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SHOW ISSUE
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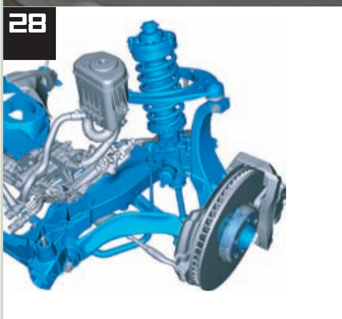
MP4-12C

Very fast, very light, and very orange:
Exclusive details of the McLaren supercar

Saturday night fever
Audi's challenger for victory at the Le Mans 24 Hours

Mass exodus
How to reduce the weight of chassis parts

State of deflation
News and views from the field of runflat tires



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A NOTE FROM THE EDITOR

Never has a new car's fuel economy and emissions performance had such a high profile, with legislative demands, tax regimes, and marketing kudos all behind the current march to lower CO_2 outputs.

In a climate where seemingly every last gram of CO_2 counts, one might have thought that every last gram of vehicle weight reduction would be equally prized. Yet everything has its price. My sources indicate that, while an extra 50 cents for 1kg less mass might happily be signed off by the OEM, any technology that brings a similar mass reduction for more than €5 is proving a very hard sell. Turn to page 30 to see some of the innovative solutions to chassis weight reduction coming to a showroom near you.

For all its resourcefulness, there are times when the car industry seems to make life unnecessarily difficult for itself. Take Nissan: having used high-tensile steels to reduce the weight of the Qashqai's body, it then offered a panoramic glass roof option. The take rate is approaching 50% for something that adds weight in completely the wrong place and puts an extra demand on the air-con to keep the car cool, thereby using more fuel and increasing emissions. Outsize wheels are a similarly illogical choice, but until car buyers decide that tin roofs and high sidewalls are cooler than tinted glass and pimped-up rims, I fear that the dynamicist's job is only going to get harder!

Graham Heeps

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CHARLES ARMSTRONG-WILSON
As the former editor of Racecar Engineering, Charles knows his onions when it comes to motorsport dynamics. In this issue he gets the lowdown on the aero-led car that Audi hopes will wrestle Le Mans glory back from Peugeot's clutches (p38)

GRAHAM HEEPS
The editor came away from a visit to the McLaren Technology Centre impressed by the firm's thorough approach to the creation of a whole new car company. The volume projections for 12C aren't huge but McLaren will certainly give the competition something to think about

JOHN HEIDER
John's Cayman Dynamics organization is doubtless working on a very interesting project that he'd love to tell you about, but can't. Instead, you can read his thoughts on the collection and analysis of chassis data (p60). As ever, you can read more of his thoughts on the VDI website

RÜDIGER HIEMENZ
Opel's amiable vehicle dynamics manager is a contributor to our feature on weight reduction (p30). We think Rüdiger can take some of the credit for GM Europe's improving recent chassis track record: both the new Astra and the Insignia OPC are impressive cars

ROGER WILLIAMS
As a former head of research at Dunlop UK and a leading light behind the annual Tire Technology Conference, Roger is an extremely well qualified author for this issue's review of the latest developments in runflat tires (p22). For an alternative take on runflats, read one of John Miles's pieces.

MCLAREN IS ABOUT TO RE-ENTER THE SUPERCAR ARENA WITH THE TECHNOLOGY-LADEN MP4-12C. **GRAHAM HEEPS** GETS THE LATEST ON THE CAR'S CHASSIS DEVELOPMENT

Clockwork orange

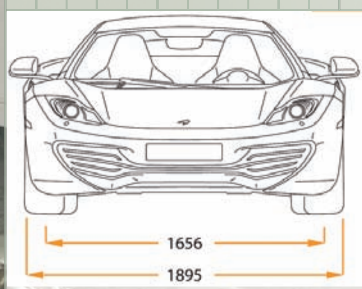
McLaren has produced high-performance sports cars before. While Gordon Murray's BMW-powered McLaren F1 is hailed by some as the greatest road car of all time, the Mercedes SLR McLaren, produced until recently, got mixed reviews.

Now, at a time when many OEMs have been getting out of motorsport, this hitherto racing-led organization has decided that it must diversify further to survive. The MP4-12C, the first street car from newly formed McLaren Automotive, will be launched in late-2010.

The McLaren MP4 pioneered the carbon-fiber chassis in Formula 1 back in 1981. Almost 30 years on, the same concept is being applied to the 12C, but unusually, this 'MonoCell' is resin transfer molded. All of the aluminum pick-up points are co-molded into the structure at the same time. Once the resin is cured, there is a post-cure procedure and the whole tub is machined in one on a five-axis CNC machine. The result is an economically viable structure that is light (<80kg), very stiff, and has a diagonal dimensional tolerance of better than 0.5mm.

The basic chassis is completed by relatively conventional aluminum subframes that are bolted to the tub. In addition, there's an aluminum screen surround with a carbon-boron steel tube to take the rollover load.

SPECIFICATIONS



McLaren MP4-12C

Dimensions: 4,509mm (L) x 1,908mm (W) x 1,199mm (H). Wheelbase 2,670mm, track 1,656mm (F), 1,583mm (R)

Dry weight: <1,300kg, weight distribution 43:57

Powertrain: bespoke 3.8-liter twin-turbo V8, developed with Ricardo. 600bhp, 600Nm (80% of it at 2,000rpm), redline at 8,500rpm. Oerlikon-Graziano seven-speed dual-clutch transmission

Suspension: all-around double-wishbone with aluminum links. Eibach springs, Tenneco adaptive damping with Kinetic hydraulic roll control

Steering: TRW electro-hydraulic rack-and-pinion, ratio and tuning unique to 12C

Brakes: standard twin cast-iron rotors 370 x 34 mm (F) and 350mm (R) with forged aluminum bell (saves 2kg per corner) and AP Racing four-pot calipers. Optional Brembo/SGL carbon-ceramic setup aimed at track use: disc diameter 394mm (slightly heavier than cast-iron ones), six-pot front calipers. Goodridge brake lines. Brake steer applied independently, electronically, at the rear to improve turn-in. Full ESC-off setting not originally planned, but now likely

Wheels/tires: 19in or 20in alloys with Pirelli P Zero or P Zero Corsa tires

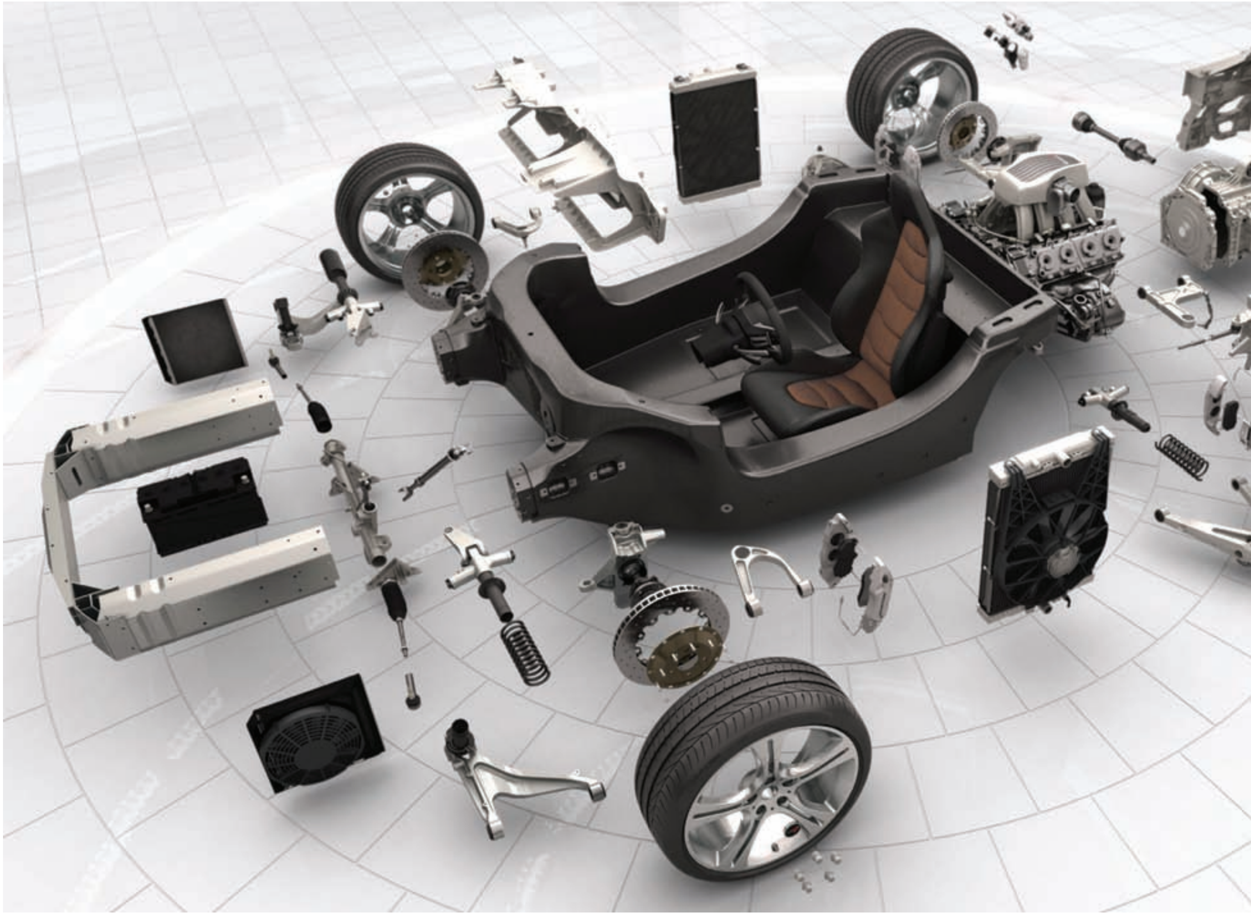
Performance: Acceleration zero to 124mph (200km/h) <10 seconds. Braking 124mph back to standstill <5 seconds, from 100km/h to standstill <30m. Standing quarter-mile 11 seconds. Top speed 200mph+

As one might expect from a supercar made by a race car constructor, the suspension is by forged aluminum suspension double-wishbones front and rear. Adaptive damping is also a predictable choice in this market segment. Where the 12C differs from all other sports cars on the market however is in its use of Tenneco Kinetic hydraulic roll control (see *VDI*, March 2007), which has previously been used primarily in off-road vehicles and rally cars.

"It's a brave call to do it completely differently to everybody else," says Chris Goodwin, McLaren Automotive's chief test driver. "People have tested Kinetic in racing applications and it's not been easy to get the response time, the feel and the control correct. Certainly no one's used it in a high-performance sports car before so it was groundbreaking stuff for us. Between this and the adaptive damping system, we spent a long time deliberating over the choice of technology, but once we'd made the decision we did an enormous amount of R&D before the hardware was used in the car. We've ended up with a very tunable and responsive chassis."

McLaren's vehicle dynamics team, led by ex-F1 dynamicist Paul Burnham, has taken full advantage of the simulation tools developed over many years by the Formula 1 side of the organization. For the 12C, McLaren developed its analysis program further to take account of the increased importance of suspension compliance, particularly in terms of vertical motions, in a road car compared to a Formula 1 single-seater.

Once an initial model had been developed, Goodwin and his colleagues spent hours driving the car in the driving simulator at the McLaren Technology Centre, which its operators believe is the most advanced in the world (see panel, overleaf). The result, says Goodwin, is that, despite the Kinetic system's complexity, "we were already in the ball park by the time we built the system into a mule car".



CLASSIC McLARENS

1995 McLaren F1 GT-R Le Mans

1974 McLaren M23 Formula 1

1971 McLaren M8F Can-Am

From there it has been a matter of fine-tuning the control system. "It's been quite fun," he claims. "The system is such that I can drive around the Nordschleife, with Paul or one of his guys sat next to me, and literally say, 'at this point on this corner at this speed, I want a bit more support on the front. As I turn in here I want a bit less, and a bit more on the rear...' We can tune the car for every segment of a corner, in as much fidelity as we want.

"It means you no longer have the age-old compromise of a stiff car to give you high-speed stability traded off against slow-corner performance. I can have the steering weight, steering characteristics, roll stiffnesses, and damper stiffnesses where I want them for a 40km/h corner where I'm braking right into the apex, and then, a quarter of a mile later, I'm going through a fifth-gear corner and the whole setup is different. You can't feel it changing, it just gives you a good handling balance in all of those places."

With so many parameters to consider, Goodwin admits that there's a danger that one could get lost in the complexity, but insists that hasn't happened at any stage.

"If you work in a logical way it's not nearly as complicated to tune as you might imagine," he insists. "The very complicated part is the code the guys have to write to work the control systems. But in terms of the actual tuning sitting in the car, wanting to separate one set of parameters from another, that's actually relatively straightforward. Once you know what you're asking for on every part of a corner, then it's very easy to deliver it. I'm relied upon to be extremely precise and I think that's what I'm good at. In turn I'm reliant on some extremely clever guys to deliver the extremely complicated control system."

So far this all sounds quite racy, but McLaren insists that it is building

More fun than Gran Turismo?

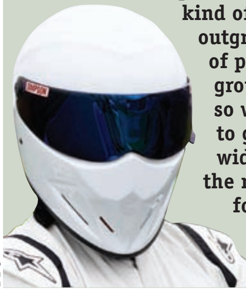
"I've been using the driving simulator since about 2001 so I've grown a bit with that project as we've developed it," says Chris Goodwin. "We've certainly benefited from having it at our disposal in our road-car project, from the concept phase right through to where we are now with the validation prototypes. Some very sophisticated models have allowed us to tune things like steering feel, suspension geometry, tires, ESC systems, chassis stiffnesses, aero modifications, and weight distribution to a very fine level of detail.

"Knowing how to drive the simulator is a bit of a skill in itself because things feel different in the simulator, but if you cross-relate at all times, and you've done as much time in the simulator as I have, it's a skill you can develop. I know what a car feels like round the Nürburgring, Dunsfold, Barcelona or wherever, and therefore I can jump into the simulator and test exactly the same spec on the virtual circuit. I know what a degree of oversteer feels like in the simulator, and how that feels in the real world. It takes time to get up to speed with that but once you're there it's brilliant; we have roads as well as tracks so you can go anywhere in Europe you want, and be home in time for tea!"

THE POWERTRAIN WAS KEPT AS SHORT AS POSSIBLE TO MINIMIZE THE REAR OVERHANG AND NOT COMPROMISE DIFFUSER PERFORMANCE. THE FIRST CUSTOMER 12CS WILL BE MADE IN THE MCLAREN TECHNOLOGY CENTRE BEFORE THE SWITCH TO A NEW, DEDICATED FACTORY IN 2011

THE STIG'S FAVORITE TEST VENUE

One of the test tracks used by the 12C team has been Dunsfold, a former British Aerospace airfield less than 20 miles from McLaren's base in Woking, UK. The facility is best known as the home of the BBC's Top Gear TV show. "We found Dunsfold during the SLR project and it's somewhere we've since used a lot," explains Chris Goodwin. "It's on our doorstep and it's very useful. The Top Gear guys did a very good job of creating the handling circuit because it offers a huge variety of corners and it's bumpy – much more like the road than a normal racetrack. It's also quick and open enough to accommodate a car with our level of performance. Our kind of car has outgrown a lot of proving grounds now so we have to go far and wide to find the right venue for our specific tests."



BBC

ON THE WEB

Watch McLaren F1 drivers Jenson Button and Lewis Hamilton try the MP4-12C at Goodwood, online at vehicledynamicsinternational.com

TEST TRACKS VISITED BY THE 12C TEAM INCLUDE ROCKINGHAM, MIRA, CRANFIELD, DUNSFOLD (SEE PANEL, LEFT), AND MILLBROOK (ALL UK); BIC (BAHRAIN); IDIADA (SPAIN); NARDÒ (ITALY); AND THE NÜRBURGRING. CLIMATIC TESTING HAS ALSO BEEN DONE IN THE USA, SWEDEN AND NEW ZEALAND. BELOW LEFT: KINETIC SUSPENSION AND THE OPTIONAL CARBON-CERAMIC BRAKE SYSTEM ARE VISIBLE ON THIS VALIDATION PROTOTYPE

a car that will be enjoyable to drive at low speeds on the road as well as more quickly on the track. To begin with, the Kinetic system's ability to offer good single-wheel articulation should help the ride comfort. Indeed, there are plenty of suitably bumpy, broken, and cambered public roads to test the ride on around the team's Woking headquarters.

At the same time, much attention has been given to the feel of the steering and brakes. "We've spent a lot of time working on the feel of the car driving at 30-50km/h because for much of the time, owners will be pootling around town," Goodwin confirms. "We especially want the driver to have good steering feel at those speeds. We can infinitely map the power steering characteristics related to road speed, steering angle, and steering rate. It gives you some nice, light, but progressively loading steering at low speeds but it gradually morphs as you pick up road speed or corner speed, or on demand from steering rate.

"For higher speeds the requirement is different," he continues. "You want a bit of stability on a highway, some weight and some resistance to moving off center, but in the middle of an 80-90mph corner we've gauged the weight to be heavy enough to

give good road feel, because you want to feel the tire contact patch in that instance more than in any other.

"That's the philosophy we've applied to other chassis elements as well, to give the correct control and feel to each different circumstance, using technology to achieve it without making a big compromise. For example, we also want the driver to have some nice brake control and feel at low speeds, so have spent a lot of time on the stiffnesses in our braking system, pad material and so on, to ensure good feel at low speed but good performance at high speed and for on-the-limit driving. Being McLaren, the expectation is that the on-the-limit performance will be excellent, so we've made sure it is, but we don't want to destroy anything in normal or low-speed driving to achieve it."

To underline its flexibility, the MP4-12C will feature three modes – Normal, Sport and Track – which McLaren claims will alter the character of the car more noticeably than the systems used by some of its rivals. The use of Kinetic on the car means that the roll stiffness is added to the list of characteristics adjusted in each mode; the others are the stability control, steering weight, and damping. Meanwhile the powertrain will have three separate modes, available independently of the selected handling setting.

"We're anxious not to just build a car for what the customers want," Goodwin concludes. "Sometimes customers have got used to something that's available but isn't necessarily good. We don't want to produce something just because it's what everybody else does; in some areas we want to do something slightly different to what people are used to – because it's better."

CLASSIC McLARENS

1969 McLaren M6GT road car

1981 McLaren MP4 Formula 1

1954 Austin Seven Special (first race win for Bruce McLaren)

NEW XJ IS THE FIRST MODEL WHERE JAGUAR HAS DEVELOPED DIFFERENT WHEELBASE VERSIONS SIMULTANEOUSLY, GIVING THE CHASSIS A DEGREE OF FLEXIBILITY FOR WHATEVER FUTURE VARIANTS JAGUAR MIGHT CHOOSE TO DO. IT'S A ROUTE THAT IS LIKELY TO BE FOLLOWED IN FUTURE PROGRAMS

The long and short of it

JAGUAR ENGINEER PETER DAVIS EXPLAINS TO **KEITH READ** WHY HE'S PLANNING TO SWAP HIS XF COMPANY CAR FOR A BRAND-NEW XJ AS SOON AS HE GETS THE CHANCE

When a key member of the team that won acclaim for chassis dynamics on Jaguar's XF and XK ranges says he'll switch to the new XJ as soon as it becomes available, you know that its dynamic performance is going to be special.

"My head tells me that the XF-R is the best car we've done, because that's the one that's given me the most pleasure in terms of driving quickly on test tracks and having great fun," says Peter Davis, technical manager at Jaguar Land Rover. "However, buried in me is a love of XJ. Some of the work I did at Dunlop while doing my degree was on V12 Series III XJ and I've been involved in every XJ we have done over the past 25 years. There is something very special about the XJ, and when the new car comes in I will have one to replace the XF I'm currently running."

Although a number of components and settings were carried over from previous XJ or the newer XF and XK, none escaped without further development, refinement, or fine tuning. A prime example is the ZF Servotronic PAS first developed for the XK. "We spent a hell of a long time developing it with ZF who, we think, are the best in the business," says Davis. Twelve critical parameters, all with very tight tolerances, combine to produce the end result in XJ. "It works really well for the steering feel that we want – the very precise connection that we always try to build into the car for an immediacy of response," he says.

The basic valve develops its pressure very quickly, allowing Jaguar to overlay what it calls soft tuneables to help make the new XJ, in Davis's words, "shrink around the driver and complement the natural agility of the chassis and not work against the driver."

There are no compromises with the steering valve, he stresses. And he agrees that the XJ's steering has moved into the realms of an intelligent system. "It's not intelligent in the sense that it has nine computers; but it is intelligent in terms of knowing what customers are sensitive to."

NEWS-IN-BRIEF

Indian tire manufacturer, Apollo Tyres is launching a range of passenger car tires into the European aftermarket. The firm's May 2009 acquisition of Vredestein Banden BV – now renamed Apollo Vredestein BV) – has enabled it to accelerate its plans for Europe.

Hiroyuki Matsumoto has been appointed as the new vice president and general manager of Mazda's European R&D center in Oberursel, Germany. He replaces Norihiro Tomita, who moves back to Japan to become a program manager in Mazda vehicle development.

VDI's sources confirm that the North American market chassis tuning for the Fiat 500 is now complete. In addition, the company's new Compact platform, which underpins the new Alfa Romeo Giulietta, was validated for North American use over several months last winter. It's not known which will be the first car Stateside to use the all-new architecture, which features ZF's dual-pinion EPS.

Davis calls this the 'handshake' from the steering. "You need to know what the car is about within the first 50m you drive," he says. "We developed a faster gear for the XF-R which gets the on-center ratio down from 17.8:1 on previous XJ to just 15.2:1 for the new model. However, our aim for new XJ to be 'surprisingly agile' was not so simple, as the vehicle also needs to underpin the duality of character that is fundamental to Jaguar. This meant that it had to be relaxed at high speed."

To achieve this, the increased compliance and roll-kinematic understeer in the rear axle (pioneered on the XF) was employed to reduce lag between the front (non-isolated) and rear axles by almost 20%.

The new XJ advances Jaguar toward achieving its objective of being known as the lightweight car company. However, universal fitment of a panoramic glass roof meant the dynamics team had to deal with a raised center of gravity compared with the previous XJ. "But we knew that the stiff aluminum body could withstand higher spring rates," he says. "50N/mm and 72N/mm give ride frequencies that are up by 15% front and rear compared with the previous XJ. This, combined with track increased by 70mm at the front and 46mm at the rear to make them both 1,600mm, meant we got off to a good start.

"We have a guideline for the contribution of the ARBs to single-wheel rate on offset undulations and stiffening the springs reduced this below 55% and reduced head-toss on demanding cross-country surfaces. Overall, the new XJ rolls 20% less than the outgoing model – 4.7deg/*g* compared with 5.7deg/*g*." The stiffer springs mean rebound springs are not required.

The new XJ uses Bilstein dampers that can be individually switched. "All you could switch on the previous car was between soft and firm," says Davis. "With the new car, the steering is monitored 500 times a second and the dampers will pre-emptively predict and switch. Our software uses the XF/XK sky-hook algorithm for road-induced events. Damping is varied at each corner through an acceleration filter to minimize disturbance from roll, pitch and heave events while maintaining connection to the road for driver confidence and passenger comfort. Driver-induced events are similarly monitored and used to modify damper settings and decay functions.

"To give us the 'plushness' of ride required, there is more free-flow past the valves in the damper than normal," he continues. "But when we switch to Dynamic mode (JaguarDrive Control), we automatically go from 1.5amps, which is full soft, to 1.3amps, so the driver will instantly feel that the car increases connection." A clever frequency-dependent algorithm prevents the car from reacting harshly to small road inputs and becoming uncomfortable.

Davis adds that switching to Dynamic also brings about a change in the XJ's steering. "It's pretty subtle, within a 5% shift of Servotronic effort, but it's enough to make you feel that the car is doing something different from a steering point of view."

Among the many features influencing the production set-up finalized for XJ and taken into account by the dynamics team were the ultra-smooth underbody topography contributing to reduced turbulence and lift – now 0.090 front and rear compared with 0.140 front and 0.130 rear on the previous XJ; and tire concept, construction, and compound. These were largely carried forward from XF-R into a new family of tires, which are up 15mm in diameter to 705mm compared with the old XJ.

The decision to utilize different sized tires – 245/40-20 at the front and 275/35-20 at the rear – assists high-speed stability and traction, says Davis. The main points of focus during tire selection and tuning were steering response, rolling 'plushness', and handling predictability.

Davis says there is little difference in the feel between standard and LWB XJs. "They run the same ride frequencies, although we have slightly different springs to accommodate wheelbase and engine size," he says. Developing both versions simultaneously was an advantage. "We ran a supercharged LWB which, in the back of our minds we were thinking we had to make sure would work in the USA, and a SWB diesel, which has definitely got to work in the UK and Europe. Keeping those two running alongside each other and making sure they were fundamentally the same character was a great way to do it. I was certainly not given any allowances for the diesel to ride less well than the LWB!"

SPECIFICATIONS

Jaguar XJ

Dimensions (SWB/LWB): 5,122/5,247mm (L) x 1,894mm (W) x 1,448mm (H). Wheelbase 3,032/3,157mm. Track 1,626mm (F), 1604mm (R)

Suspension: Front unequal length wishbones, rear multilink.

Geometry: toe-in F/R 10'/12'; camber -40' (F), -85' (R); castor 7°. Some castor/camber cross-bias is used to counter drift-pull by hand-of-drive

Brakes: Based on XK's system

Steering: ZF Servotronic rack-and-pinion. Ratio 15.2:1

Turning circle curb-to-curb: 12.3m (SWB), 12.7m (LWB)

VDI SAYS

The combination of some benchmark new engines and continuous evolution of a proven chassis concept is the foundation of Jaguar's recent success. We'll be trying an XJ very soon – check out the website for our impressions.

NEWS-IN-BRIEF

Suspension and braking specialist, BWI Group is developing a third generation of its successful MagneRide adaptive damping system. The latest model introduces a two wire dual coil (TWDC) actuation system, a new ECU, new control algorithms and various other upgrades said to improve the dynamic range and speed of response of the system without increasing its size or weight. In addition, BWI has developed a new, heavy duty version that extends the range of applications to large SUVs.

dSPACE real-time systems can now perform up to 60% faster. The new quad-core DS1006 processor board has an AMD Opteron 2.8 GHz processor to increase the power of hardware-in-the-loop (HIL) simulation. The firm says that large models can be easily distributed across the quad-core processor and executed synchronously, such that numerous simulation models that previously required several processor boards, can now run on a single DS1006.

NEWS-IN-BRIEF

Delphi Steering operations in Europe have become Nexteer Automotive, a new, independent Tier One supplier focusing on electric power steering (EPS). Laurent Bresson, Nexteer Automotive's new executive director in Europe and executive director of its global sales and marketing operations, said that the company is to invest 8% of its income in R&D.

A recently announced cooperation agreement will see the Renault-Nissan Alliance and Daimler AG develop a new, common architecture developed for the successor to the current smart fortwo, a new smart four-seater, and the next-generation Renault Twingo. All will be rear-wheel-drive and offer an electric version. The launches of the jointly developed models are planned for 2013 onwards.

Dr Claus Oberbeck is the new head of development at Hankook Tire's European research and development center, the ETC in Langenhagen, Germany. Thirty-nine-year-old Oberbeck is in charge of original equipment and compound development, as well as EU regulations compliance.

The quiet one

GUNNAR HERRMANN, FORD'S GLOBAL C-SEGMENT OVERLORD, TELLS **GRAHAM HEEPS** WHY THE NEW FOCUS AND C-MAX WILL BE THE MOST REFINED YET

Long established as benchmark products for steering and handling, Ford's best-selling C-segment cars are to be replaced in the next 12 months. Models up for renewal include the Focus hatchback, sedan, and wagon, plus the C-Max MPV, which will be offered in separate SWB five-seat and LWB seven-seat versions for the first time. And if that wasn't an ambitious enough program as it is, the cars will follow the trail blazed by Fiesta and enter the North American market too.

Gunnar Herrmann is Ford's global C-car vehicle line director. He says that the existing C1 platform architecture will continue to underpin the new vehicles but it has also been subjected to an extensive MCA (mid-cycle action) to update its attribute performance. The result is a platform that is now 80-90% Ford's own, with just a small element still used by Mazda and Volvo. Depending on the bodystyle, there will also be 80-85% commonality between the platform's different Ford models.

"We've improved it from a noise-pass, acoustic perspective," Herrmann explains. "NVH was the dominant attribute that we tried to optimize and specifically from a suspension-system [perspective] it's the road noise. We spent an awful lot of time addressing this, because it was clearly a weakness compared with our competitors. This is one of several major changes from a platform perspective to get to a performance level that will compare with any C/D segment car."

For many, it's the Golf-derived Volkswagens that currently lead the segment in terms of refinement, as Herrmann acknowledges. "Their isolation is good, their impact harshness is well managed – it sounds damped, not harsh. The acoustics of the impacts is nicely tuned, for a quality feel, and this is what we have approached as well. By changing the attachments we've changed the isolation of the rear subframe, for example."

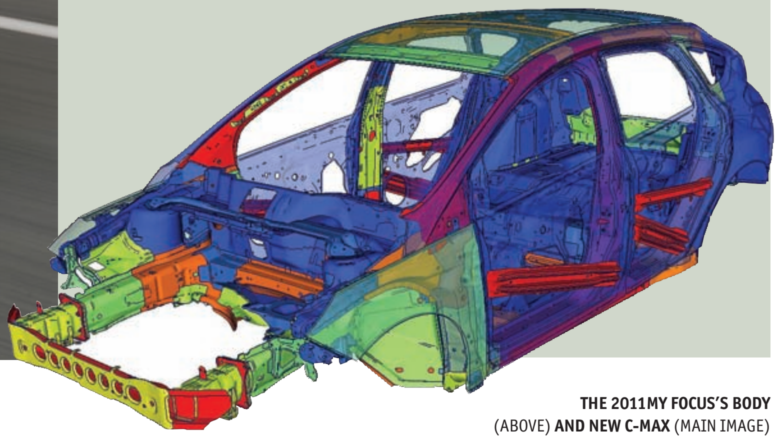
Further work has involved matching the stiffness across the chassis and body, particularly at the attachment points. "I think we did an excellent job of balancing this out on the initial Focus," he offers. "You felt this as well in the dynamics – the car felt extremely connected as a whole. We lost a bit of that on the second Focus but I think it's back on the new one. On the previous version we had almost a too-stiff chassis system for the body structure and this gives you issues in several areas, with road impacts, for example. There are other elements too, like [the area] from the pedal box to the dash panel acting like a drum. There

TOP-DOWN APPROACH

Focus and C-Max customers should also benefit from a change in Ford's approach to chassis tuning. In short, a larger wheel size is now used for the baseline tuning. "In the old approach we chose the volume tire, which was more toward a smaller wheel to trigger the development," says Gunnar Herrmann (left). "It led to the point where, when a customer was willing to spend more money to get bigger wheels, the ride quality, handling, and steering performance were falling apart.

"We learnt our lesson as we developed Kuga. We were seeing significant shortfalls on the 18in wheels. The response from the chassis dynamics guys was, well it's due to the bigger wheel! But of course, that's not how a customer would see it, and he's the one spending the money, so we had to do something about it. So effectively we did it twice, we changed the setup by starting at the other bookend and bringing it down.

"Now we use a significantly bigger wheel, almost the 'worst case', to make sure that when somebody fully loads the car he's not faced with any attribute degradation."



THE 2011MY FOCUS'S BODY (ABOVE) **AND NEW C-MAX** (MAIN IMAGE)

were several error states that we approached more fundamentally, and for which I believe we delivered an excellent solution."

Looking beyond the Focus and C-Max's European heartland, Herrmann says that accounting for the higher tire wear expectations of the North American market has had a strong influence on the new cars' suspension geometry.

The new C-models will follow a growing trend in the segment and feature electric power steering (EPS), which had originally been scheduled for the Mk2 Focus but was dropped when its performance failed to meet expectations. "The EPS system had long been discussed within Ford because we never really felt happy about it," Herrmann admits. "But with the further development of EPS systems and of our capability to deal with those systems, we've delivered a steering system that's fairly light, very intuitive, and with extremely good on-center feel. The force distribution is more like a V-shape, so the steering input and feel is extremely precise, quite enjoyable. Even the C-Max, with its higher center of gravity, has amazing handling."

Adaptive damping won't be offered however. "We have developed systems in the [current] Focus, although we don't offer it," Herrmann reveals. "But it operates at a level where I would question whether it's of value to normal customers. It is an interesting question though – we had this discussion on the Focus RS, because there we had to decide which way to go. Most people didn't like it because they said you get shake all the time and it's exhausting, but if you go a long distance in an RS you love it, because it's so connected in the way it performs. I would almost say that adaptive damping is an engineering toy. For mass production I would prefer other features that I think are more beneficial for the customer."

VDI SAYS

Comparatively poor refinement is the current Focus's biggest fault. Who'd bet against Ford's dynamics specialists improving it – and integrating EPS – without spoiling the driving experience?

Eco warrior

CR-Z FEATURES ALUMINUM FRONT SUSPENSION LINKS

HONDA IS OUT TO DISPROVE THE NOTION THAT HYBRIDS CAN'T BE FUN WITH ITS NEW CR-Z COUPE. BY **NORMAN DINGLE**

The current Honda Insight is a family-sized hybrid quite unlike the quirky, coupe-styled original. Now the Japanese manufacturer has combined some of current Insight's mechanicals, old Insight's 2+2 layout, and thrown in some inspiration from its CR-X coupes of the 1980s and 1990s to create the stylish CR-Z.

Honda says that making it fun-to-drive was the top priority. "The driving position was the first thing we fixed because I believe it's essential for sporty driving," explains CR-Z's large project leader (chief engineer), Norio Tomobe. "The hip point and accelerator pedal point were set at the very beginning and the complete car was developed around these two points."

MINI was a benchmark for the CR-Z's handling, which was honed through a cooperation between the regular development team and ace development driver Furuhashi-san, referred to in revered tones by Tomobe-san as the *Meister*.

The company's Takasu proving ground on Hokkaido was a key location for chassis tuning. It contains copies of sections of the Nürburgring Nordschleife, with comparable µ, curve radius and banking. In addition, thousands of road miles on several continents contributed to three separate tunes for Europe, Japan, and North America. According to Tomobe-san, the first two are quite similar and predictably stiffer than the North American setup, which is based on mud and snow tires, a higher vehicle weight, and a softer ride.

CR-Z mates a Jazz/Insight engine bay and front floor with a bespoke rear end. At 2,425mm, the wheelbase has been reduced by 115mm compared with the Insight, while the track width has been increased by 25mm to 1,515mm. Ground clearance is 135mm, contributing to a low center of gravity that has also benefited from mounting the 40kg of hybrid components in the rear of the car – primarily the NiMH battery pack and control unit – below the trunk. The H-section torsion beam rear suspension, adapted from the Insight, creates the necessary space.

"By selecting the battery location carefully, we achieved a good, 60/40 front/rear weight distribution and a low center of gravity, rather than the weight being a disadvantage," says Tomobe-san, whose personal car is an old CR-X del Sol.

Body stiffness has been increased from the Insight, with Honda claiming that torsional stiffness performance is now close to that of the Civic Type R. Other dynamics-focused hardware changes center on reductions in unsprung mass: a new design of 16in alloy wheel (on a 195/55 tire) saves a total of 5kg, while another 4kg is shaved by employing forged aluminum lower front suspension links in place of Insight's pressed steel items.

Also beefed up is the NSK EPS. The motor's power is about 30% higher than on the Insight so that CR-Z can have a quicker ratio. "We worked closely with NSK to develop the system," says Tomobe. "The yaw rate sensor was an important input parameter to control the steering system, give the proper level of feedback, and avoid overshoot."

MOTORSPORT-IN-BRIEF

Former Honda WTCC team, N.Technology is to locate its new N.Technology Iberia division in the technology park now under construction at the Autódromo do Algarve in Portimao, Portugal. In the future, the new company plans to work with OEMs on testing and development programs for vehicles within the European marketplace, utilizing the nearby race circuit and handling assessment facilities.

The technical regulations for the British Touring Car Championship (BTCC)'s Next Generation Touring Car, a lower-cost formula to be introduced from 2011, have been revealed. The front- or rear-wheel-drive race cars will all feature standard subframe/suspension assemblies from GPR Motorsport, as well as AP Racing brakes.

In Germany, the DTM is also working on a new set of technical regulations with a view to reducing costs and attracting more manufacturers to fight it out with Mercedes-Benz and Audi. BMW is likely to participate from 2012, while Opel is thought to be considering a return as well.

SPECIFICATIONS

Dimensions: 4,080mm (L) x 1,740mm (W) x 1,395mm (H)

Powertrain: 1.5-liter IMA, 122bhp

Performance: 0-62mph (100km/h) in 9.9 seconds

Economy: 56.4mpg (combined cycle), 117g/km CO_2

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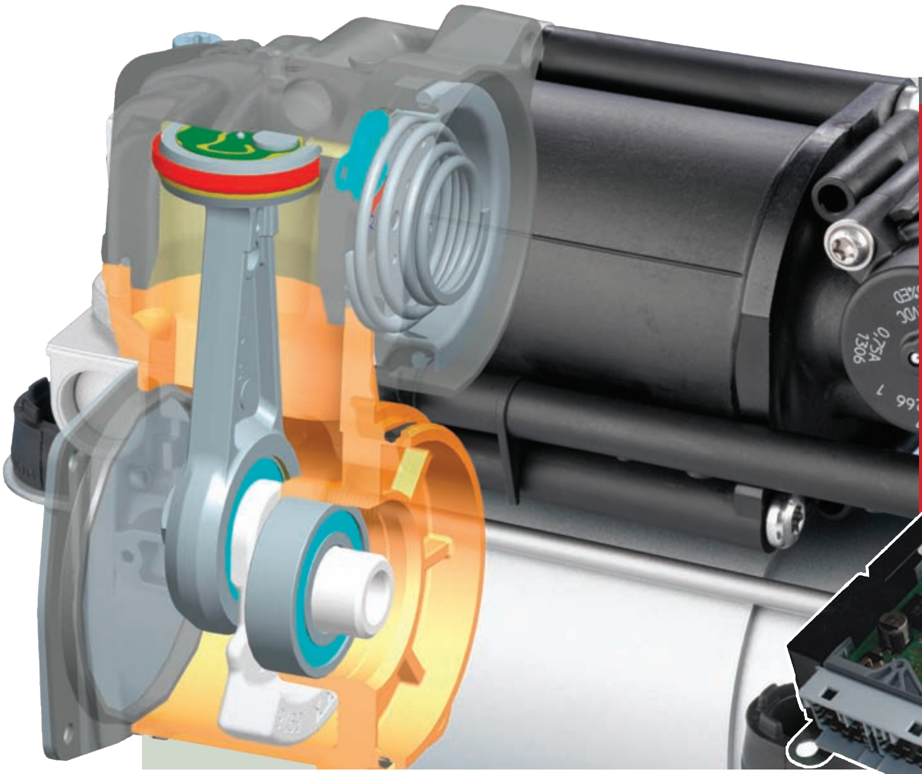
WABCO COMPRESSOR AND ECU

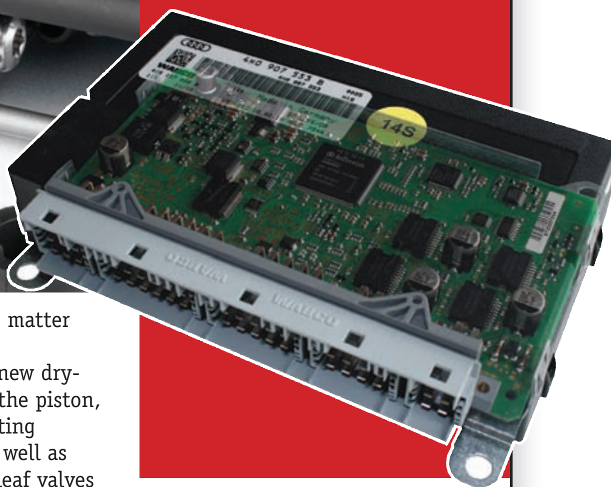
Air suspension innovations

WABCO HAS IMPROVED ITS COMPRESSOR AND LAUNCHED A FLEXRAY ECU



AUDI APPLICATION

Recently, WABCO's control unit was launched into series production on the new Audi A8. Integrating Audi's unique damping algorithm, the new A8's adaptive air suspension determines the most effective damping level based on road surface, load, speed, and vehicle body movement. It increases passenger comfort through constantly adapted vehicle ride height. Speed-sensitive lowering of the vehicle body also improves vehicle safety while reducing fuel consumption.



WABCO's air suspension compressor has been optimized to increase performance and, at the same time, reduce cost for OEMs. Improvements in key performance indicators, such as maximum pressure and lowest possible noise emission, have been challenging tasks. But WABCO's compressor design team, based in Hanover, Germany, has successfully risen to these challenges.

The piston and valves on the intake and pressure side have been redesigned entirely. The maximum operating pressure has been boosted to 18 bar, which increases air pressure capacity for reservoir systems up to 40%. Dry-running compressors with such a high-performing pressure ratio realized in a single stage are rare in the compressor market, no matter what the application.

Key elements include a new dry-running gasket as part of the piston, which reduces energy-wasting blow-by to a minimum, as well as special lightweight metal leaf valves that make more dynamic valve operation possible. Both of these changes improve the efficiency of the compression, and both have a very positive effect on noise emission. In fact, the overall sound pressure level is reduced by 4dbA.

WABCO's compressor has already been launched in several premium vehicles, such as the Mercedes-Benz E-Class, BMW 7 Series, BMW 5 Series GT, Audi A8, and Rolls-Royce Ghost.

WABCO's latest electronic control unit marks the passenger car industry's first application of air suspension using FlexRay, resulting in fast and more highly reliable integration with the vehicle's other controls and sensors. A 32-bit Tricore microcontroller has been selected to process the fast and complex data structure. This further improves performance of air suspension systems through optimal sensitivity and continually adaptive damping that reduces vehicle vibration and prevents it from increasing.

VEHICLE DYNAMICS EXPO 2010
EXHIBITOR

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On the job
Punctured dream

JOHN MILES IS YET TO BE CONVINCED THAT RUNFLATS REALLY ARE THE FUTURE

For some time, the tire industry has promised that with new technology and materials, runflat tires will no longer suffer the ride and handling deficiencies that have cursed the concept.

Perhaps it was the expectation of this promise and the hope that other manufacturers would follow its lead that prompted BMW to accept the challenge of making these weighty and stiff-sidewalled tires work on their normal model range. Having often experienced the negative influence of runflats on vehicle dynamics, I admire BMW for committing so wholeheartedly to the concept, especially as I was reminded yet again of their deficiencies during a recent chassis development exercise using our managing director's 2004 BMW 5 Series.

Having come to a full stop trying to moderate its leaden-footed secondary ride, ride shake, delayed front/rear axle lateral response phasing, and feel-less (but high aligning torque) steering, we persuaded the local tire dealer to overlook BMW directives and fit a set of conventional 245/45-17 Bridgestone Potenza RE050As. The improvement in secondary ride, steering linearity, and yaw response was considerable. In essence, the car had become almost likeable and the whole driving experience more tactile. Confirmation of sorts had also come from recently assessed BMW 1 Series, again on Goodyear NCT runflats. Excellent low-speed rolling comfort morphed into tiresome secondary ride and dubious transient handling if the stability control was not engaged (especially on the alternative Pirelli runflats) – handling losses that have always surprised me given that these tires have such stiff sidewalls.

Repairs to runflats are not normally recommended, but this will obviously depend on whether the tire has run flat for one mile or 50 miles (80km) at the legal 50mph maximum and of course how damaged it was in the first place – a likely source of dispute. After several runflat assessments over the years, my take on the subject remains that in exchange for being able to drive slowly to the nearest town in the hope that the local tire dealer has got a replacement of the same make and size in stock (and having acceptable luggage space in a RWD car), one has to accept inferior ride, handling, and steering, potentially higher tire wear rates, and most importantly at least a 30-50% greater replacement cost. Judging from the tire dealers I called, very few sizes are carried in stock, so the chances are you will have to wait to get a replacement.

We are told that with the use of new materials and design technologies, tire manufacturers will continue reducing vertical stiffness and weight, eventually being able to match the dynamic attributes of a standard tire.

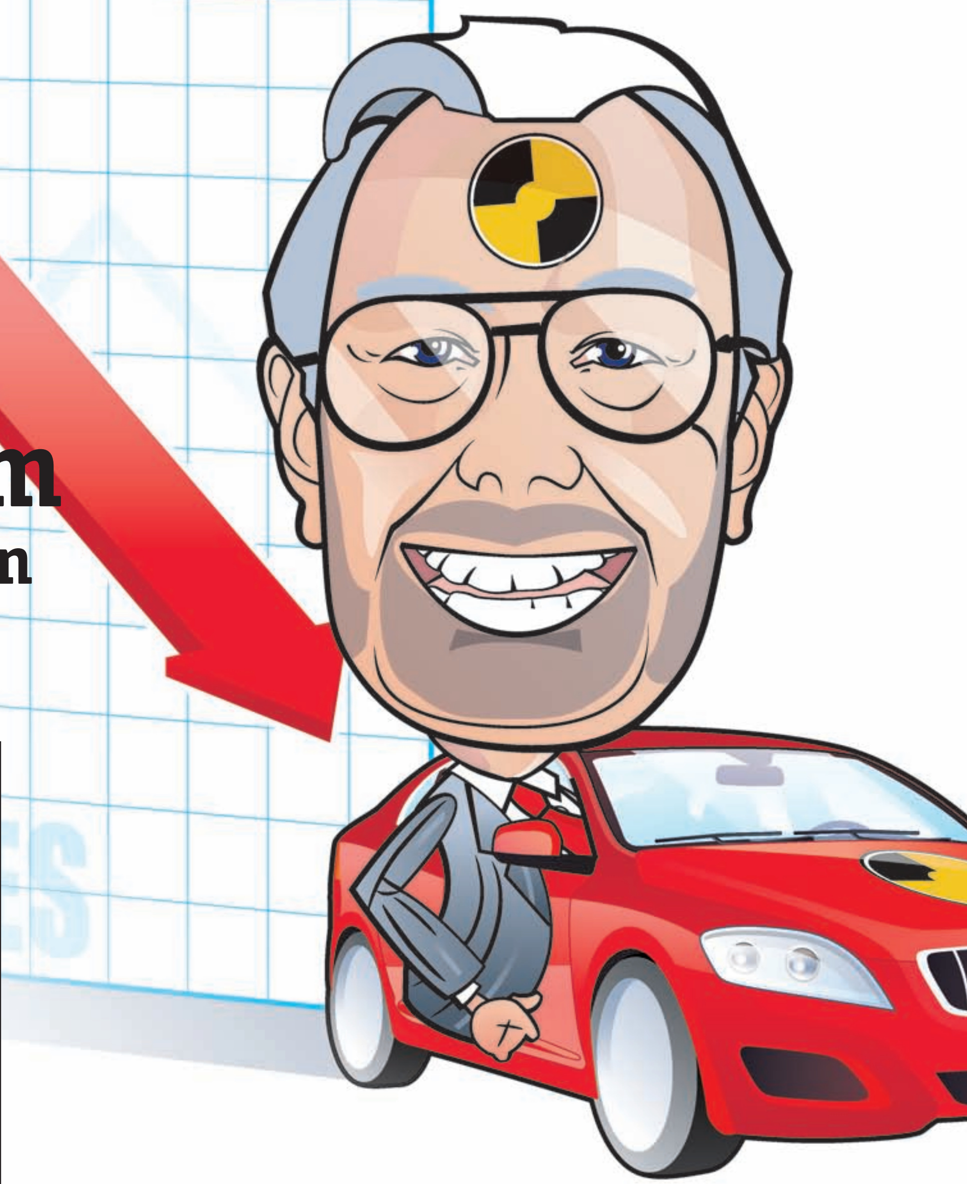
"Judging from the tire dealers I called, very few sizes are carried in stock, so the chances are you will have to wait to get a replacement"

My experience is that you rarely get something for nothing and the standard tire will move ahead in performance just as fast. It's difficult enough developing a chassis with normal rubber, so spare a thought for chassis development engineers at BMW and elsewhere struggling to overcome the stiff sidewalls and the other deficiencies that still appear to be inherent in the concept.

Sports cars and Rolls-Royces are one thing, but I regard a spacesaver or lightweight spare in a family car as a cop out. The small savings in cost and weight will mean nothing to a family on holiday caught with a flat tire in the middle of France. A pressed-steel wheel as a spare is fine, but once you have a reasonable-sized spare, how maddening to be limited to 50mph. As with runflat tires, if you want to drive normally, one is forced to seek out a tire dealer as soon as possible. A sealing-gel-charged inflation canister provided to effect a temporary seal at the roadside assumes there is no serious sidewall damage and that the cigar lighter pump works. This should get you to the nearest tire shop, but the safety implications of such roadside improvisation have always concerned me.

All the punctures I have had over the last decade have been slow deflations of which tire pressure monitoring would have forewarned. For the mechanically fearful or aged, runflat tires are sensible enough, as the reality is fewer such customers care about any dynamic losses. For me changing a wheel is an acceptable price to pay for reasonably decent steering, ride, handling, and not to have to spend hours finding a costly replacement tire.

• *More on runflat tires: pages 22, 62*



US and them

Traffic deaths down

JIM McCRAW HAILS THE ENGINEER'S CONTRIBUTION TO HIGHWAY SAFETY

The US federal government agency, the National Highway Traffic Safety Administration (NHTSA), announced recently that during 2009 the USA had experienced the lowest number of traffic fatalities in 56 years – some 33,963 deaths caused directly or indirectly by car and truck crashes.

The national rate of traffic deaths per vehicle mile traveled declined from 1.25 per 100 million miles traveled to 1.16 – the lowest level ever recorded. Vehicle miles traveled, which declined in 2008, increased by just 0.2% last year as economic activity recovered slowly. That 0.2% increase though, represents some 6.6 billion miles traveled.

According to the agency, traffic fatalities have been decreasing steadily since their peak year in 2005, decreasing by about 22% from 2005 through to 2009 – a span of 15 consecutive calendar quarters.

While we cannot be anything but sad for those 33,963 persons we lost during the year and the families that were shattered by those deaths, we can be very much heartened by this positive trend. What we cannot be too happy about was the mad dash to take the credit following the announcement. The simple truth is that a phenomenon like this one has so many causes that they cannot be separated or analyzed alone. But we're going to try.

Enforcement? Absolutely. Local and state police agencies of every kind and size will be happy to take some of the credit for the vast reduction in American traffic deaths. During the year, they used radar, lidar, lasers and cameras to arrest highway-mounted ne'er-do-wells, with breathalyzers and other tests for the drunk and drugged.

In the process, they reaped millions of dollars in fines and costs, which in turn bought more police cars, more radar, lidar, lasers and cameras to catch more bandits. State governments chimed in with informational campaigns and dire highway warning signs such as "Buckle up Or Pay Up", "Buzzed Driving IS Drunk Driving" and "Don't Drink And Drive" – a lot of lip service that may not have done as much good as state-sponsored driver education.

We have no doubt that there was just as much drunken and drugged driving in the USA during 2009 as there was in 2008, and probably more. We have no doubt that there was also as much speeding as there was before the economy crashed. And we know for sure that, with the advent of cheap smart phones for everyone, there was a huge amount of distracted driving going on. Between hands-on telephoning and texting, the average young American driver was simply not paying due attention to the task at hand, resulting in crashes, injuries, and deaths.

The economy? This is where the number-jugglers chimed in to say that in a down economy people tend to drive fewer miles per year, make fewer individual trips and buy less motor fuel than they otherwise would, simply because they cannot afford to do more driving. A secondary but important effect is that the jobless have no job to drive to and in a place like Michigan, with 15% unemployment, that's another factor to be considered.

> "The integration of ABS, EBD, EBA, traction control, yaw control and rollover mitigation took years to achieve, but is all working beautifully now"

Safer Vehicles? We think this is where much of the truth is hiding. Yes, we freely admit that the federal government has prodded and regulated the automotive industry into undertaking many great changes over the years since the Federal Highway Safety Act of 1966 was passed. Before that, the auto insurance lobby had campaigned for years for changes in minimum automotive safety regulations, as fewer claims meant more profit.

Automotive historians will point out that in the USA, Ford Motor Company was the very first car company to offer real driving safety equipment as standard fitments in its 1956 cars. This included deep-dish steering wheels with breakaway rims to prevent head and chest injuries, padded dashboards to prevent head injuries in frontal crashes, and lap safety belts for front-seat occupants.

So here's to all the engineers that have brought us the designs, materials, technologies and implementations that we now consider everyday automotive safety equipment, with a special nod to those who make our vehicles go, turn, stop and stay right-side-up no matter how hard some drivers try to make them do otherwise.

The complete integration of ABS, EBD, EBA, traction control, yaw control, and rollover mitigation systems has taken many years to achieve, but we are there now and it is all working beautifully to keep us flawed, distracted, buzzed, and drunken human beings intact. Reach around and pat yourselves on the back. And then get back to work. Target: Zero.

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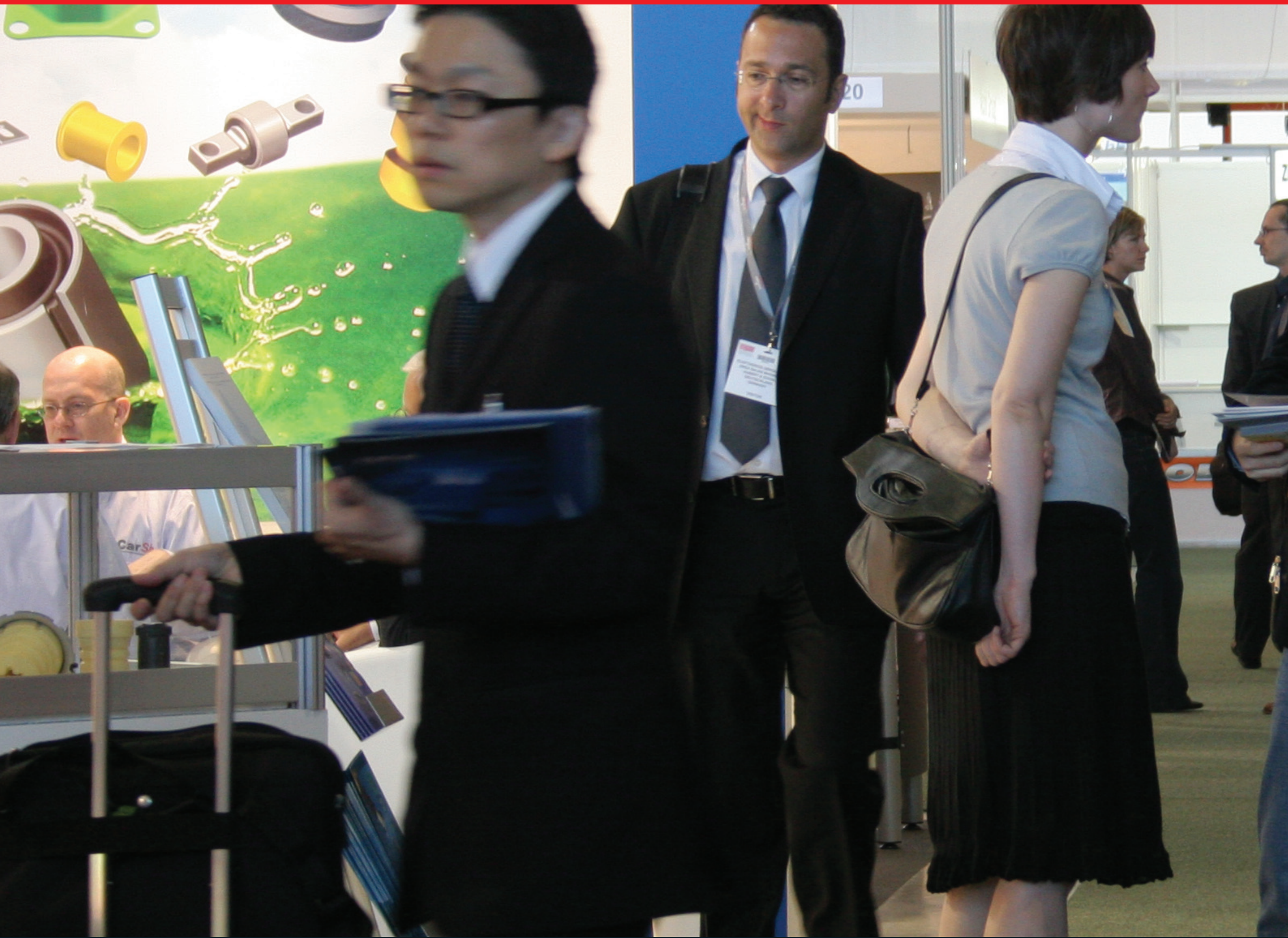

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Air support

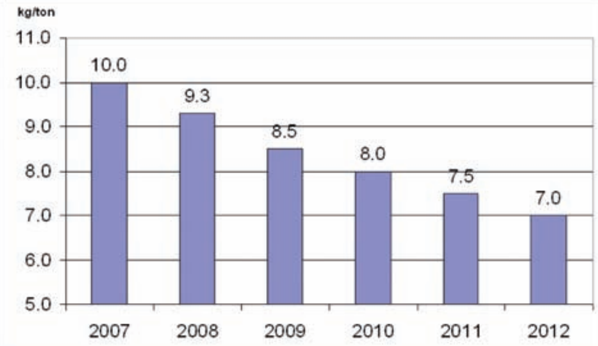
ROGER WILLIAMS REPORTS FROM THE TIRE TECHNOLOGY CONFERENCE 2010 IN COLOGNE ON THE LATEST DEVELOPMENTS IN RUNFLAT TIRE TECHNOLOGY

It has been nearly 40 years since the first commercial introduction of the runflat car tire – the Dunlop Denovo. This tire may have been considered before its time but it was introduced at the time of the original Mini and when thoughts of safety, vehicle weight and fuel savings were important customer considerations.

The difficulties experienced with the Denovo tire were exactly the same as those experienced with the second generation of runflat tires over the last six years. Difficulties included lack of comfort and runflat distance, limited availability, and the high cost of a replacement tire. Yet the attractive ideals of the first Denovo tire remain, including stability control on sudden pressure loss, convenience, personal security, and fuel and raw material savings, leading to reduced CO_2 emissions.

So what have tire designers achieved in the last 40 years? At the 2010 Tire Technology Conference in Cologne, Pirelli's Roberto Sangalli (head of new tire product development) and Giuseppe Matrascia (head of runflat tires) listed the trade-offs between conventional tires and runflats relative to tire size.

PHOTO SEQUENCES FROM BMW SHOWING A REAR TIRE BLOWOUT WITH A RUNFLAT (TOP) **AND A REGULAR TIRE**



GOODYEAR CHART SHOWING THE RUNFLAT'S DECREASING WEIGHT AND ROLLING RESISTANCE PENALTY

These can be summarized as showing a weight increase for runflat tires of between 20% and 8% depending on wheel diameter (the larger the wheel diameter the lower the weight difference). A similar position is seen with the higher rolling resistance of runflat tires at some 14% for 17in to a 6% increase for 21in. Static vertical stiffness is also higher for runflat tires, usually between plus 10% to plus 30%, again depending on wheel diameter and cross section/aspect ratio. These values are superior to the original runflat tires and must be seen in comparison with a trend to increases in tire weight, rolling resistance and reduced comfort of the lower aspect ratio, high cross section and larger wheel diameter.

Pirelli has applied FEA modeling to runflat tire design. Recent runflat design improvements that have originated from FEA modeling include improved compound physical properties and lower tire running temperatures when in the runflat situation. These recent design improvements have led to the increase in fitments with OEMs. However, Pirelli has found that indoor and outdoor tire test results do not correlate. It is felt that indoor test results are not reliable and vehicle test data is inconsistent and expensive to obtain.

The Goodyear view was given by John Renner, project manager. He stressed the key factor that runflat tires can save lives in cases of rapid deflation. Four runflat tires achieve a notable weight saving over five conventional tires and the tire/wheel removal kit. Fewer tires also means less recycling and raw material use. He also gave the view that with the introduction of TPMS, electric and hybrid cars, and smart tires, runflat tires will become more attractive.

Comparing conventional and runflat tires, Renner stated that the disadvantage in terms of weight and rolling resistance is decreasing in the most recent designs (see graph,

Runflats:

Initial indications show that the introduction of mandatory TPMS in the USA has had a positive influence on reducing road accidents. The correct use of TPMS will reduce the frequency of total tire deflations and the instances where the tires runflat ability is called upon. Europe will make TPMS mandatory by 2012.

A number of new tire regulations are also being applied in Europe. These will relate to rolling resistance, tighter controls on chemical substances, noise emissions and wet grip, together with a form of tire labeling. The USA will be introducing new tire regulation proposals this year and Japan has recently announced changes to tire performance identification. Each of these proposals will, following tradition, be claimed by the tire industry as being too tough and by the environmental lobby as not being sufficiently radical. But have they missed the most important step forward – the standardization of the runflat?

We have seen that the third and fourth generation of runflat tires can now maintain an adequate runflat distance for the majority of motorists' needs, a satisfactory level of comfort and near equality with all other tire properties, including rolling resistance. So we have a clear

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THE PIONEERING DUNLOP DENOVO RUNFLAT TIRE (ABOVE LEFT), **FIRST LAUNCHED IN 1970, WAS ORIGINAL EQUIPMENT ON THE MINI 1275GT** (ABOVE) **BY 1973**

the case in favor

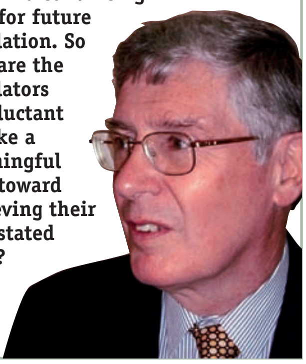
opportunity to introduce by regulation the use of runflats on the vast majority of cars, without additional initial cost to the motorist (five regular tires and wheels being equal in cost to four runflats), with reduced vehicle weight (no spare wheel) and hence a potential CO_2 emissions reduction.

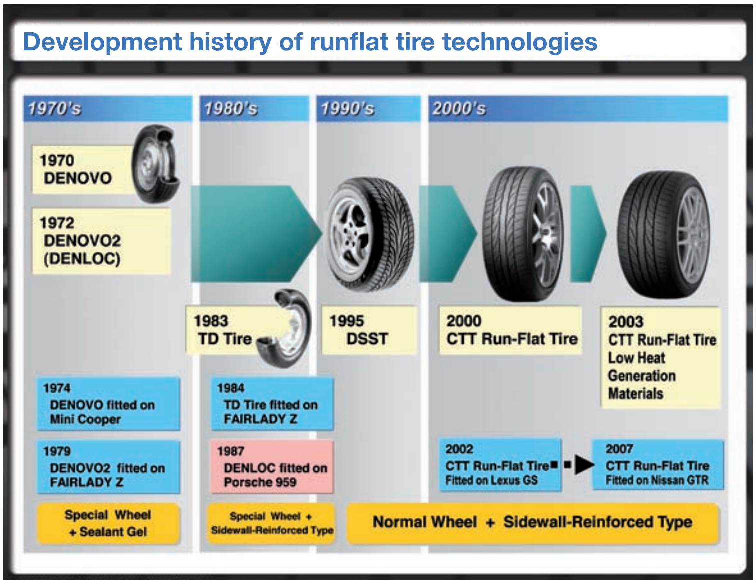
Additional benefits could be in vehicle design, as there will be no need to include a spare wheel well. It is also appreciated that in many countries around the world there are poor roads or no roads at all, journey distances are greater, and replacement tires more difficult to find. Other solutions may be required in such areas but we must consider the greater need for the majority of motorists. In addition, no one seems to have considered the waste in energy and raw materials as a result of the amount of existing spare tires that spend their lives in the trunk of a car until age determines they are scrapped.

The problem of supply has been created in part by the tire industry itself, but very much at the behest of the OEMs. The proliferation of tire sizes embracing aspect ratios, wheel diameters, tire width and prescribed use has greatly complicated the achieving of a good service for replacement tires. If this were to effectively double in complexity, with the introduction of runflat tires as an option, there will surely be problems.

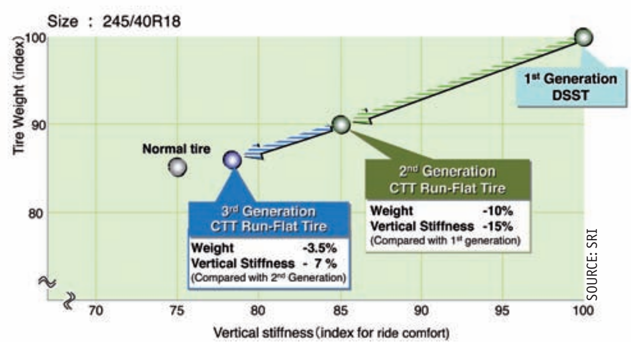
The supply situation will only be improved with runflat tires being offered as the only option for vehicle models. There also needs to be a reduction in size/range complexity, much of which is technically difficult to justify. In other words, the runflat tire needs to be standardized. But if runflats are considered suitable tires for BMW cars in the USA and Europe, and for Mercedes-Benz cars initially in the USA, then surely they are equally suitable for all makes, possibly excluding the heaviest SUVs?

The risk of moving to runflat tires must be considered low in marketing terms compared with the legally enforced regulations to introduce TPMS. The advantages of runflats in terms of safety, convenience and reduced CO_2 emissions, plus the reduction of raw materials, remain a convincing case for future legislation. So why are the legislators so reluctant to take a meaningful step toward achieving their own stated aims?





RUNFLAT DEVELOPMENT TIMELINE COURTESY OF SUMITOMO RUBBER INDUSTRIES, LTD



TOP: **CROSS-SECTION OF AN SRI REINFORCED-SIDEWALL RUNFLAT**

ABOVE: **ALTHOUGH IMPROVEMENTS HAVE BEEN MADE, THE WEIGHT AND VERTICAL STIFFNESS VALUES OF THIRD-GENERATION RUNFLATS STILL TRAILED REGULAR TIRES**

previous page). In terms of comfort, he claimed that the latest runflat tire products are at least at an equal level with respect to conventional tires.

An insight into contemporary runflat design came from SRI's Yasuo Mitarai, assistant manager of advanced technology, who illustrated the recent progress of runflat tires up to the current fourth generation (above). He explained how the challenge to make a completely acceptable runflat tire had initiated the search for new tire designs and the use of novel materials.

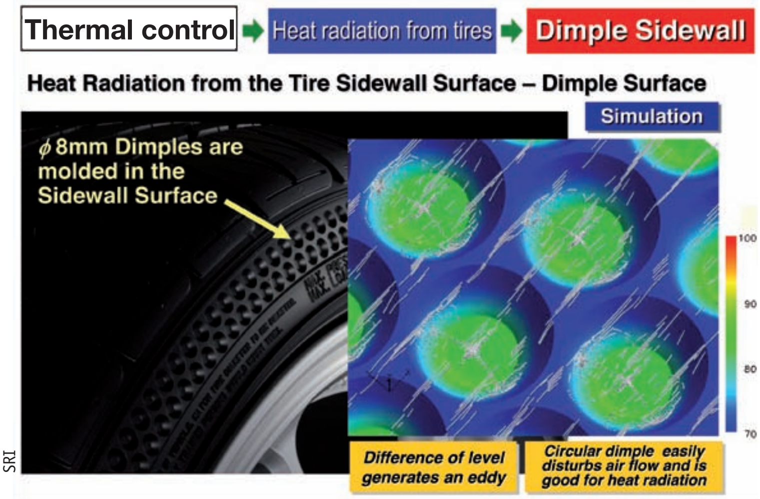
The shape of the tire has been revised to achieve high runflat performance and even advances the other tire properties, yet performs using standard wheels. Use is also made of an aramid cord casing, which, by being stiffer, reduces heat generation and also aids thermal conductivity. Any loss in comfort is compensated for by the tire's unique profile. Thermal conductivity and stiffness in the support components of the tire, when operating in the runflat situation, is enhanced through the use of carbon fibers.

Heat is also effectively radiated from the buttress and shoulder regions of the tire in the both the deflated and inflated modes through the introduction of dimples (right). Tests show that these measures reduce the deflated tire running temperature by 10°C. The runflat distance over previous-generation tires is improved by some 2.3 times.

This technology has allowed the runflat tire weight to be reduced to closely match that of the conventional tire and, it is claimed, provide a higher level of ride comfort.

Chairing the conference session on runflat performance was Hans-Rudolf Hein of Bridgestone, who was an engineer at BMW when the company pioneered the introduction of runflat tires throughout the range 10 years ago. In his opening address he recalled the 2002 forecast that 80% of new vehicles would be fitted with runflat tires by 2013. This forecast now appears too optimistic but Hein called on OEMs to do more to overcome the technical problems that exist so that the virtues of safety, mobility and the potential for new vehicle design can be exploited.

He acknowledged that runflats will be more expensive, reflecting their higher level of technology and performance. Some 80% to 85% of punctures take the form of slow deflations and current runflat tires achieve 500-1,000km (310-620 miles) in the partially deflated mode, depending on vehicle load. Under these circumstances TPMS allows for an adequate warning period and for the driver to take action. Under instant deflation conditions, he continued, runflat tires are a critical safety feature in maintaining stability and vehicle control.



SRI

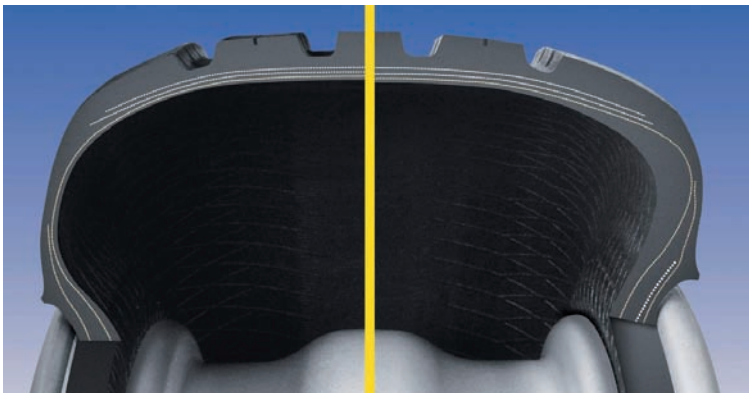
OEMs were also represented at the conference. Dirk Herkenrath, a development engineer at Mercedes, stated that tire problems account for 11% of roadside assistance calls in Germany. Although announcing that Mercedes will introduce runflat tires on all its vehicles sold in the USA, they will remain as an option for Europe. He also stressed the need to maintain vehicle comfort but considered that the third- and fourth-generation runflat tires were comparable in terms of comfort and all other properties (below left). A minimum runflat distance of 50km (31 miles) remains the target.

A rather more critical view of runflat tires was expressed by Hans Becker, manager of chassis, global core steering at Ford, Germany. Reliability of supply, improved handling, reduced replacement cost and fitment on standard wheels were his requirements regarding runflats.

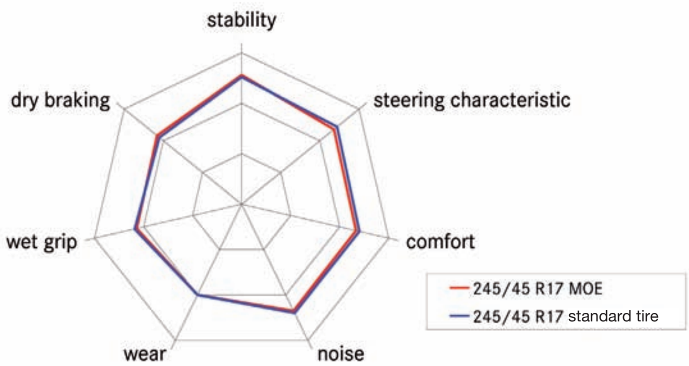
Ford, he explained, has concerns regarding the comfort levels of runflat tires on sporty/firm suspensions. Ford's engineers also believe that runflat tires should be widely available in various tire specifications, such as winter tires. Ford offers runflat tires on four vehicle models but the take-up is only 3%. It is believed this could be 20% with marketing support. Becker also stated that hire fleets prefer a full-size spare tire.

Ford remains concerned about the poorer comfort, rolling resistance, noise, weight and steering control of runflat tires, but sees positive trends with the latest tire designs.

Another problem for Ford is the use of global platforms. It is unlikely that runflat tires will find simultaneous global approval and this will hinder vehicle design improvements that could follow the introduction of runflat tires.



SIDEWALL COMPARISON FROM GOODYEAR/MERCEDES SHOWING STANDARD TIRE (LEFT) **VERSUS RUNFLAT**



STAR PLOT FROM MERCEDES-BENZ COMPARING THE PROPERTIES OF RUNFLAT AND NON-RUNFLAT TIRES

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> **"It's not that we are fond of generating an artificial feeling in the car. Quite the opposite – we try to give the car the most authentic feel, with all these modern, high-tech systems"**
> Jos Van As, BMW

Dutch master

STANDARD TIRES AND FRONT-WHEEL DRIVE? TIMES ARE CHANGING IN BMW CHASSIS DEVELOPMENT. INTERVIEW BY **GRAHAM HEEPS**

Five years ago, *VDI* spoke to BMW's then-head of chassis development, Peter Langen (see *VDI* December 2005). At the time, Langen referred to runflat tires as "a logical development", describing the slow uptake among other OEMs as "a question of body development. The overall system of the car must be able to run with runflat technology because we have higher forces."

Addressing the issue of front-wheel drive versus rear-drive, he argued, "You cannot compare the 1 Series to the Golf or something else, and the customers who bought it accept that. Other companies try to follow us with driving dynamics, but sorry, you have to design in the driving dynamics from scratch. If you start with a front-driven car, with maybe 60% of the weight on the front axle, it's not so easy to come to the DNA situation you need for driving dynamics."

Five years is an eternity in automotive development. In 2010, numerous BMW models can once more be had with non-runflat tires, and the firm is rumored to be preparing several new small, front-wheel-drive models. Time to get the inside line from Jos van As, BMW's director for functional integration – driving dynamics, who reports to Langen's successor, Markus Duesmann.

Van As, a Dutchman with 15 years' service in Munich interspersed with a seven-year spell as manager for vehicle dynamics at Audi, is responsible for chassis tuning on all BMW Group cars. He heads a department of around 100 people and drives development cars two to three days a week, so is right up to speed with his company's latest products. By regularly bringing together chassis teams from the different product groups, he tries to ensure that a common basic understanding of how BMWs should drive is maintained.

Keeping to the 'Ultimate Driving Machine' mantra is more challenging than ever, he says, pointing out that drivers in performance-car-friendly Europe have completely different expectations to, for example, the back-seat customers for a long-wheelbase 7 Series in China, where large, less agile cars remain in vogue.

As ever, BMW is employing an arsenal of the latest chassis technology in order to minimize the compromises that such contradictory requirements dictate. When it's put to him that such systems are creating an ever greater disconnect between the driver and the road, seemingly going against BMW's *Freude am*

Fahren philosophy, Van As mounts a robust defense.

"It's a big challenge but I think we have made big improvements. If we've got these very advanced systems, we try to give the car the most natural feel possible. With Integral Active Steer, you're changing the wheelbase by steering the rear wheels. To begin with, that creates an unusual feeling, but once you're used to it then you're not willing to give it up.

"It's not that we are fond of generating an artificial feeling in the car. Quite the opposite – we try to give the car the most authentic feel, with all these modern, high-tech systems. Making a two-ton 7 Series feel like a [smaller, lighter] 5 Series means the car no longer has a natural feeling because it should feel heavy, but you enjoy it because it's not."

Lotus Super Seven-owning Van As also offers a realistic assessment of the progress of EPS, with the promise of better things to come.

"Compare the electric power steering systems we have on the 5 Series now with the first hydraulic power systems," he says. "Everybody complained that hydraulic steering had no feel, and that it was different to an unassisted mechanical system. We have made some improvements both on the systems side and in how you develop the logic for a mechatronic device to improve the functionality so we can get this identical, authentic feel. It's not something we're neglecting or have sacrificed, absolutely not.

"In an old car, besides the good steering feedback, you feel the shimmying of the front wheels through the steering wheel, you don't have enough damping, there is too much kickback etc. You pay a high price for steering feedback.

"Nowadays those phenomena don't exist any more and you're left with, perhaps, a lack of feel. The good thing is, it's going to be even better. We're improving it; I can't be too precise about it, but you'll be able to try something within two years."

The conversation turns to the thorny issue of runflat tires. Van As accepts that not everyone viewed them as the way of the future, and BMW has had to react accordingly.

"We received a signal from the market that there's both a demand for normal tires, and a demand for runflats," he concedes. "Now we also offer standard tires on the standard wheel size. If you choose an optional tire size you get runflats. At the moment that applies to the 1, 3, and 5 Series, as well as the X1 and MINI.

"It's hard to say whether that will apply to all models in the future. It's not straightforward because there are some markets where you have to have a spare wheel in your car, or that insist on runflats. Other markets don't insist on runflats, so we're trying to stay as flexible as possible."

He adds that a model's base chassis tuning is done for both types of tire, but he believes the gap between the two continues to narrow. "Recently I was driving the MINI Countryman with standard and runflat tires," he says. "And it's hard to know the difference between them." He assures us that the lack of difference between the two is not the result of a too-stiff suspension setup!

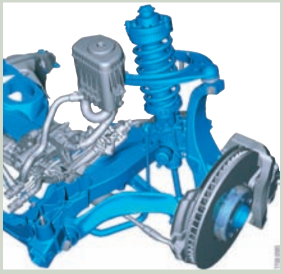
The other retreat from previous BMW dogma concerns front-wheel drive. It's hard to argue with Van As when he takes an entirely pragmatic approach to the issue.

"If you consider in which segments of the market the growth will come, it's mainly in smaller cars," he argues. "We are looking to increase our share in the small-car market. There has been a study that showed that quite a lot of people driving a 1 Series or similar cars don't know whether they've got front- or rear-wheel drive. For people who are buying cars in these segments, issues like interior space and practicality, are more important.

"If we were to create a car with rear-wheel drive, we would have made a car not according to marketing rules, but according to our own rules. We build cars for our customers, not for ourselves. If customer demand goes in that direction, we have to react, but it doesn't mean that we neglect our rear-wheel drive heritage.

"Considering all that, we said let's have a look at FWD. We have some experience now with MINI. For certain future products within the BMW Group, it could be a good option. We're not talking about the classic BMW driver, we're talking about different kinds of customers with different priorities. BMW is more than front-wheel drive or rear-wheel drive: it's an important feature but not the most important."

BYE-BYE FRONT STRUT



BMW's new PL6 platform underpins the 7 Series and just-launched 5 Series. One novelty, compared with the previous-generation architectures, is a choice of two different five-link rear axles: a steel-sprung version for the sedans, and a Vibracoustic air-sprung one for the package-space-sensitive 5 Series Touring and GT models. However, the biggest change is the adoption of a double-wishbone front suspension (above left) in place of the long-standing MacPherson strut design. Van As says there was more to the switch than better camber control.

"Due to the fact that the cars have become bigger and heavier over several generations, we kept having to make the [damper] piston rod thicker to keep it resistant against bending. You end up with quite a large diameter, which has implications for friction. That's in contradiction to a requirement for ride suppleness and absorption etc, because there, friction is poison. If you make a double-wishbone and a damper that is free from the task of guiding the wheel, you can decrease the [rod] diameter, and improve ride comfort."

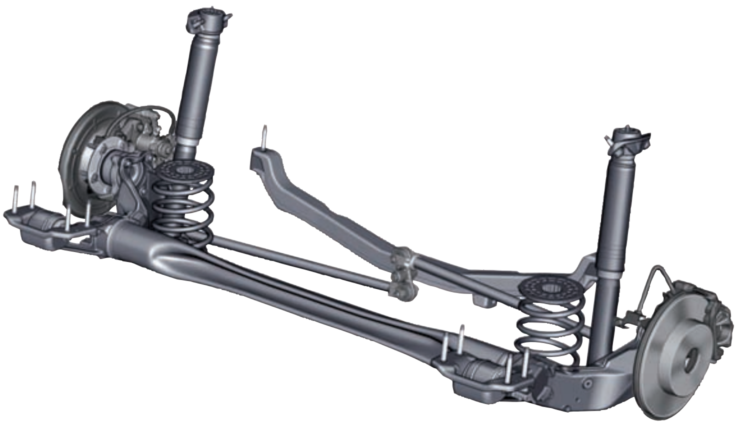
MINI COUNTRYMAN, TO BE LAUNCHED IN SEPTEMBER, WILL COME WITH FRONT- OR FOUR-WHEEL DRIVE

A question of balance

The dynamic benefits of reduced unsprung mass mean that there's never been a bad time for chassis engineers to save weight. But with fuel efficiency and emissions performance now a legislation-driven priority, even the smallest mass savings have taken on a new importance. Meanwhile increasing safety requirements and non-essential features such as glass roofs are continually adding mass back into a vehicle, and usually in a place where the dynamicists don't want it. We asked some experts how best to keep chassis weight under control.

Rüdiger Hiemenz, vehicle dynamics manager, Opel

"Our Watt's linkage suspension (right) on the rear of the Astra (above) is quite a smart idea, giving you the performance of a multilink, or in some respects even more than multilink performance, for less mass and less money. Historically you always took mass out by changing to aluminum. But the smarter way is to have a conceptual lightweight design – to use fewer components. This was one of the drivers behind the Watt's linkage suspension. When we tried a multilink, we couldn't bring the weight down enough to compete with a Watt's linkage design without getting into expensive, exotic materials. Nor is the Watt's linkage suspension at the end of its lightweight development, there's still more weight to take out. And in the future hollow damper rods will be the norm, not special as they are today. Likewise hollow stabilizer bars."



Jerry Hardcastle, VP of vehicle design and development, Nissan Technical Centre Europe

"Using high-tensile steels, as we did extensively in the Qashqai, is a way to take out weight but it's also a way to put cost into the vehicle. With the new Micra (left) we wanted to reduce weight and cost. On this new Versatile (V) platform, the secret to dropping the weight has been looking for any box sections in the construction. We've tended to use a hat section [instead] and not fill in the fourth plain, to get the strength with a weight reduction. We've managed to take 15kg out of the Micra body in white and, spec for spec, between 35-50kg out of the whole vehicle.

"Weight reduction is a virtuous circle: if you can reduce the weight then you can reduce the weight of something else. For example, because the beam suspension on the V-platform is carrying 50kg less than on the existing B-platform, you can reduce the section size of the beam, further reducing the vehicle mass. A common issue is that in the bottom-spec car you still need to carry the strength for the highest performing version, or for something else you might want to do in the lifecycle of the vehicle. For example, if there's a diesel option then you need to strengthen the engine compartment for the extra mass, which in turn builds in extra mass. What we've done on the Micra has restricted it for the moment to three-cylinder gasoline engines. When you do that you can pare everything else down.

"We haven't gone for exotic materials yet in our mainstream cars. In the future I could see us using aluminum hoods and fenders but I don't think we'll go to a full aluminum platform. There's nothing wrong with the concept but the investment required to go there will be huge.

"When it comes to chassis components, it's incumbent on the suppliers to come to us with any technology that they've got; whether we can apply it is another matter. We go to the suppliers and say we want the lowest possible price. You can pay for mass reduction on premium vehicles but it's difficult to pay for it on B- or even C-segment cars. You need to be clear in your mind how much a kilogram is worth, depending on how many grams per kilometer the weight reduction will bring, or if it drops the g/km below a certain threshold."

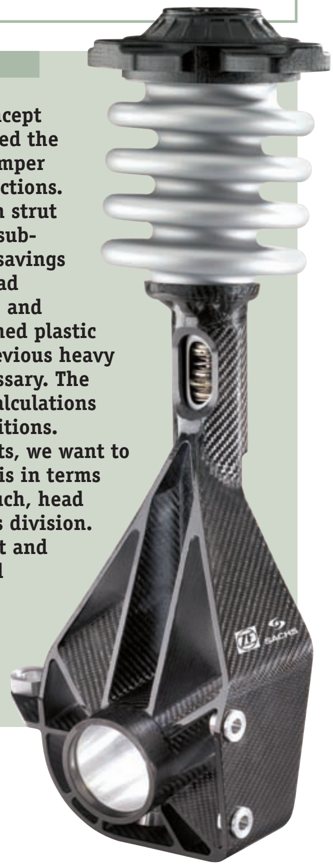
Dr Ingo Albers, ZF Lemförder

"There is some lightweight potential in control arms. We've experimented with different materials; for example we produced an upper control arm for an upper mid-class sedan in magnesium. It's not an easy material to handle, but we made a stable part that shaved a few hundred grams – a weight saving of 15-20%. In the meantime the price of magnesium has shot up so it's no longer reasonable, so now we're talking about plastics, glass-fiber-reinforced composite materials. At the IAA last year we showed a spring made entirely from composites. Composite springs are already available on the market, for example for the Mercedes-Benz Sprinter, but these are not wheel-guiding. We had the spring, stabilizer link, and control arm functions all in one part to save money and weight."

ULTRALIGHT DAMPER

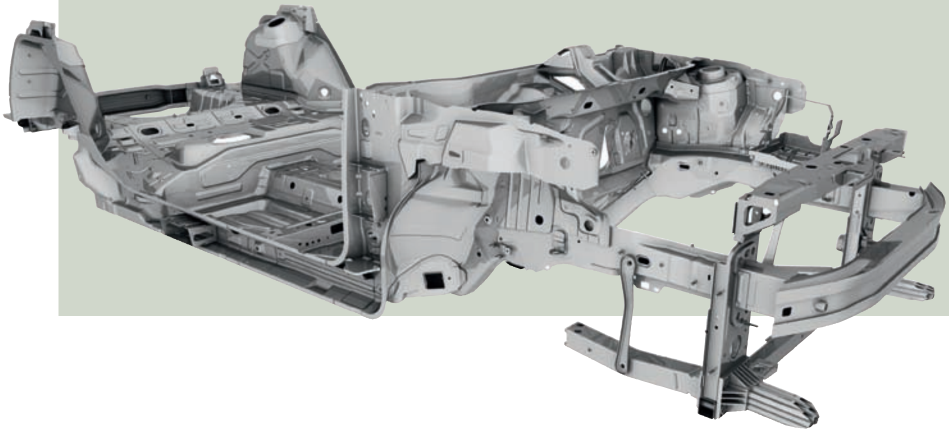
ZF Sachs has unveiled a composite damper concept for sub-1,000kg, A-segment cars that has halved the weight of a current, lightweight aluminum damper by using lighter materials and integrating functions. The Sachs study concerns an entire suspension strut with integrated wheel carrier for small, A- or sub-A-segment vehicles. On the one hand, weight savings are generated by using lighter materials instead of steel parts in the piston rod, internal parts, and module assemblies. On the other, newly designed plastic components that integrate functions make previous heavy steel components, like the spring cap, unnecessary. The functionality has been checked against load calculations based on Western European road-surface conditions.

"With our study on plastic suspension struts, we want to show above all how much potential there still is in terms of lightweight chassis," says Dr Peter Ottenbruch, head of ZF's powertrain and suspension components division. He claims that the design is realistic, with cost and feasibility analyses having shown that it could easily be transferred to volume production.



Philippe Krief, head of chassis and vehicle dynamics engineering and design, Fiat Group Automobiles

"The whole Compact platform [below, on which the Alfa Giulietta is based] has been optimized to reduce weight. From the beginning we had some precise benchmarks regarding the weight of components for the competition. Each system, chassis included, had a very severe target for weight reduction; the target was to be the new class benchmark. That meant reducing the weight of crossmembers, wheels, tires, and the suspension, of course. On the Giulietta's front strut we have an aluminum knuckle to reduce weight. For the multilink rear suspension, the main arm is in aluminum, the crossmember too. We've saved 10kg with respect to conventional multilink systems. This [architecture] will be used across all cars on the Compact platform, albeit with different tuning."



> "You can pay for mass reduction on premium vehicles but it's difficult to pay for it on B or even C-segment cars. You need to be clear in your mind how much a kilogram is worth"
>
> Jerry Hardcastle, VP of vehicle design and development, Nissan Technical Centre Europe

John Heider, VDI columnist and principal at Cayman Dynamics

"The use of lightweight components in unsprung mass has to be done prudently. If you've got a large, single-piece lower control arm that is currently a casting or a steel forging, then yes. Large components that tend to be inefficient from a material perspective present a big opportunity to go to a lightweight material – an aluminum casting or forging for instance. But you can't throw aluminum at something and think it will always be lighter. Once you add in the stiffness, durability, and manufacturing requirements, material is usually added such that there is no guarantee there will be a weight saving, and there's certainly no guarantee there will be a cost saving.

"OEMs tend to go through phases where they're on a weight-reduction kick for a program and immediately investigate aluminum components, adding in high levels of cost. But the reality is that a well-designed, stamped steel part is very difficult to beat when it comes to cost, stiffness, and durability. Certainly when you try to replace a well-designed, deep-drawn, stamped steel two-force member (such as a toe link or other or suspension links) with an aluminum part, as a rule it will look beautiful but the weight saving and cost increase just won't be favorable.

"I've seen a few things that haven't gone so well. There was once a trend to go to plastic stabilizer-bar links, which were disastrous for most manufacturers that tried them. To pass durability they were massive and weighed more than the steel equivalents. The ball joints at either end could never be made to live and the failure rate in the field was tremendous."

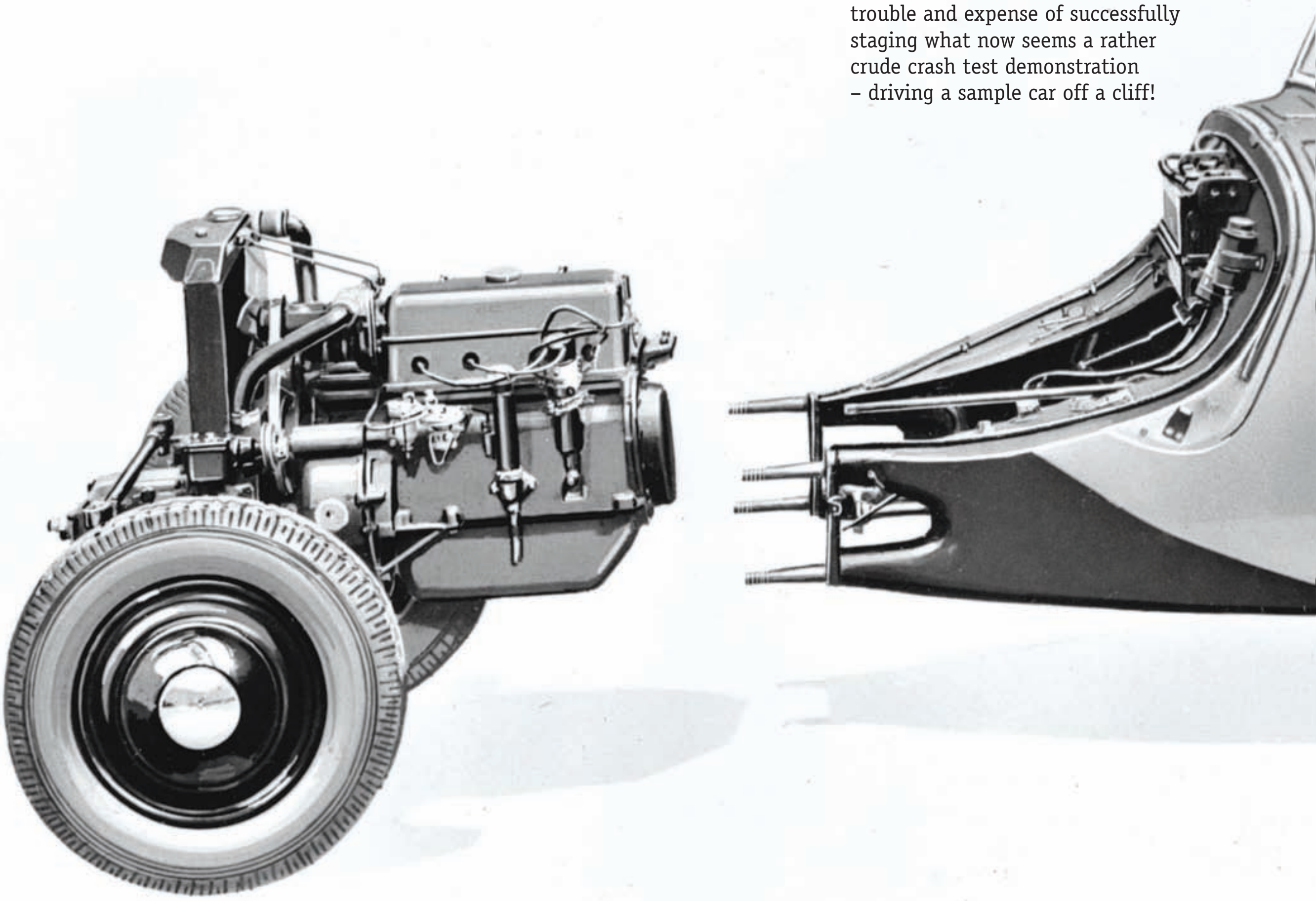
One-piece wonder

THE FRONT-WHEEL-DRIVE, STEEL-MONOCOQUE CITROËN TRACTION AVANT WAS A WEIGHT-SAVING PIONEER. **MICHAEL SCARLETT** LOOKS BACK AT A HUGELY SUCCESSFUL DESIGN

The Citroën Traction Avant was first launched in April 1934. Traction Avant is French for front-wheel drive; although it was not the first-ever front-drive car – it was preceded by the Alvis of 1928, America's Cord L29 in 1929, and Germany's DKW F1 in 1931 – it may however claim the position of the first front-wheel-drive, steel-monocoque, mass-production car.

Designed by Citroën's André Lefèbvre and Flaminio Bertoni, the Traction Avant's arc-welded, chassis-less unitary body was revolutionary at a time when the norm was to have a body, not usually load-bearing, mounted on a frame chassis. Such monocoque construction is of course the norm today, as it has been for some 60 years. Its great advantage in 1933 was weight-saving, with the vehicle-load-bearing body providing all the strength and stiffness of the car more efficiently than the body-on-chassis type of construction.

The potential for a better ratio of strength- and stiffness-to-weight from a steel monocoque body compared with traditional body-on-chassis design was not recognized by many contemporaries of the Traction Avant. Citroën actually went to the trouble and expense of successfully staging what now seems a rather crude crash test demonstration – driving a sample car off a cliff!



The layout of the design centered on a longitudinal engine mounted within the wheelbase behind its transmission, the latter beyond the differential placed in-between engine and gearbox.

Suspension was relatively novel, with the rear using a steel beam dead axle, sideways-located by a transverse Panhard rod, and longitudinally by trailing links on each side, each sprung by its own torsion bar, and pivoting from a crosswise 76mm-diameter steel chassis tube. In front, however, the car had an independent setup with unequal-length upper and lower wishbones; these wishbones were also sprung on torsion bars.

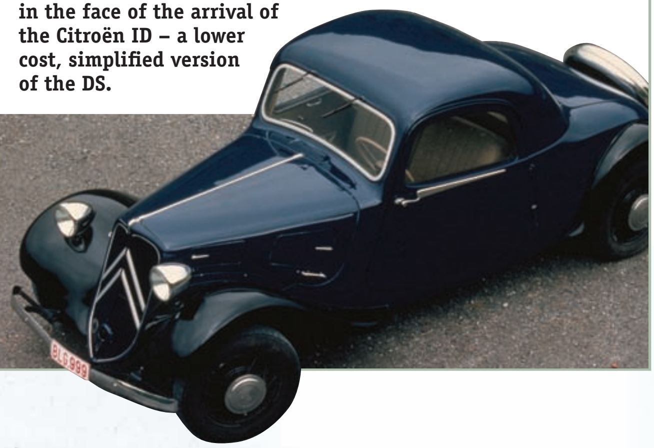
Steering on the early cars was via a cam-and-gear steering box, which tended to allow some sloppiness and play in the steering wheel. So about a year after the car's first appearance, the Traction Avant gained a rack-and-pinion system. Another post-launch modification was the adoption of hydraulic dampers in the front suspension. Brakes, meanwhile, were of the hydraulic drum type.

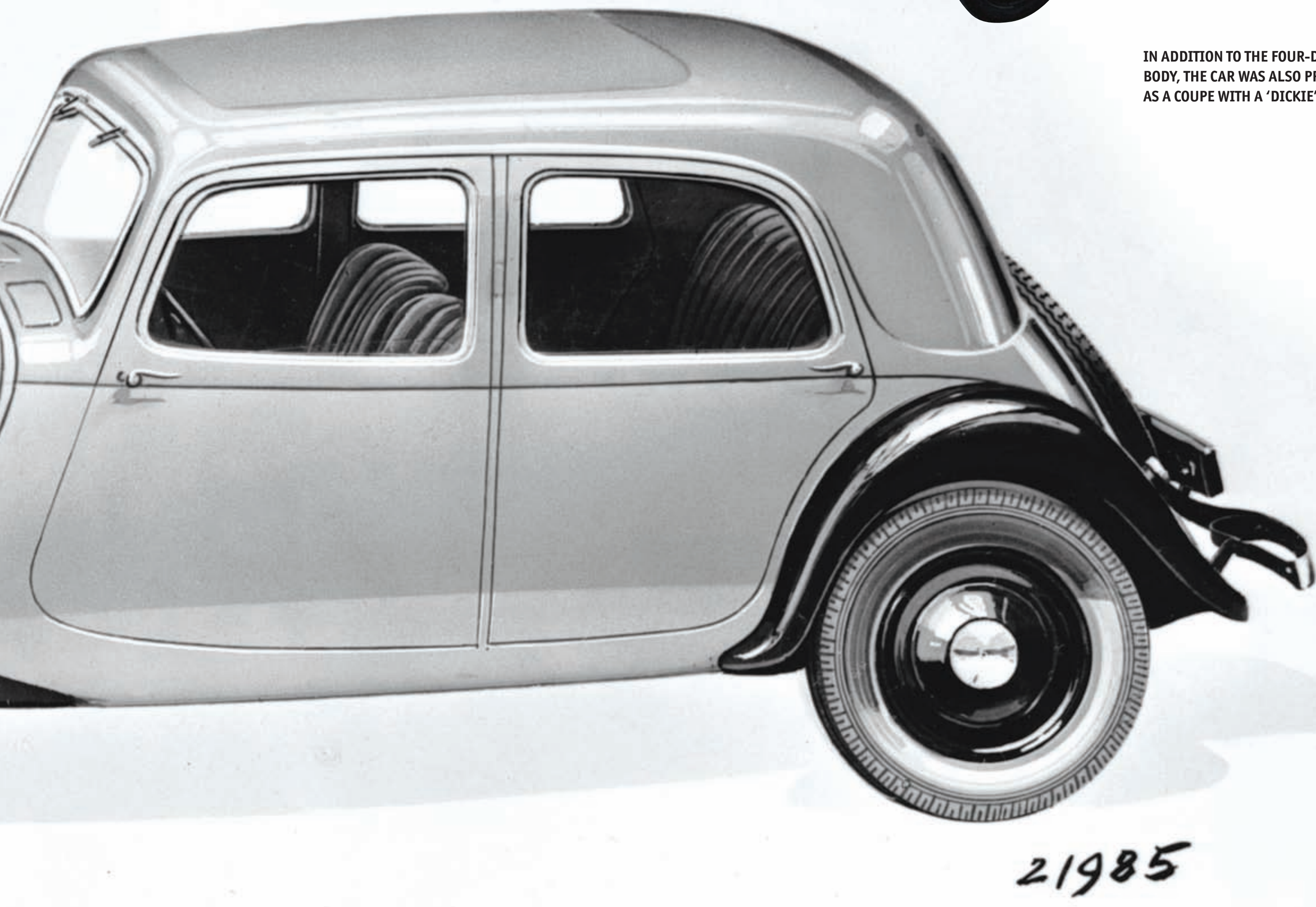
The car incorporated a number of other details of note, which made it stand out from its contemporaries. One such feature was the use of rubber engine mounts, which largely insulated the occupants from engine vibration. André Citroën had in fact first introduced such mounts into an earlier model, using a Chrysler patent. Another engine attribute was the use of wet cylinder liners.

Inside, the car had the gear change set in the dash, its lever sticking out through an H-shaped gate. With this vertical position, Citroën recognized that the 'box could possibly drop out of the two upper positions in the H, for second or reverse, so they devised an arrangement where the gear change was locked when the clutch was engaged, and unlocked

Traction Avant production

Production of the Traction Avant expanded internationally to additional plants in three neighboring countries: Forest in Belgium, Cologne in Germany, and Slough in England – the last of course in right-hand-drive form. Highest production numbers outside the Paris factory numbered 31,750 built in Forest, 26,400 in Slough, and – not surprising in view of the interruption made by World War II – just 1,823 in Cologne. Manufacture of the car continued over 23 years, during which 759,111 examples were built up to July 1957, when it ended in the face of the arrival of the Citroën ID – a lower cost, simplified version of the DS.





IN ADDITION TO THE FOUR-DOOR BODY, THE CAR WAS ALSO PRODUCED AS A COUPE WITH A 'DICKIE' SEAT

"It is said that André Citroën himself thought that speed and performance were of little concern, which may explain why the first Traction Avant was powered by 1,303cc engine"

AUTOMATIC NOT FOR THE PEOPLE

The birth of the Traction Avant was a somewhat shaky affair. Citroën himself was always keen on potentially unique selling points. One was the idea of issuing the car with an automatic transmission, based on the Sensaud de Lavaud design, an early form of CVT, but this proved to be premature in terms of reliability in the somewhat rushed context of the time available.

automatically when the clutch was disengaged for a gear change.

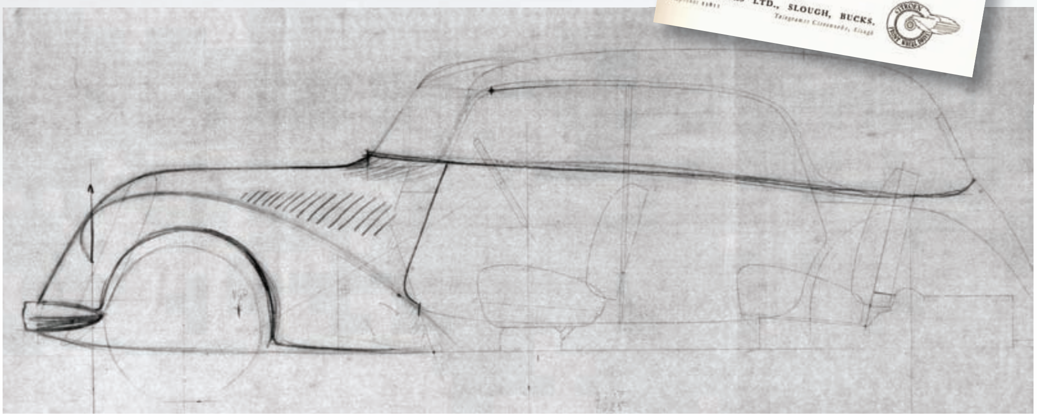
A bench front seat, an umbrella-handled handbrake, and top-hinged pendant pedals kept the floor clear and further enhanced the spaciousness of the cabin.

From the outside, the car stood out among others with its low build, so that there was no need for running boards to aid stepping in or out – a feature that was popular with most customers, and appealed strongly to people running taxis and limousines.

It is said that Citroën himself thought that speed and performance were of little concern, which may explain why the first Traction Avant, the 7A, was powered by 1,303cc four-cylinder pushrod ohv engine. This was surely helped by the car's relative lightness, but only enough for a maximum speed of around 60mph. The model number referred to the French fiscal horsepower rating, similar to the somewhat smaller RAC horsepower rating used in the UK before World War II.

It's little wonder then that Citroën, only two months after the car's first appearance, introduced the 7B with a 1,529cc engine. The 7C with a 1,628cc unit came in October 1934, while in the following month, the company brought out the 11 model, driven by a 1,911cc four-cylinder. Customers keen for more power now had to wait until the 15 version, with a 2,867cc straight-six, which made its debut in 1938.

It sounds rather contrary to André Citroën's attitude to speed and performance that another project conceived in the Traction Avant's first year was a 3.8-liter V8-engined luxury version. Apparently some 20 prototypes were built, but the idea was stillborn by the bankruptcy of the company in late 1934 due to the costs of design, production, and the redevelopment of the factory, of and for the new model, resulting in Citroën's takeover by Michelin.



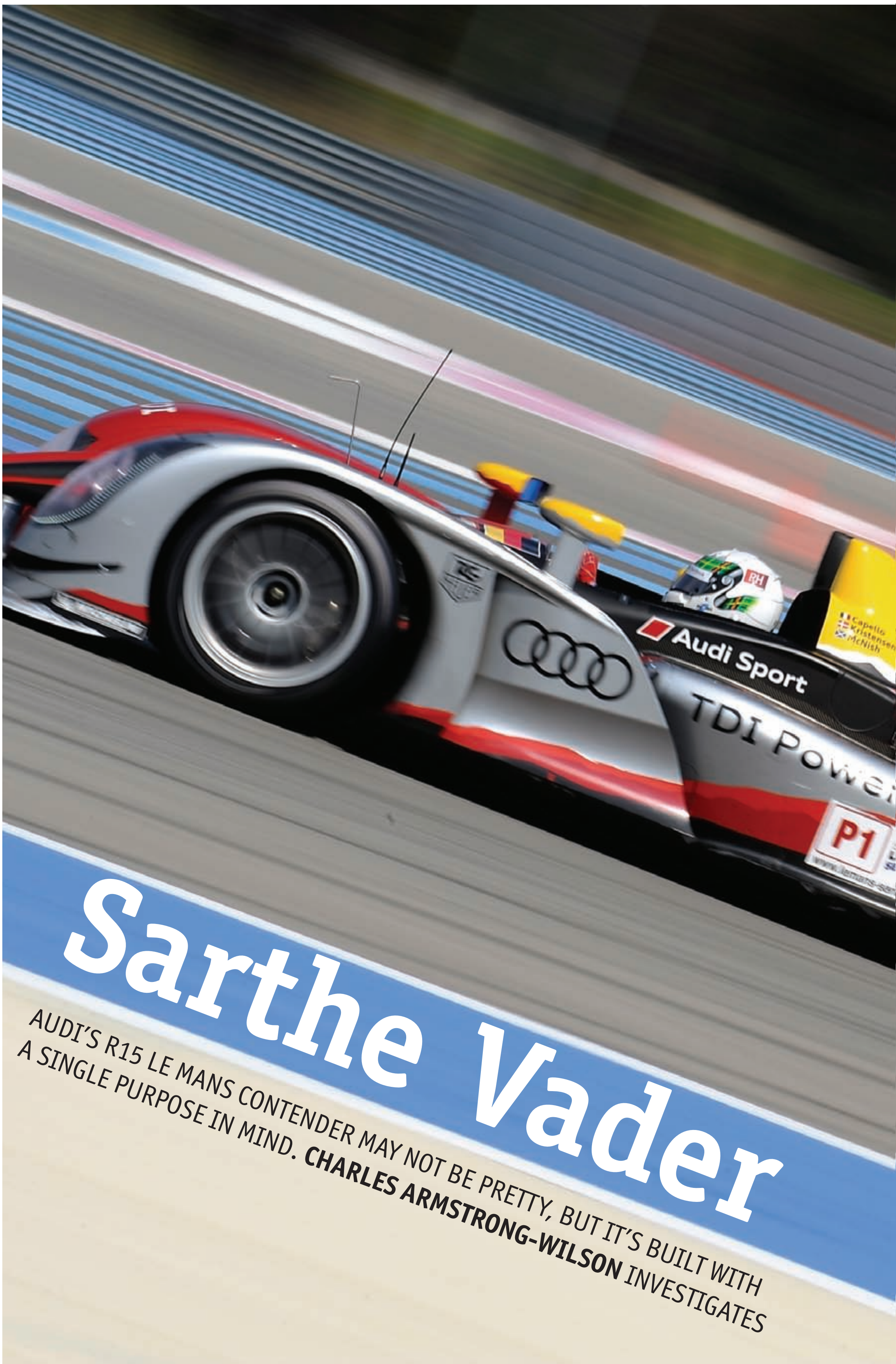
CLOCKWISE FROM ABOVE: **TRACTION AVANT CONVERTIBLE IN THE CITY OF ITS BIRTH; EARLY DESIGN SKETCH; CLASSIC DOUBLE-CHEVRONNED CITROËN RADIATOR ON A UK CAR**

The tire giant would own Citroën for the next 42 years, initially running it as a research laboratory, notably as a test bed for radial tires, and new automotive engineering development.

Under Michelin, the Traction Avant flourished, with a number of further evolutions. There were some comparatively early detail changes in the design: trunk access, for example. The original access from inside the car via a lifting rear seat was altered to the more convenient external trunk lid.

The car's original design was a four-door sedan, but that encouraged the concepts of a two-door coupe with so-called rumble seat for an extra passenger in the trunk, an open top convertible, and the extended wheelbase Familiale with three-row seating. A hatchback Commerciale was launched in 1939 that had a tailgate in two parts, the lower part carrying the spare wheel; a one-piece tailgate replaced this in 1954 when production resumed after World War II.

In that same year, experiments with hydropneumatic technology bore their first fruit, in the Traction Avant 15H variant, which had hydro-pneumatics harnessed for the rear suspension as a ride-height-adjusting addition, in part as a proof-trial for the Citroën DS due to launch in 1955 (see *VDI*, Oct/Nov 2005).



Sarthe Vader

AUDI'S R15 LE MANS CONTENDER MAY NOT BE PRETTY, BUT IT'S BUILT WITH A SINGLE PURPOSE IN MIND. **CHARLES ARMSTRONG-WILSON** INVESTIGATES

Audi's R10 LMP1 sportscar was very much an engine-led design. The V12 diesel-powered car was effective enough to win Le Mans, but the team was working around some serious dynamic limitations. Its engine was comparatively big and heavy and put too much rearward weight bias on the chassis, increasing rear tire wear, and compromising the aerodynamic package.

The balance of aero downforce needs to mirror the weight distribution, so although more negative lift could have been generated at the front of the R10, the rear-biased weight distribution dictated that the total was limited by the amount that could be found at the rear. To avoid a repeat of this situation, the Ingolstadt firm changed its strategy.

"With R15, we showed the chassis team pretty early on what we wanted to do," says Audi Sport's head of engines, Ulrich Baretzky. "They asked us to make a shorter, lighter engine, so we removed two cylinders."

The resulting R15 V10 engine even retains the V12's 90° bank angle, even though 75° would have made more sense for a V10. But, being a diesel engine, it revs much slower than a gasoline race engine, so such subtleties are not an issue. Meanwhile its higher torque – more than 1,000Nm – puts an enormous strain on the input gears in the transmission. However, once the drive arrives at the rear axle (with the revs stepped up and the torque reduced), its effect on the vehicle dynamics is no different to that of a petrol engine.

AUDI'S UPGRADED R15 PLUS WON FIRST TIME OUT AT LE CASTELLET IN APRIL 2010, DRIVEN BY ALLAN MCNISH AND DINDO CAPELLO

To help the weight distribution, the smaller unit in the R15 could now be mounted further forward and lower than in the R10. This improvement was supplemented by shifting the radiators, and anything else that could be moved, further forward in the chassis. But this gift to the chassis engineers was more than offset by the new demands of the aerodynamicists (see *Aerodynamics*, below). Flowing so much air through the car put pressures on the packaging.

Like any top sports prototype, the Audi R15 is based on a carbon fiber composite monocoque, which was designed by Audi Motorsport in Ingolstadt and manufactured by Dallara in Italy. However, with the greater concessions to internal airflow, the design team was under great pressure to reach the same weight and stiffness targets previously achieved on the R10, without being able to use all of the available space within the R15's silhouette.

In particular, the front crash structure mandated by the rules would have blanked off the airflow into the middle of the car. After a little head scratching, the engineers came up with the idea of twin crash structures mounted either side of the orifice, satisfying the rules and the airflow. The R15 also features a narrower cockpit than the R10 in deference to the airflow. Not only has this ruled some of the larger-framed drivers out of consideration, but also raised issues about access. Endurance racing features regular driver changes that have to be completed quickly and

> "With the R15, we showed the chassis team early on what we wanted to do. They asked us to make a shorter, lighter engine"
>
> Ulrich Baretzky, head of engine development, Audi Sport

Aerodynamics

The R15 is the most aerodynamically led racing car Audi has built and this factor has put pressure on all other areas of the car. According to Jo Hausner, work on the DTM R14 showed that considerable advantage could be gained by taking much of the flow inside the car. Extensive ducting of air through internal tunnels enabled a variety of aerodynamic concepts to be exploited. At the front, a broader nose gives access to air entering straight over the front wing and onto the leading edge of the flat floor. Air entering the front of the car, either side of this duct, is funneled through radiators, out of gills on the top of the sidepods, and over the long engine cover and tail, feeding the rear wing. However, some of the flow re-enters through ducts just ahead of the rear wheels, flowing between the rear wheels and the transmission, to emerge at the extreme end of the tail, beneath the rear wing. The result is a much improved lift/drag ratio – at 250km/h, the car generates 1,100kg of downforce from its 10m² plan area.

R15'S COCKPIT IS NARROWER THAN THE R10'S, RULING OUT BIGGER DRIVERS AND DEMANDING EXTRA DRIVER-CHANGE PRACTICE

faultlessly, so the drivers were given more practice in pitstop drill.

A key objective of the R15 was to reduce rear tire wear. Already an issue on the R10 with its rear weight bias, this became more pressing in 2009 as the Le Mans organizers introduced a rule that only one tire gun could be used during a pit stop. This was designed to penalize the more powerful, high-downforce cars in an attempt to level the field. In reality, it meant tire changes were expensive in lost time and the more stints cars could run without changes of tires, the better. Tire supplier Michelin was already addressing this challenge with its new tires for 2009, but Audi also aimed to tackle it in the design of the car.

In addition to the improved weight distribution, Audi lengthened the wheelbase of the R15 and the suspension was extensively reworked. The wheel rims were redesigned to move the mounting flange nearer their center, improving stiffness. Likewise the main unsprung masses, the uprights and brake calipers were moved closer to the center of the car, resulting in shorter wishbones that were also lighter and stiffer. The 14.5in-wide rear wheels run a modest 1° of negative camber, with 1.5° on the 13.5in-wide fronts. However, the R15 runs a sizeable 15° of castor and 10° of kingpin inclination, helping keep the kingpin offset to just 30mm.

With all that castor and huge rims, the R15 understandably runs an electric power-assisted steering system, although Audi is unwilling to share the name of its supplier.

In addition to the normal spring-damper units all around, operated by pushrods and rockers, the car also has third spring-dampers front and rear to handle the aerodynamic loads. These were developed by Audi in collaboration with Öhlins. This careful design work was a move in the right direction on paper, but it was when the car hit the track that the problems began.

"It was the difference between theory and what happens on the track," says Jo Hausner, the man responsible for testing all Audi's sports racing cars. "Simply put, the data you get from a wind tunnel is not the same data you get from track testing. Normally when we start testing a car around Christmas, we've got at least two or three tests for us to find a setup, to find the best possible configuration, and then do the endurance tests. Last year we were caught out because we had trouble: little things engine-wise, gearbox-wise, suspension-wise. We were in the pits most of the time."

The resulting lack of intimate understanding of the car was to dog Audi for most of the 2009 season. It picked up a win at the beginning of the season in the Sebring 12 Hours. However, that was largely due to the Peugeots faltering, and the French car's quickest lap was nearly a second faster than the Audi.

"There are some delicate things on these cars and on this concept, and that's what we had to sort out," explains Hausner. "The R10 was still a conventional sportscar type in terms of its bodywork and its aero, but this car is now completely different."

Even by the time of Le Mans in June, a full understanding of the car still eluded Audi. It was all down to knowing how to balance spring, damper, and stabilizer bar rates to subtle aerodynamic adjustments. As much as anything, the challenge was to maintain a stable platform for the aerodynamic systems to function as intended. Eventually the team cracked it, but too late to win Le Mans. Now, with a fuller understanding of how the R15 works and an upgraded 'plus' model on the track, Audi is more optimistic about its chances for 2010.

"Third spring-damper units front and rear were developed by Audi Sport in collaboration with Öhlins"

DRIVER'S EYE – ALLAN McNISH

The R15 is a lot lighter and more agile to drive than the R10 and obviously it's a lot quicker. The weight distribution really helps, but there are negatives of every weight distribution – whether it's forward or rearward or whatever – there's always a compromise. But the aero has been a big improvement. I think the car has had a wee bit of a bad rap because of Le Mans in '09. We won in Sebring and we were positioned to put Peugeot a lap down in the wet in Petit Le Mans. Ultimately, the race got stopped, but we were sitting with them without drama.

Le Mans aside, I don't think it was a negative year for the car. Unfortunately, with the result at Le Mans, it had a lot of attention focused from outside saying that it wasn't quite as good as the R10. But the facts of the matter are that it was significantly quicker.

SPECIFICATIONS

Audi R15 plus

Chassis: Carbon fiber with aluminum honeycomb

Engine: 5.5-liter, 90° V10; four valves per cylinder, DOHC; 2 x Garrett turbochargers, 2 x 37.9mm engine air-intake restrictors, maximum turbo pressure of 2.75 bar absolute; diesel direct injection; 2 x Dow Automotive diesel particulate filters; dry sump

Electrics/electronics: Lithium-ion battery/Bosch MS 14

Max power: more than 600bhp

Max torque: more than 1,050Nm

Transmission: RWD. Sequential, pneumatically operated five-speed Xtrac gearbox; mechanical locking differential; traction control

Steering: electric rack and pinion

Suspension: Independent front and rear double-wishbone suspension, pushrod system with torsion bars and adjustable dampers developed with Öhlins

Brakes: Hydraulic dual-circuit braking system, monobloc light alloy brake calipers, front and rear ventilated carbon fiber brake discs, driver adjustable infinitely variable brake-balance

Wheels: OZ forged magnesium. 18 x 13.5 (F), 18 x 14.5 (R)

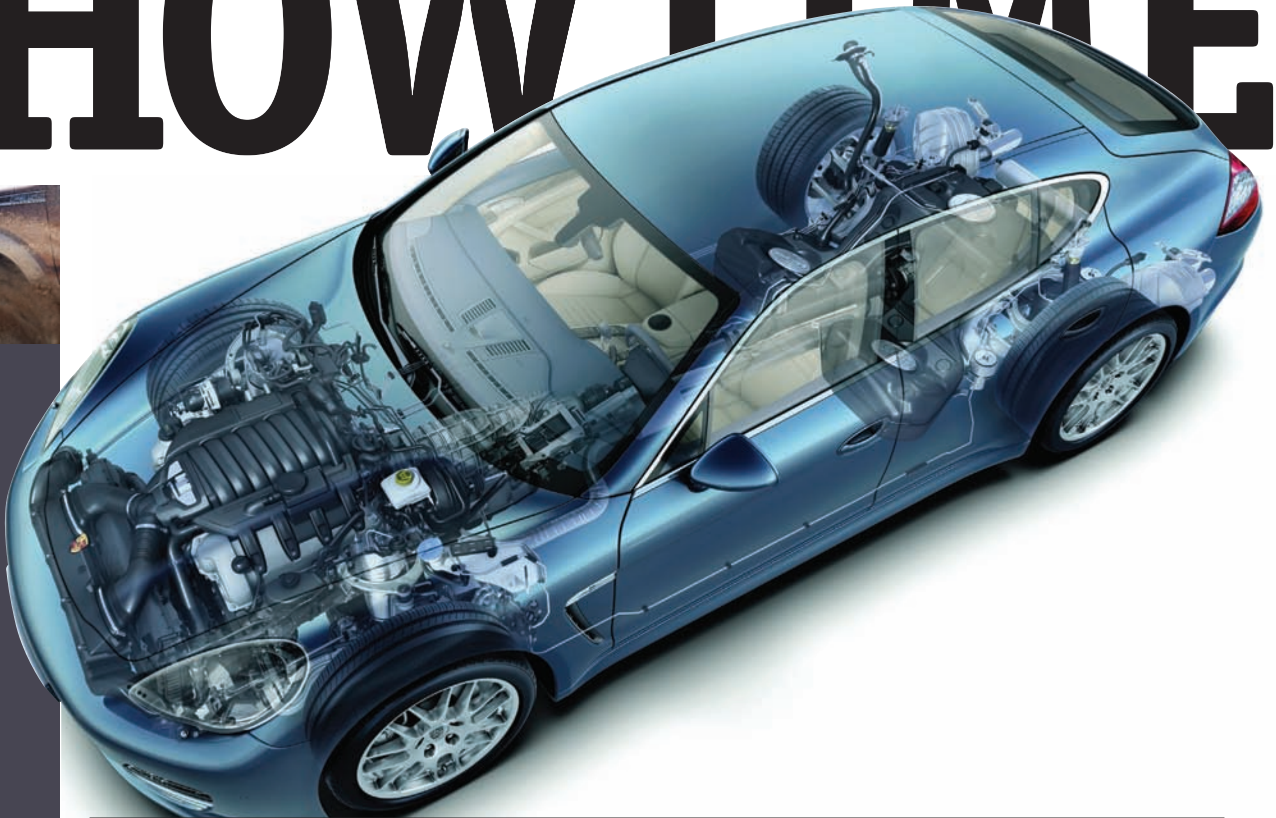
Tires: Michelin; 33/68-18 (F), 37/71-18 (R)

Dimensions: 4,650mm (L) x 2,000mm (W) x 1,030mm (H)

Fuel cell capacity: 81 liters

Weight: 930kg

SHOWTIME



FORUM:

FREE-TO-ATTEND FORUM
40 leading vehicle dynamics experts outline their very latest concepts and technologies

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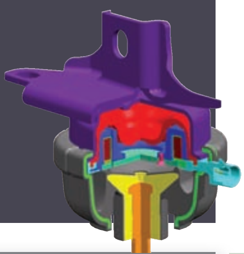


VEHICLE DYNAMICS EXPO RETURNS TO MESSE STUTTGART ON JUNE 22-24

Vehicle Dynamics Expo returns to Messe Stuttgart on June 22-24. Awaiting visitors will be the latest product and service technologies from industry-leading companies, together with a superb, free-to-attend Open Technology Forum. Nowhere else is there such a concentration of the latest innovations in suspension, steering, braking, and ride and handling!

There is a strong OEM presence in this year's Open Technology Forum. Held across all three days of the show, it will feature presentations from Fiat, Jaguar Land Rover, and Nissan. Porsche and Continental have hooked up to talk about the Panamera's closed-air suspension system (pictured above), and BMW and VI-grade will together speak on the subject of a single-driver model for multiple simulation tasks.

Naturally, there will also be presentations from leading suppliers such as Magna Steyr, ZF Lenksysteme, and Applus+ Idiada, as well as universities including Cranfield, Monterrey, and Lawrence.

Surrounding the conference area will be a wide selection of leading suppliers to vehicle dynamics engineering. This year's exhibitors come from across the spectrum: everyone from top Tier Ones including Tenneco and BWI Group, to specialists such as Vorwerk Autotec and Ixetic, plus development and test players including Add2, Tesis, and fka will be in Hall 3 at Stuttgart's New Trade Fair Center. It all adds up to make Vehicle Dynamics Expo 2010 the crucial event for anyone involved in chassis engineering and tuning.

WHO TO MEET

Karsten Landwehr,
Key account manager,
Ahle Springs
STAND 5710

PU name change

Following the introduction of the BASF corporate brand for European polyurethane sites, the names of the Elastogran companies have also been changed. Elastogran GmbH, with its head offices in Lemförde, is now known as BASF Polyurethanes GmbH. The name change has not affected existing agreements such as customer contracts. The Elastogran name lives on in the BASF brand PU Solutions Elastogran, which has been launched throughout Europe. It stands for the polyurethane system and specialty elastomer specialist's 40+ years of experience. "The change is an important indicator of BASF's commitment to its European PU business," says Jacques Delmoitiez, president of BASF Polyurethanes.

STAND 5540

EMPT systems

The need for tubular lightweight structures is becoming more and more evident, and expo exhibitor PSTproducts GmbH offers very advanced machines for the joining, welding, cutting, and forming of automotive tubes. Electromagnetic pulse technology (EMPT) is now available for automotive applications and is used commercially.

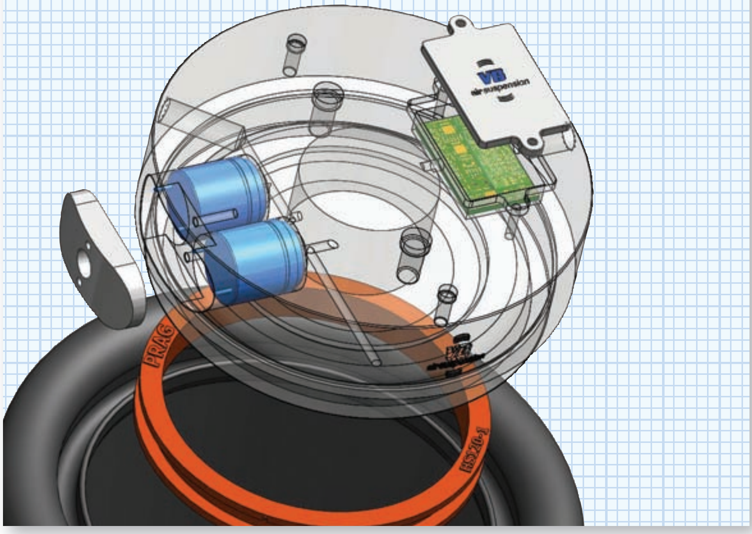
STAND 5500

Air suspension debuts

At Vehicle Dynamics Expo 2010, VB-Airsuspension BV (VBA) will be exhibiting in conjunction with Fludicon. Together, the two companies will be showing VB-eRRIde. In addition, VBA will be showing its new VB-ASCM (above) and VB-AOWS systems.

Based in Varsseveld, the Netherlands, VB-Airsuspension develops, manufactures, and markets components for OEMs and is an aftermarket solution supplier. Its range of products includes LCV air suspension systems and other suspension-related parts. Using a range of modules developed over the years, these parts are controlled by a VB-ASCU (VB-Air Suspension Control Unit).

VB-Airsuspension specializes in developing low-volume LCV front- and rear-axle air suspension systems.
STAND 5525



Conversion tool

Expo exhibitor AMET has announced the first release of AutoConvA2C, a fast and automatic converter of Adams/Car vehicle models into CarSim.

According to AMET, some of the most important features of AutoConvA2C are that it is easy to use, fast, and flexible. Moreover, each subsystem conversion can be monitored with visualization of parameters and tables. CarSim parsfiles for the whole vehicle model and single subsystems are automatically generated. There's also an integrated validation section, to launch batch simulations in both packages, and compare their results.

Claimed benefits of the new product are a huge time saving for the conversion procedure, from weeks to minutes. Uncertainties associated with a manual conversion procedure are also avoided.
STAND 5200

Chassis benchmarking

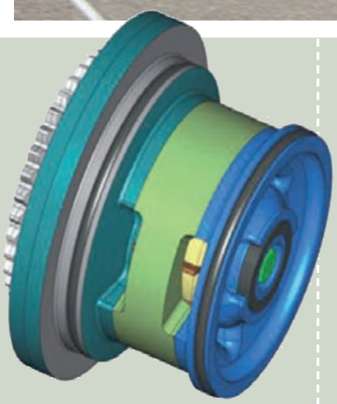
Benchmarking of chassis systems means a methodical comparison of chassis systems by objective and subjective values. Therefore fka provides chassis systems benchmarking as an engineering service for OEMs and automotive suppliers. The benchmarking process includes the objective investigation of full vehicle parameters on test benches and during on-track tests, as well as a subjective assessment by experienced test drivers. On a component level, the benchmark includes the investigation of damper and tire characteristics and a detailed design analysis of axle components. The results of these investigations enable a detailed comparison and assessment of the different vehicles and the chassis systems.
STAND 5725

New control system

Drive-Rite Air Suspensions will show its Generation II IntelliRide air suspension for use on vehicle applications. Drive-Rite's IntelliRide is an air suspension control system that can be adapted to meet the most specific needs of the OE vehicle manufacturer or converter. Designed and engineered to optimize air suspension performance, the electronic control unit reads and adapts to road, vehicle, and driver inputs to maximize air usage. IntelliRide has been certified by VCA and EU standards to meet the harshest environmental and electromagnetic conditions, and is approved by a number of OEMs.
STAND 5335

Pump technology

Expo exhibitor Ixetic GmbH, headquartered in Bad Homburg, Germany, manufactures hydraulic and vacuum pumps for the automotive industry (see picture, right). The company employs 1,200 employees and, in 2009, had a turnover of €212 million. It also has subsidiaries in Hückeswagen, near Cologne; Plovdiv, Bulgaria; Brunswick, USA; Yokohama, Japan; and a JV in Bangalore, India, as well as representatives in China and Korea. Ixetic's range of products encompasses hydraulic pumps for steering, chassis and transmission applications, vacuum pumps for brake systems, and car air-conditioning compressors. The company's customers are Audi, BMW, Daimler, Ford, Porsche, Renault, Toyota, and Volkswagen.
STAND 5210



Swift work

Motion simulator specialist Cruden has reached an agreement with US-based race car maker Swift Engineering to boost Swift's bid to design and build the next-generation IndyCar chassis. Swift's designs will be tested in accurate virtual models on a 3Ctr, 6-DOF Cruden motion simulator.
STAND 5145

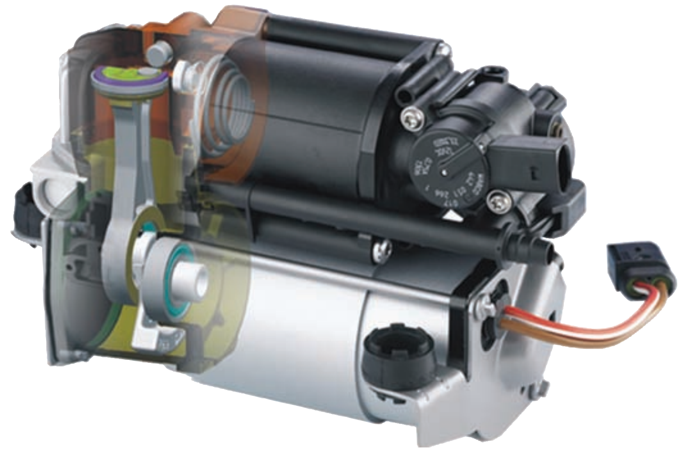
F-Series supplier

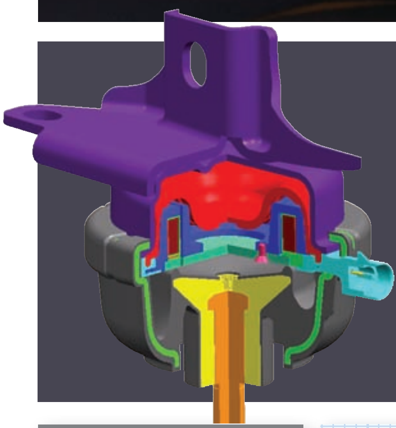
Tenneco is contributing key components to the 2011 Ford F-Series Super Duty truck. The Tier 1 is supplying its Multi-Tuned Valving System in all dampers for the Super Duty; this enhances the ride while reducing noise and improving durability. It also provides Ford's vehicle dynamics engineers with an expanded range of tuning options to tailor the truck's performance in any situation. Tenneco, which is a US$5.9 billion company with approximately 21,000 employees worldwide, is also supplying Clevite elastomer suspension isolators for the Super Duty. These are tuned specifically for the Super Duty to minimize noise and provide increased durability.
STAND 5415

Air suspension controls

Continuing WABCO's 23-year record of air suspension systems for passenger cars and light commercial vehicles, in Stuttgart the company will present its newest generation of high-power compressors, which enable air pressure capacity to increase up to 18 bar and substantially improve acoustics.

WABCO will also showcase its new electronic control unit for air suspension featuring FlexRay technology and marking a breakthrough in data networking for in-car control systems. It is the passenger car industry's first application of air suspension using the new FlexRay communications standard, resulting in fast and reliable integration with the vehicle's other controls and sensors.
STAND 5410





BWI not Delphi

In late 2009, Delphi Corp sold its ride dynamics and brakes business units to BWI Group of Beijing, China, for approximately US$100 million.

"We believe this is a good opportunity for BWI to make healthy inroads into the world's premium automotive chassis systems market, as Delphi has over the years accumulated a wealth of technical knowledge, and we will continue what the previous owner established and expand on it," comments Jianyi Fang, chairman of the board of directors of BWI.

"Suspension and brake systems are crucial for improving vehicle comfort, stability, safety, and performance, and we now have an opportunity to focus on these key features, which offer excellent value to our customers," says Dan Warrell, a Delphi veteran of over 40 years, who has been chosen to lead the BWI Ride and Brakes business.

BWI Group's Magneto Rheological Powertrain Mount (left) was named Innovation of the Year in the 2009 Vehicle Dynamics International Awards.
STAND 5720

WHO TO MEET

Michael Chepy,
Control systems and virtual analysis engineer, AMET
STAND 5200

Tapered wire springs

Miniblock springs have been implemented by Ahle Springs for automotive use for years, primarily as rear-axle and brake springs. The tapered wire, in combination with the 'principle of non-constancy', leads to a small installation space, low weight, and no coil clash. The advantages of tapered wires are not limited to Miniblock springs, however, but are also valid for cylindrical springs. In fact tapered wires enable the creation of new spring applications like very small 'super-progressive springs', for example in rebound springs or simulator springs. Tapered wire springs for off-road and heavy-duty use are available too.

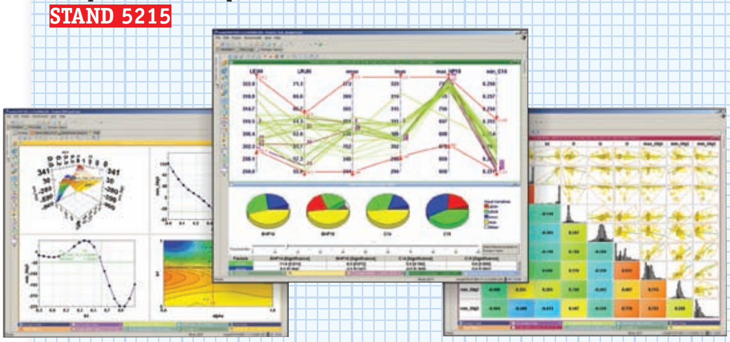
The design and manufacturing of new steel spring concepts will be shown by Ahle Springs during Vehicle Dynamics Expo 2010.
STAND 5710

Design optimization

EnginSoft is a consulting company and software vendor acting in the field of computer-aided engineering (CAE) in cooperation with CAE experts all over Europe, particularly focusing on automation, process integration, and design optimization.

At this year's Vehicle Dynamics Expo, the company will be keen to show visitors how one of its core products, Esteco's multi-objective optimization and design environment software, modeFRONTIER, can increase product quality in a shorter time. Visitors will be able to see how it is possible to integrate any CAE software and drive it automatically, always respecting the objectives that have been set for the product development.

STAND 5215



Best of both worlds

For more than 30 years, Continental has contributed air suspension systems to luxury cars, premium SUVs, MPVs, vans, and other vehicles. The principal reason for the widespread use of air springs is for vehicle levelling, with a considerable improvement achieved in ride comfort and driving dynamics at a relatively low cost. The system's potential is far from having been exhausted. Continental is developing an air suspension system with a switched auxiliary reservoir, making possible very comfortable and, at the push of a button, very sporty driving.

STAND 5520

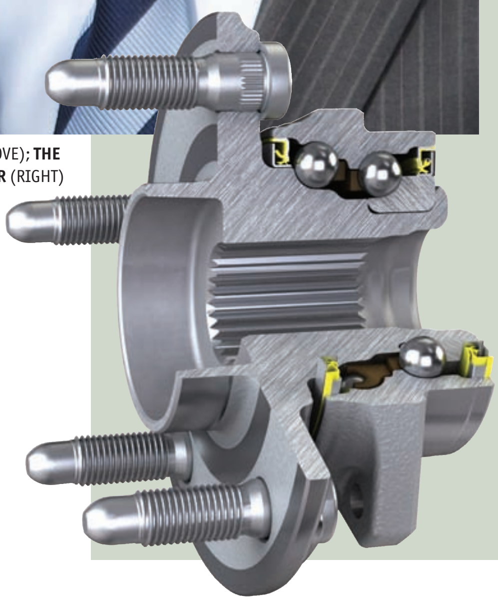
Free-to-attend Open Forum

In addition to FREE ENTRY to the exhibition, visitors will be able to attend the Open Technology Forum, where 40 leading vehicle dynamics experts will outline their latest concepts, ideas, and technologies. **Turn to page 47 for more!**

Your Vehicle Dynamics Expo badge also gives you FREE ENTRY to Automotive Testing Expo, Engine Expo, European Automotive Components Expo, and Automotive Interiors Expo – over 500 exhibitors in total. Register online to get your badge in advance. www.vehicledynamics-expo.com

Hub of activity

RAIMOND BREUKER FROM SKF'S AUTOMOTIVE DEVELOPMENT CENTER TALKS ABOUT THE LIGHTWEIGHT, LOW-FRICTION FUTURE FOR BEARINGS. BY **GINETTE PELTON**



RAIMOND BREUKER (ABOVE); **THE LOW FRICTION X-TRACKER** (RIGHT)

In response to the automotive industry's recent drive to reduce CO_2 emissions, bearing specialist SKF has developed several new products. One is the SKF Hub Knuckle Module (HKM), which uses roll-forming in the manufacturing process to minimize the use of material to integrate the hub into the knuckle. The result is a saving of up to 20% from the weight of a conventional hub-knuckle system.

Already in production on a prestige sports car, but by no means specific to high-end niche applications, HKM is now being targeted at vehicles right across the spectrum, and several other OEMs in Western Europe and China have shown interest in the concept.

The second will be a highlight of SKF's booth at Vehicle Dynamics Expo 2010. "The Low Friction X-tracker is a hub unit to reduce the frictional losses in wheel bearings," explains Raimond Breuker, who manages SKF's Automotive Development Center in Nieuwegein, the Netherlands. "It can be applied across the segments but typically it will be for applications that make use of the third-generation hub bearing unit (HBU3) design.

"The benefit from a low-friction hub unit is greatest in larger vehicles. This is also where OEMs have the biggest challenge in terms of reducing CO_2 emissions, so these are the platforms we are targeting initially: cars similar in size to an Audi A8 or BMW 7 Series, for example. Later we will move to lower segments as the market develops. The product has just been launched from a product development phase and is ready for implementation in customer projects; we expect it to be in production in about 18-24 months."

Breuker, a mechanical engineer who has spent more than a decade at SKF, makes it clear that the innovations won't stop there. "The HKM is the first step on our lightweight roadmap," he reveals. "We are developing hub-unit components of further reduced weight, where we are using innovative material technologies in order to achieve a significant weight reduction. I cannot give more detail at this stage, but you can expect more from SKF in terms of weight reduction in the near future."

Another development is in response to a growing trend toward more compact and budget vehicles, whether in traditional Western markets or the growing territories of China, India, and Latin America.

"We have a new hub bearing unit specifically developed for compact cars," he reports. "Different materials and processes enable us to reduce the overall material utilization in this design."

Also on the agenda are product developments relating to the growing hybridization and electrification of vehicles. At SKF, this has meant increasing work in the mechatronic domain, for example by integrating a commutation sensor (sensing the angle between rotor and stator in an electric motor drive) into bearings for electric motor suppliers. Breuker believes that these new drivetrain technologies are presenting the greatest challenge to suppliers such as SKF at the moment.

"The powertrain of the future will have quite a different architecture, with different components, a higher level of electronics, different key suppliers, and a different value chain – a clear change from how we do business today," he explains. "It's not just about reducing friction or weight, it's a significant rethinking of the drivetrain.

"There are many new technologies and product solutions being developed to improve vehicle efficiency. Because the market is so dynamic, the decisions that we make today – in terms of which technologies and products to invest in, and which partners to work with – will impact our future success more than they have done during the past 20 years."

OPEN TECHNOLOGY FORUM

In addition to the exhibition, visitors to Vehicle Dynamics Expo will be able to attend the FREE-OF-CHARGE Open Technology Forum, where more than 35 leading vehicle dynamics experts will outline their latest concepts, ideas, and technologies. Here's the program:

22 JUNE 2010 DAY 1 MORNING SESSION

RIDE AND HANDLING

10.30: Principal and benefits of several torque vectoring concepts for improved vehicle performance characteristics
Bosch Engineering GmbH – Peter van Vliet, system engineer

10.55: Identification of tire lateral force characteristics from handling data and a functional suspension model
Centro Ricerche Fiat – Marco Pesce, vehicle dynamics specialist, tire cornering properties

11.20: New facilities for crosswind sensibility analysis at IDIADA
Applus+ IDIADA – Jonathan Webb, vehicle dynamics manager

11.45: Advanced testing and simulation techniques in ride and handling body deformation
LMS Italiana – Valerio Cibrario, operation manager

12.10: Electric Active Roll Control (EARC)
Cranfield University – Ganesh Mohan, MSc student

12.35: The Nürburgring and its effect on the development of sports cars
SBA Motor Sports – Shields Bergstrom, professional race driver

13.00: Lunch

22 JUNE 2010 DAY 1 AFTERNOON SESSION

SUSPENSION

14.00: The closed air suspension system of the Porsche Panamera
Porsche AG & Continental AG – Claus Blattner, head of development, suspension systems and Andreas Nessel, head of CC air spring modules, division chassis & safety

14.25: Simulating advanced passive damping technologies
BWI Group – Dr Janusz Gołdasz, simulation engineer

14.50: Optimization of vehicle handling performance by increasing the ARB effectiveness
Tata Motors Ltd – Arun Prakash, manager

15.15: Implementation of an active suspension system in a prototype vehicle – ultimate comfort and safety (ACOCAR)
Tenneco – Bert Vandersmissen, research engineer

15.40: Active suspension using energy recovery actuation and dynamic power management
L-3 Electronic Systems – Roger Stopford, vice president

16.05: Application of surface modifications and coatings in suspension systems
Sulzer Metaplas GmbH – Thomas auf dem Brinke, project manager

16.30: An experimental study as reference for magneto-rheological damper modeling and control
Tecnologico de Monterrey – Prof Jorge de Jesus Lozoya-Santos, research assistant

16.55: Finish

23 JUNE 2010 DAY 2 MORNING SESSION

TRACTION, STABILITY AND BRAKING

10.30: Off-road capability leadership in the 21st century
Jaguar Land Rover – Jan Prins, technical specialist

10.55: Wheel power management for AWD vehicle dynamics and performance optimization
Lawrence Technological University – Prof Vladimir Vantsevich, associate director, Automotive Engineering Institute

11.20: Retrofit of electronic stability control systems, analysis of possibilities and benefits
Automotive Safety Research – Murat Okcuoglu, scientist

11.45: Direction Sensitive Locking Differential (DSLD) – experimental evaluation of a prototype for a FWD Saab 9-3 Aero V6
Techno-model – Jonas Alfredson, inventor

12.10: Sintered metal ceramic composite brake pads for automobiles
Redson Engineers P. Ltd – Babu Golla, chief executive

STEERING

12.35: Power clamping on adjustable steering columns – an innovation in steering systems that brings more value to the end customer
ZF Lenksysteme – Pierre Fournet-Fayard, manager

13.00: Microcellular polyurethane as steering coupling element
BASF Polyurethanes GmbH – Holger Bickelmann, project engineer

13.25: Lunch

23 JUNE 2010 DAY 2 AFTERNOON SESSION

SIMULATION AND MODELING

14.00: One single driver model for multiple simulation tasks – principles and application examples
VI-Grade & BMW Group – Diego Minen, technical director and Pavel Kvasnicka, conceptual layout vehicle dynamics and Marc Luckenbach, numerical simulations – operating strength and materials

14.25: Functional development process of the Magna electric roll-stabilizer eARS
Magna Steyr Fahrzeugtechnik – Daniel Lindvai-Soos, simulation engineer

14.50: Model-based development of predictive vehicle dynamics controllers
dSPACE GmbH – Thomas Gockeln, field application engineer

15.15: Hybrid system response convergence (HSRC) – an alternative method for hybrid durability
MTS Systems Corporation – Dave Fricke, senior staff engineer

15.40: How Simulink/SimMechanics-based vehicle models can be used in combination with a full motion simulator
Cruden BV – Maarten von Donselaar, CEO

16.05: Scalability in chassis subsystem modeling – from simple to complex models and model simplification for real-time applications
LMS Imagine – Julien Lagnier, product manager

16.30: Scenario-based testing approach for fusion algorithm and driver-assistance system models
DMC systems India Pvt Ltd – Kausalya Paila, control algorithm developer

16.55: Finish

24 JUNE 2010 DAY 3 MORNING SESSION

INSTRUMENTATION AND MEASUREMENT

10.30: High-resolution slip angle measurement
Corrsys-Datron GmbH – Michael Dörr, product management

10.55: Outlook for MEMS and sensors in automotive chassis and safety applications – a market forecast
iSuppli – Dr Richard Dixon, senior analyst, MEMS

11.20: Infogeotracking System
Prototipo – Stefano Costa, technician

CHASSIS

11.45: Optimization and robust design: Fiat Group Automobiles applications overview in chassis and vehicle dynamics
EnginSoft GmbH & Fiat Group Automobiles – Francesco Linares and Marco Spinelli, technical managers

12.10: Green thinking – from the perspective of a global automotive supplier
SKF Automotive Division – Stefano Barbero, business development manager

12.35: Ride and handling in China – demands and solutions for chassis development
TÜV SÜD Automotive – Pascal Mast, manager chassis

13.00: Solutions for safety-critical automotive applications
Freescale Semiconductor – Matthieu Reze, sensors marketing

13.25: A new and innovative method of teaching chassis dynamics
Oxford Brookes University, UK - Mike Meechan, manager – motorsport knowledge

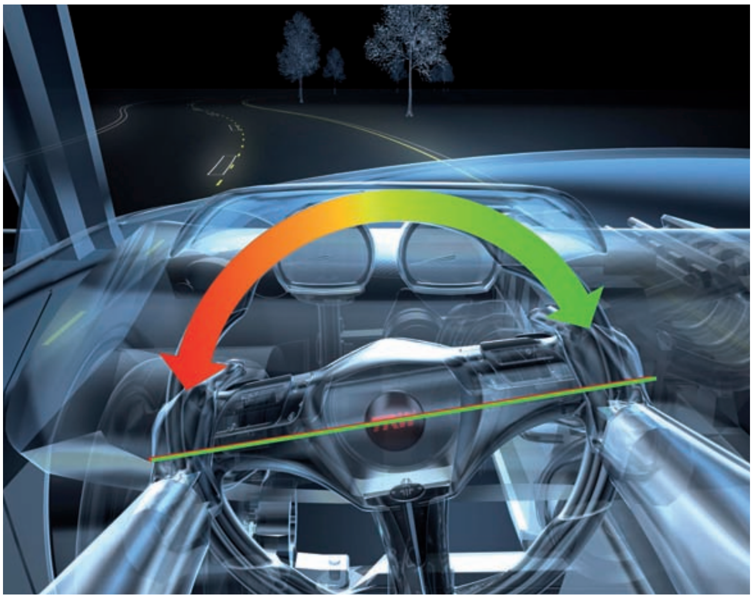
13.50: Finish

*This program may be subject to change

For more details on the Vehicle Dynamics Expo 2010 Open Technology Forum, visit www.vehicledynamics-expo.com

Feel-good factor

RIGHT: **TRW'S BRAKING AND STEERING SYSTEMS ARE PUT TO THE TEST AT THE COMPANY'S ARVIDSJAUR WINTER TEST FACILITY, IN SWEDEN**



RIGHT: **THE STEERING SYSTEM IS ONE OF THE MOST INTENSE HUMAN/MACHINE INTERFACES FOR OPERATING A VEHICLE**

Developments in electronics integration have led to the evolution of the automobile from a means of traveling from A to B to a cognitive machine that supports the driver in making safer decisions in difficult situations. But what are the implications of these technological advances on the overall driver experience and what is being done to ensure that the feel – that is so integral to the way a driver interacts with a vehicle – remains the same?

At TRW Automotive, enhancing driver experience is a key priority when developing new technologies. The company's developments in the areas of steering and braking have provided innovative solutions, which mirror the 'traditional' vehicle response, reassuring drivers that they are still in control, while offering considerable environmental and cost-saving benefits. TRW's electric power steering (EPS) and electrically powered hydraulic steering (EPHS) technologies, for example, can deliver fuel savings of 0.3 to 0.4 liters/100km, with a corresponding reduction in carbon dioxide emissions of approximately 7-8g/km.

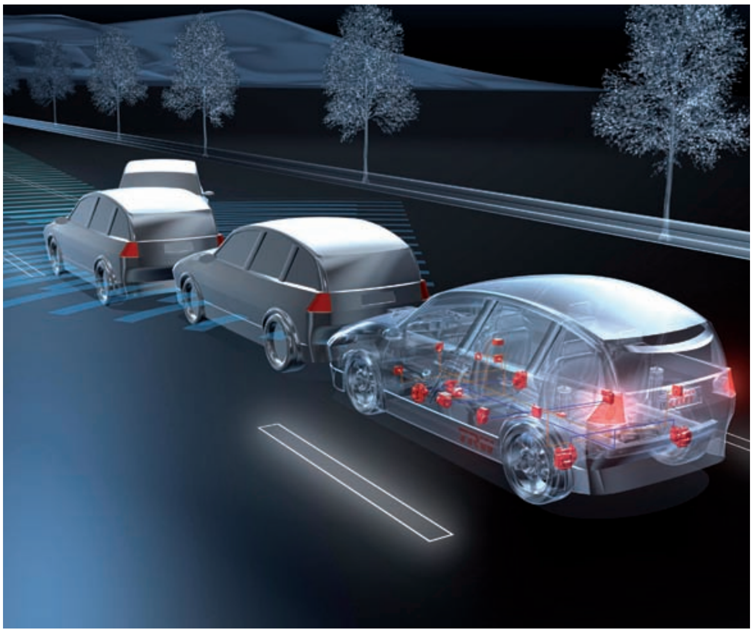
At the core of TRW's efforts to replicate traditional feel in steering and braking systems is the relationship the driver has with the vehicle and, ultimately, the degree of confidence that a driver has in that vehicle's ability to respond in a potentially dangerous situation.

Tony Burton, technical new business development manager for electric steering at TRW Automotive, explains: "The steering system is one of the most intense human/machine interfaces for operating a vehicle. As well as converting steering wheel turns into directional changes, it can provide valuable driver feedback about road surface conditions and acceleration capabilities throughout the constantly changing driving experience.

"Haptic steering-wheel feedback allows the driver to 'feel' the vehicle and the road. If the feedback is weak or if there is a delay between the command being issued and the vehicle's response, a driver experiences a degradation in control and, therefore, confidence – something which vehicle manufacturers want to avoid at all costs.

"Maintaining a natural steering feel for the driver is a primary goal during the development of an EPS system. The specific hardware setup and software 'tuning' of the steering system within the individual vehicle environment plays a critical role in achieving this," he adds.

According to Burton, TRW's approach to steering feel revolves around three core principles: attention to the sources of steering-feel 'distortion' in the core design, such as reflected inertia, mechanical compliance and friction; the deployment of robust control-theoretic approaches, using time



LEFT: **INTELLIGENT SAFETY SYSTEMS SUPPORT THE DRIVER IN AN EMERGENCY SITUATION**

and frequency domain analysis in the design development and implementation of the algorithms determining the torque delivery of the system (rather than static, 'if-then-else' or 'fuzzy' type rule-bases which can ultimately lead to an artificial steering feel); and close collaboration with the vehicle manufacturer (VM).

Burton explains: "TRW needs to be involved, as an active development partner, from the very start of the project. By using sophisticated tuning and dynamic analysis tools our dedicated international vehicle dynamics teams help our customers to form a union between chassis components and the steering system to realize an optimized steering feel."

TRW has ongoing programs to continuously enhance and develop advanced driver interaction functions to both improve driver safety (with features such as torque steer compensation and lane keeping assistance) and offer more customer choice (with features such as automatic multi-tune selection, programmable disturbance rejection and driver-selectable feel).

In the case of replicating braking feel, TRW is introducing more environmentally responsible technologies, which operate using fully hydraulic regenerative braking systems. Manfred Meyer, technical director of brake systems application engineering at TRW Automotive, explains: "With alternative drivetrains (electric or hybrid) a brake simulator might be used rather than the brake pedal linking directly to the wheel brakes and to the stopping of the car – so by its very nature, the feel is different. For component manufacturers, such as TRW, the challenge has been to successfully replicate the way a conventional brake system works so that the driver does not perceive whether the system is braking hydraulically, electrically or combined hydraulically/regenerative.

"The brake simulator corresponds to an electro-hydraulically controlled 'brake-by-wire' solution. This also creates a hydraulic backup stage – in the event of an electrical failure, the brakes are still functional, albeit with a different feel from the pedal.

"Brake pedal feel gives the driver a level of confidence in the safety of the vehicle and this is not something on which we will compromise, even in the case of simulated brake actuation – which is the likely route for hybrid/electric cars," Meyer adds.

TRW has developed a range of solutions that includes ESC-R – a modular, hydraulically closed system based on the company's proven electronic stability control (ESC) technology, which is capable of generating substantial amounts of brake pressure in the absence of engine vacuum power. ESC-R makes maximum use of standard actuation and ESC components to offer both safety and an approximate 7% fuel savings benefit across a range of driving conditions. The technology is compatible with four-wheel-, rear-wheel- and front-wheel-drive vehicles and enables the recuperation of brake energy alongside controlled brake torque blending between friction brake and regenerative deceleration.

Of course, it is not just consumers who are interested in pedal and steering feel. For some vehicle manufacturers, feel is an integral part their brand's DNA, so replicating it is of paramount importance.

Meyer continues: "A VM may want to maintain feel across a model range for example, or use it to reflect whether the car type is a sporty or comfort model, and geography may even play a role – the preferences of consumers in Europe, Asia Pacific and the USA do differ."

With many features either in production or in preparation to launch and many more under intense development, TRW's competency in electronic chassis controls, such as steering and braking, will provide further value in this field.

Meyer concludes: "Ultimately, our aim at TRW is to get the best of both worlds, by delivering technologies which provide the best possible performance without the consumer noticing any discernible difference in how the vehicle is operating – all that they should notice is an improvement in their overall driving experience."

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Vehicle control in traffic

FIGURE 1 (BELOW): **CARSIM VEHICLE MODEL, INCORPORATING VEHICLE DYNAMICS MODELS AUGMENTED WITH HIGH-FIDELITY CONTROL AND PLANT MODELS FOR ENGINE, TRANSMISSION, AND INSTRUMENTATION PANEL**

FIGURE 2 (FAR RIGHT): **ESSE MODELING AND SIMULATION OF A SMALL NUMBER OF AUGMENTED CARSIM (AUTONOMOUS) MODELS FOLLOWING THEIR LEAD CAR IN TRAFFIC**

In automotive transport, two vehicle models that provide an excellent foundation for specifying and empirically determining optimum control system architectures are Mechanical Simulation Corp's CarSim and TruckSim models.

These models are calibrated, widely used, and have several hundred parameters for specifying and tweaking the underlying high-integrity suspension, chassis, tire, and other constituent models (equation subsets). A number of vehicle subsystems, such as engine, transmission, torque converter, braking, and steering are available as abstract tables, which CarSim and TruckSim allow to be replaced by models having higher integrity functionality and timing (Figure 1).

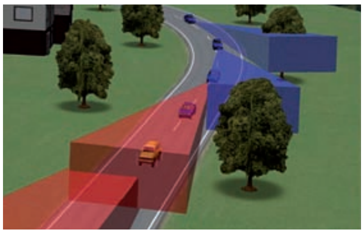
One of Embedded Systems Technology's (EST) OEM customers has integrated their internal model of a hybrid powertrain and regenerative braking system with the suspension, chassis, and tire models of a CarSim vehicle model that is parameterized to closely match the physical vehicle in question. This model's simulated behavior correlates highly with the behavior of the physical vehicle.

A vehicle-use case that demands the good functional and timing accuracy of all models embedded in a competent vehicle model is one where a vehicle loses traction on a wet and icy road, over-corrects and rotates 180° with a lateral and (now) backwards momentum. Such use cases should be in the standard testing repertoire, and vehicle control systems should be able to detect the aberrant behavior early, initiate timely corrective action with appropriate intensity, and/or ensure that a vehicle and its occupants survive with damage minimized.

A single vehicle losing control may cause a rapidly escalating wave of collisions of increasing severity. The intentional modeling of such situations imposes a paradigm of progression unlikely to correlate well with the physical analog since it is extremely difficult to predict the effects of the primary collisions.

This may be a relatively infrequent example of traffic, but it is in these circumstances that safety-prioritized design is extremely important. The requirement on the vehicle designers must still be that each vehicle's control system should be able to correct in such a way as to avoid a collision and/or ensure that each vehicle and its occupants survive with minimized damage.

This traffic use case is impossible to apply to a set of physical mule vehicles due to the very high likelihood of test drivers being killed and expensive mule vehicles being wrecked. This is not a contrived example – there are many similar



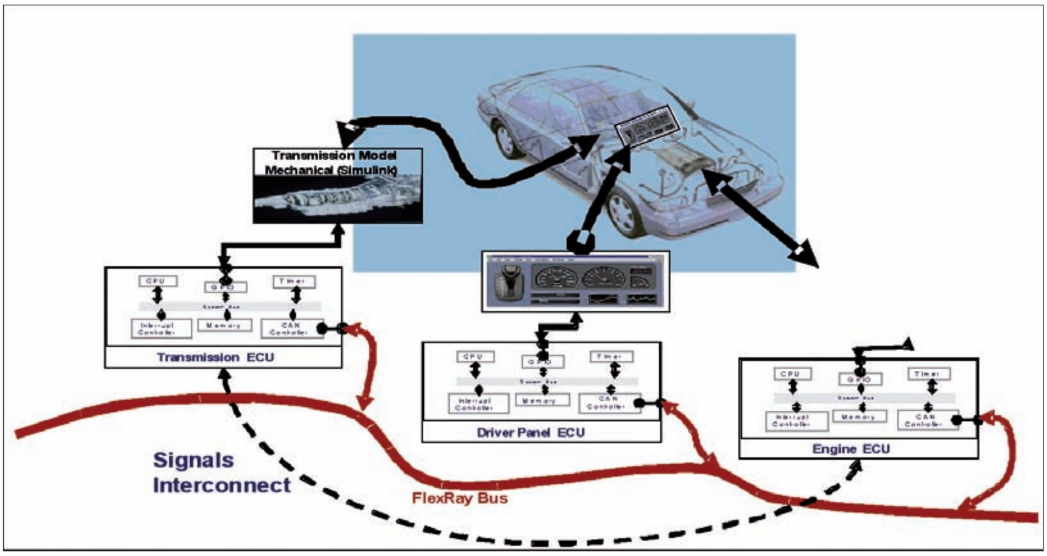
cases where it is more than useful to determine the likely outcome and to gather insight into what controls can be efficaciously applied to avoid collisions and/or minimize damage to occupants and vehicles.

Rigorous testing of corner cases in physical systems will be destructive – including for the driver, which is unacceptable. The practical and feasible approach to building and verifying vehicle and traffic control systems is via functional and timing-accurate simulatable models. For large systems, high-performance simulation is necessary.

In order to simulate a complex traffic-use case, the number of intra-vehicle physics and geometric collision and near-miss calculations to be performed at the same time as the usual inter-vehicle control system computations (probably each millisecond or so) rapidly becomes exponentially overwhelming.

However, with an appropriate competent modeling and simulation system, each vehicle model will be expected to compute the effects of impacts on itself and combine this with the responses of its internal control system, instant by instant. This requires each vehicle model to contain detailed models of its vehicle dynamics, detailed models of its relevant control and plant elements, and accurate models of the topography and road surface.

The combined information from all vehicle models reveals an accurate picture of the entire mounting disaster or resolving traffic perturbation. This modeling and simulation paradigm only requires each vehicle to keep track of what is happening to it and to make this information available to its neighbors, thereby avoiding overwhelming computations that will grind the simulation to a halt.



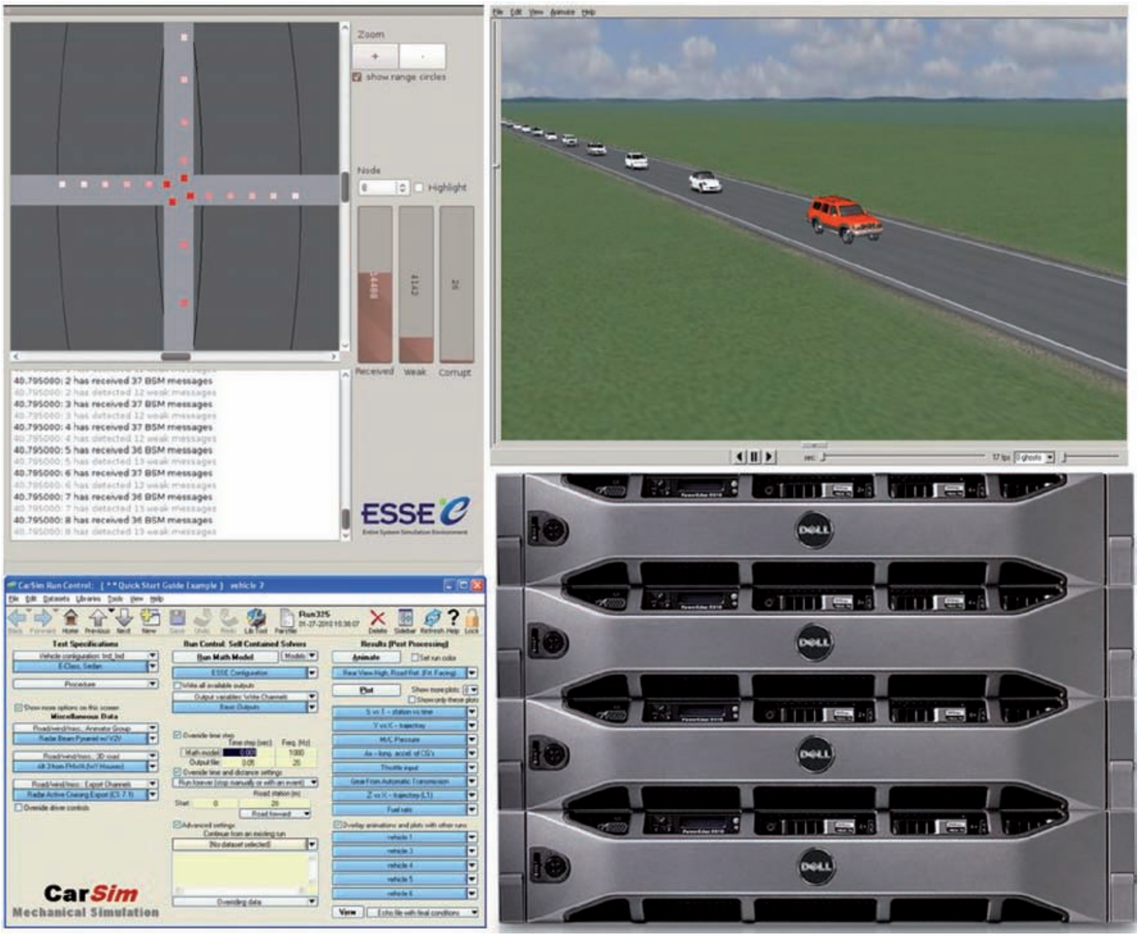


FIGURE 3 (LEFT):
[UPPER-LEFT] **THE ESSE SYSTEM DISPLAYING THE PROGRESS OF FOUR LINES OF TRAFFIC ENTERING AND EXITING A TRAFFIC-LIGHT-CONTROLLED, FOUR-WAY INTERSECTION. 50 AUTONOMOUS VEHICLES ARE COMMUNICATING WITH THEIR OWN DSRC RADIOS**

[UPPER-RIGHT] **ESSE SIMULATION OF 24 CARSIM VEHICLES IN A CONVOYING PROCEDURE, DISPLAYED USING THE ANIMATOR**

[LOWER-LEFT] **THE CARSIM GUI USED TO CONFIGURE THE VEHICLES**

[LOWER-RIGHT] **A MULTICORE, MULTINODE COMPUTER USED IN VERY HIGH-PERFORMANCE ESSE SIMULATIONS**

The EST Specification and Simulation Engineering (ESSE) system provides precisely the distributed modeling and simulation capabilities needed to build the complex vehicle, traffic, and infrastructure models that mean the distributed simulation can be performed, often faster than in real time. The ESSE distributed simulator coordinates the activity of many independent simulations – such as ESSE CarSim vehicle models, Simulink plant models, and SystemC ECU models – and supports intercommunication between simulations via high-performance, accurate models of networks, such as CAN, and FlexRay, 802.11p radio. Currently, the ESSE distributed simulation system is the highest performing, accuracy-preserving distributed simulator in the world.

In Figure 2, each vehicle is following its lead using a partial but relatively sophisticated Gipps following-driver model. In the ESSE simulation, each vehicle is a separate CarSim model running on its own core in a multicore host, multicore computer system. When the vehicle model is a CarSim model augmented with high-fidelity models of the engine, transmission, perhaps connected via a CANbus, the single vehicle model may be spread over several cores in order to preserve the highest possible simulation performance. The simulation depicted in Figure 2 executes six times faster than a wall clock (real) time, even though there are six full CarSim models being independently and concurrently simulated – in both simulation and real time – using the same infrastructure model.

Since each vehicle model is completely autonomous, but the driver model can see the other vehicles in its visual range, each vehicle-driver model can make decisions that are independent of any other vehicle-driver model. This exactly mimics reality.

Another of EST's customers, together with EST, is currently using the ESSE system to systematically identify the dominant factors controlling the minimization of fuel consumption and particulate emissions when maximizing safety in urban traffic. Up to 50 CarSim vehicle models, augmented with accurate engine models, are being simulated stopping and starting through models of the maze of downtown intersections, complete with traffic light and vehicle sensor models.

The advent of competent large-scale modeling and multicore, distributed simulation capabilities, coupled with detailed models of vehicle dynamics and control and plant systems in vehicles, is enabling extraordinarily complex, never before attempted, large-scale problems to be examined and solved.

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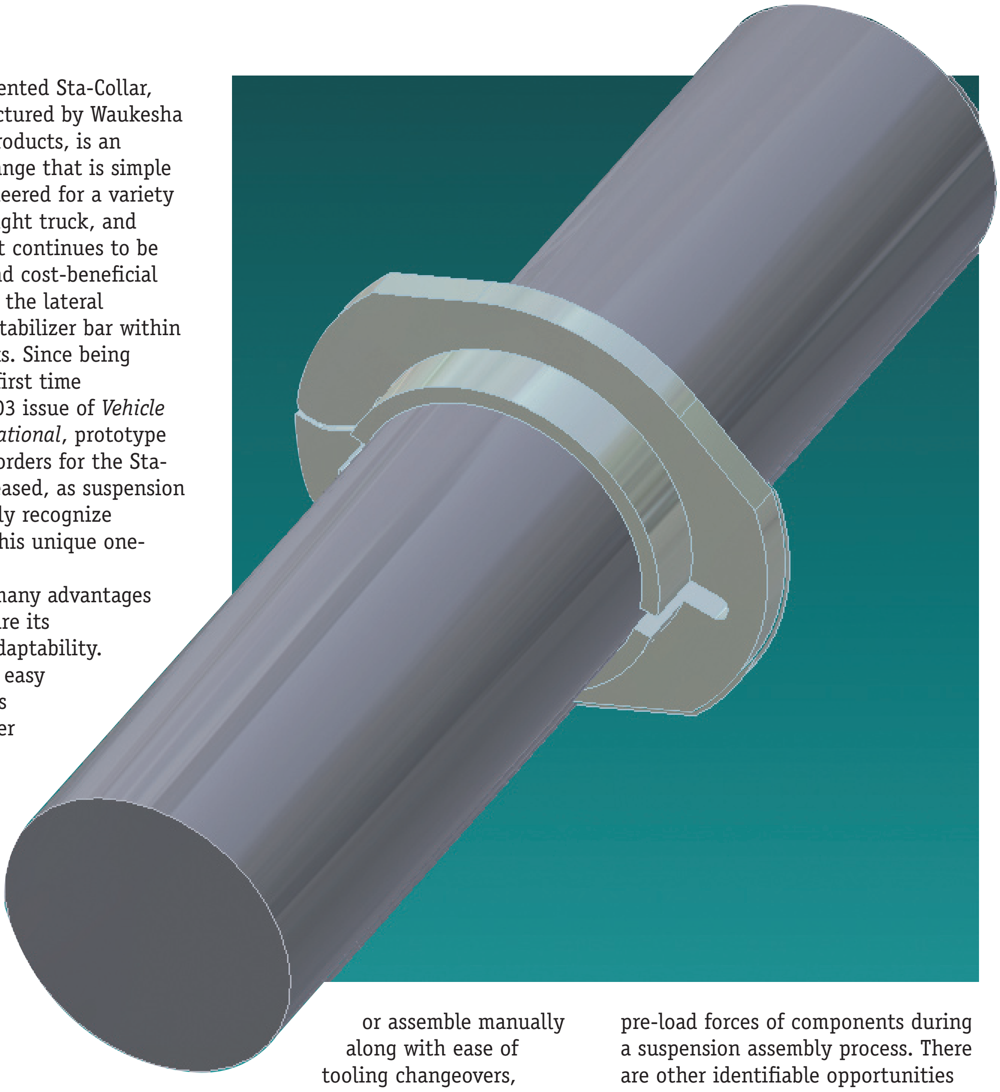
Quote ref VDI 002

Adaptable shaft flange

RIGHT: **TYPICAL EXAMPLE OF HOW THE STA-COLLAR FITS AROUND A VEHICLE'S STABILIZER BAR**



The patented Sta-Collar, manufactured by Waukesha Metal Products, is an annular shaft flange that is simple yet highly engineered for a variety of automotive, light truck, and SUV platforms. It continues to be an innovative and cost-beneficial solution to limit the lateral movement of a stabilizer bar within its isolator blocks. Since being profiled for the first time in the March 2003 issue of *Vehicle Dynamics International*, prototype and production orders for the Sta-Collar have increased, as suspension engineers globally recognize the benefits of this unique one-piece stamping.

A few of the many advantages of this product are its simplicity and adaptability. The Sta-Collar is easy to install. It slips over the stabilizer bar in any location, which allows for a simplified process, reduction of assembly time, and minimal handling, therefore lowering total costs. It is then clamped onto the stabilizer bar and spot welded to provide an interference fit, which results in high performance, consistently exceeding vehicle requirements of 1,300N to 4,000N push-off capability.

Another notable advantage is its compact design. The Sta-Collar, a one-piece metal stamping, offers positioning within tight tolerances, which allows for precise placement on the bar and for placement in tighter suspension packages. It also offers the repeatability provided by precision assembly equipment. The equipment, when automated, can apply Sta-Collars to the stabilizer bars at a rate of up to five assemblies per minute. The option to fully automate for the highest production, or assemble manually along with ease of tooling changeovers, has allowed the company's customers to realize substantial savings by utilizing one common assembly machine across multiple platforms and sizes. Waukesha's experienced engineering team will assist customers with assembly machine recommendations and specifications.

The main industries served are the automotive and light truck markets. The Sta-Collar is shipped worldwide, including use in vehicle platforms for General Motors, Toyota, Lexus, Ford, and Mazda. Though primarily used in the automotive market, continuing research and development can provide customers with new options to meet their needs. One application under consideration includes utilizing the Sta-Collar to withstand pre-load forces of components during a suspension assembly process. There are other identifiable opportunities in other markets, such as off-road vehicles, construction, agriculture, and lawn and garden.

The Sta-Collar is made of mild steel and manufactured in a progressive stamping die. Along with other options for material and finish (bare or zinc-plated), and the ability to assemble before or after powder coat/paint, the Sta-Collar annular shaft flange has proven to be a viable solution that provides the customer with an innovative, lower total cost solution to prevent lateral movement of a stabilizer bar.

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Quote ref VDI 003

Innovative steering robot

Anthony Best Dynamics (ABD) has been supplying in-vehicle robot systems since 1997. ABD robots are used for many applications, including vehicle dynamics and advanced driver assistance system (ADAS) testing. Over 170 systems are in regular use around the world by automotive manufacturers, Tier 1 suppliers and test houses.

Conventional steering robot actuators that replace the vehicle's steering wheel or clamp onto the steering wheel have several limitations. Removing the standard steering wheel on some vehicles can deactivate sensors used in active suspension and/or ESC systems, which can fool the vehicle's electronic systems into detecting a 'fault' and modifying the vehicle's response. Conventional steering robots require the steering wheel airbag to be completely disabled for safe use of the robot, and the driver is prevented from accessing steering wheel-mounted controls.

To address these problems, ABD has developed a new type of steering robot – the Torus. The SR60-Torus is an innovative and patented design of steering robot for all types of testing. The lightweight Torus motor is attached to the vehicle's steering wheel using adjustable clamps that allow the Torus motor to be centered to the steering column.

The large hollow center enables access to the vehicle's standard steering wheel controls. It also enables the airbag to deploy safely through the center of the robot without the robot motor becoming detached from the steering wheel.

The Torus motor uses a direct-drive continuous rotation brushless motor with a low-friction bearing system – there are no gears or clutches. The vehicle can be safely manually driven between tests using the integrated steering rim.

Steve Neads, ABD director, comments: "Developing the Torus motor has been a technical challenge. Extremely high precision manufacturing is required to ensure that bearing friction and assembly mass are both minimized. The motor stator and rotor have been designed especially for the application with several iterations to optimize motor performance. Enabling driver access to the steering wheel controls is going to become increasingly important for ADAS testing applications."

The performance envelope of the motor is similar to ABD's conventional SR60 (60Nm) steering robot and is designed to exceed the specification requirements of NHTSA's fish-hook and spin-out tests that specify a steering robot is capable of at least 60Nm at 1,200°/s. Steering torque data can be inferred from the demanded motor current or measured directly using a parallel force link arrangement.

The Torus motor is compatible with ABD's Omni and Mono in-vehicle robot controllers and can be used in conjunction with ABD's brake, accelerator, clutch and gear-change robots in both driverless and non-driverless configurations.

Andrew Pick, senior engineer at ABD, adds: "Many of our customers use our steering robots in conjunction with ABD brake and accelerator robots. The pedal robots enable the entry speed of dynamic test maneuvers to be precisely controlled, which improves testing efficiency and allows the driver to concentrate on other tasks."

ABOVE: **AN SR60-TORUS SCREEN-MOUNTED STEERING ROBOT FITTED TO A HONDA CIVIC TYPE-R**

LEFT: **SR60-TORUS INSTALLATION LEAVES PLENTY OF ROOM FOR THE DRIVER AND OTHER ROBOTS**

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Eco-tire technology

RIGHT: **BRIDGESTONE'S LATEST ECO-FRIENDLY TIRE IS THE ECOPIA EP150, UNVEILED IN 2009**

Bridgestone manages safety and environmental issues as integral and essential parts of its business activities, and constantly works toward a sustainable society.

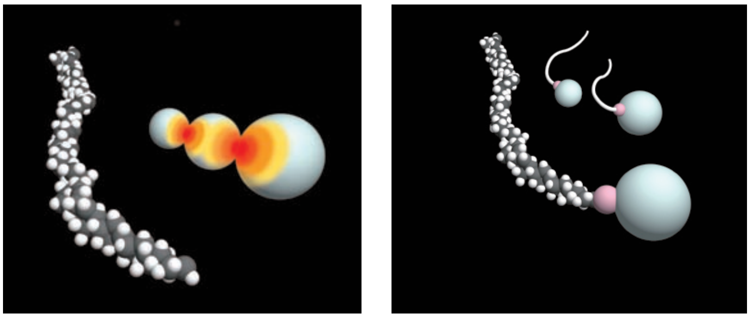
Two key characteristics of a tire are safety, especially wet adherence, and environmental performance, related particularly to rolling resistance and fuel efficiency. But higher adherence and lower rolling resistance are contradictory objectives that have traditionally required a performance trade-off.

In a long-term safety and environmental development program, Bridgestone has now developed innovative technology to overcome this natural paradox, applying it for the first time in the new ECOPIA range of tires, Bridgestone's flagship brand that contributes to the prevention of global warming by helping to reduce CO_2 emissions through higher vehicle-energy efficiency, and still offers the high level of safety of Bridgestone premium tires.

This breakthrough has been achieved through the development of a materials technology, called NanoPro-Tech. NanoPro technology reduces normally occurring energy losses that contribute to tire rolling resistance by optimizing the distribution of fillers in the compound, resulting in reduced molecular friction.

NanoPro-Tech reduces heat build-up and the resulting energy loss in the top compound during tire rotation, and produces a lower rolling resistance coefficient. This reduces fuel consumption and CO_2 emissions, and gives improved safety performance in wet conditions. The latest ECOPIA tires also have three-dimensional curves on the tread blocks to help suppress noise generation when the block is in contact with the road.

ECOPIA tires were first used on electric-powered cars in Japan, in 1991. This set the stage for the ECOPIA M881 and ECOPIA R221 series of tires for trucks and buses, released in the replacement market in 2002. Bridgestone Japan launched the ECOPIA M812 tire for light trucks in 2005, followed by the ECOPIA EP100 for passenger cars in April 2008.



NANOPRO TECHNOLOGY OPTIMIZES THE DISTRIBUTION OF FILLERS IN THE COMPOUND (ABOVE RIGHT)

In Europe, the ECOPIA brand appeared for the first time in 1999 when the ECOPIA B381 was fitted to the VW 3L Lupo, considered at the time to be the most environmentally friendly car in the world, consuming only three liters of fuel per 100km. This was followed by the Audi A2, and in 2008, the Toyota iQ city car left the factory on ECOPIA EP25 tires.

The company introduced the range of eco-friendly premium Turanza ER300 ECOPIA tires in Europe in April 2009, meeting car manufacturers' demands for improved rolling resistance coefficients without sacrificing safety, and especially wet handling. The tire is now original equipment on several car models.

Announced at the International Motor Show in Frankfurt in September 2009, the ECOPIA EP150 brings the safety and ecological benefits of ECOPIA tires to small- and medium-sized cars.

An advanced NanoPro-Tech compound, and a 3D block-and-rib design for improved road contact, gives the ECOPIA EP150 improved rolling resistance compared with other Bridgestone tires of the same dimensions. The brand is up to 3% more fuel efficient, leading to reduced CO_2 emissions.

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Quote ref VDI 005

Air spring simulation

Large- and mid-sized cars are increasingly being equipped with air suspension systems. Air springs make it possible to vary the air pressure in the bellows and set different vehicle heights. In addition to compensating levels in accordance with different degrees of loading, they also permit different aerodynamic or off-road positions.

The design of an air suspension consists of several steps. On the one hand, mechanical properties like the fatigue resistance of the bellows or the bearing load of the spring have to be defined. On the other hand, dynamic behavior like level control, thermal characteristics or comfort has to be configured.

For the second part it is almost essential to use simulation methods. A complex simulation model of an air suspension system comprises air springs, additional volumes with their valves, numerous other pipes and tubes, valves and manifolds, accumulators, and of course the compressor, both in closed- and open-circuit. The simulation can be used for vehicle dynamic, NVH analysis of automobiles or light-duty vehicles, as well as for railway applications.

The various flow deflections within the pneumatic components, and within the manifolds to which the components are mounted, do have an enormous effect on the flow characteristics. In order to simplify the parameterization of pneumatic systems' simulation, a global description for the flow behavior of the whole pneumatic component, including manifold, would be helpful.

In industrial pneumatics the parameters' b- and C-values according to ISO 6358 became accepted in order to describe a pneumatic resistor. The determination of the critical pressure level (b) and the flow conductance (C) have proven to be a reliable means of characterizing the mass flow rate. By implication the parameters can be assigned on mobile applications.

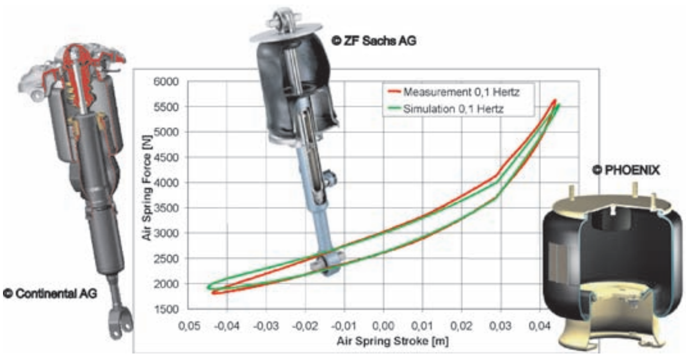
The critical pressure level b defines the ratio of the outlet pressure p2 and the inlet pressure p1 at which the flow in the smallest cross section of the analyzed component reaches sonic speed. Based on the standard state, the conductance C quantifies the mass flow rate in the transonic zone, where the flow rate depends only on the inlet pressure p1. In subsonic state, the flow rate has to be approximated by evaluating the ellipse equation.

The standalone simulation, with a sophisticated model of the air suspension system, is an important step for designing the system dynamics. The interaction with a complete car, the road surface and a driver model are the next steps in the evaluation of the system. FLUIDON supports these steps by implementing the DSH*plus* simulation tool chain. It provides the design engineer with a tool that meets all the requirements of a company- or project-wide integrated virtual engineering.

The combination of the mechanical (multibody simulation), controls and air suspension is carried out with methods of co-simulation, either in the classical way as co-simulation between two programs or as an embedded module, where the air spring model is used for example as a black-box force element in multibody simulation.

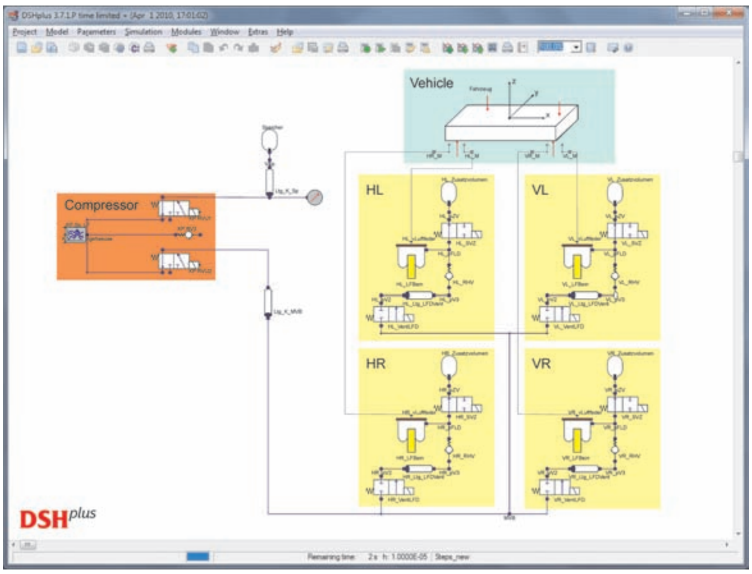
A further stage of extension is the use of the model in real-time applications. DSH*plus* automatically creates a C source code, which is applicable for different real-time platforms with help of the real-time workshop of MATLAB.

FLUIDON not only provides simulation software and services, but also test rig services and measurements. For the application described above, the FLUIDON test rig uses the determination of the values b and C for various types and sizes of pneumatic resistances. This can be achieved by varying the pressure level across the analyzed component and sub-sequential measuring of the resulting mass flow rate.



ABOVE: **A SELECTION OF AIR SPRINGS FROM TIER SUPPLIERS**

BELOW LEFT: **SIMULATION MODEL OF AN AIR SUSPENSION SYSTEM**



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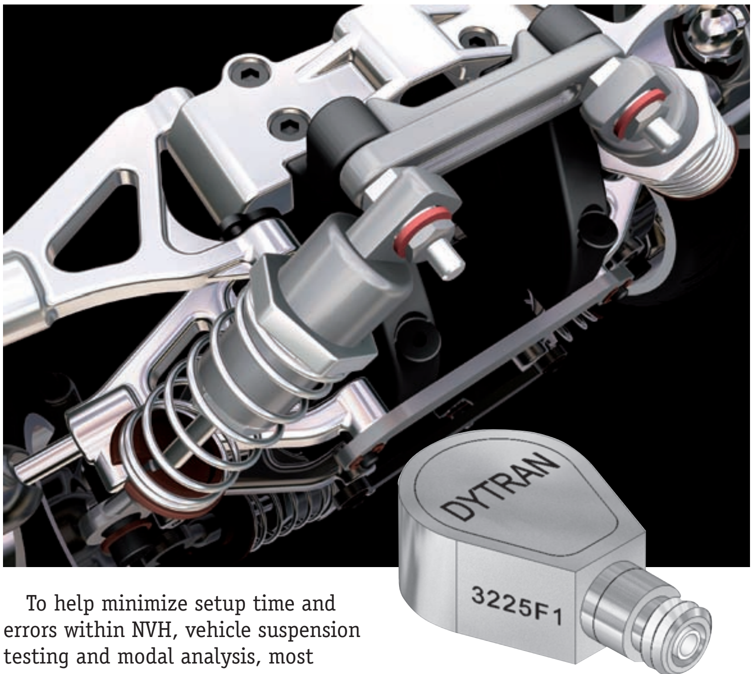
Quote ref VDI 006

Piezoelectric sensing

RIGHT: **A TYPICAL DYTRAN VEHICLE DYNAMICS APPLICATION WITH** (INSET) **THE 3225F1 MINIATURE TEARDROP ACCELEROMETER**



The effective study of vehicle dynamics relies on the collection of critical sensor performance data within demanding test cell or track conditions. Such requirements call for the use of rugged, hermetically sealed, high-performance piezoelectric sensors that are small, low-mass, offer a wide operating temperature range, and provide capabilities for onboard memory storage. The sensors must also be easy to mount in the space-constrained areas of a vehicle.

For the past 30 years, Dytran Instruments has been one of the industry's primary 'go-to' sources for a full range of standard and custom-made piezoelectric vibration sensors for vehicle dynamics, and particularly accelerometers for NVH testing, road load data acquisition, drivability, ride and handling, and powertrain testing. This includes a complete range of IEPE and charge mode accelerometers, offering reliable and repeatable dynamic measurement capabilities, as well as a variety of connector and cabling options.

IEPE accelerometers offer integral electronics, eliminating the need for external signal conditioning and greatly simplifying test setups. In addition, charge mode models offer higher temperature capabilities for mounting near engines, transmission or exhaust systems, as well as other areas characterized by wide operating temperatures.

Within NVH testing applications, Dytran piezoelectric accelerometers are typically mounted on the vehicle steering wheel, seat track, body panels, suspension and subframe attachment points, mainframe members, and suspension links, as well as across all vehicle mounts. A recommended sensor for use within these applications is the Dytran 3225F1 miniature teardrop accelerometer, with 10mV/*g* sensitivity and 500*g* measurement range. Weighing just 0.6g, the sensor incorporates a small, lightweight, removable cable and offers adhesive mounting capabilities. The low-mass design means the sensors can be easily mounted in space-constrained areas.

To help minimize setup time and errors within NVH, vehicle suspension testing and modal analysis, most Dytran piezoelectric accelerometers are available with TEDS capabilities (IEEE P1451.4 standard). TEDS sensors offer the benefit of integral onboard memory storage, enabling a test engineer or technician to retain sensor calibration and configuration data. TEDS sensors are also self-configurable when connected to TEDS capable signal conditioning, which in turn improves overall measurement accuracy.

A recommended TEDS accelerometer for vehicle dynamics is the 3273AT – a low-noise IEPE miniature triaxial accelerometer weighing just 3g. Offered in both 10mV/*g* and 100mV/*g* sensitivities, the sensor incorporates TEDS onboard memory storage capabilities, making it ideal for use in vehicle suspension characterization applications where large quantities of sensors are required within a single testing environment.

For vehicle transmission testing, the Dytran 2.3*g* 3333A1 IEPE triaxial accelerometer, is a popular choice. Offering ultra-low frequency response and low noise levels within a hermetically sealed titanium housing, the sensor offers both 10mV/*g* sensitivity and reliable operation in temperatures up to 121°C. To meet the especially demanding requirements of high-temperature engine and vehicle exhaust system testing, the rugged Dytran 3092C high-temperature accelerometer is often specified along with the 6894A stainless steel hardline cable. The sensor offers a 5pC/*g* sensitivity and wide dynamic range. Sensors and cables are typically used in combination to achieve high-accuracy measurements and provide a stable performance in temperatures up to 482°C.

As an essential accompaniment to the piezoelectric accelerometers, Dytran also recommends the use of rugged, professionally sheathed cable bundles. When used with appropriately selected sensors and instrumentation, the cable bundles can help reduce the errors associated with improper cable use, and help prevent the mis-wiring of multiple cables across long distances in complicated test setups.

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OxTS

New generation of GPS/INS systems

OxTS has launched a new generation of its popular inertial and GPS navigation systems. The RT2002 is a 2cm accurate member of the RT2000 family of GPS-aided inertial navigation systems, offering the best price/performance balance to date.

The small, turnkey system measures high-precision position (2cm), velocity (0.1 km/h), roll/pitch (0.05°), heading (0.1°), slip angle (0.2°) and acceleration, as well as other parameters. All outputs are computed in real-time with a very low latency. By combining a six-axis inertial measurement system with GPS, accurate and continuous data can be collected even in areas where a view of the sky is obstructed.

The RT2002 will be an invaluable tool for all vehicle dynamics tests and other testing applications on vehicle proving grounds. It can also be used in combination with the in-vehicle robots from Anthony Best Dynamics for applications like path-following or advanced autonomous testing maneuvers.

Far surpassing the accuracy, reliability, and performance of traditional measurement sensors,

the RT series of GPS-aided inertial navigation systems have become the standard for measuring all vehicle handling and performance characteristics.

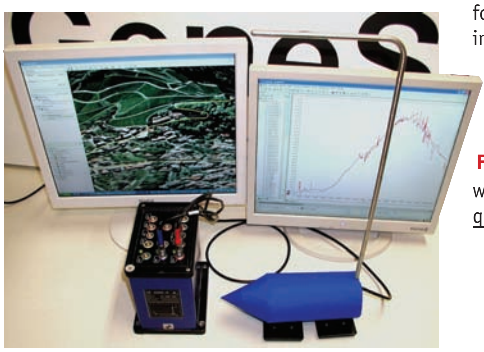
For more information go online at:
www.ukipme.com/recard/vdmcard.html
quoting reference VDI 008

GeneSys Elektronik

Determining vehicle height and position

One prerequisite of driving tests, as part of vehicle development, is to precisely determine the vehicle's position. In such applications, the ADMA (Automotive Dynamic Motion Analyzer) from GeneSys Elektronik delivers optimized and highly precise data.

Developed originally for vehicle dynamics testing, developers are increasingly using the ADMA for validating driver assistance systems, such as lane departure warning systems. Another important function of ADMA is to provide road data, including realistic height profiles. This information is needed, in particular, to optimize the design of the vehicle's powertrain.



THE BAROMETRIC HEIGHT SENSOR AND ADMA SYSTEM TOGETHER SUPPLY ACCURATE HEIGHT DATA

To ensure precise positioning even under difficult GPS reception conditions, GeneSys Elektronik now presents the new ADMA-PP post-processing software, which allows optimization of ADMA data recordings and inclusion of GPS correction data after the test drive. The software's core is a Kalman filter, which combines GPS and inertial data very well.

The real-time option continues to be provided by the ADMA system, but offline calculation has two decisive advantages. First, GPS correction data can be downloaded easily from the internet for the required test run. This facilitates installation work for the measurement process compared with the real-time mode, where GPS correction data must be supplied via a radio or GSM link from a private base station or an RTK network provider. Second, ADMA-PP is able to calculate position solutions, forward and backward, along the time axis, which improves positioning accuracy. The package is rounded off with an auxiliary module with a barometric height sensor enabling accurate measurements of critical height-related data.

For more information go online at:
www.ukipme.com/recard/vdmcard.html
quoting reference VDI 009

dSPACE

Horizon-based simulations

Modern advanced driver assistance systems (ADAS) are playing a growing role in reducing CO_2 emissions and increasing driving safety. In the future, advanced driver assistance systems in the automotive sector will rely more on information from digital street maps. NAVTEQ and dSPACE now provide closely linked tools for the simple and efficient development of map-based advanced driver assistance systems.

With the ASM Vehicle Dynamics and ASM Traffic simulation models from dSPACE, ADAS systems can be developed and tested in a complete virtual environment. Precise information on road topology via NAVTEQ's ADAS Research Platform can be imported to the ASMs through a standard interface. The virtual environment created in this way supports arbitrary test scenarios. A virtual GPS sensor sends a position signal to the ADAS Research Platform and a predictive assessment of the road ahead (NAVTEQ Electronic Horizon Algorithm), based on the current position of the vehicle, and NAVTEQ digital maps, can be coupled to the ASM simulation.

The convenient interface between ASM and the ADAS Research Platform is not limited to PC simulation. It can also be reused on a hardware-in-the-loop (HIL) or rapid control prototyping (RCP) system. This allows a seamless transition from the PC to the real world, so that driver assistance algorithms can be developed and tested with the same tools, data management, and experiment definitions.

For more information go online at:
www.ukipme.com/recard/vdmcard.html
quoting reference VDI 010

BorgWarner TorqTransfer Systems

Transmission accolades

BorgWarner's 31-03 eGearDrive transmission has won a 2010 Automotive Engineering International Tech Award and was named a finalist for the prestigious 2010 Automotive News PACE Awards. The innovation will drive the all-electric 2010 CODA sedan and all-electric Ford Transit Connect.

Specifically designed to be adaptable across a broad range of highway certified battery electric and range extended electric vehicles, BorgWarner's 31-03 eGearDrive transmission joins patented, proprietary technology with over 100 years of powertrain know-how. Its highly efficient geartrain offers a wide range of ratios, from 6.5:1 to 9:1, allowing adaptability to a variety of motor sizes and tire diameters. Combined with its compact, low-weight design, the BorgWarner eGearDrive transmission contributes to extended battery-powered driving range, which in turn reduces the amount of battery capacity needed. The transmission also achieves higher torque capacity with 97% efficiency, while providing a smooth, quiet operation.

BorgWarner eGearDrive systems enable launch assist, energy recovery, and all-wheel drive performance for front or rear secondary-driven axles. Also available are additional options including an electronically actuated park-lock system, and various electronic driveline disconnect systems. Approximately 99% of the materials used in the eGearDrive transmission are recyclable.

Further details are available from Bob Blakely, BorgWarner director, marketing at bblakely@borgwarner.com.

For more information go online at: www.ukipme.com/recard/vdmcard.html quoting reference VDI 011

Index to advertisers

Data dilemmas

JOHN HEIDER HAS SOME TIPS FOR GETTING THE BEST FROM OBJECTIVE ANALYSIS

> "Leading OEMs best understand and exploit their internal strengths in generating useful data from each method"

Many current experienced vehicle dynamics development engineers started their careers when the only available option for on-road data acquisition was subjective evaluation.

Today, objective on-road testing can be used very successfully to shorten development cycles and reduce program costs. But when gathered improperly, objective data can lead to added evaluations, lost time due to data processing requirements and program cost/timing overruns. Beyond standard practices of known equipment calibration, instrumentation techniques and standardized data reporting, there are some key techniques to successful and useful objective data acquisition.

The first is careful vehicle preparation. As the saying goes, garbage in results in garbage out. Ride heights, alignment settings, tire condition and other vehicle specifications must be known and closely controlled prior to the start of either objective or subjective testing.

Maneuvers should be limited to known, well-correlated events. All events should possess high repeatability and reliability, and be the result of previous correlation studies showing their relevance to perceived vehicle performance. Inventing new maneuvers to diagnose a specific issue is a difficult task not to be taken lightly.

Do not over-instrument. Just because you can measure something, doesn't mean you should measure it. Clearly define what you are trying to measure and limit sensors as much as possible. More channels mean more data and usually more processing time.

And finally, understand and interpret the results. There is a tendency to reduce data reports into single numbers in lieu of graphs. Vehicles are very non-linear and reporting only the slope at a single point can be an oversimplification and misleading.

Objective testing is best used for two main purposes: to compare with subjective results during maneuvers that have demonstrated good correlation, and to support CAE model results to build confidence in it for future use.

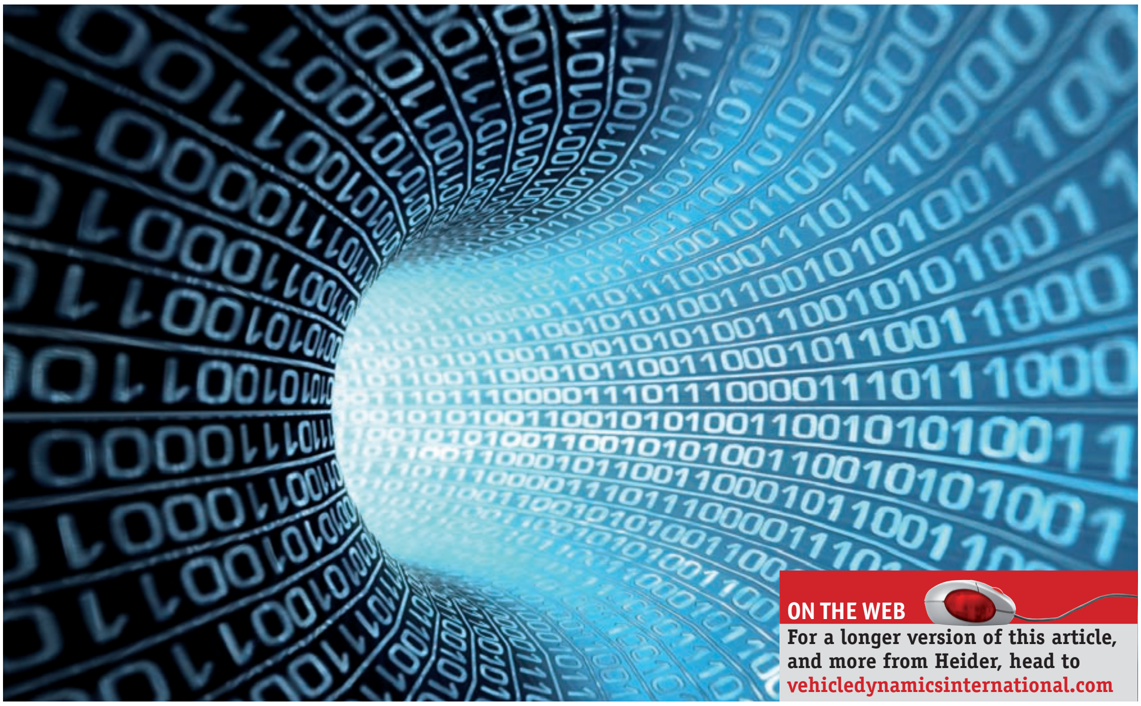
The capability of CAE simulations has grown tremendously over the past 10 years. However, there is still much debate over the ability to fully predict and develop OEM-level vehicle dynamics performance solely using CAE tools. I am not aware of any OEM who claims to have done this successfully or believes it can be done successfully at this time. The dynamics of a rolling tire, challenges in understanding the tire/road surface interaction, non-linear system and component properties, and the extremely high expectations for a modern vehicle's performance are the main inhibitors.

CAE tools have been used very successfully in two main areas. The first is raising the performance of early prototype vehicles to a high level and reducing the number of iterations required to reach the final tuning specifications. The second is improving vehicle quality to the customer by reducing the number of complaints generated by unwanted vibrations and vehicle alignment issues. Both are the direct result of CAE's ability to do what subjective and objective testing can't: perform thousands of iterations and assess vehicle performance trends with either different components or within the manufacturing tolerances of production-intent components.

There is no single formula for success. The integration of vehicle dynamics subjective evaluation, objective testing and CAE simulation methods occurs at varying levels across the industry. The leading OEMs are companies who best understand and exploit their internal strengths in generating useful data from each method to drive efficient development processes.

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

BE SURE NOT TO GET LOST IN A VORTEX OF DATA YOU CAN'T PROCESS!



ON THE WEB
For a longer version of this article, and more from Heider, head to vehicledynamicsinternational.com

BMW 5 Series

530d SE GT

JOHN MILES TRIES ONE OF BMW'S LATEST OFFERINGS: A 5 SERIES GT...ON RUNFLAT TIRES

> "Any claims that runflat tires can deliver the ride comfort of a normal tire are dispelled on the UK's rippled, cambered and frost-damaged roads"

The BMW 530d SE GT's single-turbo diesel gives an apparently moderate 245bhp but a massive 540Nm torque peak from 1,750-3,000rpm. Apart from a momentary throttle demand flat spot below 2,000rpm, the engine is a gem – most undiesel-like and seamlessly smooth round to the 4,700rpm red line. It's also quiet, save for a muted growl when shoving this big car forward. Zero to 62mph (100km/h) takes a claimed 6.9 seconds, but this belies the seamless progress thanks to a ZF eight-speed automatic transmission, which forms part of the programmable-shift-point dynamic drive control (Normal/Sport/Sport+) system. Shift quality is crisp yet smooth with no noticeable lag, transmission vibration or differential hum.

Most impressive was that on give and take roads, including a bit of hard driving, we were averaging around 36mpg according to the onboard computer. No doubt the coast down/braking-only battery charging makes some contribution to this, plus the clever 'kidney' cooling gills that motor-closed when not required, reducing drag.

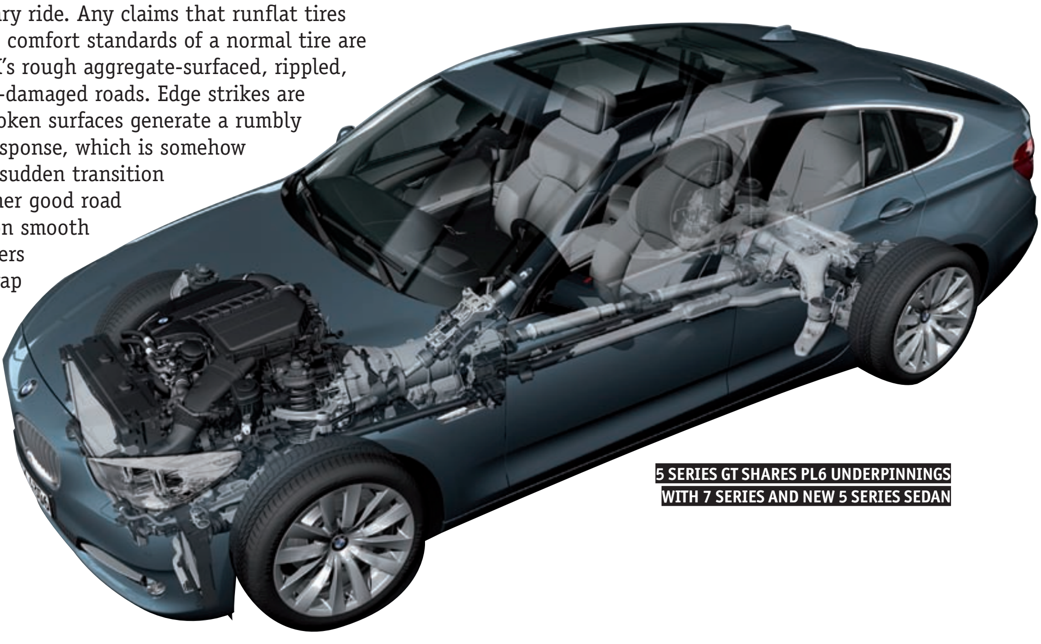
In spite of aluminum doors and hood, the car is no lightweight, tipping the scales at just under 2,000kg at the curb. To give the required response, a lot of tire width is needed, in this case provided by very low profile Goodyear R20 Excellence 245/40- (F) and 275/35- (R) section runflat tires mounted on the optional 20in-diameter wheels. After many years optimizing strut front suspension, BMW has switched to a double-wishbone system (see page 28). There are also air springs at the rear, which make levelling, if not ride comfort, easy to achieve.

Cornering roll, pitch and heave motion are very well controlled, and main-road stability rock solid. However, regardless of which driving mode (therefore damping) is selected via the fiddly iDrive system, there are real issues concerning secondary ride. Any claims that runflat tires can deliver the ride comfort standards of a normal tire are dispelled on the UK's rough aggregate-surfaced, rippled, cambered and frost-damaged roads. Edge strikes are very hard, while broken surfaces generate a rumbly and often crashy response, which is somehow made worse by the sudden transition from otherwise rather good road noise suppression on smooth surfaces. Many drivers will be happy to swap the primary body ride motion and some after-shake in 'Normal', for the shorter ride length but better shake control in 'Sport' mode.

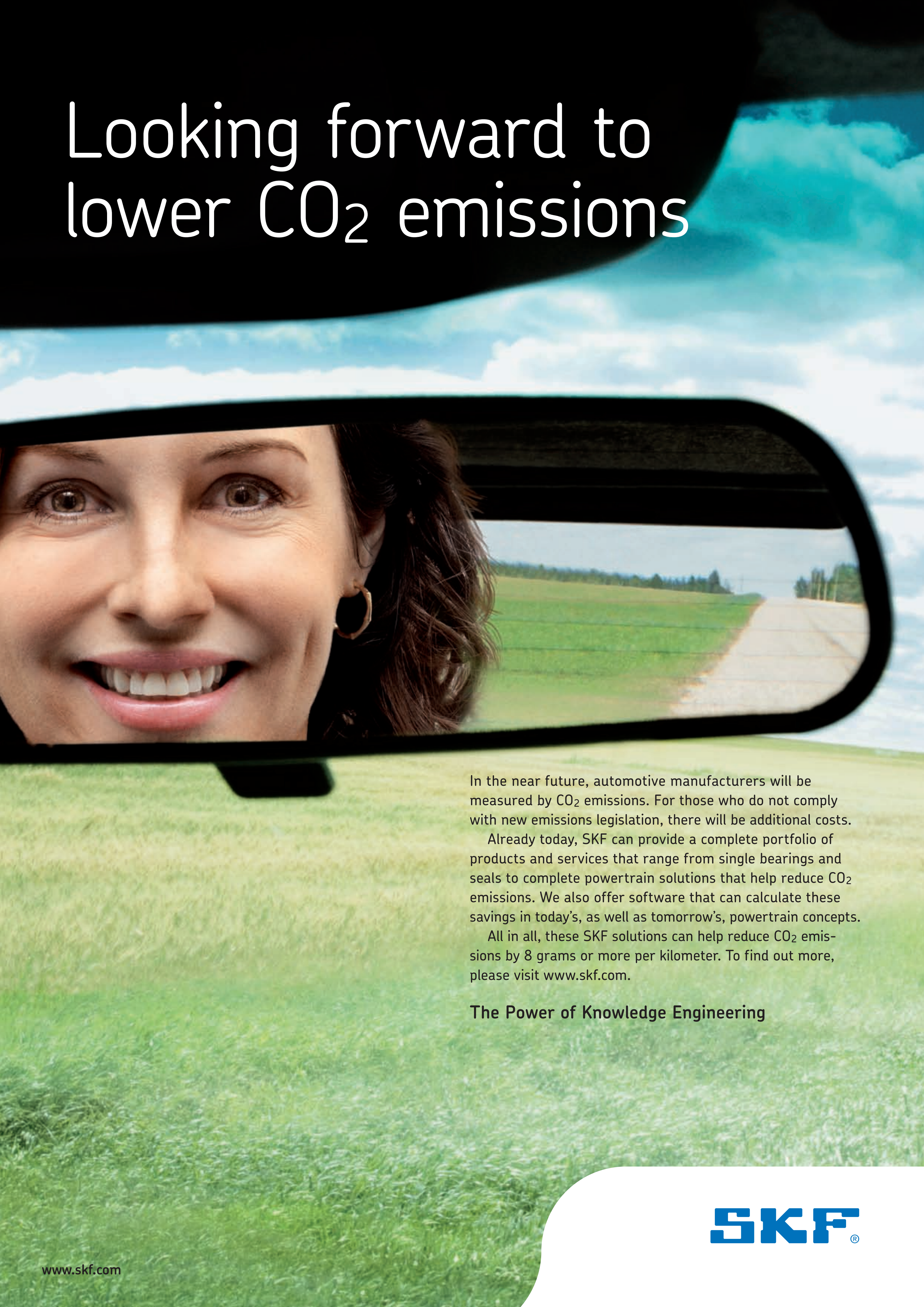
On bumpy cambered roads there remains a general stiff-legged feel to the body response, and at worst, a lot of head toss, which is at times coupled with steering-wheel tugging and spurious steering wheel aligning torque variations. This also coincides with the damping finally being unable to cope with the heavy unsprung mass accelerations, resulting in shuddering suspension activity that would surely moderate on the standard-equipment 18in wheels and tires. Tires are so fundamental to secondary ride and impact response, it is doubtful if the test car would have fared much better even with the optional Adaptive Drive package, although the 'Active' anti-roll bars might have reduced head toss on our test route's warping Fenland straights.

Much of the test was on damp roads where limit handling could not be explored, not that the stability control would have allowed it. In these conditions there was the impression of mild understeer, yet mid-corner steering aligning torque did not increase much, nor was there sufficient feedback at the steering wheel indicating the residual grip available – another by-product of very low-profile tires. With stability control switched off (DSC+), the steering was slower to respond, lacking the rather false pin-sharp response gain around center, yet in some respects there was more feel mid-corner.

BMW has always advertised rear-wheel drive as offering the best possible handling balance. Yet in today's motoring environment all RWD road car systems depend a lot on stability control to rescue or forestall a rear end slide. The standard 530d SE GT is equipped with DSC+ stability control, CBC (cornering brake control) and EBD (electronic brake force distribution). An on the road UK price of £40,810 is soon inflated by dynamic options, such as Adaptive Drive and Integral Active Steering.



5 SERIES GT SHARES PL6 UNDERPINNINGS WITH 7 SERIES AND NEW 5 SERIES SEDAN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Is this a setup?

CARS WE DROVE RECENTLY THAT DIDN'T BEHAVE AS THEY SHOULD

CASE 22: PORSCHE 911 CARRERA S, BY GRAHAM HEEPS

SPECIFICATIONS

Porsche 911 Carrera S
UK base price: £72,894
Chassis options fitted to our car (and what they cost)
Sports Suspension (10mm lower than a standard 2S's PASM chassis (20mm lower than a passively damped Carrera), with firmer springs, stiffer anti-roll bars, and a mechanical LSD): £753
Ceramic brakes: £5,349
SportDesign 19in alloy wheels: £238. Black paint finish £990!
TPMS: £428

Don't hate me. Driving a contemporary 911 on the road should be a special experience, right? Truly, I really wanted to love this car. But this Speed Yellow S wouldn't let me.

Loaded to the gunnels with £20,000 (US$30,000) worth of optional extras, this test car could be one of the most highly equipped 911s in the UK, but apparently even an average Carrera customer spends an additional 10-15% of the list price on profit-boosting, non-standard kit.

I'm not convinced that all the options fitted here improved the driving experience. In particular, there was the deafening roar from the 19in alloys on Michelin 235/35 (F) and 295/30 (R) rubber; the Sports Suspension (also optional, see panel) was probably at fault here.

Whatever the cause, this one single trait near-ruined the driving experience. Of course it's less of an issue on smoother blacktop, but coarse aggregate surfaces are used extensively in the UK so it's not a problem you can drive around. The resulting harshness, even with the PASM in Normal mode, was rather out of keeping with a £92,000 (US$138,000) sports car that's supposed to be usable every day.

Not that Normal mode was helping the usability cause. The post-winter-freeze, pot-holed roads admittedly failed to flatter the car, but even so there was a disappointing lack of compliance in the suspension of this particular 911. The optional bucket seats weren't especially comfortable for road use either, even if their black leather trim did add some style.

A more serious irritation was the lazy throttle response, the pedal requiring a decent shove to get the car moving at all. This was alleviated in Sport mode, but you then had to remember to separately switch back to a softer damper setting, to avoid an even less forgiving ride.

When your right foot finally did get through to the engine however, it revealed itself to be every bit as wonderful as you'd expect a latest-spec, 3.8-liter, 380bhp, direct-injected Porsche flat-six to be. Mild understeer developed rather earlier than expected on a wet roundabout but a circumspect approach in the adverse weather conditions of our test days precluded a more thorough exploration of the handling.

Despite my reservations, I've not lost faith that there's an excellent car in there somewhere, but this particular 911 wasn't it. From that extensive options list, I'd probably retain the PDK gearbox, the TPMS (surely this should be standard on a car this fast?), and perhaps the PCCB brakes. Not that my parsimonious spec would do to the car's residual value any favors!

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