VEHICLE DYNAMICS INTERNATIONAL

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Maserati Levante

The Italian legend is entering a new segment with something special: the world's first mechanical LSD on an SUV

Interview: Mike Cross

Jaguar Land Rover's dynamics guru discusses the effects of technology on his job, and receives some good news...

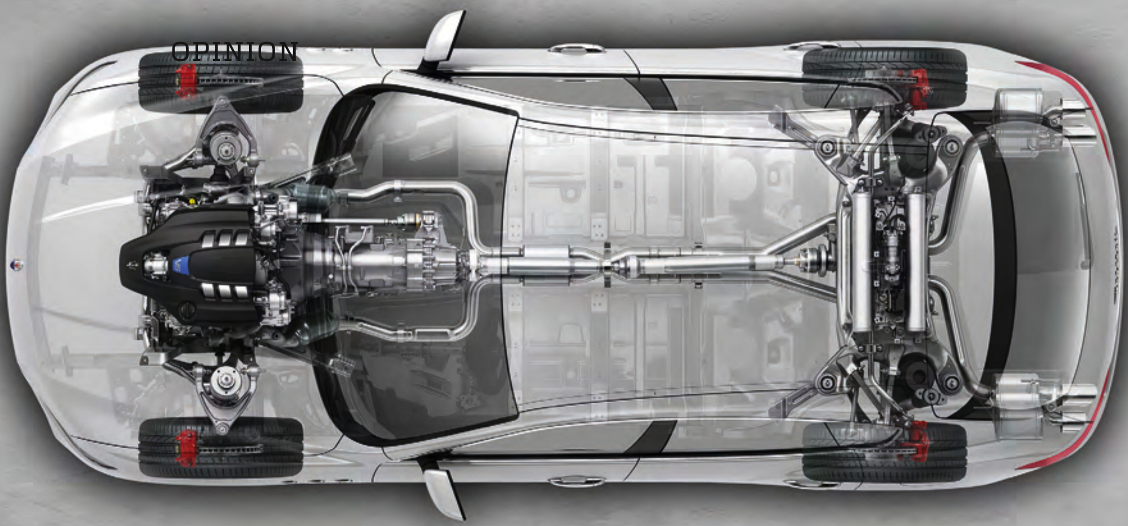
Bump stops

Back to basics: How to optimally tune a polyurethane bump stop for improved vehicle dynamics

VDI Awards 2016

Revealed: The worthy winners at this year's Vehicle Dynamics International Awards

MAY/JUNE 2016



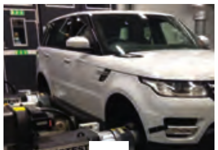
What's new?

Columns


8


22


30


34


64

Features

Product & service profiles

"We define a DNA for the JLR brands, and within those brands there is a model-specific flavor for the driving dynamics"

Mike Cross, Jaguar Land Rover, p30

A note from the editor

Big ideas

I've been away from the frontline of motoring for just a few short years, and it's amazing how many subtle yet significant changes I have noticed since my return. Power, for example. While many motorists are moving toward 'green' cars such as the Prius hatchback, the performance end of the hatchback market has gone ballistic, with 300bhp becoming the new entry point for 'hot' status. The A45 AMG has 376bhp for heaven's sake – that's more than the new 911 Carrera!

Big power figures are great for Top Trumps and pub bragging, but you don't hear too many people mentioning investing in performance driving courses. That we aren't hearing of 'widow makers' in the vein of the 1980s 911 Turbo (pah, a mere 300bhp) is testament to advances in vehicle dynamics that are making these cars not only fun to drive, but safe to have fun in.

Possibly the king of the hot hatches, the Ford Focus RS, has done rather well in this year's Vehicle Dynamics International Awards, as you can see on p22. This third-generation model has the obligatory firepower (345bhp), but it's the dynamics that truly impress, being a four-wheel-drive family hatch that likes to think it's a rear-wheel-drive racing car. A Drift mode even allows Ken Block wannabes to explore the performance envelope sideways in relative safety, with the ESC kicking in if it senses ham-fisted input. As the driver gets better, the ESC senses that correct inputs are being made and lets them play a little harder. Just incredible stuff, especially in a £30,000 (US$43,000) car.

It doesn't seem to be just power figures being discussed in pubs today; strangely wheel size has become a new point of rivalry, with bigger seemingly considered better. It will always be thus, with hard figures being key to establishing an automotive hierarchy, rather than wishy-washy notions of driver comfort, confidence and fun. Marketing departments know this too, and will keep pushing engineers for bigger numbers to throw around. One of the biggest right now is a wheel size for the Jaguar F-Pace: 22in. Such a big wheel sounds faintly ridiculous and potentially ruinous for ride quality, but there's no denying that it does look good. It is also what JLR dynamics guru Mike Cross is driving around on, and if 22in is the personal choice of our Vehicle Dynamicist of the Year – perhaps bling isn't just in, but is also best.

Adam Gavine Editor

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Raise the **trident**

Maserati's Levante SUV is a controversial but critical addition to the Italian OEM's model lineup, based on the Ghibli sedan

Words by **John O'Brien**

Maserati may be deemed to be late to the SUV party with the introduction of the Levante, 12 years after it proposed the Kubang concept, but getting the Levante right is very important for the company, given that luxury SUVs account for 60% of the vehicle market in Asia, 51% in North America, and 47% in Europe. But how has Maserati ensured that the Levante can differentiate itself in an already saturated market?

"We started to think about the car, in its current configuration, in mid-2013," explains Roberto Corradi, chief technical director at parent group FCA. "After some evaluations we decided to use an updated version of the architecture on which the Ghibli and Quattroporte sedans are based. This is because we believe that one of the key elements of Maserati's DNA is good vehicle dynamics, and by using a sedan base we were able to capture much of the characteristics that these two cars display."

Developed in Modena, Italy, the Levante has been a "pure Maserati" program according to Corradi, with only existing test programs, such as wading depths and incline testing, garnered from fellow FCA stablemate Jeep. The car retains most of the Ghibli chassis, itself a spin-off of the Quattroporte.

Tech spec

Maserati Levante

Width: 1,968mm	
Track: 1,624mm (f), 1,676mm (r)	
Length: 5,003mm	
Wheelbase: 3,004mm	
Springs and dampers: Skyhook dampers	
Brakes: Brembo six-piston caliper and 380mm discs(f) 330mm (r)	
Wheels and tires: 18 x 9in 255/60ZR18, 19 x 9in 265/50ZR19 (f) and 295/45ZR19 (r)	

ABOVE: The luxury pack gets black Brembo calipers, Sport gets red

ABOVE AND LEFT: The Levante was tested around the world, with a little extra work carried out for the Middle East market. The car is as happy on snow as on sand dunes

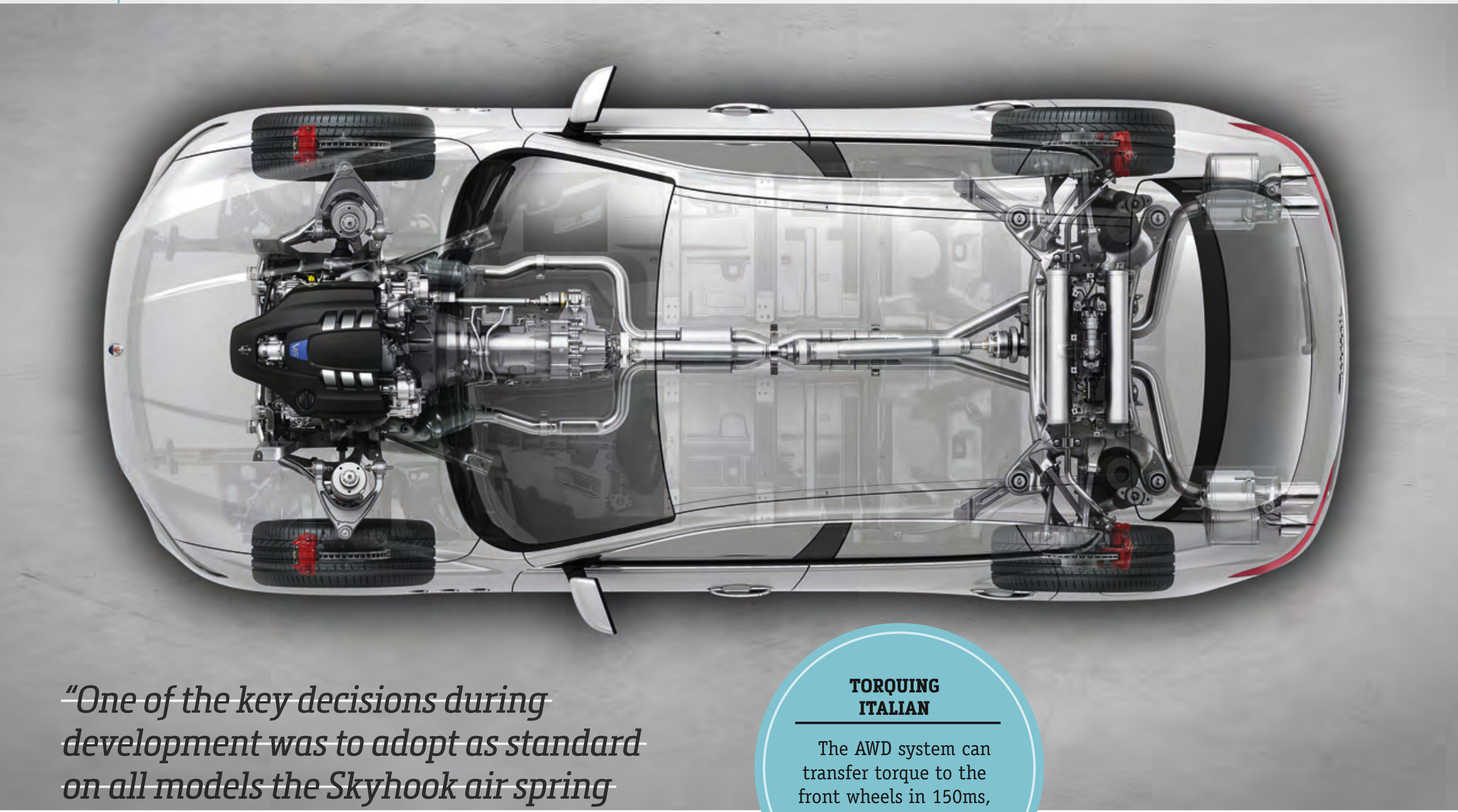
Using a mixed-material construction, Maserati was able to achieve a 50/50 weight distribution, with the doors, hood and luggage compartment made of aluminum. The front part of the chassis is an aluminum casting with a reinforcing cross strut, while the car's dashboard strut is made of magnesium.

"We basically kept the sheet metals as they are, with a slight change to the wheelbase," continues Corradi. "It increased by 6mm due to the air spring installation and the longer stroke of the suspension – so we adapted the geometry to retain camber and toe control over the various available ride heights. The structure of the car is the same, but we reinforced and strengthened the suspension towers to accept the increased loading that off-road driving may introduce."

Paired with the air spring installation is a mildly revised version of the sedan's all-aluminum double wishbone front suspension, and a multilink rear installation. The five-arm setup consists of four forged and one cast link to reduce the car's weight. Aluminum is also used on the wheel hubs, suspension towers and rear crossbeam reinforcement. Each component has been formed using new processes, which Maserati claims "ensure greater rigidity without weight increase".

"The suspension arrangement is a carry-over from the sedan. The different geometry control of the Levante has necessitated slightly revised control arms, but the basic principles and layout are exactly the same," confirms Corradi. "We chose to stay on this type of suspension to achieve the best road-handling capability. We believe that in comparison to our competitors – the Porsche Cayenne and BMW X5 – we have achieved better road behavior, with the same level of off-road capability. This is slightly different when referring to the Range Rover Sport, as it is more off-road oriented and as such it is amazing to drive off road, but we feel we far surpass that car's on-road behavior."

Further to Maserati's weight-loss program is the use of a hollow front anti-roll bar. It counters the additional mass of the closed air supply suspension, which builds on the Skyhook concept.



> *"One of the key decisions during development was to adopt as standard on all models the Skyhook air spring and continuous damping system"*

TORQUING ITALIAN

The AWD system can transfer torque to the front wheels in 150ms, altering the split to 50/50

The system comprises four independent air springs, each with a level sensor, two reservoirs mounted on a rear suspension cradle, a compressor with a valve block, and an ECU.

"One of the key decisions during development was to adopt as standard on all models the Skyhook air spring and continuous damping system," explains Corradi. "Because the air springs have no fixed stiffness, and change during the travel of the spring itself, it was necessary to include a control system that continually damped."

The pneumatic system provides six height levels, with the 'standard' ground clearance being 207mm. From this base, the car can raise or lower itself by up to 45mm, depending on ground conditions.

"Another benefit of using the electronically controlled damper and springs is that we were able to perfectly tune a number of damping curves for the various predefined ride-heights of the car," continues Corradi. "If you drive the car in 'normal' mode, it really doesn't feel like an SUV. It feels every bit the Maserati sedan. If the conditions of the road demand, you can raise the car by 45mm to clear obstacles. On the highway it can lower into one of two 'aero' modes to achieve a best-in-class aerodynamic drag coefficient of $0.31C_x$."

The AWD system in the Levante is based on the FCA-Group's Q4 system, as also found in the Ghibli, which is based on an electronically controlled, multiplate wet clutch, installed into a transfer case linked by a driveshaft to the front axle. In normal driving conditions the system provides 100% of the engine torque to the rear wheels, but can transfer torque to the front wheels in 150ms, altering the split to 50/50.

In a first for the segment, the Levante is the only car equipped with a mechanical LSD at the rear axle. Fitted as standard, the asymmetric locking feature offers 25% lock-up under power and 35% under release.

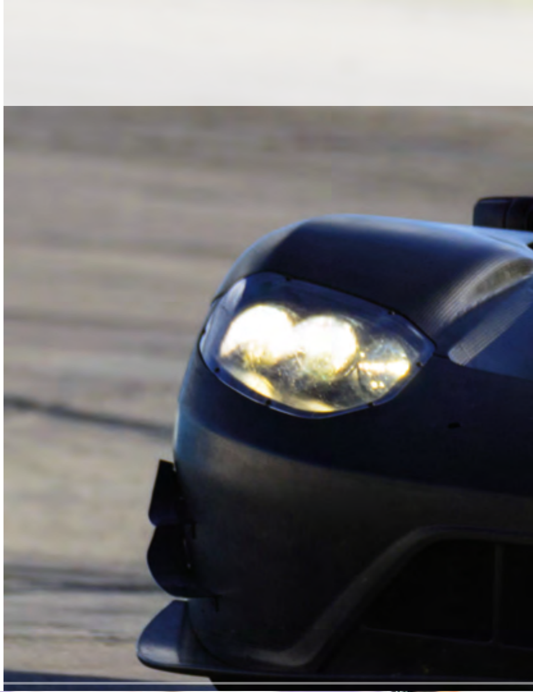
The rear differential is driven via a two-piece, 80mm-diameter lightweight steel prop shaft with two constant-velocity joints and a single-head rubber coupling, running through a cross-member mounted rubber bearing for NVH reduction.

The braking capacity on the Levante is determined by the power level of the car. The range-topping 430hp Levante S features Brembo six-piston aluminum monobloc calipers, which grip on 380mm drilled discs. Aluminum 42mm floating calipers with 330 x 22mm ventilated drilled discs are fitted at the rear. The less powerful 350hp gasoline and 275hp diesel models are equipped with two-piston 48mm floating calipers working on 345 x 32mm ventilated discs at the front. The rear brakes are the same as in the 430hp version but with solid, rather than drilled, discs. By braking the inside wheel while cornering, the system offers mild torque vectoring.

This policy necessitates two OE wheel fitments on the car, with the lesser cars being equipped with a 'square' setup of 18 x 9in wheels, wrapped in 255/60 ZR18 tires from Pirelli. The 'S' gains a staggered 19in wheel fitment, equipped with 265/50ZR19 (front) and 295/45ZR19 (rear) Pirelli tires.

The Levante is an important model for the brand and Corradi is keen to stress that it is a global car. However he does admit that the development team carried out some additional testing for the crucial Middle East market.

"In general the Levante had no more market-specific tunes than the usual Maserati model. However, we did do some specific tuning for the Middle East market, as a lot of customers there love to take their cars out to the sand dunes. We took a car out there to understand the surface better. But I'd say the Levante hasn't been influenced by individual markets any more than any other model."



Ford's all-new GT was developed in parallel as a road and a race car. **Graham Heeps** investigates the additional work required to go racing

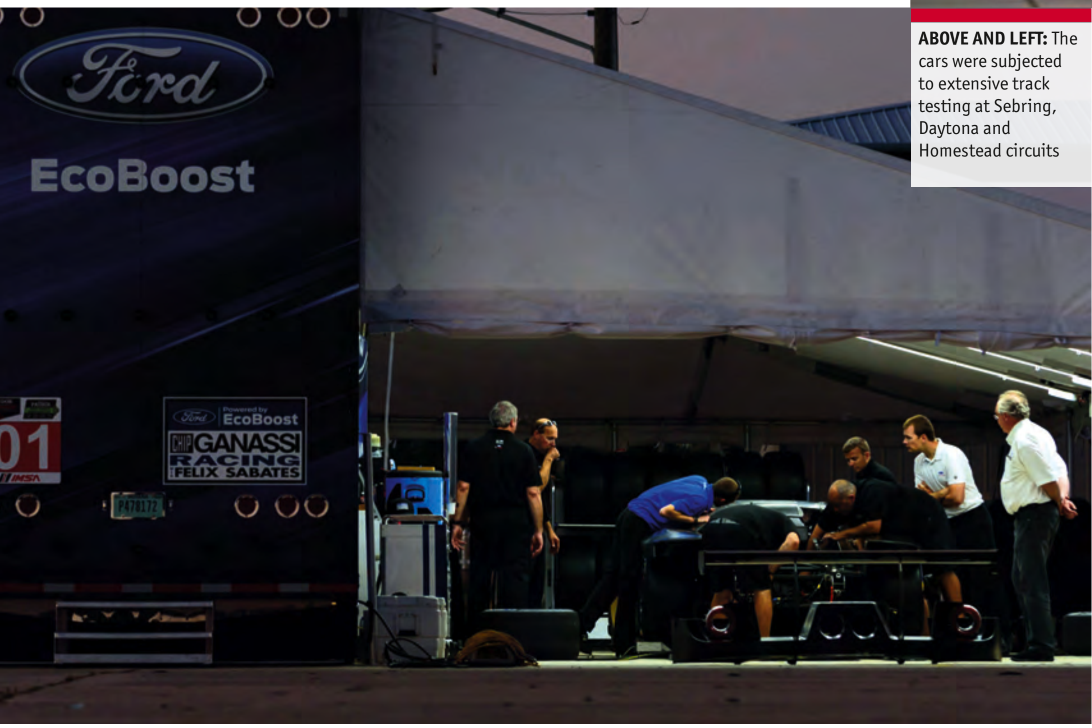
Dual purpose

All eyes were on Ford at the 2015 Detroit auto show when it unveiled a new supercar – the GT. Just a few months later, at the Le Mans 24 Hours in June, the Blue Oval confirmed what everybody had long suspected: that a track-ready GT would return in 2016, in celebration of the 50th anniversary of Ford's first win at the endurance classic.

But by the time this announcement was made, the first GT race car had already completed its initial shakedown, at Calabogie Motorsports Park, Canada, in late May. Calabogie is within easy reach of the Markham, Ontario, base of Multimatic, one pillar of a three-way development and test partnership for the new racer alongside Ford, and the ultra-successful sportscar, NASCAR and IndyCar race team, Chip Ganassi Racing.

"Our partners were chosen wisely," says Mark Rushbrook, head of engineering for Ford Performance. "Multimatic has the ability for design, chassis and vehicle dynamics, and Ganassi knows how to race a car. Combined with some of the engineering knowledge and resources we have at Ford, it was a great three-way partnership."

The road and race versions of the Ford GT have been developed in parallel, and in some areas by the same engineers, now that the former Ford Racing, SVT and Team RS divisions have been brought together as Ford Performance. This reorganization has changed the way Ford operates when it comes to developing performance vehicles and variants.



ABOVE AND LEFT: The cars were subjected to extensive track testing at Sebring, Daytona and Homestead circuits

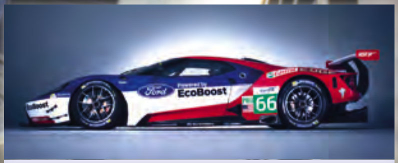
"We're all housed in one building now, so the engineers who work mainly on the racing program are sitting right next to the road car staff," explains Rushbrook. "Every morning we have a start-up meeting at which the racing and road car teams go through what we've all learned."

In addition, the development of the GT race car's tires was led by the same Michelin engineer who led the street car program, further reinforcing the track-to-street ethos.

The GT program also reflects the wider 'One Ford' development approach now adopted for all its new cars. Design work was done in both Europe and North America (extensive travel and WebEx video conferencing facilitated the required communication between teams at different sites) and all track data is being shared between the separate two-car teams competing in IMSA (USA-based) and WEC (UK).

Beginning in 2014, an extensive analytical phase of CFD and vehicle

"All the testing we've done was to hit certain mileage targets and prove components. We've hit all those targets. We're going to win"



Tech spec

Ford GT

Chassis: Multimatic carbon-composite tub with welded steel and machined aluminum subframes, integrated FIA-homologated Roll-Over Protection System (ROPS)

Suspension: Front and rear double A-arms with torsion bars. Multimatic DSSV adjustable cartridge-type dampers and blade-adjustable front and rear anti-roll bars

Brakes: Brembo calipers and full-floating rotors

Tires: 20in Michelin Pilot Super Sport Cup

dynamics simulations was undertaken to define the total vehicle architecture and establish baseline chassis settings and tuning sensitivities.

The driver-in-the-loop (DIL) simulators used by Multimatic in Markham and by Ford Performance in Charlotte, North Carolina, both feature the same simulation technology.

"That was part of our strategy," confirms Rushbrook. "The tools we use inside Ford for the GT program, and the racing side of it, are consistent with the tools Multimatic uses, both in terms of simulation, and in terms of using those simulation tools to drive the DIL simulators. We made a conscious decision two years ago to align it that way so that we wouldn't have correlation issues with different tools. We would have the same tools, the same vehicle model, and tune it together. The simulator was used for chassis and aerodynamics development, and for other things such as gearing."

The GT has a carbon/aluminum chassis clothed in carbon-fiber panels. Many parts, such as the intake, were first 3D-printed and then later replaced by carbon versions. However, some printed parts, such as the steering wheel grips, headlight pods and tail-lights, remain on the finished cars.

The suspension pick-up points are unchanged from the roadcar. Suspension is via torsion bars in a double-wishbone setup; the dampers are Multimatic DSSVs.

For aerodynamics work, Rushbrook says that a reduced scale tunnel, "where we ran iterations of the scale model to confirm the correlation with CFD", was used during development.

When the second development car came on stream in September, the team began running two cars with split test strategies. The Multimatic-run car handled some of the more fundamental development work, while the Ganassi-run car accumulated miles, making sure the car was driveable for long stints, and was also used for some of the fine-tuning.

"We did additional on-track testing at Road America because of its long straights, and because it's one of the tracks we'll race on in the future [in IMSA's WeatherTech SportsCar Championship]," Rushbrook explains. "From there we primarily tested in Florida – it had begun to get a little colder [in Detroit] and there were specific tracks we wanted to target. We used Sebring twice because it's always a challenge. It's hard on cars, great for durability and difficult to tune for. We also went twice each to Daytona and Homestead.

"We have done everything we think we can to make this car as reliable and as driveable as it can be," he expands. "This is a new program with a new car and we recognize that things can happen, but all the testing we've done was to hit certain mileage targets and prove components. We've hit all those targets. We're racing to win."

One area that took some time to resolve was the braking system – finding a combination of calipers, rotors, brake pads and other system fundamentals that all the drivers were happy with. That wasn't easy given that the team was dealing with eight full-time drivers across its four race cars. The issue was ultimately resolved with "great support from Brembo", says Rushbrook, in time for IMSA's pre-season 'Roar Before the Rolex 24' test at Daytona in January 2016, when the two newly built GTs for IMSA's GTLM class were run for the first time.

ABOVE: The engineering team visited the challenging Sebring circuit twice for evaluation runs

Rough guide

To ensure good ride comfort for customers driving on unique rough roads around the world, Ford has built a little route of horrors

Just as the public is demanding wheel rim sizes as large as their tire ratios are low, the road surfaces on which they are driving are getting rougher, making dynamicists' jobs tougher. Engineers now have to find a way to create excellent ride comfort out of a high unsprung mass and small tire sections, but Ford dynamicists, don't have to travel far to get a rough ride.

Ford has deliberately built an absolutely appalling stretch of road at its Lommel Proving Ground in Belgium, a 1.2-mile tract of driving misery that recreates some of the worst potholes and road hazards from around the world. From the convenience of their own proving ground, Ford dynamics and durability engineers can see how their suspension setups cope with the worst the world's roads can throw at them, in a time-efficient and reproducible way.

The 'best' of more than 100 road hazards from 25 countries worldwide have been squeezed into this nightmare route, with Ford engineers cramming in their favorite rough bits from roads in Austria, Germany, Italy, Russia, Spain, Switzerland and the UK, as well as Asia, Australia, North America and South America. Particular highlights include granite blocks from Belgium, cobbles from Paris and speed bumps from Brazil.

Engineers drive through the potholes (up to 12cm deep) at speeds of up to 46mph (70km/h), using sensors to record the loads and strains placed on the suspension and components. Even at 46mph, hitting a 5cm-high bump means 5*g* of force goes through the vehicle.

The capabilities of the facility might mean that engineers can spend more time testing and tuning than traveling, and Ford can save a little time and money and gain a little extra quality.

"From a rutted traffic junction in China to a bumpy German sidestreet, this road is a rogues' gallery of the most bruising surfaces that customers might encounter," says Eric-Jan Scharlee, durability technical specialist at Lommel. "By incorporating these real-world challenges into our test facilities, we can develop vehicles to better cope with challenging conditions."

Developed in Lommel

Ford is using the facility to fine-tune many of its dynamics systems, including its Continuous Controlled Damping with pothole mitigation technology, which will debut on the Mondeo, Galaxy and S-Max. The technology adjusts the suspension if it detects that a wheel has dropped into a pothole, and can help protect the suspension from damage. Ford's tire pressure monitoring and electronic stability control systems are also being further refined at Lommel.

TOP: Ford is on the lookout for potential new additions to the facility's range of rough surfaces

ABOVE: Engineers can feel the challenging surface of the Champs-Élysées without suffering the challenging traffic

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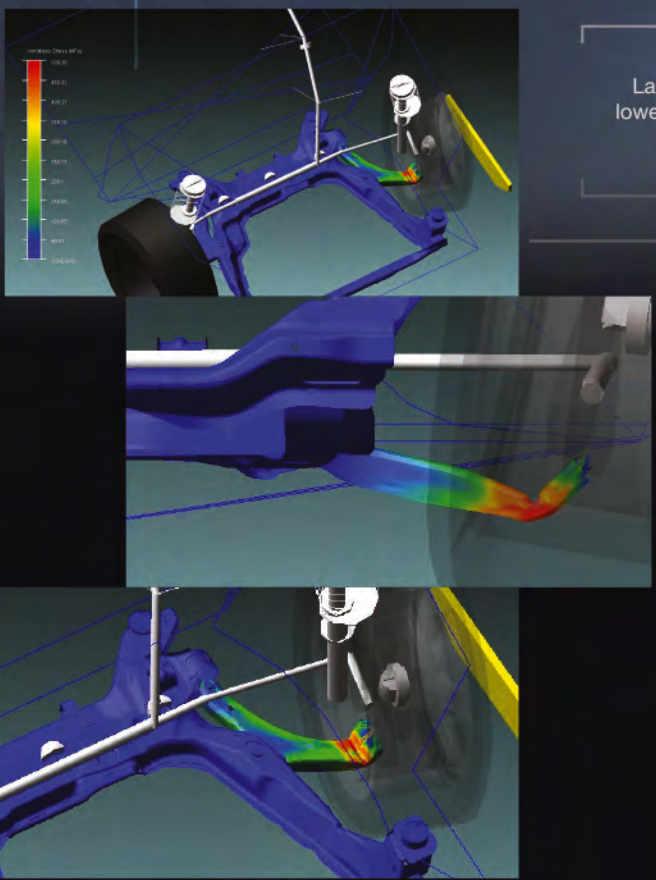

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Miles

There may be a buzz surrounding the development of autonomous cars, but **John Miles** doesn't predict the motoring public will give up their driving gloves anytime soon

It seems to me that autonomous systems working in predictable environments such as aircraft are well suited to automation, but elsewhere the fit looks a bit more problematic. It is one thing seeing early experimental autonomous cars driving themselves around a deserted test track, but surely quite another trying to deal with the huge complexity of real road conditions and today's traffic density, especially in Europe, where the conditions are so different from the wide, straight, clearly bordered freeways of the USA.

Where control-by-wire systems are concerned, my innate distrust of them stems from having worked a little on the Lotus Active Suspension in the 1990s and observed the failures and unstable states that could be caused by even the smallest electrical or transducer malfunctions. I can only imagine the effect of similar system failure modes in the knockabout environment of everyday motoring, and also the arduous validation processes that will be necessary for all the dynamic states before autonomous vehicles are ready for production.

Humans have the advantage of being able to anticipate events, whereas autonomous vehicles can only react to their immediate environment, a response determined by whatever software 'models' have been programmed, in terms of spacial limits, and pre-set speed, modal, longitudinal and lateral acceleration limits. Dynamic performance thresholds will have to be well below the actual vehicle limits, and as a consequence, autonomous cars will be prevented from making effective emergency maneuvers. Accounting for even 50% of the external events we encounter that require tailored input from the driver will surely challenge any programmer.

One assumes navigation and route finding in a macro sense will always depend on satnav, but at the current stage of development, it seems that autonomous vehicle systems cannot yet provide the detail control required on many journeys when dealing with factors such as poor road markings and surfaces, diversions, close gaps, or variable speed management. I did hear of one test car following a white line marking the off ramp before the driver took charge! The question is, will autonomous vehicle systems ever be able to provide the millimetrically perfect control required on narrow roads with little in the way of definition either side of track, especially in the wet or at night when definition is lost, or to provide seamless progress through the hurly-burly of inner-city traffic?

In the UK an autonomous car doing exactly 70mph on the highway (the speed limit) would be a nightmare: too fast for the inside lane, alternately too slow or too fast for the middle lane, and definitely too slow for the outside lane, where most people travel at 80-85mph. The 'driver' would be nervously anticipating the need to take control in case crucial input signals are lost or stability margins breached – as they might be in a stiff crosswind, for example. Then again, the majority of drivers have never experienced loss of control and would probably be incapable of vehicle correction in time anyway.

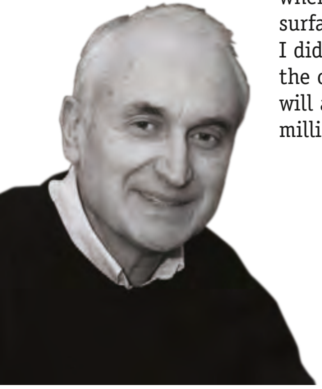
I suppose positive points for automation are that cameras don't get tired, and can look in all directions at once. There could be the potential to track other vehicles and trends in driving behavior to provide a 'heads up' of an upcoming incident. Corrections to instability can be applied to the car directly involved, and any surrounding vehicles instructed to make avoidance maneuvers. Multiple redundancy is a given for failed components, as is tire pressure motioning plus identification of tire type and size, so that the appropriate stability control calibration is selected automatically.

There are differences in vehicles themselves to contend with. Take my 2012 Ford Focus with its oddly disconnected steering response, out-of-phase yaw behavior, and quite marked differences in handling between dry and slippery surface stability (especially on snow). By sensing yaw velocity changes and steering tie-rod loads, automatic micro yaw correction is available via Bosch/VW's EPAS 'steering recommendation' system, so straight line stability could, I suppose, be fixed. But that creates yet another dynamic parameter to be validated as 100% reliable at the vehicle sign-off stage.

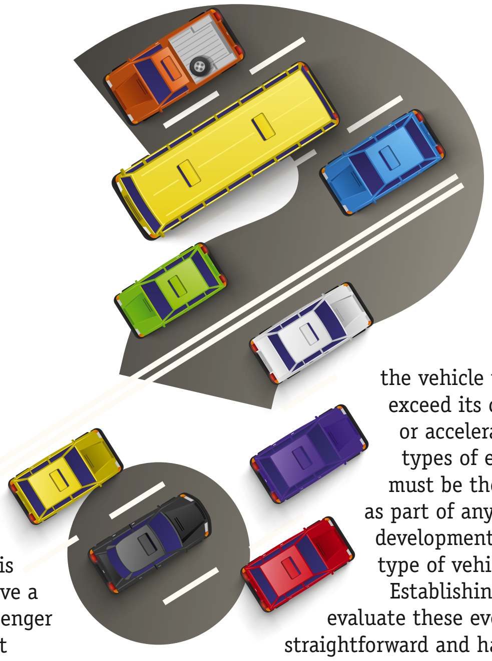
In summary, I fear that publicity inferring that soon you will be able to read a book while wafting from A to B is fanciful. Bear in mind that the typical 16:1 steering ratio dictates that road wheel angles of a few millimeters are used to control a car at high speed, so human reaction to an electronic 'drop out' should be measured in milliseconds, which is rather unlikely. No, for the moment it is low-speed routes with stop/start traffic, straight lines and only gentle bends that look like the best bets for autonomous vehicles.

"Dynamic performance thresholds will have to be well below the actual vehicle limits"

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



Heider



What is the best handling vehicle? It's a simple question that raises many complicated questions, says **John Heider**

What is the best handling vehicle? On the surface this would appear to be a simple question that should have a simple answer, but the handling performance of passenger vehicles continues to be one of the most talked about, yet least understood, attributes of vehicle dynamics.

The distinction between passenger vehicles and purpose-built racing or track vehicles is an important one. On a closed course with a GPS device mounted, lap times, segment times and cornering speeds can give a clear indication of whether a vehicle is handling 'better'. And in this instance, taking into account the ease at which the driver can control the vehicle, better means faster.

The handling performance of a passenger vehicle requires much more extensive analysis and evaluation. The first level of distinction is between customer handling attributes and emergency handling attributes. Customer handling attributes are what most people generically refer to as 'handling': roll control, steady-state cornering force, linear range understeer, and perhaps even throttle or brake application while cornering. These attributes are what moderately skilled customers can safely explore on their favorite driving roads in anything from a family sedan to a sports car. A certain British television program did us no favors by espousing the handling virtues of a vehicle solely based on its ability to be drifted (power-on oversteer to you and me) around a series of airport runways and taxiways. This is not customer handling; it is television presenters with unlimited tire budgets behaving badly.

Emergency handling performance refers to vehicle handling characteristics during events that are dictated by outside influences, or limit-handling events caused or exacerbated by improper driver inputs. Evaluating and developing emergency handling performance is often overlooked by outsiders, but is a critically important part of a vehicle dynamics engineer's job description. There are two main reasons for this: we want to keep our customers as safe as possible and our employers safe from litigation. There are many examples of emergency handling maneuvers: single or double lane changes to avoid unexpected obstacles in a vehicle's path; misapplication of braking and/or steering to reduce excessive speed while exiting a motorway; or any type of driver input that causes the vehicle to unintentionally exceed its cornering, braking or acceleration limits. These types of events and others must be thoroughly evaluated as part of any vehicle dynamics development program on any type of vehicle.

Establishing the best means to evaluate these events is clearly not straightforward and has not been agreed by all manufacturers and legislative bodies. Additionally, the widespread application of electronic stability control (ESC) systems has brought further complexities. The need to satisfy legislative requirements, yet go beyond them to protect the manufacturer in the eyes of the legal system, raises several questions when developing a process to evaluate emergency handling performance.

What type of events will be used? Single lane change, double lane change, increasing/decreasing/constant radius corners, or something else?

What loading conditions will be evaluated? Should a certain number of passengers be included, or the gross vehicle weight as stated on the vehicle used? Additional considerations include whether the vehicle is rated to carry a cargo rack on the roof or to tow a trailer.

What type of surfaces should be used for evaluation? Low friction coefficient surfaces must be considered.

What influence will the ESC system be allowed to have on vehicle performance? Some manufacturers treat ESC systems as safety-critical in the same way as airbags and seatbelts. They are not. The decision to evaluate emergency handling performance with the ESC system on or off must be considered by each manufacturer. Finally, what will the evaluation criteria be? Subjective, objective or both?

Evaluating the emergency handling performance of a variety of vehicles shows very different philosophies between manufacturers. Some produce vehicles that are extremely robust to all events, loading conditions and surface types, and exhibit exemplary performance with or without the aid of ESC systems. Others fall woefully short when an emergency handling event presents itself.

There is no simple answer to the original question about the best handling passenger vehicle. Dynamics engineers must effectively manage the development process to deliver confident, engaging customer handling attributes while ensuring the vehicle can safely manage an emergency.

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

"Evaluating and developing emergency handling performance is often overlooked by outsiders, but it is a critically important part of a dynamics engineer's job"

MAIN IMAGE: Bump-stop tuning forms part of the tough suspension development programs for Land Rover. This Discovery Sport is being given a particularly hard time

The bump stops here

One of the most valuable lessons a suspension engineer can learn is how to optimally tune polyurethane bump stops

WORDS BY **JOHN MILES**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ABOVE: Bump stops get a thorough workout during Ford vehicle suspension development and durability programs

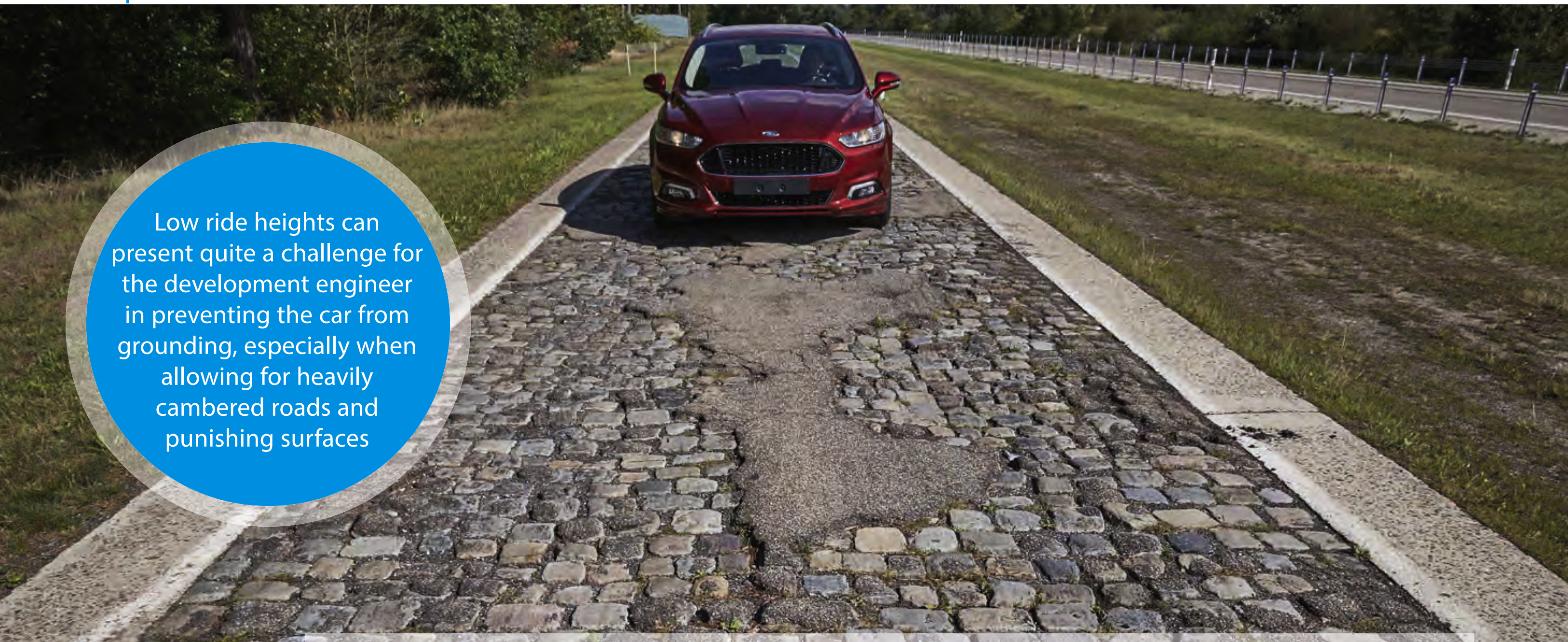
If there is one component that has contributed the most benefit for the lowest cost in the design and development of suspension systems over the past 20 years, it is the humble microcellular polyurethane (PU) bump stop or 'spring aid'. The more we know how to tune these ultra-simple and durable components, the more the chassis development engineer can use their beneficial influence, one of the biggest advantages of PU being its progressive (rather than linear) compressibility characteristics, which permit increased ride travel for a given damper stroke, and thus more efficient packaging space for struts and dampers. Compared with rubber components, PU components give a better compromise between suspension deflection, rear-axle gross-weight body control, and ultimate roll control.

Thirty years ago, rubber was the only material available for this kind of work. It worked well enough, but its linear load-deflection characteristics and liquid-like behavior under heavy compression loads caused it to expand laterally under high compression loads and spread way outside the striker plate on the damper body unless contained by a metal shroud. While the metal shroud provided progressive load deflection characteristics, it also resulted in a significantly longer block height, which in turn limited the available wheel travel.

Temperature sensitivity was also an issue. By contrast the structure of microcellular PU causes it to deform internally to a high degree, usually making the need for containment at high loads unnecessary. PU also generates useful hysteresis or internal damping, whereas rubber acts more like a spring which has to be damped. By the mid-1980s, the advantages of PU were gaining real traction in bump-stop material choice, and also for damper top mounts in the case of Jaguar. Soon the longer rear bump stops typically specified to provide support at higher vehicle loads became known as 'spring aids', whereby linear springs combined with the long corrugated PU parts work together to provide progressive springing – a much cheaper and infinitely more tuneable alternative to variable-rate coils.

PU's compressibility characteristics are a dynamicist's dream, permitting the same wheel travel for less metal-to-metal damper stroke. Other big advantages are simplicity and cleanliness of component production, which did not require heat or vulcanization. Changes in profile, length and stiffness are fast and cheap to implement, an important consideration because of the increasing sensitivity of car chassis systems to the increased grip that modern ultra-low profile tires offer. Prototype parts can even be modified or turned from raw PU bar in a workshop lathe.

Of all the major handling modes, cornering roll is probably the least liked by customers and road testers. Despite improved anti-roll bar (ARB) systems (mainly due to strut-mounted links), ARBs can never do much more than halve the roll without badly affecting ride comfort. Ultimately, bump stops and spring aids are generally the most influential components in limiting body lean, and therefore how the outside tire loadings are shared between the front and rear axles towards the limit of adhesion. Changing bump stop/spring aid stiffnesses and cross-sectional profiles adds to the effective wheel rates at any



Low ride heights can present quite a challenge for the development engineer in preventing the car from grounding, especially when allowing for heavily cambered roads and punishing surfaces

ABOVE: Ford carries out extensive bump stop tuning work on the special surfaces at its Lommel Proving Ground in Belgium

given moment, thus affecting the understeer/oversteer balance in the same way that springs do, especially during a transitional maneuver.

One of the most important considerations in bump stop setup and design is to get the 'contact point' optimized relative to wheel position (taking into account suspension velocity ratios). The design should always provide for the front bump stop to make contact with the damper body before the rear one does, and for the relative wheel rates to rise faster at the front axle, thus ensuring an understeer tendency from start to finish.

The fun and games usually start with rear weight-biased cars with marginal rear tire section widths. This is when the desire to eliminate pitching pushes the development towards rear ride frequencies that are stiffer than ideal for rear tire grip to be maintained at the limit of adhesion.

The resulting tendency toward oversteer can usually be mitigated with efforts to push as much mass forward as possible, combined with considerable damping and bump-stop development. Proof is to be found in the rear-engined Porsche models, which demonstrate that if all rear suspension frequencies have been reduced beyond the theoretically ideal, clever damping and bump-stop tuning can still result in minimal pitch sensitivity and acceptable handing.

The importance of rear bump-stop design during high-speed transient handling becomes clear from the driving seat, when one discovers that very small changes

ABOVE LEFT: Kia brought in Lotus to ensure that the suspension settings and bump stops for the Soul were appropriate for the UK's rough roads

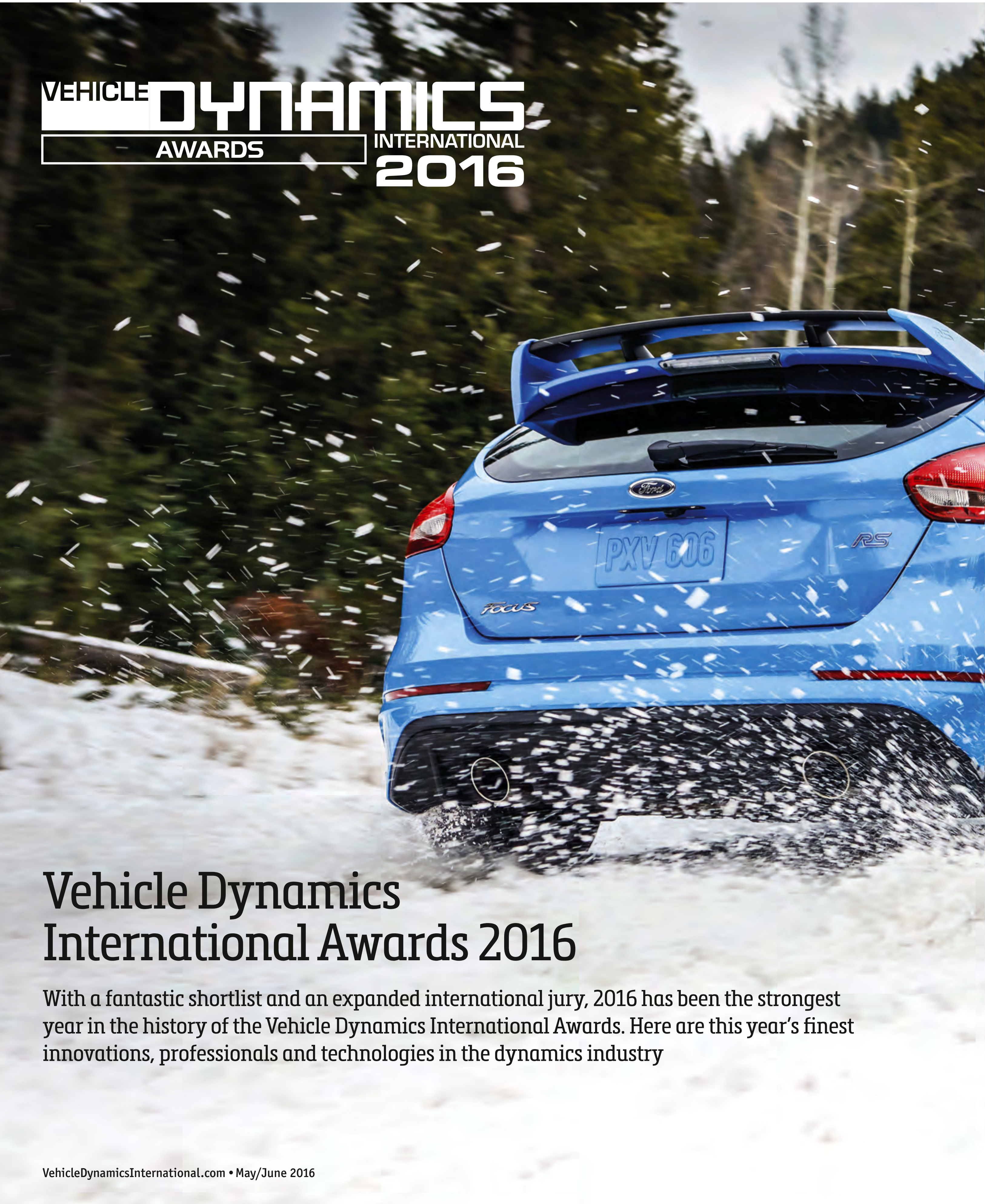
ABOVE RIGHT: The rear suspension of the electric Renault ZOE features a programmed-deflection flexible beam in order to take the weight of the battery positioned in the chassis. It has been optimized for greater comfort, with the addition of polyurethane bump stops for better damping

in stiffness progression near the limit of adhesion can materially affect breakaway characteristics, as can so many other details – down to and including elements such as the exhaust system hanger stiffnesses.

Nowadays there is an acceptance that sports cars can just about get away with a nominal 120mm design ride height. Sporty saloons need 140mm, while 160-180mm is necessary for family cars. Low ride heights can present quite a challenge for the development engineer in preventing the car grounding and dealing with heavily cambered roads and punishing surfaces, such as those found in the UK.

Nowadays it seems that with PU parts wonders can be achieved with a minimum of 60mm metal-to-metal wheel bump travel at the front axle (approximately 50mm to bump stop, hard on) and 70mm at the rear. This means that achieving an acceptable level of sporty car comfort with big bump absorption no longer requires as much compression stroke, something that results from careful tuning of the compression damping, bump stops, and damper top mounts.

More interesting is that on the 30 or so 'sporty' car projects that have used PU bump stops, all platforms made do with around 15mm of wheel travel to the bump-stop contact point on the front axle, and 20mm at the rear. Given the abuse to which the cars were subjected during chassis tuning and pavé testing, much of the energy absorption capabilities could only have been achieved through the use of bump stops and spring aids.



Vehicle Dynamics International Awards 2016

With a fantastic shortlist and an expanded international jury, 2016 has been the strongest year in the history of the Vehicle Dynamics International Awards. Here are this year's finest innovations, professionals and technologies in the dynamics industry

See our website for an in-depth look at the dynamic package of the RS

Nicol Louw, technical editor, *CAR magazine*, South Africa: "The Focus RS is not the most powerful über hatch, but is by far the most entertaining owing to neutral (and oversteer) handling characteristics that the opposition cannot match"

Car of the Year:

Ford Focus RS

Since the introduction of the first model in 2002, Ford's Focus RS has completely rewritten the hot hatch rulebook. So impressive is the 2016 model that it is straddling the line between hot hatch and all-out performance sports car. The car's 345bhp is impressive, but the dynamics package is as impressive – probably more so, in fact.

The new four-wheel-drive setup on the 2016 RS uses GKN's dual-clutch Twinster torque vectoring all-wheel-drive (AWD) system to allow for overspeeding of either or both rear wheels for greater feel and responsiveness and improved handling. To enable this setup, the torque vectoring rear-drive module, as well as the power transfer unit and CVJ sideshafts, had to be integrated into the base front-wheel-drive Focus platform – rather a tight squeeze!

New control algorithms were also developed for the torque vectoring system to give the driveline four driving modes: Normal, Sport, Track and Drift. In this latter mode, the AWD system delivers even more of the 324 lb/ft of available torque to the rear axle for the RS to achieve a controlled 'drift' through corners. Of course, being a four-door, five-seat family hatchback, the Focus RS keeps a little of its ESC safety net online, to ensure that Drift Mode is safe as well as fun.

Highly commended:

Jaguar XE

Runners-up:

Renault Mégane GT

BMW 7-Series

Opel/Vauxhall Astra

Vehicle Dynamicist of the Year:

Mike Cross

Chief engineer, vehicle integrity, Jaguar Land Rover

Mike Cross has a deep engineering knowledge and a talent for vehicle driving and evaluation that have made him something of a legend in the dynamics world. His recent work on the Jaguar side includes the F-Pace, the XE, and the revised XJ and all-new XF. With his Land Rover hat on, the Range Rover Evoque convertible is attracting great interest.

Whichever model one drives in the Jaguar Land Rover range, the dynamic performance has been optimized by Cross. Of particular note in the most recent models is the introduction of integral-link rear suspensions, adaptive dynamics, All Surface Progress Control for rear-drive stability, finely tuned EPAS systems, torque vectoring technology, and torque on-demand all-wheel-drive systems. All this is combined with lightweight aluminum architectures for stiffness, strength and near 50:50 weight distribution. Cross is helping to create superb product and is a worthy winner, who has long held immense respect in the industry.

Highly commended:

Victor Underberg, director of vehicle dynamics, Audi AG

Runners-up:

Pascali Leonardo, head of chassis & vehicle technology, McLaren Automotive

Dr Dirk Spaniel, head of vehicle dynamics, Daimler

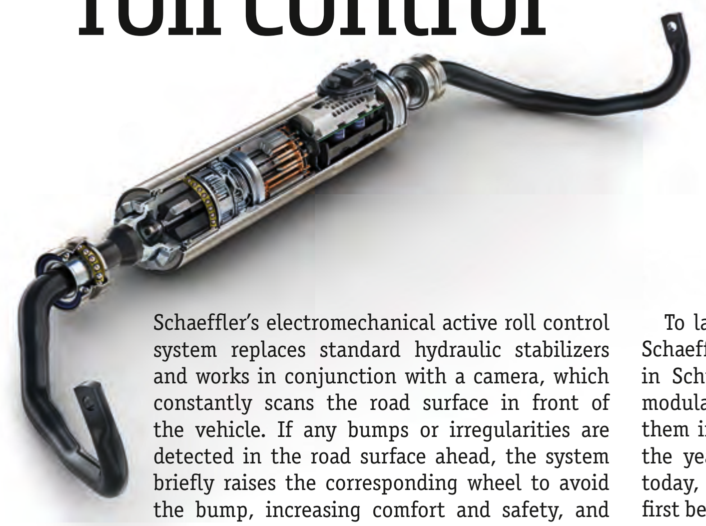
Ted Klaus, chief engineer and global development leader, Acura/Honda NSX

See p30 for an interview with Mike Cross, and to find out his views on vehicle dynamics

Jim Kenzie, motoring journalist for the *Toronto Star* and others: "In addition to Mike Cross's work on current Jaguar and Land Rover models, my vote for him is almost a Lifetime Achievement award in recognition of his efforts over a long and stellar career in this field"

Innovation of the Year:

Schaeffler active roll control



Sergio Oliveira de Melo, *El Informador,* Mexico: "This is the future of vehicle dynamics, with more control and comfort"

Schaeffler's electromechanical active roll control system replaces standard hydraulic stabilizers and works in conjunction with a camera, which constantly scans the road surface in front of the vehicle. If any bumps or irregularities are detected in the road surface ahead, the system briefly raises the corresponding wheel to avoid the bump, increasing comfort and safety, and enhancing vehicle dynamics.

To launch volume production for the system, Schaeffler has built new production facilities in Schweinfurt, Germany. The systems have a modular design, making it possible to integrate them into many volume production launches in the years to come. The system is on the road today, with two as yet unnamed vehicles, the first being a "luxury class sedan", and the second a "powerful and dynamic luxury SUV".

Highly commended:

ContiTech polyamide strut and rear-axle crossbeam

Runners-up:

NSK EPS

TrelleborgVibracoustic ZAX bellows air spring

Dynamics Team of the Year:

Ford Performance

Frank Markus, *Motor Trend,* USA: "Ford Performance is truly on a roll with the dynamically brilliant Focus RS, Shelby GT350, and forthcoming GT"

The global rebranding and expansion of Ford Performance has seen Ford introduce a number of performance-oriented models. The introduction of the third-generation Focus RS followed the reveal of the new Ford GT supercar, forming part of a 'new era' of Ford Performance that will comprise 12 new vehicles by 2020. The two new cars introduced several technologies for the brand, including the use of a heavily revised GKN Twinster differential in the Focus RS, while the knowledge garnered during development of the carbon-fiber-bodied GT supercar will form the template for all future Ford models. Combined with the Car of the Year accolade, this has been a good year for Ford Performance in the Vehicle Dynamics International Awards.

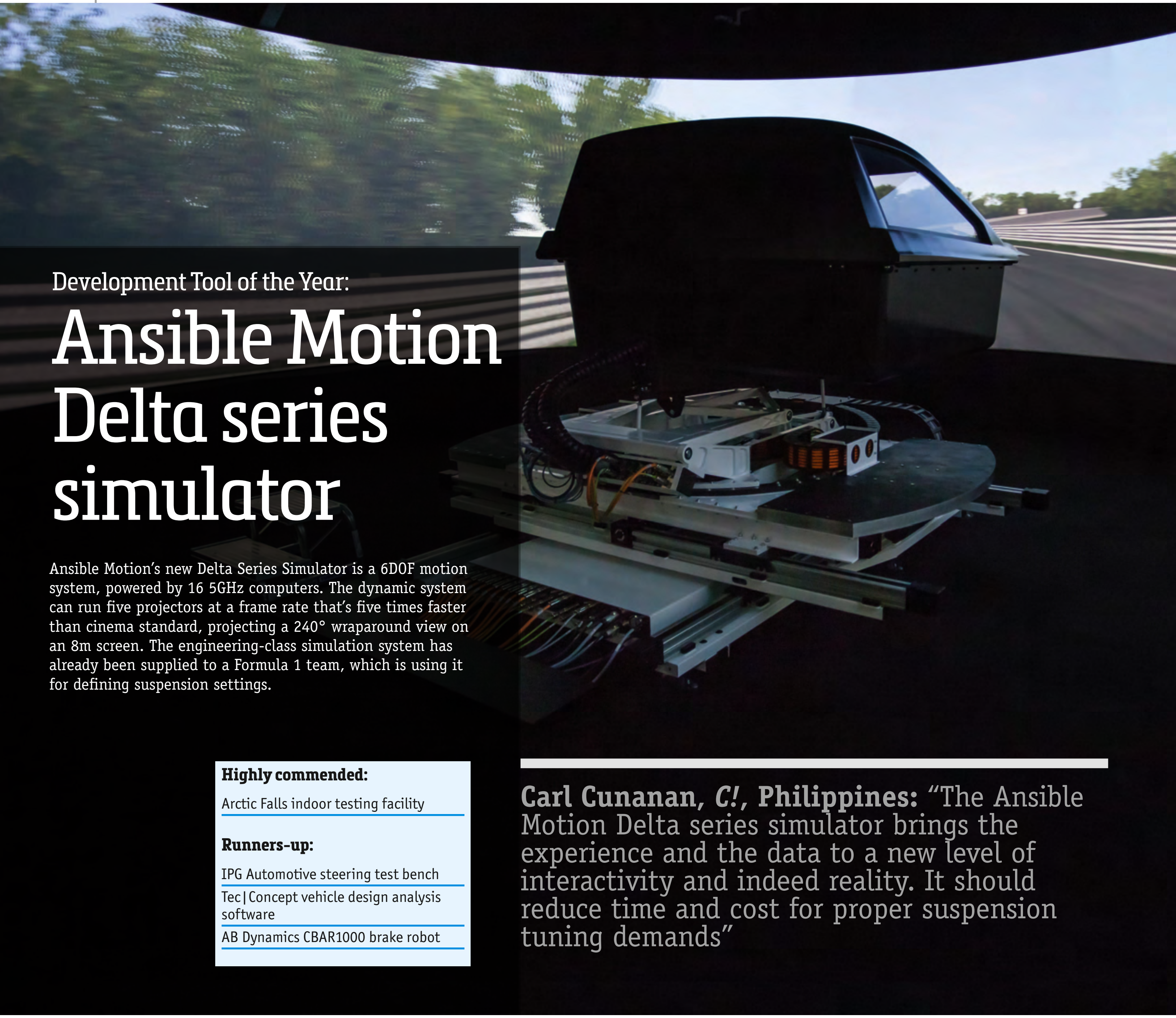
Highly commended:

Jaguar Land Rover

Runners-up:

Audi

McLaren Automotive



Development Tool of the Year:

Ansible Motion Delta series simulator

Ansible Motion's new Delta Series Simulator is a 6DOF motion system, powered by 16 5GHz computers. The dynamic system can run five projectors at a frame rate that's five times faster than cinema standard, projecting a 240° wraparound view on an 8m screen. The engineering-class simulation system has already been supplied to a Formula 1 team, which is using it for defining suspension settings.

Highly commended:

Arctic Falls indoor testing facility

Runners-up:

IPG Automotive steering test bench

Tec|Concept vehicle design analysis software

AB Dynamics CBAR1000 brake robot

Carl Cunanan, *C!*, Philippines: "The Ansible Motion Delta series simulator brings the experience and the data to a new level of interactivity and indeed reality. It should reduce time and cost for proper suspension tuning demands"

The jury:

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

How the judging process for the Vehicle Dynamics International Awards works

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

Big cat trophy

VDI spends a little time with our Vehicle Dynamicist of the Year – the industry legend that is Jaguar Land Rover's dynamics guru, Mike Cross

Words by **Adam Gavine**

For the past 32 years, every Jaguar produced – and most Land Rover and Range Rover products too – has had a driving feel carefully tuned through the hands and posterior of Mike Cross.

As chief engineer for vehicle integrity at Jaguar Land Rover (JLR), Cross guides the development of all subjective vehicle attributes, and reports on programs and gateways for each vehicle, in terms of whether they achieve the objectives and attributes of the brand DNA from a customer perspective. In short, he is responsible for making sure JLR product has the right 'feel'.

Cross does not work alone, of course – there is a 90-strong dynamics team to help him make sure "all the attributes of the car work together harmoniously".

The model range is broad. Jaguar and Land Rover/Range Rover each have five core models in their line-ups, with multiple variants of each. With two hats and such a varied model range, how does Cross approach his task? "We define a DNA for the JLR brands, and within those brands there is a model-specific flavor for the driving dynamics. On the Jaguar side, the XJ should be the most comfortable and refined, albeit we hope with agile handling and precise, connected steering. At the other end of the range, the F-Type SVR should be the most sporting and extrovert flavor of our DNA. But I think across all JLR models, good

"We define a DNA for the JLR brands, and within those brands there is a model-specific flavor for the driving dynamics"

Cross purpose

Mike Cross was appointed as chief engineer, vehicle integrity for Jaguar Land Rover in 2000, prior to which he was the senior engineering specialist for chassis development, and responsible for the development of all Jaguar products.

Cross began his career as an apprentice for Land Rover in 1984, during which period he completed a sandwich course in mechanical engineering at Coventry University. He then joined Jaguar, where he went on to become principal engineer, chassis development, a position he held until 1997. The coming together of Jaguar and Land Rover under both Ford and Tata ownership saw him become involved with development work for both brands.

"I always wanted to work in the car industry," says Cross. "I always wanted to develop cars, and I wanted there to be an element of driving in my job. I still really enjoy driving, it's never a chore. I started initially with ride and handling and slowly took on more responsibility for developing cars."

When he isn't developing JLR product, Cross is kept busy with his wife and two daughters, and also enjoys motorcycling and mountain biking.

RIGHT: The Jaguar range may have changed substantially in recent years, but certain dynamic qualities – and Cross's signature – are common to them all

steering is good steering and good ride is good ride. We just add a brand- and model-specific flavor."

The pursuit of good vehicle dynamics and driver 'feel' has been a constant in Cross's career, but a big change has been the demands of a growing number of vehicle programs, tempered by the tools available to help him in his quest.

Cross and his team make extensive use of data CAE modeling to get each vehicle close to the final product, with the final 'polishing' done subjectively. "We are producing more cars than ever, with many more programs, and we have to be able to develop cars faster and more efficiently. Simulation enables us to get closer, faster," says Cross.

However, while some technology reduces the workload, some increases it. "There are many more systems on modern cars that we need to tune and optimize. So while technology saves time in one area, the transmission, chassis, throttle and ESC settings are all driver selectable, so there are more systems to refine and integrate. The task is getting more complex, but the tools are getting more capable."

The cars are also becoming more accomplished, which stretches Cross's renowned skills behind the wheel. "The fundamental objectives of good steering, ride, refinement and performance remain, but the cars are a lot more capable. They are a lot faster and they generate a lot more lateral acceleration, so the cars are more capable, but the same objectives still apply."

It is not just the performance of the range that has grown, though: marketing requirements have seen unsprung mass increase, which has added further dynamics challenges, especially in terms of ride comfort.

"Jaguar is about sporting luxury, so there needs to be that combination of performance, agility, comfort and refinement. Tire aspect ratios are much lower than they were, and the radii are much larger, so unsprung mass has increased," says Cross, adding that today's large brake packages add further mass. "But I think the compromise is, as it ever was, about balancing refinement with precision and agility. But the systems on the car are more complex and capable, and simulation is more capable, which means we can achieve this for the customer."

Favorite car

Having worked on so many JLR programs, which is Cross's favorite? "My favorite tends to be the next one, because generally cars move forward. The team has done a great job with the dynamics of the modular D7A platform for the XE, XF and F-Pace. These models have all had a very positive reception from the automotive media, and from customers, in terms of steering, ride and handling. It's great to have a new platform that is so successful."

"The fundamental objectives of good steering, ride, refinement and performance remain, but the cars are a lot more capable"

On cats and mud

What is the dynamics recipe for a Jaguar or Land Rover? "For a Jaguar I think it's a blend of ride quality and refinement, coupled with steering precision and agility. These are feline qualities, so the Jaguar analogy is appropriate. A Jaguar needs to flow down the road and feel comparatively light on its feet."

"The Land Rover range is a bit more challenging. Land Rover's DNA is about off-road performance, so we need to deliver great on road dynamics and at the same time deliver great off-road performance."

Given the price tag of a Range Rover, are its on road dynamics being unnecessarily compromised by an underused off-road capability? "We have a lot of data that suggests that customers do take them off-road. The security of knowing how capable the vehicle is, is a key element to the buying decision of Land Rover and Range Rover customers."

ABOVE: Cross has developed the most extreme Jaguar – the F-Type SVR – with the most sporting and extrovert vehicle dynamics

Hanging out

So what does Cross enjoy doing in his spare time? He has participated in some motor racing events such as the Mille Miglia, so perhaps a little weekend racing? The car is his office remember, so the weekends involve something slightly different.

Alongside the F-Pace in Cross's garage are a brace of Ducatis (including a Panigale) and a Kawasaki. He enjoys the occasional motorcycle trackday – "I'm not very good," he says, but we suspect he isn't that bad either. Thrills aside, he enjoys that a motorcycle demands complete concentration, which he finds therapeutic.

So which would be quicker round a circuit – Cross in a car or on a bike? "If the track was twisty, and given my relative abilities with both, on the bike I would be quicker on the straights, but quicker in the corners in the car, and I would feel more comfortable under braking in the car."

RIGHT: Even Cross's hobbies are fast. He likes to unwind from his hours spent developing cars on track by jumping on his Ducati Panigale

LEFT: Asked about his favorite vehicle to drive, Cross says, "Probably the previous Jaguar XF-R, because it had a really nice combination of performance capability, comfort and refinement, and epitomized what a Jaguar should be in many ways"

ABOVE: The Evoque convertible is a prime example of evolving customer tastes. Cross insists that even such a fashion-led model should have great off-road capability as part of its DNA

The compromise may be possible, but does the dynamics purist in Cross curse the marketing department for insisting on giant wheels with ultra-low profile tires? "We need to respond to what our customers want. Jaguar is about design, luxury, refinement, performance and good dynamics, so our job is to deliver all those attributes. I welcome that challenge."

Don't think that is just a diplomatic response from a dynamicist toeing the company line: Cross's personal car – an F-Pace – can be seen rolling around Coventry on 22in rims. "They are the largest wheels I've ever had on a car, and it looks great. We knew from the outset that the 22in wheel would, in most cases, be a design choice from the customer rather than a performance choice, so we worked hard to ensure the wheel/tire combination minimized any effects on refinement or comfort."

So what's next for Cross and his team? "The control systems are getting evermore capable and need to be evermore integrated. We're striving to always make our cars lighter and more efficient. Body structures are getting lighter and stiffer, which helps us. We are trying to put a greater degree of personalization into the car so the customer can select from a menu of steering, ride, throttle progression and transmission calibration.

"I think it's a really exciting time to be in the motor industry. It is buoyant, with lots of new product being planned. It's as vibrant and exciting a time in the industry as I've ever known."

Time and motion

The latest vehicle dynamics testing technologies can cut the duration of test programs while improving their quality

DEVELOPING AN AUTONOMOUS VEHICLE?

The Autonomous Vehicle Test & Development Symposium 2016 will bring together more than 60 of the world's leading engineers in the field of autonomous vehicle research, testing, validation and development. The event takes place in Stuttgart on May 31-June 2. See www.autonomousvehiclesymposium.com for more details

Robotic durability tests

Imagine a robot completing in a mere five days a series of durability tests that took humans 12 days. According to Autonomous Solutions, the company's robotic durability testing kit recently did just that for a proving ground customer. The kit can be installed in vehicles to provide an efficient and cost-effective use of track time. Test drivers are very good at what they do, says the company, but its technology can cut durability testing time by half.

Testing time cut in half

All-in-one brake testing

How about a complete all-in-one brake test system? The latest development from Dewesoft can be used to perform various brake and ABS tests, including comfort tests and testing vehicles with regenerative braking, with braking distances measured with very high accuracy. The system uses a 100Hz GPS system with the possibility of IMU correction for enhanced accuracy, and also includes online checks for validation, visualized results in real time, additional post-processing functions and reporting tools.

Tailored driving simulation

AB Dynamics is developing a cutting-edge vehicle dynamics simulator (VDS) supported by DIL technology from Williams Advanced Engineering. The VDS will use the company's motion platform, which employs linear actuators that deliver up to 60Hz frequency response and a tightly integrated driver-in-the-loop system.

Specifically designed for commercial road car development, the simulator will be tailored to individual manufacturer's requirements. AB Dynamics believes that as much as 30% of costs incurred during vehicle development could be saved by using a DIL simulator with subjective feedback.

Test steering earlier

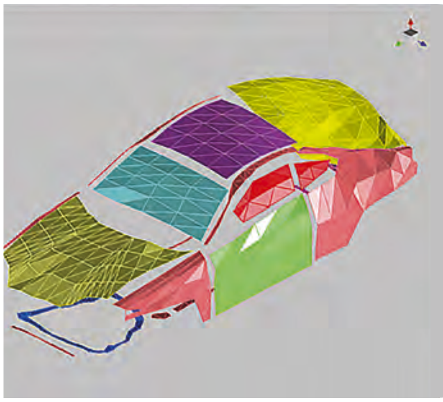
Being able to test steering components earlier could provide valuable time savings and quality enhancements. IPG Automotive says that its new steering test bench, combined with the CarMaker open integration and test platform, enables just that. The bench can be adapted to various steering systems, with all of the test bench's actuators able to be controlled separately. In combination with the sensors and the CarMaker simulation environment, the bench creates a control loop that enables steering maneuvers to be shown in a reproducible manner and the steering system behavior and feel to be tested.

Thanks to virtual test driving, maneuver catalogs can be automatically and reproducibly tested – even to the limits of driving dynamics – using the IPGDriver model.

Two electrical linear actuators give precise control, permitting closed-loop testing to be carried out. During this process, input values such as steering angle, steering torque and steering rod power are generated by the CarMaker simulation platform and fed into the EPS steering system. Sensors, such as power, torque, angle and position sensors, feed the signals back into the vehicle dynamics simulation.

LOOKING FOR THE LATEST DYNAMICS COMPONENTS?

Tier 1, 2 and 3 automotive component manufacturers from around the world will be at Global Automotive Components and Suppliers Expo in Stuttgart on May 31-June 2 to display their very latest technologies and products. See www.gacs-expo.com for more details

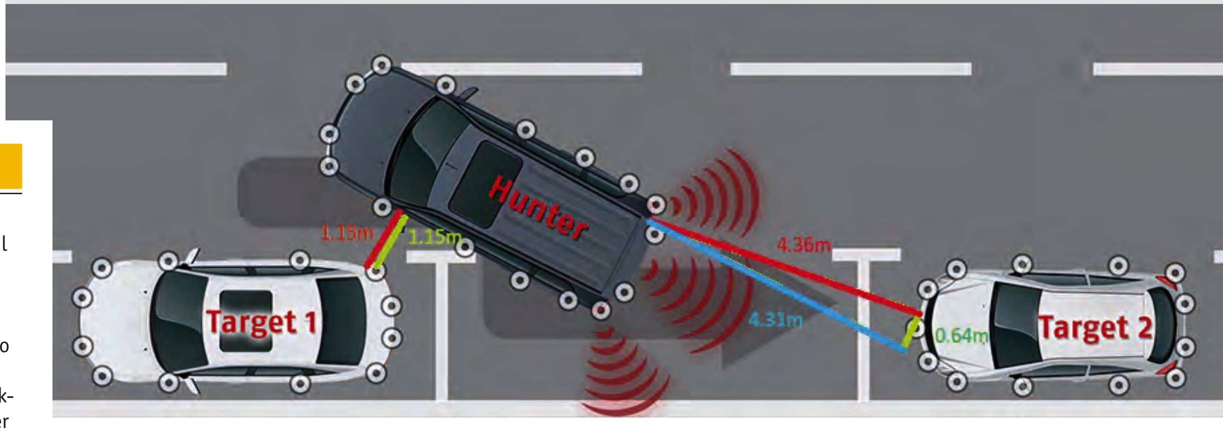


Structural dynamics testing

One company has set out to change the way manufacturers approach modal testing as part of NVH development. Using what it claims is the only commercial robotized 3D laser Doppler vibrometer in the world, ASDEC's engineers say they can measure thousands of datapoints in the time it would take conventional accelerometer-based methods to measure only tens of datapoints. This means that a 600-point test can be completed in four or five hours. The non-contact method can also correlate customer FE and CAE models using this data.

Rapid rig tests

A 'future-proof platform' test rig concept developed by Rototest enables fast and easy setup of test objects – a claimed increase in effective test time of up to 400% compared with conventional vehicle test rigs. The rig has individual wheel control and ultra-low inertia and steering capabilities that can enhance testing quality and efficiency. Designed for installation on flat floors, the dynamometer systems can be used for testing subsystems, powertrains and complete vehicles.



ADAS validation

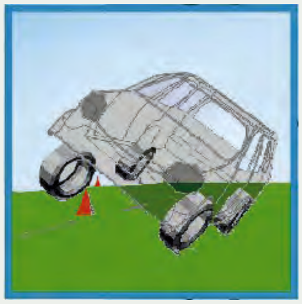
After an update to the RT-Range ADAS validation system from Oxford Technical Solutions for Euro NCAP AEB VRU tests, the RT-Range can now generate perimeter polygon measurements. This new capability enables test engineers to configure the system for the Euro NCAP AEB vulnerable road user as well as park-assist tests, and enables a vehicle under test perimeter polygon to be defined using anything from three to 24 vertices. For Euro NCAP AEB VRU tests, the seven vertices required by the protocol to represent the front of the VUT are some of the vertices used to define the polygon. The tool also offers 1cm accuracy and an inter-vehicle range of up to 1.6 miles (1km).

WANT TO SEE MORE?

All these technologies and more will be demonstrated at Automotive Testing Expo Europe in Stuttgart on May 31-June 2. See www.testing-expo.com/europe for more details

Test drive feedback

Driving behavior can be evaluated through the simulation of real-world test maneuvers such as braking, lane changes and high lateral acceleration. The workload can be high, as tests must be performed for multiple variants of the same vehicle under different loads, with different suspension setups or stability control systems. The Moses software suite from MeasX is designed to support test drivers during driving dynamics tests, with instant feedback to the driver while a maneuver is performed so that the driver can adjust their driving style accordingly, which reduces time spent at the proving ground. At the end of a test, further feedback



shows the quality rating of the complete maneuver so that the driver can decide whether the acquired data can be used in further analysis or whether the test should be repeated. All ISO-defined maneuvers – such as a steady-state circular test, step steer input and sine with dwell – are supported. In addition, Moses enables users to modify existing maneuvers and define new ones. Interfaces to acquire analog, CANbus, FlexRay and Ethernet signals, and direct access to popular IMUs and speed sensors, are also included.

Accurate brake testing

Demonstrating how to overcome the shortfalls of simple GPS systems in braking distance tests, Race Technology's new Speedbox-ins developments combine high-accuracy GPS and data from a tactical-grade inertial sensor with an advanced Kalman filter, which means that the system provides accurate and validated results, even with GPS signal interruptions. The system also continuously monitors its own performance and reports the maximum error for each test. After each brake test, the system reports both the braking distance and the maximum error – for example, 42.33m braking distance and ±3cm maximum error.

Video and GPS datalogging

The use of video is of enormous value to test engineers looking to verify and present data, whether they are working in braking, NVH or ADAS. The VBOX Video HD2 video and GPS datalogger from Racelogic is a dual-camera system that captures full HD video with embedded picture-in-picture and real-time graphical overlay, synchronized with 10Hz GPS data. Along with HD video, graphics and GPS data, the system also features 64 incoming CAN channels for the comprehensive recording of vehicle system signals. Other features include a 10-second video pre-buffer, battery backup and camera preview over wi-fi to Android and iOS devices.

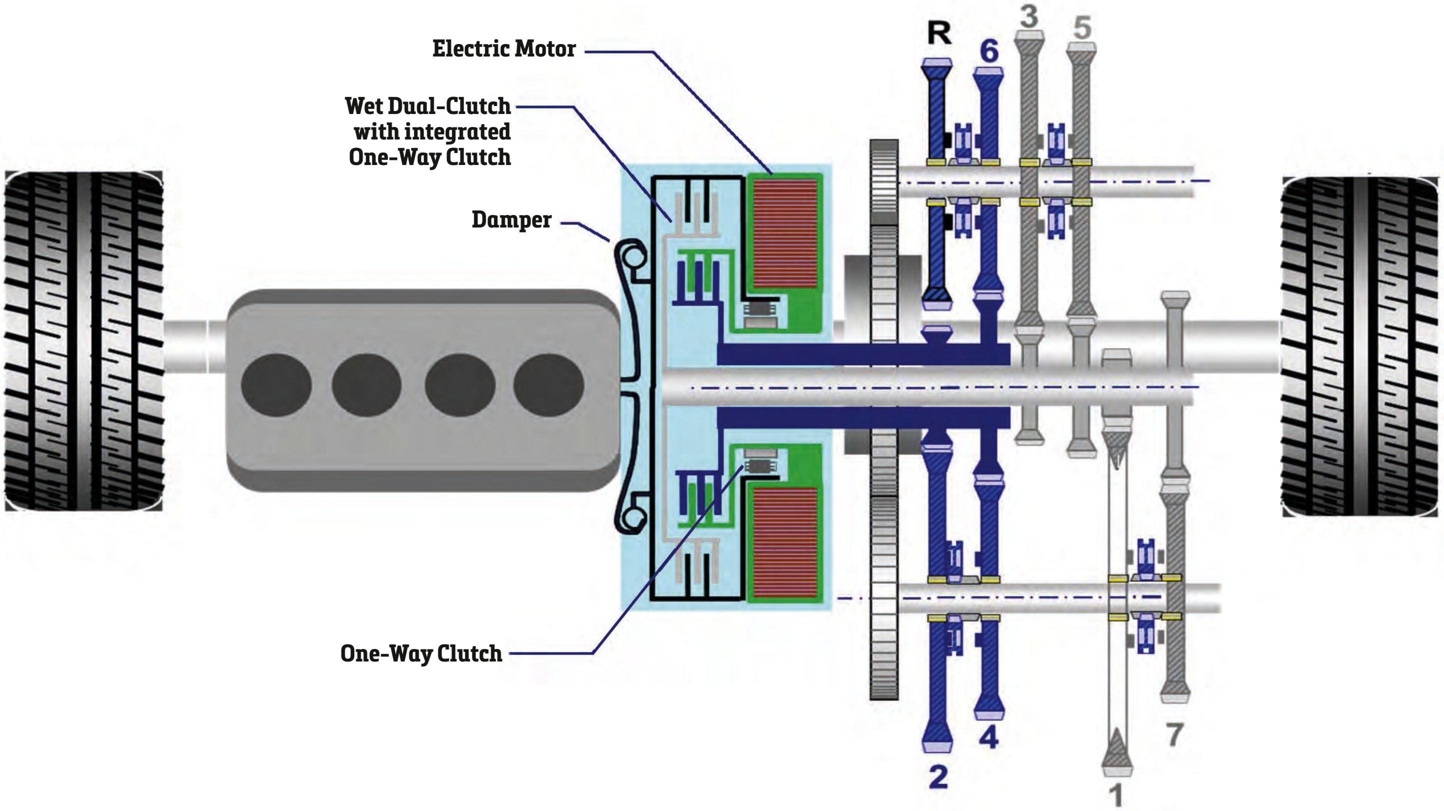
To see a video of the test rig in action, visit our website

Steering effort evaluation

KMT's CLSx steering effort sensor is claimed to set a new standard in terms of size of housing, as well as resolution and accuracy of measurement values (0.1% FS). The sensor is placed between the steering column and original steering wheel of the vehicle, preserving all steering wheel functions. During tests, the CLSx then captures torque, steering angle and rotational velocity values. The unit can also acquire acceleration in the center of the steering column (x, y and z direction) as well as rotational acceleration. Measurement data is digitized for failsafe data transfer with a resolution of 16bit (internally 24bit).

Disconnect for efficiency

BorgWarner's disconnect system for electrified drivetrains is helping OEMs hit targets for efficiency in both mild- and full-hybrid vehicle installations



ABOVE: (Figure 1) A hybrid powertrain layout with a one-way clutch highly integrated into a wet dual-clutch module

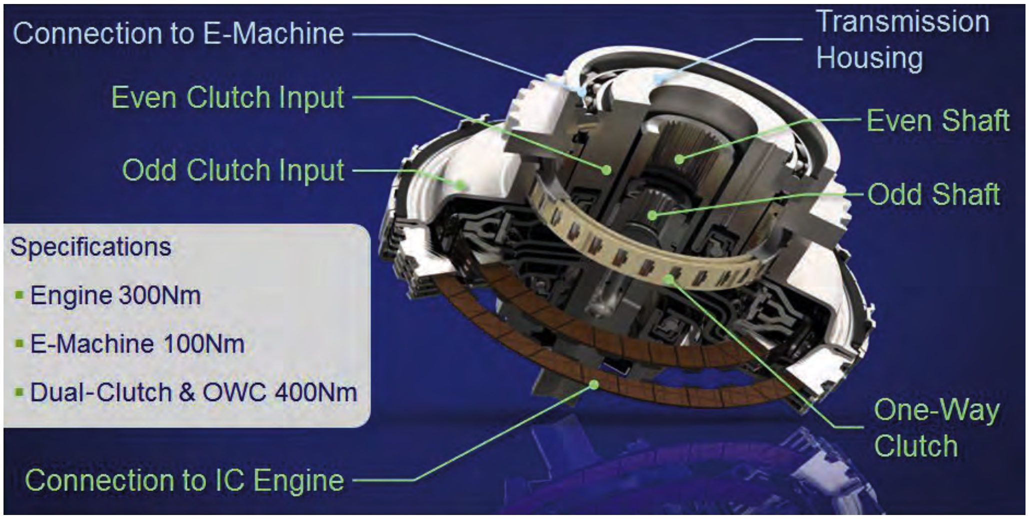
Recent developments have increased the need for more stringent emissions regulations. Since future CO_2 emissions targets are difficult to achieve with conventional powertrains using internal combustion engines only, the automotive industry has put a special focus on powertrain electrification in an attempt to further reduce fuel consumption and CO_2 emissions. This is reflected in the market, which is currently seeing the introduction of an increasing number of vehicles using a wide range of systems such as stop/start systems, mild hybrid systems, plug-in hybrid systems, and battery electric systems.

Brake energy recuperation is one option that can help OEMs to comply with emissions regulations. To make the most of it, the kinetic energy must not be lost in the form of heat at the brakes. According to simulations conducted by BorgWarner, a mild hybrid system with an electric power range of 10kW to 25kW is most suitable for adaptation since it offers a relatively low system complexity combined with high functionality. In terms of the recuperation potential of the braking energy on the basis of the New European Driving Cycle (NEDC) and the CO_2 emission target of 95g/km, which will be obligatory for new passenger car registrations as of 2020, using a mild hybrid system allows the lion's share of the braking energy of a normal passenger car to be recuperated with an electric motor featuring a power rating of about 15kW to 25kW.

For this reason, BorgWarner has developed a mild hybrid drivetrain concept that can maximize this recuperation potential, permitting disconnection of the engine without the use of an additional disconnect clutch. This innovative cost-efficient concept uses a one-way clutch (OWC) in combination with a dual-clutch transmission (DCT) (Figure 2) and a small electric motor, allowing pure electric driving or sailing while maximizing the recuperation potential, thus making it an interesting proposition for mild hybrid and 48V systems.

Disconnection of the combustion engine is the key enabler for pure electric driving and the maximization of the recuperation potential. Offering maximum flexibility in terms of electric driving in every gear, as well as the option of shifting between gears without any torque interruption whatsoever, a disconnect clutch enables engine shut-off in pure electric driving mode. The drawback to using a disconnect clutch that transmits the maximum powertrain torque is that it requires additional components, actuation, and usually also extra space between the engine and the transmission.

BorgWarner's innovative solution therefore replaces the disconnect clutch with an OWC, which overruns when the engine is shut off so that it is disconnected from the powertrain



LEFT: (Figure 2) The highly efficient dual-clutch module with one-way clutch (OWC)

while the vehicle moves along using the electric motor. In addition to extremely low drag losses, OWCs do not need any additional controls or actuation. They provide high torque density, which facilitates compact packaging, especially compared with disconnect clutches.

BorgWarner investigated numerous layout combinations, the result being a concept for mild hybrids that features an OWC, which is placed between the engine and the clutch for even gears of the dual-clutch module (Figure 1). Allowing extremely compact packaging, the electric motor is placed between the OWC and clutch, which permits the electric motor to be used for pure electric driving in all even gears, and in reverse gear. Besides being able to boost or recuperate in most gears, the combustion engine can also operate in all gears.

During deceleration, the electric motor provides the braking torque, hereby regenerating the braking energy and charging the battery. If the battery is fully charged, engine braking is realized in this powertrain concept by connecting the appropriate odd gear via the respective clutch. Being intended for a mild hybrid with an electric power of about 25kW, the only limitation compared with the setup including a disconnect clutch is the fact that it is not able to offer pure electric driving in odd gears. However, this disadvantage is negligible since pure electric driving in even gears would be sufficient for the vehicle speeds possible with this power configuration.

ABOVE: (Figure 3) The one-way clutch (OWC) offers high torque density and excellent comfort

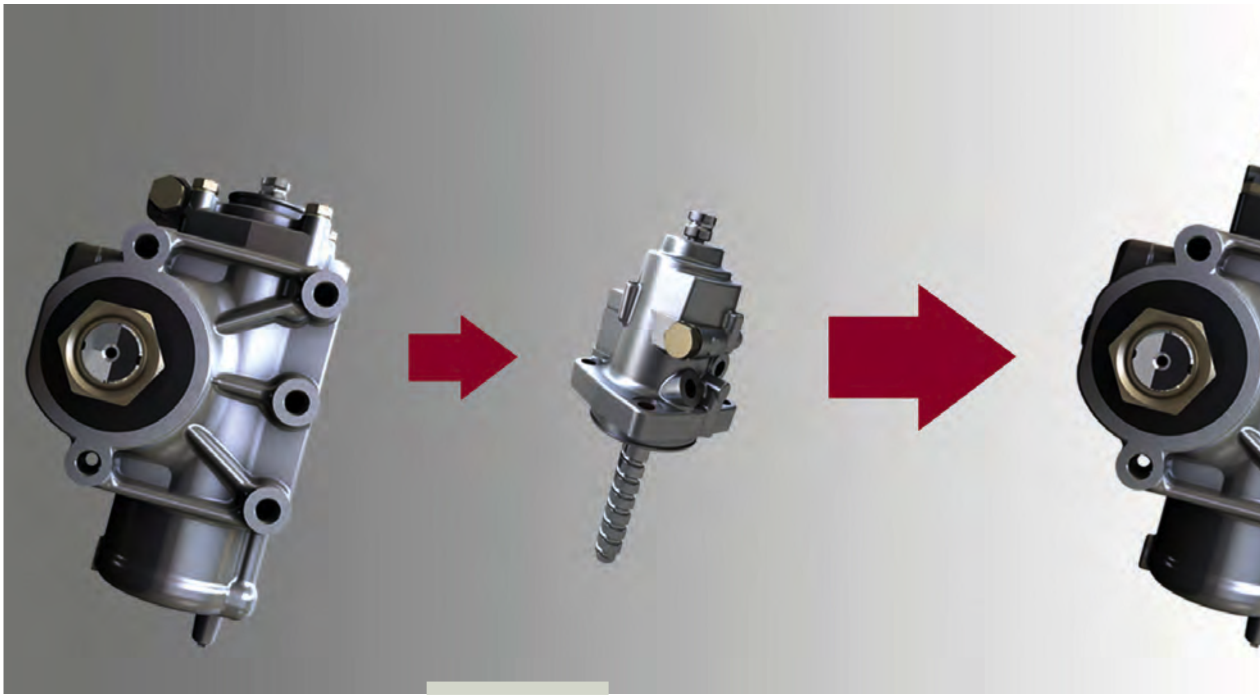
BorgWarner extensively investigated the functionality and safety of this concept specifically with regard to the main driving modes to be expected from a hybrid vehicle, which are driving with a combustion engine and pure electric driving, as well as boosting and recuperation using the electric motor. The OWC configuration facilitates all of these driving modes by selecting the correct gears and the appropriate clutch engagement. In addition, both clutches can be engaged, which allows electric boosting or regeneration in one of the even gears with a higher gear ratio than the selected odd gear, while using the combustion engine power in the odd gears for driving.

Moreover, BorgWarner tested functionality and performance of this hybrid powertrain by simulating various driving situations, including transition between different driving modes. The vehicle is initially accelerated with the help of the combustion engine, and this is followed by cruising at a constant speed. While cruising, the electric motor alone can provide the power required for sustaining the constant driving speed, and the combustion engine is switched off. In this scenario, the OWC is in freewheeling mode and the engine is disconnected. When the engine is switched on, the OWC engages smoothly as the vehicle moves along. Due to the excellent controllability and thermal robustness of a wet dual-clutch, the engine can be started conventionally by using the engine starter, or it can be activated by controlled engagement of the odd clutch while the electric motor is still driving the vehicle via the even clutch. Engagement and disengagement of the OWC are usually not noticeable, thus increasing comfort for the driver.

BorgWarner has developed an innovative and cost-efficient concept for a hybrid module, including an OWC as the engine disconnecting device, to help OEMs meet the increasingly stringent emissions regulations and improve fuel economy. The OWC (Figure 3) replaces the engine disconnect clutch and its actuation, reduces the complexity for clutch control and offers significant packaging benefits, while still supporting all driving features such as electric driving, boosting, load point shift, coasting, engine braking and recuperation.

Smart steering

Intelligent hydraulic steering-assist systems can optimize steering performance in all commercial vehicle segments



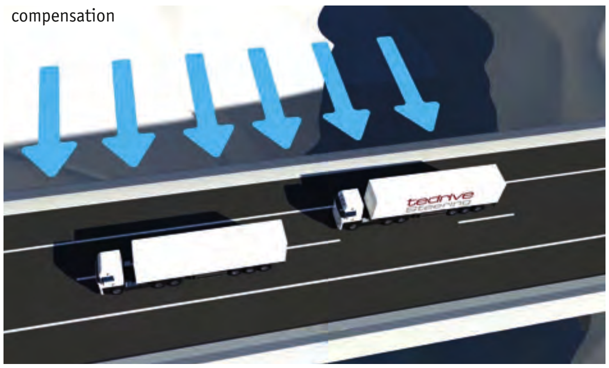
ABOVE: All driver assistance systems familiar from the car sector can now also be implemented for trucks and buses through the integration of the iHSA module from Tedrive Steering

Trucks and buses could soon be driving autonomously with the help of iHSA (intelligent Hydraulic Steering Assist). Tedrive Steering Systems of Wülfrath, Germany, has developed a system that, as an interface to all driver-assistance systems, supports active safety and comfort functions as we head toward autonomous driving. Indeed Tedrive's recirculating ball steering systems can now serve as an interface to driver assistance systems, with iHSA helping commercial vehicle manufacturers in their efforts to make automated driving fit for the future with hydraulic steering systems.

The precursors to this type of technology, among them active lane-keeping assistance, cross-wind compensation, parking assistance, city mode, and automated approach to access ramps, are examples of the functions that can be realized through use of iHSA. They provide active and direct support that takes the load off the driver.

The Tedrive iHSA module permits all regular driver assistance systems to be connected to the hydraulic steering system. This means driver assistance systems that were previously reserved for vehicles with electric steering systems can now also be made available for vehicles with high axle loads.

The vehicle must be equipped with the necessary sensors for recognizing its surroundings, and in the event the vehicle leaves the defined lane, the sensors send a correction signal to the iHSA module, which automatically controls the steering system's hydraulic valve to correct the vehicle trajectory – if necessary, without any driver input. The functionality extends well beyond the lane-departure warning systems already required by law.



BELOW: The iHSA module supports the incorporation of all current driver assistance systems such as automatic cross-wind compensation

It is in heavy commercial vehicle traffic and public transport in particular that autonomous driving promises a considerable improvement in accident prevention and the reduction of serious accidents. The technical principle of iHSA allows all relevant driver assistance systems to be coupled to Tedrive's hydraulic steering system. In combination with front and side radar sensors, such as those used for adaptive cruise control, active braking and active lane-keeping, iHSA supports major functional elements of automated driving. The iHSA module combines the benefits familiar from electric power steering systems with those of conventional hydraulic steering units, while retaining a robust overall design suitable for use in cars, light trucks, heavy commercial vehicles, buses and special vehicles that feature high front-axle loads.

What is the iHSA technology?

The iHSA technology can be used modularly in combination with hydraulic Tedrive recirculating ball steering, as well as with Tedrive rack-and-pinion systems. The power assistance in these systems is provided by the integrated hydraulic cylinder, with a hydraulic valve controlling the level of assistance.

In conventional steering systems, the steering input from the driver regulates the hydraulic assistance, which is implemented by the hydraulic valve diverting the hydraulic fluid into the respective cylinder chamber. The iHSA system uses the available hydraulic valve, but controls it independently of the driver via a compact electric motor. The motor can be very small, as it does not deliver any actual steering assistance, serving only to control the hydraulic valve. The motor's power requirement is therefore very low, which protects the onboard electric system and does not necessitate any changes to energy management and vehicle electrics.

Installed alongside the motor is a torque sensor that measures the driver's steering movements, providing the data necessary for system regulation. A control unit gathers all the signals and contains the algorithms required for controlling the steering. The system provides the interface to the vehicle communication system, such as the CANbus, and facilitates the application of hydraulic power steering in conjunction with assistance systems. This torque overlay provided by the iHSA module means, for instance, that trucks and buses can be actively kept in the correct lane without the need for driver intervention. This functionality goes well beyond the currently legislated lane-keeping warning systems. Furthermore, the plug-in module enables the incorporation of functions such as automatic cross-wind compensation, trailer stabilization, city mode, nibble control and joystick maneuvering assistance. For buses, it also facilitates an automated approach to bus stops and boarding points.

Using an additional on-demand hydraulic pump with the iHSA steering system allows for adjustment of the volumetric flow within the system. If there is no demand for power assistance, the volumetric flow drops, along with frictional losses. The use of iHSA technology means that volumetric flow can also be maintained at a low, CO_2-optimized level for small steering inputs.

ABOVE: On approach to a bus stop, the Tedrive system steers the bus to the curb at a pre-determined distance, reducing tire wear

BELOW: Tedrive increases safety and steering comfort for truck drivers with performance-enhanced rack-and-pinion steering

Active steering

The development of the Tedrive iHSA module has succeeded in transforming hydraulic steering into an active steering system.

The development of the iHSA module expands the performance parameters of hydraulic steering systems, successfully transforming them into active steering systems incorporating all the functions of electromechanical power steering. The active hydraulic solution is variable and independent of front axle load. Alongside improved steering functionalities, the plus points include optimized packaging dimensions, cost and design benefits for platform strategies, and optimized potential for CO_2 savings.

To guarantee functional safety, the Tedrive iHSA system is developed in accordance with ISO 26262. According to the company, in a comparison between iHSA steering and an electric power steering (EPS) system, the iHSA system demonstrated a lower level of risk in terms of functional safety (ASIL B/C). This is based on the fact that the maximum applied torque overlay is mechanically limited and is considerably lower than that of EPS. Thus, even in the event of a system malfunction, the driver is always able to override it, choosing instead to steer the vehicle him/herself.

Real progress

dSpace's FTire and ASM are sophisticated models for real-time vehicle dynamics simulation

ABOVE: The FTire real-time tire model simulating a Belgian block road. This is a single frame from a post-processing animation

The tire is the most important and most complex component of a vehicle's suspension. As a consequence, tire simulation requires more than just a mathematical approximation of some steady-state deflection-based and slip-based force/moment characteristics on a flat surface, no matter whether the simulation is part of a detailed CAE process chain or is used in real-time environments.

Rather, current offline and HIL simulation tools for new steering and suspension control systems, drive concepts, and vehicle architectures have to include a versatile, robust and multipurpose tire model that can be used in classic handling and ride comfort tests, and also with highly dynamic suspension, drivetrain and road-induced excitation tests.

Preparing for real time

To meet these requirements, the state-of-the-art physical tire model FTire (see www.cosin.eu) has recently been enabled for use with HIL and driving simulators. To this end, the model has been modified as follows:

• Rarely used, time-consuming model extensions such as tread-wear models, flexible-rim models, soft-soil models and air cavity models are deactivated by default;
• The animation window and time-consuming computation of extra output is deactivated, but is available offline;
• Solver numerics, based on partially implicit integration, are optimized;
• The default temporal and spatial resolutions have been lowered slightly, but both are still scalable to make best use of available computing resources;
• A highly efficient multi-threading technique, based on the parallel computation of all 2, 4, 6 or more tire instances, has been implemented;
• A fast user datagram protocol (UDP) is used for bidirectional data exchange with the calling vehicle model solver.

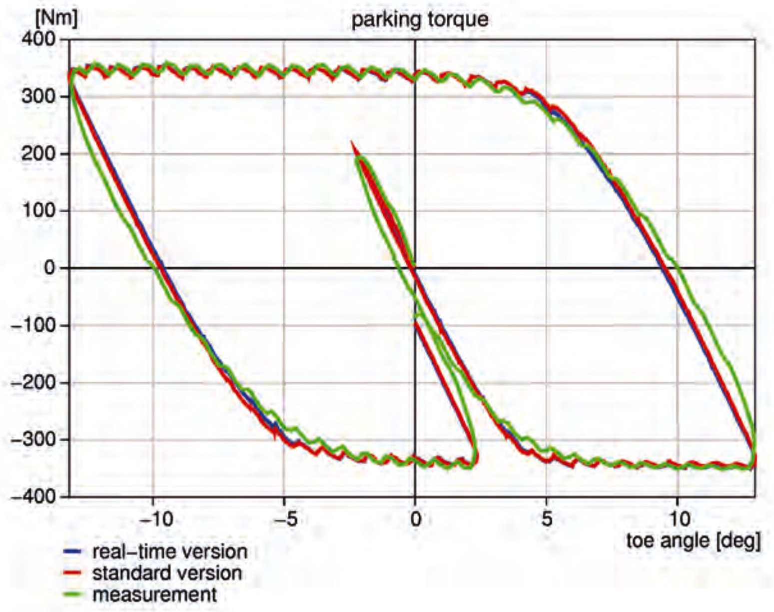
Tire characteristics in real-time simulations

The resulting tire model is completely real-time capable and yet fully physics-based. It features on-the-fly variation of inflation pressure, tread depth, tread temperature and local road friction properties. Simulations can account for radial and tangential non-uniformity, static and dynamic imbalance, run-out, tread gauge variation, conicity and ply steer while generating realistic simulation of pressure drop, tire puncture and runflat behavior. The program can also relay accurate parking torque during standstill or slow rolling, short-waved road irregularities, single high obstacles and high-frequency brake pressure variation at all rolling speeds.

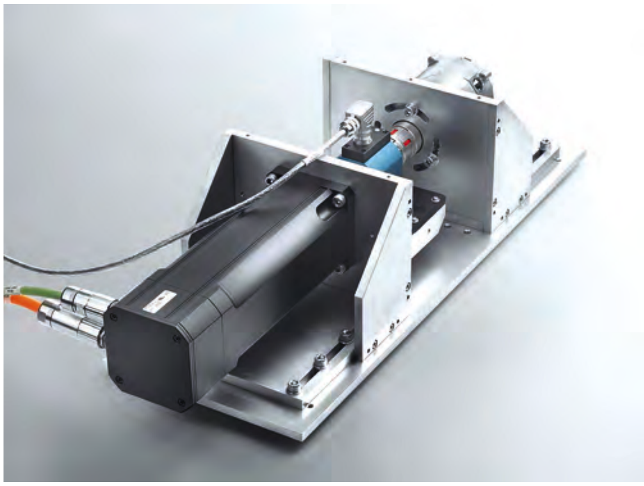
By using a versatile and highly accurate road attribute description via regular grid road (RGR) models, tire simulation for all kinds of vehicles – cars, light vans, trucks, buses, motorcycles, scooters, tractors, dump and mining trucks, aircraft and more – are possible. It has a frequency range for validity up to 200Hz, yet works perfectly with simplified suspension models based on look-up tables, as well as the same data file used by the standard FTire version. A large number of powerful post-processing and analysis tools are also used.

Simulation setup

To investigate tire characteristics under the conditions of real driving scenarios, the simulation must include models for the vehicle dynamics, driver and environment. The ASM Vehicle Dynamics Model by dSPACE provides open Simulink models for the real-time simulation of vehicle dynamics behavior in a specified environment. ASM Vehicle Dynamics is typically used on a dSPACE Simulator or



LEFT: Typical parking simulation results of a real-time simulation with ASM Vehicle Dynamics and FTire/realtime compared to the standard FTire approach and real measurement data



LEFT: A simple test setup for EPS systems featuring a separable EPS motor

dSPACE Scalexio system to perform HIL tests on ECUs, but it is also used with offline simulation platforms for early validation during the design phase of controller algorithms. The vehicle dynamics model supports all the relevant phases of the model-based development process.

ASM Vehicle Dynamics includes simulations from passenger cars to trucks and can be combined with all other ASM models such as ASM Trailer for trailer simulation, ASM Engine for virtual vehicle simulation, and ASM Traffic for ADAS applications.

Application example

When combined with FTire/realtime, ASM Vehicle Dynamics is ideal for investigating vehicle handling and ride comfort in real-time environments such as dSPACE Scalexio, where slip-based tire models fail. A typical example is testing electric power steering (EPS) controller behavior. The combination of FTire/realtime and ASM Vehicle Dynamics makes the simulation of steering model activities in standstill conditions or during parking maneuvers realistic.

For vehicle dynamics simulation, many parts of the chassis can be combined in look-up tables. However, this is not useful for steering systems, because different EPS variants have to be simulated with their respective elasticities and friction elements. The ASM steering model displays the steering components as modules and has up to four degrees of freedom, depending on the configuration.

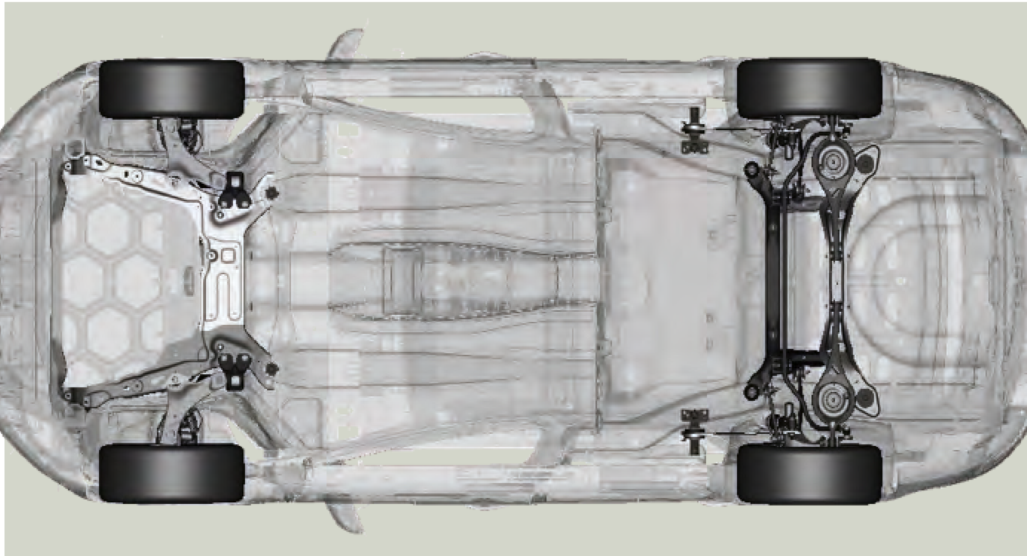
The individual components, such as the steering wheel and upper steering column, the lower steering column and the rack and pinion, and the EPS system, are coupled kinematically via Cardan joints and gear ratios, and elastically via spring-damper elements. The influence of friction is simulated using parameterizable friction elements. The variables that are needed for running the EPS controller are provided as simulated sensor variables. The model has the interfaces required for the individual EPS variants and their test systems.

The combination of FTire/realtime and ASM Vehicle Dynamics runs on a Scalexio multicore system. Due to the complex computation in FTire/realtime, one processor core is reserved for each tire. The tire and vehicle models communicate via hypervisor technology. For this, a bare-metal hypervisor (from Real-Time Systems) is used in privileged mode. This ensures high performance and low latencies in communication with the I/O.

EPS controller test systems vary in complexity. Depending on the degree of integration of the mechatronic systems, the test systems range from pure electronics testing to mechanical test benches including a steering column and rod. The ASM Vehicle Dynamics Model provides interfaces for all levels of system integration.

Minimizing mass

Altair explains how its HyperStudy and OptiStruct software has accelerated the development of Gestamp's rear twist beam (RTB)-type suspension arrangements in new car programs



ABOVE: The final layout of the Gestamp concept, created using RTB Toolbox

BELOW LEFT: Wheel center Z displacements for a full cycle of the antiphase rolling durability test

BELOW LEFT AND RIGHT: Analysis of the performance of torsion elements enabled component mass to be optimized

Rear twist beam (RTB) suspension systems are commonly used in A, B and increasingly C class vehicles due to their low manufacturing cost, small package requirement, and the acceptable vehicle handling performance they deliver.

RTB design is a complex challenge that requires careful consideration of elastokinematic performance, in addition to meeting stiffness and durability targets. Design of experiments (DOE) and optimization methods are being used to explore the available design space and minimize the mass of a low-cost RTB design.

Gestamp is a global chassis component supplier for customers including Ford, VW, BMW and Honda. Its technical centers, based in the UK, Spain and Germany, support an expanding global business with manufacturing sites throughout the world developing low-cost, high-volume chassis products. Component mass and cost (strongly linked to mass) are drivers for every customer, and Gestamp has been using an optimization-driven design process, based on Altair products, since 2005.

Shape optimization has been used to tune a low-cost 'U-section' RTB concept design for stiffness targets and to reduce the stress in critical welds for the antiphase rolling durability load case. This durability requirement has been identified as one of the main mass drivers for this type of RTB design.

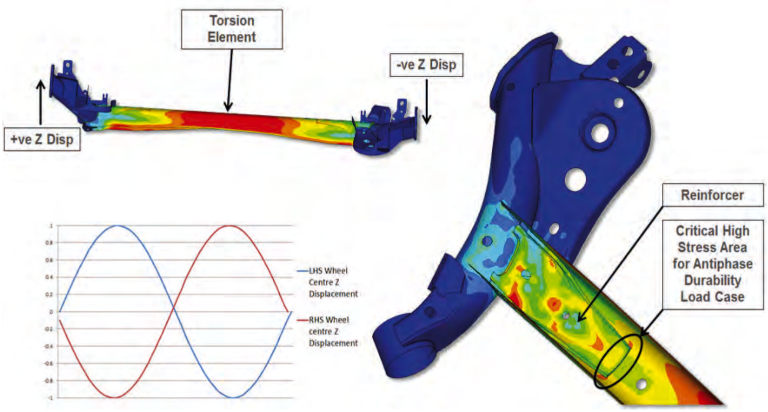
Design of a U-section RTB typically requires consideration of several interlinked targets. Two key targets that define the shape and positioning of the main structural members are roll stiffness and roll steer. Both are strongly influenced by the shape, position and gauge of the torsion element (the crossmember of the RTB).

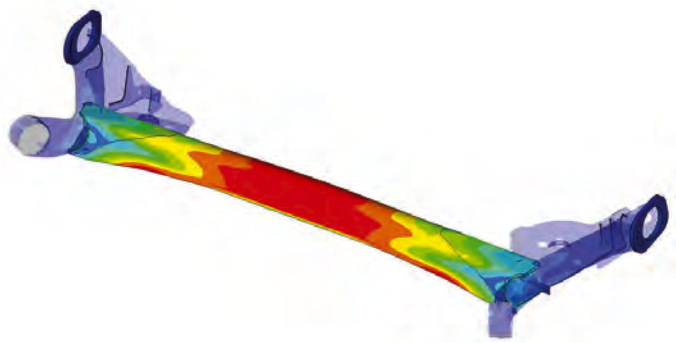
Gestamp selected Altair to develop a set of custom tools, referred to as the RTB Toolbox, which can be used to generate an initial RTB concept that meets kinematics and compliance (K&C) requirements such as roll stiffness/steer, thereby eliminating an initial trial-and-error design loop.

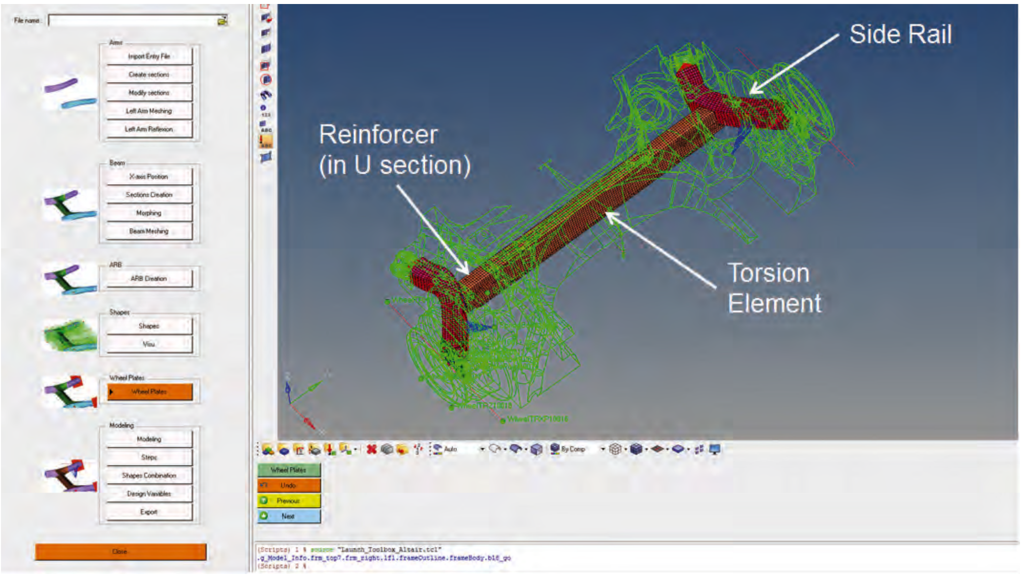
This software used the functionality available within high-performance pre-processor HyperMesh to set up shape design variables for each component in the RTB assembly. HyperStudy was used to control DOE studies, which provided a detailed understanding of the sensitivity of each target to input parameters. This was followed by a final optimization step from which the concept surfaces were generated.

The next stage of the design process was to create a CAD model from the optimized toolbox output. This model served as a baseline for work to meet durability and strength criteria.

The antiphase rolling durability load case was identified across several customer projects as a significant mass driver. In this test, opposing vertical displacements were applied to the wheel centers of an RTB system in order to







ABOVE: Process-driven RTB Toolbox design interface in HyperWorks

simulate repeated cycles of cornering. Generally an increase in roll stiffness reduced the fatigue performance.

Durability analysis and experience can be used to define stress limits for welds in critical areas such as those between the reinforcer and the torsion element. The relationship between these two components had a marked effect on the roll stiffness performance and the fatigue life in this area. A combined shape optimization of the reinforcer length and torsion element gauge enabled an optimum solution to be achieved, minimizing mass while respecting durability and roll stiffness constraints. The presence of several competing effects means OptiStruct is a powerful tool for developing the design.

The development of the RTB Toolbox resulted in a reduction in design lead time for the initial concept, which was carried through the project.

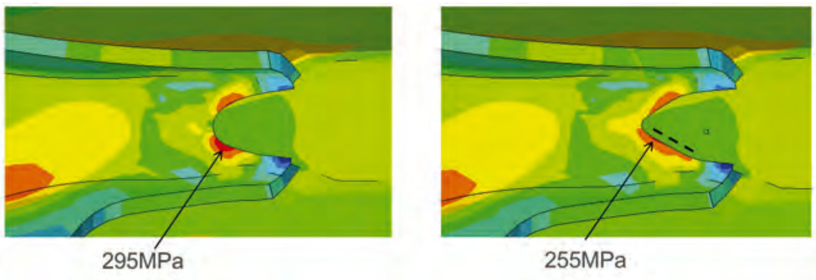
An additional benefit of the toolbox design approach was the use of DOE studies. These studies have proved to be valuable as a means of quickly gaining an understanding of the sensitivity of various K&C targets to input parameters, including the shape and position of individual parts within the assembly, along with their gauges.

The optimization capability offered by OptiStruct was used extensively to tune the Toolbox Output design in order to meet durability targets, while ensuring that K&C performance is maintained. Local shape optimization of the torsion element trim edge was also used to successfully generate design variants with several levels of roll stiffness.

RTB designs that feature a U-section torsion element are typically seen as a simple, low-cost solution. However, a material thickness of over 6mm is sometimes required to meet performance targets, which substantially increases mass in comparison with designs that use a more expensive 'squashed tube' torsion element.

Gestamp has recognized the potential for mass reduction through optimization of a U-section design. The use of the RTB Toolbox software, in addition to the HyperWorks package, enabled the quick creation of an RTB geometry that met specified K&C targets, eliminating an initial trial-and-error design loop. The shape and gauges of the torsion element and reinforcer were optimized to minimize mass while meeting durability targets. Through this process, Gestamp can react quickly to produce competitive low-cost, low-mass RTB designs.

The next steps in developing the Gestamp RTB design process include the consideration of external factors such as hardpoint positions, spring and bush rates, in order to identify a more optimized solution when looking at the system-level performance. MotionSolve would be used for this activity. The target challenge and trade-off analysis must also be considered in order to identify where small target reductions can yield large mass reductions.



LEFT: The results of the tests, which showed improvements in roll stiffness and fatigue life

High-fidelity testing

MTS's Flat-Trac Ride Comfort Roadway is an easy way to bring high-fidelity testing into the test lab

ABOVE: Lab-based tuning of active and semi-active suspensions is possible, thanks to the moving tires providing real vehicle feedback to ECUs

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

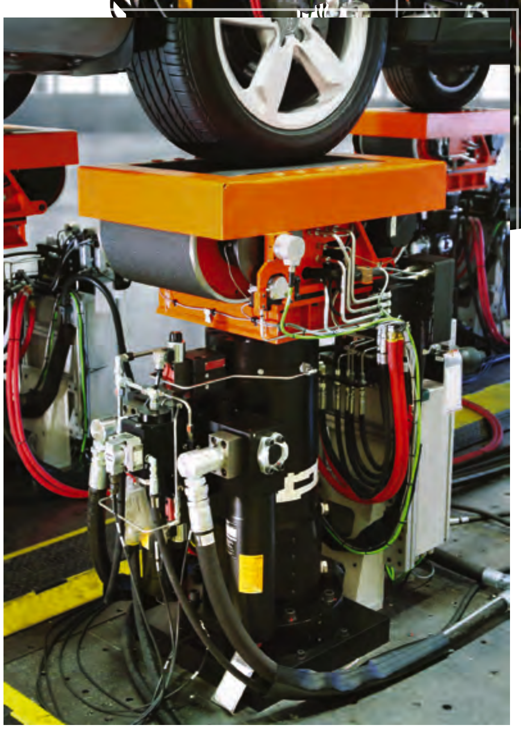
Today's emphasis on ride comfort is driven by several factors. The global focus on increased fuel efficiency and reduced emissions has led to quieter cabins, making noise and vibration much more noticeable to occupants. The increasing adoption of active and semi-active suspensions has made vehicle benchmarking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

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

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

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

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



RIGHT AND BELOW RIGHT: MTS's Flat-Trac Ride comfort roadway combines a robust four-post system with moving belts for performing ride comfort evaluation, benchmarking and tuning

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

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

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

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

Flexible approach

The **Adams MaxFlex** gives engineers the freedom to maximize non-linear flexibility in multibody dynamics simulations

In recent years, greater emphasis has been placed on high-speed, lightweight and precise mechanical systems. Often these systems will contain one or more structural components for which deformation effects are paramount for design analysis. In those cases, including the flexibility for those key components results in more precise loading predictions and improved system performance prediction.

Flexible bodies in Adams

Adams/Flex has been used by Adams users for many years to include linear flexibility in multibody dynamics (MBD) systems, enabling them to capture relatively small deformation of flexible components (up to roughly 10% of the characteristic length) during a simulation.

However, when it comes to components with geometric or material non-linearity, such as the twist beam in a suspension system or engine mounts, Adams/Flex does not provide the ability to cope with non-linearity in the simulation.

In such a scenario, engineers typically choose one of two options. The first is to export the dynamic loads from the Adams simulation and use them as the boundary conditions for subsequent non-linear FEA analysis. While it is a more realistic prediction of the non-linear stress/strain behavior than recovering stress/strain in the Adams/PostProcessor with Adams/durability, it still doesn't tell you whether the non-linear behavior of those parts is affecting the behavior of the rest of the MBD model and thus influencing the loads in the system. In this case, you won't get accurate boundary conditions/loads for the downstream non-linear FEA analysis, which basically means you will not be able to simulate those systems precisely.

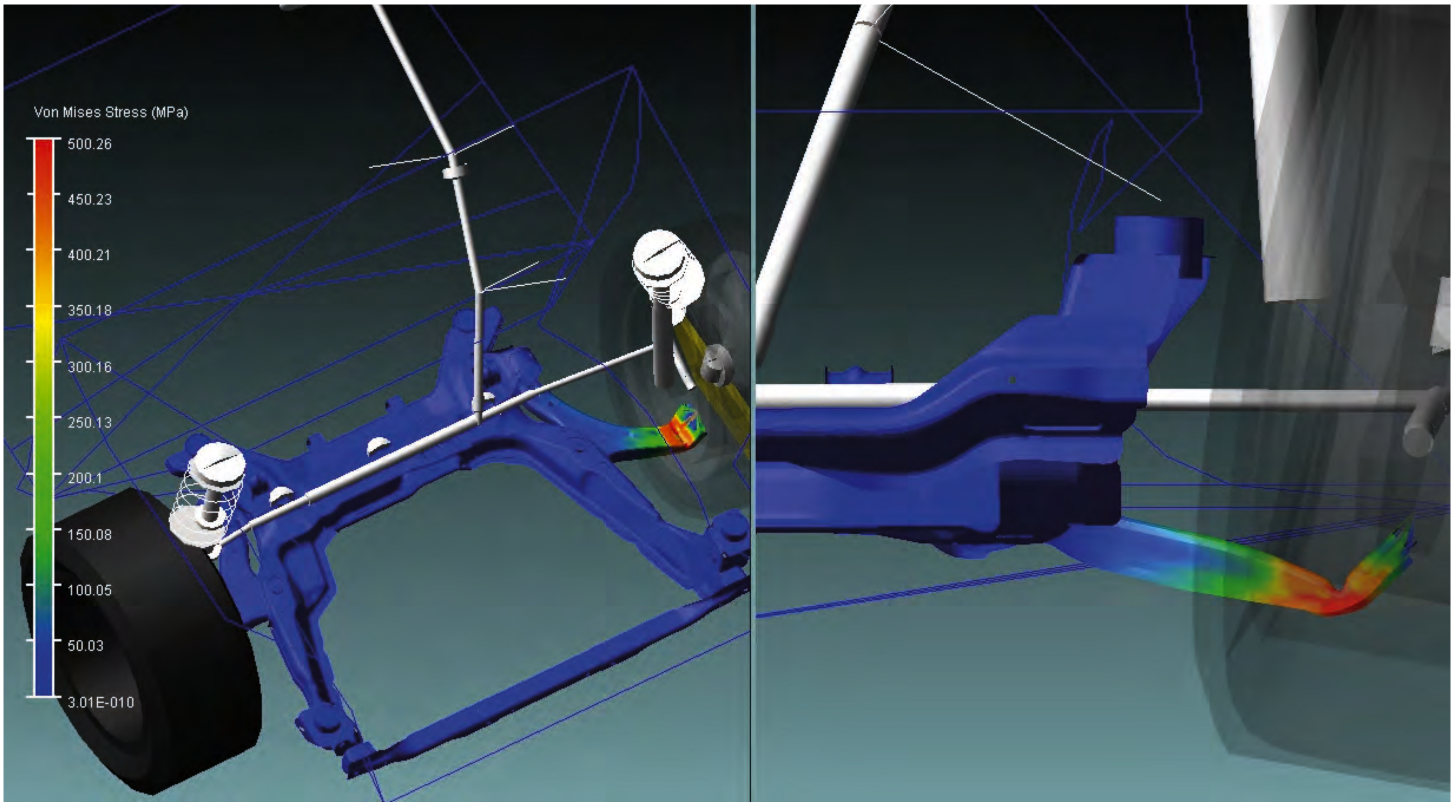
The second option is to represent the non-linear component(s) by some means other than a single linear flexible body. Separating the components into a set of rigid bodies or linear flexible bodies might suffice for geometric non-linearity, but can be inconvenient or costly in terms of preprocessing time for many users and problems. The Adams FE Part feature addresses those inconveniences, but has limitations that might not make it a practical option for some problems, especially those that require shell or solid elements. Furthermore, none of these options are practical if material non-linearity is an important part of the problem.

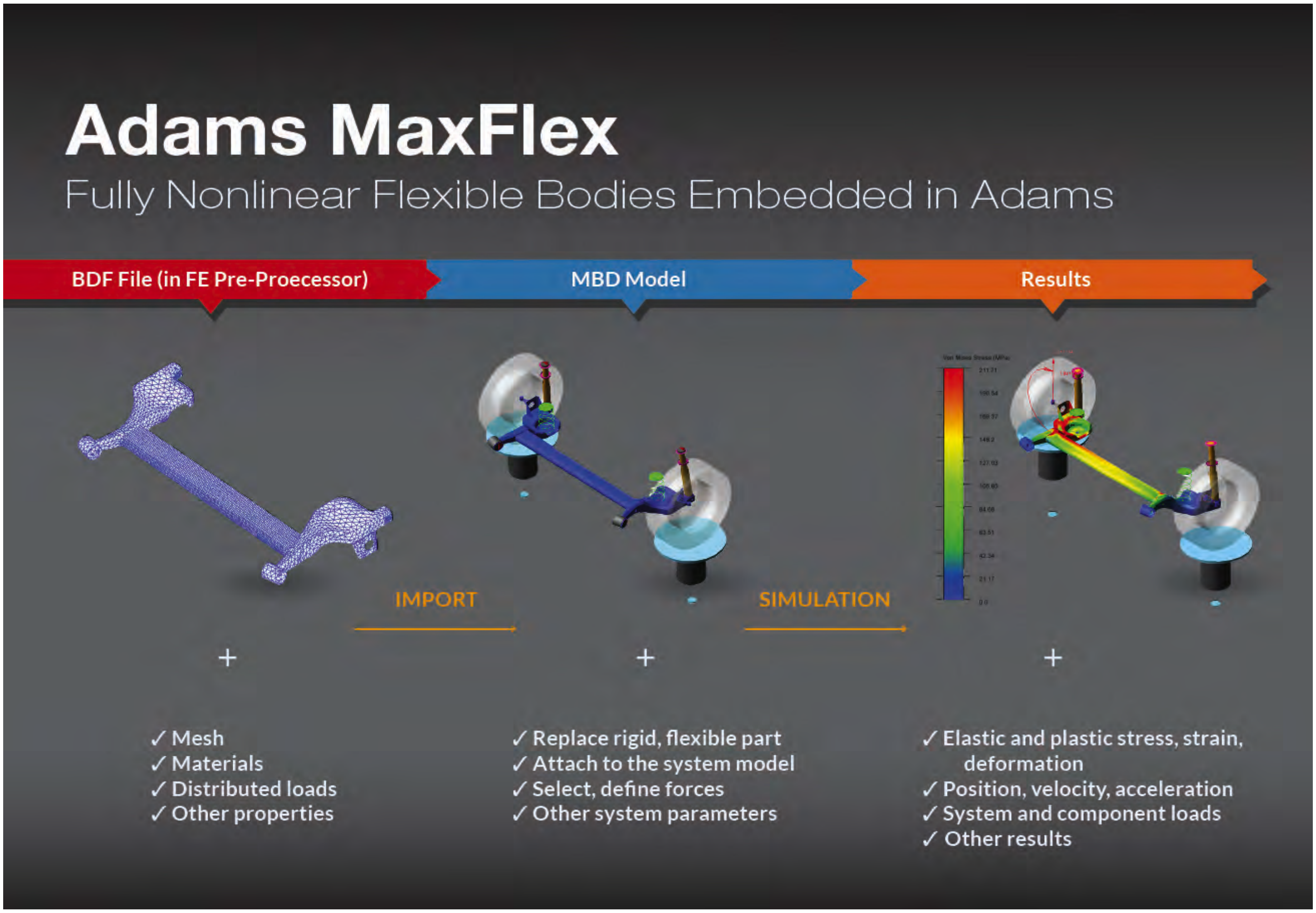
Hence, to incorporate non-linear flexibility into MBD systems, MSC Software has introduced a new methodology/tool for its users.

Adams MaxFlex

The Adams flexible body has a new non-linear option that enables the representation of geometric non-linearity (i.e. large deformations), material

BELOW: The Adams flexible body has a new non-linear option, which allows for the representation of large deformations, material non-linearity and boundary condition non-linearity. Model provided by Volvo Cars





ABOVE: Example of an Adams MaxFlex Workflow

non-linearity and boundary condition non-linearity. The option is based on implicit non-linear finite element analysis. It is not MSC's intention to provide broad finite element pre- or post-processing capabilities within the Adams environment; rather, the focus is on providing a solution for problems where the non-linear behavior of some parts and the motions and loads of the rest of the MBD model influence each other, making accurate results impossible or impractical through separate MBD and FEA analyses. While FEA technology is used to represent and solve the non-linear flexible body, it is embedded wholly within Adams. No additional FEA software is required to solve the model; this is not a co-simulation.

"We see potential use of MaxFlex in durability events, where permanent deformation of suspension components alters the load path and loads, which we were not capturing using MNF bodies. Having this capability in the MBD environment would help us in generating more realistic loads earlier in the program," explains Chandra Tangella, loads analysis engineer at Fiat Chrysler Automobiles.

MaxFlex can be used in any scenario where the engineer wants to capture non-linearity in the MBD model. For example, it can be used to simulate twist beam suspensions, stabilizer bars, coil springs, suspension bushings, rubber mounts, lower control arm buckling, and so on.

There are benefits of using MaxFlex rather than linear flexible body or co-simulation. An MBD analyst can increase model accuracy by including non-linear structural behavior; it is a streamlined workflow, similar to Adams/Flex; and simulation is conducted entirely in Adams, saving time and cost. In addition, there is shared memory parallel support to increase simulation efficiency, it is easy to set up models and run simulations, and no third-party tool is needed to generate animations with rigid and non-linear flexible parts, since it can be done in Adams/PostProcessor.

Intelligent design

Two major new orders show the value of **Tenneco's** continuously variable semi-active suspension technology

There have been some major recent developments relating to Tenneco's continuously variable semi-active suspension (CVSAe) technology. CVSAe, part of the company's Monroe Intelligent Suspension portfolio, adjusts to changing road conditions in real time. It continuously senses the road and driving conditions and adjusts the suspension within milliseconds, offering enhanced ride comfort with outstanding dynamic response.

The Monroe Intelligent Suspension portfolio includes adaptive suspension solutions (dual mode) for compact cars; and semi-active solutions with external valve (CVSAe), and two independent valves (CVSA2) for mid-range and higher-end cars. There are also the CVSA2/Kinetic and Acocar active suspension solutions for premium luxury cars, high-end sports cars and SUVs with off-road capability.

Infiniti is now introducing CVSAe technology on its 2016 Q50 sedan and all-new Q60 coupe as part of the vehicle's Dynamic Digital Suspension (DSS) system. It gives drivers the option of adjusting the feel and handling of their ride by selecting Comfort, Sport or Sport Plus driving modes.

"We are delighted to add Infiniti to our growing list of customers who want to partner with Tenneco to differentiate their ride performance with advanced electronic suspension systems," says Enrique Orta, Tenneco's senior vice president for ride performance. "Our Monroe Intelligent Suspension portfolio continues to gain traction with the world's vehicle manufacturers with a full range of electronic technology options."

ABOVE: CVSAe intelligent suspension technology adjusts to road conditions in real time

ABOVE RIGHT: Tenneco has been validating its CVSA technology in consumer tests

LEFT: The Monroe Intelligent Suspension portfolio has a scalable architecture

Infiniti is the first Japanese luxury brand to choose CVSAe dampers. The vehicles are being assembled at Nissan's Tochigi manufacturing plant in Japan.

Tenneco is also supplying its Monroe Intelligent Suspension as part of the Adaptive M Suspension option on the new BMW 3 Series. According to BMW Group, the CVSAe dampers in the Adaptive M Suspension system help smooth out vibrations caused by uneven roads in the Comfort setting, while tighter damper settings in the Sport setting create a more dynamic feel. The Sport Plus setting allows tight, precise turns and higher cornering speeds.

Drivers can alternate between suspension settings by pressing the Driving Experience control button. Sensors on the CVSAe dampers and the steering system continuously transmit data about the condition of the road and the driving situation to an onboard computer, which adjusts the dampers in real time to get the best performance in each of the three suspension settings.

"Tenneco is excited that Monroe Intelligent Suspension has been selected as an option on the BMW 3 Series, as this is the first compact luxury sports sedan in its category to offer our advanced semi-active technology," adds Orta. "Monroe Intelligent Suspension technology can add value across all vehicle categories, which was also validated in consumer testing."

Tenneco now supplies CVSAe dampers to BMW for its 1 Series, 2 Series, 3 Series, 4 Series and X3 models.

Tenneco's CVSAe dampers are engineered at Tenneco Innovación, Ermua, Spain, and produced at the company's advanced manufacturing facility, also in Ermua.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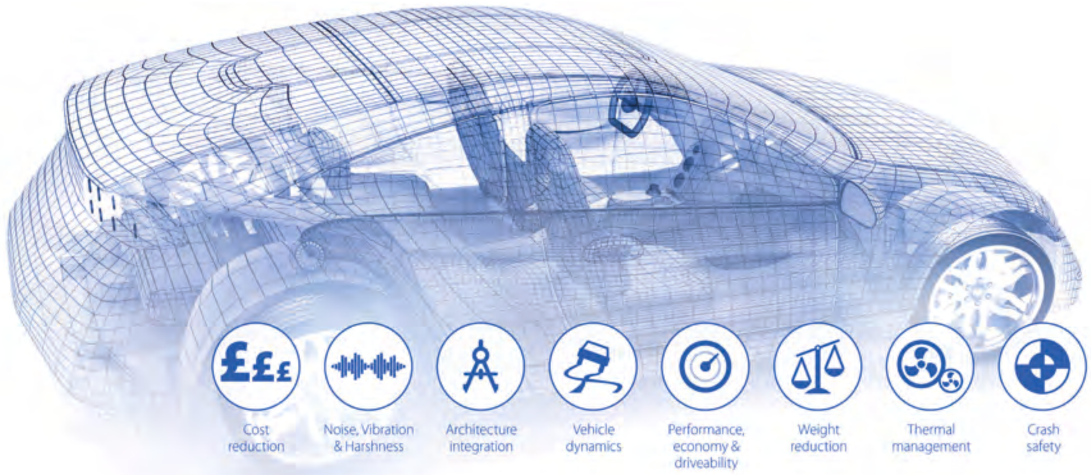
One shot

Ricardo is engineering a path to zero prototype vehicles



ABOVE: Ricardo implements cross-attribute simulations in its automotive development projects

Consumer demands and increasing competition are leading auto makers to seek greater levels of product differentiation, while necessitating ever-shorter vehicle development cycles. These twin challenges are encouraging the application of advanced CAE tools and methods, particularly at the concept design and verification stage, in order to reduce the risks and consequential costs of subsequent design changes during attribute physical tuning.

The current widely accepted approach to vehicle engineering development is to conduct attribute virtual development in isolation. Design verification milestones are the key points in the program where vehicle integration and attribute trade-off decisions are made. A drawback of this key stage method of development is that it can become out of phase with potential optimization stages, resulting in lost opportunities for optimization of the product's design.

The approach used by the Ricardo's Vehicle Systems team maximizes the opportunity for product optimization within the constraints of ever-shorter program timing, using an attribute-led vehicle engineering development process all the way from product pre-concept through to launch. Cross-attribute vehicle simulation is critical to enabling the design, development and verification of the next generation of chassis and vehicle systems.

Ricardo's team uses cross-attribute simulation for vehicle dynamics, NVH, driveability and durability work. By applying advanced simulation tools, this approach delivers vehicle-level target cascades at a system and component level, followed by verification back to the vehicle. This knowledge and experience, combined with state-of-the-art CAE functions applied to industry standard simulation tools, brings simulation closer to reality and supports accurate cross-attribute simulation.

Where advanced chassis control technologies are being deployed, comprehensive cross-attribute model-in-the-loop simulation is conducted. This key stage is the foundation to a robust and reliable output when applied to the hardware- and software-in-the-loop testing stages of the development cycle. With the next generation of chassis systems, this cross-attribute model-in-the-loop simulation is central to achieving the goal of virtual vehicle engineering with zero prototypes.

There is much more involved in virtual engineering than mere cross-attribute simulation: success in virtual engineering is reliant upon good decision making in vehicle integration, and cross-attribute balancing. The global experience of Ricardo's experts within steering, ride, handling, braking, NVH and durability can support vehicle integration and attribute-balancing decisions.

The company's virtual engineering capabilities are further supported by expertise in benchmarking, and in subjective and objective testing.

Key benefits of working with Ricardo's vehicle engineering team include having access to a breadth of capabilities with regard to attribute engineering services, facilitating informed and data-driven decisions. The team has access to proprietary tools and processes, and market-leading metrics for defining dynamic performance, which can bring simulation results closer to reality.

The team also conducts independent vehicle benchmarking with expert analysis to support balancing dynamics and other vehicle attributes during target setting and concept/technology selection. Appropriate CAE tools for cross-attribute simulation are also available for supporting concept development and validation, with next-generation tools providing more accurate performance, early identification of design issues, and reduced reliance on physical vehicle testing and validation.

Ricardo has a wealth of expertise in vehicle dynamics and has proved this competence in numerous customer projects. The company can offer the flexibility to support projects of any size, all the way from benchmarking with expert technical analysis, through to full vehicle programs. These capabilities, when combined with access to the company's world-class test facilities at locations throughout the world, make Ricardo a leader and partner of choice on the virtual vehicle engineering journey to zero prototypes.

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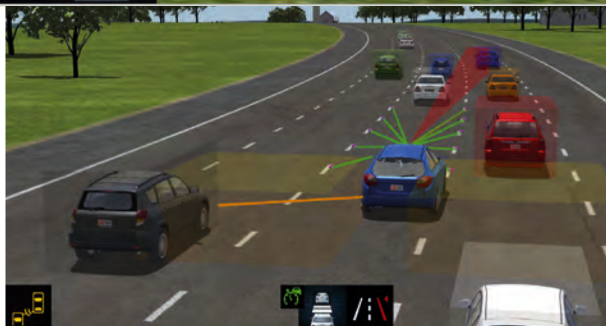
Life support

Vehicle dynamics simulation is critical to the development of **ADAS**

ABOVE: CarSim demonstration of forward crash avoidance



LEFT: CarSim demonstration of lane-departure warning, adaptive cruise control, forward crash avoidance, and blind-spot detection

In 2015, the National Transportation Safety Board (NTSB) and auto makers jointly announced that by 2022, forward crash avoidance systems would be mandatory on all cars and light trucks sold in the USA. This is the first step in what is likely to be a growing list of required advanced driver assistance systems (ADAS) features hitting the roads in the coming years. As ADAS becomes more common, the question of how to develop, test and validate these systems within the constraints of the short automotive development cycle becomes increasingly important.

Most ADAS applications, such as forward crash avoidance systems, are designed to assist the driver in emergencies while pushing the vehicle to its performance limits. In order to capture that limit behavior, it is essential to use high-fidelity vehicle dynamics software.

Mechanical Simulation Corporation provides accurate vehicle dynamics tools for ADAS, which can increase the productivity of ADAS development engineers. Although many initial evaluations of new ADAS algorithms take place on flat and level surfaces with just one other moving object, the ADAS behavior must also be evaluated in complicated scenarios involving road intersections and multiple moving objects, such as traffic and pedestrians.

The company's CarSim package enables engineers to recreate complex situations involving multiple vehicles and sensors, with easy-to-use road, path and scenario building tools. Real-world driving routes can be imported from sources such as Google Maps using Mechanical Simulation's Atlas road importer. Detailed 3D road intersections can be assembled using the built-in capabilities of the software.

Simulation can be used at each step of the development process to reduce the need for physical prototypes, reducing the time to market. This means that new ADAS features can be tested as they are developed, using common software-in-the-loop (SIL) techniques with the accurate response of the CarSim simulation model, well before hardware prototypes exist. Because a wide range of exactly repeatable scenarios can be stored in CarSim's procedure database, test procedures and replications of errors from the field can be used to evaluate features throughout the vehicle development process.

Once hardware is available, controls and other physical subsystems can be tested safely in the laboratory, with a detailed math model in place of the components that are not available. CarSim is designed for use with many common real-time (RT) systems, which enables easy integration into new or existing hardware-in-the-loop (HIL) equipment, making vehicle-level evaluation of controls and subsystems possible using the same models developed for office-only or SIL analysis.

Another important development area is the complex human-machine interactions that can be studied using realistic driving simulators. The Mechanical Simulation QuadDS driving simulator runs CarSim, so it can be used to test and develop ADAS by putting the driver in the loop. A wide range of driving styles and behaviors can be tested, which means more thorough validation and higher confidence in the ultimate calibration for production. Developers and managers alike can see real drivers interact with prototype controls systems in real-life conditions to ensure the desired performance.

The CarSim package reduces the effort and costs associated with ADAS engineers creating realistic testing environments and events, ensuring high confidence going into final hardware validation. Ultimately, this virtual prototyping improves productivity, ensures quality, and reduces both pre- and post-production costs.

Steering a safer future

ZF TRW's comprehensive range of dynamic enhancing components benefit not only driving enjoyment, but occupant safety too

To generate systems that help to shape and influence key automotive megatrends like automated driving, safety and efficiency, combining technologies in new ways has become a decisive factor for success. For ZF and its active and passive safety division, ZF TRW, this means combining the different fields of competences of the two formerly independent companies.

Secondly, it means bringing together advanced mechanics, electronics and software in one integrated system. And thirdly, it means connecting various automotive systems intelligently in order to create innovative functions with added value. A ZF steering system that was recently showcased during winter testing of a prototype compact car in northern Sweden, is a testament to all of these factors.

The vehicle features progressive, already existing ZF technologies: it is equipped with dual-pinion electrically powered steering (DP EPS) from ZF TRW on the front axle and – from the ZF chassis systems unit – an Active Kinematics Control (AKC) at the rear. The latter provides steering on-demand by wire, with a steering angle of up to 5°. Because both systems are connected via joint control electronics systems – also developed and manufactured in-house by ZF – the driving safety and dynamics of the vehicle are clearly enhanced. Even on packed snow and ice surfaces, the ZF system keeps the prototype vehicle perfectly on track, even when changing lanes or overtaking.

The connection of the two ECU-controlled electromechanical systems also offers advantages for partially or fully automated vehicles. This utilizes an additional control element in the vehicle cockpit's center console, whereby the systems at the front and rear axles can be steered completely electronically. Such a steer-by-wire concept could be used in the future to control partially, as well as fully automated, steering maneuvers, especially the overtaking and lane-change operations already mentioned. Having the AKC's support at the rear also significantly improves overall lateral dynamics, as driver assistance systems such as stability control can intervene much later than in conventionally equipped vehicles – if they need to intervene at all.

ABOVE: The ZF prototype compact car features a dual-pinion electrically powered steering system on the front axle, with Active Kinematics Control on the rear axle

In addition, this system setup also provides system redundancy, which is critical for automated driving concepts. At highway speeds, for instance, AKC can direct a vehicle without necessarily needing DP EPS at the front.

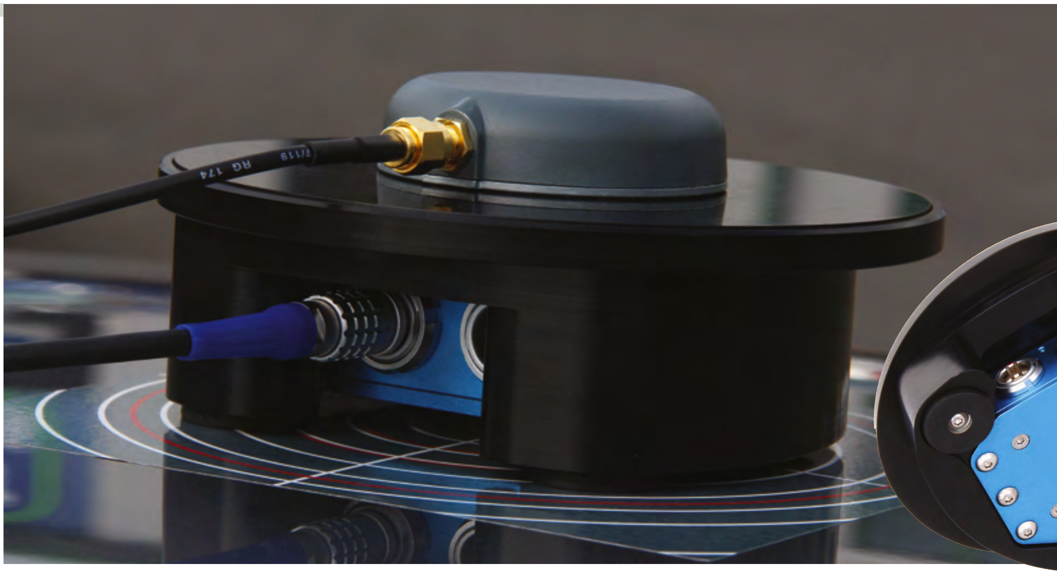
The test vehicle also features a newly developed ZF modular rear-axle concept that allows easy integration, not only of AKC, but also an electric or conventional drive module. The basic axle features a development of a semi-trailing arm rear suspension setup. As part of this design, the rear of the two outboard kinematics points of the lower control arm were replaced with an integral link and an added toe link. As an alternative to a suspension strut, which tends to be used on semi-trailing link axles, the integral link in an extreme outboard position enables a space-saving layout with separate springs and dampers.

At low vehicle speeds, AKC supports the front steering by moving the rear wheels in the opposite direction to the front wheel's steering angle. This improves the vehicle's agility and at the same time reduces the turning radius, helping to increase driver comfort. At higher speeds, the rear and front wheels steer in the same direction, improving the vehicle's stability. In this case, the vehicle's rotation around the vertical axis is reduced, enabling safer driving.

The connected AKC and DP EPS concept shown in the compact prototype represents a technology integration milestone for ZF and ZF TRW – as well as a high-value solution. In the future, safety and comfort can be further increased when the company's steering and active chassis systems are combined with other ZF technologies such as braking, as well as camera and radar systems. This will enable the next generation of automated driving and driver assistance.

Rapid dynamics tests

Racelogic has combined its high-grade GPS with inertial measurement units to create an effective off-the-shelf testing solution



RIGHT: Racelogic's co-located IMU and GPS antenna *in situ*

ABOVE: Reverse side of the roof-mounted IMU and antenna

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

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

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

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

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

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

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

LEFT: The VBOX 100Hz twin-antenna speed sensor with integrated IMU

Human resources

rFpro software allows engineers to test real-world emissions with a human driver in control by connecting a driving simulator to a drivetrain dynamometer

TOP: Data captured in a road scan

ABOVE: The road data when applied by rFpro

The clamor for more realistic emissions testing and the imminent introduction of real driving emissions (RDE) legislation introduces a new challenge for vehicle manufacturers to overcome. Established test cycles are well understood and manufacturers present their vehicles for type approval only after high confidence in their engineering has been established through extensive dynamometer and rolling road development.

The need to ensure in advance that a vehicle will achieve the desired results during RDE testing will add considerable additional cost to typical development programs. Understanding driver-influenced variables and the effect of real road conditions on test results becomes crucial. Achieving consistent, repeatable testing on real roads shared with other traffic is problematic, and affects the usefulness of test data.

ABOVE: From realistic shadows to roadside cafes, the level of realism in today's simulators is impressive

BELOW: The level of realism is achieved through lag-free, high-resolution graphics

Software developed by rFpro for driver-in-the-loop (DIL) simulators enables manufacturers to evaluate vehicle behavior under repeatable lab conditions using human drivers, in order to maximize confidence ahead of approval testing. The key factor is the level of realism provided by the software through the use of lag-free high-resolution graphics and finely detailed road surface models, including cambers, gradients and potholes, as well as millimeter-perfect elevation around the route.

"Our simulator software has already extended the use of simulators into the realm of meaningful ride and handling development. It is helping to evaluate how different drivers influence emissions and economy under real road conditions," explains rFpro's technical director, Chris Hoyle. "We have customers linking driving simulators to engine and drivetrain dynos, enabling highly repeatable tests to be conducted. The low variance between results enables statistical methods to be applied and saves time and costs."

Quantifying the influence of driving habits on emissions using on-road testing is difficult and time consuming, because of the variations between tests created by traffic conditions and weather. Virtual testing with DIL and drivetrain dynos overcomes these issues, providing full control of weather factors (temperature, humidity, atmospheric pressure) and road conditions (traffic density, stop light sequences, road repairs). This setup enables vehicle manufacturers to identify and isolate those aspects of human driving that differ significantly from computer-controlled operation, leading to improved accuracy in predicting how the vehicle will perform in an RDE test.

AVL, the world's largest independent developer of powertrain systems, is among the leaders in preparing for RDE testing, and uses DIL simulation with rFpro software. AVL estimates that by front loading engineering activity on a DIL simulator with subjective feedback, it can save more than 30% of the costs incurred in developing driving attributes.

rFpro software is unique in enabling testing, in driving simulators, of anything that affects vehicle dynamics. Such tests can also be used in human factors studies, HMI studies, and ADAS and autonomous control systems testing – all while under human control, years before a physical test vehicle is available.

Intelligent design

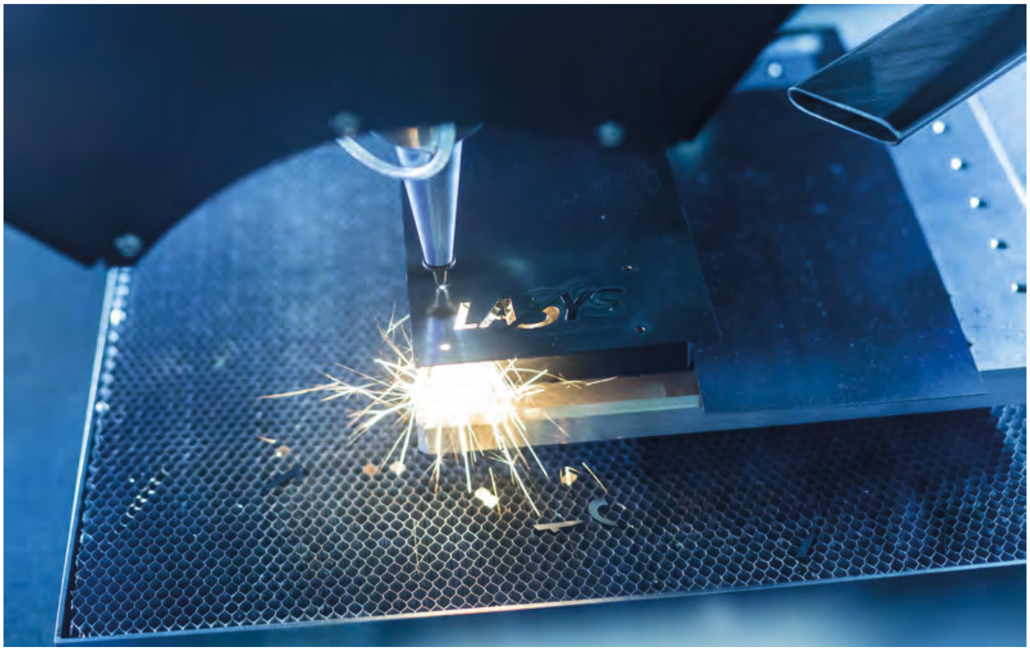
Motor vehicle construction can benefit from the new laser-joining processes on display at **LASYS 2016**

Production flexibility, cost efficiency and sustainability for products and production processes are focal points during the construction of lightweight vehicle bodies.

Innovative laser-joining technologies are ideal for this task as they offer a cost-effective way to produce highly durable lightweight structures. Exhibitors at LASYS, the international trade fair for laser material processing, will demonstrate their expertise and present their latest solutions relating to this topic from May 31 to June 2 at Messe Stuttgart in Germany. The LASYS show is solely focused on laser material processing, and its anticipated 200 exhibitors will present established and innovative laser production systems and laser-specific components and subsystems.

Exhibits on show will also include solutions for economical and challenging laser-joining processes, such as welding together different metals, for example light metal with steel.

Visitors to LASYS 2016 will have the opportunity to take home many new ideas for new solutions, especially relating to the efficiency and cost-effectiveness of laser material processing systems. The show covers all industries and materials, and is primarily aimed at international decision makers.



In 2016, LASYS will again be held concurrently with automotive shows arranged by UKIP Media & Events, publisher of *Vehicle Dynamics International*: Automotive Testing Expo Europe, Engine Expo, Automotive Interiors Expo, Global Automotive Components and Suppliers Expo, and the Autonomous Vehicle Test & Development Symposium.

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Maserati 250F

While the new Levante SUV may split opinion, the 1954 250F is perhaps Maserati's most loved car, being widely regarded as one of the finest, and most elegant, front-engined race cars to enter F1. By John O'Brien

The introduction of the new 2.5-liter naturally aspirated Formula in Grand Prix racing in 1954 gave Maserati a new opportunity to return to motorsport's top flight following a five-year absence. Its answer to the new engine regulations was the 250F, once described by Sir Stirling Moss as the "finest handling front-engined Formula 1 car ever made", a compliment that was soon validated when the car won on its 1954 debut in the hands of Juan Manuel Fangio.

Just 26 Maserati 250Fs were built, all featuring a multi-tubular chassis that resembled a traditional ladder frame. It was the work of former Ferrari chief designer Gioacchino Colombo and former Ferrari engineer Valerio Colotti, the latter being responsible for designing the car's wishbone independent front suspension and the rear de Dion suspension. Much like the period Ferrari competition cars on which he had worked, Colotti chose to place the de Dion tubing ahead of the transaxle for improved weight distribution.

Power came from a 270bhp straight-six, with the car's 1,477 lb slowed by 13.4in ribbed drum brakes, behind wire wheels wrapped in cross-ply tires. The car's balance allowed for a very controllable slip angle, which made for a great racing spectacle.

"It steered beautifully, and inclined toward stable oversteer which one could exploit by balancing it against power and steering in long sustained drifts through corners," Moss explained at a post-race interview.

"It rode well on the normal type of relatively smooth-surfaced course, although its small coil springs and leaf spring rear-end would use up available suspension movement over the bumps at the Nürburgring."

During its second year, development work on the car's chassis was limited to the one-off appearance of streamlined bodywork for the Monza round of the championship. In 1956, however, multiple changes were made throughout the season in an attempt to reduce drag, which resulted in further tapered nose cowls, higher cockpit sides, and a full wraparound screen. The chassis was also revised to allow a 5° change to the engine mount position, which cantered the engine over and lowered the car's center of gravity.

In what transpired to be somewhat of a swansong year for Maserati, 1957 saw a new 'Tipo 2' lightweight spaceframe chassis developed for the 250F, which significantly improved the car's structural rigidity. The chassis could also accommodate a 2.5-liter V12 engine, which made a rather unsuccessful debut at the final race of the season at Monza.

Nevertheless, the straight-six-engined Tipo 2 car of Fangio claimed four victories from the season's eight races, which was enough for him to claim the title. At the end of 1957, financial difficulties saw Maserati go into administration, and the remaining 250Fs sold off. The 250Fs lived on though, with 60% of the starting grid at the opening race of 1958 being 250Fs, with examples campaigned up until 1960, some six years after its competition debut.