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LE MANS 2014

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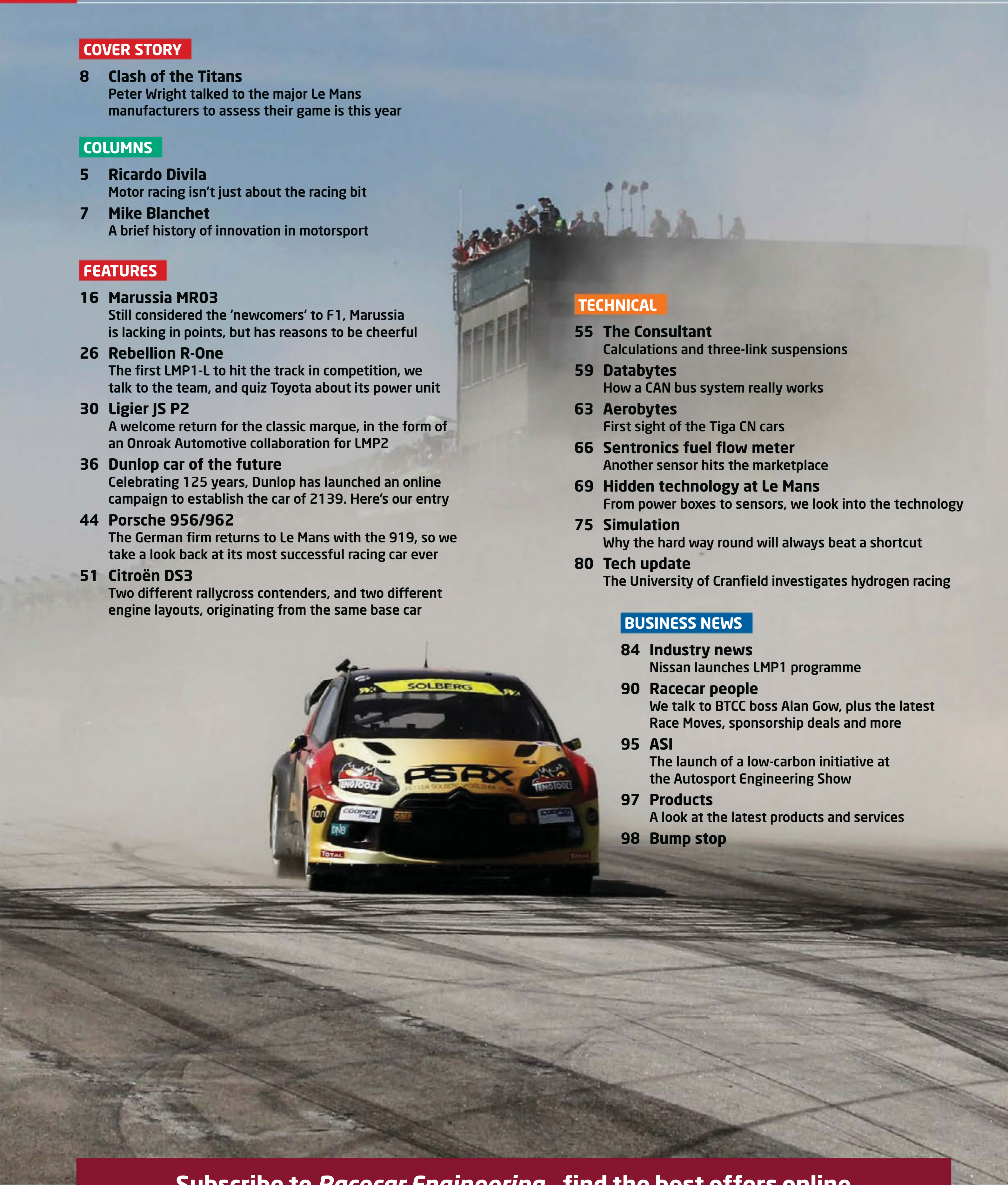


Racing's vicious circle

Keep spending, and remain competitive enough to keep the sponsors interested

In my early days of racing in Europe, I used to drive myself to the circuits, which gave me a lot of time to think. Nowadays, I fly to most of them, and apart from catching up with sleep, there is still some time available.

It is an occupation most of us do not take seriously enough. Ideas are easy – they have no mass, and they are unaffected by gravity. But most importantly, they don't cost anything except the sugar your neurones need. However, that is not a small affair, considering the brain is 2 per cent of the body mass, yet consumes 20-30 per cent of the calories and oxygen you intake.

Inevitably, my next thought will generally be about what the managing bodies of racing are thinking about the future of motor racing. The start of the racing season in GTs brought us to the usual sandbagging seen in Goldilocks racing, where cars from different manufacturers go through the usual motions of being weighed and restricted so they are not too fast and not too slow, but just right.

Having killed off several championships by dominating them, I can understand the need for a certain balance in production classes, where diverse cars aimed at different markets have different performance when translated into racing versions.

But the pinnacles of racing should be only restricted by the goal of going as fast as possible, within some accepted engine type, with a given capacity, or the quantity of energy that can be used during a race. Artificial maybe, but so is all sport, and even wars are bridled somewhat by the Geneva Convention.

There is a slew of Goldilocks racing – not too fast, not too slow, just right for the amateurs who finance the racing. Only some classes are not in thrall to the paying gentleman driver, but maybe his surrogate – the driver that brings sponsorship, and whose driving talents might be excellent in his home country. This scenario has come round time and time again, with the cost of racing now having escalated to the realms that only major manufacturers can pay for it, the odd billionaire being too transient in his enthusiasms to be a trustworthy long-term Maecenas.

It has also brought in a mode of racing which is biased towards giving sponsors entertainment and a nice day out at the track, but only if the surroundings are sanitised and suitably VIP labelled. Nothing wrong with that – a product is being sold, even if only image and vapourware – but the plain truth is that a standard F3 team now has a structure better presented, financed and crewed than a top F1 team of the 1970s.

The emphasis of presentation is not a necessity, merely an escalating vicious circle of costs. As teams fight to rake in paying drivers and sponsors, the peripherals start increasing, much as the toppings added to the American hamburger, that now when ordered with 'everything' can be a problem to eat in a low headroom building. But they do not intrinsically increase the performance or improve the driver experience. It seems that more money is spent on track event and corporate guest buildings than on track facilities.

The sight of a series of immaculate truck cabs lined up with the associated semi-trailer behind it in the paddock gives me more an impression of a vast logistical exercise than something dedicated to sport. The crowning touch, rapidly proliferating now, is the immaculately trimmed potted shrubs flanking the passage between the obligatory pair of artics in the back of the pits.

Perhaps the reasonable way is to look at the cost of racing relative to the world's GNP, or the number of spectators as a percentage of the world's population. The return from each fan is several orders of magnitude bigger than that achieved by the spectators at the first GP at Silverstone in 1950.

Keeping the audience interest by esoteric methods – ie double points for the last race to ensure that the championship goes to the wire – is logically justified, much as our sporting instincts might bridle at it. Remember: racing is now an entertainment business rather than a sport.

XPB

Michelin star food is *de rigueur* in motor racing paddocks around the world

Racing is now an entertainment business rather than a sport

F1 differs from football – and other team sports – because the fruits of the audience appeal does not percolate back to the teams themselves. The relative percentages of income that goes to them is a much smaller fraction of the pot, with the added aggravation that motorsports – due to the sheer costs of the equipment – dwarfs sports where the principal ingredient is the individual sportsman, sportsmen that are exceedingly well paid, admittedly, but still – percentage-wise relative to turnover – quite small in the total costs.

Some manufacturers have made a very successful use of other sports to enhance the brand – Ferrari being the prime example, not using any advertising at all, but trading on name recognition related to sport. Others have used a full spectrum approach by integrating all channels of media to sell their image.

Branding is a slippery concept, but still primordial. Name recognition plus image helps sell a product. 'What is in a name,' asked the Bard, 'a rose by any other name shall smell as sweet...' But how else do we explain the Skoda Octavia, based on the same platform and running gear as the Audi A3, but also the Audi TT, VW Golf, VW Jetta, VW Eos, VW Tiguan, VW Touran, VW Scirocco, SEAT León, SEAT Toledo, SEAT Altea, selling for a different price and a different market, but intrinsically the same car? Why does Porsche keep on selling the 911, which is light years removed from the original product but retains its 1950s brand image?

Of course it includes the peril that your brand gets thrashed by other brands, bringing negative connotations to your image, which is why when they are involved in racing, manufacturers will throw everything into the pot and more, to prevail. A perfect mechanism for price escalation.

So there you have it, sport sponsoring is logically untenable, but very effective in reality, with the caveat that you win. Accepting these constraints almost inevitably leads us to the conclusion that ultimately the return from spectators be shared equitatively between the participants, therefore financing the base of the sport by having the organising entity receiving a proportion of it and redistributing it to build up the grass roots, creating the next generation of participants and crew at a reasonable cost. So we reach the ultimate conclusion – motor racing must be wrested from the banks. Easy, *n'est ce pas*?


SUPERTECH

Advanced engineering

Evolution and innovation has always driven racing – but what's the next giant leap?

Peering into the cockpit of the latest Porsche 919 LMP1 at Silverstone, I was struck by the ever-increasing complexity of instrumentation, displays, cameras and so on. How totally different from its proclaimed ancestor, the revered 917. Even in its day, this brute was remarkable for the sheer starkness of its cabin with the absolute minimum of instrumentation and controls. It prompted me to acknowledge the quality of racecar engineering that we now take for granted, as well as how this has moved in cycles over the last century.

The very first racing automobiles produced around the turn of the 20th century were crude, heavy and still influenced by their horse-drawn carriage ancestors. Cast iron chassis and engine parts were prevalent. But surely there has never been a time in motor racing when inventors and engineers could have such a clean sheet on which to work, when fundamental concept, design and manufacture was so open, free and ready to be discovered?

The first world war drove advances in materials and processes, and designers of racing machines on both sides of the Atlantic took advantage. This represented a huge engineering step forward – away from the previous 'blacksmith' approach – and promoted a variety of often eccentric solutions to the objective of going faster.

The hum of lathes and milling machines now filled the workplaces. What fun the creators must have had – along with the inevitable blood, toil, tears and sweat that anything to do with racecars entails. Supercharged motors, higher compression and more revs - imagine some of the spectacular test-bed explosions that took place in fume-filled sheds around Europe and America... danger wasn't just on the track! The engine men weren't having all the glory. Having found that going like a dingbat on the straights wasn't key to winning on a track with real corners – the importance of handling and braking hit home. Oh to be a talented engineer in those exciting times – perhaps working at the sharp end of aeroplane development as the day job, doing the same for racing machines in the evenings and weekends. Rose-tinted spectacles? Probably.

The real seismic shift in racecar engineering occurred in the 1930s via the fearsome Silver Arrows. With massive R&D facilities behind them, Mercedes-Benz and Auto Union brought science into the sport, replacing a largely artisan approach. It all became a bit serious, but the cars laid the foundation for design for two decades to come – low and streamlined due to stiffer twin-tube chassis and dry-sumped blown vee-engines, limited-slip differentials, hydraulic brakes and more supple independent suspension. Not a bad move with over 640bhp on tap. The sheer quality of the open chequebook engineering impresses even now.

After 1945, Alfa's 158 pre-war hope for taking on the Silver Arrows dominated initially. New regulations banning supercharging meant that engine development then focused on better breathing, increased compression and higher RPM, with Ferrari and Maserati leading the way. Lighter multi-tube spaceframe construction took over but designers had learnt from the past, using De Dion rear and front wishbone suspension. However, with nothing like the same resources and driven by commercial as well as sporting considerations, equally there was nothing like the same attention to testing and detail, and reliability often suffered. Some of the 'engineering' took place ad hoc on the shop floor – it was a time of some retraction from the outstanding work of the 1930s. Mercedes returned to GP racing in the mid-1950s and innovation re-appeared, but detail engineering was as much a cause of it cleaning up in sportscar competition as well. Their brief interlude shook up the sport and made it more professional. Vanwall undertook serious aerodynamic research into drag reduction, Jaguar had already led the way at Le Mans.

TMG

Advanced wind tunnels have helped with aerodynamic development

Ferrari, meanwhile, upped their game overall and designed a very effective GP car.

When Cooper proved that you don't have to be fancy to be fast with its mid-engine F1 cars, racecar engineering took a backward step again. The cars were crude – no beautiful forgings and machining, instead an inelegant if rugged tube chassis and simple suspension parts, some from road car parts bins! Nevertheless this set the pattern, in increasingly refined form, until Lotus introduced the monocoque chassis, soon combining this with the DFV engine as a fully-stressed member and ratcheting up the engineering game anew. This concept became the standard, including in IndyCar and sportcar racing, through into the 1980s. New CAD-CAM tools permitted more complicated fabrications and billet-machined parts, encouraging higher engineering standards even in production racecars, typified by Lola and others.

The real seismic shift in racecar engineering occurred in the 1930s via the fearsome Silver Arrows

THE AERO ERA

When wings and ground-effect meant that aerodynamics began to dominate racecar performance, the peripheral tools such as moving ground wind tunnels became of much greater importance, inserting a new layer of engineers not directly concerned with the car design itself. Honeycomb aluminium, then carbon composite monocoques and bodywork/wings became essential, bringing a significant advance in fit and finish as well as scope for more complex shapes.

Just as science changed motor racing engineering, so too did technology. The advent of the micro-chip brought the most up-to-date computer technology into racecar engineering and operation, including use of sophisticated simulation tools. Yet further layers of engineering have been required, and a further step up in racecar quality achieved. And not just at the highest level – Dallara's F3 customer chassis for instance is a little jewel.

Energy efficiency is where we are now, racing cars incorporating energy recovery power units and software control of many elements that were previously unimaginable. In the search for optimising every performance advantage, engineering quality has reached a new high, the latest F1 Silver Arrows, as with the LMP Audi (Auto Union), superior even in context to their fabulous 1930s forebears.

Where will it go next?

The question of equivalence

EoT has caused headaches for teams, but could result in some close and fascinating racing

BY PETER WRIGHT

IMAGES: XPB

"The handicappers have learnt a trick or two, and they know that the only time the true performance will be displayed by the competitors is at Le Mans"

Having spent several years running the FIA's GT Balance of Performance (BoP) programme that enabled the phenomenal growth of GT3, I gained an intimate insight into the intricacies of trying to provide a close competition among extremely technically diverse cars, raced by highly skilled and competitive people.

It was a game that someone named 'Fool the Handicapper'. The handicapper (the FIA) can pretty accurately balance the demonstrated performance of each car, using sophisticated simulation and validation tools. However, the skilled competitor will try and stay one step ahead by dribbling out, race by race, the performance he has up his sleeve, only demonstrating enough to stay under the handicapper's radar. Some of the chief protagonists were very good at it.

The FIA's two new-for-2014, prime championships - F1 and WEC - are both balanced formulae, to a greater or lesser extent, but one is not allowed to call it BoP. In the name of cost control and close racing, F1 has very restrictive technical regulations permitting only major developments in the induction-combustion-exhaust system and in the integration of ERS systems, which mainly involves software. If not messed about with by people with other agendas, this will produce close performance from the four powertrain suppliers in the long term, even if Mercedes' technology and its ability to integrate combustion engine, electric power systems and chassis is currently 1-1.5 seconds/lap ahead of everyone else.

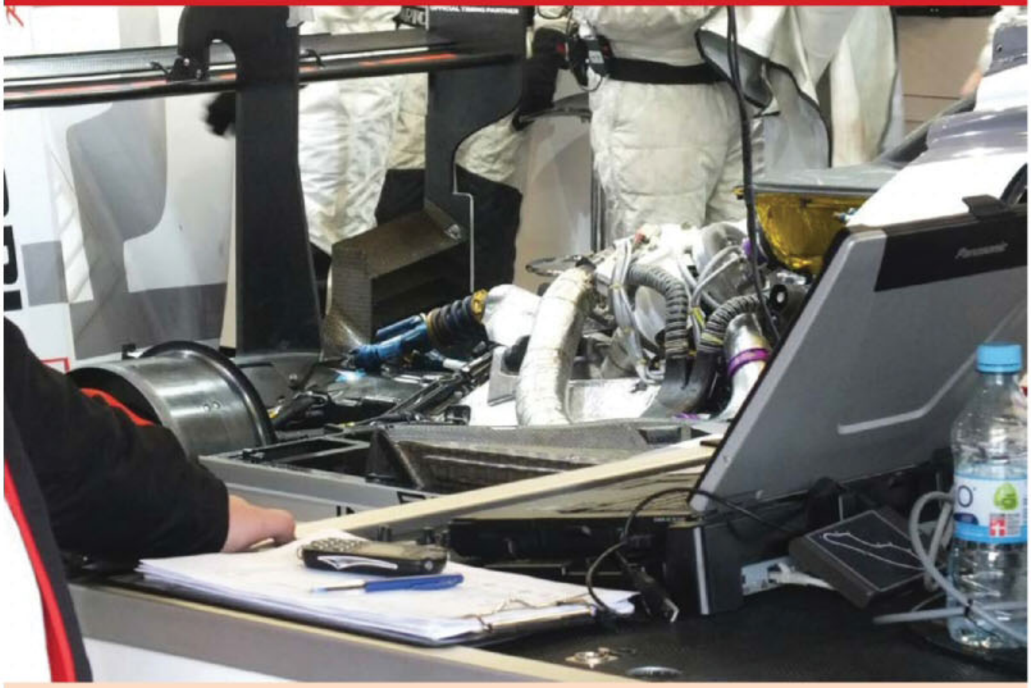
In contrast, the WEC regulations, jointly drawn up by the FIA and ACO, approach the issue very differently - and for very good reasons. Because the ACO wants to attract manufacturers to Le Mans, they have offered them the opportunity to showcase the diverse solutions to their road cars' environmental challenges in a way that gives an equal opportunity to be competitive and win races. 'Bring what you've got, and we will balance it.' Of course, it's not BoP, but rather EoT - or Equivalence of Technology - and a mighty complex thing EoT turns out to be.

The EoT regulations run to seven pages of definitions, rules, equations, and references, plus additional files of Parameters, Sensor Lists, Fuel Flow Metering Processes, Torque Metering Processes, Powertrain-ERS and Weight Parameters. These are combined by computations of Fuel technology factor (FTF), K technology factor (KTF), ERS incentives, and penalties for trying to fool the handicapper, and so the various technology combinations are balanced. Ricardo Divila's brilliant synopsis in April's RCE set out to explain this in plain English.

By these means, diesel and gasoline; NA and turbo; V4, V6, and V8; exhaust gas energy recovery or not; single and twin ERS-K's; flywheel, battery and ultracap energy storage systems; 2WD and 4WD are all permitted and encouraged, and given equal chances of winning Le Mans and the WEC. Manufacturers must declare what they will run, including how much recovered energy they will use per lap, and have their arrangements homologated each year. But the handicappers have learnt a trick or two: they know that the only time the true performance will be displayed by the competitors is at Le Mans, because Le Mans

The 2014 Audi R18 and Toyota TS040 toughing it out during round 2 of the WEC in Belgium

PORSCHE'S TRICK SUSPENSION



Porsche has developed what is considered to be a trick suspension system. It attempted to patent the system in Korea, but the patent was rejected. Unfortunately our Korean is not sufficient to work out why the application failed. 'This looks like a self-levelling system to me,' says our technical consultant Peter Wright. 'The description seems to indicate that the levelling cylinder is in series with a spring, which connects to each end of the ARB. The suspension seems to meet the regulations, provided it has fixed characteristics.' At the Spa 6 hours, Porsche had a rear damper failure, yet was able to change it quickly.

'Changing a connected actuator is quite an issue, as the volume of hydraulic oil in the connecting hoses is critical,' says Wright. 'Also, any air in the system would affect it.'

is the event that counts to the marketing departments, and the other races are really just preludes to Le Mans and R&D for the following year. After Le Mans, the Endurance Committee of the WEC issues the EoT in the form of a table of fuel energy per lap and instantaneous maximum fuel flow for each 'class', diesel and gasoline, and the selected ERS energy/lap: Appendix B of the Technical Regulations. This is then firm for 12 months, until after the next Le Mans.

Of course, this is not going to work for the first year of these regulations, 2014. Originally the Endurance Committee stated that it would monitor performance through testing, the first two races and the Le Mans test in order to finalise the EoT for Le Mans this year. It would even impose penalties if necessary during the race. Under pressure from the manufacturers, they have fixed the EoT just prior to the Ricard test in March, based on data supplied to them by the manufacturers and following homologation of each car. Some final tweaking of the figures may have occurred subsequent to the test, with the final publication of Appendix B on 7 April 2014. Hence the need for the threat of penalties, ie 'don't you dare exceed your supplied data!'

POWER STRUGGLES

To enable such a system, each car is effectively a mobile powertrain dynamometer. The power of the combustion engine and ERS motor/generator(s) are continuously measured and telemeted to the FIA/ACO, along with the instantaneous and accumulated fuel flow figures. There are two new key sensors – fuel flow rate and torque – to go along with all the usual ones of RPM, temperatures, electrical volts and amps. Doubts have been cast over the maturity of the Gill fuel flow sensor, as well as the stability of the torque sensor, and one must hope that these issues are resolved before they dictate the result of the sporting contest.

To go off somewhat on a flight of fancy, there is a big game that takes place at the ACO saloon. It is not the biggest game in town, but there are some high rollers at the table. The game is called LMP1, a Franco-German adaptation of poker, and it has been played for a number of years now. There are only ever two or three big players who are prepared to bet large stakes, but there are always a few smaller gamblers with smaller stashes, which they lose. The big winner of the last few years is Diesel Audi, and in some years he has had no other big gambler to play against. A couple of year's ago there was Diesel Peugeot, but he left in the middle of a game claiming urgent business to attend to back at the ranch. His seat was quickly taken by Gasoline Toyota, a player with a very different style to Diesel Audi. Just recently, the saloon doors swung open, and in swaggered Gasoline Porsche – a seasoned gambler who has been away playing some of the other games in town. Now related by marriage to Diesel Audi, he sits across the table close to Gasoline Toyota. The only sign that Diesel Audi acknowledges that the stakes have just gone up significantly is that his eyes have narrowed to the gap between a piston and its liner at full power. Why are the two gasolines sitting so close? Could they possibly see each other's cards?

SHOWING YOUR HAND

The dealer is ACO, owner of the saloon. Recently, however, he has been using card decks supplied by the new sheriff, FIA, who has stated his intention to ensure fair play, and consequently fewer shootings.

Each player is dealt three initial cards: the Technical Regulations, the Sporting Regulations, and the EoT regulations. They are the same for all players. Each places his bet, registered in a process known as homologation. The next part is a little strange – each player gives the dealer a card with his performance secrets listed on it, and the dealer gives him back a card with his energy allocation detailed. This is what's known as the Appendix B card. What is odd is that after they have handed in theirs, all the players see each others' performance cards, and the Appendix B cards dealt by ACO (what influence does the sheriff have?). In previous years, players have been able to add to their bets before the final showdown at Le Mans, where the winner takes all. This year, something's happened and Diesel Audi's eyes have narrowed to such an extent that his pistons may seize.

All the manufacturers have been deeply involved in drawing up the Technical Regulations and the EoT process and equations. As you would expect, although they are head-achingly complex and so dependent on critical

One must hope that issues with the fuel flow and torque sensors will be resolved before they dictate the result of the sporting contest

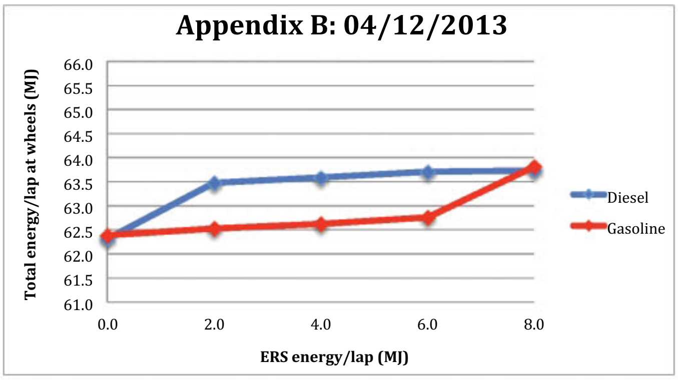


Figure 1: preliminary Appendix B figures for the run-up to 2014

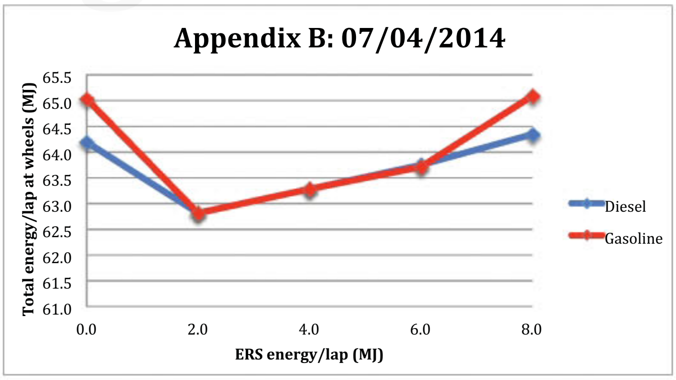


Figure 2: the latest, and final, figures for Le Mans 2014

sensors, they are also very soundly based. Without this level of complexity it would not be possible to fairly balance the performance of such wildly different technology packages.

I will try and put the EoT into a single, short paragraph (if Genesis 1 can describe the creation of the World in under 800 words, how can the EoT take more?).

It basically states that: the energy density of diesel will be balanced against that of gasoline; the efficiency of the state-of-the-art diesel engine will be balanced against that of a gasoline engine; the weight of the state-of-the-art diesel engine will be balanced against that of a gasoline engine, because this dictates the mass available for energy storage within the minimum weight; there will be an incentive to select the higher levels of energy storage. After computation according to natural laws, a table of instant and per lap fuel energy flows, and fuel tank sizes listed for each fuel type and ERS class will be issued, as Appendix B.

The potential problems lie in the different timings of the homologation period (February/March each year for 12 months) and the EoT period (post-Le Mans each year for 12 months). On top of this, there has been some difficulty in establishing Appendix B figures for all of 2014 through to post Le Mans 2015. The mismatch of cycles does not encourage competitors to be highly fuel-efficient this year. The Brake Specific Fuel Consumption (BSFC), as calculated from the data generated by the mobile dynamometers in each car, are all balanced out in the FTF calculation, and so high efficiency is not rewarded. Giving away too much efficiency technology in 2014 doesn't make sense as it can be fed in from the start of 2015, under a new period of homologation, and run at Le Mans that year with 2014 EoT energy allocations. The real efficiency challenge starts in 2015. The ACO says it doesn't want to see any big steps in technology introduced in 2015, defined as greater than 2 per cent. But surely that is the point of the competition? Surely at some point manufacturers will want to show that their technologies are actually better than the others?

Manufacturers will eventually want to show that their technologies are better than the competition

In December 2013, the FIA first published a preliminary Appendix B for the run-up to 2014 – see **Figure 1**. To make sense of these numbers, I have turned them into MJ of energy/lap available at the wheels, plotted against ERS class for diesel and gasoline. To do this, in the absence of knowledge of the factors that the FIA has applied, I have had to make a couple of assumptions. In the early draft of the regulations, the BSFC values used for the diesel and gasoline engines were stated, along with the energy density of the two fuels to be used at Le Mans. From this, one gets the fuel energy available at the wheels, give or take some mechanical transmission losses. I then assumed that the FIA has set out to balance diesel against gasoline at 2MJ ERS, which is the minimum allowed to the manufacturers, and that in the latest, 07/04/2014 Appendix B they are made to be exactly equivalent. This required me to make a small correction to apply to the latest data available, but only 0.5 per cent.

SWITCHING SUMS

I have assumed that the ERS energy/lap is measured pretty close to the output of the motor/generator(s), and so I have given it 100 per cent efficiency, give or take some mechanical transmission losses. Applying the same correction factors to the 04/12/2013 Appendix B figures, gives the plot shown in **Figure 1**.

It would appear that the 0MJ ERS Privateers' cars have been balanced, even though there are no diesels, and that the FTF and KTF used have favoured the diesel at the stage when these figures were published. The slope, or ERS incentive, is small at 0.05MJ at the wheels per MJ ERS, until gasoline gets to 8MJ, at which level it catches up with the original deficit to diesel. It is on these figures that Audi chose just 2MJ of ERS, and that makes some sense – more on this decision later.

The latest, and final figures for the 2014 Le Mans give a very different picture – see **Figure 2**.

The 0MJ ERS figures give 0.8MJ/lap more to diesels, possibly to compensate for greater weight. The manufacturers, who must have hybrid systems, become equal at their base line 2MJ ERS (this is of course the assumption I made earlier). This has been achieved by changing the combination of FTF and KTF by 1.6 per cent in favour of gasoline compared to diesel. Both then gain 0.225MJ/lap at the wheels per MJ of the ERS selected – a significantly increased incentive – until 6MJ, where gasoline again jumps an extra 0.8MJ/per lap. Why? Possibly because in practice only the gasoline cars could possibly run at 8MJ and the FIA/ACO wanted to provide a big incentive for them to do so.

With the unanimous view among manufacturers that 1MJ of ERS equates to 0.5secs per lap at Le Mans, this means that 0.25MJ/lap at the wheels equates to 0.5secs per lap. On this basis, using the earlier 04/12/2013 Appendix B figures, Audi had 63.5MJ per lap at the wheels having selected 2MJ ERS, and Toyota and Porsche would have had 62.8MJ, both having selected 6MJ. Advantage Audi, by 1.4secs per lap.

According to the latest 7/4/2014 Appendix B, Audi has 62.8MJ per lap at the wheels compared to the gasoline cars' 63.7MJ. Audi's advantage 1.4secs per lap has, theoretically at least, turned into 1.8secs per lap deficit – or nearly 4 laps after 24 hours. No wonder their trigger finger is getting twitchy. They made a decision to select to run at 2MJ ERS based on one set of figures, and found themselves at a significant disadvantage according to the final figures. The fact that the final figures represent a pretty good balance between diesel and gasoline hybrids is probably of little comfort to them.

Now let's look at how and why Audi went for such a low ERS selection, and only a single

ORIGINAL APPENDIX B VALUES OF ENERGY AND POWER FOR LE MANS

		No ERS	ERS OPTIONS			
Released Energy	MJ/Lap	0	< 2	< 4	<6	< 8
Released Power	kW	0	Not limited	Not limited	Not limited	Not limited
Car Mass	kg	850	870	870	870	870
Petrol Energy	MJ/Lap	150.8	146.3	141.7	137.2	134.9
Max Petrol Flow	kg/h	95.6	93	90.5	87.9	87.3
Petrol capacity carried on-board	l	66.9	66.9	66.9	66.9	66.9
Fuel Technology Factor	-	1.061	1.061	1.061	1.061	1.061
K Technology Factor	-	1	0.983	0.983	0.983	1
Diesel Energy	MJ/Lap	142.1	140.2	135.9	131.6	127.1
Max Diesel Flow	kg/h	83.4	83.3	81	78.3	76.2
Diesel capacity carried on-board	l	54.8	54.8	54.8	54.8	54.8

AMENDED APPENDIX B VALUES OF ENERGY AND POWER FOR LE MANS

		No ERS	ERS OPTIONS			
Released Energy	MJ/Lap	0	< 2	< 4	<6	< 8
Released Power	kW	0	Not limited	Not limited	Not limited	Not limited
Car Mass	kg	850	870	870	870	870
Petrol Energy	MJ/Lap	157.2	147.0	143.3	139.5	138.0
Max Petrol Flow	kg/h	100.9	94.3	91.9	89.5	88.5
Petrol capacity carried on-board	l	68.3	68.3	68.3	68.3	68.3
Fuel Technology Factor	-	1.074*	1.074	1.074	1.074	1.074
K Technology Factor	-	1	0.987	0.987	0.987	1
Diesel Energy	MJ/Lap	146.4	138.7	135.2	131.7	128.5
Max Diesel Flow	kg/h	84.6	80.2	78.2	76.1	74.3
Diesel capacity carried on-board	l	54.3	54.3	54.3	54.3	54.3

ERS, where two are permitted. Though wary of saying so directly, Audi has never been overly keen on hybrids, believing them to be a drift away from true efficiency and only viable on road cars to enable CO_2 targets to be met.

For endurance racing, they do not like equalisation of the minimum weight irrespective of technology. Hybrid technology is heavy, and costs 0.4 secs/lap per 10kg at Le Mans, and they would rather run light; hybrid systems must justify their mass. Diesel technology is also heavy (30 to 50kg heavier compared to gasoline) and adding ERS is yet more mass. Audi has also put a premium on reliability, enabling them to win Le Mans on more than one occasion when they have not had the fastest car. The decision to select the 2MJ ERS class must have been taken by Audi quite early on, as down-rating the motor/generator, flywheel storage, cooling etc could not easily be done at the last minute.

They tested with an ERS-H unit fitted to the turbocharger, but the rear biased weight high up in the car compromises other performance parameters. With no direct feed from the MGU-H to the MGU-K, additional inefficiency is introduced compared to the arrangement permitted in F1. The uncertain reliability of an 100,000rpm, hot electric machine also made them lean away from deciding to race with it. The original Appendix B numbers indicated that 2MJ would be sufficient, delivered through the front wheels. Discovering it might not be was a surprise, and Audi does not like surprises this close to the start of the season, and particularly post-homologation.

Toyota, my dark horse for 2014, was originally thought to be going for 8MJ, with their two powerful ERS-K systems. With over 1000cv available for some of the lap, the car will be very effective in traffic, a key element of the 24-hour race at Le Mans. Although very different to the Porsche, Toyota's gasoline competitor, they are considered to be in the same class, and the car with the best FTF and KTF is used to set gasoline vs diesel equivalency. The second best suffers in comparison. Pascal Vasselon warned me not to assume that the Toyota's big, NA V8 was any less efficient than Porsche's tiny, turbo GDI V4. As he explained, big lazy engines are the way to go for racing, which is 60 to 70 per cent full throttle. Downsized turbos are better for part-throttle road use. Which engine is actually more fuel efficient, he declined to say.

Toyota has chosen 6MJ, perhaps based on the predicted ability to recover brake energy at Le Mans, and because its systems – both IC engine and ERS – are proven technology. That is the other reason why I consider Toyota to be the dark horse. Toyota has focused on aero development, which is likely to be a significant differentiator in 2014, where everything else is balanced.

Audi has never been overly keen on hybrids, believing them to be a drift away from true efficiency

KEEPING COOL

Porsche intended to go to 8MJ, but testing showed up a cooling issue in the electrical system – they didn't say if it was in the MGU, battery storage, or electronics. When Toyota selected 6MJ, they heaved a sigh of relief and went for 6MJ as well.

Apart from the ERS class, Porsche has gone its own way in most things. After an initial severe vibration problem with the V4, a redesign has given them a compact engine with apparently good power. Their ERS-H system is unusual in that the second turbine is separated from the turbocharger and it alone drives the MGU (actually just a GU!). Just how much peak power this is rated at, and how many MJ per lap it harvests from the exhaust are not divulged. I was told that these devices are rated at 90kW, but do not necessarily run at this level.

Porsche has demonstrated speed, but are speaking cautiously about reliability. The vibration issues lost them six months development and they are only newly returned to endurance racing at LMP1 level. The team has many F1 people in it, not surprising considering Alex Hitzinger's recent history, and they are all adjusting to the different demands of 12 times the life of many components. But they are learning fast.

One could believe that the performance success of the cars is simply down to the engineers, particularly the software developers. As in F1, that would be to overlook the enormous contribution of the drivers, and to underestimate their importance to the development of the cars, both in the simulator and on the track. Listening to them speaking, and sometimes not saying things at Ricard was revealing. With only Audi's drivers having previous experience of a 4WD LMP1, the Toyota and Porsche

Porsche planned to go to 8MJ in the WEC, but following cooling problems, they were relieved to join Toyota in the 6MJ category

drivers hinted at not really liking the way the torque was delivered to the front wheels. Being used to exiting a corner on the throttle, balancing the rear axle with steering, the torque fed into the front wheels results in understeer. The power of these new cars, particularly the Toyota, means that they must be straight before unleashing full throttle – and then 'whoosh!' This is more typical of the way heavy, powerful cars are driven, and yet the most efficient use of fuel is to maintain a high cornering speed, as with an underpowered racing car: remember Mini vs Galaxy?

The smaller tyres for 2014 and the lower brake temperatures due to greater brake energy recovery means less grip, which is not helped by less downforce. That has also limited the amount of brake energy that can be recovered. Drivers have had to re-learn tyre temperature management. Some claim that the simulator is not variable enough to teach the driver to manage the fuel consumption. They believe that drivers can learn very quickly on track and become very accurate at sticking to the allowance per lap. It is not only essential to not use too much fuel, but also not to use too little. The allowance is per lap, and underuse cannot be recovered later – very different from F1, where the total allowance is for the whole race.

NEED TO KNOW

Of course the engineers wish to help the drivers drive accurately to the fuel schedule, and all manner of displays are being evaluated. The trick is to give the driver just the information he needs without distraction, particularly at night. Ultimately the control of fuel use is down to the driver, and he can always override the software to demand absolutely full power in a situation where safety is involved.

The cars are now homologated and the EoT values issued. By the time you read this, the first two races at Silverstone and Spa will have taken place and each of the three leading competitors will have shown a little of what they can do with the hands they hold, but they will not have shown everything. Perhaps the most important thing demonstrated is the reliability and repeatability of the key sensors – fuel flow and torque – to provide a fair sporting contest. The FIA fuel flow meter specification calls for ±0.25 per cent, and Gill has delivered this.

Audi's diesel requires two sensors to determine net fuel flow rate, and the return line sensor runs at cylinder head temperature, which is around 100degC. Each car also carries a spare sensor for comparison with the main fuel flow reading. Questions posed to the manufacturers about these sensors resulted in a tightening of the lips. If it proves necessary at any point to revert to the engine's own fuel flow systems, ie the injection systems, the accuracy falls to ±1-2 per cent, not good enough to regulate a sporting contest. 1 per cent power equates to about 0.5 seconds per lap at Le Mans.

Is Porsche ready for 24 hours against two manufacturers who are racing proven technology?

We will not get the answers to the reliability question: is Porsche ready for 24 hours against two manufacturers who are racing relatively proven technology?

We may learn whether the 6MJ cars are faster than a 2MJ one, and whether Toyota's 1000cv shows up under race conditions as a real benefit. I hope we will get a result that promises a fantastic technical contest in the WEC this year. And yet, there may be more to the contest than just winning the prize of Le Mans, or the World title. There is talk of the contest between Audi and Porsche being more than the VW Board hedging its bets on both gasoline and diesel. Whichever goes home to Germany with the prize will have achieved an enhanced technical status within the Group – a status that may affect technical leadership as the industry progresses further into new road car technologies.

There is also honour at stake. Porsche is the Le Mans legend, Audi the interlopers. Even if Cologne-based Toyota steals it from under their noses, it promises to be a Teutonic contest. Who'll be left standing when the gunsmoke clears?

Innovation on a budget

They might lack the financial might of some of their F1 rivals, but Marussia's engineering talent is looking to punch above its weight

BY SAM COLLINS

IMAGES: JAMES MOY

"We always strive to give our people freedom for creativity - and they come up with some very nice solutions"

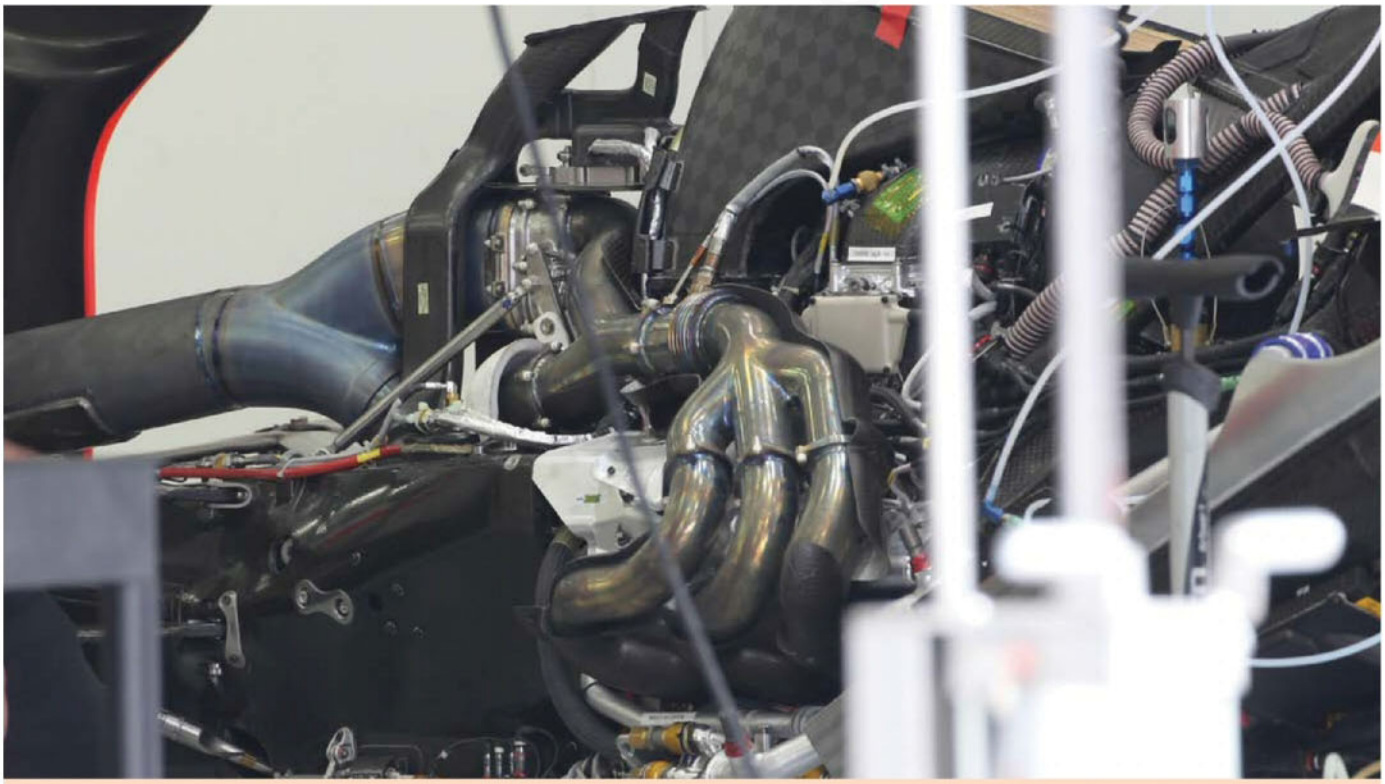
The Marussia Formula1 team started life in 2009 as Manor Grand Prix, an offshoot of the well-known Manor Motorsport junior formula team. Before it had ever taken to the track, investment from English entrepreneur Richard Branson saw it rebranded as Virgin Racing. Then, in 2011, the organisation became part of the nascent Russian supercar constructor Marussia Motors.Its latest car – named the MR03 – took to the track for the first time at the Jerez circuit during the official 2014 F1 pre-season test.

At first glance the red and black machine was a fairly conservative design, at least externally. But the bodywork masked what is one of the more interesting cars on the 2014 Formula 1 grid. 'This car is the biggest step we have ever had from the perspective of innovation,' says Dave Greenwood, Marussia F1's chief engineer. 'I think the scope of innovation on the car is testament to the people we have on the team. We work them incredibly hard, but strive to give them the freedom for creativity and they come up with some very nice solutions.'

Much of that innovation has been focused on integrating the Ferrari 059/3 power unit into the back of the car, a big task for a team that only utilised a 'KERS' hybrid system for the first time in 2013.

'Obviously there is help from Ferrari with the whole power unit but there is also a change in skills from our side in order to integrate that,' Greenwood continues. 'All of the systems that link up to the power unit we have to do ourselves by regulation – that means all of the cooling, the pipework, plumbing and pumps. That's all got to integrate with the Ferrari bits, which is not easy. It has placed a huge emphasis on our electronics guys.'

The only significant external sign of the work that the Marussia engineers have done on that integration is around the roll hoop and air box inlet of the car, which does not feature exposed supports like every other car on the grid, but instead has an additional pair of cooling ducts routed around the roll structure. 'We have done something there – a bit of innovation – and that's what you have to do to move forwards. We are really happy with what we have done there,'



EXHAUSTING POSSIBILITIES
Pictured above is the rear end of the MR03 with bodywork and heat shields removed. The exhaust layout is of particular interest – the headers curve around the cylinder head, and then join together in a collector (one on each side linking three pipes). Downstream of the collectors, the pipes then split in two. The Ferrari turbocharger is reportedly split in a similar – though less extreme – way to the Mercedes design, with the MGU-H sat between the two sides of the turbo. The pipes heading down to the turbo can be seen here. The other pipe heads upwards to a unit thought to be the wastegate. The left bank pipes enters this housing at its base, while the right bank enters it above. A single exit pipe joins with the pipe leaving the turbocharger.

says Greenwood. 'You can see the trend of what's behind the roll hoops, and ours is about providing ducting for some coolers. We determined that it was the best way to minimise the cooler volume within the sidepods of the car. It works really well, and we will use the same concept in 2015. We are not the only ones to do it, but ours is the biggest and we are using it to cool two really key systems.'

KEEPING COOL

Cooling the new-for-2014 power units is no easy task, as demonstrated by some of the very public difficulties experienced by other, bigger teams. But the Marussia has, according to Greenwood, been fairly strong in this department. 'The car cools well and the data we got from Ferrari was fine – no holes needed to be cut once the car started running,' he says. 'We have worked massively hard on it, and everything has been evaluated in terms of downforce vs cooling. That said, we were slightly conservative at the start of the year but are now testing things that gain back downforce at the expense of cooling.'

While it could be expected that the turbocharger itself would be the most taxing part of the power unit to cool – especially as it is buried deep in the bell housing region between the V6 engine and the transmission – Greenwood claims that other areas were a headache for Marussia. 'One of the biggest challenges is the amount of electrical boxes – there's a huge number of them, and cooling them is a big deal. The turbo is a factor too, but we have not really been involved with that as it is very integrated with the engine and gearbox.'

All of the different subsystems of the power unit have meant that the car needs a large number of heat exchangers, many with differing demands and locations. For efficiency reasons, the MR03 has not placed them all in the sidepods of the car, unlike some of its rivals. Nonetheless, the sides of the car are still exceptionally crowded. 'The sidepods are clearly different from side to side – there's a lot to package in there like intercoolers, watercoolers, oil coolers and gearbox coolers,' adds Greenwood. 'There are coolers for the hybrid system, including the energy store and both MGUs, and all of them require different types of cooling. Aerodynamically the sidepods have very similar performance, then it's just differences on how it's laid out.'

"We were conservative, but we're now trying to get more downforce at the expense of cooling"

With the cooling issue largely solved, Greenwood, chief designer John McQuillam and the rest of the Marussia team are looking at ways of improving performance, especially with the power unit, and in some areas that actually means reducing some cooling.

'Some of the electronic boxes are over-cooled, so we are finding ways of reducing that and getting some performance back. But the big task now is the mapping,' says Greenwood. 'When I say that, I do not mean the engine mapping specifically, but rather the way that the ERS is working, the diff and the general torque mapping for driver demand. We are collaborating with Ferrari on that and it's a big area of performance to unlock. That's what we are concentrating on, going into the second quarter of the season.'

As the MR03 uses the Ferrari carbon fibre transmission, it shares its inboard suspension pickup points and turbo housing with the Ferrari F14-T as well as the Sauber C33. It is the first time a Marussia – or Virgin – has used a composite main case, but it has not provided many challenges for the team. 'It is identical to the casing used by Ferrari,' says Greenwood. 'We buy

STOPPING THE MARUSSIA MR03

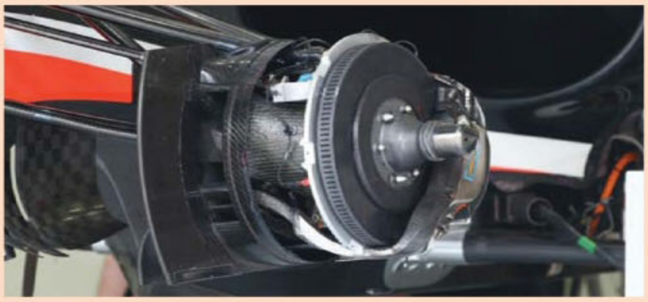
In Formula 1, most teams use friction material from either Carbon Industrie or Hitco, with a few – including Marussia – also using Brembo when the situation demands. In theory this means that the braking of the car should not really be a factor, but the introduction of the new hybrid power units in 2014 has raised a number of issues with a car's braking system.

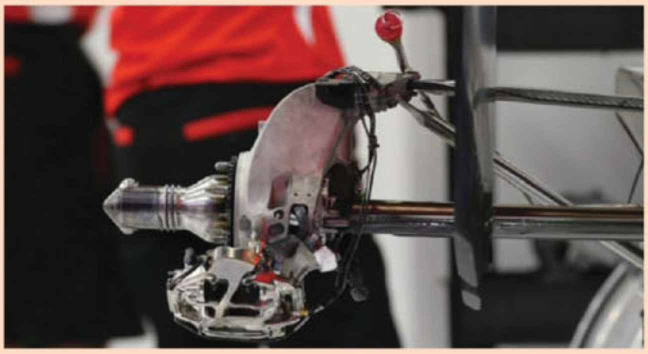
'There are big elements to what is going on in braking with us,' says chief engineer Dave Greenwood. 'There is the pure generation of braking torque, by which I mean the front axle that is totally driven by the brake disc and caliper. The material is something we look at and experiment with different suppliers. We work a lot with one supplier in particular and develop some of their products so we are totally happy with that element.

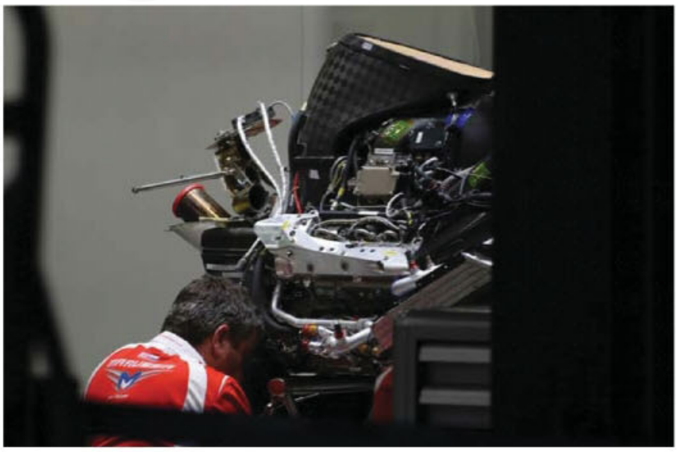
'On the rear axle, however, the brake torque is generated by the engine, the brakes and the MGU-K. That's much more complicated, and the control of the rear caliper is determined by the brake-by-wire system. There are a lot more elements to getting the braking right this year compared to 2013, and the control systems related to it are very complicated. In the early part of the season we struggled a lot with it, but so did many other teams. We improved it a lot at the Bahrain test, but it's a major area of focus still.'

One of very few areas of modern racecar design that there is not a particular trend on is brake caliper position. On the rear of the MR03, the caliper sits at almost the lowest possible point, but at the front it is mounted at the rear of the caliper rather than at its base. 'I don't think you will find a consensus on where they should be positioned,' says Greenwood. 'It's something of designer preference. Mounting at the base of the disc gives you a lower cg, and they are striving to always go in that direction. But there is the factor of ease of use to consider too. You need to be able to bleed your brakes, your bleed nipple needs to be a high point and a very low slung caliper is harder to bleed.

'But the bottom line is that it is something that the designers do when they are creating the upright and working with the caliper supplier. Aerodynamically, the way you do the internal ducting inside the drums is also something that is looked at, and these things are getting more and more complex, but that development has a lot of effect. We do a lot of work on the brake dyno, and it's a much more repeatable process than using the car at a test.'







The Ferrari 059/3, 1.6-litre V6 engine, which has a single turbo

it from them and then from that point we add our external and internal suspension. But it's not something where we have had to do anything different due to the change of material – all of that work is done by Ferrari.'

One area where the Marussia differs to the other two Ferrari-powered cars in 2014 is the rear wing support. At the opening races of the year, both the Sauber and the Ferrari used near-identical twin pylons, but the Marussia had a single pylon which split at the base to allow the exhaust to pass through it, then attached to the same mountings on the top of the transmission casing that the other two cars use. 'We term the rear wing support a Y-lon, as it is an inverted Y in shape,' says Greenwood. 'We evaluated all of the different options – both single and twin pylons – and found that this was the best compromise in terms of structural support for the rear wing and minimum impact un the underside of the rear wing.' Interestingly, McLaren independently developed a near-identical concept, and at the Spanish Grand Prix – doubtless inspired by its customer – adopted a layout very similar to that of the MR03.

But while the inboard rear suspension is largely defined by the transmission supplied by the Italians, things are different at the front. The MR03 is unique in modern top level car construction in that it features a metal front bulkhead – everything else in F1 and LMP racing has a carbon fibre front. It houses the inboard suspension pickup points, steering racks and master cylinders as you might expect.

'We realised that we could get a much better designed car, which was lighter, stiffer and had better tolerances with a machined bulkhead,' says Greenwood. 'It's machined from billet, then bonded to the chassis. It's not that complex and it's a nice solution. It's not something we will move away from any time soon either. Doing the bulkhead this way has solved a lot of little issues. When you have carbon parts with inserts, you can always have annoying issues as time goes on, but when you do this it all goes away. We have not found any weight penalty either.'

"We got a car which was lighter, stiffer and had better tolerances with a machined bulkhead"

THE JOYS OF SPRING

At the top of the bulkhead between the torsion bars, a spring damper unit can be seen mounted across the car. This unit plays a key role in the car's suspension layout. 'It is no secret that everyone on the grid has an interlinked suspension system that incorporates Cambridge inerters front and rear,' says Greenwood. 'The way you get all of those elements working together is a way you can get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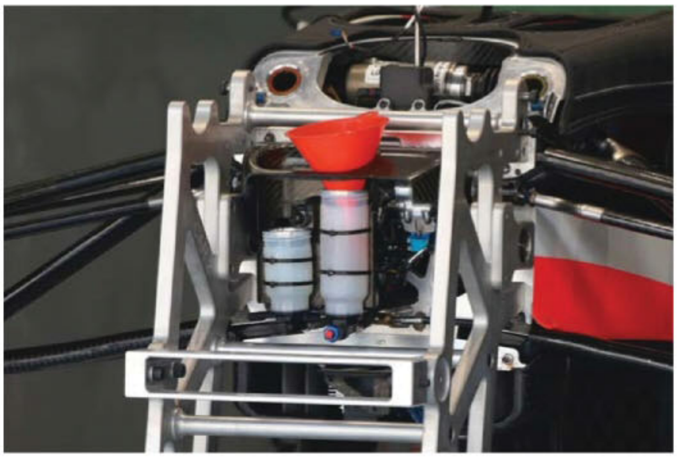
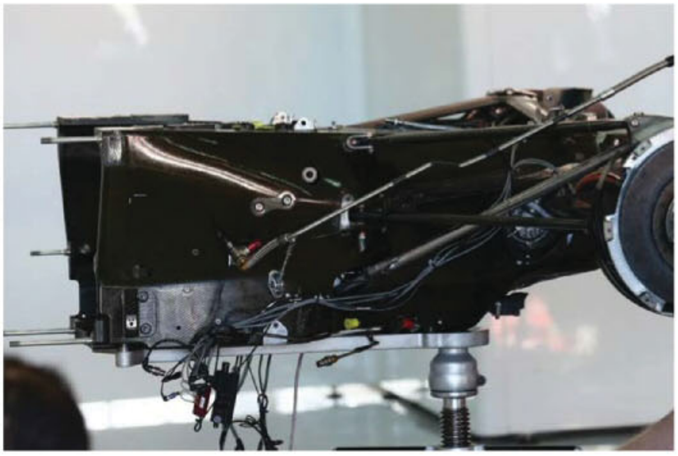
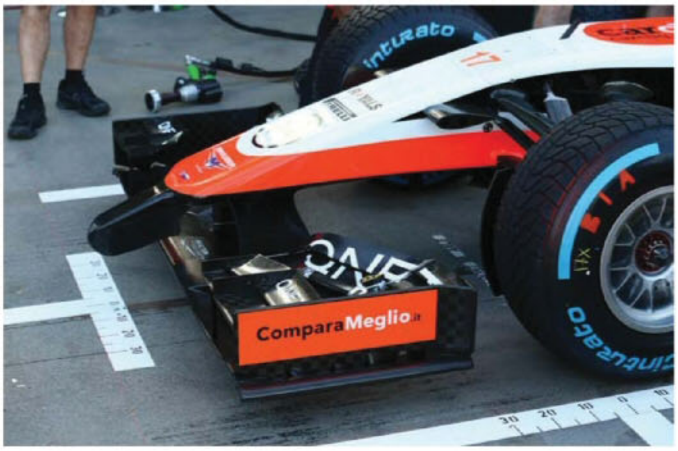


The front bulkhead is machined from billet, unique in current top level racecar construction. Note the spring damper unit between the torsion bar holes



The Marussia shares its transmission with the Ferrari F14-T and the Sauber C33. The MR03 is the first car with which Marussia has used a composite main casing

Close-up view of the Y-lon rear wing support



The nose is defined jointly by regulations and aerodynamic demands

performance. It's not just ride-driven either – it's about securing the best aero platform too, the way you can move the car through the aero maps. You find a spot where the car has the most downforce and that's where you want to run it as much as possible. Then you have the way that the car shifts going through a corner, and the way you make the suspension work is to optimise where the car is in terms of ride height. That unit combines lots of elements that you would normally separate, and it allows us to have something that gives us gains in ride and aero performance with as little weight as possible.'

One of the few things carried over from the 2013 MR02 is its reliability, which saw rookie driver Max Chilton finish every race of the season, a trend he has continued into 2014 (up to and including the Spanish Grand Prix).

'Reliability has been the strong part of the car so far,' says Greenwood. 'I think we are pleased with the design from the car weight point of view. We hit our targets, we have had a few non-finishes in races, but they tend to be for accident damage rather than unreliability. Reliability has been strong with both the power unit and the chassis.'

LIGHTER WEIGHT

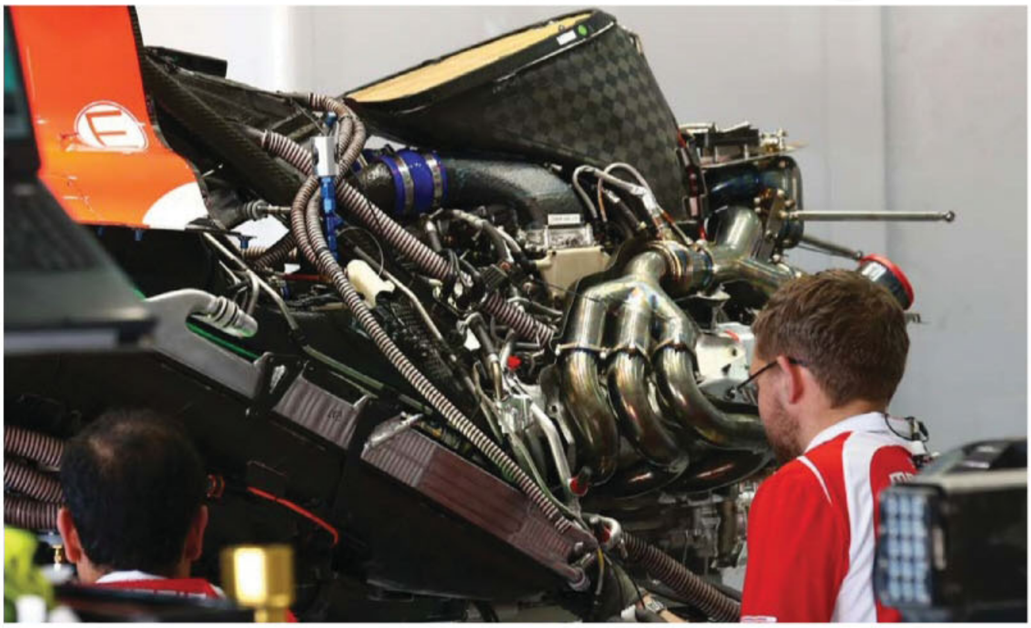
Weight has been a major problem for some cars on the grid in 2014, notably the Sauber C33, which although mechanically is very similar to the MR03, was overweight at the first races of the year. Greenwood, however, reveals that this has not been a problem for Marussia, or rather it was one that the team solved before the season. 'Normally when you talk about reliability, you talk about weight as well,' says Greenwood. 'Generally speaking, lighter components are less reliable, so we have achieved reliability with the car on the weight limit. We are where we want to be, and that's testament to John McQuillam, [deputy chief designer] Rob Taylor and the gang of designers have done a great job from that point of view.'

In 2014, as in previous years, the weight distribution of the cars is tightly restricted, something that was originally introduced in 2011 to ease Pirelli into F1 as the sole tyre supplier, but the regulation has remained even though the car weights have changed. This means that this season every car must have a weight distribution resulting in no less than 319kg on the front axle and 375kg at the rear. With a minimum weight of 691kg, this gives teams just a 7kg window to work with. Meanwhile, with the number of coolers fitted to the cars, it is inevitable that they will be unequal in weight side to side.

'At the moment we don't look at side to side weight distribution at all,' says Greenwood. 'Generally weight is such a challenge with these cars, you would balance the car left or right for each track if you could. But this year it has just been about getting things to the weight limit. With this year's car it's been hard to get there because there was no data to go on, and as a result it was something we were very worried about during the build.

'Ultimately we have been fairly successful. The weight distribution is roughly where we wanted it to be, though there is always some room for improvement. One thing you don't want to do is add weight to get to the distribution window and we have not had to do that, so that's good. We are at the

"This year has been about getting things to the weight limit. There was no data to go on, which we were worried about during the build"



The rear end of the MR03 with heat shielding and transmission removed – many interesting things to see here

The MR03's roll hoop is the only one on the grid without exposed supports. Instead it features a pair of cooling ducts behind the driver's head

minimum weight at the end of the race. But next year's car will be much easier because we'll know what we had in reality and not in the virtual world as was the case with this one.'

AERO DEVELOPMENT

With a quarter of the 2014 season completed, things have not gone quite as well as Marussia might have hoped. It remains locked in a battle with the Caterham team that commenced right back in 2010, not for points but for the highest finishing position. Generally, however, the MR03 has finished better than its green painted rivals.

'Our aero performance is not bad, and we are strong in certain places – especially high speed corners,' says Greenwood. 'But we are not getting the benefit of the aero in low speed corners. It is a problem that is exaggerated by a related issue with the car's stopping power. We feel that braking is one of the big areas that we need to concentrate on – all the team in F1 now have GPS allowing them to look at all of the other cars. That is an area where we are poor. We are looking to find gains – there is significant lap time to be had there, and if we find those gains than we should be regularly in Q2.'

The car's aerodynamic deficit in low speed scenarios also has a factor in the braking performance. 'These cars are different to what we are used to aerodynamically and while we are happy with downforce in high speed corners, we have a lot to do in terms of generating downforce in the braking zone,' says Greenwood.

'We lost the effect of exhaust blowing, so we are working to get more downforce in that area – it has an impact on how we perform on track too. Monza, for example, is not a great venue for us, but Barcelona with lots of medium and high speed corners was better – it's the aero dominated circuits and not the braking dominated tracks that we are looking forward to. I think our relative performance will improve at tracks like Silverstone.'

The Marussia MR03 is perhaps the strongest car yet produced by what is still seen as one of Formula 1's new teams, but the obvious deficit in resources has led to a equally obvious deficit in on-track performance, which is why the team's management is keen on the introduction of a cost cap. The team's job list is as long as any better funded team, but it doesn't have the same resources to work through it.

If a cost cap does happen, then the next Marussia – for the 2015 Formula 1 season and created by this team that has shown its ability to innovate on a relatively tiny budget – could be much further up the grid.

TECH SPEC

Marussia MR03

Chassis construction
Carbon fibre composite

Front suspension
Carbon-fibre wishbone and pushrod suspension elements operating inboard torsion bar and damper system

Rear suspension
Carbon-fibre wishbone and pushrod suspension elements operating inboard torsion bar and damper system

Wheels
BBS

Tyres
Pirelli
Fronts: 245/660-13
Rears: 325/660-13

Brake system
Carbon/carbon discs and pads with rear brake-by-wire system, AP Racing

Steering
Marussia F1 team-designed hydraulic PAS

Fuel system
ATL Kevlar-reinforced rubber bladder

Electronic systems
MAT SECU TAG 320/ Scuderia Ferrari

Seatbelts
Sabelt

Engine
Ferrari 059/3 1.6-litre six cylinder single turbo. V6 90 degree. Bore 80mm, stroke 53mm, 4 valves per cylinder, 500 bar-direct injection

ERS
Battery energy per lap 4MJ, MGU-K power 120kW, MGU-K max revs 50,000rpm, MGU-H max revs 125,000rpm

Dimensions and weight
Overall width: 1800mm
Wheelbase: 3700mm

Radio
Riedel

"Our aero is strong in certain places, especially high speed corners, but we are not getting the benefit from it in low speed corners"

May the force be with you

The Swiss Rebellion team linked up with ORECA to design its new R-One LMP to take on the might of the manufacturers at Le Mans

BY ANDREW COTTON

MAIN IMAGE: XPB

"We have a very efficient engine and we're seeing a significant improvement on our 2013 figures"

With a budget that is dwarfed by the major motor manufacturers competing at Le Mans, the Rebellion team has taken a mighty step and developed its own car with the help of French team ORECA – the R-One – to contest the World Endurance Championship.

Like a starfighter coming up against an Imperial Class Star Destroyer, the R-One has a few tricks to help it compete. The non-hybrid column of the now famous Appendix B is for privateers only, and contains some incentives to help the privately-developed cars.

The LMP1-L cars can compete at 850kg, 20kg lighter than the hybrid cars. They are allowed to use their fuel faster than the hybrids, closing the performance gap. However, by the calculations in Appendix B, the non-hybrid cars are only able to complete 12 laps at Le Mans on a tank of fuel, compared to 13 for the hybrids.

All of the LMP1 cars have to run with a restricted fuel flow, meaning that the Toyota customer engine that powered the Rebellion team's Lolas in 2013 had to be extensively reworked for 2014.

'The basis of the engine is the 2013 RV8KLM engine used by Rebellion Racing, which was a high-compression engine specifically tuned for an air restrictor at the intake air entrance,' says Ralf Richter, project leader for TMG's customer engine programme. 'When we saw the new regulations for 2014, one of the first decisions we had to make was to optimise the compression ratio for the new regulation where engines run without an air restrictor.

'In April 2013 we began development of the 2014 engine using calculation and simulation techniques at TMG. The target was to understand what is needed to maintain high performance while improving the fuel efficiency. In 2013 we were running over 10,000rpm and we wanted to reduce this because high revs means high consumption.

'We started to look at the cam timing, the intake length and the compression ratio. From these calculation results we could complete a optimised package which delivered improved efficiency without a negative impact on performance.

'The first dyno run was in August 2013, using the correct E20 fuel as specified in the 2014 regulations. It was not possible to do this earlier as the fuel was not available, and we decided it was not worthwhile to test using different fuel.

'These dyno tests enabled us to decide on the mechanical package and settings that include intake lengths and cam timing, as well as allowing us to validate our calculation data with actual testing data. After those August tests we finalised the specs of the engine – items such as exhaust and intake length, cam timing and compression ratio.

'We decided on a completely new intake system. It has double injection with two injectors per cylinder, one on the top and one on the bottom. This configuration improved the engine response when the engine is running in lean mode.

'After those tests, we also began production of the new parts and ran the updated engine on the dyno again in January 2014. In total we used around 2000 litres of fuel during these tests, in order to achieve calibration results as specific as I want to be.

'All in all, we are happy with the results. We have a very efficient engine and this is a significant improvement on our 2013 figures. We are still optimising the details of engine settings and in particular we are now working to improve engine response.'

CHOICE OF GEARS

The gearbox chosen was Xtrac's 1159 transverse LMP 'box, featuring seven gears which allows more flexibility in this fuel-sensitive era of racing. Launched as an LMP1-L version for use in 2014, the gearbox also has a geartrain system on the front to make it compatible for LMP1-H, a hybrid system which can be used immediately, but which is likely to be debuted in 2015 at the earliest. Through thorough use of a wide range of available in 'out bevel and final drive ratios', all engine permutations can be accommodated, and the gearbox is capable of handling up to 820Nm of torque. Gears are selected through Megaline's new direct drive e-motor. 'For 2014, for the first time there are Formula 1-style crash tests, with rear impact, side push off and wheel tether mountings,' says Xtrac's technical director Adrian Moore. The gearbox has been designed with a future LMP2 application in mind, and the anticipation is that the category will also introduce crash-testing.

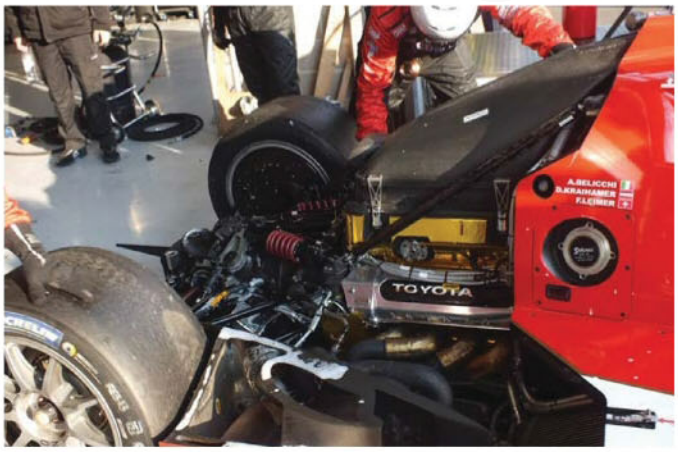
Getting the engine ready to run lean was one aspect of the car's development, but the ORECA team also had to work on an all-new chassis, suspension and aerodynamic kit to reduce drag and conform to the new regulations. At Spa, there was a clear resemblance to ORECA's previous prototypes, including headlights that were clearly based on the Peugeot 908 HDi FAP, the windscreen that appeared to come from the Lola and the aerodynamics have a clear nod towards ORECA's own ORECA 01. However, says ORECA's chief designer Christophe Guibbal, the car concept and components are completely new due to the new regulations.

'The target for the car was to reduce the drag and work on the engine intake to achieve this,' said the Frenchman. 'We started the project exactly 363 days before the first roll out – the first CFD model was produced at the end of May 2013.'

IN WITH THE NEW

'I don't understand why people say that there is carry-over from previous prototypes,' added Guibbal. 'The windscreen is a completely new design due to the new chassis. We don't use the same headlights as the Peugeot, but we do use the same concept, as we had to compromise to achieve the price, the efficiency and to reduce the weight on the front axle. We used a chrome surface treatment on the carbon to make it work.'

Reducing the weight of the car was the key target for the design team and there were some hurdles that were thrown in their way, namely the side intrusion panel that has been introduced for the first time this year, but which adds weight. 'It was important that we achieved a good design of the chassis,' said Guibbal. 'It was not easy to save weight, but we have touched on all parts to hit the target.' The team was apparently successful – at the car's first race in Spa the Rebellion team was privately calling for a reduction in the minimum weight, for the first



Due to the fuel flow restrictions, the 2013 RV8KLM Toyota customer engine has been extensively reworked for the Rebellion's current campaign

In the regulations, LMP1-L cars including the R-One can run 20kg lighter than hybrids, as well as using their fuel faster to close the performance gap

year at least, to 800kg – a weight that ORECA believes it could comfortably achieve with the car.

'We have almost had to steer the ORECA course to meet the timeline, so we haven't had the opportunity to debate,' says Rebellion team manager Bart Hayden. 'Like any new car, it will evolve. We were able to carry forward a lot of information regarding the ECU, but we had to have a lot of software written into it to have what we wanted for fuel saving – it was significant. From the aero and suspension concepts, there was very little carry forward from the Lola due to the narrow tyres, and so on.

'They really led on the design targets. We challenged them a little bit, but they are confident in the numbers. Where we are behind is that we haven't had track time to correlate what the computer is saying with what

Xtrac 1159, a hybrid capable gearbox

we are seeing on the track, but the initial data looks good. We are quietly optimistic. The big challenge will be reliability.'

Another area for development was the front suspension and pedal box. By regulation, the box is larger this year, which affects everything from the front aero to suspension design, and the team took the opportunity to tidy up the design of the dampers, third element spring, anti-roll bar and

TECH SPEC

Rebellion R-One

Type: Le Mans Prototype (LMP1-L)

Chassis: carbon fibre composite monocoque

Bodywork: carbon fibre composite
Length: 4650mm
Width: 1900mm
Height: 1050mm
Weight: 850kg

Steering: hydraulically assisted

Windscreen: polycarbonate

Powertrain: Toyota
Designation: RV8KLM-L
Configuration: 90deg V8
Capacity: 3.4-litre
Power: over 500PS
Weight: +/- 120kg

Engine management: TMG

Lubrication: dry sump

Fuel: Shell petrol

Lubricants: Shell

Gearbox: Xtrac transversal with seven gears, sequential

Clutch: Carbone AP racing

Differential: Xtrac viscous mechanical locking differential

Suspension: independent front and rear double wishbone, pushrod-system

Dampers: PKM

Brakes: Brembo ventilated carbon disks
Front disks: 380mm
Rear disks: 337mm

Tyres: Michelin radial
Front tyres: 31/71-18
Rear tyres: 31/71-18
Rims: OZ Magnesium forged wheels
Front rims: 13x18in
Rear rims: 13x18in

all the steering components. This also tidied up the front design, but the car remains complex, with sophisticated electronics delivered through the Cosworth Pectel unit.

The first competitive run for the car was the Spa 6 hours in May, a show that was treated as a test session rather than to be able to show the car's potential. One car completed the race, another was stopped due to an electrical problem. There is still a long way to go in the development of this car, but early signs are promising.

"Like any new car, it will evolve. From the aero and suspension concepts there was very little carry forward from the Lola due to the narrow tyres"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en•dur•ance
noun
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• the capacity of something to last or to withstand wear and tear.
ORIGIN late 15th cent. (in the sense [continued existence, ability to last] ; former also as *indurance*): from Old French, from *endurer 'make hard'* (see ENDURE).
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Ligier returns to Le Mans

Having spent recent years in German Formula 3, the classic French brand revisits high-profile racing with an assault on LMP2 at the Circuit de la Sarthe

BY SAM COLLINS

IMAGES: DPPI, RUAG Aviation

"Once we knew we were aiming for LMP2, we only had six months – and you really need a year to create a car like this"

"Once you have all the moulds and tooling for LMP1, you can also do LMP2 – but you have to make a different body"

Ligier is perhaps best known as a Formula 1 team and manufacturer of microcars, but the firm actually started out by building sportscars. The popular team in its patriotic blue colours of France contested the Le Mans 24 Hours every year between 1970 and 1975, before focusing on grand prix racing.

Ligier's racing activities came to an end shortly after winning the 1996 Monaco Grand Prix, and it seemed that the company would focus purely on road cars after that. However, in 2005 Ligier acquired Automobiles Martini (its neighbour at the Magny-Cours circuit) and released a new Formula 3 design – the JS47. While it only contested the German Championship, it helped Nico Hülkenberg into Formula 1 after he used it to good effect in the 2006 season.

The revival of the Ligier brand caught the attention

The JS P2 was developed by prototype constructor Onroak Automotive

of entrepreneur Jacques Nicolet, who encouraged the organisation to develop a new sportscar for the CN category. The result was the Ligier JS49, which went on to dominate the class and sell in great numbers.

In early 2014, it was revealed that the Ligier name would be returning to Le Mans with a brand new LMP2 design developed by Nicolet's Onroak Automotive firm which had previously reworked the Pescarolo 01 into the Morgan LMP2. 'This is the first chassis for Onroak, but its not really the first car,' says Thierry Bouvet, technical director at Onroak. 'The Morgan used the Pescarolo chassis, but everything else was Onroak. There were not many parts left from that car really, so yes – this is the first complete car.'

STEPPING DOWN

But the Ligier programme did not start life aimed at the junior Le Mans Prototype category – Nicolet had wanted to contest the top class. 'We started perhaps a year-and-a-half ago,' says Bouvet. 'The drawing office started to design a 2014 rules LMP1, and then in the middle of 2013, it became clear that LMP monocoques could be used in LMP2. From there Jacques decided it would be a good way to get a coupé in the class.'

On the face of it it may seem a slightly strange decision – after all, the Morgan LMP2 is still a very competitive design, and it's something that confused the designers at first. 'Why would he want to do this when we already have an open car which is working quite well?' laughs Bouvet. 'We thought that at first, but then when you think about gentleman drivers, they are all about safety and want a roof over their heads. You can understand that, so this was an obvious way to do that.'

With a LMP1 design on the board, it may have seemed that it was merely a case of changing the stickers and the engine to allow the car to race in LMP2. But in reality the aerodynamic regulations between the two classes are very different, and this meant that Bouvet and his team had to push hard to complete the design in time for the 2014 season.

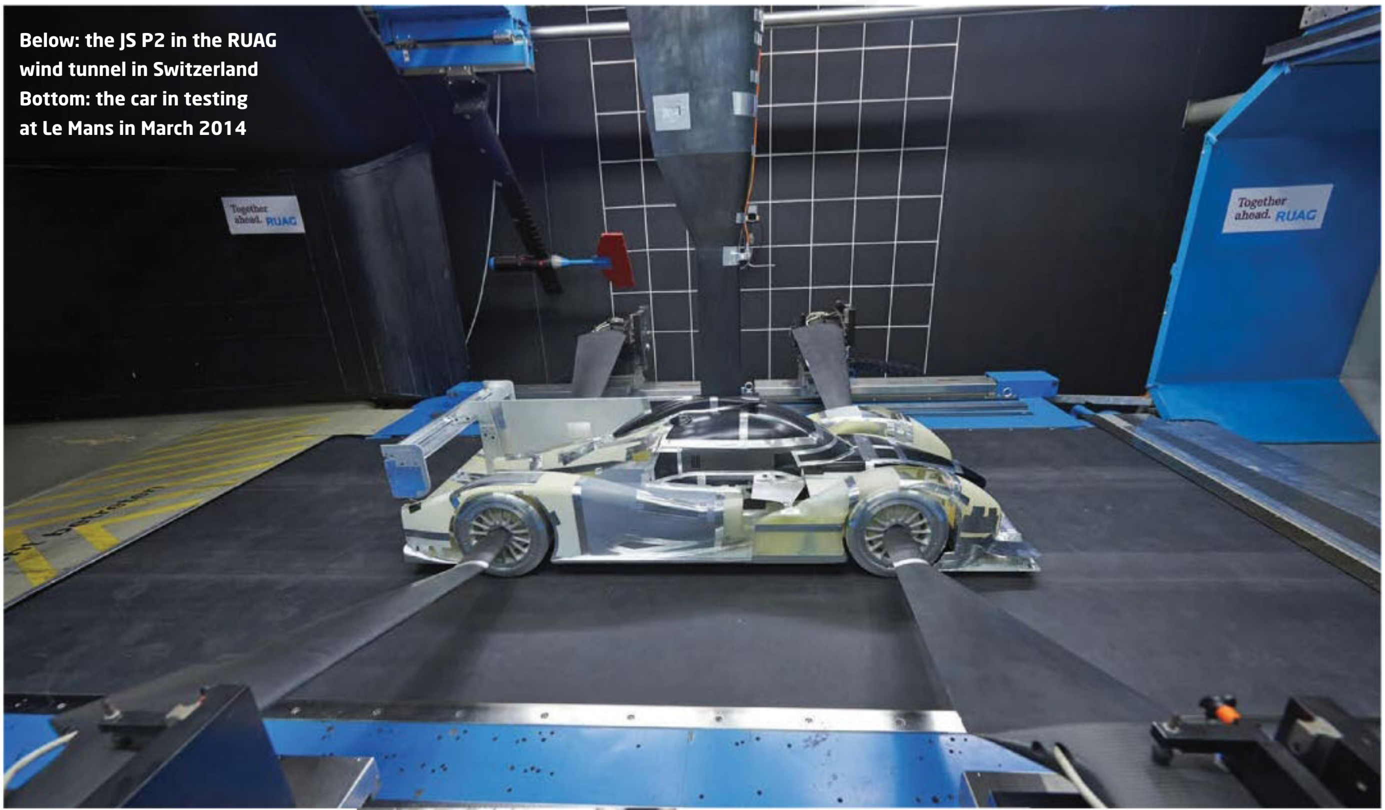
'In aerodynamic terms, the 2014 P1 cars are hugely different – the only real similarity on the body are those parts that are on the monocoque,' he says. 'The reason the ACO allowed the chassis to work in both is really to cut costs a bit. Once you have the moulds and tooling for LMP1 you can save money to do LMP2 – but you have to do a different body.'

"In aerodynamic terms there is a fine line between a coupé and the open car – it's always a compromise"

Onroak have worked closely with the RUAG wind tunnel and aero consultancy in Switzerland for a long time, developing its Pescarolo 01s in both the LMP1 and LMP2 classes, and continued that work for the Ligier. 'We did a combination of work starting with CFD and moving to the wind tunnel,' Bouvet says. 'In aerodynamic terms there is a fine line between a coupé and the open car. Some is in favour of a coupé, and some in favour of the open car – it's always a compromise. There is a reduction in drag with a coupé, but you are not talking a massive amount.'

He adds that he does not feel that just using a closed car gives any clear advantage: 'A coupé throws up a lot of complexities, windscreens, demisters and wipers. It's why it takes people a long time to go coupé – look at the Audi R15. When Peugeot already had a coupé, Audi decided not to.'

In order to meet the tight deadlines, many mechanical design elements of the Morgan LMP2 were integrated into the new car. 'At the rear, the car is traditional,' says Bouvet. 'We kept the same gearbox casing as the Morgan, so that means that the



Below: the JS P2 in the RUAG wind tunnel in Switzerland
Bottom: the car in testing at Le Mans in March 2014

rear suspension is very similar. We had only a short time to do the new car – once we knew it was P2 we only had six months and you really need a year for this. We decided to keep the gearbox from a reliability point of view – we know what we have got and that it works. You can't quite take the rear end off a Morgan and put it on a Ligier, but almost.'

The braking and chassis electronics also carry over from the older design. The front end, however, is a different story with a new 2014 monocoque built at HB Composites which features some up-to-date design trends including legality bumps to meet the minimum chassis height rules and torsion bar front suspension. 'We have a torsion bar front end, and it is much better in terms of packaging,' says Bouvet. 'Obviously, it is lighter.'

At the rear of the tub, installations have been done for both Honda and the popular Nissan LMP2 engines – and the latter brand has some involvement with the project. 'The difference between the Nissan and Honda are the bell housing and some work on the cooling side, but housing the turbo is quite different,' Bouvet says. 'We are using the Zytek-tuned Nissan as we had those engines arranged already.'

As the car was originally developed for the LMP1 class, there may be some questions about its legality in terms of the cost cap used in LMP2 – but Bouvet insists that the Ligier complies. 'The car meets the cost cap, but if you want to sell the car it has to be right, and it can so easily be wrong if you don't do everything the right way,' he says. 'You have to think about the cost cap when you design the car. But the cap is not where it should be, €450,000 would be a more reasonable price. Of course our car meets the cap of €370,000 in 2014, but when you look at a season budget, the cost cap element is nothing. I think it's really good to have a cap however because it stops people going crazy, but it should be raised a little bit. If someone ignores the cap they could be very strong, but people must be very careful about this as it could kill the class. The rules are set so that if anyone is too strong, BoP will bring them back, so that they would be very strong for one race only. But the BoP has never been used.'

The Ligier JS P2 is set to make its race debut in the Le Mans 24 Hours, a tough ask for an all-new car.

'We wanted to race at Silverstone and Spa, but we could not do it properly. If we rushed and did things badly, we would rather do it properly and do lots of testing,' says Bouvet. 'For me as a Frenchman, it was not special to design a Ligier, mainly because we did the car and then later found out that it was to be a Ligier! But the name means a lot for some people, and that's nice.'

CLOSED CONTENDER

A few days before the Ligier JS P2 was rolled out at Magny-Cours, another new Ligier appeared – the JS55 – a new closed FIA CN design.

'The idea of the JS55 is to take the existing car JS53 Evo and put an LMP2 roof on the top,' says Bouvet. 'The roof is not structural at all – it has a tubular frame. Again it's because gentleman drivers want a roof, so we tried to find a cost-effective way of doing that. The ACO want a roof for LMP3 too, but the car is not fully compliant with the LMP3 rules – it is a CN car. The JS53 can be converted to a JS55. The aero development was done in CFD, and when the car was developed there were no aero rules, it was done to check that it worked rather than to get performance.'

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Future forecast

Ambitious engineering concepts feature in Dunlop's project, which imagines how motorsport might look in the year 2139. Here are our predictions…

BY SAM COLLINS

Tyre company Dunlop has launched a social media-based project – the Future Race Car Challenge. It is a collective design project that explores the future of racecars, with the focus on the year 2139. The best submissions will be incorporated into one, final design brought to life in a forthcoming computer game.

Exploring this subject is a fascinating exercise that highlights some clear directions that the motorsport and high-end engineering industry is already working on. Here we reveal our own vision of what racing will be in 125 years time. But this is not science fiction – the designs and concepts detailed here are based on current technological development in the motorsport, defence and aerospace industries.

CHASSIS
THE LIVING SKIN

Materials technology will be a key factor in the design and construction of racecars in the future. With ultra-light, ultra-thin, ultra-tough and ultra-strong composite materials, many current and foreseen limitations of car design will no longer be a factor. In the car's bodywork there will be widespread use of 'smart materials' which will change shape and position as the

conditions demand. So, on high speed sections the bodywork will be configured for low drag, while in cornering the bodywork will create maximum downforce. This active adaptive bodywork will also see the car breathe through constantly changing ducts like a fish's gills, cooling slots will appear and disappear as required, as will the openings for combustion air – if indeed there is such a requirement. In the event of a crash, the bodywork will – to an extent – be self-repairing.

Defence companies have been researching these ideas for a number of years, and some such as QinetiQ have proposed its introduction into Formula 1. One technique being developed by the University of Sheffield in England is a thermoplastic self-healing system developed by Dr Simon Hayes, which employs a thermoplastic dissolved in a thermosetting resin system, which can be induced to heal when heated. He is also working on alternative methods of healing involving the development of supramolecular polymer systems. Hayes, a lecturer in aerospace engineering, explains: 'Upon impact, there is generally substantial matrix damage in the form of matrix cracks and delamination. In this event, by and large the cracks are closed, rather than open. In our

system, application of heat to the panel will enable the soluble thermoplastic to mobilise and diffuse through the thermosetting network. As the crack faces are closed, some of the thermoplastic chains will diffuse across the crack face, and so upon cooling the crack will be bridged and mechanical performance is recovered. To date we can recover between 40 per cent and 70 per cent of the pre-damaged strength.'

While the research is at a purely experimental stage, in 125 years time such a concept is likely to be commonplace – and indeed in many cases it may be partially automated. 'As well as the solid-state self-healing technology, we have a self-sensing system which uses changes in resistance to monitor the location and extent of damage,' says Hayes. 'This can follow the changes in the panel arising during healing and detect subsequent impacts. In addition, because we have electrical contacts, we can apply a power source to them and cause the panel to heat locally in the region of damage.'

As well as the self-healing sensing systems, all of the 2139 car's electronic and fluid connections will be integrated into the bodywork. Fuel lines, cooling pipes and all of the electronic systems will run through it, with the bodywork also able to change and reroute systems if one area is damaged or destroyed. Within the material there could be a honeycomb of veins and capillaries, all capable of transmitting smart fluids that are routed where required with fuel, coolant and hydraulic fluids all moving simultaneously through the same system without contaminating one another. High voltage electrical power and low voltage electrical control supplies could be distributed through the car's skin using the same concept.

bf1systems of Norfolk, England has been offering its patented wire in composite concept for some years now and with the passage of time, it is likely that not only will some wiring be built into the bodywork, but in fact some if not all of the onboard computational equipment as well. This could also see the car become much more intelligent, with a large portion of the car's data analysis, component lifing and even simulation built into the bodywork. This could reduce or even eliminate the need for race engineers as the car itself will know the best setup, and learn the driver's preferences.

As the bodywork is so strong and adaptable, it becomes the most important component of the car, also acting as the chassis – a sort of super-monocoque. Almost every part of it becomes structural in some way, making this an exceptionally efficient design. These techniques will likely be commonplace in production car design in 2139 as well. With its integral electronics, it could also be possible to change the branding and colour scheme of the car.

Many people assume that in 125 years everyone will have flying cars – but this seems quite unlikely

STAYING ON THE ROAD

TYRES

Many people assume that in 125 years everyone will have flying cars, but this actually seems quite unlikely unless there is a major technical breakthrough that is not yet forecast. So it is probable that the cars will still have wheels and tyres of some kind. Dunlop commissioned professional futurologist Dr Ian Pearson to look into what the racing tyre of 2139 will be, and he believes that the tyres, too, will have the ability to change their properties in use.

'Electronically controlled materials might be built into the tyres as well, enabling variable grip and wear trade-offs,' he explains. 'Polymer gels linked could easily make a short, fat component become a longer thinner one. If millions of these are laid down using 3D printing as tyres are made, then as the tyre wears, new layers of micro-spikes could come to the surface, and these could be withdrawn or protruded on demand. So, strong fibres could be made to stand on end to increase grip on the ground and fold flat to reduce drag on the top of the tyre, or sweep away water. Imagine it as a miniature Eiffel Tower, if the base columns were to be squeezed together, you'd expect the height would obviously increase. At a scale from microns to millimetres, microstructures such as this would offer enormous potential for variable grip that could be precisely controlled at high speed.'

With climates likely to change significantly by 2139, racing in adverse conditions seems to be a certainty, but some technologies now in development could have a significant impact on road holding, according to Pearson. 'Graphene will be especially useful as it allows water to pass through, but is super strong, so graphene flakes in tyres would give excellent grip in the wet,' he says. 'This material would allow more of the tyre surface to stay in contact with the road surface and still let water through to be diverted, possibly via graphene foam-filler materials or tubes. Such materials would be difficult and expensive to make today, but firstly car racing is a high budget sport, and secondly, 3D printing will allow tyres to be fabricated in layers and include very complex fill structures. Thirdly, the costs of doing this will inevitably decrease.'

The tyres may also change shape for aerodynamic reasons. Some tyre-makers are already experimenting with sidewall

shape to reduce drag and reduce brake cooling. Yokohama, for example, has been experimenting with dimpled sidewalls and fins to improve airflow around the wheels. But while pure flying cars may not be on the agenda with the very high speeds expected, it is unlikely that the car will spend all of its time fully grounded. To reduce rolling resistance in some situations, the car may actually skim over the surface using wings in ground effect, rather like the famous 'Ekranoplan' – although on a much smaller scale.

PROPULSION

THE POWER STRUGGLE

Propulsion is a very difficult area to predict, as even in 2014 it is a grey area. Pearson suggested that plasma thrusters could be employed. 'With room temperature superconductivity, extremely powerful electric engines and plasma thrusters could be built, and undoubtedly others so far unimagined,' he explains in his Dunlop report. 'Plasma thrusters could be a lot of fun, offering lots of potential propulsion systems. Using electron pipes and other compact accelerators to bombard a gas with electrons would make it into a plasma, and superconducting coils could create enormous electromagnetic fields to propel it. Computer gamers already have a very familiar name for this – it is essentially a plasma rifle, or cannons. Newton's laws of motion dictate that as the cannon fires a high speed pulse out of the rear end, the car gains equal forward momentum.'

But it is likely that in 125 years there will be several power solutions vying for superiority. The chassis constructors of 2139 will have to design their cars to accept propulsion systems using concepts like the Woodward effect, nuclear photonic rockets, nuclear turbines, and new concept combustion engines, as well as plasma thrusters.

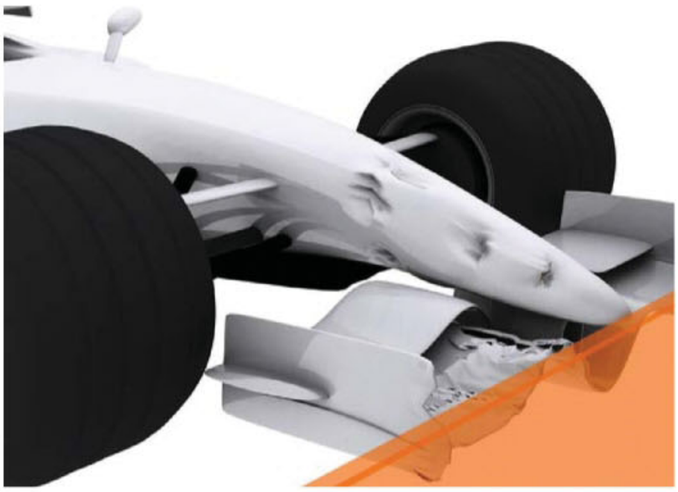
What seems certain is that the cars will feature very efficient energy recovery systems. Hot parts of the cars will feature energy recovery systems such as thermoelectric generators, steam turbines and perhaps even piezoelectric energy harvesting. Motorsport's rule-makers will continue to be driven by the production car and vehicle market, and will likely place a major focus on energy efficiency as a result. Purely electric vehicles will not likely feature in 2139 due to ongoing issues with energy generation, and even if many nuclear power stations started construction today and the entire power distribution infrastructure started to be re-developed, it is unlikely that electric cars would be a mass-market solution in 125 years time. In 2014, some race circuits struggle to keep the lights on during races!

DRIVERS

THE ENHANCED HUMAN

It has been suggested that the racecar of the future will be a fully automated drone, but this is almost certain not to happen. Drones would not create an exciting racing series as they would execute every manoeuvre to perfection, they would never make errors and the speeds would climb so high that the race would no longer be a spectacle, it would be a pure engineering exercise. For racing to be exciting it needs a human in the loop, not only for the facts that humans are fallible, but also for the perception of danger.

In 2139 there will still be racing drivers as a result, but they will be nothing like the drivers of the 21st century, at least in physical terms. With the much higher speeds and g-loadings, the limits of human performance will be reached in terms of reaction times and ability to withstand sustained G loadings, so to push these limits the drivers themselves will be enhanced. Parts of their bodies will be removed and replaced with mechanical versions to increase capabilities, using drugs to improve attentiveness, stamina and reduce fear. The driver's limbs could be augmented with strengthening members or indeed replaced altogether with mechanical versions. Inside the brain, artificial electronics could not only improve functions such as recall and emotion, but they



QinetiQ's self-repairing concept suggests that a car would pass through a beam of heat, energising the composite structures to repair themselves

RACING CLASS: GP800. MAXIMUM SPEED: 750KPH+

The most glamorous racing league in the world sees some of the most famous brands and drivers competing on the toughest tracks around the world. From courses like Le Mans, Indianapolis and Monaco with their roots in historic tracks, to purpose-built modern venues like Sino Speedway and Eurasiaring, this series is where manufacturers of the most advanced cars and sub-orbitals show off their vehicles, while the rich and famous network in the exclusive track pods.

The cars are cutting-edge single seat designs, which look fast even standing still. Purpose-built to the GP800 technical regulations, these are the most advanced machines in existence. Propulsion comes from a range of unrestricted power units.

could also control and record other factors, interacting directly with some of the car's systems, meaning that the hands and feet are free to operate the control column and pedals. The cockpit would then as a result be almost entirely free of other controls, though some would probably still appear as backups.

These biomechatronic humans would be almost perfect drivers, able to react faster and withstand more than natural humans.

Enhancing humans has been on the sporting agenda for many years, and even with recent crackdowns on performance-enhancing drugs, the problem is still rife. It has even been suggested that some runners should have their legs surgically removed and replaced with Oscar Pistorius-style blades which are believed to improve speed, and that athletes should be able to take all the drugs they like. Some of course were squeamish and certainly the practice would not be acceptable in the early-21st century, but by the 22nd, life and health may not be valued as highly.

Whether you like it or not, death – or the perception of mortal danger – is one of the key attractions of motorsport. That will not change and it is another major reason that the driver will remain a part of the system. By 2139 the population of Earth may have grown hugely, in fact almost doubling according to the UN. This will lead to shortages in resources, while off-planet exploration will likely lead to the creation of substantial colonies on local celestial bodies such as the moon, Mars, and Titan. Most of these will be focused on mining to supply the Earth with the minerals and resources it requires, but many will also provide living room for major populations. There are already serious companies setup with the intention of going asteroid mining in the near future.

Danger in sport will be more acceptable in 2139 and that means that there will be more of it, and the cars built will be less defined by safety regulations than now. However, the stronger materials used, and some basic clothing will still provide drivers with some protection. G-Suits similar to those used by fighter pilots will be used by all drivers, further improving their ability to withstand high G loads. Crash helmets will be smaller, again rather more like that of a modern fighter pilot, but with the addition of a head-up display which is controlled directly by the driver's brain as with other systems on the car. They will also feature the perfect mix of breathing air, actively adapted by the demand recorded by the electronics embedded in the brain.

The cockpit itself will be a removable section mounted inside the chassis. If an accident of extreme violence is recorded (or indeed imminent), the car would automatically eject the whole cockpit pod into the air where it would parachute to the ground.

'It's hard to say how final death actually will be,' adds Pearson. 'Perhaps a person's consciousness – or major parts of it – could be downloaded, and that person could live on in the digital world.' It may mean that in 2139, should death occcur, a driver's essence remains, and so could continue to race after death. The same could be true for the top engineers and designers who could remain alive with their brains as part of a biomechatronic system. In other words, Adrian Newey could continue designing cars for hundreds of years to come.

QinetiQ proposed new driver information systems, such as head-up displays

GRAND PRIX 2139

THE FASTEST SHOW ON EARTH

The tracks where races are held are likely to be somewhat different to now. They will likely be surfaced and have a large number of banked corners. In some cases they would be built off-shore as the surrounding land is too overcrowded. Spectators would sit much closer to the tracks than they do now as strong polymer membranes protect the fans from being hit by debris or errant cars, giving a thrill unseen in motorsport in the 21st century.

Races would be held all around the Earth, with most having short durations of perhaps only 5-15 minutes. There may be many races on a single evening. For those at home, the traditional race broadcast would continue, but using far more advanced technology using methods yet to be fully explored yet, but three dimensional holographic projection is certainly a possibility (and already being experimented with). Races would be filmed using camera-equipped UAVs, which could position themselves in far more dangerous positions than a human cameraman could ever be placed, resulting in race coverage more like a Hollywood film than a sportscast.

Signals from the driver's eyeballs could be captured by electronics in their brain and beamed via the broadcaster to the television viewer's brain – they would then 'see' exactly what the driver saw without the need for onboard cameras. Sponsor messages, timing and scoring information could replace the driver's head-up display for the viewers at home.

For more 2139 predictions, visit www.racecar-engineering.com

RACING CLASS: UNLIMITED A/T ROVER. MAXIMUM SPEED: 300KPH

This series has grown up from the mining colonies on the moon, Mars, Titan, Phobos and Deimos. Using the abundant number of prospecting rovers, bored residents of the mining settlements on the various celestial bodies started to race each other. Over the years the vehicles began to be modified for racing purposes, and after a series of accidents which damaged valuable prospecting equipment, a formal racing class was established.

The rugged all-terrain characteristics of these vehicles see two-man crews tackle a huge range of hostile terrain, from the rocky wastes of Cydonia, Mars, to the methane lakes and frozen tundra of Titan. Due to the varied gravitational and thermal conditions, the series is seen as the perfect proving ground for the various exploration buggies on the market.

There are two types of race: 2000km full course classics where the cars run point-to-point as fast as they can, and the 1000km colonial short course races where 20 laps of a roughly 50km course must be completed. These races start and finish in specially constructed arenas on the edge of the larger colonies. A single 500km race takes place every year on Earth in California, and this Baja race is seen as the most prestigious event on the calendar.

The technical regulations state that the vehicles must share the chassis and power unit with a mass production planetary exploration vehicle, the crew must wear exploration suits in case of accident or the vehicle requiring a repair. It must also carry enough breathable air onboard to complete the full event unless the race is on a colonial short course where refuelling and re-gassing can be conducted.

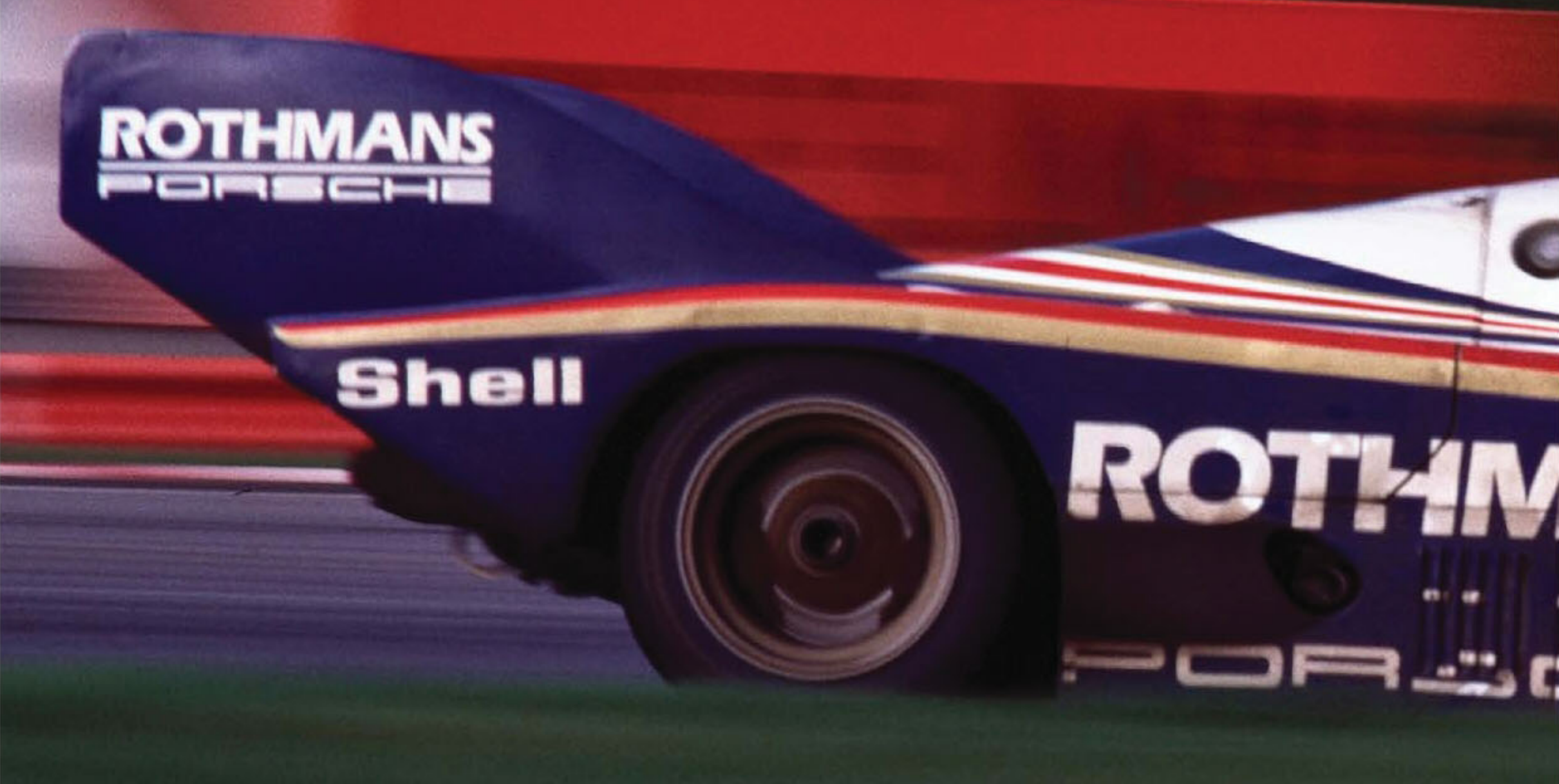
A/T Rover racing is looked down upon by most elite people, but is hugely popular among workers such as those on the mining colonies.

Enduring memories

Porsche returns to top tier sportscar racing after an absence of 16 years, but 1982 saw the beginning of an era that defined the brand

BY SERGE VANBOCKRYCK

IMAGES: John Brooks



While the arrival of the 919 Hybrid marks the return of Porsche to the top echelon of sportscar racing for the first time since 1998, it has in fact been more than 30 years since Porsche last developed a thoroughbred prototype racecar capable of winning the Le Mans 24 Hours outright. And while the 919 Hybrid is certainly capable of eventually dominating the global sportscar scene, it will, however, be impossible to ever achieve the same level success that its predecessor enjoyed. For that car, the Porsche 956/962, is, and doubtless forever will be, the most successful purpose-built competition vehicle in automotive history.

Key to the success of the 956/962 was a unique set of circumstances. First, there was the sorry state of the World Sportscar Championship which, since its inception in 1976, had attracted just three manufacturers – Porsche, Renault and Alfa Romeo.

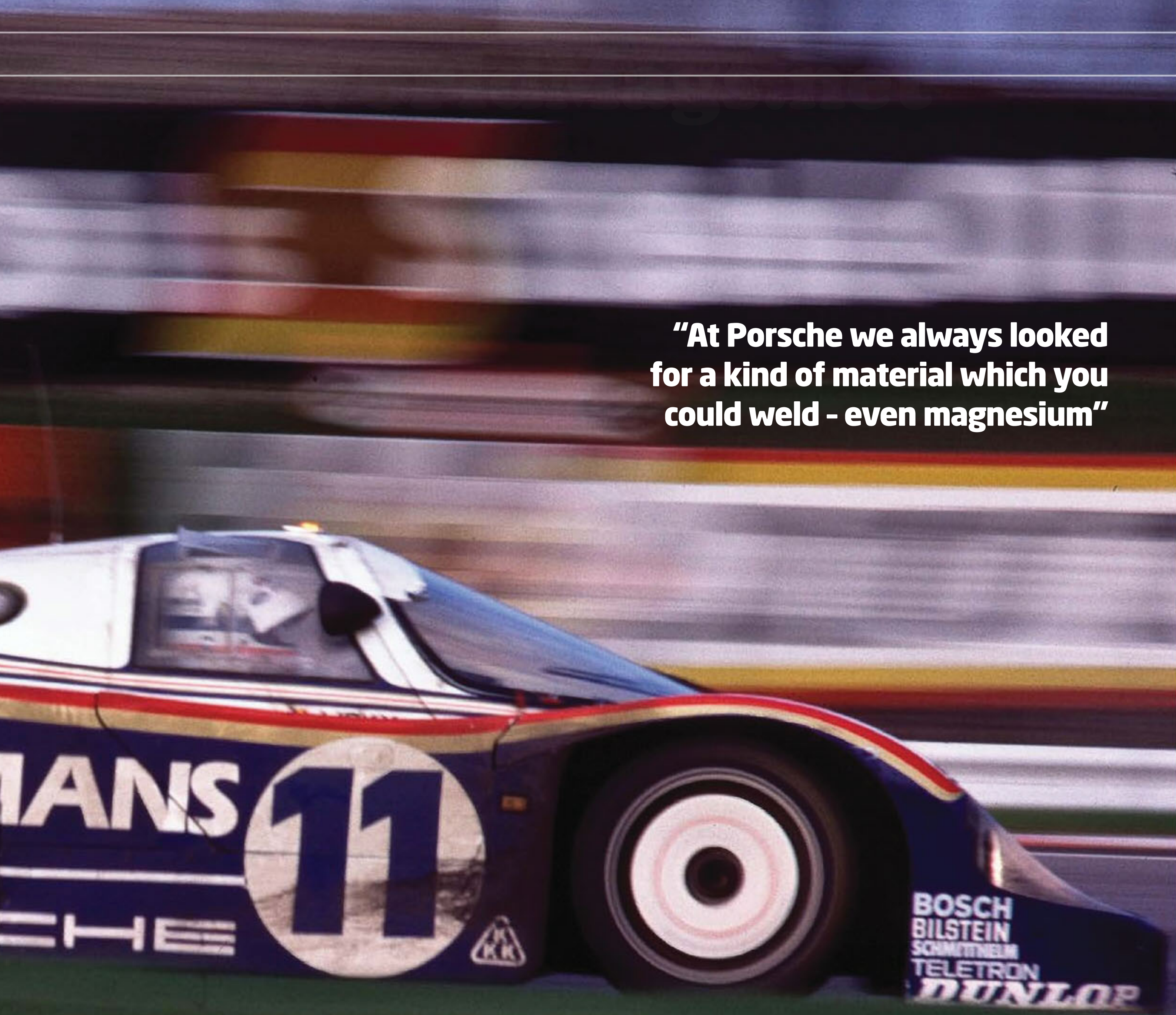
The first two, after competing against each other in the inaugural season – which Porsche easily won – decided to just concentrate on Le Mans, while Alfa pulled out after winning the 1977 season when entries barely made the double-digits. Once Renault had won the 1978 edition of the French endurance classic, it, too, retired from sportscar racing to concentrate on F1, while Porsche called it a day a year before later trying its luck at the Indy 500. Henceforth, the WSC would become the playground of privateers, some more ambitious than others.

Secondly, there was the arrival of Berlin-born American Peter W Schutz at the helm of Porsche in January 1981. When he took stock of Porsche's racing plans for 1981, he was appalled to hear that, as per his predecessor's decision, Porsche was to concentrate on running the 924 Carrera GTR in the GT class, as the front-engined Porsches were earmarked to succeed the 911 model.

Not only did Schutz get rid of that plan by deciding that the 911 should be kept alive, but he also ordered technical director Norbert Singer to come up with a plan to win Le Mans outright. Singer, never short of a brilliant idea, suggested dusting off the 936s which had been stored under tarps, and drop the engine from the firm's aborted Indy project in the back. The rest, as they say, is history: Jacky Ickx and Derek Bell won the 24 Hours with ease, and that sixth Le Mans win made Schutz sign off on Porsche's next motorsport project for 1982 and beyond: Type 956.

LONG-DISTANCE REVIVAL

Earlier in Paris, the FISA had been pondering over the next generation of sportscars needed to revive the interest in long-distance racing. The working group quickly agreed that the new class of cars should have the same grace and elegance as those vehicles from a decade or so earlier – the Porsche 917 and Ferrari 512 – but should also incorporate technical challenges for the future. The first part was achieved by using more or less the same outer dimensions of those cars of the early 1970s



"At Porsche we always looked for a kind of material which you could weld - even magnesium"

- the cockpit dimensions of the Group C cars were actually defined by measuring up a 917 in the Porsche Museum - while the latter part was met by stipulating that the fuel consumption of these cars would be limited, in return for allowing engine manufacturers to run whatever type and size of engine they liked. In fact, then as now, it had been the ACO that had first come up with the idea of limiting the amount of fuel, ie energy, to be used way back in 1949, when they first ran their race again after the second world war, when resources such as fuel were still in short supply. Then, the number of laps between each fuel stop was defined by the regulations, while now the amount of fuel available was set in stone: 600 litres for 1000km or 6-hour races, and 2500 litres for Le Mans.

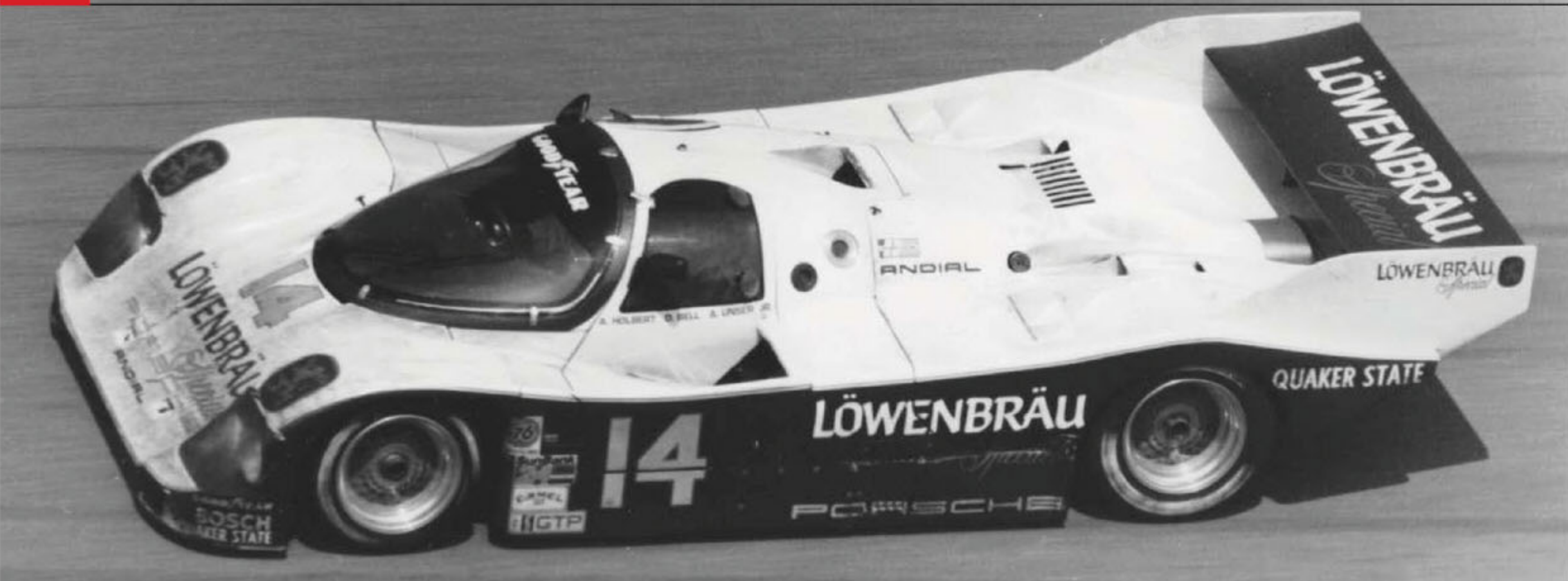
Work on Porsche's Type 956 had started in the summer of 1981, which left Singer and his men with less than a year to come up with a worthy successor of the likes of the 917, 935 and 936 to win Le Mans. Needless to say, they did just that.

MATERIAL THINKING

For the first time in the company's racing history, the 956 would not feature a spaceframe chassis, but an aluminium monocoque. The reason for steering away from what Porsche knew best was that a few years earlier the concept of ground effects had been pioneered in F1, whereby the underfloor of the car was sculpted to mimic an inverted wing shape in order to generate downforce from the air passing underneath the car. This was impossible with a spaceframe, hence the obligatory monocoque - and stressed engine - that Singer and Horst Reiter had to design. But, as R&D boss Helmuth Bott famously said to Derek Bell when discussing the latter's contract: 'We've never designed a monocoque before, but we've also never been wrong before!'

'I went to Dornier in Ludwigshafen and asked them for the basics, because an aeronautic company is the best you can ask,' Singer says. 'In those days you had a kind of aluminium which we wanted to use for the monocoque but which you couldn't weld. And at Porsche we always looked for a kind of material which you could weld, even magnesium. But since you needed a certain stiffness, we had to ask Dornier. We just wanted to have an overview, on who we could ask and where we could get the right answers. This was done in half a day, and then we started learning to build our first monocoques, because you had to learn how to do it, how to glue and rivet these parts together, how you treat the materials and so on. This we learned in four weeks. We did some measurements on parts, bending them to check torsion and stiffness, comparing materials, thickness, which kind of rivets and so on. We actually never changed the chassis. We had to adapt to the longer wheelbase of the 962, but in principle it was always the same.'

The engine for the 956 was the same as that which had propelled Porsche to victory the previous June - the mixed-cooled, 2649cc, Type 935/76.



The Porsche 962 of Al Holbert, Derek Bell and Al Unser Jr at the 1986 Daytona 24 Hours

With its twin KKK turbochargers, mechanical Kugelfischer injection and 7.2:1 compression ratio it delivered a more than ample 620bhp at 1.3bar of turbo boost.

Aerodynamically, the 956 resembled an elegant crossover between a 917 and a 1977-spec 936. At the front, the car featured a rather blunt nose, with two air intakes for the front brakes and an inverted wing-shaped floor right underneath the front axle to generate additional downforce, soon known as the Singer Dent. Air to the intercoolers and radiators was fed through two large NACA ducts located in the horizontal top of each door, with air for the rear brakes and gearbox intercooler supplied through a single central NACA in the engine cover.

The single-element rear wing sat high between large endplates, supported by two aluminium struts sitting on the trailing edge of the engine deck. The engine deck stopped midway of the maximum allowed rear overhang, but the wing sat almost entirely behind it, positioned there to work best with air funnelled through the venturi and therefore generate maximum downforce.

From the outset, Singer had designed a low downforce variant for Le Mans. In this version the 956 was referred to as a 'longtail' but was in fact of the same length as the standard model. For Le Mans the engine deck was lengthened to the maximum permitted 480cm with the rear wing sitting low over it, with the venturi were adapted to match.

Chief of Porsche customer motorsports, Jürgen Barth, had the honour of rolling out chassis 001, late on the afternoon of 27 March 1982 – and not unexpectedly discovered that the car had no vices. A few days later Ickx and Bell put the car through its paces in a five-day test at Paul Ricard, where the only real issue discovered was the need for better cooling for the radiators, intercoolers and rear brakes – an easy fix. After some more details were altered and tested, the car made its race debut in the Silverstone 6 Hours that May. The team had signed a sponsorship deal with tobacco company Rothmans, for this race and Le Mans, with an option to extend the agreement for the remainder of the season after the French classic. Rothmans had come close to signing with the Lola team, whose car been ready long before the 956, but in the end decided to risk it with Porsche. It would prove to be a wise decision.

At Le Mans in 1982, Porsche put in its most dominant performance, with three 956s on the podium

ENDURING DOMINANCE

Ickx put the 956 on pole by over a full second over the works Lancia, and although the 956 looked like the car to beat, Messrs Singer, Bott and [Peter] Falk knew all too well that they would have no chance at all to win first time out. The rules allowed the same amount of fuel for 1000km and six-hour races, and on the ultrafast Silverstone track the winner was expected to cover at least 1100km in six hours. Since the works Lancias had been built to the grandfathered Group 6 regulations, they could run without fuel limitations, and therefore were the only real candidates for victory. Ickx and Bell knew they were in for a long afternoon, but for Porsche this race had always been considered a 'live test' more than anything else anyway. The turbo boost was reduced to 1.0bar in practice, with the drivers instructed not to rev over 6000rpm – instead of 8200rpm – and use fifth gear as much as possible. All this reduced the power to 580bhp and the 956 was duly beaten by three laps by the winning Lancia. Yet at Porsche no one was unhappy about the result, quite *au contraire*: everything looked good for next month's race in France.

In Le Mans, Porsche put on its most dominant performance yet, with the three Rothmans Porsche 956s with racing numbers 1, 2 and 3 finishing in first, second and third, having absolutely obliterated the opposition along the way. Porsche duly entered the remaining races of the 1982 WEC season, and won them all, as well as the Manufacturers and Drivers' titles. Privateer teams had been knocking on Porsche's door to buy customer 956s even before the car had been built, and by the end of the season, the queue was only getting longer. Porsche decided to build a dozen 956s for customers, in exactly the same technical spec the works cars had been at the end of the 1982 season – bar the Bosch Motronic engine management system which had been developed over the course of the season. Not surprisingly the entire 'Who's Who' of 1980s sportscar racing had sent a 620,000 Deutschmark (£258,000) cheque to Porsche to buy a 956: Alain de Cadenet, John Fitzpatrick, Preston Henn, Richard Lloyd, Reinhold Joest, Dieter Schornstein, Jürgen Lässig… even Universal Pictures had ordered a couple for a (later aborted) John Frankenheimer movie centred on Le Mans.

The works team soon regained control, but later in the season at Brands Hatch, another team beat the factory courtesy of an unfair advantage as well as a clever idea. In typical British weather, the John Fitzpatrick 956 benefitted from superior Goodyear rain tyres, but Fitz had also figured out how to get rid of the undertray cooling slots which upset the airflow through the venturi and so influenced the overall handling of the car. By installing two aluminium fans driven through the turbochargers via a small bypass, Fitzpatrick could seal the slots and vastly improve the way that the car behaved.

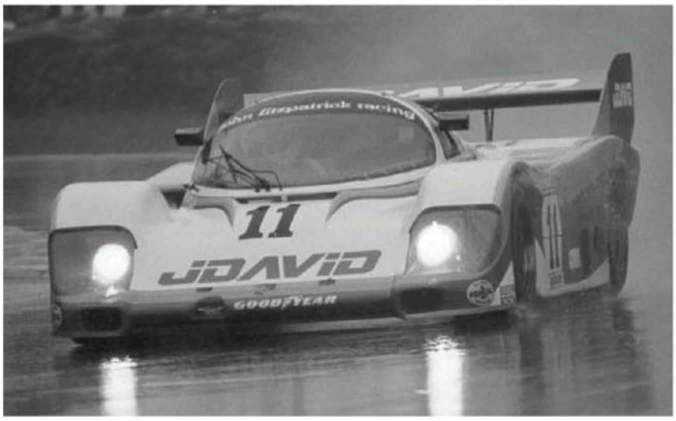
For the 1984 season, Porsche built another six customer 956s for European teams, but also the US-derivative needed to attack the IMSA GTP series.

180 MPH WITHOUT MOVING AN INCH

After endless negotiations between Porsche and IMSA, the latter feared another German domination if they allowed the 956 in as it was and issued regulations which required the pedals of the car to sit behind the front axle centre line – quite unlike the 956. Twin-turbocharged engines were equally handicapped by the sliding scale weight charts used by IMSA. Bott, Falk and Singer responded swiftly and developed a 'long-wheel base' variant of the 956, equipped with an air-cooled, single-turbo engine from the 935. Porsche immediately sold cars to stalwarts Bruce Leven, Bob Akin, Al Holbert and Preston Henn, but since delivery only started in April it was a March-Chevrolet which won the championship. However, five wins from the 13 races in which the 962 participated gave the competition a clear indication of what was to come. Indeed, over the next decade, the 962 would score a massive 55 IMSA GTP wins, including six Daytona 24 Hours and four Sebring 12 Hours.

Over in Europe, the 956s continued to dominate the WEC. While the factory continuously developed its works cars and sold on these enhancements to the privateers once they'd proved their worth, some still decided to go down their own engineering path. One such owner was Richard Lloyd, who had hired the services of former F1-designer Nigel Stroud to first improve the aerodynamics of the car (the 956/962 was conceptually understeering) and then do something about the chassis stiffness.

The solution to the first problem made its debut at the Brands Hatch WEC round, when the Canon-sponsored 956 of Lloyd sported not only a twin-element rear wing, but also an add-on front wing. The front wing (actually the rear wing on an F3 car) was said to dial out the understeer and when Jonathan Palmer and Jan Lammers dominantly won the race, all the 956s – bar the works cars – ran homemade front wings six weeks later in Spa. The reason the works cars didn't run front wings was made clear by Singer: 'What you do with a front wing



The John Fitzpatrick Porsche 956 in the wet at Brands Hatch in 1982

The following year at Brands Hatch, the Sorga SA Porsche 956 of Bob Wollek and Stefan Johansson, which finished sixth

is spoil [the effectiveness] of the rear wing. So you get less downforce on the rear and to the driver it feels like he has more grip on the front. It they'd lowered the rear wing it would have had the same effect.'

By Spa, the Lloyd 956 featured another novelty, though not one immediately visible to the naked eye, and one which would start a trend among privateers. Since Brands, the Canon Porsche had been stripped and rebuilt around an aluminium honeycomb monocoque that Stroud had designed. It was said to be stiffer and safer, something Jonathan Palmer could testify a year later at the same track. Indeed, the fatal accidents of Stefan Bellof, Manfred Winkelhock and Jo Gartner in 1985 and '86 made many privateer teams run for honeycomb monocoques built by the likes of Fabcar, Chapman or TC Prototypes, even though it's highly unlikely any of the three would have survived their accidents in one these monocoques. In the US, too, team owner Jim Busby was looking at a 'cottage industry' honeycomb monocoque to replace one of his crashed cars, but when Al Holbert – Porsche's US motorsports director and 962 team owner/driver – heard about Busby having ordered a monocoque from Californian Jim Chapman, he quickly made a deal to make it his and use it to secure the 1985 title. Though Holbert always claimed to have built his own monocoques for his 'HR-spec' 962s, they had actually been fabricated by Fabcar and Chapman.

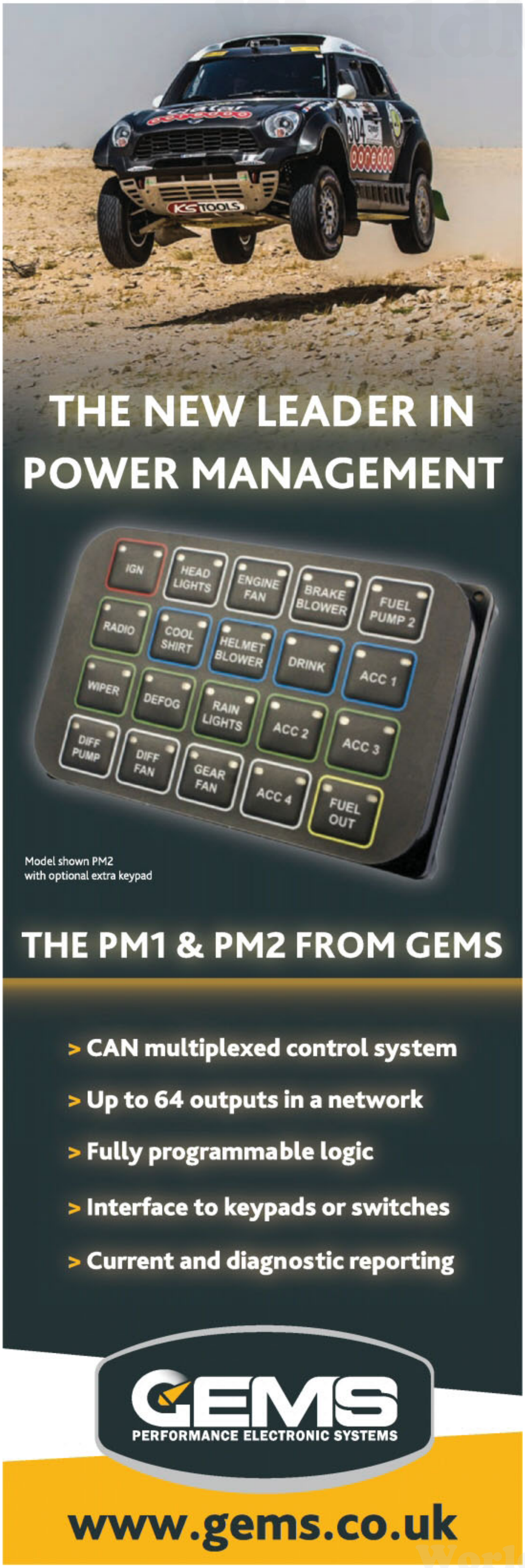
SUCCESS STORY

When the FISA applied the same rules regarding the position of the pedals to the World Championship from 1 January 1985 onwards (though 956s could be run until the end of the 1986 season), Porsche immediately decided to adapt the IMSA-spec 962 to their Group C needs by grafting the rear end of a 956 to the front of a 962, therefore creating the 962C. The success story of the Group C Porsche continued over the next few years, with the 956/962s scoring 39 World Championship wins, five Manufacturers/Teams titles and as many Drivers titles. The opposition from Jaguar and Sauber-Mercedes and the lack of development of the 962C post-1987 meant that the cars from Weissach were no longer the dominating factor. Porsche had embarked on a disastrous IndyCar programme which required all of its motorsports resources, though Singer was allowed to do some basic development again in 1989 and 1990. Yet by then the renown of the 962 and 962C were such that in fact more customer cars were built and sold in 1990 – when the cars had zero chance of winning – than in any year before.

Even when overtaken by the competition, the technology and regs, the 962 kept coming back

But even when overtaken by the competition, the technology and the regulations, the 962 kept coming back for more, and would actually get more. In 1994, thinly veiled as a roadgoing GT car, the 962 again won Le Mans for a record seventh time. In January 1995, 13 years after the first 956 hit the track, the 962 – now as a spyder – won Daytona for the sixth time, an unprecedented feat. By then, the 956/962 had also refined ABS and developed PDK for both track and road use. Engines had gone from 2.6-litre, mixed-cooled to 3.2-litre, water-cooled units and fuel consumption had been reduced by 15 per cent.

In total, between 1982 and 1991, exactly 114 Porsches 956, 962 and 962C have been built by the factory or its subcontractors, with roughly the same number built by privateer teams on monocoques from private constructors. Together these cars ran in over 500 races, winning 290 of them between 1982 and 1999. And unless Porsche decides to sell the 919 Hybrid en masse at the end of the current season, it is quite inconceivable that these numbers will ever be bettered, regardless of motorsports discipline.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Vive la difference

Innovation is key in rallycross, and two World Rallycross teams have taken very individual approaches to going racing with the Citroën DS3

BY SAM COLLINS

Citroën has been a mainstay of rallycross for many years. The AX, BX, Xsara and C4 models were all regular sights in the top category of the sport, and often campaigned by the pseudo-works team of Swede Kenneth Hansen. But with Hansen joining Peugeot in 2014 and Citroën turning its attention to WTCC, its customer teams have been left to go it alone in the newly formed FIA World Rallycross Championship.

Two outfits are campaigning Citroën DS3s in the full World Championship, neither of which are based on the last Hansen Citroën – Sébastien Loeb's DS3 XS which contested (and dominated) a single event in 2013. One team is run by one of Loeb's old rivals – Petter Solberg, the 2003 World Rally Champion, and the other is run by the leading family of British Rallycross, the Dorans.

The two organisations have very different approaches to car design and it provides one of the most fascinating rivalries in the World Championship. While the LD Citroëns are visually similar to those run by the works team in the World Rally Championship, they are anything but according to the team's lead engineer, Toni Reunanen.

'When we started this programme we set out with an MTechnologies-built DS3 – but we modified that a lot,' he says. 'There is so much that has changed that there is nothing left of the original car. We changed the roll cage, subframes, arms, uprights, engines and transmission.' Using production shells to build rallycross supercars is becoming standard practice, initially as the small mostly amateur teams did not have access to the works designs, but today they have found ways to exploit the open rulebook beyond the scope of WRC chassis.

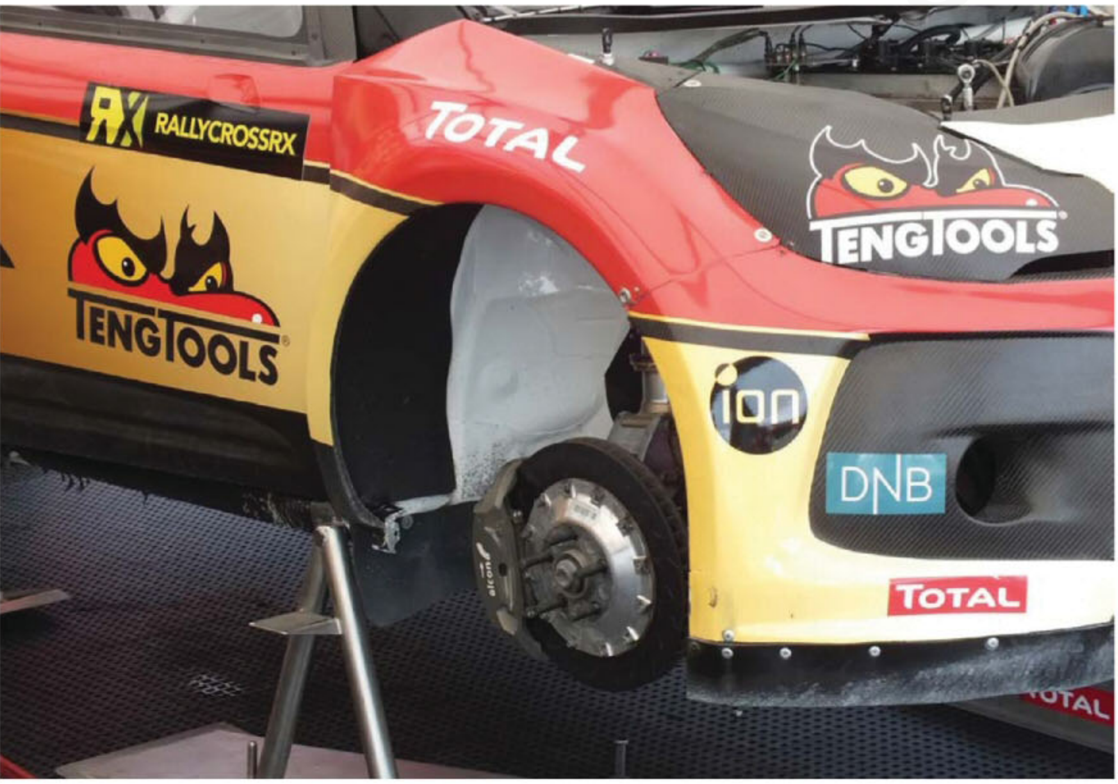
'The shells on this year's cars started life as production cars that we strip and dip and start again, but the next shells we will use will be bought from Citroën,' adds Reunanen. 'We get the standard body, put it in a jig and change many things. There are now no standard mounts between the suspension and the original body – it's all new. By regulation we have to use the same point, and our new mounts are in those areas.'

The dampers on the car are supplied by Reiger, and while the LD engineers are cagey about the exact specification, they concede that they are not simple off-the-shelf units.

'It is something slightly different to the Reigers used by the Marklund VWs,' Reunanen says. 'We probably have special dampers, but I'm not admitting it!'

The Finn has done a lot of work on calculating the correct suspension geometry, but it is not yet fully optimised. 'First we calculated all of the roll centres,

Petter Solberg celebrates after the first round of the 2014 FIA World Rallycross Championship at Montalegre, Portugal



Alcon brakes are a common feature in both team's offerings. Pictured above is a Solberg car. LD, meanwhile, claims that it has 'something a little special in the discs that nobody else has'

then we work out what we have to do,' says Reunanen. 'This year we have new uprights and suspension arms – we had to improve the handling.'

The size of the LD drivers is another variable. Liam Doran is a tall, solidly-built Englishman while Derek Tohill is a slight Irishman. But due to the DS3's compact design, Reunanen doesn't see this as a problem. 'Driver size and weight does not change the car that much, because we are so far under the weight limit. We still have to use the ballast.'

The brakes, too, were also meant to be something a little special, according to the team – but the season was upon them too fast. 'We had planned to move to different brakes but the lead times were too long, so the Alcon caliper we are using is OK, it's cost effective, and it works. We have something special in the discs that nobody else has, so while it looks like everyone is using the same Alcon, there is actually a lot more going on.'

One of the reasons that the LD DS3s look rather like the works WRC versions is the fact that some of the body components have been carried over. 'The wings we run come from the Citroën WRC

Polish driver Krzysztof Skorupski in one of the LD Motorsport Citroën DS3s

basically – aerodynamics is the big area in rallycross which is quite open and underdeveloped,' says Reunanen. 'As the cars spend a lot of time sideways at relatively low speeds, there is not much research done. There's a lot to gain there, but it's really expensive to do. The dimensions of our wing are limited, and we cannot mount it like the WRC cars do either.'

The DS3s must use the regulation PSA group engine block, though LD has them prepared by the English tuner Julian Godfrey.

'We are always finding new things to do with him, like different turbos,' says Reunanen. 'It depends on the tracks – on some of them we just need pure power, and on others driveability, so you need different turbochargers. You can use two turbos per event, so it becomes like a setup tool.'

"Positioning the engines longitudinally is old technology. Perhaps there is an advantage – it depends on the track"

DRIVELINE CHOICES

The engine is mounted in a transverse position and the near-universal Sadev transmission is also employed. But the differences are in the details, according to Reunanen. 'We use the same Sadev housing as most other people, but while it looks the same, it's not the same. The ratios, diffs, ramps and final drive are all different. You do see some driver preferences in how you set the diffs as well.'

The installation of the transmission has meant that in 2014 the LD Citroëns do not fully comply with the technical regulations. 'Our cars are slightly outside the rules due to a small cut in the chassis rail which we use to accommodate the gearbox,' says Reunanen. 'But in 2013 it was allowed, and in 2015 it will be allowed, but in 2014 the rules say that it is not. It is not a problem.'

POSITIONAL SENSE

The biggest obvious difference between the LD Motorsport Citroën and the Solberg DS3s comes with the engine position. While the English team has opted for the traditional transverse position, Solberg's engineers have gone for a longitudinal layout, something that does not impress Reunanen.

'Doing it longitudinally is old technology. Perhaps there is an advantage – it depends on the track. We believe that transverse is better, others do not. There are big differences in what you can achieve, but right now in terms of lap time there is nothing in it. There is nothing the same between our cars and the Solberg cars. I think they are using old technology. Perhaps there are those in this paddock who know how far some other cars are from the regulations.'

Pernilla Solberg, Solberg team CEO and wife of Petter, strongly disagrees that the longitudinal layout is old technology, and argues that it actually gives them a number of freedoms in terms of car design. 'One of the biggest advantages of the longitudinal

Unlike the LD team cars, Solberg's Citroën DS3s have their engines mounted longitudinally, requiring major surgery to the bulkhead area

layout is that you can find more suppliers to do gearboxes. You also have engine builders that prefer it. We have a Swedish gearbox from a company called Unic – it's a very good system from a good guy who has been a friend of ours for a long time. We like to have local suppliers, and many things on our cars are made around where we live.'

As is the case with the LD cars, the Solberg Citroëns are built up from production cars rather than WRC shells, despite the team having access to the works version from its now defunct rallying programme. 'We start from a totally bare shell, bare metal and we take that to Ingvar Gunnarsson in Sweden and he starts to reinforce the areas where we are allowed to change things, especially in order to accommodate the engine,' says Pernilla. 'The Citroën DS3s from the factory come with a transverse engine, but we modify the chassis to accept a longitudinal engine. We open up the bulkhead, and put in a tunnel to accommodate the gearbox and exhaust. The roll cage is done by Ingvar. So when it gets to us, it's almost a rolling chassis.'

HOMEGROWN RACING

The Solberg team is one of those that sits between professional and amateur. Running out of small premises at the family home, the team is capable of running with the best in the world and is revelling in the freedom of the RX Supercar class. 'The thrill about this sport is that you can build and design all of the uprights and things yourself,' adds Pernilla. 'In the WRC where we were before, you could only use homologated parts off the shelf. Here you can be more inventive and do your own things.

'I'm really proud of our uprights. They are really beautiful, with lots of small details that are made locally. The dampers are from Holland though, from Reiger. We also use Öhlins on one car. We like to try different things, but they are both good. The most important thing is to have suppliers willing to help.'

The two Solberg DS3s do not only differ in terms of the damper suppliers – there are a number of other subtle variations. 'The two cars are not the same overall,' says Solberg.

'In terms of suspension, they have wishbones that are slightly different lengths and positions. It's the same concept, but slightly different detail. The engines in the cars are different too – one is done by Julian Godfrey, and then we have Pipo in Petter's car. Pipo now look after both as it was silly to have two suppliers in the awning, but Julian still provides parts. We have steel blocks rather than the aluminium blocks used by Loeb.'

As is common throughout the RX field, aerodynamic development in the Solberg cars owes much to cars Petter Solberg has driven in the past. 'The rear wing on the car is our own,' says Pernilla. 'It's Petter's idea from rallying and is inspired by the Subaru WRC. We have not done CFD and wind tunnel work on it.'

"In the WRC you could only use homologated parts off the shelf. Here you can be more inventive"

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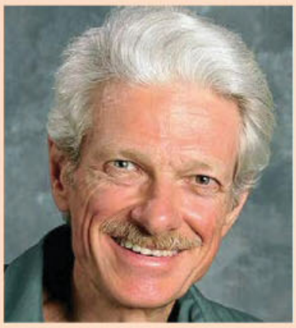
Correctly defining your calculations

Making sure your sums are right when your design is non-standard



Mark Ortiz Automotive is a chassis consultancy service primarily serving oval track and road racers. Here Mark answers your chassis setup and handling queries. If you have a question for him, get in touch.
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A: Mark Ortiz, 155 Wankel Drive, Kannapolis NC 28083-8200, USA

QUESTION

I have been reviewing my lateral load transfer calculations using one of your newsletters, which provided a good summary of the applicable calculations and variable notation scheme for presenting the calculations for elastic, geometric and unsprung load transfer.

It has occurred to me that I am not sure where you, if at all, define the neutral roll axis based on your chosen coordinate system. The x axis is defined as one half rear track (at least that is what I usually use with a beam axle rear) longitudinally with positive forward in the direction of travel and the y axis laterally at one half the average wheelbase with positive y to the driver's right and z down with the axis system on the ground plane.

I realise that you consider the front and rear roll centre height locations to be undefined laterally (undefined in y) and I agree with that. What puzzles me is the calculation of the sprung mass roll angle phi which is then used to work out the front and rear elastic load transfer. It's not the calculation or the resulting load transfer that I question, rather where you consider the roll angle phi to be located?

I know phi is considered to be the angle of roll around the x axis by definition (SAE axis system) and is usually presented as being around the NRA on a symmetrical car, but do you still consider the NRA and phi to be on the car centreline for a car with, for arguments sake let's say, a high left side percentage which offsets the cg substantially to the left of centre when viewed from the rear?

In your video Minding Your Anti you use two diagrams from RCVD from the chapter on wheel loads, one side view to illustrate the locations of the cg, roll centres, roll moment arm and NRA and another for a wheel pair in a banked condition with an offset cg to illustrate your point about how the forces act on these respective point parallel to the ground plane, very effectively in my opinion, and I agree.

But should there be a correction added to the calculation for roll angle based on a significantly offset cg?

If the NRA and phi remain on the x axis which we have defined as the car track centreline then the sprung weight of the car is acting, in this example, downward at some distance to the left our x axis as viewed from the rear.

If this is so, doesn't mS acting at the cg create a moment that would reduce our total sprung moment MeS = mS*ay*rcgsx by an amount equal to mS*(cg offset distance)? Which would then reduce the roll angle and then by definition reduce the elastic load transfers front and rear? In my long ago education in physics, I was taught that torque= r*F*sin(theta) is the cross product of the position vector ro and the force. I have worked this out with the assumption that the position vector goes from the point intersected on the NRA by the moment arm rcgsx to the cg with two forces acting on the cg, that of lateral inertial reaction to lateral acceleration and that of the sprung mass mS acting downward. This results in very different values for the roll angle phi and the resulting elastic load transfer front and rear.

Should there be a correction added to the calculation for roll angle based on a significantly offset cg?

Now, to get all this to square with our total vehicle load transfer delta - Fz=m*ay*t - we would also have to correct total load transfer by an amount m*(cg offset distance).

THE CONSULTANT SAYS

Considering a simple two-dimensional front-view half-car model (in the y-z plane), the lateral offset of the cg (its y coordinate) does result in a roll torque, but only in response to z axis accelerations. (If we like, we can consider gravity to be a form of acceleration, as has become common nowadays.)

Y axis (transverse or lateral) ground plane forces act horizontally, and the accelerations that result from them produce inertial reaction forces at the cg that likewise have a horizontal line of action.

Lateral load transfer in the British Touring Car Championship

We can consider the roll moment about the ground plane, which is reacted suspension geometry and by elastic devices (springs and anti-roll bars). We can also consider only the component reacted by the elastic devices, which is commonly represented as moment of the sprung mass inertia force about the roll axis. Either way, if the acceleration is purely horizontal, the centripetal force acts horizontally, and the centrifugal inertia force does too. The moment arm then is simply the vertical (z axis) distance between the two. It doesn't matter what the y location of the cg is.

In more general terms, if we have a force applied to a body at some application point, with some line of action, we can move the application point to any other location along that line of action and the forces and moments on the body will not change.

This does not mean that the y location of the cg has no effect. It does influence yaw moments in response to x axis accelerations. It does influence roll moments in response to z axis accelerations. It affects roll moments through dips, over crests, and in banked turns. It affects what the right and left wheel pair loads are in cornering on a flat surface, but only because it affects what their values are statically. It does not affect how much they change from static. Having the cg towards the inside of the turn is definitely beneficial, because it results in more equal tyre loading when cornering. However, it does not accomplish this by reducing load transfer, or roll. It merely introduces a static inequality of loading that partially compensates for the dynamic load transfer.

The action of gravity on the offset cg does introduce a moment about the track midpoint, or a greater moment if we take moments about the further contact patch than about the nearer one. This shows up as higher scale readings on the nearer wheels. But this moment does not change in response to a pure y force at the cg.

With independent suspension, the amount of geometric anti-roll usually varies somewhat depending on the distribution of y axis ground plane force at the contact patches. Since cg offset affects this distribution, it can affect front and rear lateral load transfer distribution. However, it is impossible to generalise about such effects. They will depend on the geometry of the particular car.

An effective three link solution?

Evaluating the pros and cons of an interesting late model suspension

QUESTION

We race ARCA/Main Event Racing Series outlaw late model oval track asphalt race cars throughout Michigan, Indiana and Ohio. One of the newer chassis builders has been very successful. One of the main differences on their cars is the design of rear three link suspension. The trailing arms are much shorter, they attach to the rear end axle tube housings and they also float on the tube similar to a dirt car bird cage suspension. They also run the rear springs in front of the rearend with large spring rates 650LR, 750RR or soft 150lb springs with bump stops on both the LR and RR.

My question is: do you think this is a advantage over the traditional three link suspension, if so why? By running the trailing arms and springs this way, how does it change wedge or wheel loads?

THE CONSULTANT SAYS

The questioner's pictures show what appears to be a conventional three-link pavement car rear end with a long Panhard bar and coilovers, except that as he notes, the links are all raised compared to most such layouts, and the lowers are about two feet long. The lowers attach to a small birdcage with a clevis at the front of it. The front of the link has a regular rod end.

The top link is shown very high above the axle, but this is adjustable. The front end heights of all three links appear to be adjustable. The brake calipers appear to be on clamped brackets, which is customary on such cars.

I don't see any big advantage or disadvantage to making the lower link pivot exactly about the axle tube centre. Without the clevis, the link would try to locate the axle laterally and a bind would result, but with the clevis I don't see any reason that it should create any problems. On the other hand, I don't see that it does anything that couldn't be done with a clamp bracket and a conventional link with rod ends front and rear, and it's a little less adjustable.

Raising the lower links increases the loads on them and on the top link under power and braking, for a given top link height. This can be addressed by mounting the top link higher, but the entire system gets taller. That's acceptable if there's room, but there's no advantage. There is some advantage in mounting the lower links as low as possible and the upper as high as possible, in terms of reduced friction and wear at the rod ends. In general, any desired combination of anti-squat, anti-lift, and roll steer can be had with high or low mounting of the lower links.

Mounting the coilovers ahead of the axle has more effect when we use a compliant pull bar for the top link, or a compliant torque arm

There's a slight weight saving in keeping the brackets short, but the brackets don't weigh much compared to the rest of the axle.

Where length is concerned, there isn't any huge difference between two feet and three feet, for the amounts of wheel travel seen in pavement cars. When you start getting up to four feet, sometimes the links will bend instead of the rod ends moving. The angle and height of the link are what matter. The length just affects how much the angle changes as the suspension moves.

Mounting the coilovers ahead of the axle has more effect when we use a compliant pull bar for the top link, or a compliant torque arm. But the setup in the pictures has rigid links. If the side view swingarm length is short, the spring-to-axle motion ratio in ride gets smaller. That makes the wheel rate in ride softer compared to the wheel rate in roll, a bit like having a wider spring base or having an anti-roll bar. However, this effect is dependent on the adjustment of the side view swingarm length, and that complicates adjustment of the car.

Overall, I'd have to say that this design is more of a harmless gimmick than a real advantage. It doesn't do anything that can't be done by other means, but it doesn't do anything awful, and it looks different. If a builder's cars are well supported and setup, and have a feature that just makes them visibly different, that feature can sell cars, because people will tend to assume that the difference they can see is what makes the cars successful.


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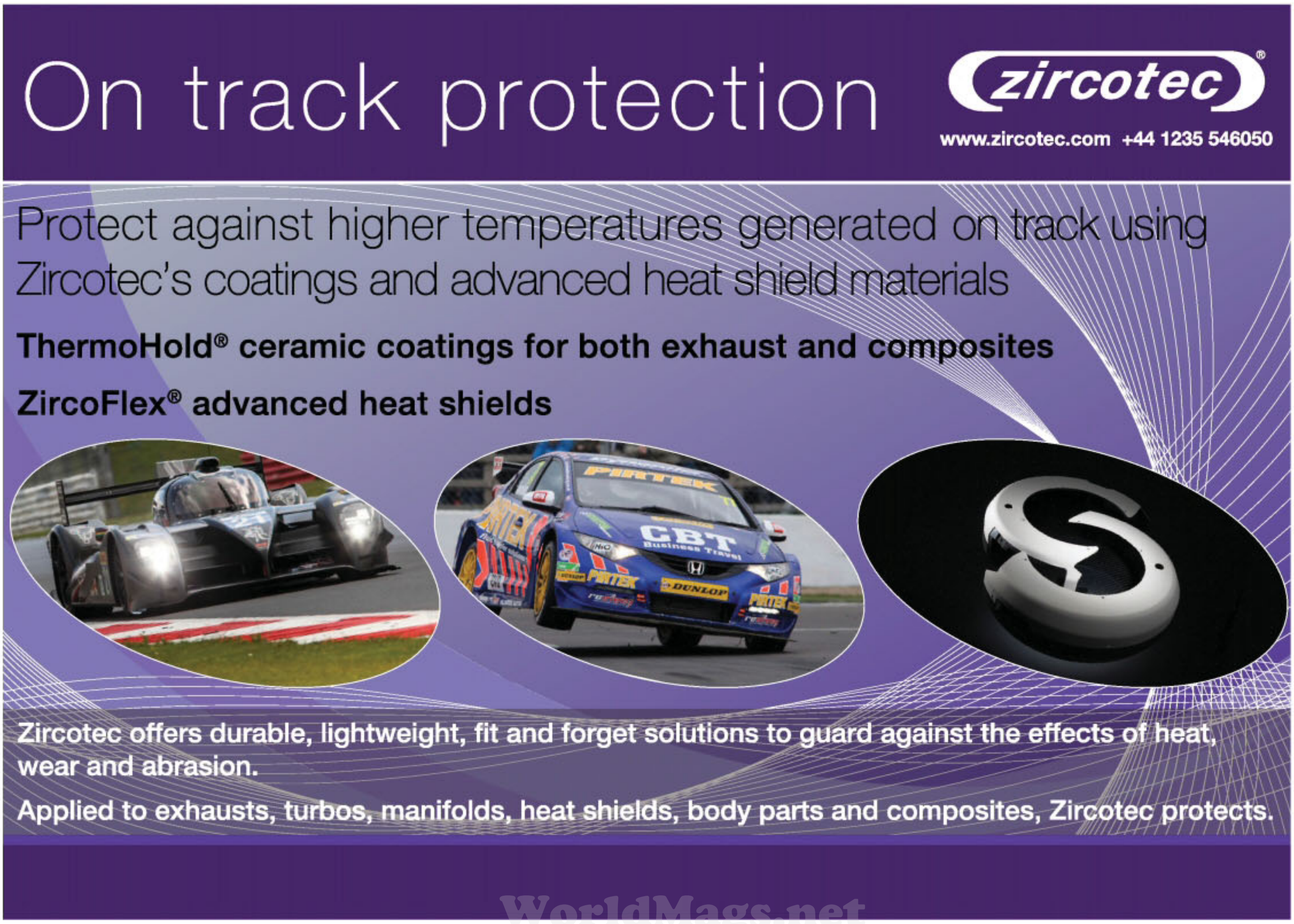
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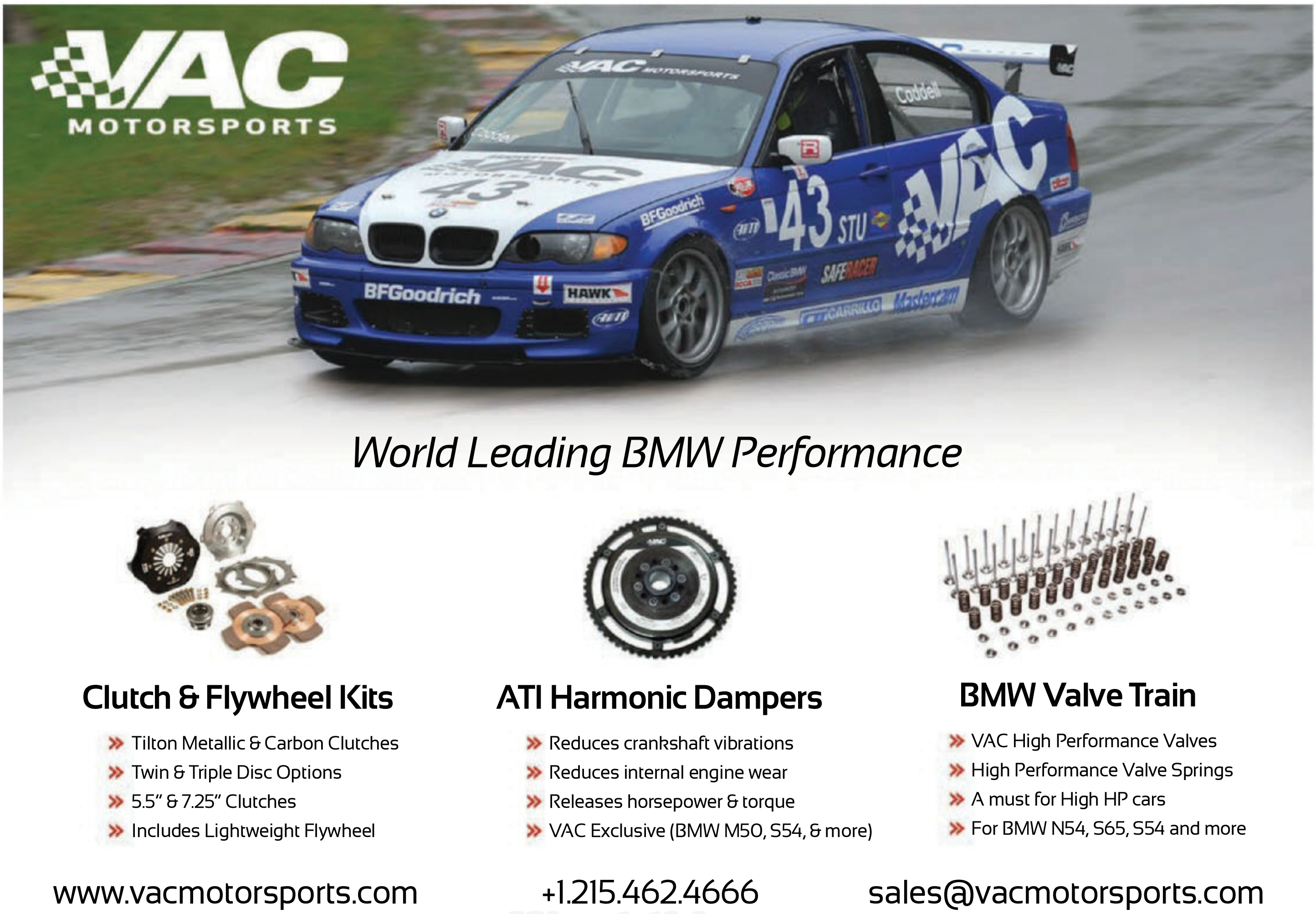

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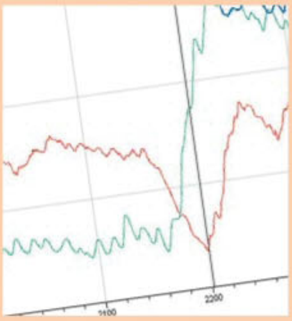


Databytes gives you essential insights to help you to improve your data analysis skills each month, as Cosworth's electronics engineers share tips and tweaks learned from years of experience with data systems

Racing with a CAN-do attitude

The growth of electronics calls for efficient, durable wiring solutions

Modern racecars can have a lot of electronic devices that all need to communicate with one another in order to work efficiently. Good examples of this are the new generation of Le Mans prototypes, where teams are free to choose whichever control and monitoring systems they want – and therefore may end up with several different suppliers. Controller Area Network (CAN) was originally developed for road car use, but has since been adopted by racecar manufacturers as a very efficient way of linking devices together.

CAN bus wiring is a simple solution, and can be extremely robust – providing certain rules are adhered to. There are only two wires – CAN high and CAN low – which need to be a twisted pair, while any spurs should be no longer than 30cm. If multiple devices are on the bus, they need to be wired in a daisy chain where the wires go in and out of each device. The CAN bus needs to have ends of line or terminators which can be done using 120 Ohm resistors. These can either be wired directly into the bus or – in most cases – CAN devices have a software option that allows the user to choose whether it is terminated or not.

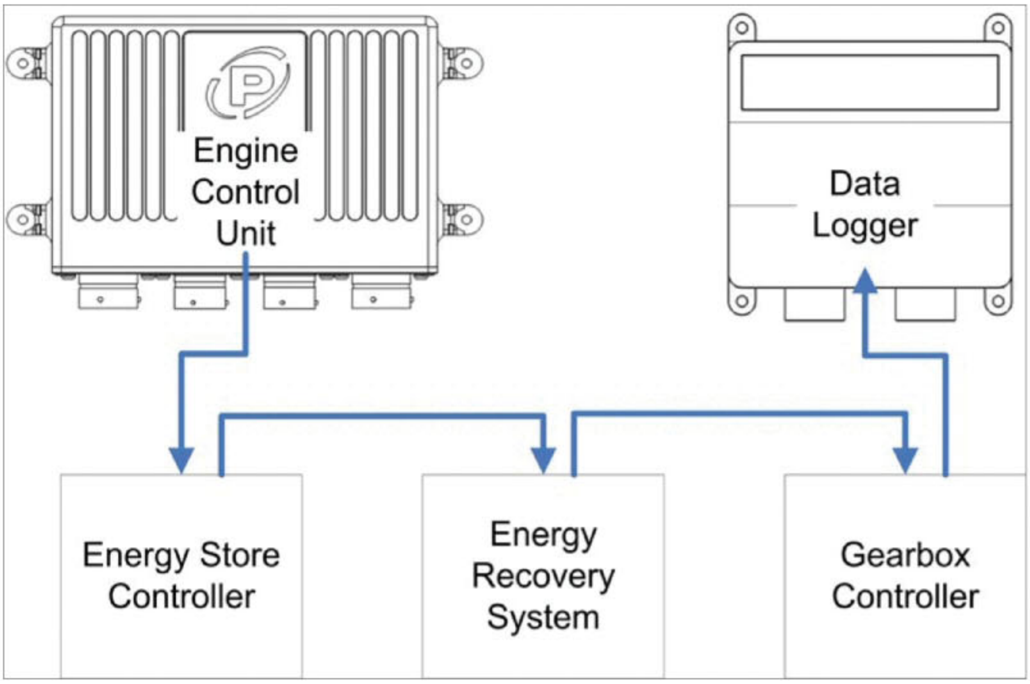
Without going too deeply into the principles of how a CAN bus works, we can look at some of the basics of how data is transported and manipulated. In essence we have 0s and 1s aligned into bytes to form different numbers. For simplicity it's best to work in chunks of bytes – 8, 16, 32 and 64 bits. This gives us plenty of options when it comes to sending various values. In essence, one byte (8 bits) allows us to send anything from 0-255, two bytes 0-65535 and so on. Take an example of a simple value, such as oil pressure, to be transmitted in bar over to another device. The expected value is in the range of around 0-10 bar and it needs to have a two decimal place precision. This means in the 0s and 1s world that we need a minimum of 4 significant figures as the value cannot be transmitted as a floating point number. This is best explained by imagining a value of – say – 5.67 bar pressure. The transmitting device will send out 567 and on the receiving end the value is divided by 100 to get the correct number. In this case, it is best to use two bytes to represent this value even though the full scale will not be used.

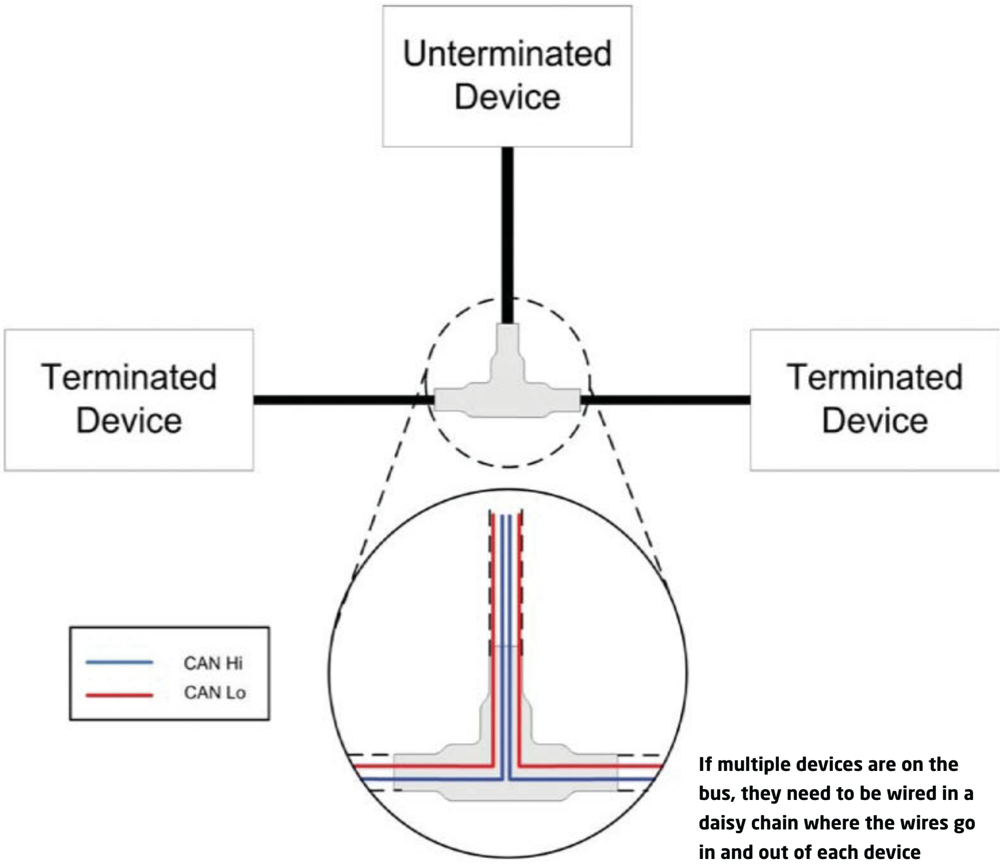
ON THE BUSES

Now that the value has been determined, it is necessary to look at the structure. A CAN bus holds frames or packets that each has to have a unique identifier. In motorsport, the 11-bit identifier is most common, although the extended 29-bit identifier is also sometimes used. Each packet is able to hold 64 bits of information, so it is for example possible to send four channels using 16 bits each or eight channels using 8 bits each. The ID of a packet serves not only as its identifier but also denotes the hierarchy – the lower the packet ID, the higher priority it has on the bus. This can be of significance when designing the CAN bus layout and which IDs each device should use. It goes without saying that when designing a racecar electronic layout it is important to spend time mapping all the CAN IDs that will be present on each CAN bus. Cars have often not started because there is an ID clash and the ECU thinks that the gearbox is engaged, meaning the car goes nowhere.

There are several different ways to write the code needed for a CAN packet. The most convenient format is known as dbc – this format makes the CAN packets

CAN bus wiring is relatively simple and – if certain rules are adhered to – is very robust





If multiple devices are on the bus, they need to be wired in a daisy chain where the wires go in and out of each device

Example of an XML code snippet defining a CAN packet:

```
        BaudRate="1000000"
        Timeout="1">
<CanStream.Packets>
    <CanPacket Id="357" Length="64" Rate="50"
            PacketType="Standard"
            Endianness="Big"
            BitNumbering="FollowsEndianness">

        <CanPacket.Contents>
            <Channel Name="RPM"
            Start="48" Length="16" DataType="U16" ScaledDataType ="F32"
            Quantity="angular velocity" Unit="rpm" />

            <Channel Name="Injector Mass"
            Start="32" Length="16" DataType="U16"
            Quantity="mass" Unit="mg" ScaledDataType ="F32"/>

            <Channel Name="Lambda"
            Start="16" Length="16" DataType="U16"
            Quantity="user type" Gain="0.01" ScaledDataType ="F32" />

            <Channel Name="Ign Timing"
            Start="0" Length="16" DataType="U16"
            Quantity="angle" Unit="°"
            Gain="0.1" ScaledDataType ="F32" />
        </CanPacket.Contents>
    </CanPacket>
</CanStream.Packets>
```

very easily readable and many automotive systems allow a direct import or use of a dbc file. Other methods include XML and C code, but these normally require a compiler of some sorts in order to generate code usable by control systems. Some control system or logger configuration tools also have proprietary systems that allow the user to define the CAN stream. In any of the cases there are a few standard variables that need to be configured – baud rate is the speed of the CAN bus and needs to be the same for any device on that bus. The maximum speed is 1Mbit/s, and this is the most commonly used speed. The packet identifier type – either standard (11 bit) or extended (29 bit) – effectively controls how many unique identifiers are possible.

DATA LOCATION

Then there is the endianness. This is always a bit of a hot topic even though it is relatively simple. Endianness is either big or little and refers to the location of the most significant byte. There are two different methods of declaring endinness – little endian or big endian. The confusion comes up when those two refer to Intel or Motorola, little endian and big endian respectively so named after the architecture used by each company's processors. Endianness is all about how a number is stored in memory – where the largest component of the number is kept and ditto for the smallest. Standard numbering for humans is big endian, and if we look at the number 234 we know that the left most digit 2 has the largest value. If, however, we normally used little endian format the same number would be 432. It should therefore be clear that the endianness is quite important!

We have only just scratched the surface here, but this knowledge is enough to get you going where using and debugging CAN buses is concerned.

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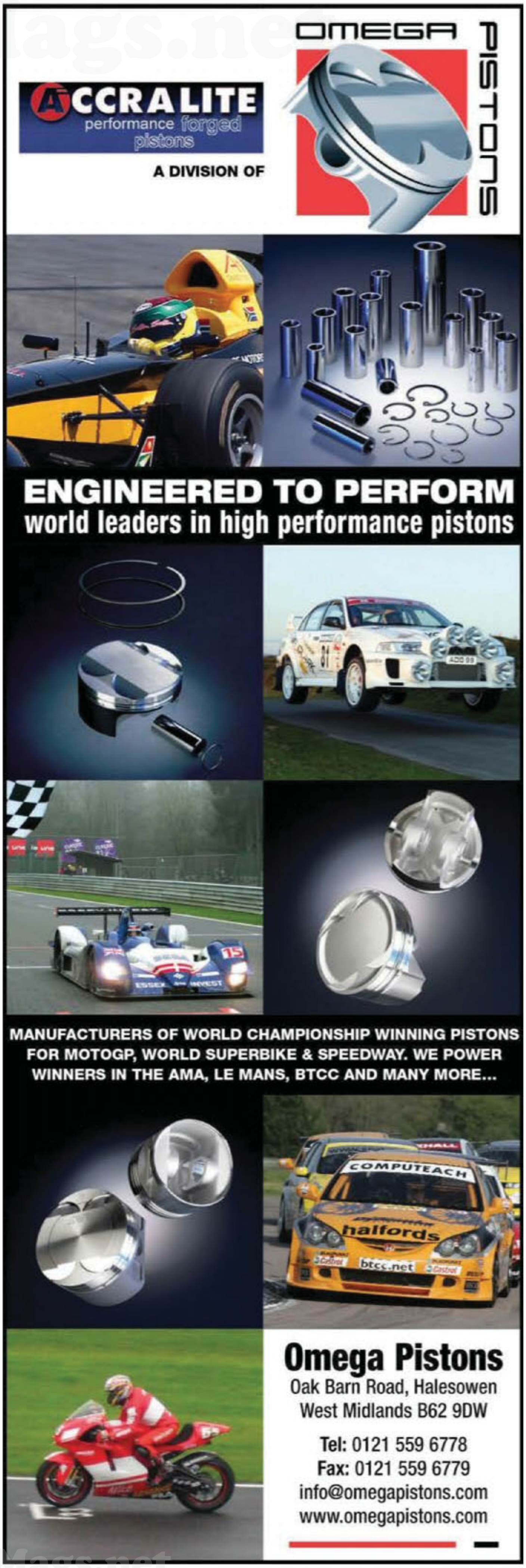
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Simon McBeath offers aerodynamic advisory services under his own brand of SM Aerotechniques – www.sm-aerotechniques.co.uk. In these pages he uses data from MIRA to discuss common aerodynamic issues faced by racecar engineers

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Two times a Tiga

We revisit open top CN sports racers in the MIRA tunnel with an evaluation of very different solutions to the same problem

We start a new study this month on two distinct open top Group CN sports racers that share a well-known name but little else. Both cars are now branded 'Tiga' after LMP2 driver and businessman Mike Newton acquired the Tiga name in 2012 and – with neighbours Orex Competition and aerodynamics consultant James Kmieciak – commenced development programmes on these CN cars.

Tiga CN212A, based on an earlier Chiron design, in blue, red and white (see **Picture 1)**, and Tiga CN212B, an update and evolution of a WFR design, in orange (see **Picture 2)**, differ most obviously in the location of their rear wings, Tiga A's being very low. Dimensionally the cars are very different too, Tiga A being some 220mm narrower. The combination of narrow width and the low wing location meant that Tiga A's frontal area was approximately 25 per cent less than Tiga B's. However, being shorter overall too, its plan area was also some 15 per cent less than Tiga B's. So how would the aerodynamic data stack up between the cars?

SPEED SENSITIVITY

Let's look first of all at the baseline data as the cars arrived at the MIRA wind tunnel, running at 60mph and 80mph to see if there was any sensitivity to speed in the data. See **Table 1**.

Looking at how the two cars' data changed with speed, there are similarities and differences as the flows developed. In both cases, increasing speed saw CD decrease, -CLfront increase; -CLrear decrease, %front increase and –L/D increase. The principle difference was that overall –CL increased on Tiga A, but decreased on Tiga B with increasing speed, with Tiga A's -CLfront increasing more than its -CLrear decreased. In contrast, Tiga B's -CLfront increased only very slightly, but its -CLrear decreased more. It was curious that the -CLrear values on either car should decrease at all with increasing speed – the opposite might have been expected. However, Tiga A's rear end may not have aerodynamically changed much at all as speed increased, so that the gain at the front end produced a small mechanical loss at the rear. Tiga B's response is harder to explain, the decrease in -CLrear being larger than could be explained simply by the mechanical effect of the small increase in -CLfront. **Pictures 3** and **4**.

The other striking aspect of **Table 1** is the big difference between the coefficients of the two cars. However, to make fair

Table 1: baseline aerodynamic coefficients at 60mph and 80mph; changes are in 'counts', where 1 count = a coefficient change of 0.001

Tiga A	CD	-CL	-CLfront	-CLrear	%front	-L/D
60mph	0.725	1.414	0.268	1.146	19.0%	1.950
80mph	0.719	1.427	0.291	1.135	20.4%	1.985
Change	-6	+13	+23	-11	+1.4%	+35
Tiga B	**CD**	**-CL**	**-CLfront**	**-CLrear**	**%front**	**-L/D**
60mph	0.502	1.381	0.366	1.014	26.5%	2.751
80mph	0.493	1.371	0.374	0.996	27.3%	2.781
Change	-9	-10	+8	-18	+0.8	+30

Table 2: comparing Tiga A and Tiga B in similar balance states

Car	Balance	CD.A	-CL.A	-CLfront.A	-CLrear.A	-L/D
Tiga A	21.6%front	0.785	1.562	0.338	1.224	1.990
Tiga B	21.5%front	0.740	1.833	0.394	1.437	2.477
Tiga A	35.2%front	0.738	1.319	0.464	0.855	1.787
Tiga B	34.0%front	0.789	2.079	0.706	1.372	2.635

Table 3: comparing the Tigas with the Ligier JS49

Car	Balance	CD.A	-CL.A	-CLfront.A	-CLrear.A	-L/D
Tiga A	35.2%front	0.738	1.319	0.464	0.855	1.787
Tiga B	34.0%front	0.789	2.079	0.706	1.372	2.635
Ligier	35.3%front	0.771	1.973	0.696	1.277	2.557

Picture 1: Tiga A's front view highlights its small frontal area. From this angle in particular, the rear wing is almost invisible

Picture 2: Tiga B presents is a more conventional CN car layout – note that the dummy driver was installed during testing!

Picture 3: yes, there was a wing tucked down there at the back

Picture 4: Tiga B's wing exploited the maximum permitted height

Table 4: nose section data, with changes in counts

Tiga A	CD	-CL	-CLfront	-CLrear	%front	-L/D
Convex	0.719	1.427	0.291	1.135	20.4%	1.985
Concave	0.720	1.433	0.310	1.123	21.6%	1.990
Change	+1	+6	+19	-12	+1.2%	+5

Picture 5: Tiga A's concave nose; compare to the gentle convex shape inboard of the wheel pods in Picture 3

Picture 6: dive planes produced an unusual response on Tiga A

Table 5: data with and without dive planes; changes in counts

Tiga A	CD	-CL	-CLfront	-CLrear	%front	-L/D
No DPs	0.677	1.210	0.426	0.784	35.2%	1.787
With DPs	0.691	1.225	0.430	0.794	35.1%	1.773
Change	+14	+15	+4	+10	-0.1	-14

comparison between two different cars, data in similar balance states has been used, and coefficients multiplied by frontal area have also been used as these are directly proportional to the measured forces. See **Table 2** for further comparisons in two different %front conditions.

We can now see more clearly that the two cars actually produced fairly similar levels of drag, within 6 per cent or 7 per cent, this despite the much smaller frontal area of Tiga A, and that Tiga B generated more downforce than Tiga A in either balance state shown here – especially so in the 34-35 %front condition. Part of the reason for this is that Tiga A was only able to produce 35 %front when the rear wing was adjusted to generate less rear downforce, whereas getting Tiga B to the 34 %front level involved the addition of significant front downforce – this will be explored further next month.

I have made frequent reference in recent Aerobytes columns to the Ligier JS49 CN car tested in 2008, and this month is no exception! **Table 3** shows data from the Ligier in a similar 35 per cent-plus condition to the Tigas.

From this we can see that Tiga B and the Ligier were in the same ballpark, with Tiga B generating 2.3 per cent more drag and 5.4 per cent more downforce, -L/D being 3.1 per cent better overall. Against the background of applicable regulations, this represents a modest gain over five or six years.

NOSE JOBS

Tiga A came with two different nose designs. First was the convex shape in which it was baseline tested, with gentle convex sections between the wheel pods and the central chassis cover, and a bluff vertical face above the rear of the splitter's upper surface. The alternative had gentle concave sections between the wheel pods and central chassis cover with no bluff panel above the splitter, the concave sections extending forwards to the splitter's leading edge **Picture 5**. The same splitter was used in each case, and **Table 4** shows how the data compared.

The concave nose section was therefore slightly better for front downforce and overall downforce, with essentially no difference in drag. The relatively modest 6.5 per cent increase in front downforce would have reflected a loss of some positive pressure on the splitter's upper surface with the convex nose vs a gain in positive pressure on the upper surface of the concave nose section.

Later in the session, after a significant change of rear wing location, pairs of dive planes were installed on each front corner of the concave nose, **Picture 6**. The data between comparable configurations, in **Table 5**, show some interesting responses.

The dive planes added 14 counts of drag and 15 counts of total downforce, so were not a very efficient addition in this instance. Unusually, the gain in front downforce was very small, and even more unusually the rear also gained a small amount of downforce. Ordinarily we would expect a bigger front gain and either little change or a loss of downforce at the rear. Is it possible then that the rear wing, in its very low location, actually benefitted from the fitment of dive planes in this case? Dive planes generally create vorticity that rolls down the sides of the car, so perhaps this was adding downwash ahead of the low wing and increasing mass flow to it? The change was minor, but fascinating nevertheless.

Next month we'll look at some interesting front end changes to Tiga B, together with some other intriguing and sometimes surprising alterations.

Racecar Engineering's thanks to Mike Newton at Tiga Racecars, Dave Beecroft and crew at Orex Competition and James Kmieciak at Percam Engineering

A sense of economy

With one fuel flow sensor already homologated and introduced for F1 and WEC, Sentronics have emerged with a rival solution, set to undergo testing after Le Mans

Track testing of the ultrasonic fuel flow sensor began in November 2011 in a Core Autosport ALMS LMPC car at Palm Beach International Raceway. Pictured left to right: David Aronson, Neville Meech, Dan Partel, Jamie Jones and Andrew Burston

BY ANDREW COTTON

'Efficiency' is the buzzword of motorsport this year. Key to measuring the efficiency of the engines is a super-accurate fuel flow sensor, as required for Formula 1 and World Endurance teams and engine manufacturers in competition this season.

One sensor has already been homologated and introduced, but there is another that is coming to market, one developed under the radar, but which is priced to meet the needs of different series, including not only F1 and WEC but also DTM, Australian V8 Supercars, and even GT racing.

The new fuel flow sensor, which may be tested by teams after Le Mans and which will undergo final track testing between Le Mans and the next WEC round in Austin in September, is designed and built by Sentronics Limited, a consortium of sensor manufacturer Reventec, precision machining firm Mikina Engineering, electronics specialists Polyhedrus and Hyspeed LLC, which oversees marketing and finance. Former lead motorsport engineer at Gill Sensors, Neville Meech, has co-ordinated the effort to create a new sensor.

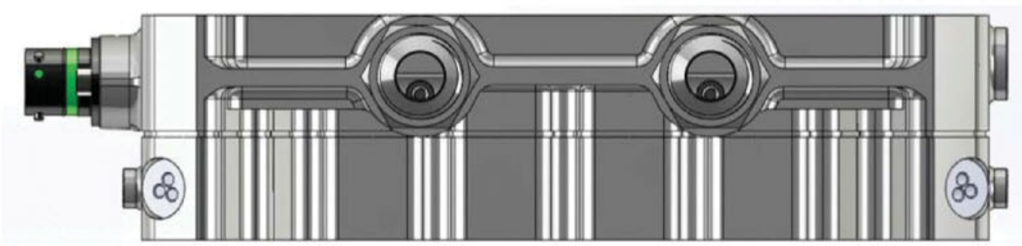
'We remain convinced that the ultrasonic measurement principle is the best way of accurately measuring fuel flow,' says Meech. 'Reliability, repeatability and accuracy are the key criteria for any sensor in motorsport, more so than ever when measuring fuel flow rates. Using our understanding of ultrasonics in an environment we understand well has enabled us to develop a product suitable for multiple categories, from F1 to GTs.

'Numerous considerations are required to design a device which will be robust and easy to use, remain consistent over time in variable conditions and above all be affordable, especially in lower categories. So, we set out to build a device which would be simple, make appropriate use of available materials, and lend itself to different series through multiple specification levels. One example of this is the use of a single material for critical parts in contact with the fuel, which has helped us to control thermal expansion and optimise accuracy across the temperature range. We've employed PFC seals where needed and avoided the use of plastic or composite parts within the fluid flow chamber.'

> **"Reliability, repeatability and accuracy are the key criteria for any sensor in motorsport"**

Meech was part of the original team developing the fuel flow sensor currently used in Formula 1 and LMP1 racing, but left to form Reventec in mid-2013. From premises in the same building as Mikina Engineering, Reventec was soon up and running with its own products and Mikina manufacturing components. The final technical piece was put in place when Meech called on Polyhedrus, a small team of electronic hardware and software experts that had previously worked for clients such as Siemens and the UK Ministry of Defence. Having worked closely with Hyspeed

From left, Reventec's Neville Meech and Jamie Jones, and former Hyspeed technical director Andrew Burston, founder and head of Calibra technology



CAD image of prototype Sentronics ultrasonic fuel flow sensor

since 2010 on the ultrasonic fuel flow sensor concept, agreement was reached in late 2013 to form a joint venture and create a new sensor aimed at realising Hyspeed's original vision of fuel flow control as a tool for pushing efficient engine development and performance balancing at all levels of motorsport.

LIGHTWEIGHT TECHNOLOGY

Sentronics has been able to produce a compact yet robust sensor that weighs in at around 250g, half the maximum weight permitted by the FIA. The fuel line and electrical connectors are also to FIA specification, making the device a potential drop-in replacement for the sensor currently used in F1 and WEC. However, unlike its competition, Sentronics does not manufacture its own ultrasonic piezo transducers. 'We aren't experts in transducer design,' says Meech. 'We contacted a specialist, presented our problem and asked how they could help. They have 40 years of experience, specifically in bespoke transducers. Working with them has resulted in an aerospace-grade, volume-production transducer which gives us the confidence and support we need in this critical area.'

Sentronics intends to offer the sensor for F1 and WEC use at a very competitive price, which includes an initial calibration by Calibra Technology – the FIA's homologated calibration service provider. Sentronics also detailed plans to produce lower cost sensors for other series.

'Efficiency gains in the design and manufacture of the sensor, expanding into more motorsport markets and accepting a longer-term return on our investment all help us on the pricing front,' says Dan Partel, chairman of Sentronics.

'We plan to produce a range of models to suit different markets. Australian V8s are not going to be able to justify F1 prices for a flow sensor, even though they have real challenges balancing performance across five engine manufacturers.

'So in addition to F1 and WEC, we are targeting second- and third-tier championships looking to implement fuel flow control with sensors whose capabilities are tailored to their needs and priced accordingly. We have also been speaking to Calibra about adjusting the levels of calibration to match the needs of each series. We are also committed to offering a comprehensive warranty and the kind of service and support that motorsport customers expect. As racers ourselves, we know what that entails.

'If we can deliver a pro-efficiency solution to limiting peak power and balancing performance for less than it costs to make a car less efficient by adding air restrictors, drag or ballast, then we will be able to support markets down to F3 and GT3 – even Formula 4. Why not?'

Partel added: 'We are confident that we've come up with a second-generation ultrasonic fuel flow sensor that represents a real improvement in both performance and value. Now we are in the final development phase, which includes further bench and track testing with OEMs. We are currently presenting the sensor to sanctioning authorities worldwide with a view to adoption for 2015 and beyond.'

How to handle the rise of race data

The increasing strains of endurance racing, with ever-growing amounts of information being transmitted, calls for strong management and control systems

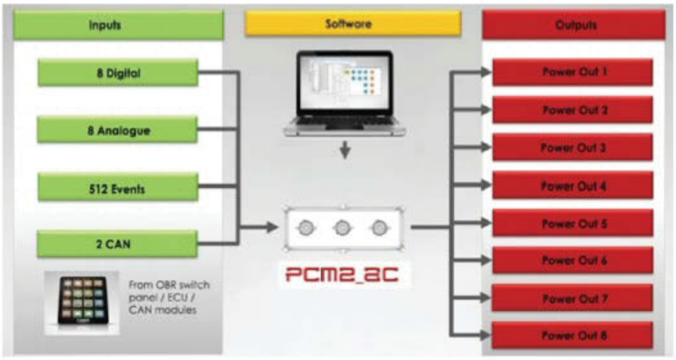
BY GEMMA HATTON

When the Audi R18 E-Tron Quattro flies past the pit lane, the equivalent of 10,000 A4 size pages (20Mb) of data is sent to the pit wall – the result of teams now being able to monitor over 1000 parameters on the car.

With the continuous integration of hybrid technology in our championships, electronics are quickly becoming the most vital part of a racecar, with components such as MGUs and battery invertors requiring their own individual control units. This places a huge processing demand on the primary ECU (electronic control unit). For example, the current F1 specification ECU is now capable of dealing with 4000 MIPS (million instructions per second) as opposed to a standard Internal Combustion Engine ECU that processes a mere 400 MIPS – and the rate of development in motorsport is only accelerating. As the complexity of these on-board electronics further increases, it is no wonder that 'electrical failures' are becoming the cause of more DNFs, as we have recently seen with in Formula 1 and in sportscar racing.

The Power Control Module (PCM) is therefore an important part of the electrical 'brain' of the car, especially in endurance racing such as the Le Mans 24 Hours where reliability is top priority. The PCM is a solid state module, which means that it uses integrated circuit assemblies as memory to store data. It replaces relays and circuit breakers to protect the electrical circuitry – similar to a fuse. 'It also monitors the status of all the outputs such as current draw and temperature,' says Ole Buhl, managing director of Ole Buhl Racing, which is renowned worldwide for its advanced PCM designs. 'Then there is a microprocessor that controls the logic behind the controlling of the current draw and the switching of outputs, so you can make very sophisticated control strategies.'

Ole Buhl Racing's PCM2, which is specifically suitable for Le Mans 24 Hour racing applications due to the high number of power outputs (48), four individually programmable CAN buses and 64 CAN inputs



Flow overview describing how a power control module (PCM) works

"GT and prototype customers usually have between two and five spare channels on a PCM"

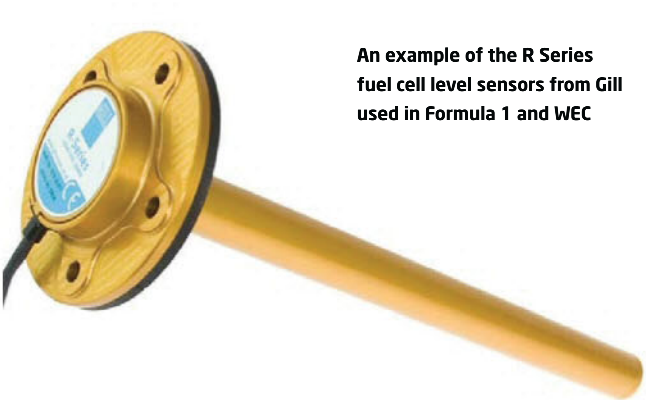
The PCM exchanges data with all the other power modules around the car via multiple CAN ports to monitor the activity and performance of the complete electrical system. Therefore every data value or packet that is recorded can be exported and shared over the complete CAN network. If there is a problem – such as a spike in the current supply – the module is advanced enough to decide the best cause of action. This may be switching the circuit on and off, or re-distributing the current supply to avoid a current drain. An example is found in the starter motor of any vehicle, where hundreds of amps are required. The PCM shuts down other EMS (Engine Management System) circuits until the engine has reached the required cranking speed, and the circuits can be switched back on again – and then the engine can be fired. The power box, as it is also known, offers further advantages of simplifying the wiring looms by replacing untidy wiring and so results in an overall reduction in weight.

One of the best suited designs for applications such as the Le Mans 24 Hours utilises 48 channels, as Ole Buhl highlights. 'Our PCM2 is the top of the range and offers all the features a professional GT or Prototype team requires,' he says. 'These customers usually have between two and five spare channels, so there is definitely a demand for a power box with such a high number of outputs.' This is the underlying reason why the PCM2 has been so successful, together with four CAN ports and 30 additional analogue and digital inputs. 'This gives the ability to have direct inputs hardwired into the box to monitor sensors, switches, speeds, and the conditions of these inputs can be written by the team, offering incredible flexibility. We have not yet had to say no to a customer's desired control strategy.'

To deal with the demands of a 24 hour racer, the PCM2 has a continuous output maximum current of 300A and an in rush

BF1 systems Infra Red Tyre Pressure and Temperature Monitoring System (IRTPTMS) wheel sensor mounted in the wheel rim

The GT bf1systems TPMS 'learning' package includes the digital antenna, Mini Analyser, Low Frequency Trigger, ECU and wheel sensor



An example of the R Series fuel cell level sensors from Gill used in Formula 1 and WEC

current of 1000A, however this can be much higher. 'We have listed the maximum current very conservatively in our specifications,' says Buhl, 'and are now increasing this recommended load because the PCM2 can handle so much more.'

The latest Ole Buhl model is the PCM2_Lite, which has 34 channels and is the first to utilise environmentally sealed, lightweight automotive connectors as opposed to the traditional mil-spec connector for cost-effectiveness. 'Whereas our competitors have distinguished between low and high power outputs, we have everything set up for high power outputs for flexibility,' says Buhl. 'As well as two CANs there are 18 inputs which we are very proud of because they can be configured as either digital or analogue within the software – a unique feature.'

As with all electronic components, the push for higher performance leads to more data storage and transfer in more compact devices, something that Ole Buhl are developing alongside combining more power modules throughout the car.

SENSORS SENSIBILITIES

A tyre is compressed 6500 times over one lap of the Le Mans circuit – just one example of the huge demands placed on endurance racing tyres. Michelin's latest specification can withstand 120 times its own weight, the equivalent of a 75kg person supporting a load of nine tons, and with the constant drive for reliability these tyres can now cover 35 per cent more distance than tyres from 10 years ago. However, regardless of the effectiveness of the compound, the behaviour of the tyre needs to be continually analysed to ensure ultimate reliability throughout race conditions. This is where technologies such as the bf1systems Tyre Pressure Monitoring Systems (TPMS) comes into its own.

'It is no good having a system which is anything other than bulletproof in reliability, because the difference between finishing the race or crashing out, can be just driving past the pit entry with a rear tyre slowly deflating and the system not notifying the team,' says James Shingleton, business development manager at bf1systems. There are four components that make up the technology. First is the wheel sensor itself, which is mounted on the back of a custom valve and transmits tyre pressure, air temperature and other diagnostic data such as battery life wirelessly to two or four digital antennas mounted on the car. An ECU collects, processes and then communicates this data to the logger and car's display via a high speed CAN bus. This system can be seen on Nissan, Aston Martin, Ferrari and Porsche GT cars.

The wheel sensors in particular have been designed to operate at extreme temperatures (max +150degC) for long durations because these conditions are not just experienced when the car is running, but also when the wheels are in tyre ovens, tents and heaters. 'This is why our sensors undergo demanding design proving, for example, spin testing at 300mph at 100degC,' says Shingleton. 'Now, our wheel sensors are lasting between two to potentially five seasons, depending on usage. One of our competitors who uses batteries, cannot achieve one year of racing with their sensor. This, combined with the lack of external aerials, means that our sensor is less likely to be damaged during tyre mounting and dismounting, so our TPMS wheel sensors are the most reliable on the market.'

At 22 hours into a race when exhaustion is an issue, teams want systems that are easy to use

At 22 hours into a race, when exhaustion is a major issue , teams want systems that are easy to use. A 'positioned' TPMS is used for LMP cars, where each wheel sensor is assigned to a particular corner of the car. For GT, a 'learning' TPMS is implemented, providing a fit-and-forget solution where the system automatically learns the positions of the sensors, and removing the need to manually re-assign sensor IDs.

A Low Frequency (LF) trigger is located in each wheel arch and broadcasts a request signal over a one metre range, and any wheel sensor within the range responds by emitting a radio frequency (RF) datagram back to the antennas. The ECU then uses each LF trigger to determine which sensors are fitted to the car and continues to request datagrams from the wheel sensors, even when the car is stationary. When the vehicle starts moving, the system checks the wheels it has learned by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using accelerometers within the sensors to filter out any non-moving wheels (eg spare wheels fitted to the car), and soon learns to focus on data from a complete set of moving sensors. When the wheels on the car are changed, the system will automatically learn the new sensors fitted to the car, so no user interaction is required.

MOTOR MONITORS

To assist the TPMS, teams also use the Mini Analyser, which uses an RF receiver and LF transmitter to interrogate wheel sensors mounted in wheels, or on rims with no tyres, allowing engineers to check tyre pressures and temperatures when the wheels are on or off the car. There is also a Garage Monitoring System which allows the status of up to 240 tyres to be continuously recorded. Here, an antenna is mounted in the garage to receive datagrams transmitted by the wheel sensors when they are stationary or have been interrogated by a Mini Trigger, which is then processed by the ECU and transferred to the PC software. Alarms are set for minimum and maximum pressures and temperatures, so if a sensor falls outside these limits, it is immediately highlighted on the screen, allowing teams to ensure that all their tyres are at the optimum condition, all the time.

'Four years ago, we introduced the InfraRed Tyre Pressure and Temperature Monitoring System (IRTPTMS) which utilises a wheel sensor containing an infrared temperature sensor that can measure the internal tyre carcass temperature and report this in real time. While this is currently used mainly by F1 teams, we are seeing it filter down into other formulae who are seeing the benefits for chassis setup, and in particular during qualifying to ensure that their tyres are in optimum condition.'

Shingtleton added: 'There is always the requirement for developing smaller and lighter parts, which we are always looking at. In 2013 we introduced our latest generation TPMS wheel sensor which was 17 per cent lighter than the previous generation. 2014 saw the introduction of a combined

The GS Position side rotary sensor offers an innovative solution for measuring shaft position with no moving parts resulting in the highest reliability

ECU/antenna box, reducing the components required on the car; saving further weight.'

There are over 200 sensors on a modern F1 car, and similar for endurance cars. And following Daniel Ricciardo's F1 Melbourne demotion from second to last place, the world of sensor technology has come to the forefront of the motorsport world. The sensor in question measures the fuel flow rate and is manufactured by Gill Sensors, which is the official supplier for the F1 Championship as well as the WEC.

As well as withstanding temperatures exceeding 100degC, sensors can experience 50g of shock in under 60 milliseconds, high acceleration loads to 10KHz, and the build-up of oil and dirt ingress at racing speeds up to 350km/h. Therefore, sensors have to be developed to not only deal with these tough environments, but to also deliver continuous real-time measurement data.

One example of a new innovation from Gill Sensors is the GS position side rotary sensor – ideal for measuring either shaft position, grip throttle sensing or gearbox shafts. It uses induction technology to sense the position of a metallic 'activator' which is mounted to the moving object. As well as measuring position through 360deg, it provides a 300rpm speed of rotation, boasts an accuracy of +1 per cent and can operate in temperatures between -40degC and +160degC. Due to no moving parts, mechanical wear is minimal – another factor behind the high reliability of such sensors.

Overall, the winners of endurance races are not necessarily the fastest, but to stand a chance of winning, the cars must cross the finish line. Being able to effectively monitor the status of thousands of parameters in a racecar throughout an entire race is essential to achieve the highest levels of reliability, which is the only road to success.

OILS AND FUELS

Oils: Le Mans drivers cover approximately 5400km, the equivalent of completing a 20 race F1 season in only one day. The demands on endurance racing engines are astronomical and therefore require the best lubrication to maintain the effectiveness of the components. The Audi R18 e-tron Quattro races with Castrol Edge Fluid Strength Technology Oil and has been tested under simulated race conditions for over double the distance of the Le Mans 24 Hours. The oil constantly reacts and adapts to the loads it is placed under, maintaining its strength and ability to keep metal surfaces apart.

Oils undergo a fluid strength test, which analyses the amount of metal contact as Gareth Dowd, Castrol technologist explains. 'We reviewed a series of engine components and found the one that experiences the most pressure, which is in the valvetrain. For example, the pressure exerted on the cams is equivalent to having two elephants stood on a stiletto heel during part of the cycle, which equates to around 10 tons acting on a square cm.'

The oil responds to this pressure by getting thicker and reducing the metal-to-metal contact, so it is the oil's response to temperature and pressure that is so crucial. The test proved that Fluid Strength Technology Oil was 40 per cent stronger and had the lowest metal contact than other competitors.

Fuels: conserving tyres and fuel can mean saving two pit stops every three hours during the Le Mans race, which is the equivalent of half a lap over your rivals. Combine this with the fact that the 2014 regulations encourage a 30 per cent reduction in fuel consumption when compared to 2013 and you can understand the drive to develop the most efficient fuel.

Shell's V-Power will be fuelling all the Le Mans racers, with Audi going down the diesel route and Toyota and Porsche sticking with gasoline. 'To improve efficiency and reduce fuel consumption, it is a combination of three things: the fuel properties, enabling a new engine design and the energy recovery storage systems,' says Richard Karlstetter, racing fuels technology manager at Shell.

'In 2014 we want to move to the next stage and so we have doubled the bioethanol content. This is an increase from 5-10 per cent in diesel and 10-20 per cent in gasoline. Endurance racing is one of the fastest and toughest test beds for fuel development. During a 24 Hour race at Le Mans, the insights we get from our fuel and lubricants equals about one year of engine dyno work here in the lab.'


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Some hard truths

Whether quantifying aero or deciphering engine curves, there's no room for shortcuts

BY DANNY NOWLAN

One of the greatest undercurrents that I see in motorsport is the 'magic bullet racer', where people pay someone money and expect to instantly go faster. In some respects it's always been a part of motorsport and is peculiarly specific to our business. In some respects it's very much the motorsport version of a toddler's security blanket. Spending it in most cases it does absolutely nothing, but it makes teams feel better. In the modern era I see this crop up in teams paying a fortune for the magic damper, or the magic engine or teams paying a fortune for exclusive factory support.

The focus of this article will be to show you in no uncertain terms that the responsibility for engineering the car must be conducted in-house by the race team. In particular we will be discussing the importance of quantifying the performance of the racecar. Rather than giving you an esoteric list, I'm actually going to show you some examples of what you are in for when you abandon responsibility for doing your homework.

If you are serious about being good at anything, it's about you reaching a standard. In my career both on and off the racetrack I have had the privilege of meeting the world's best at what they do. This has spanned motorsport, military aviation, academia, radio-controlled flying – even partner dancing, to name just a handful. What makes these people champions is not just the talent they are born with – they work their arses off. They study their art and they practice long after everybody else has gone home.

The first area that we need to discuss here is quantifying aerodynamics. As far as I am concerned, this is one of the core responsibilities of the race engineering department of any race team. I have discussed on countless occasions what you need to do to quantify your aero, and to reiterate this I will be presenting two case studies of what happens when you blindly follow what somebody else has done.

Money is racing's version of a toddler's security blanket – spending it simply makes teams feel better

The first case study we need to discuss is what happens when you use a racecar manufacturer-supplied aero map without using any validation. What you are about to see was taking directly from the aero manual of a high downforce open wheeler. Due to confidentiality requirements I will be blanking out scalings. What you will be seeing though is the comparison between actual and simulated data.

The first comparison we will discuss is the results generated from the manufacturer-supplied aero maps. This comparison is shown in **Figure 1**.

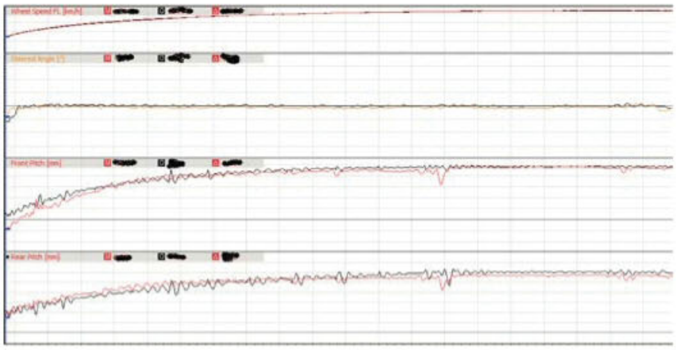


Figure 1: comparing actual and simulated data using the standard aero map

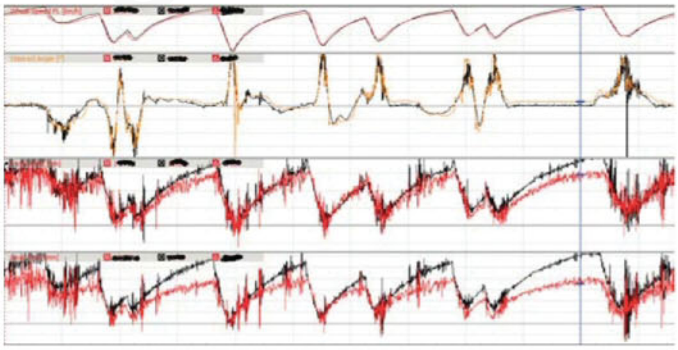


Figure 3: comparison of actual data against manufacturer-supplied CFD map

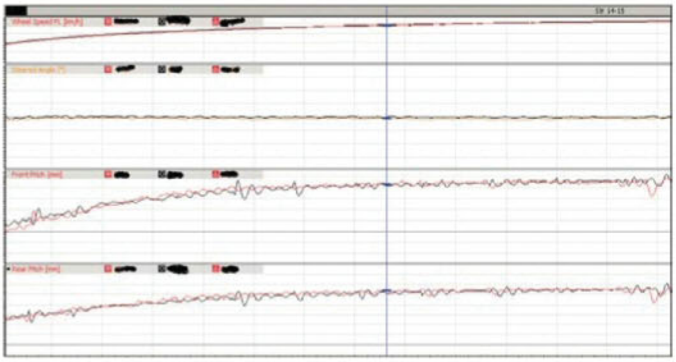


Figure 2: comparing actual and simulated data using their own aero map

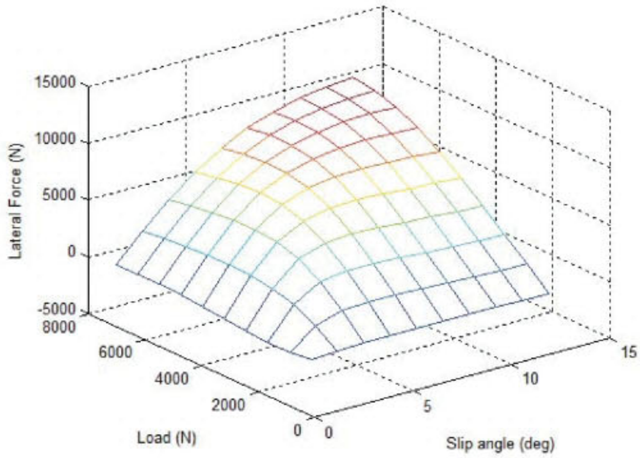


Figure 4: lateral force v slip angle for multiple tyre loads from test rig results

The real data is coloured and the simulated data is in black. Let's walk through the various traces. The first trace is speed, the second trace is steering the third trace is front pitch (the average of the two front dampers) and the last trace is rear pitch (average of the two rear dampers). We are using pitch because it is a very clear indicator of downforce.

What we can divine from **Figure 1** is that while the standard aero map has done a reasonable job at estimating downforce and drag, the pitch sensitivity has fallen short. This is particularly apparent in comparing the front and rear pitches. At medium speeds the front is way too optimistic (in the order of 2-3mm). As we get close to top speed it actually gets pretty close, but now the rear downforce is overestimated. What this shows you is that the standard manufacturer aero map will do a reasonable job of estimating downforce levels and getting the gears right. Where it will struggle is giving you a direction in setup due to the fact that the pitch sensitivity hasn't been quantified correctly.

In contrast there was a large improvement when the team in question did their own aero modelling. The results are shown in **Figure 2**.

As can be seen, it is a night and day difference between **Figure 1** and **Figure 2**. In particular, the front and rear pitches which in **Figure 2** are for all intents and purposes on top of each other. If you have the pitch sensitivity quantified, then all of a sudden you can start doing serious work on refining your bump rubber and spring combinations. It's also going to lead to much more accurate tyre modelling since you have your loads correctly quantified. I can tell you from experience that something like **Figure 1** will get you by. When you have done the hard work yourself and produced an aero map that gets the results of **Figure 2**, this will help you to win races. Also, just for the record, **Figure 2** was generated using the ChassisSim Aero modelling toolbox.

However, the ultimate fallacy of relying on someone to generate aero maps for you came from another customer of mine. This particular customer was running a high downforce racecar. I am being deliberately vague about who the customer was because the aero numbers they where provided with were appallingly bad. Anyway, to set the scene – a couple of years ago at their engineering office, the performance engineer presented me with **Figure 3**.

For clarity I've kept the same convention as **Figures 1** and **2**. As we can see, the speed trace is way too optimistic and the simulated pitches (shown in black) are way too high. This is a night and day sign that someone has been unrealistic with their downforce and drag numbers.

After expressing my thoughts with some choice words, the first thing I got him to do was to show me the aero map. I was informed that this had been generated by CFD with no on-track validation. Anyway, I looked at the numbers and started to laugh, so the first thing we did was to do a hand calculation. The downforce had been overestimated by 30 per cent and the drag was underestimated by 20 per cent.

In one supplied aero map, downforce had been overestimated by 30%, and the drag underestimated by 20%

The upshot of this particular tale is that this supplied aero map was completely useless. At least the first aero map we discussed in **Figure 1** had some useful application. But the aero map presented in **Figure 3** was a trainwreck. Not only couldn't it be used for gearing, but the aero map was so inaccurate that a setup deduced using it would have been a total disaster. This is what you are opening yourself up to if you never do any aero validation work.

The next key area of responsibility faced by a race engineer and/or team is quantifying tyre performance. Here you must always validate, because there are big time consequences if you don't.

This next example is arguably some of the worst tyre test rig results I've ever seen in my life. What made this particularly notable was that within a week I had emails from multiple customers in the same category asking me to sanity check them because they had serious misgivings. This was from a modern high downforce open wheeler. This category was also a relatively senior category. When I

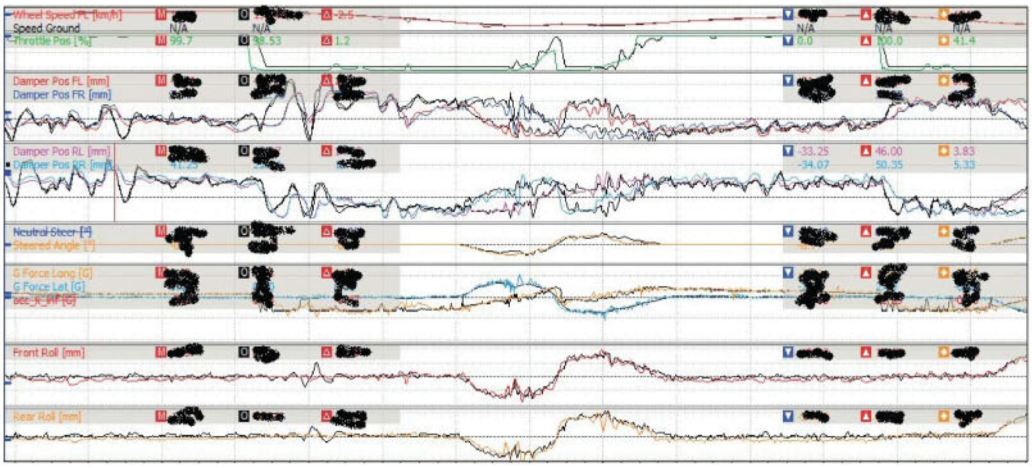


Figure 5: correlation using a tyre model generated from the ChassisSim tyre force modelling toolbox

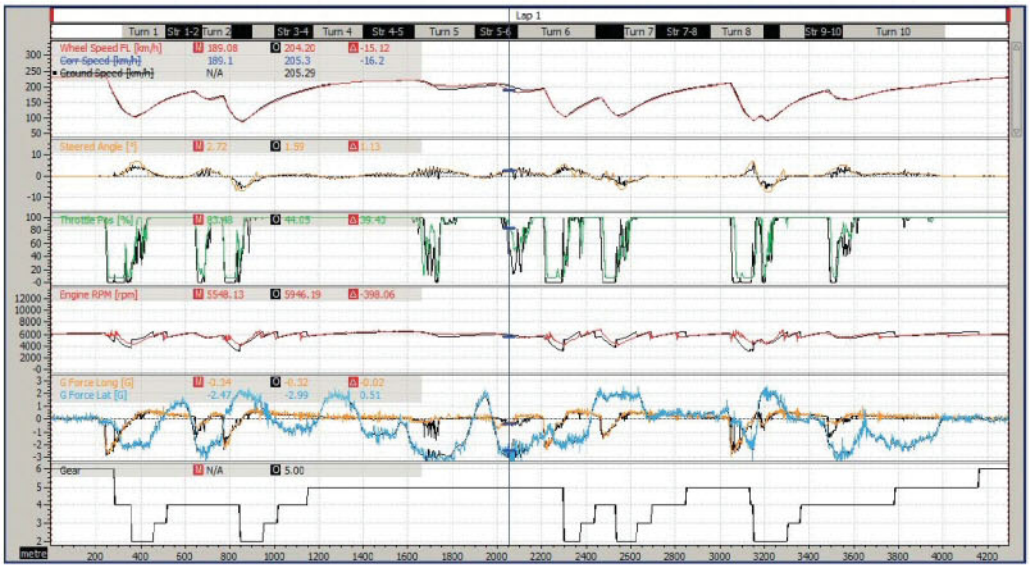


Figure 6: F3 correlation using a generic engine curve

sanity checked it I couldn't believe what I was seeing – the results are presented in **Figure 4**.

The reason these results are so bad is due to the peak slip angle migration. To put this into context, most open wheeler racing tyres have a peak slip angle of 6 to 7deg. It varies a bit, but it's a good rough rule of thumb. What we are seeing in this graph is that as the load increases, so does the peak slip angle. At a load of 6000N (about 600kg) there is a peak slip angle of 10deg. If this was truly the case, what you would see on the steering trace is that while the initial turn in would be reasonable, as you progressed to the mid-corner stage the steering lock would be very large – possibly in the order of 15-20deg at the wheel. These particular cars do not get anywhere near this. I promptly told them to ignore the figures.

Had these results been adopted, any simulation work they would have done would have been totally irrelevant. The simulated results would have pushed them to minimise steering lock, and part of that would be to soften the car up. Given the amount of downforce these particular cars's carry, this would have been nothing less than a complete and utter unmitigated disaster.

In complete contrast to this, the users of the ChassisSim community have the tyre force modelling toolbox at their disposal. This allows them to quantify tyre performance from race data. It allows them to achieve correlation like this on a daily basis.

Again – actual data is coloured, while the simulated data is black. The first trace is speed, the second is throttle. The third and fourth are front and rear dampers, the fifth trace is steering, the sixth trace is lateral and longitudinal and the final traces are front and rear rolls. As you can see there is hardly any difference. This is the pay off you get when you do your homework, because results like **Figure 5** are the foundation of race wins.

The other fallacy I see in this business is race teams getting all hot and bothered about manufacturer-supplied engine curves. To put this in perspective, here's an example of how far you can get with a generic engine curve. Consider the F3 correlation shown in **Figure 6**.

Actual data is coloured and simulated data is black. I am the first person to admit that this is not perfect, but the speeds (shown in the first trace) are almost indistinguishable and the shift points showing in the fourth trace are also close. These shift points won't be exact since ChassisSim will hit them perfectly consistently. However, this is more than sufficient to do gear ratios and advanced setup work. I can testify to this one from direct experience. Granted, you might struggle a bit on ovals, but for road courses this is a complete non-issue.

Another fallacy I see is race teams getting hot and bothered about manufacturer-supplied engine curves

What we have shown here is that there are no easy solutions if you are serious about winning. As we discussed in **Figures 1-3**, if you don't do aero validation you are leaving yourself at the mercy of others. In the first case study, the pitch sensitivity wasn't appropriately quantified and the aero map used in **Figure 3** was completely useless. It is also worth keeping in mind that if the manufacturer has seriously screwed up, they will not tell you! Meanwhile, the tyre result that was presented in **Figure 4** is woefully inadequate. God help you if you were to use it as the basis for any simulation work. Also, as we discussed in **Figure 6**, you don't need the magic engine curve to get going.

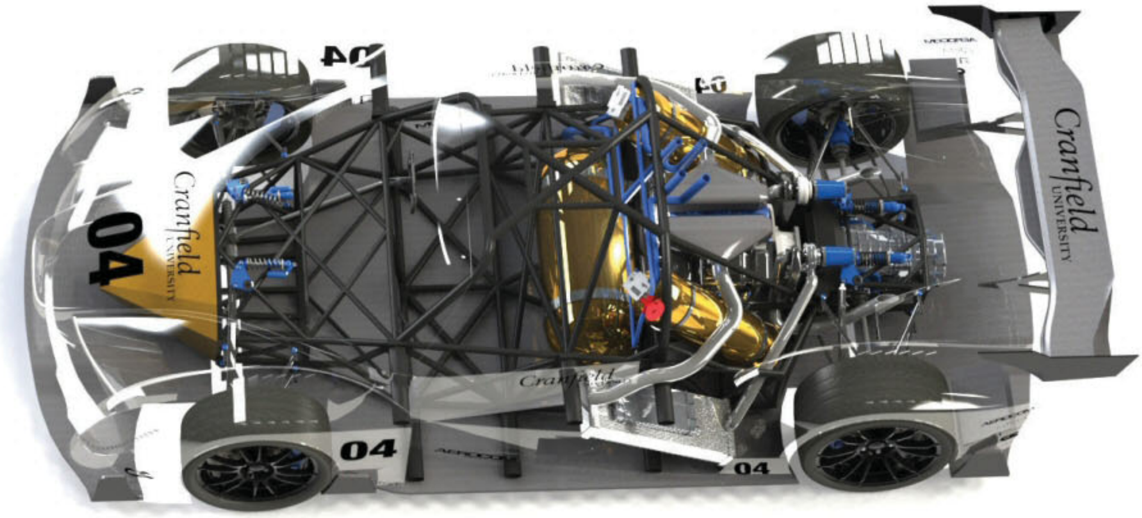
It's also worth reflecting that I am not writing about the importance of quantifying racecar performance because I gain some weird academic pleasure from it. I'm ramming home the importance of this because this wins races. I've seen it first hand in the work I have done. But what gives me even greater pleasure is to see the members of the ChassisSim community rolling their sleeves up and getting the job done. It makes their success that much sweeter.

The bottom line for those of you reading this article is breathtakingly simple. Yes, you can pay others to do your hard work for you. You might get lucky and they might do a reasonable job. However, the aero modelling case studies and tyre force case study highlight that you could very well by playing the engineering equivalent of Russian roulette.

The final nail is that if you are serious about winning, you have to do the hard work of performance validation yourself. There are no shortcuts on this. None whatsoever.

Cranfield takes on hydrogen power

For a challenging design project, students were asked to envisage a racing series using a hydrogen-fuelled internal combustion engine. Here's what one group came up with...



The students reworked the Radical RXC chassis into what is essentially an all-new design

Every year Cranfield University sets the students on its MSc Advanced Motorsport Engineering course a tough group design project. This year it asked them to take a look into the near future. It is a future where the hydrogen economy is real, mass market vehicles use the gas in both its liquid and gaseous states as fuel and there is an established supply chain.

The students set out to investigate the potential for an accessible racing series using a hydrogen-fuelled internal combustion engine. The Radical RXC acted as the base line in terms of cost and chassis structure, as did one of the two engines used in that model – the Ford Ecoboost V6 or the RPE V8. As this car is aimed at the club racer, composite chassis were outlawed.

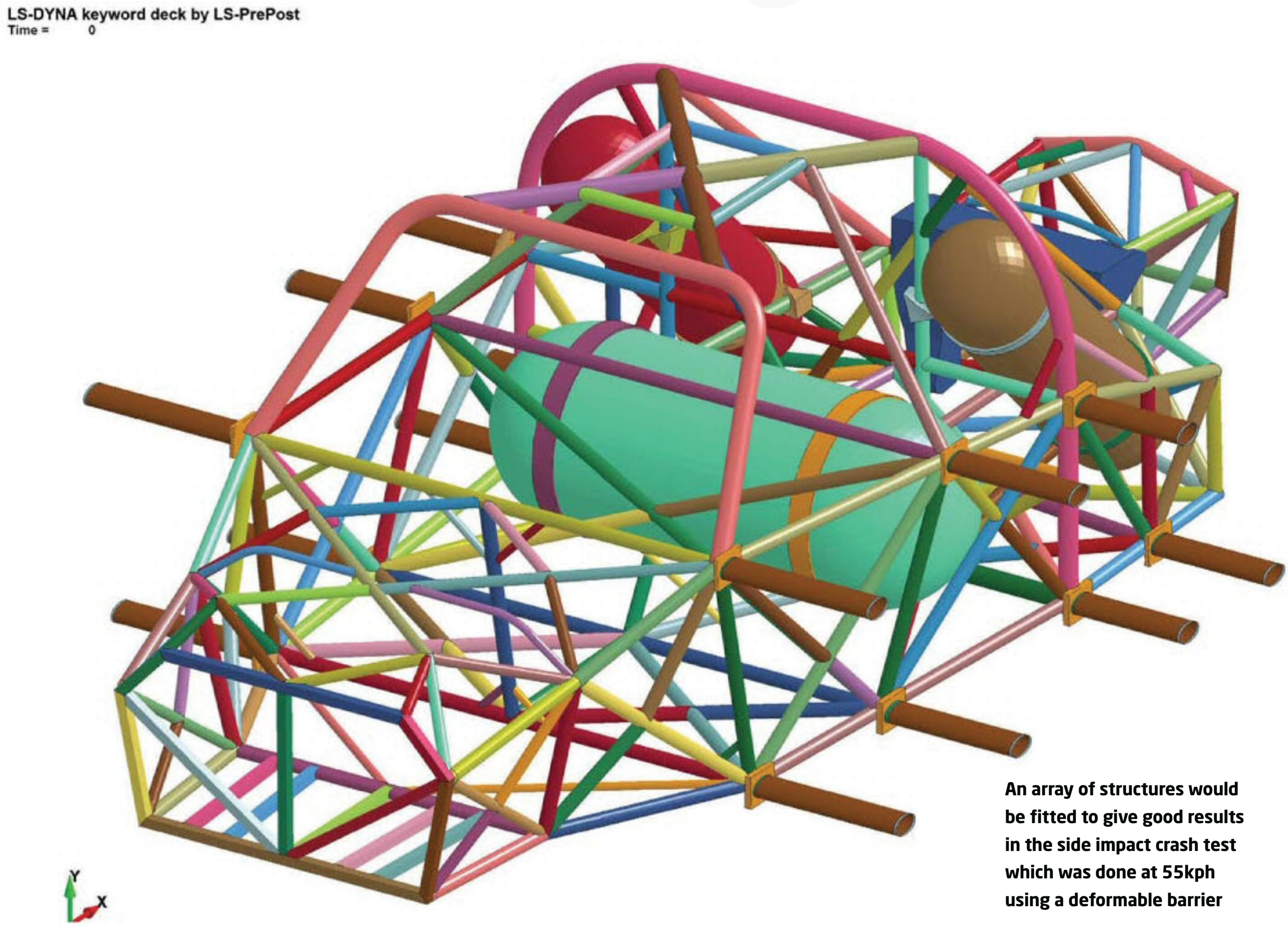
In addition to formulating a workable concept for the overall chassis which could accommodate the hydrogen storage system and accommodate it in a side impact, the students also had to design the storage system itself as well as the delivery system to the engine. The engine also had to be optimised to run on hydrogen and its expected performance figures was to be given.

PROJECT FOCUS

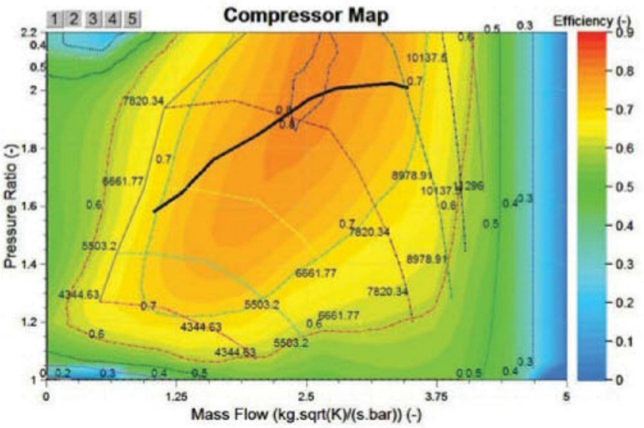
Racecar Engineering selected the project developed by a group of eight students to focus on. What appears in this article is based on the work of John Binks, Daniel Bridgman, Robert de Chazal, Xu Chen, Thorsten Lajewski, Alfonso Rodriguez, Pierre Salmon and Sudeep Thangiah.

The group chose to use the Ford V6 engine as they felt it offered lower frictional losses and higher torque, as well as a lower compression ratio. It also features direct injection as standard and would be easier to convert to run on hydrogen compared to the RPE V8.

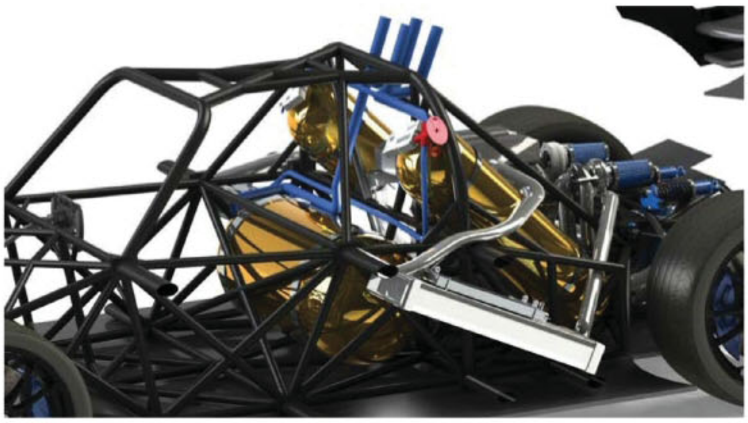
Once the engine was chosen, the team modelled a



An array of structures would be fitted to give good results in the side impact crash test which was done at 55kph using a deformable barrier



New turbochargers were selected with the addition of external wastegates to regulate the compressor's operating region



Three hydrogen tanks are mounted in the chassis, the largest in the conventional fuel cell location, while a pair of smaller tanks are mounted on the roll hoop supports. Vent pipes exit on the roof of the car

1D theoretical model of a cylinder's stroke cycle. The associated friction losses were formulated in Matlab, which gave the group an initial understanding of the mathematics behind engine simulations and expected performance indicators allowing for validation of results using AVL Boost.

To maximise the performance of the Ford engine running on hydrogen, new turbochargers were selected with the addition of external wastegates to regulate the compressors operating region. A fuel map was also created with an algorithm that optimises the fuel flow rate dependent on the mass remaining in the storage system.

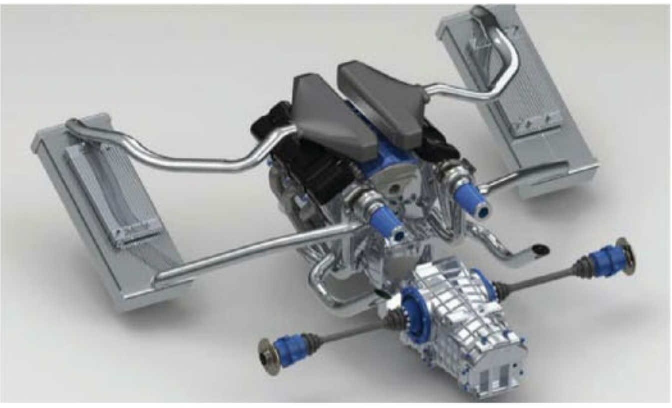
That storage system would consist of three tanks containing gaseous hydrogen, the team choosing not to deal with the complexity of a liquid system. The storage system layout would be based on the requirements laid out in the draft EU regulations in existence, and in-tank regulators would be fitted to avoid pressure issues. A solenoid valve would ensure that the two highest vessels would empty first in order to lower the car's cg during a race.

VENTING TANKS

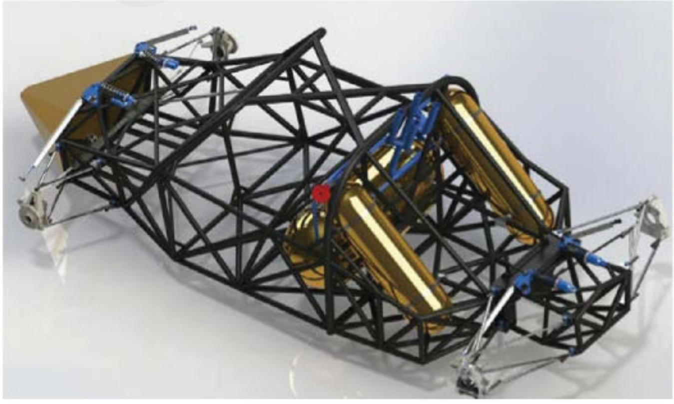
In the event of an accident or an issue with the fuel system, the tanks would vent the hydrogen to the atmosphere via four pipes on the roof of the car. It would take around 150 seconds to empty a full storage system.

Attention then turned to the chassis, and analysis was done on several materials starting with the steel used by Radical on the RXC, but also other grades – and even aluminium. The samples were subjected to destructive testing, including tensile testing and three point bent tests to derive true stress strain curves. Peel tests and tensile tests were also done on joints to see what the properties of the heat-affected zones were.

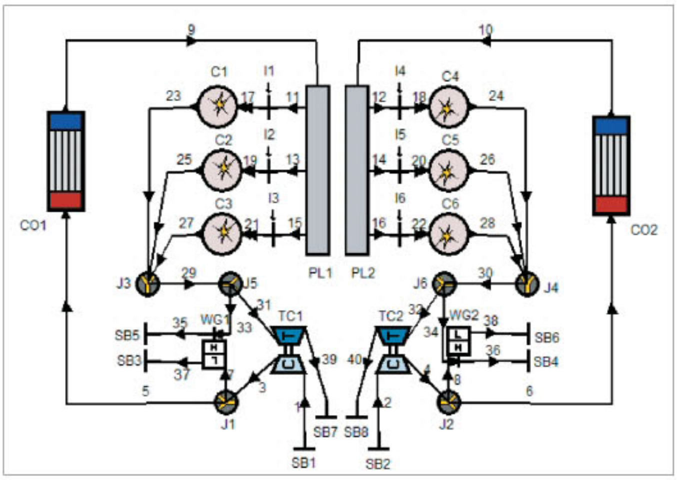
FEA simulations were developed to validate the material



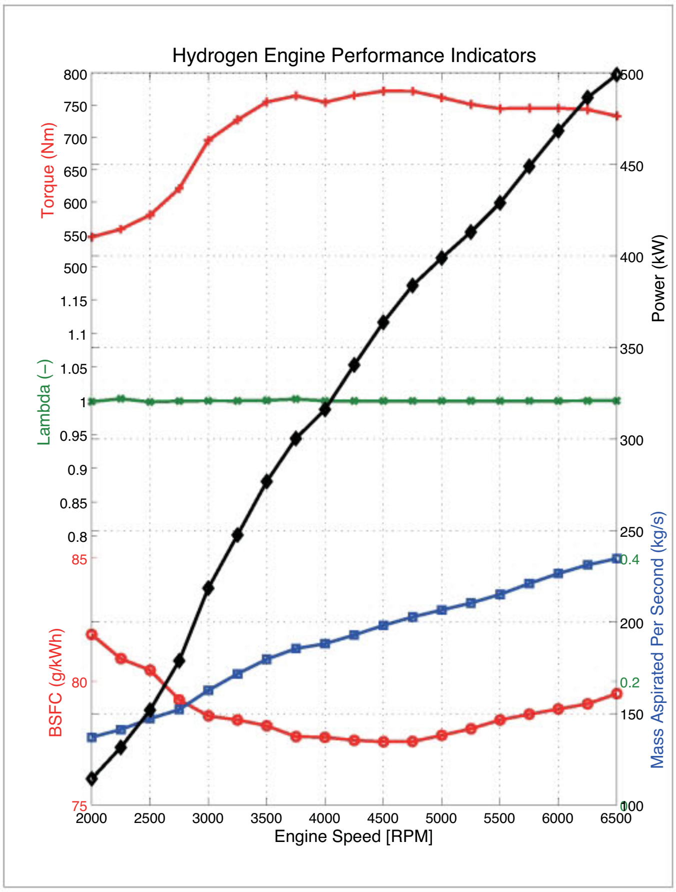
The revised Ford V6 engine with the additional coolers it would require, shown above in rendering form



The complete revised chassis with the fuel system installed. A shift from steel to Aerocom 33 was proposed



Diagrammatic illustration of the cooling solution required in the revised Ford V6 engine



Engine modifications resulted in a peak deliverable torque of 768.3Nm at 4750rpm, and peak power of 498.6kW at 6500rpm

Although the vehicle weight has increased to 1330kg, the power-to-weight ratio is still 24 per cent more than on the base car

data input, using an iterative process with LS-DYNA as well as a material card.

Using this data, the team redesigned the RXC chassis, revising the triangulation (and increasing it in some areas), and changing the roll hoop shape and location to accommodate the hydrogenate storage tanks. The largest of the three tanks would be stored in the traditional location behind the driver, while the two smaller tanks would be mounted above on the roll hoop support. A shift from the steel used by Radical to Aerocom 33 tube would be implemented in many areas of the chassis.

With all of the modifications, the team simulated the performance of the revised car, they found that the engine modifications resulted in a peak deliverable torque of 768.3Nm at 4750rpm and peak power 498.6kW at 6500rpm - a notable increase in performance over the original engine performance. However, the vehicle weight increased to 1330kg, although the power-to-weight ratio is still an improvement of 24 per cent over the base. A race simulation showed that the 6.4kg hydrogen fuel load would be adequate to complete a 20 minute race including laps to green and back to the pits.

Ultimately, the project proves that the hydrogen car could be a viable option if the hydrogen economy happens. If and when that happens is a very different question.

TANK SPECIFICATION

Nominal pressure: 70MPa

Filling pressure: 85.6MPa

Burst Pressure: >160MPa

Vessel volume: 1x 112.5L and 2x28.75L

Total hydrogen mass: 6.69kg, (6.40kg useable)

Material: Toray T700S carbon fibre 14.3mm wall thickness with a 5mm HDPE liner, 10mm foam protective end caps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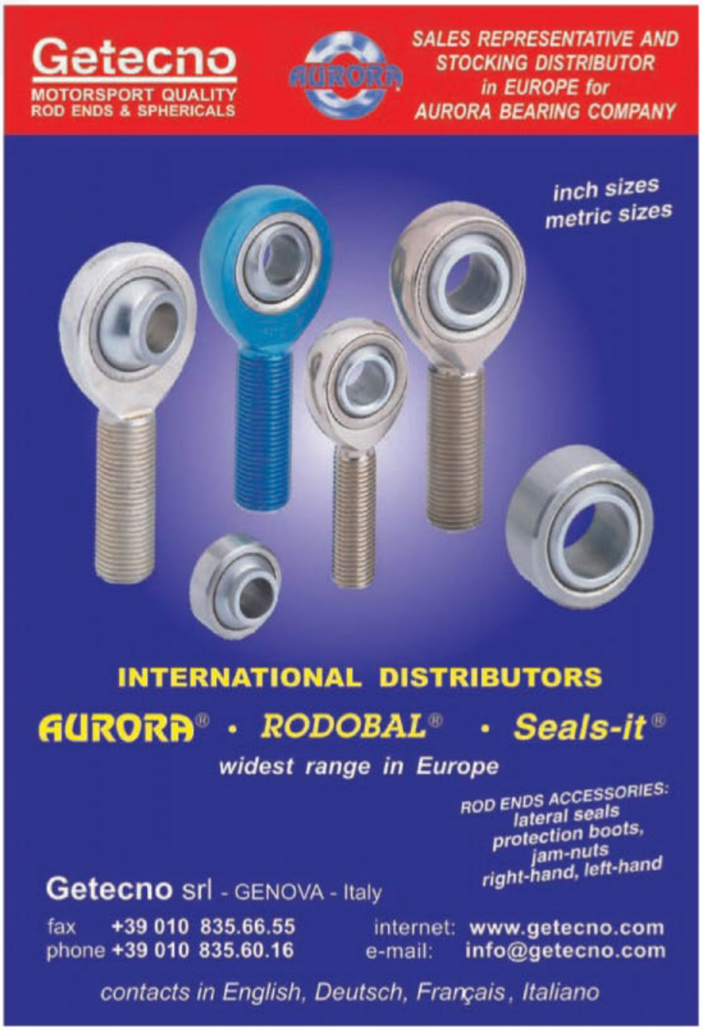
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Nissan announces Le Mans return with all new US-built LMP1 car

Nissan has confirmed that it will return to Le Mans in the LMP1 category with the GT-R LM NISMO, featuring technology that has not yet been explored by the three existing manufacturers, Audi, Toyota and Porsche.

Nissan, which contested Le Mans in 2012 with the DeltaWing and in 2014 with the ZEOD, is expected to confirm Ben Bowlby to design the car from the US, although hints were dropped that Nissan's test facility in Cranfield will be used in addition to Nissan's test facility in Arizona.

There was no announcement of the technology to be used, although the indication was that lessons learned from the series hybrid ZEOD project, developed by RML in the UK, would be carried over. However, there was speculation that Cosworth's 1.6 litre V6 Formula 1 engine project would be revived in the back of the car. Another possibility is that parent company Renault's F1 engine could also be used, although sources indicate that this is unlikely. ACO technical director Vincent Beaumesnil said that they would be welcome with whatever technology they wanted. 'There are some rules, and it is up to Nissan to make a car that is in accordance with them,' said Beaumesnil at the launch. 'The rules allow people to be creative and different, so this is what we are expecting.'


XPB

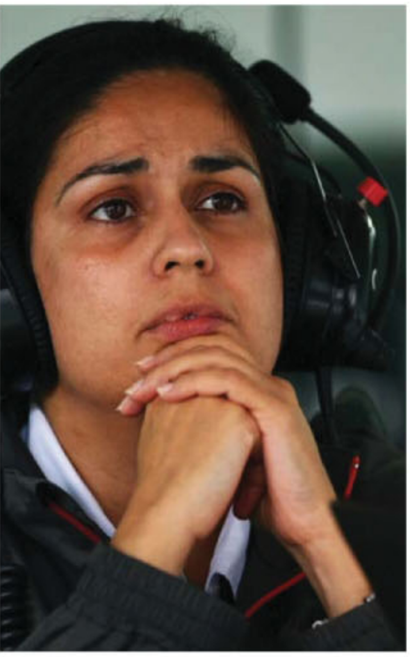
The Nissan LMP1 will take design cues from the production-based GT-R

The prototype will carry design cues from the Nissan GTR roadcar, has been in CFD design for nine months, and will be track tested for the first time in October 2014. 'We are starting to cut carbon at the moment,' said Nissan's Global Head of Brand, Marketing and Sales, Darren Cox. 'We have an engine mule on the dyno. The technical details are all decided, and you will see some familiar NISMO faces around the project.

'You have got three different manufacturers with three different outcomes, we will be a fourth with a fourth,' added Cox. 'We have looked into the regulations, and there are some really exciting things that we can do on the energy side, so we are not going to come with something that anyone else has in terms of a solution. Our simulations say that it is going to be competitive. The ACO's regulations are right, the right guys are in the right jobs, so the stars are all aligning.'

The programme was welcomed by the FIA, and the ACO. 'You have only happy people in the WEC paddock with this news,' commented Gérard Neveu, general manager of the World Endurance Championship, which Nissan will contest in 2015.

Ukraine crisis hits Sauber Formula 1 sponsor talks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Monisha Kaltenborn says that the political situation has halted talks

Sauber team principal Monisha Kaltenborn has admitted that the recent unrest in the Ukraine has halted the team's negotiations with prospective Russian sponsors and investors.

The long-running negotiations with a group of Russian aerospace companies are thought to be vital to the Swiss team, with many calling it a 'rescue deal' when it first came to light last year, but now talks have stalled in the face of economic sanctions against Russia and uncertainty about the future in the region.

Kaltenborn said of the Ukrainian situation: 'We've definitely seen an effect because a lot of talks which are very advanced have virtually come to a standstill because people are waiting, and seeing what's going to happen and nobody really knows the entire impact it can have because the sanctions that have now been imposed are really biting some of them.'

She added that Sauber was now waiting for an improvement in the political situation: 'They're very careful. We simply have to wait and there's nothing we can do about it. So we really hope that the situation can be clarified soon and all our deals can be sorted out.'

Other teams have also felt the effect of the fallout from the crisis, with Toro Rosso's Franz Tost saying that it has also had problems with sponsorship negotiations with Russian companies (it's running Russian driver Daniil Kvyat this year). 'Of course the political situation affects our negotiations with companies in Russia, because no one knows exactly which way it goes,' Tost said. 'I just hope that it will end up in a positive way and we will go to Sochi [for the first Russian Grand Prix in a century in October], because that's very important.'

Since the troubles started, a World Superbike round due to be held at the Moscow Raceway in September has been cancelled, while the DTM has said it may drop the Russian round of its championship.

Tost added: 'I personally just hope that we can go there because the Russian market is quite important for us. I hope that we will have this race. Until October there is a long time and I hope they can sort out all the troubles that they have currently.'

FIA president Jean Todt has said that as things stand F1 will race in Russia: 'At the moment there is no change to the calendar. Russia is on,' he said.

Non-F1 Strategy Group teams say cost cap can still work

Some of the smaller Formula 1 teams have said they think there is still a chance of a cost cap being introduced in F1 and that they believe it could work, despite the fact the F1 Strategy Group has recently rejected it.

The F1 Strategy Group, which is made up of six teams – Red Bull, Ferrari, Mercedes, McLaren, Williams and Lotus, plus the FIA and FOM – recently voted against a cost cap on the grounds that it would be impossible to police.

Teams within the Strategy Group have since come up with other cost-saving measures – including the use of more spec parts and even the re-introduction of active suspension. But some non-Strategy Group teams – Force India, Caterham, Sauber and Marussia – have urged the FIA to stick with the decision to apply the cap, which was unanimously agreed at a meeting in Geneva in January this year.

Rob Fernley, deputy team principal at Force India, said: 'I think the main issue we are having is that the FIA are comfortable that a cost cap can be administered and we respect their opinion. So we question – as we always have done – the legitimacy of the Strategy Group to overturn the Geneva decision.'

But Fernley does not believe the cost cap is dead in the water: 'As far as we're concerned it's still in the hands of the FIA to progress what was unanimously approved.'

John Booth, team principal at Marussia added: 'Marussia very much share that view,' he said.

Sauber team principal Monisha Kaltenborn, while agreeing that the cost cap could still happen, also questions the Strategy Group's view that it would be impossible to police: 'I don't think it's dead because first of all there is a unanimous decision and I think it is very much possible to police it, because it's something that can be policed, it is figures. It depends on the people that put down the figures, if they are right or wrong. We do that with all of our companies. I think there's no country where our teams are situated where we don't have book-keeping, so I don't think it should be an issue.'

XPB

Some Formula 1 teams have insisted the FIA's cost cap plan is still viable

Venezuelan oil settlement bolsters Williams income

Williams saw a sharp increase in its income last year, which was partly down to a multi-million pound sponsor pay-off which helped to ease driver Pastor Maldonado's switch to Lotus.

The Grove-based group has posted a boost in income for 2013 of close to £27m over 2012, much of which comes from a 'special non-recurring sponsorship deal' secured by the Formula 1 team, which saw a big increase in income from 2012, going up to £108.5m from £86.4m the previous year.

This non-recurring deal is believed to be a pay-off from Maldonado's long-term sponsor PDVSA, the Venezuelan government owned oil giant, which is said to have bought the driver out of his five-year deal with Williams after the team's disastrous 2013 season. It's believed that PDVSA paid Williams somewhere in the region of £15m.

The earnings for the group before interest and taxes (EBIT) was £12m, while for the F1 team alone it was £11.5m. Williams Advanced Engineering's results are more in line with 2012, the part of the group that markets F1-derived technology raking in some £15.6m (£15.5m in 2012), with an EBIT of £6m, down a little from £7.6m the previous year.

Williams also tells us that over the last 12 months it has closed its Qatar Technology Centre – which is set to be relocated to the UK – while it has recently announced the sale of its Hybrid Power arm to GKN for £8m.

Team founder Frank Williams said of the results: 'Although 2013 was a difficult season for the team on the race track [it scored just five points], we report these full year results at a time of much optimism for the Williams Group. We have started the 2014 Formula 1 season well and hope we can continue to improve our performance.'

XPB

Pastor Maldonado took PDVSA backing from Williams (pictured) to Lotus – but thanks to a £27m settlement, Williams was not left with empty pockets

Mike O'Driscoll, Group CEO, said: 'We began the process of refocusing and restructuring midway through last year and we are making good progress against our strategic objectives of strengthening our F1 performance and building a robust and profitable advanced engineering business.'

Silverstone future 'secure' despite sale talks breakdown

The future of Silverstone circuit and its place as the home to the British Grand Prix is secure, despite the recent collapse in talks to sell the circuit, according to the British Racing Drivers' Club (BRDC).

The Club, which owns Silverstone, revealed last autumn that it was in the process of selling the track operating arm – Silverstone Circuits Ltd (SCL) – in conjunction with the sale of a long-term lease on the historic racetrack.

XPB

Silverstone sale has fallen through, but BRDC says the circuit's future is safe

The announcement was made at the same time that the BRDC revealed it had signed a deal with commercial property business MEPC to lease 769 acres around the periphery of the venue. The financial reasoning for this deal, which raked in an immediate £32m with which the BRDC was able to pay off its borrowings, was to attract investment to secure the British Grand Prix's future at Silverstone, the then BRDC chairman Stuart Rolt said at the time. It still has 17 years to run of its contract with Formula One Management to host the race.

The undisclosed potential buyer of SCL was said to be going through the final stages of due diligence when the MEPC deal was announced, and the BRDC board had hoped to proclaim this second deal to its members at the club's annual general meeting in October. However, the deal to sell SCL and lease the track was held up and has now fallen through.

But the new BRDC chairman, John Grant, insists that this will not affect the future of the venue nor the British Grand Prix. 'With or without another investor, the futures of both Silverstone and the British Grand Prix are secure,' he said.

'The circuit business has enormous potential and MEPC's development of Silverstone Park – a hi-tech business park on land surrounding the circuit – will enhance the circuit's image and value over the next several years. We are delighted with the progress MEPC is already making. They are proving to be excellent partners and strong believers in our shared vision for Silverstone.'

Following the breakdown of the deal, the BRDC board has now decided to shelve efforts to sell SCL and to lease the track.

Camping World keep trucking

NASCAR has signed a new deal with Camping World, which will see the camping supplies vendor continue its title sponsorship with the Truck series until the end of 2022.

The new agreement comes on the back of a major expansion for the Kentucky-based company since it first signed up as Truck sponsor in 2009. Camping World has increased its number of stores by 35 per cent in that time, and the company says its revenues have now reached $3.4bn a year.

Marcus Lemonis, Camping World and Good Sam Enterprises chairman and CEO, said the decision to extend with the Truck series was based on results: 'Six years ago we felt strongly that the sponsorship would dramatically increase our customer base and it's delivered. We expect continued success in the coming years.'

Steve Phelps, NASCAR chief marketing officer, added: 'The NASCAR Camping World Truck Series has one of the most consistent and durable audiences in all of sports, averaging approximately 800,000 or more television viewers per event over the past six years. Camping World's seven-year continued commitment to our sport demonstrates its confidence in our on-track product and strength of our loyal fanbase.'

According to Experian Consumer Research, NASCAR fans are 40 per cent more likely than non-fans to go camping, while when it comes to camping gear they are at least 50 per cent more likely than non-fans to own tents and other camping equipment.

Funding boost for Formula E

The new for 2014 Formula E Championship for electric racecars has secured €50m ($69m) of new investment from existing partner Qualcomm and private equity fund Amura Capital.

Formula E Holdings, the company behind the new series, announced that the money marks the completion of its first round of financing. Qualcomm Incorporated – through its venture capital arm Qualcomm Ventures – and Andorran-based Amura Capital, will now join existing investor Causeway Media Partners, which owns of the Boston Celtics NBA basketball team.

These three investors will join the board of directors alongside current shareholders, Spanish entrepreneur Enrique Bañuelos and Alejandro Agag, the chief executive of Formula E Holdings. Qualcomm originally signed a multi-year deal to become a founding partner of the Formula E Championship (FE) back in September of last year, the US company eager to showcase its wireless technology, which will be a feature of the championship's electric pace car.

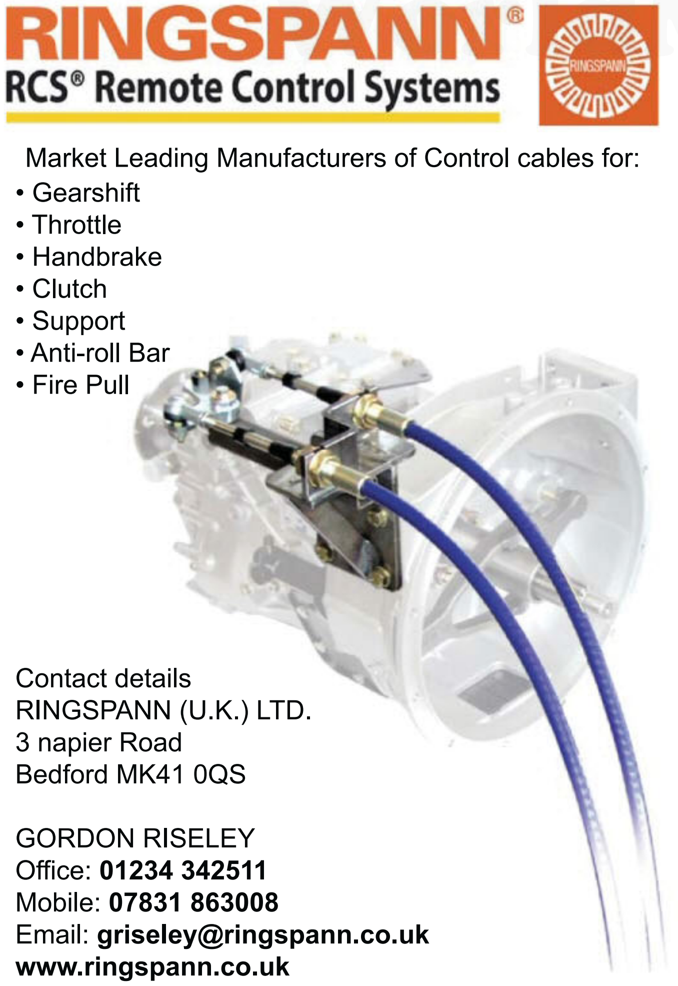
Steve Pazol, general manager of wireless charging for Qualcomm, said: 'We are extremely excited to deepen our relationship with

The new €50m investment comes from Qualcomm and Amura Capital

Formula E. We look forward to demonstrating our technology throughout the race series, including our Qualcomm Halo wireless charging on the Qualcomm Safety Car, and wireless data connectivity and more on the racecars themselves.'

Ivan Comerma, chief information officer at Amura Capital, said: 'FE is a project that shares many of the same values of our company, going that one step further by investing in the environment and sustainability with large doses of innovation.'

FE says three more shareholders will be announced soon, all of them receiving a seat on the Formula E board of directors. Its inaugural event is on 13 September, with Beijing's Olympic 'Bird's Nest' Stadium hosting the races.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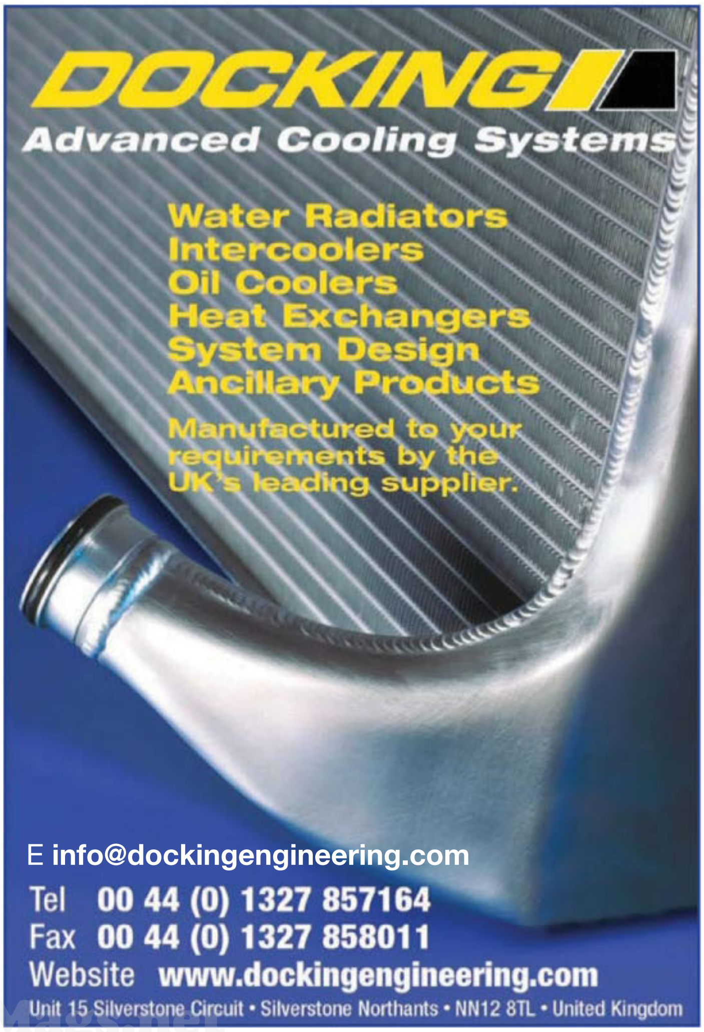
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Australian General Motors brand commits to V8 Supercars

V8 Supercars stalwart Holden has quashed speculation that it is to end its involvement in the premier Australian motorsport category by extending its deal with champion team Triple Eight.

There had been rumours that Holden, the antipodean arm of General Motors, was about to pull out of the championship after it only signed a single year deal with Triple Eight for 2014 – this in the wake of an announcement that it would not be producing cars in Australia from 2017 onwards. This new agreement should end the speculation, although the length of the deal has not been disclosed.

While the confirmation that Holden will continue to compete in V8S will be a relief to its CEO, James Warburton, it will not be a surprise, as recently he told *Racecar* that the decision to cease manufacturing cars in Australia was more likely to cement Holden's place in the sport. 'I see V8 Supercars being even more relevant than ever to support their marketing and brand objectives. Don't forget that while cars may not be made in Australia, they will be sold and marketed in Australia,' Warburton said.

The tie up with Triple Eight is also connected to its Red Bull sponsorship – a Holden fleet deal with the energy drinks firm was signed at the same time. Triple Eight has won every championship

V8S CEO James Warburton is delighted with the new Holden deal

since its switch to Holden's Commodore back in 2010.

Roland Dane, team owner at Triple Eight, said that the deal shows just how important V8S is to the Australian motorsport industry: 'It's a natural step for us to continue our incredibly successful partnership with them,' he said. 'Their continued commitment, in what is a changing marketplace, not only demonstrates their faith in V8 Supercars, but it also highlights the importance of motorsport as a fantastic sales and marketing tool.'

Warburton said of the deal: 'Holden is an iconic Australian brand with a long and successful history in motorsport. We are delighted that they have once again committed its support to V8 Supercars.'

At the time of writing it was not known whether Holden would also extend its deal with its other top-line outfit, Holden Racing Team.

World Rallycross coverage to reach 100 countries

The World Rallycross Championship has unveiled an impressive suite of TV deals, giving the new-for-2014 series a claimed potential reach of over 816 million homes worldwide.

World Rallycross, which staged its first event in Montalegre, Portugal in May, says that it will broadcast in more than 100 countries this season, via a network of over 30 different broadcasters. All of these will show extended highlights of each round, while at least 25 will show the championship live or 'as live' with a two-hour programme.

Martin Anayi, MD of the championship, said: 'It's extremely exciting to have the support of more than 30 broadcasters. Even though it's our first season as a full world championship, we've already secured commitment from some of the world's biggest pan-regional broadcasters such as FOX Sports Latin America and beIN Sports, as well as our existing deals. We're still in discussion with some other regions so we may have even more broadcasters to add to our TV portfolio.'

Rob Armstrong, global head of IMG Motorsport – the company promoting the championship – said: 'Enthusiasm for World RX is growing quickly at the moment and I'm delighted that so many broadcasters have committed to televising our championship. There's no denying that rallycross is a fantastic spectator sport, but it is also one that lends itself perfectly to the small screen.'

Among the countries taking World Rallycross TV packages are Mongolia, Cambodia and Myanmar.

To download our free digital World RX supplement, visit www.racecar-engineering.com

New entry-level UK single-seater formula seeks backers

A British engineering company has released a concept for a new entry-level single seater championship which aims to fill a perceived gap in the market, and it is now looking for partners to take the project forward.

DEE-Ltd has conceived a spaceframe car – to FIA safety standard – which will run with Toyota's three-cylinder 1KR-FE engine packing a supercharger, which will take its output to 120bhp. The company has built a rolling chassis, minus bodywork, and it is now looking for partners with which to develop the formula.

The car, which has provisionally been called a Formula Genesis, will cost less than £25,000 – with engine – and budgets are expected to be around the £30,000 mark. DEE-Ltd has not yet decided whether it will be a spec or open formula – this and other details will be up to its partners, should they be attracted to the project.

It is to be aimed at both karters progressing to cars and club racers.

DEE-Ltd's head of motorsport, Nathan Poole, has worked in F1 design and at Reynard and TWR. It holds the European rights for the import, distribution and application of Toyota engines, and this, says Poole, was the starting point for the project. 'The fact that the engine is a 1-litre, three-cylinder lightweight engine fits the road map for low carbon and downsized, boosted engines,' he said.

'The market is very crowded towards the £90,000 to £100,000 a season mark, but we're talking about a £25,000 car, and £30,000 a season. Carbon chassis and winged formulae cost a fortune to compete in, but there's nothing to do at a club level.'

The company hopes to launch the formula as early as next year, but that depends on its success in finding partners to help with the project.

Formula Genesis will pack a three cylinder Toyota engine boosted with a supercharger


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INTERVIEW – ALAN GOW

The golden era

The British Touring Car Championship is enjoying one of the best seasons in its 50-year history. We talked to its boss to find out just what makes BTCC 2014 so special

The British Touring Car Championship has enjoyed its fair share of halcyon periods: Cortina vs Galaxie in the 1960s, the fire-breathing Sierra Cosworths of the 1980s, and the big money Supertourers of the 1990s to mention just three. But in future years will 2014's incarnation of the long-running saloon car championship also be looked back on as a golden time? The indications are that it will, for whether the measure is grid size, spectator numbers, star drivers, sponsor involvement, or the highly enjoyable show, the UK tin-tops seem to be in tip-top condition.

One man who is enjoying this BTCC boom-time more than most is Alan Gow, the busy Australian who is series director and administrator – as well as being chairman of the MSA and president of the FIA Touring Car Commission. 'I don't know if it could get much better,' Gow says. 'We've got 31 cars on the grid – 11 different makes – all new cars that have been built to the new regulations, so we're on a roll at the moment. There are seven champions on the grid and the racing's fantastic.'

GENERATION NEXT

Gow puts the success of the current era of the BTCC down to the NGTC (Next Generation Touring Car) regulations, a cost-focused formula that is largely based on the use of a number of spec parts, and has been phased in since 2011 – all the cars are NGTC for the first time this year. It's not just about technical regulations, though, for there has been another major change for this season, and where 2014 differs noticeably from previous years is in the robustness of the BTCC grid, for this year there

BTCC series director Alan Gow

are no teams or drivers dipping in and out of the championship, coming and going as they please. This is because of the new British Touring Car Licence (TBL), which secures places in the championship in return for a guarantee that the teams will turn up to every event.

'It's a way of giving something back to our teams,' Gow explains. 'It's not a franchise system or anything like that. A franchise means they get shares and profits; a licence is merely a licence to enable you to compete. You can't enter a car in the BTCC unless you have the licence, which means that all of those teams that have committed to us, we've made that commitment back to them. As part of the licence system they also have to commit to doing every round of the championship, so it's a two-way thing. But the licence means more to them than it probably does to us.'

What the licence gives teams is something tangible to own beyond cars and equipment, and to sell on if they wish. 'If anyone wants to come in to the BTCC they have to do it through one of the licence holders,' Gow says. 'The teams have got a fantastic asset now, which they didn't have to buy – we gave it to them.'

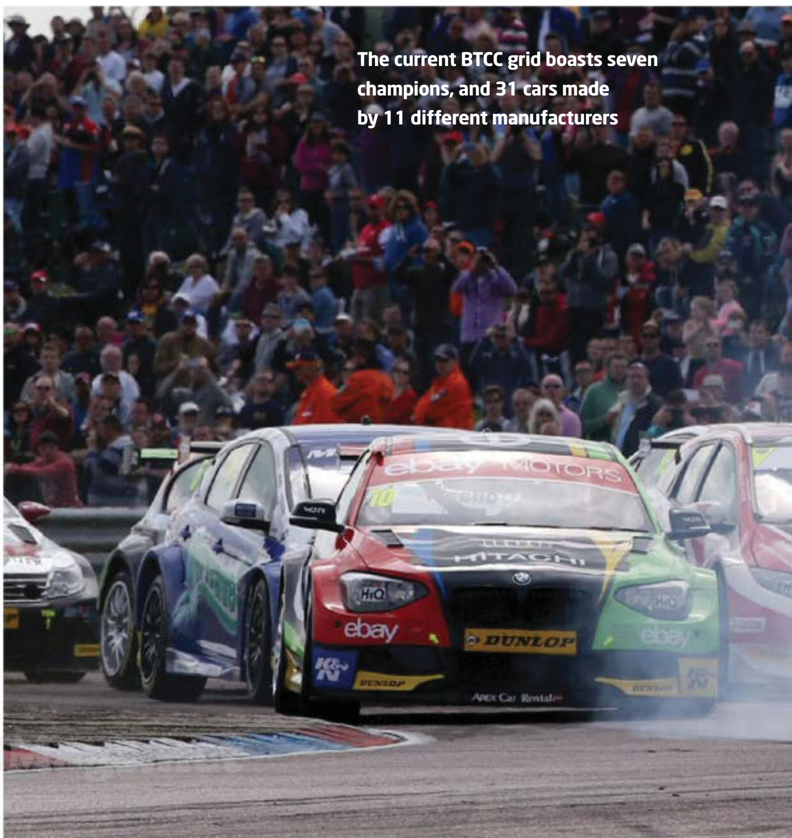
If a manufacturer wanted to enter the BTCC it would have to do so through buying, borrowing or leasing a licence from one of the existing holders, then, and it's easy to imagine the smaller teams sitting on their TBLs and rubbing their hands waiting for the car-makers to knock on their workshop doors with bags of cash.

But is there actually a place in the BTCC for a big influx of works teams right now? 'There's good and bad in that,' says Gow. 'We saw in the '90s that when the manufacturers depart they leave a huge vacuum, and we don't want to get into that position again. So what we've done is create a set of regulations that anyone can build a car to. Yes, if you're a manufacturer team you will have a bit more expertise and resources available to you, but they can't do that much better than everyone else. They might be able to have smarter transporters but there are such restrictions on the cars that if you came in with £3m you probably wouldn't do any better.

'You're seeing that in all motorsport around the world. There's less and less dependence on manufacturers. That does not mean we wouldn't like to have manufacturers involved, of course we would, but it doesn't hinge on their involvement.'

BANG FOR YOUR BUCK

Gow says a budget for one car in a top team is around £400,000 these days, which has to be good value for a televised series which is attracting crowds of up to 40,000 – a staggering amount for UK racing, matching and even beating figures for many Premier League football matches. But while the BTCC might rival top tier football in this respect, Gow has no illusions when it comes to its importance in the sporting pecking order: 'You've got to know



The current BTCC grid boasts seven champions, and 31 cars made by 11 different manufacturers where your place is, and we don't have the support or attraction that football does. We're very much on the motorsport ladder, and in the UK we're very much second to Formula 1 – and a long way second at that. You just have to know your audience, you have to know your product, and you must not tilt at windmills.'

It's a realistic approach. But where does the BTCC stand in relation to its global cousin, the World Touring Car Championship? Gow says they are not competitors in any way, pointing out that the WTCC does not even race in the UK, while the BTCC has no plans to race abroad. Yet the two have been linked recently, largely as a result of Gow's role with the FIA's Touring Car Commission and talk that there is to be a new feeder category for WTCC. 'There are two different things going on here,' he says. 'One is that the WTCC promoter, Eurosport, needs to start looking at ways of getting teams in with a feeder series. But that's a totally different subject from what the FIA is doing, which will be drawing up a set of regulations that national championships can choose to use. Going on from there, if Eurosport decides that's also a set of regulations they could use for their feeder series then that's fine, but these are two totally different things.

'We will not be writing new regulations, we will be using a couple of sets of regulations that exist. There will probably be two levels of regulations – one for a much more standard sort of car – and then we will formalise it so that any national championship around the world can use those.'

But Gow does admit that this new global touring car blueprint could be to the NGTC regulations. 'It could. What we are going to do is have a look at the regulations of all the series around the world and see which is the most appropriate. Obviously NGTC would have to be fairly high up, but I'm not in it to sell the NGTC concept to anyone.'

Whatever happens to NGTC worldwide, the BTCC itself is in a happy place right now. It's in rude health just as the UK is dragging itself out of recession. So what will future race fans say when they look back on BTCC 2014? Will it be: 'now there was a golden time', and will they then add: 'and that was just the start'?

Mike Breslin

"You have to know your audience, you have to know your product, and you must not tilt at windmills"

RACE MOVES

McLaren has appointed two new aerodynamicists, with **Tony Salter** arriving from Sauber and **Guillaume Cattelani** from Lotus. The signings are to help fill the gap left in its aero team as it waits for **Peter Prodromou** to join next year – after his Red Bull gardening leave is up – and while the legal uncertainty over whether **Dan Fallows** is contracted to Red Bull or McLaren is cleared up.

Francesco Nenci has started work as **Jules Bianchi**'s race engineer at Marussia F1, taking the place of **Paul Davison**, who was promoted to the role of head of vehicle performance earlier this year. Davison continued in the race engineer role until Nenci was released from his previous team, Sauber.

Top Mercedes DTM team HWA has split with its technical director and CEO **Gerhard Ungar**. The news came just days after Mercedes made a disastrous start to the DTM season, failing to score a point in the opening round. HWA board member **Ulrich Fritz** will now take over Ungar's responsibilities while the company searches for a replacement.

Benoît Dupont has now left his post as Renault Sport Technologies (RST) sporting manager to take up a position with the all-new FIA Formula E championship for electric racecars. Dupont had been with RST for 10 years.

Nigel Vaulkhard, the co-founder of Bamboo Engineering, which last year raced in the WTCC and this year is competing in the WEC in an affiliation with Craft Racing, has died at the age of 66 after a mountain bike accident. Vaulkhard, a former Porsche and historic racer, set up Bamboo with **Richard Coleman** in 2009.

Bob Bell, currently technical director at Mercedes, is to leave the F1 team at the end of this season. Bell, the former tech boss at Renault, announced his intention to leave the team at the end of last year. Mercedes is to drop the role of technical director when Bell leaves, with executive director (technical) **Paddy Lowe** taking on his responsibilities. Bell joined Mercedes in 2011.

XPB

Dickie Stanford (above), who stepped down from the position of team manager at Williams F1 earlier this year, will now take on the post of general manager at Williams Heritage, a new division of the group that will look after the large collection of pensioned-off Williams F1 cars, which are often used for on-track demos. Stanford joined Williams as a mechanic in 1985.

Former Australian saloon car racing team boss and engineer **Harry Firth** has died at the age of 96. Firth was the man who set up the factory-backed Holden Dealer Team and was also a successful driver before he turned to team management, winning Australia's most prestigious race, the Bathurst 1000, four times. He retired from motorsport in 1977.

Former Aston Martin and Ford race mechanic and GT40 preparation wizard **John R Etheridge** has died at the age of 72. After great success fettling racecars for others, Etheridge set up his own company specialising in Aston Martins, Ferraris and the Ford GT40 in 1968, but was particularly known for his work with the Blue Oval's fabled sports racer.

Legendary Indianapolis 500 car builder and mechanic **AJ Watson** has died at the age of 90. Watson took six wins as a constructor at the Brickyard, and four as a chief mechanic, in the late-1950s and early-1960s.

Caterham management restructure sees Smith replaced by committee

Mark Smith is no longer the technical director at Caterham, while a 'technical committee' has been formed in a bid to improve the struggling F1 team's woeful form.

Smith, who has been with the team since 2011, will not be replaced, and the technical director role is now defunct at Caterham. The new committee, which will now make the technical decisions, is made up of former performance director John Iley, chief engineer Gerry Hughes, and former deputy technical director Jody Eggington. The committee will report to team principal Cyril Abiteboul.

Iley will now be known as head of performance engineering while Eggington takes on the job of head of design and manufacturing. Hughes will still be chief engineer, but he will also assume the role of head of trackside operations.

Mark Smith has parted company with Caterham 'on good terms'

Abiteboul insisted the restructure was vital if Caterham is to improve its performance: 'I would like to thank Mark for his time and dedication to the development of our team since he first joined in 2011. We and Mark part company on good terms and with our best wishes for the future. It was obviously a tough decision to see someone of Mark's calibre go, but we have identified the need to restructure as a key aspect of increasing our on-track performance and forming a new technical committee composed of John, Jody and Gerry will allow us to do exactly that.'

Caterham's dismal season plumbed new depths at the Spanish Grand Prix, where they were not only out-qualified by tail-end rivals Marussia, but the times posted were beaten by the top 13 cars in qualifying for the GP2 support race.

BRIEFLY

Made for Orleans

IndyCar is considering racing at the NOLA Motorsports Park, just outside New Orleans, with some reports saying a race at the 2.75-mile road course could be on the calendar as early as next season. If the event goes ahead it will be promoted by Andretti Sports Marketing, while it's understood that the state of Louisiana has pledged to spend around $4.5m towards the upgrades required to bring it up to IndyCar standard.

Honda limit

Honda's motorsport boss Yasuhisa Arai has said that the Japanese company will not supply any teams other than McLaren when it makes its return to F1 next year. 'For year 2015, McLaren is our only customer,' he said. 'If teams want to use our engine or power unit, we can deliver after year 2016, but right now there are no plans.'

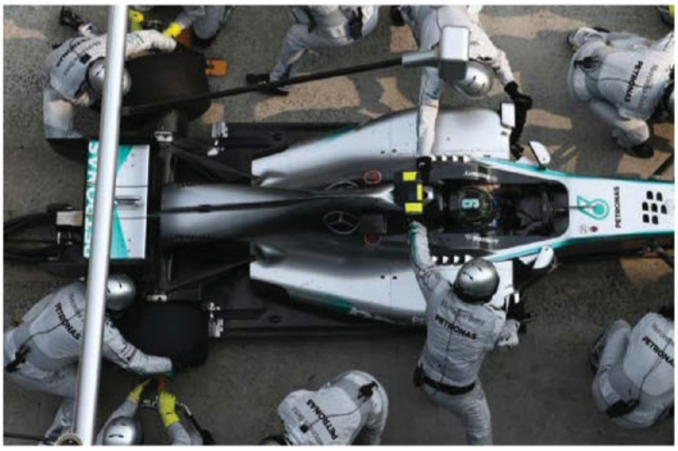
All in the mind for Mercedes

Mercedes has confirmed that it is now working with a noted sports psychologist, but he has not been brought in for the benefit of drivers Lewis Hamilton and Niki Rosberg.

Former professional soccer player Dr Ceri Evans – who worked with the New Zealand All Blacks rugby team during its 2011 World Cup winning campaign – was at the Chinese Grand Prix, where he observed and assessed Mercedes engineers and mechanics as they went about their race-weekend work, particularly during high-pressure situations such as pit stops.

Mercedes executive director Toto Wolff has confirmed the hiring of Evans. 'At Mercedes we want to optimise every aspect of performance, and we believe that there is much to learn from other sports. This includes the performance of the whole team and how we act and react in key moments,' he said.

Evans is a former Oxford United and New Zealand international football player.


Dr Ceri Evans has observed and assessed Mercedes crew in high pressure situations during race weekends, such as pit stops

OBITUARY - SIR JACK BRABHAM

Sir Jack Brabham AO, OBE, triple Formula 1 World Champion, has died at the age of 88.

Sir Jack passed away peacefully at his Gold Coast, Australia. Formula 1 World Champion in 1959, 1960 and 1966 and double Constructors' Champion (1966 and 1967), Sir Jack was one of the most accomplished drivers and team owners in the sport's history. The first driver to be knighted for services to motorsport, Jack rose from racing midgets on dirt ovals in Australia to dominate global motorsport. His first two titles in the Cooper Climax marked the end for front-engined Formula 1 cars. The third made him the only driver in history to win a World Championship in a car of his own manufacture, the Brabham BT19. Technological innovations brought about by the Brabham team helped to shape the sport today.

Jack scored his final win in the 1970 South African Grand Prix, but his legacy continued with all three of his sons achieving global success. Sir Jack is survived by his wife, Lady Margaret, sons Geoff, Gary and David, and their families.

Sir Jack Brabham 1926-2014

SPONSORSHIP

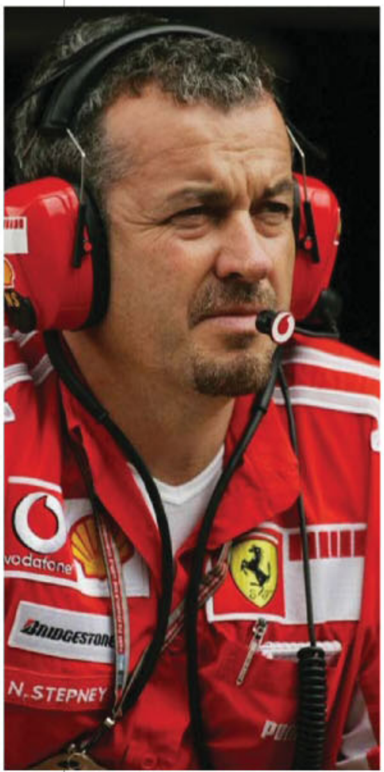
Force India has signed a major deal with the **Smirnoff** vodka brand, which is part of drinks giant **Diageo**. Diageo is currently in the midst of a bid to buy **United Spirits**, the alcohol group owned by Force India boss Vijay Mallya.

International tech firm **Silanna** has signed up to sponsor **Caterham** F1. The company specialises in the design and manufacture of semiconductor devices.

Singapore Airlines is now title sponsor of its home grand prix. CEO Mr Goh Choon Phong said of the deal: 'We are thrilled to be taking up the title sponsorship of one of the most exciting races on the F1 calendar, and especially pleased to be doing so in the lead-up to Singapore's 50th birthday next year.'

OBITUARY – NIGEL STEPNEY

While he might always be remembered for the part he played in the spying scandal in 2007, Nigel Stepney, who died in a traffic accident in May at the age of 56, had a varied and successful career in motor racing, which included playing a crucial role in the most successful era in Ferrari's long Formula 1 history.



Stepney started his motorsport career at the Broadspeed touring car team as an apprentice mechanic – in an interview with *Racecar* he said its Jaguars were his favourite racers (*V23N12*) – before moving to Formula 1 with Shadow.

He joined Lotus in 1980, where he went on to work with Ayton Senna, before a move to Benetton (1989) gave him the opportunity to also work with Michael Schumacher for the first time. There was then a brief spell managing a Formula 3000 team in 1992, before he returned to F1 with Ferrari, where he eventually became a key cog in the machine that ripped up the Formula 1 record books in the first part of the 2000s.

In 2007, by now head of performance at the Scuderia, Stepney was increasingly disillusioned with the way Ferrari was operating, and soon became embroiled in the notorious 'Spygate' scandal – in which he was accused of passing on secrets to McLaren. This ended his career in Formula 1, the FIA recommending that teams did not employ him – although he told *Racecar* that the FIA later offered him a position working within the governing body itself. He was also handed a suspended prison sentence.

Turning the FIA offer down, Stepney went on to work in sportscars, first with the Gigawave GT team and then, since 2010, with JRM. James Rumsey, the owner of JRM, said of him: 'From the moment Nigel joined JRM in 2010 he was a vitally important member of the team and brought a level of engineering experience to us that was unrivalled. The rest of the engineering and race team here at JRM learned an unimaginable amount from Nigel in the four short years he was with us and his death has shocked everyone to the core.'

Rumsey added: 'The motorsport world has lost one of its greatest characters and competitors.'

Nigel Stepney 1958-2014

CAUGHT

NASCAR Sprint Cup crew chief Kenny Francis has been hit with a $25,000 fine after the Hendrick Motorsports Chevrolet he tends was found to be under the weight limit during post-qualifying scrutineering at the Talladega round of the series. As a result of the infraction the Kasey Kahne-driven car was also relegated to the back of the grid – he had originally qualified in 17th place.

FINE: $25,000

RACE MOVES

Former Lancia rally and Alfa Romeo racing manager **Giorgio Pianta**, a man renowned for his organisational abilities, has died at the age of 78. The Italian was initially a driver, in both racing and rallying, and was well-known for his talent as a test driver. He subsequently found a place as a test driver in Fiat's Abarth competition arm in the 1970s, where he helped to develop the Fiat 131 with which Walter Röhrl took the 1980 World Rally Championship. Pianta went on to manage the Lancia rally programmes for the Fiat group and oversaw the Lancia Rallye 037 and the Delta Group B campaigns in the 1980s. When Alfa Romeo became part of Fiat Pianta spent 10 years at Alfa Corse, both in the DTM and the BTCC, before leaving in 1996, when he took up a consultancy position with the Italian motorsport federation. Pianta's driving career started in the 1950s, and he went on to race in a wide variety of formulae, including F2 and F3. He also competed at Le Mans and in the Targa Florio during a career that stretched into the 1980s.

XPB

NASCAR's chairman and CEO **Brian France** (above) as been honoured at the Cynopsis Sports Awards in New York. NASCAR Sprint Cup team owner Rick Hendrick presented France with the Vision Award, which recognises the executive of the year from a sports league or organisation who has 'demonstrated innovation and transformed an industry'.

The Motor Sport Industry Association (MIA) has taken on **Nick Wills** as its new business development director, with the brief of enhancing the connections between motorsport companies and the defence sector. Wills, a former army officer, is a founding member of the MIA's Motorsport to Defence initiative and has worked on the project since its inception in 2007.

Andrew Coe has left the position of chief executive of International Motor Sports Ltd (IMS), the Motor Sports Association's (MSA) commercial subsidiary. Coe joined IMS from the International Tennis Federation in 2001, and his duties had included managing the British round of the World Rally Championship, Wales Rally GB.

Ben Taylor, the development and communications director at the MSA, will now fill Coe's role by becoming the managing director of International Motor Sports. He will perform his IMS work in parallel to his existing duties at the MSA.

Pit crew coach **Lance Munksgard** has left NASCAR Sprint Cup outfit Hendrick Motorsports, where he was involved with the crews that tended the **Jimmie Johnson** and **Dale Earnhardt Jr** cars. **Greg Morin** and **Chris Krieg** will cover his work until the team find a full time replacement.

Gunther Steiner is to be the team principal at the new-for-2015 Haas Formula 1 team. Steiner, who despite the German-sounding name is actually Italian, has F1 experience with Jaguar and Red Bull, while he has also worked in World Rally.

Peter Jung has joined NASCAR as senior director of growth segment marketing, coming to the organisation from Mastercard. **Nicole Smith** has also joined as director of growth segment marketing, reporting directly to Jung. Both have been brought in to focus on NASCAR's youth and multicultural marketing efforts.

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

Clarion call to cut racing carbon

Alongside the 25th Autosport Engineering show next year, a new trade event is launching which recognises the growth and importance of low carbon racing

Plans for the 2015 Autosport Engineering Show, held in association with *Racecar Engineering*, are well under way with a new concept recognising low carbon racing. In step with the rapid proliferation of low carbon technology in motorsport and global road car manufacturing, Haymarket exhibitions is launching a trade-focused event for the low carbon technology sector.

The Low Carbon Racing and Automotive Show (LCRA) will take place alongside Autosport Engineering and Autosport International. The Autosport shows – which like *Racecar* will be celebrating their 25th anniversary in 2015 – supports the Motorsport Industry Association in staging an 'industry-only' one day Low Carbon Racing conference, which takes place at the NEC the day before the show opens. The creation of the LCRA alongside the show will deliver broader exhibitor and visitor bases, which will offer even greater value and opportunities for suppliers and buyers of advanced motorsport and automotive technology.

But what is low carbon?

Low carbon technology has become a by-word for fuel economy. Reducing carbon emissions has become a critical focus of attention for major car companies, which are faced with EU emissions targets of 130g/km of CO_2 by 2015, and 95g/km by 2020 for the entire fleet.

According to the EU, cars are responsible for around 12 per cent of total EU emissions of carbon dioxide, the main greenhouse gas. This equates to a reduction of 18 per cent reduction on 2007 figures, and a 40 per cent reduction by 2020. In terms of fuel consumption, this works out as a target of 5.6 litres per 100km of petrol, and 4.9 litres per 100km of diesel. The 2021 target equates to 4.1 litres for petrol and 3.6 litres for diesel.

Emission limits are set according to the mass of the vehicle, using a limit value curve. The limit value means that heavier cars are allowed higher emissions than lighter cars, while preserving the overall fleet average.

In 2012, an average of 65 per cent of each manufacturer's newly registered cars had to comply with the 130g/km limit value curve set by the legislation. This rose to 75 per cent in 2013, 80 per cent in 2014 and goes up to 100 per cent from 2015 onwards. For the 95g/km average, 95 per cent of each manufacturer's new cars will have to comply with the limit value curve in 2020, and 100 per cent in 2021.

There are financial penalties applied to any manufacturer that fails to meet the targets – for every car registered, the penalty is €5 for the first g/km exceeded, €15 for the second g/km, then €25, and €95 for every gram exceeded thereafter.

RACING TARGETS

The new targets mean that manufacturers are looking for technologies to reduce carbon emissions, and racing has taken a bold step, with new hybrid regulations in F1 and sportscar racing. Racing is the perfect platform for rapid development, with prototype cars able to be used for testing purposes, and proven in competition.


The low carbon initiative embraces the emphasis on reducing emissions

The new regulations have attracted Honda to F1, Porsche, Audi, Toyota and Nissan into LMP1, and more are expected to come onboard. The low carbon initiative at the Autosport Engineering Show, in association with *Racecar Engineering*, reflects the task that has been set by legislators, and embraced by manufacturers involved in racing.

Q&A WITH OLA LENNSTROM, ÖHLINS

Öhlins has been an integral part of the motorsport industry since 1976. With such experience in the automotive sector, we speak to Ola Lennström, marketing manager, to find out how its extensive product range has changed, and what we can look forward to in the coming months.

Q: What were your experiences of the 2014 show?

A: Öhlins has been a regular exhibitor at Autosport International and we feel it is a show with a very high international mark. We always leave the event with a number of good leads and contacts, so we make sure we give it the highest priority.

It is the most important motorsport show today, with excellent opportunities to meet the industry and our clients, which is why we keep coming back!

Q: In 2015, we will celebrate 25 years of Autosport International. How has your business changed over the past 25 years?

A: We are currently seeing a move from conventional suspension over to mechatronic and electronically controlled suspensions in a number of sectors. This has been a constant change for a few years now and is especially true for road-going vehicles, whereas in competition, electronically controlled suspension is often not allowed. However, even with electronically controlled suspension, good hardware is still the most important factor and therefore the development within electronics and conventional systems goes hand in hand.

At the same time there has been, and still is, constant development in all areas of so-called conventional suspension such as valve technology, materials used and oil.

The motorsport industry itself has gone through a lot of major changes during the last 25 years and, as a supplier to the motorsport industry, we have been affected by all these changes and new challenges.

Q: What can we look forward to seeing from Öhlins in the coming years?

A: Since Öhlins is involved in so many different areas within the industry, that is a hard question to give a short answer to!

Obviously continued development into the electronically controlled system, but also into new markets such as mountain bikes.

We are looking at expanding this area of the business as well as launching a variety of new competition and road products for both the car and motorcycle sector.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HEADLIGHTS

Melectronics LED headlights

The progress of technology in recent years has seen big budget teams introduce fully custom LED headlights to their prototype machines, giving them a technical and aesthetic 'wow' factor. But the benefits of using such technology are based in function as well as form, with tangible performance advantages on offer.

In terms of headlights, weight and space can be saved with the LED approach, causing less physical restrictions in the critical front area of the car. Furthermore, LED headlights are more efficient than their traditional equivalents – yielding a saving in power or a gain in targeted light output for your given power budget.

Such advantages are no longer the preserve of the highest budget teams and Melectronics have addressed this with their latest range of LED Headlights. The off-the-shelf items are simple drop-in replacements for traditional 90mm parts, making the switch to LED simple.
www.melectronics.co.uk

SENSORS

Bosch acceleration sensor

The MM5.10 sensor was designed to measure the physical effects of rotational and lineal acceleration. In order to achieve this, the sensor includes MEMS measuring elements connected to an appropriate integrated circuit. A rotational acceleration around the integrated sensing elements generates a Coriolis force which changes the internal capacity of the micromachined sensing parts. Furthermore, a pure surface micromachined element is used to measure the vehicle lineal acceleration in all three axes. This combination of rotational and lineal acceleration sensors enables a precise measurement of the vehicle dynamics.

The main feature and benefit of this sensor is the combination of three lineal and two rotational accelerometers and its high speed 1 Mbaud CAN-signal output.
www.bosch-motorsport.com

FABRICATION

SS Tube Technology

An engineering-based fabrication business manufacturing exhausts and thermal management solutions for high-technology industries, SS Tube Technology has recently invested significally in new facilities. This includes a six axis laser cutter, electronic CNC tube bender and two laser scanning probes. This allows the business – which serves F1, IndyCar, WEC and touring car series to react faster, reduce process costs, increase capacity and process more complexity while ensuring quality and consistency across the product portfolio.
www.sstubetechnology.com

BRAKES

Winmax brake pads widen distribution

Japanese brake pad manufacturer Winmax has started distribution in Europe, Russia, Africa and the Middle East. The company is the market leader in Japan in motorsport brake pads.

The firm has been well-known in Japan for many years, and since the early-80s has designed and produced high quality brake pads for cars active in rallying, racing, and formula racing. It quickly became the choice of champions and proved its qualities by featuring on a host of top cars in Japan.

At the beginning of 2014, Winmax started to export, co-ordinated from Winmax Europe, based in Belgium. Initially, dealers signed for local distribution rights in Belgium, Spain, Portugal, the Netherlands and the Czech Republic. Further negotiations are currently ongoing with another 10 potential dealers, and Winmax continues also its search to expand its dealer network.

In the meantime, Winmax Europe has started several tests with official manufacturer teams as well in rallying (WRC and ERC), Rallycross RX, Cross-Country (Dakar) and in other forms of racing (WTCC, GT). All tests to date have been extremely positive, with great feedback from teams and drivers. Key points highlighted by them have been in relation to the superb grip, the constant performance, and the limited damage experienced by the discs. Winmax brake pads are available in several different compounds – see the website below for details.
www.winmaxeurope.com

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As you were, gentlemen

The failure of manufacturers to reach agreement on the future of GT regulations has been met with indifference by one of the leading figures in the world of GT racing, Stephane Ratel. The Frenchman, who oversaw the introduction of the BPR series, the FIA GT Championship, the Blancpain Endurance and Sprint series, and more aptly created the GTE and GT3 regulations, never saw the point of the convergence talks, and has consistently stuck to his theory.

Once again, he has proven to be correct as, late in May and with the prospect of the June World Council meeting to present bullet points for the unification of key elements of GT and GT Plus cars, manufacturers failed to reach an agreement and instead the plans were shelved. There is still a plan to propose standard chassis regulations for 2016, but this is nonsensical as it maintains the instability and uncertainty for the class.

The FIA Endurance Commission set out to establish common platforms between the two categories in a bid to reduce the cost of GTE racing. On the fundamental point of engines, however, there was no agreement. As talks wore on, the point of them became more and more obscure. 'In my opinion, if there is to be a reduction of cost, it would be understandable,' said Michelotto's Luigi Dindo at Spa in early May. 'The two categories, especially GT3, are working. The talks were necessary to see how to improve what exists, but no one was willing it. What exists now is working very well. What do we need? We need to reduce the cost of design, and of the cars, and of maintenance. This was the request.'

By leaving the door open, the commission would leave GT racing in limbo

The first talks took place in November, 2012. At the time, there was frustration from the manufacturers that they could not even find a starting point. Should GT3 cars be made into GTE? Logic suggested yes, with the cars cheaper to buy and run than the GTE cars, and just as fast. Yet that wasn't possible as GT3 was literally a Balance of Performance formula, with no clear technical regulations. How could manufacturers compete on this platform?

Eventually, it was accepted that common engines and roll cages would feature in both categories, but then came the crux of the problem – what to do with the engines. There were clear sides: those who wanted production-based engines (normally those who ran GT3 only programmes), and those who wanted to build race engines and control them with sonic restrictors.

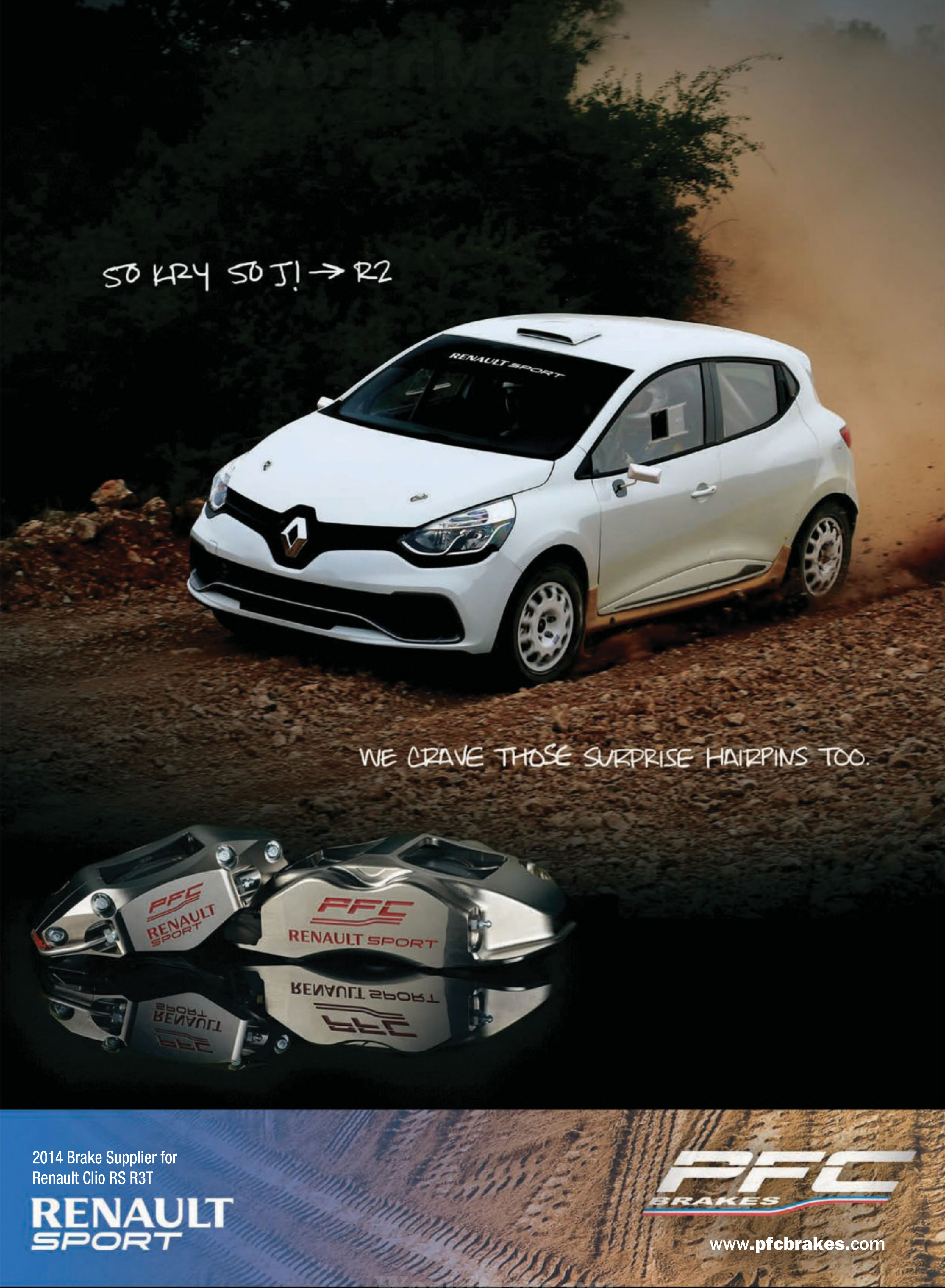
Then, in May, the FIA introduced a plan to use accelerometers to balance performance and continue with production-based engines. (At this point, Porsche asked for a definition of production-based engines...) The FIA considered this to be a cheaper solution to building bespoke race engines, but there were obvious hurdles to overcome. The gauges have to be located in the driveshafts, which are therefore likely to be custom-made. They then need to be calibrated and tested across a wide temperature range, with the data then analysed. Data analysis alone from the Spa 24 hours would take either weeks, or a lot of money to do it quickly. Neither was satisfactory. 'It came down to timing – to introduce the accelerometers in 2016 or 2017,' said Aston Martin's John Gaw. 'There were four options in total: to stay as we are, to introduce accelerometers in 2016, to introduce accelerometers in 2017 or to go to sonic restrictors. The GT3 teams wanted accelerometers as quickly as possible, but we wanted more time to develop them properly. The problem with accelerometers is that a closed loop system, if not done properly, would be very expensive. Imagine that it has to work in the wet, the dry, on old tyres, on new tyres, with pro drivers or with amateurs – you can imagine the level of the closed loop system that you would have to develop. It could have worked, but it would have taken time.'

However, the fact that the talks have been ongoing for so long suggested that the plan was flawed, according to Ratel. 'It is not going to happen mainly because I don't think the manufacturers want it,' said the Frenchman. 'We presented GT3 to the commission in July 2005. By April/May 2006, we had 52 cars entered in the GT3 championship, despite opposition or interference from most people. Now, for me, it is clear. If after two years of talks there is still opposition, it is not a good sign.'

There is a natural point at which the regs should be changed, says Ratel, and that is when the inevitable question of GT hybrids comes, perhaps as early as 2018, maybe by 2020. That is when there will need to be an overhaul through necessity rather than choice.

By leaving the door open to a change in 2016, the commission has left GT racing in limbo. McLaren, Audi and Aston Martin all have new or facelifted models coming. Let them come, and don't try to fix what ain't broke.

EDITOR
Andrew Cotton



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