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Subaru GT300
The extreme Japanese BRZ

Green GT
Is hydrogen the future? Swiss innovation unveiled

Le Mans 24 Hours
We examine the strategy behind Audi's victory

Nissan Leaf NISMO
Electric car makes competition debut at Crystal Palace

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Let battle commence

An engineer's eye view of the Le Mans experience

Monday morning with Le Mans hangover brings forward all the clichés for a column title… 'The longest night', 'A hard day's night' and, of course, 'Good vibrations,' if you were running a flat-crank V8.

It doesn't need superlatives because it is what it is. Let the sprint racing single seaters have their two hours of racing and maximum 305km length, that's wimp's stuff. Endurance racing is what it says on the package – 24 hours, 5600km, and if it breaks or gets broken, it gets rebuilt damn fast and goes out again.

I can wax lyrical about the sheer beauty of cars pounding around, falling to bits, encounters with other drivers, being rebuilt in an astonishing short time and launched again into the fray. If you are lucky, the weather will be late Spring balmy, and the cherry on the cake, a full moon to light up the arena.

If you are even luckier, your chosen team will breeze through, doing routine stops – fuel, fuel, fuel, fuel, tyre and driver – and eventually arrive at the flag, a bit dirty and in an useful placing, with crew members looking like the Red Baron after a Fokker Dreidecker flight, wearing that faraway look one gets after a 36-hour adrenaline burst.

Sunday scrutineering is a hallowed tradition, held in the centre of town. The cars used to be driven on public roads to the *Parc des Jacobins*, but today it involves a somewhat inconvenient half day of lugging cars onto transporters.

Tuesday is a day spent to the soundtrack of grinders and bone cutters chomping at carbon due to the teams finishing off spare bodywork, (several sets of it, as punctured tyres on that special Le Mans gravel, other cars being attracted to one's car, plus sleep-deprived drivers not keeping it between the white lines will use up most of what you prepared).

Also sundry earnest meetings with team managers and drivers ('we want you to go fast, but don't fall off, don't hit the kerbs and don't hit other cars'); tyre suppliers ('we want softer /harder / longer lasting / more'); engine builders ('we need more power / less fuel consumption / more low-end torque), then endless standard pit stop practices, plus the esoteric ones, changing noses, bodywork and rear wings.

All this whizzes by very fast, and soon we find ourselves in Wednesday's practice session. This is when you find out if all the poring over data from previous weeks' test brings proper results or have reverse engineered the car to unwittingly make it slower.

"always, like fishermen's tales, slightly exaggerated"

Proceedings become even more earnest as the next session involves qualifying all your drivers, plus trying to set a banker time before it's too dark in case the weather turns sour for the Thursday qualifier. As a lap of Le Mans is worth 3m30s, it eats up 55 minutes of your two hours just for that.

Qualifying ends at midnight, but then driver debriefs, job lists and checking data takes you to 1.30am, so one's sleeping patterns take a beating, especially with an 8am start for the second day of qualifying.

If you have prepared conveniently, all running gear, race suspensions, engine and gearbox have been pre-shaken down, and will be fitted on the Friday break, enabling crew to finish early and get the rest needed for the very long weekend, as warm-up starts on the Saturday at 9am.

Note the use of the conjunction if here. Sometimes the overspill from having had a shunt (us, this year) or engine blow up (also us, this year) will make Thursday night run into Friday morning and, in the ripeness of time, run into Saturday morning, adding 48 further hours to the 24 hours previously budgeted.

The three-hour wait on the grid before the chariot has a chance to do a final run, coming though the pits to top up fuel and send it around to grid to stew for another 40 minutes, is spent anxiously looking at clouds, checking wind speeds and peering at radar screens to see if rain is coming.

The start at 3pm is a welcome relief to the crew. If all goes well, it means they will have the first break in a week to catch up with sleep, eating and finally seeing the car operate as it should, as it will then settle into the pattern of doing 50-minute stints. And, if all remains well, it will then be pounced upon for a frenzied 50 seconds whilst tyres are changed every four stints, windscreen cleaned and car topped up with fuel for another stint.

The pattern is broken every now and then by the sudden warning on radio that all is not well, as engine / gearbox / steering / cooling / tyre has a problem spotted by driver or seen on telemetry, or the vision of car in replay bouncing off a wall / Armco / other car means it will be arriving back at pit soon.

A pit stop at Le Mans, and Divila (third from left) sees his plan come unstuck

The erstwhile snoozing mechanics leap to the pit lane, galvanised, dragging balaclavas helmets, gloves and goggles on, while engineers huddle at the telemetry screen trying to fathom what needs to be done, or peering at the TV screens to ascertain what body damage the car has. If so, the gaggle of team VIPs and sponsors get trampled in the rush to collect nose / splitter / spare tyres. Women and children first? On the Titanic maybe, but not in a racing pit.

In a remarkably short time by the clock, but an eternity in perception, the car is out and calm reigns again. Rinse, repeat for 'n' hours and there we have it. The worst case is the lame duck car that gets repaired, drags itself around for a while, then has another pit call, rather like the zombie that can't be killed. In this case, having a stake in the back of the pits to plunge through its heart can be solace for the team.

Wandering out behind the pits to indulge in a tobacco addiction and topping up the caffeine level mid-race gives the opportunity to see members of the opposition and exchange terse bits of information re: their problems so far – always, like fishermen's tales, slightly exaggerated.

And so, beaten by column length, one must bid fond *adieu*, condensing another year of no sleep, adrenaline overdosing and far too many cigarettes and coffee, with little to show for it except a car that took the flag unclassified due to a major mid-race rebuild and, finally, the engine coughing up blood, four kilos of weight lost (the silver lining in the dark cloud) and still a lactic acid hangover a week after.

Will I be back next year to do it all again? Damn yes!


One Man Machine Shop
Change from heads...
F69 ATC
F69 ATC
ROTTLER
ROTTLER
...to blocks
and back again in minutes!

Competition costs

Sam Collins on the reality of customer car formulae

'New regulations are a part of Formula 1. It is just a shame that regulation changes are always restrictions,' Adrian Newey told the assembled media at the launch of the Red Bull RB8. 'The danger is that if the restrictions become too restrictive, then we all end up racing GP1 cars, though we haven't quite got there yet.'

It is a concern echoed by many at the moment, as Formula 1 seems to be heading inevitably towards a cost cap. Talk of customer cars has flared up, and the question asked whether a team like Marussia or HRT could look to buy a set of season-old McLarens or Ferraris. Even Caterham, a car manufacturer, refused to rule out the use of a customer chassis in future.

It's possible the man on the street would not know, or even care. After all, it was never much of an issue when Toro Rosso and Super Aguri ran customer cars, even if it was clearly outside the regulations. But just look at the current F1 cars. They are incredibly similar – they all have the ugly step in the nose, the high chassis and the same basic overall shape. Yes, I know the McLaren and Marussia are a little different, but everything else on the grid looks like the Force India, or is it the Mercedes?

Mechanically too, the cars are near identical. So much so that one alarmingly detailed technical specification could cover them all, even down to the ECU software and crankshaft centreline height.

Yes, the devil is in the details, but those details are fiercely guarded secrets, and they are usually just refinements anyway. So, for the average punter, what difference would it make?

It's not just in Formula 1, either. The whole of motor racing has descended into a nightmarish, identikit world of spec racing, from which there appears to be no escape. The once great racing classes have become the technical equivalent of a bowl of plain boiled rice. Formula 2 is a mere parody of the name, IndyCar is a North American version of GP2 in a plus size outfit, and even Formula 3 has become a Dallara-only zone. All of these series, bar IndyCar (which has its own bizarre idea of aesthetics) strive to make their cars look more like Formula 1 cars, despite the fact that nobody likes the look of Formula 1 cars.

The argument for going over to spec cars is simply to cut costs (much as they are trying to do in F1), but I find that argument very odd. If you only have a single supplier for everything, then surely that supplier controls the cost? I think an economist would argue that competition creates lower costs, as long as a certain standard of product is kept up. He would likely roll out a set of formulae that would essentially show cost vs level of quality over sales. I can't find out because that same economist is rather more interested in telling me about the Euro-shaped elephant in the room, but I'm not interested in that as it is not covered in the regulations.

"The once great racing classes have become the technical equivalent of a bowl of plain boiled rice"

Of course, a cost cap does not *have* to mean a spec series, or even a partly spec series. Handled correctly, it can in fact allow the technical regulations to be opened up. But rule makers should be very aware of unexpected situations with cost caps. Just look at LMP2 these days. It's basically an ORECA-03 spec class, with a few others like the Zyteks thrown in for good measure. The reason ORECA dominates the class? Quite simply, economies of scale. The French firm was given the contract to supply around 30 Formula Le Mans (LMPC) cars. It used its LMP2 chassis and, in doing so, spread the tooling and R and D costs across a far higher number of cars than Lola (RIP) and Zytek could manage.

So perhaps that is why some teams in F1 are clamouring for customer cars. If you are supplying two teams then, essentially, you get twice the budget under the cost cap, along with twice the tyre data and twice the testing mileage. Hardly seems fair does it?

That said, Formula 1 is contemplating two other measures in the same breath as reducing costs – new engine regulations and increasing the number of races. The latter will increase TV revenues, but will also mean the teams will have to build more cars and recruit more staff. The change in engine rules, on the other hand, will pretty much wipe out any savings made and actually lead to teams spending more, not less money.

Perhaps that's the goal anyway? Let half the grid run customer chassis and turn F1 into a powertrain formula. It seems a shame but, like the cost cap, it rather seems inevitable.

The future? A Formula 1 car in a box. Just add your team logo and go racing...

Lasting legacy

The first of many or the last of the few? The Subaru BRZ and the future of GT300

BY SAM COLLINS

"Crowds at Super GT races in Japan are falling, whilst interest in south east Asia is growing rapidly"

Despite only having a 2.0-litre turbocharged engine, Subaru hopes to capitalise on its proven chassis and braking technology to take the fight to its bigger capacity class rivals

"Not much remains of the original road car at all"

For many years Subaru has been synonymous with rallying, its four-wheel drive range of cars a regular sight on gravel stages around the world. The distinctive low growl of its turbocharged flat four is firmly placed on the soundtrack of the forest stages, but one place you do not expect to hear it is coming from the exhaust of a high downforce, rear-wheel drive GT car. Until now.

That car, called the BRZ, is a major departure for the motor manufacturing arm of Fuji Heavy Industries. Developed jointly with Toyota, it is the only two-wheel drive car in the current Subaru line up and has been prepared for the hotly contested GT300 class of the Super GT championship. That class is made up of a mix of FIA GT3 cars, purpose-built JAF GT300 cars and a mixed bag of one-off specials.

The BRZ GT300, which rolled out for the first time in early 2012, replaces the Subaru Legacy STi that has raced in the series since 2009. People were immediately struck by its looks, particularly as the outgoing Legacy B4 had been anything but a pretty car.

Its design is certainly unusual by Super GT standards, and is built to JAF GT300 regulations, which essentially allow engines of any capacity as long as it comes from that manufacturer's range. The BRZ only has a 2.0-litre engine, the well known EJ20 boxer. In comparison, the Toyota Prius APR, which is built to the same rulebook, is fitted with the firm's RV8K 3.4-litre V8, which is also found in GT500 and LMP1, as well as its hybrid system.

'We developed the Subaru BRZ GT300 aiming to take advantage of Subaru's characteristically low c of g,' explains Hideharu Tatsumi, deputy general manager of Subaru Tecnica International's (STi) motorsport project office, which developed the car.

'The development and engineering capabilities of Subaru / STi have created a wonderful car. We have to make full use of it to get good results, which will undoubtedly put us under more pressure than last year,' explains Shinji Motojima, team director of R&D Sport, the team behind the campaign that ran the Legacy in 2011. 'The regulation has changed a little for this year to allow for a larger restrictor diameter, so I expect races with faster top speeds. This year's challenge for the 2.0-litre is how competitive it can be against cars with larger displacements on a straight. However, we have the advantage in cornering and braking performance, so we need different strategies depending on the circuits.'

Subaru's management hoped that some of the inherent characteristics of the BRZ, including the aforementioned low c of g, would make up for being down on capacity, but it seems the engine's c of g

TECH SPEC

DBA-ZC6 (Subaru BRZ)

Engine: EJ20	
Type: turbocharged flat four	
Displacement: 1994cc	
Restrictor: single 39.9mm	
Power: 350ps or more	
Torque: 45Kgf-m or more	
Dimensions: 4530 x 1920 x 1110mm	
Clutch: ATS	
Transmission: Hewland	
Brakes: front - AP Racing six-piston; rear - AP Racing four-piston	
Tyres: Yokohama F: 300 / 710-18 R: 330 / 710-18	
Wheels: BBS F: 11.5J x 18in R: 13J x 18in	
Weight: 1150kg	
Wheelbase: 2630mm	
Track (front / rear): 1655mm / 1600mm	
Lubricants: Motul	

2.0-litre, turbocharged, EJ20 boxer engine is producing upwards of 350bhp. Dampers sit right above the engine

Though Subaru are being coy about who designed the aero package, there's no denying it is an extreme solution

is not as low as it may seem, as Minoru Sawada, technical director of R&D explains: 'It is the engine we used in the Legacy B4, and we have continued its development. There are positives and negatives to using a boxer in this application. The crankshaft centreline is lower in a boxer than in a conventional engine – that's a good thing – but the flip side is that the exhaust exits below the engine so you have to mount it higher up, making the overall c of g higher than it would be with a V6 or a V8. If we ran the exhaust sideways, like you do with a V engine, of course it would be much lower, but the convention with boxers is to run the exhausts under the engine.'

DIFFERENT DEMANDS

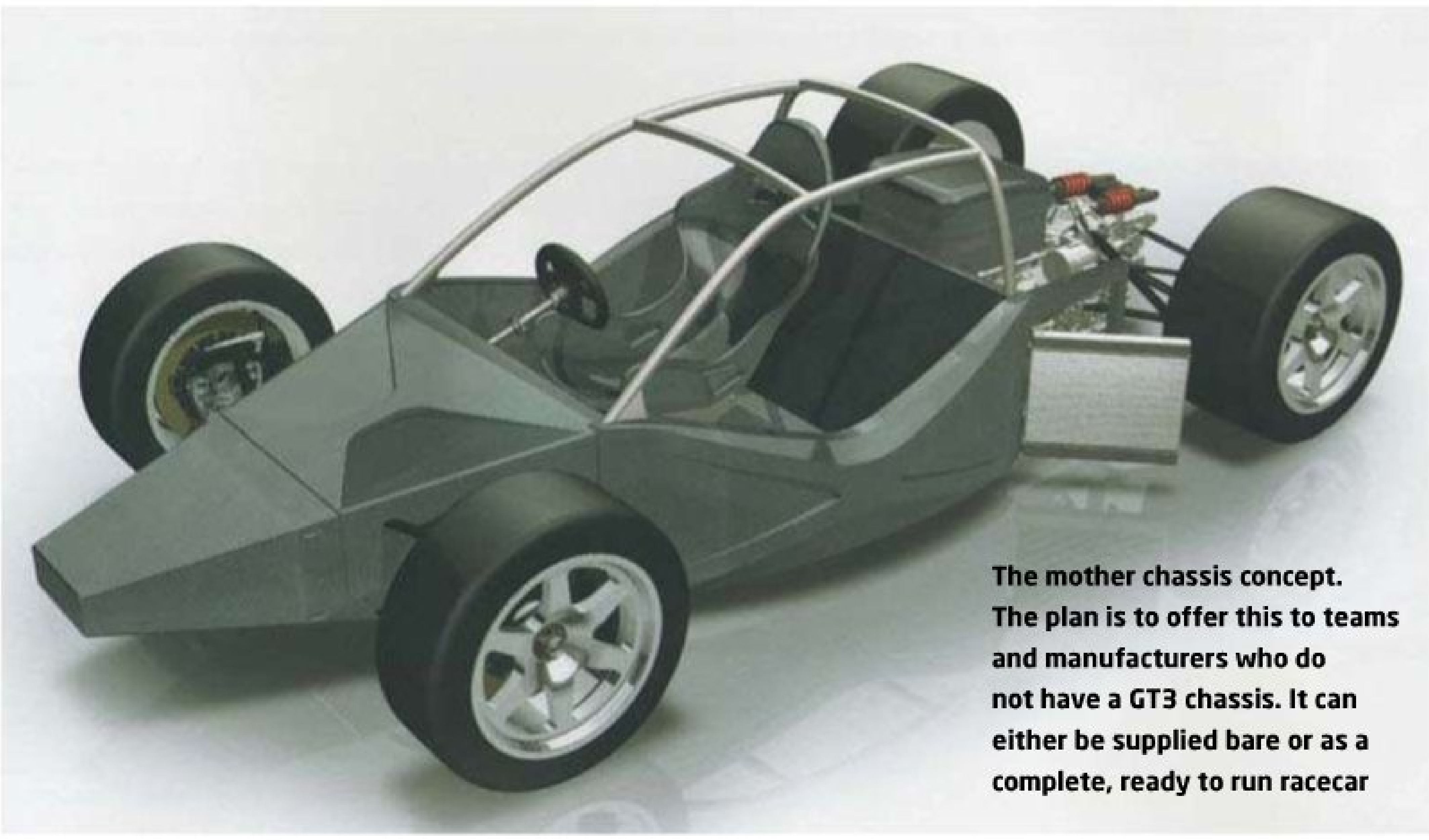
Subaru, and specifically STi, have plenty of experience with 2.0-litre, turbocharged flat fours, having won the World Rally Championship three times using one and it still contests major international events with the current R4-spec Impreza. However, the GT300 powerplant is slightly different to those engines, as Sawada reveals: 'The engine has different dimensions to the WRC unit and is built to withstand different demands. A rally car is meant to slide around, whilst a race car has long, sustained cornering loads, so this one is prepared with that in mind.'

Whilst the engine has a direct relationship with the one found in the road car, the chassis itself has very little in common with the production model, as is typical in GT300. 'Not much remains of the original road car at all,' smiles Sawada. 'Only the headlights, tail lights, roof and the a and b pillars. The rest of the car is bespoke, with a tubular steel chassis. The weight, however, is not all that different - 1100kg, as per the regulations - but the balance is a huge difference, much better. The c of g is much lower in the GT300, but the front-to-rear bias is similar to the road car.'

The transmission also carries over from the Legacy, with both STi and R&D Sport preferring to stick with what they know. 'STi had used Hewland [six-speed sequential] gearboxes for some time, so it seemed to be the natural thing to use. Also the Mola team used to run a pair of 350Zs in GT300. They used this gearbox and it was enough for them for all of that time. We knew it would be good enough for us.'

Much of the mechanical design for the BRZ has carried over from the Legacy B4, meaning it is largely a known quantity from a component standpoint, but the differences are enough that the team is still finding its way with the car overall. 'The suspension

Rear suspension is traditional, with unequal length double wishbones and horizontally-mounted inboard dampers



The mother chassis concept. The plan is to offer this to teams and manufacturers who do not have a GT3 chassis. It can either be supplied bare or as a complete, ready to run racecar

essentially is from the Legacy, with unequal length double wishbones with inboard dampers,' Sawada explains. 'The brake set up is the same, too. A few things and positions had to change from model to model, but it is essentially the same.'

TRIAL AND ERROR

With the BRZ's development still actively ongoing, it is clear the car is not yet up to its full potential, as Tatsumi explains: 'We've also made some changes in the suspension geometry. We are doing a lot of trial and error at the moment, playing with suspension geometry as we are still learning a lot about the car. At Sepang we adjusted the rear suspension geometry and at Fuji we changed the front.'

The car's aerodynamic package is, in reality, a mix of work between Subaru's in-house stylists and a collaborative aerodynamic R&D programme. 'There is no one person or organisation you could call the father of this car's aerodynamics, it was a collaborative effort between R&D Sports and STi and a specialist consultancy who are well known in Japan,' explains Sawada. 'The overall concept was, of course, a balance between drag and downforce, but we were fully aware that if we produced too much downforce then the organisers would change the regulations. One of the focuses for the BRZ was to increase front downforce using the front splitter, and improve the balance of the car overall compared to the Legacy. We have constantly updated it though. At its second race, which was held at Fuji speedway, we did a low-drag body for the car, but at Sepang we did a high-downforce update.'

"There are positives and negatives to using a boxer in this application"

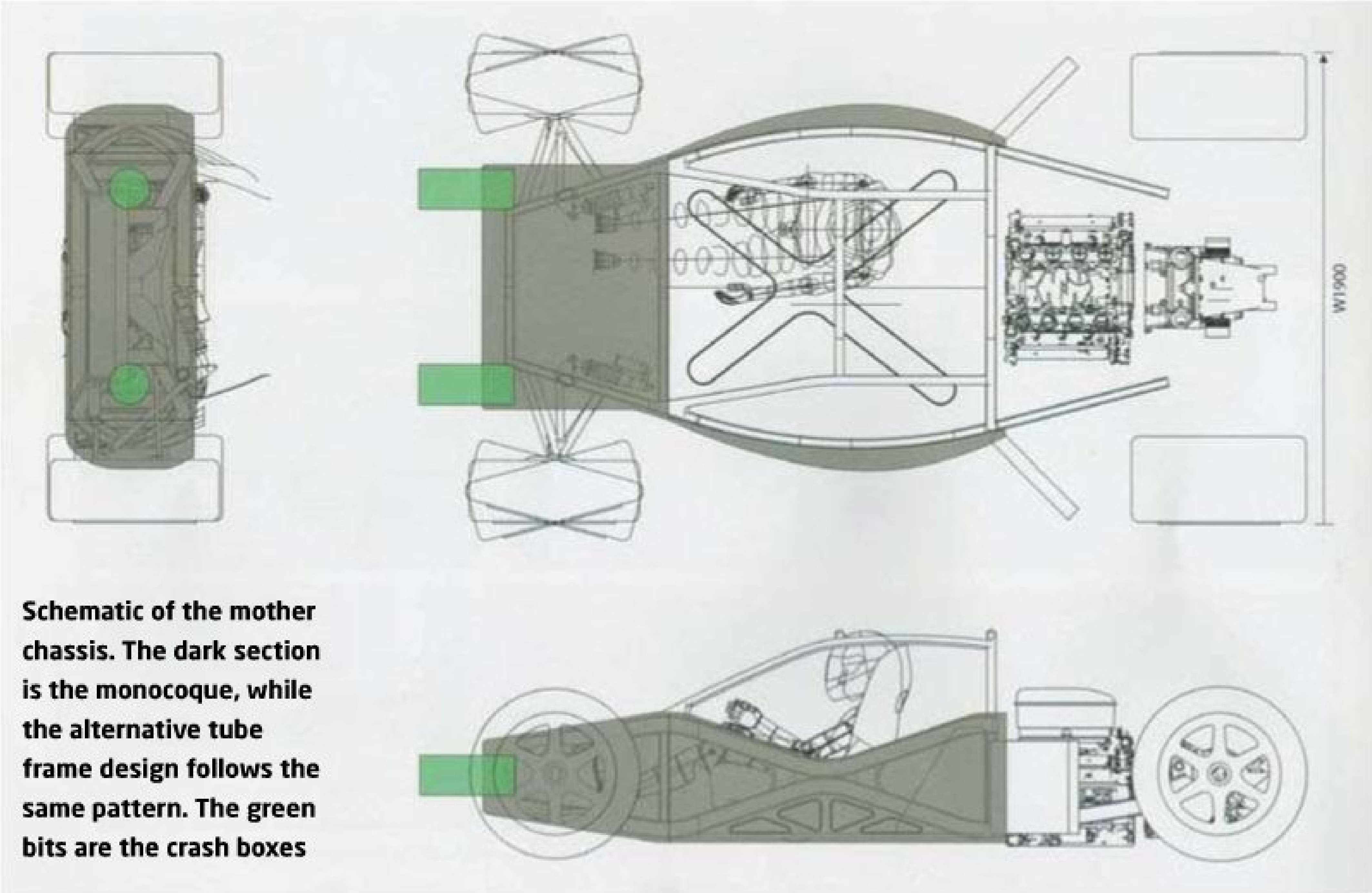
The result of the fairly liberal aerodynamic regulations in GT300 mean that whilst the more powerful FIA GT3 specification cars have a straight-line speed advantage, the JAF GT300's are much faster through the corners. In theory, this should balance out in terms of lap time, but in practice it's not a total success.

At the time of writing, there is only a single BRZ GT300 in existence, though Sawada is keen for another to be built. 'Unfortunately, it is not up to me. It is Subaru's decision, but I am always hoping!' he says. The Super GT organisers are also hoping that a second BRZ will be built, as the sole example is one of only two full JAF GT300's taking part in Super GT at the moment, the other being the Toyota Prius hybrid. A works Honda CRZ is due to take part in some races this season, but has yet to be revealed publically. If it does, that will still only take the total number of full-blooded GT300 cars to three. It is a situation that GTA, Super GT's governing body, is not happy with. The rest of the grid is filled with FIA GT3-specification machinery, and a handful of somewhat off-the-wall specials, including a heavily modified Daytona Prototype.

'It's good to have the GT3 cars as it gives many manufacturers the opportunity to join the GT300 series,' explains Masaki Bandoh, head of GTA. 'At the same time we want to increase the number of JAF GT300 cars racing in the series.'

To achieve this, Bandoh has an intriguing plan that will see a major change to the regulations in GT300 and increase the size of the grid. The starting point for this will be the Toyota GT-86, which as a road car is essentially identical to the road going BRZ, apart from the engine. They even roll off the same production line. However, the plan Bandoh has formulated with the help of the JMIA and Dome founder,

Minoru Hayashi, will see the GT300 BRZ and GT-86 have very different designs indeed.



Schematic of the mother chassis. The dark section is the monocoque, while the alternative tube frame design follows the same pattern. The green bits are the crash boxes

MOTHER CHASSIS

'GTA will create what we call a mother chassis,' Bandoh reveals. 'We will provide that to the teams and car makers who do not have their own chassis in GT3. We can provide everything – the chassis, the suspension, the bodies, the engine and the gearbox – or we can provide the bare chassis and any parts they need. We want to base this mother chassis on Japanese car makers standards, like Toyota GT-86.'

The plan is no pipe dream either. It has been fully developed and essentially is a scaled-up version of the concept used in F4 racing in Japan (see V21N12). However, as is the case in F4, teams and manufacturers will not be obliged to use the mother chassis concept. FIA GT3 cars and current-style JAF GT300 cars will also continue to be eligible. The concept is simply to allow manufacturers and teams who do not have the capability or inclination to build a full Super GT car an easier, more cost-effective route to the grid.

'There will actually be two mother chassis,' explains Bandoh. 'One for front-engine cars and one for rear. For mid-engine cars like the new Honda NSX, the chassis will just sit a bit further forward. The Toyota GT-86 will be the first of these new mother chassis cars. It should be on track by December this year.'

Dome has already been selected as the supplier of the carbon fibre monocoque mother chassis, which is not a great surprise as it already supplies the GT500 monocoques to Honda (and reportedly Nissan, too), and Minoru Hayashi has pushed ahead with detailed designs already. 'We have proposed a design to GTA, and it is quite versatile. You can mount any engine or transmission by modifying the subframe, and with its light weight it is also ideal for an EV, too,' he explains. 'The chassis is designed to minimise the overall volume, which allows for maximum freedom in bodywork design. Also the chassis can be supplied part machined so the user can install non-standard parts such as their own suspension.'

ASIA APPEAL

Dome has also proposed a lower cost, tube frame version of the mother chassis, which may also be taken up by GTA. One of the reasons Bandoh is keen to grow GT300 and attract more manufacturers is the downturn in interest in motor racing amongst the Japanese youth.

THE 'OTHERS'

Alongside the JAF GT300 cars and the FIA GT3-spec cars in GT300, there are a number of other cars liberally grouped together as 'others'. There have been moves to outlaw them, but they are regularly granted a seemingly endless stay of execution.

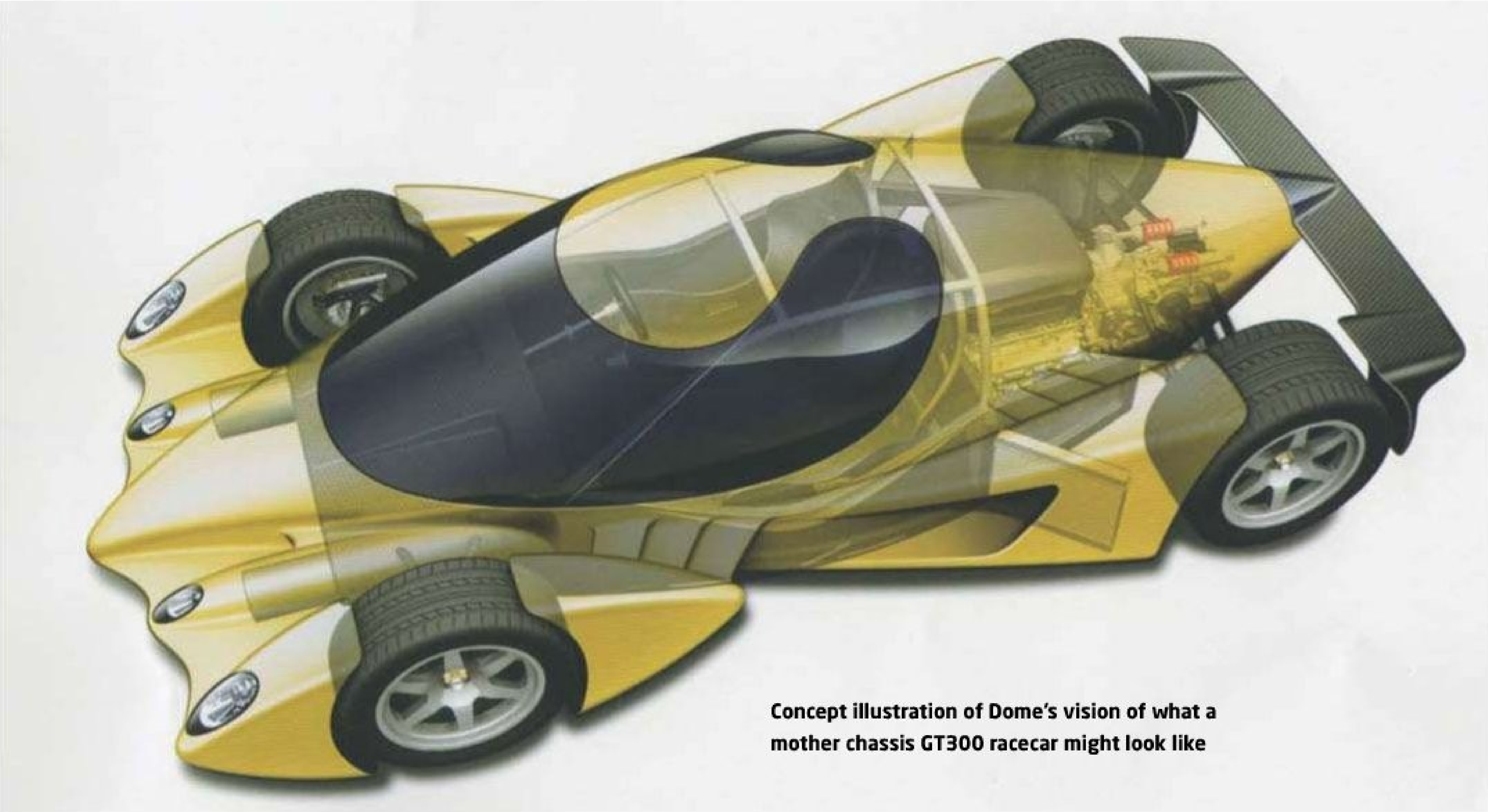
'I think these original GT300 cars, the others and the JAF GT300 cars, give the series its uniqueness,' says Raja Zaini, ThunderAsia team director. An example is the Malaysian who ran a Mosler GT300 (see V21N9) in the 2011 series and as a wild card entry in the Sepang 300km in 2012. 'These cars are the trademark of Super GT. These Prototypes, if you like to call them that, the fans still love them, just look at the Playstation games. I think these cars should stay. As far as I'm aware, there are more than a dozen big GT3 series in the world. If this was just another GT3 series, what would make it different from the rest? It would have no uniqueness.'

Super GT's organisers have the very tough job of attempting to balance the performance of all these very different cars, and it tends to do this by using air restrictors, with the 'others' given the smallest. However, in 2012, all of the cars' restrictor sizes were increased to spice up the racing and allow the JAF cars and the others to be more competitive with the GT3 field.

'One of the most exciting things about 2012 is that the speed of the GT3s on the straights is getting very close to the GT500s. That makes it more exciting as the GT500 cars attempt to lap the GT300s.'

However, Zaini is keen to stress that he feels both the JAF cars and the Prototypes should be given more freedom, compared to the FIA-spec cars. 'Some of these cars are really just built in a big garage, and they are fighting against manufacturer-built and supported GT3s with all of the resources they bring. I think the JAF GT300 cars should have more freedom. One of the things about the home-built cars, the Prototypes, is they are built with passion. They also present a great engineering opportunity, for suppliers in mainly Britain and Japan, companies like AP Racing and Judd. Smaller makers such as Zytek can also get into this market. With GT3 there is nothing unique. There is no engineering, just maintaining. We must have exciting cars, not GT3! For teams, GT3 is so much easier to run as you don't have to carry as much in spares. Everything is given to you. With the Prototypes, it's more of a challenge. You have to engineer the whole thing.'

Finally, Zaini says he is unhappy with the balance of performance (BoP), and feels Super GT should plough its own furrow when it comes to balancing cars. 'GTA needs to stop following the European BoP though, as it results in strange things like the Porsches dominating GT300. This is not like a GT3 series because we have total freedom with tyres. We have a six-way tyre war, with some manufacturers using special tyres made for individual driver / car combinations. This skews the BoP badly if the European model is copied.



Concept illustration of Dome's vision of what a mother chassis GT300 racecar might look like

Crowds at Super GT races in Japan are falling, whilst interest in South East Asia is growing rapidly. The attendance at the Sepang 300km race in June, for example, exceeded 70,000, rivalling the turn out for the Malaysian Grand Prix, and is by far the biggest crowd at a Super GT race. To illustrate the growth in attendance, the 2011 running of the same race only attracted 50,000 spectators.

Bandoh has already signed up to have a non-points race in Korea in 2013, and possibly also China. He sees GT300 as the key to tapping into these new markets: 'The aim with these cars is to have a wider market that will include stand alone GT300 races all around Asia, with perhaps a short series of GT300 races in China, Malaysia, and Korea and then a big race somewhere to see who is the champion,' he explains. 'These cars will also be able to race in GT Asia (currently a pan-Asian GT3 series) and also we are going to have discussions with other organisations about running these GT300s in wider series.'

It seems then that the Subaru BRZ may be one of the last of the current breed of JAF GT300s, but perhaps it should better be seen as sitting alongside its sister car, the Toyota GT-86, as the first of many.

THE FALL OF AN EMPIRE?

Minoru Hayashi, founder of Dome: 'At one time motor racing was one of the most popular sports in Japan, but things have changed. Baseball players have replaced racing drivers at the top of the girls' 'hot lists'. There are still a lot of racing series and events in Japan, but none of the five major newspapers are interested any more. Free-to-air television stations hardly broadcast any of the races, the drivers are hardly asked for their autographs on the street, as they once were, and you can only buy one monthly motorsport magazine. Motor racing has, sadly, become a minor sport here in Japan.

'There are too many reasons for the decline of Japanese motor racing to list here, but the fundamental problem is that all of the racing series in our country have been set up with the sole purpose of training drivers. The whole automobile industry has supported this policy and the only reason the industry survives at all is because of the imperial donation of the big automotive companies. These donations have been fairly stable, which is why Japanese racing looks stable, despite its unpopularity.'

So is the future of Japanese motor racing promising, we asked? 'No way. The empire governed by the Japanese car makers only cares about developing drivers to race in Formula 1 or at the Le Mans 24 Hours. It does not care about technological competition, which was the original root of the sport. Instead, the empire has been using one-make cars imported from Europe or the USA. As a consequence, motor racing technology in Japan is getting weaker and weaker.

'So with South East Asian motor racing growing rapidly, I advise you to look at Japanese motor racing as a negative example. There is great business potential in that part of Asia and I hope it is nurtured in a different way. It is probably fair to say that what the Japanese motor racing industry has after half a century and what the South East Asian industry has now after just a few years is very similar. It is as if the two are at a crossing point on a graph, with an inclining curve for SE Asia and a declining curve for Japan. Needless to say, South East Asia has a brighter future than Japan in motor racing.

"motor racing technology in Japan is getting weaker and weaker"

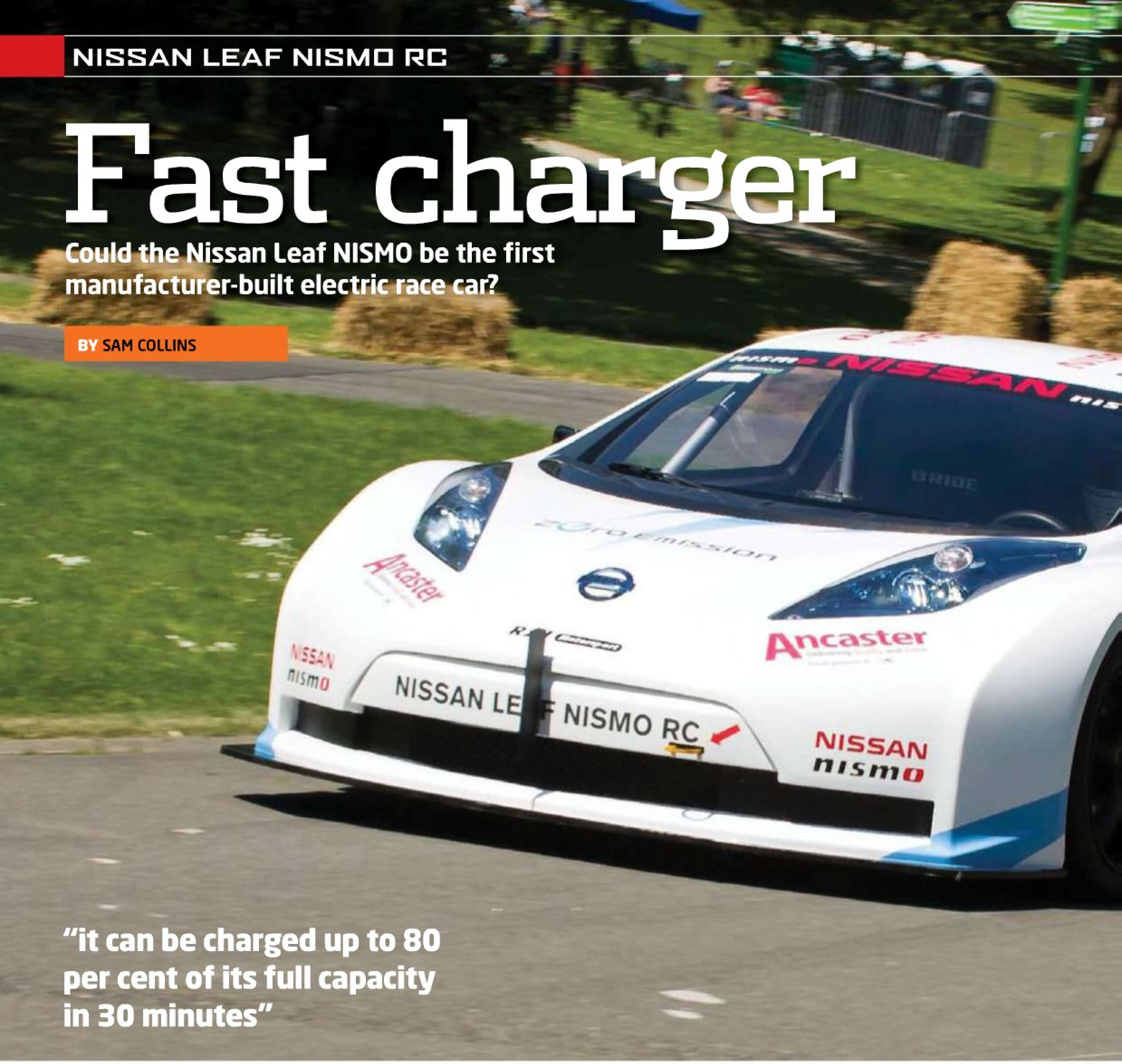
'But be aware, in order to have any racing in South East Asia, where there are no Sportscars being produced, the only option is to import European cars, which was the same destructive path Japan followed. My suggestion is a policy of 'if you don't have one, make one'. The new mother chassis is the basis of that. You can buy just the chassis, or a complete car design, and build an original car around that chassis. This will allow the focus of racing to be on technological competition, and not all about the drivers.'

Minoru Hayashi, *Dome*

Fast charger

Could the Nissan Leaf NISMO be the first manufacturer-built electric race car?

BY SAM COLLINS



"it can be charged up to 80 per cent of its full capacity in 30 minutes"

In 1899 Britain hosted its first proper motorsport event, held on a public holiday in May at the Crystal Palace in London. Taking part that day was an electric car, which was not considered remarkable at the time. It ran strongly but retired before the event was finished. Some who saw it that day thought it to be the future of motoring, but it never came to be.

113 years later, an electric car won its class at the same event, and once again many people believe the electric vehicle (EV) has an important role in the future of motoring. The car that took the honours at Crystal Palace in 2012 looks every inch a full-blooded JAF GT300 racer, and it's no great surprise. The Nissan Leaf NISMO RC was developed by the same engineering team from NISMO that supports the GT500 GT-R in the Super GT series, and the GT3 cars running in the FIA GT1 World Championship. According to Nissan, the Leaf NISMO functions as a platform for further advancement in 'green' motorsport, by being a 'driving laboratory' for electric vehicle technology and aerodynamics.

Like the commercially available Nissan Leaf (a rather cringing 'bacronym' for Leading, Environmentally-friendly, Affordable, Family car) the Nismo RC is equipped with 48 compact lithium ion battery modules and a high response AC synchronous motor developing 80kW and 280Nm torque. Utilising the quick charging port inside its rear cowl, it can be charged up to 80 per cent of its full capacity in 30 minutes. However, the similarities between the road car and the Leaf NISMO end there.

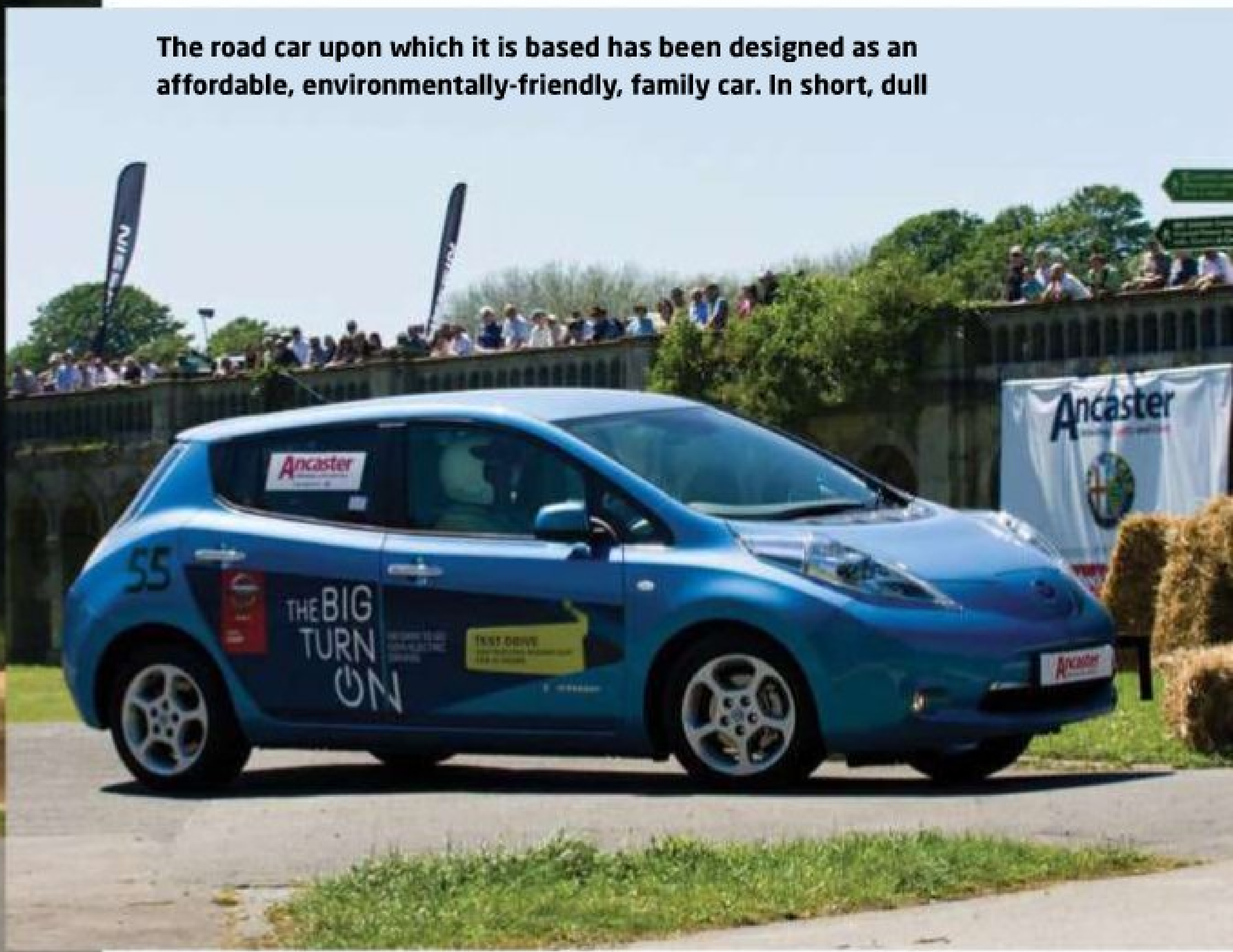
BONA FIDE RACECAR

The race version uses a carbon fibre monocoque chassis and has been designed and built as a *bona fide* racing vehicle. The three-part body allows for the front and rear sections to be detached in a similar way to the mother chassis concept of the GTA / Dome (see GT300 feature, p8). In addition, fixed position windows and LED head and tail lights are employed, while the rear wing is adjustable.

The Nissan Leaf Nismo RC's body is 20mm longer, 170mm wider and has a wheelbase 99mm shorter than the production version, but the most notable difference is the drop in ride height, down to 60mm from the 160mm of the standard car. The vehicle's weight has also been reduced by 40 per cent.

The battery pack, motor and inverter have been moved to the middle of the vehicle, and the drivetrain changed from front

Longer, wider, lower, lighter and with a shorter wheelbase, the RC version of the Leaf is a purposeful looking car. It also has new suspension, brakes, balance, aero and a carbon chassis. In short, it's a racecar



The road car upon which it is based has been designed as an affordable, environmentally-friendly, family car. In short, dull

ELECTRIC MOTORSPORT

Whilst undoubtedly a success, the car's competition debut highlighted a number of issues with the use of electric cars in modern motorsport events. The almost total absence of regulations, particularly when it comes to safety, is startling. At Crystal Palace, electric cars run in a catch-all 'alternative fuels' category, which is a number of amalgamated classes, as the governing body of UK motorsport (the MSA) does not want cars of different fuel types to mix and lead to arguments about equivalency. The team from RJN Motorsport that were running the Leaf were fully trained on its high voltage systems and equipped with KERS Marigolds, but the race marshals and rescue crews were not. And currently, there is no requirement in the MSA's regulations to run a light indicating when an electric car is energised, even though both the ACO and Formula Student insist on this for hybrids and fully electric vehicles.

It is not just the MSA at fault here, it seems the whole of motorsport is struggling to come to terms with the use and regulation of alternative fuel vehicles, and this is especially true at amateur level.

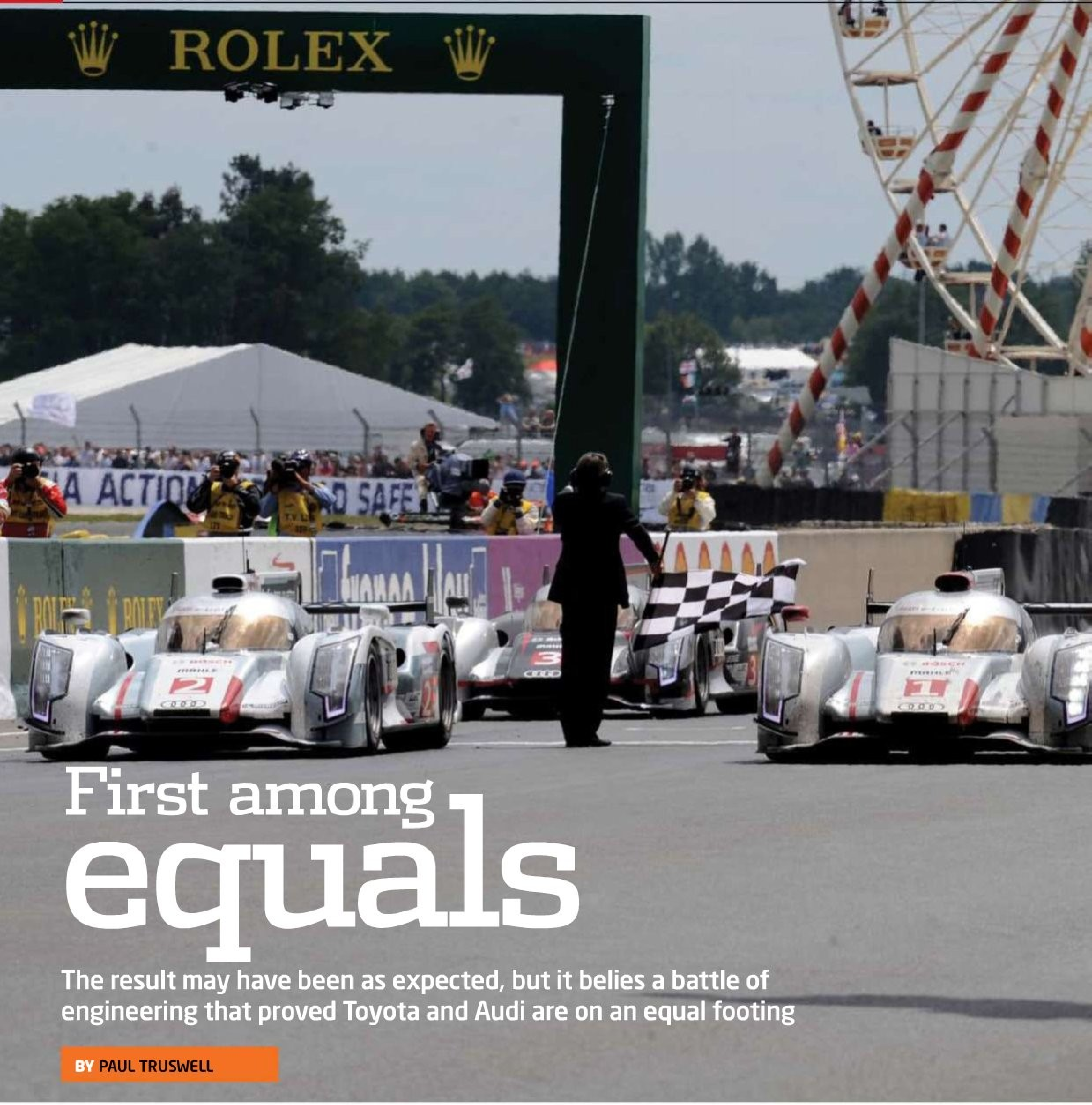
to rear-wheel drive. Also, the suspension employs a double wishbone configuration front and rear, with driver-adjustable brake balance. Also driver adjustable is the map for the powertrain, which is divided into five increasingly aggressive maps (including one purposely designed for drifting on some of the Japanese domiciled cars). The car can also be set up for driver experience or weather conditions.

NISMO constructed eight identical cars and shipped them to the UK for use in promotional events and on demonstration runs, including Goodwood FoS.

Indeed, when the car was first revealed at the 2011 New York International Auto Show, the accompanying press kit said it had been developed specifically to give a new meaning to the term 'green racing' (the RC in the name standing for Racing Competition), yet Nissan had no intention of doing any racing or competition with it. That all changed though when they decided earlier this year to lend one to *Racecar Engineering*. With the support of Darren Cox, in May this year the Leaf NISMO RC made its competition debut at Crystal Palace, and on the strength of that it seems Nissan is keen for more competitive running. A set of slick hillclimb tyres has been ordered to replace the treaded Bridgestones currently fitted to the car, and a more aggressive throttle map has been ordered from NISMO. Indeed, some senior NISMO staff were enthusiastic about running the car in GT300 Sprint races, should they ever happen, though they admitted the car's very limited range is still a concern.

"developed specifically to give a new meaning to the term 'green racing'"

With the eight Leaf NISMO RCs built to date all being used for PR purposes, it may still languish as a mere technology demonstrator, though the same NISMO personnel told *Racecar Engineering* at Le Mans that they would be willing to sell the cars to teams interested in using them in competition, as long as the price was right. If anyone takes them up on that offer, the Leaf may yet become the first manufacturer-built electric competition car openly available to teams.



First among equals

The result may have been as expected, but it belies a battle of engineering that proved Toyota and Audi are on an equal footing

BY PAUL TRUSWELL

Somewhat against the odds, the 2012 Le Mans 24 Hours turned into a superb sporting contest. Audi, with 10 outright wins at Le Mans behind them and four cars entered, came to the race as the clear favourites, especially as the cars had already raced and won over six hours at Spa-Francorchamps and had undergone extensive tests. The threat from the two Toyota TS030s was an unknown quantity. The cars had not raced before, testing had been limited, and expectations from the German-built, French-managed, Japanese-entered cars were realistically measured. Nevertheless, the prospect of seeing how the rear-wheel drive, super-capacitor system measured up against Audi's flywheel system was intriguing.

In the event, the race was made by two factors. Firstly, the Toyotas proved that for six hours, they were a worthy opponent for Audi – Nicolas Lapierre was even able to take the lead on the track in a daring overtaking manoeuvre, just before the safety cars were deployed to deal with the aftermath of Anthony Davidson's clash with the AF Corse GTE-Am car being driven by Piergiuseppe Perazzini.

Secondly, Audi raced each of its four cars without team orders playing any part. In theory, this would enable the hybrid technology of the e-tron quattro, effectively delivering four-wheel drive at speeds in excess of 120km/h, to be directly compared with the non-hybrid R18 ultra. In practice, the last three quarters of the race turned into an all-out battle for the lead between the two hybrids, which were more than a lap ahead of all their rivals,

Audi arrived at Le Mans the clear favourite and, despite some stiff opposition from Toyota, ended the race where it began - at the front

including the non-hybrids. It was a race to rival last year's dogfight between Audi and Peugeot. At least until Allan McNish lost control of his R18 e-tron quattro through the Porsche Curves with under three hours remaining.

Additionally, the race was run without any of the rancour that characterised some elements of last year's 24 Hours, yet there are questions outstanding, that a look at the data from the race might go part way to answering. For example, how close really were the Toyota and Audi hybrids? How much slower were the non-hybrid Audi R18 ultras? What was the gap, in performance terms, between them and the privateers?

Let's first look at the relative performance of the Audi and Toyotas. The first and most obvious difference was that the Audis could all go 12 laps on a tank of fuel, whereas the Toyotas could only manage 11.

Surprisingly, though, the story of the first five hours of the race was of Toyota, without quite having the speed of Audi, staying on terms by virtue of better reliability. **Table 1** shows how three of the four Audis had all been delayed by 8pm on Saturday evening. But pit stop time alone cannot explain how Toyota led Le Mans as the five-hour bulletin was issued.

The average lap times for those early stints are shown in **table 2**, and it looks like both Audi and Toyota were experimenting with tyre compounds in the early stages. On the other hand, I am told that Audi engineers do not set the car up for ideal handling in the early stages of the race, as they know that the track will change as the race wears on, and it is better to anticipate those changes and have a car that becomes faster as the race goes on.

"a quadruple stint on a single set of tyres was not achieved by any of the Audis this year"

It is, of course, pure conjecture what would have happened had Perazzini not turned in on Anthony Davidson, or had Kazuki Nakajima not damaged the other Toyota in his collision with the DeltaWing. But without doubt Toyota, despite losing both cars from the race before half-distance, did not embarrass itself on the debut of the TS030 hybrid, especially when one considers the limited development time that was available and the high technology of the car concerned.

As far as the rest of the race was concerned, we were treated to a splendid battle, which boiled down to just two cars. Having pitted early in the race to have debris build-up removed from the suspension, the number 2 Kristensen / McNish / Capello car was at a disadvantage to the number 1 car of Tréluyer / Lotterer / Fässler. Following Capello's first 'fuel only' pit stop at 21:30, the Italian resumed almost exactly two minutes behind the similar R18 e-tron quattro of Marcel Fässler.

Over 14 hours later, at 11:45am, just after an equivalent 'fuel only' stop for Allan McNish (now in the number 2 car), the gap was down to just 16 seconds - an improvement of 106 seconds in 14 hours. With just over three hours to go, would the number 2 car have been able to regain the lead by the end of the race? Sadly, we were denied a close finish, due to McNish hitting the wall at 12:10, Sunday lunchtime.

Figure 1 shows the fluctuation of the gap between the two hybrid Audis up until McNish's 336th lap. A positive gap indicates a lead for the number 1 car, a negative gap implies that the number 2 car leads. Note first how the gap had come down in favour of the McNish / Kristensen / Capello car after Fässler had a long pit stop (2m17s) to repair the rear bodywork following contact with the barrier at Mulsanne Corner avoiding a GTE car on lap 276. With the lead swapping back and forth between the two cars at each pit stop, it was going to come down to the refuelling schedule on each car.

Figure 2 shows a projection of what might have happened, from lap 300 onwards, had (a) McNish kept his car on the road and (b) there been no further safety car periods to the end of the race. Crucially, in this phase of the race, the number 2 Audi was completing 12 laps between fuel stops, whereas the number 1 car was only doing 11. Also, the number 1 car was due its driver change nine laps before the number 2 was due to change from McNish to Kristensen. For the purposes of this projection, I have given the number 1 car a faster average lap time of more than a second a lap, it does not compensate for the advantage of running that extra lap on a tank of fuel.

On the subject of running 11 or 12-lap stints, examine **table 3**.

At no time did any Toyota run 12 laps (without a safety car intervention). However, the Audi ultras certainly seemed more comfortable with running to 12 laps than the e-tron quattros. The number 3 car actually achieved a higher percentage of sub-3m 30s laps on 12-lap stints than the number 2 car did running either 11 or 12 laps. Possibly different strategies were at play, but possibly also there is a link to the number of laps that could be run on a single set of tyres. This information is shown in **table 4**. Obviously, circumstance often affects the way that the tyre strategy is called – punctures, safety cars etc. But what is interesting is that, unlike last year, a quadruple stint on a single set of tyres was not achieved by any of the Audis this year.

Table 1: time spent in pits in first five hours

No	Car	Number of stops	Time spent in pits
1	Audi R18 e-tron quattro	7	7m 30.7s
2	Audi R18 e-tron quattro	7	11m 08.6s
3	Audi R18 ultra	8	20m 32.8s (in pit)
4	Audi R18 ultra	7	10m 21.5s
7	Toyota TS030 Hybrid	7	7m 48.7s
8	Toyota TS030 Hybrid	7	7m 58.8s

Table 2: average lap time for full stint (up to 20:00)

No	Car	Driver	No of laps	Ave lap time
1	Audi R18 e-tron quattro	Lotterer	34	3m 30.4s
7	Toyota TS030 Hybrid	Lapierre	44	3m 30.8s
8	Toyota TS030 Hybrid	Buemi	44	3m 31.2s
7	Toyota TS030 Hybrid	Wurz	31	3m 32.3s
1	Audi R18 e-tron quattro	Tréluyer	48	3m 32.3s
8	Toyota TS030 Hybrid	Sarrazin	30	3m 32.7s

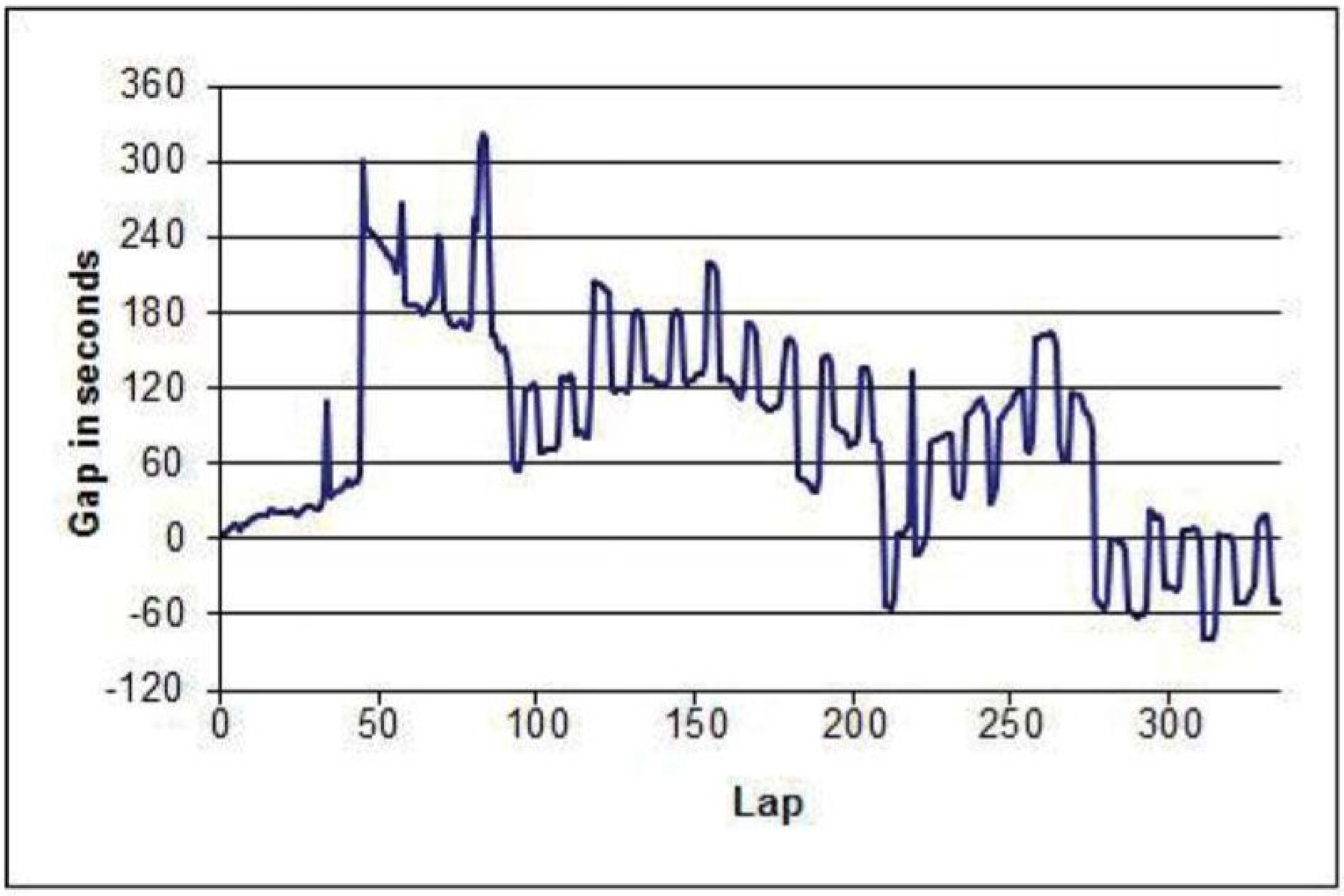


Figure 1: the fluctuation of the gap between the two hybrid Audis. A positive gap indicates a lead for the number 1 car, a negative gap implies that the number 2 car leads

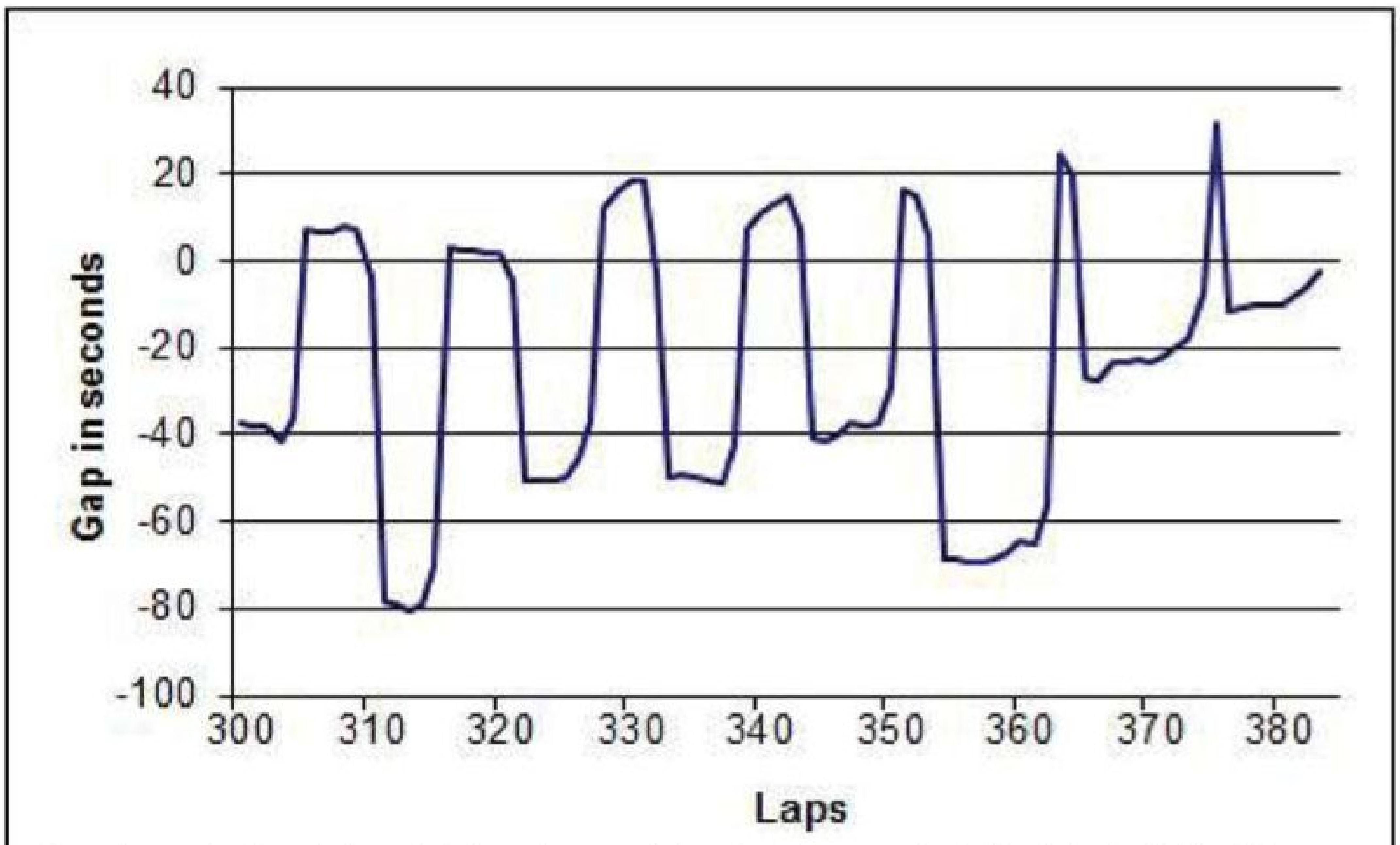


Figure 2: a projection of what might have happened, from lap 300 onwards, had both Audis finished the race

Leena Gade, engineering the number 1 car, also made some interesting calls during the safety car periods in the race, compared to those made by Dominic Zeidtler, who was in charge of the number 2. At the first full course caution, Leena called the number 1 into the pits at the same time as the number 7 Toyota, and was able dramatically to grab the lead in the pits – despite the fact that the car had sufficient fuel aboard to stay out and take the lead anyway. Dindo Capello did just that – staying out for more than 1hr 30mins at the wheel of number 2.

At the second full course caution, at 4:50am on Sunday morning, to deal with the consequences of the accident of the ProSpeed Porsche at the Porsche Curves, the number 1 car was called in at the first opportunity under yellow, and was held for nearly two minutes at the pit lane exit, waiting for the next train of cars to pass by. Both of these were possibly questionable strategic calls, which cost the car overall time in the race.

Zeidtler only brought the number 2 car in once during a full course caution, and that was right at the end of the second period, when the car was due a driver change. It was perfectly timed, and allowed Capello to take over from McNish just as the green flag flew and the car was able to accelerate straight back out onto the track without being held at the pit exit.

We've already seen how well matched the Audi hybrids and Toyotas were in the first few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Taking the lead at nine hours after an engine failure, the Starworks HPD ARX 03b Honda LMP2 never relinquished it

Table 3: analysis of 11-lap and 12-lap stints

No.	Car	No of 12-lap stints	Under 3m 30s	Percentage	No of 11-lap stints	Under 3m 30s	Percentage
1	Audi R18 e-tron quattro	14	0	0%	12	8	67%
2	Audi R18 e-tron quattro	16	4	25%	11	3	27%
3	Audi R18 ultra	22	7	32%	2	1	50%
4	Audi R18 ultra	25	3	12%	0	0	N/A
7	Toyota TS030 Hybrid	0	0	N/A	8	1	13%
8	Toyota TS030 Hybrid	0	0	N/A	5	0	0%

Table 4: maximum number of laps on a single set of tyres

No.	Car	Maximum number of laps with SC intervention	Number of laps under green flag	Notes
1	Audi R18 e-tron quattro	38	35	Also twice 34 laps
2	Audi R18 e-tron quattro	38	36	On three occasions, and one 35 lap stint
3	Audi R18 ultra	39	36	On five occasions
4	Audi R18 ultra	40	36	On three occasions

Table 5: best stint average lap time for each Audi driver

No	Car	Driver	Stint from-to	No. of laps	Ave Lap Time	Notes
2	Audi R18 e-tron quattro	McNish	10:58 - 11:39	12	3m 27.1s	
1	Audi R18 e-tron quattro	Tréluyer	10:40 - 11:57	2 * 11	3m 27.3s	Two identical stints
1	Audi R18 e-tron quattro	Lotterer	06:38 - 07:16	11	3m 27.5s	
3	Audi R18 ultra	Duval	07:22 - 08:03	12	3m 27.7s	
3	Audi R18 ultra	Dumas	09:30 - 10:12	12	3m 28.1s	
2	Audi R18 e-tron quattro	Kristensen	08:13 - 08:54	12	3m 28.2s	
3	Audi R18 ultra	Gene	13:22 - 14:03	12	3m 28.3s	
4	Audi R18 ultra	Jarvis	11:27 - 12:08	12	3m 28.8s	
4	Audi R18 ultra	Rockenfeller	13:15 - 13:57	12	3m 29.0s	
2	Audi R18 e-tron quattro	Capello	10:18 - 10:56	11	3m 29.2s	
1	Audi R18 e-tron quattro	Fässler	08:38 - 09:16	11	3m 29.4s	
4	Audi R18 ultra	Bonanomi	08:30 - 09:12	12	3m 30.3s	

hours, but what about the non-hybrid R18 ultras? **Table 5** shows the best stint for each driver in each car. This is calculated by taking the time taken from leaving the pits at the start of a stint, until the time the car is brought back into the pits, and dividing by the number of laps completed. The crucial 'in' and 'out' lap times are also accounted for (although the length of time taken to travel the length of the pit lane is excluded from the calculation).

Needless to say, McNish is the star – but Lotterer and Tréluyer are not far behind. But I wonder if Ralf Jüttner is looking at the less quick times being posted in deciding drivers for next year? It is unlikely that the Ingolstadt brand will again run four cars, so inevitably some drivers will have to go.

PRIVATE PARTIES

As far as the privateer Prototypes are concerned, the Strakka Racing HPD, although very quick, was always going to be at a disadvantage as more than 20 minutes of the race had elapsed before it exited the pits to begin its first lap. The Pescarolo team was in some disarray, with the number 16 '03' ex-Aston chassis completing just 20 laps, and the superb-sounding Dome spending more than half an hour in the pit in the first three hours.

This left the way open for the Toyota-engined Rebellion Lola coupés and, apart from a late race clutch failure on the number 13 car, they had relatively trouble-free races. It is interesting to compare the lap times of these cars with those of the works cars though, and in **table 6**, the average lap times for each driver's best stint in the two Rebellion Lolas are shown, along with those of the Strakka drivers.

This seems to suggest that the Lola coupés at least had the potential to go quicker than the Strakka HPD (which itself was substantially quicker than the JRM version). It is also glaringly obvious that Neel Jani and Nick Heidfeld can operate at a different level from the rest.

And lest anyone suggests that Nick Leventis doesn't warrant his place in the Strakka driving

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squad, note that he is not the slowest driver in the table – in a car that is not the quickest!

LMP2

We were expecting a close battle in LMP2 this year and we weren't disappointed. To simplify matters, **figure 3** only shows four of the leading contenders in the class – the three podium finishers, along with the class leader for most of the first nine hours – the number 24 Oak Racing Morgan-Judd. When the engine failed in the Morgan, the Starworks HPD took over a class lead it was not to relinquish. This graph shows the pace of each car, plotted against a (largely arbitrary) average lap time of 4m 04s. The steep downward slopes are due to the three safety car periods – the rest of the time, the cars are lapping considerably faster, so exhibit upward gradients.

The traces clearly show the recovery drive of the Thiriet by TDS Racing Team car number 46, following an eight-minute pit stop after an off-course excursion on lap 42. The Pecom Oreca 03 Nissan lost time when Ayari went off on lap 267, but the graph shows how the Argentine car was able to recover, before being caught out by the appearance of the final safety car, and then dropping away on pace during the last two hours.

An interesting feature of the LMP2 class is the mandatory inclusion in the driver squad of a silver or bronze graded driver. This driver has a minimum driving time of four hours, in order for the car to be classified. Table 10 shows the time spent behind the wheel for the silver / bronze driver for the top six finishers in the class. In addition, the average lap time (for the driver's best 25 laps of the race) and the combined average of the co-drivers in that car are also shown for comparison purposes. Note that none of the laps that are included in the calculation of the averages were behind the safety car.

These things are relative, so the relatively long time that silver driver Rusinov drove compared to Potolicchio is more than compensated for by his speed relative to his co-drivers. The Starworks team certainly maximised it resources.

Table 6: best stint average lap time for leading Prototype privateer drivers

No	Car	Driver	Stint from-to	No. of laps	Ave Lap Time	Notes
12	Rebellion Lola Toyota coupé	Jani	13:53 - 14:32	11	3m 32.6s	Staying ahead of no. 3
12	Rebellion Lola Toyota coupé	Heidfeld	09:58 - 10:41	12	3m 33.5s	
21	Strakka HPD ARX 03a Honda	Watts	09:57 - 10:40	12	3m 34.3s	
21	Strakka HPD ARX 03a Honda	Kane	08:08 - 08:51	12	3m 34.6s	
13	Rebellion Lola Toyota coupé	Primat	21:23 - 22:07	12	3m 37.7s	
13	Rebellion Lola Toyota coupé	Bleekemolen	17:04 - 17:47	12	3m 37.8s	
13	Rebellion Lola Toyota coupé	Belicchi	08:35 - 09:19	12	3m 38.4s	3:38.3 on 11-lap stint
21	Strakka HPD ARX 03a Honda	Leventis	12:52 - 13:36	12	3m 38.5s	
12	Rebellion Lola Toyota coupé	Prost	21:46 - 22:30	12	3m 38.6s	

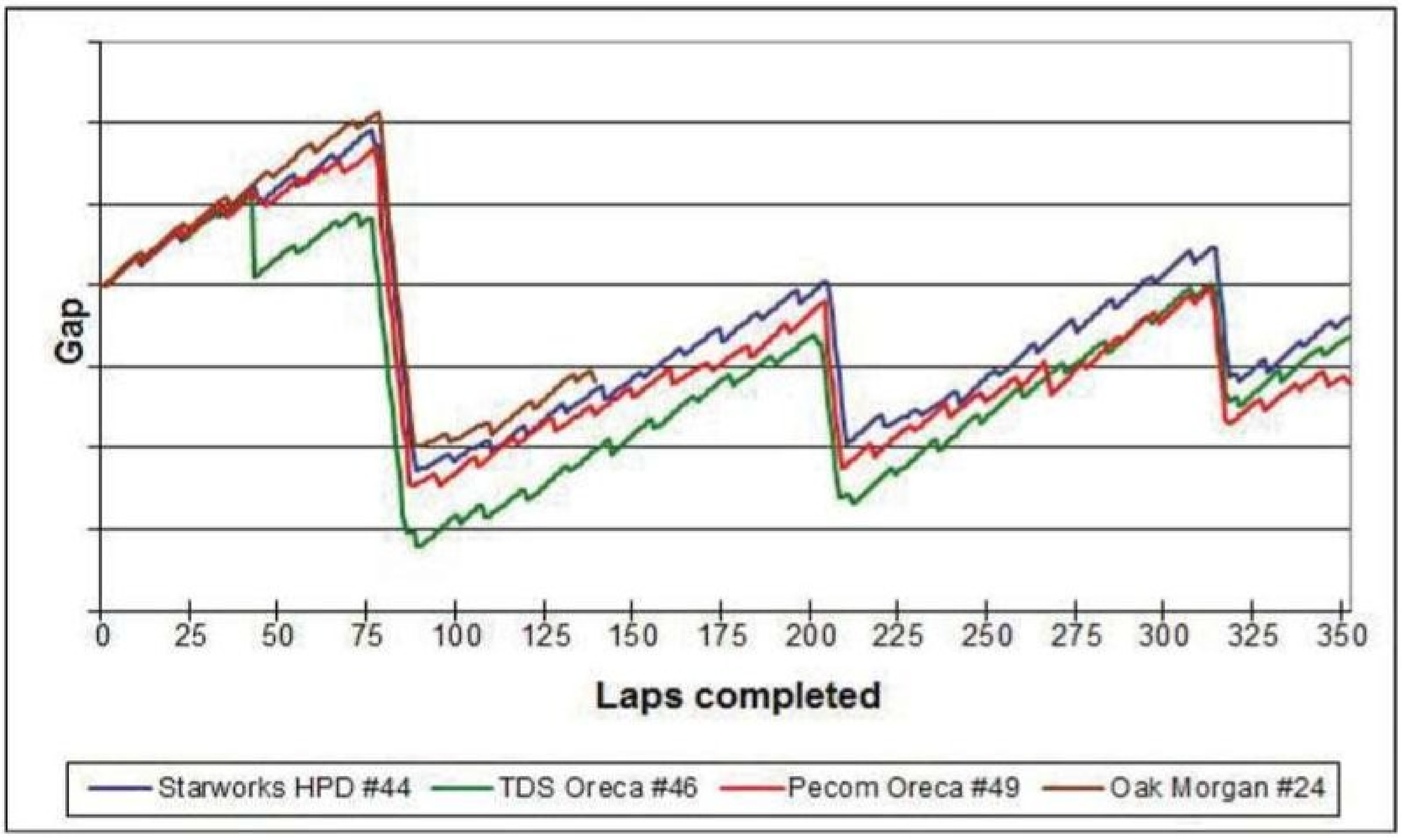


Figure 3: the pace of the four leading LMP2s, plotted against an average lap time of 4m 04s. The steep downward slopes are the safety car periods

SUMMARY

An enthralling race – with many further 'what if' analyses just waiting to be made. Many assumptions have been made here in order to make the numbers more manageable. The fact that the race this year was, for the first time in many years, part of a championship, meant that some teams would have been looking for points in a race usually characterised by a 'win at all costs' mentality.

At least it stayed dry throughout the race – those with a mind for such things will have been collecting data in order to be better prepared for next year, for which Toyota must have high hopes indeed. And as for 2014 – new regulations promise further great racing in the grand prix d'endurance!

Table 7: stint analysis for silver / bronze drivers in leading LMP2 cars

No	Car	Silver / bronze driver	Grade	Time driven	Stints	Average lap time (25 laps)	Compare with	Percentage slower
44	Starworks HPD ARX 03b Honda	Enzo Potolicchio	Silver	4h 02m 55s	2	3m 49.7s	3m 42.4s	3.2%
46	Thiriet by TDS Oreca Nissan	Pierre Thiriet	Silver	5h 50m 02s	3	3m 44.8s	3m 42.4s	1.1%
49	Pecom Oreca Nissan	Luis Perez-Companc	Silver	5h 25m 44s	4	3m 46.2s	3m 42.1s	1.8%
26	Signatech Oreca Nissan	Roman Rusinov	Silver	6h 10m 05s	3	3m 45.0s	3m 44.5s	0.2%
41	Greaves Zytek Nissan	Christian Zugel*	Bronze	4h 45m 28s	2	3m 55.4s	3m 44.0s	4.8%
25	ADR-Delta Oreca Nissan	Tor Graves	Silver	6h 46m 04s	4	3m 43.7s	3m 41.6s	0.9%

*Zugel was sharing with a Silver and a Gold driver

Torque of the Devil

The ACO's New Technology entry is designed to encourage the development of alternative powertrains. Green GT have chosen a hydrogen fuel cell

BY SAM COLLINS

The DeltaWing may have grabbed all of the headlines leading up to the 2012 Le Mans 24 Hours, but before it had even turned a lap of the Circuit De Le Sarthe its successor had been revealed.

Le Mans organiser, the ACO, tore up its own rule book to allow the DeltaWing to take part in the race, albeit unclassified, and then promptly wrote another one, which allows a single 'New Technology' entry to take part in the race. For 2013, that car will be the Green GT H2, an all-new, purpose-built Le Mans Prototype that essentially has its own power station on board, in the form of a hydrogen fuel cell.

Such fuel cells generate electricity through a process of oxidation on an electrode in a fuel - in this case hydrogen - coupled with a reduction on the other electrode of an oxidant, such as the oxygen contained in the air. This is the reverse of electrolysis. The chemical reaction produced by the oxidation and the meeting of gases produces electricity, water (which is discharged as steam) and heat, with operating temperatures ranging from 60-120degC, depending on model.

Proton exchange membrane fuel cells, also known as polymer electrolyte membrane fuel cells (or PEMFC) are a type of fuel cell developed for transport applications, and which operate in lower pressure and temperature ranges. The fuel cell on the Green GT is of this type. 'From the hydrogen tanks we feed the fuel cell, which is mounted centrally in the car where you might normally expect to find an engine,' explains Christophe Schwartz, engineering and programme manager at Green GT. 'The fuel cell also needs oxygen, so we feed it compressed air using a pair of compressors, one mounted on each side of the car. As the car makes its own electricity onboard, it feeds twin electric motors driving the rear wheels through a bespoke gearbox. The air compressors are a really nice feature for this car because they are noisy. We started it up in the workshop and people will love the noise. It's like a little fighter jet at take off. You will certainly hear it coming and you'll hear it going past. The noise is there and noise is part of motorsport.'

This set up gives the car a potent potential output, and a

> **"The noise is there, and noise is part of motorsport"**

TECH SPEC

Green GT H2

Class: LMP NT

Chassis: carbon fibre monocoque by Welter Racing

Engine: Type 2 three-phase permanent magnet synchronous Brusa motors

Power: 2 x 200kW, or 544bhp DIN

RPM: 13,500 maximum

Torque: 4000Nm at the wheels

Transmission: direct drive without clutch to the rear wheels; Green GT patented electronic torque vectoring differential

Fuel cell: 18 stack SymbioFCell; 340kW linear power; experimental 'high temperature' membrane; optimised assembly with 'aviation-type' lightweight elements

Air supply: twin electric turbochargers

Fuel cell weight: 320kg

Consumption: 12.5kg of H^2 per hour (equivalent to 36 litres of petrol)

Hydrogen storage: 2 x 160-litre carbon fibre and aluminium tanks (equivalent to 25 litres of petrol); built-in pressure reducer inside, designed to meet industry standards

Brakes: Brembo calipers with carbon discs and pads

Wheels: BBS, front 11 x 18in, rear 13 x 18in

Dimensions:
Length: 5151mm
Width: 2000mm
Height: 1200mm
Weight: 1240kg

potential major headache for the driveshaft manufacturer. Each electric motor produces 200kW and the combined torque is in the region of 4000Nm. But, whilst the performance of the powertrain is substantial, so is its weight. The fuel cell alone accounts for 320kg. As a result, the car weighs around 1200kg, compared to other LMPs, which tip the scales at around the 900kg mark.

AERODYNAMIC DRAG

A further factor limiting the performance of the Green GT is its aerodynamic drag. The frontal area is clearly larger than that of a conventional prototype, and this too is symptomatic of the fuel cell. Schwartz explains: 'In order to operate properly, the fuel cell needs to run at 80degC and, as the difference between the ambient temperature and the operating temperature is quite small, we need really big radiators [with electric water pumps to circulate the flow]. And for that you need to get the air in with a big scoop. Then you have to get it out again, so those big fins you see allow air to exit. But, as this car was designed around an electric drivetrain, the aerodynamics have to follow that.'

The ACO is aware that new technologies create new challenges, and allows for them in the technical regulations for the so-called NT cars. Schwartz explains: 'The rules we had to follow were for experimental cars, which have a lot of freedom. That means there are lots of innovative things we can do that you cannot do on the regular cars. That will help us make up for the high weight, but we still have to innovative somewhere else, and we have the huge torque from the e motors to help.'

EXTERNAL TANKS

Curiously, the car uses two monocoques. The forward tub follows conventional Le Mans Prototype practice, and has been developed by Welter Racing specifically for this project, whilst the rear tub houses the fuel cell. What is surprising, though, is that neither of the two parts has a void for a fuel tank – a move that has worried a number of people who have seen the car. Instead, two hydrogen tanks are mounted externally on the car's flanks. Each weighs about 4kg, and the team say they will be able to swap in new ones in roughly the same time it takes to refuel a conventional car. However, they also say they may not swap them at all, and are currently investigating a re-filling solution.

'At the moment, we have enough [power output] to do about 30 minutes at Le Mans, but we think with development we can extend that to over an hour. The pressure is 350bar in the tanks, which are made of aluminium and carbon fibre. We wanted a reliable system because this is an endurance race, and 350bar is the most reliable, though we are investigating a higher pressure solution,' reveals Schwartz.

These external tanks were the main source of concern when the car first broke cover, with observers immediately questioning what would happen in a typical Le Mans-style accident, such as the one that eliminated the DeltaWing in this year's race, and suggesting they would spark a conflagration on the scale of the Hindenburg disaster. But Schwartz does not believe we will hear John Hindhaugh of Radio Le Mans repeating Herbert Morrison's plaintive 'Oh, the humanity' commentary. Indeed, Schwartz argues that hydrogen is a safer and superior fuel to petrol, and that the tanks are strong enough to withstand an impact. 'Depending on what angle you hit the tanks at, they are between three and 10 times stronger than the FIA-homologated monocoque, so it's no issue to put them outside. We did an extensive risk analysis with the ACO and the fire marshals and came up with a whole catalogue of failure modes. Even if you were to tear off a tank, or puncture a line, the worst case scenario is that you would have an equivalent to 20 litres of petrol spilt. With the new breed of high pressure, direct injection engines, if a line is pulled of on those you spill about 30 litres of petrol.'

Schwartz also points to the energy density of hydrogen as one of the car's key advantages: 'In an electric vehicle, to replace one litre of petrol you need about 25kg of batteries, depending on the chemistry. That same litre of petrol can be replaced by 300g of hydrodgen. It has a higher energy density than diesel too, and that is why we have chosen to go this route.'

CULT FOLLOWING

The initial design of the Green GT H2 will not win any beauty contests, but it may build up something of a cult following like the DeltaWing, simply because it is different. Schwartz: 'You have to congratulate the ACO for allowing innovate and experimental cars like this. It is giving motorsport a new shape. If you look at NASCAR or F1 they are all the same – the same shape, the same bore angles the same cylinder spacing – where is the competition? It is all in the fine details and that means nothing to casual fans or the wider market. So here in endurance racing it's great to see that motorsport is still as it should be.'

Unusually, the chassis uses two separate carbon monocoques, a standard tub built by Welter Racing and a second for the fuel cell

Rear suspension is conventional, but that's where it stops. Twin electric motors drive the rear wheels through a bespoke gearbox

Wind tunnel testing took place at the adaptive wall tunnel at the St-Cyr Aerotechnical Institute in Brittany, France

The fuel cell. Inside which the reverse of electrolysis occurs and a chemical reaction occurs producing electricity, water and heat

AMR-One reborn

The Pescarolo 03 is incarnated from the Aston Martin AMR-One, but was beset with problems on and off track ahead of its competition debut at Le Mans

BY ANDREW COTTON

The omens were not good before the Pescarolo 03 even arrived at Le Mans. The car was beset by problems from all angles: the green light for the project had not been given until January this year; funding issues had delayed its competition debut until after the Spa 6 Hours in May; in practice at Le Mans, Jean-Christophe Boullion crashed the car and damaged his ribs, and was so scathing about its performance he refused to drive it, and then in the wet warm-up session, the Judd engine blew, causing the team to miss the start of the race.

As public debuts go, this was not one of the best, but designer, Nicolas Perrin, a former data engineer at Williams who has set up his own design company in Oxford, is confident that, with time, the car will reach its potential and challenge at the front of the LMP1 petrol grid.

'I started when I left Williams a year and a half ago, and the aim was to put an LMP1 on the grid at Le Mans this year,' says Perrin. 'It was ambitious because I didn't know which team or which car, but I had a clear idea of what I wanted and how I wanted to do it. My priority was to work on the development of the project and then sell it, so I could have all the freedom I wanted.'

The first step was to create a design that would be competitive in LMP1, but time and funds were short, and so as with the DeltaWing programme, Perrin turned to Aston Martin to purchase two tubs, the gearboxes and the suspension, in order to create a ready-to-race car.

Purchasing these proven components had a two-fold effect – firstly, the project could get on schedule and secondly, the development performance could be accurately monitored.

'I was interested in the chassis because I realised that no one would invest in a new tub because of the 2014 rules,' Perrin explains. 'The time was too short to do a new monocque and this chassis was on the market – a modern chassis and close to what I wanted. We worked on making sure we could have more of a partnership with Aston Martin. It was in their interest to sell the components, and show that we could make a good racecar out of it.'

Aston Martin also offered technical support to help the Prototype make it onto the grid. The chassis, suspension and gearbox were all taken straight from the AMR-One, while Pescarolo's long-standing relationship with Judd meant that the Judd HK V8 engine was mated to the chassis and gearbox, fitted with spacers as it was shorter than the original straight six deployed by Prodrive.

'The chassis shape is pretty much what I wanted, but some has been a compromise,' says Perrin. 'We had to raise the

Though the chassis, suspension and gearbox all came straight from Aston Martin, the aerodynamics and cooling systems were all designed from scratch, including modifying the front suspension to suit the aero package

"My priority was to work on the development of the project, and then sell it, so I could have all the freedom I wanted"

"When we are in the right temperature window with the tyres there is no issue"

gearbox by 25mm because the crank height is different, but I am happy with the results. Even though the car was not meant to work with a V8, it works well.

'We completely changed the philosophy of the car from the aerodynamics and cooling standpoints. I started from a blank sheet of paper. I just had to do my own integration of the engine, make sure the cooling level was right, and that seems to be the case. The balance of the car was very close to what we were expecting to start with. You never know if the overall balance will be in the window, but we were pretty much on it. After some work and test sessions we could find a decent balance.'

The rear suspension kinematics were changed by moving the inboard pick-up points and the profile of the wishbone for the front suspension was changed for aero reasons. The radiators and cooling systems were all new, as was the airflow through the car, as Aston Martin's design was integral in the cooling for the straight-six engine.

There were some initial installation problems, including high temperatures at the engine cover and ancillary integration, but overall the design team was happy with the product. Initial

Car has been designed purely in CFD, with no wind tunnel time, so now needs track time to validate the calculations and to continue development

examination of the data figures showed worrying trends, but on track there were no stability issues, and the car was not much slower than the Dome S101.5, which was also being run by the Pescarolo team. The biggest challenge was to generate temperature into the front tyres, a problem that affected most of the LMP1 grid that had been supplied with Michelin's confidential tyres, developed primarily by Audi and Peugeot for their high-downforce, high-torque diesels and designed to run up to five stints at Le Mans.

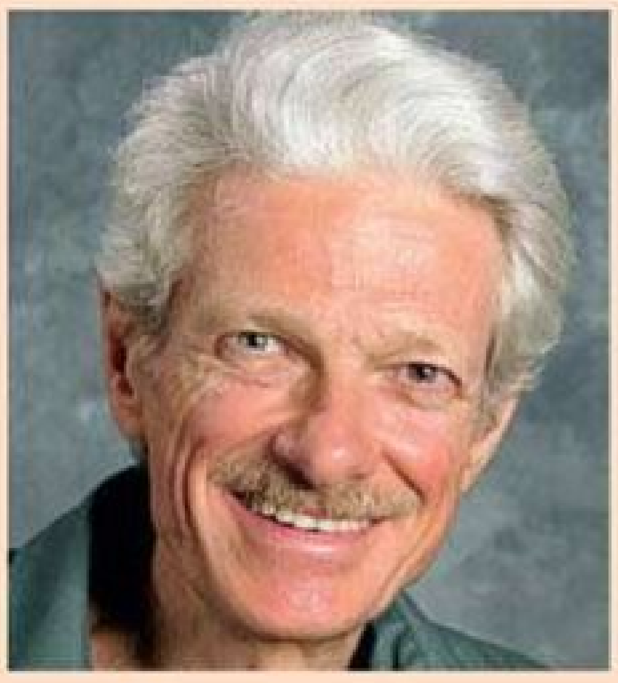
'The issue is something that everyone will have with these tyres if you are not able to run at the pace of the front runners,' explains Perrin. 'The tyres are designed for much faster cars, and they will be able to generate the temperature if they are going fast enough, but in some conditions we are struggling. When we are in the right temperature window with the tyres there is no issue. The challenge will be to make sure in the right conditions to put the temperatures right in the stint.'

The debut of the car at Le Mans was disappointing, but if the funding can be secured for further testing, the design team is confident that the car can challenge the Lolas and HPDs.

Yet to see a wind tunnel, the Pescarolo 03 has been designed entirely in CFD with the knowledge that it needed more track time to validate the figures. However, a legal case brought by driver, Julien Jousse, delayed its arrival at the Le Mans test, and that was after Henri Pescarolo and Luxury Racing parted company mid-programme amid financial wranglings.

'We have a spare tub so we could build a second car if we want, but you always need a second car in the truck as spares,' says Perrin. 'Now we are not sure what will happen after Le Mans because of the finances to secure our entries in the next races. As far as this car is concerned though, it is important for me and for the project to finish the car and do the track testing after Le Mans.

'My aim is to get it to its full potential so when we race it in 2013, it is a front-running car in LMP1. Max power is something, torque is something else but, if you look at the Dome compared to the Hondas and Toyotas, we are lacking, although the difference will be a smaller deficit on smaller tracks.'



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Short track simulation

Stand back and watch the sparks fly…

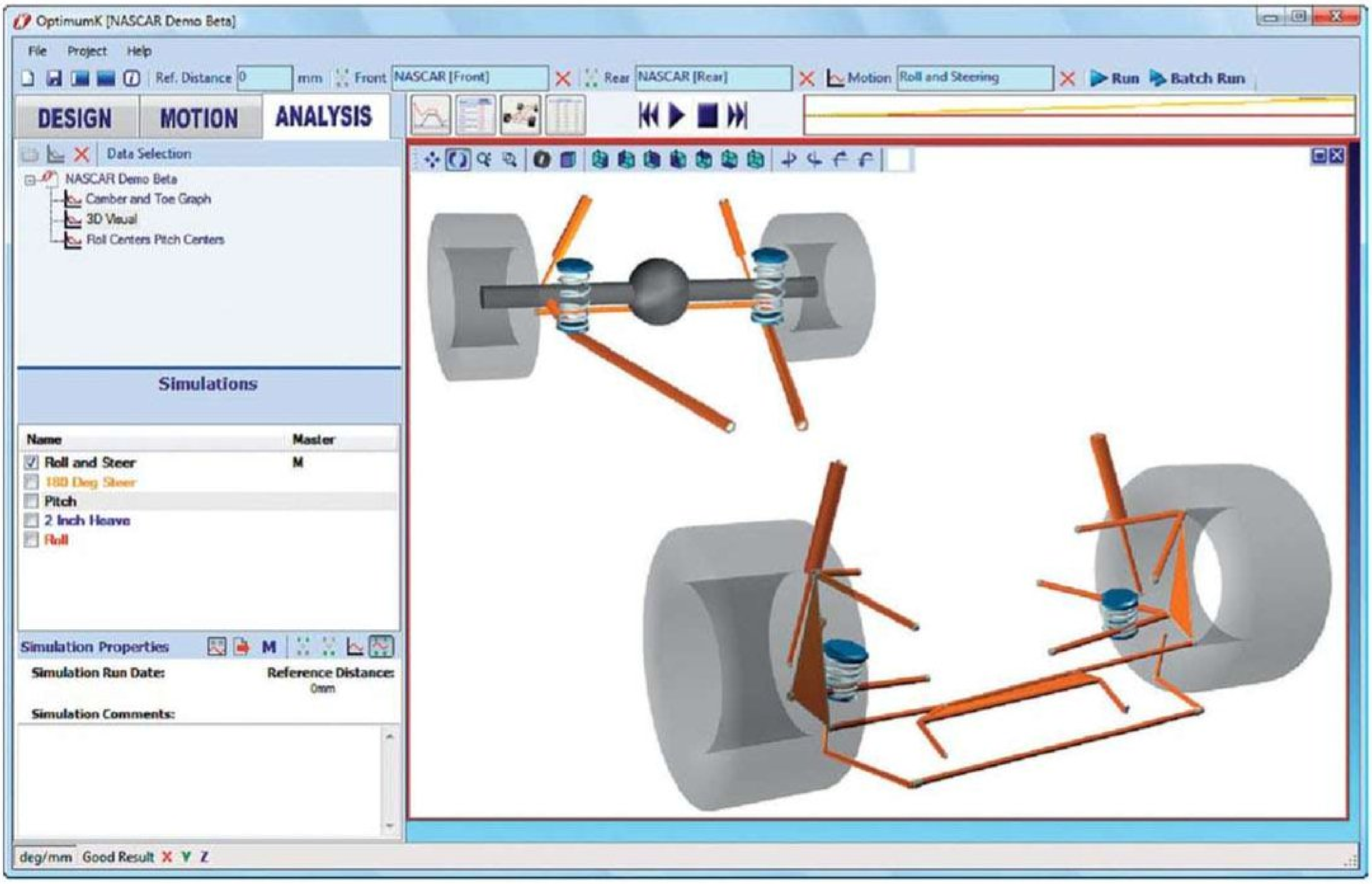
Q Are there any simulation programmes available to the short track racer that can be used to model set ups before going to the track? I ask because track testing is not much of an option due to cost, and practice time is limited. Along with that, what, if anything, can be used for tyre data when none is available from the maker?

Big, well-funded race teams write their own simulation programmes, and pay degreed engineers a great deal of money to do it. The programmes are then closely guarded. I have not personally seen any affordably-priced software that even claims to simulate anything more than suspension displacements and tyre loads for given lateral and longitudinal accelerations. Those I have seen presented have generated clearly anomalous outputs, and the people promoting them have displayed serious qualitative misunderstandings of vehicle dynamics. I have never personally had a client using any simulation programme.

The basic idea is to start with a set of accelerations, perhaps derived from instrumented testing on the track we are setting up for, and estimate what the normal and ground plane forces at the four tyres would be. Knowing that, if we are good, we can calculate actual normal forces at the four tyre contact patches, and then see if they look like our initial estimates.

Once we have a set of displacements – normal forces, and ground plane forces that look believable – we might then go to tyre data and try to predict what slip angles and percent slip values the tyres would have to have at those

Top end software like OptimumK (below) simulate vehicle kinematics reliably, but is there a low end equivalent?



forces, and / or if they would be incapable of generating those forces. That would tell us if the car as modelled is oversteering, understeering, or in the wall.

Even if we suppose that everything but the tyres is properly modelled and analysed, the behaviour of the tyres themselves is very complex. The tyre companies have good reasons for not publishing data.

First of all, to get tyre data, the process is to test the tyre on a TIRF machine, which rolls the tyre in a controlled manner against an abrasive belt that simulates a road surface, and measures the forces. This has to be done over a range of camber angles, normal forces, slip angles, percent slip values and so on. Ideally, we want to use a variety of inflation pressures as well, and maybe a variety of rim widths.

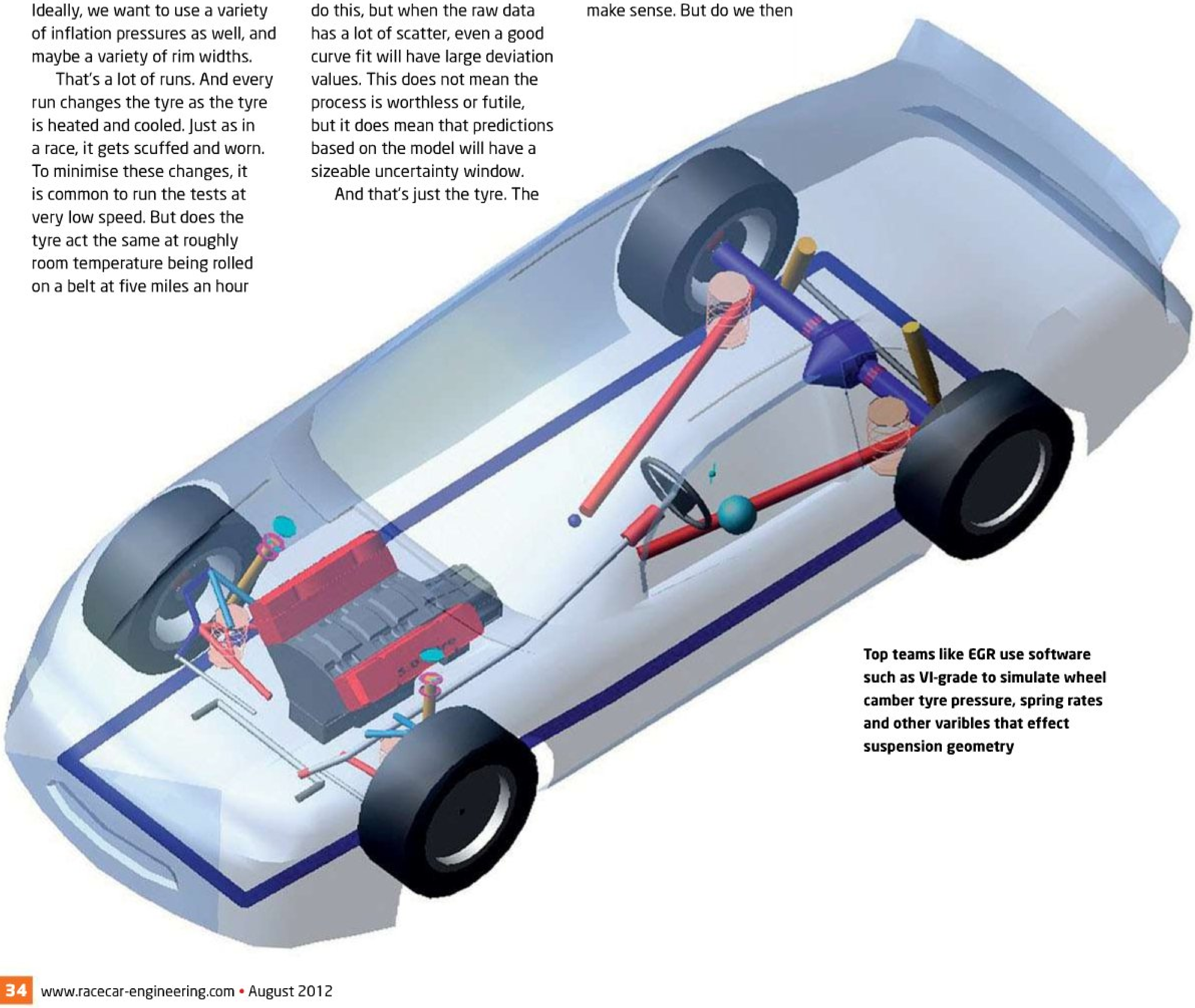
That's a lot of runs. And every run changes the tyre as the tyre is heated and cooled. Just as in a race, it gets scuffed and worn. To minimise these changes, it is common to run the tests at very low speed. But does the tyre act the same at roughly room temperature being rolled on a belt at five miles an hour as it does at racing speed and temperature? Probably not. On an oval track, the tyre doesn't even have identical properties during the first and last parts of a turn, because it heats up.

Even when the process is simplified, say by testing at only one inflation pressure, the raw data exhibits a lot of scatter. It then falls to engineers to curve fit this raw data, nowadays typically using the Pacejka equation format. It is possible to do this, but when the raw data has a lot of scatter, even a good curve fit will have large deviation values. This does not mean the process is worthless or futile, but it does mean that predictions based on the model will have a sizeable uncertainty window.

"predictions based on the model will have a sizeable uncertainty window"

And that's just the tyre. The tyre doesn't do anything by itself. Not only does it need a car, it also needs a road surface. The road surface is commonly represented in tyre modelling simply by a coefficient indicating the relative grippiness of the surface. Reasonable enough, but how precisely can we know that? We can back calculate from test data, and try to figure out what reasonable grip coefficient values might be for that test, to make the rest of the modelling make sense. But do we then know what those values will be at a different temperature, or after rain, or after a few seasons' use?

The bottom line is there is considerable inevitable uncertainty in even the best modelling, because there is considerable uncertainty in the behaviour of tyres and pavement. This does not mean modelling and simulation are junk, but it does mean they cannot reduce car behaviour to precise predictability. Rather, they are an enhanced means of getting to the thing some of us imagine them to be a way of avoiding: qualitative insight.



Top teams like EGR use software such as VI-grade to simulate wheel camber tyre pressure, spring rates and other varibles that effect suspension geometry

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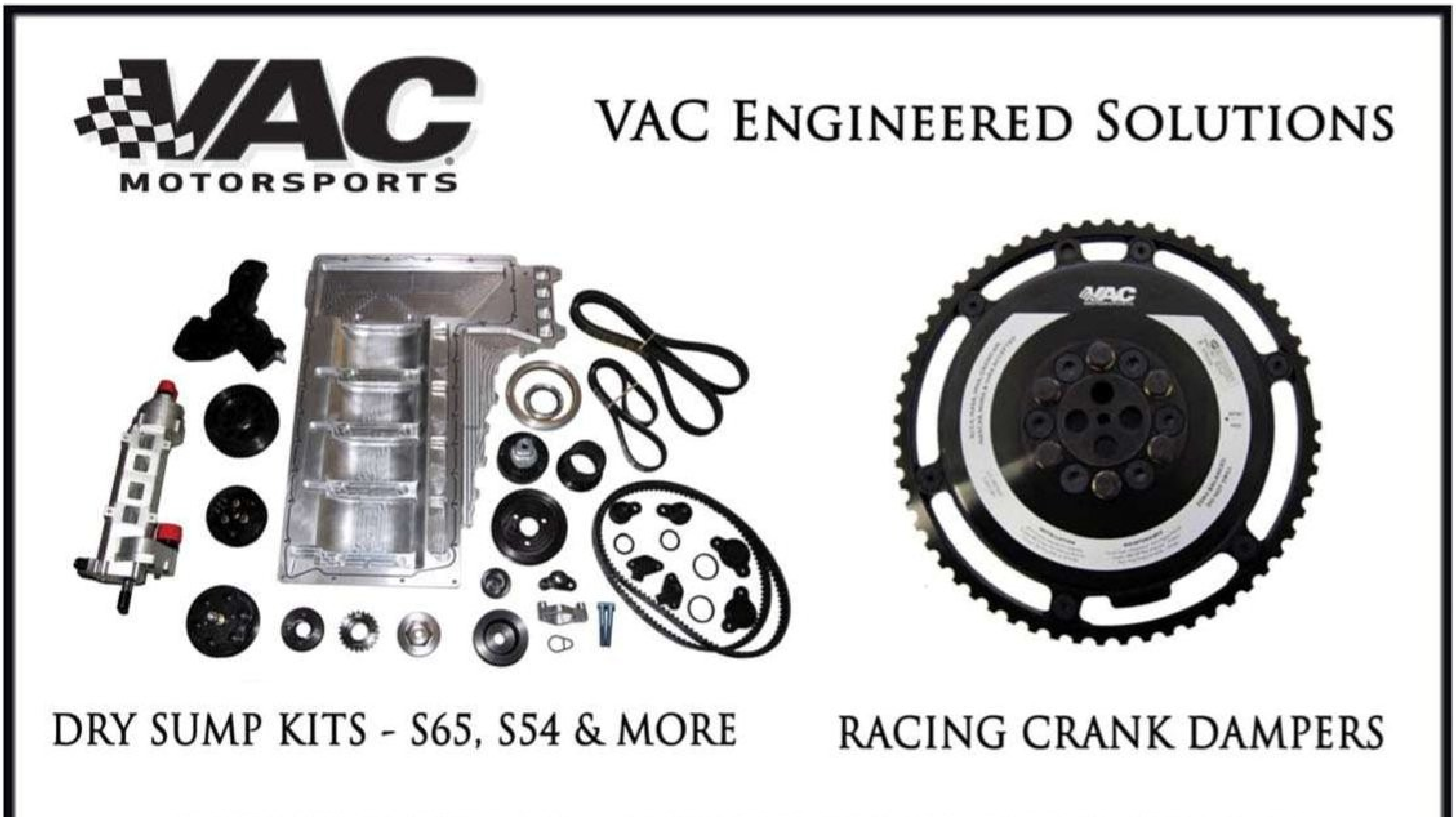
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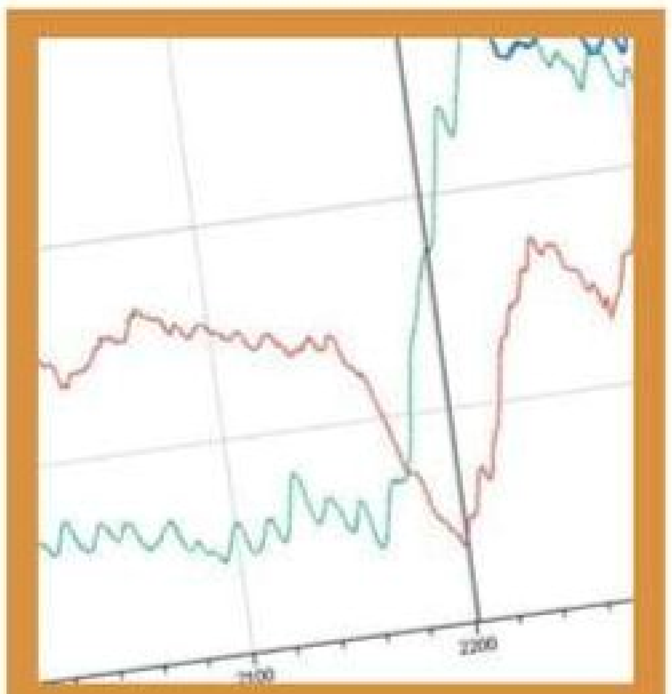


Databytes gives insights to help you improve your data analysis skills each month as Cosworth's electronics engineers share tips and tweaks learned from years of experience with data systems. Plus we test your skills with a teaser each month

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

Scrutineering data

It's not only race engineers that can benefit from data logging

In the fast-paced world of motorsport, it is not only the teams who need to be up to date with modern technology, the scrutineers also need to be technically up to speed. By utilising advanced data logging equipment, scrutineers can log data from each car on the grid, giving them the information they require to verify their legality. Depending on the series' electrical configuration, the scrutineer may use a separate data logger or a special partition on the teams' data loggers to record the necessary channels.

Data logging provides scrutineers with a powerful tool to make sure entrants are observing the rules. With CAN messaging systems featuring heavily on vehicle electronic systems, scrutineers can receive most of the information they require directly over CAN without needing to install any extra sensors on the car. Some sensors, such as boost pressure, can be installed on the car separately so scrutineers can ensure readings are correct and calibrated.

Below is an example of how a data logger can be set up for scrutineering use. There are effectively two logging tables present on the logger, but the team can only access one of them. Only the scrutineer can specify the channels and rates to be logged and then download the data. Access to the scrutineering data is then restricted using special encryption keys.

Once the data has been offloaded from the logger, the scrutineer then needs to analyse this to make sure that the entrants are staying within the rules. By using advanced data analysis software, the scrutineer can set up a worksheet to highlight any irregularities.

For example, if there is a series rpm limit, the scrutineer can make use of maths channels and events to highlight any time when the car has gone over that limit. By creating an event that is triggered every time the rpm exceeds the series' limit, and also when the car has a longitudinal acceleration of greater than 0 ie

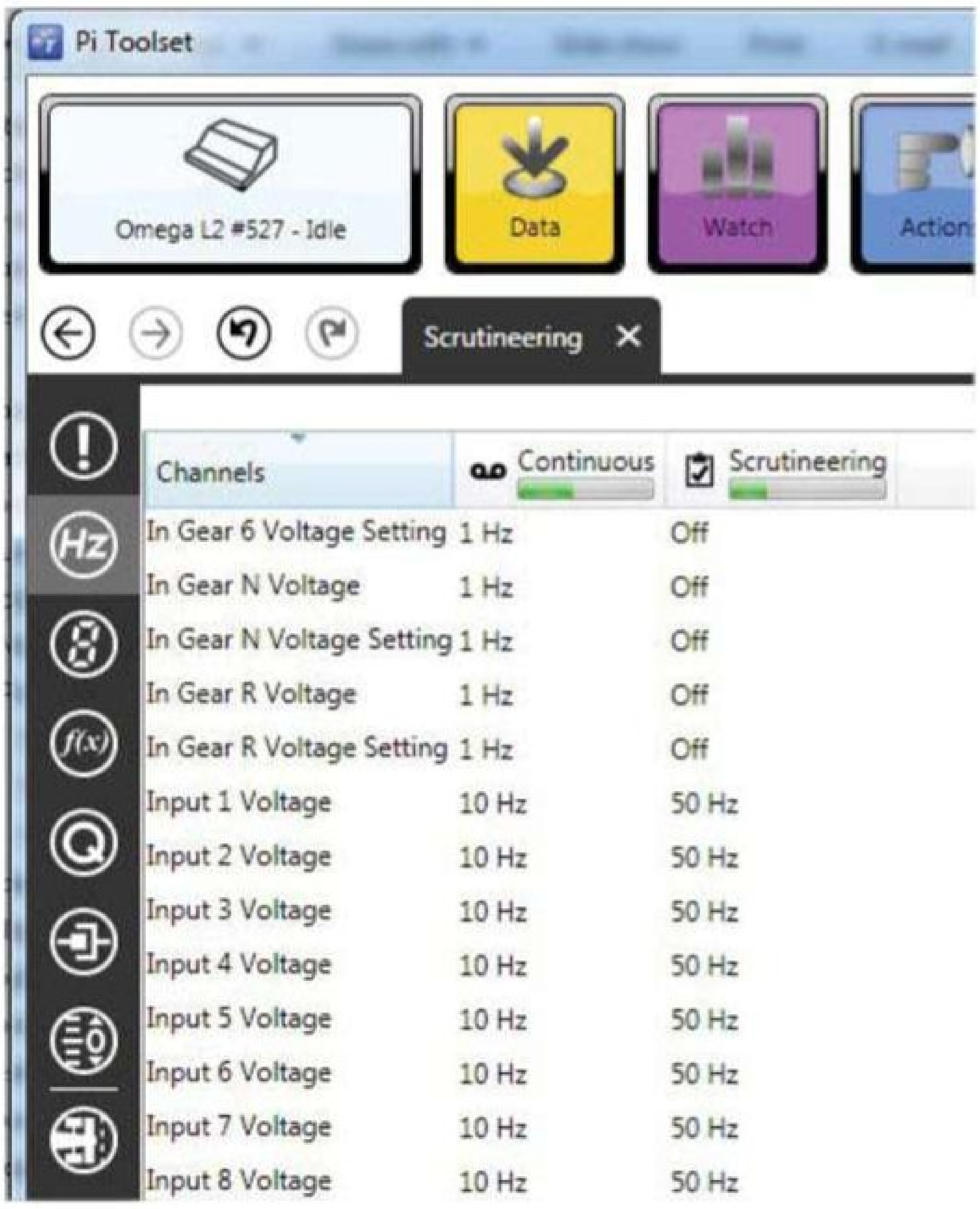


Figure 1: two separate logging tables – one for the team and one exclusively for the scrutineer

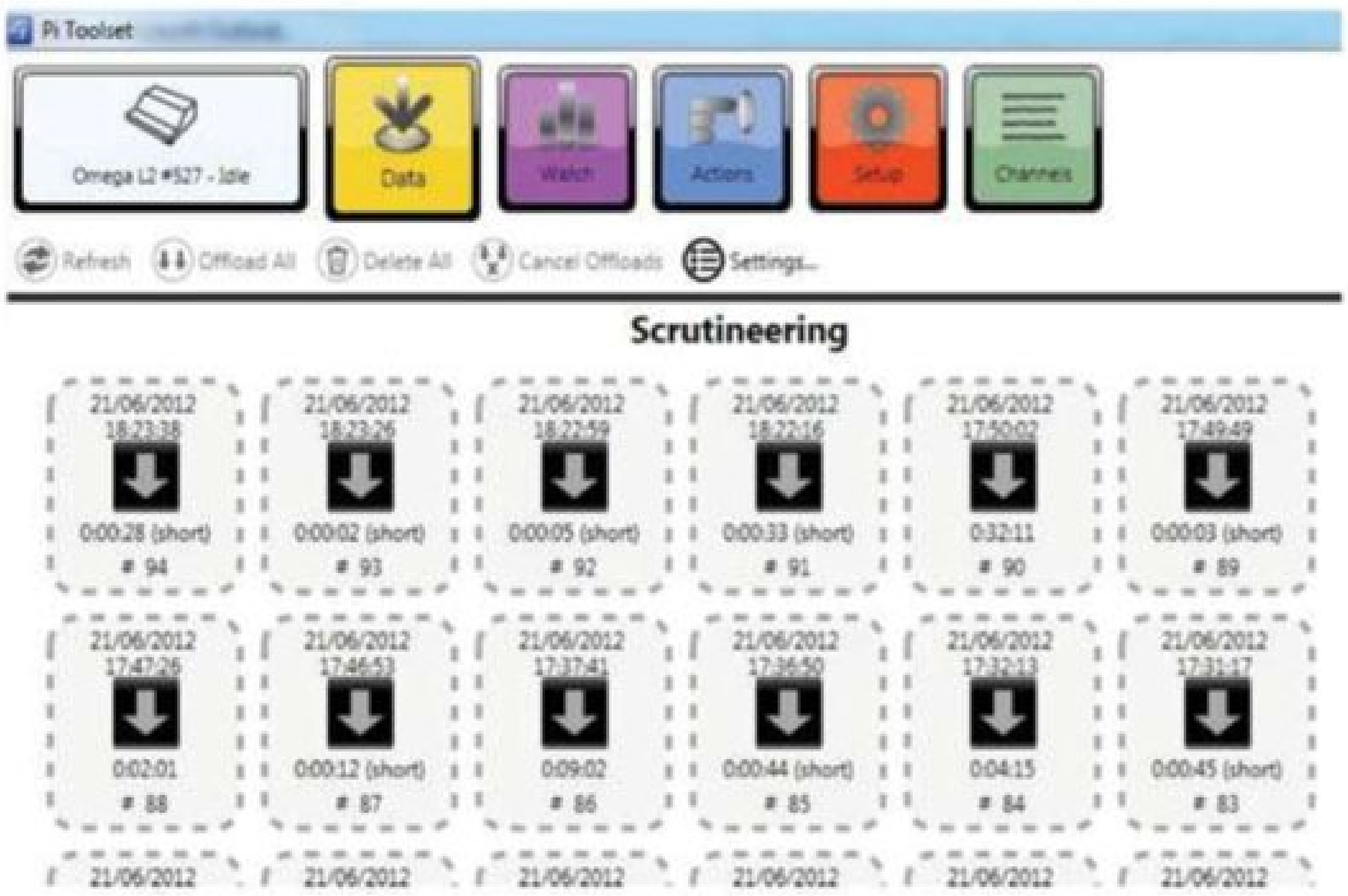


Figure 2: the scrutineering data can only be accessed by the scrutineer and, more importantly, can only be erased by the scrutineer

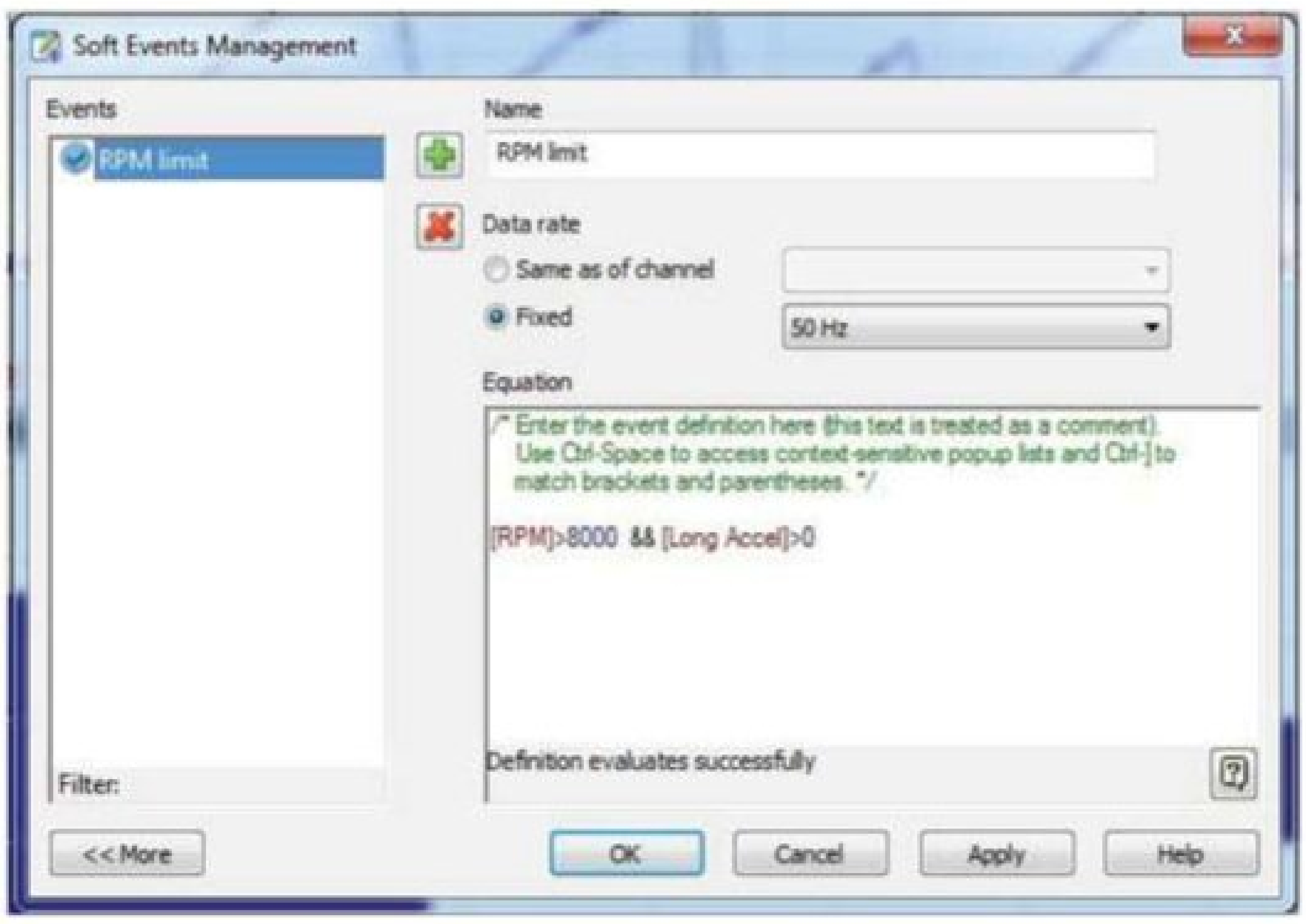
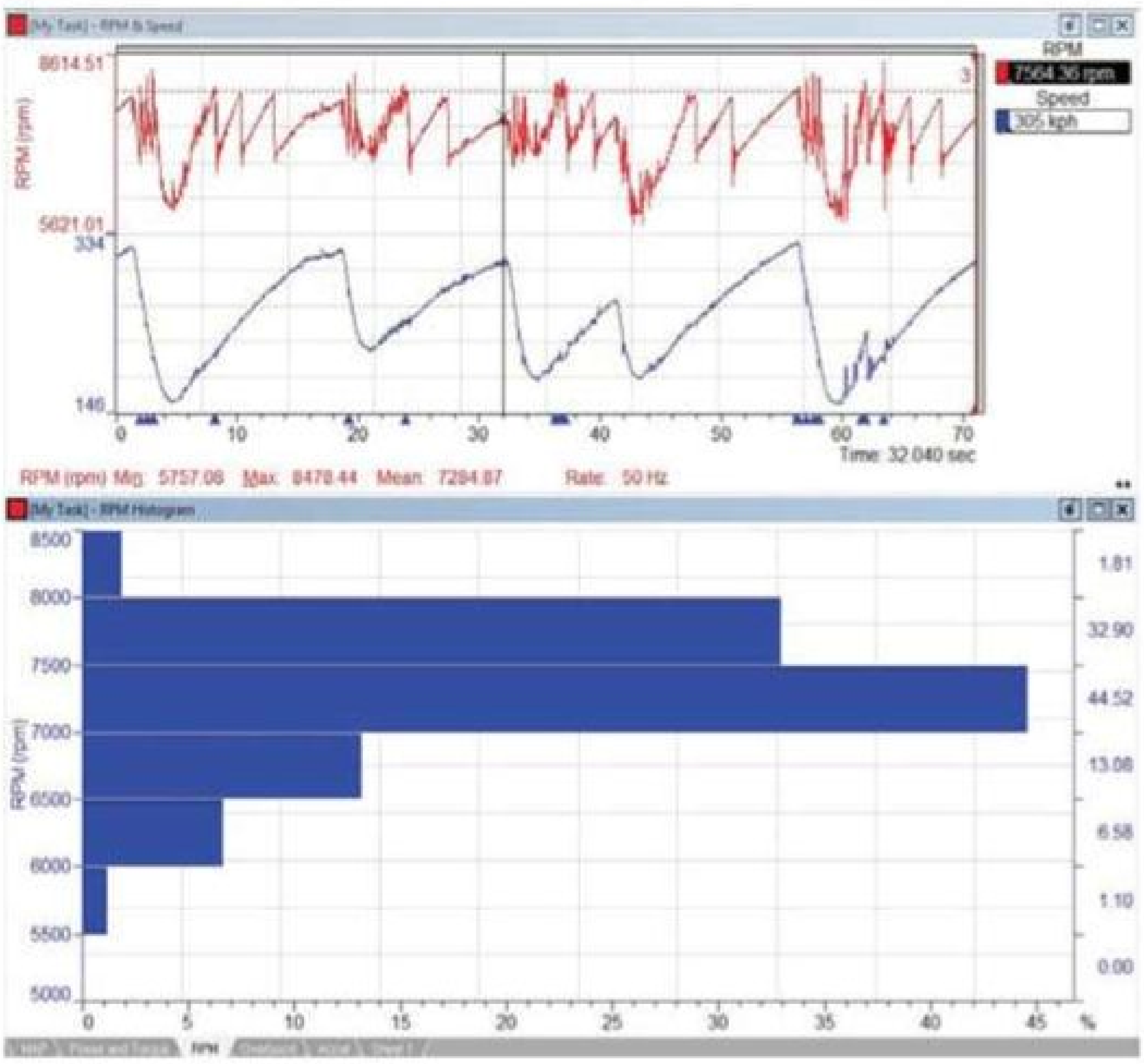


Figure 3: maths channel to trigger an event when rpm is over 8000 and longitudinal acceleration is more than zero



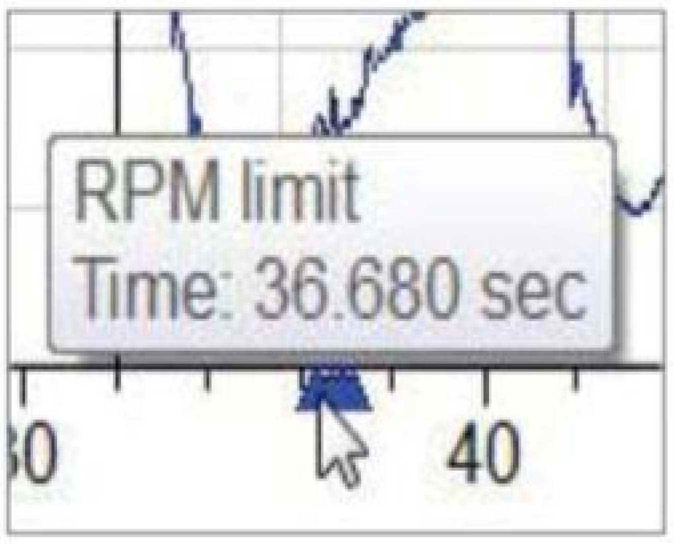


Figure 4: two different ways to spot when rpm is over its limits. The time / distance graph shows triangles on the x axis to show the point where the rpm is above its limit based on the maths channel event. Right is a histogram of rpm showing the percentage of lap time spent in each rpm interval.

when the car is accelerating, therefore ruling out downshift spikes, the scrutineer can check easily if the car is driving through the rpm limit.

By plotting the rpm on a histogram, it can also be seen what percentage of rpm is over the limit. Here it is 1.81 per cent, which the scrutineer may deem acceptable or unacceptable, depending on when the limit is exceeded. Looking a little closer at the example here, it can be seen that the events occur in a low gear (at a low speed) where the driver has been late to change up. This is likely to be deemed more acceptable by the scrutineer than if the car had exceeded the rpm limit when at full speed, as it is unlikely to have gained any significant advantage by doing so.

This process, using advanced data logging equipment and software, can be taken further to give much more information to scrutineers. It can also be used to help identify illegal strategies that may be being used, such as traction control, or to calculate what gearbox ratios are being used by each team.

Finally, scrutineering data systems give series' organisers an excellent tool to base performance balancing on.

"an excellent tool to base performance balancing on"

When used properly, data logging is therefore invaluable to scrutineers, and is becoming more and more popular in parc fermé, as well as on the grid.

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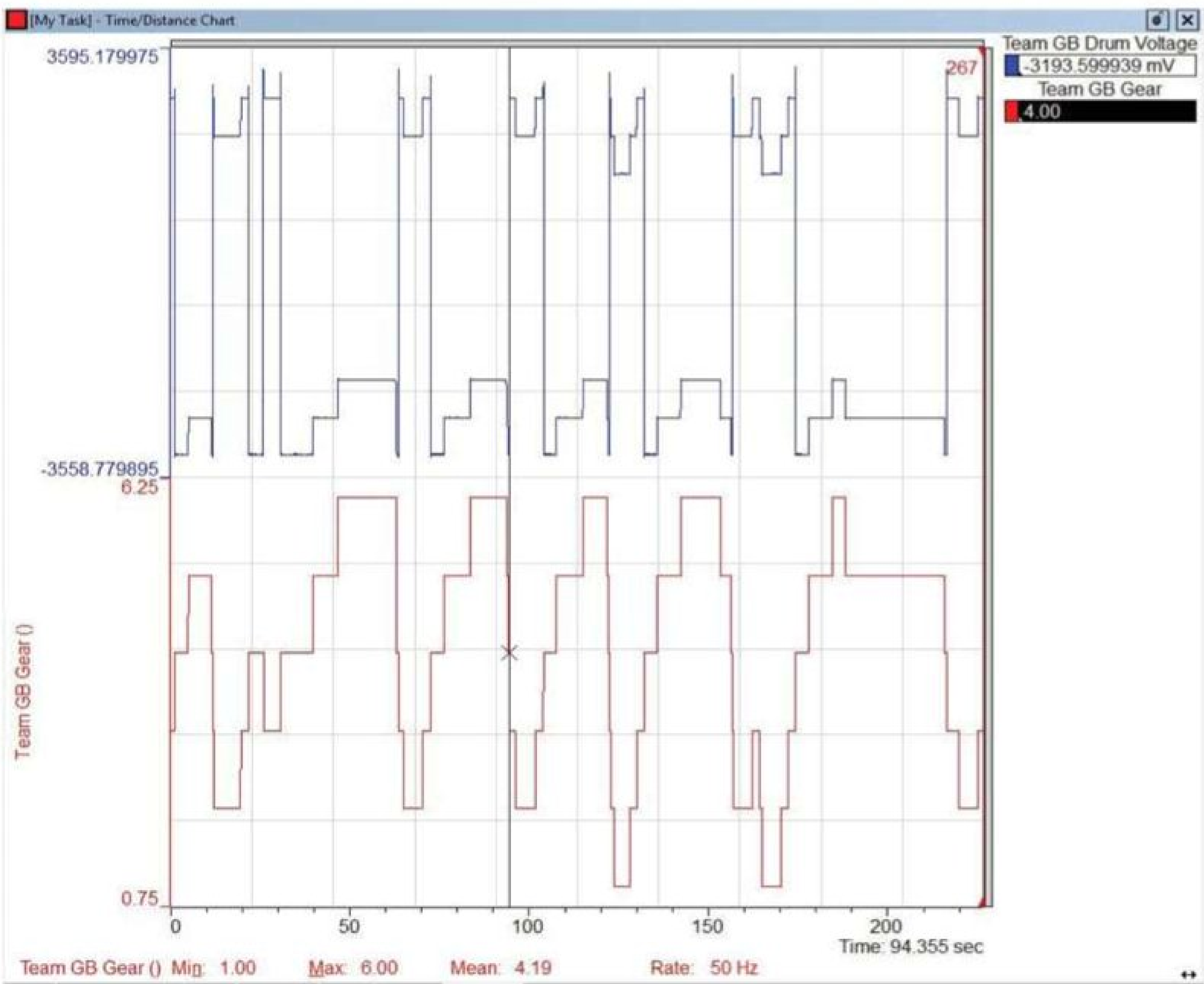
CHALLENGE



With CAN messages featuring heavily in motorsport, it is important to be able to identify any issues in the messages being sent. Can you identify the problem with the Team GB drum voltage channel?


ARROW

More tales of yaw

The new Dallara F312 under the wind tunnel spotlight

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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MIRA

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Once again this month, we are fortunate to have the opportunity to examine some of the aerodynamic intricacies of the new and previous generation F3 Dallaras in the MIRA full-scale wind tunnel. And this time we looked at the yaw responses of the two cars over a range of angles, from the straight ahead position up to six degrees, which is thought to be roughly equivalent to the slip angle at which maximum grip occurs.

We had at our disposal an F308 in 2011 specification, and what at the time of our test last winter was a very recently delivered F312. Our feature in *Racecar Engineering* V22N6 described the F312 in full, but to briefly summarise, the F312 featured cleaner bodywork with less aerodynamic paraphernalia, a higher nose, a larger front wing (with no raised centre section) mounted slightly further forward and a sharply terminated engine cover, with a gearbox top shroud below.

One of the first evaluations made was to sweep the cars across this representative range of yaw angles, and the results were very interesting. Perhaps the most important parameter to look at over a yaw sweep is aerodynamic balance, which we report here as '%front'. That is the percentage of total downforce felt on the front axle, and this value is plotted in **figure 1** for the two cars.

The initial difference in %front values between the two cars was examined in last month's Aerobytes, and was essentially down to the new car having a much more potent front wing. So what we're looking at here is not the different levels of %front, but rather how that value changed as yaw angle was increased. And the two plots are fairly similar, showing that balance shifted off the front by a reasonably benign 1-2 per cent across the yaw range tested. However, in absolute and in proportionate terms, the changes felt by the new car were slightly smaller Also, the 2011 car appeared to lose slightly more at the highest yaw angle tested, the graph steepening at that point.

However, while both cars saw a modest loss of %front as yaw increased, the manner in which other aerodynamic parameters changed across this yaw range was utterly different between the two cars. For example, the effect on total downforce saw almost a mirror reflection between the plots of the two cars, as **figure 2** illustrates.

"the most important parameter to look at over yaw sweep is aerodynamic balance"

The F308 featured a medium height nose and lots of vortex-generating componentry under the nose

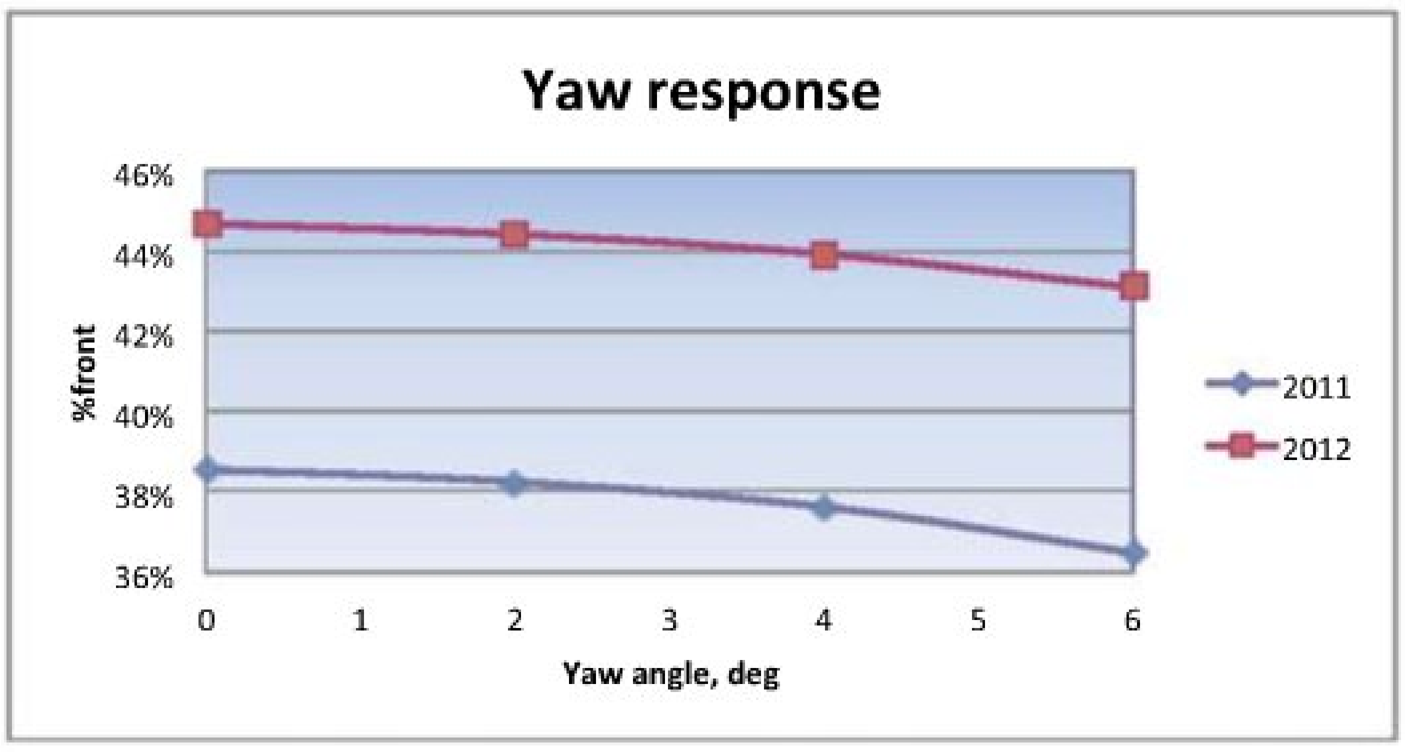


Figure 1: the effect on '%front' of rotating the Dallara F308 and F312 F3 cars over a representative yaw range

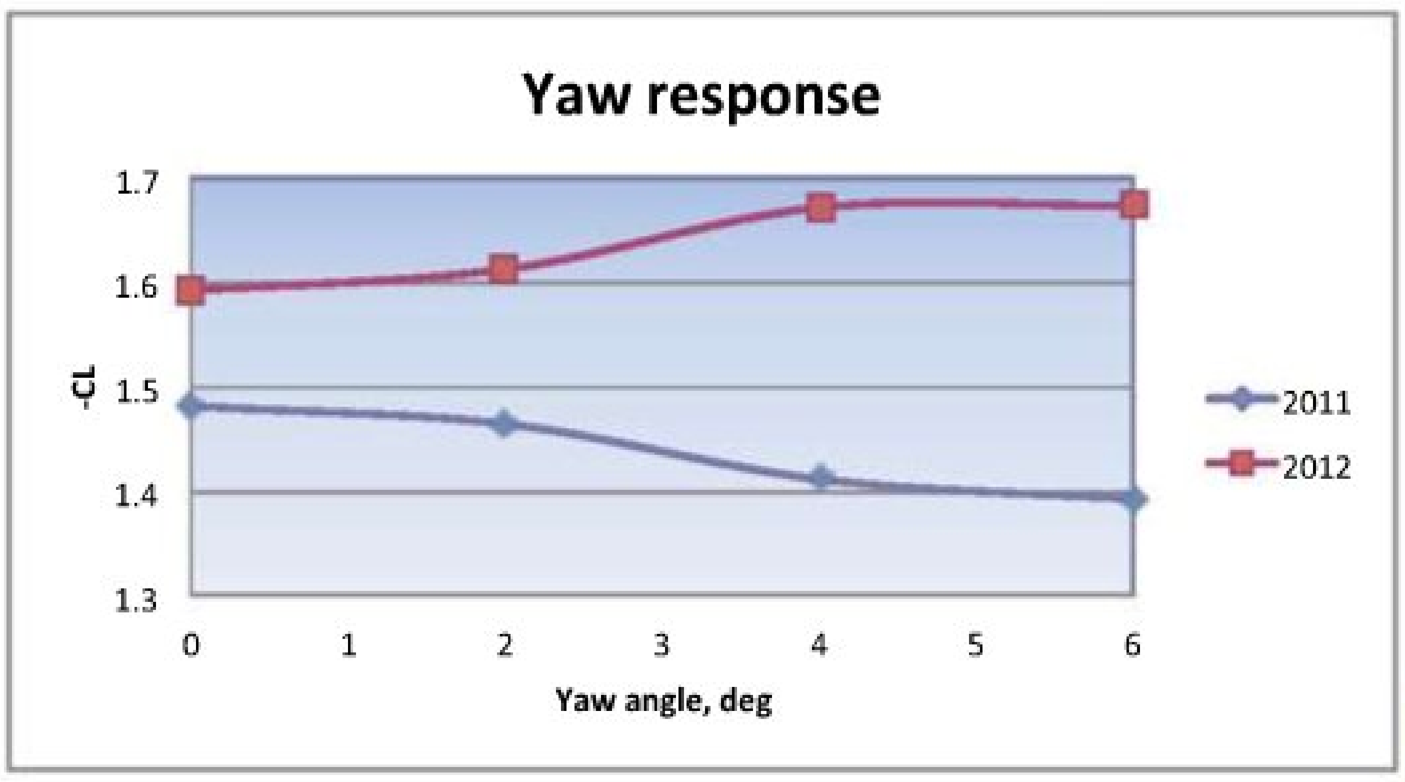


Figure 2: the effect on -CL, or total downforce, of rotating the Dallara F308 and F312 F3 cars over a representative yaw range

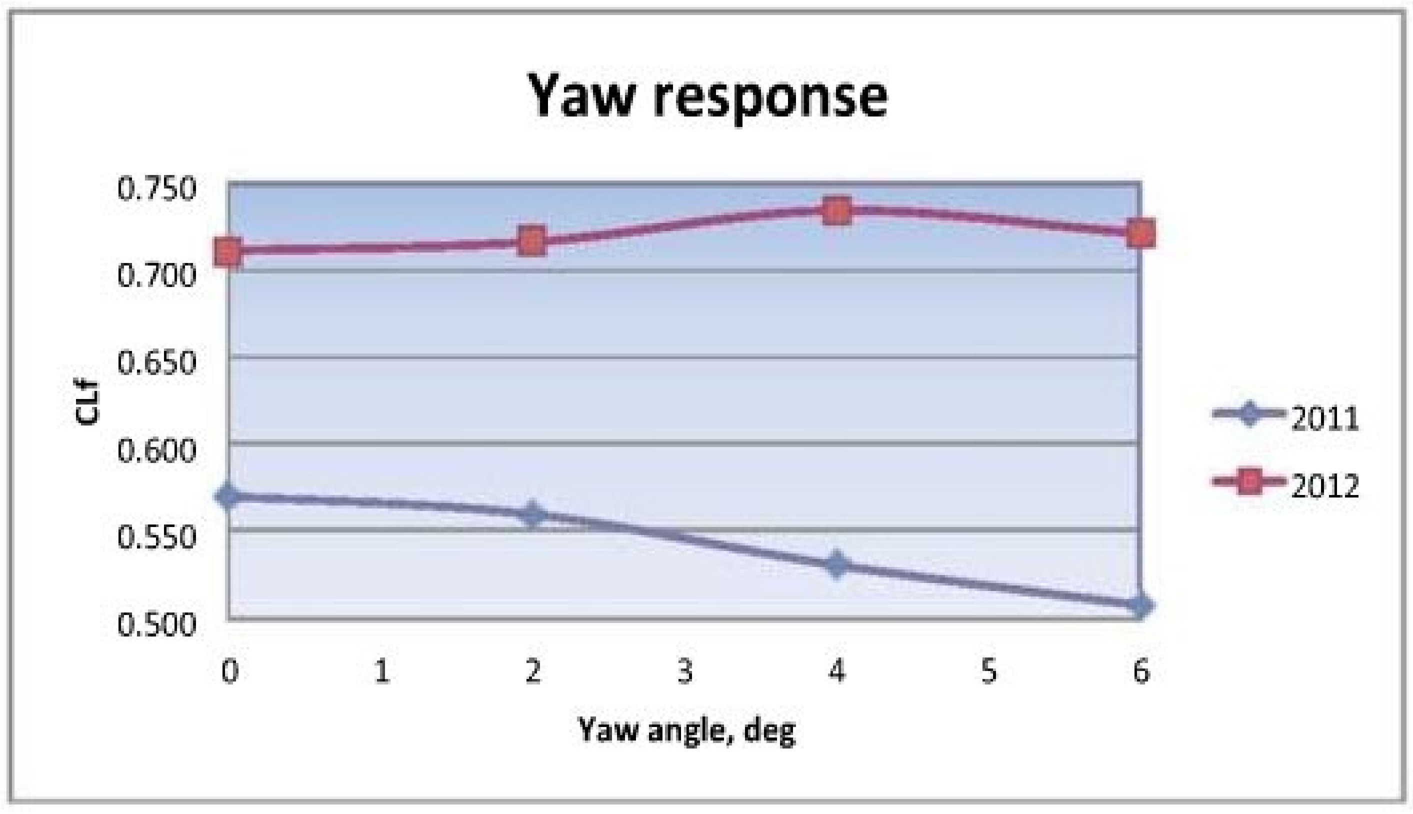


Figure 3: the effect on -CLf, or front downforce, of rotating the cars

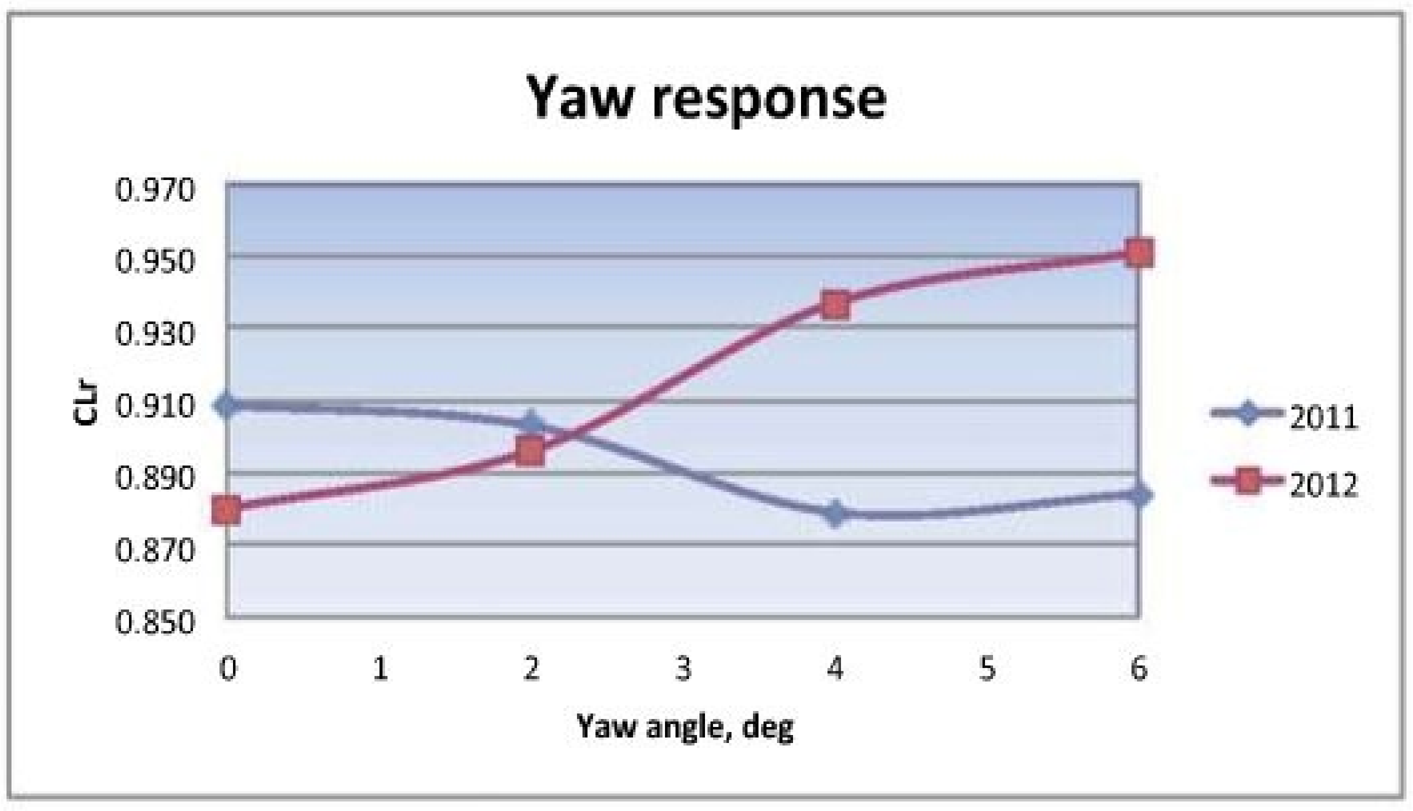


Figure 4: the effect on -CLr, or rear downforce, of rotating the cars

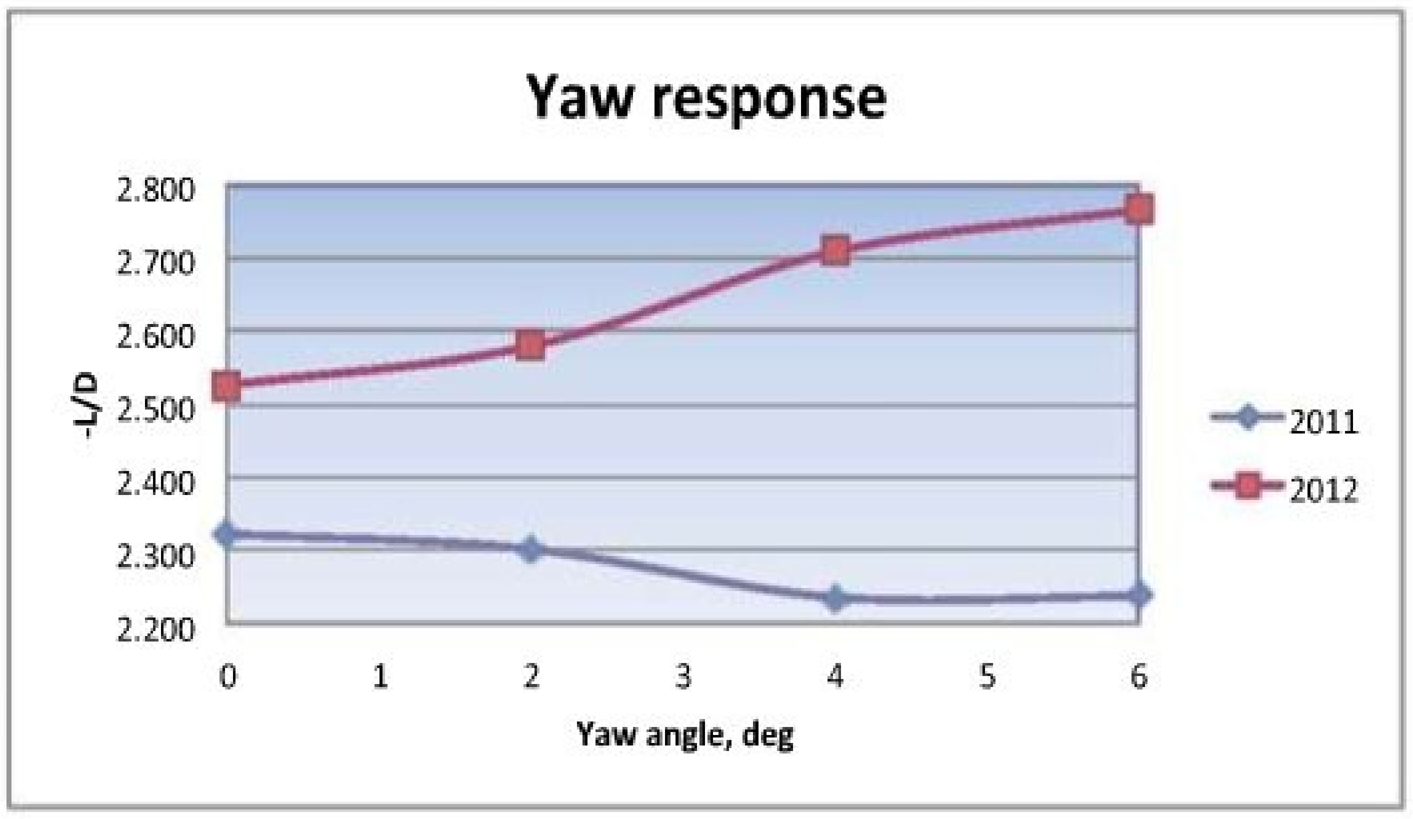


Figure 5: the effect on -L/D, or efficiency, of rotating the cars

The new F3 regulations prohibit the use of aerodynamic devices in various regions around the car, so the F312's nose is higher but 'cleaner' beneath

The response of the 2011 car was along the lines of what one might expect, given that we assumed the front and (identical) rear wings to both lose effectiveness as yaw angle was added, resulting in a decrease in total downforce. However, if that was the case, then it could be that something other than the wings was responsible for the increase in downforce seen on the 2012 car as yaw increased, unless the front wing of the new car performed very differently. So a look at how the front lift coefficient responded to yaw adds further clues to what was happening here. Here we see that, as yaw increased, the 2011 car's front end lost downforce in a similar pattern to the loss of total downforce, but the new car did indeed pick up front downforce as yaw increased.

The dominant device in terms of front downforce generation has to have been the front wing, but the reality is we can't tell whether it was the front wing or the forward floor that was performing better as yaw angle was added, and a combination of the two seems at least as likely as either one alone.

Adding credence to this notion is the plot of the two cars' rear lift coefficients vs yaw angle, as shown in **figure 4**.

This time we see that the old car's rear downforce decreased as yaw angle increased, but the new car's rear downforce increased. Since both cars used the same mandatory rear wing elements, which were set in exactly the same configurations here, it is safe to assume that other factors were contributing to the F312's increased rear downforce. And one of these other factors may be that the underfloor's performance was better when at yaw than when running straight ahead. Perhaps in wondering how this might be we should remind ourselves here that the F312 has a significantly higher nose and very few of the vortex-generating bits and pieces that proliferated under the nose of the F308.

The inevitable, if tongue-in-cheek comment on the day of the test was that the F312 could be aerodynamically better in a straight line if set up with a static six-degree yaw angle. That is, with six degrees toe out on one side of the car and six degrees toe in on the other. And the plot of -L/D, or efficiency, in **figure 5** tends to back this up.

DRAG DECREASE

Furthermore, drag decreased across the yaw range by 15 counts on the F308, but by 25 counts on the F312. And this, combined with the increase in downforce attained on the F312 over the yaw range, saw efficiency increase by 9.5 per cent when at six-degrees yaw compared to straight ahead.

> **"eficiency increased by 9.5 per cent when at six-degrees yaw compared to straight ahead"**

Facetious observations aside, Dallara seem to have done an excellent job on the F312. If these characteristics are confirmed on track, a racecar that sheds some drag but also gains some downforce in a reasonably well balanced way as it enters and sets into an 'aero-speed' corner has got to be pretty desirable. As ever though, we have to mention the dual caveats that MIRA's fixed floor, but with boundary layer control fence to better simulate a moving floor, and fixed wheels, but with 'trip strips' to better simulate rotating wheels, are not the same as the real world. So it will be interesting to find out how the cars felt when they hit the track for pre-season testing.

More on the 2011 and 2012 Dallara F3 cars next month.

Racecar's thanks to Fortec Motorsport.

Efficiency drive

The Automobile Club de l'Ouest and the FIA finally unveiled its plan for 2014, but there are more questions than answers in its document

BY ANDREW COTTON

The future of endurance racing will be based on efficiency, according to a document released by the ACO to the press at Le Mans, and roundly the manufacturers agree that the most efficient car will win the 24 hours in 2014.

However, despite the regulations being six months later than Audi, Porsche or Toyota wanted, they are still not complete and are undergoing revisions ahead of their full publication, which the ACO said would be the week post Le Mans, but are still not made public.

Topics still to be confirmed include the size of the cockpit, the calorific value of the fuel, which in turn leads to the final calculations for the balance of energy and the size of the fuel tank. A dramatic 10-litre increase in fuel capacity was introduced for diesel between regulations seen by *Racecar Engineering* in April, and the document released by the ACO in June.

Part of the problem is that both powertrain and aerodynamics are being changed at the same time, and with a completely new concept applied to regulating engines – through an ultrasonic fuel flow sensor – no one is exactly sure what the outcome will be in terms of top speed, aerodynamic stability or lap time at the Le Mans circuit.

The rule makers need to make a competition with wildly varying cars. To work out the correct balancing energy flow and tank size, they need to know the performance and efficiency of all the cars, including weight, power, thermal efficiency, hybrid efficiency, drag, and L/D.

The fuel flow sensor is key to the whole concept of the 2014 regulations, and any delay in its introduction into Formula One could leave Sportscar racing 'completely screwed', according to one engineer.

ENGINE

Despite pressure from Audi and Porsche, the ACO has committed to four-stroke engines for the 2014 regulations. Maximum cubic capacity for manufacturers is free, while privateers are limited to 5.5-litres. Turbo boost pressure is limited to 4bar.

Two companies are believed to be in the running to land the contract for exclusive supply of the fuel flow sensor – Gill Sensors and Canadian company, EESITEC Technologies.

Porsche has already requested that the regulators submit the two sensors, which need to be accurate to better than 0.5 per cent, to its testing rig, as it already has its own meter that, on the dyno, meets the criteria, and they can then measure how accurate the proposed sensor is.

A back-up system is to be discussed in the event of fuel flow metering not being ready or accurate enough in time for the 2014 regulations.

The move to a fuel flow sensor means the controversial air restrictors that Toyota says limits the development potential of a petrol engine will be removed. That should open the door for the development of efficient petrol engines that will also be supported by powerful hybrid systems.

Fuel injection pressure is free, but exotic materials such as electro-magnetic valves (which were being considered right up to the last moment in the manufacturer meetings) will be banned on the grounds of cost. Variable geometry exhausts are also banned, as is variable valve timing and variable valve lift profile systems.

The number of engines used in a season will be limited, and they will have to be more efficient by regulation. The target efficiency of an engine is 220g/kWh for petrol, while diesel

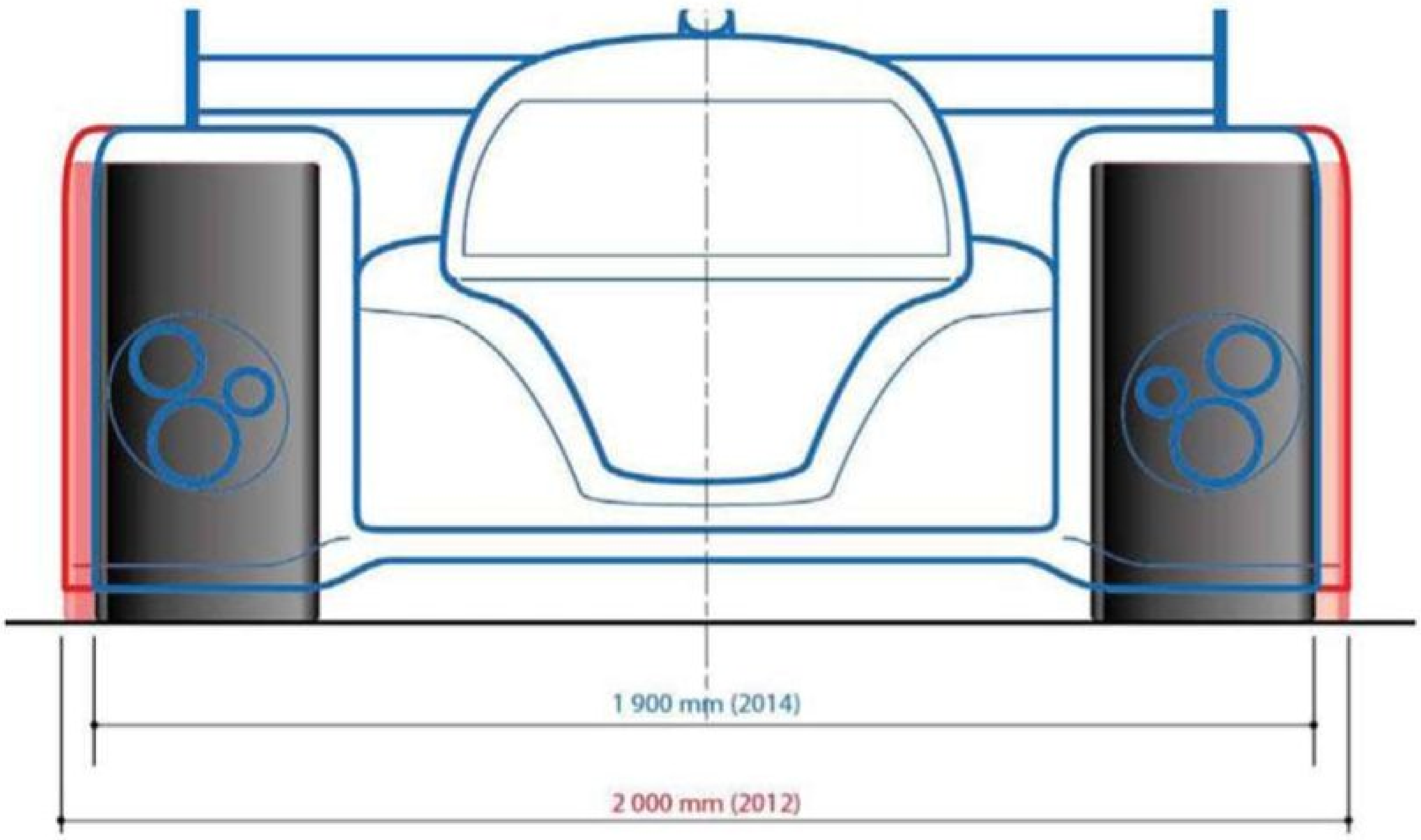
2014 LMP1 SYNTHESIS TABLE

This table enables each manufacturer to choose the option that best suits its project and budget. For the public, the distinction is simple: all the cars are Prototypes in the LMP1 category, whether petrol or diesel. Final regulations will include energy per lap only

		Private teams only	All teams			
	2011 cars	2014 cars	2014 cars			
	2011	non-hybrids	hybrids			
Energy ERS – Hybrid (size of hybrid system)	0MJ	0MJ	2MJ	4MJ	6MJ	8MJ
Car's weight	900kg	830kg	850kg			
Fuel allocation per lap	Not limited / estimation 6.13l/lap	4.95 l/lap	4.8 l/lap	4.65 l/lap	4.50 l/lap	4.42 l/lap
Fuel consumption reduction		19 per cent	22 per cent	24 per cent	27 per cent	28 per cent
Fuel tank	75 litres	64.4 litres	64.4 litres			
Diesel allocation l/lap	Not limited / estimation 5.26 l/lap	3.99 l/lap	3.93 l/lap	3.81 l/lap	3.68 l/lap	3.56 l/lap
Fuel consumption reduction		24 per cent	25 per cent	28 per cent	30 per cent	32 per cent
Diesel fuel tank	60 litres	53.3 litres	53.3 litres			

is 195g/kWh, already a huge step up over the 2012 engines, although they are air restricted and therefore not working to full efficiency.

Material control applies mostly to the engines, with titanium alloys banned from the pistons, piston pins, crankshafts, timing gears and camshafts. Titanium alloys are, however, allowed in the con rods and valves, while ceramics may be used in the reciprocating and rotating components of the engine.



Overall width is to be reduced to 1900mm from the current 2000mm for improved drag reduction

HYBRID

Hybrids will be mandatory for works teams in LMP1, with four levels of hybrid system allowed. Privateers will be able to run at a lower weight without such a system. The four bands of hybrid are divided by the capacity of the storage systems, including up to 2, 4, 6 and 8MJ.

To quote one leading engineer, to work out the best route would have to be simulated, and is 'f**king complicated.' For the press conference only, the ACO converted the amount of energy allowed for each car per lap to a fuel allowance. The reasoning was that a quantity of fuel could be easily understood, while a quantity of energy could not. However, that led to considerable confusion, and engineers in the Le Mans paddock were advising observers to ignore the published figures.

Notionally, however, fuel capacity will be reduced by up to 28 per cent, should any team manage to build an 8MJ storage system and package it in an LMP1 car, while at the same time meeting the new 850kg weight limit. However, regulators do not think this is a realistic target due to weight and packaging issues, and instead believe that the 2MJ and 4MJ categories will be the chosen ones for the majority of manufacturers competing. The reason for having so many classes was that the regulators did not want to have too big a gap between 2MJ and 8MJ.

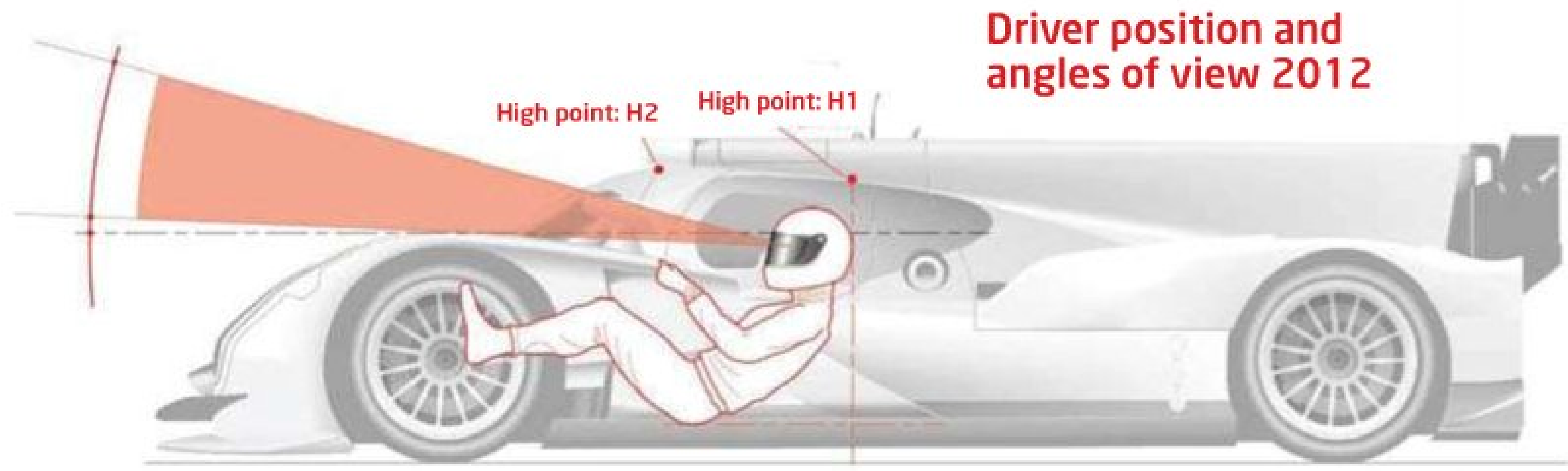
These categories demonstrate a 22 per cent and 24 per cent reduction in fuel consumption, a dramatic improvement considering Audi published its fuel consumption figures at the 2012 event at 33.34 litres per 100km – an improvement of 10 per cent over 2011 – having reduced the weight of its R18 TDI by the same 10 per cent, which equated to 85kg.

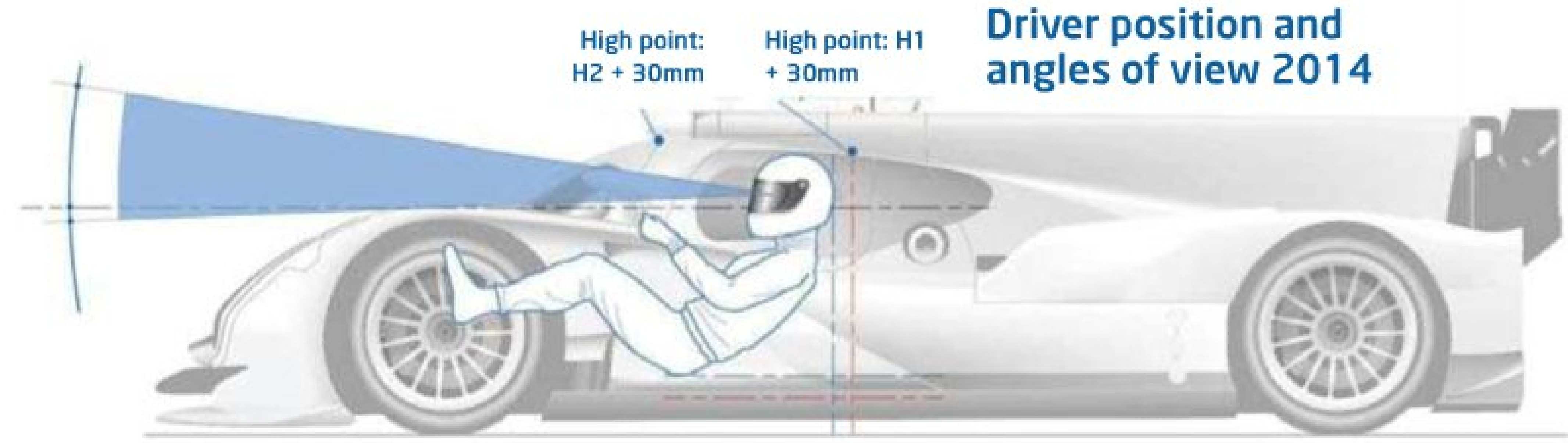
The target energy release is 400kW. Under the regulations, a manufacturer must inform the regulators as to how the flow of energy through the hybrid system may be monitored as this is open to potential abuse.

Customer teams believe that the factory cars running ERS systems will be able to stay out longer on each tank of fuel, while regulators and manufacturers point out that the extra power will be used for performance only, leaving the privateers languishing in terms of lap times, and therefore competitiveness.

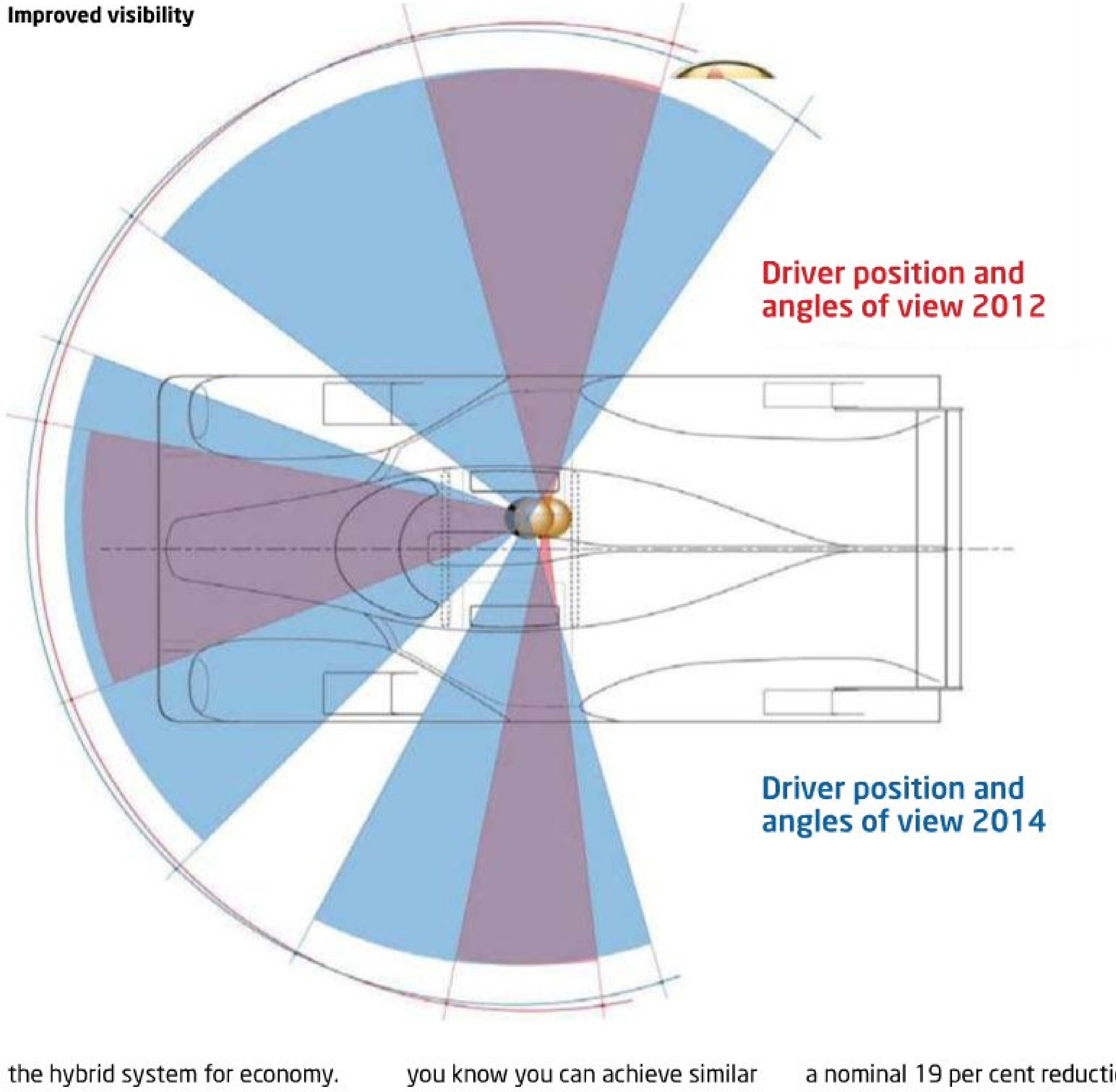
The consequence on lap time of turning down the hybrid system for efficiency is so little that it makes no sense to use

"The target efficiency of an engine is 220g/kWh for petrol, while diesel is 195g/kWh"





Improved visibility



the hybrid system for economy. 'As the regulation is written, it looks like without an ERS you will still be able to produce a similar performance in terms of lap time compared to cars that run ERS, but you won't be able to go as far in a stint, which is where a deficit will be,' says Nicolas Perrin, designer of the Pescarolo 03. 'As a privateer, it gives you more motivation in the game if you know you can achieve similar lap times. It is not the situation we have at the moment with the current regulation, and when you arrive on the track for the first practice session it is nicer to see your name at the top of the time sheets, even though you know that during the race you will struggle a little bit with how many laps you can do in a stint.'

Privateers have been given a nominal 19 per cent reduction in fuel consumption compared to the 2012 cars, although few expect that to remain the case. Larger fuel tanks will allow the teams to run their engines richer, delivering more power. The target lap time set by the ACO for LMP1 cars is 3m35s, and the target top speed is above 320km/h. However, privateers must remain competitive and insiders suggest that they could get more than the 64.4 litre fuel allocation and 830kg weight limit for a non-hybrid car. 'The privateers can run in a category without hybrid,' said Pierre Fillon, president of the ACO. 'When Vincent [Beaumesnil, general manager of the ACO] presented the figures, it is just the beginning. We have to adjust them after one or two races. That target is to have a category where we can adjust the level for the customer teams as we want.'

The final set of regulations concerning energy permitted per car will be set once the chosen fuel supplier – at the time of writing thought to be Shell – releases the calorific value of its fuel, both petrol and diesel.

"The target lap time for LMP1 is 3m35s, and the target top speed is above 320km/h"

The fuel will be standard E20, up from E10 in 2012. Until this is finalised, no complete set of figures can be released.

AERODYNAMICS

The aerodynamic regulations are yet to be finalised as the seating position of the driver has still to be decided. The compulsorily coupé cars will continue to be two seaters, and their width will be narrowed by 100mm to 1900mm. An adjustable front wing will be homologated for the season. The front will be lower to improve efficiency without compromising stability in case of loss of control, and holes will be put onto the inside edge of the wheelarches.

However, the height of the cars has yet to be defined and, after the injuries suffered by Timo Bernhard at Sebring, and Guillaume Moreau and Anthony Davidson at Le Mans in 2012, the angle at which the driver sits will also come under close scrutiny. Visibility will be improved over the front wheels and to the side, although the size of the a-pillar was never considered

necessary to change. It must still be possible to remove the helmet while the driver is seated in the car, but the regulators do not want cars that look like Daytona Prototypes, which feature high cockpits and narrow bodies.

With the reduction in overall size of the car, regulators are unsure as to the effect of delivering extra power to the driving wheels and the effect it will have on top speeds and lap times. Bodies are expected to be more efficient and drag reduced.

Side impact protection zones are also to be introduced, but not regulated, according to Bernard Niclot, technical advisor to the FIA. Using Zylon, a highly resistant polymer also called PBO, lateral protection and a rear crash box will be mandatory. 'We will essentially find some mandatory thickness for Zylon,' says Niclot. 'We will not do a side impact crash test, it will be in the regulations. We have to define in detail, but we have very few weeks to finalise this.

'The problem with aero is drag, not downforce. We are not looking for more downforce, we are looking for an improvement in drag. [Reducing the width by] 100mm will help a bit. It also helps to reduce the weight.

'We have other concepts in mind that we have not put into the rules, because they are too extreme, and too early, and we didn't want to get the manufacturers in trouble with what they need to develop. We have been conservative on the aero side and you have other possibilities that are road relevant that could improve drag.

'We didn't want to go with too small cars because we didn't want to have cars that look like a tube. In the past we had the low cd cars at Le Mans that were very efficient aerodynamically but they were a bit too extreme. We would have to reduce the tub, the carbon chassis and have less side structure and that would be detrimental to safety, so we made this compromise.'

CONCEPT

The idea is to create free technical regulations with a set cost criteria. That means putting in boundaries, and both the FIA and the ACO have done so by committing to running road-relevant technology – a plan that coincides with attracting more manufacturers.

'We must control the budgets so there have to be some limits,' says Beaumesnil. 'If you can open the engine capacity and restrictors, you have many ways to do clever things, without using crazy, expensive materials.

'We had one manufacturer [Peugeot] pushing for [a minimum weight of] 700kg, and they are not here any more. You must be reasonable. Reducing the weight of the car is incredibly expensive. And when you have to introduce hybrid systems of a certain weight, it is expensive already.'

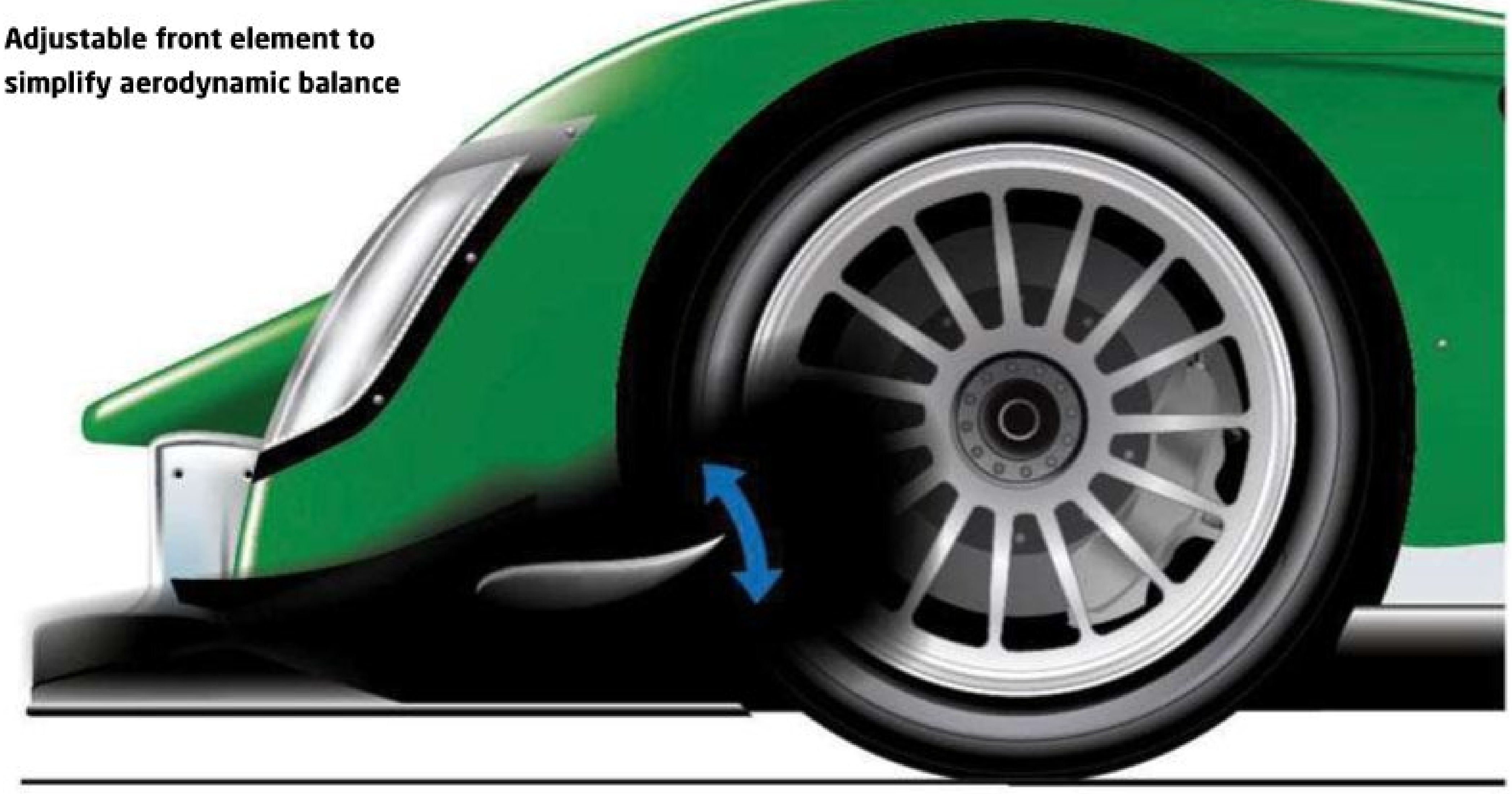
One potential problem on the horizon is the number of privateers in LMP1, and with Lola in administration, Zytek and ORECA saying that they will not build new cars as there is no market, and no other major manufacturer likely to step in before 2014, options are limited. Privateers will have the opportunity of running hybrid systems, and Zytek is preparing an off-the-shelf system for this application. With Lola representatives sitting on the committee, the ACO does not foresee problems with private competition in its top category.

'I think for privateers they have new challenges,' says Beaumesnil. 'You can run 2013 cars for one more year and we will discuss this in the Summer. Pescarolo has a new car this year, and so does HPD. It is not building a new car that is expensive. The expense is the running costs. We have figures for costs in our heads. Some technologies are reasonable and affordable, some are not road relevant and expensive, so we will not allow them.'

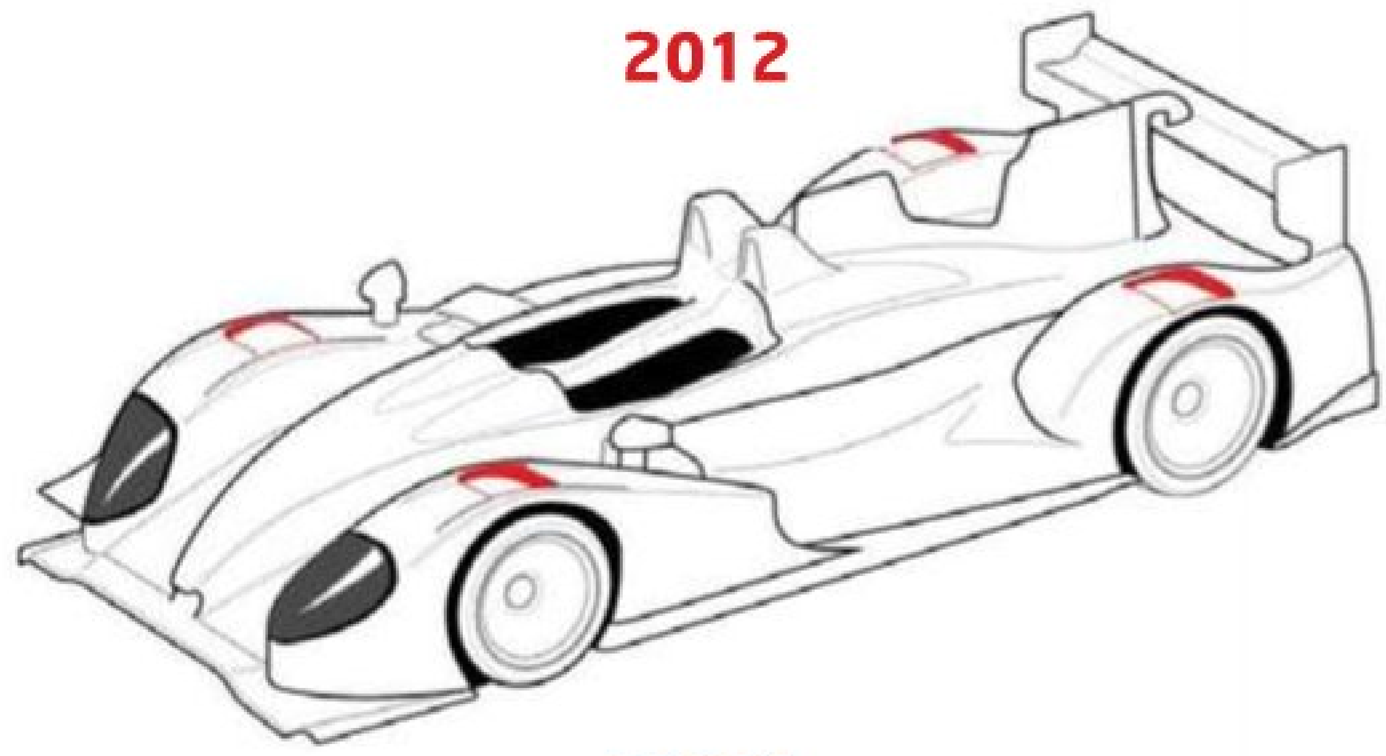
Balancing the energy should allow petrol and diesel to compete against each other on a level playing field. Historically, however, that has not been the case but that, says Henri Pescarolo, has nothing to do with technical advances. 'It has never been a technical problem, it has been a political problem. Now Peugeot is speaking again, and [technical director] Bruno Famin told me I had to congratulate my technical team because every time we said their power, we were right!

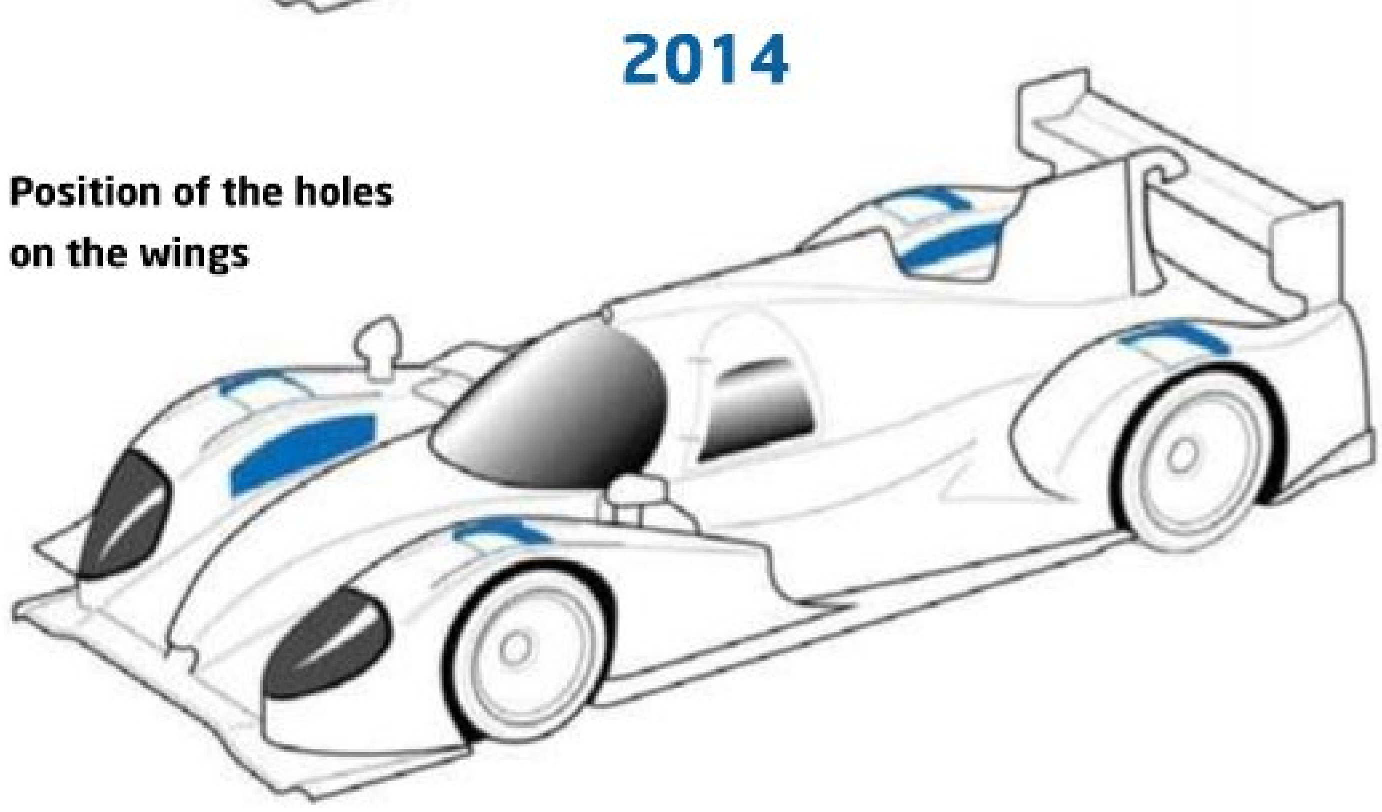
'With a 5.0-litre engine it was possible to be competitive with a diesel, it just needed a different size restrictor. Either they want fair equivalence or they don't. It was easy to have a nice balance between petrol and diesel. We have been asking for seven years to have the same quantity of energy into the cylinder, but with a hybrid system they can do what they want.'

The regulations, it seems, are still far from being agreed. As one negotiator put it, however, 'If you leave the room with everyone upset, you have done a good job. If someone leaves the room smiling, you have done something wrong.'



Adjustable front element to simplify aerodynamic balance





Position of the holes on the wings

Body of change

NASCAR has listened to the fans and the manufacturers, and the new look Sprint Cup car bodies should bring them back in droves

BY SAM COLLINS

The cars that currently race in the NASCAR Sprint Cup are ugly. It is a sentiment that has been almost universally held from the moment the NASCAR Sprint Cup Car of Tomorrow (CoT) was introduced in 2007. It became even more apparent when a new, better looking version of the concept was rolled out for the second tier Nationwide series in 2010. It was clear that something would have to change.

'Once we got the Nationwide car finished, everyone looked at it and realised that we could build a better looking, more representative Cup car,' explains Howard Comstock, manager of engineering for Chrysler Group's Street and Racing Technology Motorsports division. 'The Car of Tomorrow was a huge technological advance. They were a lot stronger, safer, and many things about it were better, but one of the things that it was not was better looking. It was not a good looking racecar in any shape or form and, quite frankly, it turned the fans off. We needed to get the fans back on our side. The proportions, in my opinion, were not good. They were not representative of current passenger car design. For example, I don't think the roof was anywhere close to being racecar-like and the c-posts were splayed to keep air off the spoiler, which hurt our ability to move the tail forward.'

The manufacturers, too, were becoming increasingly unhappy

"We all made a pact that we were going to listen to the stylists first, then dump the problem on the aero guys"

The new look Sprint Cup cars give manufacturers the opportunity to ape current performance styling. 2013-style cars are already on track in private testing

with the almost total lack of brand identity on the Cup cars. Stock Cars had always had at least a nod to the shape of the production cars they emulate, but the introduction of the CoT meant every car on the track was essentially an identical shape beneath the stickers. They also wanted to go further than they did with the Nationwide car. 'On the Nationwide car, from the middle of the bumper upwards to the base of the windshield is the area we were allowed to put in brand identity. The rest of the car is common, which is basically from the windshield base rearward, including the sides and tail, and then the lower nose,' said Bernie Marcus, Ford Racing's aerodynamicist who has worked on every NASCAR vehicle since the 2004 Taurus. 'We were able to basically put on the upper nose with the grille, headlights and then a hood [bonnet]. We went away from true Stock Car racing and got to a point where the cars we're racing in Sprint Cup were very vanilla.'

It was something that irritated senior figures within the manufacturers, and was genuinely raising questions about future participation.

'My management was making it very clear that our car had to have more Dodge identity. It had to look like a Dodge or they would be far less interested in continuing with racing in the series. It was something echoed by all of the manufacturers, and we all went separately to NASCAR and said we need a better looking Cup car. They quickly sent that up the line and the management there agreed wholeheartedly, so their technical people and our technical people got together. As a result, NASCAR made the pretty big decision to let the four OEMs go a long way down the path to see where we ended up,' reveals Comstock.

MANAGEMENT STRATEGY

But to achieve what the senior management of 'the big three', and Toyota, all wanted, the technical departments of the four manufacturers would all have to work together.

'There is a group of four of us – one from each manufacturer. We know each other and we see each other every week,' Comstock continues. 'We wanted to start out by correcting the errors on the car as it is now. We thought the nose was too short so we lengthened it by three inches. The tail was way too long, so we put an extra six inches into the centre of the vehicle and put some crown into it in plan view. The car now has the short tail, longer hood [bonnet] look that we think is representative of more current passenger cars.'

Once the broad parameters of the new design were set, the manufacturers each went their own way with the car design, developing their own range of body panels and shapes.

'NASCAR encouraged us to put a lot of identity into the front of our cars without limiting us to designated shapes. We moved the base of the windshield ahead by five inches, and made it look sleeker, longer and lower, even though the centre roof height is the same, and even though the car would have the same chassis, the same track, the same wheelbase and the same wheel and tyre combo.

'The upper and lower fascia are unique to each manufacturer, the tail is also going to be different for each make and, for the first time ever, NASCAR has opened up the sides of the car for us to put identity into the sides, as well as adding wheel [arch] flares. So we can closely emulate trends in performance car design. Pretty much any production performance car has flares. We all made a pact that we were going to listen to the stylists first, then we would dump the problem on the aero guys.

'Fortunately, NASCAR wanted to keep the downforce / drag balance and side force close to the existing car. Not exactly the same, but close. They wanted to give enough latitude that the cars would be different, and they thought we could shift some of the balance if we needed.'

Once these sections were decided, the stylists were essentially given free reign over the look of the car, and each manufacturer tackled it in their own way. For Ford, the process behind developing the 2013 body was significantly different to some of the previous models, where race teams such as Penske Racing and Roush Racing actually built, designed and did the majority of the development on the Ford Taurus, prior to its debut for the 1998 season.

'We started by going back to our design community and nosed around with guys that have been with the company the longest. We can't remember the last time designers were involved with helping NASCAR,' said Andy Slankard, Ford Racing NASCAR operations manager. 'This time, we had the luxury of support from the Ford Design Center to give us these sleek shapes and new look. Only designers could do that, not a bunch of engineers or racecar guys.'

GM has yet to fully reveal its finished body (above), but Ford is very proud of its full scale model, now in Woods Brothers' colours

A self-professed race fan, he embraced this opportunity and called it one of the highlights of his time so far at Ford.

Some of the challenges the design team faced centred around various NASCAR rules, and those common areas such as the greenhouse that all of the manufacturer vehicles share, but there were other, more obvious ones that had to be overcome.

'There is a size difference between the production and the racecar, and the proportions are so different. The street Fusion is a front-wheel drive, front-engine car, and the racecar is a front-engine, rear-wheel drive car with a really long hood, and a much lower and wider stance,' explained Nicoghosian. 'The fundamentally different profiles and proportions of the two vehicles, as well as other constraints, presented a bigger challenge than simply taking a Fusion and putting NASCAR stickers on it.

'The challenge was to design a racecar with the look and feel of the production car,' Nicoghosian said. 'To do this, you have to rely on design identity. We paid close attention to the way we shaped the details on the racer, such as the headlights, grille and fog light openings, as well as the body side sections, character lines and overall surface language. When parked side by side, the racer and the street car 'feel' the same, even though the two share absolutely no common surfaces.'

'We've really embraced the Design Center's philosophy and process of how they would design a car for the street,'

"The challenge was to design a racecar with the look and feel of a production car"

DESIGN CHALLENGES

One of the people heading up the Design Center part of the project is Garen Nicoghosian, design manager for specialty vehicles.

Ford used its time honoured clay modelling technique to develop the shape of its 2013 car. Though the greenhouse dimensions and certain other areas are specified by NASCAR and common to all cars, the rest was free

Flared arches were a key feature of the new car, as used to great effect on the Dodge (above). The front and rear ends, though, are where manufacturers have really been able to stamp their brand identities

With the styling signed off, it was down to the aerodynamicists to develop the shape into a workable racecar. Wind tunnel facilities such as Aerodyn were used to develop the cars such as the Ford (above)

explains Pat DiMarco, Ford Racing NASCAR programme manager. 'We started with some conceptual drawings that our design team did, and worked with the aerodynamicists to see what was feasible and what was not.'

That resulted in some 40 per cent clay models that helped assess the car's overall look and how it would react aerodynamically in the wind tunnel. Eventually, a full-size clay model was constructed and reviewed.

Dodge, on the other hand, took a rather more pragmatic approach to the car's design: 'We wanted to see a car go past and be able to tell what it is just from the side,' explains Dave Bailey. 'We had a lot of fun doing that because we grafted the body of a current production Charger onto a CoT. It wasn't all lined up properly or anything but that was the first concept we showed to NASCAR. It was really a production car sat on a racecar chassis, and we made a model of it and showed it to Robin Pemberton, NASCAR's vice president for competition. I remember he liked it and that meeting went well!'

Once all the designs were ready from a manufacturer perspective, they then had to present the final designs to Pemberton and his team at NASCAR R and D, who would then work with all four designs to ensure a level playing field, from an aerodynamic standpoint.

AERO TARGETS

'When we ran the car for the first time in the tunnel we were quite surprised that we were within reasonable range of what NASCAR was looking for, and with only minor corrections we were able to meet the balance they required. NASCAR put aero targets on all four OEMs and, by June, we had to hit targets for drag, horsepower, downforce and side force,' Comstock reveals.

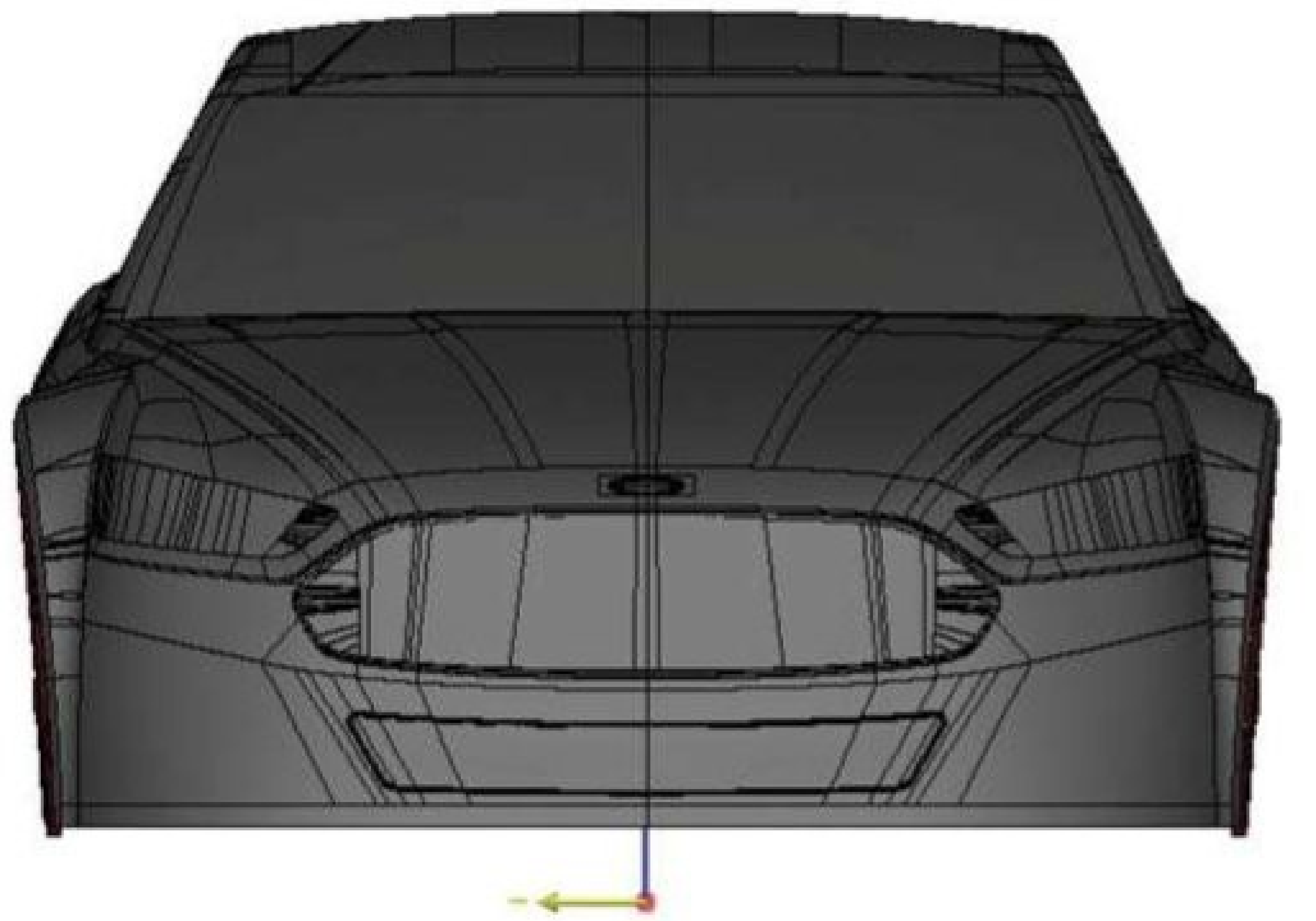
Unusually, for a competitive series with multiple manufacturers, all four used the same base car to do the official aerodynamic tests, both at Dodge's full-scale wind tunnel in Detroit and at the similar size but specially designed tunnel at Aerodyn in North Carolina.

'NASCAR built a chassis with universal body mounts, which they sent to us as a CAD file. What we have done is make body panels. As the greenhouse is common they put that on and it was fixed. Each of us then made a set of bits and took them to the wind tunnel. We ran a control body first, then each of us ran our kit of bits on the car. Once that was done, they took the car out and scanned it for each manufacturer,' Comstock continues.

Part of the aerodynamic programme was to develop the car to work in the real world, but also to ensure no manufacturer was at an advantage.

'We not only ran at inspection height and attitudes, we ran in the wind tunnel at real world ride heights. There are some universally accepted numbers about what the car runs at when it is on the race track, and we put the car at those heights and checked the cars at the attitudes and yaw angles you would experience in reality. So now we have a good idea on the aero.

We found that with a shorter tail we needed to do a fair bit of work on the greenhouse, so we



would quit expelling air off the side of the car so it didn't get to the spoiler. We now had to encourage air to the spoiler so we could keep the same amount of rear downforce, as we don't want the cars to be aero loose flat out at Talladega,' explains Comstock

OPEN BOOK DEVELOPMENT

The manufacturers had an open book on each other's aerodynamic figures on the test car and, as you would expect, there was some discord about balancing the cars.

'Some were draggier and some had more downforce than others. So NASCAR had to decide what the targets were going to be. Some people cried, some people cheered. But it's NASCAR's game and we have to play to their rules. We were all smiling though,' enthuses Comstock. 'We found that what we expected was really the case. CFD is a hugely useful tool for production car design and we kinda stole those guys in Detroit to work on the racecar, so we had a pretty good idea it would work, and it did.'

The arrival of the new bodies for the 2013 Daytona 500 will see most Cup teams having to re-think the way they work. Instead of the bodies being largely fabricated by the teams from sheet metal, most of the body will be supplied to the teams ready to fit. The roof, hood (bonnet), fenders (wings) and sides will be supplied as stamped steel parts, whilst there will be a 'new' material for the nose, tail and trunk (boot) lid – something that may surprise many when they see it employed in NASCAR bodies – carbon fibre.

Toyota Camry (top). Scale wind tunnel model testing was done by Ford at ARC (middle). CAD model of the Ford (bottom). Much use was made of CFD by the designers before the first bodies were made and tested in the tunnel

However, this does not mean that North Carolina will suddenly be awash with unemployed sheet metal workers. Indeed, Comstock believes that initially there will actually be more demand for them: 'I think there will be more fabricators on it. Whatever anyone supplies, the teams will always find a way to make it better. We will do what NASCAR asks – supply the panels and the teams will no doubt then try to make them better.'

This 'making it better' can often stray beyond what is strictly allowed in the regulations and new bodies, new methods and new materials will mean NASCAR's technical inspection process will also have to change.

'We all did our final wind tunnel runs in June and, once everyone passed, then NASCAR scanned all of the cars and will use that as an electronic record. It's all so much easier in the electronic age. They have every square millimeter of our surfaces in there. As a result of that, the templating process will be very different. There will be fewer big, shaped aluminium claws and more fibreglass moulded plugs to fit over areas of the car to keep the teams honest.

'Scanning too is a tremendously successful tool, but we may not see it on Friday inspection. Now though, if you win a race, the car goes back to the tech centre on Monday for a detailed scan of the body surfaces, and NASCAR knows exactly what is required of the cars and exactly what the tolerances are!'

The new bodies will not be limited to Sprint Cup for long, and the new processes being implemented will have significant impact on lower level classes such as ARCA and Late Model Series. 'I think there is no end to how much better we can make the cars look in a whole range of series,' said Comstock. 'The [one-piece fibreglass] body [on the Dodge] at the launch [at the Las Vegas Motor Speedway] showed how easy it is now. With the improvements in the way we can make one-piece bodies, it seems to me that a lot of the lower series could instantly have better identities, so the ARCA guys could just leapfrog over the CoT and go direct to 2013.'

All four manufacturers have now shown off their cars in public, though Chevrolet has yet to reveal the exact model its design as the production car it is based on has not been launched yet. The 2013 cars will make their race debut in the Bud Shootout, and it is sure to be a fascinating race.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Spring installation ratio and wheel rate

The essential information required to set up a car's suspension ratios

BY OLIVIER CHAMPENOIS

Having been involved within mid- to high-level motorsport engineering for years, I have always been surprised how many important engineering decisions are still taken on the basis of wrong assumptions, or even faulty calculations. Often the maths involved are not fundamentally complicated (from what I have seen, all 16-year old college students should know enough maths and physics to be a good 'average' race engineer), but I have seen enough mistakes to make me realise it is sometimes better to sit back for a few minutes and take a look at the fundamentals.

Everybody makes mistakes. I have personally made many, and I will make some more in the future, so my goal here is certainly not to give lessons as a professor to ignorant students. However, I am sure some people can learn from the ones I have made and seen made by others, including at the highest level of our sport. In the end, is having made and seen mistakes not what some call experience?

One fundamental for race engineers is the conversion from spring / damper measurements to wheel measurements ie displacement, force and stiffness. This is particularly true because displacement sensors are often installed in parallel with the spring and / or damper, and stiffness is often directly measured or known at the spring and not at the wheel. In order to accomplish this step, the concept of installation ratio or motion ratio is generally used.

Looking at figure 1, the definition of the spring-to-wheel motion ratio is straightforward. It is the ratio between the displacement of the spring, Ds, induced by a given vertical displacement of the wheel, Dw. On the figure, the instantaneous centre of rotation of the upper suspension arm to the chassis is marked as IC. Actually, both definitions of motion ratio exist. Some might use the spring-to-wheel convention, some wheel-to-spring, but as this can lead to confusion, we will only use the spring-to-wheel convention, and stick to it.

In the case of figure 1, you will notice that applying the intercept theorem, the motion ratio, MR, is as follows:

$$MR = Ds/Dw = Ls/Lw \quad (1)$$

Ds being, in this case, smaller than Dw means MR will be somewhere between 0 and 1.

Now, if we look at the forces applied on the wheel (Fw) and on the spring (Fs), a static moment equilibrium of the upper arm to the chassis around IC leads to the following equation:

$$Fw \times Lw = Fs \times Ls$$
$$Fw = Fs \times Ls / Lw$$

due to (1):

$$Fw = Fs \times Ds / Dw = Fs \times MR \quad (2)$$

Which defines the force at the wheel, Fw, as the product of the force applied at the spring, Fs, by the motion ratio, MR. In the case of figure 1, the force at the wheel will be lower than the reaction force applied at the spring, because MR is lower than 1.

Finally, let's take a look at the stiffness. Stiffness is defined by the ratio between the applied force at one point and the induced displacement. Therefore we can write, for the wheel and the spring:

$$Kw = Fw/Dw \quad (3)$$

$$Ks = Fs/Ds \text{ or } Fs = Ks \times Ds \quad (4)$$

Successfully by (2), (3) and (4):

$$Kw = Fw/Dw = (Fs \times MR) / Dw$$
$$= Ks \times Ds \times MR / Dw$$
$$Kw = Ks \times MR^2 \quad (5)$$

Equations (1) and (5) are the ones to remember. They mean that, in order to get the wheel rate in N/mm, you have to multiply the spring stiffness in N/mm by the square of the motion ratio (spring-to-wheel).

Figure 1 is a simplified 2D sketch of the true story, but the formula can be generalised to all configurations of suspensions. And depending on the suspension kinematics, the motion ratio can then be approximated by a constant or vary with wheel displacement.

Practically, there are two main methods for determining the actual spring / damper motion ratio of a suspension configuration. The first one is direct physical measurement of the spring / damper displacement and the related wheel displacement (or ride height change of the whole car). The second one is computer simulation using a suspension kinematics software. The last method is generally accurate, but requires the correct positions and dimensions of the suspension points and components.

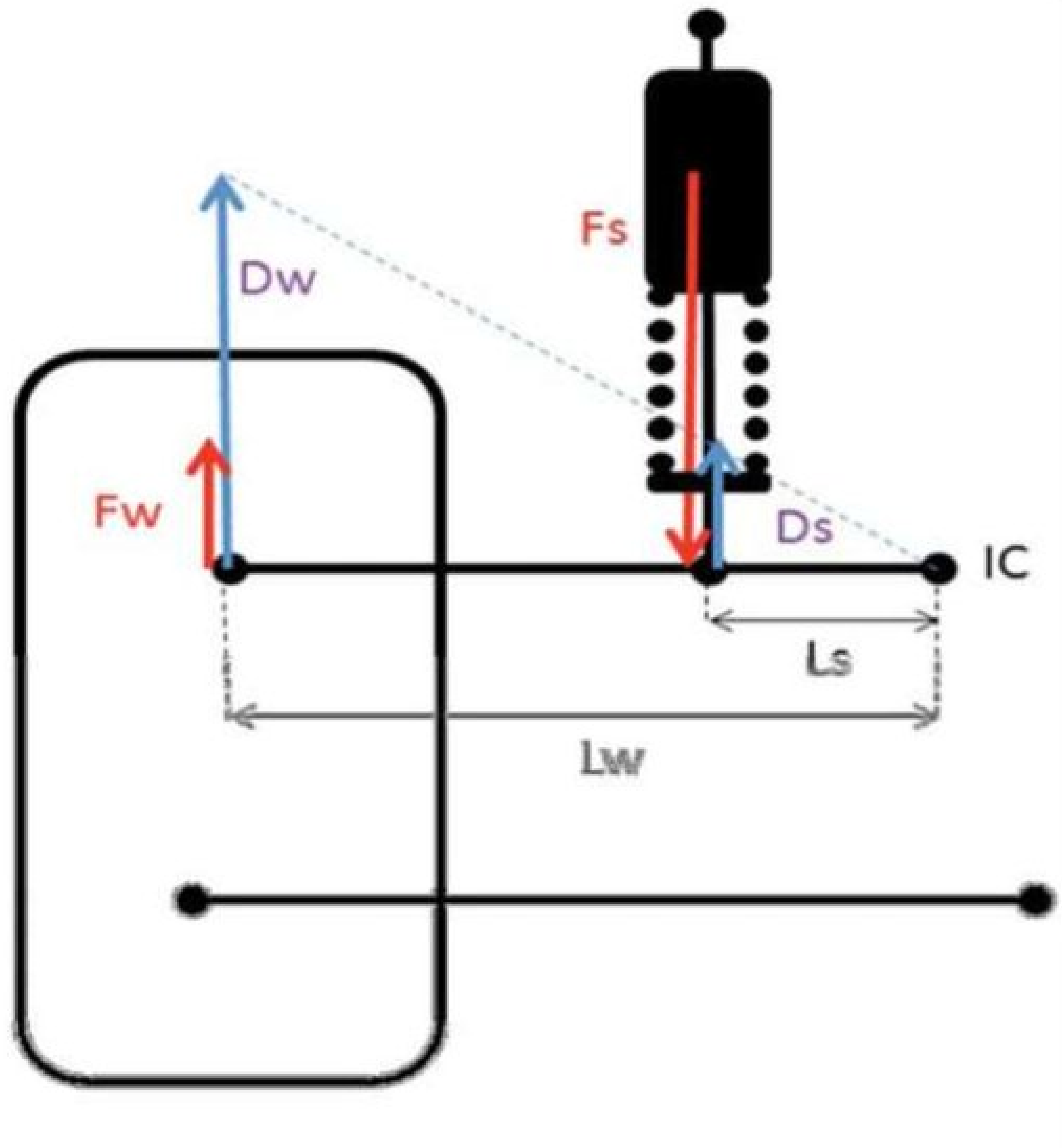


Figure 1

TIPS

1. Always try to use the same definition of motion ratio: spring-to-wheel.
2. More displacement means less force at that point (and vice versa).
3. The side (spring or wheel) which moves the most is the softest.

Disruptive technology

It's never easy changing the established direction of racecar engineering, but DeltaWing gave it its best shot

BY PETER WRIGHT

When Ben Bowlby launched his DeltaWing concept on an unsuspecting motorsport community, it didn't take long for the movers and shakers of this world to recognise that this was possibly the ultimate in disruptive motorsport technologies, at least of the order of some of Team Lotus' pioneering concepts that changed the direction of racecar design. The effect was to immediately polarise reactions, in exactly the way Harvard Business School professor, Clayton M Christensen, describes in his book, *The Innovator's Dilemma*, in reference to a new technology that unexpectedly displaces an established technology.

Christensen separates new technology into two categories: sustaining and disruptive. Sustaining technology relies on incremental improvements to an already established technology. Disruptive technology lacks refinement, often has performance problems because it is new, appeals to a limited audience, and may not yet have a proven practical application.

Christensen also points out that large corporations are designed to work with sustaining technologies. They excel at knowing their market, staying close to their customers and having a mechanism in place to develop existing technology. Conversely, they have trouble capitalising on the potential efficiencies, cost savings or new marketing opportunities created by low-margin disruptive technologies. He goes on to demonstrate how it is not unusual for a big corporation to dismiss the value of a disruptive technology because it does not reinforce current company goals, only to be blindsided as the technology matures, gains a larger audience and market share and threatens the status quo.

SUSTAINING OR SUSTAINABLE?

The big four classes in motorsport – F1, LMP, NASCAR and IndyCar, all use more than 600bhp to propel them. After all, that's what the fans expect, isn't it? The governing regulations then apply minimum weight limits, aero bodywork rules and maximum tyre sizes to control the performance, both in lap time and top speed. The big corporations and teams write the rules and the technology is 'sustaining'. But is it sustainable?

Along came Bowlby and showed us a car concept that halved everything, especially energy consumption, yet potentially delivers the same performance. That is definitely disruptive, but it is also a big step towards helping motorsport become sustainable.

After an abortive attempt to persuade IndyCar to take up the challenge and make the DeltaWing the basis of its new-for-2012 formula, the ACO, with their history of encouraging

"motorsport needs to be more open if it is going to attract the interest of new, younger fans"

TECH SPEC

Engine:
Four cylinder, 1.6-litre Nissan DIG-T (Direct Injection Gasoline-Turbo)
Maximum power: 300bhp
Maximum torque: 312Nm

Dampers: coilover hydraulic

Anti-roll bars: torsion bar rear; no front anti-roll bar

Transmission
Gearbox: five-speed sequential
Clutch: 4.5in two-plate carbon
Shift system: electrically-actuated direct barrel rotation paddle shift
Crown wheel and pinion: planetary final driver potentially featuring efficient torque vectoring differential technology

Driveshafts: equal length, tripod-jointed halfshafts

Brakes: carbon / carbon
Brake bias: 40 per cent torque bias front
Cooling: ventilated uprights, air cooled

Wheels
Type: one-piece forged magnesium
Size: 15in front; 15in rear

Tyres
Front: 10/31 - 15 Michelin
Rear: 310/620 - 15 Michelin

Chassis:
Target homologated weight: 575kg
Type: FIA-homologated carbon fibre monocoque
Jacking: air jack

Fuel and exhaust
Fuel system: 40-litre, FIA-spec petrol fuel cell
Exhaust system: Inconel four-into-one; solenoid-controlled wastegate actuation

Bodywork
Tub and body panels: carbon composite

Aerodynamics
Twin vortex underbody downforce system, with BLAT (Boundary Layer Adhesion Technology)
Centre of pressure: 25% front
Coefficient of drag: 0.313

the demonstration of efficiency, offered Bowlby the Garage 56 slot at Le Mans. This started a negotiation between the two parties as to what 'regulations' it would run under. Prime consideration was that it must be as safe as an LMP car, both in terms of its aerodynamic stability when spinning and its crash performance. The ACO set a target lap time of 3m 45s, nearer to LMP2 times than LMP1, and a top speed not too much in excess of 300kph. It also had to fit in the pit lane space allocated, and have a pit stop cadence similar to the other cars. Bowlby promised around half the fuel consumption, so a 40-litre fuel tank was agreed. And that was about it.

With just seven months to design and build the car, and three to develop it ready for Le Mans, what could the DeltaWing realistically hope to prove? For its designer, the target was to show his theory that current racecar performance can be delivered at half the energy consumption is correct. For the rest of the team involved in designing, building, developing and racing the car, it was to show that it would race for 24 hours. Le Mans is a challenging environment to launch a whole new car concept, but doing so ensures the rest of the world will notice.

While the DeltaWing is a very sophisticated concept, much of the execution is very simple. With the time and resources available, using proven technology where possible makes enormous sense, hence the existing CFRP monocoque, tubular frame engine and rear suspension structure, the Nissan engine and most of the systems. *Racecar Engineering* has covered the design and construction of the car extensively, so here I just want to look at the specific problems the configuration of the DeltaWing poses, and how they have been addressed. For a racecar designer, Bowlby is unusually open about his creation. Perhaps this is partially because he is not directly competing with anyone else, but much more it is his philosophy that in the future motorsport needs to be more open if it is going to attract the interest of new, younger fans.

To reduce costs, information needs to be out there and open source, so each development, from whatever origin, is incremental instead of parallel and needlessly duplicated.

To achieve the DeltaWing target of delivering the performance of a conventional car with 50 per cent of the energy consumed, it doesn't take a lot of maths to conclude that an engine with 50 per cent of the power will be needed. To achieve the acceleration, half the weight is also essential. To achieve the top speed, half the drag is required. To achieve half the drag, some combination of reduced form drag, skin friction drag and induced drag to add up to 50 per cent is needed.

All the unfavourable opinions about the car's handling with its tiny front tyres have now been proven wrong and, prior to it being pushed off track, everything was pointing toward unprecedented levels of tyre life

The frontal area and the wetted surface areas cannot be halved, so the emphasis ends up on the efficiency by which the downforce is generated, and the total downforce itself (to reduce induced drag). With half the weight, only half the downforce is needed. That, in theory, deals with the steady-state analysis. The rest is dynamics.

To alleviate the ACO's concerns about the car taking off in a spin, magnetic flaps were added at the rear, which deploy if the car goes backwards

WEIGHT DISTRIBUTION

Without the time or resources to carry out a thorough FEA on all the components, the design team has relied on keeping the car simple, yet building in contingency to cover the unknown. As much of a challenge to get the overall weight down to the target, was the need to achieve the design weight distribution of only 28 per cent on the front axle. The simple thing to do would have been to push the front axle forward, lengthening the wheelbase, but the ACO gave DeltaWing strict limits on overall length. The front axle assembly, completely removable by undoing the quick release AMR front nose box fixings and the steering column, is wonderfully light and compact. The tiny bevel-gear steering box is probably a first for a racecar, maybe any car (contradictions on a postcard, please).

But with 78 per cent of the weight on the rear axle, it is not possible to spin the wheels in the dry, even in first gear? In Ben's words, 'In the wet, it is bionic!'

Another luxury DeltaWing has had to go without is one or more 30-hour endurance tests. With a four-cylinder engine shaking the car and all its components, Bowlby decided to AV mount the engine to obviate the problem.

AERODYNAMICS

To meet the key target of half the drag and half the downforce, with aero distribution to suit the weight distribution, wings had to go, and all the downforce had to be generated by the underbody. The wider AMR monocoque, compared to the original DeltaWing's single-seater monocoque, ruined the downforce by nearly 50 per cent. The big rules break the DeltaWing has is that the shape of the under surface is not governed by regulation, and so does not have to have a large flat area and limited diffuser. Some might say that this negates the comparison between the DeltaWing configuration and a conventional car, but that would be missing the point. With the large under-car area of the current LMP cars, the potential for downforce is enormous – flat bottoms constrain it somewhat. The high weight and high drag require high power and high fuel consumption. The DeltaWing reverses that spiral, and points to how new regulations should be drawn up.

This freedom enabled Gurney's BLAT (Boundary Layer Adhesion Technology) to be employed. This works in a similar way to the F-18's LERX (Leading Edge Root Extension) at high angles of attack. The sharp, delta-shaped leading edges generate strong vortices, which are channelled under the car. Not only do they generate the downforce the car needs, but also give it very beneficial heave characteristics, helping stabilise the car at high speeds.

TYRES

Michelin has given out very little information about how it arrived at the tyres for the DeltaWing, other than to say that the size for the front wheels is the same as for a Citroën 2CV! The tyre tread width per kg for the car is slightly higher than for a conventional LMP car, and the distribution front to rear looks right. Bowlby reckoned they would be able to at least five-stint the tyres (see post-race analysis on p64). With only about six scheduled tyre changes during the 24 hours of the race, the decision to go to a three-stud attachment for the front wheels seems a reasonable trade-off for the lighter weight of this arrangement.

SAFETY

Understandably, the ACO were adamant that the DeltaWing exhibit the same levels of safety as the other cars, both in terms of its ability to withstand impacts and its aerodynamic stability. The AMR monocoque went a long way towards satisfying the first requirement, but the second needed demonstrating.

DeltaWing chose TotalSim to take care of all the CFD analysis and development, which was an auspicious decision as the company has also worked closely with the FIA on the aerodynamic stability of LMP cars. Much of the latter work was in developing a procedure for assessing the stability as the cars spun at high speed, so carrying over these approaches to a new configuration was fairly straightforward. As the aerodynamic development of the car progressed, the stability of each configuration was checked, and a high degree of confidence developed that the car was not only safe, but inherently *safer*


The car's Aston Martin lineage is evident in the driver control panel and steering wheel

than conventional Sportscars.

Because the diffuser is much steeper than LMPs, and there was a worry that the light car would tend to lift if travelling backwards at high speed, an automatic flap system at the trailing edge of the diffuser was developed. These automatically stow away above 30mph in normal running, and are held in place by magnets. They deploy, and spoil the flow if the car goes backwards. At the same time, the adjustable rear flap moves to an extreme position, aiding keeping the car on the ground.

In an interesting exercise, Bowlby, aided and abetted by his children, ran a series of tank tests to finally check the stability issues. He calculated that a 1:18 scale model falling through water at its terminal velocity has the same Reynolds Number as the full-size car in air. He therefore dropped models of the car, pointing forwards, sideways and backwards, down the side of his swimming pool. Without gravity holding the car to the wall (ground), any tendency to lift or roll would be accentuated. Each test was videoed with an underwater camera and makes fascinating watching. He also tested an IndyCar single seater and a NASCAR car, with and without roof flaps deployed. The latter was a good validation of the test, as without flaps the car barrel rolled, but with them deployed the car was stable. The DeltaWing showed remarkable stability, even when excited in roll by hitting a small ridge in the wall of the pool. Neat!

DIFFERENTIAL

With many questions raised about the effects of the narrow front track, the lack of weight on the front axle and the ability of the driver to control yawing moment through the steering, the DeltaWing team decided they might need torque vectoring on the well-loaded rear axle. By taking control of differential torque across the axle, or the differential slip ratios of the two rear tyres, the car's yaw moment can potentially be controlled by inputs from the driver's steering wheel and the car's response.

Conventional differentials control differential torque by adding friction to the differential motion, where the magnitude of the friction is either:

- **Infinite - spool**
- **Proportional to a function of input torque - Salisbury, Torsen, ZF**
- **Proportional to a function of differential speed, via the temperature characteristics of a viscous fluid - viscous**
- **As a function of computer-controlled, hydraulically-applied clutches - 'active'**
- **As a function of differential braking of the wheels or output hubs - fiddle brakes on Trials cars, traction control**

The more precise method employed by the DeltaWing deviates from normal differential operation by putting the differential rotational speed of the wheels under computer control and taking control of the relative slip ratios. To do this, the two outputs of the conventional open differential are fed to the output shafts of another differential, with the direction of one of them being reversed. If the two rotational speeds are identical, the 'input' shaft of this second differential will not rotate. Speed one up and it will rotate one way, and vice versa. By taking control of the direction and speed of the second differential 'input' shaft, the relative rotational speed of the main differential output shafts is controlled, and hence the torque of each rear wheel.

"The need for full torque vectoring control has proved to be small enough"

This differential speed control device was used on the 1939 Mercedes Benz T80 record breaker. The speed of the twin driven rear axles was fed to one side of a differential, and the other side was driven by the front axle. If the rear axles over sped the front axle, the 'input' shaft of the differential rotated and was connected to the Bosch direct fuel injection system on its 3000bhp aero engine, providing traction control.

The DeltaWing's torque vectoring system has a high-speed electric motor connected to the geared 'input' shaft of the second differential. Control of direction and speed of this motor provides torque vectoring of the axle. All manner of devices could be used in place of the electric motor: a small disc brake (frictional control); a viscous brake (speed control); it could be locked (spool); or a small flywheel (acceleration control). The flywheel or inerter system allows un-resisted yawing of the car, but provides strong resistance to one wheel starting to spin. The need for full torque vectoring control has proved to be small enough, and the time to develop the system short enough that either a spool will be used, or the flywheel 'inerter' system. Is this the first time a differential controlled by the rate of change of the relative speeds of the two wheels has been tried?

So, what will Le Mans prove? By far the most interesting result will be to find out where the DeltaWing lies on the lap speed vs fuel consumption curve, relative to the LMP1 and LMP2 cars. But then what? Probably the most that can be expected will be a detectable mind shift among regulators and promoters. It is unlikely all future formulae will be for delta-shaped cars, primarily because it is seen as a three wheeler, and racecars have to have four wheels to meet existing regulations. But once the concept of reducing weight, power and drag to achieve substantial reductions in fuel consumption has been proven, hopefully motorsport will move in that direction. One thing I know for sure, though, is that Colin Chapman would have loved it!

Post-race analysis

In spite of a string of bad luck: a plastic bag in the radiator intake; a failure of a small, standard component in the gearchange system; and a coming together with one of the Toyotas, which ended the DeltaWing's race after 75 laps, the car met all its performance objectives and covered three GP distances.

In qualifying, the DeltaWing recorded a 3:42 lap time. The following lap, which was aborted when the fire extinguisher came loose, Bowlby believes would have been in the 3:39s, right up with the leading LMP2s at the time of running. So all the expert opinions that said it would never work have been proved wrong.

In the race the car achieved a 3:45, right on the ACO's target for the car. The fuel consumption was such that 12-lap stints with its 40-litre tank were possible and, once Michelin had confirmed the tyre degradation, 10-stint runs on them were planned – twice the conservatively predicted number – equivalent to completing the race with just two tyre changes. Compare this with the Toyotas' four-stint tyres.

So where does this put the DeltaWing in the overall scheme of things? Unfortunately, the detailed figures for the fuel consumption of the other competitors is not available, but using the maximum stint length for each class leader and the DeltaWing, and assuming they all run with the same contingency fuel (one lap contingency would introduce a nine per cent error), one could plot the best race lap time against litres / lap, knowing the tank size for each car. This represents performance achieved per unit of fuel. The picture is a little distorted by the the diesels, so plotting as lap time against energy / lap gives performance per unit of energy.

"12-lap stints with its 40-litre tank were possible"

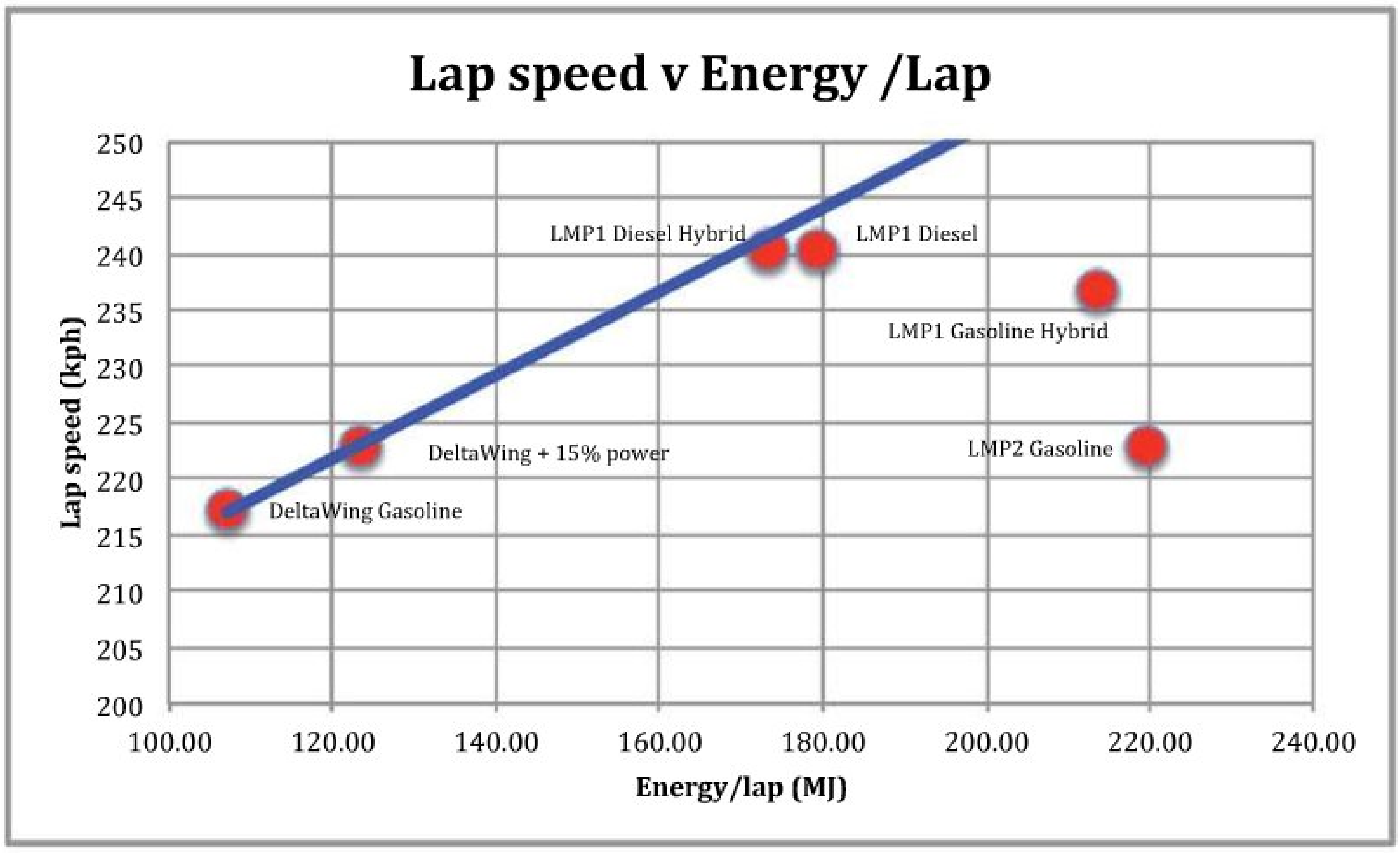
The superior efficiency of the diesels is clear and also, interestingly, a small increase in efficiency of the hybrid.

In order to bring the DeltaWing up to the performance of its competitors, we can use the lap time power sensitivity to add power and, if we assume proportional fuel consumption and no increase in weight – a reasonable assumption considering how little extra power is needed - we obtain the line through the DeltaWing point on the graph. Now we can put a number on how much more efficient the DeltaWing is for the same performance.

The obvious comparison, based on performance and budget, is the DeltaWing vs LMP2. To be able to lap Le Mans at the same pace as the best LMP2 car but using just 56 per cent of the energy is stunning. To do anything today with half the energy it takes to do it with established technology is game changing. Imagine if it was a diesel engine in the DeltaWing...

Bowlby and his team have come up with a radically different dynamic and aerodynamic configuration of racecar, at half the weight of a conventional one. The efficiency automatically follows the numbers involved.

ENERGY CONSUMPTION	
DeltaWing vs LMP1 diesel / hybrid	98%
DeltaWing vs LMP1 diesel	95%
DeltaWing vs LMP1 petrol / hybrid	75%
DeltaWing vs LMP2 petrol	56%



What was unexpected by many is that it worked! The drivers found it stable and manoeuverable, and the spectators loved watching it. To have achieved all this on a budget probably 1/10th that of the big manufacturers is a triumph of ingenuity.

In a responsible world, why would anyone want to go racing with technology that uses nearly twice as much energy as one that is demonstrably possible? Oh yes, because it obsoletes every other existing single seater and Sportscar, turning them instantly into Historics. Now that really is disruptive!

So where does the DeltaWing go now? The FIA has worked hard with the ACO to come up with new WEC Technical Regulations that provide fuel consumption and tank sizes according to the level of hybridisation, including none. This is a forward-thinking approach to encouraging the development of hybrid systems, yet allowing close racing among manufacturers and privateers.

However, with a large part of the motor industry now seeing hybrids as an expensive solution to achieving NEDC test results for fuel consumption and CO^2 emissions, an increasing number of manufacturers are moving away from hybrids and concentrating on the key technologies that truly reduce energy consumption.

The two main commodities a car consumes are fuel and tyres, and the technologies that most affect these are weight and drag. The WEC 2014 regulations are currently focused on powertrain efficiency, but it would be a wasted opportunity not to add an additional column to the fuel / lap and tank size table for reduced weight and drag. The DeltaWing has amply demonstrated what can be achieved by going down this route, and has attracted the attention of the motor industry and consumers in doing so.

Why not allow such concepts into the main arena, to compete against the other technical solutions for efficiency, and see what is eventually possible?

Current trends in composite thinking

With new regulations, the emphasis is on light weight and thermal resistance

BY ALAN LIS

While composites became a buzz word in motorsport in the early 1980s, when McLaren International technical director, John Barnard, pioneered the use of laminated sheets of carbon fibre in the manufacture of the monocoque of the 1981 McLaren MP4 Formula 1 car, in the strict definition of the word, composites have been in use in motorsport since the 1950s, in the form of glass fibre moulded body panels. Then, in the USA in the mid-'60s, Jim Hall's Chapparal team built Sportscar chassis from this material. During the same period in the UK, Marcos built sports cars for the road and track based on plywood chassis structures, a technology later used in the Protos Formula 2 car.

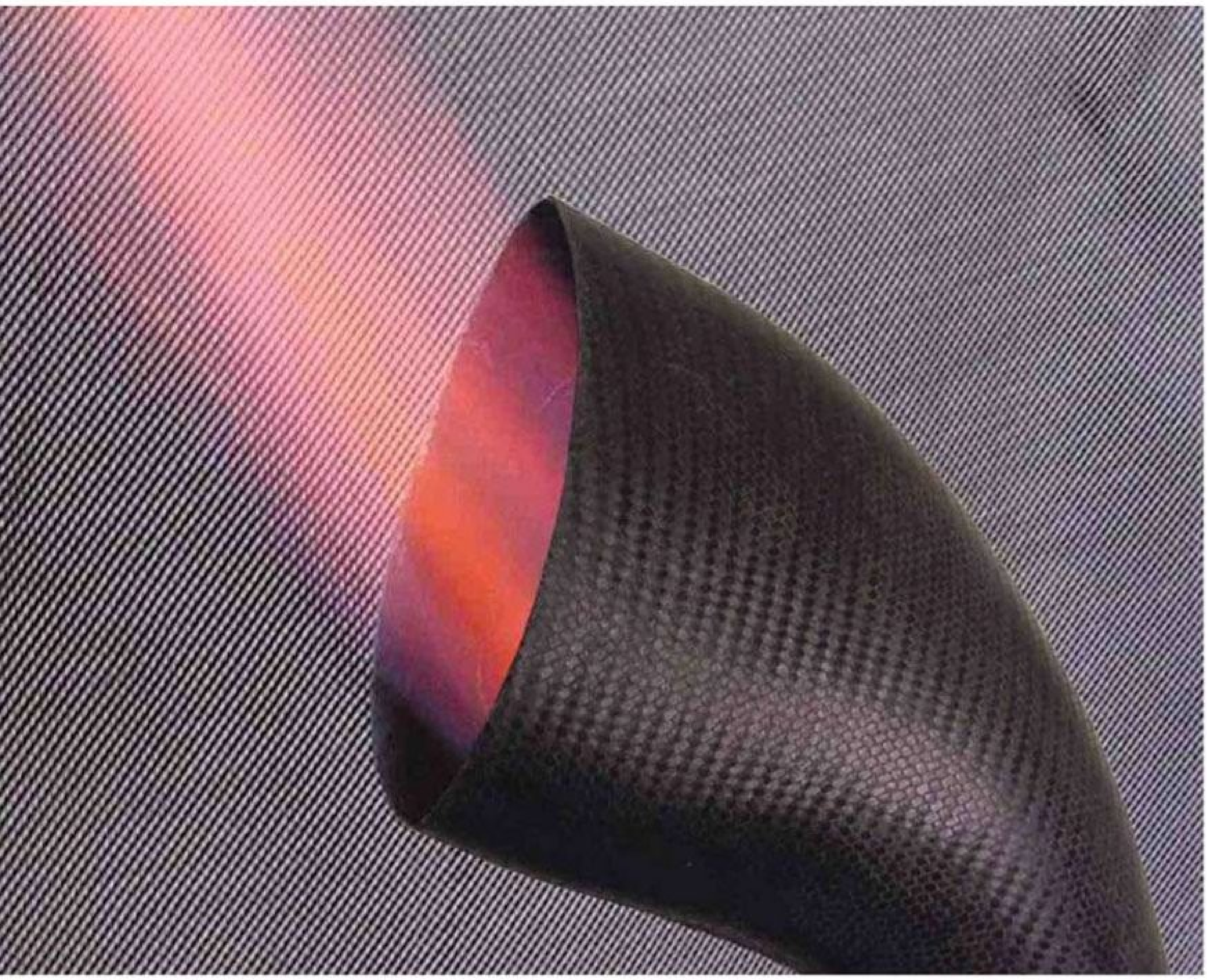
"seasonality is the biggest challenge to a composite supplier"

The first Formula 1 car to be raced that incorporated composite material in its chassis was the 1966 McLaren M2A, which featured panels of Mallite – a composite formed of alumimium sheets over a core of end-grain balsa wood. Although the McLaren benefited from a chassis rigidity advantage over its rivals, the technology was not pursued in later models.

Carbon fibre was first used in motorsport in the late 1960s, as reinforcing strands bonded to the glass fibre body panels of the Le Mans-winning JW Automotive Ford GT40s, and the McLaren CanAm cars.

The McLaren and Lotus F1 teams both introduced carbon chassis in 1981. McLaren sub-contracted the manufacture of this first model to Hercules Aerospace in the USA, who used moulding and layout methods that were the forerunners of the techniques still used today, while Lotus opted to build its chassis in house, opting for folding sheets of composite material in a similar manner to the way chassis had previously been fabricated using

Oxeon's TeXtreme fabric offers the option of interlacing the fibres at different angles for added structural optimisation



Pyromeral's Pyrosic is a ceramic matrix composite reinforced with silicon carbide fibres, suitable for high temp use

Laying out carbon fibre is a specialist and labour intensive exercise, but processes are improving all the time

sheet aluminium and aluminium honeycomb.

Sceptics predicted that a carbon fibre chassis would crumble into a pile of black dust in a heavy impact and, in 1981, McLaren driver, Andrea de Cesaris, assisted research into the crash worthiness of the then new material with a series of incidents, but it was John Watson who proved the concept. At the 1981 Italian Grand Prix, his MP4 hit a barrier hard enough to cause the engine and rear axle assembly to brake off, yet the monocoque remained intact. There was no fire, no pile of dust as predicted and Watson stepped out unharmed.

By the mid-1980s, all F1 cars had carbon fibre composite chassis. It is clear that this technology has not only aided the massive performance gains made since the early 1980s, but has also been a vital element in making motor racing a far safer sport than it was in the past.

Against the background of new Formula 1 rules, due to come into effect in 2014, that will further test the teams' ingenuity, and the impending introduction of a new generation of game changing nano-composite materials, we look at what the future might hold for the motorsport composites industry.

The rule changes coming to F1, with the re-introduction of turbocharged engines and higher powered kinetic energy recovery systems, are likely to mean that, at least initially, the cars will be heavier, which will put the emphasis on finding areas where weight can be saved. The fact that vehicle weight will increase also means that forces will be greater in an impact, so the cars will also have to be stronger, which bring its own set of challenges.

The greater temperatures associated with turbocharged engines will mean an increase of use in heat resistant composites. In their natural state, carbon fibre composites are stable up to approximately 600degC, but above this level they start to oxidise. To protect against this, carbon fibre needs to be encased in a protective matrix, such as a high temperature ceramic resin.

The French company, Pyromeral, has been working on the development of high temperature resistant composites since the early 1980s and became a supplier to motorsport in the late 1990s. Pyromeral's Pyrosic product is a ceramic matrix composite reinforced with silicon carbide fibres, which is claimed to be resistant to sustained temperatures of up to 1000degC, and even higher for short periods. Pyrosic has found use in Formula 1 in the manufacture of heat shielding for bodywork and suspension parts. Its lighter weight, relative to steel and Inconel, and dimensional stability at high temperature led to it also being used for the manufacture of exhaust systems. However, this is now outlawed by the F1 technical regulations.

Many scientific research groups are currently engaged in the development of nano-materials, which are widely seen

MARK PRESTON – MANAGING DIRECTOR – FORMETCH COMPOSITES

Formtech Composites was established when the German parent company acquired the assets of the Super Aguri Formula 1 team in 2008. This included a fully equipped composites manufacturing facility, including on-site autoclaves and clean rooms, at its base in the Leafield Technical Centre in rural Oxfordshire, UK.

Initially, Formtech considered entering Formula 1 in its own right, but has since become a manufacturer and supplier of composite parts, such as bodywork, wings and heat shielding, to the motorsport industry, with a client list that includes almost all of the UK-based Formula 1 teams. Formetch's largest project for 2012 has been the manufacture of monocoques for the Marussia Formula 1 programme.

In 2010, Formtech Composites developed a new rapid prototyping method for the production of an f-duct for one of its F1 clients. 'We call the process RCTC – Rapid Complex Topology Composites,' says Preston. 'It's very useful for composite jobs with a tight deadline and for situations were conventional composite manufacturing processes can't be used.'

RCTC involves the three-dimensional printing of mandrels onto which composite material is laminated before the part is given a first cure. The mandrel material is then washed out of the part before it undergoes a second cure. 'That's a service we can offer to our customers, but we typically don't get a call for it until something has gone wrong...' quips Preston.

In 2011, motorsport represented approximately two thirds of Formtech Composites business, but Preston observes that the current trend is away from this market. 'There's no other sport or business sector that uses such high performance concepts and materials that is out of synch with motorsport,' he says. 'It would be perfect if we had motorsport going crazy from November to March, and then something else going crazy for the rest of the year, but to date we haven't found anything like it. For that reason, motorsport isn't great for long-term development.

'That seasonality is the biggest challenge to a composite supplier. Motorsport is a prototyping competition. Every part that is released is a prototype and therefore there can be things that are still not quite right about the design. It's not like serial production, where you make one and then make thousands of replicas of it. For motorsport, the manufacture is done in such a tight time frame, even though you are targeting high quality. Being responsive in a way that achieves both of those aims is a challenge.

COST CUTTING

As Preston explains, the cost-cutting measures introduced in recent years have also had an impact on motorsport supplier infrastructure: 'When in-season testing went away, the requirement of car components was reduced by around 50 per cent. Before that, teams would complete around 80,000kms

to be the future of composites. Currently, the only mention of nano-materials in the FIA F1 technical regulations is the banning of the use of hollow carbon nano-tubes in the chassis structure. Other nano-materials such as graphene are effectively outlawed by the simple fact that none can be supplied in sufficient volume at the present time to make their use viable.

One of the more recent material innovations was made by the Swedish company Oxeon, with its TeXtreme technology. TeXtreme fabric is made from spread tow tapes to achieve thinner laminates. According to the manufacturer, the TeXtreme fabric has straighter fibres that result in reduced crimping, to the benefit of the material's strength. The reduction in crimping also allows for a reduction in plastic, ie resin content, again leading to a reduction in weight. TeXtreme also offers the option of interlacing the tapes at different angles, giving advantages in structural optimisation.

Resin system developments are closely linked to the evolution of new materials.

Many of the resins used in motorsport composite manufacture were originally developed for aerospace applications but, of course, there have been many updates over the years. Much of this work has been aimed at making the resins easier to handle from a laminating point of view, such as optimising the cure temperature, either so energy can be saved by curing at a lower temperature or at a higher temperature to enhance the top end capability of a component.

"most of the conceivable applications of composites on a racecar have been attempted"

MANUFACTURING PROCESS

While composite manufacturing techniques have evolved over time as the technology has found wider use in different industries, the low volume / high performance requirement of motorsport means that in this sector much of the composites process is still manual. Typically, materials are laid up by hand in custom-made tooling prior to being pressurised and vacuum bagged in an autoclave. However, techniques such as filament winding and out of autoclave processes such as resin transfer moulding (RTM), and pultrusion, are being evaluated.

In Formula 1, filament winding is principally used in the manufacture of pressure vessels such as the air bottles used to power pneumatic engine valvetrains, although one team

a year at race weekends and tests. When annual mileage was reduced, the number of parts required also fell and, of course, that has implications for all the motorsport supply chain.'

To varying degrees, Formtech, and its fellow members of that supply chain, are also at the mercy of the FIA with regard to technical regulations. 'As a supplier, we make whatever the client designs to their specification,' says Preston. 'If they can design it, we can probably make it. The RCTC methodology we developed enables us to make things that can't be tooled in any other way. We can almost make any shape if we try hard enough. That's a characteristic of motorsport – no one ever usually says 'No, you can't do that.'

'Of course, that's not to say that there aren't limitations. Any limitations on the types of material that can be used are really the concern of the client. When they design a part, they have to work within the group of materials allowed by the regulations. As far as we are concerned, we don't see that as a limitation because it's not an aspect that we control. We've had discussions with clients who want to try new materials, but their use has to be approved nowadays before they can be added to the approved list.'

While nano-materials are still under development, their potential future is still something of a grey area, but one that Preston says he's looking forward to exploring: 'We've certainly talked to the universities and people developing nano-materials about them. Currently, the most you can buy of any of these materials is one square metre. As soon as they are available in quantities of 10 square metres or more, they will become viable for making parts. I did enquire about buying graphene and was told that it might be possible for an R and D group to supply me with an A4 sheet of the material – obviously not enough for serious use.'

According to Preston, most of the conceivable applications of composites on a racecar have been attempted. 'I believe someone has tried making composite connecting rods, and I know others have tried suspension uprights, exhausts and driveshafts. Unfortunately though, the potential for the application of composites gets more difficult as thickness stresses increase. Techniques like z-pinning can help, but generally large, relatively lightly loaded structures are the best applications for composites. They are not very good for very small parts with complicate stress fields. That lack of 3D – through thickness – capability makes the use of composites less viable for small, highly stressed parts like gears. It's hard to design a true three-dimensional composite that takes into consideration all the complex stress directions. On a big piece of bodywork, or a wing, the loadings are defined and the stresses are easy to predict, so it's relatively easy to design a laminate that can handle the loads in the most efficient way.'

The Audi R18 tub crashed by Mike Rockenfeller at Le Mans in 2011. Despite the lightweight construction, it survived a high-speed impact intact

is rumoured to have also tested filament wound driveshafts. Filament winding is a highly efficient, automated method of manufacture with a high level of quality control. However, it is currently limited to the production of relatively simple shapes and, as Formula 1 is all about optimisation, which means a tendency towards complicated shapes, its use is limited.

RTM is more suited to series production, due to its requirement for metal tooling and the cost associated with that. There is also an issue with the relative fibre content of parts made with RTM, relative to parts made with resin pre-pregnated (pre-preg) material. While a pre-preg part will have a fibre content of 50-60 per cent, an RTM component is said to have a fibre content of 45-55 per cent at best. This performance drop is a major reason why the motorsport industry continues to favour pre-preg composites.

But RTM does offer advantages in lean manufacturing, since the fibre and resin can be purchased and stored separately, and typically offers a longer shelf life than pre-preg material. RTM is therefore more suited to production motorsport applications where cost is an issue.

Although three-dimensional woven composite materials are currently banned by the F1 technical regulations, techniques such as z-pinning are permitted (although this is usually employed as a remedial measure when a job has run into trouble). Increasing the inter-laminar capability of the material by z-pinning can be particularly useful on a part such as a roll hoop, though it is time consuming and currently quite difficult to do as the process is done with a machine similar to a nail gun. As a rule of thumb, designing a part correctly from the outset is the preferred option.

Generally, out of autoclave (OOA) curing isn't used in Formula 1, simply because all the teams have their own autoclaves, or at lest have access to one, but they are expensive to buy and operate, so OOA curing would perhaps be more relevant for volume motorsport applications. As you would expect, tooling costs are less, but there is also an associated performance drop off. While F1 teams won't accept that sort of compromise, for a one-make series where 25 or 50 sets of the same bodywork parts are needed, it might be the right thing to do, and would certainly help keep the cost down.

"large, relatively lightly loaded structures are the best applications for composites"

FUTURE TECHNOLOGY

With regard to the future use of composites, Audi Sport's technical project leader, Christopher Reinke, offers some valuable insight: 'As costs have come down, the motorsport community uses fibre qualities that are available in only limited quantities. Generally, we use what is left over from the build of aircraft. Formula 1 might have more strength of input, but we go with the market.

'In China, T700 was legalised, but only to re-enforce buildings, so we expected that the price would come down, and that meant we were going to use that fibre. The Chinese building industry therefore determined the fibres that we were going to use at Le Mans.

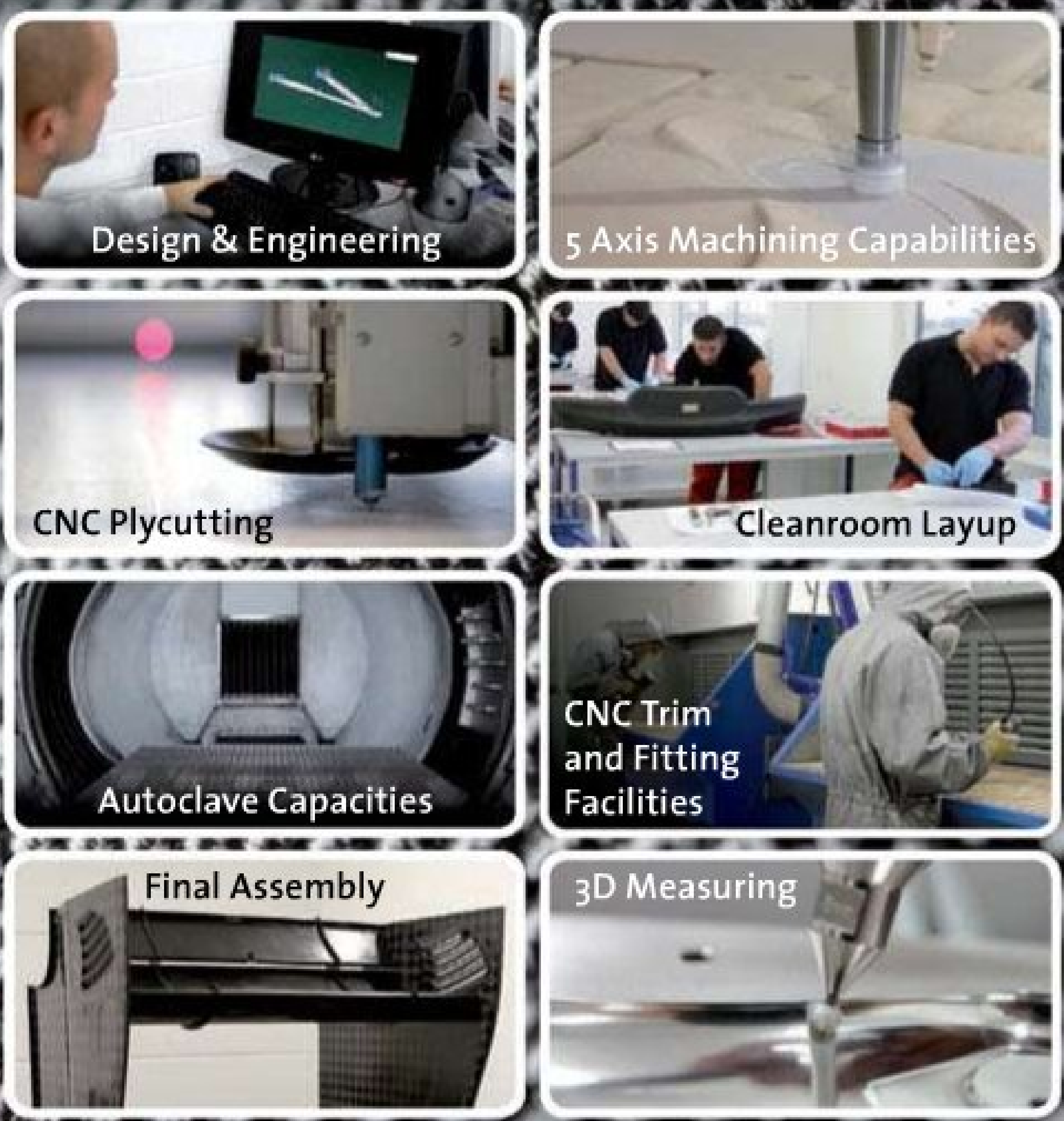
'We did have the possibility to use the top-of-the-line fibres [in the R18], but could not get hold of them. We could build two cars, but not a third. It was decided early in the design stage what we were going to use. If a production car uses carbon fibre, can we join forces? We had that with the GT project, to use the same fibre spec as the road cars because it was good enough for us, and for them, so it made sense.

'We expect in the future that the market will get more extreme, so we will have stronger fibres, but I think the biggest change will come in alternative fibres. I don't think that carbon fibre will be the only future. Basalt fibres seem to be strong to the market, but they vary too much in quality so they dropped out again, but people are investing heavily in it. It would be a similar product for the more efficient price.

'Are [composite] things more heat capable? That is an interesting question for us. That is something we can judge, to see if there is more to come. Ceramics are coming on a higher degree level, but the stuff that has been developed for the 400-450degC level has been available for a long time. The regular stuff at the 200degC level is a good way off, though there have been improvements, but I expect there to be more because there is a desire for it.'

Currently, heat resistant coatings are being applied to composite components, and with great effect, but there is still a downside, as Reinke points out: 'The coatings can get damaged or scratched and then you have to throw the part away. If the material already [has the heat resistant capability], though the raw material might be more expensive in the first place, over a season it will pay off, especially in endurance racing where, unlike F1, we re-use parts. And we are talking the whole car here, so a cost saving is achievable.'

Whatever the future for composites is, it is clear they will play a major part, as motorsport seeks to become ever more efficient, which invariably means lighter and stronger parts with a longer product life cycle.


Design & Engineering
5 Axis Machining Capabilities
CNC Plycutting
Cleanroom Layup
Autoclave Capacities
CNC Trim and Fitting Facilities
Final Assembly
3D Measuring

Connecting the dots Part 1

How to get started using racecar simulation

BY DANNY NOWLAN

Over the last couple of months, as I have been travelling and talking to clients and colleagues I have noticed a theme emerging. What I have been seeing is that while a lot of race engineers are convinced of the need, and indeed necessity, for racecar simulation, what is holding them back is they don't know how to connect the dots. What I mean by that is they are not sure how to get started, and, once they do get underway, they are unsure of what they should be doing. This is what I will be addressing here. And hopefully, you'll see it's not as hard as you might think.

I am going to break this into three parts. Part 1 will revolve around model set up. That is what you need to measure up and the procedures you need to construct your initial model. In part 2 we'll discuss circuit model creation and what to look for. Then, in part 3, I'll discuss what you need to do to dial in the model so you can use it in anger. We need to break this up because it is simply too big to handle in one article.

I should also add that everything we'll be discussing has been motivated by solving real-world problems. Consequently, this will be a hands-on article that will show you how you apply racecar simulation.

To get underway, the first step in constructing any racecar model is to measure the racecar. I realise this borders on the ridiculously obvious, but some times a lot of mistakes in this business originate from not doing the basically obvious. To this end I would refer you to an article I wrote in *Racecar Engineering* approximately two years ago where I explored this matter in some depth. You can chase down this article through back issues, but you'll also find it on the ChassisSim blog.

However, there are a couple of key things that would be very prudent to review. The first is measuring up suspension geometry. If you will recall, we discussed the following worksheet for measuring suspension geometry. This is illustrated in **figure 1**.

Remember to measure across the car and then divide by two.

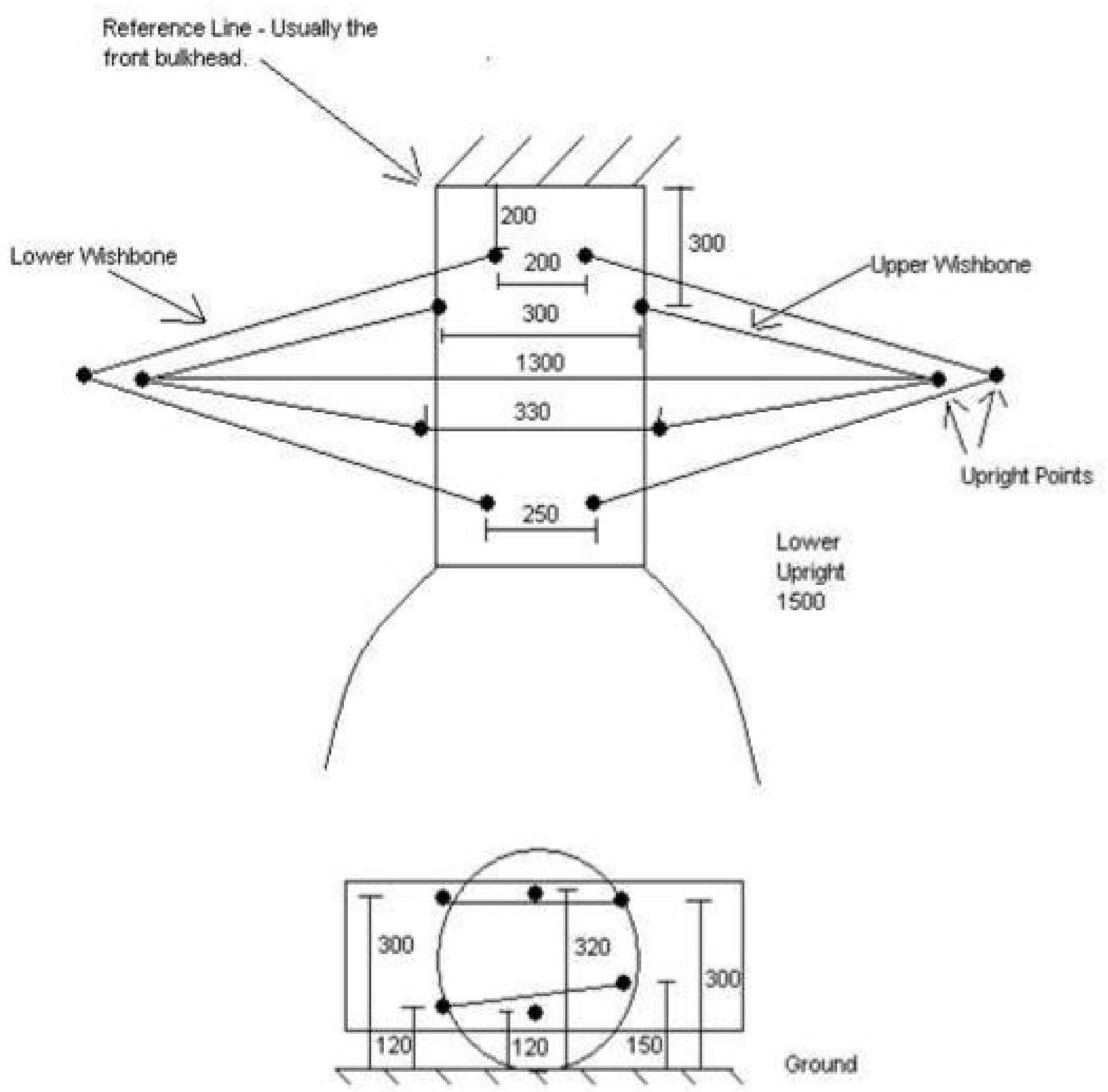


Figure 1: worksheet for measuring suspension geometry

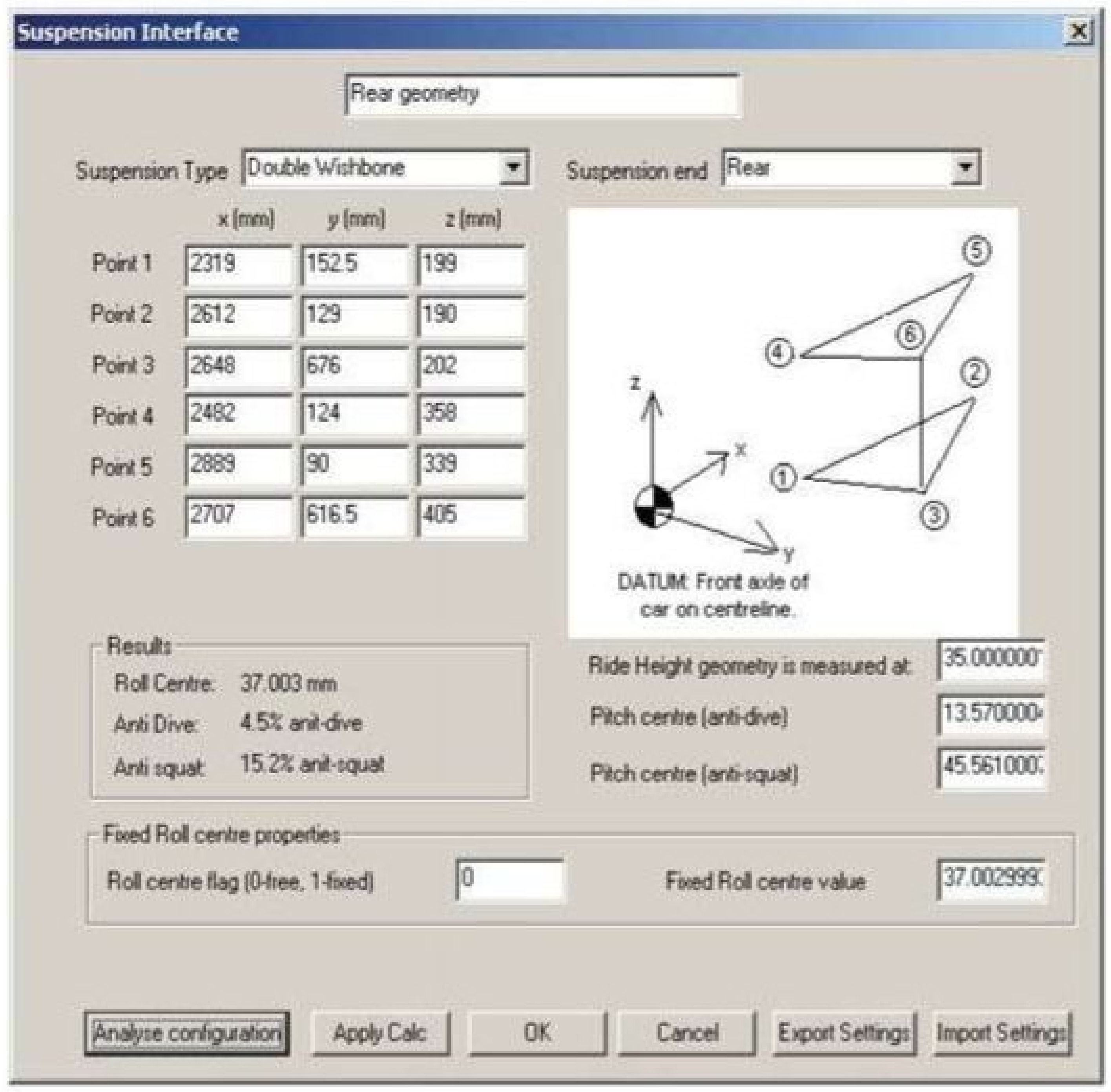


Figure 2: ChassisSim suspension geometry calculator

And have your suspension geometry calculator / software open and sanity check what you are measuring. An example of this is the analyse configuration button in the ChassisSim suspension geometry calculator. This is illustrated in **figure 2**.

The next thing to discuss is what to do about aerodynamics. If in doubt, start with a hand calculation of the downforce and drag and aero balance at the end of the main straight. Also calculate the ride heights at this point. I have found this to be an excellent start point. There are a number of ways you can go with this. The first is to fix the aero levels constant at the values you have calculated. This is the safe option, but you lose the pitch sensitivity. However, if you want to include pitch sensitivity, this is the procedure:

- **Select an equivalent car**
- **Re-scale the ride height bounds to what your current car is running**
- **Use a utility such as the downforce, drag and wing forces editor in ChassisSim to scale the maps up**

The last thing I would like to review is preparing the racecar data you'll use for validation, in particular damper data. This is often overlooked but, if you're not careful, you can drive yourself crazy. In particular, let's talk about whether dampers should be zeroed in the air or on the ground. This is something I have gone back and forth with during my career, and something I have discussed at length with my customers in fields as diverse as V8 Supercars, F3 and the IRL. Even though in theory the car's true zero point is at full droop, just as it is about to connect with the ground, in my experience you should be zeroing on the ground for the following reasons:

- **Getting a consistent reading in the air will always be difficult. There is always going to be differing compliances and asymmetric pre-loads as you're playing with platform heights**
- **It greatly simplifies any hand calculations you have to do. This is particular apparent with the aero**

The question is though, how do we grab a good zero point? In my experience, a really good place to zero is as the car is trundling down the pit lane on the speed limiter. To illustrate this, consider **figure 3**.

You know when you have it right, particularly on a symmetrical racecar, because when you are going down the straight the damper displacements will be close to identical. The reason I have chosen this as a place to zero is that on paper we really should be zeroing as the car comes off the jacks. However, also in my experience, as you are going down the straight you know for sure you are definitely logging and getting a good signal.

"a really good place to zero is as the car is trundling down the pit lane on the speed limiter"

Once we are at this point we are ready to start creating our simulation model.

The first step to prepare for this is to load in a racecar model from a list of pre-described templates and a circuit you know. You are going to do this for the following reasons:

- **There is absolutely no point being a hero. By loading in a model that most closely resembles your racecar, it ensures you have a good 60 per cent of the ground work**
- **The pre-loaded circuit will be used to check the model works**

Once you have loaded this template, or racecar model, save it in a directory structure you can easily access. I refer to this as the car file, and the directory structure I recommend is: *C:\ChassisSim\Models\My car name\TrackName\Session*

So, for example, if we had an F3 car being run at Silverstone, the directory structure would be: *C:\ChassisSim\Models\F3\Silverstone\Test Feb 2012*

Another thing I have found very useful is to put your data and car file in this directory. It will greatly ease things when you need to do model refinement.

For initially putting your model together you will be changing one thing at a time and then running it on the pre-loaded circuit. The reason you are doing it this way is that if you make a mistake you can see what you did wrong and undo it. Once the change is made successfully, you save the change and move on to the next change. The other thing I would encourage you to do is to log the data from the simulation run and check the data to ensure it is sensible. For example, if you've made a mistake on suspension geometry, you'll see the logged cambers going out of range. As with everything else, the better you get at this the

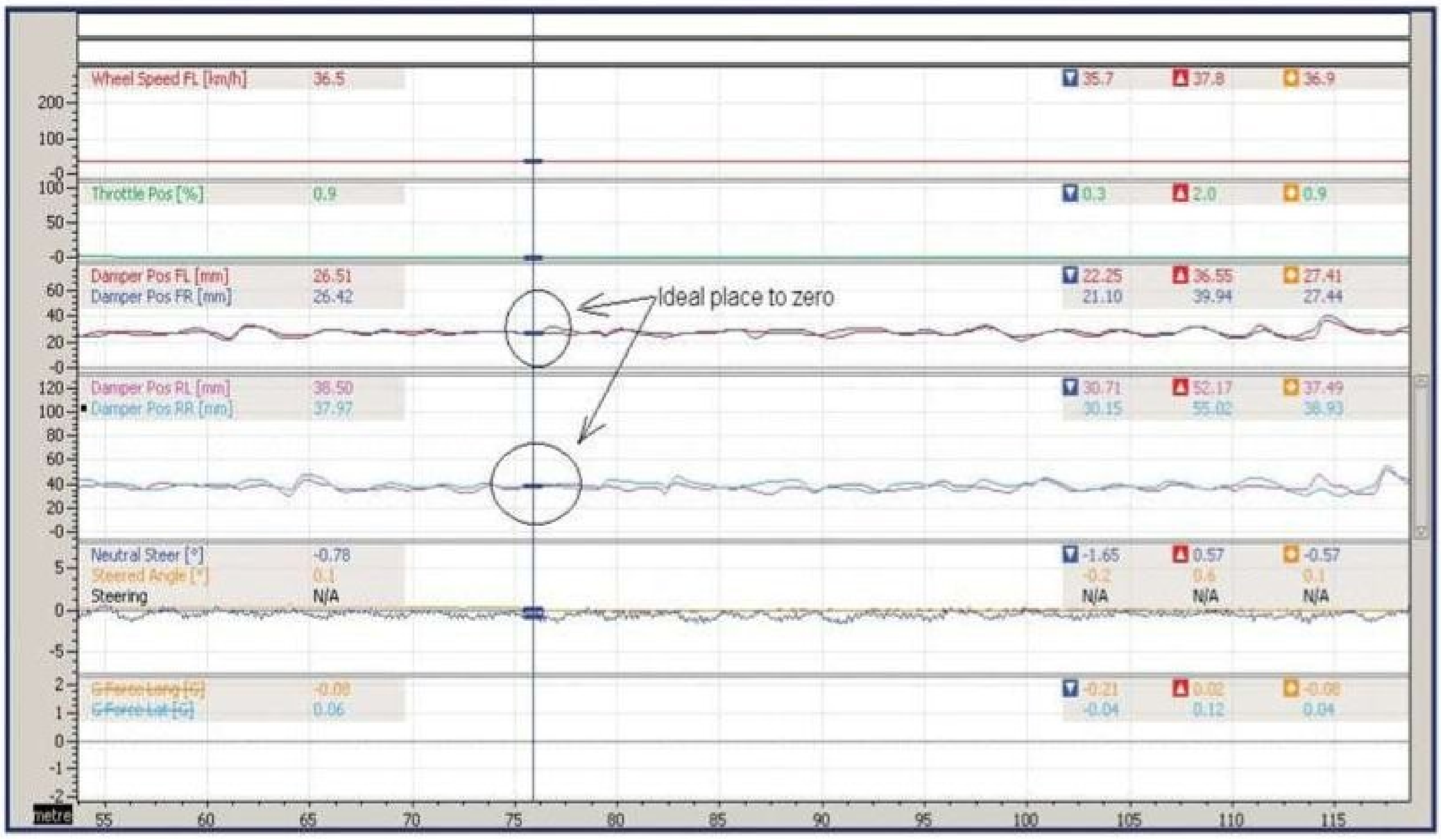


Figure 3: places where you should be zeroing

Rather it is a tool that will help you create an initial start point.

This illustrates that to be successful with racecar simulation, you have to start with a simple model first. If you try and get everything perfect with your model, I guarantee, particularly if you are a novice user, you will spend months going nowhere. You are much better off getting a start and taking broad brush strokes, building up experience and refinining the model as you progress. Remember, you don't learn by reading alone. You learn by studying, then practicing. That's how you learn to do anything, and racecar simulation is no different.

more aggressive you can be with your changes. But if you are a novice simulation user, stick to one change at a time.

The next step is to link your data with your simulation model. How this is done will vary between simulation packages, but I refer to this as the monster file. Typically, the data you are going to need is data from a flying lap of the following parameters:

- **Speed**
- **Track distance**
- **rpm**
- **Lateral and longitudinal *g***
- **All four damper displacements (or three if it's a monoshock)**
- **Steering angle (measured at the tyre not the steering wheel**
- **Throttle**

Believe it or not, you can do quite a bit with this data, such as reverse engineering aeromaps and tyres. I had a client in the ALMS who created a Sportscar model from a blank sheet of paper using this data. If you have it, the nice optional extras are:

- **All four tyre loads**
- **Vertical *g***
- **Laser ride heights**

Typically, you export this from your data at a specified frequency. With the ChassisSim monster file its 50Hz. I've found this has worked very well for both street courses and ovals. For those of you about to get grumpy about exporting at this rate at a super speedway, I'll give you a hint: remember the damper plots are a response, and look at the frequency output to input behaviour beyond 20Hz.

While not wanting to get bogged down on the specifics of exporting data, because it will vary for different simulation packages, here are some tricks of the trade you can use:

- **Make sure the speed trace is smooth and consistent**
- **Check the quality of sensors to ensure they are okay**
- **Make sure distance is exported to at least two decimal places**
- **Make sure you zero the dampers consistently**

I have found that if you do those things, it will assist you in achieving consistent results.

Once you have this, the next step is to use the reverse engineering part of your simulation package to reverse engineer the aero and tyres. As with the monster file, this will vary depending on the simulation package. For ease of illustration, I'll show you how to do this using ChassisSim, but the principles are very similar. First we will create the aeromap, then the tyre model.

We create the aeromap first because that determines the tyre loads. Once we know what the tyre loads are, the tyre model falls into place.

To create the initial aero model in ChassisSim, you use the one touch aero modelling function. What this does is takes the monster file, calculates the aero loads and takes its best guess of an aeromap. I've spoken of the importance of doing aero testing properly and thoroughly a number of times before, but one thing I want to state very clearly here is that one touch aero modelling does not replace this. Quite to the contrary, you still need to do this. However, we have found it to be a valuable tool to get you started, which is what it's there for.

Once the one touch aero modelling is completed, you move on to tyre force estimation. This feature is the little brother of the ChassisSim tyre force toolbox. It's designed to estimate the traction circle radius vs load characteristic. As with aero modelling, though, it does not replace this feature.

"it's just a matter of taking your time, and using a series of simple procedures"

CONCLUSION

So, to conclude, let's re-cap what we need to do. My recommended procedure is as follows:

- **Measure up the racecar**
- **Start with a model that most closely resembles your racecar**
- **Load in a test circuit**
- **Make changes one at a time and test, always remembering to save as you go of course**
- **Create a 'monster' file**
- **Run the aero one touch modelling and tyre force estimation features**

When you are at this point, you will have a model you can start to use for basic validation, circuit creation and basic model refinement. Also just note here, everything we have done up to this point has not been hard. Rather it's just a matter of taking your time, and using a series of simple procedures. It really is that straightforward.

This concludes part 1, and now you have a basic model up and ready, which was our goal for this month's installment. In part 2 next month, I'm going to show you how to create a circuit model, what to look for, and when to apply things such as road camber, bump scale factors and grip scale factors. Once we have this we'll discuss model refinement. This will be covered in part 3, which will then give you a vehicle model you can use in anger.

Cracking the code: Pirelli and Formula 1

As teams work to balance the new tyres, viewers are being treated to a real show

BY SAM COLLINS

More than ever before, tyres have become a key performance differentiator in Formula 1, and the teams are facing a race to get on top of the latest Pirelli compounds. Currently, this is making Formula 1 highly unpredictable and, in the course of the first eight races, seven different drivers won a race driving six different car designs. This has raised many eyebrows and has lead to grumbles in some corners of the grand prix racing community.

'I don't know why people are complaining about it,' says Pirelli's Paul Hembery, 'we have the most exciting racing in history. The times are so close, often in Q2 there is only 1.2 seconds covering 15 cars. Last year that covered the top three, or five. That means every issue, every tyre management approach, every error, every time you do something different can be dramatic in terms of result.'

Hembrey argues that whilst the tyres themselves have changed, the bigger changes are to the cars. 'In reality, the changes to the tyres are not that huge. The operating window is not narrower than it was in 2011, but it has moved higher. We knew from our testing programme that the cars have changed a lot. Last year we were using an updated Toyota TF109 from TMG, but this year we are using a 2010 Renault. The changes to the diffusers are substantial, and that's changed a lot. You see the cars oversteering a lot more and, if they are doing that, then they are heating up the tyres a lot more. All the teams understand the tyres, they know exactly what's going on with the tyres. What they don't understand is the interaction between the car and the tyres.'

Mercedes GP boss, Ross Brawn, echoes Hembery's comments as his team struggles to get on top of the current breed of tyres: 'We know what is needed to get the tyres working everywhere,' he reveals. 'We just don't know how to achieve it. The thing is don't get them too hot and don't get them too cold. The difficulty is that you have four tyres on the car and, at a circuit like Barcelona, the left ones get too hot and the right ones get too cold. It's a case of working out how to get all of the tyres to work well together, and get the best balance.'

This challenge is largely what has created the unpredictable nature of this year's races. At some races, the teams find a set up that works well with driver and tyres and that car dominates. As yet, no team has been able to do this consistently.

'What is fascinating is that for some of the race you see cars that are quite ordinary suddenly coming into the window and becoming quite extraordinary. You can complain about it or you can get your head down and work to get the best out of it. There's a little plateau you need to be on. If you drop off it, your tyres get too cold and you can't go fast enough to get the temperature back in. That's not unique to these tyres though. They are challenges, but every challenge is an opportunity.'

Brawn believes eventually the teams will get a handle on the rubber and the racing will settle down, but right now they are doing all they can to comprehend that tyre / car interaction: 'It's about how you get the most from the tyres. It's a philosophy rather than a technical innovation like the double diffuser. It's about how you set the car up and get the best out of it. It's about what programme you put together in free practice to get the best out of it on Sunday and how you react in different conditions.

'There are tools we are using on the track in terms of temperatures and measuring the amount of duress you are putting the tyres under. That loops back into things like our driver-in-the-loop simulator, and we use that model to work with the properties these tyres have.

'It will be a breakthrough when someone can have a tyre model in their driver-in-the-loop simulator that represents the tyre we have now. That will be a very powerful tool. Everyone is working on trying to do that, but the more complex it is, the harder it is to achieve. It's a case of empirical measurements on track, on suspension, temperatures, and we use devices called Correvits, which measure the sliding speed of the car. We take all of that and stick it into our simulation.'

"It's a philosophy rather than a technical innovation"

Companies like Stack and Texys have started to develop tools to help the teams' understanding of the Pirelli rubber. The Texense IRN8 was released in 2009 specifically for this reason, and dedicated to tyre temperature monitoring.

It allows the user to measure a line of eight spots on a tyre width and, if installed at the correct distance, will give the surface tyre temperature distribution. These eight channel temperatures are then directly sent on the CAN Bus of the data logging system. It is accurate at 180degC (+/-1 per cent FS) and is the ideal solution to measure surface tyre temperature across the whole width in the most severe conditions. The dimensions (31 x 11 x 17mm) and weight (15g, with cable) offer an easy installation in the tight confines of an F1 car. In addition to its compact size, the mounting distance between 200 and 700mm could give a reading of total width between 152 and 532mm in 260 milliseconds at 200degC.

Monitoring the loads through the suspension is also critical for understanding the interaction between car and tyre. Here too, specialist suppliers are developing dedicated tools. English firm, bf1systems', force measurement department is helping teams to minimise the costs associated with having separate suspension components for testing and racing. 'Our new dual gain intelligent amplifier allows teams to analyse both dynamic loading and aerodynamic loading from a single strain gauge installation on a pull and push rod,' says electronics manager, James Shingleton. 'Crucially, it allows engineers to look at aero balance during race weekends and also allows these race specification push rods to be used for straight-line testing, therefore reducing the part count and the associated costs. The dual gain intelligent amplifier retains the micro-processor-controlled temperature compensation to ensure the part's outputs are unaffected by changes in its ambient temperature, and its very small form factor.'

Tyre performance and degradation are still defining the 2012 F1 season and, while nobody appears to have a handle on it yet, Sauber claims to have cracked the problem. More on them next month.

MIA maps out the future for motorsport technology

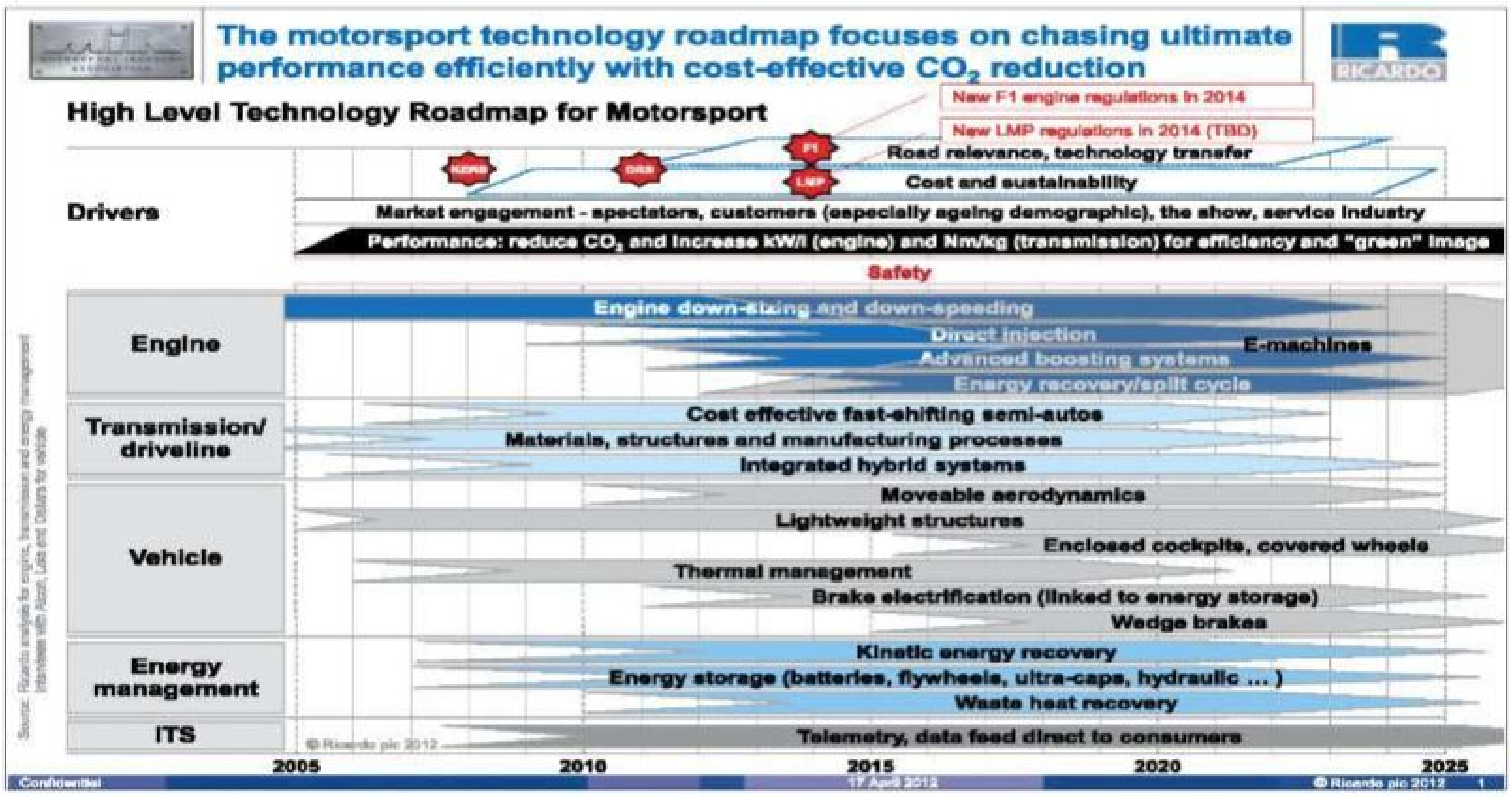
The Motorsport Industry Association (MIA) has issued a 'road map' to help companies involved in the sector to spot trends in technology, tie up with OEMs when road and race technologies overlap, and even secure government funding.

MIA CEO, Chris Aylett, stressed that the 'map', designed to signpost the direction of future motorsport technology until 2025, is a work in progress and the MIA has asked for extra input from the industry at large.

Aylett explained: 'The successful effect, which the Automotive Council technology road map has had on the UK automotive industry over the past two years, is most impressive. For this motorsport technology road map, we invite all in the business of motorsport to share their thoughts with others. By working together, our sector can deliver these ambitions more effectively and to mutual benefit.

'In due course, we expect our road map will highlight valuable crossover points, when our technology path is ahead, or level, with that of the automotive sector and others. When these are highlighted, motorsport companies can secure valuable R and D partnerships with major OEM, or Tier Ones, to accelerate these technology overlaps.'

The MIA points out other UK sectors have created similar road maps recently, providing the sort of 'clear strategic direction' that has led to the securing of funding.



The MIA's motorsport technology road map, designed to highlight opportunities with other engineering sectors

Ricardo researched and wrote the initial MIA motorsport technology road map, which defines future motorsport development in five key areas: engine; transmission and driveline; vehicle; energy management and intelligent transportation systems.

The road map forecasts that engine downsizing / down-speeding, direct injection, advanced boosting systems and energy recovery / split cycle will grow in importance. Hybrid transmissions, energy storage, lightweight structures, telemetry, moveable aerodynamics, thermal management, electrified braking and waste heat recovery systems are amongst other predicted areas of development.

But Aylett insists this is just a start: 'We call for comment, observations and ideas from all engaged in the technology of the motorsport industry. All such input will make this map more robust and relevant. It is restless and will never cease to be constantly reviewed, and publicised, so all can benefit from our findings. We ask for all suggestions to be sent to roadmap@the-mia.com'.

Quaife snaps up Tran-X transmissions

Renowned UK motorsport and performance drivetrain specialist, Quaife, has taken control of the Tran-X transmission brand.

Quaife has purchased all the tooling, designs and intellectual property of the brand after buying Tran-X from its parent company, Auto Sport Engineering of Coventry. The Kent-based concern will now be able to offer Tran-X's existing trade and retail customers the vast majority of the firm's current range – including the popular Tran-X clutch plate limited slip differentials, close ratio gear kits and Ford English / Atlas axle crown wheel and pinion sets.

Quaife has transferred production capability for the Tran-X range to its Sevenoaks headquarters, where manufacturing of new Tran-X stock is already underway. The company says existing retail pricing for the Tran-X brand will be held in the short term, but placed under review. Quaife also aims for a continuation of existing sales relationships with Tran-X's trade clients, both in the UK and overseas.

Peter Edge, a director at Auto Sport Engineering, said: 'We feel we have taken Tran-X as far as we can and are delighted that a market leader such as Quaife will be involved in the future development of the brand.'

Quaife director, Sharon Quaife-Hobbs, added: 'Tran-X was launched over 30 years ago and the brand is well known amongst professional motorsport teams, club racers and car enthusiasts. The acquisition of Tran-X by Quaife allows us to seamlessly integrate the company's product range into Quaife's facilities and stringent quality criteria, whilst bringing it to a much larger potential market.'

IndyCar issues new Indy Lights car requirements for 2014

IndyCar has put the contract for the new Indy Lights car, due to hit the tracks in 2014, out to tender, and has sent a wish list outlining what it wants from the car to a number of chassis and engine manufacturers.

The new car will replace the current Dallara chassis, which has been in use since 2002, and it's IndyCar's intention that it will be modern and yet flexible enough for use on a variety of tracks.

'As we look to the future for Firestone Indy Lights, we believe it's important that we do everything we can to attract new drivers, teams, partners and manufacturers to our series to continue to improve our formal system of driver development,' Firestone Indy Lights director, Tony George jr, said. 'The debut of the new car in 2014 will be a key step in this process.'

IndyCar has sketched out its desired attributes for the 2014 Indy Light cars, which include: [It must] 'Reflect current contemporary racecar design with a forward-thinking, sophisticated and exciting formula. Chassis must be adaptable to compete on road, street and oval circuits with a minimum of facility-specific parts.'

IndyCar also wants the chassis to 'surpass all current FIA static and impact regulations, while having the flexibility to accommodate a broad spectrum of drivers and seating positions,' while it should also feature 'improved aerodynamic performance that must also allow for enhanced sponsor placement opportunities on the car.' It also requires an 'improved technological package to include... paddle shifting, data systems and sensors.'

The final point on IndyCar's wish list is that the car should have the potential to integrate an alternative fuel source.

'With our premium on safety, our goal is to develop a car that is technology relevant to the new IZOD IndyCar Series car,' said series technical director Vince Kremer. 'It is our intent to remain a spec series as it creates the right platform to identify driver talent and contain costs. While it is important for us to gain a manufacturer badge for the engine and receive the endorsement of the auto industry, we want to make sure it is done in the right economic structure for our teams.'

The project will be under the supervision of IndyCar vice president of technology, Will Phillips, and Kremer, who said Dallara, Swift, Elan and others are in the runnning for the contract. Kramer added: 'We want to continue the safety platform that was incorporated in the new IZOD IndyCar Series Dallara. [But] It doesn't have to exactly look like the IZOD IndyCar Series car.'

PEELING BACK THE STICKERS NO.5: MARLBORO

One of the most iconic, yet also the most controversial, sponsors in Formula 1. Ironically, these days it also happens to be invisible.

Cigarette manufacturer, Marlboro, has been involved in Formula 1 since 1972, with BRM and ISO Marlboro-Ford, but it was in 1974 that its red and white chevrons really came to the fore, when it started a sponsorship relationship with McLaren that lasted until 1996.

Yet even when it was sponsoring McLaren, Marlboro was also forging a relationship with Ferrari, becoming a secondary sponsor in the mid-'80s, and then the Italian team's main sponsor in 1993. It signed its latest contract with the Scuderia in June of last year, which will see the relationship continue until 2015.

These days Marlboro is the only cigarette firm in F1, which is a far cry from 1999 when seven teams ran with tobacco title sponsorship, worth close to $300m to the sport at the time. Yet, while it might be the last of the cigarette brands, it's also by far the most generous of all current sponsors, forking out an estimated $100m per season.

What makes this figure all the more remarkable is that because of European anti-smoking legislation, the company logo is nowhere to be seen on the car. And since last year, Ferrari has not even used Marlboro in its official team name. Ferrari last ran with full Marlboro branding in Bahrain in 2006, and used a barcode design until 2010, when it then switched to its new logo.

Some say the current logo is intended to be similar to the top left corner design of a Marlboro cigarette packet but, even if it is, there's no resemblance beyond the colour scheme – something Ferrari is unlikely to change. In a world where it is becoming ever more difficult to advertise cigarettes, Phillip Morris, the US company behind the Marlboro brand, clearly think its vast expenditure is worth it.

Amanda Sandford, research manager for anti-smoking group ASH, believes the advertising is subliminal: 'There must be something in it for them otherwise Marlboro wouldn't do it. There is a subliminal effect. Tobacco companies have just been manipulating people for decades and I think this shows that they are still doing it,' she told *Racecar Engineering*.

Subliminal or not, it's not hurting Marlboro. Its annual report for 2011 showed reported net revenues of $31bn (up by 9.2 per cent on the previous year) and some 915bn cigarettes shipped. Of course, it's impossible to tell how much of that is down to a racecar faintly resembling a cigarette packet.

But for all the macho posturing, with Marlboro Man and motor racing, it's interesting to note the brand originally came into being as a cigarette for women in the 1920s, and only became popular with men after it was marketed as a 'safer' cigarette, because of its filter, in the '50s. Oh, the irony.

With tobacco branding now banned, advertising has become subliminal

Lola misses out on multi-car single seater deal

Lola was on the cusp of signing a deal to build and supply new cars for an international single-seater series when it was forced into administration in May, *Racecar Engineering* has recently discovered.

The British racecar manufacturer was in talks with Auto GP promoter, and former F1 team boss, Enzo Coloni, about the possibility of it building a fleet of cars to replace his formula's ex-A1 GP car, which were also built by Lola seven years ago.

Auto GP announced it was to replace its ageing cars, leased to its teams on a season-by-season basis, earlier this year and it was widely reported the new car would be built by Coloni Motorsport itself.

However, Enzo Coloni then decided to entrust Lola with the work: 'We had two options: a completely new car, with a new chassis, or a major update of the current one,' Enzo Coloni told *Racecar Engineering*. 'In both cases, anyway, Lola was going to be our choice for the job. We were in advanced talks when the sad news of the administration came, and that changed everything.'

Coloni explained that the original decision to go with Lola, and not build the car in house, was taken because of costs and time constraints: 'Our company has a strong tradition for manufacturing racecars. Coloni was in F1 from 1987 to 1991 and the car was completely built in house, as was the Formula Nissan years later [1998]. We definitely have the skills to do a top notch job, but we needed to keep the cost low and the timing was tight, so handing the project to an established manufacturer like Lola was the right thing to do in my opinion.'

Auto GP will now most likely keep the current car, though Coloni said there will be some updates: 'We had to stop for a moment and reconsider our options. That doesn't mean there won't be any update, but probably it won't be as major as we'd have liked.'

While it might not have saved Lola Cars, landing a big single seater contract, probably for 20 cars, would have been lucrative. The last single seater deal it clinched was for the Jim Russell Racing Drivers' School at Sears Point, which it supplied with cars based on its 2003 F3 design. Before that it supplied the cars which are now used in Auto GP to A1 GP in 2005.

Meanwhile, the administrator for Lola, CCW Recovery Solutions LLP, has told *Racecar Engineering* it's looking at selling the group's two companies – Lola Cars and Lola Composites – as separate entities, although they also say that one purchaser could still buy both. Interest is said to be strong and both companies are continuing to trade, with 95 members of staff working across both, though a further six redundancies at the end of May bring the total job losses to 66.

BRIEFLY

Power failure

Minister Racing Engines, one of the great names in the Formula Ford world, has gone into liquidation. The company will be remembered for its part in the story of the legendary 'Patch' engine, a serial Formula Ford Festival-winning Kent 711 lump built by Minister and named for the steel patch that covered the damage done when a rod went through the block. More recently, Minister had built a reputation for its work on the Rover K-Series engine.

Asian LMS

The Automobile Club de l'Ouest has announced a six-round Asian Le Mans Series, which will kick off next year. It will feature three-hour races for 2013, extended to four-hour events in 2014. The Asian series will be similar in nature to the European Le Mans Series, with classes for LMP2, GTE, GT3-GTC and Formula Le Mans. Winners of the LMP2, GTE and FLM classes will be invited to compete in the Le Mans 24 Hours, though FLM teams would have to run an LMP2.

NASCAR to develop hi-tech media centre

NASCAR has teamed up with HP Enterprise Services to develop a state-of-the-art 'Fan and Media Engagement Centre'.

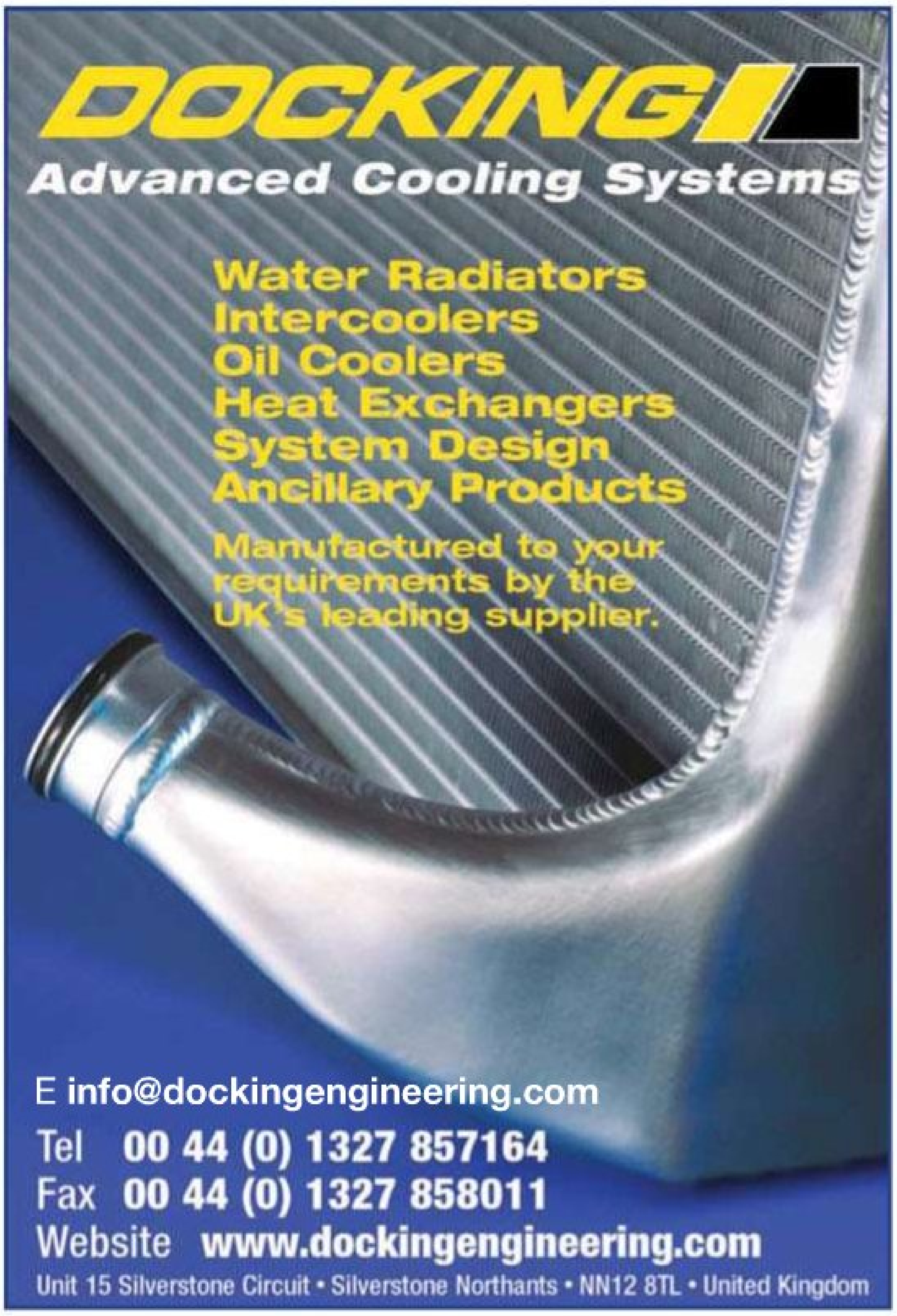
The facility will be installed at NASCAR's Charlotte, North Carolina offices, with the stated aim of serving media and fans with near real-time response to news and events. It will be staffed and managed by the NASCAR Integrated Marketing Communications team and is slated for testing in October, with a full roll out expected by the start of the 2013 NASCAR season. The facility will be housed in a 500sq.ft, glass-enclosed area, outfitted with touch screens, television monitors and multiple seated viewing areas and work stations.

'The Fan and Media Engagement Centre will leverage industry-leading technology from HP in order to better engage with the massive community that is the NASCAR fan base,' said Steve Phelps, NASCAR senior vice president and chief marketing officer. 'This is a clear example of our commitment to using cutting-edge technology to better inform our sport. Ultimately, this tool will help our industry connect with media and fans more effectively and efficiently.'

NASCAR says it will design the Engagement Centre in collaboration with HP to be a dynamic tool that is specially tailored to meet the evolving needs of NASCAR's unique industry. In addition to listening to, and engaging with fans in real time around NASCAR content, the centre will provide '360-degree traditional media monitoring'.

'Social media has forever changed the sporting world and how fans interact,' said Rob Vatter, vice president, communications, media and entertainment industry, HP Enterprise Services. 'HP's broad social business and analytics portfolios and industry consulting services will enable NASCAR to continue to deliver innovative fan-engagement opportunities for its sponsors – while also delivering the fan experience it has become known for.'

With social media sites sweeping the world, NASCAR is moving with the times and offering its fans '360-degree traditional media monitoring'. Wow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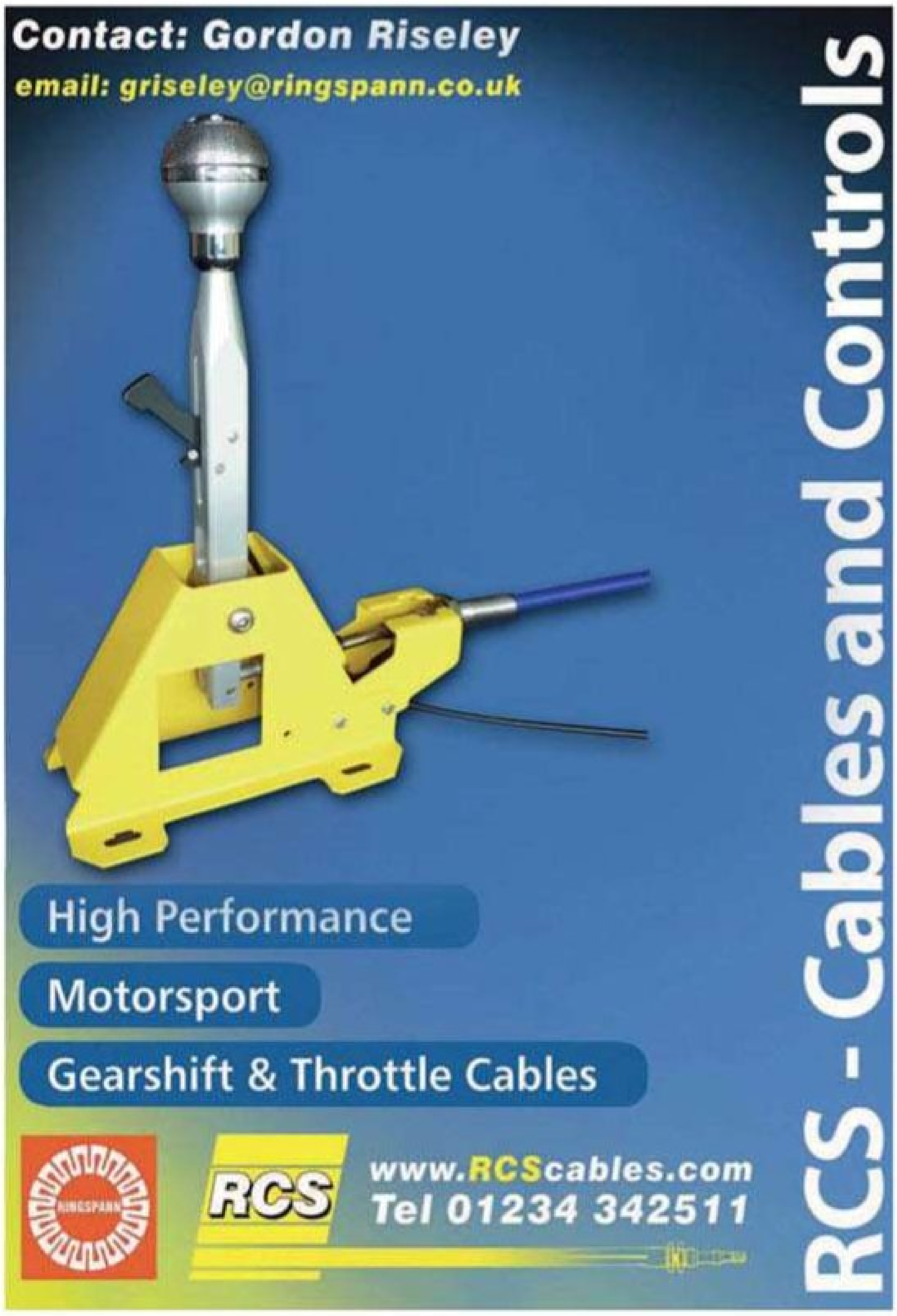
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CVC sells chunk of F1, while circuit owners team up

CVC Capital Partners has sold off a large part of its share in Formula 1's commercial rights to a trio of investment funds, and what was once a 63.4 per cent stake in the sport now stands at just 35.5 per cent.

The move is believed to have netted the company $2.1bn in total, but CVC still retains control of the sport. A condition of its stake in Delta Topco, F1's parent company, is that CVC can appoint veto-holding board members.

Shares have been sold to well-known asset management concerns Waddell & Reed, Norges Bank and BlackRock (they now own 21 per cent between them) and the sale has netted CVC a good profit on the business – it initially bought F1 for $1.1bn. The floatation is actually on hold for the moment anyway, due to the continued volatility in the markets, with Bernie Ecclestone making it clear that an offering will now not be made until October at the very earliest.

Meanwhile, the political topography of Formula 1 has radically shifted, with the emergence of a new power in the shape of the circuit owners, who have teamed up to protect their interests.

The Formula One Promoters Association (FOPA) was registered in Geneva in May and is chaired by Ron Walker, the man in charge of the Australian GP in Melbourne. Among its articles it states that it was set up to: 'encourage ticket sales and promote a better understanding of Formula 1 racing in the media and general public'.

Fees from circuits and promoters amount to the largest individual revenue source for Formula 1. In 2011, the circuits paid around £330m for the right to host grands prix, while some 3.4m spectators attended F1 races last year.

FOPA has been created just as the teams, the FIA and FOM, hammer out a new Concorde Agreement – the contract that governs F1 – which runs out at the end of this year, and the setting up of the body is intended to give the promoters more of a say in the regulation issuing side of the sport, and particularly the frequency of rule changes. One of the issues FOPA is keen to address is the perceived loss of aural excitement when F1 switches to 1.6-litre turbo engines in 2014.

It's believed Bernie Ecclestone will see the new organisation as an ally, firstly because he also opposes the changes to the engine formula, but also because Ron Walker is a good friend. However, the issue of the cost of hosting races is sure to cause friction between both parties in the long run, with those events which do not attract government money hit hard by escalating costs.

CAUGHT

NASCAR Nationwide crew chief, George Church, has been fined after the no 41 car he oversees failed to meet the minimum height at the front during post-race inspection at the Charlotte Motor Speedway round of the second tier US Stock Car series. Team owner, Rick Ware, and driver, Timmy Hill, were docked six points each in their respective championships as a result of the transgression.
FINE: $10,000 (£6420)
PENALTY: six points

Philippe Lopez, crew chief for the no 43 NASCAR Nationwide car, and Michael Wright, its car chief, have been penalised for rules infractions discovered during opening day inspection at the Charlotte Motor Speedway round of the series. Lopez has been fined and placed on NASCAR probation until December 31. Wright has also been placed on NASCAR probation until the end of the year. The car was found to be running with unapproved front bumper covers, and is one of a number of teams to be caught out for this particular infringement in the Nationwide Series this season.
FINE: $10,000 (£6420)

NASCAR Nationwide crew chief, Luke Lambert, has been fined after his no 2 car failed to pass the ride height test at the Iowa Speedway event. The car's owner, DeLana Harvick, and driver, Elliott Sadler, were both docked six points each in the owners' and drivers' standings.
FINE: $10,000 (£6420)
PENALTY: six points

IndyCar outfit, Dale Coyne Racing, was docked five championship points and fined following the Texas round of the series after its race-winning car, driven by Justin Wilson, was found to be running a top deck to the sidepod that was not a part of the permitted aero package. Wilson was allowed to keep the win position.
FINE: $7500 (£4820)
PENALTY: five points

Owner / driver, Ed Carpenter, was also caught out by the scrutineers at the Texas IndyCar round, landing a fine and losing five points for using a Gurney flap that did not meet the required dimensions.
FINE: $5000 (£3210)
PENALTY: five points

Lotus transformer

The Lotus LMP2 team, which is actually German outfit Kodewa with Lotus branding, is to build an all-new LMP2 car for 2013. The team plans for the car to also serve as an LMP1 in 2014. The concept for the car is for it to be built to 2014 LMP1 dimensions, but to run with smaller LMP2 wheelarches in its first year.

The new car will replace the Lola the team has been running this year and, when it is in LMP1 trim, the team has said it could well be powered by the Judd-developed, 2.2-litre V6 turbocharged Lotus IndyCar engine.

SPONSORSHIP DEALS DONE

Crack V8 Supercars outfit, **Triple 8 Australia**, has lost its sponsorship deal with **Vodafone,** a tie up that has lasted for five seasons. Worries that the pull out may cast doubts on the future of **McLaren's** deal with the telecoms giant were put to rest by the Woking F1 team, which has said that this was a regional decision confined to Australia.

The beleaguered **World Rally Championship** has suffered another blow with the news that **Nokia** has abruptly finished its sponsorship deal with the WRC. The deal is said to have been worth £2.5m a season.

F1 team **Red Bull Racing**'s contract with **Nissan Light Commercial Vehicles** has been extended for the 2012 season. Nissan will supply a fleet of over 30 vehicles to the team.

Lotus F1 has announced it has signed a three-year deal with business consultancy **Avanade**, which is majority owned by **Accenture**. Lotus has had Avanade branding on the E20 since Monaco.

INTERVIEW – FRANK KALFF

Frank Kalff is a trained automotive engineer (who also holds a business administration degree) who worked at Mitsubishi Heavy Industries and Littelfuse before joining FCS Control Systems, which emerged from Fokker at the end of the 1990s. Later FCS became Moog, at which time FCS Racing Simulation evolved into Cruden. Cruden sells simulators into the motorsport, automotive and engineering markets, as well as working on research with academic organisations.

Q. How much of an advantage is it that you're a trained engineer when it comes to selling into motorsport?
It helps very much. There's a lot of technology involved, and before you come into the commercial part of selling something you're really talking to engineers all the time.

Q. What is Cruden involved in on the motorsport side of the business?
We're almost always involved in some Formula 1 activity or other. This can vary from consultancy, software, the whole simulator or part of the simulator. We can't really say much more than that, apart from the ones that are publicly known. We were the ones that designed and started the Ferrari simulator, for instance.

Currently, we're doing a project for one of the DTM teams, so that's a completely different style of body. We also work with GP2, GP3, and Formula 3 teams, and we're looking at a Le Mans project as well.

Then, of course, there's the US, where we're talking to both IndyCar and NASCAR teams and hoping to start something there. In Europe everybody uses a simulator in some form or another. But in the US, simulators are not of the same sophistication and their use is primarily for drivers to gain track familiarisation, for which the gaming style of simulator is deemed to be sufficient. So there's huge potential there.

Q. How is the simulator business changing?
Formula 1 teams will mostly have their own simulators developed in house, with either a full Cruden system or elements of it, and then they do a lot of development themselves. But then there's this other market where some teams won't have the funds to invest in that level of equipment but they've got a budget to send their team to somewhere like Wirth Research, AOTech or Bhai Tech. These places run Cruden simulators with motion. But it's not just about driver familiarisation, it's also about vehicle development.

Q. What sets Cruden apart?
First of all, we're the only company that really builds the whole simulator by itself – meaning the hardware, the software, the top platform, the mechanics, the electric motors, everything. Besides that, the motion tuning is very complex maths, and needs an understanding of human physiology. You have to understand the neuro-muscular system, you have to understand how the body works, and these are things that other manufacturers don't really add. For us it's very, very important to have this know-how in house. I think in terms of building a simulator, we probably have the best team in the industry.

Q. Why do you think Cruden is so successful?
I think the reason is that we're always developing. We're always looking for new technology and we always improve our systems. We put a large amount of the profits into research and development. We know that the only way to stay ahead of the competition, or to be able to advance yourself as a company, is to constantly develop, whether it's in the computing power of the PCs, whether it's in software development because the computing power has gone up, whether it's saving weight, whether it's making it stiffer, whether it's making the access easier, or all of the above.
The other reason, I think, is we're a very flexible company. Although we have standard products that we can just sell if somebody puts an order in, we're always willing to customise. In fact, most simulators for professional motorsport use are customised in some way.

Q. How much have limitations on testing in various formulae helped Cruden grow?
It certainly has helped. But the DTM contract we have now, and the GP2 and GP3 stuff we're doing, is really coming from the fact that the teams are growing up. And while our simulators are not getting cheaper, the price is not increasing, either. Also, these teams are seeing the benefit of being able to test whenever they like. The fact that you can do all these things so quickly, so easily, in a confined space, not having night,

Bahar ousted from top job at Lotus

Dany Bahar is no longer the CEO at Group Lotus, casting a shadow over the company's ambitious motorsport programme.

Bahar was dismissed just two weeks after he was suspended following a complaint about his conduct. A Group Lotus statement said: 'The decision was made by the Board of Group Lotus plc following the results of an investigation into a complaint made against him by the company's penultimate holding company, DRB-HICOM Berhad.'

Aslam Farikullah is the company's new CEO and, at the time of writing, it was unknown whether he would carry on with the motorsport programme, which was widely believed to be one of Bahar's pet projects.

Currently, Lotus Racing, the team's motorsport arm, is involved in IndyCar, endurance racing, single seaters and Formula 1, though much of its involvement is through branding and technical partnerships.

A spokesman for the company told *Racecar Engineering*: 'The new CEO has not been in place long enough for us to know. But clearly different chief executives have different views and so he might put more money into [the motorsport programme] or he might take it out.'

Meanwhile, Group Lotus owner, DRB-Hicom, insists it remains focussed on securing a future for the company, despite speculation that it was open to selling it. Dato' Sri Haji Mohd Khamil Jamil, group managing director of DRB-HICOM Berhad, said: 'I would like to assure you we remain committed to ensuring the ongoing and future business operations of the Lotus Group as we take the Lotus Group to the next level to remain relevant in the global automotive industry.

'I look forward to bringing mutual benefits to not only DRB-HICOM and PROTON Holdings Berhad but also the Lotus Group and its employees, as well as contribute to the growth of the British automotive industry.'

not having rain, not having change in temperatures, is something that - given that the computing power is so good, and how a simulator can work these days - has really helped the market.

Q. What's the future for simulator technology, where will it be in 10 years?
Computing power will have gone up, which makes the models more accurate, but I think the main difference is going to be the visuals. They are going to be so much more impressive. There's almost going to be no difference between real life and the visuals, and that's going to help so much for the immersion, the feeling that you are actually in a racecar.

Q. What's new at Cruden?
Well, we have a new base. We're still in the Amsterdam area, near Schiphol Airport, but we're also only five minutes from downtown. We're in a new area with a nice building with a lot of office and production space.

Also, on the vehicle modelling side, we have our own vehicle dynamics package, which is based on Simlink, but we can also interface with any packages out there, so if it's CarSim, Vi-Grade, IPG Carmaker or veDYNA, we can integrate that, which means we don't limit ourselves to any one kind of software.

McLaren GT to move into old Formula 1 base

Racecar manufacturer, McLaren GT, which was launched as a brand within the McLaren Group last year, is to set up shop in the old McLaren F1 factory in Woking, close to the current F1 base at the McLaren Technology Centre.

McLaren GT has now supplied 25 12C GT3s for racing in Europe in 2012. It will be based in the premises occupied by McLaren Racing between 1987 and 2004, which will be turned into what the company has described as a 'dedicated engineering and vehicle assembly facility'.

The 60,000sq.ft factory will provide office space, a workshop and preparation and test bays, as well as a state-of-the-art engine development centre, and will be home to the fleet of 12C Sportscars it runs in its Europe-wide 'Pure McLaren' customer test drive programme.

Andrew Kirkaldy, project director for McLaren GT, said: 'I am excited that McLaren GT will be establishing our operations so close to the home of McLaren Racing. We have a new racecar that comprises a unique package of F1-inspired technology, and we are working with customers to ensure the potential performance of the 12C GT3 is realised this season.'

'This relocation underlines the commitment and support within McLaren Group that is behind McLaren GT, and will be a benefit as we aim to offer a world-class engineering support service to our new customer teams.'

Canada GP invests in future

François Dumontier, the promoter of the Canadian Grand Prix in Montreal, has revealed that the cost of new investment in facility improvements at the Circuit Gilles Villeneuve will be around CDN$20 million.

The current contract for the race runs until 2014 but, with the support of Québec premier, Jean Charest, Dumontier's Octane Racing Group is already engaged in negotiations with Bernie Ecclestone with a view to securing a 10-year extension. Formula One is also seeking to increase its hosting fees.

The hosting fees and other costs are currently covered by approximately $15m in public subsidies. In 2010, the Canadian GP reportedly attracted a weekend attendance of more than 300,000 people, while th 2011 event generated a profit of approximately $4.7m (almost exclusively from ticket sales), and an additional $18m in tax spin-offs from hotel rooms and other expenditure by spectators.

RACE MOVES

Bernie Ecclestone has hired **Michael Payne,** a former marketing director at the International Olympic Committee, as Formula 1's chief marketing consultant. Payne will be joined by **Christian Vogt,** who has previously handled the TV rights for football governing bodies FIFA and UEFA. The appointments fill the void left by **David Campbell,** who resigned as F1's marketing director earlier this year.

Coventry University motorsport engineering student, **Peter Hutyan,** who is heavily involved in the Formula Student team, has won the Baroness Platt of Writtle Award for 2012. The award, which is presented by the Worshipful Company of Engineers, in conjunction with the Institute of Engineering and Technology, recognises the outstanding achievements of final year engineering students in the UK.

Irish rallycross driver, **Willie Walsh**, is the new managing director of the Lydden Hill circuit. Walsh is part of the Pat Doran-headed consortium that bought the Kent track from McLaren in 2008. McLaren had hoped to turn Lydden into its own test facility, but failed to secure planning permission for the venture.

Former Renault F1 technical director, **Pat Symonds**, has joined the judging panel for the Dewar Trophy, which is presented by the Royal Automobile Club (RAC) for technical achievement in the automotive world. Recent winners include Mercedes-Benz High Performance Engines, for its first F1 KERS system.

HRT mechanic, **Craig Stubley**, was hospitalised during the Canadian Grand Prix weekend after he was hit by Pedro De la Rosa's car in the pits at Montreal during the first session of free practice. The team later reported that Stubley suffered only bruises and a swollen knee as a result of the accident.

Willie Walsh

LAT

Graham Muff is now composites manager at Norfolk-based Musset Composites, which supplies Formula 2, M-Sport and a number of F1 teams. Muff has previously been employed at a number of motorsport businesses, including Racing Technology Norfolk and the TWR-owned composites company, ASTEC. He also worked in Formula 1 for Team Lotus in the early '90s.

BRDC president and former Formula 1 and Sportscar racer, **Derek Warwick**, is now a member of the FIA's Endurance Commission. Warwick is also an FIA Formula 1 steward.

Steve Herbst, who has overseen NASCAR's broadcasting and global media rights since May 2011, has been chosen to lead what was formerly known as NASCAR Media Group Productions as vice president, broadcasting and production. This department has now been re-branded as NASCAR Productions. Herbst will report to senior vice president and chief marketing officer, **Steve Phelps.**

In other NASCAR media moves, **Steve Stum** has been promoted to vice president of operations and technical production, **Tally Hair** has been named managing director of production and programming, while **Seth Bacon** has been elevated to senior director of broadcasting.

The crew of the **Michael Waltrip** Racing no 56 Toyota in the NASCAR Sprint Cup Series has scooped the first quarter Mechanix Wear Most Valuable Pit Crew Award, which is determined by a vote of each team's crew chief and given quarterly to the top-performing pit crew. The crew comprises crew chief **Chad Johnston, Brian Chase** (jack man), **Eric Maycroft** (front tyre changer), **Craig Curione** (front tyre carrier), **Brandon Hopkins** (rear tyre changer), **Adam Mosher** (rear tyre carrier) and **Wes Evans** (fuel). **Greg Miller** is the team's pit crew coach.

NASCAR has reinstated crew member **Keith Wolfe** upon his successful completion of its Road to Recovery

Earnhardt

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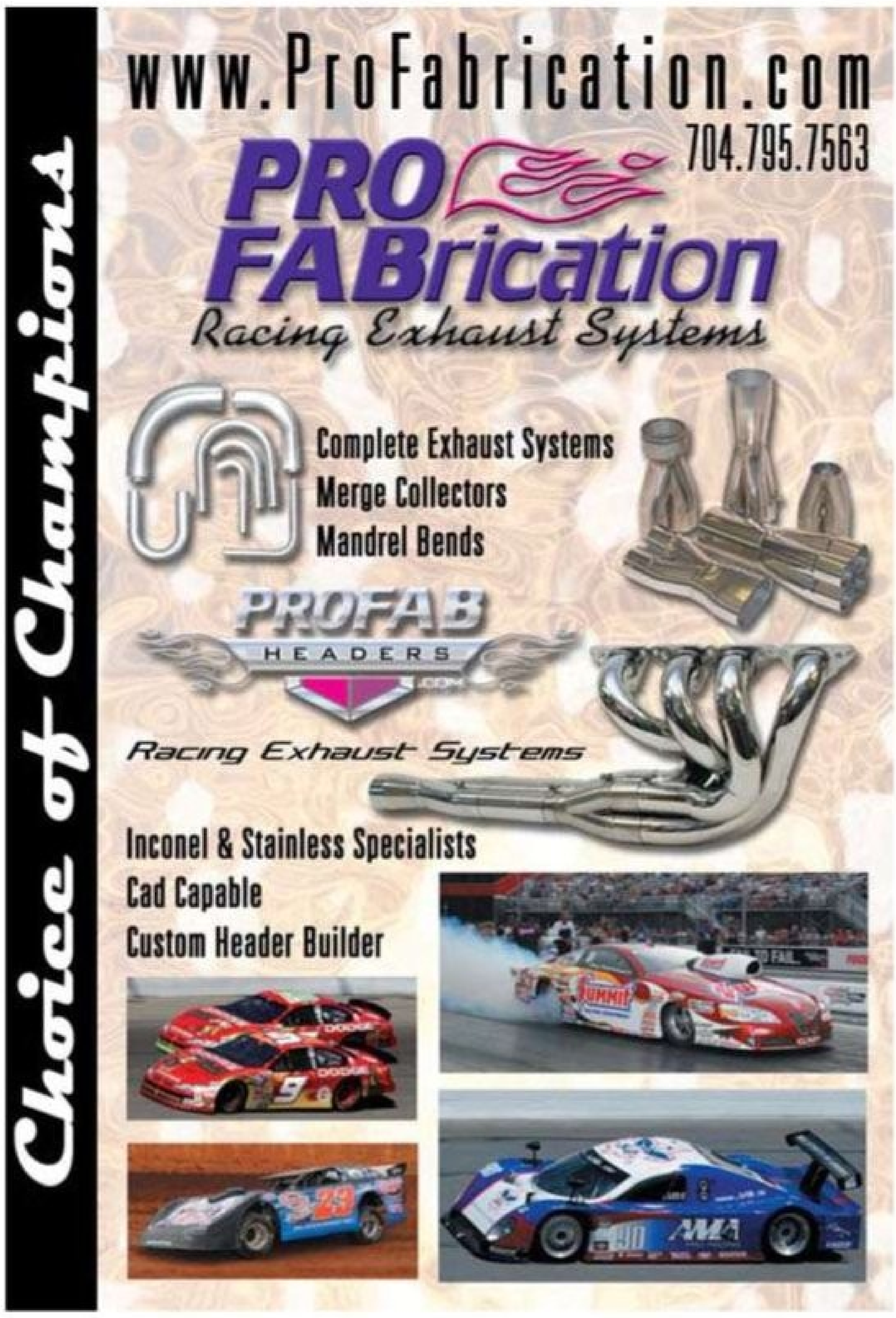
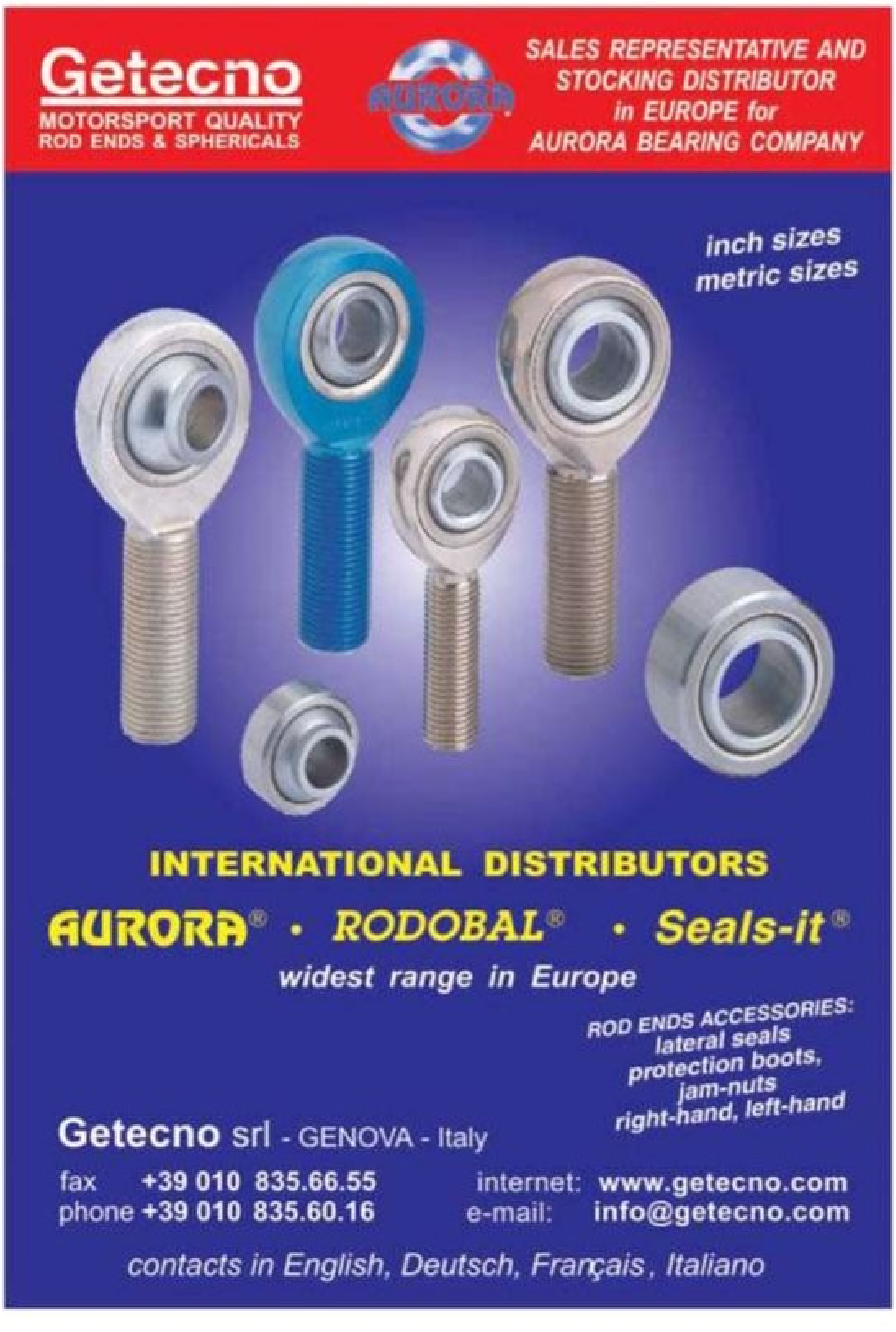
Interested candidates meeting qualifications should contact Laura Whittaker at lwhittaker@ganassi.com or (704) 662-9642
We look forward to receiving your application

About Chip Ganassi Racing Teams, Inc.

Chip Ganassi has been a fixture in the auto racing industry for over 25 years and is considered one of the most successful as well as innovative owners the sport has anywhere in the world. Today his teams include two cars in the NASCAR Sprint Cup Series, four in the IZOD IndyCar Series, and one Daytona Prototype in the GRAND-AM Rolex Sports Car Series. Overall his teams have 14 championships and 148 victories, including four Indianapolis 500s, a Daytona 500, a Brickyard 400 and four Rolex 24 At Daytonas. Ganassi boasts state-of-the-art race shop facilities in Indianapolis and Brownsburg, Ind. and Concord, N.C., with a corporate office in Pittsburgh, Penn.





OBITUARY – COTTON OWENS

Legendary NASCAR team owner, Everett 'Cotton' Owens, has died at the age of 88 after a long battle with cancer. Owens enjoyed success as both driver and owner in NASCAR. Behind the wheel he won nine times in NASCAR's premier series competition, including the 1957 Daytona Beach road course race, while he very nearly won the 1959 championship – finishing second to Lee Petty.

But it is as a team owner he will be remembered, standing out as one of the greats of NASCAR's early era. Owens was particularly well known for his ability to spot driver talent, hiring Junior Johnson in 1962, the same season in which he signed another future star, David Pearson. Owens notched up 38 race wins during his time as a team owner and, just before his death, was voted into the NASCAR Hall of Fame.

Buz McKim, historian at the NASCAR Hall of Fame, said of Owens: 'Cotton Owens was one of the first heroes of NASCAR. He was exciting to watch, as he thrilled early-day fans with his patented broadsliding on dirt tracks. Not only a gifted driver, he was a fine mechanic and was a championship car owner.'

Brian France, NASCAR chairman and CEO, said: 'This is a sad day for the NASCAR industry, but we are all consoled by the fact that Cotton was voted into the NASCAR Hall of Fame before his death. Today we have lost a portion of our past. But people like Cotton Owens are the reason our sport thrives today – and can look forward to a promising future.'

Cotton Owens 1924 – 2012

New, more powerful engine will not hit budgets, claims GP3 promoter

GP3's switch to a significantly more powerful 400bhp engine for next season will not radically affect the budgets of the teams, says the man behind the spec single-seater championship.

The series, which is now into its third season, will introduce an all-new, naturally aspirated engine for 2013, which will replace the current 280bhp, 2.0-litre turbocharged unit.

However, while the hike in power will move GP3 above F3 in terms of lap time – the series predicts an average of four seconds a lap improvement – its CEO, Bruno Michel, insists budgets should remain the same, largely because it will stick with the same Dallara chassis. The current budget is around the €500,000 (£400,000 / $624,850), although drivers are known to pay much less in some cases.

Michel said: 'This new car will be much more selective [adjustable] and powerful. The modifications on the car will be implemented in an upgrade kit in order to save the teams from purchasing a brand new chassis, thus being cost effective.'

The revisions to the current Dallara GP3/10 chassis will centre on its nose, sidepods and the engine cover, while it's believed the engine will once again be built by Renault.

Michel: 'When we started to think about our next generation car, we based our design on what has made the series a success since its inception, which was a low cost machine that best prepared the drivers for GP2.

'But we also want our car to be more powerful and more selective in order to make it an even better learning tool for young drivers who wish to graduate to GP2 and then to F1.'

The series will now tender for nine teams and 27 cars to fill its ranks next season (down from 30 this year), Michel feeling that is the perfect number.

RACE MOVES

programme. He was suspended from all NASCAR competition earlier this year for violating the sanctioning body's substance abuse policy.

Motorsport's heavy hitters feature prominently in a list of the 50 most powerful and influential people in the car industry that's been compiled by motoring weekly *Auto Express*. Unsurprisingly, Bernie Ecclestone heads the racers, coming in at number six, while **Ron Dennis** (number 10), **Ross Brawn** (number 18), **David Richards** (number 30), and **Frank Williams** (number 44) also feature.


John Gaw

LAT

The 2013 NASCAR Hall of Fame class has been announced, with legendary crew chief **Leonard Wood** and team owner **Cotton Owens** (see obituary) joining drivers **Buck Baker**, **Herb Thomas** and **Rusty Wallace** on the roll of honour.

NASCAR has added a new media award to its annual Hall of Fame event (see above). It will be called the Squier-Hall Award for NASCAR Media Excellence, named after its first recipients, broadcasters **Ken Squier** and **Barney Hall**.

Pirelli's motorsport division has appointed **Mathew Corby** to head up its activities at its Didcot, England, base, which is now set to expand to cover other motorsport operations beyond its core Formula 1 programme.


Roy Salvadori

LAT

Roy Salvadori, who won the Le Mans 24 Hours in 1959, and was also for a time the manager of the Cooper Formula 1 team, has died at the age of 90. As an F1 driver, his most successful year was 1958, when he stepped on to the podium twice and finished fourth in the championship.

Graham Macdonald is the new CEO of the Caterham Group – the parent company of the Caterham F1 team, Caterham Cars, Caterham Composites and Caterham Technology and Innovation. Macdonald, who was previously the CFO of Caterham Cars, replaces Ansar Ali in the role. Ali has now left the company.

Motorsport marketing organisation, JMI, has appointed **David Webb** to a new position of president, international. Webb, who will report to JMI founder and CEO, Zak Brown, was previously head of sponsorship at RBS, managing its title partnership with Williams F1, while earlier in his career he was also head of marketing at Jaguar Racing.

The Motor Sports Association (MSA) has awarded **Ken Blackburn** from the Isle of Man with its Officiel d'Honneur Award, which he has received for his 35 years of continuous service to the sport.

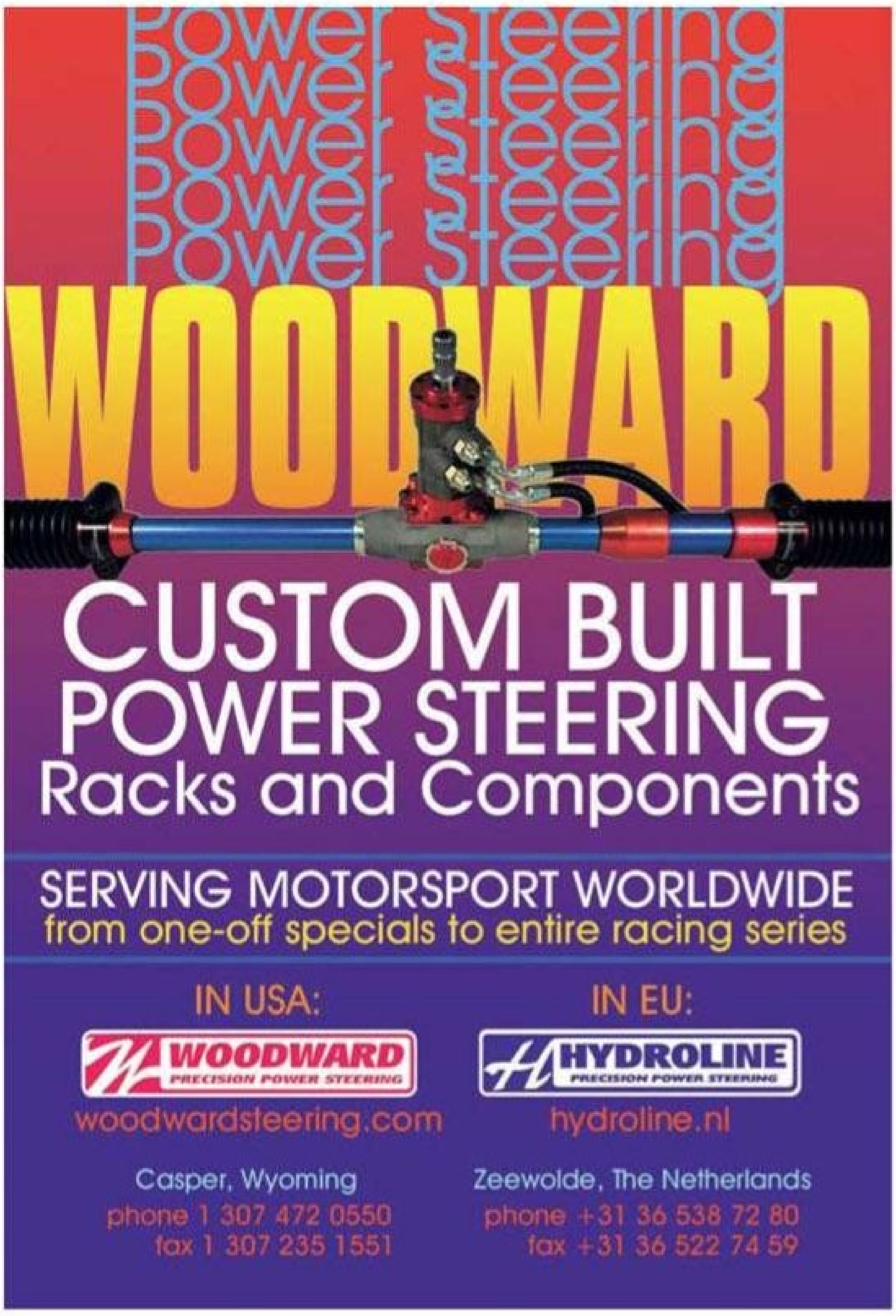
Aston Martin Racing managing director, **John Gaw**, took the controls of a Vantage GT3 car during practice for the Rockingham round of the British GT Championship. It's understood he plans to race in the series in a similar car some time later this year.

The road car arm of the McLaren Group, McLaren Automotive, which is responsible for its 12C sports car, has appointed **Mike Flewitt** as its chief operating officer. Previously Flewitt was vice president, manufacturing, Ford of Europe, and corporate officer, Ford Motor Company. Before joining Ford he held senior manufacturing and operations roles at TWR Group, AutoNova AB and Rolls-Royce and Bentley.

John Bagshaw, former managing director of Australian car maker Holden, and a man widely credited as one of the creators of the Holden Dealer Team, has died at the age of 87. Bagshaw was MD of Holden from 1987 until 1990, but he helped set up Holden 'Dealer' Team much earlier in 1969, as a way of circumventing a General Motors' policy that forbade works entries.

Nick Fry, chief executive officer at the Mercedes Formula 1 team, has been awarded an honoury degree from Cranfield University.

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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New Le Mans regulations could spell end for privateers

The new LMP1 regulations could spell the end for customer chassis in the World Endurance Championship's premier class, claims a leading team owner and racecar producer.

ORECA boss, Hugues de Chaunac, told *Racecar Engineering* he believes the new regulations have been formulated with the manufacturers in mind and he does not think future customers will be interested in taking part in a category in which they will not be able to compete.

De Chaunac, whose ORECA concern built the Formula Le Mans Cars and has run a number of top-line LMP1s, said: 'I don't have any plans for a customer LMP1 chassis because I think under the new regulations in LMP1, it really is a car for the manufacturers. Secondly, even today in LMP1, if you do not have a manufacturer engine, you cannot do anything, and I don't think in the future customers will be interested in LMP1.'

He added that ORECA will not be lost to the WEC, although it will now only race in the secondary class: 'We will continue in LMP2 because there is no change. Our car is homologated until 2015 and there probably will not be a change for the future because it is very important to control the costs.'

The new LMP1 regulations – which are examined in detail in the feature starting on page 45 – are based on a variable fuel allocation according to a car's energy recovery systems. They also call for all cars to be closed coupés, while the overall width is to be reduced by 100mm, both measures making older LMP1s obsolete at a stroke.

It is difficult to say whether any company could now build an LMP1 car for customers, with the recent loss of Lola – depending on the results of efforts to sell the company by its administrators – there are few concerns with the capabilities to produce an LMP1 car, and with little chance of a privateer being competitive, a customer base might be hard to find, even if a company should commit to a project.

Speaking of the Lola situation, de Chaunac said: 'The loss of Lola is very bad news because it is the name of Lola, but also because it is a strong warning for the racing industry. If such a company with such a big financial commitment goes, it is not good for racecar manufacturers.'

BRIEFLY

Filter company scoops award

UK-based performance and motorsport filter manufacturer, Pipercross, has picked up a prestigious export award in recognition of its sales performance overseas.

Pipercross was one of 100 companies to be awarded with the Queen's Award for Export, out of 10,000 originally listed. The Northamptonshire-based manufacturer – along with its parent company, Filtration Control Ltd – was recognised for its 'exceptional endeavours in creating new markets in 52 export regions.' It was one of just a handful of automotive companies to win the award.

Pipercross sales manager, James Pearman, said: 'We are delighted and honoured to receive this award, particularly when you see the other names that were in the mix. We are very proud to be a British manufacturer, creating jobs and helping to develop talent here in the UK. We still believe there is a place for hand-finished, precision engineered and British-made components on the world stage, and happily, this award reflects that. It's a great encouragement for us to keep pushing sales overseas.'

New motorsport development centre opens in Italy

A brand new advanced simulator centre for racecar and driver development has opened in Padova, northern Italy.

The Bhai Tech Advanced Vehicle Science Centre offers a state-of-the-art full motion driver simulator, proven simulation and modelling software, driver development programmes and a wide range of on and off-track technology services.

Bhai Tech has been set up by Ferdinando Bada, the head of automotive and motorsport supply companies, Bimecc Engineering and APP TECH, who has 30 years' industry experience, including co-ownership of a Formula 3000 team and, most recently, a GP2 team. Running the company on a day-to-day basis will be managing director, Keith Parmar, while technical director at the centre is experienced race engineer Roberto Costa.

Costa said of the initiative: 'Motorsport is rapidly changing and accurate simulation and exhaustive preparation are essential for teams that want more than an average performance. Bhai Tech is committed to researching and offering new, integrated methods to dramatically condense the learning process for drivers and engineers, as well as expanding their potential.

'Unlike most other motorsport engineering houses, Bhai Tech has been conceived from the outset to anticipate future needs and serve multiple customers with the most complete range of technical services, from under one roof. We are not tied to one customer, technology or area of expertise,' Costa added.

Bhai Tech uses a new 6-DOF driving simulator, developed with Cruden, set up for both driver and vehicle development in a formula car configuration. The simulator is fully immersive, with five off-board projectors and a 210-degree, 8m diameter curved screen. It also has many advanced features including a revolutionary harness loading system and a sophisticated rear view mirror set up, where the view behind the racecar is played through screens and reflected onto the simulated car's actual mirrors.

Bhai Tech's state-of-the-art simulator uses the latest immersive technology

HARDWARE

DC carbon coil packs

UK-based DC Electronics is now supplying carbon fibre coil packs, to provide a lightweight ignition solution. The packs, which weigh only 990g (2.18lb) come handed for left or right end cable connection with electrical connection via Deutsch Autosport connectors (pin out is directly compatible for NASCAR EFi applications). The packs are suitable for any four or eight-cylinder installations, with two packs required for an eight cylinder engine. Spark energy is 50mJ per cylinder for a primary circuit draw of 8.5amps. David Cunliffe, owner of DC Electronics, commented on the new design: 'This product has been produced using the Bosch P50 coil as sometimes they are difficult to mount. The majority of our customers were using four or eight-cylinder engines, so we designed the carbon enclosure to house four coils, making it quick and easy to change one if required. Carbon fibre has been used in order to save weight and we have added a layer of glass within the housing to reduce electrical emissions.'

See www.wiringlooms.com for more information

PIT EQUIPMENT

ATL Drum-Break

In many forms of endurance racing, overhead refuelling rigs, dump cans and vent bottles can still be seen throughout the pit area and, although the refuelling process has evolved over the years, one concern still remains – how to transfer the unused fuel back into a central drum or container for safe storage.

ATL have now developed a simple solution to this problem – the Drum-Break – a 2¼in or 1½in female dry-break receptacle that threads into the 2in bung of any conventional 15, 30 or 55-gallon steel drum, instantly turning that drum into a 'quick-fill' storage container for residual fuel. Race teams can now deposit any unused fuel in a fast, easy and safe manner.

In addition, ATL says the drum-break also provides a performance advantage, as race teams can now efficiently empty the vent line of their overhead rig in between pit stops, thereby ensuring the absolute quickest refuelling stop possible.

See www.atlinc.com for more information

HARDWARE

XRP check valve adapter

XRP have released a new adapter engineered to attach directly onto the Bosch factory check valve, included with its 044 fuel pump. The 044 is a very popular pump for motorsport use and features on many cars with fuel injection systems. XRP's new adapter allows you to maintain the factory performance capabilities of the Bosch pump because it works in cooperation with its stock check valve, but eliminates the need for an additional check valve elsewhere in the system.

XRP's check valve adapter is non-restrictive and threads directly onto the Bosch valve's M12 x 1.5 male thread, while outputting to a -10 female thread.

See www.xrp.com for more information

COMPUTER HARDWARE

dSPACE Scalexio

Test systems specialist, dSPACE, has recently released Scalexio, a new solution for scalable, hardware-in-the-loop (HIL) simulation of computationally demanding simulation models with large quantities of input and output (I/O) channels. Extensive models with numerous I/O channels can now be distributed conveniently across several processor cores to guarantee real-time simulation, while also providing adaptable failure simulation technology that scales with growing numbers of I/O channels.

There are two ways to distribute a model on the processor cores: one is to create the overall simulation model first and then partition it, the other is to design it as several sub-models from the beginning. The main advantage of the latter method is they can be developed and maintained simultaneously and independently by several teams, reducing the overall model development and validation effort.

See www.dspace.com for more information

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PIT CREW

Editor Andrew Cotton
Deputy editor Sam Collins
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Contributors George Bolt jr, Lawrence Butcher, Ricardo Divila, Alan Lis, Simon McBeath, Danny Nowlan, Mark Ortiz, Paul Trusswell, Paul Weighell, Peter Wright
Photography LAT, WRi2
Deputy managing director Steve Ross
Tel +44 (0) 20 7901 8011
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Head of business development Tony Tobias
Tel +44 (0) 207 901 8026
Email tony.tobias@chelseamagazines.com
Advertisement Manager Lauren Mills
Tel +44 (0) 207 901 8026
Email lauren.mills@chelseamagazines.com
Publisher Simon Temlett
Managing director Paul Dobson
Editorial
Racecar Engineering, Chelsea Magazine Company, Liscartan House, 127-131 Sloane Street, London SW1X 9AS, UK
Tel +44 (0) 207 901 8000
Advertising
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Dying to use diesel

Much has been made of the development of diesel technology in motor racing since Audi debuted the technology in 2006, but on the Tuesday of Le Mans week, the World Health Organisation (WHO) fired a torpedo across the bows of the German marketing campaign with a report that linked the fumes from diesel engines to lung cancer and potential bladder cancer, too.

The news hit the French headlines, just as Mazda announced it was developing a production-based diesel engine for LMP2 running at Le Mans. Diesel exhaust fumes have been re-classed as carcinogenic to humans (Group 1) based on sufficient evidence that exposure is associated with an increased risk for lung cancer. This was an increase on the 1988 finding that diesel was *probably* carcinogenic to humans (Group 2A). The fumes from petrol, meanwhile, remained unchanged from their previous listing as possibly carcinogenic to humans (Group 2B).

'There is a strong interplay between standards and technology,' read the report. 'Standards drive technology and new technology enables more stringent standards. For diesel engines, this required changes in the fuel, such as marked decreases in sulphur content, changes in engine design to burn diesel fuel more efficiently and reductions in emissions through exhaust control technology.

'However, while the amount of particulates and chemicals are reduced with these changes, it is not yet clear how the quantitative and qualitative changes may translate into altered health effects.

'In addition, existing fuels and vehicles without these modifications will take many years to be replaced, particularly in less developed countries... It is notable that many parts of the developing world lack regulatory standards, and data on the occurrence and impact of diesel exhaust are limited.'

For the naysayers, this was music to their ears. Diesel is not the future, it is harmful to health, and should not be put near a motor car, or a tractor. Or an underground mine. The immediate response from Audi's head of engine technology, Ulrich Baretzky, could never be published, but his on-the-record statement was scathing enough: 'First of all, the most dangerous thing is stupidity, and this by far kills more people than diesel engines. We have the big discussion of CO^2 and how the automotive sector is destroying our environment. The reality is that the output of all transportations, including airplanes, ships, cars and trucks, is 12 per cent of CO^2 [produced in the world]. So 88 per cent is somewhere else – heating, industry or whatever. If somebody now comes and says that diesel engines are killing people, you have to look at how many diesel engines are in this 12 per cent. How many are built in China? And then you look at Audi, which is running Euro 5 and Euro 6. You can use these engines as an air cleaner in Peking. You have cleaner air behind than in front of it.'

"You can use these engines as an air cleaner in Peking"

Presumably, Audi's expansion into China is a positive step for the future of diesel engines, but the report looked into the health impact of diesel particulates, and exposure to the chemicals in diesel, including sulphur.

'We are racing here since 2006 with our diesel engine, and they made us prove that our exhaust is clean after the race,' continued Baretzky. 'I burned my fingers because even after an hour it was still very hot, but it was clean.

'The after treatment for exhaust gasses is huge. We have catalytic converters for the diesel engines, BlueTec, and we have particulate filters. If you had the car in the garage with the door shut, and you let the engine run, you would die of hunger, but you would never be poisoned by the exhaust. I never had the time to do it because it takes days to run out of fuel. Maybe I will come back from Le Mans 5kg heavier and my wife will send me to the garage, and I will come out three days later 10kg lighter, but if she asked me to do that I would be suspicious.'

Certainly, the existence of the report was a surprise to Bernard Niclot, technical advisor to the FIA. 'This will be analysed deeply by the manufacturers,' he told me at Le Mans. 'I am not sure the answer is to ban diesel, because there has been a lot of progress in terms of health. Personally, I believe diesel technology will continue because there are ways to address the health issues with filters and high pressure injectors.'

Rest assured, *Racecar Engineering* will follow up the contents of the WHO report later in the year.

EDITOR
Andrew Cotton

PAGID RS

Brake control from green light to chequered flag.

Pagid RS had a strong start
to the 2012 racing season
at the two classic US endurance races:
24 h Daytona – All of the top 6 finishers overall
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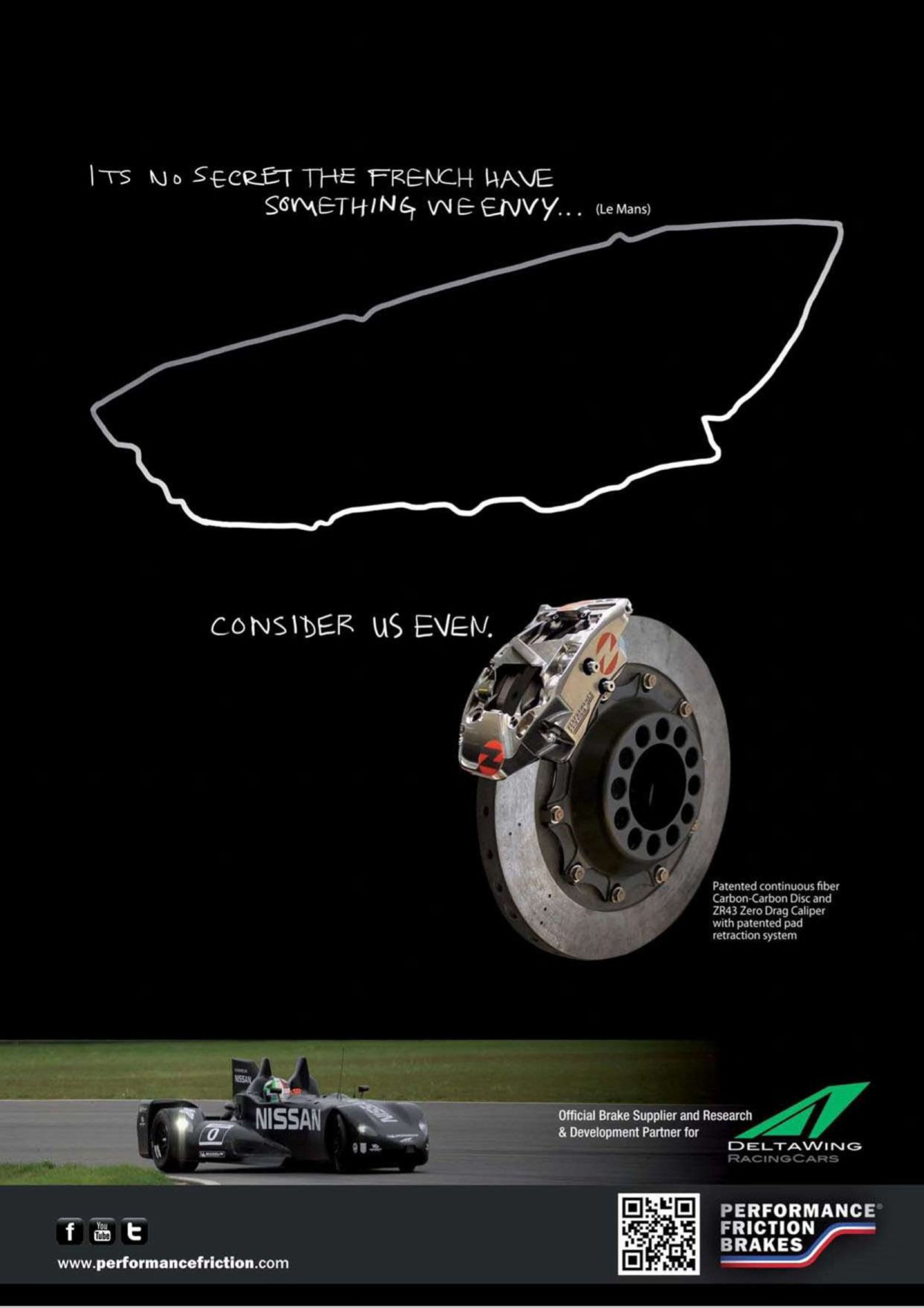
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