving less than ideal for meeting these evolving demands. The proving ground approach is expensive, time consuming, not repeatable and requires access to prototypes, which are in increasingly short supply. Lab-based four posters, while more affordable and repeatable, lack spinning tires and therefore offer a low degree of accuracy for ride comfort testing. Lab-based dynamic roadways, while repeatable and fully equipped to address new demands, represent major investments in facilities and capital. What has been missing is a ride comfort solution that achieves a more practical balance of functionality and affordability.

To fill this void, MTS has developed the Flat-Trac Ride Comfort Roadway – a lab-based, four-post system with moving belts at each vehicle corner that provides far more realistic simulation than conventional four posters and represents an affordable alternative to full-featured dynamic roadways and proving ground testing.

With this new roadway system, test engineers gain an accurate



BELOW AND MAIN: **MTS's FLAT-TRAC RIDE COMFORT ROADWAY COMBINES A ROBUST FOUR-POST SYSTEM WITH MOVING BELTS FOR PERFORMING RIDE COMFORT EVALUATION, BENCHMARKING, AND TUNING**

LEFT: LAB-BASED TUNING OF ACTIVE AND SEMI-ACTIVE SUSPENSIONS IS POSSIBLE, THANKS TO THE MOVING TIRES PROVIDING REAL VEHICLE FEEDBACK TO ECUS

and repeatable means of performing directly observable full-vehicle vibration analysis, benchmarking, suspension tuning and validation. Engineered to deliver high-fidelity ride comfort simulation, it enables fast and efficient acquisition of meaningful component, subsystem and full-vehicle performance data earlier in the development cycle. In other words, engineers can run more iterations in the lab, reserving the test track for final validation.

The Flat-Trac Ride Comfort Roadway enables testing to be performed with a vehicle's engine turned on or off; driving in gear or towing in neutral; or with wheel hubs attached or detached. This permits isolation and analysis of vibration transmissibility from sources throughout a vehicle, including suspensions, tires and powertrains. The roadway system also enables the isolation of differential vibration by varying the speed of individual flat belts to simulate cornering.

Advanced benchmarking and tuning of active and semi-active suspensions are made possible with the system's four moving belts, which enable spinning tires to provide real vehicle feedback to electronic control units (ECUs). Modification of road profiles enables the roadway system to be used for conducting evaluations of new suspension designs while they are still in the model stage. Additional applications for the system include basic rolling loss and fuel economy studies.

The new roadway system includes MTS hydraulic linear actuation, patented Flat-Trac moving belt technology, MTS digital controls and MTS TestSuite software. The hydraulic actuators apply ±50mm of vertical displacement to vehicle tires at accelerations up to 20*g* and frequencies up to 50Hz. Flat-Trac moving belts enable the vehicle to run at speeds up to 180km/h (112mph), ensuring correct stiffness at each tire. Real-time controller feedback loops enable highly accurate replication of real-world driving conditions via time-history playout or synthetic (programmed) inputs. In addition, the system can integrate both human and autopilot drivers, and an automated track and wheelbase positioning system accommodates a wide variety of vehicle geometries and facilitates rapid testing throughput.

The new roadway system builds on the existing range of MTS Flat-Trac roadways, which includes the Flat-Trac Dynamic Roadway and the Flat-Trac Handling Roadway. This roadway range, in turn, belongs to an even larger portfolio of MTS Flat-Trac solutions, which employs patented flat-belt technology to address applications ranging from tire force and moment testing, to aerodynamic simulation. All these solutions are backed by MTS's global service and support organization, which provides local, responsive service, advanced test consulting and complex systems integration expertise.

Overall the new Flat-Trac Ride Comfort Roadway is designed to bring affordable, high-fidelity testing into the test lab, providing a balanced, practical and efficient solution for ride comfort evaluation, benchmarking and tuning. It will help test engineers meet increasingly complex ride comfort evaluation demands, accelerate lab-based testing, and reduce reliance on prototypes and expensive proving ground testing.

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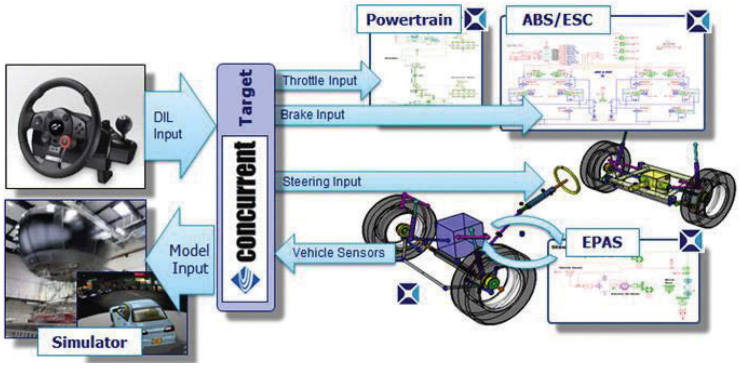
To learn more about MTS, visit www.ukipme.com/info/vdm

Multibody simulation

CREATING COMPLEX MECHATRONIC MODELS FOR MULTIBODY SIMULATION IS POSSIBLE WITH LMS VIRTUAL.LAB MOTION

RIGHT: **THE HIGH-FIDELITY MBS VEHICLE MODEL IN A REAL-TIME ENVIRONMENT EMBEDDED IN A CONCURRENT RT PLATFORM**



Siemens PLM Software has developed a new full vehicle multibody modeling technology, including chassis subsystems such as steering, brake and transmission. The subsystems are modeled in a 1D environment, and the 1D-3D co-simulation is able to run in real time for software-in-the-loop (SIL) and hardware-in-the-loop (HIL) applications.

Most OEMs use a reduced version of the physical suspension arrangement, by means of K&C look-up tables. These simplified vehicle models can easily run in real time or faster. Most automotive suppliers have no choice but to use such simplifications as they don't have information about hard point locations.

Those models can, however, only provide acceptable accuracy for lower frequencies, typically covering roll, pitch and heavy modes of the overall vehicle. But for ride comfort and harshness, the dynamic effect of the bushings in the active suspension also have to be taken into account. This calls for the frequency validity range for real-time simulation to be extended to the same level as full high-fidelity models.

Siemens PLM Software engineers have developed a new methodology that maintains the complexity of the full vehicle MBS model and can still run in real time, by employing new modeling techniques and taking advantage of computation technologies. LMS Virtual.Lab Motion software is a highly efficient, integrated solution used to build multibody models that accurately simulate the full-motion behavior of complex mechatronic system designs. The software has been set up to perform both offline applications for multi-attribute vehicle performance optimization or robust design analyses, as well as difficult real-time applications such as SIL or HIL.

The real-time, high-fidelity MBS vehicle models, built in LMS Virtual. Lab Motion, employ co-simulation with 1D chassis subsystems such as ABS, ESC and EPS, in the LMS Imagine.Lab Amesim environment.

Siemens PLM Software succeeds in running complex high-fidelity MBS vehicle models in real time, thanks to the implementation of several software improvements. LMS Virtual.Lab Motion solvers have been expended with new solver and solution schemes, and new functionality has been implemented for co-simulation with the 1D multiphysics software, LMS Amesim.

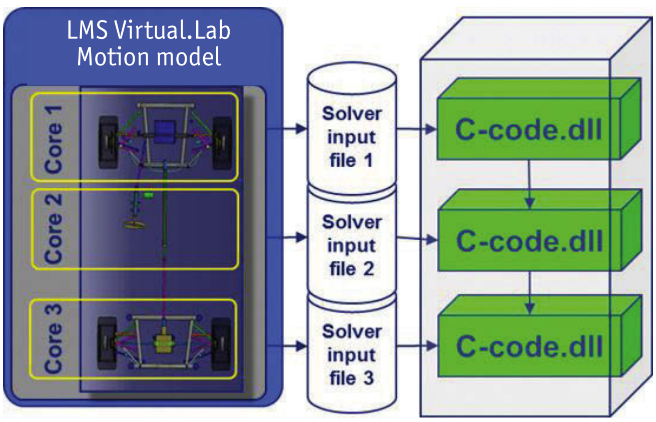
For real-time simulation, it is crucial that the turnaround time of a time-step (i.e. the time it takes to compute the system's state at the next discretized point in time), is *a priori* known to be less than the simulated time-step. Using explicit integrator schemes, this can be accurately predicted. However, the inclusion of suspension-compliant elements such as hydraulic system equations for steering can result in numerically stiff systems, which should preferably be tackled by an implicit solver for reasons of stability and accuracy. The turnaround time for those unfortunately depends on the required number of iterations.

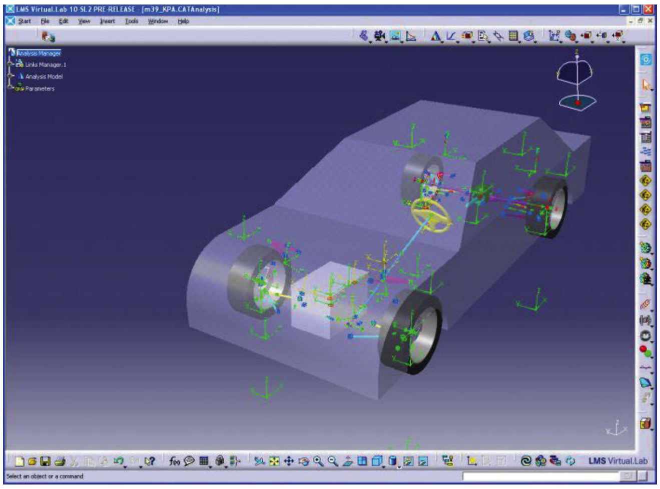
Furthermore, in offline MBS, the order of the time integration scheme is varied along the time-step to optimally fit the numerical model. This is a problem when the calculation time for every step is expected to predictable.

Siemens PLM Software has armed LMS Virtual.Lab Motion with stable implicit integration schemes that use a limited number of iterations and a fixed integration order, by employing an analytical or exact Jacobian instead of a discretized one. This reduces the computational cost and enables real-time simulation of more complex MBS models.

At the same time, the solver scheme has been adapted to fully make use of parallelization. To handle the difficult task of solving sparse matrices in parallel, an approach has been implemented to subdivide the model into different portions and solve them in a co-simulation environment, on separate cores. This approach indirectly addresses the matrix factorization difficulties by splitting the model into sub-parts and solving each part on a separate processor. The model can be split into two or more pieces of which each piece is then solved on a different processor. The subdivision can, for example, be a cut-joint approach, although for vehicles it might be more practical to cut the chassis body and to have a chassis body on each processor. LMS Virtual.Lab Motion real-time software is implementing a special technology to split into sub-models, based on ModelLink bushing elements. In the example shown to the left, a rear-traction vehicle model

BELOW: **THE CAR MODEL SPLIT FOR A PARALLEL SOLUTION ON THREE PROCESSOR CORES**





ABOVE: **FULL-VEHICLE MBS MODEL**

is split into three cores, each of them treating front suspension, rear suspension and transmission.

Simulations with LMS Virtual.Lab Motion real-time solver software can also include a 1D representation of vehicle subsystems. LMS Imagine.Lab Amesim software provides a large set of libraries for detailed modeling of mechanical, electric and hydraulic systems, and has a dedicated interface with LMS Virtual.Lab Motion to interface 3D and 1D models. These 1D models run fast and bring another level of detail and multiphysics to the complete vehicle model. Although standard applications require the same integration step (typically 1ms = 1KHz) to be used by all subsystems involved in the real-time co-simulation, LMS Virtual.Lab Motion real-time solver capabilities have also been expanded to manage multi-rate simulations, and to cover specific requirements for high-frequency input from subsystems like engine combustion loads, for which a frequency rate up to 5KHz can be needed to achieve accurate results.

LMS Virtual.Lab Motion real-time solver has been validated through several industrial scenarios. A customer-based, full-vehicle model (shown above right) was used to test the new LMS Virtual.Lab Motion real-time solver. Bushing compliances and full non-linear kinematics of suspensions were taken into account. There were 146 DOFs determined by 181 bodies.

The full model has been divided into two subsystems by splitting the chassis into front and rear sections, connected by a ModelLink bushing element to allow the solving parallelization process. The goal of this project was to validate handling scenarios, so a 10-second J-turn maneuver was simulated through a kinematic step steering input. No driving torques were applied at the wheels, so vehicle speed was expected to decrease during the cornering maneuver.

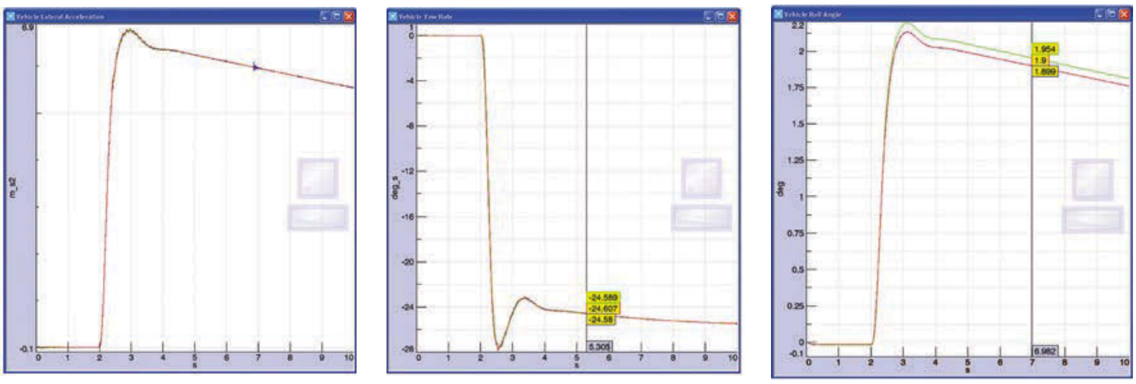
Offline analysis results of the original high-fidelity model, calculated with the standard solver, were compared with those from the adapted model solved using the LMS Virtual.Lab Motion real-time solver. All the main handling characteristics were predicted with the same accuracy as offline simulation. A small difference can be seen only on the roll angle of the rear chassis, due to the finite stiffness of the bushing element connecting the chassis halves.

A second validation project, performed in a hybrid powertrain control scenario, confirmed the results. A detailed LMS Virtual.Lab Motion model was used to simulate a straight-line standing-start, acceleration and deceleration event, with a focus on the longitudinal dynamics of the vehicle. A path-following steering control was used to follow a straight line, whereas the front axle was driven by a torque signal from physical tests. LMS Virtual.Lab Motion real-time solver provided highly accurate results when compared with offline simulations.

The real-time solution was performed using a DS1006 Quadcore dSPACE machine. The duration of the analysis was set to 20 seconds, with a fixed integration time-step equal to 1ms. For all time-steps, the turnaround time was lower than the 1ms time-step, with some margin still left to allow for any increased complexity of the model.

A validation study on a driving simulator was also carried out for a customer, in which several subsystems, modeled in 1D using LMS Imagine.Lab Amesim, were simulated together with a detailed 3D full-vehicle LMS Virtual.Lab Motion model. A 1D representation was used for the braking, EPS assist, driveline and high-frequency engine elements.

The real-time co-simulation between LMS Virtual.Lab Motion and LMS Imagine.Lab Amesim has been evaluated in a driver-in-the-loop scenario, in which inputs from the driver were used to drive the full-vehicle model to obtain real-time output data (streaming more than 120 channels in real time to the operating system), which could be used as input for a driving simulator system.



LEFT: **THE RESULTS ACHIEVED USING THE LMS VIRTUAL.LAB MOTION REAL-TIME SOLVER WERE MUCH MORE ACCURATE THAN THE OFFLINE SIMULATIONS**

Adjustable damping systems

THYSSENKRUPP BILSTEIN BELIEVES THAT ADJUSTABLE DAMPERS CAN BENEFIT EVERY CAR, NOT JUST SPORTS MODELS

In recent years, the demand for electronically controlled, adjustable damping systems has increased considerably. No longer the sole reserve of luxury-class cars, OEMs are steadily increasing the choice of dampers that can be adjusted to several different road conditions to improve safety, agility and ride comfort, across all models.

As a long-standing development partner for damping systems in the automotive industry, ThyssenKrupp Bilstein is eager to participate in and influence the global market for adjustable dampers. It was the first company to introduce conventional monotube dampers in the automotive industry and is still globally recognized today for this type of damper.

Monotube dampers are the basis for dampers with adapted external valve systems, such as ADS and DampTronic sky.

The ADS adjustable damping system was the first damping system to use two independently working discrete proportional valves for individual switching of rebound and compression. The switching between four settings, combined with skyhook capability, isolates the body from amplifying forces and leads to improved body stabilization of the vehicle. This million-seller technology is currently mainly used by large sedans and SUVs to optimize their ride comfort and safety.

DampTronic sky is the successor technology to ADS and has the advantage of offering continuous damping adjustment with comfort-oriented valve technology. Like the ADS damper, DampTronic sky is based on monotube technology, where the oil and gas chambers are separated by a dividing piston. This damper is also fitted with a bottom valve, whereby the gas pressure – in contrast to conventional monotube dampers – can be reduced to give less friction at the piston rod seal. The main innovation is the individual adjustment of rebound and compression in milliseconds. The benefit for the customer is a broad spread of soft and firm settings, particularly in the start-up area. Combined with the skyhook capability, this high-end system offers elevated ride comfort at a competitive price.

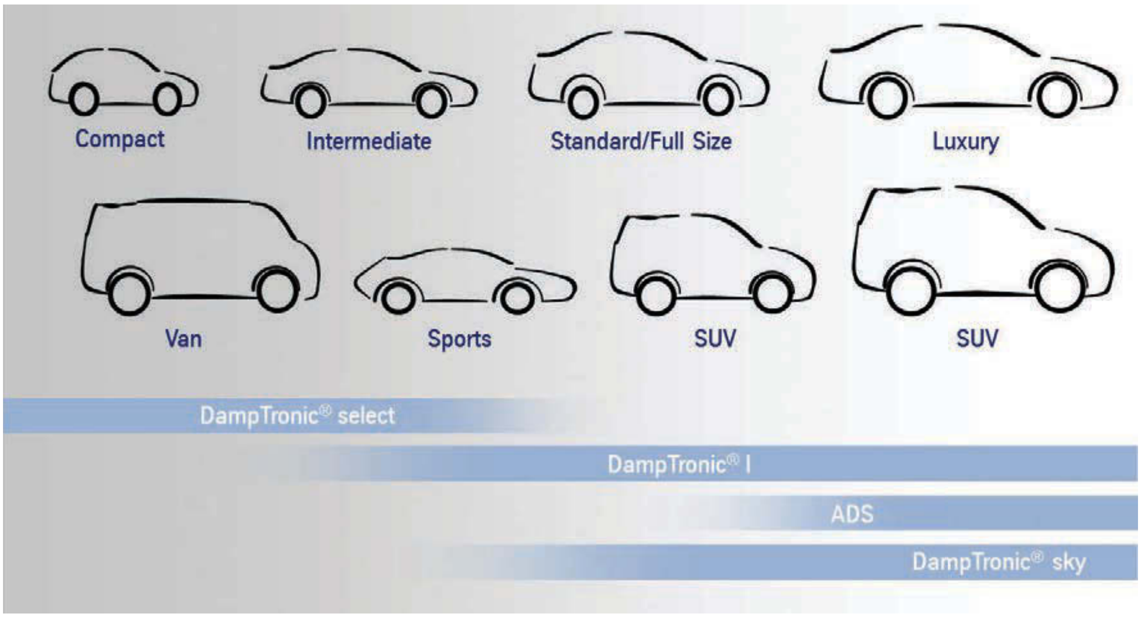
As well as these two damper technologies with adapted external valve systems, ThyssenKrupp Bilstein also offers damper technologies with integrated valve systems, which can be used for monotube as well as for twin-tube dampers.

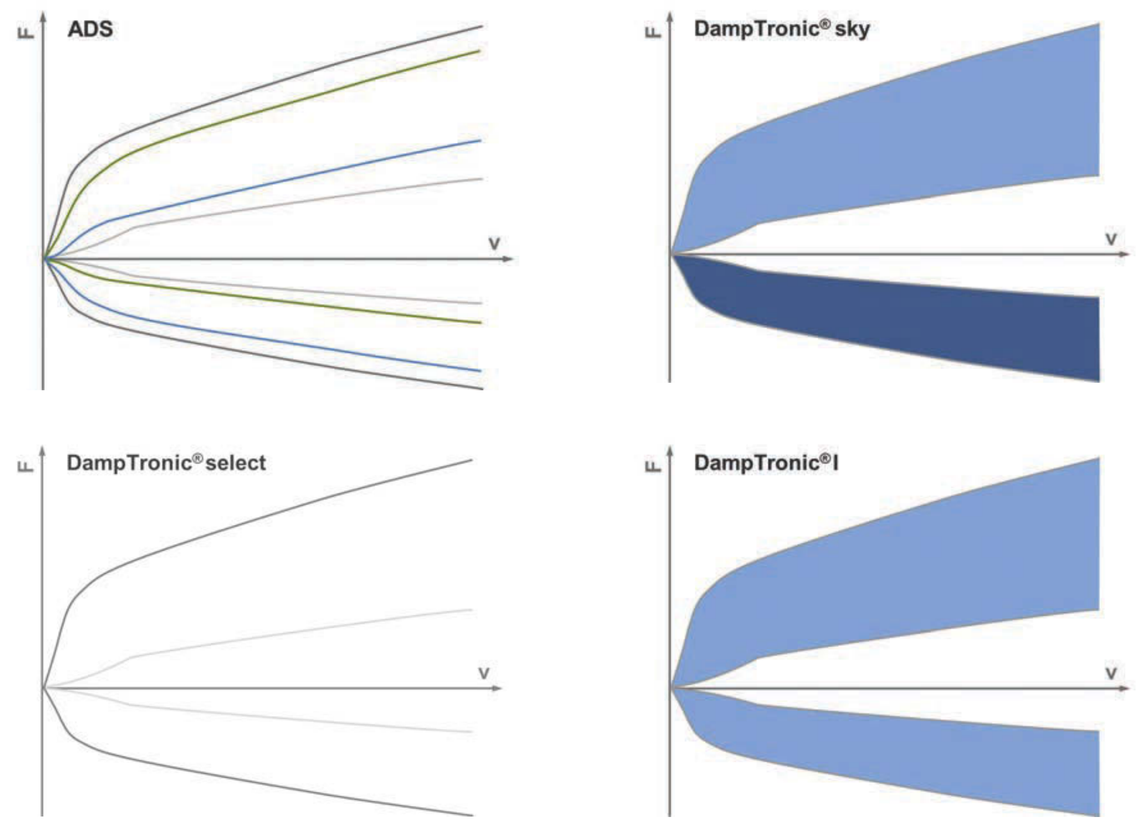
For the B and C car segments, DampTronic select is the adjustable damper of choice. It is an integrated, compact, two-stage, adjustable damping system with reduced system complexity. Besides the four dampers, only a simple ECU and a dashboard switch are required; complex and expensive sensors are not necessary. The dashboard switch puts the driver in the position of being able to choose his own way of driving at the touch of a button – a soft setting for comfortable cruising, or firm for speedy fun trips. These properties position DampTronic select perfectly between established adjustable damping systems and classic conventional dampers, and offer additional value for compact cars with sporty genes.

The continuously adjustable DampTronic I was introduced in 2004. Since then, it has been applied for various customers in different car types and is still a top-of-class system today. It is applicable for any axle design.

Its integrated piston valve contains a proportional solenoid that controls the bypass oil flow to a conventional

RIGHT: **THYSSENKRUPP BILSTEIN HAS IDENTIFIED SEVERAL TARGET SEGMENTS FOR ITS ADJUSTABLE DAMPING SYSTEMS**





LEFT: **DYNO GRAPH PLOTTINGS OF THYSSENKRUPP BILSTEIN'S FOUR ELECTRONICALLY ADJUSTABLE DAMPERS**

shim valve system. This combination leads to a wide range of application possibilities. This is why the DampTronic I system can successfully achieve a balance between a soft ride for comfort and the dynamic agile characteristics needed for driving for racetracks.

The latter property was recently proved when a Porsche 918 Spyder achieved the fastest lap of the 12.8-mile-long Nürburgring Nordschleife track by a street-legal car. The Porsche achieved a lap time of 6min 57sec, partly due to being equipped with customized Bilstein DampTronic I. A short time later a Nissan GT-R Nismo, also using DampTronic I, compounded this triumph by completing a lap in 7min 08sec. Results such as these explain why the Nürburgring is ThyssenKrupp Bilstein's 'tuning homeland'.

Currently, ThyssenKrupp is developing a new, integrated continuously adjustable valve system. The development of this technology contributes to the group-wide R&D project InCar plus, which is the continuation of the successful InCar project, introduced in 2009 to improve the strategic development of ThyssenKrupp. The group applies its engineering expertise to the achievement of sustainable progress and is reacting to the global need for 'more' with 'better' products – also with regard to continually growing mobility demands.

For the automotive sector, the key technological market trends are lightweight design, electrification, energy efficiency, and safety and comfort. This is where InCar plus comes in, offering, in 30 projects, more than 40 individual solutions that can meet these demands in a tailor-made fashion within the powertrain, body, and chassis and steering sectors. All InCar plus innovations will be shown for the first time in autumn 2014.

The demand for electronically controlled adjustable damping systems will increase in the coming years and ThyssenKrupp is well prepared for it. The market introduction of the adjustable damping system is being steered by the company's headquarters in Ennepetal, Germany. After a secure ramp-up, the technologies are rolled out into the global production network. All these adjustable damping technologies can be individually designed to meet any customer needs. This also includes combining them with air or coil springs. Its goal is to cover all market requirements with this portfolio and to ready the company's customers for the challenges ahead.

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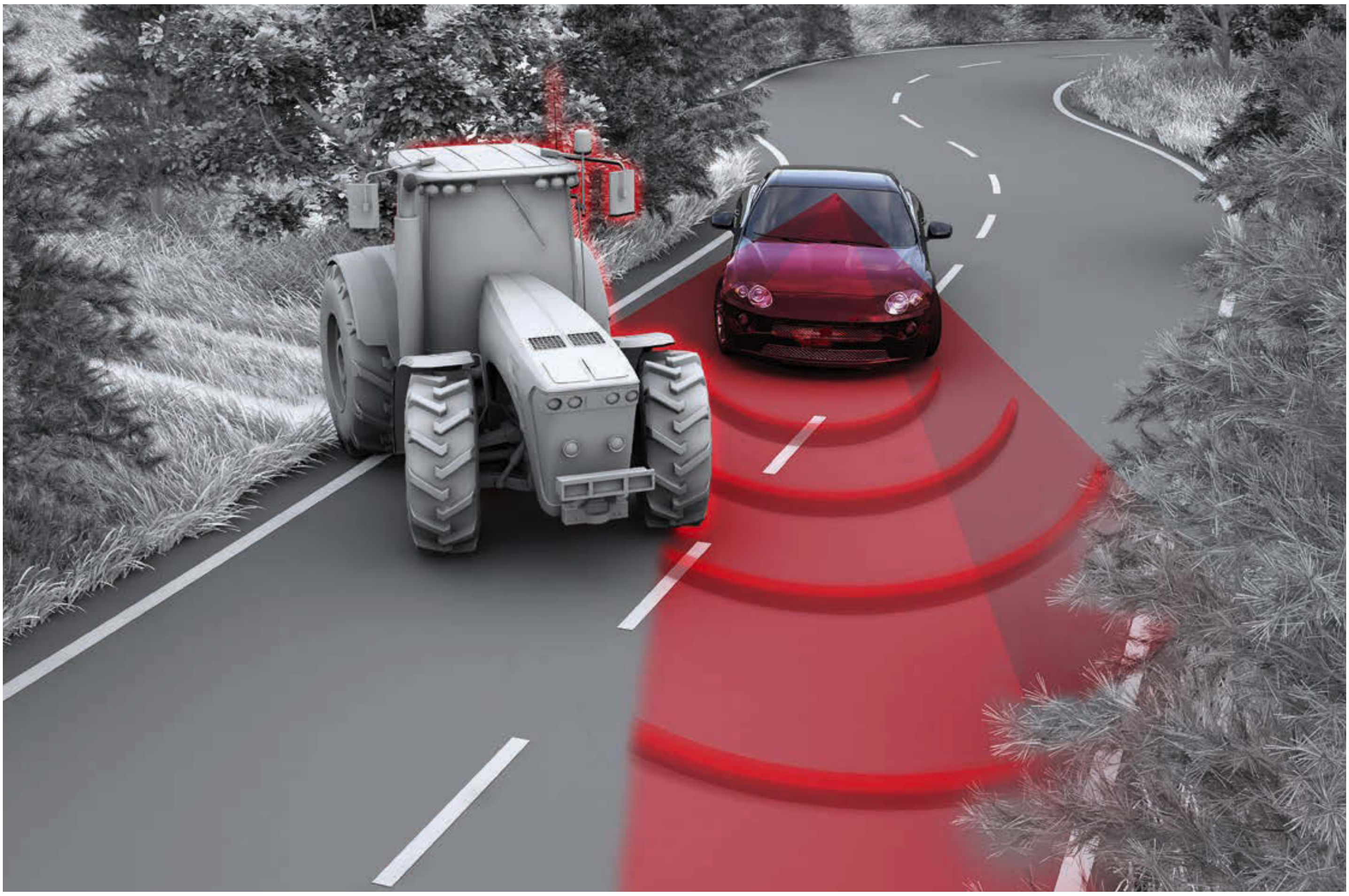
Evasive maneuvers

EVEN THE BEST DRIVERS NEED A LITTLE HELP SOMETIMES. ENTER TRW'S COLLISION AVOIDANCE TECHNOLOGIES



ABOVE: **EMERGENCY STEERING ASSIST ENHANCES DRIVERS' REACTIONS TO DANGERS**

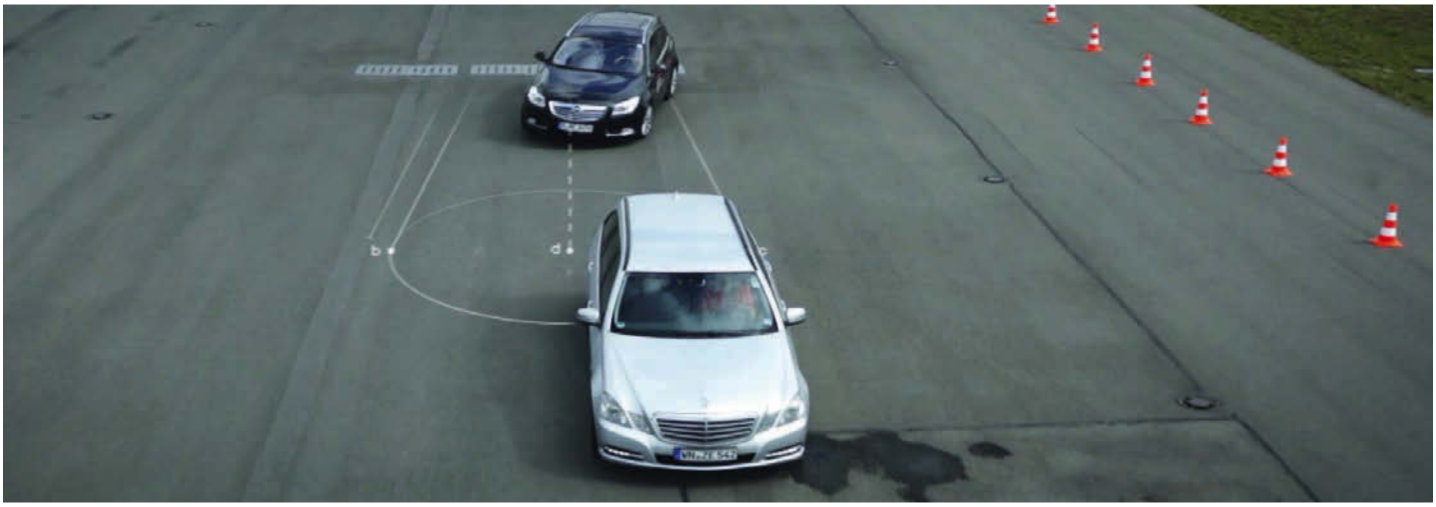
A steering system that enhances driver response by promoting faster and more accurate reactions is one of the latest collision avoidance technologies by TRW Automotive. Emergency Steering Assist (ESA) helps provide support to drivers in emergency situations that involve an evasive steering maneuver. If swerving to avoid another car, ESA calculates optimal trajectories around the target vehicle and applies additional steering torque to help the driver and stabilize the vehicle during the evasive action.

Backed by an electrically powered steering (EPS) system, ESA works by combining data from forward-looking radar and video systems to provide a complete, accurate and real-time image of the road ahead. Systems under development use 24GHz or 77GHz radar in combination with an object-recognition video camera. This is the same sensor configuration and fusion of data as in autonomous emergency braking (AEB) but with an additional interface to either a column- or belt-drive EPS system.

TRW's ESA does not make autonomous evasive maneuvers. The driver remains responsible for deciding whether to steer or do nothing. Some drivers may not steer sharply enough initially while others may overreact and steer too much. In each case, ESA will calculate the correct level of response and adjust steering torque overlay accordingly. The result is that drivers will be guided on an optimal trajectory around the obstacle.

Steering plays an important role in vehicle safety, and TRW's technologies have evolved from adaptive cruise control to AEB systems and now to ESA. Current generations of EPS systems have fast-acting motors that are ideally suited to ESA applications, but the level of torque input may have to increase from the 3Nm currently used in lane-keeping assist applications to around 6Nm. The exact level of input would be decided at the applications engineering stage with the customer's safety engineering team.

Engineers at TRW's Düsseldorf Technical Center are developing the system in collaboration with technical students at TU Dortmund University. TRW is providing the physical systems, including the radar, camera, steering technology, torque sensors and braking system. Doctoral student Martin Keller and a team are responsible for research on the control algorithm, which will eventually fuse ESA with AEB.



ABOVE: **THE ESA SYSTEM DOES NOT MAKE AUTONOMOUS DECISIONS; IT SIMPLY ASSISTS DRIVERS IN MAKING STEERING INPUTS**

Just two years into the project, ESA is being tested as a standalone system on an Opel Insignia fitted with TRW's belt-drive EPS, AC100 radar and S-CAM scalable camera, and EBC450 braking system with ESC capability. The next step is to integrate ESA with AEB on the same vehicle and have it ready for demonstrations in mid-2014.

The control algorithm for ESA applications is complex and it is in this area that Keller and his team from TU Dortmund have been developing the required software. While an ESA system has only a single interface – the torque overlay at the steering system – it has to react in an instant to the sensors with which it is fused (camera and radar) and also to the vehicle dynamics signals being received. To help in the creation of this algorithm, TRW has developed a simulation model.

In a scientific paper *Control Concept for an Emergency Evasive Assistant* jointly authored by Martin Keller with TRW Automotive's Dr Carsten Hass and Dr Alois Seewald, and TU Dortmund's Professor Torsten Bertram, the team outlined the two main parts of the ESA control system. The first calculates steering angles for the emergency maneuver, while the second helps 'teach' the driver these steering angles, using a cascaded controller.

A challenge for the control engineers was calculating the friction coefficients and velocities involved in an emergency maneuver. The paper proposes a simple solution that provides an approximate friction coefficient for a whole ESA event, calculated from the first part of the maneuver. Simulation techniques suggest that this works very well.

TRW and TU Dortmund's steering prototype vehicle is equipped with several TRW technologies. The Electromechanical Belt Drive EPS is the most efficient power steering system that TRW has to offer. At its heart are a brushless AC servomotor, toothed belt, and a low-friction ball nut assembly with the pulley and bearing integrated into a single unit. This setup results in lower inertia and friction for high power applications, as well as a more direct steering feel and response. The control algorithms and the ECU design allow dynamic steering characteristics that are not possible with hydraulic steering.

The TRW S-CAM is designed to fulfill current and future requirements for advanced video sensing by packaging all the required recognition functions together with customer functions in a single compact camera. At the heart of the system is the Mobileye EyeQ chip, its architecture, algorithms and a customer-specific microprocessor.

The latest S-CAM3, to be launched in 2015, has six-times the processing power of the previous generation, providing a high level of performance and several advanced new functions. As a standalone sensor, when combined with braking systems, it can enable automatic cruise control (ACC) and AEB. And when integrated with other environmental sensors, chassis controllers and actuators, provides a platform for semi-automated driving.

This is in addition to the AC100 medium-range radar sensor, which uses the 24GHz ISM narrow frequency band to allow operation in Europe beyond 2013. The sensor enables ACC functionality with an effective control range up to 100m, which is sufficient for most ACC traffic situations. Performance has been optimized for highway driving at up to 140km/h (85mph). Additional functions include distance warning and collision warning. With its improved waveform, AC100 has enhanced fixed obstacle detection capabilities, which is needed for follow-to-stop ACC. The collision mitigation braking function is suited to traffic jams and city traffic.

Finally, the model is fitted with EBC 460 – the latest slip control system. The system supersedes the EBC 450 units being used in the demonstration vehicle and is part of a modular family that offers options for vehicle manufacturers, including ESC and regenerative braking. The system achieves high pressure apply dynamics for emergency braking, with improved NVH and pedal comfort. The system incorporates an electronically controlled deceleration (ECD) function for typical ACC maneuvering. Additionally, the system can be configured to offer hydraulic brake boost (HBB) functionality even under very low-vacuum conditions. In the case of vacuum reduction or vacuum failure, the hydraulic support will substitute brake pressure for the vacuum booster and will help support the driver with adequate brake pressure to stop the vehicle.

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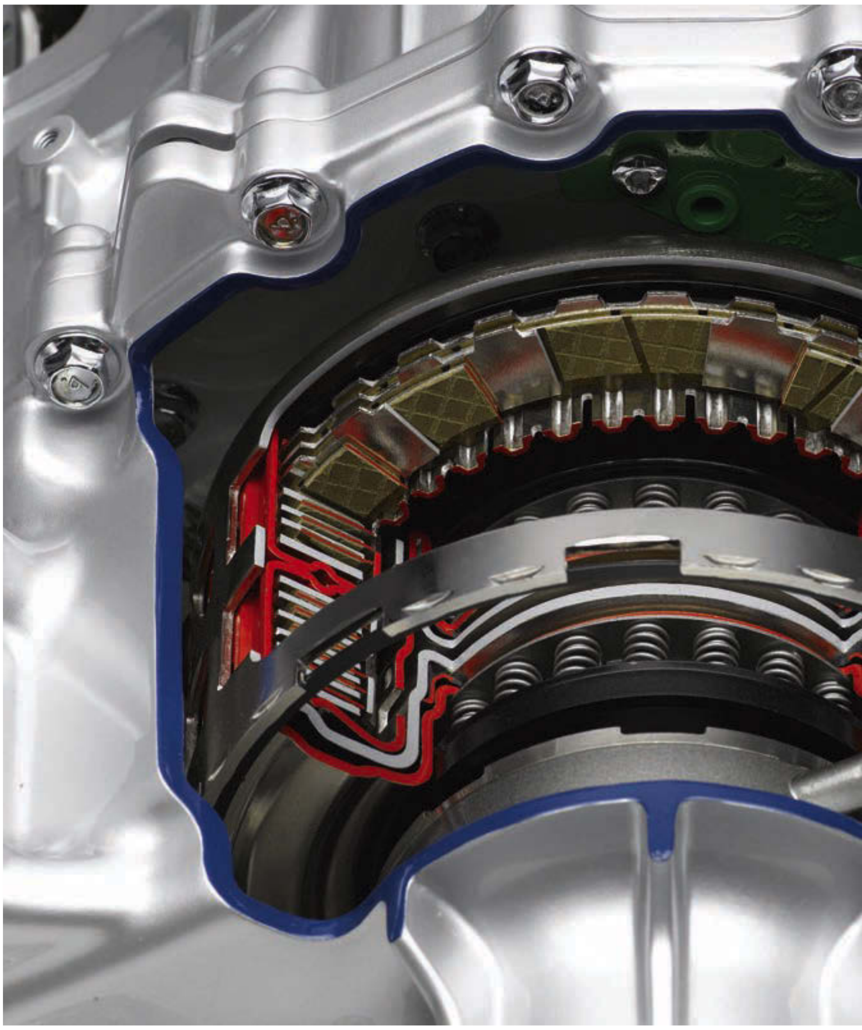
Friction elements

BORGWARNER'S LATEST FRICTION PLATES ARE IMPROVING AUTOMATIC TRANSMISSION EFFICIENCY

RIGHT: **MODERN AUTOMATIC GEARBOX DESIGN AND PACKAGING ARE DICTATING MORE EFFICIENT FRICTION PLATE SOLUTIONS**



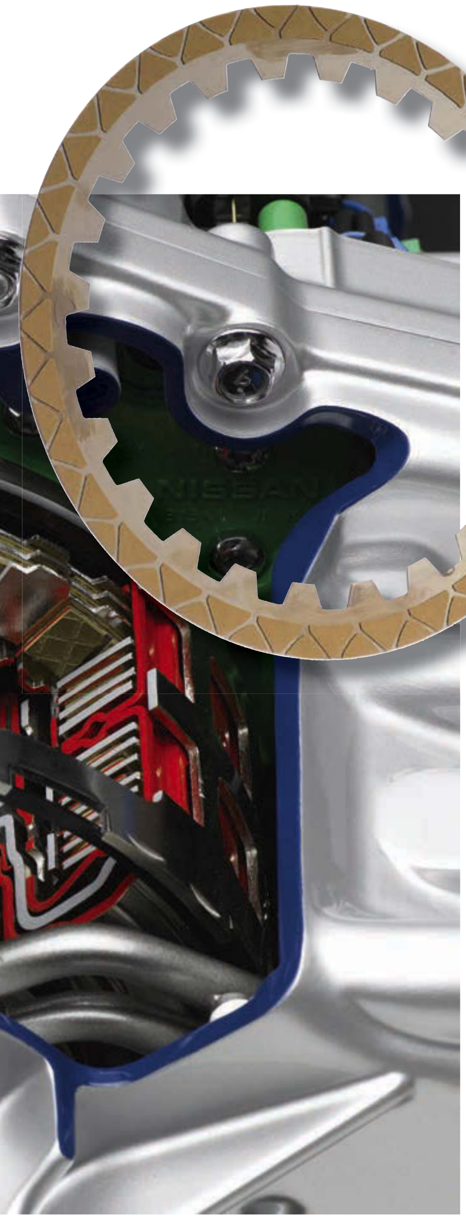
In the development of new vehicle components, manufacturers are obliged to consider customers' needs, such as fuel efficiency and shifting comfort. Current trends in automatic transmission design take these considerations into account and focus on reduced package size, increased torque density and durability as well as improved efficiency and shift quality. Suitable friction enablers with great reliability, even at high temperatures, are essential for this.

Today, modern 8- to 10-speed transmissions require friction materials that can handle increased power density and higher energy levels. In conjunction with the necessity for minimal dimensional changes in the lining, smoother clutch engagement demands a consistent positive µ-v relationship of the friction torque curve throughout the entire life of the transmission under various operational conditions. The friction performance of a wet-clutch system is affected by the chemical and physical interactions of various fluids with friction materials. Wet friction elements are used in shifting or starting clutches and have to provide stable friction characteristics as well as high temperature resistance. They must be able to handle limited oil flow and higher torque, which can be generated using higher unit loads or materials with high friction coefficients. In addition, simulation tools help to reduce drag torque by optimizing the friction plate design.

Being based on specific requirements, the design of the friction plate is unique for each application. On receipt of the Statement of Requirements (SOR) from the customer, the first steps in the design process comprise the verification of the geometric layout by calculating the net pressure on the basis of the required torque capacity and the thermal calculation of the interface and oil outlet temperature according to the shift cycle specified by the customer. After drag torque calculation using analytical, CFD and neural network simulation tools, the fourth step covers a lifetime prediction based on duty-cycle data and durability testing at different energy levels. All steps result in the definition of the friction plate design with regard to lining/friction material, groove geometry, core plate geometry and manufacturing in terms of segmenting and post processing.

Modern friction materials provide improved heat resistance even at lower cooling flows, thus facilitating safer operation over the entire lifespan. Also, they necessitate further and continuous advance, such as friction elements with a high surface-adsorption capacity. These readily adsorb the oil friction modifiers in the automatic transmission fluid (ATF) while not being affected by degraded ATFs.

BorgWarner's newly developed family of friction materials helps to fulfill these requirements. Specifically designed for wet starting clutches, torque converter lock-up clutches, torque transfer clutches and hybrid disconnecting clutches, the BW 6910 friction material provides resistance to oil degradation and glazing, withstands high interface temperatures and maintains a stable and positive µ-v characteristic. It thus enables a low-lube concept to be used, and the reduced cooling oil flow permits the use of more efficient pump systems and optimizes transmission efficiency. In addition, the friction material facilitates the



ABOVE: **THE USE OF CFD IN THE DESIGN PROCESS HAS RESULTED IN CREATIVE SOLUTIONS TO REDUCING DRAG ON FRICTION PLATES**

handling of higher surface pressures and a reduction in the number of surfaces or the friction diameter. Vehicle measurements of shudder at acceleration under micro slip conditions verified the advantages of this material in contrast to standard launch friction material.

Recent automatic transmission architectures demand a higher differential speed on the shifting clutch elements. Extreme shifting conditions at 70m/s and an extremely low oil flow can cause a severe accumulation of hot spots on separators. Specifically for shifting clutches in modern automatic transmissions, BorgWarner developed the new BW 5000 friction material family, which is extremely elastic, has a uniform oil retention surface and features a high-temperature fibrous surface.

Reducing drag losses inside a wet clutch plays an important role. In a dual-clutch transmission, for instance, drag losses can be classified into three sections: losses occurring during pre-selection, idle-D losses and drag losses at the seal rings or bearings. Nevertheless, most of these negative effects can be reduced or avoided by optimizing the software of the transmission control unit or via implementation of an engine stop/start system. In addition, an optimized clutch design as well as improvements in the applied friction material are additional possibilities for reducing drag torque.

Various calculation tools can be used to predict drag torque reliably. Analytical modeling, for example, uses a calculation program with adjustment based on actual measurements. The neural network method applies artificial intelligence that depends on previously collected data, while a third method using CFD software performs exact calculations of fluid behavior inside the clutch. The latest calculations resulted in the following friction material design solutions for effectively reducing total drag torque: waved friction plates, waved separator plates, an optimized groove pattern, active separation and two-step lining.

The core plate design offers further potential for optimization. One new concept is the 'hemmed spline' design, in which a double-folded core plate steel in the spline area increases the spline contact area, thus allowing the clutch pack length to be reduced without reducing the contact area of the splines. In general, hemmed spline design enables a reduction in weight, axial space and material costs.

A further modification method is the segmentation of the core plates. This facilitates the more efficient use of the core plate steel and is therefore a reasonable cost reduction effort. BorgWarner started series production with an OEM customer in 2012.

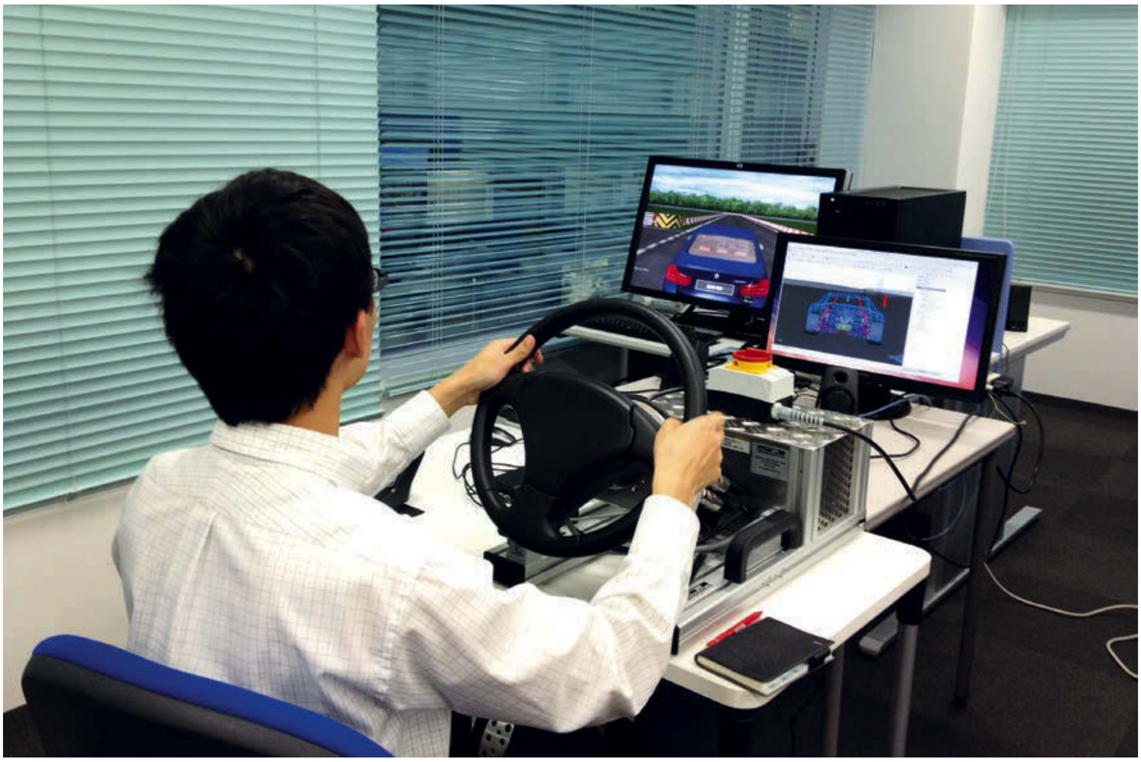
Recent transmission design trends necessitate improvements in friction materials. Choosing the appropriate friction product depends on the individual application and must be predicted using simulation tools in close cooperation with transmission and vehicle manufacturers. These simulations help to predict the drag torque and enable optimization of the friction plate layers during the design phase.

BorgWarner's BW 6910 friction material allows clutch systems with a low-lube strategy, provides a high torque density and improves durability as well as NVH robustness. Also, advanced friction materials, like the BW 5000 family, allow shifting at high differential speeds and prevent the severe accumulation of hot spots on separators. Drag torque, packaging and costs can be further improved by the use of new design concepts, such as the hemmed spline design and segmented core plates.

Real-time dynamic models

SIMPACK REALTIME IS A DIRECT REAL-TIME SIMULATION SOLUTION, REQUIRING NO TIME CONSUMING CODE- OR LOOKUP TABLE GENERATION BEFOREHAND

RIGHT: A **DESKTOP SIMULATOR BEING USED IN COLLABORATION WITH SIMPACK REALTIME**



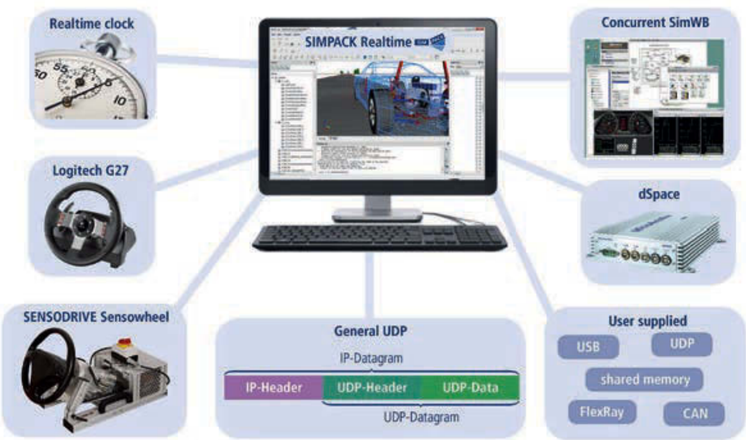
Following a long history of successful realtime implementations, SIMPACK has developed the next step in real-time simulation, SIMPACK Realtime. First released in January 2013, SIMPACK Realtime enables the use of complex models for a wide range of performance-critical real-time applications, such as hardware-in-the-loop (HIL) and software-in-the-loop (SIL) scenarios. Typical applications include handling and comfort simulators, ECU testing and component test rigs, for example with gearboxes and engines.

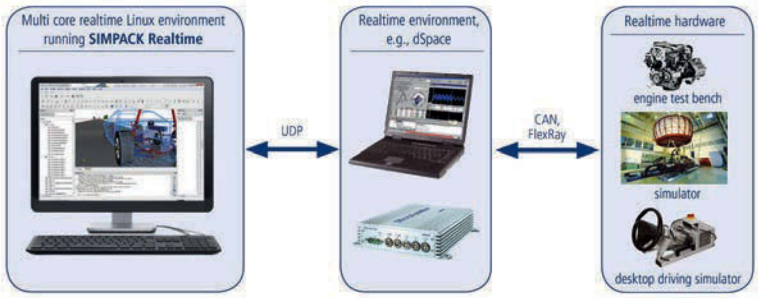
To achieve real-time for complex models, SIMPACK Realtime runs on Intel x86 hardware and Linux realtime operating systems (RTOS). This brings real-time simulation to an unprecedented level of performance. For example, detailed vehicle models with more than 250 DoF, and frequency content up to 40Hz, including highly non-linear bushings and flexible bodies, can be solved reliably and robustly in real-time.

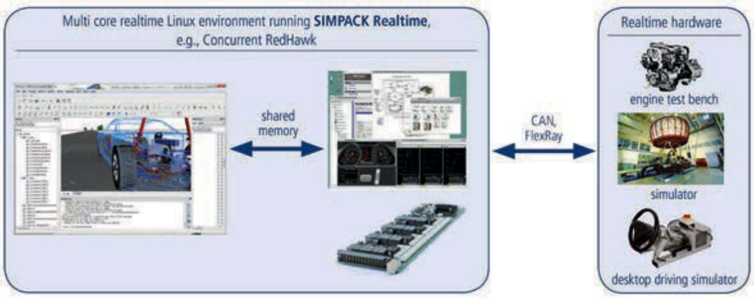
With SIMPACK Realtime, the user can remain in the SIMPACK environment and start the SIMPACK Realtime solver directly, without a time-consuming code generation and compilation process. Unlike previous realtime solutions, SIMPACK Realtime works directly with fully parameterized SIMPACK models without the need for model reduction or a lookup table generation process. SIMPACK Realtime supports a wide variety of targets, including dSpace, Concurrent and Simulink.

SIMPACK Realtime is designed to run on Linux RTOS such as Concurrent RedHawk, SUSE Enterprise and Debian. The communication between SIMPACK Realtime and proprietary realtime systems takes place via either a dedicated peer-to-peer User Datagram Protocol (UDP) network communication (this is a dual-computer setup, see Figure 3), shared memory (a single computer setup, e.g. with Concurrent

RIGHT: **FIGURE 1: PREDEFINED COMMUNICATION WITH A WIDE VARIETY OF REAL-TIME TARGETS**







Simulation WorkBench, see Figure 4), or a user-defined communication library. The interaction with the SIMPACK model can be defined via u-Inputs and y-Outputs.

Communication with a wide variety of realtime targets, such as dSpace and Concurrent Simulation WorkBench, is predefined (Figure 1). A direct interface with SENSODRIVE SENSO-Wheel and the Logitech G27 force feedback wheel for (desktop) driving simulator applications is also included. SIMPACK Realtime provides a general UDP interface to interact with realtime environments and supports user supplied target interfaces as well. For highly detailed animation and for testing advanced driver assistance systems, SIMPACK Realtime supports, among others, rFactor Pro and PreScan from TASS International. A Simulink target for testing Simulink control algorithms in the design phase is also included.

The Realtime package contains the SIMPACK Realtime solver, Realtime animation and Realtime logger.

The specific SIMPACK Realtime solver enables direct realtime integration of the model. Depending on model size and complexity, frame rates between 0.2ms and 1ms are typically achieved. A complex model solved in real-time can include flexible bodies, non-linear and frequency dependent bushings and mounts, as well as comfort tire models, such as CDTire and FTire. To fully employ the latest multicore processor hardware, the SIMPACK Realtime solver contains a parallel computation feature that automatically distributes the workload to solve the model across multiple CPU cores.

The SIMPACK Realtime animation displays the simulation results in realtime as a 3D animation, which can run on the same computer as the Realtime solver, or a different machine, and utilizes one or more CPU cores. The Realtime animation communicates with the Realtime solver over UDP.

The SIMPACK Realtime logger operates similarly to the Realtime animation. The logger runs on a separate CPU core or even a separate computer and receives the data to be logged via a UDP network connection from the Realtime solver. Data is written to disk in a standard SIMPACK format so that the results can be readily used in SIMPACK Post for plotting and animations.

In conclusion, SIMPACK Realtime introduces a new way to run SIMPACK models in a stable and robust manner in realtime and eliminates the need for model reduction or a time-consuming code- or lookup table generation process. SIMPACK Realtime runs on standard realtime-enabled Linux operating systems and communicates with other real-time environments via a dedicated network connection, shared memory, or a user defined communication library. Users don't need to leave the SIMPACK environment and can utilize the full range of SIMPACK modeling elements to set up models for real-time applications. The SIMPACK Realtime solver supports automatic parallelization in order to utilize multiple cores and can be used with off-the-shelf hardware; complex dynamic models run in real-time for industrial applications.

ABOVE: **FIGURE 2: THE SIMPACK REALTIME DESKTOP DRIVING SIMULATOR USING A HIGH-PRECISION SENSODRIVE STEERING WHEEL**

TOP LEFT: **FIGURE 3: DUAL COMPUTER SETUP, SIMPACK REALTIME COMMUNICATES VIA UDP NETWORK WITH A REALTIME ENVIRONMENT**

ABOVE LEFT: **FIGURE 4: SINGLE COMPUTER SETUP, SIMPACK REALTIME COMMUNICATES VIA SHARED MEMORY WITH A REALTIME ENVIRONMENT**

Living without copper

ECO-FRICTION BRAKE PADS LAST LONGER, AND ARE UP TO 35% QUIETER THAN TRADITIONAL VARIANTS

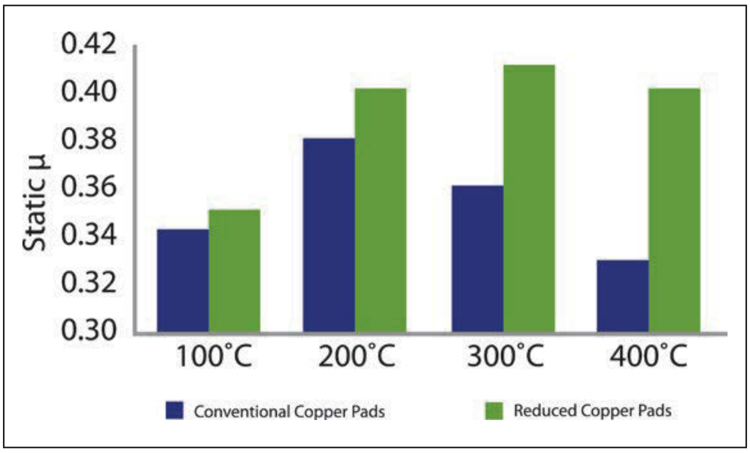
RIGHT: **ECO-FRICTION PADS ALSO ADDRESS ENVIRONMENTAL CONCERNS, WITH REGARD TO COPPER CONTENT IN FRESH WATER**

Copper has been an essential ingredient in brake pad formulations for many decades, limiting pad and rotor wear, noise and judder, and contributing to stable friction values over a wide range of operating temperatures. Accounting for up to 20% of the mass of friction material in a typical pad, copper interacts with dozens of other ingredients to provide the NVH control, stopping power, fade resistance, long life and resistance to wheel dusting demanded by today's vehicle manufacturers and consumers.

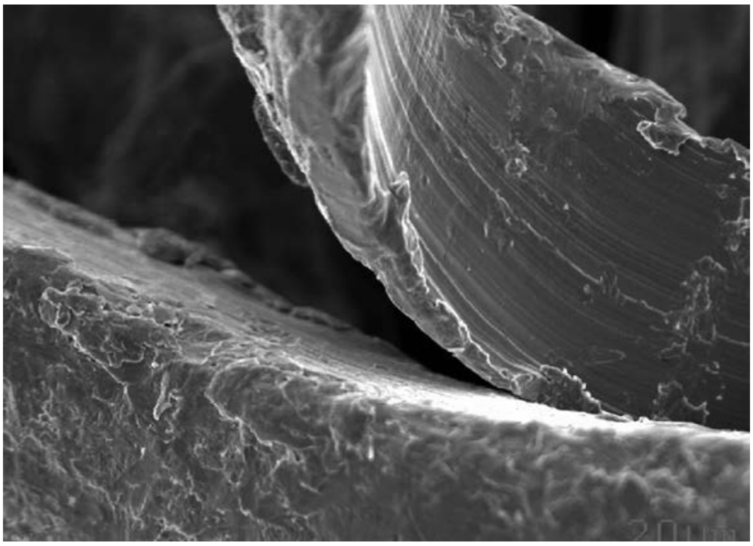
Concern is rising about the effects of copper particles in brake dust on freshwater environments and organisms, leading to recent legislation in certain US states that will progressively eliminate copper. By 2021, the content will be limited to less than 5% of total pad weight, and by 2025 no more than 0.5%. Rather than approach low-copper requirements as a challenge limited only to a few states, vehicle manufacturers have called for a single approach that can be applied to all vehicle platforms and markets.

There is no single direct replacement for copper. Brake pad materials are a balanced formulation of 20 to 30 materials, each with different functions, often interacting in a synergistic way to provide the required performance. Standard raw material characterization in the industry focuses on the analysis of the chemical and physical properties of the raw materials. In a brake pad, however, the interactions of the raw materials define the pad properties, and interactions change over the wide temperature and pressure range. As a consequence, the tribological characteristics of each raw material must be understood to identify alternative raw materials and raw material combinations to eliminate copper. To meet the challenge of eliminating copper, Federal-Mogul used a process termed 'tribological fingerprinting' to assess the range of elements that might be used as alternatives.

The company's materials scientists systematically deconstructed the attributes provided by copper, expressing these as data sets for the various tribological properties, such as friction and wear properties at different temperatures, loads and rubbing speeds. The corresponding characteristics were then identified for a range of approximately 1,500 other raw materials and compared to copper in a screening process to identify potential alternatives. Based on this screening, a sequential addition of the identified raw materials led to the main formulation 'skeleton' consisting of 8 to 11 different raw materials. The formulation build-up targeted physical properties, as well as wear and friction characteristics, and



	CONVENTIONAL COPPER PADS	REDUCED COPPER PADS
Static Friction	✓	✓
Dynamic Friction	✓	✓
Noise	✓	✓
Wear	✓	✓
Pulsation	✓	✓
Zero Copper content	✗	✓



non-linear correlations were identified by the sequential formulation build-up. Once the main formulation skeleton is defined, the final product development is application-specific, using multifunctional DoEs to create customer-specific product solutions.

The end result was a complex combination of metal sulfides, minerals, abrasives, fibers, ceramic particles and types of graphite that, together, achieved the same wear and friction characteristics as brake pads containing copper.

In direct comparison-testing against pads with copper, the new formulation was 35% quieter; provided 15% more stopping power with up to 40% greater fade resistance; lasted longer; and reduced dusting. The zero-copper pads, branded as Eco-Friction, also provide better corrosion protection for the brake rotor and increased static friction performance, which is especially beneficial for parking brake operation.

Although time-consuming, five years of R&D by 150 engineers and technicians has provided additional benefits. What began as a search for copper-free formulations that could match existing performance levels has led to a new way of working.

Conventional brake pad product development requires several iterations, with the longest activity being the definition of the formulation's main structure for wear rate and friction level. The extensive materials database created during the development of copper-free products has provided greater insight into the complex chemical characteristics and relationships between the different friction material constituents, and has reduced the time required to identify optimum solutions. In practical terms, development lead times for new materials can be as much as 50% faster because the traditional 'trial and error' phase is removed.

Although the most severe legislative limits are not introduced until 2025, several vehicle manufacturers are taking up the copper-free formulations early, in applications such as the Mercedes-Benz C-Class. In total, over one million vehicles will be using Eco-Friction pads by 2015.

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TOP LEFT: **COMPARISON OF THE STATIC COEFFICIENT OF CONVENTIONAL BRAKE PADS, AND REDUCED COPPER ITEMS**

TOP RIGHT: **COMPARISON OF THE OVERALL PERFORMANCE FRICTION BETWEEN CONVENTIONAL, AND REDUCED COPPER BRAKE PADS**

BOTTOM LEFT: **SCANNING ELECTRON MICROSCOPE IMAGE OF A COPPER FIBER, TYPICALLY USED IN CONVENTIONAL BRAKE PADS**

BOTTOM RIGHT: **LEGISLATION IN CERTAIN U.S. STATES IS MANDATING THE EVENTUAL PHASE-OUT OF COPPER FROM BRAKE PADS**

Improved accuracy

INERTIAL MEASUREMENTS CAN BE USED EFFECTIVELY TO AID GPS TEST SYSTEMS, RESULTING IN BETTER DATA

RIGHT: **INTERRUPTED GPS SIGNAL. THE BLUE TRACE IS GPS POSITION ONLY; THE RED TRACE IS THE CORRECTED POSITION DATA OBTAINED VIA INTEGRATION OF THE ACCELEROMETER DATA FROM THE IMU AND GPS SIGNALS**

It is largely accepted that the most accurate and cost-effective way to carry out vehicle dynamics testing and development is with the use of GPS equipment. In some situations, however, it pays to also use an inertial measurement unit (IMU) to augment the available data, or to overcome problems encountered in certain environments – such as a test track that isn't in an entirely open area, or one that suffers from an obstructed view to open skies.

Racelogic has been supplying IMU integration with its VBOX3i 100Hz GPS data logger for a few years. Now it has introduced a new Inertial Measurement Unit, which has a much higher performance than the previous IMU03, due to tighter GPS synchronization, better calibration, and a higher internal sample rate.

ABOVE: **VBOX3I WITH THE NEW IMU04**

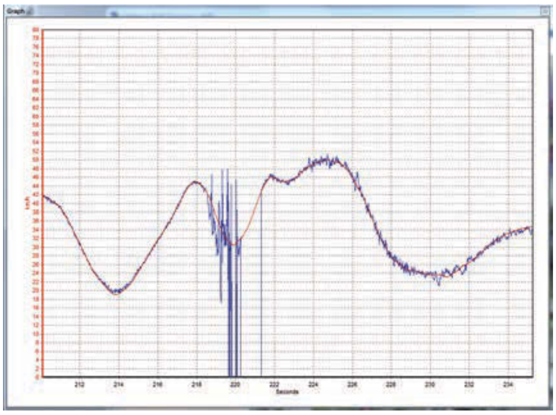
A new Kalman Filter ensures the IMU04 has improved levels of velocity smoothing to cope with interruptions to the GPS signal; the Kalman Filter blends the inertial data with that of the GPS system. Although most test tracks are situated in open areas, any over-hanging trees and bridges can lead to signal degradation. The integration with the IMU ensures that GPS dropouts are eliminated.

This means, for instance, that maneuvers such as a coast-down test (the results of which are critical to a manufacturer from a homologation perspective, as these form a significant proportion of the calculations of fuel consumption data released to the public) can be completed on a course that takes the vehicle under a bridge, which would not have been possible in the past using GPS alone. IMU integration ensures a consistent velocity log is maintained during the momentary loss of satellite signal lock.

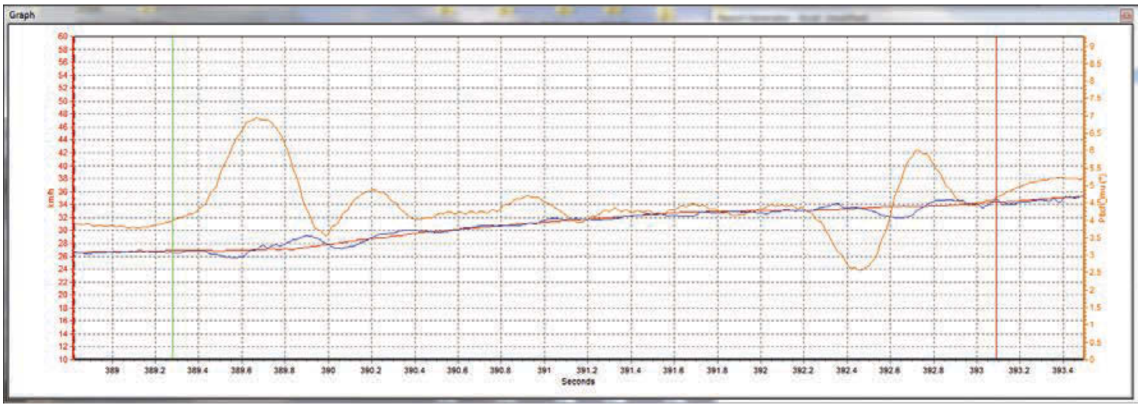
Indeed, there are some facilities that are not ideal places in which to conduct other procedures, such as high-dynamic brake stops – these may be tree-lined – but are still used because they're conveniently located. Integrated inertial and GPS measurements allow for this convenience to be fully exploited because it can provide the same level of accuracy normally only possible from testing in an entirely open arena.

In terms of handling and dynamics, the new IMU integration enables pitch and roll angles to be measured to an accuracy of 0.1° (RMS) – giving anyone with a VBOX3i the ability to measure

BELOW: **IN THIS EXAMPLE YOU CAN SEE THAT THE GPS VELOCITY TRACE (BLUE) DROPS OUTS UNDERNEATH A BRIDGE. THE IMU INTEGRATED DATA (RED TRACE) GIVES A MUCH CLEANER AND UNINTERRUPTED SIGNAL**



LEFT: **IN THIS EXAMPLE OF A HIGH-DYNAMIC BRAKE STOP, THE BLUE TRACE (GPS SPEED) OVERSHOOTS AT THE INITIAL POINT OF BRAKE APPLICATION, AND THEN EXHIBITS A DAMPED OSCILLATION AS THE DECELERATION CONTINUES. THE IMU-CORRECTED DATA (RED TRACE) ACCURATELY RECORDS THE BRAKE STOP FROM THE VEHICLE'S CENTER OF GRAVITY**



LEFT: **ON THIS GRAPH, THE BLUE TRACE IS GPS SPEED, THE ORANGE TRACE IS PITCH AS MEASURED BY THE IMU, AND THE RED TRACE IS INTEGRATED SPEED (GPS SPEED BLENDED WITH THE IMU OUTPUT). THE TRACES BETWEEN THE GREEN AND RED VERTICAL LINES ARE OF A CAR GOING OVER A SPEED HUMP – NOTE HOW THE GPS SPEED ALTERS AS THE VEHICLE ROOF MOVES INDEPENDENTLY OF THE COFG AS IT GOES OVER THE HUMP. THE INTEGRATED SPEED LOGS THE CORRECT SPEED OF THE VEHICLE.**

the pitch/roll/yaw rates and angles simultaneously.

In the field of brake stop testing, the placement of a GPS antenna on the roof of a vehicle can lead to a certain amount of unwanted variation in GPS speed output. This occurs because of the way that a car pitches as it travels, and particularly during deceleration – the roof momentarily travels faster than the rest of the vehicle, and because this is where the antenna is placed, this 'lever-arm' effect can cause an overshoot in the GPS speed. This is particularly prevalent on cars with a high roof, which typically will also have long suspension travel, exacerbating the problem as the antenna is moved away from the center of gravity. Some vehicles exhibit the effect even without performing any kind of dynamic movement – a tractor roof can pitch and roll around the center of gravity as it simply drives in a straight line, for instance.

Compensating for lever-arm is now possible using the IMU04 with a VBOX3i. The GPS speed, measured at the antenna point on the roof, is translated to the CoG where the IMU is mounted, thanks to the pitch and roll angles calculated using the IMU. As a result, the speed measurement more closely represents the speed of the vehicle at the CofG.

Counteracting the lever-arm effect will also help test engineers when conducting high-dynamic maneuvers as it isn't something that occurs only during brake stops. Slip-angle measurements can now also take this into account.

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Model-based design

MAPLESOFT'S LATEST PROJECT ON MODEL-BASED DESIGN AND CONTROL OF NEXT-GENERATION GREEN AUTOMOBILES IS AN AWARD WINNER

A collaborative project between Maplesoft, Toyota Motor Manufacturing Canada (TMMC) and the University of Waterloo (UW) has won a Synergy Award for Innovation. Instituted by the Natural Sciences and Engineering Research Council of Canada (NSERC), the annual Synergy Awards for Innovation recognize examples of collaboration that stand as a model of effective partnership between industry and colleges or universities.

The Maplesoft-TMMC-UW project was recognized for its success in designing automotive systems and model-based controllers that improve vehicle safety and comfort while reducing fuel consumption and emissions. Dr John McPhee, professor and NSERC/Toyota/Maplesoft Industrial Research Chair in mathematics-based modeling and design at UW, and his research team, developed the core technology behind Maplesoft's modeling and simulation platform, MapleSim. As an end user of the technology, TMMC in Cambridge, Ontario, and the Toyota Technical Center in Ann Arbor, Michigan, brought crucial technical support, experimental assistance and industry expertise to the project.

"The partnership between the University of Waterloo's Dr John McPhee, Maplesoft and TMMC is an excellent example of university researchers working side-by-side with industry to achieve mutual benefits," says Janet Walden, chief operating officer of NSERC. "Their collaboration accelerated the exchange of ideas and information that enabled Maplesoft to expand the market for its modeling software and for Toyota to improve the design, comfort and efficiency of its vehicles. Facilitating these productive research partnerships is an important part of NSERC's role."

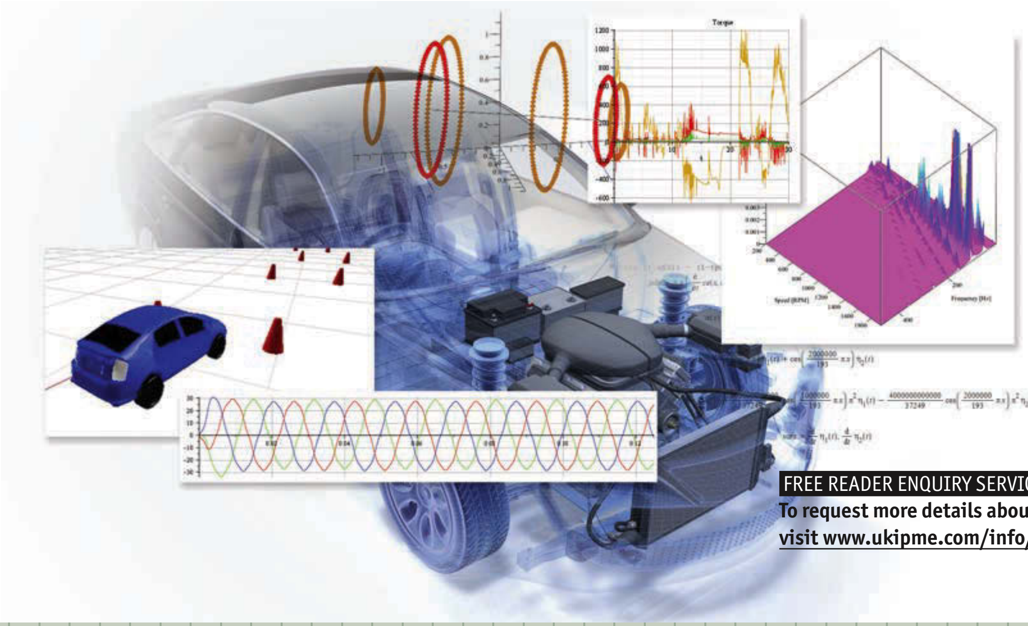
"Our partnership with Maplesoft and Toyota has enabled us to accelerate advances in green automotive technologies by customizing software models for batteries, engines, suspensions and other components in hybrid electric vehicles," says Professor McPhee. "Together we have achieved what would have been far more difficult, if not impossible, to do on our own. I strongly believe this work will set new levels in advanced automotive technology and engineering computation."

Implementing technology from this partnership has resulted in shorter design cycles, less expensive testing and improved product quality. MapleSim software is now extensively used to develop new model-based designs and controllers for automotive, aerospace, robotic, electronic and other systems.

"This long and productive relationship with Professor McPhee of UW, which has been strengthened by our collaborative partnership with Toyota, has given our company a real competitive advantage among commercial modeling software tools," says Jim Cooper, president and CEO, Maplesoft. "In addition to the core benefits of our primary mathematical and modeling framework, these new modeling methodologies and technologies will set us apart from our international competitors within the green automotive field, arguably the most important trend in the history of automotive technology."

"We wanted to learn and understand how we could improve vehicle dynamic performance and make an even better driving experience," says Ray Tanguay, chairman, Toyota Motor Manufacturing Canada. "By using a scientific approach and partnering with experts, we were able to evaluate the design through modeling and simulation and give feedback to our design groups. This project has elevated our company profile and recognition. NSERC played a pivotal role in building synergy between manufacturing, high-tech industries and academia."

NSERC awarded the University of Waterloo a research grant of C$200,000, while Maplesoft and TMMC will each have the opportunity to hire an NSERC Industrial R&D Fellow for two years.



RIGHT: **MAPLESOFT'S MAPLESIM SOFTWARE HAS FORMED THE BASIS OF THE COLLABORATIVE PROJECT BETWEEN THE THREE ENTITIES**

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Precise brake tests

INNOVATIVE TECHNOLOGIES TAKE THE ADMA-SPEED SYSTEM A STEP BEYOND STANDARD GPS SPEED SENSORS

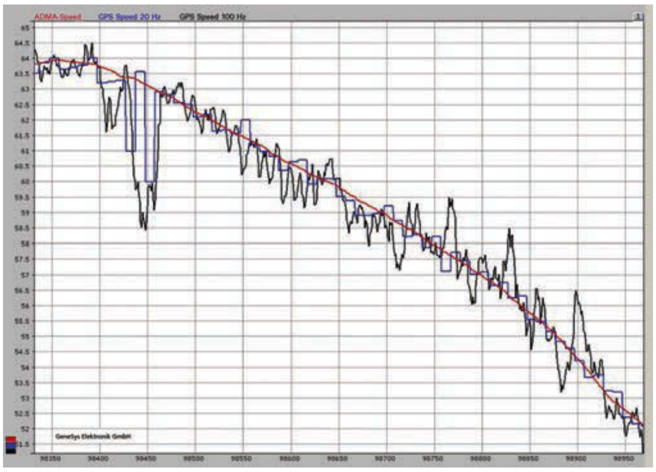
The ADMA-Speed GPS speed sensor with integrated inertial sensor-based technology. ADMA-Speed is designed to eliminate the well-known disadvantages of standard GPS speed sensors. The compact unit is optimized for brake tests and supplies exact acceleration, speed and braking distance data in real time via a CAN interface. All vehicle movement data is calculated using proven Automotive Dynamic Motion Analyzer (ADMA) technology. ADMA-Speed is compact and easy to install. These characteristics make ADMA-Speed ideal for measuring braking distance.

There are various ways to measure braking distance: radar sensors, optical systems, electrical wheel impulses and GPS. However, further development of vehicle and brake technology places added demands on the accuracy, quality and repeatability of measurements, plus the need for enhanced technology.

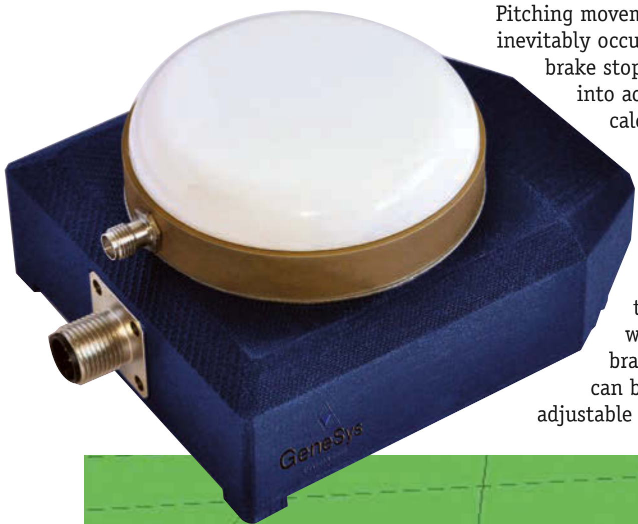
ADMA-Speed is the little brother of the ADMA. At the heart of the extremely precise speed and braking distance sensor is a GPS antenna with integrated inertial sensor-based technology. In contrast, the standard GPS measuring method has the disadvantage of requiring a clear view of the sky to ensure accurate measuring results. In real-life situations, the GPS signals and the achievable measurement accuracy are affected by buildings, trees, fences and vehicles. These effects are further influenced by satellite constellations. Quite often, repeatable measurement results are not possible. The inertial measuring unit suppresses signal interference during poor GPS reception or temporary GPS failure. The combination of a GPS and inertial measuring unit in ADMA-Speed therefore provides a smooth and consistent speed signal compared with a standard GPS signal. Furthermore, ADMA-Speed compensates GPS data latency and corrects acceleration-dependent GPS signal distortion.

Pitching movements, which inevitably occur during the brake stop, are also taken into account for the calculation by the new speed and braking distance sensor. Signal inputs for a brake trigger or light barrier are integrated in the unit. In other words, a covered braking distance can be triggered via adjustable speed thresholds and via external signals using a physical switch on the brake pedal, or a light barrier. Moreover, ADMA-Speed allows determination of deviations from a straight calibration line when the brakes are applied. Yaw can therefore also be calculated.

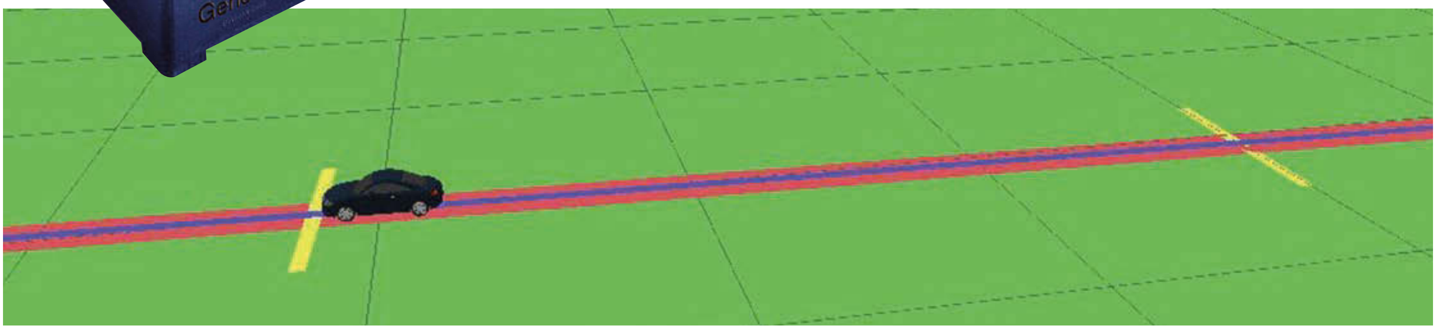
The simplest way to attach the speed sensor is to the test vehicle's roof, directly above its center of gravity, using strong magnets. The movement data of the vehicle at its center of gravity is calculated in the evaluation unit with proven ADMA Kalman filter technology. The acceleration, speed and braking distance data are outputted – in real time – via the CAN interface. The advantage is quite obvious: in this combination, ADMA-Speed guarantees precision, compactness and ease-of-use for this type of test, while meeting all the demands of industry test standards.



TOP: **ADMA-SPEED PROVIDES A MUCH SMOOTHER SPEED SIGNAL COMPARED WITH STANDARD GPS**



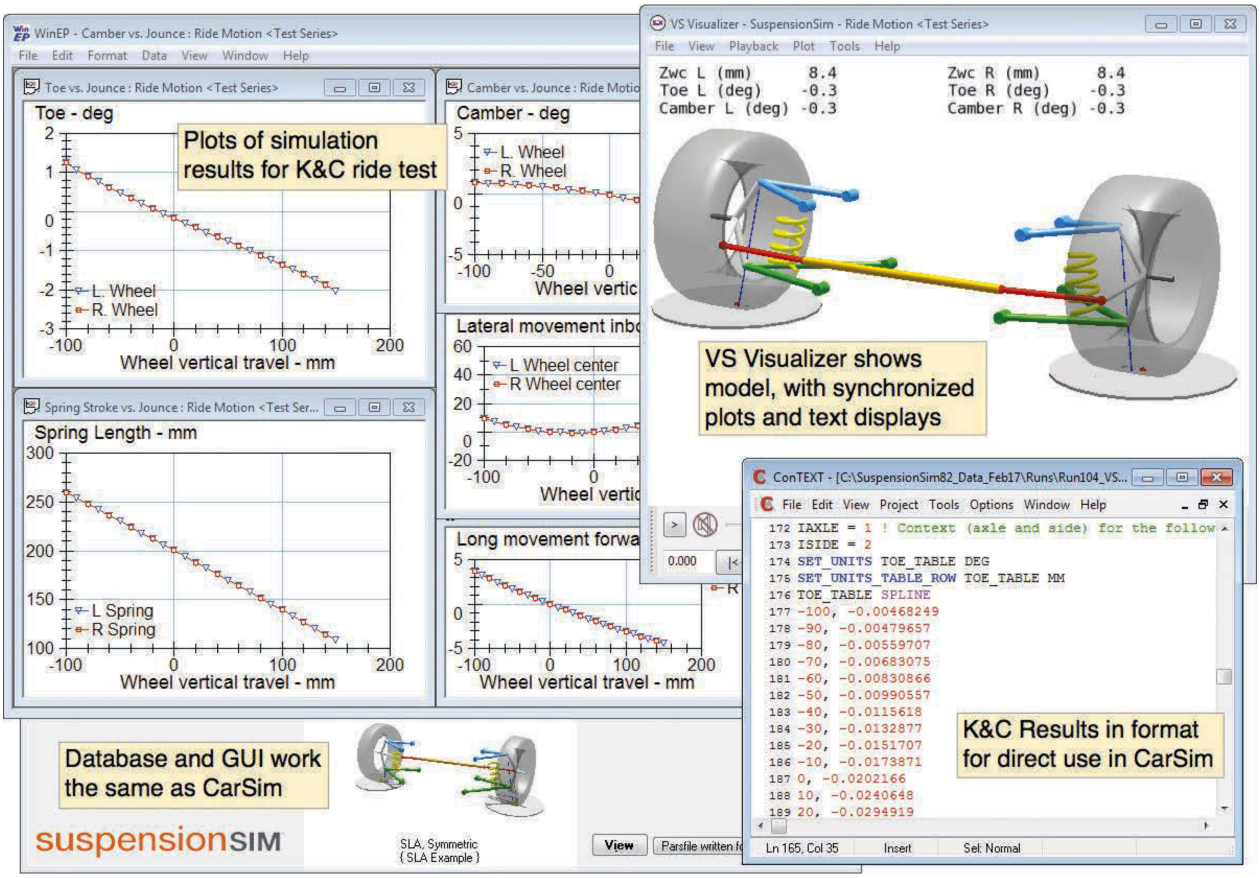
LEFT: **THE NEW ADMA-SPEED SPEED AND BRAKING DISTANCE SENSOR WITH INTEGRATED INERTIAL SENSOR-BASED TECHNOLOGY IS OPTIMIZED FOR BRAKE TESTS**



BELOW: **DRIVABILITY TEST MEASURING THE VEHICLE BRAKING DISTANCE**

Suspension simulation

MECHANICAL SIMULATION HAS COMPLETELY REWRITTEN ITS MULTIBODY STATIC SOLVER, SUSPENSIONSIM, OFFERING IMPROVED INTEGRATION WITH VEHICLESIM



ABOVE: **THE SCREENSHOT SHOWS THE VARIOUS FUNCTIONS OF SUSPENSIONSIM**

Automotive manufacturers and suppliers routinely use simulation tools, such as CarSim, to evaluate the response of a virtual vehicle to a driver's controls and a multitude of electronic safety systems. Often the simulation is a mixture of software- and hardware-in-the-loop, requiring that the mathematical model simulation operates in real time.

Vehicle models of this nature represent the elastokinematic behavior of the suspension with system-level parameters and non-linear functions that fully describe how the suspension positions the wheels relative to the chassis, but do not include the details of why it behaves as it does. Suspension data for these system-level vehicle models is typically obtained either by physical kinematics and compliance (K&C) testing, or by simulation of the K&C testing with a multibody program using a model with the individual suspension components.

SuspensionSim is a CAE tool that has been used for decades to simulate quasi-static K&C tests. Over the past year, Mechanical Simulation has rewritten the original mathematical model and extended the software to add capabilities available in the commercial vehicle simulation tools CarSim, TruckSim and BikeSim.

The new version, SuspensionSim 8.2, has unprecedented integration with the VehicleSim tools. It generates data set files that can be used directly by the vehicle simulation models. For example, users can adjust hard-point locations or bushing compliances in SuspensionSim and then immediately run a series of HIL tests with CarSim to evaluate the effect of the suspension adjustment. Any of the most common HIL systems may be used for this analysis. The integration also works in the opposite direction; simulation results for a vehicle model in CarSim, TruckSim or BikeSim can be loaded into SuspensionSim to see details of how the parts move and how the loads are distributed.

In addition to the integration with vehicle models, SuspensionSim 8.2 makes use of the latest VehicleSim technology for visualizing results, extending models with the VS Command scripting language, performing automatic load adjustments and managing databases. As a general multibody tool, SuspensionSim has already been used to handle models ranging from a single-wheel motorcycle suspension and three-wheeled vehicles, up to a four-wheel motorsport vehicle chassis setup.

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Load measurements

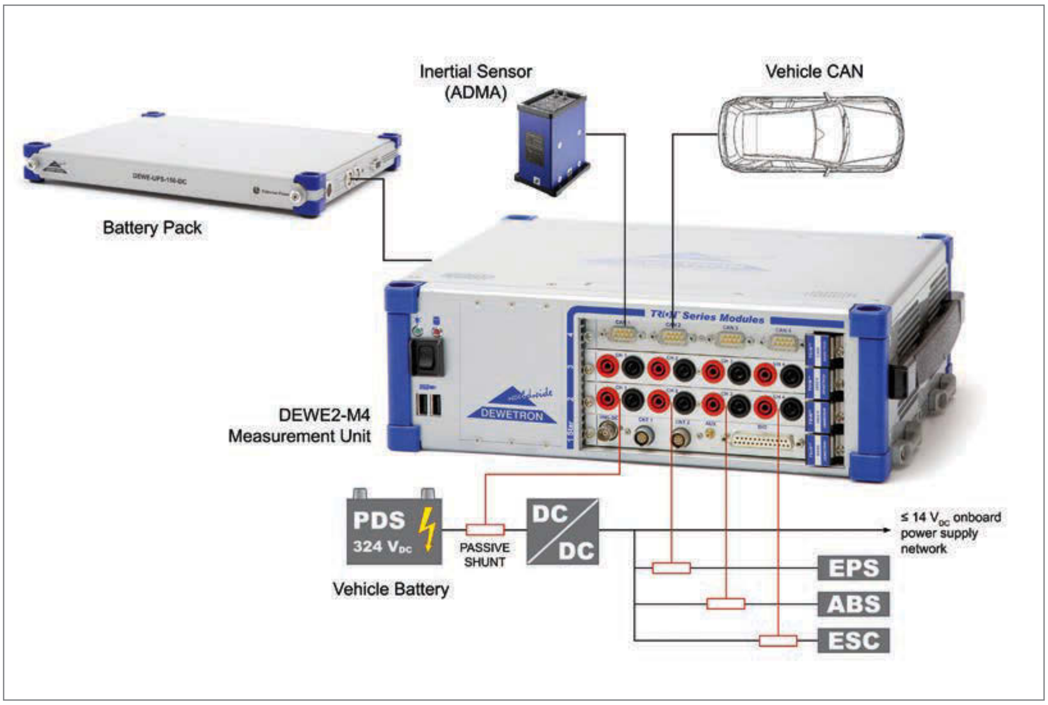
DEWETRON'S DEWE2-M4 INSTRUMENT ENSURES ACCURATE ANALYSIS OF ELECTRICAL SYSTEMS FOR PDS DEVELOPERS

Imagine you are the proud owner of a pure electric vehicle and you have spent two great days skiing in the Austrian Alps. The next morning, you leave your hotel at sub-zero temperatures. The vehicle battery cannot provide its full power, but you are lucky – the vehicle starts and the heating function does its best to warm you up while you carefully drive down wintry roads.

Approaching a hairpin bend, you decelerate and your dashboard lights up like a Christmas tree. When trying to steer into the curve you realize it is almost impossible to turn the steering wheel. After sliding uncontrollably straight forward you think yourself lucky that you hit a huge pile of snow instead of an oncoming vehicle.

This is what might have happened in your car:

ABS: "Anti-lock Braking System calling Power Distribution System! I have kind of an urgent issue down here."
PDS: "Sorry, I'm busy supplying the heating and radio with power. What's up?"
ABS: "Driver stepped on the brakes and we're not slowing down. I need additional power."
PDS: "Roger that. You know you're my top priority."
ESC: "Hey PDS, this is Electronic Stability Control. It looks like we're on ice. Me and my buddy ABS are in charge of controllability here. Counting on your support."
PDS: "I copy. I'm kind of low on energy, but I'll cut off the heating and radio so you should be fine."
ESC: "Appreciate that."
EPS: "This is Electrical Power Steering. Sorry to interrupt, but believe it or not this guy wants to steer now too! Kindly requesting power for steering support."
PDS: "Negative. All available power is distributed to higher priority systems. Please wait until resources are available again."
EPS: "Are you kidding me? How do you expect our driver to get two tons around the corner? Hello, anyone there? All right, I'm outta here."



ABOVE: **MEASUREMENT SCHEMATIC SHOWS HOW THE DEWE2-M4 INTERACTS WITH THE TEST VEHICLE**

...Moments of silence while the car crashes into a pile of snow...

PDS: "Darn. I guess we messed that up."

Especially, but not only, electrical vehicles are prone to such critical situations, where limited resources must be able to cover the power requirements of vital systems. This is a big challenge for PDS developers. It's one thing to design the PDS for theoretical loads, but quite another to test and measure the load under real conditions, such as low temperatures, critical driving situations and additional payloads.

The main task is to measure the total current on the main battery side (e.g. Li-ion with 24kWh capacity and 300V DC system voltage) as well as specific currents on the consumer side for EPS, ABS and ESC.

Additionally acquired are vehicle CANbus data and vehicle movement data, including position, acceleration, rotational velocity and speed measured by an inertial sensor. Perfect synchronization of all signal sources is crucial to enable R&D engineers to understand the interdependency of all systems.

With the mobile DEWE2-M4 instrument with Sync-Clock technology, Dewetron provides a turnkey solution for this challenging task to synchronously acquire all sources and display the live data online.

The DEWE2-M4 is equipped with CAN and high-speed analog input modules (for fast current gradients) to measure the currents of specific consumers via shunts.

The results show the main parameters for PDS developers – circumstances that provoke critical power demands, current maxima and the current gradients (how fast is it needed) for each vital system.

In practical tests we saw current maxima of ~300A and gradients of up to 140,000A/s. In any case, the voltage must not drop below 6.5V, otherwise the on-board power grid breaks down. These facts make it clear that PDS developers have challenging work to do.

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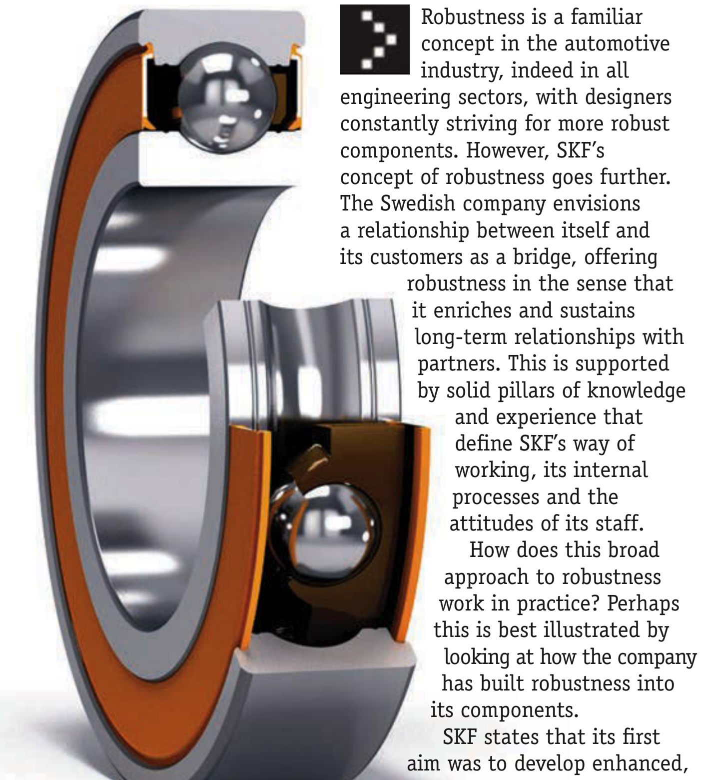
Robust dynamic solutions

ROBUSTNESS IS NOT A NEW CONCEPT IN THE AUTOMOTIVE INDUSTRY, BUT SKF HAS ADOPTED A BROADER APPROACH TOWARD IT



ABOVE: SKF's EMPHASIS ON ROBUSTNESS CAN BE SEEN IN ITS STEERING RACK BEARING

Robustness is a familiar concept in the automotive industry, indeed in all engineering sectors, with designers constantly striving for more robust components. However, SKF's concept of robustness goes further. The Swedish company envisions a relationship between itself and its customers as a bridge, offering robustness in the sense that it enriches and sustains long-term relationships with partners. This is supported by solid pillars of knowledge and experience that define SKF's way of working, its internal processes and the attitudes of its staff.

How does this broad approach to robustness work in practice? Perhaps this is best illustrated by looking at how the company has built robustness into its components.

SKF states that its first aim was to develop enhanced, high-performance products to cope with the most stringent demands of the changing business, social and technology environments. Creating products that deliver a long-lasting solution, while meeting a range of customer needs.

The secondary aim was to ensure that all its experience is channeled toward investing robustness in the solutions developed. Having evaluated and researched customers needs, the company then focused on the more traditional and familiar meaning of robustness in the engineering environment – reducing the sensitivity to influence from surrounding components in new steering and suspension solutions by making them fault tolerant.

The outcome was that SKF renewed its existing products, to provide robust solutions that would satisfy contradictory customer demands. For example, improved sealing with the least possible friction; the ability to predict friction under conditions never before evaluated; and silent bearings whatever the application

The following examples explain how we met those demands in specific applications.

Automotive manufacturers are increasingly introducing electronic driving assist systems, from electronically controlled throttle response to pedestrian monitoring hardware with autonomous brake application. However, relatively few innovative steps have been made toward a new generation of suspension and steering systems.

In developing a more robust MacPherson suspension bearing, the main target was to increase the sealing ability of the solution to cope with the most challenging environments in which mud and pollution contribute heavily to performance deterioration. However, SKF also needed to decrease friction torque to provide faster and smoother steering. The solution delivers a 20% reduction in friction torque, which is capable of fulfilling the most demanding customer test cycles for pollution. This patented solution is on the market and has the potential to benefit a growing number of users, as the range expands.

The company's robust steering rack bearing for EPS systems was developed to manage the frictional behavior of the bearing under quasi-static conditions. These conditions occur when the driver adjusts the vehicle trajectory when driving straight or on a wide turn. This was an important need to cater for, from the perspective of bearing suppliers, since quasi-static conditions are common. The challenge for SKF was that the possibilities available for predicting the bearing's frictional behavior in such conditions are extremely limited. However, with extensive use of numerical simulation it has been possible to define the components' geometry to reduce friction under operational conditions by 30%.

The main goal for the automotive market is to reduce the distance between man and automobile and get a more direct, fully integrated and safe link between the driver's intentions and responsiveness of the vehicle. In terms of suspension and steering architecture, the focus is on reducing the gap between driver feeling and the precise and effortless responsiveness of the car. Likewise, because the steering column is the closest system to the driver and passengers, it is the place where the most silent components on board need to be. Thanks to another patented solution, SKF can now offer a silent bearing for steering columns, capable of reducing the actual level of acoustic emission by 20%.

These state-of-the-art bearing solutions for suspension and steering applications represent an important contribution to automotive design, combining safety aspects and helping the driver to concentrate fully on driving and ensuring maximum control of the car for a high performance driving set up, even on standard road cars.

SKF continues to take on and tackle the challenges faced by the automotive industry, increasing its product offering to be the preferred development partner for its customers. The automotive market is challenging and demanding, but the company has the knowledge and expertise to embrace those opportunities, and explore further the synergies between steering and suspension.

SKF's core competencies – friction and noise – will remain the focus of its innovation while developing solutions that address the increased level of complexity and interconnection of systems found in steering and suspension applications.

BELOW: SKF's MACPHERSON STEERING BEARING REDUCES FRICTION TORQUE BY 20% OVER CONVENTIONAL UNITS

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Citroën Hydractive

CITROËN IS PLANNING THE NEXT EVOLUTION OF ITS HYDRACTIVE SYSTEM IN THE COMING YEARS, BUT DON'T FORGET WHERE THE SYSTEM BEGAN – THE DS

BY JOHN O'BRIEN

LEARN MORE ABOUT CITROËN'S PLANS FOR THE NEXT-GENERATION HYDRACTIVE SYSTEM ON PAGE 39

Actually the statement above isn't strictly true. Citroën aficionados will know that the company's first attempt at hydropneumatic suspension didn't debut on the DS. Rather, a simpler, early version of the system featured on the rear axle of the Traction-Avant 15CV-H in 1954. The DS, however, demonstrated the true capabilities and flexibility of the hydropneumatic system, with high-pressure hydraulic assistance to the suspension as well as to the power steering, brakes, and gearbox and clutch assemblies.

Hydraulic assistance to the gearbox and braking systems was something that Jaguar was also experimenting with in around the same period. However, Jaguar was using the systems on its Le Mans racers rather than its road cars.

Early versions of the DS used a mixture of vegetable oil and nitrogen within the suspension's 'spheres', which offered the ability for the system to self-level. In a period of time when very few cars had independent suspension on all four wheels, the application was revolutionary.

However, the high-pressure system – rated at a pressure of between 130 and 150 bar – had a fundamental flaw in the way it operated. The hygroscopic qualities of the oil used, whether vegetable or synthetic, introduced water to the hydraulic components. Each operation of the system drew fluid through it, bringing in moisture and potentially dust and other debris, which was absorbed into the fluid each time. Ironically, degradation of the system was often accelerated through infrequent use of the vehicle.

Mineral oil, introduced to the system in 1967, helped alleviate this problem, as its chemical make-up reduced the tendency of drawing moisture into the system.

Citroën continually refined the system over the DS's 20-year production run, during which 1.5 million examples were produced. One interesting development that was tested, but never made it into production, was an anti-roll element. An anti-roll control system was trialed as early as six months after the DS's debut, and the idea was continually refined over a 13-year development program. Six prototypes were trialed over 4,000 miles, before Citroën abandoned the program to focus on the soon-to-be launched GS.

The DS has gained a cult following, with late-spec Décapotable (convertible) versions changing hands at auction for upwards of US$250,000. With the DS considered one of the most influential cars of all time, ranking third in the 1999 'Car of the Century' competition behind Sir Alec Issigonis's original Mini and overall winner the Model T Ford, it is not hard to see why.

INDEX TO ADVERTISERS

tedrive Steering Systems

Commercial comfort

The incorporation of active driver assistance systems has previously been the preserve 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 communication 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 e.g. 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.

PICTURED LEFT: **iHSA MODULE FOR RACK-AND-PINION STEERING**

PICTURED RIGHT: **iHSA MODULE FOR RECIRCULATING BALL STEERING GEARS**

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.

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