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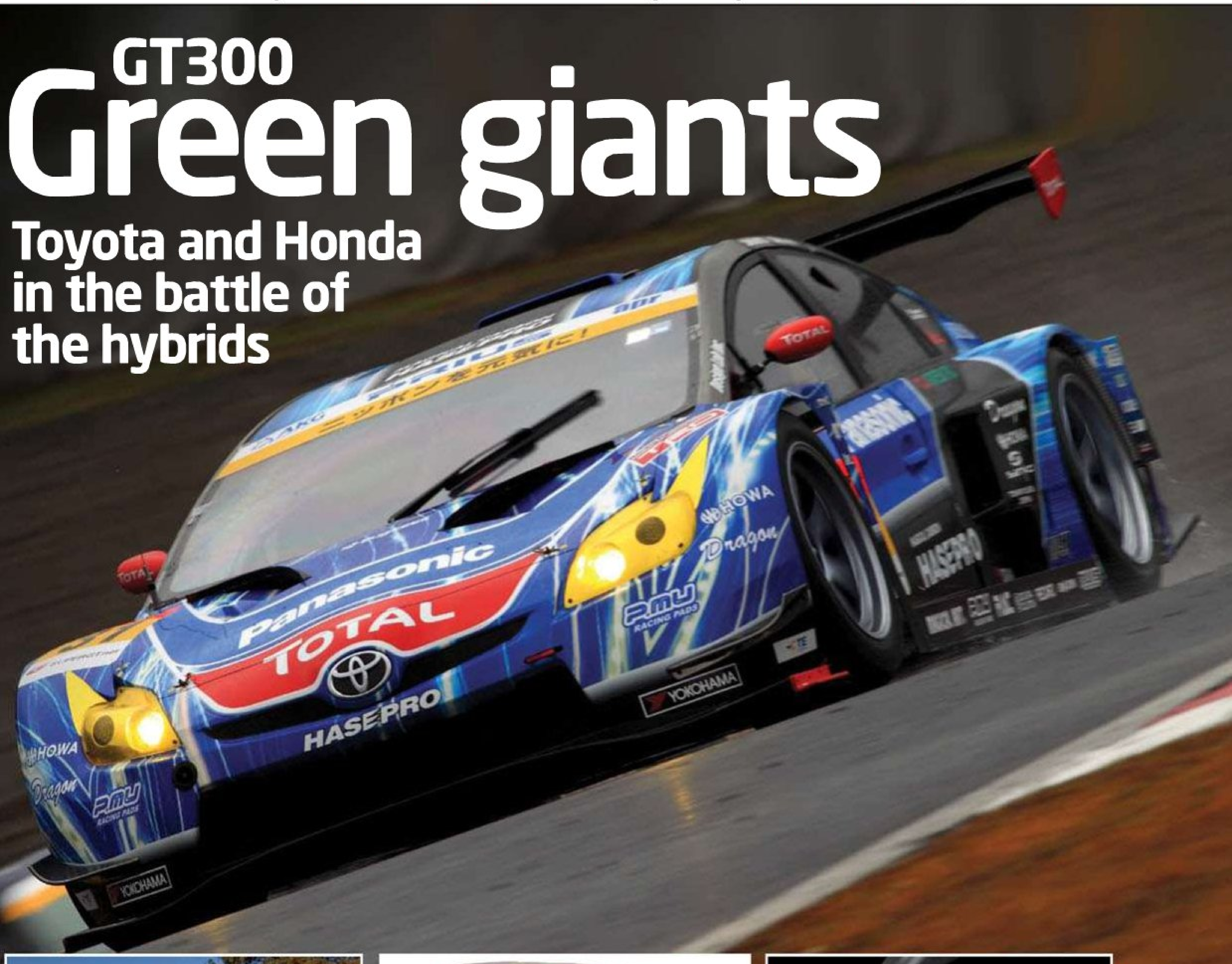

GT300
Green giants
Toyota and Honda in the battle of the hybrids

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Electrifying racing

The next chapter in the history of electric cars is about to be written

Engineers have a high tolerance to the driver syndrome 'the older I get, the faster I was,' due to their rational immune system.

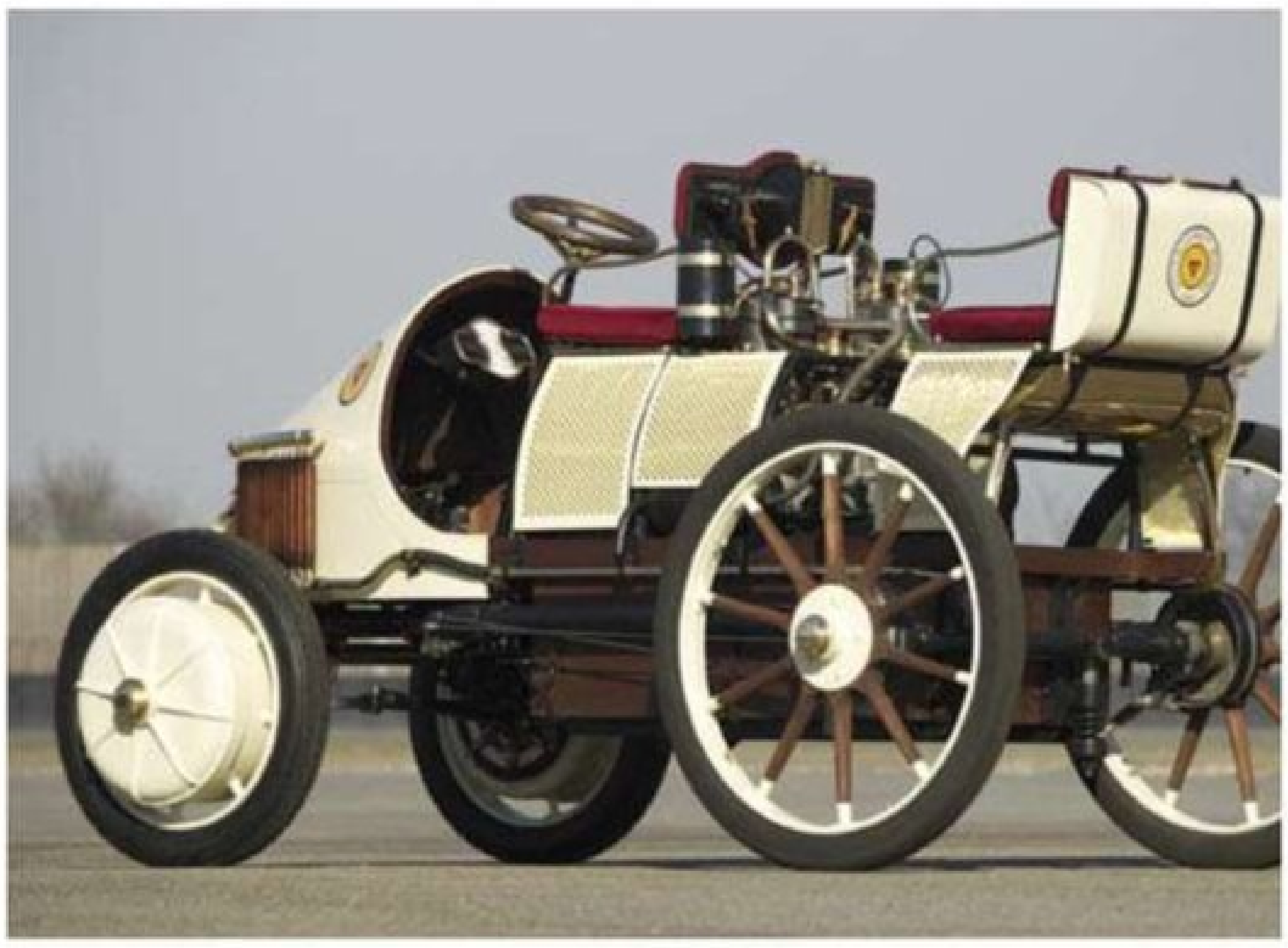
Objectivity is elusive, but eventually something like balance creeps into our assessments, and every now and then one can look back at one's work and think 'that was good ' (substitute 'awesome' for over the Atlantic readers).

Ferdinand Porsche could do that easily. In 1898, his first design, at Jacob Löhner & Co, had electric power, driven by front hub-mounted electric motors. Each single internal-pole electric motor supplied 2.5hp (1.9kW) to 3.5hp (2.6kW) at 120rpm, and could supply 7hp (5.2kW) for up to seven minutes by a 80 volt 44 cell lead battery of 300 ampere-hours which enabled approximately three hours normal use.

The rotor of the direct current (DC) motor ran round the stator attached to the wheel, operating without any mechanical friction losses at 83 per cent efficiency. Overall weight one tonne (1.205kg), of which 410kg of batteries.

The Löhner-Porsches were not cheap, costing between 10,000 and 35,000 Austrian crowns depending on the model, considerably more expensive than a car with a combustion engine. The banker, Baron Nathan Rothschild, Prince Max Egon von Thurn und Taxis, Julius Meinl (the Viennese coffee magnate), Margrave Sandor Pallavicini and Emil Jellinek-Mercedes (the Daimler representative in Nice) all drove Löhner-Porsches.

Even the car company, Panhard-Levassor bought one, perhaps to examine how it worked. It handled well for the time, the specialised press holding it to be particularly safe to drive. As they also pointed out, the car 'did not skid in sharp corners or on slippery, muddy streets – or at least only a few moments, just like horse-drawn carriages where skidding is extremely brief and rarely unpleasantly noticeable.'



The Löhner-Porsche Mixte, the world's first hybrid car from way back in 1901

Add two more electric motors to the rear wheels and presto, four-wheel drive, probably the first car to have it. (The Spyker 60hp was introduced in later, in1903 by Dutch brothers Jacobus and Hendrik-Jan Spijker, and Daimler claims Paul Daimler's Dernburg-Wagen was the world's first all-wheel-drive passenger vehicle, but also later.)

It was done for a car ordered by the Löhner agent in the UK, EW Hart, in 1900 and was presented at the Paris World Exhibition that year after to being taken to Chislehurst, where the Automobile Club of Great Britain and Ireland had organised a trial for electric cars.

Otherwise known as the Toujours Contente, it partnered two more entries by Hart, the Presque Contente (built by Wehrlé-Godard) and his own creation. Only the Löhner-Porsche eventually competed. The Contente moniker was an oblique joke on the name 'Jamais Contente', Camille Jenatzy's electric powered record car that was the first to break 100kph.

It had coil-sprung battery containers to protect the fragile 270 ampere-hour capacity batteries, four forward speeds, three reverse, electric brakes and battery energy recuperation on overrun, missing only a internal combustion engine in the mix to metamorphose into a series-hybrid, now being touted as the modern advanced concept car.

Nonetheless it was a curate's egg of a car. There were good bits and bad bits, and the bad bit was the weight of the battery pack, all 1800kg of it. It potentially had 56hp to push its all up weight of 4 tonnes, so the 110kg weight of each front wheel made for a reasonable sprung to unsprung ratio.

In 1901, still with Löhner, Porsche took the next logical step and introduced the Mixte with an internal combustion engine turning a generator to drive the electric hub motors and (for vehicle reliability) a small battery pack.

Bingo! Porsche had created the first petroleum-electric hybrid vehicle on record, a series-hybrid, and an arrangement common in diesel-electric or turbo-electric railway locomotives today. In all, Löhner went on to produce about 300 of these vehicles, counting all the models.

"The Toujours Contente's 110kg wheels made for a reasonable sprung to unsprung ratio"

In 1906, Porsche was hired by Daimler-Benz as chief designer. Jacob Löhner said, at the time: 'He is very young, but is a man with a big career before him. You will hear of him again.' Indeed, we have.

The Löhner-Porsche's design was studied for Nasa's Apollo programme's Lunar Rover, and many of its design principles were used in the Rover's design, so one can say the first car to run off this planet was derived from it.

In 2008 the SARD Toyota Lexus had a similar system, with the regenerated braking power stored in super capacitors, electric motors in the front wheels, and went on to win the Tokachi 24 hour race, being the first hybrid to do so.

And finally, this year's Le Mans gave us a winner with the Audi R18 E-Tron with another diesel hybrid system, with front wheels driven by an electric motor, brake regeneration, although with a flywheel as the power storage system.

The Toyota TS030 takes another tack, power storage being in super capacitors, as in the 2008 Tokachi car and the motor being housed in the bell housing, but a front wheel drive has been tested.

One can safely say that at least until the LMP rules change in 2014 they are the favourites for the win in all races, barring mishaps. And even then we will see the return of Porsches to Le Mans with a petrol hybrid, details of which are understandably scarce at the moment, apart from being with a full electric (ie: no flywheels).

I look forward to a couple of volumes to be added to the racing driver's multi-volume book of excuses, all electrical-related.

Dr Porsche can proudly say the four most beautiful words in any language: I told you so.

Where are they now?

Staying in racecar manufacturing for the long haul isn't for the faint-hearted

The business of making and selling racing cars in volume, as an independent concern, is a hazardous and often shortlived occupation. Britain used to be the centre of customer racing car production and I need only mention Cooper, Lotus, Brabham, Ralt, March, Reynard and now Lola as just some of the leading lights which have disappeared after stellar achievements over many years. Behind this lies a veritable A-Z of smaller companies that have shone and then burned out in the cold and unforgiving wasteland of aspiration over viability. Competition can indeed be cruel – the financial bottom line is the ultimate chequered flag.

Having been intimately concerned in the past with managing what was the largest and most diverse racing car manufacturer worldwide, I can assure you that the unrelenting balancing act of paying the workforce and keeping the doors open while investing heavily in technology, design and development, and next year's new cars is not the best environment in which to promote a good night's sleep.

In the past dozen or so years, there has been a centripetal move to continental Europe for the production racing car industry. Dallara is now the outstanding manufacturer with its current near-stranglehold on single-make markets and has arguably taken over the role which the major UK companies held for such a long time. Outfits like Oreca, Norma, Ligier (formerly Martini) and Mygale in France now represent between them the equivalent of the smaller British constructors of yore. One should not overlook Radical in the UK, but it is primarily a supplier of cars to its own eponymous (and cleverly-devised) multiple one-make series.

Lest you have missed it, there is a certain pattern that emerges from all this.

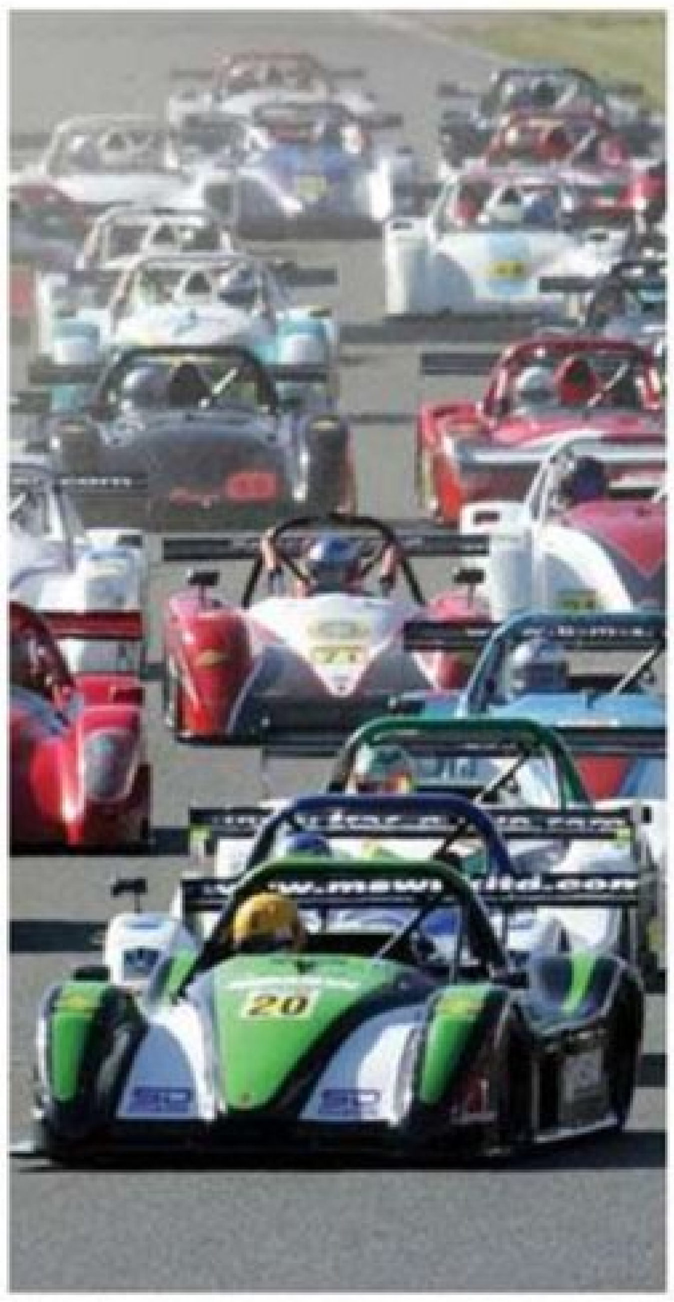
Firstly, single-make-chassis formulae now dominate. If a racing car manufacturer succeeds in winning the tender for a one-make series, providing it doesn't screw up it has a strong chance of retaining the chassis supply when the next tender becomes due. This is because a known quantity that has performed well will be automatically favoured by the series promoter.

Successfully supplying one series makes it easier to gain other similar deals because (a) the basic product and service is proven, and (b) concepts, tooling and aero development plus some common components can be carried over to another formula.

In summary, if you're 'in' then you are well in, and likely to remain so for some time.

Secondly, manufacturers which do not succeed in securing multiple long-term exclusive chassis supply contracts and are therefore 'out' find that the remaining pickings are very thin indeed. Among the main reasons for Lola's recent demise is that it lost its profitable single-make business, including Indycar. That left it primarily with Le Mans Prototypes and annual sales of half a dozen cars of this complexity cannot make a return on the high R&D and tooling expenditure required. Realise, also, that at some point in the future the benefactor will pull the plug, making it essential for the racecar company to maintain its own brand.

One of the very few international multi-make racing categories is CN, for 2.0-litre production engine-based sports prototypes, exemplified in the VdeV and SPEED Euroseries championships. This class has developed impressively over the past few years and boasts an increasing number of makes.



UK manufacturer Radical follows a different business model

Thirdly, for long-term survival a racing car manufacturer needs to be more than simply that. Taking Dallara and sportsracing car specialist Oreca, both also carry out a significant amount of R&D, prototype and manufacturing work for paying customers, inside and outside racing. The latter has an engine division as well and a large retail operation selling a huge array of racing and other automotive kit and accessories – the 'Demon Tweeks' of France. Both firms are also well-connected with their individual country's racing authorities and I suspect receive support from their local regions, not something that normally applies in Britain. This multi-faceted structure helps keep the ship afloat when financial storms occur. Lola did have this with its aerospace business, but its overheads were simply too high.

Which leads me into another scenario in which, as with the major auto industry, there may be the need for more collaboration between racecar manufacturers. In France, Ligier, Mygale and others came together. with the assistance of grant support, to develop an eco-friendly vehicle, each contributing to different aspects of the project.

For another example, to break into F3 and challenge the Dallara dominance perhaps requires a couple of manufacturers to swallow some pride in favour of pragmatism, and pool resources as a way of achieving something which they couldn't justify independently (Dome in Japan and Lola did just this a few years ago and were achieving success before the two parted ways.)

An amalgamation between an existing sporting roadcar manufacturing company and a race car maker could develop mutual benefits. Excessive overheads being the killer of many an enterprise, combining 'back office', sales and marketing staff plus sharing engineering and shop floor workforce as well as premises, equipment and financial resources would make a considerable reduction to these. Exploiting each firm's complementary skills and technologies, and creating the all-round high performance image, could make sense and establish a more diverse commercial base.

I do not believe that it's possible to maintain a purely racecar manufacturing business of scale long-term. Only a drastic reduction in the number of different formulae to concentrate grid sizes and the opening up of single-make racing to multi-make might allow this activity to continue in the future.

In summary, if you are not up for the challenges and always need a good night's sleep, then racing car manufacture is not for you!

"If you are 'in', you are well 'in', and likely to remain so"

Eco warriors

Although built to the same rulebook, the Honda and Toyota GT300 hybrids are very different machines, with very different goals

BY SAM COLLINS

"This double braking system is all about feeding back to Toyota for production cars"

Cameron Diaz famously has one of Toyota's cuddly eco-friendly hybrid cars. Since its launch back in 1997, the Prius has become the status symbol of anyone who wants to be seen to be 'green'. While it no doubt has a trendy image, it most certainly is not an exciting or sporty car, or at least it wasn't until the start of the 2012 Super GT season. At the end of the 2011 season GTA - the governing body of the series - quietly opened up the GT300 regulations to accept cars with hybrid powertrains, and predictably Toyota was the first to bite with perhaps the most unlikely GT car of all time, the humble Prius.

But instead of handing the development to one of Toyota's motorsport preparation specialists, TRD and TMG, it was a small racecar constructor based in Atsugi, Japan, who was given the task of turning the Prius into a competitive car in the GT300 category.

Hiroto Kaneso founded apr-racing in 2000 with the sole purpose of building racing cars, but the firm has a much longer history. 'Since 1989, we have been working with Toyota, especially TRD,' he says. 'We developed the MR2, Supra and Corolla Axio into GT300-spec cars for example. About two years ago we started to think about racing hybrid systems. We chose to develop the Prius as it is the first hybrid machine in Japan. If you think about hybrid, you think about Prius.'

But this was not a straightforward case of building a typical GT300 car which is little more than a silhouette of the production car - apr had an important partner in the car's development and it demanded that the car raced using relevant technologies. 'We knew that we had to use stock components, that is very important for us so we can feed back to Toyota,' says Kaneso. 'We are working closely with Toyota and TRD on this project and share all of our data, so while it is not a works team, Toyota do assist the project financially.'

TESTING, TESTING

Utilising stock components is not simply a case of proving how capable the Toyota hybrid system is, but instead the

GT300 car is really a test bed for future production cars. This has led to some key design elements of the car. This first became obvious when the car was launched at a Japanese motorshow early in 2012; the car had two rear brake calipers, one typical multi-piston unit from AP Racing on the leading edge of the a disc, and one much smaller caliper from Project Mu.

'When you brake, the motor recovers energy from the rear wheels and that feels to the driver like engine braking,' Kaneso explains. 'But when that KERS braking phase ends due to the battery being full, you lose that retardation. For the driver it is important to retain the brake feeling, so that's why we have the second caliper – when the battery is full, the second caliper maintains that feeling and retardation. The second brake caliper is fully electronically controlled and operated with no master cylinder.

'This double braking system is all about feeding back to Toyota for production cars. If you imagine you were driving down a mountain using only the KERS braking, you would have to have some other method of slowing the car down to the same degree as the energy recovery when the battery gets full. We don't really need it for racing. Project Mu are not only a racing supplier – they also supply street cars.'

However, GTA decreed that the car was not allowed to use this braking layout, but the team still utilises it in testing. The twin caliper layout was a clue to the most important aspect of the GT300 Prius – its use of a totally stock hybrid system.

'This is a totally different approach to other hybrid competition cars,' adds Kaneso. 'It's a big advantage as it is really easy to feed back to Toyota. The system on the LMP1 Toyota is really pure racing stuff. The TS030 was designed with only racing in mind, but we have a different aim. Our feedback will be used by TRD in the development of a new sports-hybrid production car, so it's crucial that we use racing to develop and understand the production car hybrid components.'

The electric motor on the GT300 Prius is mounted at the rear of the car, leading to far from ideal weight distribution


The battery and PCU are mounted in the passenger compartment as is typical for hybrid racecars

While the racing Prius uses components from the production car, it doesn't use them all in the same way. A road-going Prius is fitted with two electric motors – the smaller of the two is simply used as a generator, while the larger unit provides propulsion. On the GT300 version there is only one motor, the larger of the two found on the production car. This is mounted at the extreme rear of the car, far from ideal for racing.

'The weight distribution is too far from the centre – it is much too far rearward,' complains Kaneso. 'It is 44/56, and the rear overhang is so heavy due the position of the big electric motor. It is too heavy! The most important thing is to fit and test each motor, so we use this layout. If the Prius was only used for racing development, we would put the motor between the transmission and engine, but that is not the point of this programme.'

BATTERY INCLUDED

As is the case with the rest of the hybrid system, the battery comes directly from the production line. However, instead of the more common nickel-metal-hydride batteries found in the majority of models, the GT300 car uses the lighter lithium ion battery used in the Prius estate car.

'We have no real choice about where we can put this equipment as it is big heavy stuff, so it has

Comparing the front end layout of the Prius (top) with the CR-Z (above) shows that they are remarkably similar in this area. Note, however, how the Honda has a split radiator to accommodate a front crash structure

to go in the passenger footwell area,' explains Kaneso. 'Also stock is the power control unit (PCU). Using these standard components means that the hybrid system weight is 105kg. The motor can do 60kW, but the battery limits that to just 25kW.'

Reorganising a production car hybrid system and using it in a racing environment is not a minor undertaking. Indeed Kaneso makes no secret of the troubles he and his engineers have had trying to get the Prius to work properly. 'There has been so much trouble getting the hybrid system to work in this environment. Using production components is difficult. We are a car constructor so we don't have much experience with computers and programming, but TRD staff are expert in that area so they assist here.

'We have learnt a lot – we have even burnt the car out once when it caught fire! The hardest thing is that the PCU is a really advanced system and it is very complex. If you put in some code that the system does not like, it can fail or be damaged beyond repair. They cost 300,000 yen (£2185) each, and we have broken more than 20 of them so far. That's one of the things we have had to learn. A lot of tuners want to tune the hybrid system, but they cannot programme the PCU. We can.'

The hybrid system created other unexpected issues for the team. The 2012 Super GT series had one overseas race, at Sepang in Malaysia. But the company shipping the cars would not let the Prius travel if it was fitted with its battery, so the car ran at that race as a non-hybrid.

While much of the development effort was put into making the hybrid system work properly, the rest of the car is quite conventional and owes a lot to apr's previous GT300 machine, the Corolla Axio. Like the Corolla, the Prius uses the proven Toyota RV8K 3.4-litre normally aspirated V8 with a pair of small restrictors limiting it to around 450bhp. This is mated to the versatile Hewland NLT transmission. 'It's an off-the-shelf box, with slightly thicker ratios due to the demands of the racing that we do,' says Kaneso. 'We have used this transmission in many of our previous GT300 designs – we have the data and there was just no need to change.'

WEIGHT ISSUES

The weight of the hybrid system meant that the chassis of the 2011 Corolla Axio could not be carried over, but it's hard to tell the two designs apart. 'In terms of the chassis and body, there is not very much of the road car on the racecar – just the A-pillar, B-pillar and half of the roof,' says Kaneso. 'The chassis is basically a tubular steel frame, largely based on the Corolla Axio. Because of the weight of the hybrid system we have tried to lighten the chassis by using thinner walled tubing, but that has cost us some stiffness.'

Aerodynamically, the Prius is very different to the older car. 'By regulation the profile of the car in the centre must remain the same as the production model,' explains Kaneso. 'This gives us an advantage over other models with higher drag body shapes. For the aerodynamic development we have had a lot of support from Toyota, but so far we have relied on CFD and not been to the wind tunnel yet. The Prius is clearly faster than the Corolla due to the shape of the base model which is much lower drag due to its origin as an eco car. But thanks to Toyota's assistance, the GT300 Prius also has almost the same amount of downforce as a GT500 class car.'

The car's first season has not been a total success, with many technical issues. A high point came at the sixth round of the series fittingly held at Fuji Speedway, Toyota's home track. The Prius was on class pole, and finished the 300km race in second, but the next time the car visited Fuji for the prestigious end of season Fuji Sprint Cup the Prius was beaten on home ground by a very different hybrid, one that was built by Toyota's arch rivals...


IMPERIAL RANGE
METRIC RANGE
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BUMP STOPS
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STRAKKA RACING

The striking Mugen CR-Z GT300 features little of the original road car, and makes use of an aerodynamic package which has been created via 'trial and error' without the use of a wind tunnel

The racing car without guilt - Mugen CR-Z GT

The difference between Honda and Toyota, according to some in Japan, is that Toyota is a road car maker that happens to go racing, and Honda is a racing company that happens to make road cars. So it is no surprise that Honda launched the first mass market sports-hybrid in 2010, dubbed the CR-Z. The stated aim of the production car's design team was to create a new model with fun-to-drive and sportscar-style driving characteristics. It was, according to the project manager, 'a sportscar without guilt'.

In reality it is not really a sportscar at all - more a hot hatch-style car, which makes it a rather unlikely choice for a new GT car. But that is exactly what it became when Honda teamed up with regular collaborator Mugen to turn the CR-Z into an extreme new competition car.

'Environmental issues are key for a lot of companies,' explains Satoshi Katsumata, director of Mugen's motorsport business department. 'It's not a fashion, but it is certainly a trend. If you look all around the world of racing - even in Formula 1 - hybrid systems are coming, or have already arrived. We wanted to be part of that, and we wanted to do motorsport activity with a hybrid system.

'We had already done the Shinden electric bike for the Isle of Man TT. At the same time we were looking into using hybrid technology in racing, and we had an enquiry from Honda about racing one of its hybrids in Super GT. The CR-Z was the automatic choice. It was already our target to build a GT300 car, and Honda had the same target.'

> **"Environmental issues are key for a lot of companies - it's not a fashion, but it's certainly a trend"**

EYECATCHING DEBUT

Mugen was tasked with designing, developing and running the new car, while Honda would supply the powertrain and significant funding. It made its race debut at the Sugo 300km midway through the season, and immediately turned heads. The bodywork appeared to be the most extreme of all of the cars built to the JAF GT300 regulations, with very wide arches, similar to those seen in the GT500 class. There was very little of the original CR-Z left. Indeed, only the upper portion of the cabin section of the production car remains, and that is in heavily modified form. But despite having almost no components from the production model, many elements of the design are influenced by the version found in the showroom.

This combination of base model and technical regulations are the reason for the car's striking looks, as Junichi Kumakura, chief engineer of the 3rd Section motorsport business department at Mugen, explains. 'We have designed the bodywork around what we are allowed to do under the GTA regulations,' he says. 'We have made the car the maximum width we can within the regulations, so that's increased the frontal area, but also increases downforce. I think both the Prius and BRZ both maximise the bodywork width within the regulations, but the CR-Z is narrower than the other cars, so it looks more extreme.'

In GT300, a maximum bodywork width of 1950mm is permitted, while the production CR-Z is only 1,740mm, giving the car its dramatic look, though the stock Prius is only 5mm wider.

A substantial amount of the car's look is down to its aerodynamic package. As with all of the cars in the class the bodywork features a significant number of aerodynamic devices, as well as the mandatory flat bottom. 'We did not have a lot of time to build the car and things were all a bit limited due to that,' continues Kumakura. 'We built the CR-Z using our knowledge of the [Dome-built] Honda GT500. Things like location of dive planes and rear wing shape are all based on our knowledge. It is all trial and error. But we have not used a wind tunnel. We are still trying to improve it, but there are not target aero figures that we are trying to achieve. The work is still not complete.'

Another area of the car's design influenced by the base model is the wheelbase and overall length. The regulations allow for the wheelbase to be extended by 5 per cent from the base model for those cars that are under 2600mm in showroom trim. This saw the Mugen engineers add 122mm to the CR-Z, which has a wheel base of 2436mm as standard, giving a total of 2558mm. In comparison, the showroom specification Toyota Prius has a wheelbase of 2700mm. For cars with a wheelbase of more than 2600mm in showroom trim, the GT300 regulations only allow an increase of 1 per cent. The apr team were only able to add 27mm to its rival design. In both cases, the midpoint may be changed within the range of +/-30mm from the midpoint of the original vehicle. 'As the production CR-Z is a smaller car than the production BRZ and Prius, we have a shorter wheelbase in comparison,' says Kumakura. 'This has led to some disadvantages in fast corners, but on the other hand, on sections of track with slow corners - like sector three at Fuji Speedway - we can use our short wheelbase to our advantage. The twisty Sugo circuit suits our car well for this reason.'

At the heart of the GT300 CR-Z is its purpose-built hybrid powertrain. While the standard car is fitted with a 1.5-litre inline four mated to Honda's 10kW IMA hybrid system, that unit simply does not produce the performance required for Super GT. GT300's engine regulations

The rear of the CR-Z is just about capable of housing the LMP2 twin turbo V6 developed by HPD. Thermal management has posed a considerable challenge for Mugen, and work in this area is ongoing

TECH SPECS

Mugen CR-Z GT

Transmission: Ricardo

Clutch: Multi-plate

Suspension: Double wishbone with pushrod actuated dampers

Wheels/tyres: SSR wheels with Bridgestone tyres

Engine: HPD HR28TT 2.8-litre twin turbo V6

Electronics: Cosworth, Zytek and Honda

Restrictors: 2x29.3mm

Weight: 1305kg

apr Hasepro Prius GT

Transmission: Hewland NLT

Clutch: AP Racing

Suspension: Double wishbone front and rear. Twin pushrod actuated dampers front, triple dampers rear.

Wheels/tyres: Yokohama racing slicks/wets, 330/710 R18

Brakes: AP Racing double system on the rear for testing with AP and Project Mu calipers acting on a single steel disc

Engine: Toyota RV8K 3.4-litre V8 normally aspirated. Tuned by Ogura.

Hybrid system: Toyota THS with single 60kW motor

Restrictors: 2 x 28.5mm

Weight: 1305kg

are liberal to say the least stating: 'An engine from another model of car can be mounted if it derives from the homologated or registered vehicle of the same manufacturer. The mounting position, location and orientation of the engine are free, provided the engine is situated fore of the front bulkhead or aft of the rear bulkhead.' Almost everything else is free. These regulations and the performance demands left Mugen and Honda with two choices of engine. The obvious choice on paper was the 3.4-litre normally aspirated V8 used in the Honda GT500 cars, but in the end the HR28TT 2.8-litre twin turbo V6 LMP2 engine was selected.

'The engine is too big to be mounted in the front of the CR-Z due to the size and shape of the car,' says Kumakura, 'So we had to mount it in the back of the car in a mid engine layout. The engine is the same one you see in the HPD Le Mans Prototype, but with different restrictors and mapping.

'The engines come from Honda and we simply install them. Honda is responsible for that part of the car, but we went for the V6 unit with the hybrid system as it had already been used in other categories, so we had good data from it.' Another key element was the car's small size, which meant that despite the smaller size of the V6, it is still a tight squeeze.

The engine drives through the same Ricardo 6-speed sequential found in the GT500 HSV-010, but the casing is modified to accept a Zytek hybrid system, with the electric motor mounted on the side of the transmission. Zytek also provides the gear shift mechanism.

"We are still learning how to really take advantage of hybrid technologies in racing"

HUSH HUSH

Both Mugen and Honda are cagey about the details of the hybrid system, but it is known to weigh 57kg, and be capable of producing 50kW, though is more normally run at 32kW. The inverter is mounted on the top of the battery pack with both situated in the passenger compartment alongside the driver, a layout that is becoming standard for hybrid competition.

Mugen's engineers single out the installation of both the hybrid system and the V6 engine as the most challenging element of the car's development. 'The hardest thing [to manage] was heat management,' says Kumakura. 'The CR-Z is such a small car, and putting in the V6 twin turbo in the back, and still be able to cool it, was hard. The engine installation and the cooling system was one of the hardest things on the car, and we are not there yet. We also found that using a hybrid system in racing is very difficult, so we are still learning how to really take advantage of hybrid technologies in racing.'

The Honda CR-Z and Toyota Prius are not what many would think of when it comes to high performance racing cars, but motorsport is changing, and it looks like perhaps these two GT300 hybrids will soon leave the confines of the Super GT paddock and travel further afield.

'As we are in the car's development phase, it's hard to know the true potential of the car,' says Katsumata. 'If we can get the most out of the hybrid system, we think we can be the best of the JAF GT300 cars. But it is just our first year and we did not do the full year. We are interested in taking part in the Asian Le Mans Series or World Endurance Championship. We have a dream to do something like this as well as GT300.'

Kaneso echoes this. 'We hope we can do the WEC race in future, but we do not think we can last six hours,' he says. 'The car will probably break or catch fire again! But Toyota is trying to sell Prius across Asia, so commercially it would be good for us to enter Asian Le Mans and things are converging in that direction.'

Perhaps it won't be too long until the hybrid battle at Le Mans will not be limited to the LMP1 teams.

Swede dreams

Peace has broken out in a Scandinavian racing war, with intriguing results

BY SAM COLLINS

The Super 2000 regulations were designed to allow manufacturers and privateers to run top-level touring cars in series around the world. In concept, the idea was brilliant, with the likes of BMW, SEAT, Chevrolet, Alfa Romeo, Volvo and Ford able to take their cars to their most important market. The icing on the cake was that they would be able to sell their year-old cars to privateers, creating a revenue stream and allowing grids to be bolstered with quality entries.

The cars were designed to use the Global Race Engine, a 1.6-litre turbo that could be used in various applications around the world. It was all designed to allow manufacturers freedom to move to their most important markets, but perfection is hard to find.

Instead of adopting the Super 2000 regulations, and the Global Race Engine, the British Touring Car Championship introduced instead its New Generation Touring Car rules, and in Sweden, the picture became even more complicated as they opted for extreme DTM-looking hybrids.

The Swedes considered the S2000 regulations to lack excitement, and setup the Touring Car Teams Association (TTA) series to rival the Swedish Touring Car Championship. The TTA is made up of the four biggest racing outfits in Sweden, and the series created a set of rules pitching high-powered KERS-equipped silhouette saloons against each other. Represented were Citroën with its C5, Volvo with the S60, Saab with the 9-3 and BMW with a 3 series. The TTA wanted a series that rewarded the best team and driver combination, not the team with the biggest research and development budget.

'Motorsport must be cool, exciting and fair,' explained Anders Gustafsson, managing director of Volvo Cars Sweden. 'We must fight our meanest competitors in our best-selling models. We must be able to win by doing the best job and it should be easy for importers in the country to change racing car when changing model without the need of a heavy factory programme.'

"It's built to be a racecar from the start – there is some almost single-seater feeling in it"

As a result the TTA turned to French constructor Solution F to create the new car. The firm is best known for building the Renault Megane V6 Cup car and, not surprisingly, the new TTA design is similar. It mates a NISMO-developed 3-litre V6 engine producing 420bhp to the steel tube frame chassis.

A Denso capacitor-based KERS hybrid system is also fitted to all cars, and drives the front wheels, while a six-speed sequential transmission drives the rears, making the cars four-wheel drive for at least part of the lap.

The body styling has been influenced by both GT300 cars and by the DTM. While all four bodies look very different, they share a number of common components, with the front splitter, diffuser and rear wing being common to all cars. DTM-style Hankook tyres were also fitted to all of the cars.

The Saab 9-3 TTA, which lines up on the grid of the Swedish series alongside entries from Volvo, Citroën and BMW

Wind tunnel testing of TTA cars at Volvo's facility in Gothenburg

Viktor Hallrup takes a Citroën C5 TTA through its paces at Anderstorp in June 2012

TECH SPEC

Length: 4700 mm

Width: 1970 mm

Height: 1205 mm

Wheelbase: 2750 mm

Track width: 1660mm front/ 1630mm rear

Suspension: Double wishbone, three-way dampers, etc

Body: Carbon fibre

Engine: 3.5-litre V6 with hybrid system

Drive: RWD

Power: 420bhp

Gearbox: 6-speed sequential with paddles on steering wheel

Hybrid system: Kinetic Energy Recovery System (KERS)

Rear wing: 1600mm width/ 300mm depth

Brakes: Front - 4-piston calipers, 370mm ventilated discs
Rear - 4-piston calipers, 360mm ventilated discs

Rims: 18" with centre wheel nut

Tyres: Front - 260/660-18
Rear - 280/660-18

By October 2012, the picture became clearer as the TTA and the STCC merged, adopting the Global Race Engines for 2014, a move that has attracted Volkswagen into the fold. 'We are looking forward to be a part of such a group with representatives from other manufacturers, STCC and the Swedish Automobile Sports Federation,' said Jost Capito, head of Volkswagen Motorsports. Citroën made no secret of its desire to see the move to the GRE when it joined with the C5 this year, and welcomed the move to adopt manufacturer-specific technology in 2014.

Volvo, which flirted with the World Touring Car Championship and the V40 under Capito's guidance, was also involved in the formation of the 2014 regulations. 'The earlier more manufacturers engage in a future STCC entry, the sooner it is possible to introduce more of our own technology in the cars,' said Derek Crabb, head of Volvo Motorsport.

The inclusion of SAAB was something of a surprise, as the famous car maker is in receivership, but the programme run by Flash Engineering was supported by SAAB dealers and parts suppliers. Team Tidö will also run a pair of 9-3s.

Citroen became particularly interested by the promise of a switch to 1.6-litre turbo engines. Tuning company Polestar Racing, which has competed in both the STCC and World Touring Car Championship, ran the Volvos in the championship this year. Finally, BMW Dealer Team WestCoast Racing ran the German marque's cars.

The driver lineup for the series is pretty impressive, taking in former STCC champions Tommy Rustad, Richard Göransson, Fredrik Ekblom, Jan 'Flash' Nilsson and Thed Björk, who boast a dozen titles between them. Other significant names include former British Formula 3 driver Robert Dahlgren and 2010 STCC privateer champion Andreas Ebbeson.

Richard Göransson was immediately impressed with the performance of the car. 'The car is spontaneously great fun to drive,' he says, 'pretty much because it has got a lot of power and is cutting-edge on all areas. It is much more of a racecar. I can tell you this in comparison, I drove the Swedish WRC this year. I used to drive a Group N car and this year I got to drive a WRC car, a car built to be a real rally car. The TTA car is built to be a racecar from the start. There is almost some single-seater feeling in it.

'That provides you with much more response on all commands you give it: throttle, braking and so on. It is a complex car and I think it is going to be great fun. The car gives a big span of adjustments, making the optimising skill of the team more important than resources to develop the car. The teams are themselves going to be responsible for their results.'


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Lighter.
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The need for speed

It took more than 100 years for the British to claim the steam land speed record from the Americans. Now, they want it back...

BY ANDREW COTTON

The tailfin of the Team Steam USA car bears the figure 1777. This is the year that is America's proudest, a date when the country was declared independent and a year in which the nation defeated the British army. Team Steam driver Nelson Hoyos hopes that he will be the man to take the steam driven land speed record from the British, who claimed it in 2009, back to the USA with a 200mph run, and intends to extend that to 400mph by the end of 2013.

The US held the record between 1906 and 2009, when the British Inspiration team took the record up to 148mph. As the British also hold the outright Land Speed Record (as this is written), the rivalry is as intense as ever.

Not that Hoyos carries any malice. Far from it, although he takes great delight in the fact that the British spent £10m claiming the record, and he intends to take it back on a budget less than one tenth of that. The team will take an engine that was developed for the military, and place it into a chassis that has already proven itself up to 440mph with a piston engine.

'The engine is unique,' says Hoyos. 'It is a six cylinder radial design, and has a unique spider bearing, which is held to the crankshaft. All the connecting rods are connected to the spider bearing.

'We can get even-fire cylinders instead of odd-fire cylinders. In the standard engine there is a condenser at the bottom of the engine that holds the water that is piped through the cylinder to pre-heat it. It is then piped up through a combustor, which has 1200 linear feet of tubing. We have six injectors firing an open flame in a circular fashion, hence the cyclone effect, so we are superheating this water. We take it from 700 degrees to 1400 degrees when it comes out at over 3200psi.

'It is injected into the top of the piston, pushes the piston, and it has ports on the back of the chamber and exhausts back into the condenser. We have a dry sump system to bring it back into the water tank.'

The engine creates 200bhp, which is not a great deal, but it generates 1100ft/lbs of torque. Such torque and relatively low speeds mean that the car does not require gears, and so has direct drive and works with cog belts, like a Harley Davidson bike. The car will be pushed

Team Steam USA's Cyclone vehicle will first attempt to hit 200mph, before its target increases incrementally towards 400mph

to 60mph before the engine will kick in and drive the car up to 200mph in the first quarter of 2013, if all goes according to plan.

Following that, the team intends to go faster, and has a target of first 300mph, and then 400, although they realise that significant car modifications would be necessary to hit this target. The car body is based on Ron Main's Speed Demon car, and from the cockpit forward, Main's design is unchanged. The rear has been modified to accommodate a much smaller engine, so the track has been reduced by 18 inches to just 30 inches, the chassis is sorter and the tail fin smaller, making the car even more aero efficient.

'We licensed the body design,' says Hoyos. 'We duplicated the car that has gone 440mph so we know that the aero works. We have shortened the car a little bit, and made it a bit thinner at the back – as we are direct drive we didn't have to have a differential. Ron's car has a bubble in the back for the tyres but this car didn't need it. We think this is a little bit better than his, but it works. The chassis underneath is a dragster. We have the in-line wheel setup, which means that we have it inside the cockpit so nothing is exposed, and if we lose a tyre I have another holding it up.

'We have a big bulkhead between the driver and the engine. The engine is two feet by two feet, we drive a pump, a 20 gallon water tank, and batteries to drive the pump system. We have two goals – one is to take the record away from the Brits, the other is to validate this motor concept and put it into a automobile application down the road.'

The programme is designed as a marketing tool for Cyclone Technologies, which reckons that the engine can run underwater,

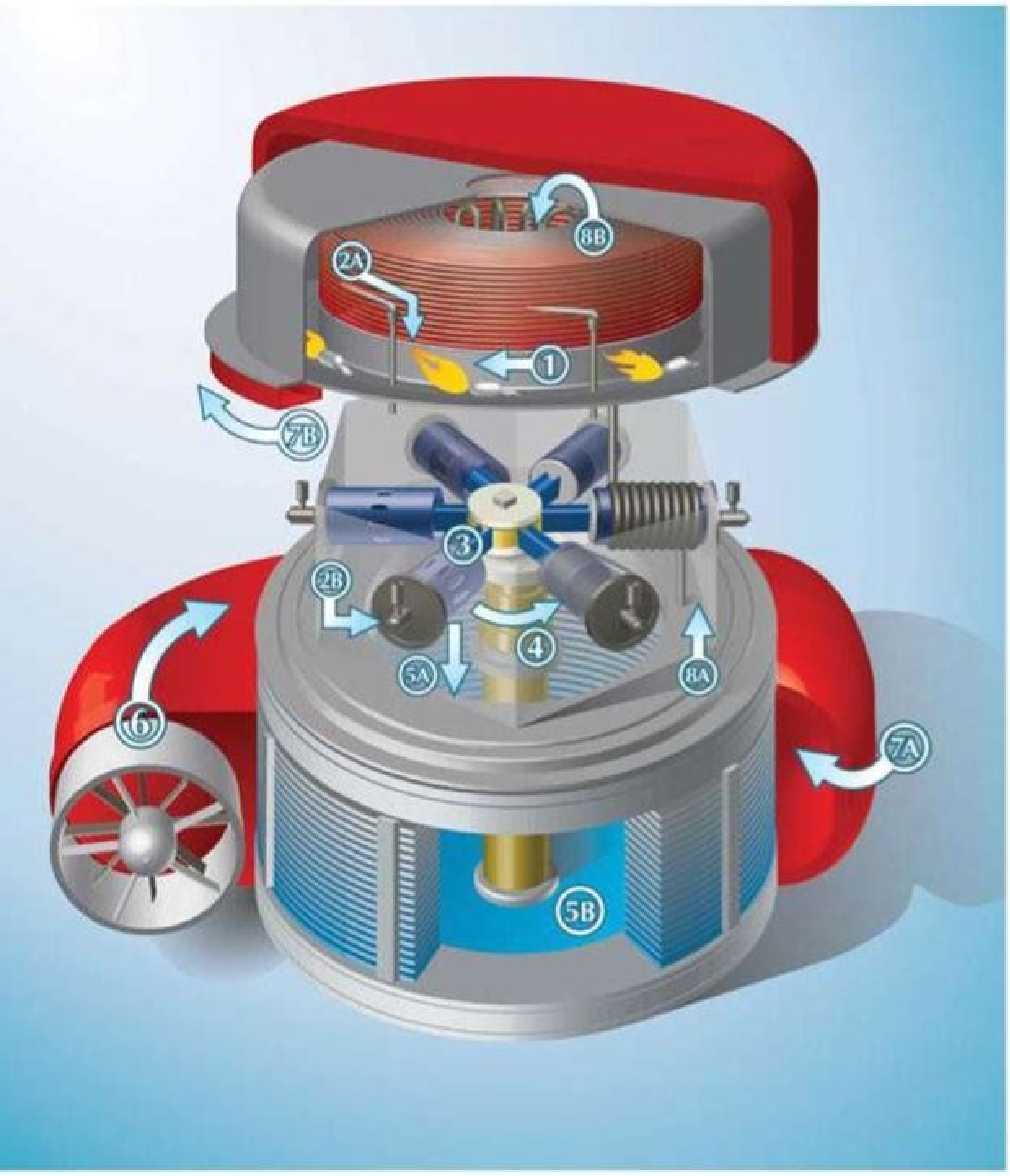
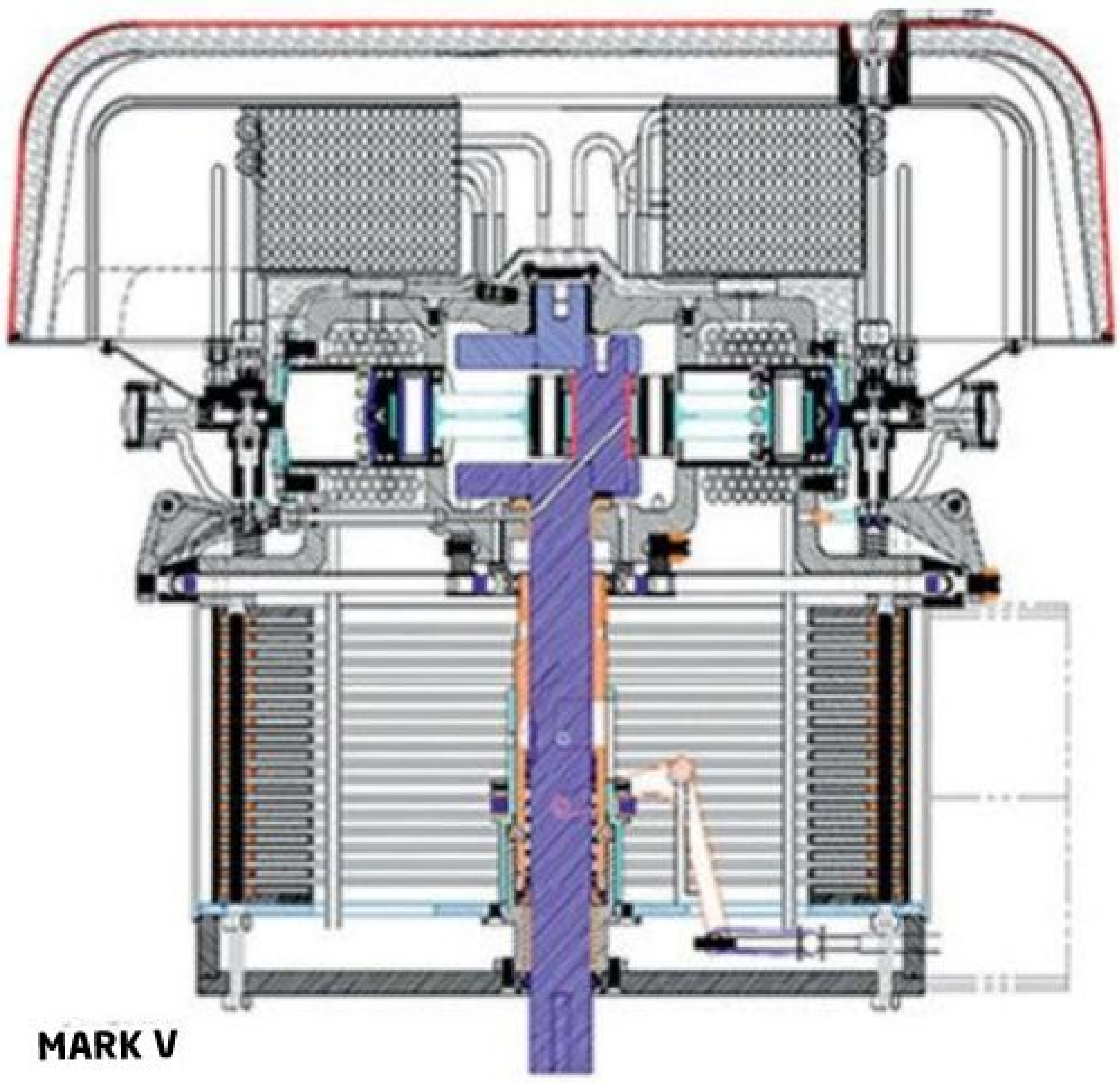
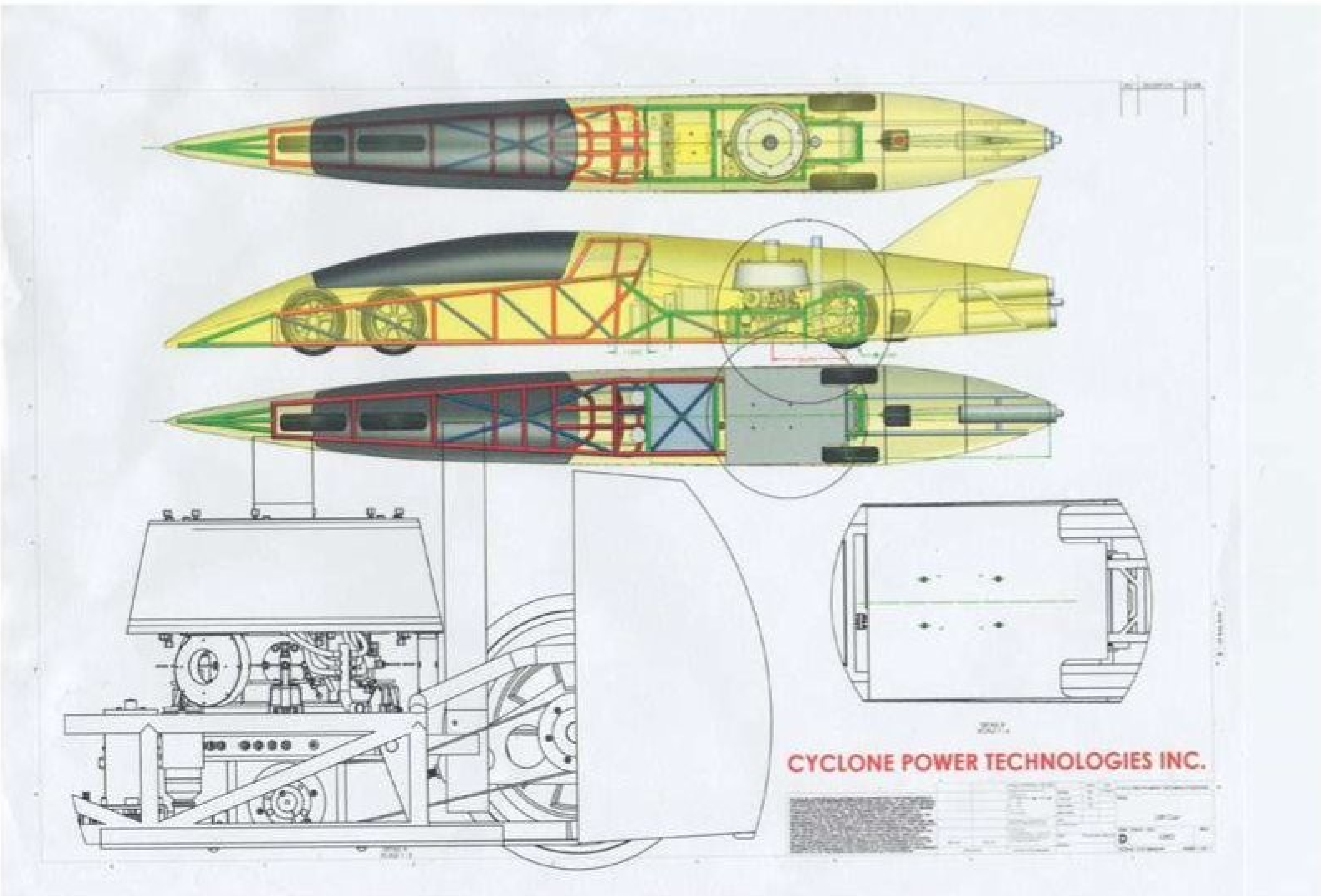


Diagram of the six-cylinder radial-format Cyclone Engine



Profile cross-section of the Mark V automotive engine



or in space. Able to run on any fuel that can burn, the team believes it has something that will benefit production cars in the future (see sidebar, p22).

'This is an all-fuels engine,' says Hoyos. 'It does not need fuel to run. It needs fuel as a BTU source to heat the water to steam. It could run on diesel fuel, vegetable oil, orange delaminate, jet fuel, regular gas – whatever can burn. It makes it interesting for potential world motor, because we are not limited to a specific fuel source. It is also water lubricated, so it has no oil in the system at all, so environmentally it is great and it has little moving parts. It's ceramics and composites so it is durable and we think it does have potential in a vehicle for the world down the road.'

The team has another engine in the workshop, an increase in capacity to to 3-litres, produces 2650ft/lbs of torque and can take the car beyond 400mph. 'At that point we would have to change the car around a little bit to accept that kind of power, but I think this car could do it,' says Hoyos, a drag racer who is used to such speeds. 'Ron Main has proven with a piston engine that he can do 400mph safely, 26 times, so we know the car is proven, so now it is how do we apply it to our technology. This project is less than six months old, it requires safety equipment, some plumbing and electrics, the engine is dyno testing at the moment to get patterns so that I can learn how to drive it. This makes an enormous amount of power from the start. Our goal is by February to be testing.'

The plan is to hit 200mph, before prepping the car for a 250mph run at Bonneville salt flats in the summer. The new engine will then be fitted with a target of 400mph, nearly three times the current speed. 'The goal is to be above 300mph with it, and if we can go 400, that would be super but that will be a challenge,' says Hoyos. 'Once you go a little faster, everything becomes exponentially harder.

'Although we have the power to go 400, it would take more time. The suspension would change and the car would change. The major overall piece will be the same, but the car will be longer and wider, and the body will change because we have a motor which is wider. Then weight distribution changes, so we have to go back into the wind tunnel to check those changes. I anticipate doing a bigger wing at the back of the car – the original car that Ron Main has is 6ft longer, has a larger rear wing, and is also 18 inches wider, so we may have to go for his design completely to go with the power we're going to have.'

"As you go faster, everything becomes exponentially harder"

The cyclonic aspect of the engine in impressively fiery action

CYCLONE POWER

This is an engine that its designer reckons could be taken to production cars, reducing the cost of motoring, improving 'green' credentials and changing the way that third world countries generate power.

It all sounds too good to be true. 'The powerplant has tremendous efficiencies because multi-fuel capabilities, and the reason they have high efficiency is that they can operate at high temperatures,' says its inventor, Harry Schoell. 'That has been the plague for small engines. You know how tough to build that is – you have to build the turbine. The turbine has a water rate, how much water you have to evaporate to make the engine go. The turbine has one speed that it operates at, very high water rates and very low efficiency. With a piston engine you have a 20-40lb water rate. This has seven. The heat exchanger is much smaller.

'We can operate at very high temperatures and pressures so we have a half-litre engine that puts out 1000ft/lbs of torque. You don't have to have any special gearing, and we have an engine that burns any kind of fuel, is not expensive to manufacture, is very low polluting, and we have something that is commercial. This can be used in cars, buses, trucks, and it's clean and inexpensive power. In most applications you don't need a transmission. This will run underwater, can run in outer space – everything.

'It just takes time to get it there. The LSR is to prove that we have a viable product. People have to see it. We have generators running, but to see something like this has excitement to it. We also have a boat we are going to run to show the viability of the product. It is amazing to us, we have been at it for a few years, and every time we show it people haven't heard about it. We have grown making generators and products for other applications.'

That's all fine, but in a production car, how much further could a Cyclone engine go? 'If you make an automobile go somewhere, you always hear rpms. That's because these engines don't have any torque at the bottom end so you have to scream them up high, run through a bunch of gears, and gear losses can be 10-18 per cent. We don't have any. We start off with torque at 1rpm. Rpm is different for us. Theirs is revolutions per minute, ours is revolutions per mile. We can run one mile with a standard car and the engine would turn 1700 times. Not 1700rpm.

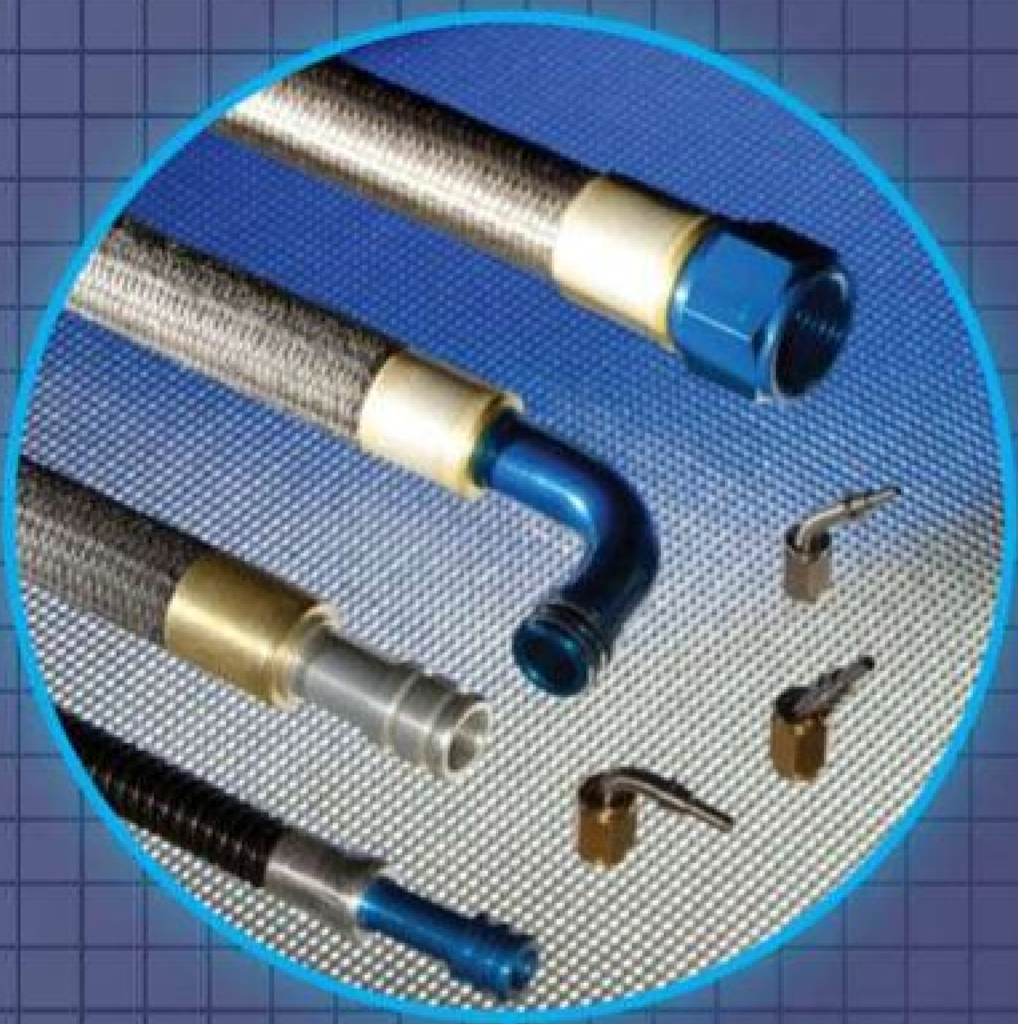
'You could go perhaps 1.5 times further in mileage. On a straight highway, you can get a 20-25 per cent gain, but in the city the engine doesn't have to idle. When you move, it moves. Point to point, you are talking revolutions per distance.

'It would do a great job in city buses. And it is not only mileage – less expensive fuels can be burned. You can fill it with anything: gasoline, diesel, alcohol – it makes no difference. You will burn less fuel with the higher BTU, but sometimes the higher BTU fuels are the least expensive. The engine can run on kerosene and biofuel. We run algae fuel from oil, so it doesn't have to go to the refinery again and be turned into something else. We have run powdered coal through the fuel injector. Extractions from chicken farms and pig farms can go to a digester, where they go into a tank and methane can be pumped, light the methane with a match and make electricity.

Things like that can go into third world countries and power them easily. Solar has 5-8 per cent efficiency, and how do you store it? Lead acid batteries? That's not a good thing. If you use a thermal battery, it never runs out, is inexpensive, and at the end of the life cycle is fertiliser. You can run a cyclone engine with less expensive heat collectors, and generate electricity in the 20-25 percent range. You can store the heat and use it down when you want to.'

So, the first target is to earn the right to be the fastest kettle in the world. After that, there is a dedicated plan to take the technology to schools and universities to educate students as to how it works. From there, the sky could literally be the limit.

CONNECTING INTELLIGENCE



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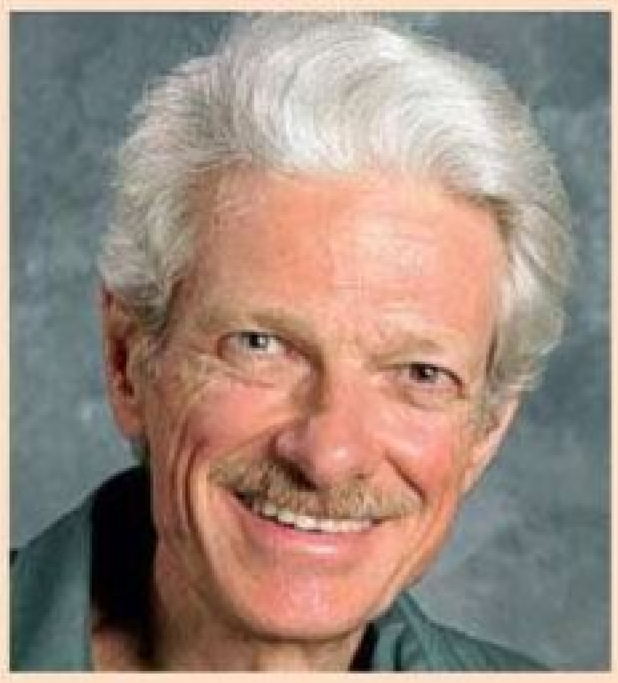

Mark Ortiz Automotive is a chassis consultancy service primarily serving oval track and road racers. Here Mark answers your chassis setup and handling queries. If you have a question for him, get in touch.

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Frame torsional stiffness

Could more flexible chassis really be all they're cracked up to be?

Q Recently I was asked to assess a northeastern dirt modified car which has the tendency to consistently crack one particular welded joint in the tubular plus 2 x 4 mild steel chassis.

The car in question is much the same in design as those created by two leading northeastern modified chassis builders – it is actually designed to be more flexible, or so the builder claims.

I must confess that even though I have worked with these types of cars recently, I had never really taken a step back and studied just the 'naked' chassis structure. All I see is a 'wet noodle' that only resists torsional loads on the sheer size of the material used. The 2 x 4 frame rails are required by rule but the rest of the chassis is just a 'stick built house'.

So my question to you is why do the folks who build and race oval track dirt cars still insist, rather strongly, that a flexible chassis is the 'hot ticket' to get the car to turn in to the corner? That is the claim I hear the most in defending flexibility.

I was trained to believe that you go as stiff as you possibly can up to the point of incurring a weight penalty and adhering to the required safety rules.

The claim is that the flexible chassis is easier to tune. I agree because to me it is to a certain degree un-tunable, with an undamped fifth spring doing the work.

The only drawback to going as stiff as possible with a dirt car chassis that is required to use a beam axle front and rear is that, in my opinion, it would narrow your setup window and in effect, yes, be a little harder to zero in on a fast setup with just springs, shocks and anti-roll bars.

One additional piece of information: the engine is not used as a structural member and in fact besides the engine plate which fills the bay below the A-pillars, the mounts are designed to promote engine movement as well.

I really need a sanity check on this one. What should my counter-argument be to the 'flexi' folks?

Dating from carriage building, vehicles with beam axles at both ends have used torsionally flexible frames with decent results. Most trucks are still made this way. They don't even use poorly triangulated space frames; they use channel-section ladder frames. The stresses in the frame rails are such that they are heat-treated, and frequently carry cautionary labelling discouraging welding on them lest the heat treat condition be altered.

I am not convinced that a torsionally flexible frame is an advantage, for turn-in or otherwise, but with softly sprung beam axle suspension at both ends, it doesn't make much difference because the torsional loads on the frame are small.

A torsionally flexible frame does make the total chassis more warp-compliant, but as the questioner notes, the compliance is largely undamped.

Excessive torsional flexibility can give rise to torsional oscillation. One commonly accepted rule of thumb is that for the suspension to work as it should, particularly as regards damping, frame twist should be no more than a tenth of the total compliance in the warp mode, suspension and tyres included.

With an existing car, we can test this. We need a flat support to place under one wheel, or alternatively two of these for two diagonally opposite wheels. These should be large enough to fully support the contact patch, and tall enough to create significant suspension displacement, yet not exhaust the suspension travel at any corner of the car. When we set the car on the support(s), we create a known displacement at the contact patches. If we are working in inches, we can get this in angular terms by dividing 57.3 by the track width, then multiplying by the height of the support. Alternatively, we can measure the angle directly with a long straight-edge and an angle finder. If we do this at both ends of the car, the angular warp displacement is the sum of the front and rear displacements. We then know how much warp, twist or cross-axle articulation we have at the contact patches.

"Cars with flexible frames are less touchy to small adjustments"

We can measure the frame twist by measuring angle from gravitational vertical or horizontal at any reference surfaces at the front and rear of the frame, first with the car on level floor, and then with the car on the support(s). The change in the front/rear difference is the amount of frame twist under the load imposed. The frame twist should be no more than a tenth of the warp at the contact patches.

It will be apparent that stiffer springs, bars and tyres will call for a stiffer frame, to meet this requirement. A suspension that uses high roll centres to get its roll resistance, rather than relying on the springs and bars, will not require as much frame stiffness.

Is a car with a flexible frame easier to tune? Well, it is less responsive to changes in springs, bars and even roll centre height. It is therefore less prone to being overly touchy to small adjustments, but cars with compliant tyres and soft suspensions tend not to have such a problem anyway. Indeed, even pavement cars with really stiff suspensions are also more often under-responsive to changes, due to insufficient frame stiffness, than over-responsive due to excessive stiffness.

A flexible car will respond differently to changes in track conditions than a stiff one. That doesn't necessarily mean it will change less, but it won't change the same as a stiff car. If the car corners on three wheels, like the one we discussed last month, frame stiffness does not affect wheel load distribution, past the point of wheel lift.

Live rear axle suspension design

Assessing the options available to take the strain on a modified 1970 Pontiac

Q **I have a few questions for you regarding different suspension types, setups etc. The vehicle in question is a 1970 Pontiac that will be heavily modified for GT1/Solo 1 racing. It will also be licensed for the road. My main concern is regarding the rear suspension set-up. I have a full-size Winters Quick Change closed tube live rear axle.**

There are a few systems that I have looked at: Satchell link, 4-link with Watt's linkage, and a criss-cross-under 4-link that I saw a while ago. Your article on the Satchell link was informative – it would be great to use a Weismann differential, if possible, with this set-up. I have seen someone use this for GT1 regional racing at Mosport, my home track. It looked composed in most corners. Still, one wonders if there is enough lateral restraint with this system. Could another lower link be introduced with the use of a rod end with an additional lug grafted on to it? That way, one link would be at 30 degrees, and the other at 60 degrees from the axle line. If all the link lengths and bracketry were geometrically congruent, could this work and provide the additional lateral strength?

The 4-link with Watt's linkage obviously appears to be the strongest system. Would there be an advantage of laying out a Z-linkage on birdcages as opposed to a trailing arm 4-link, also on birdcages? One concern is with the centre section of the quick change. It is sand-cast aluminum with a steel retaining ring for the yoke. Affixing a Watt's linkage to this for lateral control makes me nervous.

Finally, I have seen a crisscross-under 4-link that was on a dead axle on a four-wheel drive car. Each link crossed over-under each other at the centre of the beam and connected to the chassis on the opposing sides. It resembled a shallow angled X-type layout. I realise that there are obvious roadblocks in applying this to a live rear. If it could be done, would this be a viable alternative? Does it have potential for quelling torque reaction of a live rear as well as providing lateral control?

My vehicle has a 118-inch wheelbase, 66-inch rear track and will have either 16x12 or 17x12 wheels. I plan to use the JRZ RS1 twin tube dampers with 2.25 ID coilovers. Gross weight will be around 2900lb with 50/50 forward-rear weight distribution.

A general principle of beam axle linkage design is that if you use more than four links (or single link substitutes, such as a Watt's linkage), at least two of them have to be equal length and parallel to each other or you will get binding, unless you use at least one birdcage.

If you have two diagonal semi-trailing links that cross each other, they must either be at different heights, have bends in them, or they will hit each other in some condition of suspension movement. This would be true regardless of whether the axle is powered or dead.

Crisscrossed or not, the ability of diagonal links to react torque depends mainly on their angle. The closer they are to longitudinal, the better able they are to react torque and thrust. The closer they are to transverse, the better they are able to react lateral force.

Crisscrossed links will not cancel driveshaft torque reaction, if that was the meaning of the question.

People do successfully attach lateral locating devices to the noses of quick change rears, and also the undersides.

If you use Z-linkages (longitudinal Watt's linkages using birdcages), don't attach the brake calipers to the birdcages. Either attach them to the axle tubes or use brake floaters. Otherwise, the anti-lift will vary excessively as the suspension moves.

To a considerable extent, the choice of a general layout comes down to what roll centre height you want, how you want roll centre height to vary as the suspension moves, and what packaging and mounting constraints you have. Cost and complexity are also factors.

I like the idea of non-parallel trailing links on the right side, with enough anti-squat to cancel driveshaft torque, and on the left side a birdcage mounting the caliper, with trailing link geometry similar to the right. Or, a brake floater on just the left can give comparable effects. The idea is to have asymmetrical anti-squat under power, to eliminate torque roll and wedge, yet have symmetrical anti-lift under braking.

"I like the idea of a Watt's linkage with the rocker mounted to the frame"

For lateral location, I like the idea of a Watt's linkage with the rocker mounted to the frame, not the axle, at least if the front suspension is independent. This makes the rear roll centre move compatibly with the front roll centre in heave. Unfortunately, packaging and mounting that type of mechanism is not always practical, but in some cases it will be.

One lateral locating device that may be convenient when using a quick change and stock frame rails is a somewhat angled Panhard bar running from one frame rail to a bracket on the opposite axle tube, ahead of the diff, passing above the driveshaft. This may more easily provide a strong anchorage for the bar than hanging a bracket for it behind the axle.

Whatever arrangement is used, it is important to make things strong and rigid, and strive for good load paths. Lateral compliance in the axle locating mechanism will not feel good to the driver.

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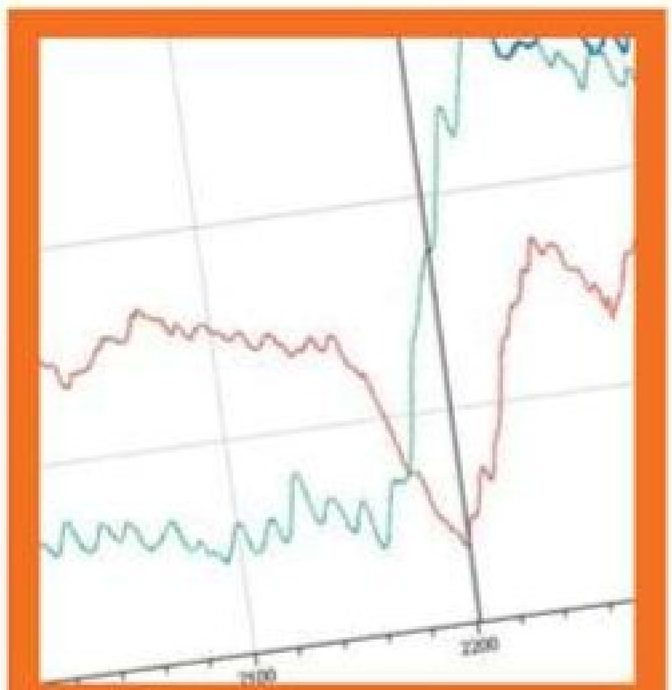


Databytes gives insights to help you improve your data analysis skills each month as Cosworth's electronics engineers share tips and tweaks learned from years of experience with data systems. Plus we test your skills with a teaser each month

To allow you to view the images at a larger size they can now be found at www.racecar-engineering.com/databytes

Fly-by-wire throttle control

The added precision coming from replacing mechanical links can prove mightily useful. And the possibilities don't end there...

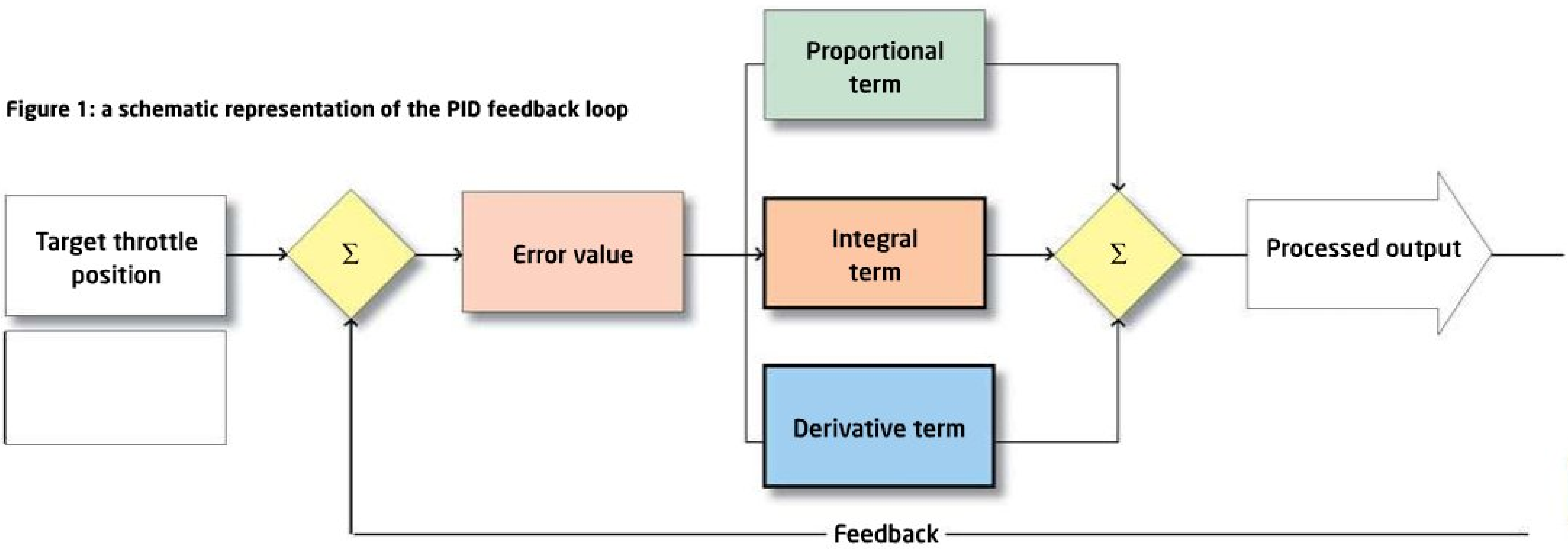
The technology behind fly-by-wire, as its name would suggest, comes from aviation. The principle is to replace mechanical or hydraulic systems with computer-controlled actuators, or motors. In an aircraft, this replaces heavy and often fragile systems with a lighter and more robust solution. In engine control the use of fly-by-wire technology is used to replace the mechanical link between the throttle pedal and the engine throttle. In this case the weight saving is insignificant and in reality the fly-by-wire might even be heavier due to an electric motor being required on the engine throttle. The added precision in controlling the engine and throttle behaviour more than outweigh this, however.

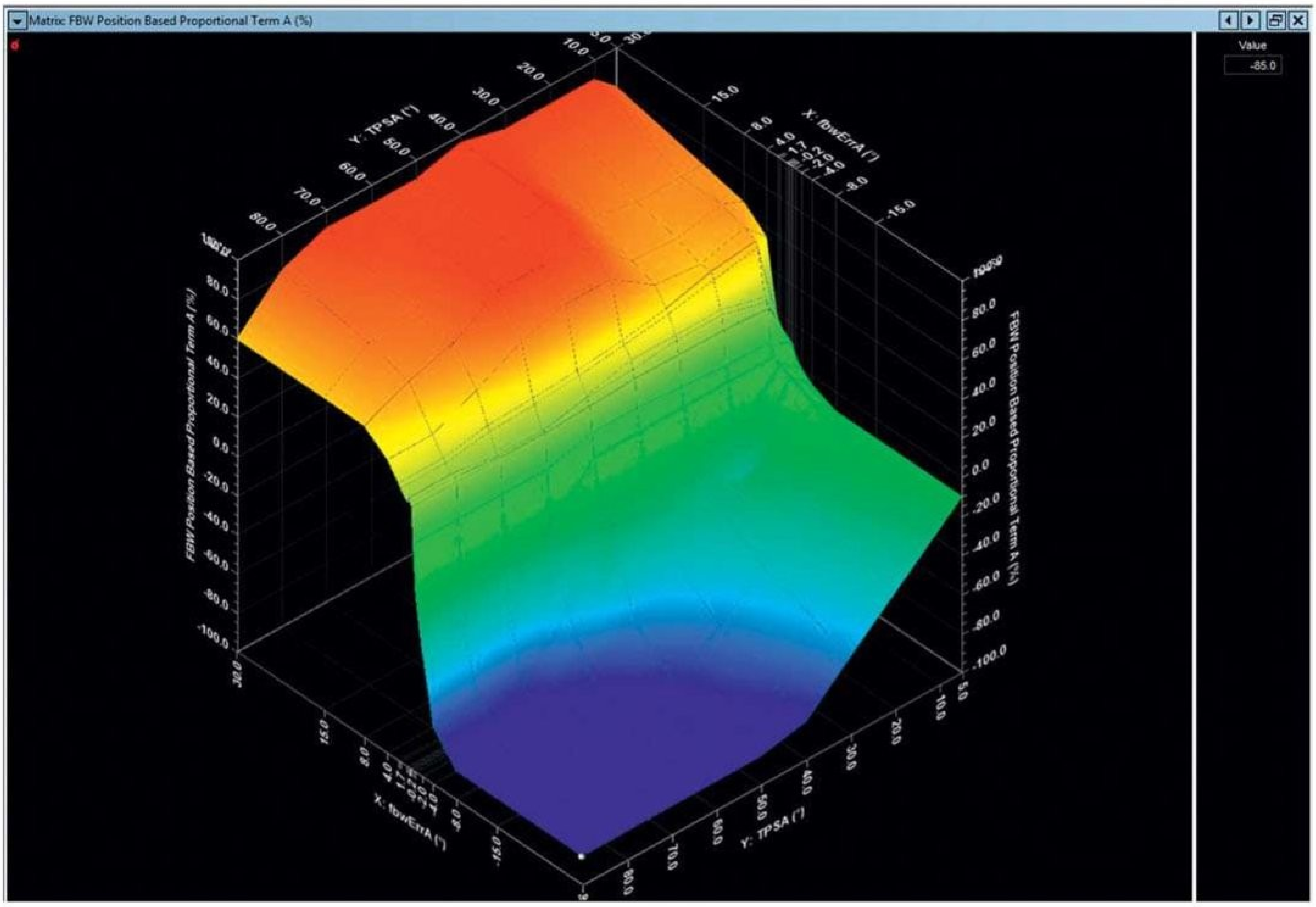
A typical fly-by-wire system for throttle control consists of sensors for the pedal and throttle positions, a control computer and a high duty cycle motor to control the engine throttle. Where multiple throttle bodies are being used, as is often the case with race engines, there can be one or more motors employed to move the throttles. The main thing to understand in those instances is to make sure the response is uniform, and that if only one motor is used to drive more than one throttle, that the mechanical load on it is not excessive – any mechanical issue will be clearly felt as a lack of throttle response or, in the worst case, a failed motor assembly.

The sensors used for fly-by-wire throttle installations should have two outputs each. This is generally achieved by using twin track rotary sensors, as this simplifies the installation requiring only one physical sensor. The use of two outputs allows the system to operate safely, and to recognise any error state should either track deviate from the expected calibrated value. This also means that the two tracks should be calibrated differently. A good example of this is to reverse the tracks so the slopes have opposite signs. The immediate advantage here is that both tracks can have the maximum resolution. When choosing sensors for the pedal and throttle positions it is important to recognise the travel of each component. A throttle will generally rotate through 90 degrees, so a 0-100 degree sensor would be a good option. If a larger range sensor is used, the voltage output will be considerably smaller reducing our resolution. In many cases a 0-100 degree sensor will also be acceptable on the pedal, but this depends very much on how the sensor is installed. If the sensor is mounted directly on the pivot point of the pedal, the movement will be much

"In aviation, the controls replace heavy and fragile systems with a lighter and more robust solution"

Figure 1: a schematic representation of the PID feedback loop





smaller than 100 degrees and a 30-degree sensor would most likely be more appropriate.

The strategy employed for a fly-by-wire throttle is a well-known feedback control loop, used in many industrial control systems called Proportional Integral Derivative controller (PID). As a feedback controller the PID calculates an error value that represents the difference between a target throttle position value, and the measured value of the position sensor. The controller then uses the three terms that make up its name in order to minimise the error and hit the target value. The terms can be represented based on time where the Proportional term is based on the instantaneous error, the Integral term is the sum of the instantaneous errors over time looking at past errors, and the Derivative term determines the slope of the error over time to predict the future error. Each term is then assigned with a gain to determine the effect on the output.

The P, I and D terms all have an individual map in the controller that allows them to increase or decrease the effect they have on the output. The idea is to bring the motor to an ideal position as fast as possible, without overshooting the target value. In many applications, the gain factor of I and D terms can be set to zero, and an adequate control can be reached – the control loop then effectively becomes a P or P-I controller.

Once the PID controller has been mapped and there is sufficient control over how the throttle is moved by the fly-by-wire motor, it is possible to start developing a pedal-to-throttle map. The significance of this is that there is now full control over the characteristic of the throttle response, so it can be tuned to a driver's feeling and allow the driver a much more detailed control over the throttle. Not only that, now that a control system has been introduced in the loop, it is possible to take inputs from other sources than the throttle pedal, use them to influence the position of the engine throttle, and allows the engine builder to produce different maps for different conditions.

"Possibilities are there for a very precise form of traction control"

This opens up possibilities of a very precise form of traction control. Even if traction control is banned, the map can be used to manage torque delivery, for example a different map for wet or slippery conditions can be hugely beneficial. Being able to influence the throttle outside of direct throttle pedal movement also opens up a good way of controlling pit lane speed limit or allowing the engine to pass air through itself on the overrun as made infamous by Formula 1 teams in their blown diffuser strategies.

Figure 2: mapping of the Proportional term based on throttle position and the calculated error value

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Simon McBeath offers aerodynamic advisory services under his own brand of SM Aerotechniques – www.sm-aerotechniques.co.uk. In these pages he uses data from MIRA to discuss common aerodynamic issues faced by racecar engineers

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Efficient air travel

It's the final instalment of our wind tunnel analysis of the Honda RA107, and we've saved the best until last...

We conclude our current mini-series on this superb Honda F1 car this month. The opportunity to study this pre-2009 regulation change F1 car has given us an idea of the aerodynamic performance of cars from the period, and our profound thanks once again have to go to Bjorn Arnils and Nadine Geary, the lucky owners of this fabulous F1 machine, as we work our way through some especially significant configuration changes made during an enthralling half day session.

BETTER BY BARGE

Prior to the major bodywork regulation changes of 2009, Formula 1 cars had sprouted all manner of 'off-body' aerodynamic devices. One of the longstanding devices to have been in use though, and which still prevails today, is the bargeboard. The Honda RA107 featured two pairs of these, which we'll refer to as the forward and rearward pairs, though both pairs were located well forward on the car as our photos demonstrate. We removed the front pair (fp) first, and then the rear pair (rp), and the results are set out in **Table 1**, which shows the coefficients before and after each step, and also the changes ('Δ or delta values') expressed in 'counts' where one count is equivalent to a coefficient change of 0.001.

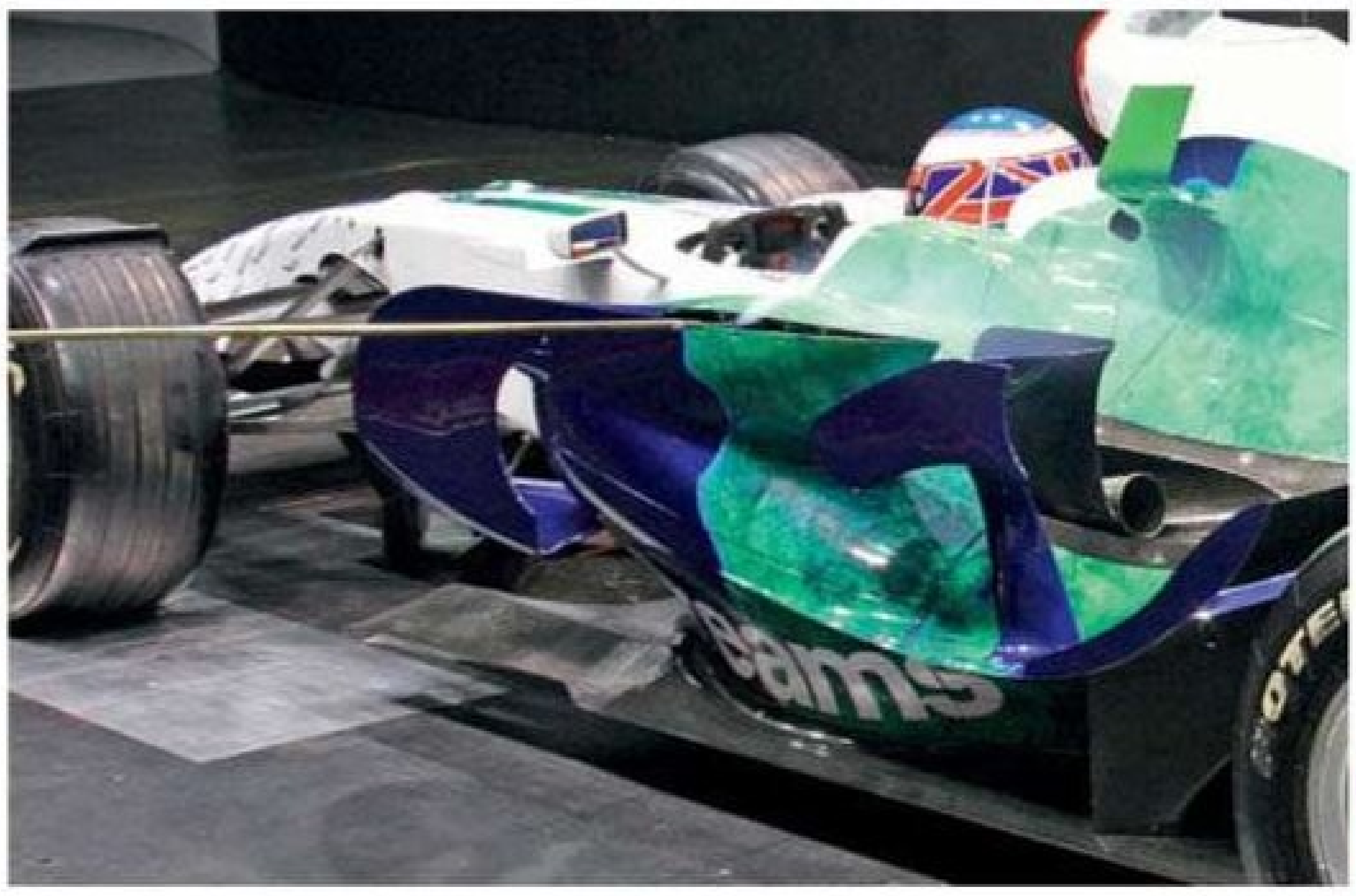
The first and most obvious conclusion from this data set is that these bargeboards were extremely powerful devices, especially the rearward ones. We must include the usual caveat here, which is that although 'trip strips' were attached to the wheels to simulate the effect of wheel rotation, the MIRA wind tunnel floor is stationary, so our downforce data, especially with respect to ground proximity devices, will have been underestimated. However, it might also be that the bargeboards, which are known to act in part as vortex generators, may also have served to 'refresh' the near-ground airflow to mitigate the fixed floor issue to some extent.

But just taking the data at face value, it is apparent that the bargeboards together produced an increase of 39 per cent to the total downforce of the bargeboard-less car, with 86 per cent more front downforce and 21 per cent more rear downforce. And these substantial downforce increments came for just 3.9 per cent more drag, meaning that efficiency (-L/D) increased by more than 33 per cent. This seems extraordinary for what are little more than two pairs of well-located curved plates with small horizontal lips and serrations on their bottom edges. However, such is the potency of the combined effect of turning the wakes of the front wheels and front wing outwards so that they do not adversely affect downstream components, and also generating vortices with low pressure cores that enter the underbody and augment the downforce generated there.

Table 1: the effects of bargeboards

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Datum	1.041	2.194	0.795	1.399	36.24%	2.108
Remove fp	1.027	2.067	0.718	1.349	34.74%	2.013
Δ 'with' fp	+14	+127	+77	+50	+1.50%	+95
Remove rp	1.002	1.578	0.426	1.152	27.00%	1.575
Δ 'with' rp	+25	+489	+292	+197	+7.74%	+438
Total Δ 'with'	+39	+616	+369	+247	+9.24%	+533

Bargeboards proved to be very potent



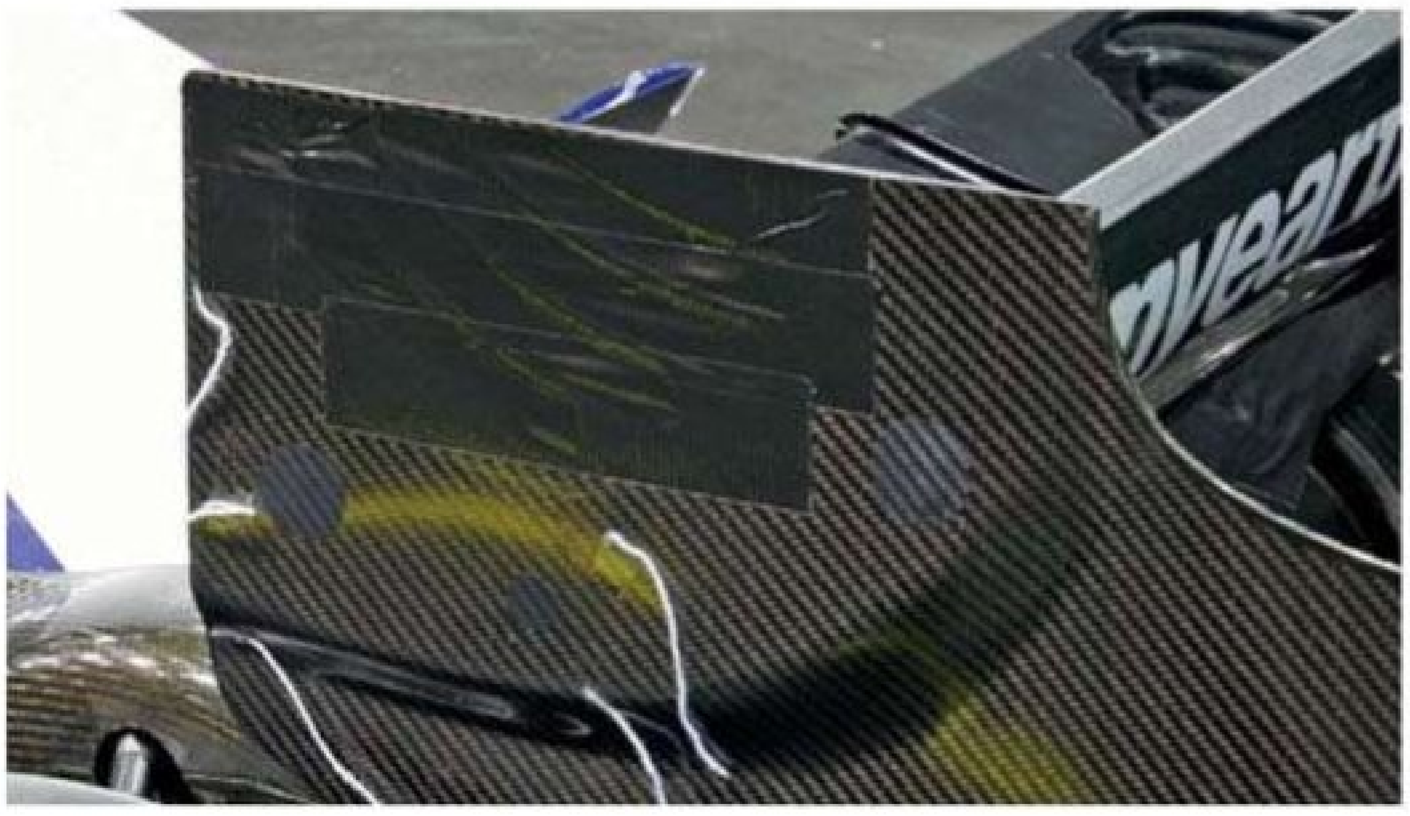
The main radiator exit chimneys

HOT AIR

The air exiting from the Honda's radiators emerged primarily through the chimneys that emerge from the top surface of the sidepods, more or less alongside the driver. But inboard of these chimneys there were removable panels that lifted off to reveal the rear face of the radiator.

Panels inboard of the radiator exit chimneys were opened up

The louvres in the upper rear wing end plates were taped over



End plate louvres were taped over to prevent air passing through

It's been a great ride, but we have to move on from the RA107 now...

Whether these panels would have been removed or replaced with panels with openings to provide additional cooling is not clear, but we tried removing them to see what effect this had on the aerodynamic coefficients, and **Table 2** summarises the data. Note that this trial was carried out with no bargeboards, and the 'aero stalks' that were previously located aft of the radiator exit chimneys (that we discussed in last month's issue) had also been removed.

While fitting the radiator exit cover panels had the effect of reducing drag and increasing downforce, so efficiency increased, and balance was shifted fairly significantly rearwards. This was a modification that was quite surprising in terms of the magnitude of the effects and also the 'reach' of the effects. This may simply have been down to improving the flow to the upper rear surfaces that produced an increase in rear downforce, which in turn saw a decrease in front downforce due to the mechanical leverage effect.

CLIPPING THE WINGS

When these features first appeared on F1 rear wing end plates, one's first reaction was that they would probably be losing a small amount of downforce by bleeding away some of the high pressure above the wing's upper surface, but that this was presumably being traded against a reduction in vortex drag and/or efficiency. **Table 3** shows what happened when we taped over the outside flat surface of these louvred slots.

Again, keep in mind that there had been some upstream changes made to the car at this stage, but hopefully the effects on the rear end plate louvres that we observed will serve to illustrate their generic effect. In reality what they did was to provide the expected drag reduction, but they also generated a small increase in rear downforce, not the expected decrease. How could this be? It would appear that the sectional profile of the 'blades' between the louvred openings is of an aerofoil shape, obviously designed to minimise drag from the air passing through the louvred openings. But could these also have generated a small downward force component sufficient to offset, and indeed reverse, any loss of downforce arising from bleeding away positive pressure from above the upper wing surface?

Overall the magnitude of the louvres' effect was quite modest, but in percentage terms, drag reduced by just under 0.9 per cent, and rear downforce increased by just under 0.6 per cent, resulting in a net gain in efficiency (-L/D) of 1.21 per cent. Though these effects seem modest, they would no doubt be cause for a small party in the aerodynamics department of the F1 team that hit on the idea!

Join us next month when we embark on a new project.

Racecar's eternal gratitude once again goes to Bjorn Arnils and Nadine Geary

Table 2: the effects of removing the radiator exhaust cover panels

	CD	-CL	-CLfront	-CLrear	%front	-L/D
With panels	1.002	1.578	0.426	1.152	27.00%	1.575
Without	1.032	1.554	0.474	1.080	30.50%	1.506
Δ 'with'	-30	+24	-48	+72	-3.50%	+69

Table 3: the effect of taping over the rear wing end plate louvres

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Louvres open	1.032	1.554	0.474	1.080	30.50%	1.506
Louvres covered	1.041	1.549	0.475	1.074	30.66%	1.488
Δ 'with'	-9	+5	-1	+6	-0.16%	+18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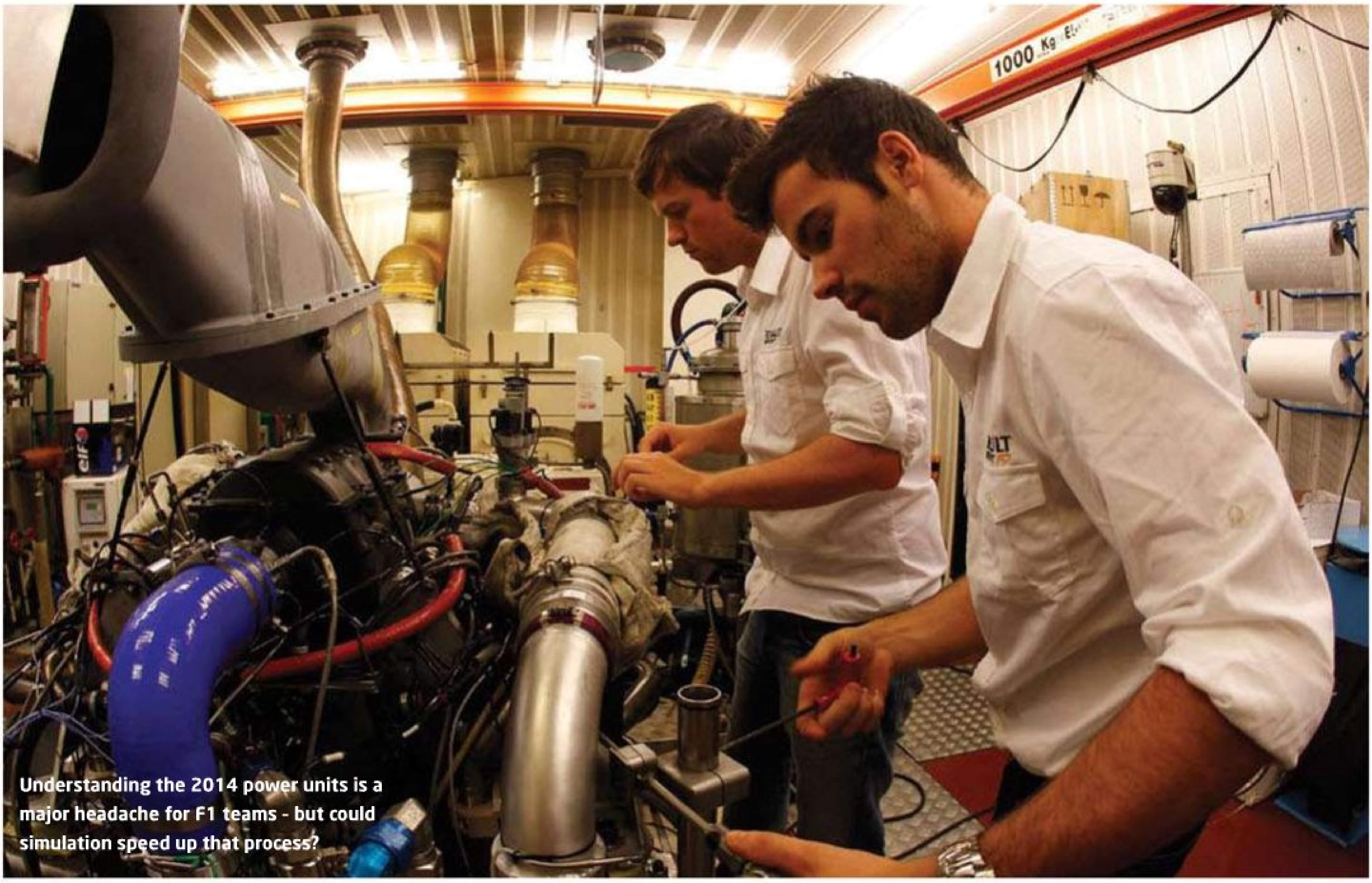
Simulating 2014

With new F1 specs on the horizon, one English company, Claytex, has been working to emulate the new car to help teams get ahead of the pack



Understanding the 2014 power units is a major headache for F1 teams - but could simulation speed up that process?

In 2014 a new powertrain specification will be introduced in to Formula 1. This new specification will change the landscape significantly with the current breed of 2.4-litre, normally aspirated V8s replaced with a 1.6-litre, V6 turbocharged gasoline direct injection engine, with increased use of Energy Recovery Systems (ERS). Formula 1 teams are already working hard on the designs of the new breed of car and that means a heavy reliance on simulation software. One English company, Claytex, has already conducted significant research into the new regulations and how they will affect the cars, and in the following article discuss how that was done using Dymola. The model presented includes the new powertrain specification together with a complete multibody vehicle dynamics model that can run in real-time. This model is suitable for use in many applications, including driving simulators. It allows the teams to work out the best energy usage strategies as the power unit contains a pair of motor-generator units (MGUs) which can be used to charge the battery, power each other, power the car or work as anti-lag, or indeed any combination of those modes.

The ERS (Energy Recovery System) will replace the currently used Kinetic Energy Recovery Systems (KERS). The new style ERS will incorporate two motor generator units, connected to the engine crankshaft and turbocharger respectively (see V22N12). The gearbox will contain eight forward gears plus a reverse, though the latter is not a regulatory requirement.

The engine itself will be a 1.6 90-degree V6 with a rules-limited maximum speed of 15,000rpm. The engine will have two inlet and two exhaust valves per cylinder, no variable valve timing or variable valve lift. The fuel mass flow rate must not exceed 100kg/h and below an engine speed of 10,500rpm the fuel flow rate is limited according to the following formula:

$$Q\left(\frac{kg}{h}\right) = 0.009N\,(rpm) + 5$$

A single stage turbocharger will be permitted, but it must not use variable geometry or variable nozzle turbines.

The ERS will consist of:

- **Motor Generator Unit - Kinetic (MGUK)**
- **Motor Generator Unit - Heat (MGUH)**
- **Energy Storage (ES)**

The MGUK is comparable to the current KERS. The motor generator will be mechanically linked to the drivetrain with a fixed speed ratio to the crankshaft, which could be clutched. The maximum power delivered by the MGUK to propel or brake the car will be no greater than 120kW. The energy stored from MGUK to the ES will not exceed 2MJ per lap and the energy used by MGUK from the ES will not exceed 4MJ per lap. The electrical output of the MGUK will be measured.

The MGUH will be mechanically linked to the exhaust turbine of the turbocharger with a fixed speed ratio, which could be clutched. The ES stores energy from the ERS. The form of storage is not specified by the regulations, however its total weight will be between 20-25kg. When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the car is on track the delta between the maximum and minimum states of charge will not exceed 4MJ. Measurements will be taken at the input and output of the ES. These changes in the powertrain specification introduce a number of challenges for the teams – the overall control strategy of the powertrain will need to be optimised to deliver the performance, fuel economy and driveability targets to enable the drivers to achieve the best lap time. At the same time the systems place an increased demand on the engine and electronics cooling systems.

Claytex has created a complete model of the 2014 Formula 1 car including the engine, gearbox and energy recovery systems, in Dymola. This model is based on a number of the commercial Modelica libraries: Engines, VDLMotorsports, Alternative Vehicles and uses the Vehicle Dynamics Library model architecture as the framework to integrate the systems.

The top level of the vehicle model consists of the driver, car, track and environmental conditions. The car model is broken down into the major subsystems: engine, transmission, driveline, chassis and brakes. The ERS is included within the engine model.

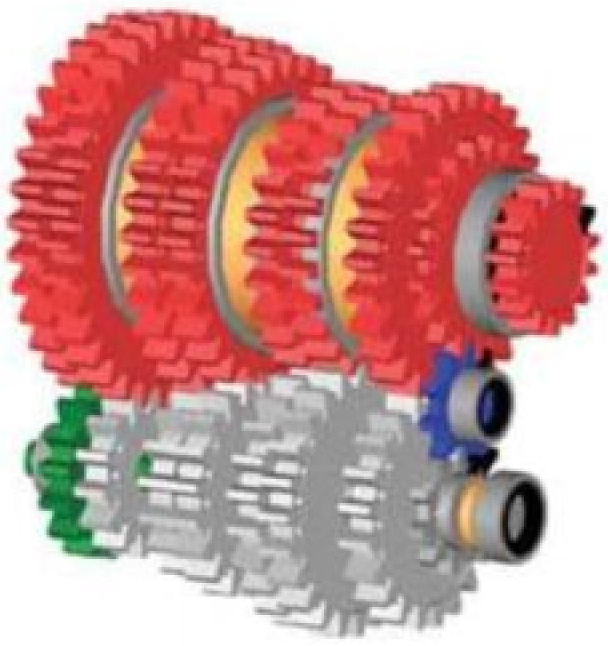
The model architecture makes use of the Modelica replaceable classes concept which makes it very easy to plug in different fidelity models into each part of the model. For instance, a simple ideal gearbox can be replaced with a high-fidelity model, including all of the shift mechanism details without requiring changes to the other surrounding models.

THE POWER UNIT

The Engines Library has been used to create a model of the 1600cc V6 turbocharged engine to be used in 2014. This model includes all the major features of the power unit including the motor generators attached to the turbocharger and crankshaft, the intercooler and the cooling systems.

A mean value engine model has been used to enable Claytex to achieve real-time simulation while still capturing the major transient effects that influence the performance and driveability of a turbocharged engine. The model includes airflow through the intake, turbocharger, intercooler and exhaust systems capturing the pressure and temperature transients. The mean value combustion model takes into account these effects together with the air, spark timing and other factors to determine the torque output and exhaust gas temperature.

The forthcoming standard Formula 1 ECU, new for 2014



Animation of a gearbox model in the Dymola software, which includes the individual bearings

The Engines Library supports both mean value and crank angle-resolved engine models and the model architecture is common to both. The only changes required to switch from a mean value model to a crank angle-resolved model, is to include the valve train and change the combustion model. The piston mechanics, crankshaft and intake and exhaust models do not have to be changed.

Using a crank angle-resolved model, Claytex was able to investigate the torque pulsations due to each firing event, and look in detail at the pressure and temperature during the engine operation. This included being able to explore effects such as split injection, multiple injection and cylinder deactivation.

In the engine and ERS model, the crankshaft is coupled to an electric motor generator through a gearset in the MGU-K block. The motor-generator can be used to assist the traction torque of the engine or recharge the battery during braking. Compared to the current specification KERS, the 2014 spec will support a higher power output from the motor generator and allow more energy to be stored in the battery each lap.

The turbocharger shaft is also gear-coupled to an electric motor-generator and can be used to spin up the turbocharger to improve throttle response. This is modelled in the MGU-H subsystem. It can also be used to control the turbocharger shaft speed and recharge the battery if excess turbocharger shaft power is available.

The model enables the control strategy to be developed and refined by exploring the overall system characteristics and interactions. For example, the model can be used to identify when it would be possible to use the MGU-H to charge the battery or power the MGU-K directly without storing the energy.

The electrical systems are modelled using a table-based approach as defined in the Alternative Vehicles Library. These models capture the main characteristics of the motors and power electronics, while enabling the simulation to run in real-time. For more detailed analysis, the higher fidelity motors and power electronics models from the Smart Electric Drives Library could be used to replace the real-time models.

Claytex found that the cooling system for the engine and power electronics could also be incorporated into the model. The engine cooling system could be modelled as a lumped capacitance heat transfer network, or as a 1D thermofluid system. The level of detail in each of the components can be varied to support simple sizing studies as well as the detailed investigation of heat exchanger geometries and stacking effects.

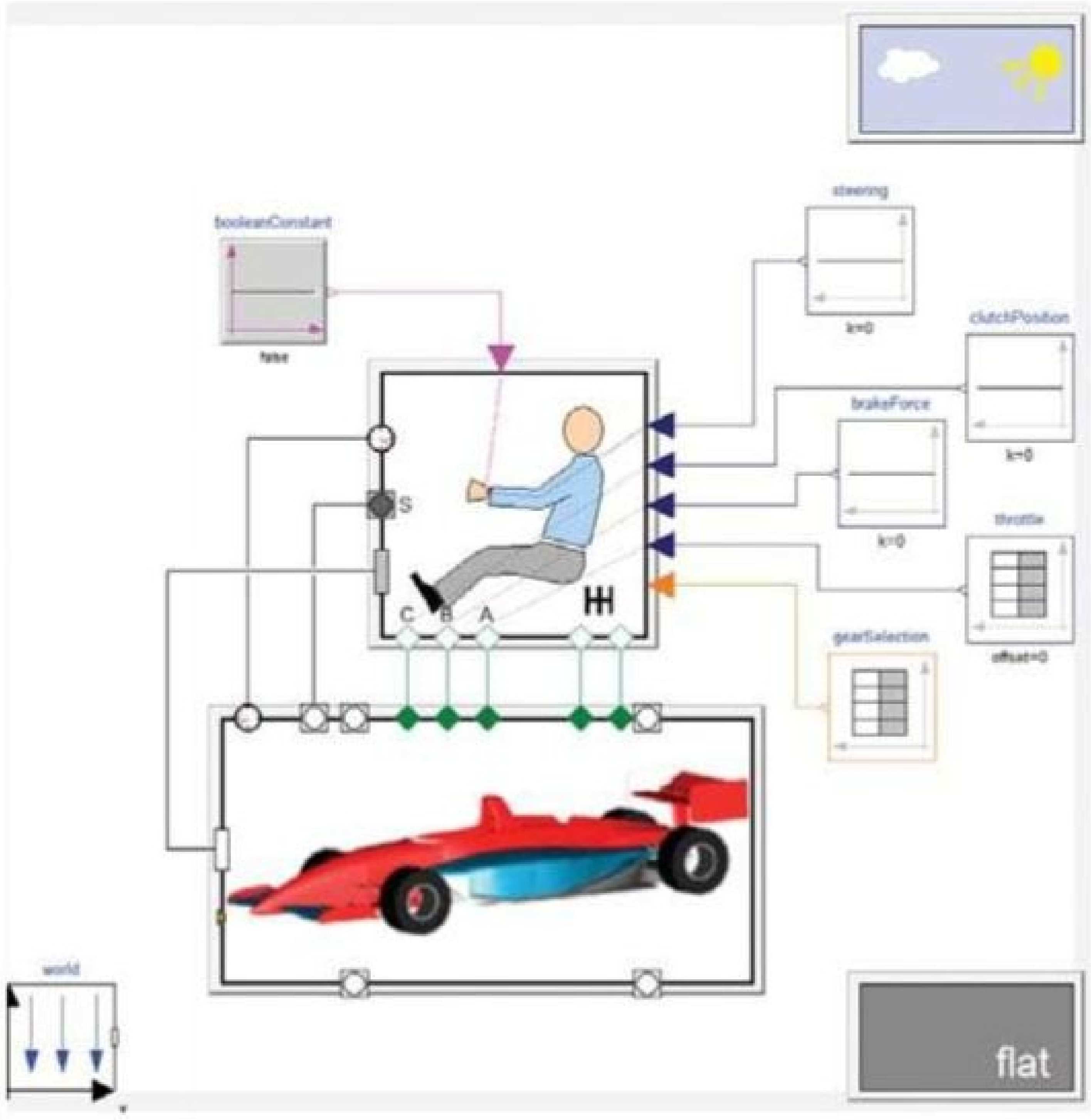
Claytex was focused on the power unit with the aim of achieving real-time simulation in its study, so only used a low-fidelity model of the transmission and driveline. However, it would be possible to include more detailed model using the Powertrain Dynamics Library.

The full torsional response of this system, including the shift dynamics, could be modelled (see above left) – this could include the individual bearings with friction, mesh points with efficiency, stiffness and backlash and torsional compliance in all the shafts. The VDLMotorsports Library was used to create a full multibody chassis model. The library contains a number of double wishbone suspensions with pushrod and pullrod examples with different rocker arrangements for anti-roll and heave control. The compliance in the chassis can also be optionally modelled.

"The new systems place an increased demand on the engine and electronics cooling systems"

The suspension model incorporates the adjustments, to enable the suspension setup to be defined in a realistic manner. Once the basic geometry of the suspension is defined, the characteristics can be adjusted by changing the shim thickness in the pushrod and suspension links. The library contains setup experiments for determining the adjustment shims and preloads required to achieve the desired suspension setup. The tyre model uses the Pacejka 2002 tyre slip model to calculate tyre forces. The model architecture for the tyre makes it very easy to replace this slip model with your own in-house model that could be written in Modelica, or as C-code, and linked to Dymola. Aerodynamic effects are included in the car body model, which features separate aerodynamic models for the body, front and rear wings and tyres. Simple aerodynamic models are used based on coefficients, but these can easily be extended to use available aerodynamic data.

Claytex found that using this approach with its code and binary export tools allowed the models to work with some of the in-house team software such as the trackside and lapsim tools which could be quickly updated to the latest car specification as soon as the model development is completed. For use in lapsim applications, the model equations are coupled to a QSS solver or optimisation routine and used to solve the quasi-static problem at each point around the lap. For integration in trackside tools, the model equations and integration method are exported as one object and integrated in to the existing tool as a Windows dll or FMU.



Complete vehicle model with an open loop driver model

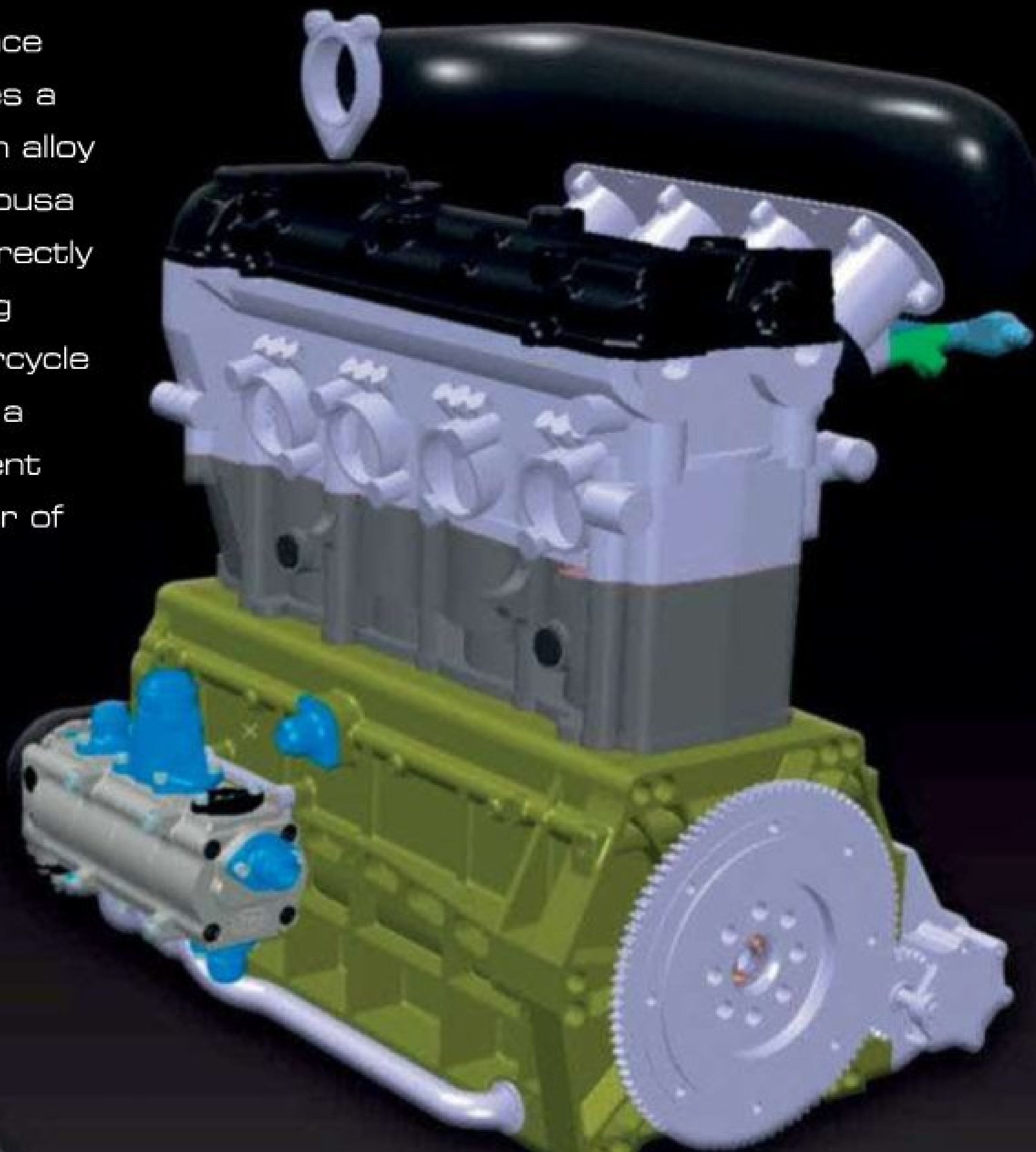
Dymola enables a complete model of the Formula 1 2014 specification car to be modelled and simulated in a variety of different ways. The Modelica-based modelling approach means that the models can be quickly created from a number of existing, and proven, application libraries minimising the model development time. This means more effort is spent on the development, integration and optimisation of the new systems.

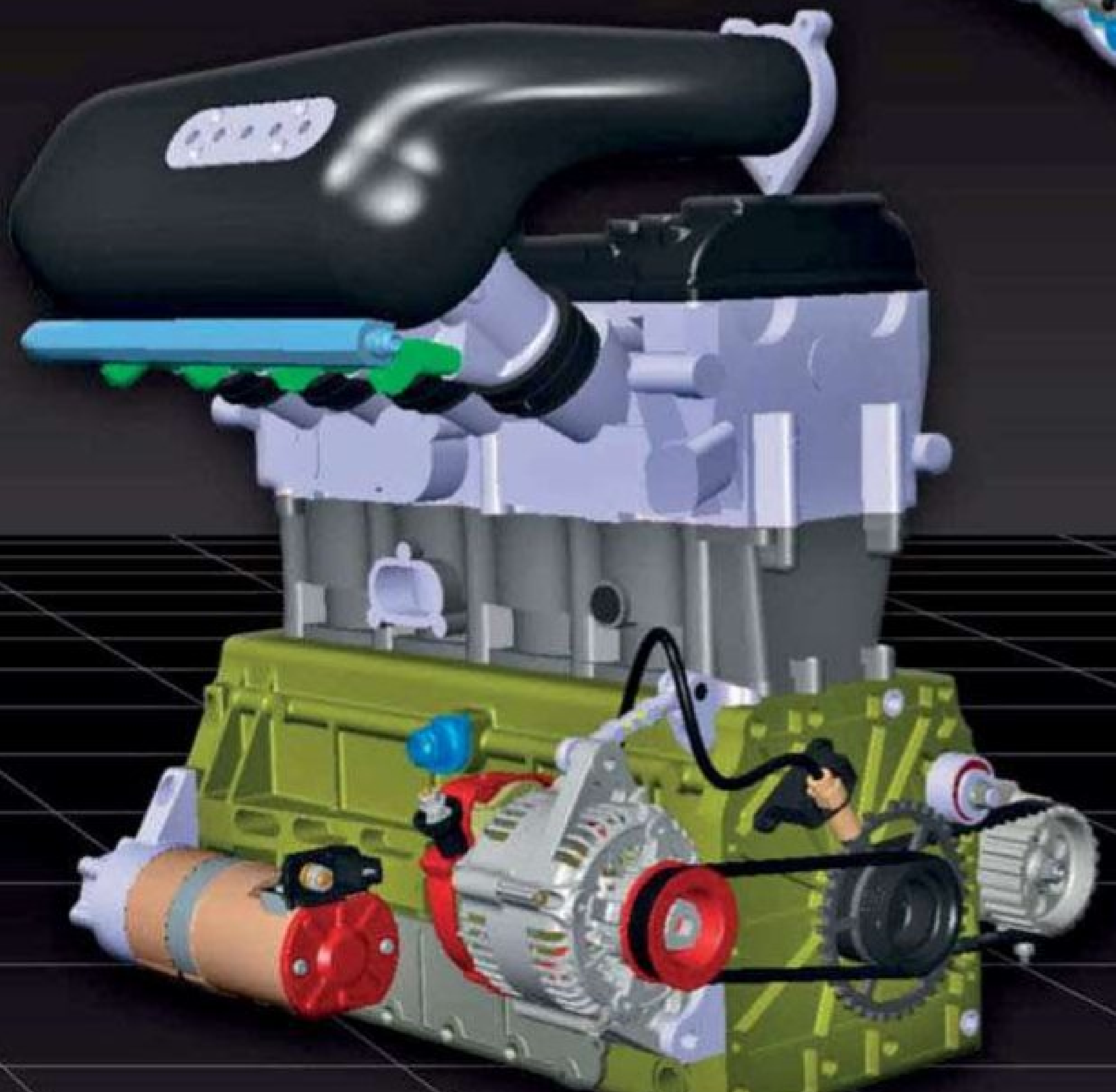
Dymola enables the same model to be used for many different applications including different types of analysis on the desktop as well as integration with other parts of the development process such as SIL, HIL and Driver in the loop testing. By using a physical modelling tool to provide the models for all of the systems quickly and efficiently, there is a reduction in the modelling effort across the team and an improvement in the consistency of the tools used.

Mussett Racing MR-1500T 4-cylinder turbo engine.

Conceived as a lightweight, high output performance engine, the new Mussett Racing MR-1500T utilises a CNC machined, aerospace specification, aluminium alloy crankcase mated to a highly modified Suzuki Hayabusa head. This design allows the engine to be bolted directly to the vehicle bulkhead and removes the packaging problems normally encountered when using motorcycle engines in automotive applications. The addition of a turbocharger and sophisticated engine management system gives a power output of 500bhp at 1.7 bar of pressure. A big punch in a little package.

The partnership of Mussett Racing, a division of the Mussett Technology Group and Geoff Page Racing gives the guarantee of quality, performance and reliability to this engine, which is hard to beat.





Engine specification
Mussett Racing MR-1500T
4 cylinder, 16 valve, twin cam turbo
Bespoke designed steel crankshaft
Dry sump lubrication system
2kW axial starter motor
55A Alternator
Professional Motorsport Wiring Harness
By DC Electronics

Dimensions

Length	497mm
Width	450mm
Height	466mm
Dry weight	76kg

Mussett Racing MR-1500T

Capacity	1489cc
Power	500bhp
Torque	380lbft
Maximum revs	10,200rpm
Bore	81mm
Stroke	72.25mm
Compression ratio	9.23:1

MR-1500T

Tel: 01508 522500 | Fax: 01508 528769 | Email: sales@mussett-racing.co.uk | media@mussett-racing.co.uk | technical@mussett-racing.co.uk

Regressive damping revisited

We take another look at Penske Racing Shocks' regressive dampers, and get some updates from the racetrack

BY SIMON MCBEATH

Damper tuning can offer a wide range of possibilities, with independent adjustment not only of compression and rebound but also of the low and high shaft speed ranges within each of those functions. These adjustments add tune-ability to the intrinsic damping characteristics offered, as given by the force versus shaft velocity curves available. For some time now it has been possible to provide variations on the simple linear damping 'curve', with 'digressive' damping, seeing the rate of rise of damping force reduced at a certain shaft speed. But genuine 'regressive' damping, wherein the damping force actually drops above a certain shaft speed (see sidebar, p46), has only relatively recently been made widely available.

In our V19N10 (October 2009) edition we revealed how Penske Racing Shocks had introduced and applied for a patent on a new regressive valve. Three years on the company has made further hardware enhancements to enable better exploitation of regressive characteristics, and has achieved success across a range of racing disciplines. So we spoke with PRS's director of competition, Aaron Lambert, and director of R&D Bill Gartner, to catch up on the latest.

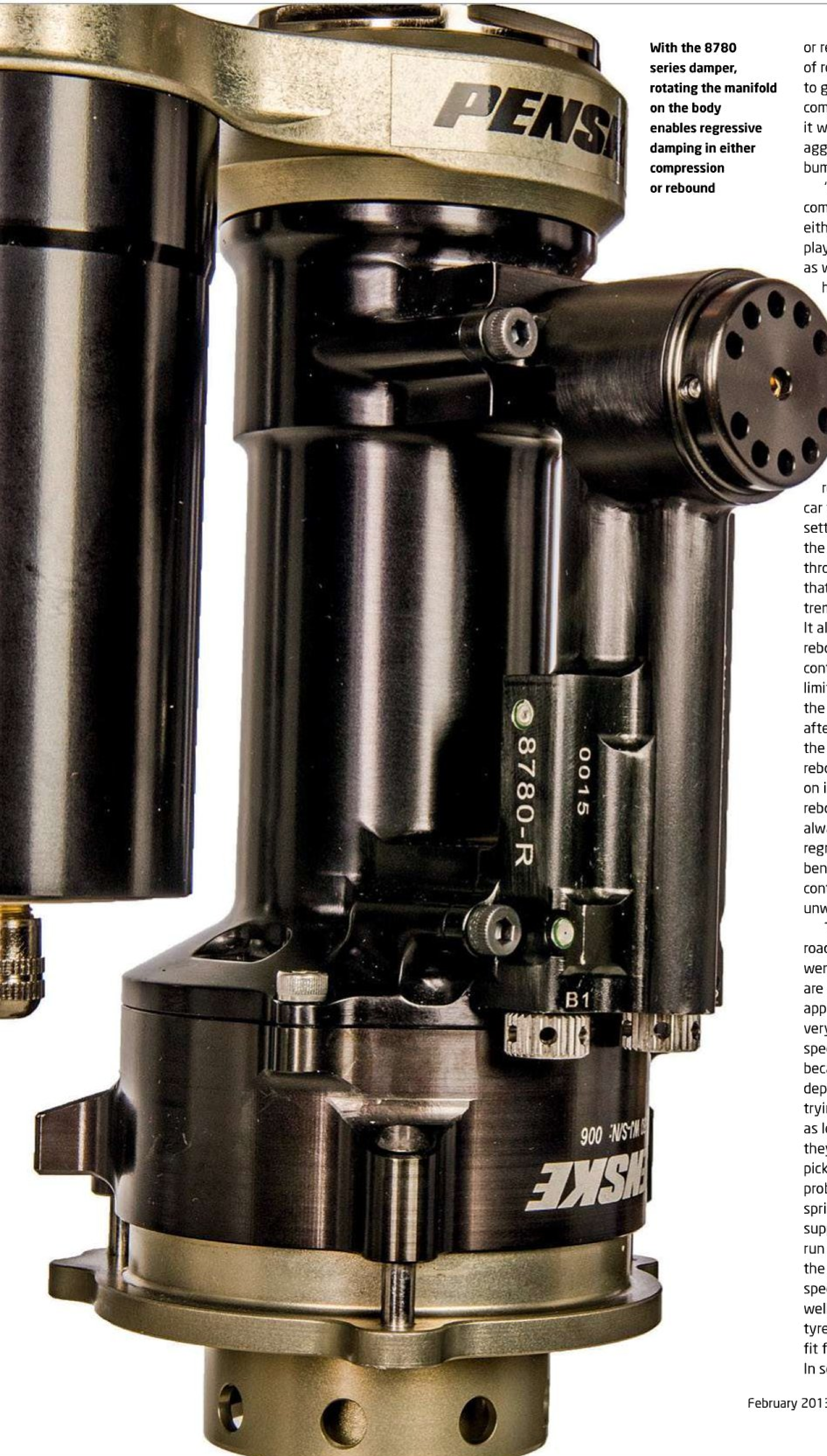
SPREADING THE BENEFITS

PRS has been utilising regressive damping in widely differing racing applications, and Lambert remarked that 'this has spread to grass roots type racers too'. 'SCCA racers have started to see the benefits of regressive damping, and Formula Fords have been working really well here in the States and overseas,' he says. But the technology has been exploited in NASCAR, IndyCar, short track (Sprint Car, Modifieds, Late Models), sportscars, Formula Ford and Formula Vee, to name but a few.

So what benefits have users been reporting? 'In each category we have seen an increase in grip, stability and driver feel,' Lambert says. 'In some cases we will tune for either compression regressive

"At the rear you typically want the car to recover over bumps, allowing the driver to get back on the throttle quicker"

The regressive damping technology has been favourably received by several racing manufacturers, including IndyCar team KV Racing



With the 8780 series damper, rotating the manifold on the body enables regressive damping in either compression or rebound

or rebound regressive. In the case of road racing we see a tendency to gain more of a benefit in compression, simply because it will allow a driver to be more aggressive over kerbs or large bumps without upsetting the car.

'But sometimes utilising compression and rebound in either the front or rear will also play a big role. For instance, as we have said, if a driver is having issues getting through kerbing, utilising a front compression regressive curve allows the suspension to 'blow' when it hits the kerb [allowing the impulse load from the kerb to be absorbed without upsetting the car]. At the rear, typically you want the car to recover over bumps or settle more quickly, which allows the driver to get back on the throttle quicker. We have found that rebound regressive helps tremendously in these cases. It allows us to add low speed rebound damping, which helps control the spring and, in turn, limits the number of oscillations the suspension goes through after hitting a bump. Normally the downside to just adding rebound is the effect it has on increasing the high-speed rebound, and this will typically always hurt tyre wear. The regressive valve allows you the benefit of increased low speed control while eliminating the unwanted high speed damping.'

This seems clear cut in the road racing context, but Lambert went on to explain how benefits are also being seen in other applications. 'In NASCAR, it is very important to maintain low speed rebound damping control, because the cars are so aero dependent,' he says. 'Teams are trying to keep the front splitter as low to the track as possible. If they can achieve this, they can pick up a lot of downforce. The problem comes with the high rate springs they have to run to just support the car, so they have to run high force rebound. Again, the downside is that the high speed rebound forces are high as well, and this in turn really hurts tyre wear. Regressive is a perfect fit for high rebound applications. In sedan type racing we see

Left: The REG-A valve has been run with success in Formula Ford
Above: Close up of the REG-A valve shows the spring that is pre-loaded to hold the valve closed at low shaft speeds

similar results, everything from SCCA World Challenge to Grand-AM GT classes. Teams again are utilising the increased low speed damping to control the "platform", and regressing the high-speed damping to save their tyres.'

Interestingly, the benefits seem to be felt whatever the car's weight, and whether or not it is aerodynamics-dependent. Lambert continued on this theme: 'Formula Fords have been working really well. These cars typically use very soft spring and damping set-ups because of their [low] weight and lack of downforce. Also they run fairly narrow tyres, so there is always a trade-off between allowing the car to move around to try and maximise mechanical grip, but then in-turn you can lose control [of the chassis]. A lot of drivers in these classes have come up through karting, where the karts are extremely stiff, with no roll or pitch at all. Naturally these drivers prefer a stiff set-up. But with a car with low downforce and narrow tyres, the stiffer the suspension, the less mechanical grip you will have.

'So you end up walking a very fine line between platform [control], grip and driver feel or preference. The regressive valve again gives you the ability to run increased low speed damping, which gives a more stable platform, and less high speed damping which helps with tyre wear and the ability to drive through bumps. So you don't have to be a top professional team to see the gains of regressive damping; our weekend racers are benefitting as well!'

PRS has made some significant steps on the hardware front to make regressive damping more accessible, and to improve its usability. 'The original version of the regressive valve eliminated the shaft adjuster,' says Lambert. 'So there was a drawback to the original valve, in that if you didn't have your rebound forces figured out, you were stuck with what you had. Depending on what series you were running in, you may not have had enough time to remove the shocks and rebuild them. We have a valve that now enables the retention of the adjuster in the shaft – most commonly a rebound adjuster, a very popular tuning tool – allowing the retention of all the adjusters on the damper. This has become extremely useful in allowing us to achieve optimum damping levels more quickly by using all the adjusters.'

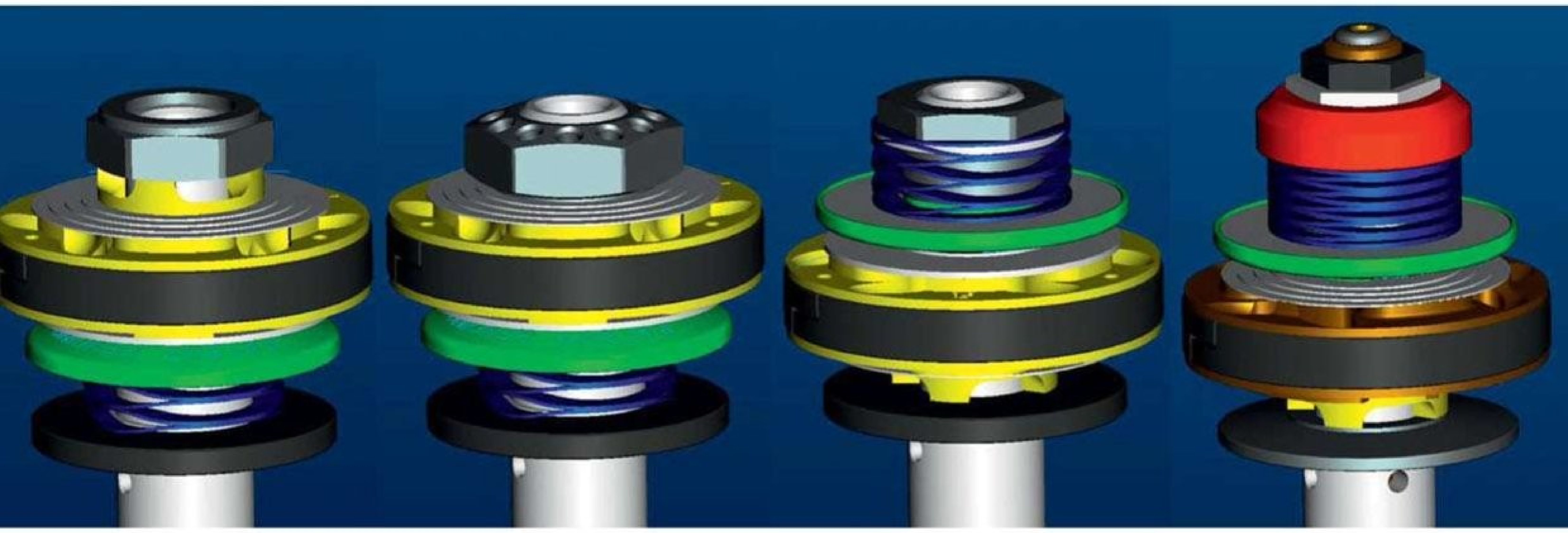
REGRESSION THERAPY

The company now also offers two different forms of external adjustment of the regressive characteristics. 'The first can be utilised with our new 8780 damper,' continues Lambert. 'We have designed the regressive valve into our adjuster manifold. This allows the user to tune the regressive curve, both with bleed and where the curve starts to regress. The bleed portion of the curve is the initial force the damper produces. This is typically measured between 0-3 inches (0 to 75mm) per second shaft speed. Bleed is simply a flow path the oil can take to bypass your main piston and shims. This allows the shock to move with little to no resistance, which increases mechanical grip. Drivers are very, very sensitive to bleed or low speed damping, and it also controls your platform, so it's clear why it is very important to maximise your low speed damping. Sometimes a good driver can feel the difference between 5lbs of force at these low speeds. This is why having externally adjustable bleed is so useful – you can really fine tune your low speed damping for driver feel, grip and platform control. High end teams have the luxury of using things like shock dynos and even shaker rigs to see the exact effect these forces have. Ultimately, we find the driver is the best tuning tool.

'Another feature with the 8780 is that by rotating the manifold on the body, it enables the user to utilise the regressive damping in either compression or rebound. This current manifold has been run by numerous teams in IndyCar with great success.'

The second version can be run in any of PRS's 45mm or 55mm dampers, and is designed to be adjustable in rebound only. 'We have been running rebound regressive damping in NASCAR type applications with great success,' says Lambert. 'We made this rebound adjustable version

"You don't have to be a top professional team to see the gains of regressive damping – our weekend racers are benefitting as well"



Compression regressive setup | **Adjustable compression regressive setup** | **Rebound regressive setup** | **Adjustable rebound regressive setup**

to be utilised in our most popular mono-tube applications. It can be run in all of our dampers, including our new 7150 (aimed at short track racing), 7500 single- or double-adjustable (for a range of applications), and the 7300 series (currently used in NASCAR, Grand National, Truck, ARCA, ASA and Late Models among others).'

QUANTIFYING THE BENEFITS

It is apparent then that gains from regressive damping are being accessed across widely differing categories, and that the PRS designers have made improvements that enable more applications to exploit the principle. And on a very pragmatic note Lambert happily confides that 'one of the main benefits comes down to saving time.

'When we introduced regressive style damping, there was a lot to learn on how much and when you wanted the curve to go regressive,' he says. 'Initially, to change this you would have to re-valve the damper, which sometimes takes a bit of time. By being able to externally adjust the regressive curve, we reduced the time it takes to optimise the damping levels.'

Examples at opposite ends of the single seater spectrum make for an interesting comparison. 'IndyCar has been our biggest success in 2012 with regressive damping,' says Lambert. 'This was due in part to our 8780 damper that allows us to switch the regressive damping from rebound to compression very easily. As it is not always known if rebound or compression regressive is going to be better, by utilising it in our manifold a team can very quickly flip the manifold and go from compression to rebound, where previously you'd have to have a spare set of shocks that were valved completely differently, to enable back-to-back tests. Also, the 8780 has the widest range of adjustability, so this makes it very easy to fine-tune the damping levels and optimise the setup.'

'We have also won quite a few races this year in Formula Ford. We have a few of the top shops running the REG-A valve with great driver feedback and winning results. REG-A is our latest regressive valve, which you can run in conjunction with your main piston. This version is not externally adjustable, but it does give the user rebound adjustment back in the shaft. To adjust the regressive force, you have to adjust the pre-load which is done by re-shimming the valve internally.'

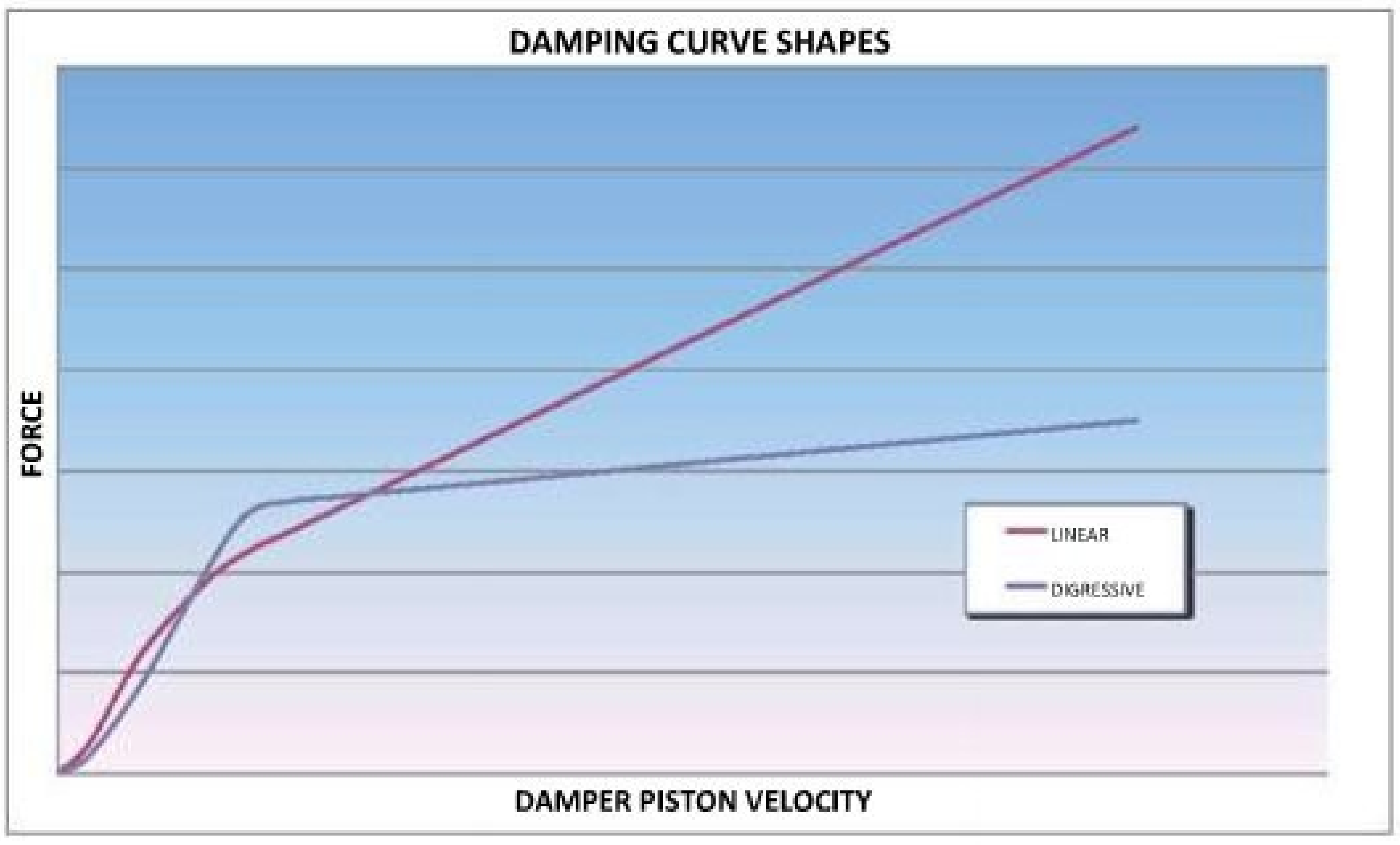
USER REVIEWS

It would appear, then, that there are various benefits to be had from regressive damping. But it's one thing to get the manufacturer's perspective, another to get feedback from users at the track. Some quotes from apparently very happy customers would, however, appear to back up the manufacturer's claims. Take IndyCar team KV Racing's engineer Olivier Boisson for example, who said: 'We found a few benefits to the regressive manifold system. First, due to its adjustability, and to our

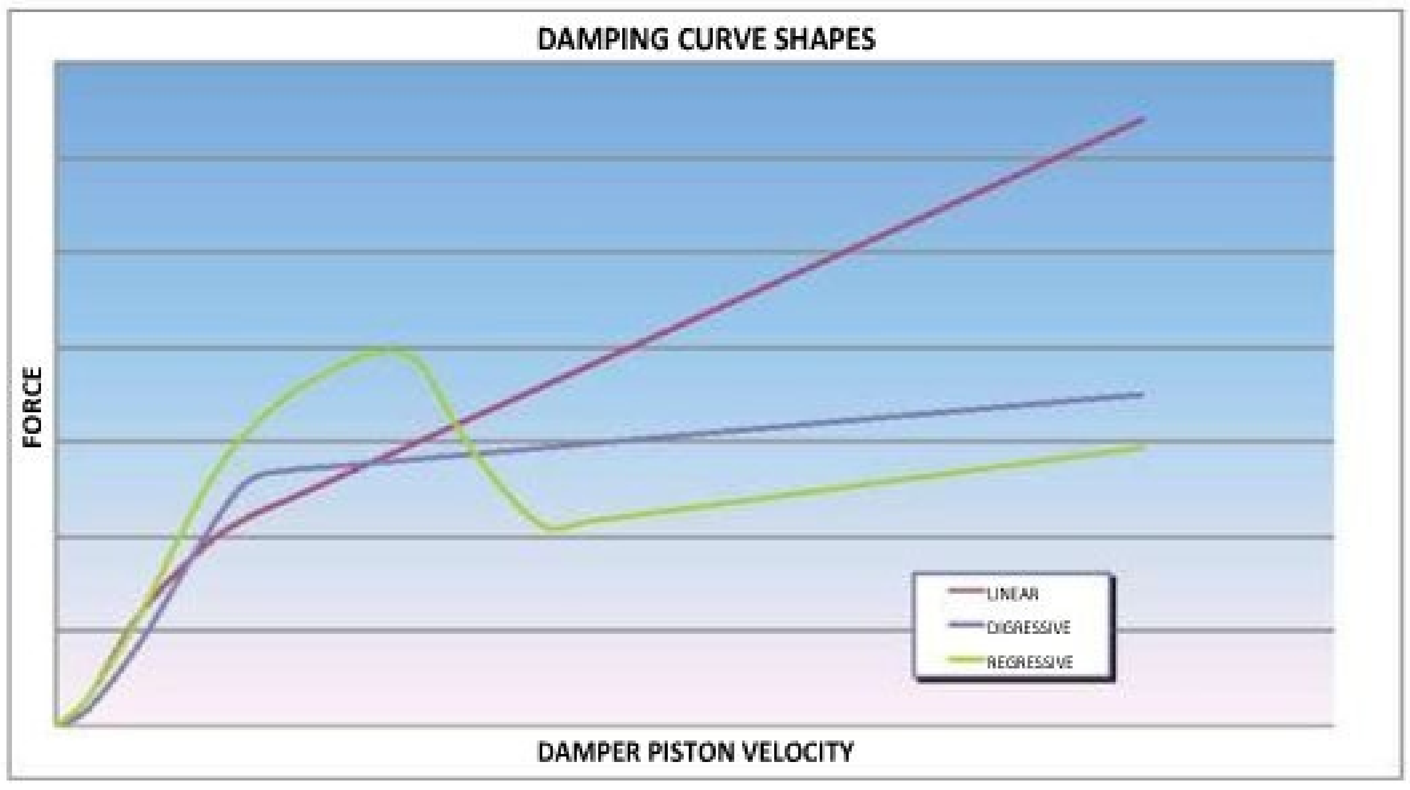
LINEAR, DIGRESSIVE AND REGRESSIVE CHARACTERISTICS

Why is regressive damping so useful? Because it circumvents, at least to an extent, one of the basic problems of hydraulic damping – that damping forces ordinarily rise with the speed at which the damper shaft and piston move through the damping fluid. If a simple damper with a linear damping curve were made to provide just the right level of damping for dealing with bumps (producing shaft speeds probably in excess of 15in/sec, or 381mm/sec and possibly up to 40in/sec or 1016mm/sec), it would be grossly under-damped for the slow velocity movements like roll and pitch, and our racecar would handle very sloppily. Conversely if the dampers were made to provide the correct roll and pitch damping (at shaft speeds up to 5in/sec or 127mm/sec might be typical), giving the driver responsive, confidence-inspiring handling that is generally much preferred, when hitting bumps the dampers would be far too stiff. This would provide not only a very harsh, choppy ride but also a loss of tyre compliance and grip, potential symptoms being wheel patter, lack of traction, premature sliding, wheel lock up and greater tyre wear as the dampers are unable to even out the vertical loadings and keep the tyres on the track surface.

The first step to alleviating this basic problem was digressive damping, where the rate of rise of damping force reduces at a certain shaft speed (see **Figure 1**). This enabled higher damping rates to be run in the low speed region to provide better chassis control without immediately compromising the ability to deal with track imperfections and kerbs. So digressive damping was useful a step forward, but as Penske's Bill Gartner commented: 'With digressive, low speed damping levels could still only be increased to a point where the higher speed damping started to erode performance. For some applications a very flat digressive curve worked just fine, but this didn't go far enough for some. Regressive damping began in Formula 1, and was meant to provide the requisite level of low- and mid-speed compression damping for good driver feel and small bump absorption, but then cause drastic reductions in compression damping levels at higher shaft speeds (see **Figure 2**) when hitting kerbs.'



Typical linear and digressive damping curve shapes



The regressive damping curve contrasts with the linear and digressive curves

ability to turn it off completely, it gave us the flexibility to try different options during a session.' Lambert adds: 'Yes, we can completely turn off the regressive part of the curve by externally adjusting the valve to "fully closed". At this point all the fluid must flow through the piston and the curve characteristics are now based solely on the main piston itself.' 'This also saved us a lot of precious time in the pit lane by not requiring us to change dampers to try something different,' continued Boisson.

'The fact that adjustment is on the manifold enabled us to combine it with other options, such as the hybrid [damper inerter] or through-shaft damper, which would not have been possible with the original shaft regressive option. And finally, the regressive characteristic let us go further in some directions than we could with standard damping curves. They have shown positive results at the shaker and good driver correlation at the track. The drivers' feedback was positive, and the option helped us get closer to the direction the drivers were asking for.'

Aaron Lambert has already described how Formula Fords have found benefit from regressive damping. PRS's man in Australia, Bill McKenna, has forwarded quotes from drivers and teams who preferred to remain anonymous. One team reported that 'we only get six tyres for each meeting, comprising qualifying plus three races, so tyre management is key. With the REG-A valve we have proven that we can eke out an extra three or four laps initially with consistent qualifying speed, and then also extend the tyres' life during the course of the race meeting.' Various other drivers made comments like 'the rear end feels supported for the first time', 'more stable under brakes', 'more front turn, can feed into the corner smoothly – no longer chopping at the steering', and 'eating the bumps and kerbs well.'

"The regressive characteristics have shown positive results and good driver correlation"

HOW DOES THE REGRESSIVE VALVE WORK?

Bill Gartner, director of R&D at PRS and inventor of regressive technology, explained the function of the regressive valve: 'The main concept behind our regressive damping technology involves a play on pressure area within the damper. During low velocity movements, the regressive valve is held closed by a preloaded spring. At these velocities, damping is controlled via bleed past the piston, or adjusters within the shaft, and the shims on the main piston may also begin to open allowing some flow and damping control.

Within the valve, the pressure generated in these lower speed movements is only allowed to act upon a small surface area of the valve. In the case of the newest valve, this is a shim that seals against a face in the valve, and only the port area of the shim is acted upon. When higher velocities are encountered, and pressure levels rise, spring preload holding the valve closed is overcome, and the valve begins to open. This opening allows high pressure flow to flood the chamber under the entire shim or valve. Because flow area has increased, the overall pressure differential across the main piston is relieved, and damping forces decrease even though the damper is travelling faster. However, because the pressure area is now much larger, the valve is able to resist the spring preload, and keep the valve open at the lower pressure. This play on pressure area variation within the regressive valve plays the key role compared to traditional damping arrangements that are limited to function using a constant pressure area.

'However, the real key to making these valves work effectively is getting the ratios of both flow and pressure areas right. In addition to blowing open in the correct way, the valve also needs to recover, and begin to actually add damping force when velocities slow on the back side of a bump or at the end of a driver input. Otherwise, the platform and feel that the valve was providing would instantly be lost when a bump in encountered. It's not such an easy engineering exercise, but we've become rather good at hitting the nail on the head with these valves with many years of development, and help from some very experienced drivers under our belts!'

FUTURE POSSIBILITIES

From the SCCA's Pro Racing Pirelli World Challenge, the 2012 GTS class champions RealTime Racing Acura crew chief and race engineer Paul Truess remarked that 'regressive damping was something we have always wanted but thought wasn't truly possible'.

'On our Acura TSX we previously had a trade-off between enough damping to control the mass of our production based car while trying to not make it too harsh over the kerbing,' he said. 'Now with the Penske regressive damping, we are able to tune more to the best of both requirements. Our cars have gone from some of the worst over the kerbs to one of the best. This performance increase helped us win both the 2012 Manufacturer Championship for Acura and the driver title for Peter Cunningham.'

For any team trying regressive damping for the first time, there is obviously work to be done in finding the right shaft speed at which the damper goes regressive, and how much damping there is in the regressive region, that much really goes without saying.

The possibilities appear to speak for themselves.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Fuel for thought for Le Mans 2014

What can we expect to come out of the innovative regulations for next year?

BY CHRIS VAN RUTTEN

Last June, the ACO released a concept of the future regulations for the Le Mans race. The organisers' stated aim is to challenge the entrants to develop a more efficient car. So, instead of imposing restrictions to the engine, in order to keep the power under control, they limited the amount of fuel which may be used. Since power is relative to the fuel used, multiplied by engine efficiency, this simple rule limits the engine power as well. In return the entrants are granted more technical freedom to design their power plant.

It could have been an option to limit the amount of fuel for the complete race, which, contrary to the amount of fuel per lap, would lead to an even more complicated puzzle. The design would have to take many irregularities into account which might occur during the race, such as yellow flag periods, and rain. Next to that, it could open possibilities for teams running faster than they could continue for a complete race, just for the sake of extra attention of leading in the early stages. It would be quite confusing for the spectators. The choice of specifying an amount of fuel per lap is much more straightforward and will guarantee that there is still a race for the drivers.

Based on this regulation, what is there to expect? By using a simulation package, such as LapSim, an estimate can be made in which direction the LMP cars will develop. How will the fuel limit influence lap times and top speeds? What kind of engine may we expect? Will the trend go to low drag vehicles? How sensitive is the fuel limit to parameter changes of the vehicle?

"Specifying an amount of fuel per lap will guarantee that there's a race for the drivers"

AS THINGS STAND

As a reference, we have a model of a current LMP1 petrol car that we've made in LapSim. Main chassis specifications are vehicle weight including driver 1000kg, and an aerodynamic efficiency of 4.37. Other main parameters of the chassis can be seen in the setup overview in **Figure 1**.

With the engine simulation in LapSim, a power curve can be generated for the current engine of an LMP car, a 3.4-litre V8 with a 43.4mm restrictor. Optimising the engine parameters results in the power graph as shown in **Figure 2**.

The advantage of the engine simulation is that not only is a power curve generated, but also the efficiency of the engine in the complete power band is calculated. Thereby combining the power curve of the engine simulation with the lap simulator, the software will also simulate the fuel consumption over a lap. The results of simulating a lap at the Le Mans track can be seen in **Figure 3**. The lap time of the model is 3:32.81.

TOTAL WEIGHT / Weight Balance FR	1000 [kg]	46.6 [%]
WHEELBASE / Height C.O.G.	3000 [mm]	350 [mm]
TRACKWIDTH front / rear	1700 [mm]	1700 [mm]
RIDE HEIGHTS front / rear	35 [mm]	50 [mm]
DRAG COEF. / Frontal Area (A)	0.38 [ ]	1.9 [m^2]
DOWNFORCE COEF. front / rear	0.67 [ ]	0.99 [ ]
DIFFERENTIAL friction faces / preload	12 [ ]	0 [Nm]
Drive 30 [%] / Brake 29 [%]	30 [°]	30 [°]
ANTI-ROLL BAR stiffness front / rear	221 [N/mm]	71 [N/mm]
SPRINGS FRONT main / helper	220 [N/mm]	
SPRINGS REAR main / helper	230 [N/mm]	
CAMBER FRONT (left / right)	-2 ° 0'	-2 ° 0'
CAMBER REAR (left / right)	-2 ° 0'	-2 ° 0'
Optimal Longitudinal TIRE SLIP	5 [%]	
BRAKE BALANCE Front	60 [%]	
Steering Ratio	12 [ ]	

Figure 1: overview of chassis parameters in a 2012 LMP

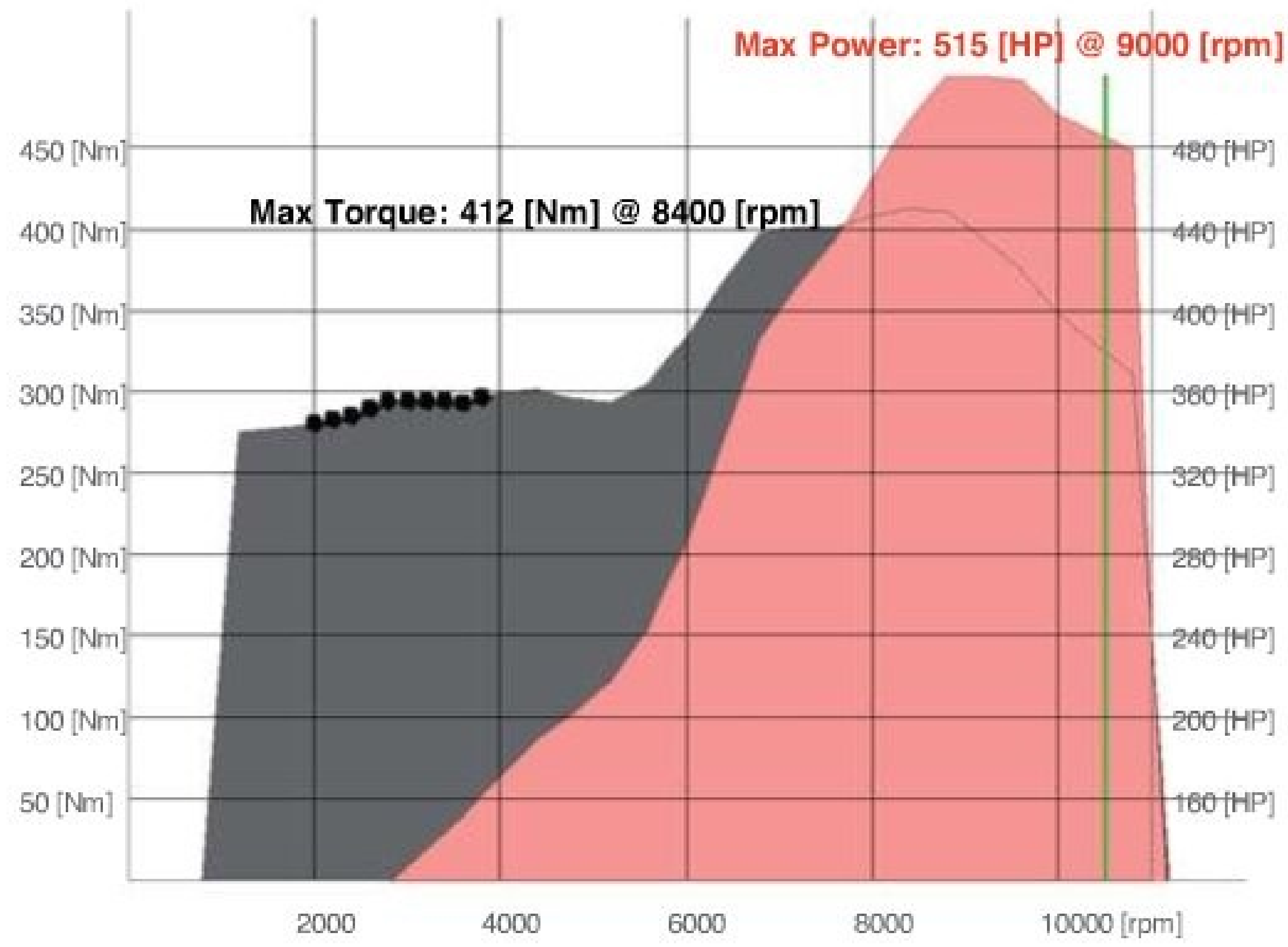

Figure 2: power curve for a 2012 LMP

The model reaches a top speed of 311km/h, as can be seen in the top figure. Below the speed graph, the engine rpm, throttle and selected gear are shown. The bottom three figures show the fuel flow in ml/sec, middle figure the accumulated fuel over the lap (6.18-litre total) and the bottom figure shows the theoretical efficiency of the engine.

This model is used as a reference to view the implications to the 2014 regulations.

THE 2014 EFFECT

In a first attempt to reach the fuel limits of 2014, a smaller engine is simulated. With a 2.8-litre, 6 cylinder engine with 84mm bore and 86mm stroke engine, the model seems capable

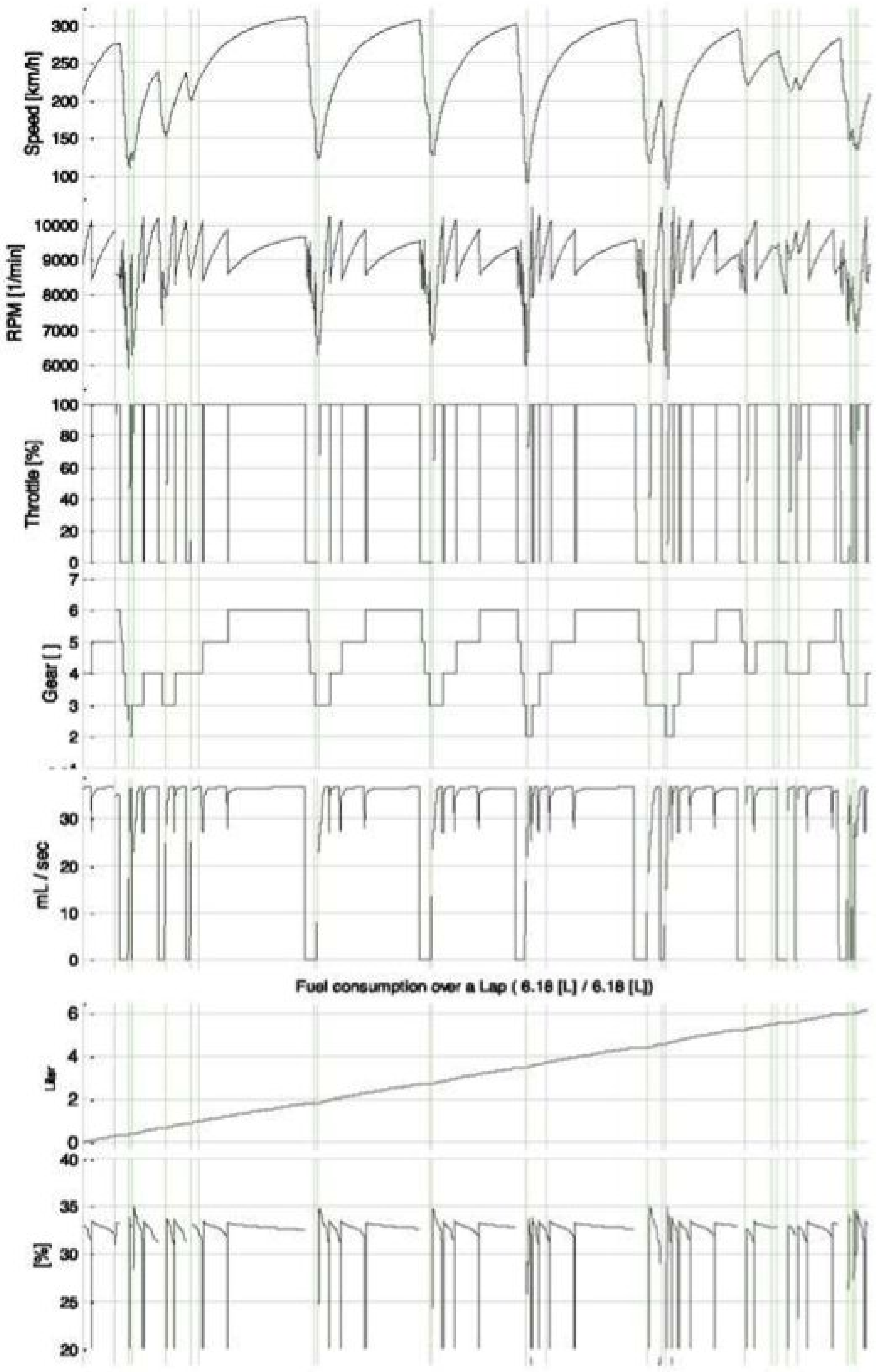

Figure 3: simulation results for a 2012 LMP

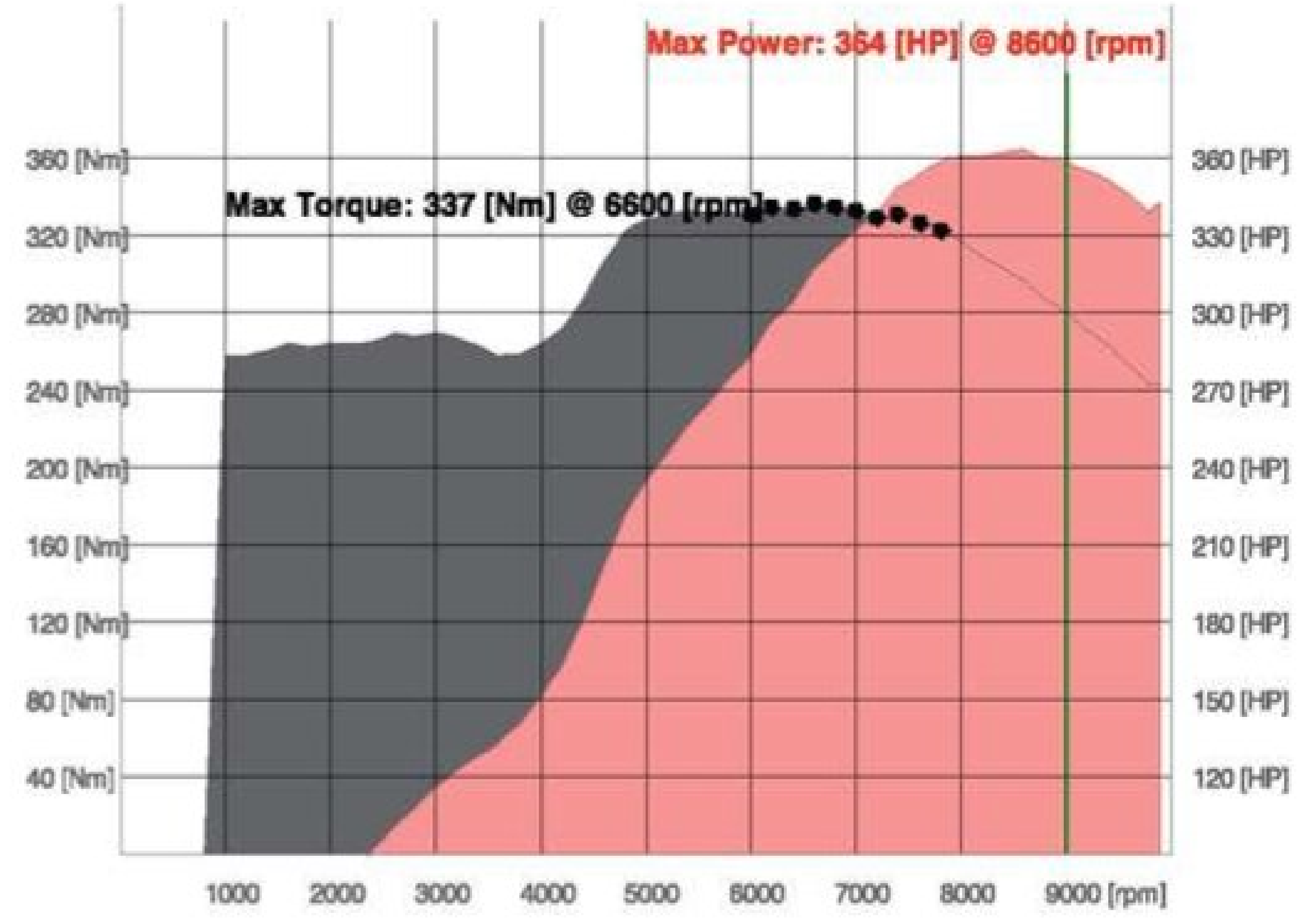

Figure 4: a 2.8 litre 6 cylinder engine for a 2014 LMP

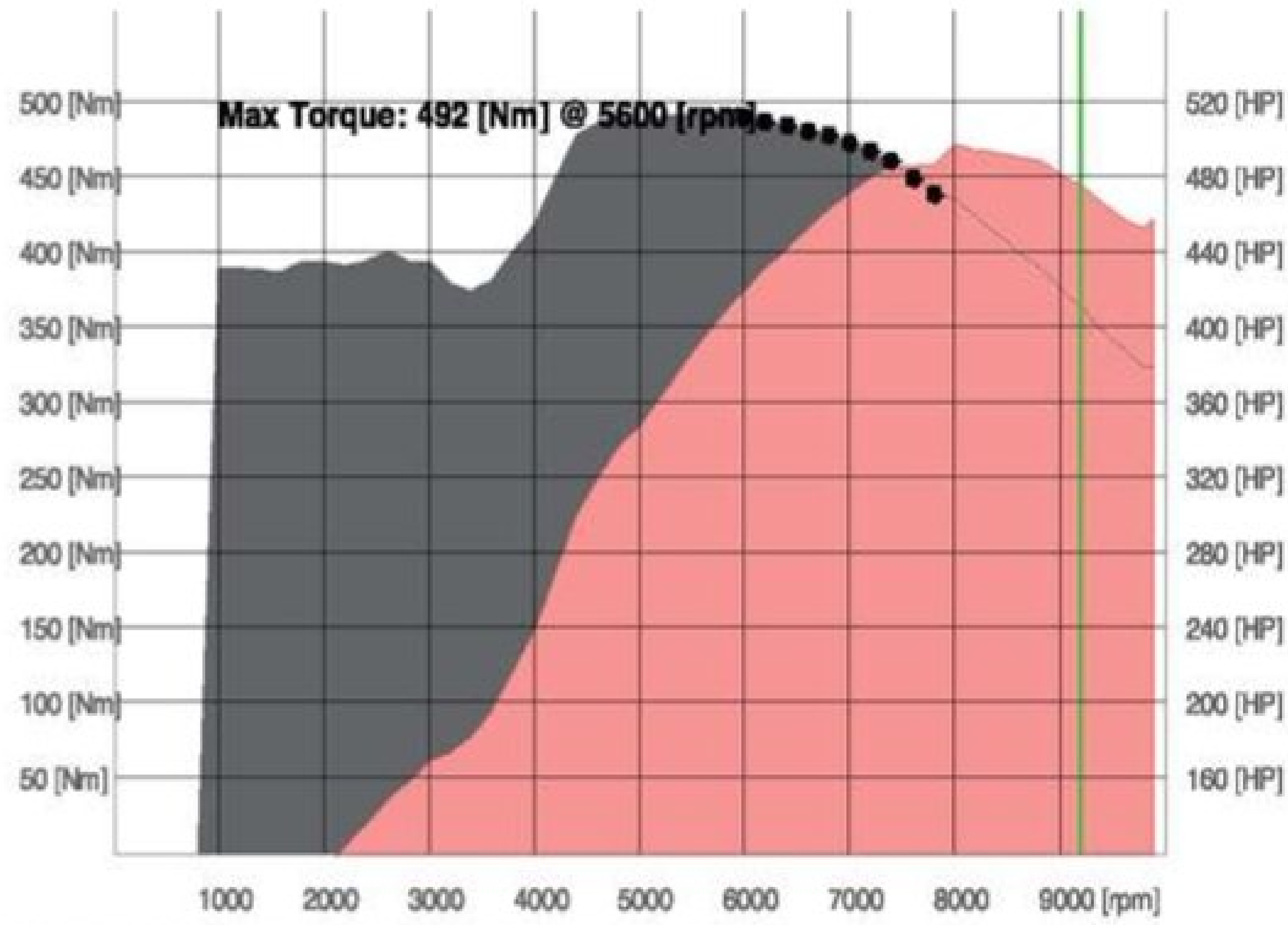

Figure 5: option 2; a 4-litre V8 for a 2014 LMP

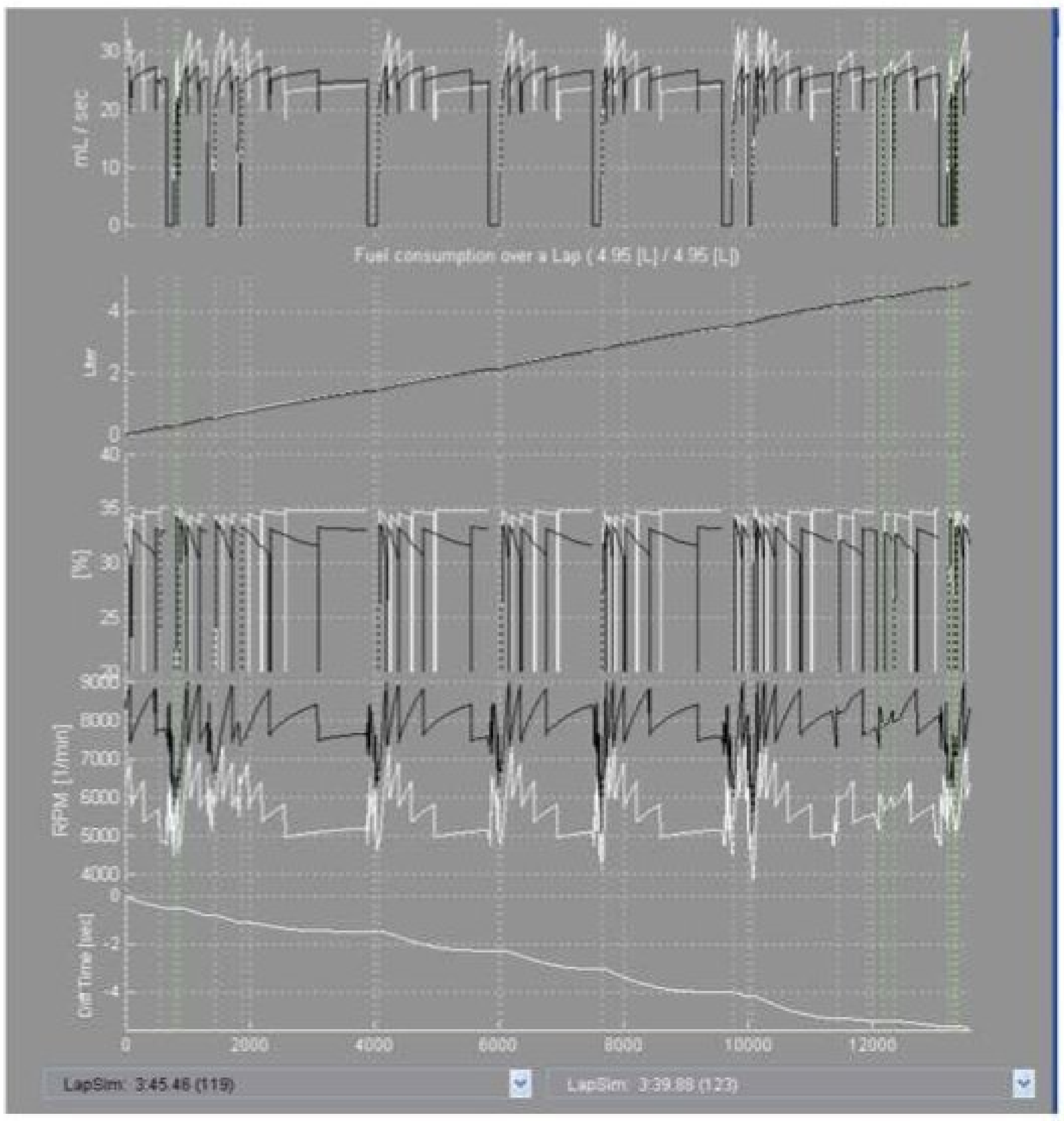

Figure 6: comparison between a 2.8-litre and 4-litre engine

of reaching the fuel limits. Combined with appropriate valves and camshaft timing, it develops 364hp between 8000 and 8800rpm **(Figure 4)**.

The engine is combined with an appropriate 7 speed gearbox to suit the 2012 chassis. However, for fuel economy reasons, sixth and seventh gears are chosen longer compared to those used for the fastest lap time. Chassis parameters are kept the same, just the total weight is reduced to 930kg. This combination results in a lap time of 3:45.46, a top speed of 276km/h and a fuel consumption of 4.95-litres over a lap. In order to reach this fuel limit, the higher gears needed to be short shifted, otherwise the fuel consumption would be more. When it comes to lap time, short shifting the higher gears is the most effective way of reducing the fuel consumption.

This would be the classic approach when running an engine more or less on full power, as would reducing the engine size in order to reach the fuel limits. A second option would be running a "too powerful" engine in a torque range where it is most effective. As a comparison to the 2.8-litre 6 cylinder, a 4-litre V8 with 86mm bore and 86mm stroke is simulated. The camshaft timing has been changed in favour of more low end torque. This engine delivers 497hp and 492Nm of torque, as can be seen in **Figure 5**.

In order to reach the fuel targets, the gearbox ratios have been chosen way too long from a classic setup perspective, as

"When it comes to lap time, short shifting the higher gears is the most effective way of reducing the fuel consumption"

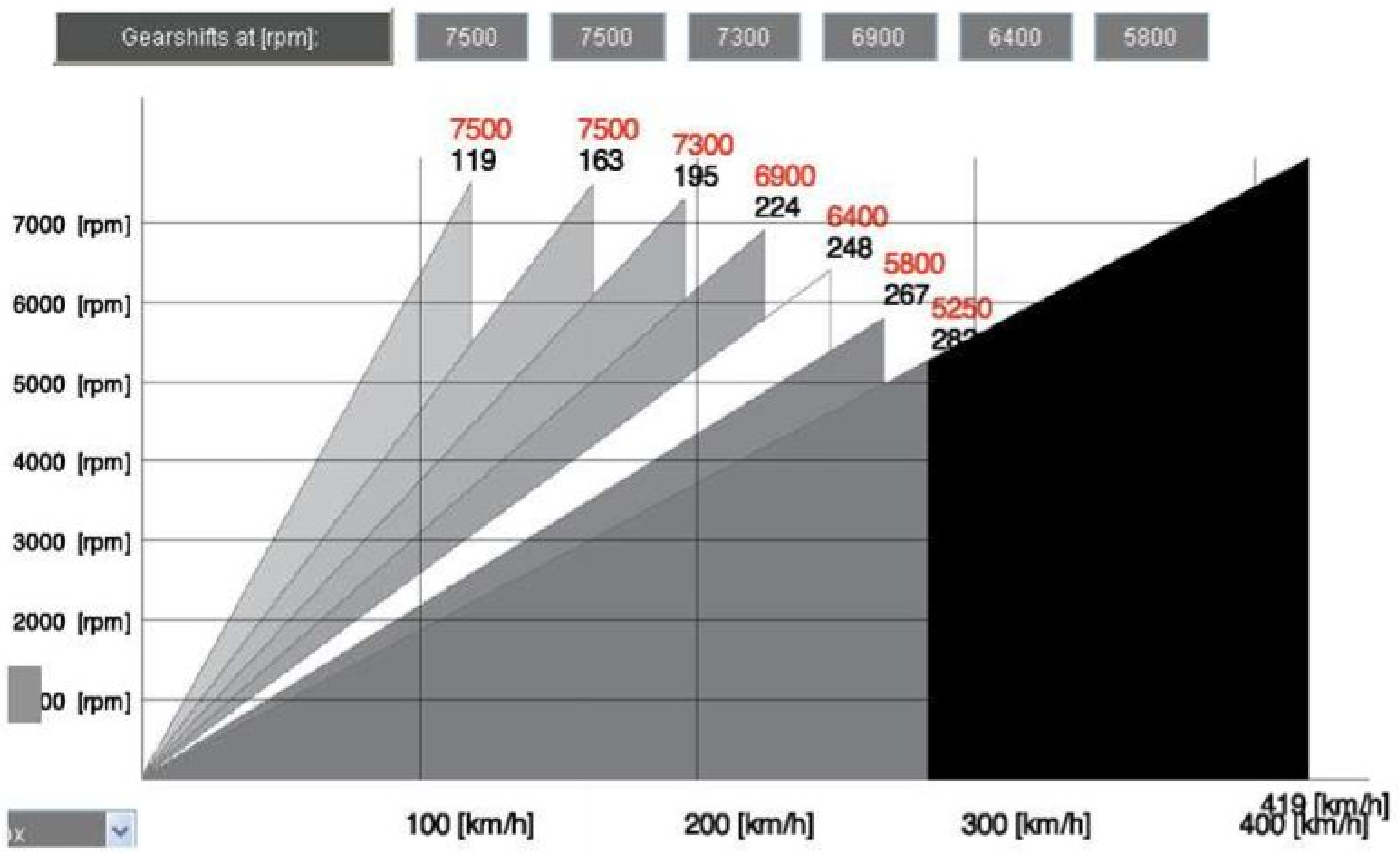

Figure 7: gearbox graph for a 4-litre with a 34ml/sec flow limit

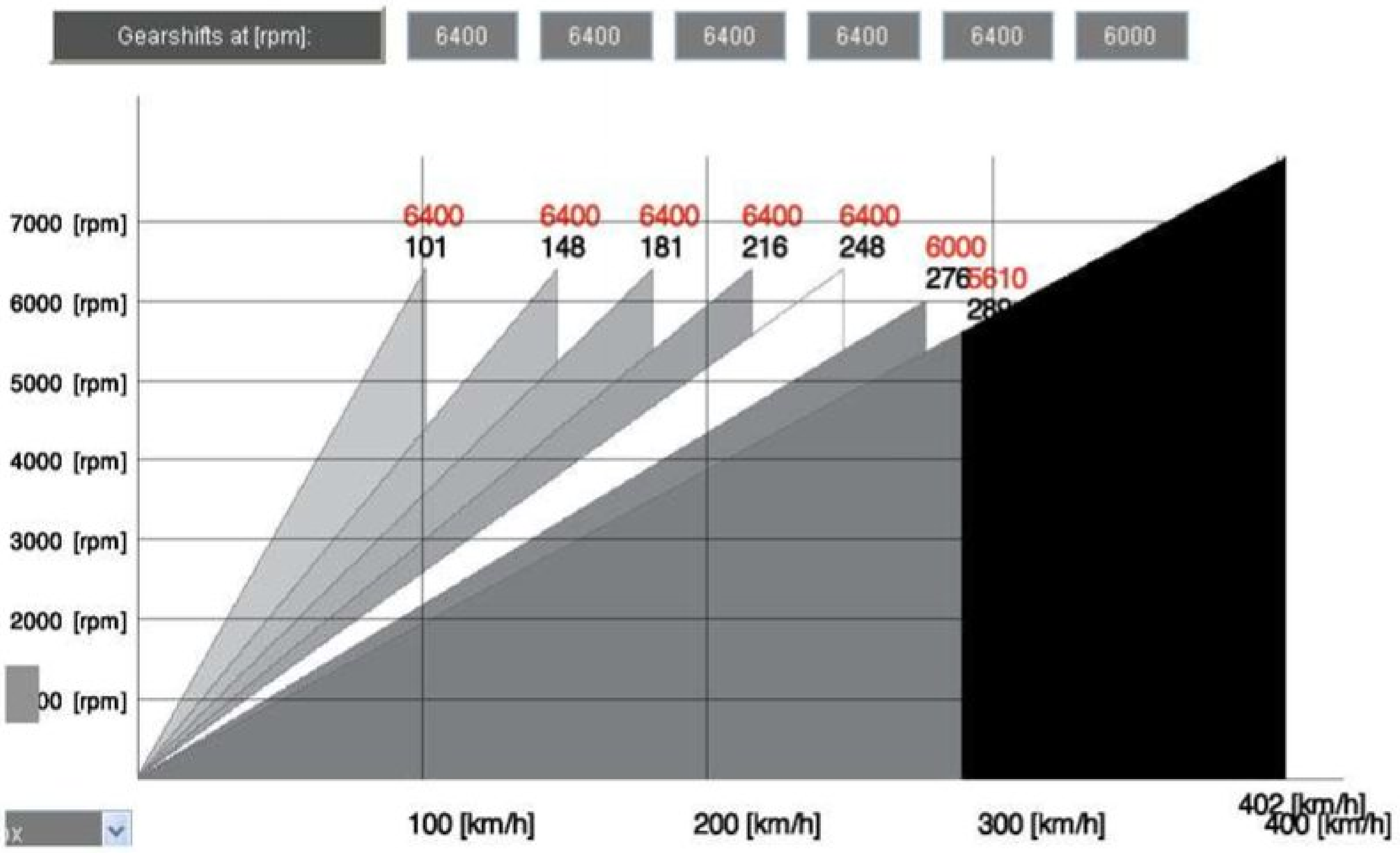

Figure 8: gearbox graph for a 4-litre with a 30ml/sec fuel limit

shown in **Figure 7**. All the gears are short shifted in order to keep the engine in its most efficient range. This combination of engine, gearbox and shift points results in a lap time of 3:39.88 and a fuel consumption of 4.95-litres over a lap. Top speed is also 277km/h.

Comparing the graphs of the fuel consumption explains the reason for this much faster lap time, with equal fuel consumption.

In the top graph of **Figure 6**, it can be seen that in the lower gears, the extra power is used to accelerate faster out of the corners, which helps a lot for the lap time. At this moment the stronger engine uses more fuel compared to the less powerful engine. However, as both setups shift to the higher gears, the bigger engine is more and more short shifted, reducing the engine rpm and subsequently the fuel consumption. Next to this advantage, in the third graph it can be seen that the more powerful engine is constantly run in a more effective rpm range. Its theoretical efficiency is close to 35 per cent whereas the smaller engine runs 32-33 per cent.

FUEL FLOW LIMIT

In the draft regulations of August 2012, the ACO stated a maximum fuel flow of 34.4ml/sec. The V8 engine detailed on the previous page does not even reach that limit. So one could go even a small step further, increasing the engine a bit more to accelerate fast out of the corners and perhaps run subsequently part throttle in highest gear, or even let the car roll from a point onwards.

As a comparison, a fuel flow of 30ml/sec would cause the bigger engine to short shift also in the lower gears, in order to remain below the 30ml/sec limit. If there would be a fuel flow limit of 30ml/sec, the gear ratios and shift points need to be altered as in **Figure 8**.

Running the model on the Le Mans track leads to a lap time of 3:40,72 with again a fuel consumption of 4.95-litres. With this setup, the model reaches a top speed of 284km/h.

In **Figure 9**, the simulation results shows that due to this shift strategy, the model loses in the initial acceleration, but wins by the end of the straight, resulting in a higher top speed. The white line represents the 30ml limit configuration, while the black lines show the results when setup for the 34.4ml/sec limit. The 30ml/sec limit will cause the car/driver to drive a normal "full power" strategy. With the higher limit, there will be an active fuel save strategy on the straights, leading to possible strange and potentially dangerous racing behaviour of the drivers.

In the example above, the model is roughly 174 seconds on full throttle, and 10 seconds on part throttle. To simplify things, lets assume that in the part throttle period, the engine consumes on average half of the full throttle amount. This would mean that the 4.95-litre needs to be consumed in 174 + 0.5 x 10 = 179 seconds. So the average fuel flow would be 27.65ml/sec.

If the lap time is reduced by 10 seconds to 3:30, for simplicity reasons one could assume that the 179 seconds will be reduced to 169 seconds, which would mean an average full flow of 29.29ml/sec. In order to see the drivers really having a race, and not backing off on the straights, it seems beneficial to reduce the maximum fuel flow limits compared to the values proposed.

AERODYNAMIC EFFECTS

How do the aerodynamics of the vehicle influence the result? Will there be a tendency to go to an absolute low drag, no wing chassis?

In the example, the chassis has a frontal area of 1.9 [m²]. The drag coefficient is 0.38 and the total downforce 1.66 (0.67+0.99). So the aerodynamic efficiency (downforce/drag) is 4.37. Comparing the figure to the CW value of street cars, it seems already quite a low drag variant, considering the amount of downforce that is generated.

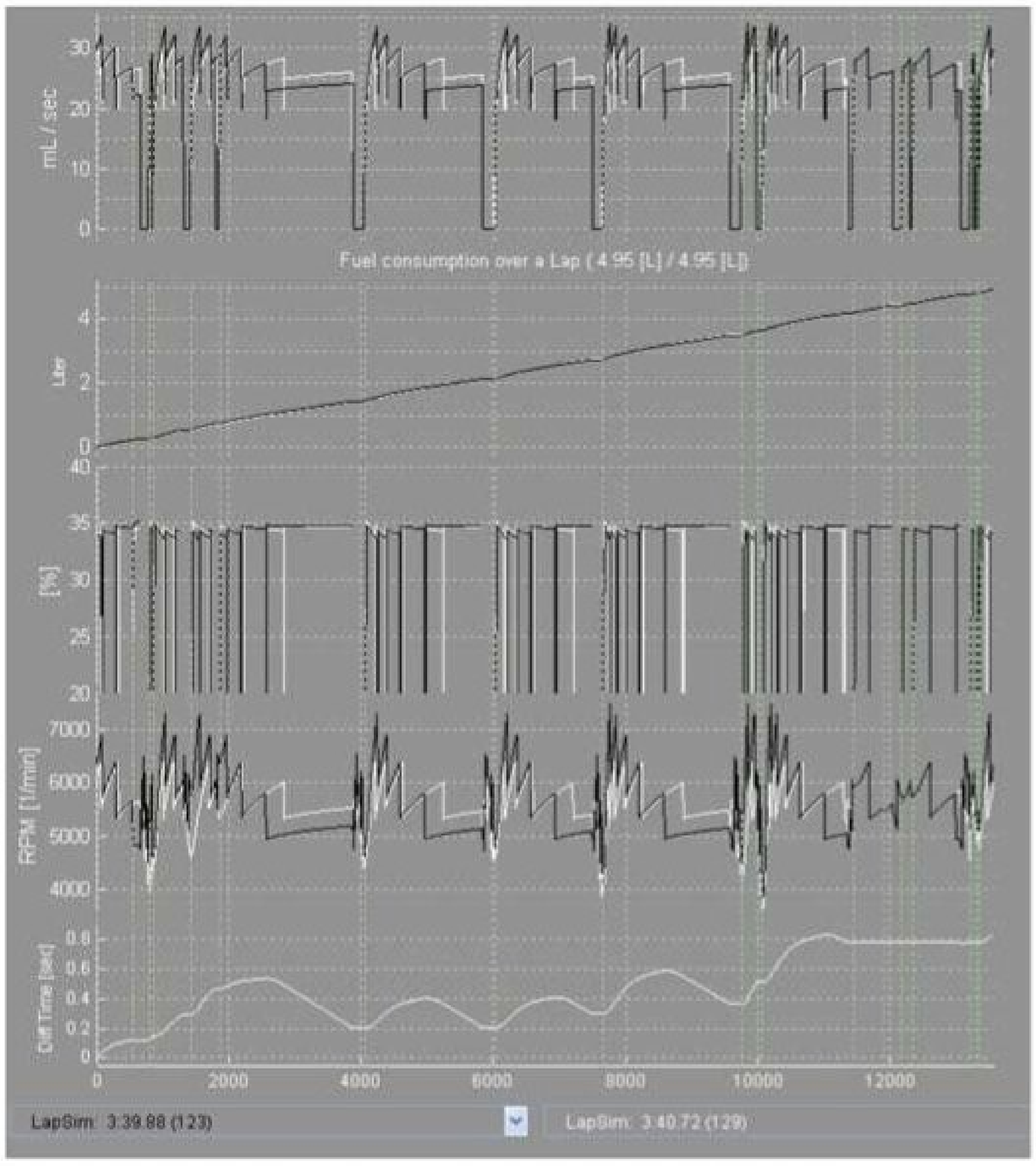

Figure 9: comparison simulation results 4-litre with a 30ml/sec (white) or with 34ml/sec (black) fuel low limit

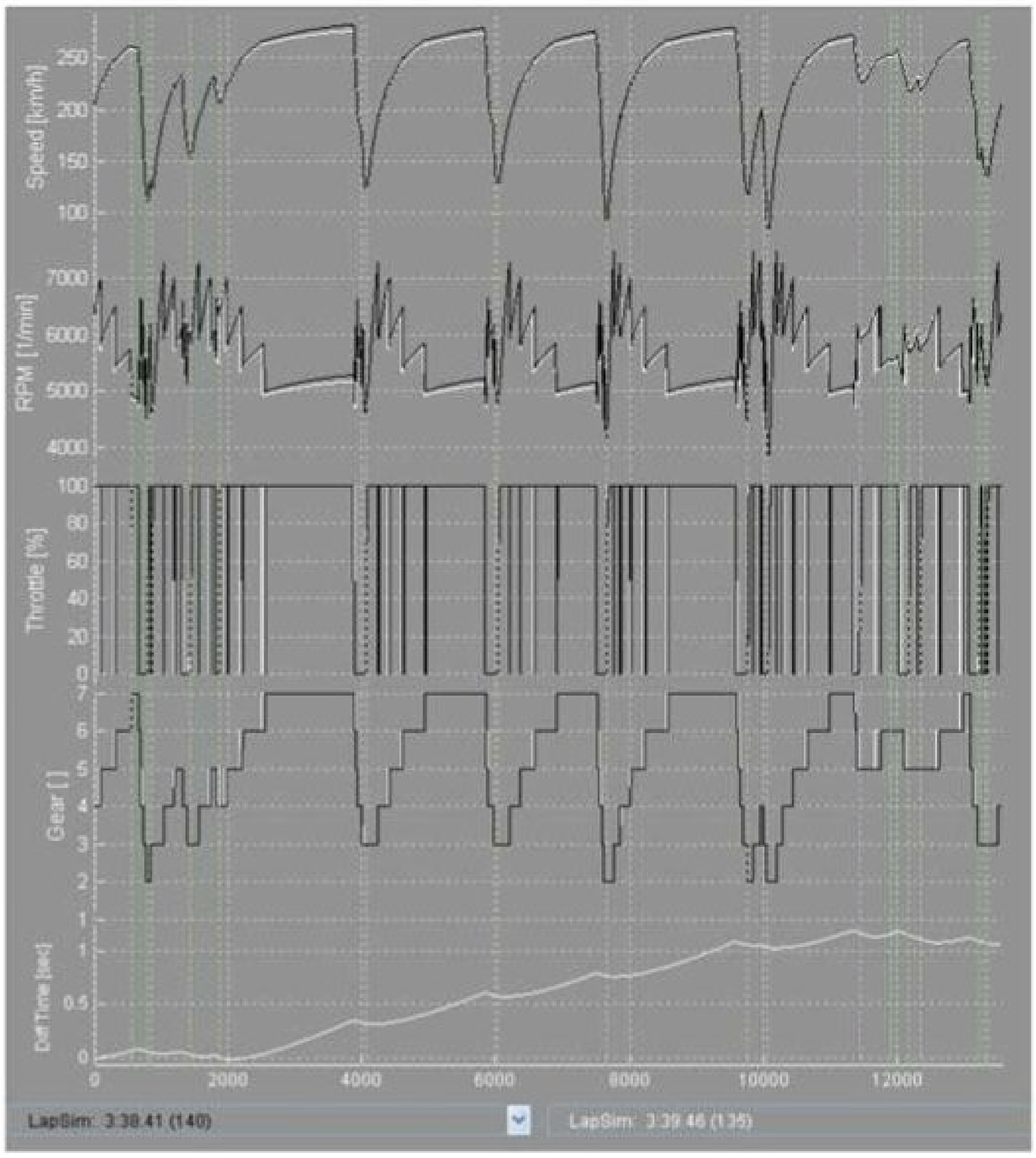

Figure 10: illustrating a direct comparison between +5 per cent downforce and -5 per cent drag

As an alternative, a variant 5 per cent more downforce is calculated. Drag coefficient remains the same at 0.38, and downforce coefficient is increased to 1.75 (0.71+1.04). The shift points need to be slightly reduced in order to reach the fuel limit. With 4.95-litres consumed the lap time is 3:39.46, an improvement of 0.42 secs.

Going in the opposite direction, reducing the drag by 5 per cent to 0.362 leads to a lap time of 3:38.41 with 4.95-litre fuel used. This would mean an improvement in lap time of 1.45 secs.

As a comparison, a sensitivity analysis is made for the engine efficiency. What would be the effect of a five per cent more efficient engine? To get a first impression and to keep things simple, a pretty quick and dirty solution can be found simply by increasing engine power with the same engine efficiency. In order to simulate the increased engine efficiency, both the fuel limit as well as the maximum fuel flow is increased by 5 per cent, meaning 5.20-litres per lap and a maximum 36.1ml/sec. As a reference, the standard aero variant is chosen, so drag is 0.38 and aerodynamic efficiency 4.37.

With optimised gear ratios and shift points, the lap time is reduced to 3:36.47, with a top speed of 282km/h and the desired fuel consumption of 5.20-litres. This leads to a lap time improvement of 3.41 seconds.

SHIFTING DEVELOPMENT

Announcing the regulations, FIA Endurance Commission president Lindsay Owen-Jones said: 'Thanks to in-depth work and excellent collaboration, the ACO and the FIA have announced a unique set of extremely innovative technical regulations for 2014 that are in phase with the times we live in. It should encourage the development of powerful and spectacular cars, and also the development of technologies that have real meaning for the everyday motorist.'

There will be a increase in lap time, but the cars will still be fast and be driven flat-out. Instead of developing engines which run in a maximum power state, which is unrealistic for every day driving, they will be run in a state which has much more relevance for our daily driving. Reducing drag will still be important for race victory, but maximum downforce, for the first time in decades, significantly loses its relevance. An increase of 5 per cent engine efficiency will lead to a reduction in lap time of more than 3 seconds, whereas an increase in downforce of 5 per cent brings only 0.42 seconds. There will be a huge shift to the development of engine efficiency and drag reduction, two areas where the public can profit from the factory's racing efforts. Congratulations to those involved for making such a simple, but very effective regulation.

OVERVIEW

	Mass	Drag	Downforce	Fuel	Fuel Flow	Lap Time
LMP 2012	1000 [kg]	0.38	1.66	6.18	No Limit	3:32,81
2014 364 HP 2.8 6 Cyl	930 [kg]	0.38	1.66	4.95	34.4 [mL]	3:45,46
496 HP 4.0 V8	930 [kg]	0.38	1.66	4.95	34.4 [mL]	3:39,88
max 30 [mL/sec]	930 [kg]	0.38	1.66	4.95	30 [mL]	3:40,72
+5% Downforce	930 [kg]	0.38	1.75	4.95	34.4 [mL]	3:39,46
- 5% Drag	930 [kg]	0.362	1.66	4.95	34.4 [mL]	3:38,41
+5% Engine Efficiency	930 [kg]	0.38	1.66	5.20	36.1 [mL]	3:36,47

Chris van Rutten graduated from Delft University, under Prof Hans Pacejka, in 1995.

He began development of LapSim software in 1997 – the first release was in 2000. In 2005 the development of an engine simulation started. This had the same goal as the chassis simulation: easy to use, accurate and fast, supplying answers.

Over the years, LapSim has been used to develop sophisticated traction control algorithms, both for petrol as diesel engines. Cars running these traction control systems have won Le Mans, both in GT, LMP2 and LMP1 class.


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Comparative values

Following a season of hybrid cars running alongside their non-hybrid counterparts, the data makes interesting reading. And it appears that each have their strengths...

BY PAUL TRUSWELL

Audi packed the podium at Le Mans with a 1-2 for their R18 e-tron entries, with an R18 ultra taking third

Head of Audi Motorsport, Dr Wolfgang Ullrich, revealed earlier this year that Audi Sport began to think about the hybridisation of a Le Mans sports car soon after the first successes of the TDI engine in 2006. It wasn't until May 2012, though, at the Spa 6-Hours, that the first hybrid Audi, the R18 e-tron quattro, was ready to race. At both Spa and Le Mans, rounds two and three respectively of the World Endurance Championship, Audi entered two of the hybrid cars alongside two of the non-hybrid R18 ultras, and at the next two World Endurance Championship races at Silverstone and Interlagos, one of each variant was on the grid.

This provided the Audi Sport Team Joest crews with plenty of opportunity for comparing the two technologies, especially since the R18 e-tron quattro and the R18 ultra were designed to the same specifications: the only exception being the flywheel-driven hybrid system.

Now that the dust has settled on the season, it is possible to look back and compare in detail the performances of the two technologies, particularly with regard to the effectiveness of the hybrid system.

In terms of outright lap times, there seemed no doubt at Spa that the electric energy that the hybrid system delivered to the front wheels - worth, according to Audi, around 200 extra horsepower out of the corners - provided the e-tron quattro with an important advantage over its conventional cousin.

But - as shown in **Table 1** - the difference wasn't so clear-cut in the other rounds. There's not much to choose between the times.

However, in terms of top speed, the difference between hybrid and non-hybrid is plain to see, as **Table 2** shows. Counter-intuitively perhaps, it is the non-hybrid that has the higher terminal velocity. In all the cases shown, the speed trap is located at the end of a long straight, by which time the benefits of the hybrid's superior acceleration have been lost, and the residual drag of the hybrid motor has a small but significant effect.

Note that both **Tables 1** and **2** show the best result of the event, which means that all the free practice sessions as well as qualifying and the race are included.

The stated objective of the ACO in encouraging hybrid

TABLE 1: AUDI

	Event best lap time (including practice and qualifying)			
	Hybrid		**Non-hybrid**	
Car No	1	2	3	4
Spa	2m 01.851s	2m 01.579s	2m 02.437s	2m 02.093s
Car No	1	2	3	4
Le Mans	3m 23.787s	3m 24.276s	3m 24.078s	3m 25.514s
Car No	1		2	
Silverstone	1m 43.663s		1m 43.628s	
Car No	1		2	
Interlagos	1m 22.765s		1m 22.953s	

TABLE 2: AUDI

	Event top speed in km/h (including practice and qualifying)			
	Hybrid		**Non-hybrid**	
Car No.	1	2	3	4
Spa	299.2	296.7	300.0	302.5
Car No.	1	2	3	4
Le Mans	326.1	326.1	330.1	331.1
Car No.	1		2	
Silverstone	275.5		276.2	
Car No.	1		2	
Interlagos	282.0		284.2	

technology in the WEC was not just as a means of improving performance, though. Since 2009, when the Le Mans regulations expressly allowed energy recovery systems for LMP1 cars, it was the benefits for road car technology and greater overall efficiency that motivated developments in the arena of hybrids. And it was with this objective that Audi embraced the new regulations; in parallel, obviously, with maintaining its dominant position in the category.

Encouraging efficiency is nothing new. From the early days of the Le Mans 24-hour race, the Index of Performance and more particularly, the Index of Thermal Efficiency were integral (and very rewarding) elements of the event. Despite the occasional appearances of diesel-engined cars directly after the second world war,

"It is far from clear whether hybrid technology is any more efficient than non-hybrid"

however, neither the 'Index' nor the 'Formula' made any provision for the superior energy density of diesel fuel, something that will be scrutinised closely in the regulations for 2014.

At the simplest level, efficiency in racing can be measured merely by taking the ratio of average speed against fuel consumption. **Table 3** shows the detail of the calculation for the hybrid and non-hybrid Audi R18s raced at Spa, Le Mans, Silverstone and Interlagos.

Some words of explanation for the calculations in the table are needed here. The average speed is calculated from the distance travelled in each race divided by the time spent on the track (time spent in the pit lane is subtracted). Fuel consumption uses the European convention of 'litres per 100km' - dividing the number of litres of fuel used during the race by the distance covered. For this purpose, it is assumed that the tank is full at the start of the race, and is empty at the end, which is not necessarily true, but at least provides a basis for the calculation.

Apart from Spa, where the weather played a role, it is far from clear whether 'hybrid' - in the Audi sense of the technology - is any more efficient than non-hybrid, although there is a temptation to suggest that, since three times out of four, the most efficient car is the one being driven by Tom Kristensen and Allan McNish, that driver experience might have some role to play.

As a matter of interest, in 1961 the Index of Thermal Efficiency at Le Mans was won by the 1600cc Sunbeam Alpine of Peter Harper and Peter Proctor, with a score of 1.07. Using the same method for calculation, the Audi R18 e-tron quattro of McNish, Kristensen and Dindo Capello, would have scored 2.08, which demonstrates the improvements in efficiency in the last 50 years!

The approach that Toyota brought to the table this season was very different, of course. Their solution was to store

TABLE 3: AUDI SPORT TEAM JOEST

	A				B				B/A			
	Fuel consumption in litres/100km				Average speed in km/h (excluding time in pits)				Efficiency (higher is better)			
	Hybrid		Non-hybrid		Hybrid		Non-hybrid		Hybrid		Non-hybrid	
Car No.	1	2	3	4	1	2	3	4	1	2	3	4
Spa	34.47	32.43	34.64	34.99	190.33	189.38	190.80	190.37	5.52	5.84	5.51	5.44
Car No.	1	2	3	4	1	2	3	4	1	2	3	4
Le Mans	33.28	31.91	32.86	32.14	220.75	220.96	219.29	218.83	6.63	6.92	6.67	6.81
Car No.	1		2		1		2		1		2	
Silverstone	34.65		34.70		193.99		193.64		5.60		5.58	
Car No.	1		2		1		2		1		2	
Interlagos	34.65		33.91		179.43		179.89		5.18		5.31	

TABLE 4: TOYOTA/REBELLION

	A			B			B/A		
	Fuel consumption in litres/100km			Average speed in km/h (excluding time in pits)			Efficiency (higher is better)		
	Hybrid	Non-hybrid		Hybrid	Non-hybrid		Hybrid	Non-hybrid	
Car No.	7	12	13	7	12	13	7	12	13
Le Mans	42.01	43.70	42.91	213.90	214.50	210.32	5.09	4.91	4.90
Car No.	7	12	13	7	12	13	7	12	13
Silverstone	51.41	49.07	46.90	194.48	189.59	188.90	3.78	3.86	4.03
Car No.	7	12	13	7	12	13	7	12	13
Interlagos	48.86	48.56	48.13	180.41	177.46	175.78	3.69	3.65	3.65
Car No.	7	12	13	7	12	13	7	12	13
Bahrain	60.99	52.50	50.93	176.84	170.80	169.89	2.90	3.25	3.34
Car No.	7	12	13	7	12	13	7	12	13
Fuji	50.66	49.66	49.74	180.79	175.72	174.20	3.57	3.54	3.50
Car No.	7	12	13	7	12	13	7	12	13
Shanghai	53.72	52.56	50.23	176.85	171.70	170.57	3.29	3.27	3.40


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FIGURE 1: TOYOTA HYBRID (THS-R) Drive control

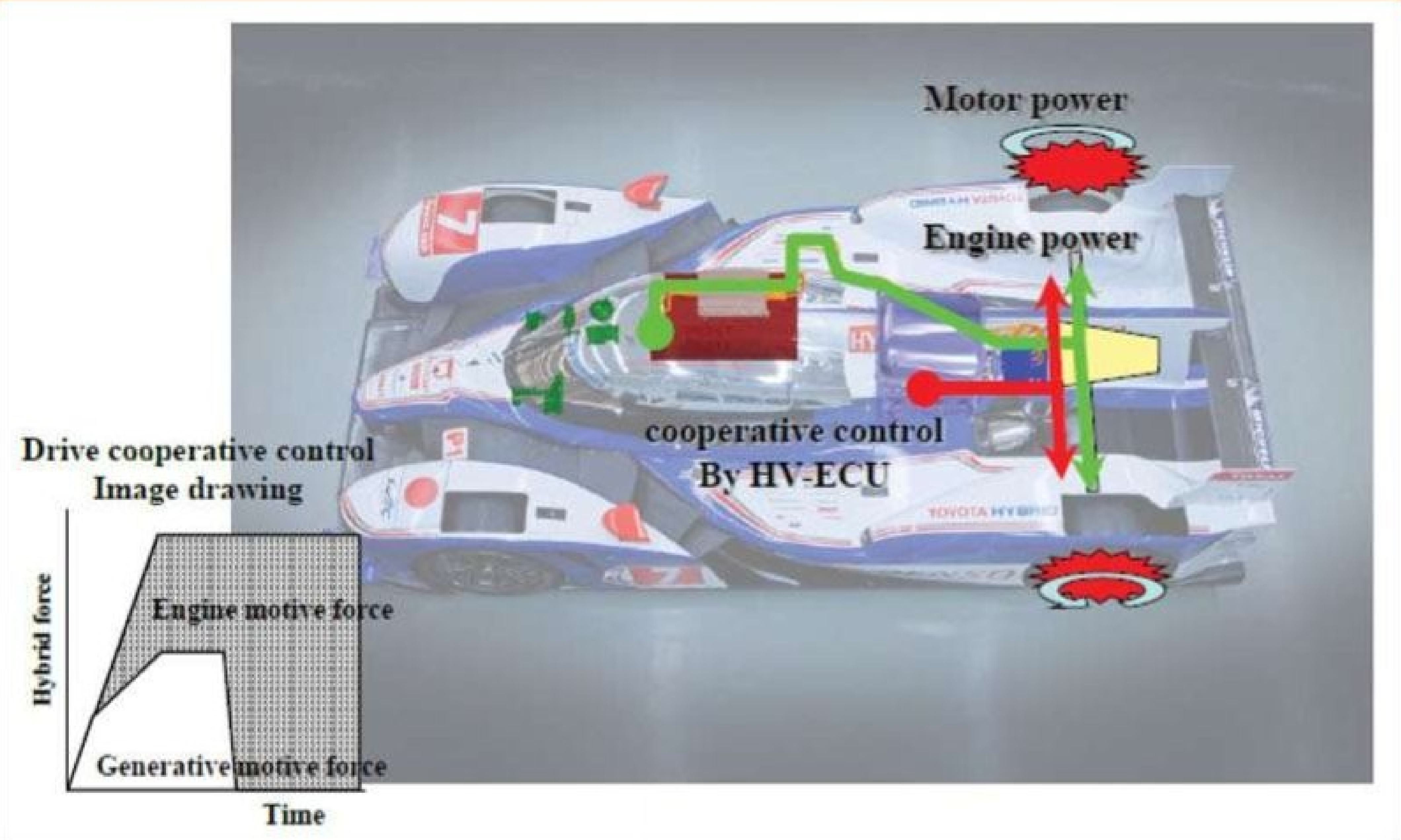
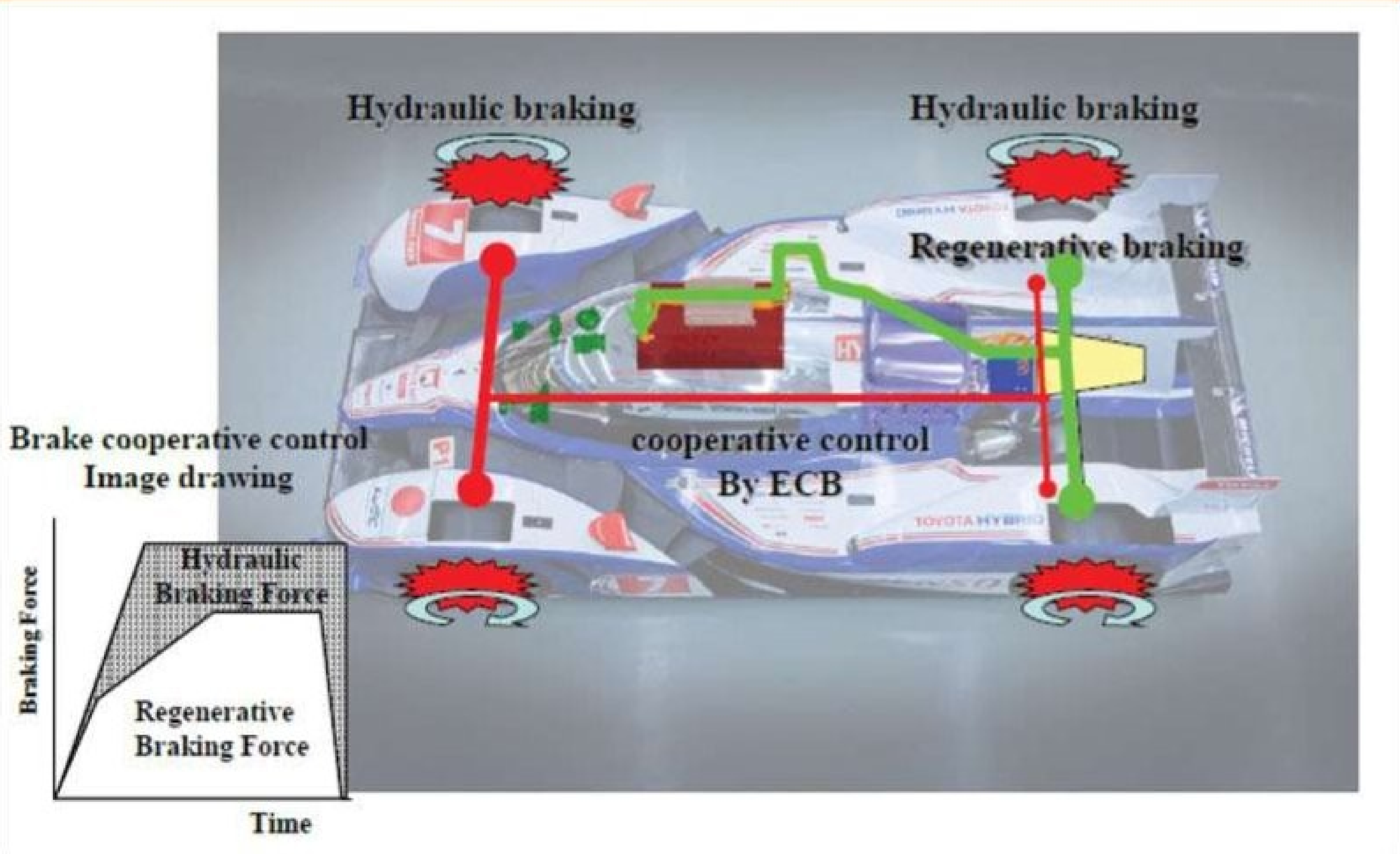


FIGURE 2: TOYOTA HYBRID (THS-R) Braking control



energy in a capacitor, and to use this to power an electric motor driving the rear wheels. They were free of the restriction of only providing power above 120km/h that severely affected the Audi. The trouble is that there was no non-hybrid version of the TS030 to enable any relative efficiency evaluation of the hybrid motor to be made. However, Toyota Motorsport, in simulation exercises, estimated that the hybrid was giving them between two and two-and-a-half seconds per lap at Le Mans.

Anthony Davidson was extremely positive about the 'boost' of the hybrid at Le Mans, commenting that 'it gives you a real kick as you accelerate'. Figures suggest that it is providing 50 per cent more power than Audi's flywheel system, and is certainly capable of exceeding the limit of 0.5MJ mandated by the 2012 regulations.

The regulations also prevent Toyota from harvesting energy from the front wheels, so the braking at the front is 100 per cent hydraulic, but this could be altered, if the regulations would change. Equally, drive could also be delivered to the front wheels using the current technology, should that become allowed in the future.

What is not really feasible, based on these numbers, is a comparison of efficiency between the diesel- and petrol-fuelled cars. However, while the customer variant of the 3.4-litre normally-aspirated V8 engine used by the Rebellion Lolas was not the same as the works hybridised version, a comparison of efficiency is still interesting and can be seen in **Table 4**. It is very clear that the Hybrid is faster, as is the fact that it uses more fuel. What these figures reveal is that Toyota's hybrid motor is not being used as a tool to improve efficiency, but rather one to boost performance over a lap.

The appearance, at Silverstone, of revised rear bodywork to provide more downforce is testament to the fact that Toyota felt that there was performance to spare. Certainly, sacrifices were made in the speed recorded through the official speed traps. At Shanghai, where the Japanese manufacturer had perhaps their most convincing victory, the best speed of the TS030 Hybrid was more than 12km/h slower than the Audi. Compare this to Le Mans, where Toyota was using 'conventional wheel arches' – ie a normal width rear wing – and where the Toyotas were recording the fastest speed through the speed trap just before the first chicane on the Mulsanne straight.

Toyota's sophisticated hybrid system has required a lot of fine-tuning, not only in the traction control used to deliver the power but also in the harvesting of the energy under braking. Toyota uses an electronically controlled brake (ECB) system, which blends the braking forces from the regenerative and the hydraulic brakes in order to optimise the capacitor's charging level.

Once charged, the capacitor delivers power to the rear wheels through an electronic co-operative drive control system (HV-ECU), which optimises power delivery, and hence provides the startling acceleration. There are two stages of this that need to be considered: not just the traction control, but also the delivery of the boost from the capacitor to the drivetrain.

Hisatake Murata, the hybrid project leader at Toyota Racing, describes the whole fine-tuning process as 'an elaborate dance' – Toyota schematics of these systems are shown in **Figures 1** and **2**.

With the regulations for 2014 now under close scrutiny, it will be interesting to see to what extent the use of new technologies, whether hybrid or not, will improve both performance and efficiency.

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Helping to give the opposition the slip

Advances in lubrication technology have served to reduce engine wear and increase fuel efficiency. And the benefits don't stop there...

BY BY SAM COLLINS

The world has changed over the last 20 years. Growing environmental concerns and the digital revolution has shifted priorities in every element of life. Motorsport especially has been significantly affected, as more ecologically astute rule-makers have forced engine designers to switch their focus from outright performance to overall efficiency, and they have to consider the whole car in this process.

This means that friction reduction is more crucial than ever, and that really comes down to two things: coatings, which will be dealt with in a future issue, and lubricants. Racing teams such as those in Formula 1 have already started to use the oils in the transmission and engine as a key design component. The viscosity of the lubricants plays a decisive role. It conditions the performance of the running gear: crankshaft, con rods and pistons. The film of oil between the metal parts must be thin enough to ensure maximum slip speed. These components and the oil have to cope with enormous physical constraints. A piston, for example, goes from 0 to 37m/s almost 600 times per second. If some parts of the engine like the middle of the ring of the piston's skirt or the bearings – outside their critical cycle – have an oil film whose thickness is relatively satisfactory (2 to 3 microns), there are others, like the distribution, for example, that are separated by a few thousands of microns.

"Being able to run the engine hotter allows the oil cooler to be made smaller, reducing drag"

But this race for power must not compromise reliability. In the area of the distribution the pressures generated are in the realm of a Gig Pascal (100 tons/m2) under which the oil solidifies. The lubricant is heated and splits, and the film can disintegrate. High-pressure contact between metallic parts leads to a loss of power and the risk of engine failure. So it's necessary to have the right formula to protect the engine from wear – not too thin but not too thick either. It is also possible to work on the additives to create an additional film that protects the surfaces.

As a result, all of the top teams have lubrication partners such as Petronas with Mercedes or Mobil 1 with McLaren. These firms are constantly developing new oils to give performance and efficiency gains, and not only in the engine department. For example, developing a lubricant that allows the engine to run hotter without failing means that there can be some significant aerodynamic gains.

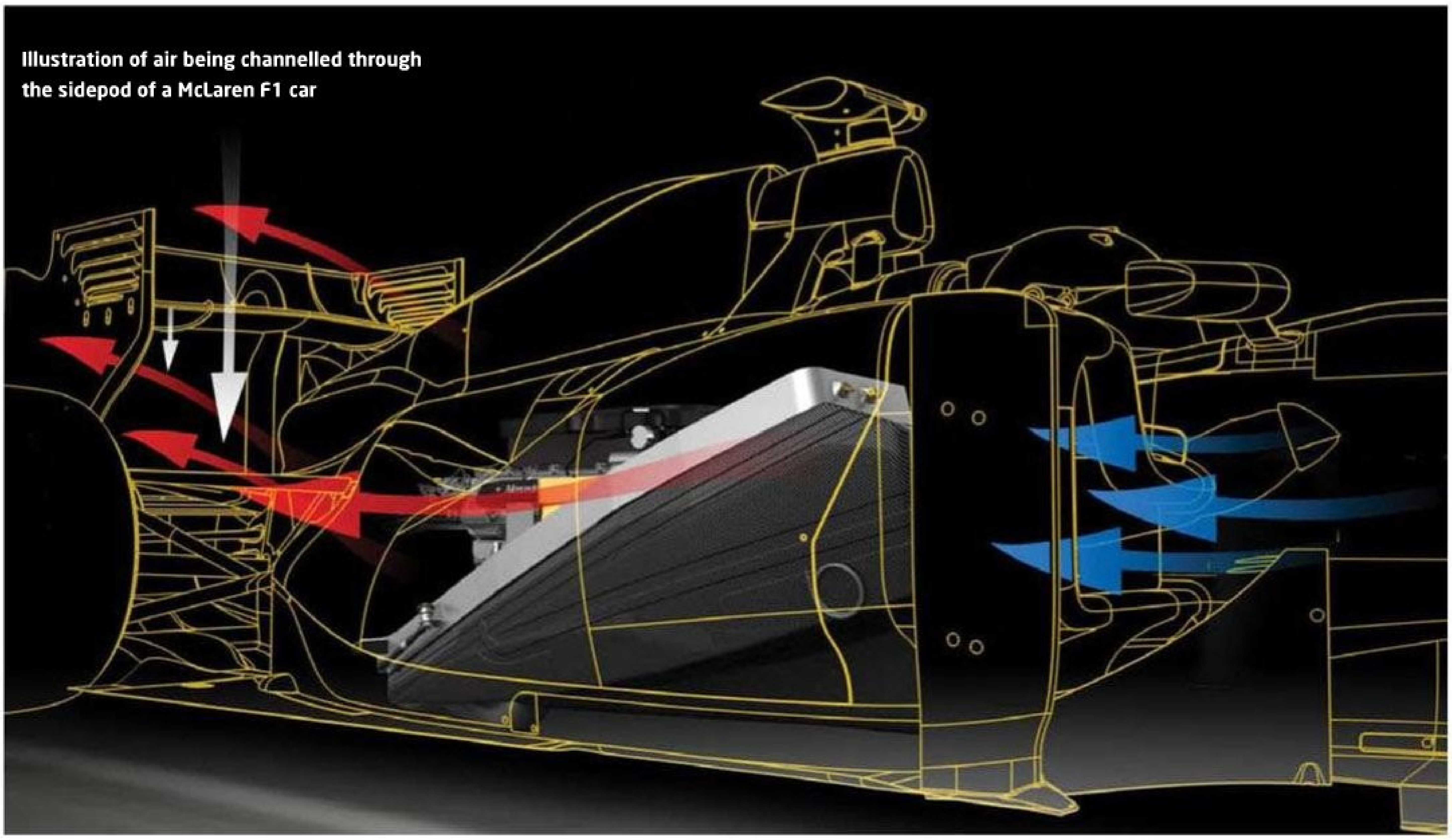


Illustration of air being channelled through the sidepod of a McLaren F1 car

Shell's Track Lab, which accompanies and supports Ferrari at every Formula 1 weekend, conducting oil and fuel analysis

F1 cars tend to have an oil cooler mounted in one of the two sidepods – being able to run the engine hotter allows that cooler to be made smaller, reducing drag. Increased rear downforce can also be achieved through aerodynamic improvements to the exit ducts. In an F1 car the engine oil which flows through the radiator cools down by approximately 40degC, while the air channelled through the sidepod inlet heats up to about 75degC.

It's not just Formula 1 teams that have specialist lubrication partners – in NASCAR the situation is no different. Back in 2011, NASCAR felt that speeds in Sprint Cup races on super speedways had gone too high with the so-called two-car tango drafting style. So it decided to make some changes to the car to prevent it. The cooling duct on the nose was shrunk in such a way that if drivers attempted to do the two car tango the trailing car would lose all of its cooling.

'NASCAR must have forgotten that we are racers, and we will continue to try to find ways to go faster. That is our job, and it is what we love to do,' enthused Lake Speed, a certified lubrication specialist at Joe Gibbs Racing who was tasked with finding away around this problem.

'One of the first ideas was to increase the volume of oil moving through the engine. Water is not the only coolant in the engine. The oil can do as much as 40 per cent of the cooling, so we set out to find ways to increase that. Increasing the capacity of the oil system was an easy way to dissipate heat energy over a larger volume of oil, and then we built oil coolers as large as the radiator to help to cool the oil. Even with these mechanical modifications, we had to make some chemical adjustments to the oil in order to compensate for the higher oil temperatures.'

In the two-car tango only the trailing car ran a high temperature, and the leading car ran as normal. But in a Sprint Cup race, any car could be leader or trailer, meaning that the oil had to be able to cope with both types of running conditions.

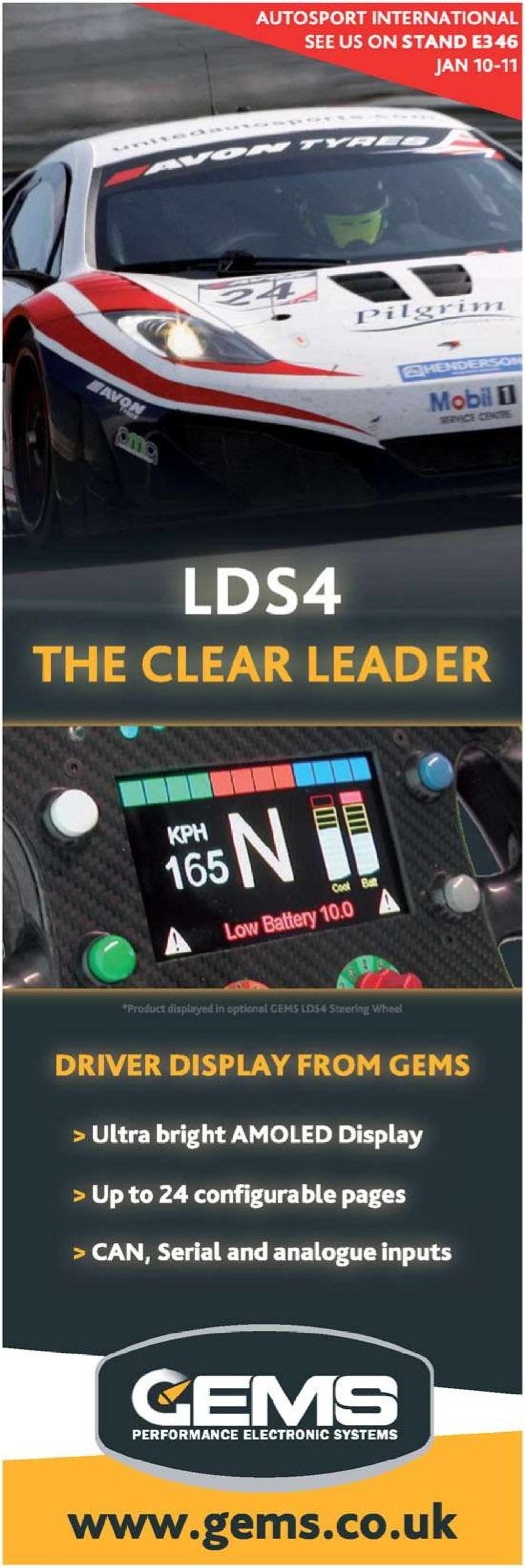
'It was common to see oil temperatures above 135degC during the race. Previously, 105degC was normal and 115degC was cause for alarm. Of course, the "cold" temperatures of 105degC allowed us to use very thin oils – 0W-10. Now with temperatures reaching 140degC or more, we increased the viscosity of the oil to 0W-20. That was a step in the right direction, but pack racing led to sustained high temperatures,' explains Speed. 'We could have gone to a much heavier oil, say a 10W-40. That would have raised oil pressure. However, a thicker oil actually generates more oil temperature, so we did not want to do something that contributed to higher temperatures.'

"A thicker oil generates more oil temperature – we don't want to contribute to that"

What was needed was a lightweight oil, and Speed found the solution in an unexpected place – a wind turbine. 'Chevron Phillips has recently pioneered a new generation of synthetic base oils that provides greater thermal stability,' he says. 'Developed for wind turbine gearboxes, these new synthetic base oils provide a much higher viscosity Index. The higher the viscosity Index, the less the oil thins out at higher temperatures. Using these new higher viscosity index base oils, we created a new 0W-10 oil that would not thin out too much at high temperature.'

The experience and expertise these teams are gathering has started to filter down to other parts of the sport. The Joe Gibbs products, for example, are made available to rival teams as well as smaller outfits as part of the 'driven' range of products.

The top teams in motorsport use fully synthetic lubricants which offer better properties at high temperatures, but those products tend to be more expensive. A synthetic lubricant contains more highly refined base oils than those used in conventional mineral oils, and compared to mineral oils they are much more free-flowing. The performance of synthetic oils is more robust, especially in terms of low temperature pumpability, high temperature stability and protection against deposits. These attributes translate directly into less engine wear, increased fuel economy and longer engine life. This has been critical in F1, where the regulations have both frozen the specification of the engine but also substantially increased the mileage. Each unit has to complete, and oil has been crucial in this process.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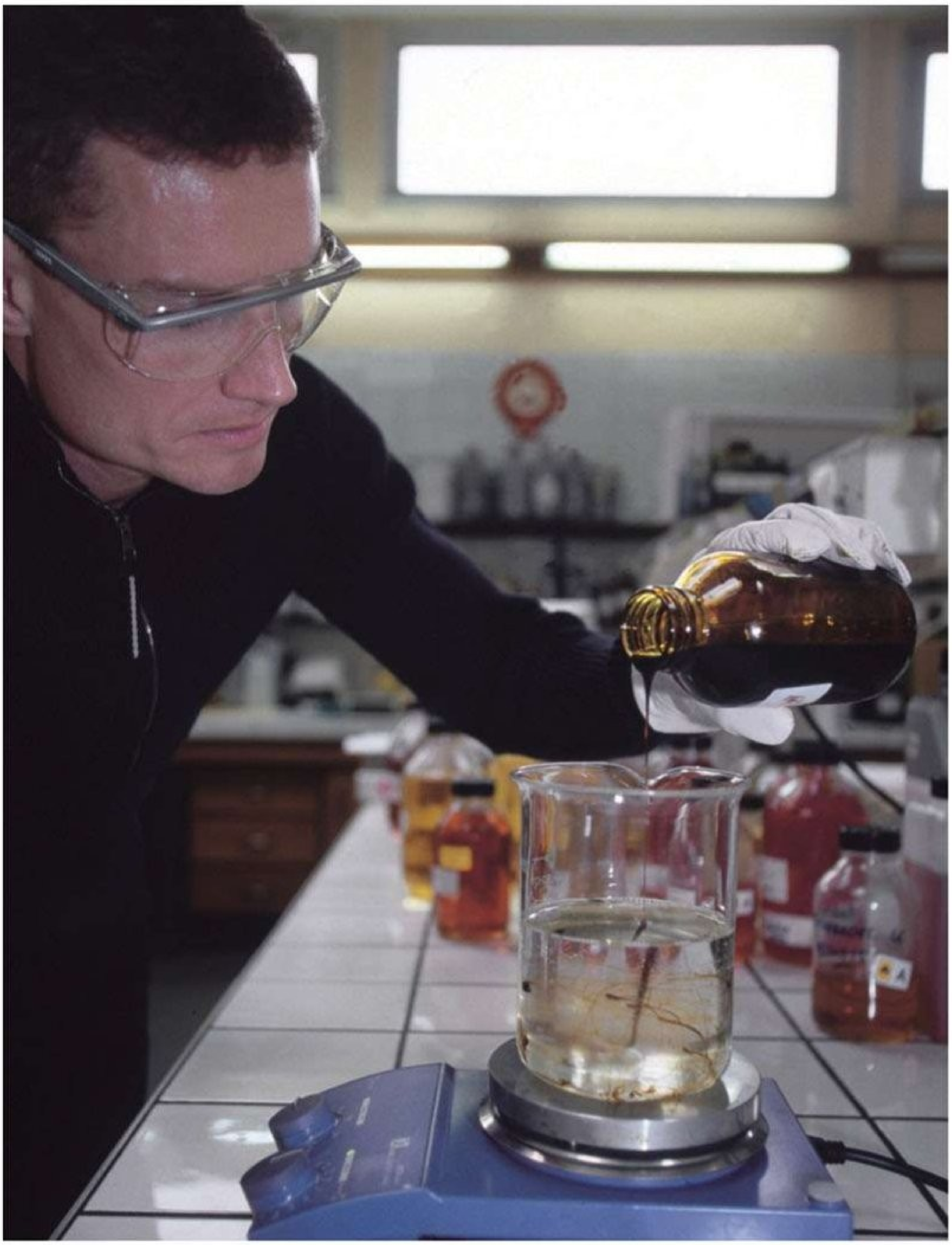


F1 veteran David Coulthard hits the laboratory and weighs in on the chemistry side

It comes back to the emphasis on efficiency. A more fuel-efficient engine requires less fuel to go a set distance, while producing a given power output than a less fuel-efficient one producing the same power. With refuelling not permitted in Formula 1, the teams are striving to save weight by carrying less fuel, while still keeping the engine alive. Some teams even have dedicated lubricant analysis laboratories in their race trucks, such as Shell's Track Lab which accompanies Ferrari. As the engines are sealed, the teams use the oil to diagnose wear rates and to highlight any issues by monitoring the levels and types of metal traces present in the oil. Too much iron? It's likely to be a combustion problem. Too much chrome indicates abnormal wear of the piston rings. Excessive copper or tin indicates the big end bearings may be in poor condition.

When the 2.4-litre V8 engine formula was introduced in 2006, engine wear was such that an engine nearing the end of its multi-race cycle would be significantly less powerful than one at the start of its life. That's no longer the case thanks to the advances in lubricants. Of course the teams and oil companies keep the exact details of the fluids a closely guarded secret, as it's the one area of Formula 1 that has almost no regulatory restrictions.

'It's mainly at the level of the formulation of the fuel and the lubricants that it's possible to gain some extra horsepower when there is an engine freeze,' explained pitlane veteran Denis Chevrier in 2007. 'In the first case, combustion is optimised according to specific constraints like the engine's maximum revs. In the second, the role of the chemists is to find a viscosity that limits friction to the maximum. But the lubricant must always contain some basic anti-wear properties to guarantee reliability.'

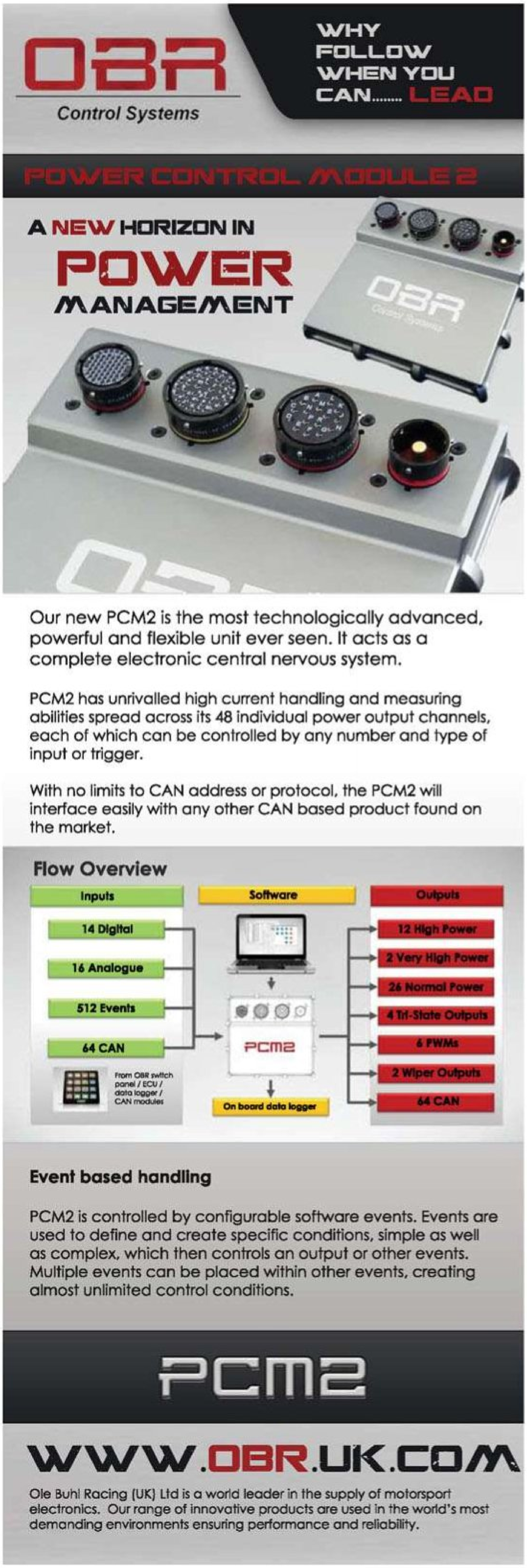
For the mid-range or club competitor, many specialist high-performance lubrication companies offer a semi-synthetic racing oil. These oils are a blend of traditional mineral oil with up to 30 per cent synthetic. They offer many of the same benefits as the synthetics but at a lower price. For example, a litre of Ravenol 10w-50 fully synthetic racing oil costs £12.49 whereas the same firm's 15w-50 semi synthetic retails for £8.25.

RACING CHEMISTRY

Lubrication specialists like Speed aren't motorsport engineers or engine builders in the traditional sense – they're more like chemists dealing with substances at the molecular level. Additives like Zinc dialkyldithiophosphates (ZDDP) have been utilised by companies like Cam-shield to prevent wear on critical components, especially in engines with flat tappet cams. These cams and lifters undergo very high boundary layer pressures and/or shear forces at their contact faces, and ZDDP has been shown to reduce the wear in this area as well as in other regions such as big-end/main bearings, and piston rings and pins. Sometimes, as is the case with Cam-shield, the ZDDP is an aftermarket additive, but in some competition oils like Valvoline VR-1 it comes as standard.

Often the additives in lubricants are given brand names, like 'Estorline Technology' and 'TechniPlate Lubricity Systems' in the case of mid-range lubrication firm Klotz. What all of these things do is integrate the bonding process with generous amounts of phosphorous and zinc. The end result protects critical engine components from shearing and power-robbing friction.

This push for efficiency has a real relevance beyond motorsport. In production cars, the goal is the same – increasing efficiency and improving fuel consumption in addition to reducing emissions. It is here where motorsport is still improving the breed through largely unregulated technological development that filters down directly to the car in the showroom.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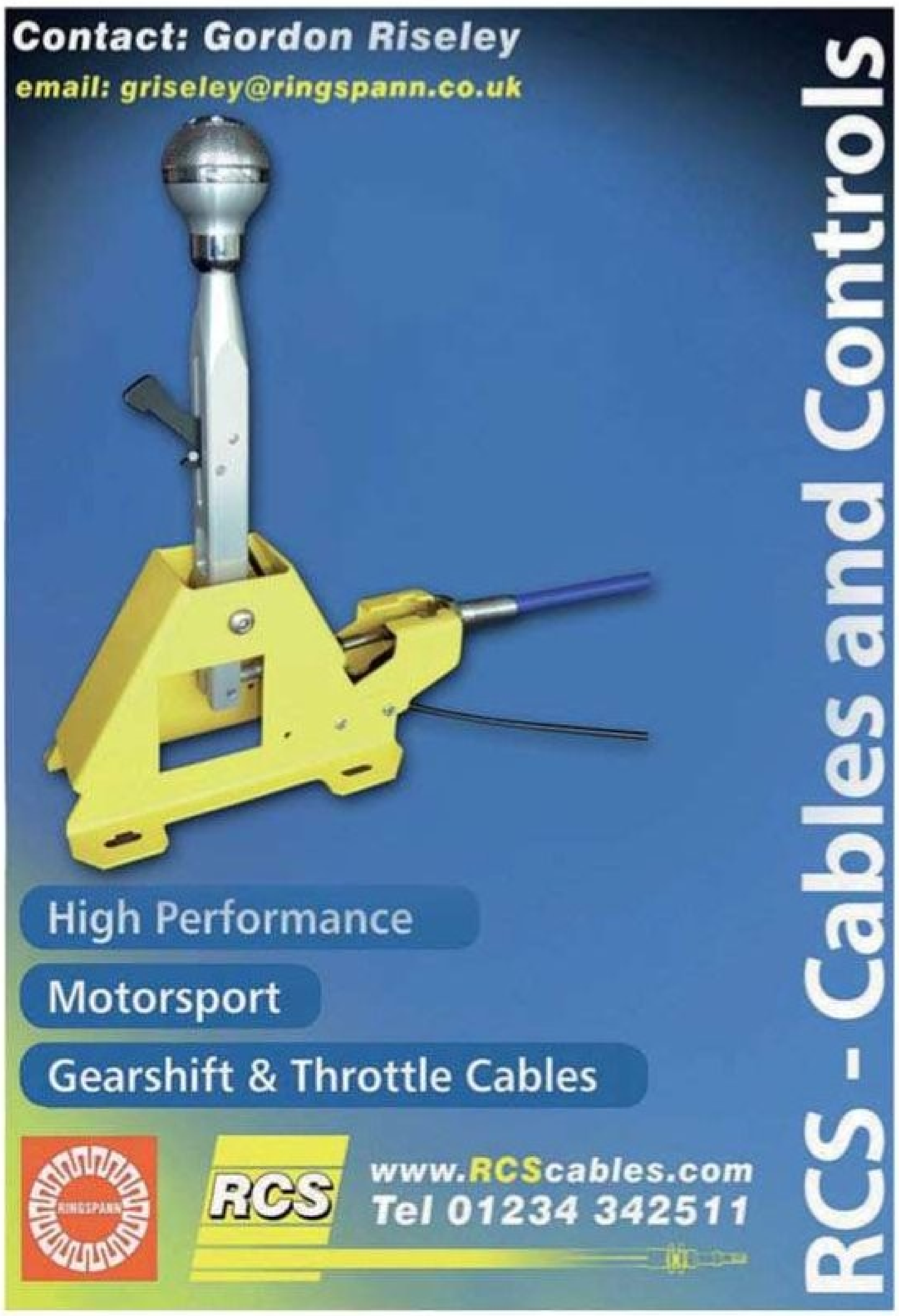
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Measuring up

Accurate measurements are critical in motorsport – thankfully there's ever-more reliable and versatile systems available

BY GEMMA HATTON

The fight to be the quickest is escalating, whether it be on track, or in the factory. The rate of development is quickly becoming one of the most vital elements for a team's success, and the technological advances in the metrology industry have a huge role to play.

'We're always looking for something to improve the process and reduce the lead time from design to car,' says Chris Charnley, quality manager at Red Bull Technology, 'but now we're getting to the difficult stages – looking at the finest details of how technology can help to improve our process.'

The Hexagon Group is a global leader in design, measurement and visualisation technologies, with over 20 production facilities and 70 precision centres worldwide. The UK arm of this organisation is Hexagon Metrology, based in Telford. Hexagon Metrology focuses on a wide range of products and services for all industrial metrology applications.

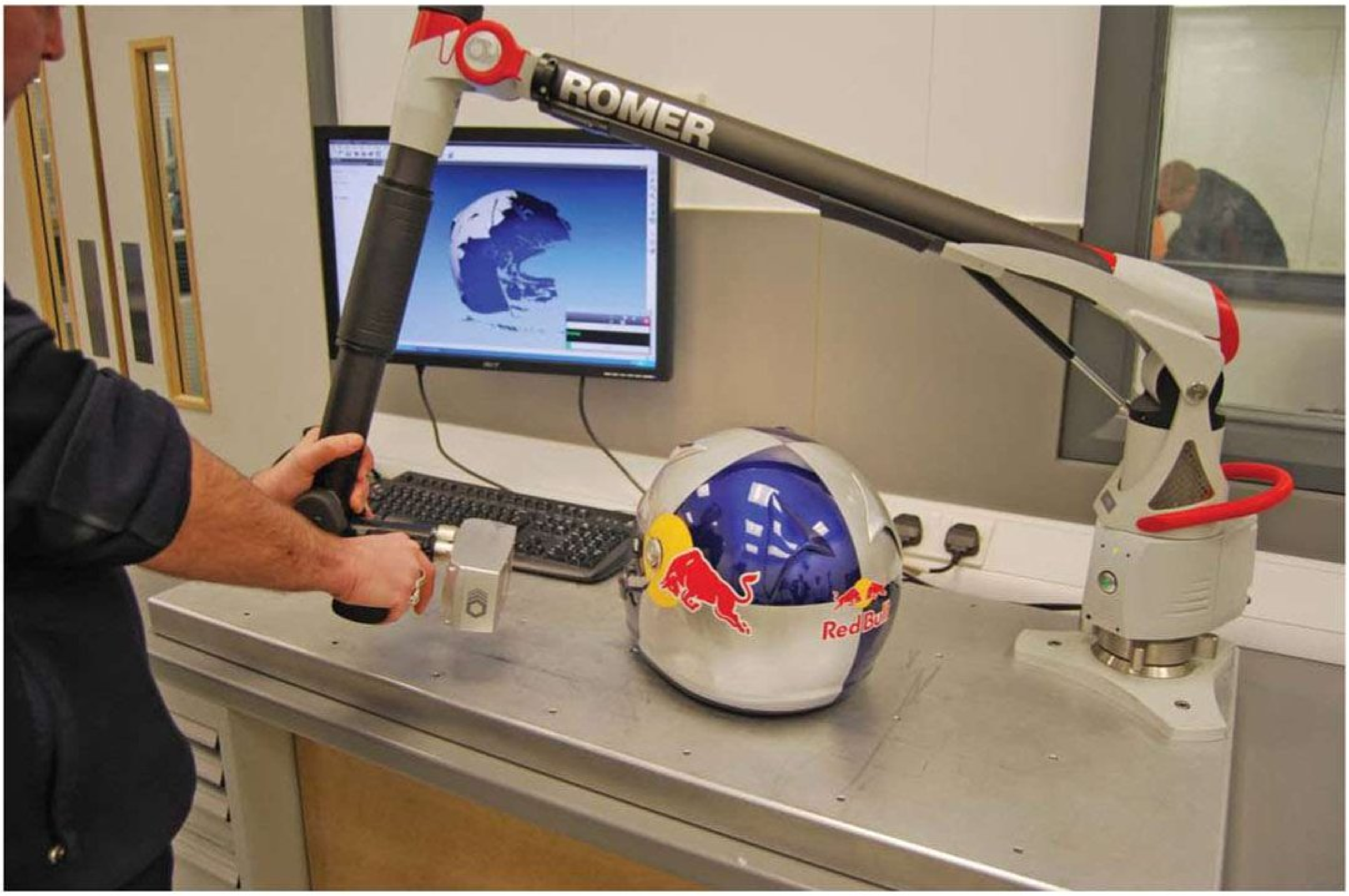
Of particular interest is Hexagon Metrology's involvement within motorsport. This is a highly successful sector for the company, as Steve Shickell, Hexagon Metrology UK sales manager highlights: 'We have a whole range of our products such as laser scanners, CMMs and hand tools in all the major F1 teams in the world – all of them have got our equipment to a degree.'

Red Bull Technology are one of these teams and have fully utilised the products Hexagon have to offer, specifically the Leica Absolute Tracker and Leica T-Probe system and the ROMER Absolute Arm.

THE LEICA OPTIONS

The Leica Absolute Tracker is a portable large volume measurement machine which remains in a fixed position during measuring. The Leica T-Probe, meanwhile, is a handheld, six degree of freedom device. When a measurement needs to be taken, the T-Probe is placed in the desired position, with the probe touching the surface. A visible laser beam is generated inside the 'head' of the tracker which then hits a corner cube reflector situated on the T-Probe (also known as a target). Due to the corner cube prism, the laser bounces directly back to the tracker. The laser beam automatically connects to the T-Probe thanks to 'PowerLock' technology. The tracker head uses angle encoders and simple trigonometry to define the x and y coordinates of the 'target' (reflector), and therefore the point being measured. Furthermore, a camera on the laser tracker traces a series of LEDs on the T-Probe to measure the orientation. So, the probe is moved around the surface, the camera follows, and the measurement is taken.

For example, the front wing would be measured and the Leica Absolute Tracker would sit in



The Romer Absolute Arm and CMS108 Laser Line Scanner in use, measuring and analysing a Red Bull helmet


Making use of the Leica Absolute Tracker system and handheld T-Probe at Red Bull

front. The software imports the CAD model and, once aligned with the wing, the T-Probe can then be placed on any area that needs inspection. The T-Probe has a ruby stylus, so it is a contact probe which physically touches the surface and analyses the deviations. Displayed on the screen is a colour map of the part, and each individual measured point will be green if in tolerance and red or blue if out of tolerance, so problematic areas can be quickly identified.

Of course, with such complex shapes, it is extremely difficult to access hidden areas because the laser always needs to be in line with the reflector and the camera always needs to trace the LEDs. This is where the innovation really lies – the T-Probe has an adjustable stylus length which can be up to 600mm long, and attached to the end is the actual probe. Therefore, the reflector and the LEDs remain in line with the laser and the camera, but the stylus can carry out measurements on areas hidden behind parts.

'The Leica Absolute Tracker with the T-Probe is a most innovative tool that has come on to the market,' says Charnley. 'The T-Probe makes it so easy to use. In fact, with very little training, most people can use it. The difference it has made to how we process parts is unbelievable – we have reduced the measurement time from two hours to 20 minutes in most cases. The nature of the business is change, and components do, so we need to have equipment that offers the most flexibility.'

Each week Red Bull Technology produce many components that need checking ,and using a CMM created bottlenecks within the process. The use of the Leica Absolute Tracker has eased this bottleneck, because now every part can not only be inspected, but the car has a higher quality finish and any problems can be rejected before it goes on track.

'The whole concept of improving measurement technologies is the aim to capture problems before the next stage of the process,' says Shickell. 'It's like an upside-down pyramid, where if you find a problem at the base, it is relatively inexpensive and quick to fix, but if found later on, that problem is magnified and in Red Bull Technology's case it could cost the race.'

Formula 1 is renowned for pushing the boundaries of technology, and it's no different here. The Leica Absolute Tracker and Leica T-Probe can achieve an accuracy of 20-30 microns. Bear in mind that a strand of hair is approximately 70 microns in thickness, so to be able to measure to this degree of accuracy is impressive. This gives the team the opportunity to exploit the tolerances as much as possible to maximise or minimise the dimensions of the car to their advantage within legal limits.

Altering the dimensions of an F1 car by a few microns may seem like a lot of effort for what could appear to be a minimal gain, however this is not so, as Shickell explains. 'In 2005 I did a demonstration at an F1 team where I measured the car using the Leica Tracker system and the results were astonishing,' he says. 'There was a total of 9mm error on the front wing which the engineers could not believe. After that, they used me as a measurement service to set the cars up, and that was the first weekend that their driver not only achieved pole, but won the race, so they were instantly bought into the technology.

'F1 teams spend time developing the car in the wind tunnel with CFD software to, in theory, have a good car, but they could never physically manufacture it accurately enough. The teams have always struggled with the correlation between the designed car and the physical manufactured car. The Leica Absolute Tracker helps translate what they do in the wind tunnel to the physical car, maximising this correlation. Now, they can guarantee that when they build a car, it will replicate their design intent.'

"Find a problem early, and it's relatively inexpensive to fix. Found later, it could cost the race"

THE ROMER ROUTE

The ROMER Absolute Arm has seven axes that it can physically move in. There are carbon-fibre tubes that reciprocate and at each knuckle joint there is an angle encoder, similar to the Laser Tracker, seven angles are measured and at the end of the arm there is a probe which can be of two types: either a ruby stylus, (which makes contact with the surface – similar to the Leica T-Probe) or a CMS108 Laser Scanner. This is a 'flying dot' scanner, so it generates a laser line which is composed of a series of dots.

A major problem when scanning is the effect of the material characteristics and the surrounding environment. For instance, reflective surfaces or different colours can generate noise in the data. If the environment is too dark, the camera won't be able to pick up the laser points, resulting in no data at all. To resolve this, other companies spray the part in a development powder, so the laser measures the powder, but this introduces a level of uncertainty because not only are you not measuring the actual surface, but it also

The ability to measure to a high degree of accuracy means that Formula 1 teams value the technology

contaminates the part. To avoid this, the CMS108 has the ability to autorange and change the intensity of each point as it scans. Also, the laser line width can be adjusted to the work piece geometry. The non-contact design ensures that the surface of the part is not deformed in any way, and to be able to scan 30,000 points per second makes the ROMER Absolute Arm extremely efficient.

Similar to the Leica Absolute Tracker, a CAD model is used and aligned to the part. The engineers project the points on the surface using the ROMER Absolute Arm and the attached CMS scanner and the output is a colour map, where green means in tolerance and red means out of tolerance.

The ROMER arm with the CMS scanner also enables reverse engineering, which is a major advantage for teams with such high development rates. 'If we have to suddenly incorporate a new design, for instance altering the shape of a particular part for a better fit, then we can scan this area and generate the corresponding CAD surfaces,' says Charnley. 'This enables the next iteration to have that modification accurately built into the design, ready for manufacturing.'

'I've been looking for four years for this type of innovation where I can scan any component without having to change a lot of settings. The output of this system is a report which we then give to the design office so they can instantly see where the error lies, and by how much. It is actionable information which is exactly what the process has delivered.'

Both the measuring arm and the laser tracker are revolutionary scanning systems, but which are used, when and why? 'Every piece of metrology equipment has its forte,' explains Charnley. 'The Leica Absolute Tracker has got a massive range that we can work on, it's flexible and we can get into lots of different areas, with different types of probe as long as we've got line of sight. We use the ROMER Absolute Arm to check individual components and sub-assemblies before they get to the car. If you've got a repeat task in a localised area, you'd use an arm; if you've got complex variety and size then you'd use a tracker.'

Although the ROMER Absolute Arm comes in different sizes, there are limitations of up to 4.5m measurement range, whereas Leica Absolute Trackers will measure within a volume of up to 320m with the reflector and up to 50m with the T-Probe. A further example of how the ROMER Absolute Arm can be used is for measuring the dimensions of the driver to develop moulds for the seat and helmet designs. Teams have even scanned driver's feet so they can maximise the pedal positions inside the vehicle.

'This technology has been around since 1988 and over the years we've continuously evolved it. It was initially invented for applications that were difficult to measure, such as exhausts on vehicles, or pipework. We found that the ROMER Absolute Arm is a strong platform and we've been adding new features, such as making it battery-operated, and enabling wireless scanning to make it more portable. The speed of the scanner has also increased; it only used to scan 30,000 points per second and now it can achieve 50,000 points a second. We're always developing the design, making it more robust, lighter, stronger, and making it easier to use with the software.'

Red Bull Technology specifically wanted something robust and reliable that gave high quality data – they were trying to measure areas they couldn't reach, and when they used other scanners in the marketplace there was just noise in the data. Essentially, it was the only scanner in the market that could capture good quality data on the components they were looking to measure.

"We're always developing the design and making it easier to use with the software"

SURVEYING THE HORIZON

CT (computerised tomography) scanners are currently a major topic because they can be used for measuring gearboxes, for example, without having to strip it down – similar to x-ray machines. The problem at the moment is the high expense but also, the bigger the CT scanner, the less accurate it is. 'It's a catch 22 situation, because some of the parts you want to measure are inside a big assembly. You're talking millions of pounds for a large CT scanner, but there's certainly mileage for a portable device that can see through things to measure – this will certainly be the future for metrology.

'As an organisation, Hexagon Metrology is quite big. Not only do we supply equipment for the majority of industry sectors, but also companies such as Ordnance Survey in the UK who use all Hexagon's GPS equipment for plotting the maps. One of the key things about Hexagon is the aftermarket side of our business. For example in F1, the demands are so high, if there is a problem, engineers have minutes to make a decision and they need our support now, not tomorrow. If we can satisfy the demands of an F1 team, we can satisfy the demands of any business.'

Shaker rigs revisited

Virtual alternatives to heavy-duty test equipment can be very powerful tools

One of the first articles I ever wrote for *Racecar Engineering* was on 4-post and 7-post shaker rigs. That article was over five years ago, and a lot of water has flowed under the bridge. The ChassisSim 7 post rig/shaker rig toolbox has been employed in racing categories as diverse as F3, V8 Supercars, IndyCar and GT categories. The purpose of this article is to bring you the lessons learned through using this toolbox, because it's proven to be a very useful tool to tune for mechanical grip.

Before I go into the meat of this article I want to point out that I have not been at the forefront of using this toolbox. The people who have made best use of this toolbox have been the members of the ChassisSim community who have told me what they have done. Usually these conversations have been, 'Hey! I did this – what do you think?' Typically I ask if it worked, and if they answer in the affirmative then I tell them to carry on. You can thank the ChassisSim community for the insights I'm about to present to you.

To kick things off, what the shaker rig brings to the party is that it shows you what is going on with the car in the frequency domain, as opposed to the time domain. What this means is that we subject the car to a frequency input, and we compare the ratios of inputs and outputs of the amplitudes and how far the frequencies lag behind.

To quantify this, let's consider a typical cyclical road input as illustrated in **Figure 1**.

The car will respond with the same frequency to this input, but typically with different amplitude, and a different phase angle that will lag behind the input signal. This lag is caused by the car catching up to the input signal that is applied to it. This is illustrated in **Figure 2**.

BY DANNY NOWLAN

The shaker rig measures this data for a wide spread of these signals. To appropriately measure this, we need to be looking at this data in the frequency domain as opposed to the time domain. But how do we quantify this? Fortunately a French physicist by the name of Joseph Fourier came to our rescue. He postulated that for any group of signals that repeat (which is what we get all the time in race data) they could be represented by the following:

Equation 1

$$y = \sum_{f=0}^{\infty} A_f \sin(2 \cdot \pi \cdot f \cdot t + \phi_f)$$

Where **y** is what we are looking at on the graph, **t** is time; **f** is the frequency of each component and A_f and $Ø_f$ are the frequency amplitude and phase lag respectively of each of the sine signals or frequency components. The Σ symbol means we are summing all the measured frequencies together. When we are measuring this response in the frequency domain, we are plotting A_f and $Ø_f$ for each of the frequencies we have measured on the shaker rig. To come up with A_f and $Ø_f$ we use a tool called the direct Fourier transform, but I will leave that to the interested readers to investigate in their own time.

In terms of the testing regime that is applied to the car, we put the car on a set of pads and subject it to a swept sine test where we hold the peak velocity of the input constant. What this means is that the test will start at a large amplitude and will go down to a small amplitude at higher frequencies. This amplitude can actually be quantified by taking the derivative of the input signal. This input signal can be quantified by the following:

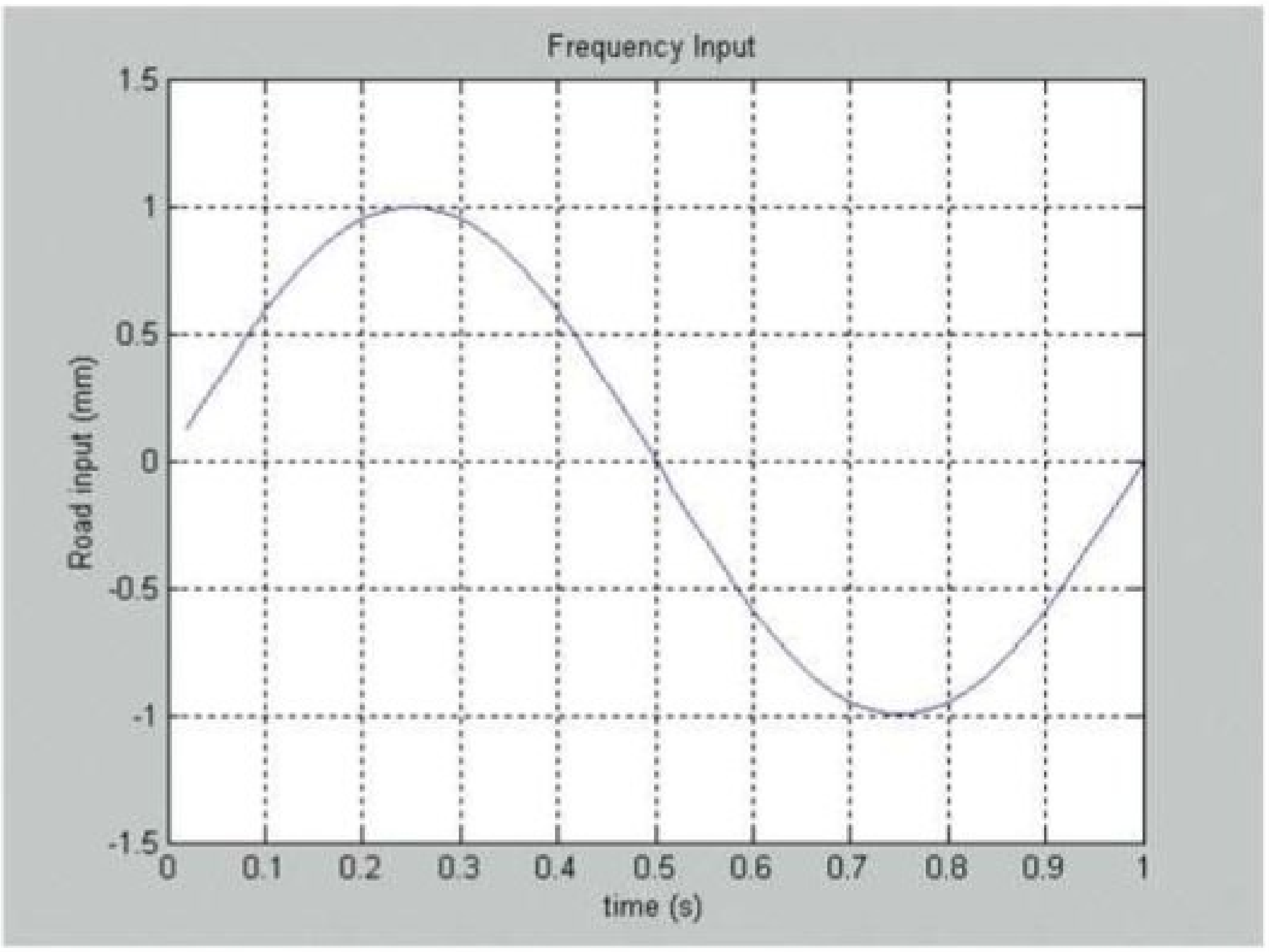


Figure1: cyclical road input

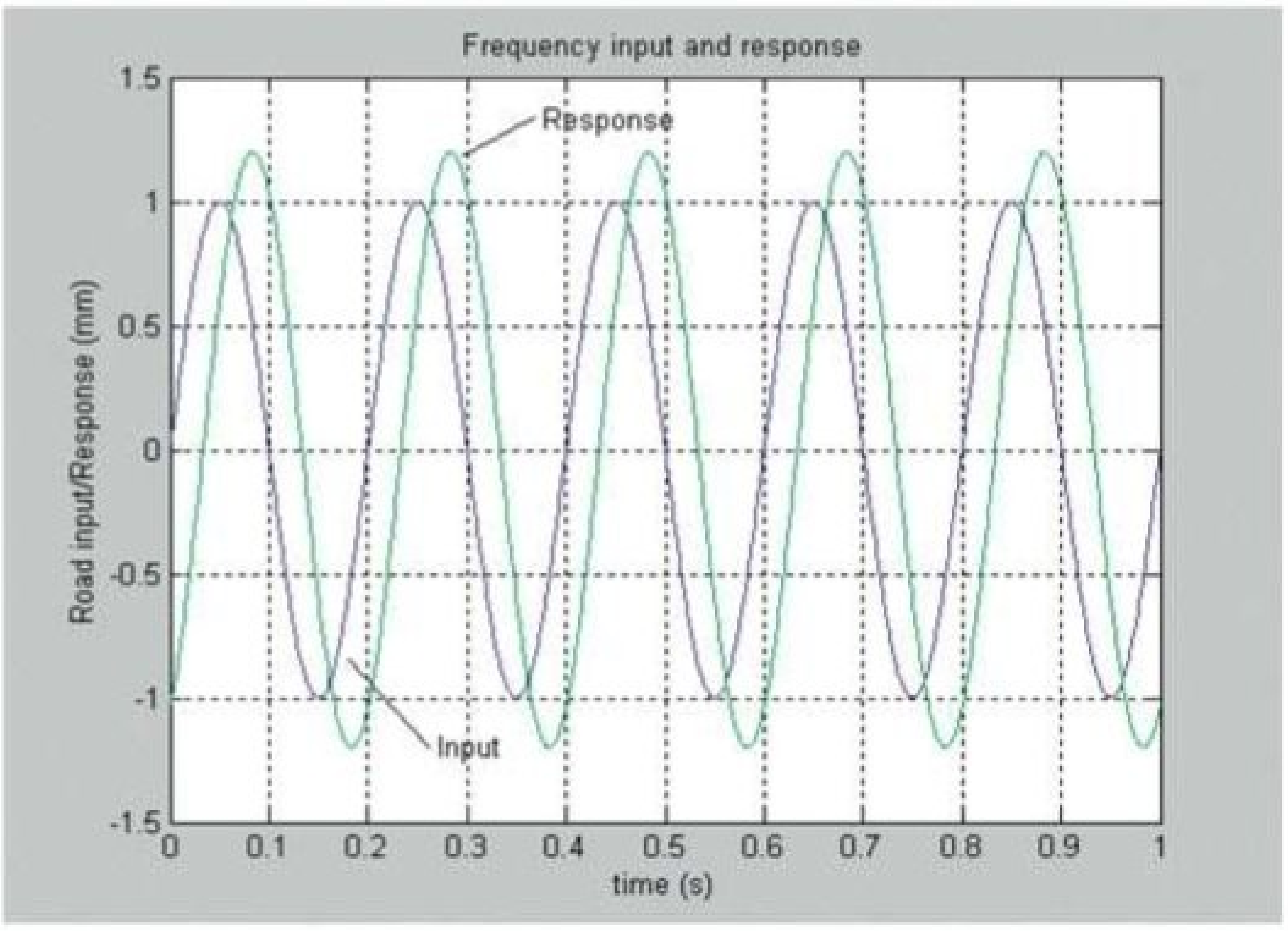


Figure 2: cyclical input versus cyclical output

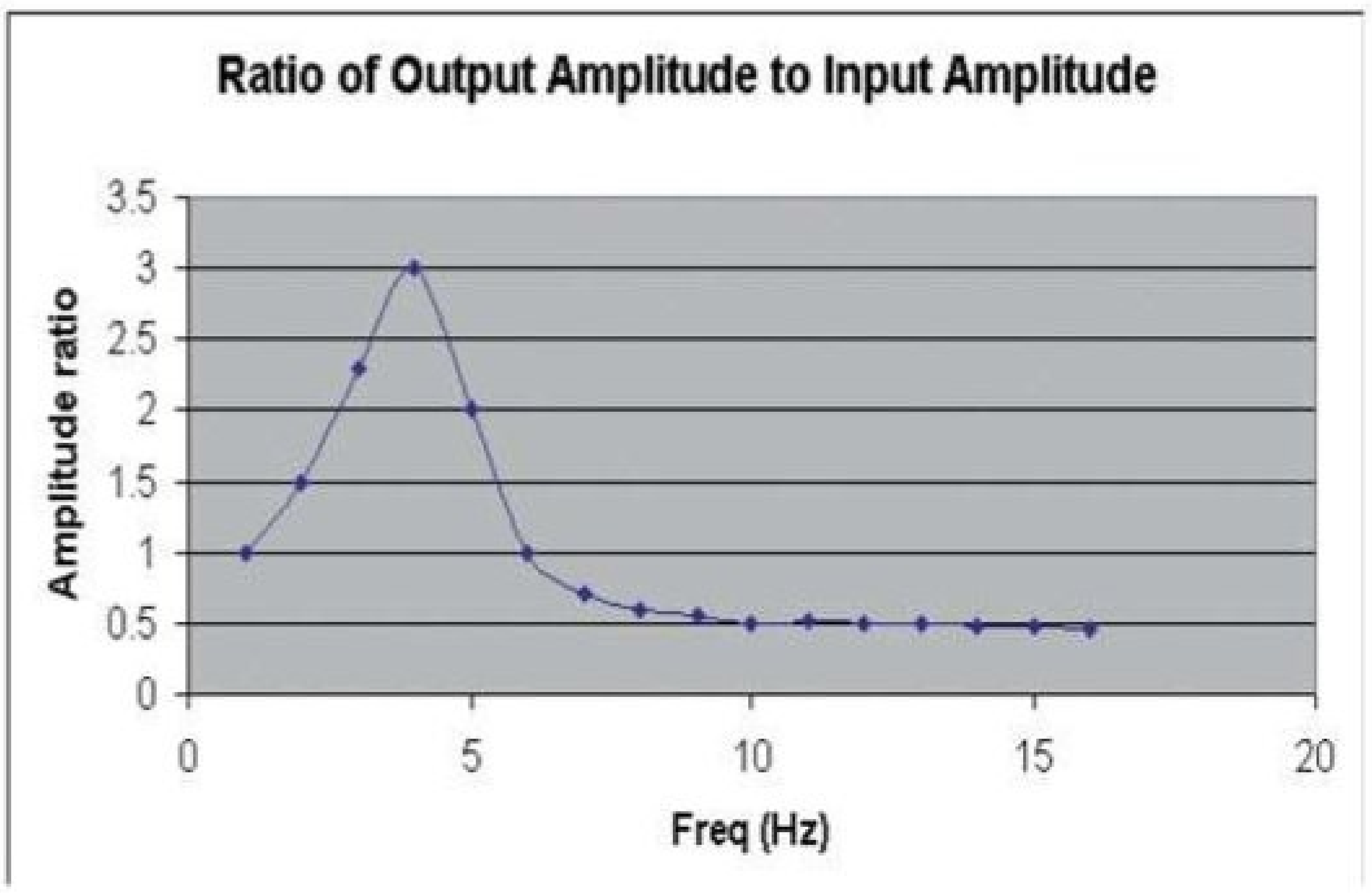


Figure 3: typical shaker rig response

Equation 2

$$y = A_f \sin\left(2 \cdot \pi \cdot f \cdot t\right)$$

Here, **y** is the actual road input. To prove this all you need to do is take the derivative of **Equation 2**. What we are doing here is logging suspension displacements and accelerations. There are a number of measures that are used to classify a cost function for a shaker rig test. One way is the contact path load variation given by Kowalczyk[1]. This is defined below:

Equation 3

$$CPL = \frac{\Delta Load}{\Delta acc_{input}}$$

The deltas represent the maximum from the equilibrium condition for a given frequency. At the end of the run, these are added up and averaged. The CPL is defined, as is load variation divided by input acceleration. Another formulation of a cost function is shown below in **Equation 4**.

In this equation the terms are:

cf = cost function values
c_1-c4 = user defined constants
Δz = change in z (heave) from rest condition
z_0 = heave at equilibrium condition
$\Delta\theta$ = change in f (pitch) from rest condition
θ_0 = pitch angle at equilibrium condition
Δz_f = change in front damper position from equilibrium condition
z_{f0} = front damper position at equilibrium condition
Δz_r = change in rear damper position from equilibrium condition
z^{r0} = rear damper position at equilibrium condition
ΔL_f = change in total front load from equilibrium condition
L_f = total front load from equilibrium condition
ΔL_r = change in total rear load from equilibrium condition
L_r = total rear load from equilibrium condition

Equation 4

$$cf = c_1 \frac{\Delta z}{z_o} + c_2 \frac{\Delta\theta}{\theta_0} + c_3 \frac{\Delta z_f}{z_{f0}} + c_4 \frac{\Delta z_r}{z_{r0}} + c_5 \frac{\Delta L_F}{L_{F0}} + c_6 \frac{\Delta L_R}{L_{R0}}$$

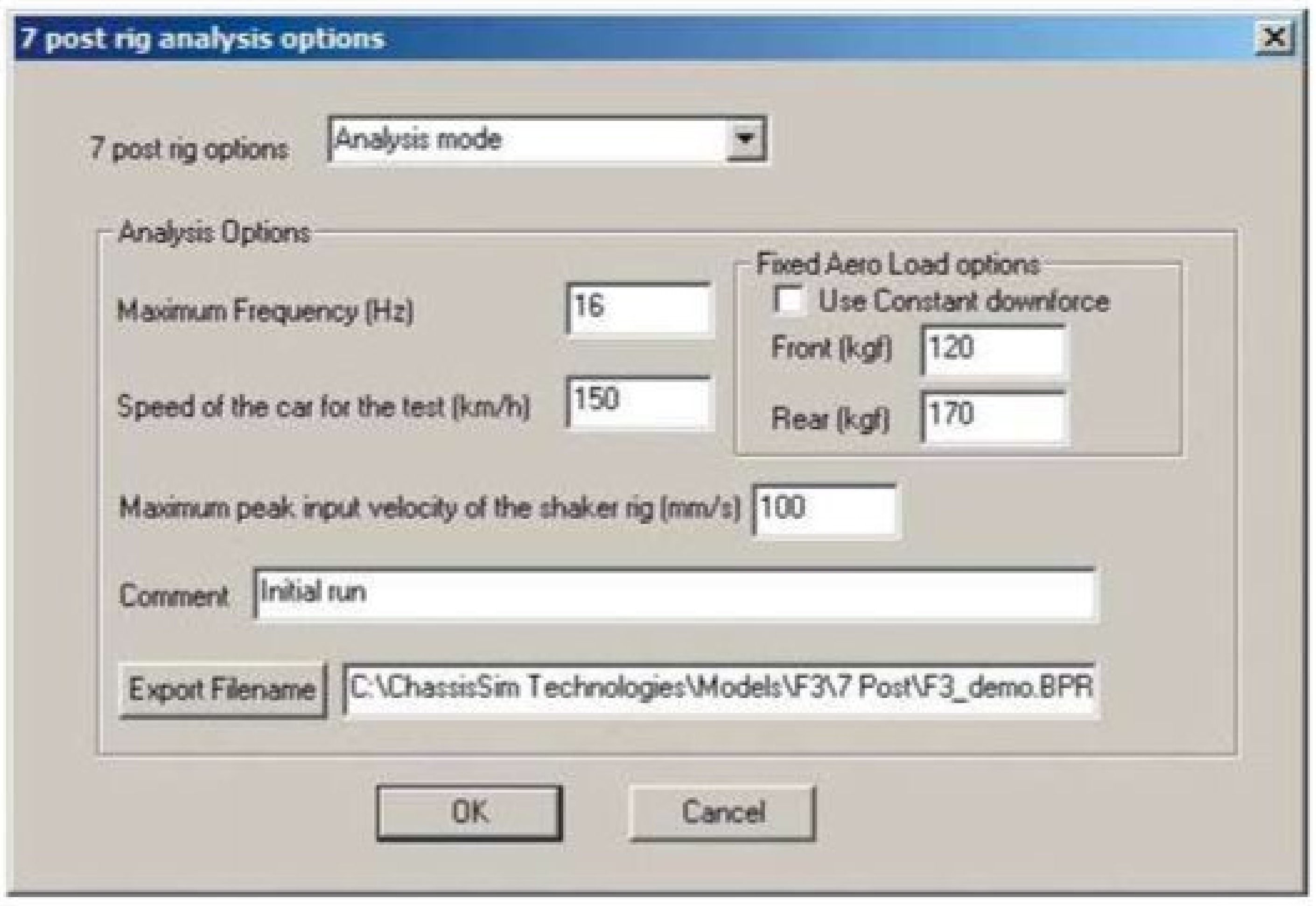


Figure 4: setting up a frequency run

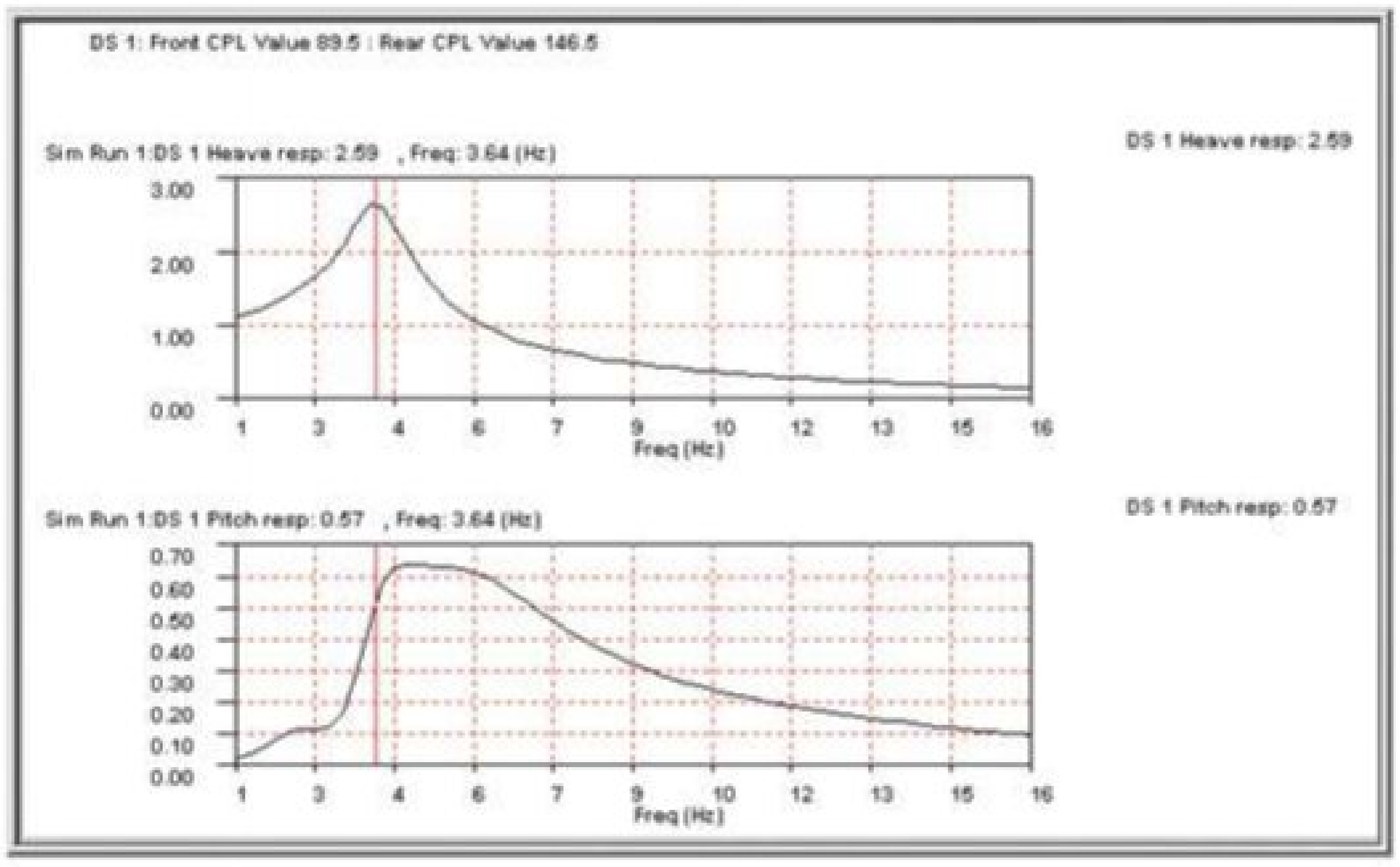


Figure 5: output of the shaker rig toolbox

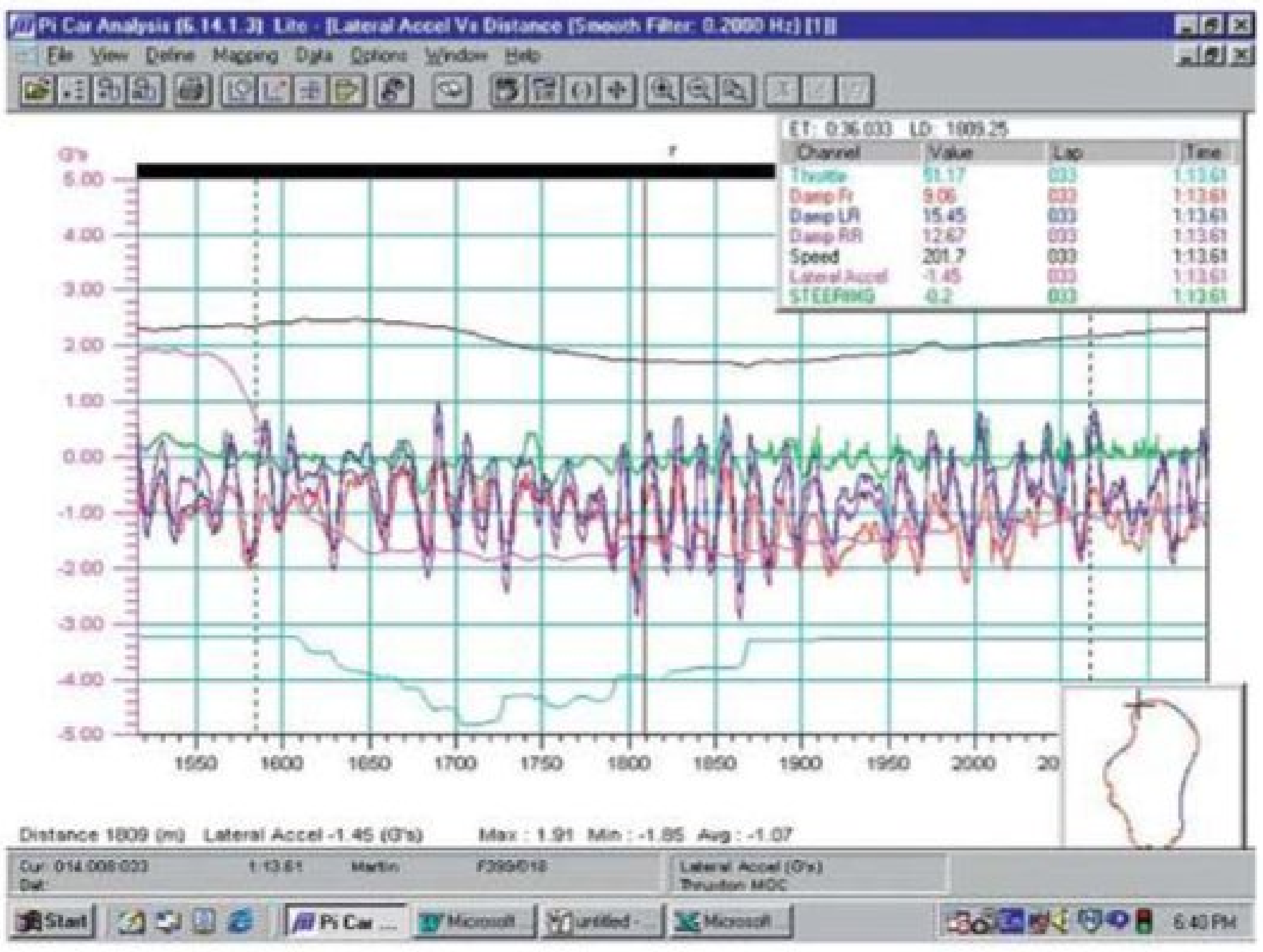


Figure 6: resonant behaviour for an F3 car

Equation 3 is computed for each frequency. These are then added up and averaged for all of the measured frequencies to return the final cost functions.

Each of these measures are very much user dependent. There will be some who will swear by either method. The advantage of the CPL is that it does give you a very good measure of mechanical grip. The lower the CPL numbers, the better the grip. The advantage of the cost function route is that it can be customised very readily to what you want to get out of it. There's also no reason you can't use both. For example, if you are running a car that has a lot of downforce, you can increase the cost function for the pitch and heave terms. Consequently you'll get penalised for changes that result in large pitch and heave variations which is an absolute premium for cars that are pitch sensitive and run a lot of downforce.

But the question is: can we simulate this before we get to the rig so we can make our rig time more valuable? The answer is a resounding yes, and in that regard I'd like you to walk you through the ChassisSim 7 post/shaker rig toolbox. The first part of the toolbox is setting up the frequency test. This is illustrated in **Figure 4**.

The comments and filenames are pretty self explanatory. Just put in something relevant to the setup and store the log file for test where you are going to remember it. However, the controls you need to pay attention to are the speed of the test and the peak input velocity of the road input.

You choose the speed of the test to choose the corners you want to simulate. If you want to simulate a low speed corner, choose, say, 100 km/h, or if you are looking at a high speed corner you choose, say, 150-170 km/h. You'll also notice you have an option to set the downforce at a fixed value. This is OK for validation work, but personally I prefer to leave this off. The reason for this is that the ride height map will impact on the frequency response of the car and in high speed corners this will make its presence felt.

In terms of the peak input velocity, you choose a value that represents the peak input velocity that is representative of the road input. There are a number of ways you can do this. For a rough rule of thumb, 50 mm/s approximates a relatively smooth surface, 100mm/s is middle of the road, and 150mm/s represents a pretty bumpy circuit. Another way you can do it is to look at the data. Look at the peak damper velocity and divide the results by, say, about three. It's a rough measure but it will get you by. If in doubt start the test at 100mm/s.

In terms of what this toolbox is, it will return a plot of Output Amplitude on input Amplitude. The output of the toolbox is shown in **Figure 5**.

You'll see that the Contact Patch Load variation (CPL) is shown in the top of the graph. This is averaged over the whole frequency run and the units are kg. This is the delta load variation from the static load for the conditions specified for the test. The plots below are the ratio of output vs input amplitudes. Here we have shown heave and pitch for a heave input to the car.

The first thing you will get out of this, is that it will tell you the frequencies you need to be looking for in the data. The frequencies we need to be watching for are the frequencies at which you see the peak responses. This is called resonance, and you ignore this at your peril. The way you translate this to looking at data is, if you have a particular handling problem, look at the data in the time domain. You are looking for damper frequencies that correspond to the resonant frequency. If you see this, that is your cue – you need to do something in the setup. An example of what to look for is this situation illustrated in **Figure 6**.

Note here how the dampers are oscillating like mad and the steering response is responding in sympathy. If you have a car handling like this, typically the driver will be referring to you in negative terms (the four letter variety).

However the real power of this toolbox is tying the CPL figures with the frequency response. This technique was actually pioneered by a colleague of mine, Pat Cahill, when he was engineering a GT car at Bathurst in 2011. The technique is breathtakingly simple. The first part of the process is that you play with springs and large damper adjustments to minimise CPL. When you get into the zone, the CPL will hit a minimum and actually won't vary too much. Once you hit this, you start playing with minor spring and damper changes to get the shape of the frequency response that you want. It's actually that simple. This technique has been used very successfully in cars with CLA numbers from 1.2–2.7. The result of this has been a marked improvement in mechanical grip without compromising driver feel.

When you make these changes, it's critical that you don't go silly with the magnitude of them. Remember, when you go to a shaker rig, whether it's virtual or actual, don't forget what makes the car work. The results you get are a tuning tool, not a magic wand that will make you 20 seconds a lap quicker. So keep the spring changes in the range that will still keep the temperature in the tyres, and don't think you can make outrageous changes to bump and rebound just because it makes the pitch response look impressive.

The techniques we discussed here have been applied to cars with low to medium downforce, but what do we do about high downforce cars. For cars in the CLA of, say, 3.5 and above, the heave and pitch response start to outweigh the mechanical grip. The technique here was very well explained by Kowalczyk. In this technique you actually tune the pitch cross response almost to the expense of the initial heave response. The thinking here is that if you get into trouble you can just raise the ride heights. However, I would refer you to the paper by Kowalczyk because he articulates this very well.

Put simply, the shaker rig toolbox when used properly is a very powerful tool. It gives you a window into the world of the frequency response of the car that yields valuable information into what to look for in the data. The key to getting the most out of it is to make sure you set the correct speed to represent the downforce levels and represent the peak input velocity of the road inputs.

When using the ChassisSim shaker rig toolbox, tune for CPL and then tune the frequency output to get the responses you are after. However also be mindful when running high downforce levels this might need to change. Used in this fashion you should see a measurable improvement of the mechanical grip of the car.

1) H Kowalczyk – Damper Tuning with the use of a 7 post shaker rig, SAE Technical Paper Series , SAE 2002-01-0804, 2002

Deltawing makes show debut

One of the most groundbreaking racecar concepts of the generation, the DeltaWing, will be on display at Autosport International 2013 through Aurora Bearings. Originally designed by Ben Bowlby as a potential IndyCar chassis, the project made its sportscar debut in 2012 in association with American motorsport heavyweights RML, Dan Gurney, Don Panoz and Duncan Dayton.

Powered by a bespoke four-cylinder 1.6-litre Nissan DIG-T engine producing 300bhp, and weighing just 575kg with fuel and driver, the DeltaWing features a unique tapered design, with a narrow front track and downforce generated by the underside of the wingless car.

DeltaWing made its race debut in last June's 24 Hours of Le Mans, running outside of official classification through 'Garage 56'. Its first official 'race' came at Petit Le Mans, finishing fifth, ahead of a full American Le Mans Series campaign in 2013.

The concept will appear on the Aurora Bearing Company stand, alongside its range of rod end and spherical bearings. Visit their stand (number 8330) in Hall 8 to see this remarkable machine.

Data acquisition technology revealed

The latest developments from Australian engine management and data acquisition systems specialists MoTec will be on show. The firm's new HD Video Capture System leads its latest range, the lightweight unit providing superior video quality, with 1080p at 30 frames per second, and the capability to record up to five hours of footage.

It will be joined by an Accident Data Recorder, which can be used as a standalone unit or in conjunction with other devices, such as GPS, data loggers or ECUs, and MoTec's new range of colour displays and data loggers. Visit them on stand E170.

MoTeC will be far from the only electronics supplier with new products on show. English company GEMS Performance Electronic Systems will showcase its latest DA2 data logger and PM3 power switching units at Autosport Engineering. The successor to GEMS' first miniature data-logger, the DA1, the DA2 is a full specification system the size of a USB stick, capable of logging up to 2GB of data. The PM3 is a CAN-controlled power switching unit for use in a multiplex power management system, reducing the complexity and weight of the wiring loom. These products can be found on stand E346.

A real highlight will be the official debut of the PCM2 from Ole Buhl Racing after a prototype version was shown off at PRI in December. In 2005, with help from Porsche Motorsport, Buhl and his engineers started to develop a microprocessor controlled PCM. In the spring of 2006, Porsche tested the first samples and later that year the first generation Ole Buhl PCM was made available to customers. It has already undergone extensive testing, both in the lab and in real world conditions, and during the 2012 season it was used in international championship winning rally and racing cars with great success. Its usage looks set to grow too as the FIA has already inspected and homologated the module for use in WTCC and in WRC cars. Pay a visit to stand E496 to find out more about what could well be the most innovative product at the show.

Going global

The British government organisation UK Trade and Investment will again help local companies access global trade opportunities through the UKTI International Business Exchange (IBEX) at Autosport Engineering on 10-11 January. The unique IBEX creates targeted meetings between UK companies and international visitors, with key decision makers from motorsport and high-performance engineering firms to attend. Already confirmed are Igor Yermilin, adviser to the president of Russian Automobile Federation (RAF), Anastasia Bendikova, director general of ASPAS, official consultant and promoter of F1 Grand Prix in Russia, and Vaclav Trkola, Škoda Motorsport's head of bodywork construction.

Micros Racing and Prati-Donaduzzi from Brazil, ZF Sachs Race Engineering from Germany and Finland's Print Sport Rally Team will join them, with rallying companies featured for the first time. Business development and chief technology officers from across the globe will also be at the NEC, and able to provide one-to-one advice.

For the latest updates or to register for IBEX, check out www.autosport.ukti.gov.uk

Handling the heat

Versarien will showcase its newest advanced heat transfer material as the next generation of cooling mechanisms for space-constrained environments such as engines and electronic systems.

Developed at the University of Liverpool, VersarienCu is a groundbreaking, micro-porous metallic material that will be up to 10 times more effective at transferring heat energy than conventional micro-channel heat sinks of equivalent size. With its increased surface area, the new material achieves a heat transfer coefficient of approximately 150-200kW/m2K.

Versarien Ltd
Hall 9, Stand E845
www.versarien.com

Get the winning edge

The Motorsport Industry Association will host a number of fascinating workshops and seminars during the show, which are well worth attending. The first of these takes place the day before Autosport Engineering opens its doors on January 9 at the NEC, and it is not to be missed.

The annual MIA Low Carbon Conference has become a crucial part of the show and the often heated panel debates are very enlightening.

A world-class lineup of contributors has already been confirmed with more to come. Speakers will include Ben Bowlby, designer of the DeltaWing, and Jean-Francois Weber of Green GT, the hydrogen-electric racecar which will follow in the footsteps of the DeltaWing at Le Mans 2013. Ulrich Baretzky, head of Audi Sport Race Engine Development, is always a highlight, while newcomer Fabrice Lom, head of Powertrain at the FIA, will be giving an important presentation.

In addition to this, Lord Drayson – former UK science and innovation minister – and pioneer behind the 850bhp B12 electric racing car which thrilled the crowd at Goodwood this summer, will outline the future for electric powertrains and the much debated FIA Formula E. Tim Woolmer from YASA Motors, the innovative electric motor company which was fitted to the Drayson car, will add his thoughts on future developments.

Alex Burns, CEO of Williams F1 who led his outstanding F1-based company to diversify into energy efficient solutions, will also be speaking. Burns also set up a green technology centre in Qatar and helped Audi to win Le Mans 2012. Tony Harper, head of research at Jaguar, will explain the technology strategy of the Automotive Council in the UK and how it opens up opportunities for innovative suppliers from motorsport companies, while Steve Sapsford, global markets director of Ricardo will present, for discussion, the latest Motorsport Technology Road Map and demonstrate how this links into automotive technology plans and new business.

The MIA's School of Race Engineering will also host a series of 'Winning Workshops' on Friday 11 January at Autosport International. The half-day workshops will be led by Jay Davenport, chief engineer for GP3 title-winning outfit MW Arden. A wide range of setup topics will be covered, giving attendees an overview of the key aspects in preparing a car.

Finally, a wide range of free workshops will be held in conjunction with the Motorsport Industry Association at Autosport Engineering in association with Racecar Engineering.

Among the seminars, the CRP Group will showcase its transfer of motorsport technology to the automotive and aerospace arenas, while the Northamptonshire Enterprise Partnership will outline commercial opportunities in the region for engineering companies.

The MIA itself will also conduct a number of workshops, including dedicated seminars on applying motorsport technology to arenas such as defence. Other companies hosting seminars include MPA Accountants & Tax Advisors, Prova PR, CDD Design and Catlin Insurance.

For more information concerning availability for these events, visit **www.the-mia.com,** or **Zoe.Chilton@the-mia.com**

Vero's new versions

CAD/CAM specialists Vero Software will showcase the 2013 versions of three of its newest releases, with upgrades to its ALPHACAM, EDGECAM and VISI packages.

For wood, stone and composite solutions, ALPHACAM 2013 R1 offers reduced programming time and material wastage, and improved material surface finish, part quality and tool life.

Meanwhile, the updated EDGECAM system features a brand new wire EDM function, providing an intuitive environment for the comprehensive programming of all-wire EDM machine tools.

The annual update for the VISI CAD/CAM solution for mould and die industries features a host of upgrades, including improved graphical rendering, a new tool-building engine and new toolpath algorithms.

Vero Software
Hall 9, Stand E1161
www.verosoftware.com

SHOW INFO

Show opening Times

The show is open from 0900-1800 hours daily. The essential trade days run in conjunction with the Engineering show on 10-11 January 2010. The international show, which is open to the general public, continues through 12-13 January.

Tickets

Tickets are now on sale for the public show. Adult tickets cost £31, with children's tickets priced at £20 (children under five years of age go free). Group tickets are also available. For more ticket information call 0844 581 1420 or visit www.autosportinternational.com.

Travel

Access to the Birmingham NEC is excellent. Birmingham International railway station is part of the same complex of buildings as the NEC itself, and is served by fast and frequent trains from central London and Oxfordshire. From the NEC, the centre of Birmingham is 10 minutes journey by train but rather more by road, due to the heavy traffic in the area.

Another part of the NEC complex houses the international airport, which has scheduled flights from the US, as well as a range of European cities.

Road travel is well catered for too, with easy and well signposted access from the M1, M6, M40 and M42 motorways and there is on-site parking for 21,000 cars.

For more travel information visit www.autosport-engineering.com

New gear on show

Among its Autosport International presence, Quaife will launch an uprated, five-speed sequential gear kit for the popular Honda Civic Type R.

Designed as a direct replacement for the Civic's standard, six-speed, H-pattern unit for use in motorsport, the QKE8J features a strengthened outer casing and five wider gears. Available with either a straight cut or helical close-ratio gears, the kit retains the stock EP3/FN2/DC5 clutch, diff, driveshafts and mounts. An LED digital gear position indicators, and Quaife ATB differential for standard driveshafts or uprated shafts are among the other options available.

Quaife Engineering
Hall 8, Stand 8500
www.quaife.co.uk

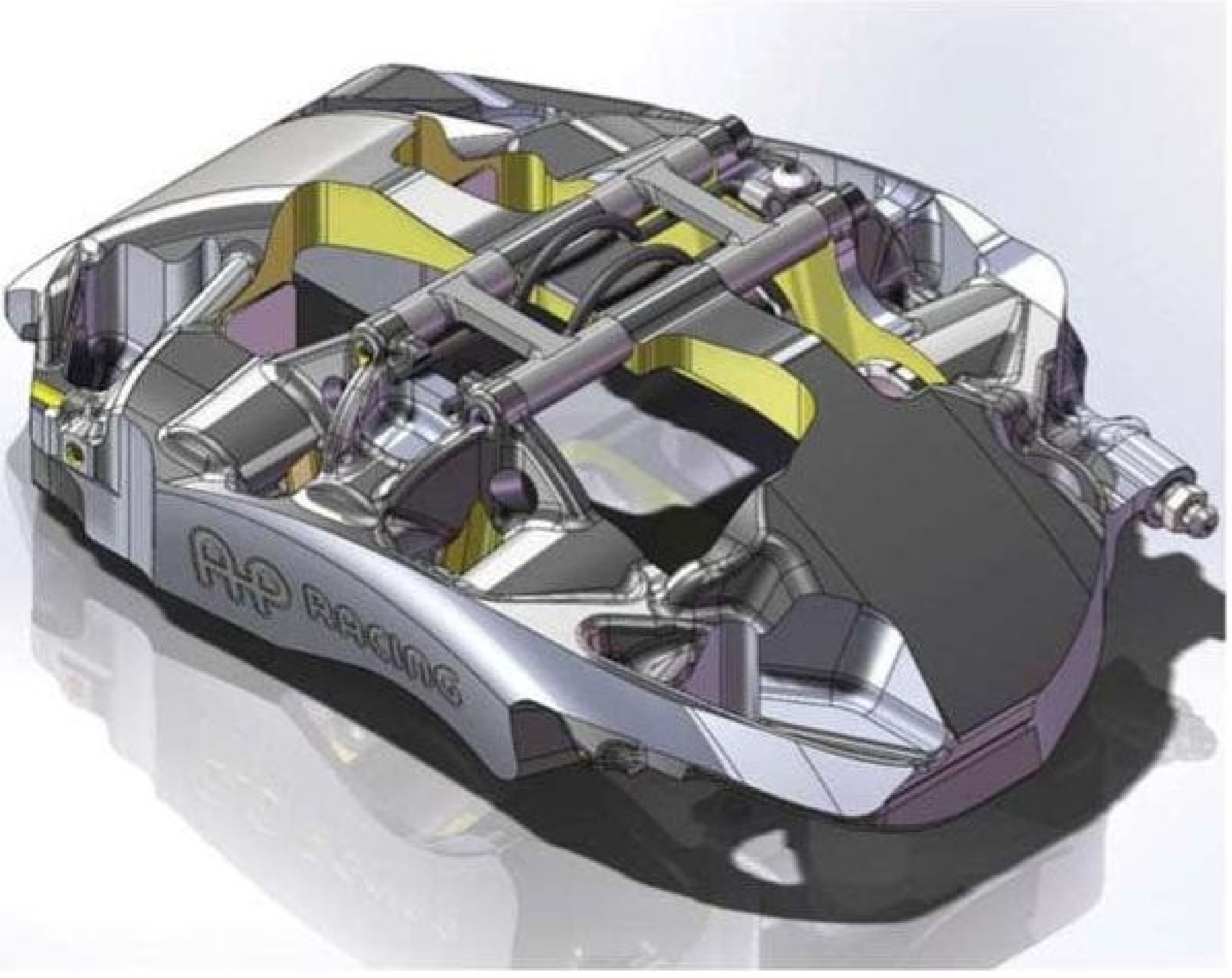
GT and more

Having won its 700th grand prix as a Formula 1 clutch and brake component supplier in 2012, AP Racing will start 2013 by showcasing its expanded Radi-CAL range.

Three new calipers for GT competition have been developed, the CP6083 designed for GT and GT3 use with iron disc brakes, the CP6165 for GT/LMP applications with carbon or iron discs, and the carbon brake disc-optimised CP6169. All three calipers feature stiffer, dome-backed titanium pistons and offer weight savings.

Rally, Formula Nippon, and Touring Car versions of the Radi-CAL range have also been developed.

AP Racing
Hall 7, Stand 7500
www.apracing.com



Still going strong

Celebrating its 40th anniversary in 2012, Nicholson McLaren Engines (NME) continues to evolve its skillset.

The company was formed in 1972 by John Nicholson to maintain the Cosworth DFV engines used by the McLaren Formula 1 team, including the powerplants used by world champions Emerson Fittipaldi and James Hunt in 1974 and 1976, and has remained entrenched in the sport.

Now, they're helping to keep some historic Matras on the track, having remanufactured a set of ten V12 engines designed by the French manufacturer, the first time NME has completed such a project. Commissioned by a collector racing the cars, the set has been developed over the last three years.

With the first unit having completed its maiden on-track test, the engines will be used in a range of cars in historic competition in Europe, America and Australia, including the Formula 1 Matra MS120 and the Matra 650 and 670 sportscars.

Nicholson McLaren Engines Ltd
Hall 9, E380
www.nicholsonmclaren.com

Visit us and vote

As usual Racecar Engineering is the media partner of the Engineering show and we will have a stand for you to visit at E370. This year, however, it will be a little bit different as we are asking everyone who visits our stand to vote for the greatest motorsport innovation of all time. A shortlist has been drawn up by a group of leading engineers including Adrian Newey, Ross Brawn, Ben Bowlby and Norbert Singer. If you would like to discuss this, or any other topic, then make a point of dropping by. Members of the editorial and advertising teams are scheduled to be in attendance throughout the two days and will be more than pleased to have a chat or provide a guided tour of the interesting exhibits on the stand.

We look forward to meeting you there.

Andrew Cotton, Editor

Dee-lightful

DEE-Ltd will launch its new D-2GR-FE, an upgraded version of Toyota's 3.5-litre V8 engine for aftermarket sales, during Autosport Engineering.

With a range of options from an entry level power of 274hp through to 450hp, the new engine is the latest addition to the West Midlands company's range, joining 1.6-litre and 2.0-litre I4 DOHC units.

DEE-Ltd manufactures new crate engines, tuned and preassembled to a clients' build standard, and matching transmissions, with the rights to sell aftermarket Toyota powertrain products across Europe. Update kits for the Lotus Elise, Evora and Exige are also planned, with a range of options for each, including a 500hp version for racing and track days.

Development Engineering & Enterprise Ltd
Hall 9, Stand E1071
www.dee-ltd.co.uk

In praise of simulators

Ben Bowlby's name is associated with one of the great innovations in modern motorsport, the DeltaWing. But without his nomination for the Technical Excellence Awards, it wouldn't have been possible...

Nissan's motorsport strategy in Europe draws heavily on computer simulators. Indeed, its GT academy features drivers that compete online for a lap time, takes the fastest and tries to establish who is the best. For young Spaniard Lucas Ordonez, that took him to the top step of the podium at Le Mans, and the new crop of drivers is proving to be equally adept behind the wheel.

I didn't believe in the academy until I had to engineer Lucas, and it was like, 'Oh my God, this is incredible – the guy is really good and three years ago he hadn't driven a car.' It was amazing, so my nomination is for the collective developed capability of vehicle performance simulation.

It is the ability to model and simulate a vehicle. Without that, the DeltaWing would not have been possible. For Michelin to know that they could make a tyre for such a car, and the ability to accurately predict vehicle performance through mathematical simulation, lap time prediction, aerodynamic prediction of capabilities and how it interacts with the rest of the vehicle is going to be the ultimate access to finding new directions in the future.

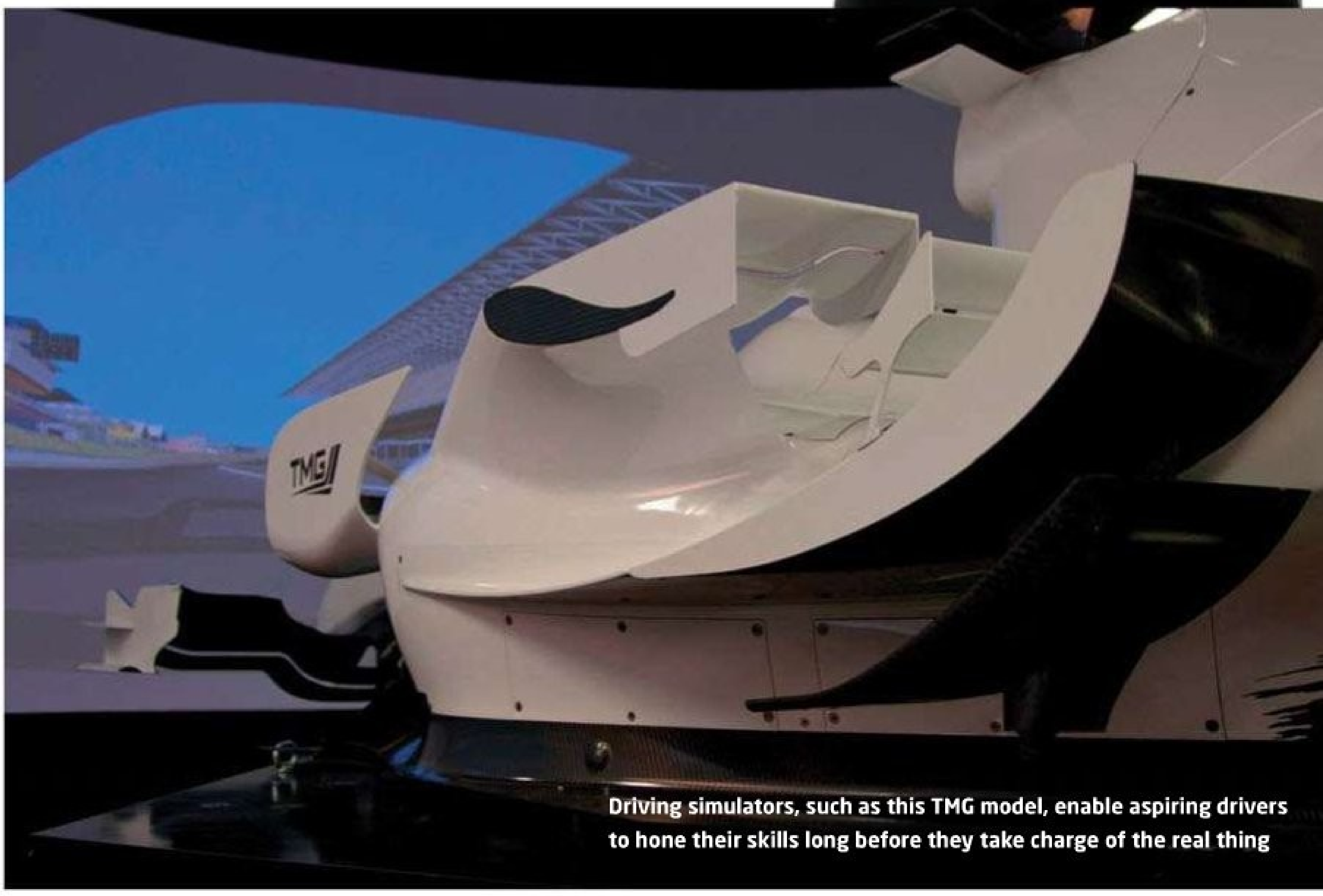
For the road car industry and even the sophistication of the simulation engine that is widely available now, the tyre models, the aero and the mechanical capability, the ability to programme a simulator means that an aspiring driver can actually have a sufficiently good understanding of how a car behaves before even driving a car.

This is my nomination, but I had to think long and hard and rack my brains because my first reaction on being asked to nominate, for no very good reason to be honest, was the Austin 7, because I realised that it pretty much created British motorsport at a grassroots level and gave so many people a start. I am named after my father's Austin 7 racing project that never saw the racetrack. I think it was a massive source of accessible racing potential, but it is not a racing innovation, so I couldn't nominate that. Could I?

Each of the five nominations featured in the magazine will be displayed on our stand, E370, at the Autosport Engineering Show at the Birmingham NEC on 10-11 January.

Racecar Engineering has secured copies of the extremely valuable ***'Who Works in...'*** *guides (www.whoworksin.com) to give away to the first 50 readers who cast a vote for the winning nomination. Stop by our stand to vote, or go online to www.racecar-engineering.com/technicalexcellence.*

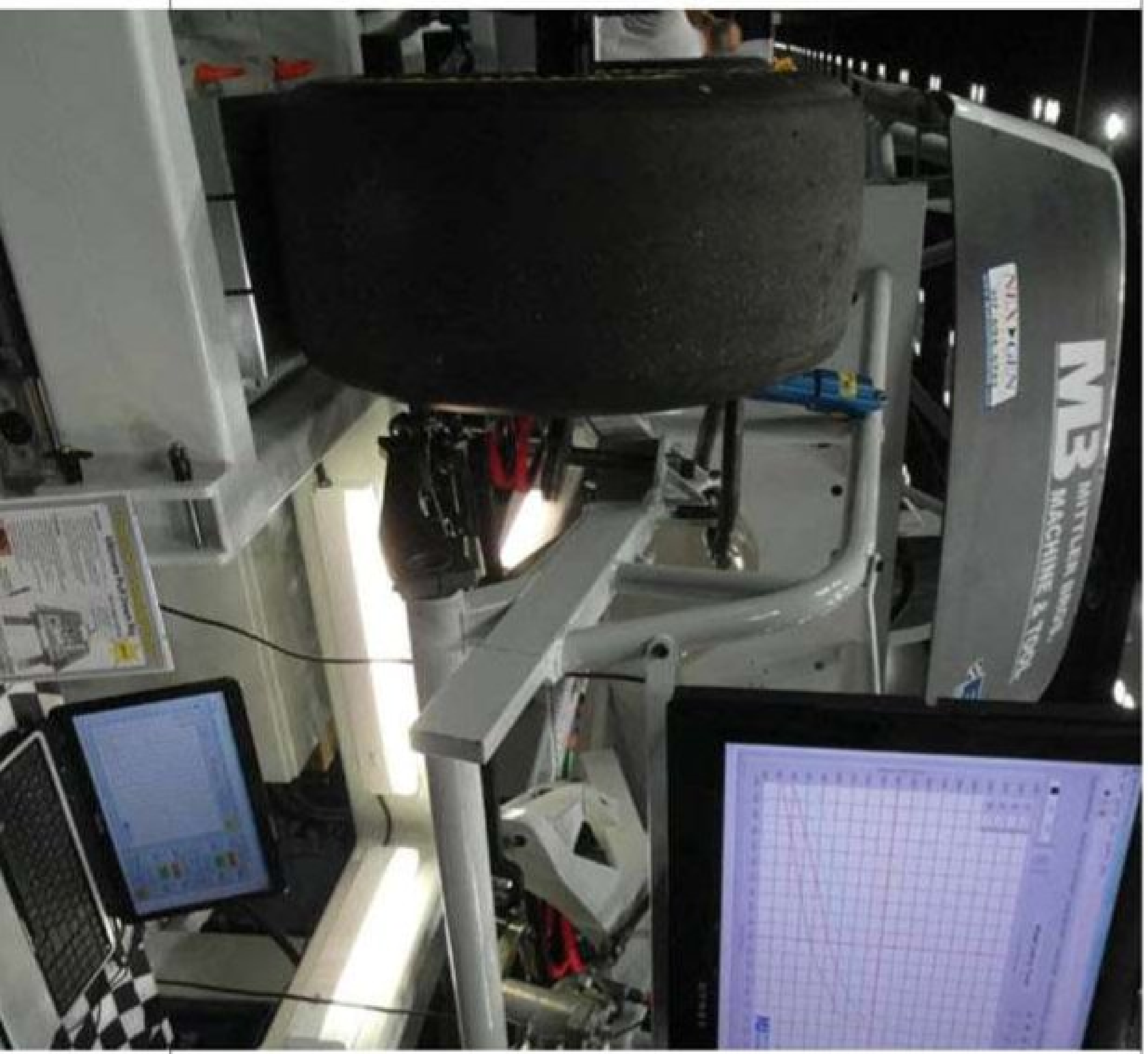
Tickets to the show can be booked at www.autosportinternational.com, or call ***0844 581 1420***



Driving simulators, such as this TMG model, enable aspiring drivers to hone their skills long before they take charge of the real thing

HARDWARE

Mittler Bros pull down



Pull down rigs are a vital tool in the Oval racer's armoury, but they tend to be out of financial reach for many teams. US-based Mittler Brothers is marketing a new rig, with pricing that starts at $64,000 (£39,316).

A pull down rig does exactly what its says on the tin, simulating the effect of downforce on a chassis. This allows engineers to fine-tune bump stop ratings or coil binding as well as investigate other factors such as bump steer and camber changes. The Mittler rig is sold as a complete setup, including scales, a tilting table and even a laptop ready loaded with data acquisition software. The results from this software can be transferred directly to either Excel or the industry standard Pi Toolbox.
Check out www.mittlerbros.com for more details.

FLUIDS

Viper Performance catch tanks

Fluid transfer specialists Viper Performance's new aluminium universal breather tanks combine a catch can and a breather outlet all in one. The 550ml tanks feature a 1/8" NPT thread at the bottom connected to a drainage valve, which can easily be removed to use the NPT thread as a return, or remote drain. The top of the tank has a single -12 ORB female port. A third port on the side of the tank serves as a connection to the breather filter of your choice. Available in mirror polished finish, or black, the breather tanks can be obtained directly from the Viper website.

Viper Performance
Hall 8, stand 8305
www.viper-performance.com

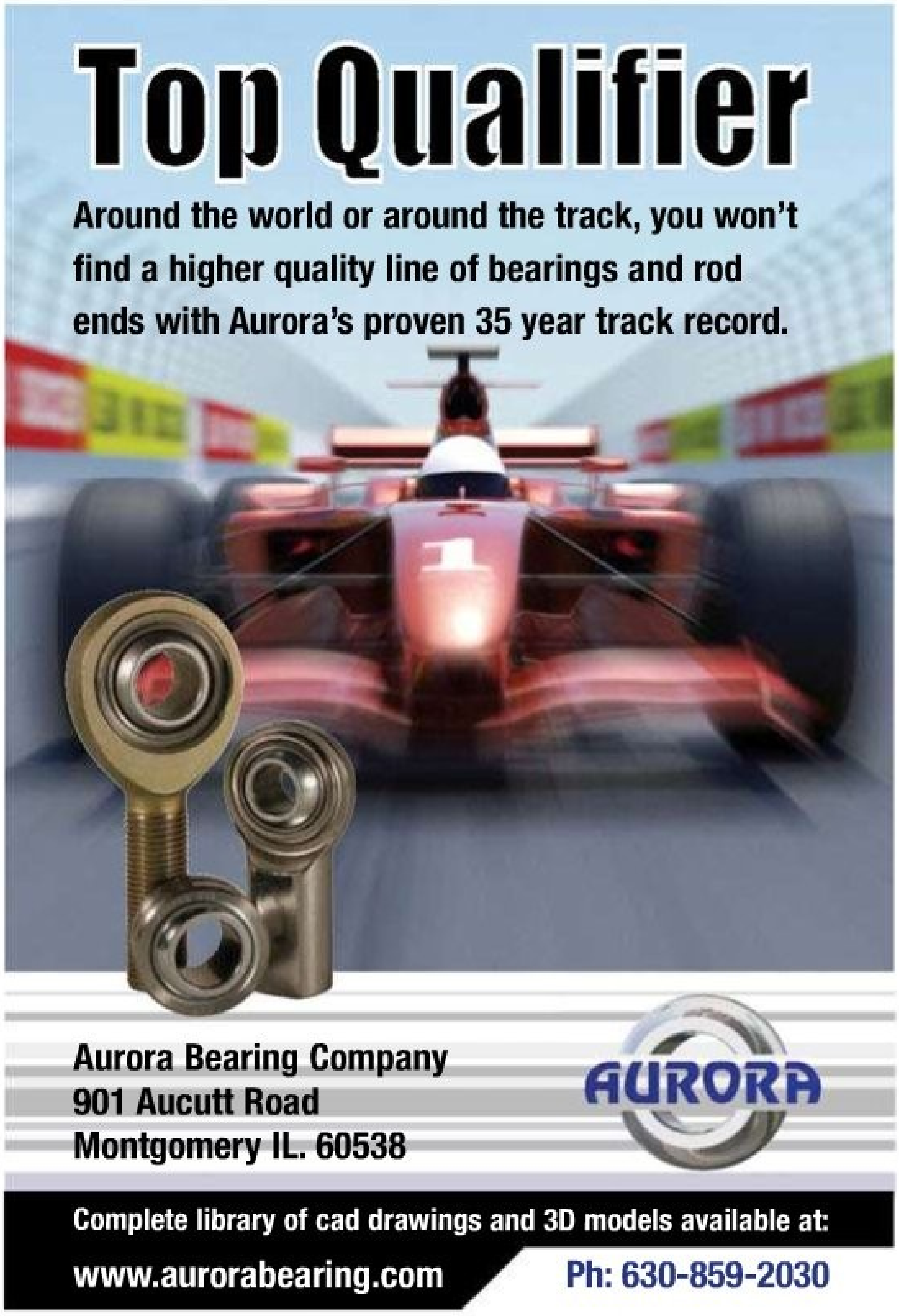
LIFTERS

Crower EnduraMax lifters

Pushrod V8 engines will invariably feature roller lifters unless regulations specify the use of flat tappets. Roller lifters provide an excellent, low friction interface between the camshaft lobes and pushrods.

However, they do have their weak points, notably the roller bearing. These rollers almost universally feature a needle bearing which, while providing very low rolling resistance, are susceptible to damage. If a fault develops with the bearing, there is tendency for it to disintegrate, shedding metal throughout the engine, leading to a catastrophic failure.

To combat this, US-based engine component manufacturer Crower has developed its new EnduraMax lifter range. Following two years of development, these lifters see the needle bearings replaced with a solid bushing. The material used for the bushing is proprietary to Crower and eliminates the problems associated with needle bearings while still providing a low friction interface.
Check out www.crower.com for more details.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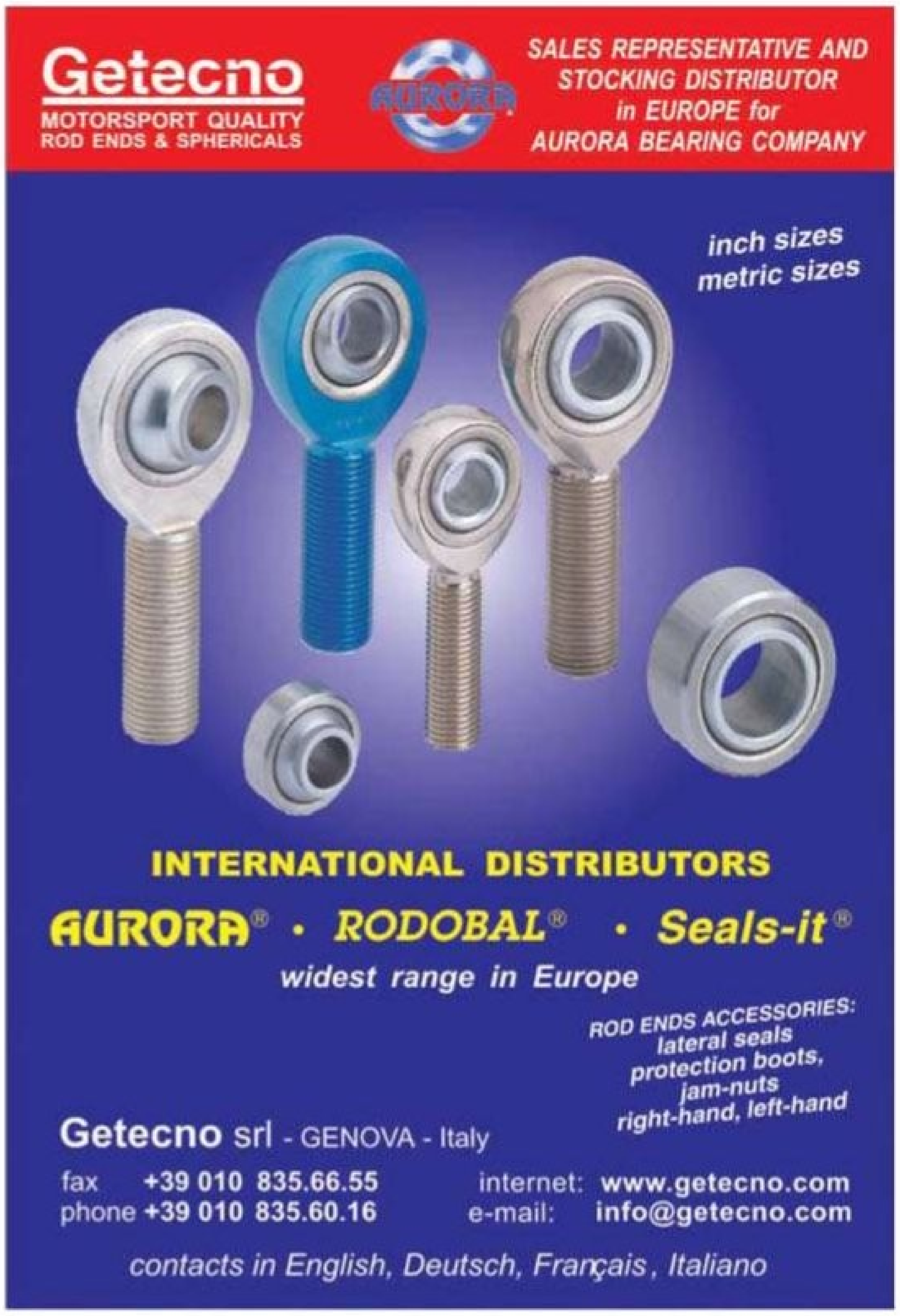
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BRAKING

PFC developments

The end of 2012 saw US brake manufacturer PFC release two new products to market. The first is its new 'V3' disc retention system, designed to replace standard disc/bell attachments. Instead of bolts or top hats to secure a floating disc, the disc and bell are held together by a retention ring, very similar in appearance to a piston ring. This allows completely tool-less changing of discs in addition to providing a saving in unsprung weight.

The company has also released a new range of pad compounds, intended to allow racers to accurately tailor their pad selection according to track conditions. The compounds are called simply 11, 12 and 13. 11 is a medium friction material, designed to give good pedal feel with smooth release characteristics to eliminate locking at the end of braking events. 12 provides similar performance but with greater durability and is intended for endurance racing. 13 is a very high friction material intended for high grip tracks where greater braking force can be deployed.

PFC
Hall 9, stand E970
www.pfcbrakes.com

PFC BRAKES

TUBING

SSAB Steel

Swedish steel manufacturer SSAB has recently entered the motorsport market with its DOCOL range of steel tubing. The material has been specifically developed for the automotive industry, and the company's DOCOL tubing is designed as a replacement for traditional 4130 chrome molybdenum steels. The key benefit the new tubing brings is a reduction in brittleness at welded joints, the inherent weak points in many welded safety structures. This performance is due to the high purity of the steel used and exceptionally low carbon content. The material has recently been certified by the SFI for use in SFI 25.X specification roll cages for full bodied drag cars, and SSAB is working on gaining additional certifications. The tubing is available in most common sizes.

SSAB
Hall 9, stand E946
www.docol.com

SENSORS

Gill Blade20

Motorsport sensor specialists Gill Sensors recently released their Blade20 rotary position sensor in response to customer demand for ever smaller, faster and higher resolution sensors.

The new sensor features the company's patented induction technology, introduced over a decade ago and continually evolved to meet new requirements. In this latest application the core electronics are 40 per cent smaller than the previous generation while still offering 12-bit resolution capable of up to 15KHz update rates. The technology used in the Blade20 has also been integrated into a number of custom position sensors designed to monitor clutch actuation and throttle pedal position in Formula 1, with each custom sensor homologated by the FIA.

Mike Rees, Head of Marketing for Gill Sensors commented. 'The Blade20 represents a significant breakthrough in position sensing technology, with a single product allowing the measurement of linear and shallow-arc motion, and even long-stroke measurement with a single micro sensor. With a fast update rate for quick positional feedback, it is suitable for a wide range of harsh environment applications that require fast, accurate position measurement.'

Gill Sensors, Hall 9, stand E433
www.gillsensors.co.uk

BRAKING

New AP Racing products

Brake and clutch manufacturer AP Racing recently releasing several new components. Aimed at the rally market, the CP5540 is a lightweight double-ended, or tandem, master cylinder with two separate hydraulic chambers, which can be employed for either front and rear brake circuits, or a handbrake and differential release assembly. It has a high-efficiency push-type design, mounted via spherical bearings, and the handbrake version is available with an additional spring to delay pressurisation, allowing differential release before handbrake application.

AP's Radi-CAL range has been expanded, further increasing the breadth of applications for the company's flagship caliper design. The first, the CP6840, is a four piston version designed for the WRC/S2000 and the new FIA cost cap regulations. It's a radial-mounted forged four-piston monobloc caliper designed to operate with 300-355x34mm ventilated iron brake discs.

The second new development is the CP6382, a 6 piston billet caliper designed for the Formula Nippon series. This 202x35mm centred radial mounted caliper has been designed to operate with a 280mmx28 or 31mm iron brake disc. This caliper is available with nickel plating, to reducing the absorption of radiant heat, or an anodised body surface treatment, while stainless steel pistons and wear plates are fitted as standard.

The final iteration, the CP6287, is designed for Touring Car and GT championships. It is a 4 piston forged monobloc caliper designed to operate on 355x32mm iron brake discs. It can also be utilised as a front caliper on Formula type racecars.

AP Racing
Hall 7, stand 7500
www.apracing.com

McLaren profits from its sparkling heritage

McLaren has revealed that its stock of pensioned off race and road cars is worth close to £100m – more than the annual budget of most Formula 1 teams. The figure comes from the company's annual report for 2011, which also reveals it made a profit of close to £21.7m in that year.

The team's collection of 'heritage assets' consists of 138 racecars, six F1 road cars, five 'historic vehicles,' and 20 spare F1 monocoques. McLaren claims that: 'On a one-by-one basis, these cars are considered by the directors to be worth well in excess of £100m.'

However, McLaren goes on to say that as values for historic cars can fluctuate and as they will go down if sold in greater numbers – if the entire collection was sold, for instance, the supply would far outstrip the demand, driving prices down. They have given the cars a balance sheet valuation of £75.7m. The collection is valued every five years.

McLaren says it made a retained profit of £21.7m for the year ending December 2011, up 49 per cent on the previous year (2010 profit £14.5m). The company says its success is partly down to its expansion into new markets – for instance McLaren Electronics' five-year deal with NASCAR to supply it with ECUs. In 2011 it also signed a new deal to provide F1 with spec ECUs from 2013.

McLaren is able to trade on technologies both old and new, according to recently released financial reports

Meanwhile, McLaren has now found a new revenue stream with the news that it's to supply engines, transmissions and electronics for the Formula E electric car racing championship. McLaren will work with new company, Spark Racing Technology, to ready the cars that will race in the series, which will start in 2014.

Spark Racing Technology is part of the consortium of international investors who are in charge of the commercial rights for Formula E, and it will be headed by Frédéric Vasseur, team principal of the ART GP2 outfit.

McLaren Group chief operating officer Martin Whitmarsh said of the deal: 'I'm a passionate believer in the role that motorsport can play in showcasing and spearheading the development of future technologies, and regard the Formula E concept as an exciting innovation for global motorsport.'

Red Bull hit with $3.3m entry fee for 2013

World Championship-winning team Red Bull Racing has been forced to pay three-quarters of a million dollars more entry fee than closest rival Ferrari, as the FIA's new points-based sliding scale comes into force.

Red Bull had to pay $3.26m this year, while Ferrari paid $2.5m, and McLaren $2.36m. This is the result of a new structure that replaces the old €309,000 ($406,000) flat fee for every team. Each team must now pay a basic fee of $500,000, with the constructors' champions then paying $6000 per point scored, while all other teams pay $5000 per point.

The FIA has upped the entry fees to increase the revenues it gets from the sport. It is believed the governing body is hoping to accrue an income of $40m from F1 in 2013. The entry fees should bring in just over $16m while it is thought the FIA is also close to agreeing a deal with Bernie Ecclestone, as part of the Concorde Agreement, where he will pay the governing body $24m. Other revenue should come from a hike in the drivers' F1 Super Licence fees.

Meanwhile, HRT did not appear on the 2013 entry list after it failed to find a buyer before the deadline for entry fee payments. It now looks unlikely that the Spanish team will make the grid this year.

HRT had been put up for sale by its owner, Thesan Capital, just before the penultimate round of the championship, with Chinese car company Chery Automobile said to be showing an interest. However, talks appear to have come to nothing and the team is now said to be working on paying off its creditors.

While there has been no official word on the team's demise – and its Madrid HQ is not contactable – HRT technical director Toni Cuquerella has admitted: 'Four years ago I suggested to a friend to start an F1 team. Today, after three years, the final page of the story is being written for HRT.'

Team/2012 points/ 2013 entry fee

Red Bull	460 - $3.26m
Ferrari	400 - $2.5m
McLaren	378 - $2.39m
Lotus	303 - $2.015m
Mercedes	142 - $1.21m
Sauber	126 - $1.13m
Force India	109 - $1.045m
Williams	76 - $0.88m
Toro Rosso	26 - $0.63m
Caterham	0 - $0.5m
Marussia	0 - $0.5m

Palmer pulls plug on loss-making Formula 2

Formula 2 will not now run in 2013, organiser Motor Sport Vision (MSV) having decided to axe the one-make formula after a disappointing financial performance over its four-year history.

The FIA-affiliated championship for spec Williams-designed and built single-seaters, powered by turbocharged Audi engines, was run centrally by MSV with no team involvement. But, despite a low asking price for drivers for a championship at this level (£265,000 including insurance), it has not been as successful as hoped and MSV has struggled to make money from it.

Formula 2 financial statements show that the championship made an operating loss of £1.2m in its first year of operation, 2009. This was followed by an operating loss of £1.6m in 2010 and £1.7m in 2011. Figures are not available for 2012, but suffice to say the championship made an operating loss of £4.5m in the first three years of its four-year existence.

MSV boss Jonathan Palmer has now cancelled the championship, saying its failure was largely down to the centrally run concept, a method he pioneered with Formula Palmer Audi back in the 1990s: 'As the FIA intended, F2 has always provided outstanding value and equality for its competitors,' Palmer said. 'However, it has become progressively clear that the single operating team concept that enables these benefits has compromises that have, overall, reduced its appeal to drivers.'

While MSV has told us there has not yet been a decision as to what it will do with the fleet of F2 cars, any resurrection of the

MSV boss Jonathan Palmer

championship will not feature a centrally run concept, says Palmer. 'We and the FIA are in agreement that any future F2 should operate on a more conventional, multi team basis,' he said.

Palmer also said that competition from rivals – such as GP3 and A1GP – made it difficult to compete in the marketplace. 'Other championships at F2's level have also increased their appeal through recent performance upgrades, and it is logical to conclude that in F2's final year [MSV had a five-year contract with the FIA] grid numbers would reduce, perhaps significantly.

'I believe we have a responsibility to competitors planning their 2013 seasons and careers not to operate F2 if we are not confident of another strong season, and have therefore discussed this matter with the FIA who understand and accept our recommendation not to continue.'

The team responsible for running Formula 2 is currently busy working on the build programme for MSV's new entry-level spec championship, Formula 4, which has been designed from the start as a formula for teams, rather than one single operating organisation.

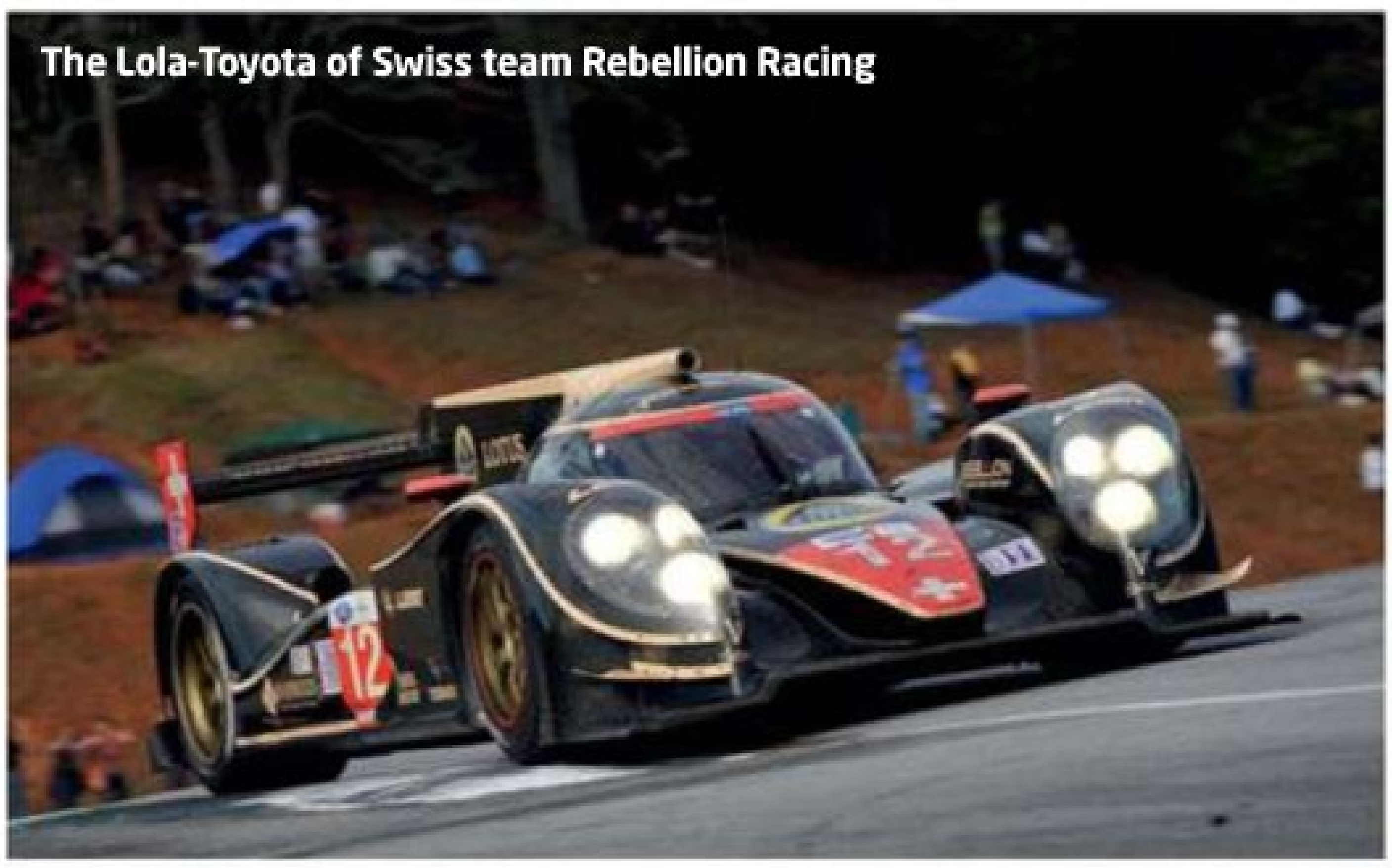
Hunger for glory sends Rebellion Stateside

One of the few private teams competing in LMP1 in the World Endurance Championship in 2012 has now committed to the ALMS for 2013, in the hope of picking up the outright wins its sponsors crave.

Swiss team Rebellion Racing enjoyed a successful season in the WEC in 2012, winning the LMP1 Trophy for privateers, but the highlight of its year was its overall win in the last round of the American Le Mans Series (ALMS), the Petit Le Mans.

The Swiss team has now decided that the publicity generated by outright wins in the ALMS is of far more worth to its sponsors than a campaign in the WEC, where it is unlikely to beat the works teams of Audi and Toyota. Bart Hayden, team manager at Rebellion Racing, said: 'The visibility generated by overall wins [in ALMS] is more in line with what our partners require and desire.'

With the above in mind the team will race its Lola B12/60 Toyota-powered car in the ALMS, kicking off its season with the 12 Hours of Sebring – where it will also run a second Lola-Toyota.



The Lola-Toyota of Swiss team Rebellion Racing

In the 2012 FIA WEC Endurance LMP1 Trophy, Rebellion secured six wins (Spa, Le Mans, Silverstone, Sao Paulo, Fuji and Shanghai) and six pole positions, but it says these results were overshadowed by the overall results of the manufacturer cars.

However, Hayden says he still pleased with the team's performance in 2012: 'It was the most demanding, but also the most successful season in the history of the Rebellion Racing team. We won the FIA WEC Endurance Trophy for private LMP1 Teams with six victories from eight races, including Le Mans, where we finished fourth and prevented a clean-sweep by the manufacturer cars. Added to that, in our only race in the ALMS we took the overall victory to win Petit Le Mans,' he said.

This does not necessarily mark the end for Rebellion in the WEC, though, and Hayden says it's hoping to put together a WEC programme which could run alongside its ALMS effort: 'The WEC is a world championship and we would like to find a way to continue racing there too,' Hayden said. 'Over the coming weeks, we will be striving to put together a programme to complement our presence in the ALMS.'

BRIEFLY

Radical RXC

Prolific sports racing car producer Radical has made a bid to join the ranks of the supercar constructors with its new Radical Xtreme Coupe (RXC). The first roofed-in Radical features a tubular steel spaceframe and packs a 380bhp-plus 3.7-litre V6 that comes from the Ford Mustang, coupled to a bespoke seven-speed Quaife transmission. The car also features front and rear wings and diffusers and is expected to generate some 900kg of downforce at top speed. While Radical has made much of its possible attraction to supercar buyers – a road-going version will be available in the summer – expect to see some of these on track in various GT series across Europe, and the Radical European Masters Series, throughout 2013.

PEELING BACK THE STICKERS. NUMBER 10: MARS

After a while, acronyms and initials become the thing in itself. For example, no one gives much thought to what NASCAR actually stands for (National Association for Stock Car Auto Racing). The same goes for one of its most successful sponsors, M&M's.

The two Ms are actually from the surnames of Forrest Mars Sr and Bruce Murrie, of Hershey's, and it's the company that bears the surname of Forrest that now manufactures and markets the product around the world. Forrest Mars Sr invented M&M's after seeing soldiers in the Spanish civil war eating a similar product – he was in Europe to set up Mars in the UK after a falling out with his Mars-founding father Frank C Mars. Incidentally, Forrest also invented the Mars Bar and was said to be worth $4bn at his death in 1999.

The little sweets have had a colourful presence in NASCAR since 1990, and it's a presence that has paid big dividends, according to research by Mars. A recent study by the global confectioner found that it receives a very impressive four-to-one return on its investment in NASCAR (as measured by Mars' tracking data) while it also says its sponsorships create a fifth season of sales for the brand – said to be on par with the size of the company's Christmas selling period.

That's a pretty good return on what is believed to be an investment of around $20m a year on the Joe Gibbs Racing Toyota (Mars would not comment on how much it pays out, but that's around the going rate for a primary sponsorship deal in the Sprint Cup). There will be extra expenditure on linked promotions – such as for TV commercials during races – that will up the money, but one thing is for sure, Mars can afford it: the corporation has net annual sales of more than $30bn across its six business segments, comprising Petcare, Chocolate, Wrigley, Food, Drinks and Symbioscience.

The partnership with Joe Gibbs Racing, and its driver Kyle Busch, has been so successful that at the close of 2012 Mars was presented with the NASCAR Marketing Achievement Award. 'Mars' execution of a fully integrated strategy within NASCAR exemplifies the spirit of the award and has been the catalyst to the brand's success in the sport,' said Jim O'Connell, chief sales officer for NASCAR, when the award was announced. 'One of our longest standing partners took full advantage of its sponsorship, raising the bar with innovative ideas designed to engage our brand loyal fanbase, its associates and ultimately move product off the shelf.'

For its part Mars believes much of that success is down to NASCAR, especially the loyalty of its fans and the sheer size of that fanbase: 'The NASCAR sponsorship model is driven by brand loyalty and Mars has been behind the wheel of a best-in-class partnership,' said William Clements, vice president of sponsorships and sports marketing for Mars Chocolate North America. 'Our successes have been led by innovation that extends to customers, consumers and associates, and capitalises on NASCAR's broad fanbase that represents approximately one-third of the US adult population.'

Or, in other words, NASCAR and Mars enjoy a *sweet* partnership.

Red Bull welcomes Coca-Cola to F1 party

Red Bull Racing boss Christian Horner has said he welcomes the competition the arrival of energy drink brand Burn will bring to Formula 1's commercial arena.

Burn, which is a Coca-Cola brand, has recently signed up with Lotus as its title sponsor, putting it in direct competition with rival energy drink sponsors Red Bull (which also owns its eponymous team), Monster (Mercedes), Lucozade (McLaren) and TNT (Ferrari).

But Red Bull team principal Horner says he welcomes the competition another energy drink brand will bring to the sport. 'I think that Red Bull welcomes competition and that's the way it is in the marketplace. Red Bull's positioning is quite unique, not only what it's achieved as an energy drink, but in terms of what it's done and the way it carries itself in Formula 1. There would be no concerns from our side.'

The deal represents something of a coup for Lotus, as Coca-Cola has long been courted by F1 teams, and while there are few details about the partnership, Burn has said it intends to 'break the conventions of traditional Formula 1 sponsorship'.

Group director of worldwide sports and entertainment marketing at Coca-Cola, Emmanuel Seuge, said of the deal: 'The creativity of teams and the passion for speed and energy that fuel the sport of Formula 1, make a partnership with this iconic sporting property a compelling proposition for the Burn brand.

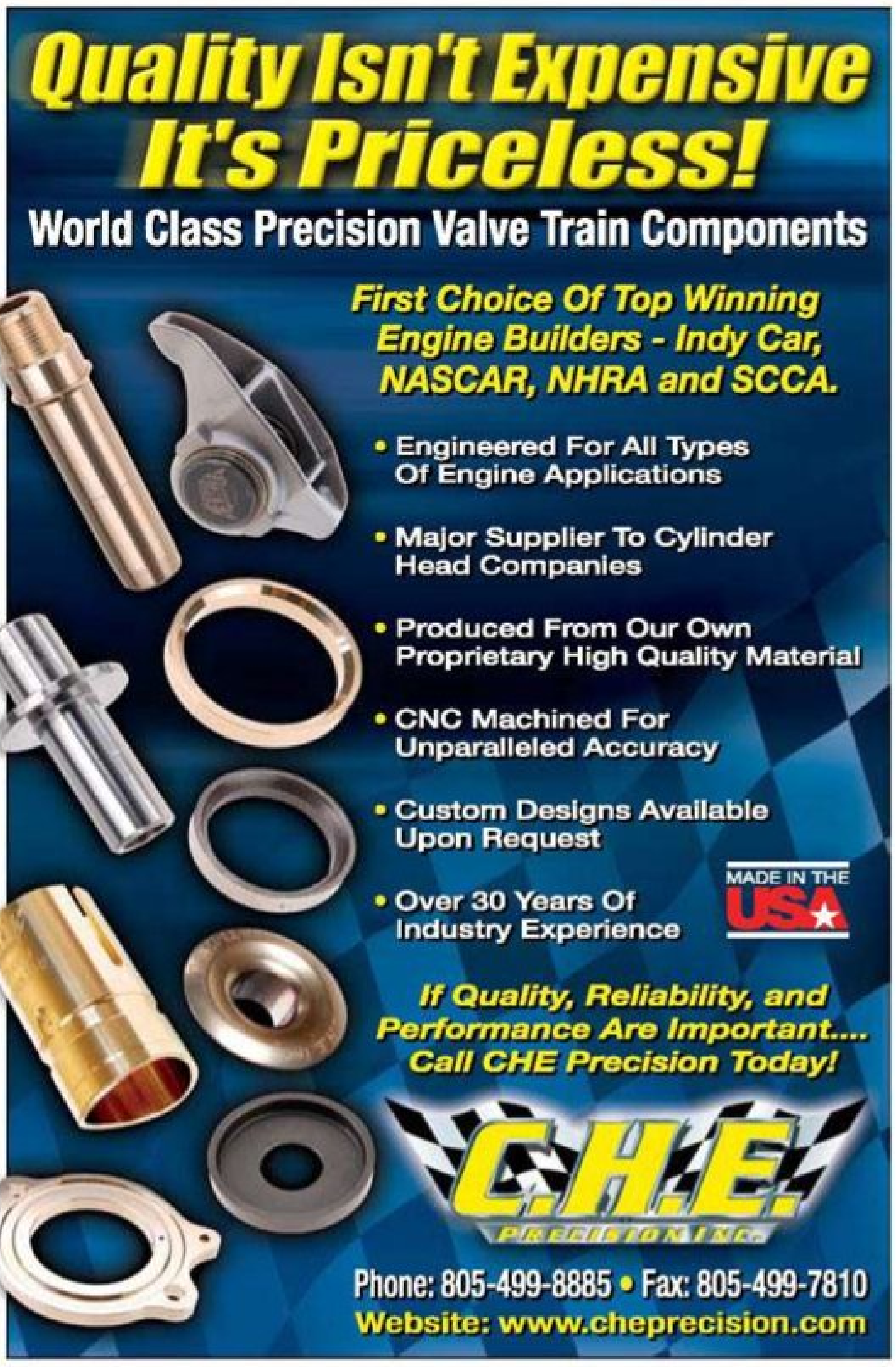
'Lotus F1 Team, as the number one emerging challenger in the sport, has demonstrated exceptional creativity in their approach to Formula 1 racing and their collaborations with partners – an approach that mirrors the philosophy of Burn. We will bring that same creativity, incorporating art and music in a way that will break the conventions of Formula 1 sponsorship marketing.'

Lotus team principal Eric Boullier would not comment on how much the deal was worth but said it would make a difference: 'Whatever it is, it's always welcome so it's obviously more budget for next year, and the next year. It's going to be good to have this brand on the car – it will mean promotion for the team and Formula 1,' he said.

CAUGHT

NASCAR Sprint Cup driver Brad Keselowski has been fined $25,000 for a rules violation at the Phoenix round of the championship. NASCAR says he broke the rule that states: 'Cars and drivers will not be permitted to carry onboard computers, automated electronic recording devices, electronically actuated devices, power distribution modules, power conditioners, micro-processors, recording devices, electronic digital memory chips, traction control devices, digital readout gauges and the like, even if inoperable or incomplete.' Yep, Keselowski had a mobile phone in his car...

FINE: $25,000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New NASCAR team Swans into Sprint Cup

The NASCAR Sprint Cup is to feature an all-new team, Swan Racing, as it starts its 2013 season at Daytona in February.

Swan Racing is the creation of Brandon Davis, CEO of independent oil and gas company Swan Energy Inc, and it will field a Toyota for David Stremme throughout the season. Davis, who competes in dirt-modified in the United States Modified Touring Series (USMTS), bought the assets of Inception Racing in 2012 to help get the project off the ground.

NASCAR's newest team owner insists Swan Racing is a serious effort: 'Swan Racing is here to race competitively every week – the days of starting and parking are over,' Davis said. 'I am confident that we are putting together the personnel to one day produce a championship contender.'

Davis has hired Steve Hmiel as Swan Racing's director of competition. Hmiel is a NASCAR veteran with over 35 years of experience as a crew chief, car chief and competition director. Most recently he was competition director at Earnhardt Ganassi Racing.

'Steve [Hmiel] is among the best and brightest technical experts in the NASCAR garage area. His experience and expertise will be a crucial part in Swan Racing's success,' said Davis.

For his part, Hmiel said: 'This is a great opportunity to build a team from the ground up. Brandon is completely committed to winning; he has a long-term vision. I am excited to be part of it.'

The team is based in Mooresville, North Carolina, and will source its engines from Triad Racing Technologies.

Swan Energy will be the primary sponsor on the No 30 Toyota, but discussions with additional backers are said to be under way and further sponsor announcements are expected soon.

Swan Racing hopes to be a title contender in the coming years

SEEN: DAKAR SMART CAR

As if the Dakar is not tough enough, Jose Luis Alverez thought he might spice it up a little by doing it in a Smart car. Alverez isn't completely bonkers, though, as this is not exactly your average city runabout – in fact it's an XP 900 Polaris Quad clothed in a Smart body. The 2013 Dakar is currently under way in South America (5-20 January) and will cover 8000km (close to 5000 miles) in three countries: Peru, Argentina and Chile.

Porsche to give it the works in LMP1

Porsche is to resurrect its factory racing team to spearhead its return to top class sports prototype racing in 2014.

The German car maker has said a full works team based at its Weissach, near Stuttgart, research and development HQ will be responsible for the LMP1 hybrid racecar, which is set to hit the tracks for the first time in the middle of this year.

Porsche's new challenger is currently being designed at Weissach, and will also be built and developed there. It's believed there are around 200 people working on the project.

The Weissach facility has been upgraded since its last major programme with the LMP2 RS Spyder, which was run by the Penske team in the US and by customer teams in Europe.

Porsche R&D boss Wolfgang Hatz confirmed the factory programme, saying: 'The car will be run by our own works team based here at Weissach. The first rollout of our new LMP1 car is planned for mid-2013.'

Most of Porsche's 16 Le Mans wins have come with teams run direct from the factory, including its final victory with the 911 GT1 in 1998.

Meanwhile, there has also been a shakeup within Porsche Motorsport, with Fritz Enzinger – formerly of BMW – now taking over the LMP1 project, while Hartmut Kristen will retain control of the manufacturer's 911-based programmes.

The company will also run a factory team in the 2013 World Endurance Championship at a GTE level, fielding a 911 RSR in conjunction with Meuspath, Germany-based Manthey Racing. The new team will be known as Porsche AG Team Manthey.

BRIEFLY

Daimler spends

Daimler now has full control of the Mercedes Formula 1 operation after it bought the stake previously owned by Abu Dhabi-based Aabar Investments. Aabar's involvement in the team dates back to the days when it was known as Brawn in 2009, but the recent deal means Daimler is now the sole owner of the Brackley-based team.

Crossle snapped up

The UK's oldest surviving racecar constructor, Crossle, has been bought by historic racer Paul McMorran, a long-time customer of the 55-year-old company. McMorran, who made his fortune working in the Russian oil industry, is the third owner of the firm, after John Crossle and Arnie Black.

Transmission accomplished

Xtrac continues to diversify with its 'hybridised' automated manual transmission that will allow future luxury supercars to meet Europe's 2020 95g/km CO_2 emission requirement. Designated '1010', the prototype-ready gearbox is aimed at manufacturers in the premium luxury road car sector.

INTERVIEW: JAMIE CLARE

Q. How did Greaves 3D Engineering come about?
At Greaves Motorsport we came to the point where we were manufacturing pretty much all of the equipment that we needed in the garage and pitlane, and it was starting to get quite stressful having to have one-off prototype parts made, in terms of having them delivered on time, or even at a sensible price. So we decided we'd look at getting just a few machines so we could look after ourselves and not really have to worry about relying on a third party. But as we spoke to other teams and other businesses it soon became apparent there was a gap in the market for this type of business.

Q. What exactly does 3D Engineering do?
There are actually two sides to the business. There's more to come, but at the moment we're trading as a company that provides quite a comprehensive range of garage and pitlane equipment – and we can now manufacture all that ourselves, and offer it at competitive prices. We also have the capacity to do projects, sub-contract machine work and fabrication for pretty much anything you like – and it doesn't necessarily have to be motorsport.

Q. How closely linked is Greaves 3D Engineering to the race team?
Greaves 3D Engineering shares a 14,000sq ft facility with Greaves Motorsport, into which the team moved at the end of 2011. We've been operating as a race team from the facility over the 2012 season, and then, towards the tail end of the season, we basically did a new fit-out of the building, which is now split between the motorsport and engineering businesses – the advantage is that being so close to a quality race team like Greaves Motorsport, there's a synergy of values in place.

Jamie Clare, general manager of Greaves 3D Engineering, started his motorsport career as an apprentice at Pilbeam Racing Designs in 1998 and is a time served machinist and mechanical engineer. During his career he has worked for many well-known motorsport businesses, including RML and Radical Sportscars, and he has been involved with WEC team Greaves Motorsport for the past seven years. Clare now heads up the organisation's new business, Greaves 3D Engineering, which manufacturers and supplies pit equipment while also offering a contract machining service to motorsport and other businesses.

Q. What equipment have you invested in?
We've probably spent somewhere in the region of half a million pounds on setting up this venture, so again that speaks volumes when it comes to questions of commitment. We're not playing at this. Everything we've bought is brand new, cutting-edge, state-of-the-art, for the field that it's operating in. We have a five-axis milling capacity with a DMG DMU-50, large CNC turning capacity with live tooling with a DMG CTX-510, and further three-axis milling and conventional CNC turning. We also have an inspection and metrology room which can cater for many types of engineering projects, while there's a well-equipped fabrication suite where we produce much of the pit and garage equipment that's offered for sale.

Q. What are your plans regarding 3D rapid prototyping?
With the 3D rapid prototyping there are various technologies you can use, depending on whether it's for a demonstration part or if it's to be functional in some way. You can buy what's described as a printer for as little as £10,000, but it's only going to make something as big as a teacup, and it's not going to be functional, it's just for show and tell purposes really. Or, you can buy a selective laser sintering machine (SLS) which will produce parts in different materials; high strength plastic or composite materials, which you could, for instance, use on a racing car – and our Zytek chassis do run rapid prototype components on them – and that's the machine we're looking at. We've done the research and we've been in contact with the manufacturers of these machines, and we plan to offer this in 2013.

"The best showroom for what we do is the team garage – we make all of the ancillary equipment"

Q. What pit and garage products do you supply?
The best showroom for what we can do is actually the team's garage. Point at something in the garage, and we can pretty much provide it. We make all the ancillary equipment in the garage, from the stands to the lifters that we use to raise the car, on to set-up equipment, fuel rigs, and the booms and gantries that go over the car. Products currently on sale are tyre trolleys, fuel rigs, pitlane booms and car lifters.

Q. What sort of materials do you use for your products?
To take, say, the boom system we use for running the airlines over the car, that's a mixture of carbon composites and high grade aluminium. The fuel rigs use honeycomb panels to make them lightweight and stiff and strong, and then for the garage equipment we typically use a lot of stainless steel.

Q. Why do you think this venture will succeed?
Well, we've invested in the right areas with the machine tools, but it's not just about big lumps of metal and machinery in the workshop. They're useless unless you've got the expertise to drive them, and also the expertise to translate a customer's requirements into something real. While we've spent good money on the equipment side, we've also invested wisely on the staffing side. We expect that the umbrella we've created within the business, of expertise and tools, will tackle any problems that we're presented with.

Q. How important is to have a wide skill base in your workforce?
We're quite flexible. We've got a very wide and very in-depth base of knowledge to draw from here. In-house we've got very skilled fabricators, and on the machining side we've got people who are running five-axis machining centres. We've got people in-house who are skilled as designers, right down to the guys who run the racecars – and as a Le Mans-winning race team, that sort of quality speaks for itself.

Billionaire goes out on a Lim to build F1 track

Wealthy Singapore investor Peter Lim is reported to be planning a $1.2bn motorsport development for Malaysia.

The project, which will be known as Motorsport City, will have a 4.5km Formula 1 standard circuit as its centrepiece, to be penned by an as yet unnamed track designer. It will be built in the Iskandar region of Malaysia, in the south of the country and close to Lim's home state of Singapore.

Motorsport City has been rubber-stamped by Malaysian state-owned UEM Holdings and it's expected to be up and running by 2016. It will be operated by Fastrack Autosports, a company that is majority-owned by Lim, while the ownership of the development will be split between Fastrack (70 per cent) and UEM (30 per cent).

Malaysia and Singapore already have a grand prix each, the former held at Sepang and the latter through the streets of the city, and Lim has told press in south-east Asia that he believes 'the region is fast becoming a hub for motorsports'.

Lim, who is a shareholder in McLaren Automotive, is said to be worth $1.5bn (according to Forbes magazine) and is known to be interested in sports investment – in the past he has been spoken of as a possible buyer for football clubs Glasgow Rangers, and Liverpool. He also owns a chain of Manchester United themed bars and clubs throughout Asia.

Lotus pulls out of IndyCar

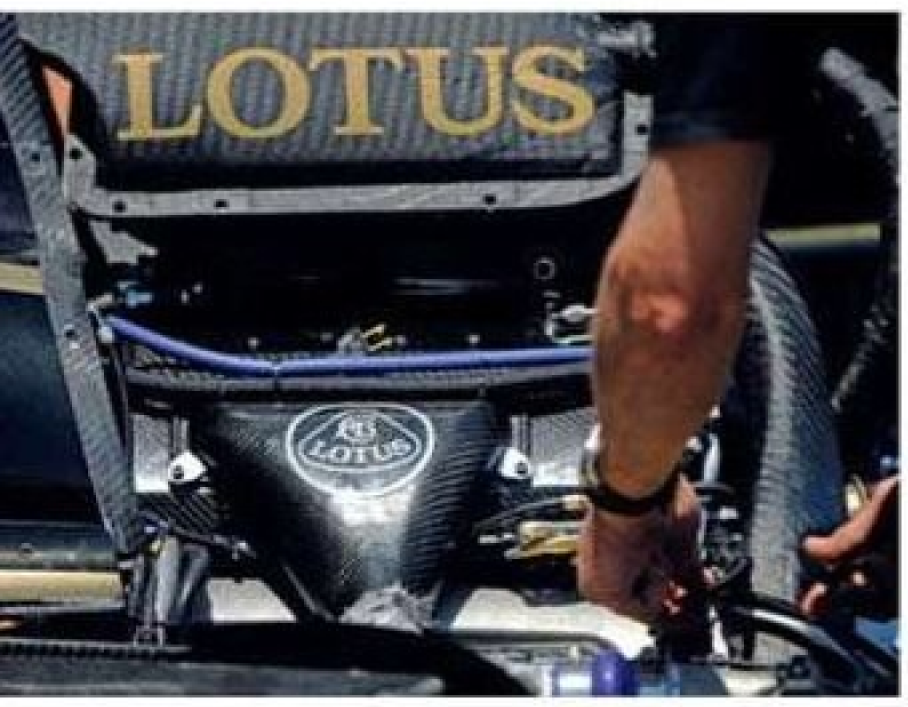
IndyCar is now down to just two engine suppliers after it released Lotus from its contract to supply powerplants to teams in the series.

Lotus joined Chevrolet and Honda as an engine supplier to the premier US single-seater championship for 2012, but its programme was hit with problems all year. It started the season supplying four teams: HVM, Herta Autosport, Dragon, and Dreyer & Reinbold, but was left with just HVM flying the green and yellow flag after the Indy 500.

IndyCar has now announced that Lotus had been released from its contract after the company told IndyCar it could not honour its contractual obligations due to business reasons. IndyCar president of operations and strategy, Brian Barnhart, said: 'We appreciate the effort that Lotus made in helping return manufacturer competition to IndyCar. However, Lotus has made a business decision not to return in 2013 and asked for its release. We wish them well and would welcome their participation again in the future.'

Lotus chief operating officer Aslam Farikullah said that its withdrawal will not necessarily mean the end of Lotus in IndyCar: 'Lotus is grateful to IndyCar for the opportunity to compete during the 2012 season and for the support provided throughout,' he said. 'The decision not to continue was not an easy one and Lotus does not discount the possibility to re-enter the series at some time in the future. For the time being, Lotus will focus on core business activities as a leading sportscar manufacturer and world-class engineering consultancy.'

The Lotus decision means that both Chevrolet and Honda must now each be able to supply a minimum 60 per cent of the 2013 grid, as per the terms of their contract with IndyCar.



RACE MOVES

McLaren GT, the arm of the McLaren Group that deals with its 12C GT3 racecar, has made three high-profile appointments. **Andrew Bailey** (middle) has moved to the role of operations director, **Ian Morgan** (left) has joined as chief engineer, while **Tim White** (right) has taken up the position of engine operations manager.

Former F1 race engineer **Tim Wardrop** has died at the age of 62. Wardrop worked for McLaren, Wolf and Williams during his time in Formula 1, and was the engineer for **Arie Luyendyk** when he established his still unbroken Indianapolis Motor Speedway lap record of 237mph back in 1996.

Former FIA Sportscar and Lola communications manager **Sam Smith** has launched his own PR concern. Sniffer Media will provide PR and media strategies for motorsport – and also football – and can be found at www.sniffermedia.com.

James Strong has been appointed non-executive chairman of the Australian V8 Supercars series, taking the place of **Tony Cochrane**. Strong served as a director of the Australian Grand Prix and of Dorna, the company behind MotoGP, and is also on the committee of the 2015 ICC Cricket World Cup. He was formerly a long-serving CEO at Australian airline Qantas.

Mark Miles has replaced **Jeff Belskus** as chief executive officer of Hulman & Co, the company behind the Indianapolis Motor speedway and IndyCar. Belskus, who filled the role on an interim basis following the departure of **Randy Bernard,** will now just concentrate on IndyCar. Miles, who has been on the Hulman board for several months, spent 15 years as CEO of the Association of Tennis Professionals.

Greg Erwin has been taken on by Penske's NASCAR Nationwide operation to act as crew chief on the No 12 Ford of **Sam Hornish Jr**. Erwin has most recently been crew chief on the Richard Petty Motorsports No 43 Ford, but has worked with many other top NASCAR outfits in his time, including Roush Fenway Racing, where he teamed up with **Greg Biffle** to win five races, qualifying for the Chase on three consecutive occasions.

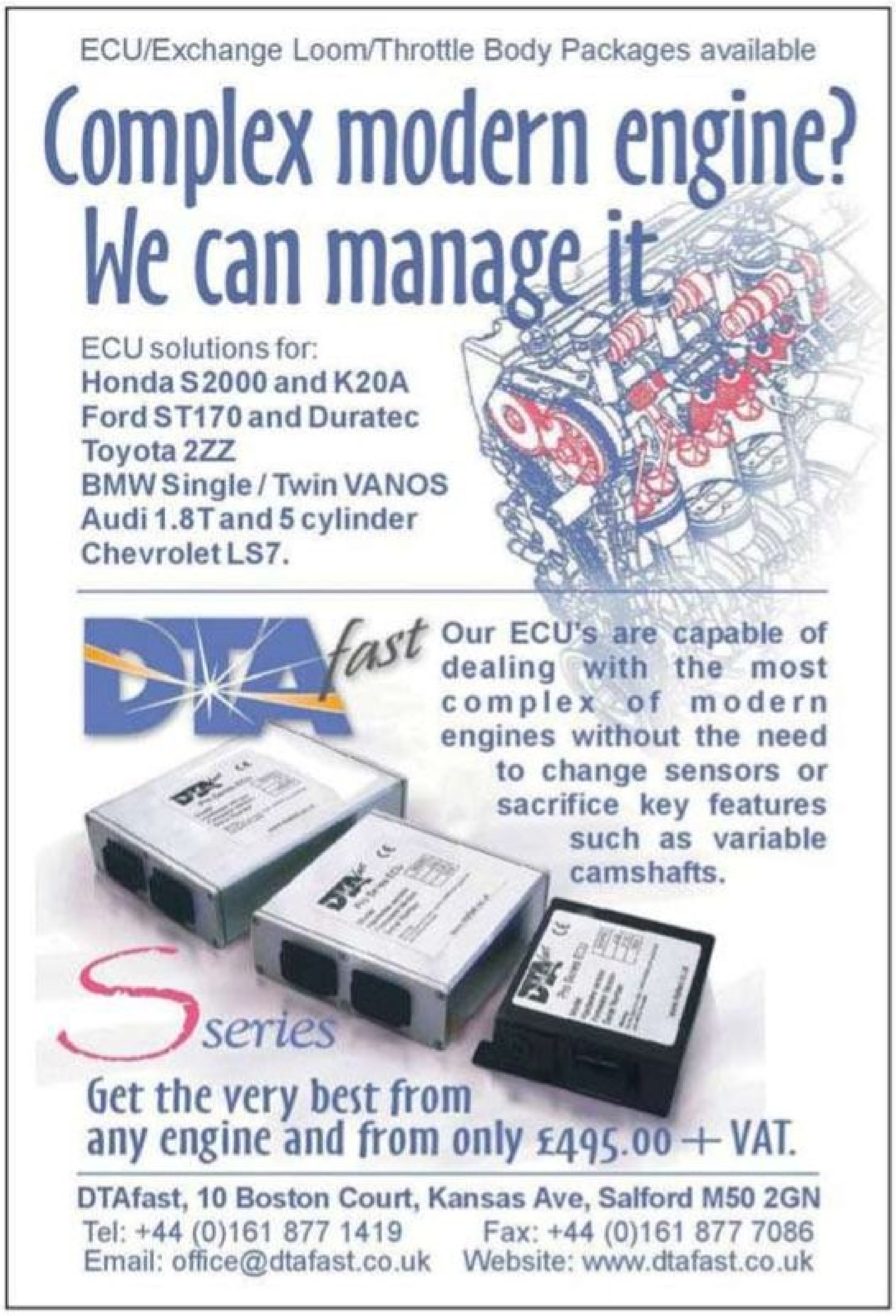
Greg Ives is to be the crew chief on Regan Smith's JR Motorsports No 5 Chevrolet in the 2013 NASCAR Nationwide Series. Ives has been in NASCAR for nine years, the entire time spent at Hendricks Motosport where he was the race engineer for **Jimmie Johnson,** helping him to win five Sprint Cup crowns.

Martin Pott is now business development manager for motorsport at electrical harness company Tekdata. Pott has been in the motorsport industry for over 35 years, and in that time he has worked in team management, business development and event management, both in Europe and the USA.

Veteran NASCAR crew chief **Jimmy Fennig** will tend the **Carl Edwards**-driven No 99 Roush Fenway Racing Sprint Cup car in the 2013 season. Fennig is one of the most successful crew chiefs in NASCAR history, with more than 800 starts and 36 Cup victories during his 30 plus years in racing. Joining Fennig at Roush Fenway will be **Scott Graves**, who is to act as crew chief on the No 17 car, to be driven by **Ricky Stenhouse Jr.**

Cyril Abiteboul is now team principal at Caterham F1, with **Tony Fernandes** having stepped back from the day-to-day running of the team. Malaysian entrepreneur Fernandes, who always said he would step down when a suitable replacement was found, will now concentrate on the company's road car tie-up with Renault, as will deputy chairman **Kamarudin Meranun.**

Charles J Henry, crew chief on the No 38 truck in the NASCAR Camping World Truck Series, has been indefinitely suspended from all the US stock car racing governing body's competitions after he was found to have violated its strict substance abuse policy.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Long-time motorsport boss Haug leaves Mercedes

Norbert Haug has stepped down from his post as head of motorsport at Mercedes, a position he had filled for 22 years. A statement from the company said it was a decision that was arrived at with 'mutual agreement with the board of management.'

Haug oversaw the German marque's return to Formula 1 in 1994, to begin with as an engine supplier, and was then instrumental in it becoming a full constructor when Mercedes bought and rebranded the Brawn squad at the end of 2009.

Since 2009, success has eluded the team and in 2012 it finished a disappointing fifth in the constructors' standings, despite a win in China. That said, since 1994, Mercedes engines have powered 87 grand prix winning cars, and helped drivers to six titles as an engine supplier, while across DTM, ChampCar, GT, sportscars and Formula 3, Mercedes has won 439 of 986 races contested during Haug's time at the helm.

The 60-year-old's position had been the subject of some speculation recently, since the appointment of Niki Lauda in a non-executive role that links Mercedes GP and the board of its owner, Daimler. As yet, there has been no word on whether Lauda will now take on any of Haug's responsibilities.

Haug said of the decision: 'I would like to thank the best car company in the world for more than 22 years, which never had a single moment without passion for me. I particularly wish to thank the board for the trust and freedom they have always given me with all my activities.

'Since 1991, we had tremendous achievements and wins, for which I want to thank all of my colleagues. Unfortunately, with one victory in 2012 since founding our own Formula 1 works team in 2010, we couldn't fulfil our own expectations. However, we have taken the right steps to be successful in the future. Our team and our drivers will do everything to achieve these goals.'

Dieter Zetsche, CEO of Daimler, paid tribute to Haug's commitment over the past 22 years: 'Norbert Haug was the face of the Mercedes-Benz Motorsport programme for more than 20 years,' he said. 'For me, he put his stamp on a whole era and, as a highlight, he was responsible for the successful comeback of the Silver Arrows to Formula 1.'

At the time of writing there was no word on Haug's future plans.

RACE MOVES

Jean-Francois Caubet has retired, and is no longer the managing director of Renault's Formula 1 engine group. His responsibilities will now to be taken on by the company's president, **Jean-Michel Jalinier.** Caubet originally joined Renault in the 1970s, rising to the position of managing director of Renault's F1 team before it withdrew from the sport in 2010.

NASCAR team Furniture Row Racing, which runs the No 78 Chevrolet for **Kurt Busch** in the Sprint Cup, has announced that it will develop, train and oversee its own over-the-wall pit crew. It has been using crews employed and trained by other NASCAR teams such as Stewart-Haas Racing. **Mike 'Tiny' Houston** has been hired as the pit crew coach for the team and he will oversee the new six-member crew.

NASCAR has reinstated crew member **Ryan Hess** upon his successful completion of its Substance Abuse Policy Road to Recovery Program. Hess had been indefinitely suspended from NASCAR last August after violating the sanctioning body's strict substance abuse policy.

Mike Henry and **Erik Pender** have left Australian V8 Supercar championship winning team Walkinshaw Racing. Henry was racing operations manager at the team while Pender was team manager for the outfit's No 66 entry.

Tom Rann has been named the winner of the Telstra Racing Recruit programme. The 21-year-old from Spring Grove in New South Wales will now complete his apprenticeship working as a mechanic with Australian V8 Team Ford Performance Racing.

Former NASCAR vice president of corporate communications, **Jim Hunter,** is to be posthumously inducted into the National Motorsports Press Association Hall of Fame. Hunter is one of three new inductees; Pocono Raceway founder **Dr Joseph Mattioli** and pioneer sports broadcaster **Ken Squier** being the others. Hunter died in 2010.

Nick Langley is now development director at the Motorsport Industry Association (MIA). Langley has worked in motorsport for 25 years, having spent 13 years as sales and marketing manager for Dallara and 12 at Lola as business development manager.

Paul Wonnacott is now managing director at Capricorn Automotive, replacing **Martin Keswick**, who had been MD for the past eight years. **Sebastian Howell-Smith** has also joined the company's board as technical director.

Transmission manufacturer Hewland Engineering has made four key appointments. **Malcolm Rooker** is now a non-executive board director and **Ken Wallace** has been appointed to the role of business development manager. Wallace will work closely with **Alex Thornton**, who has joined the company as sales co-ordinator, while **Dave Hawke** is the company's new operations manager.

New NASCAR Sprint Cup outfit Swan Racing has hired **Tony Eury Jr** as crew chief for its No 30 Toyota. Eury has been in NASCAR since 1991, most recently as crew chief and co-owner at JR Motorsports in the Nationwide Series.

Andy Cowell has replaced **Thomas Fuhr** as managing director at Mercedes High Performance Powertrains, the company responsible for the German marque's F1 engines. Fuhr had been MD since 2009, but has now taken up a post outside motorsport. Cowell was previously engineering director at the organisation.

A memorial service for **Professor Sid Watkins**, the former FIA medical delegate who died in September at the age of 84, is to take place on January 18 in London. The service will be held at the Marylebone Parish Church, 17 Marylebone Road, at 11.30am.

MSA chief executive **Colin Hilton** has been elected to the Executive Committee of the FIA Institute for Motor Sport Safety and Sustainability. He has also been appointed deputy chairman of the FIA's Sports Development Task Force.

Former Mercedes F1 lead mechanic **Dan Shufflebottom** has set up a team to race in the European Le Man Series. Shufflebottom, who left Mercedes midway through 2012, has teamed up with an anonymous Middle Eastern backer to form RAM Racing, which will field two Ferrari 458 Italias in the GTE class of the ELMS.

Moving to a great new job in motorsport and want the world to know about it? Or has your motorsport company recently taken on an exciting new prospect? Then send an email with all the relevant information to Mike Breslin at bresmedia@hotmail.com


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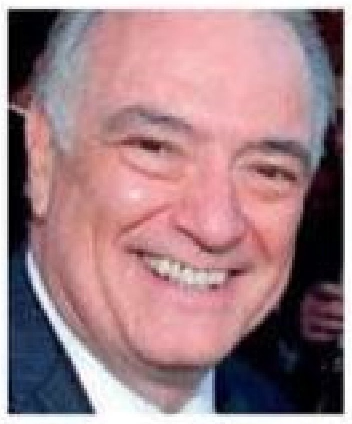

Exporting success

As trade show season continues, many motorsport companies are reporting increased sales, with a host of bumper deals being made

The recent MIA Business Survey shows Motorsport Valley UK companies enter 2013 with cautious optimism. More than 60 per cent of these UK companies increased sales during 2012, most increased their staff, and plan further recruitment in 2013 too.

A record 80 per cent now export, and more than half report having diversified into new sectors in recent years. Generous R&D tax credits were claimed, from the UK Government, by 55 per cent who are reinvesting in increasing R&D work.

A successful industry then, overturning negative news from other manufacturing sectors, working hard to find new business in new sectors, and new overseas markets. China has appeared on the export charts for the first time, but the USA remains, far and away, UK motorsport's largest export market, and also the one with 'most potential'.

I have just returned from PRI, where many were chasing new business with the MIA and UK Trade & Investment, one securing a $1.5m order to set a record day for UK companies. I watched orders still being written, even after the show closed! While UK Government budgets are being cut, the MIA secures increased financial support from UKTI, which provides enormous help. Just last week, a further £45m was made available to help firms to export from the UK – pro-active exporting and international trade just have to be the best way to counteract recession.

This was the last PRI Show in the Orlando sunshine, as it returns to Indy next year, the new owners, SEMA, having merged the show with IMIS. The vast potential of the USA motorsport market can then be reached at one, vast PRI Indianapolis show from 12-14 December 2013. If the USA market is on your radar – and it should be – don't miss the PRI Show 2013, where the MIA will help UK companies secure UKTI support to exhibit there.

The talk of PRI was the merger of ALMS and Grand-Am, becoming one series from January 2014. The France family, at a stroke, increase their influence on global motorsports. With their ownership of NASCAR, Grand-Am, ALMS, Sebring, Road Atlanta, and a majority shareholding in International Speedway Corporation with 13 race tracks in the USA, they effectively now 'own' stock car and sportscar racing in the world's largest motorsport marketplace.

Make no mistake, NASCAR are determined to increase the popularity of sportscar racing in the USA. They will benefit from the different demographics, sponsors, media and – most important – TV audience compared to their NASCAR programme. This move brings more racing to their tracks, better relationships with their automotive partners, increased content for TV partners and an exceptional opportunity for competitors and sponsors. NASCAR resources, when focused on USA sportscar racing, will make an enormous difference, so expect some surprises.

UK companies have been doing a roaring trade at recent shows

Any supplier, hoping for sportscar business in 2014, simply must visit the Rolex 24 at Daytona on 26 and 27 January – just an hour from Orlando, direct flights from London, and low-cost hotels plus every team, sponsor, manufacturer and organiser in attendance. This is the time to meet the right people to share in the new future of US sportscar racing – don't leave it too late.

The growth of off-road racing was widely discussed at PRI. This largely unregulated, fast expanding motorsport is growing out of south-west USA with large budgets, and good TV. The racing, either point-to-point across hundreds of miles of desert or long laps of six miles or more, is attracting an ever-growing audience. The teams are wide open to new innovations and suppliers. Their needs are not the same as rallying, their sporting demands are so different that suppliers need to get into the desert to meet the buyers, and see for themselves. To help European companies get close to this new business, the MIA is running an Expo In The Desert at Parker, Arizona, just three hours from Las Vegas, from 30 January to 3 February 2013. The show surrounds all 250+ competitors, so they see the products, meet exhibitors and agree what to change to meet their specific use. All these customers want is to 'go faster, and last longer' in the desert. Cars and trucks cost over $1m each, and entries exceed 400 vehicles in one event - check www.the-mia.com to join us and write new business in the desert.

The Motorsport Expotech Show in Modena, from 31 January to 1 February, will again host many international visitors seeking business with the successful high performance cars from that region, and the MIA team will be there too. Modena's superb car and motorcycle makers continue to look for new suppliers and innovations.

There will also be plenty of new business being written at the Autosport International Show in January. I love to hear about your export successes, and new areas of business, and want to help you to grow your sales, come and visit the MIA on Stand 8020 – the show's International Business Lounge and make 2013 a great year.

Social networking

Men are at a considerable advantage when it comes to social invitations. Normally, an invitation will dictate what we are going to wear. If it says 'lounge suite' we have a pretty good idea what to put on. 'Black tie' means that the room will look like it's been filled with penguins and, previously, 'casual' was the only slightly problematic area. Porsche, for it's Night of Champions in December, created the mother or all confusion. The invitation for this event said: 'Dress code: Elegant.'

By and large, boys don't do 'elegant'. No one was really clear what it meant. Some took it to mean national dress, others black tie, others lounge suits, and one turned up in jeans. The media corps opted to swap the word 'elegant' for 'usual', and picked up the suits that we have used for the last five years. My take on 'elegant' was to wear it without a tie. This seemed to be acceptable.

The Night of Champions is an extraordinary affair. Present were Wolfgang Hatz, Porsche AG board of management member for research and development, Wolfgang Duerheimer, head of the Volkswagen Group's strategic development, and Mattias Muller, chairman of the executive board. All were freely available for a chat over a cocktail at the end of the formal prize-giving and unveiling of the new 991 Cup car that will be used in the Carrera Cup in 2013.

Wolfgang Duerhelmer says he still has to understand what Audi's strategy is

At this event last year, Mr Duerheimer made it clear that one of the brands would be heading into Formula 1, and we assumed he meant Audi. With Porsche returning to sports car racing, it made sense for Audi to vacate the spot rather than compete against its sister brand.

'At present, Formula 1 is not a subject for one of the brands in the Volkswagen Group,' said Mr Duerheimer, a little pink of the eye, at 3am this year. 'I do not remember exactly the context that we spoke about Formula 1 last year, but at present it is not a subject. All the brands are busy with their decided projects. Volkswagen has a big challenge in the WRC to be competitive, and hopefully to get close to the top. Porsche has a clear decision to go to Le Mans, Audi will remain in Le Mans for the time being, so everyone has a clear target. Skoda is doing well in rallying, and we need to take care about SEAT, that they are coming back into good competition in the WTCC. Lamborghini will be active in GT3, and I am very happy that Bentley introduced the GT3 car. I liked it very much, and hope that they have a straightforward development in 2013 so that we will see the car on the grid in 2014.'

So, what about FIA President Jean Todt's view that Audi, Porsche and Toyota should build engines that will be suitable for Le Mans, and Formula 1, and that the cost of producing such engines for Formula 1 could be spread for Renault, Ferrari and Mercedes with a wider customer base?

'I think this is one of the subjects that he is pushing, and Jean Todt is [making it] very beneficial in introducing new drivetrain technologies that make it easier for brands that race to switch between different race categories, because in the past it was very expensive to develop a completely new car and drivetrain when you wanted to switch series. But, with the existing regulations in Formula 1 and rules in LMP, we are still a fair distance ahead from this dream coming true.'

That's a no, then. However, the question still remains: what will happen to Audi? Duerheimer joined Audi from Bentley late in 2012, and says that he still has to understand what its strategy is, where the brand would like to go, and how that fits with his vision for what it should do. The message was clear for now – the North American and Asian markets. Audi could remain in endurance racing, but would have to produce an LMP2 car, or a Daytona Prototype, neither of which is likely. There's nothing that promotes the technical innovation like a Le Mans programme yet, and Mark Raffauf, who at the Porsche party was busy trying not to make a large vase fall off the bar, hinted that this was not a direction for Grand-Am anyway.

For Audi, the DTM link with the Japanese could be a way to leverage that market, but what about the US market? There was talk of the DTM cars being available in the US too, a global platform for the new cars. Could Audi push this hard enough, and make it happen? Or, could it be as simple as to take the brand into Formula 1, the only series with a satisfactory market in all of these regions? That's unlikely.

'In the North American region, there is still a gap to our main competitors Mercedes and BMW, and in Asia we are the number one brand in terms of premium segment, and we want to defend this title in terms of racing,' concluded Duerheimer. 'The racing scene is well defined in the top and bottom, and in the midfield it is necessary to fill it out pretty soon, and this is what I want to emphasise.'

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Andrew Cotton

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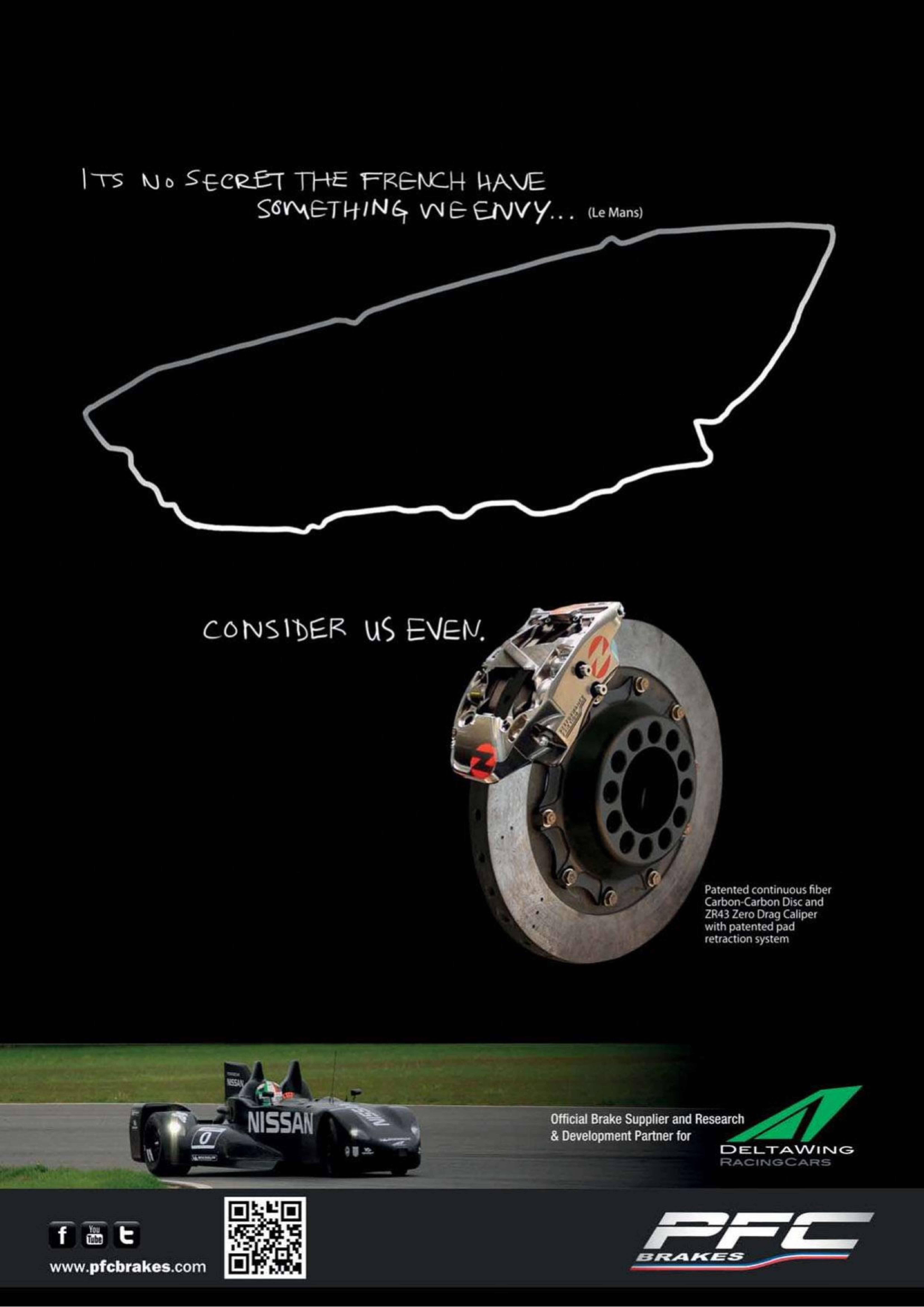
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