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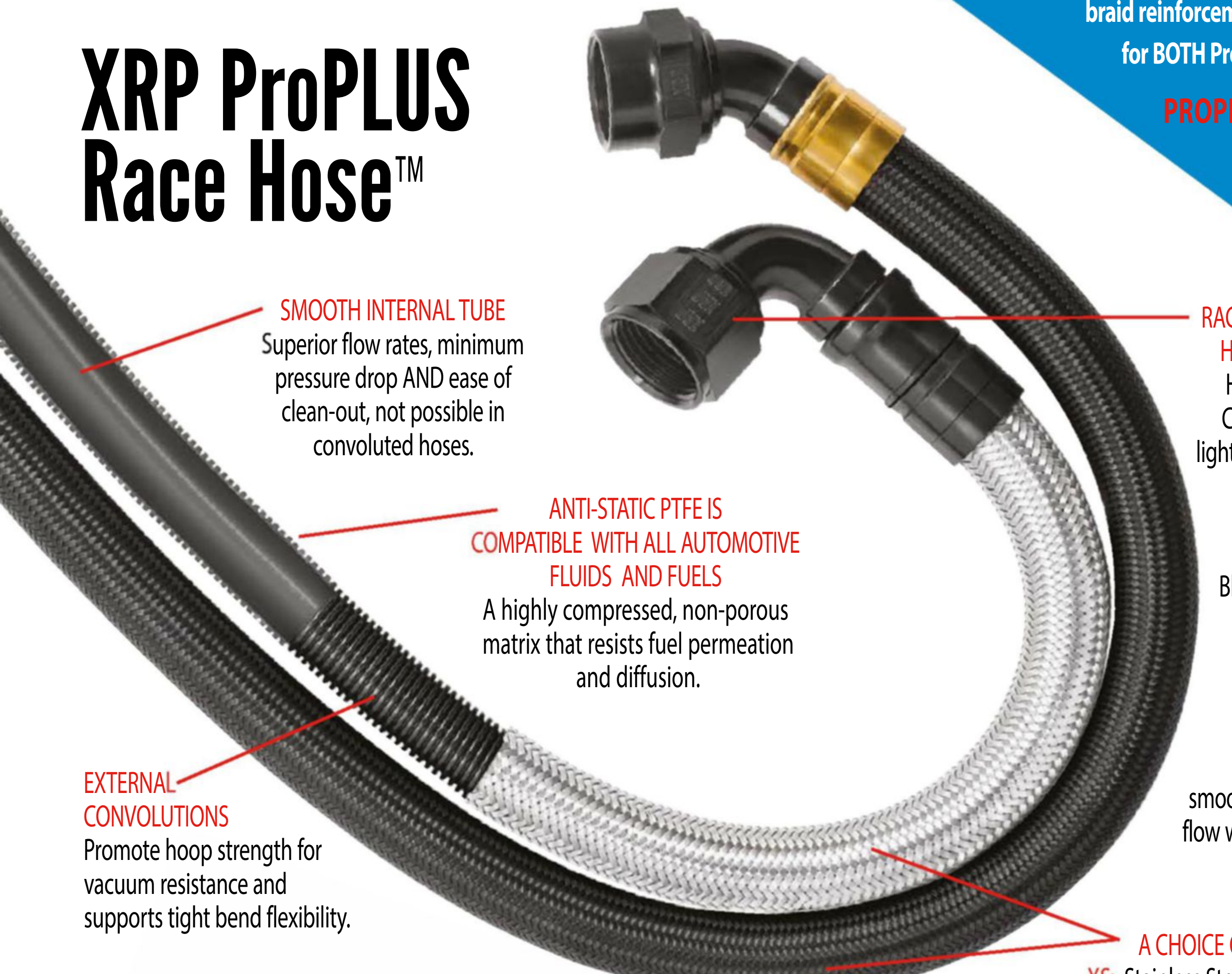

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The Lexus LC500 was developed in secret by Toyota as a replacement for its RCF Super GT GT500 racecar. The result was this truly epic machine

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SIMULATE ENGINEER MAKE TEST RACE

Beetle mania

How a twin-engine VW took the fight to pukka Le Mans cars in Brazil back in 1970

I have always been fascinated by extreme racing cars, probably a sign of that inner six-year-old. Not for me the humdrum, run-of-the-mill spec racer, and probably the spectators think likewise, if we look at what captures their imagination.

Let us wind the time machine back to 1970. Emerson Fittipaldi had just captured the British Formula 3 championship and was back in Brazil. Meanwhile, at the Fitti team an Alfa Romeo 2-litre 4-cylinder engined sports-prototype was being built, with the intention of it being ready for the 1000km race in Rio at the end of the year.

So far, so good, until the castings didn't arrive in time and, worst of all, due to the opening of import restrictions, suddenly the entry list was populated with some fearsome beasts. One Alfa Romeo T33, two Lola T70s and a Ford GT40. Putting on one's extreme thinking hat a solution was found. It was easier than it first appeared to be, coming down to power-to-weight ratio.

Bringing out the trusty Faber-Casell log-log slide rule we threw in the parameters. Location: Jacarepagua race track in Rio. Characteristics: twisty short straight venue, low top speed, so drag a second order issue. Opposition: Ford GT40, 908kg and 440bhp; Alfa T33/2, 580kg and 270bhp; Lola T70, 869kg and 438bhp. Respective power to weight ratios: Ford, 2.227, Alfa Romeo, 2.148, Lola, 1.984.

Here be Herbies

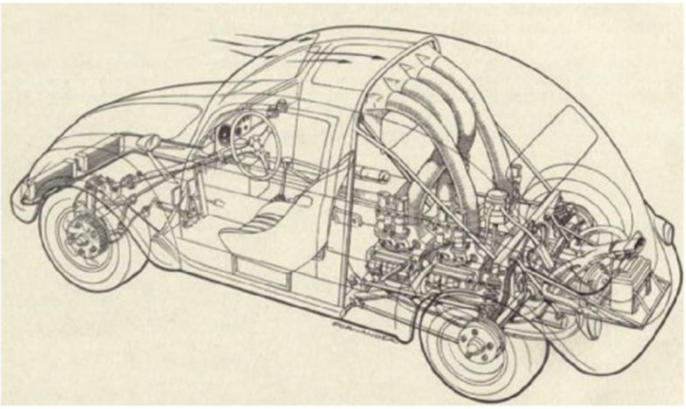
Looking around the workshop there were several VW 1600 flat-four engines in racing trim, with about 160bhp and sporting two twin-Weber 40 DCOE carburettors. There were also fibreglass hoods and doors (Fittipaldi produced parts for racing Beetles) and one experimental version bored out to 2.2 litres, of unknown horsepower as the local dyno only measured up to 200bhp and had pegged. There was also a Porsche RSK Spyder 5-speed gearbox, that we had used in the earlier Fitti-Porsche prototype racer.

Whipping the slide-ruler into frenzy came up with the solution, inspired by an issue of *Hot Rod* magazine featuring Tommy Ivo's twin-engined dragster and taking into account the fact that we had five weeks to build and prepare for the race.

Two engines at 160bhp gave weight required of 420kg for an interesting 1.312 ratio. And the double 2.2-litre version an even more appealing 1.05kg per hp, if we could produce two engines in time. Meanwhile, using the same Goodyear Blue Streak tyres mounted on alloy wheels as the opposition meant handling would not be too compromised, even though we would keep the original front trailing link suspension and rear swing-axles.

How to get down to weight? Building a spaceframe chassis would take too long, so a quick check of a VW Beetle platform bereft of metal bodywork showed it at 180kgs. Putting two 74.5kg engines mid-ships meant that we could slice the platform just behind the driver and lay them on two 4-inch tubes. Bingo! There was another 80kg off the weight, and it left the rear looking like a classic 1930s racing car twin tube chassis.

Its appearance at the test caused a lot of mirth in opposing teams



KARL LUDWIGSEN

It had two engines and a huge air scoop, and was quicker than Lola T70s and a GT40 at Jacarepagua – the Fittipaldi VW Beetle was a very special creation

The engines were connected by a rubber donut off the locally built Alfa Romeo 2000, with a rather dubious flange bolted on to the back of the front engine and on to the bored out bolt-holes off the fan pulley on the nose of the rear engine. The entire fan/shroud unit was thrown away and, given that we were sitting the driver practically on the floor to lower the centre of gravity, we used the ensuing head-room to do a false roof that doubled as a duct to ram air into the engine and cool the cylinders. The intake was simple. Lean back the windshield and you have the worlds biggest racing scoop.

Beetle juice

We moulded the body straight off a production beetle, as thin as it could go. First try produced a rather flexible translucent 17kg fibreglass body that grew to 22kg when fitted with all the necessary gubbins and then painted. The resulting beast weighed in at 417kg all-up, with some interesting design short cuts. And when I say design, I mean the local *churrascaria* (cooked meat) napkins on which it was sketched during lunch breaks.

As we were running ethanol (which also helped cool the engine) with a Stoichiometric air-to-fuel ratio of 9.1 compared to the gasoline opposition with 14.7 to one we had to carry 60 per cent more fuel than them; a headache when it came to locating the resulting 160-litre fuel tank. The solution was to make the passenger seat an aluminium tank to that size, satisfying the two-seater Group 4 regulations and centring the mass – with the slight inconvenience of subjecting the race driver to the barbecue treatment if anything went amiss. We were a bit blasé about the safety back in those days.

Jokeswagen

Having tested the car in secret at Interlagos we were staggered at the results, as it fulfilled all the predictions calculated. Hmmm, physics works …

Its appearance at the first test caused a lot of mirth in the opposing teams, until they saw the car run, and then the final grid positions then silenced them completely. The Beetle was second fastest, albeit two and a half seconds behind Carlos Pace in the Alfa, but not bad, considering it was the first run in anger and we were only on the 3.2-litre version, which produced a measly 320bhp, rather than the 4.4, which would have been more potent.

Worries about handling proved groundless, it sticking to the track like the proverbial waste matter to a blanket, aided and abetted by the very low CG and the massive tyres. It also proved that sprung to unsprung weight ratio can be ignored sometimes.

What could not be ignored was the fact that the torque produced by 3.3 litres was a wee bit above what the RSK gearbox could cope with, and promptly stripped first gear during practice. This problem was solved by the elegant overnight engineering solution of eliminating first gear, and running with the subsequent 4-speed box.

In the race the Beetle was out-dragged at the start due to a very long first gear (well, second really) but swiftly clawed its way back to second, improving its lap time to equal the Alfa. This romp was sadly foreshortened when the bolts on the nose of the crank was sheared off around mid-race distance. But quoting Usain Bolt 'If I get to be a legend, I've achieved my goal.'

The Twin Beetle did this in spades …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Aims and aspiration

Does Sauber's decision to use 2016 engines next year betray a lack of ambition?

When assessing the next-year potential of the fourth oldest team in F1 versus the youngest entrants, I was very surprised to learn that Sauber F1 will be retaining 2016 Ferrari power units in 2017, despite having picked up 'substantial backing' via new owners Longbow Finance SA. On top of announcing that the team will rely on paying drivers for next season, one has to question the validity of the business model to which Sauber/Longbow is working. There is nothing here to suggest that the team can expect to be a regular points-scorer come next season, unless several other teams get their 2017 racecar design sums badly wrong.

Clearly the driver modus operandi is dictated financially, which doesn't bode well for the real level of investment that Longbow is putting in, or support the stated objective to again make the team successful and competitive in F1. In sacrificing power unit performance for chassis improvement it seems to me that Sauber has just swapped one aspect of performance-limitation for another (this year they have competitive engines but a poor chassis) while probably running the same drivers. Toro Rosso has indisputably proved this season that the disadvantage of having year-old power units is too great to be regularly overcome, especially as the season progresses. Unfortunately it all adds up to one thing. Sauber for 2017 has mediocrity stamped all over it, and I can't even see it as a true rebuilding year.

Aiming low

What I struggle with is that the financial value of getting into the top 10 in the Constructors' Championship is worth many millions of dollars on top of points payments. So 'going for it' by recruiting at least one driver based on talent and obtaining the best motive power available could in due course result in payback far outweighing the short-term financial savings and present a much better long-term investment. One might expect a very wealthy financial institution, even if unfamiliar with motor racing at the sharp end, to understand this as being a worthwhile venture capital risk.

Contrast this with Manor, where there seems to be a clear aspiration under the ownership of enthusiastic but feet-on-the-ground and successful businessman Stephen Fitzpatrick. The drivers for 2017 are as yet unknown, but the team this year was successful in negotiating with Mercedes, not only for power unit supply but also a seat for their driver protege Pascal Wehrlein, and subsequently to similarly take on Esteban Ocon, both young hotshots. Having experienced management and engineering men Dave Ryan and Pat Fry on board as well has led to the team winning one precious point so far this year and increasing respect within and outside of F1. This all implies smart thinking. Without making exaggerated claims. This outfit is quietly getting on with establishing itself and moving forward at a planned pace.

XPB

Despite new investment Sauber has decided to use this season's Ferrari engine in its 2017 chassis. Will this mean another poor year for the team?

The progress of rookie F1 Team Haas Racing next year must depend to some extent on how well Ferrari has done its homework before and over the winter, assuming that Haas will continue to obtain much of its hardware from the Italian racing giant. Although it has to sort out its own aerodynamic concept, packaging and even suspension points will be largely dictated by this arrangement. Gene Haas has said that on reflection it would have been easier to buy out an existing team rather than starting from scratch; nonetheless he and Guenther Steiner have demonstrated a clever way of getting off the mark quickly at a respectable level. Two fifth place finishes to date plus additional points finishes are not to be sneezed at, even if they occurred in the early part of the season. It's good for F1 to have an identifiable American team; had Haas just acquired an European outfit, it would not have been seen in the same light. With Liberty moving into the F1 frame big-time and wanting to increase F1 exposure in the USA, this could play heavily into Haas F1 Team's future marketing and sponsorship plans. To move more consistently up the grid, however, it appears to need better track engineering and strategy-calling, and the obvious continual building of its engineering strength.

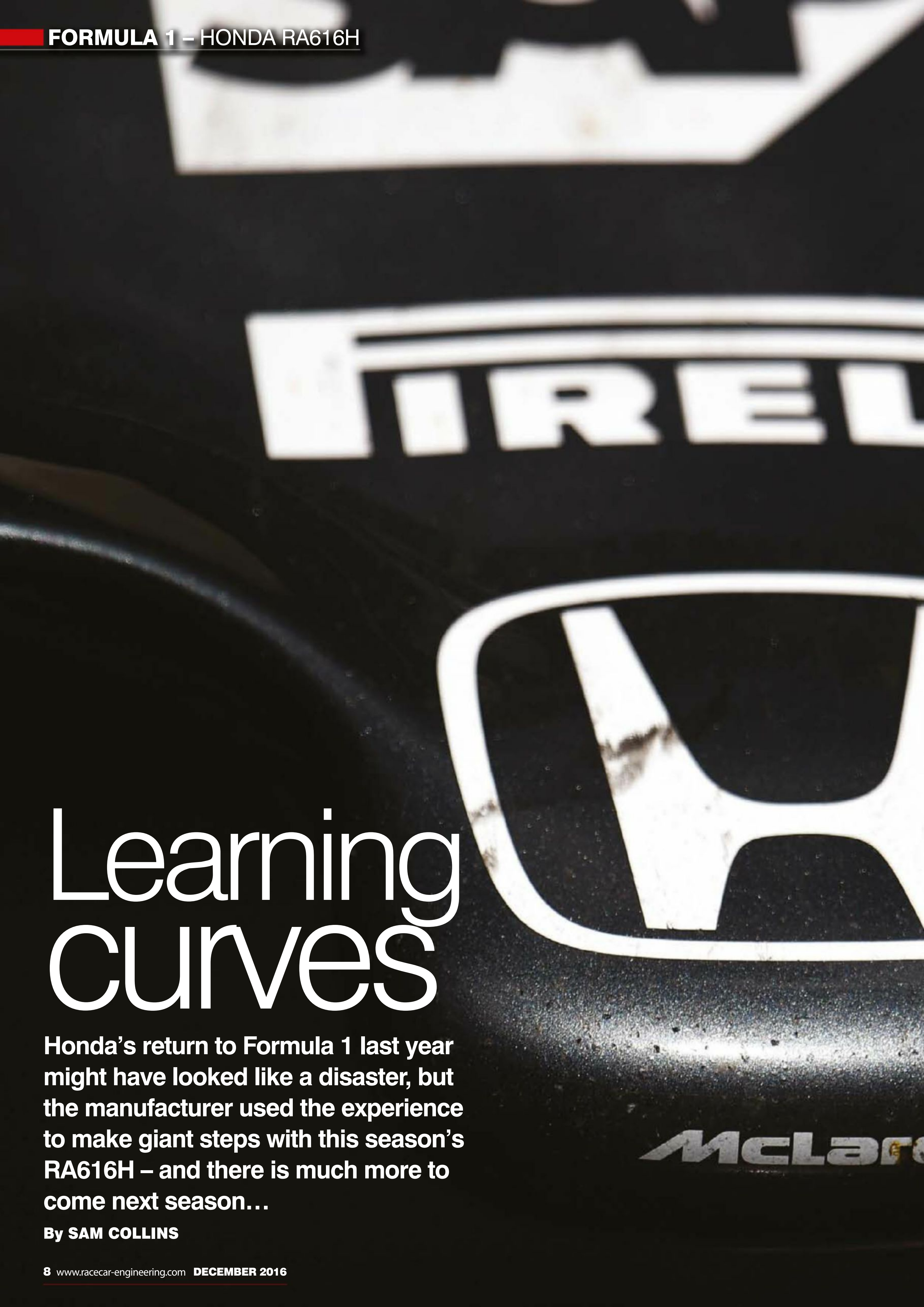
Renault woes

At the opposite end of the financial scale from Sauber, Renault F1 (classed as a young team now) is not looking all that good for 2017, apart from signing Nico Hulkenberg. This seems to be due to uncertainty about its direction. Given the 'bitsa' 2016 car dictated by late adaption of the chassis from Mercedes to a very different power unit and being committed to two inexperienced drivers, it might have paid Renault to continue to run the team as Lotus this year to avoid the ignominy of seeing two yellow and black cars at the tail end of the grid. Whatever, it is essential it bolsters its design and engineering resource, but as well as the time involved in high-end recruitment Renault has to convince potential candidates of the worth of joining at this stage. Right now it is not sending the right signals, due to the apparent friction between team principal Frederic Vasseur and Renault F1 managing director Cyril Abiteboul. Whatever the reasons, Renault top brass have to sort this out pronto, and make the right decisions. Abiteboul, apparently having a family connection to the Renault board, might not make this easy, but the task is hard enough without office politics. The foundations that the team lays down in 2017 are critical to its progress over the next few years, because this is what it will need to build on season by season, as Mercedes and Red Bull have proven in recent years.

No compromise

Despite the unknowns presented by the new 2017 technical regulations, one certainty is that it will still require a combination of excellent chassis and power unit performance, strong technical and team management, good strategies and highly-talented drivers to achieve consistent results. Any built-in compromises cannot be tolerated. Hence my disappointment with Sauber.

In sacrificing power unit performance for chassis improvement it seems to me that Sauber has just swapped one aspect of performance-limitation for another



Learning curves

Honda's return to Formula 1 last year might have looked like a disaster, but the manufacturer used the experience to make giant steps with this season's RA616H – and there is much more to come next season…

By SAM COLLINS

In reality it is a story of learning from failure, of engineering challenges, and of a major fight back

These were the words of one well known commentator over a drink during the 2015 Italian GP: 'I don't know why they just don't give up on F1. The programme is a mess and there is no way that thing will ever be competitive.' He was talking about Honda's return to Formula 1 and the unreliability of its power unit. Yet while Honda's latest spell in F1 has been presented by many as a tale of complete catastrophe, the reality is quite different.

In reality it is a story of learning from failure, of engineering challenges being met, and of a major fight back. In less than a season and a half, Honda went from struggling to get its engine to even fire-up in winter testing to regular points finishes and challenging for the podium during the most technologically advanced era Formula1 has ever seen.

That's not to say that Honda didn't struggle in 2015. It did. Indeed, it had its worst ever season in Formula 1. Winter testing was a debacle and, making things worse, once the season started Honda engineers discovered that when the power unit had been designed a crucial error had been made. The turbine was simply too small to do the job, and it was causing a lot of problems with many other systems on the power unit. This meant that the combustion engine lacked power and the MGU-H simply could not recover enough energy.

Energy issues

Yasuhisa Arai, Honda's F1 Large Project Leader (LPL) in 2015, said: 'It had a huge impact because with the discovery, we realised that in the races and testing we needed more energy to actually use the ERS deployment effectively. But in the meantime we knew that we could not change the turbocharger and the MGU-H in the actual season because it was a basic layout issue.

'The current regulations of the whole power unit package are very complicated, so one small component triggers a domino effect of other items leading to the issues that we have been seeing,' Arai added. 'Let me put this concept of the domino effect into a technical example. If you try to harvest energy using the MGU-H, it puts a strenuous workload on the turbo. When the turbo is under stress, it cannot do what it is supposed to do, which is to force more air into the engine, thus leading to decreased power output. This is the result of one component working against the others, instead of working together. These types of technical chain reactions which lead to vehicle stoppage were definitely more than we had calculated, or more than we had envisioned.'

One of the reasons that the turbine was undersized was that Honda had tried to make the power unit as small as possible in order to make the 'size zero' concept of the McLaren MP4-30 work. This meant designing a compact power unit, which sacrifices performance for size, and in turn allows more freedom at the rear of the car for aerodynamic work.

Once it was realised that Honda had simply gone too small, the staff at its motorsport R&D facility at Sakura City, Japan, also realised that there was little they could do about it. To change the turbine and related components it would have to spend upgrade tokens. The token system split the whole power unit into various smaller development areas and gave each one a value in tokens. The total amount of tokens when all of the power unit was taken into consideration was 66. Between the 2014 and 2015 seasons the FIA gave each PU manufacturer 32 tokens to use on performance upgrades. The idea was that all of these tokens had to be used before the season started, but a clerical error made by the FIA actually allowed the manufacturers to use these tokens during the season as well. Honda, however, which had not taken part in the 2014 season, would be disadvantaged by this in-season development as it had no tokens at all. So it was agreed that it could have the average amount of tokens spent by its three rivals ahead of the Australian GP. The result of this was that Honda was given just nine upgrade tokens to use during the whole 2015 season. Beyond those tokens, the only changes that could be made to a PU were on grounds of cost, safety or reliability. Honda therefore did not have enough tokens to make all the changes it needed to in order to fully develop its power unit in 2015.

Deep analysis

At the end of the 2015 season Honda had used up 12 complete or partial power units on each of the McLarens; the maximum allowed by the rules was just four. Honda and Renault, who had also struggled with reliability, had been granted a fifth power unit per car.

So, looking at the bare statistics, it did indeed seem like the 2015 F1 season had been a disaster for Honda. But behind the scenes a deep analysis was underway, and lessons were being learnt.

Other manufacturers were keeping an eye on Honda, too. Andy Cowell, the managing director of Mercedes-Benz AMG HPP, said: 'The GPS data told us that Honda was 50 to 60bhp down on us. I'm

'The rate of development of the Honda in 2015 was really, really good'

not saying at what point in the season that was, but they then did enough for us not to discount them. The rate of development of the Honda in 2015 was really, really good. While it may not have seemed that way from outside our data showed the improvements, clearly. Give them time,' he warned, early in 2016.

From midway through the 2015 season Honda was focussed on developing its 2016 PU, and set itself clear goals. 'We kept the philosophy and concept of the size zero packaging but we improved on it and made a more sophisticated size zero,' Arai said. 'We cannot make the power unit any smaller, it's very difficult because we're almost at zero! But we use that particular design, a very specific and aggressive design, and we should keep that.'

The new for 2016 version of the Honda power unit was called the RA616H. It had the same basic overall layout as the RA615H, but almost every single detail had been improved in some way. This is immediately apparent when looking at the two power units side by side. The RA616H is much neater in terms of design and manufacture.

The turbine housing on the RA615H featured an integral wastegate, aimed at reducing PU size. This year a new rule was introduced in an attempt to make F1 engines louder, which forced Honda to change this layout on the RA616H (pictured)

On the RA616H the turbine is mounted at the rear of the block, while the compressor is situated in the V of the engine about halfway along the ICE, right above the central pair of cylinders and underneath the plenum

Split the difference

The RA616H is, in common with all current F1 power units, a turbocharged 1.6-litre V6 with direct injection. It features a variable inlet system and a cylinder bank angle of 90 degrees. In terms of the energy recovery system it has a motor generator unit linked directly to the turbocharger (MGU-H) and another linked to the flywheel (MGU-K). While visually quite different to the RA615H, in reality the 'new' power unit is really a heavily modified version of that used in 2015, and not a completely new design.

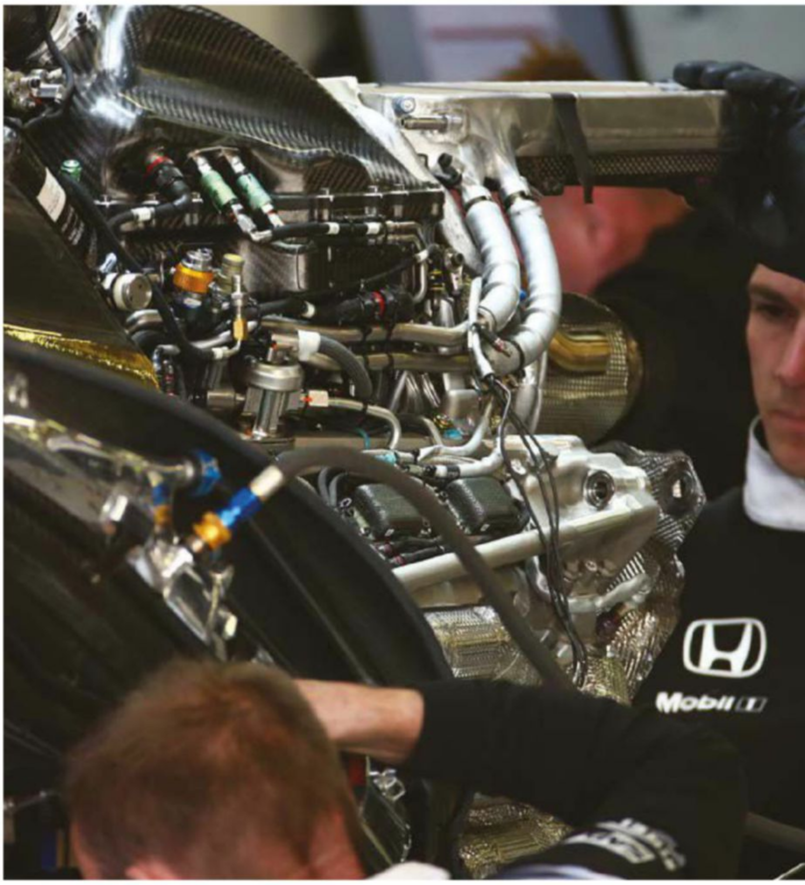
But the actual layout of the components on the RA616H differs to other F1 power units in a number of areas, most notable of which is its particular use of a split turbo. Mercedes was the first to do this in Formula 1, mounting the compressor at the front of the engine block and the turbine at the rear, the MGU-H was mounted in the centre of the V of the engine and linked to the two halves of the turbo by a common shaft. This layout gives a packaging advantage and also allows the compressor to be positioned far away from the hot exhausts and turbine. On the RA616H Honda uses a variation of this theme. The turbine is mounted at the rear of the block, while the compressor is mounted, rather surprisingly, in the V of the engine about halfway along the block – above the central pair of cylinders and under the plenum.

The MGU-H sits between the two halves of the turbo, but there's no extended shaft like there is on the Mercedes layout. It is quite hard to see how this layout offers benefits in terms of keeping the compressor cool (as the Mercedes does by having it right at the front of the block). As with other Formula 1 power units the MGH-K is mounted on the side of the engine block, below the exhaust manifold.

Leadership change

Arai headed up the F1 PU project from its inception and right through the 2015 season – including the development of the RA616H. But his advancing years led to him handing over the role of LPL to a younger man during pre-season testing. The new LPL, Yusuke Hasegawa, had been involved in Honda's F1 programme in the late 1990s and into the early 2000s. 'It is true that I couldn't add something new when I started, as much of the work for 2016 had already been decided, but I had to make some judgements about how to go forwards,' Hasegawa explained when asked about the evolution of the RA615H into the RA616H. 'It is clear to say that we started the season with a new much larger turbine and a different MGU-H. Actually the MGU system was the biggest area for us, we changed

Left side of power unit from rear. The 2016 PU is in reality an update of the RA615H but Honda tells us almost every single aspect of it has been improved in some way



A view from the left side. The key to the success of the update is the new larger turbine which allows the MGU-H to function more effectively and also raises the deliverable power of the unit significantly

it a lot for this season. There has also been development on combustion and on the ICE in general and we have improved reliability a lot.

'The aim was to make the car faster. Simple as that. Of course, to do that we must improve three areas: first there is reliability, the second is ICE power, and the third is turbine. That development started some time in 2015.'

As mentioned above, while visually quite different to the RA615H, the RA616H is in reality the same power unit, though heavily modified. The key to the update is the new larger turbine which allows the MGU-H to function more effectively and raises the deliverable power of the unit significantly. In making these changes Honda used up 18 of the 32 tokens it was granted (the same as the other three manufacturers) and had plans to spend all of the remainder during the season.

From the outset, Hasegawa seemed to be somewhat less willing to compromise the power unit this year, as Honda had last year. 'Packaging is always important in Formula 1, especially for aerodynamic performance. But from last year's performance we have to think about the engine performance and the reliability.

'We do not want to sacrifice engine performance for the chassis layout, so there is a lot of discussion with McLaren at the moment,' Hasegawa said during winter testing.

'We asked McLaren to modify the inlet area, for example, and accommodate the bigger turbine,' Hasegawa reveals, adding: 'So far the packaging is okay, but we have to consider the overall car, we don't want to put on a one-metre long intake pipe even if it gives great engine performance, we must be sensible, because packaging is very important.'

Going large

While Honda has not disclosed all of the changes it's made to the RA615H to convert it into the RA616H, some are clearly apparent, among them that new turbine. It was obviously much bigger than the one used in 2015, though it remains a twin scroll design.

'I think the original turbine was developed with size constraints as the first priority, and performance was the second priority; that has changed now,' Hasegawa says.

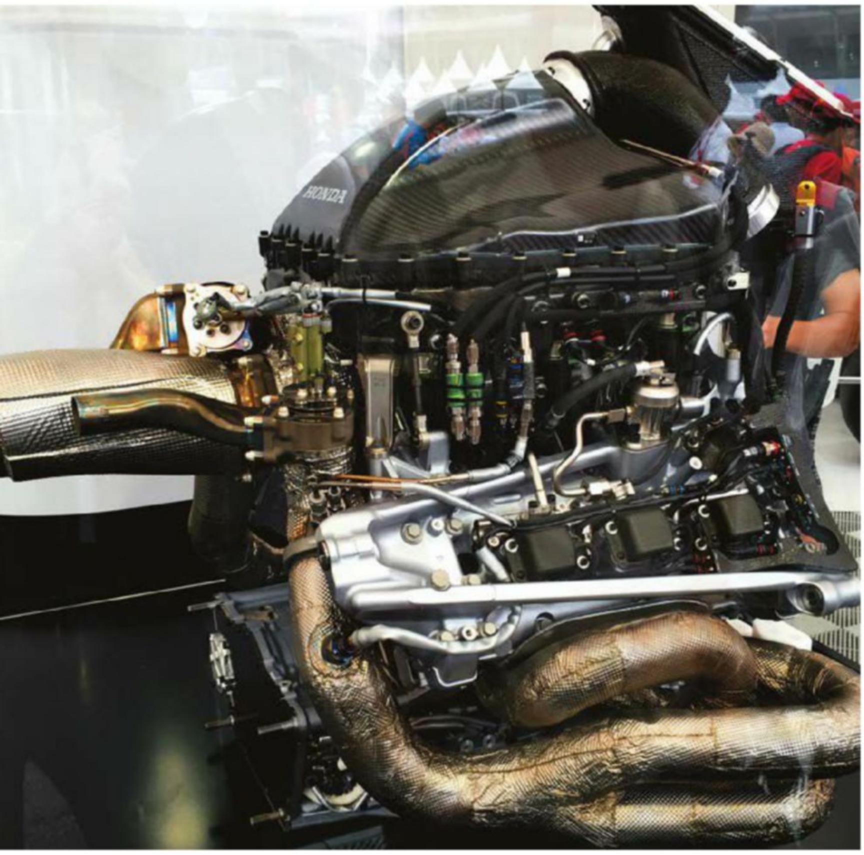
'This year we increased the size of the turbine,' he adds. 'We have also introduced a brand new compressor. It too, is bigger, so everything on the turbo is bigger. But in that whole system we didn't make a big change to the MGU-H. The twin exit on turbine cost a token, and we made a pure performance gain from using a token in that area.'

On the RA615H the turbine housing featured an integral wastegate, a clever bit of design aimed at reducing size overall. But in 2016 a new rule was introduced which forced Honda to change this layout. In an attempt to make Formula 1 cars louder every power unit would have to be fitted with a separate wastegate exit pipe (see RCE V26 N4), something which would have been impossible with the original Honda concept. There are two wastegates on the RA616H's turbine, each with their own tail pipe, but the layout is not symmetrical, The left wastegate sits higher on the turbine casing at an 11 o'clock position with its mechanism sitting over the main tailpipe. The right hand unit is at a three o'clock position with the mechanism positioned vertically.

Noise has actually been a big topic in F1 since the current power units were introduced in 2014, with many in the mass media complaining about how quiet the cars are. The Honda has a distinct engine note which makes it easy to identify, the harsh stuttering and low thumping noises are sometimes accompanied by a sound which some liken to a World War 2 era pulse jet. It is especially noticeable in flowing corners such as Sector 1 at Suzuka. 'On some areas of the lap we use a cylinder cut system, and it is a bit different to the other cars, and you can hear that clearly,' Arai explained before his departure. 'It's a different thing. It is case by case

'We cannot make the power unit any smaller, it's very difficult because we're almost at zero!'

LAURENCE EDMONDSON



This season updates were introduced to the RA616H's turbine in Canada and to the variable inlet system at Silverstone. Honda's pre-season target of reaching Q3 qualifying has also been achieved

Right side intercooler. The power unit is tiny, continuing the philosophy of its predecessor, which was designed to fit inside the shrink-wrapped McLaren

for each track, how much and where we use it. The initial on-throttle period is very important to make horsepower, it is very important and very effective, using things like a shutter valve.'

From the first few laps with the RA616H fitted in to the new McLaren MP4-31 at Barcelona in pre-season testing the new power unit seemed a vast improvement over the old one, and the drivers enthused about it. Hasegawa set the target for the McLaren-Honda package of being a regular participant in the third segment of qualifying, the top 10 shoot-out. This was a goal achieved by mid-season.

'Perhaps it is because we are behind and started late that we can develop so fast, we have a very clear target and we must achieve it,' Hasegawa says. 'We look at the data and the pictures of the other power units and while we don't copy, we keep a close eye on them. I think we have done a very good job improving. I don't think we have done any magic though. But it's clear that starting from behind has some benefits. We are trying our best but we are not satisfied yet. We have a strong motivation to spend tokens to improve performance, if we have an update that brings better performance I won't hesitate to use it. Even if it means penalties.' That last point became evident at this year's Malaysian Grand Prix.

'We are now developing some quite advanced projects, things like pre-chamber ignition'

ICE pick

The MGU issues of 2015 are now just a memory and the energy recovery system on the RA616H is thought to be as good as the Mercedes system. So attention has now turned to the combustion engine. Updates were introduced to the turbine in Canada, and variable inlet system at Silverstone, with these costing two tokens each. 'Its very challenging to do, but this variable inlet and the whole plenum area is smaller, simpler, lighter and better than 2015. We spent two tokens to modify this ahead of Silverstone to improve it further. We changed the turbine in Canada; it was modification but I cannot reveal the details,' Hasegawa says.

This focus on the induction system of the V6 is the start of a series of substantial upgrades and new concepts introduced to the combustion engine which Honda hopes will, in time, allow it to not only catch up with Ferrari and Mercedes, but to eventually overtake them. But it is a process which will run into 2017. 'We are developing some advanced projects, things like pre-chamber ignition and even partial compression ignition. We have done that three or four years ago, but I think now it is the first attempt to introduce it on a racing engine. I don't know when that project will be ready but as soon as its ready I will introduce it, I promise,' Hasegawa reveals. 'The combustion process at the moment is everything, so we are working on not just one element of it. We are asking Mobil 1 a lot about creating new fuels with anti-knock properties, but there is a lot more to come in all areas. In some of the individual experimental tests we see some of the benefits, but we can't prove it as a complete engine.'

However, Honda cannot introduce all of the upgrades it has in development. As was the case in 2015, it simply does not have enough tokens to complete the work. 'We don't have enough time to change everything, we don't have enough tokens, so we will just introduce some of the new parts when we can,' Hasegawa says.

This will not be a problem for Honda moving in to 2017, as a rule change was announced part way through the 2016 season which will see the token system abandoned for next year. That means that there will be a clean sheet approach for the next season. 'The 2017 power unit will be completely different to 2016, we are researching every area, not just combustion, but we are still unable to confirm the complete specification and there is hard work going on in all areas. The regulations don't give much room to change. But it will be another very small unit, that is the right thing in Formula 1, a size zero concept,' Hasegawa says.

Likely to be called the RA617H, the new power unit is expected to see Honda take a major step forwards in performance and possibly finally achieve its aim – to return to the front of the pack in Formula 1.

Gripping yarns

Formula 1 embraces a new formula which allows for more downforce and mechanical grip next year – but how can Pirelli test its 2017 F1 rubber when the new cars don't yet exist? *Racecar* investigates

By SAM COLLINS

The problem is, Pirelli does not really know what the requirements for the 2017 tyre really are

In the closing stages of the 2016 Formula 1 World Championship a number of stories dominated the group press conferences held at the end of each day of a grand prix weekend. Among them were Lewis Hamilton's use of social media, and the future ownership of the sport. But one issue overshadowed all of them, every conference was dominated by a single question: 'Where will the 2017 pre-season tests be held?' The press pack, of course, are especially interested in this issue; as they want to book the best rooms, in the best hotels, for the best price. But the real story was the reason for this uncertainty – the development of new tyres for the 2017 season.

Back in 2014 it was announced that F1 would get a new set of chassis regulations in 2017 which would result in cars which looked more aggressive and had a much higher level of downforce. A key component of this was the re-introduction of much larger wheels and tyres, and this meant that the sole tyre supplier in F1, Pirelli, would have to develop a totally new product for 2017. The problem was, and indeed is, that Pirelli does not really know what the requirements for the 2017 tyre really are.

'It was a mix of aesthetics and performance, really, when they came up with this plan for the bigger tyres,' Mario Isola, Pirelli's racing manager explains. 'When the new regulations were proposed there were two main targets. The first was indeed aesthetic, make the car look more aggressive, but the second was to make the cars more difficult to drive, so bigger tyres and higher apex speeds. Physically the car will be harder on the drivers, too.'

Stretching rubber

The final agreement was for the front tyre, which is currently 245mm wide, to increase to 305mm. The rear tyre was set to grow from 325mm to 405mm. So the new sizes for slick tyres will be 305/670-13 at the front and 405/670-13 at the rear (the total diameter will go from the current 660mm to 670mm). Wheel rim diameter remains unchanged at 13 inches. The new tyres are more than 60mm wider at the front and more than 80mm wider at the back. Consequently, the 2017 tyre increases in width by 25 per cent compared to the current size. Indeed, the 2017 front tyre is actually quite similar in size to the rear tyre of 2016.

'It is hard to compare the new tyres to 2016 as we are still experimenting a lot,' Isola says. 'We have found some interesting constructions and interesting new concepts. It's all quite different to the current spec. It's different materials, different geometries, different profiles and different manufacturing processes, we are experimenting with them all. There is so much you could try but time constraints limit you. If you look at any different element of a tyre you probably have a choice of 15 or more different materials, it ends up with millions of different combinations.'

Low profile decision

For some time before it was agreed to move to wider rubber F1 had very seriously considered a move to low profile tyres and larger rims, something Michelin initially pushed hard for – at the time it was seriously considering returning to grand prix racing. Pirelli went as far as constructing a few sets of the low profile tyres and testing them on track with the Lotus team at Silverstone, but the low profile plans came to nothing. 'A choice was made by the teams to stay on a 13in tyre,' Isola reveals. 'We tested the 18in tyre, and got very close to supplying that to GP2. But the choice was made to make the tyres wider and not change the rim size.'

But the new Formula 1 tyres would clearly need track testing. With no 2017 cars available (as they do not exist yet) Ferrari, Mercedes and Red Bull constructed test mules based on older chassis and the FIA allowed Pirelli and those teams 25 days of private single car testing. Once that testing started, however, it quickly became clear that while the test mules had some value

Pirelli has been the sole F1 tyre supplier since 2011, but developing the rubber for the new high-downforce formula, which comes in to F1 next season, could be its biggest challenge yet. It launched its 2017 tyres at Monaco earlier this year (above)

Some teams, including Ferrari, have supplied mule cars to aid Pirelli with its 2017 tyre development, but the tyre firm says that while these have been of some use they have not had the level of performance it's expecting from next year's racecars

There had been talk of a switch to 18in rims and low profile rubber for 2017, driven in part by Michelin which had been considering entering F1 once again. This has now been shelved, although Pirelli did produce some tyres to this spec (above)

they were not really good enough to replicate the expected loads of 2017.

'The mule cars are better than nothing and we are happy to have 25 days with them, but they are not really that representative,' Isola says. 'In 2017 the new cars will behave differently and we need feedback from the proper 2017 car. The mules cannot deliver that. It's the first time I can remember Formula 1 introducing regulations to increase performance rather than restrict it. This is why we struggle with the mule cars, if we were restricting performance you can just take a recent car, limit the performance and you get good data. But if you increase the performance it is not easy for the teams to make a big step up like that. Our simulation shows that the cars will have similar top speeds to 2016, but significantly higher apex speed with a lap time three to four seconds better than now, it's just not something the mules can replicate.'

Data supply

To aid Pirelli's development the teams have been supplying its engineers with a range of data based on wind tunnel results and simulation (though there has been some suggestion that not all teams are giving accurate data). 'We had a similar situation on a smaller scale in 2014 when the new power units came in as we only had some numbers from the manufacturers about the increased torque, but we had no power unit available,' Isola says. 'So we had to design a tyre with that in mind, according to the data we had to design a tyre with much higher stress on the rear compared to 2013, but when we got to the track we discovered that the performance was not what was predicted.

'Now it's the same, but on a bigger scale. The cars have about 30 per cent more downforce compared to 2016, but then you have to consider drag, which is increased. The rate of development is likely to be incredible, we expect to see very big changes in performance, so the teams are supplying simulation of performance at the end of 2017. But for the teams it's hard to estimate this. Every two months they give us new data and we update our models accordingly, and that creates new data. It's a loop, the more times around that loop the closer we are to reality. But that is all for the start of 2017. What happens at the end of the year is very difficult to predict. It's a big challenge.'

The teams have something of a challenge on their hands, too, as Pirelli is still developing the 2017 tyres to suit the teams' estimates of 2017 car performance, while the teams are still developing their 2017 cars around the data they get from Pirelli, which really means it is something of a voyage into at least the uncertain, if not the unknown. 'We provide a

'We have found some interesting constructions and some interesting new concepts. It's all quite different to the current specification'

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The visual impact of the new rubber is particularly evident from the rear. Some have questioned whether high-downforce and more mechanical grip, both a feature of the new Formula1 regulations, will actually provide better racing in 2017

The new Mercedes eight-wheeler has been turning heads … Okay, not quite. But this image does give a very good indication of the difference between the 2016 spec tyres (on the outside) and the new-for-2017 tyres, that are affixed to the racecar

Next year the tyres are more than 60mm wider at the front and more than 80mm wider at the rear. The 2017 tyre increases in width by 25 per cent compared to the current F1 tyre, and the 2017 front tyre is close in size to a 2016 spec rear tyre

tyre model for all the teams to use on the DIL simulators and in other simulation packages, and that gives a good indication in terms of the tyre construction, but in terms of compounds it is still not enough. We are working on some more predictive models, but they are not completed yet,' Isola says.

Tyre shape and distortion is crucial in the aerodynamic development of modern open wheel cars and Pirelli, as part of its contract as sole tyre supplier, must provide the teams with tyres to use in the wind tunnel at either 50 per cent or 60 per cent scale (depending on what size the wind tunnel model is). But at the time of writing the teams are apparently still using the first iteration of wind tunnel model tyre.

Tunnel tyres

'The size was really known in late 2015,' Isola says. 'We had a fairly clear idea then, but as soon as the size was confirmed, the next day all the teams were asking when we would deliver the wind tunnel tyres. We had to tell them to wait, we had to develop them. It's not just a case of making a 60 per cent scale version of the tyre, it also has to behave dynamically in the same way the full scale tyre does. It's not easy at all. We supplied the first version of the tunnel tyres in March and April, but as development progresses on the full scale tyre we have to create a new wind tunnel tyre to replicate that more accurately. It's an ongoing activity and there will be more versions coming.'

But teams were already starting to conduct wind tunnel tests of the aerodynamically very different 2017 cars well before Pirelli were ready to supply the model rubber to them. 'We got the wind tunnel tyres quite late, so we ran our first model with rear tyres on all four corners to get some idea of what was going on because we didn't have the tyres available at that time,' Pat Symonds, chief technical officer at Williams says.

The teams also need more detailed tyre data to finalise other parts of the car, including some long lead time items such as the monocoque and transmission casing. 'We and all teams regularly update the FIA and Pirelli with their latest simulations and it's an ongoing process,' Symonds says. 'So as we refine our estimates of loads, as we refine the vehicle dynamics and the aerodynamics, we regularly have to feed information in a given template to the FIA who then check it for the coherence of the data, and then pass it on to Pirelli.'

Pirelli has made it clear in various public statements that in order to give the teams reliable data it really needs to test the 2017 tyres on track with proper 2017 cars, as simulation data alone is probably not adequate. 'We want to test the integrity, the carcass, the

'As soon as the size was confirmed, the teams were asking when we would deliver wind tunnel tyres. We had to tell them to wait.'

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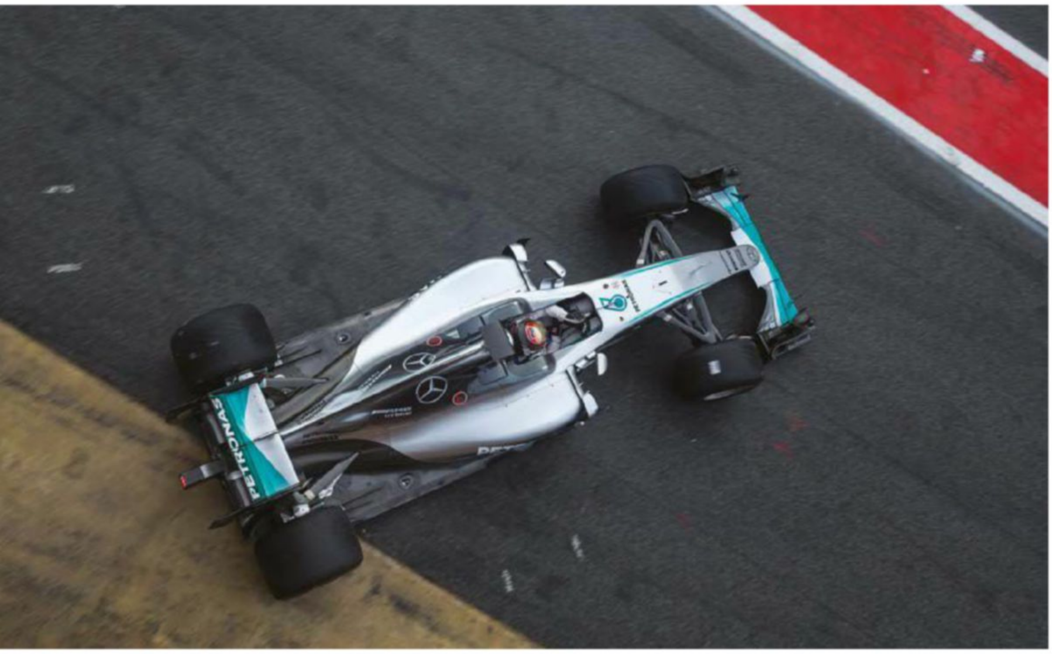
construction,' Isola says. 'We can do some indoor testing, and simulation. The teams have given us the expected performance levels at the beginning of 2017 and at the end of '17. So when it came to working out the required integrity of the tyre we looked at the data for the end of 2017 and added a margin. We have tested that on the rig, but in terms of compounds it's very hard to work out on the rig; you can get some idea but you really need to run on track and get the real data. The suspension of the cars will be totally different and the loads through them and the chassis will be totally different to now, too, as a result.'

With a larger contact patch and much higher downforce levels from the 2017 aero changes, the loads through the suspension are likely to increase, but by how much nobody is really sure. The data generated by both the teams and Pirelli relies on simulation software and wind tunnel data, but there is little real world data which gives a clear indication of the thermal behaviour of the tyres on track. 'Temperature models are the most difficult to make, this is the hardest part of the development and that's why we need to test on track,' Isola says. 'With the increase in performance you have more energy going into the tyres, so that may increase temperature, but a bigger contact patch could balance that out. If you fitted a 2017 tyre to a 2016 car we could probably go two steps softer in compound as the current cars are not able to generate enough energy to warm up the tyre to the right level. But with the new cars the two could be balanced and the tyre temperatures should be similar to now. The teams will have to design suspension and mounting points but they have to put in a factor of safety. Nobody really knows what the loads will be, it's just simulation and we all need real data.'

Pirelli has only been able to take so much from the mule car tests and is also relying heavily on data based on wind tunnel results and simulation that the teams have been supplying. Meanwhile, the teams are calling for more tyre data from Pirelli



Mercedes has said it's in favour of a test in Bahrain in the Middle East before the start of the 2017 Formula 1 season but many other F1 teams, mindful of the cost of testing outside of Europe, have said they would prefer to test at Barcelona

'It's the first time I can remember that Formula 1 has introduced new regulations to increase performance rather than restrict it'

Set-up data

Even the car set-up is pretty difficult as accurate tyre performance data and degradation data is simply not known. For example, it is expected that teams will run with less camber, indeed the regulations will force them to run a little less, but exactly what level will be run is simply a vague guess at present.

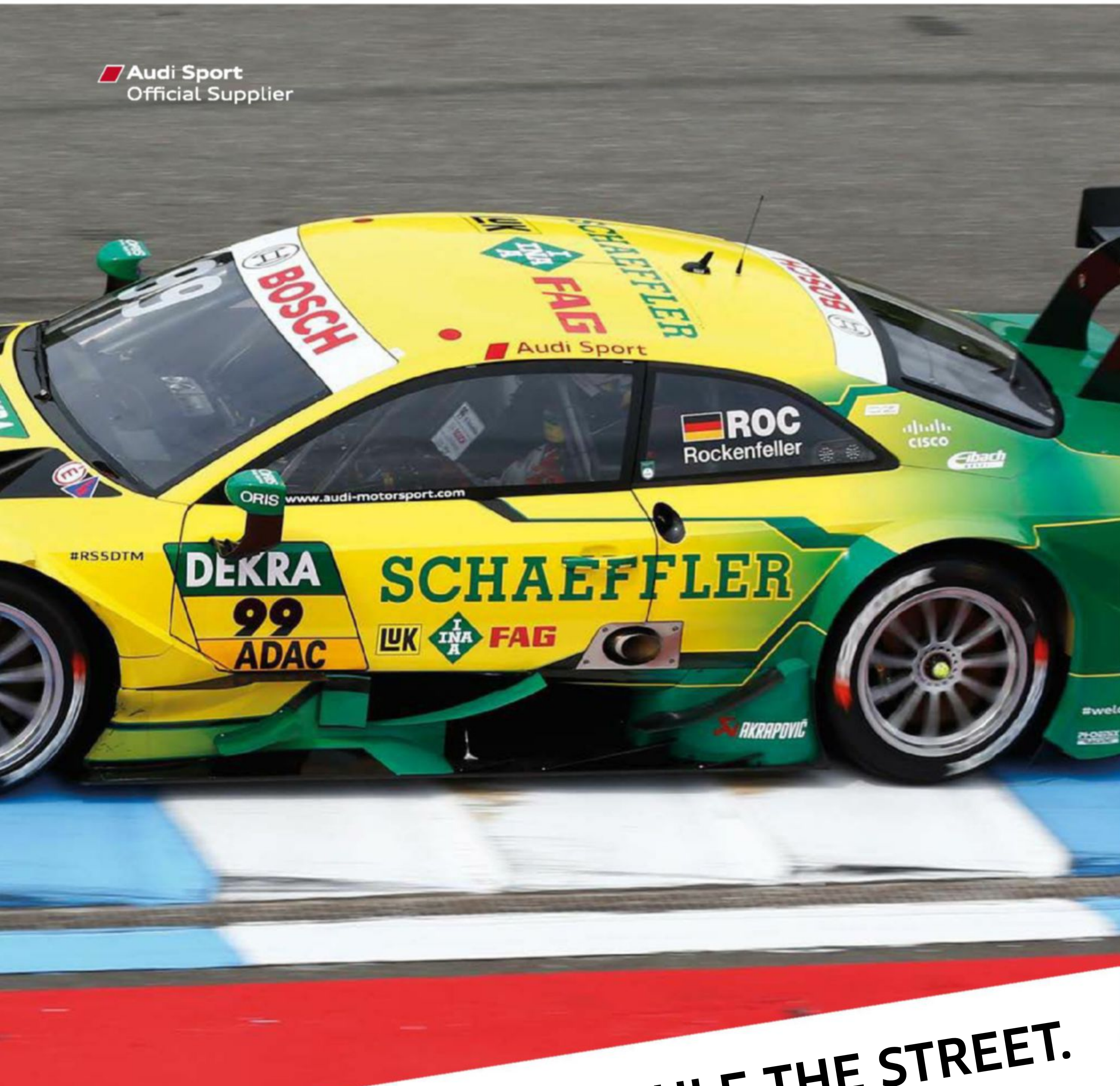
It is for this reason that Pirelli has been fighting for pre-season testing to be shifted to Bahrain, where it feels the track is more representative of the range of venues visited by Formula 1 than the Barcelona circuit is. 'Next year it's all new; the cars are new, the performance is just from simulation, the tyres are new and a different size, so we need to prepare a plan and have a contingency. The test in Bahrain would give us time to react,' Isola says.

Testing controversy

However, with all of the cars built in the EU, and teams pushing car builds to the last possible moment, a test outside of Europe has met with very strong resistance from many teams, not only for reasons of expense, but also for reasons of logistics. Many have become used to flying in parts from their factories in the UK to circuits in Spain (Barcelona or Jerez typically), something which would be impossible to do at a track outside of the EU, due to customs delays.

'It's no secret we prefer to test in Bahrain as it is more representative conditions,' Isola says. 'Testing in Barcelona is not really representative. It is not the best place to assess the compounds. In Bahrain we can get a good understanding of the Medium, Soft and Super Soft tyres and some indication of the Ultra-Soft, so that's four tyres and it's a pretty good amount, though it's not an ideal place to test the Hard compound. Abu Dhabi would also be possible, but it's marginal for the Medium and the Hard is out of the question. Another option might be Malaysia, on the way to Melbourne, but by then it would probably be too late,' Isola adds.

Pirelli's argument is understood by some of the teams. 'We have the biggest change



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in tyre regulations probably for one or two decades and Pirelli have asked to test in Bahrain,' Paddy Lowe, executive technical director of Mercedes F1 says. 'As I understand it, a majority of teams support that request. For me, the important point is that Pirelli were asking for some hot condition testing of the compounds particularly. The structure of the tyre is created and tested in the lab but the compounds can only be evaluated in real circuit conditions and unfortunately the mule car programme which is running at the moment has delivered three cars, which are very helpful to the process, but they are not delivering the level of aerodynamic load that will be seen next year.

'So, for me, it's a matter of supporting Pirelli's request to contain the risk of arriving at the first race as being the first event with hot conditions, and then there's real risk to the show. We've seen what can happen, for example, at Indianapolis in 2005. We mustn't forget that we need to put on a show. We need to run a 300km race with sensible numbers of tyres, so that's not an inconsiderable risk and should be covered. So that's why we particularly support that request.'

Cost issues

However, not everyone sees things the same way. Other teams, typically those not backed by a manufacturer directly or indirectly (though Renault has actually stated it wants to test in Barcelona) want to test in Europe. 'The cost of doing a test outside of Europe is vast,' Symonds says. 'Depending on exactly how you do it and how much you have to ship back to the UK, how much you can ship on to the first race – we're talking of a minimum of £300,000, probably a maximum of £500,000, so a likely figure sitting in the middle of that. Now, to a team like Mercedes, I'm sure that they can put contingencies in their budgets to cover things like that. A team like Williams simply can't, it's a significant amount, it is unaccounted for and therefore I think it is the wrong thing to do.

'The Indianapolis situation,' Symonds adds. 'I don't think that that's an acceptable reason to go testing in the Middle East or elsewhere. I think it's very, very clear in the requirements that Pirelli have signed up to that we're not running cars to test the safety of tyres. That has to be done off the car, that has to be done before they ever see a track. So, yes, there will be difficulties but, you know, we're in the same boat. We are having the tyres selected for us for the first few races which I think is a good thing. If we have to do it, it's going to make a very, very serious dent in our budget. If we do it, I think we need to consider where we do it because we do act like sheep quite often in Formula 1 and there's this thing of "oh well, we've tested in Bahrain before, let's go to Bahrain". Personally, I don't think Bahrain's a very good circuit to go testing. We have tested there in the winter, some people remember some years ago that there was a test there which was effectively sand-stormed off rather than rained off.'

Bahrain demands

As *Racecar* closed for press Pirelli was refusing to budge on relocating the test stating that: 'if we don't get that test in Bahrain then it will be really difficult for us to get an understanding about the compounds, their degradation and thermal operating range, that could lead to us making a poor choice for the opening races, and once that choice has been made, there will be no possibility in terms of production and logistics to make a change.'

In reality, it does seem that this is all an issue that perhaps could have been foreseen. Added to this, the 2017 regulations have been on the table for a very long time now and two major concerns about them have yet to be fully understood, yet alone addressed. The whole idea of the 2017 regulations was to improve the show for fans both at the track and watching on television and online, but the increased grip and downforce levels could actually prove to be counter productive. Also, many in the paddock have suggested that with higher apex speeds and shorter baking distances it may actually become harder for cars to overtake. Indeed, with Pirelli's uncertainty over the tyre performance and car performance it has already admitted that it will probably be quite conservative in terms of tyre degradation with most races now being a one stop strategy.

More concerning, perhaps, is the impact of higher apex speeds on the race circuits themselves. A number of tracks, including Monaco, Monza and Suzuka, could become rather marginal in terms of safety and barrier position as a result of the much faster cars, and it is this which some F1 engineers believe will see the tyres, the cars, or both, pegged back to limit the apex speeds once more, as soon as the risk is fully understood.

'Nobody really knows what the loads will be, it's just simulation and we all need real data'

Wet weather tyres

Pirelli not only has to develop a new range of slick tyres for Formula 1 in 2017, it also has to create two different types of wet weather tyres, and with a much larger contact patch they will be quite different to those used in 2016.

As Mario Isola explains: 'We have an idea from simulation how much water they can shift and when you can use them, but until they are run on track in wet conditions we do not really know for sure. It will displace more water, we know that, we are designing some solutions now and simulating them. When we have some strong potential designs we will hand cut some slicks. Maybe if we go to Silverstone for a test and just wait a couple of days it will be wet for sure. But it's important that we get to test these designs as we need to know the crossover point between wet and intermediate tyre. You cannot work off 2016 data at all.'

While some wet testing has been conducted with the mule cars issues around loads and cornering forces remain. If Pirelli does not get to test the wet tyres properly before the start of the season then the FIA and the teams will simply have no idea when conditions become unsafe for racing, or indeed when they are safe. Additionally, they will have to rely on driver feedback alone in order to make the switch from wets to intermediate tyres. In some ways, however, this does seem like the basis of a rather compelling and unpredictable race, and the first race is scheduled to be held in Melbourne, where wet conditions are not unknown.

With a much larger contact patch than the current tyres Pirelli knows its new wets will displace more water, but it needs to properly test its two rain tyres in order to pin down the crossover point between the full wet and the intermediate rubber

FLexing muscle

Toyota has unveiled its new Super GT challenger in the shape of the Lexus LC500, a car built to the new regulations using lessons learnt from its RCF predecessor. Here's the story of its development

By SAM COLLINS

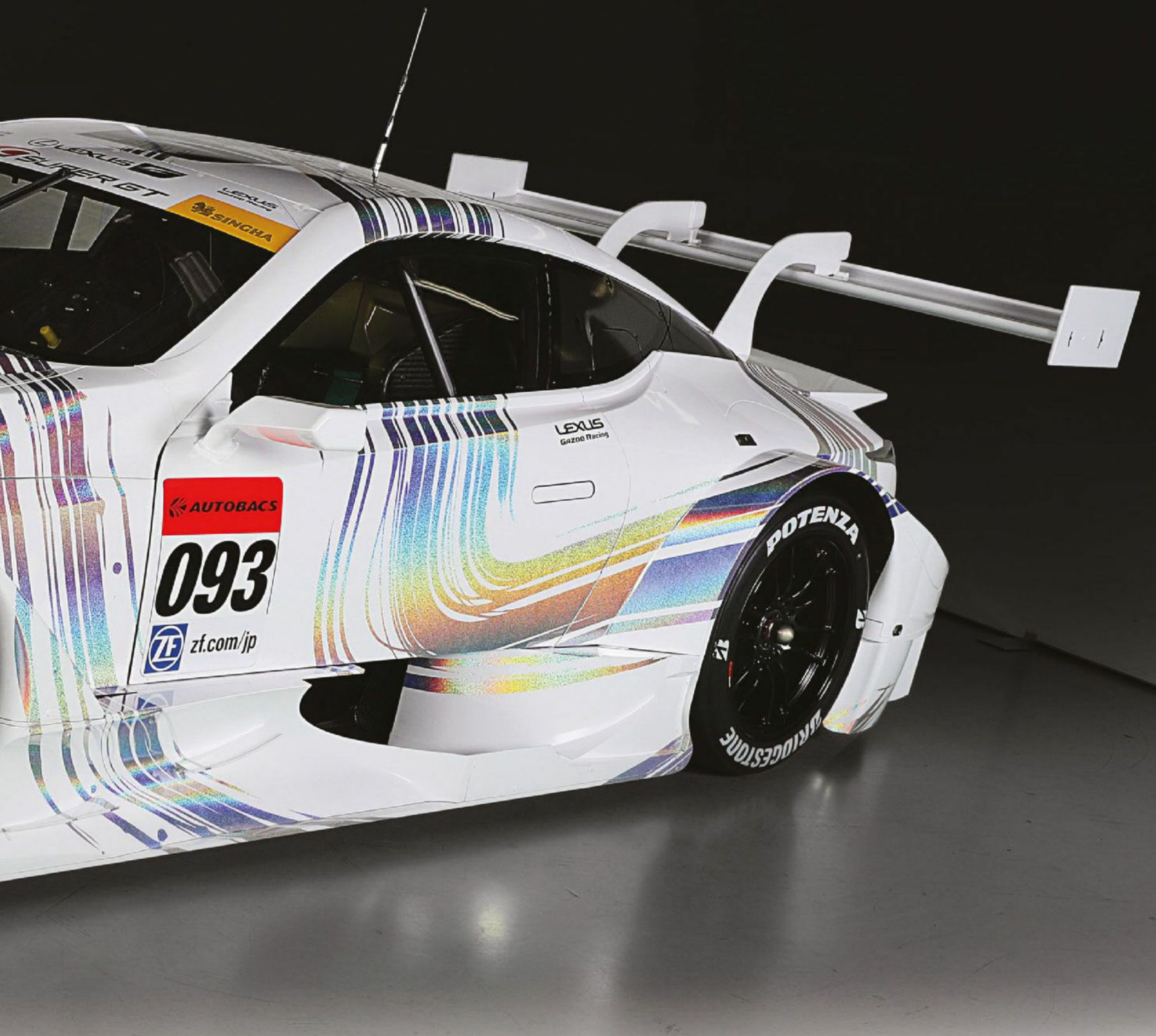
The 2014 Fuji 6 Hour race was something of a turning point for the Super GT championship. Earlier in the year it had become clear that the new breed of GT500 car was much faster than the old, but when the World Endurance Championship arrived for its Japanese round the speed increase was put into context. The fastest GT500 car in qualifying would have found itself seventh on the grid had it been taking part in qualifying in the WEC, within a second of the Audi R18s and more than two seconds ahead of the two Rebellions. GT500 was quite clearly a match for LMP1.

While this is very impressive, it raised serious concerns for Super GT organiser GTA. LMP1 cars are only permitted to race on FIA Category 1 circuits (with the exception of Le Mans) due to their high performance, yet Super GT races not only on Category 1 tracks such as Fuji Speedway but also on domestic circuits such as Sportsland Sugo, with a lower level of safety homologation.

As a result of these very high speeds the aerodynamic specification of the GT500 cars was frozen at the end of the 2014 season. However despite this, speeds continued to rise and the GT500 cars had reached qualifying speeds which would have placed the fastest of them fifth on the 2014 LMP1 grid at Fuji, within a tenth of a second of the fourth placed Toyota and ahead of both of the Audis. It was clear that more drastic action would have to be taken.

This story started in 2012 when it was announced that Super GT would introduce a completely new rulebook for its premier GT500 class in 2014. The chassis and aerodynamic

The new model had been developed in secret by TRD, with news of its impending appearance only emerging part way through the 2016 season



regulations were based almost entirely on the rulebook introduced by the German DTM series, with many common parts shared between GT500 and DTM, including the transmission, uprights, brakes, dampers, springs, and the overall monocoque design. The long term ambition was to eventually have a single unified series with six manufacturers or more.

'The new regulations gave us very small scope for development, the rule book is very thick,' Yoji Nagai, general manager,Toyota Racing Devlopment (TRD), says. 'The aerodynamic freedom is very small. In terms of suspension there is some small freedom. In terms of the overall car, perhaps about 70 per cent of it was fixed before the first race of 2014 and couldn't be developed at all from that point onwards.'

Even with a single design of chassis and rollcage used by all cars (apart from the Honda which has a slightly different version as it's mid-engined) the bodies used must be proportionally identical to the standard car, but with the rules tightly defining the width, height and length so the dimensions of the standard shape have to be stretched or shrunk according to a set of equations defined in the regulations.

In both the DTM regulations and GT500, aerodynamic development is restricted to certain areas of the car. An imaginary 'design line' runs along the side of each car above both wheel arches and along the side of the door. Above the line bodywork is restricted to the original shape (albeit rescaled) of the production car, everything below that line is free. However, the floor is a fixed design. Additionally, the bonnet and some areas of the rear of the car

The Lexus RCF racecar has been campaigned by Toyota Racing Developments since the 2014 season in the GT500 division of the Super GT series. Pictured is the launch car from that year

The RCF is to be replaced with the LC500 next year in line with new regulations aimed at slowing the GT500s, which lapped Fuji at LMP1 speeds two years ago

The 2015 RCF from the rear. The suspension is a relatively free area for modification, but all cars must use common uprights. Geometry is changed to suit tyre developments in-season

The big change for the LC500 is the 25 per cent cut in downforce which is the result of the new regulations. TRD believes it will claw some of this back in 2017

are also free, as are the wing mirrors. The rear wing and its mountings are a single specification component.

TRD opted to use the new Lexus RCF model as the basis of its 2014 GT500 car, and the new machine made its public debut ahead of the 2013 Suzuka 1000km, before then undergoing extensive private testing. 'The key to these regulations is getting the most out of the small areas where you are allowed to work,' Nagai says. 'Below the legality line we have to look at drag and downforce trade offs as you would expect, so at Fuji Speedway the top speed is very important but at most other tracks downforce is more important. In 2014 we could make a Fuji specific front end and rear wing, but that was outlawed for 2015 onwards and the spec was frozen.'

Early promise

The RCF was successful from its first race, with a one-two finish at Okayama, but ended the season runner-up to the works NISMO GT-R. The 2015 season started the same way, again with a victory, but it could only manage a fourth place finish in the championship. Clearly, the RCF was more than a match for Honda's NSX, but struggled somewhat to best the Nissans.

But Nagai is open about the relative shortcomings of the RCF. 'I think that our cooling package was not as good as perhaps it might have been, so perhaps in terms of cooling and the total aero package the GT-R might be a bit better. Overall it was perhaps the cooling package that was the weakest element of the RCF. Cooling was crucial during the aerodynamic development of the RCF; with a turbocharged engine it means you not only need to look at the overall engine cooling but also the intercooler. The brake cooling is also very important and influences the whole car in terms of airflow, so the underbody aerodynamics are critical with these cars.

'While the internal ducting was not frozen, the total area of the opening and the heat exchangers was fixed so it was very important to get it right first time, as in reality, while we were not restricted in terms of the ducting, there was really not a lot we could modify between 2014 and 2016,' Nagai adds. 'It was a little different for Honda as they had special regulations just for them as they had a mid-ship car, and in 2014 the Honda cooling and engine performance was not good. So they were allowed to modify the cooling and intercooler package. That was agreed by all the three car makers.'

Tunnel time

TRD conducted much of its aerodynamic development at the Furyusha wind tunnel in Maibara, Japan, using a 50 per cent scale model. When work on the RCF began the tunnel was owned by Dome, but Toyota has since acquired the whole facility. 'With our acquisition of the wind tunnel at Maibara we now have 100 per cent of the time available to us there, but before we purchased it we had perhaps only 30 per cent of the time there. But through 2015 and all of 2016 it was not really important for the RCF, as the aerodynamic package was frozen,' Nagai says.

Another area where the RCF lost out to the GT-R was under the bonnet. Unlike the DTM series, GT500 adopted a modern engine formula with extremely advanced 2-litre turbocharged in-line four cylinder engines featuring direct injection. While chassis engineers at all three manufacturers complain that they are a bit

'In terms of cooling and the aero package the GT-R might be a bit better'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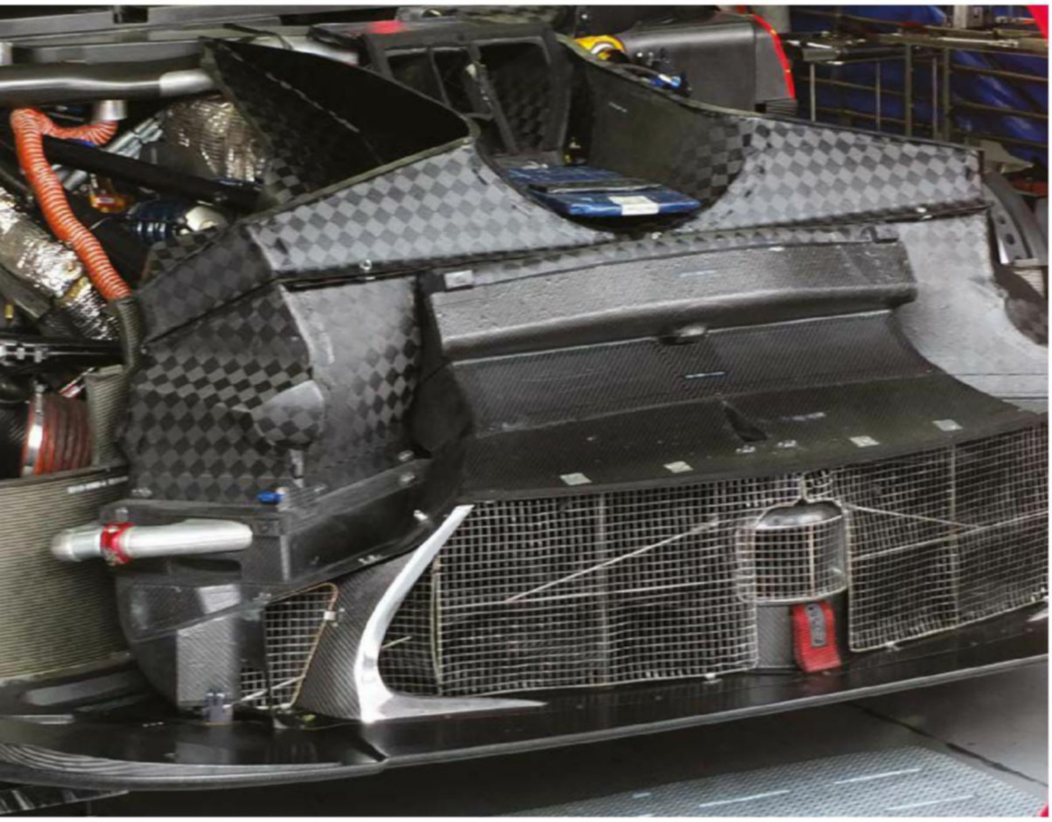
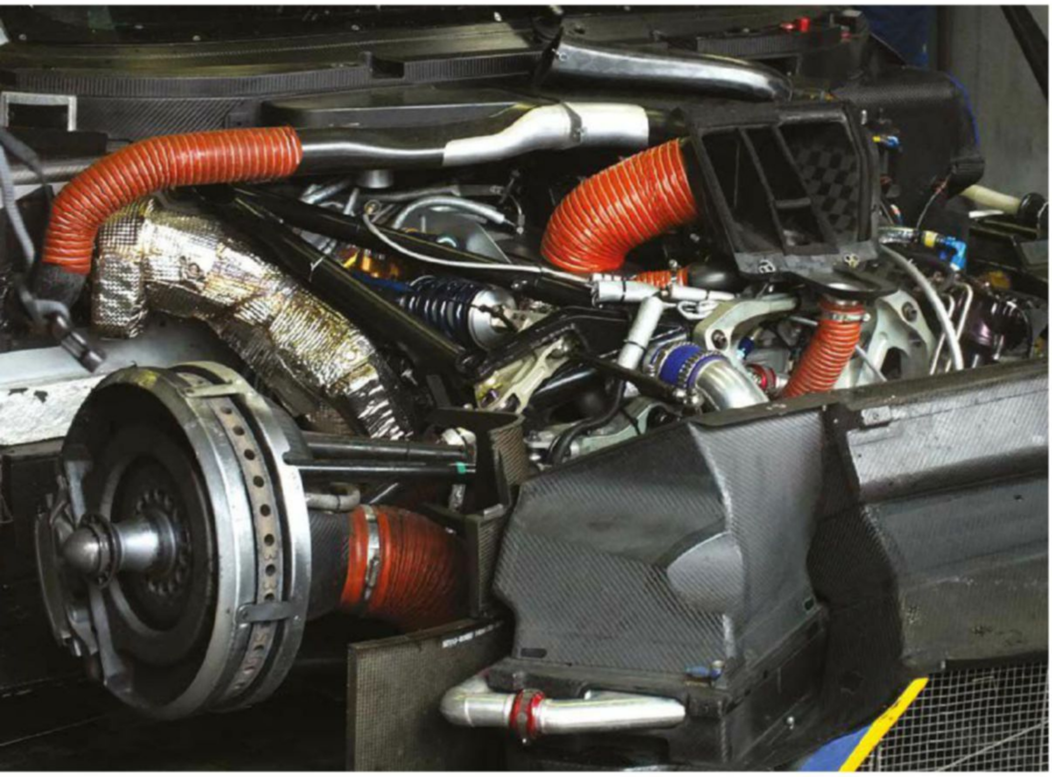


One of the weaker aspects of the RCF has been its cooling. While the internal ducting was not restricted in the regulations the positioning of the inlets and the heat exchangers were fixed. Improving cooling for the new LC500 has been a priority



The brakes are one of many common parts shared between GT500 and the DTM. These also include the transmission, uprights, dampers, springs, and the overall monocoque design. There is still some talk that the series will be unified in 2019

'The engine guys are really happy, the regulations were created jointly by Nissan, Honda and us, and there is a lot of freedom in that area'

frustrated by the restrictive rules, the engine departments see things rather differently.

'It's a political issue. As an engineer I want more technical freedoms, of course, but racing is not just for engineers there are other concerns which restrict us, particularly cost issues,' Nagai says. 'An example is that the engine guys are really happy, the regulations were created jointly by Nissan, Honda and us and there is a lot of freedom in that area. The rules allow for development and relevant research, and there are some great engineering challenges, much better than the old V8s. These engines are a new technology and give a lot of scope for us to try things. In terms of performance the fuel is a limiting factor, without special fuel, like they have in Formula 1, we can't get the knock resistance we need to push in the directions we want to. I think we would get a notable power increase, but we have to use commercially available fuel, the same as production car fuel.'

Engine strategies

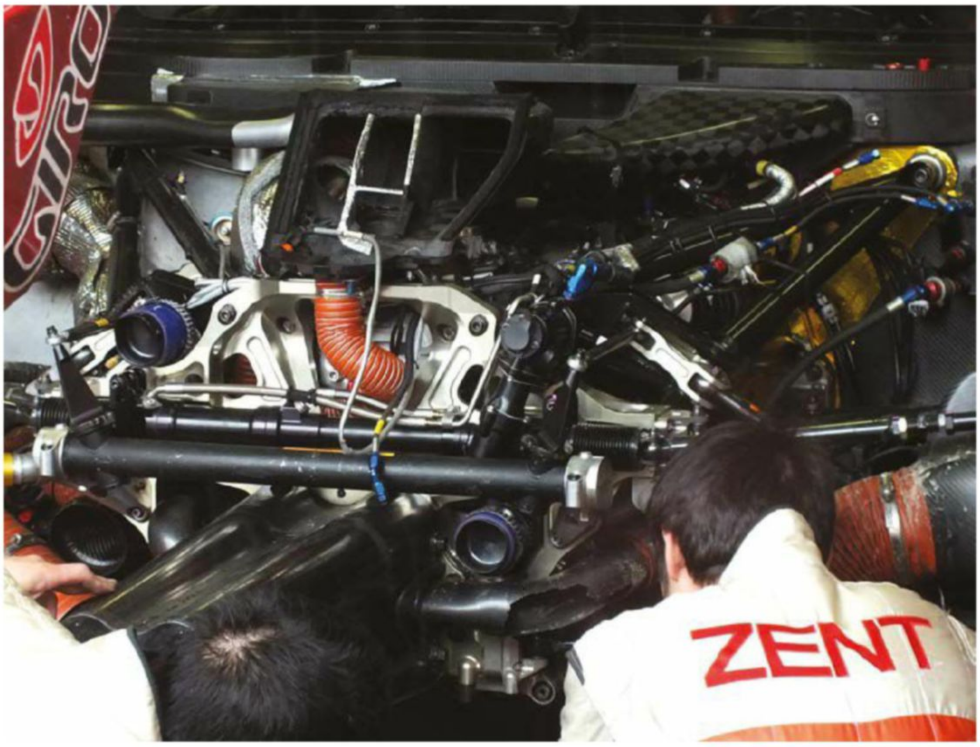
Both Honda and Toyota supply these new NRE engines, not only to GT500 but also to Super Formula. Nissan, on the other hand, only supplies its engine to GT500. 'In the season we are allowed three different specifications of engine per year and it's up to us when to introduce them,' Nagai says. 'So in 2016 we did the whole season on two different specifications, then with the final two rounds at Motegi we introduced a very specific special engine, that was the third and final 2016 specification for the RCF. But when you consider we also make two specifications of the engine for Super Formula as well, actually we have five different specifications per year, not including experimental and test units.'

'In 2014 we felt that perhaps the Nissan engine was a little better than ours, but we pushed hard and by 2015 I think we were as good or better than them. Honestly, at the start of 2014 we were surprised that Nissan had such good engine performance, we could not understand how they did it. In some ways they have the advantage of not developing an engine for two very different cars, the Dallara SF14 and the GT500, but in other ways that is a disadvantage as we get a lot more test data and race data than they do. Our engineers look at the data from both Super Formula and GT500 and that allows them to try different mappings and grow their knowledge much faster. At first our focus was on the car and chassis development, but after that focus was switched to the engine, as to an extent that was all we could work on and we made some gains.'

As *RE* closed for press TRD was set to introduce the final evolution of the RCF engine, a single event special for the 2016 Super GT Grand Final at Motegi, which it hopes will be enough for a Lexus to clinch the title at last.

By part way through the 2015 season Nagai believes that TRD had been able to match

Engines in GT500 are relatively free and unlike its DTM cousin it has a modern engine formula with an extremely advanced 2-litre turbo in-line 4-cylinder unit featuring direct injection. Toyota also develops a version of its engine for Super Formula



TRD was allowed three different specs of engine this year and it opted to do most of the season on just two specifications, then for the final two rounds at Motegi it introduced a special unit. For next year just two engine specifications are allowed

‘Our engineers look at the data from both Super Formula and GT500 and that allows them to grow their knowledge much faster’

NISMO in terms of engine performance but could do little about the aerodynamic deficit, but did work hard on other areas of the car. ‘We made a big step going into 2015 as we started to understand how to optimise the car and particularly the set-up within these really restrictive rules,’ Nagai says. ‘So our chassis engineers caught up and we became more competitive. The suspension geometry is actually one area where development can be done, we have to use common uprights and transmission casing, but on the latter there are quite a lot of fixing points so that gives us some freedoms to exploit.’

Tyre war

Super GT is an open tyre series with Bridgestone supplying rubber to all three manufacturers, Yokohama supplies both Nissan and Toyota, Dunlop supplies a single Honda, and Michelin exclusively supplies Nissan. ‘We do specific geometries for the different tyre suppliers, Bridgestone and Yokohama, we have five teams and sometimes they try different things themselves, too,’ Nagai says. ‘Initially we give the teams some recommendations based on our testing, simulation and rig data but they can adjust from that. Perhaps there are two or three geometry changes per season per team. Tyre development is a key issue in GT500, probably the biggest thing, that is why the geometries are changing through the season.’

Looking back over the first three seasons since the introduction of the DTM rules not everything has gone smoothly. Senior engineers have claimed that the chassis is perhaps not as stiff as it could be and that they would prefer a lighter and stiffer Japanese designed product instead. Additionally, in 2014 and 2015, it was found that there was an issue with the propshaft. ‘We found that it would vibrate then break,’ Nagai says. ‘Nissan struggled most and later a modified specification was introduced. We all adopted it. Well, not Honda, obviously!’

Best of breed?

Reviewing the whole RCF project Nagai seems reasonably satisfied with 10 victories for the car since 2014. ‘The strong point was the engine of course. I’m an engine guy so of course I say the engine. But actually the best point of the whole car was its reliability. I think ours was the best of all the GT500 cars,’ Nagai says.

But, as mentioned earlier, the iterative performance gains of TRD and its rivals at NISMO and Honda R&D had seen the cars becoming far too fast for the smaller tracks on the calendar. As a result for 2017 a drastic step was made and a revised set of aerodynamic regulations was introduced, and this gave the opportunity for new models to be introduced too.

As was the case with the RCF, TRD chose the Suzuka 1000km to launch its new GT500 car, based on the brand new Lexus LC500. The new model had been developed in secret by TRD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The resemblance to a DTM car is more clear from the rear. Here the design line has now been lowered from 400mm to just 195mm while the diffuser height has also been more than halved from 206mm to 101mm. Wing width has been increased

With the new for 2017 regulations the mechanical elements of the car remain largely unchanged, but the overall car length has been reduced from 4775mm to 4725mm, with all of this coming from a 50mm trimming of the car's front overhang

with news of its impending appearance only emerging part way through the 2016 season.

'With the new car we started on it during 2015 when we knew what the new rules would be. So we selected a new model, and one major objective was to improve the cooling package overall. The focus has again been on the overall car rather than just the engine, as in terms of the engine R&D that was ongoing,' Nagai says.

GT500 2017

The new for 2017 GT500 rules see the mechanical elements of the car remain largely untouched, though hybrids have now officially been banned (no hybrids raced in GT500 in 2016 anyway) and engines will be limited to just two specifications per season in an attempt to reduce costs slightly. In terms of the aerodynamic changes, the overall car length has been reduced from 4775mm to 4725mm, with all of that reduction coming at the front of the car with a 50mm reduction of front overhang. At the rear, the design line has been lowered from 400mm to just 195mm, while the diffuser height has also been more than halved from 206mm to 101mm. The rear wing is significantly increased in width, however, up to 1900mm from the 1390mm plane used in 2016 at all tracks other than Fuji Speedway.

'Next year the changes are obviously very big. We have 25 per cent less downforce in theory, but that is really just the launch spec car, we will recover between now and the start of the season as much of that as we can,' Nagai says. 'At Suzuka the simulation data suggests that the 2017 car will lap at about the same pace as the 2016 despite having a lower downforce level. That lower downforce has directly resulted in the car having less drag, so the losses in the corners at Suzuka are made up with speed on the straights. At some other circuits like Okayama, which have more corners, the cars will be perhaps 0.7 or 0.8 seconds a lap slower.'

Shifting balance

The LC500 may look to have a smaller greenhouse compared to the RCF when the two are side by side, but in reality the frontal area is the same, Nagai says. 'That's regulated. In terms of the overall shape it looks like it should be better in aero terms but in reality it is similar. The car really is a launch specification and there is a lot more to come, but you won't see that until March and pre-season.'

While the LC500 has no real mandated mechanical changes compared to the RCF, the aerodynamic changes will create a different balance, and that in turn will have a knock on effect in other areas. 'It not just the aerodynamics, I think that there will be a big step on the whole car,' Nagai says. 'With a lower downforce level the load on the tyres could change but we have set some targets. Yes, the initial car is 25 per cent down, but the total load also must take into account the car weight and other factors. If we meet our targets with the LC500 the tyres will not need to be all that different to the late 2016 spec. We have already told the tyre makers our target downforce levels and predicted loads, so they will adjust the tyre specification in accordance with that.'

Harmonisation

The LC500 will make its race debut at the opening round of the 2017 season, which as usual will be held at Okayama. Aerodynamic development will again be frozen at the start of the season, but there is a possibility an upgrade could be introduced at the start of 2018.

Beyond that the future of GT500 is a little clouded; 2019 is the target set my GTA chairman Masaaki Bandoh for full harmonisation with the DTM in order to finally create the long awaited Class 1 rule book. This could result in the development of a new monocoque and package of standard parts and indeed the introduction of new models once again, but it seems little has been fully decided.

The future of the DTM itself seems uncertain and if the unification is to ever happen the German brands would have to finally commit to introducing their new four cylinder turbo engines, something that was originally scheduled for 2016 but appears to have been delayed indefinitely. In addition there is the key obstacle of GT500 featuring open and ongoing engine development and DTM using frozen units. It seems that until these issues are resolved the Lexus LC500 will still be flying the flag for Toyota in Super GT.

'It's not just the aerodynamics, there will be a big step on the whole car'

Major league

Akira Kurashita is the new boss of Japan's Super Formula series. *Racecar* talked to the former baseball player about his vision for the future of this hyper-fast single seater category

By SAM COLLINS

Super Formula cars are fast enough to make the F1 grid at Suzuka. The new president of the series would like them to race outside Japan on occasion

Japan has the fastest national single seater championship in the world. Super Formula features cars which can lap Suzuka at speeds fast enough to qualify for the 2016 Japanese Grand Prix (well, within the 107 per cent time). Known until 2012 as Formula Nippon the series is organised and promoted by Tokyo-based company JRP.

Earlier this year former Honda F1 project leader Hiroshi Shirai stepped down as president of JRP and handed over the reins to Akira Kurashita, a former baseball player. 'I don't really know why I was appointed to become the president of JRP,' Kurashita says. 'I worked for Fuji Television's sports division for more than 20 years, so several times I had to go to London and negotiate the broadcasting rights for F1 with Bernie Ecclestone. Those were very tough meetings! Fuji TV actually is a JRP shareholder so I was a board member for some years too. The company is called JRP which stands for Japan Race Promotion, so we need to promote! We need people to watch on TV, to come to the track or to watch and follow online. So I think that is also why I was selected.'

First base

Kurashita claims that his appointment came as a surprise, as he had never expressed any interest in the role. 'I think the other board members had got together and decided to appoint me. I think the idea was that Super Formula has improved greatly in recent years and now was the right time to increase promotion. So they felt that maybe someone with a TV and media background would be a good choice.'

Earlier this year Shirai outlined his vision for the future of Super Formula and it appears that Kurashita is keen to implement that same plan. 'Shirai-san is still a central part of what we do here, he is the technical advisor and without him there is no way I could do this. He had set out a direction for the series which has Super Formula becoming accepted as a premier racing championship like F1 and Indycar; high level racing with manufacturer involvement and star drivers, not a feeder series in any way.'

One area of key interest under Shirai's plan was to increase the international profile of the championship, perhaps by holding races overseas. 'We had for some time been looking at an Asian expansion, and that was the focus, but now that for whatever reason has fallen by the wayside' Kurashita says. 'Since I started in June I have put together two project teams, the first will be looking at international development and looking at where we could hold races. It is a bit tricky as not everyone in the paddock or the organisation is that interested in racing overseas. This category is really exciting and I want to share it with people, and other partners feel the same. The advice I have been given is that if we take the series overseas it should be to a country which already has F1, and also it should be a country where we already have a driver active in the series,' he says.

Home run

The series has only ever left the shores of Japan once, in 2004, with a one off visit to Sepang, Malaysia. 'It does not take too much money to host a race overseas, and perhaps people here don't realise that taking this Japanese racing series overseas will not only open people's eyes to it, but also let people here in Japan realise the opportunities it brings with it,' Kurashita says. 'But there are interesting opportunities in Japan too, the Fuji Speedway Sprint Cup could be something good to bring back, a joint race with Super GT could happen again, and I would like that.'

Super Formula has used the same Dallara chassis since 2014, which was originally designed to accommodate a hybrid power unit based around the NRE 4-cylinder engines which Super Formula shares with the GT500 cars in Super GT. The hybrid systems were tested on track but were never raced for cost reasons. However, Kurashita is now looking to the future and the next generation of Super Formula car. 'The second project team which has been created recently is focussed on defining the next Super Formula car. There are discussions ongoing, but I think we will probably stay with Dallara, but we will work on ways of making the cars much better than they are now,' he says. 'Formula 1 has a big change next year, and I have my doubts about how good those rules will be for the show. So I think I will wait to see how that develops before fully defining our direction. We will look to bring in the new car in either 2019 or 2020, and the SF14 will last until then. Right now the Super Formula cars are very good according to the foreign drivers, for example, but there are some small issues.'

Strike one

One criticism made of Super Formula by non-Japanese, or *gaijin*, drivers is that the current cars, while fantastic to drive over a single lap, make overtaking very difficult, especially with the very high apex speeds. Every SF14 is fitted with an overtaking boost system, which can be activated for a period of 20 seconds and for a maximum of five times during the race. The device can increase the engine speed from 10,300rpm to 10,700rpm. When it is activated the lights on the roll hoop flash so spectators (and rival drivers) know the car in question has a performance increase of about 50bhp.

'I have heard these complaints about overtaking, too, so we are looking at things to make that better. One of the issues is the boost systems on the car. While the following car can use his boost to try to overtake, the leading car can also boost to defend. But we can use GPS to stop the leading cars from using boost to pass. It's a bit political, though. There are some people who don't think it would be Super Formula without that way of using boost. I think we need to add something to add to the thrill of the races, we have some other ideas. We have an opportunity to introduce DRS, for example. It's hard right now with the SF14 to follow another car as the turbulent air off the rear of the leading car disrupts the aero of the following car, so we are working to improve that with Dallara. Right now the following car can often overheat its brakes when following another car close, and that's a problem we must fix, too,' Kurashita says.

Big hitters

At the start of the 2016 season the series switched from Bridgestone to Yokohama tyres and JRP is now actively working with the new rubber supplier in order to improve the show. 'We are actively looking at introducing different compounds with different degradation rates, but the compounds should be about two seconds a lap different to each other, so that is an area of interest. We have already tested this but the time difference between the tyres from Yokohama was too small, just 1.5 seconds, so we need a super soft. The corner speeds are already very high, so perhaps the new super soft tyre will actually be the current tyre and we will introduce a much harder tyre as the other compound so the corner speeds don't go even higher,' Kurashita says.

International drivers are a key part of JRP's growth plan, and the series is very proud of its high standard of driving talent, which in 2016 included Stoffel Vandoorne, Andre Lotterer and Kamui Kobayashi. The idea is to pit the best Japanese talent against the best the rest of the world has to offer. Many expected Vandoorne to dominate this season, but the standard of drivers is illustrated by the fact that the McLaren man has only won a single race this year (as *RCE* closed for press the final round had yet to run).

'I think we will probably stay with Dallara, but we will work on making the cars much better than they are now'

'Good drivers are coming from around the world to race in Super Formula, guys like Vandoorne and Lotterer. It's not about the money, it's a real drivers' formula. So going forwards it is important to keep that, races with great battles and unpredictable results,' Kurashita says, before adding that it is not just drivers he wants to bring into the championship. 'I'd really welcome Nissan to this series, everyone here thinks that them joining is unlikely, though. I don't think at this time there are any other manufacturers interested in the series at this point, but maybe it would be possible to attract them in future. Teams, too. I think we have an attractive proposition for teams who want to race here, not just Japanese teams, but those from all over the Asia-Pacific region, and maybe even Europe and the USA.'

Former baseball player and Fuji TV man Akira Kurashita took on the role of president of JRP earlier this year

It's not a surprise that Kurashita highlights Nissan as a target for future participation, as it already has an NRE engine which it uses in Super GT, and it has already tested at least one of its large pool of talented drivers in Super Formula. But the brand has yet to publicly express any interest in competing in the championship.

Unsurprisingly for a television and media expert Kurashita has some plans to improve the coverage, but was not willing to go into detail quite yet, his attitude very much 'watch this space'. He says: 'Right now this series is still not at the level we want to reach in terms of international reputation. We need people to realise that this is a top category. But there are things we need to do. We need to look at the prize money available to drivers, perhaps it needs to be increased, also we need to be more active on social media, not just as a series but the drivers, teams and partners, too. These are all things we are working on. Right now we have coverage in 108 countries, with highlights packages on many channels, but we need to increase that promotion overseas and gain more fans.'

Under the plan first laid out by Shirai-san, and the management of Kurashita, Super Formula seems to have a bright and expanded future, and that can only be a good thing as it increases the return on investment for those brands already involved in the series.

Electric **dreams**

Hot on the heels of Formula E comes a new category for electrically motivated sportscars – but can Electric GT's ambitious plans really change the shape of EV racing?

By ANDREW COTTON

Motorsport's march towards future propulsion mechanisms has taken another step with the recent launch of the new Electric GT World Series, which will kick off in Barcelona in September 2017 and, according to its founder Mark Gemmell, will be made up of a series of electric racing 'festivals' at full-sized FIA circuits around the world.

The driving philosophy behind it is both simple and familiar: 'I thank fossil fuels for getting us to where we are. They are saving lives every day by keeping the ambulances on the road,' says Gemmell. 'But we are all smart enough to know that our future is not running fossil fuels and the sooner we switch, the better. It will mean changes in industry, but smart people will know they have to change.'

The first cars to be used will be Tesla's S P85 and P85+, designed to be FIA compliant, which will run with Pirelli tyres and in almost standard trim. However, the series has targeted more cars to join in future, including the Mercedes SLS AMG Electric Drive, Citroen's electric GT concept, as well as EVs from other big players such as Porsche, Nissan and Audi. Races are expected to last for half an hour before a recharge period, during which spectators will be treated to other electric races, for bikes and perhaps rallycross, too.

Gemmell came up with the idea, and then linked up with engineer Agustin Paya, who developed the car to meet with the technical regulations in his new role as technical director for Electric GT Holdings, the owner and promoter of the new championship.

'Motorsport exists for very good reasons,' says Gemmell. 'It started hundreds of years ago to show what manufacturers were capable

'Electric cars are our future and as soon as the public start to get enthusiastic about that they will demand cars from manufacturers'

of doing, and for manufacturers to flex their muscles. Motorsport came about to motivate people to buy cars, and show who was better, and we are getting to that stage again. Electric cars are our future and as soon as the public get enthusiastic about that, they will demand such cars from manufacturers.'

One manufacturer already heavily involved in EVs is Tesla. 'We saw that the Tesla was a great car, we wondered why it was not on the race circuit,' Gemmell says. 'Agustin [Paya] answered my question: "Why are Teslas not on the track?" with, "Because no one said let's do it". So we sat down and said, "let's do it". In doing so, we fulfilled the fundamental promise of motorsport, which is to show people what the technology is capable of doing, and excite them about what technology will bring in the future.'

Faster than FE?

Gemmell believes that the Tesla will be faster than the Formula E over a longer distance, but on that score the maths do not quite add up. Formula E cars produce 28kWh, the cars weigh 900kg, and take part in 20 minute races, equalling an 84kW average. The average power to weight ratio is therefore 0.9kW/kg. For the Tesla S, the same calculation is 85kWh, 2300kg including the driver, 30 minute races, which is 170kW average power, giving a power to weight ratio of 0.74kW/kg.

The cars will have lower drag and less downforce than a Formula E car, but will run on grand prix circuits, rather than the narrow and twisty street tracks favoured by the FIA-backed single seater series.

The decision to go with Tesla was principally taken because the car is ready to run. 'For the first time an electric GT championship talks about an electric racing car with high performance, like high performance with combustion,' says Paya. 'For the first time the electric car will compete in the same places as a combustion engine on a race circuit; and a high quality, prestigious circuit, and this is a new thing.

'I respect Formula E, but I think the electric GT Tesla is more powerful, double the power compared to the Formula E, and more important is the environmental impact,' Paya says. 'The battery will evolve with FE, but so will Tesla. The car's bodywork is full carbon, which is not a surprise in motorsport, the roll cage is to FIA standards, the brake system is similar to a combustion car.'

Open circuits

'We know the car, it's good,' Paya adds. 'It's potentially available to customers if they have the right money, and so we figured it's easier to take a car that they have built 100,000 of already, rather than a car that they are going to build tomorrow or next year. It is the best car with the right horsepower to do the job. But This is not a Tesla championship. If Samsung bring out a Tesla killer, they know where to bring it. There are so many exciting changes coming in this industry.'

The cars will be fully compliant to the FIA's regulations surrounding electric racing

The Tesla is all FIA-spec racecar on the inside with a full rollcage and all the necessary gubbins. The steering wheel is the same as that used in the DTM. Electric GT is currently looking for drivers to take part in the series

Tyres will be supplied by Pirelli while the car is equipped with the indicators and warning lights an electric racecar is required to have in order to make it safe for marshals to handle at events

Recharging would take around an hour from empty to 100 per cent charge using the Tesla charger from the grid

including the location of indicators for the warning lights, and the FIA has already seen the car. 'It is absolutely our intention to have a car homologated by the FIA so we can run with FIA marshals,' says Gemmell. 'All safety will be FIA, regulations are standard FIA, the marshals, local authorities, the structure is bog standard. We are trying to build a standard race series with electric cars. It's that easy. The tyres are from Pirelli, but that's not an innovation. The suspension is race suspension. The same for the brakes, the steering wheel is from the DTM.'

Electric bills

While manufacturers are being attracted to Formula E, Electric GT seems to have a price structure more in line with private teams. The cost of entry to the series including purchase of two cars is estimated at around €787,000. The additional costs will be the pit crew, insurance and travel, plus any agreement with the driver, and the Pirelli tyres. On its website, the series is actively looking for drivers to take part in the inaugural series.

'We intend to have standalone [events], and have full electric festivals,' says Gemmell. 'The challenge is to fill the circuit, and fill the time. We have one single race day, dealing with several additional electric events including electric rallycross, electric karting and electric bikes, a full electric spectrum for the public to try, and we have the professional drivers on circuit in these different vehicles. There are environments where we have to reconsider. We know that the Nurburgring is a more complex environment to race in; the German authorities are stricter in some respects, so we may co-host in some events. We are realistic about it.'

Charged up

Recharging would take around an hour from empty to 100 per cent charge using the Tesla charger from the grid, although there are other options available. Shipping containers of batteries charged through solar energy is one solution, or bio fuels such as Aquafuel could also be used, as it is in Formula E. 'They are taking advantage of glycerine, which is a by-product of bio fuel production,' says Gemmell. 'If you have to regenerate and use power from this source or from the grid, to charge 20 racecars you need a serious 2mW of power, and that is too much for the grid. We need some storage or Aquafuel solution. That essentially moulds the way that the races work. We have to fit the races into what the batteries allow. We are not going to do car swapping, but we will essentially do a solution like in the DTM, so with a 30 minute race, which is quite frankly more than most people can tolerate these days.

'Personally I am a fan of the rallycross format, lots of heats, short races, that would be a nicer thing to do, but we are flexible,' Gemmell adds. 'A half hour race, that's not a problem, we don't expect to go below 20 per cent charge in that time, so we won't go into serious power limits.'

Due to the nature of electric racing, it can take place in the evening with LED strips under


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The Tesla S P85 is the first car to be readied for Electric GT competition but this is not a spec series and organisers hope other EV manufacturers will join up once it's up and running

the car, under-car lighting, and so on. The series hopes that an evening session will lead to more of a party atmosphere, one of the main criticisms of a Formula E event.

The topic of car ownership in future is also one for consideration. At the Autosport International Show at the start of this year, industry leaders shared their thoughts that the current model of buying a car, or more accurately, and increasingly, leasing a car on three or four year deals, will change. Companies expect that a rental programme will be more likely, with families and individuals renting a car for purpose rather than buying a single model and living with it for three or four years. This, says Gemmell, makes racing even more important. Race results can lead to increased popularity of a brand, and any car that can win, and be seen to win, will become more popular. Under this model, racing will become more, not less important.

'This is quite new,' says Gemmell. 'Uber has brought this to the fore, and for some reason autonomous driving has been brought into this as well. Tesla has brought this idea in as well, about semi-owned and shared. It does reflect positively on motorsport. If you are thinking about choosing for the weekend a vehicle, and want a bit of fun, you want to know which car is kicking Tesla's arse today and that's why sport is important. If you buy a car, you are married to that car for the next three or four years. This idea of looking at cars that won at the track, and then doing a car share with that car at the weekend, is something far more dynamic and flexible. If you can switch from one car to another for the weekend, you can look at that Mahindra that handed Tesla its backside at the weekend, I want to car swap that and see if it's true, you can do that. That is why it is positive, and that is why it is cool to have the battleground and evolve it week by week in competition.'

Current affairs

However, would that not lead to less money available for a manufacturer to invest in battery development? Apparently not, says Gemmell, as evidenced by Tesla's launch of its most recent model, the Tesla 3, that the company will sell for $35,000. Almost half a million cars have been ordered and deposits paid, leading to financial experts questioning the financial state of Tesla. 'They will have the money to invest, because an order book of 400 to 500,000 cars, if you took that to any financial institution, it is not an 'I would like' deal, it's cash on the table and orders,' says Gemmell. 'They have taken that to the financial markets and had underwriting to build the factory that will produce half a million cars a year. That's a success story. Order books are a great idea. There is nothing wrong with getting a full order book. It surprised Tesla, it surprised everyone, but there's nothing wrong with it.'

Electric Avenue

'If we do rental, then the main impact is that we will buy fewer cars,' Gemmell says. 'They will not be stopped, they will be used. But that means that they will get switched quicker because a car that has done 200,000 miles in a year, it is done. It has amortised its cost. They will get used and abused, off the market, recycled and a new one coming out, so we will see more innovation in the market. If your cars are getting churned every two years, you are still manufacturing tonnes of them, they are just not sitting around on the streets. The only other way is that we stop travelling. We work from home … One way or the other if we don't leave our homes, that's a different society, but if we enjoy driving around a track, we are going to do kilometres or miles. But fundamentally we are using the same cars.'

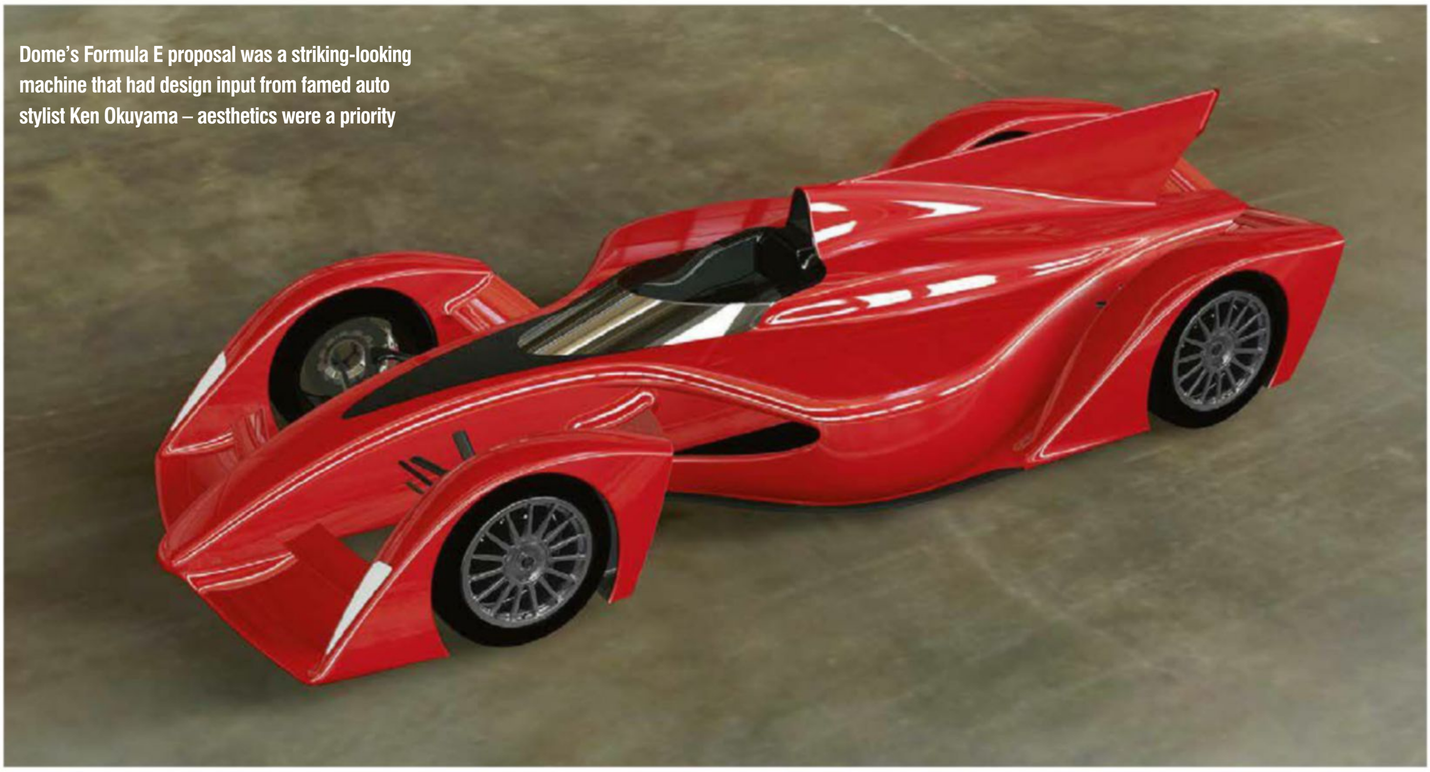
On paper the Electric GT series does have potential, but turning that into reality is another matter altogether. It's hard to find reliable data on the long-term high performance of a modern Tesla, but it would also be foolish to write off the concept. If electric really is the future, a family-friendly festival could stand a chance of success.

'We have to fit the races into what the batteries allow. We are not going to do car swapping'

A case of watt if

When the call went out for an all-new Formula E chassis Japanese racecar constructor Dome was quick to respond. Its stunning design will not now be raced, but it certainly deserves a closer look

By SAM COLLINS



Dome's Formula E proposal was a striking-looking machine that had design input from famed auto stylist Ken Okuyama – aesthetics were a priority

When Formula E was first announced few in the motorsport industry gave it very much credence. The business model didn't seem to make much sense and the championship didn't seem to be very sustainable. But in 2016, as season three begins, Formula E now has more manufacturers involved than any other major series other than the WEC, full grids, and a slowly growing fan base.

From its first season (and until the end of season four) Formula E has utilised the same car, the Dallara built Spark 01E. But a new car was called for for the next phase of the championship, one which would eventually be able to complete a full race distance. A tender was issued in order to find a constructor for the new racecar, which will be introduced in 2018, and there were a number of proposals put forward, from a range of companies.

One perhaps surprising candidate for the deal to design and build the new car was Japanese constructor Dome. The firm is best known for its Le Mans Prototypes and development of cars to race in the Super GT series, but over the years it has also worked extensively in F1 (including with its own design in 1996), F3 and F4 – it is the sole chassis constructor for the Japanese championship.

Interest sparked

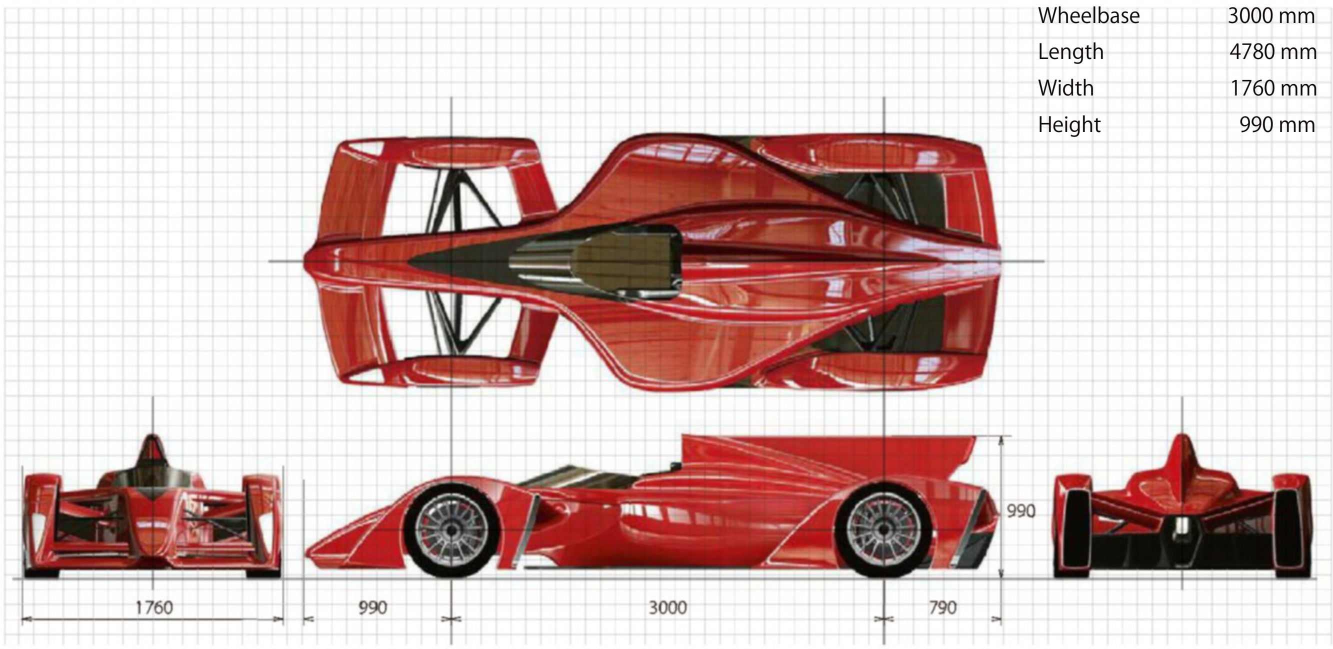
But why the interest in Formula E? 'We set out to do Formula E because we felt that it was a good technical showcase,' Hiroshi Fushida of Dome says. 'If you win the bid it's a reasonably good business proposition too. In some classes, LMP3 for example, you have a good technical showcase but the business proposition is pretty difficult. FE gives you the best of both worlds, a good technical showcase and a good business proposition. With all those manufacturers showing an interest you know it's stable for five years at least and with the trend to EV in some parts of the world it should be stable longer.'

While initially not an obvious choice for the Formula E chassis deal, Dome is perhaps the most experienced constructor of EV competition cars in the world. Though the only publicly acknowledged project it has done previously is the Nissan Leaf NISMO RC, it is also thought that the firm was involved with Mitsubishi's Pikes Peak car. 'We have done a number of EV cars like that, the Nissan readers of your magazine know about, but the others are still confidential,' Fushida says.

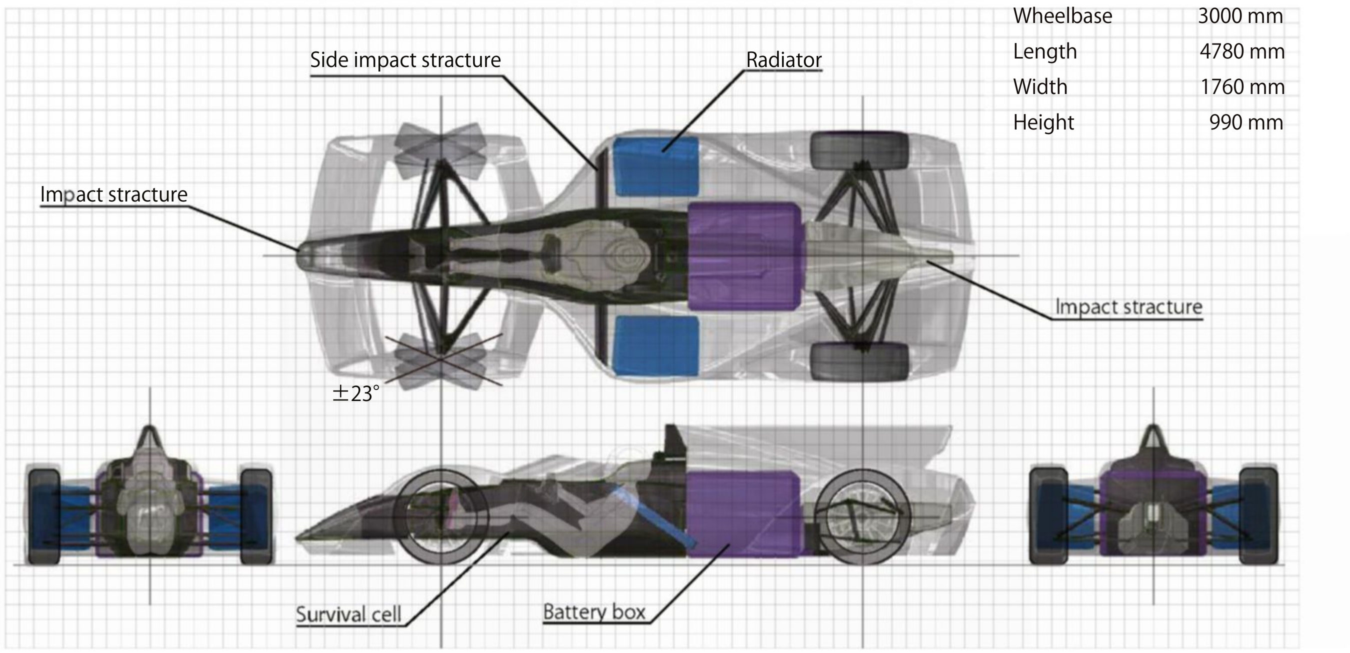
In order to create its Formula E concept to put to the FIA Dome's engineers teamed up with Ken Okuyama to give it a distinct look. 'He was a senior designer at Pininfarina but many years ago he worked for Dome. He created cars for Ferrari and Porsche, for example, so the Formula E proposal was like a joint venture with him,' Fushida adds.

In the invitation to tender the FIA called for a futuristic look while still achieving aerodynamic efficiency. The technical regulations could be disregarded for bodywork and styling elements of the car. However, a drag (sCx) target was set at 0.65 lower than the current car which has a figure of 0.75.

The FIA called for a futuristic look while still achieving aero efficiency



The Dome Formula E was to be an all-new design and not based on a previous racecar. Sadly Dome pulled the plug on the project before the decision on the FE car was made



The monocoque was to be constructed to 2015 FIA F1 safety standards and would feature a low nose. Anti intrusion panels would have had to be fitted in to the cockpit side area

The styling of the racecar was expected to be in the vein of the Red Bull X2010 concept car.

The response to this from Okuyama and Dome was the striking looking design you see on these pages. Notably it features partly enclosed wheels with the front wheel pods lined to the body via a set of front wings including one at the trailing edge of the pods. At the rear there's no traditional wing but a set of wing profiles between the rear impact structure and the rear wheel pods. Earlier iterations of the Dome design featured what appeared to be a version of the centreline downwash generating or CDG wing proposed for Formula 1 a few years ago.

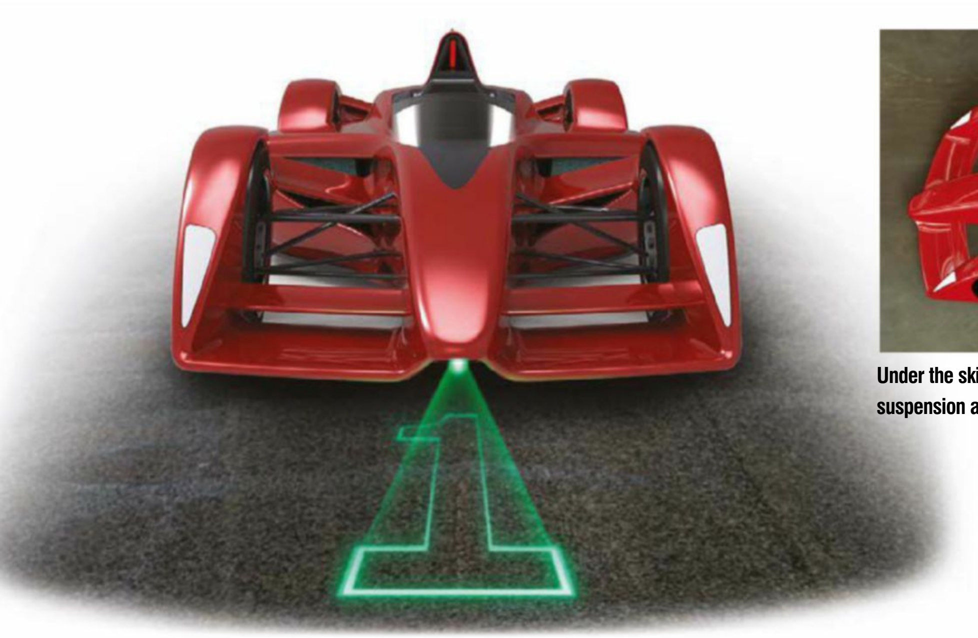
Dome meets ohm

The philosophy behind the design is clear: 'It doesn't really matter how fast the car is, it has to look good and the racing must be good, the rest does not really matter,' Fushida says. 'We decided to go for a wingless rear end so the final design had no rear wing, the speed is not so high, the downforce comes from the floor and the bodywork.'

The FIA tender was for the supply of up to 34 cars with a maximum cost of €270,000 each. Technically the tender called for a car with a minimum weight (with driver) of 888kg, with a weight distribution of 38 per cent front (without driver). In terms of the monocoque it must be constructed to 2015 FIA F1 safety standards and feature a low nose (the current car has a high nose). Anti intrusion panels would have to be fitted in the cockpit side, front and rear impact structures would have to be employed.

Mechanically, the Dome design seems relatively conventional with all of the major components located in the usual locations with double wishbone suspension all round and pushrod actuated dampers front and rear. There has been some suggestion in the motorsport community that some of the tenders for the new FE car simply re-purposed existing chassis from F3 or other championships but Fushida makes it clear that this is not the case. 'The monocoque is all new, not based on an older car, so while it may on these early designs look like the battery box does not sit forward in the monocoque the detail design had not been done but I know we were considering doing it like the rear bulkhead of the S102 LMP1 with a recess in it so the battery pack is further forward. We would supply the battery box too, but we have good experience of things like the cooling requirements from other EV projects we have done with manufacturers.'

Dome has been well known over the years for not being all that keen on spec racing and while that attitude has eased a little in recent times there is still clearly a feeling that the company prefers open championships. 'I think it's right that initially FE was single make,' Fushida says. 'If you had open

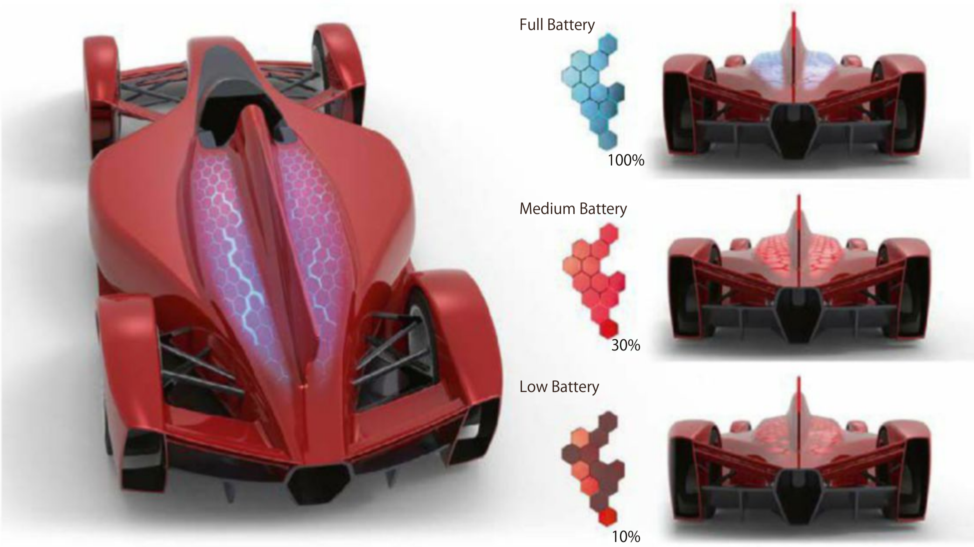


One of the more quirky ideas Dome had for its Formula E was the car number, or a car's position in the race, being projected on to the race track in front of it as it competed. This was do be done with a laser projector

Under the skin the Dome is conventional, the racecar utilising double wishbone suspension all round with pushrod actuated dampers at the front and the rear

technology it would have been tough to get enough entrants, but in my opinion the series must not continue in that way. They should open it up fully. I understand the reasons to keep it single make and keep costs down. But in the future the cars should be fully open for development. That will put the price up, though, because the big automakers will spend money, like they do in Formula 1. But it has to be like that in five to 10 years from now.'

One of the elements of the proposals submitted to the FIA were ideas for spicing up the Formula E show somewhat. In this area the Dome engineers, with Ken Okuyuma, came up with some very interesting concepts which could be applied in other series. 'We had loads of ideas for the sporting side of things, like projecting the car number or position in the race on the track ahead of the car using a laser projector; panels in the bodywork could light up to show the state of charge of the car, using lighting systems embedded into the composite panels; you could even have drones chasing each car,' Fushida says.



Another clever gimmick Dome suggested was the lighting up of panels in the bodywork to show the state of the available electric charge in the Formula E racecar, which would add another element to the spectator's involvement in the event

Unplugged

But the Dome Formula E car will never be built, it seems. The Japanese project was withdrawn from the process before a final selection had been made. 'We didn't win the bid," Fushida says. 'Originally the tender was open to anyone, but after we submitted our tender the conditions were changed and we decided to withdraw. I think our proposal was very good, it is a shame, we were very disappointed.'

Exactly what was changed Fushida would not divulge but other sources in the UK suggest that the FIA, or Formula E, was keen to work with its own preferred racecar designer, thought to be Dan Simon of Cosmic Racers fame. Notably, Simon also penned the Roborace concept car. The suggestion is that those tendering would have to build a racecar to Simon's sketches and it is thought that this is why Dome (and some others) withdrew from the process as they would lose control of the design and performance of their racecar.

Ultimately Dallara with Spark Racing Technologies won the tender, and will now continue to supply the one make chassis to Formula E until at least season seven.

There is no conventional rear wing but there is a set of wing profiles between the rear impact structure and the rear wheel pods. Earlier versions of the design had a centreline downwash generating or CDG wing, similar to that once proposed for F1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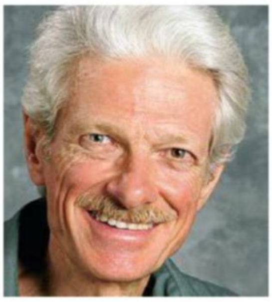

Adapting a Sprint car for a road course

Is it possible to use a US short oval racecar on a regular circuit?

QUESTION

I'm a pavement Sprint car guy that went road racing this season for the first time (in American Sedan) and I have completely fallen in love with it. I now want to marry the two disciplines, so to speak. I want to take a Sprint car and turn it in to a road racer, or at least a decent track day car.

Our track here in Michigan, Waterford Hills, is a short road course at approximately 1.45 miles, so one can get away without having a gearbox. One of the guys I race with is geared to never shift out of third once we go through the rolling start. So I'm not worried about putting a trans in the car for this. I think putting a quick-change late model rear end with a diff in the car would solve the right turn dilemma at the rear, along with taking any offsets out of the car (make a new centred up motor plate, and so on).

My question is, when making a new front axle is there anything I can do to make the car turn better with the beam axle other than making sure the car is 'straight up'? The car will be an older pavement car, 90in wheel base with a 45in measurement from the rear axle to the back of the engine (front of the motor plate), which is a Beast chassis measurement for good pavement handling.

Like I say, this is mostly for fun, and to see a Sprint car out on a road course. But it would be nice if the beam axle can work decent like it does on the pavement, so the car can be really fast. Of course, here we won't have the rear stagger and offset to help us in turning.

Also, would you use two right rears for the rear tyres or two left rears? Would using LRs let the car turn in better because of less rear grip, with smaller overall contact patches?

THE CONSULTANT

There is some history of open-wheeled oval track cars running successfully on road courses against cars intended for road racing. One famous instance was Rodger Ward's 1959 Formula Libre win at Lime Rock in a midget.

This really was a remarkable feat. The midget was 11 years old at the time and had run about 1000 races. It not only had just 1500cc and one gear, but also had no front brakes. It was up against sportscars with much bigger engines and even a Maserati 250F grand prix car. Most of the sportscars were front-engined, but there was also a Cooper Monaco, which is rear-mid-engined and packs 2.5 or 2.7-litre Climax power.

Lime light

Much of the credit has to go to Ward's driving, but also the track was conducive. Lime Rock is relatively small but is a momentum track with mostly short straights and not a huge variation in car speed compared to many road courses, and all turns but one are the same direction. They're right turns, not left, but it would be possible to use tyre stagger on a locked rear axle (bigger tyre on the left, for right turns) and only have locked axle push on the one left turn. I have no idea whether Ward's car had any tyre stagger, but such a strategy would work better at Lime Rock than most tracks.

Ward had also entered a midget earlier that year in the first US Grand Prix, which was held at Sebring. Sebring is much more a stop-and-go track. It has long straights and some tight turns, and plenty of turns in both directions. The midget did not do so well there, up against the Formula 1 cars.

Turning right

I've been to Waterford Hills. In 1991 I lived in Warren, Michigan, and attended some events there. It looks small when you're there. There is a back straight down the east side, with a fairly fast turn leading on to it, but it's only about a sixth of a mile long and has a fairly slow turn at the end. The rest of the track is mostly turns, and none of them are really sharp. The track runs clockwise, so right-handers predominate, but there are enough left-handers so the car has to turn left well. So the questioner is probably right that the car should be able to do well with just an in-and-out quick change, as long as this is combined with a diff.

This would be an unusual rear axle, but I don't see any reason you couldn't put one together. It would have the usual Sprint car torque tube and centre section, with probably a Winters Track or equivalent worm gear diff

This would be an unusual rear axle, but I don't see any reason why not

US Sprint cars turn left on short oval tracks but this month's question involves adapting one to run at a road course venue. Work would need to be done on the rear axle in particular, but on shorter circuits it could perform very well

IMAGES BY PAUL TULLY PHOTOGRAPHY

UK equivalent to a Sprint car is called a stock car. This one has an aerodynamic package optimised for racing on shale

and closed tubes. Birdcages could be specially made to fit the closed tubes and pick up the existing trailing links and torsion bar arms.

The car will need two rear brakes. I would mount the calipers to the axle tubes, not the birdcages. This is because if they are on the birdcages, anti-lift in braking will vary a great deal as the suspension moves.

Beam axle front ends work just fine on road courses. I'd consider giving both the front and the rear wheels a little static negative camber – probably no more than a degree.

Bias removal

It isn't really necessary to have everything centred in the car. It's just necessary to avoid having the car left-heavy. For a clockwise track, the car might even be fastest if it's a bit right-heavy. If we're replacing both front and rear axles, we can get any right or left percentage we want by moving the wheels to the desired location with respect to the rest of the car. There should be no need to move the engine with respect to the frame.

The car probably should have dual master cylinders, with a balance bar. Finding room for that might entail moving the engine over, but hopefully not. I also recommend running a proportioning valve in the rear brake line in addition to the balance bar. This allows the car to have more rear brake on gentle application than on hard application. This is particularly helpful when it rains – which happens a lot in Michigan.

Ideally, the torsion bar arms and the shocks should be the same distance inboard from the wheels on both sides of the car. This might call for cranked or offset torsion bar arms. However, a little asymmetry here probably won't be disastrous.

The spring rate at the end of the torsion bar arms should probably be the same, or at least very nearly the same, right and left. This calls for unequal size torsion bars, because the bars are transverse, one behind the other, making the right and left arms about two inches different in length.

Bar rates

Sprint car torsion bars are stamped with a 'rate' number that doesn't actually indicate their rate; it indicates the diameter of the active part of the bar in thousandths of an inch, if they're solid, or the diameter of an equivalent solid bar if they're gun-drilled. The rate in pounds per inch at the arm end varies inversely with the square of the arm length and directly with the fourth power of the bar diameter.

This means that to get equal rates from two bars with different arm lengths, the effective bar diameter needs to vary with the square root of the arm length. The numbers on the bars need to be in a ratio equal to the square root of the arm length ratio. For example, if the arms are 12 inches and 14 inches, the number on the bar with the 14in arm needs to be bigger by a factor of the square root of about 1.08. If we have a bar stamped 1000 on the 12in arm, we would want a bar stamped about 1080 on the 14in arm.

Regarding tyre sizes, for this application we are not constrained by any rules. We don't have to run tyres intended for sprint cars. So we probably want the biggest tyres we can fit on the rear. The front tyres should be whatever size gives an acceptable understeer gradient when the car is set up, so it just barely lifts the inside front wheel exiting a right turn.

Unless we plan on staying off the track when it's wet, we'd like tyres we can get with a rain tread, although the wets don't necessarily have to be exactly the same size as the drys. For enjoyment on track days, we probably want a compound that is not highly temperature sensitive. However, the highest coefficients of friction come from tyres that need to be hot (but only when they are hot).

Aero options

If the object is just to have fun, we might want to run without wings, but if the idea is to go fast, we want wings. Probably it's no news to anybody anymore that wings really pay off, and on a slow, short track they need to be as big and aggressive as possible, because the drag is not much of an issue.

Actually, though, for a track day toy, we can run any wings we want, so if wanted we could put as much wing on the car as possible. There's no reason the wings couldn't be passively moveable, as on east coast Supers – mounted with air struts so the wings flatten out as air speed increases. Both front and rear wings could be like that. However, for Waterford the wings would probably be fixed, with little penalty. But we would definitely want the main wing to be adjustable fore and aft, as it is on most Sprint cars.

The side plates on the wings should be symmetrical rather than staggered as on a left turn car. They should be big. And if there are no rules, powered downforce is legal too.

Of course, the more we pursue downforce, the less the car visually resembles a Sprint car. But if the idea is to go fast on a short circuit, there are no rules, and the car has lots of power, then downforce offers the biggest available bang for the buck.

It isn't really necessary to have everything centred in the Sprint car. It is just necessary to avoid having the car left-heavy

CONTACT

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Analysing wheelspin out of tight corners

Recognising wheelspin in the data will put you on the right track to dialling out the problem and increasing your speed on the straights

One of the main areas where a driver can lose time is on the exit of a corner. And one of the biggest causes of this is often wheelspin. It is very common on a lot of race circuits where a slow speed hairpin is then followed by a long straight, and even a small amount of wheelspin on the exit of a hairpin can have a dramatic effect on the acceleration and consequently the top speed by the time you are at the other end of the straight.

Car wheel speeds are key to identifying wheelspin. **Figure 1** shows all four wheel speeds of a car overlaid, with throttle position across the bottom. You can see that the rear wheel speeds are faster than the front wheel speeds as the car exits the turn. The driver reacts to this by reducing the throttle input until the rear wheels regain grip and then he reapplies the throttle.

Most readers are probably aware that the wheelspin can also have an effect on how the car handles. This is much more of an issue on a rear-wheel-drive car, such as this example, than a front-drive. If the front wheels spin, generally the car carries on in roughly the same trajectory as it was before the wheelspin occurs. However, with the rear wheels, the car will rotate or yaw to one side.

Messy exits

This car doesn't have a gyro sensor fitted to it, but you can gather some interesting information and understand how this wheelspin effected the handling by looking at the steering trace. **Figure 2** is the same image but with the steering trace added. You can see that the initial wheelspin was quite gradual and was controlled by a combination of partial throttle application and opposite lock as the rear began to slide. You can also see that after the driver goes back on the throttle, there is another rise in wheelspin that is much sharper than the first. You can see that in this case the driver did not lift off, but managed to catch the snap oversteer with opposite lock, as seen in the steering trace.

If we then compare the overall car speed of this lap against another lap in blue, without much wheelspin and corrective steering, you can see how big the difference is by the time the car has accelerated down the following straight, see **Figure 3**.

Now we have been able to identify the presence of wheelspin,

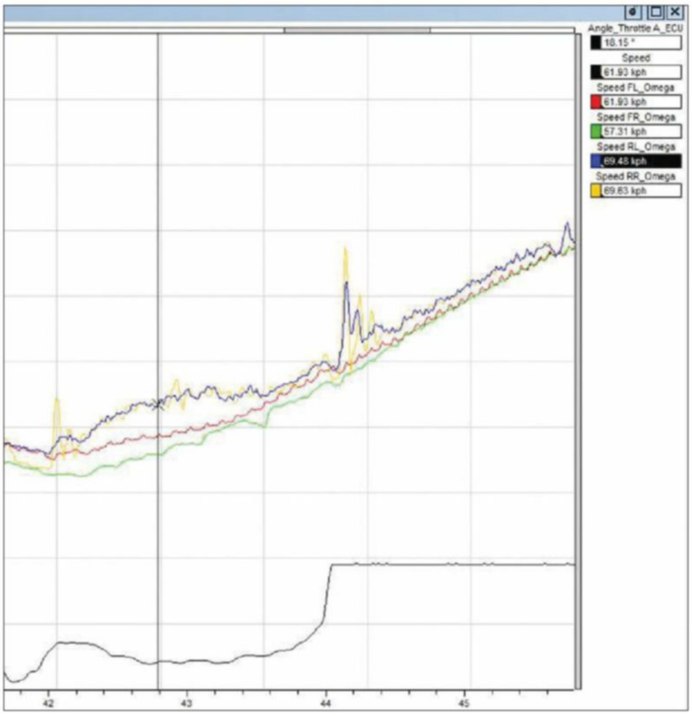

Figure 1: Rear wheel speeds are faster than front as the car exits the turn. The driver reacts by lifting off the throttle until the rear wheels regain grip

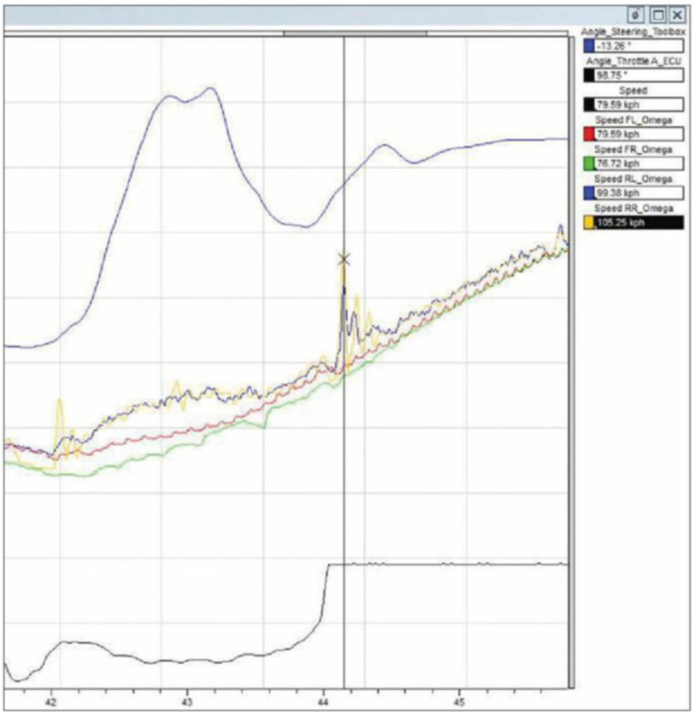

Figure 2: This is the same as Figure 1 but with the steering trace added. Note how the driver catches the oversteer with a deft application of opposite lock

The racecar's wheel speeds are key to identifying the wheelspin

It's easy to blame the driver, but we want to try to improve the car

there are a number of factors that can influence why it occurred. The bottom line is that the amount of power being applied to the wheels by the engine is greater than the amount of grip that the rear wheels have, and the person that controls that engine power delivered is the driver. However, it's easy to blame the drive, but we want to try to improve the car so that it can deal with this and maintain grip. Finding ways to improve this is down to the engineers and the car's set-up, using things such as tyre pressures, camber, and differential settings.

It is a very difficult balancing act, as a good driver will always be driving the car to the limit as much as possible, holding it on the borderline of the tyres' grip and wheelspin in order to go as fast as possible, and will be constantly making small steering adjustments to hold it within the limits. It is the engineer's job to try and increase these limits further. Therefore, the engineer often relies on the driver's feedback as well as the data to do this. It may be that the engineer can make these limits higher, but if this makes it hugely difficult for the driver to hold it at these limits, you will probably actually end up slower, or worse, in an accident if the car is too unstable.

Most GT cars now have traction control to help assist with this and make life easier for the driver to find and hold the limits, but this does rely on good calibration to obtain maximum performance.

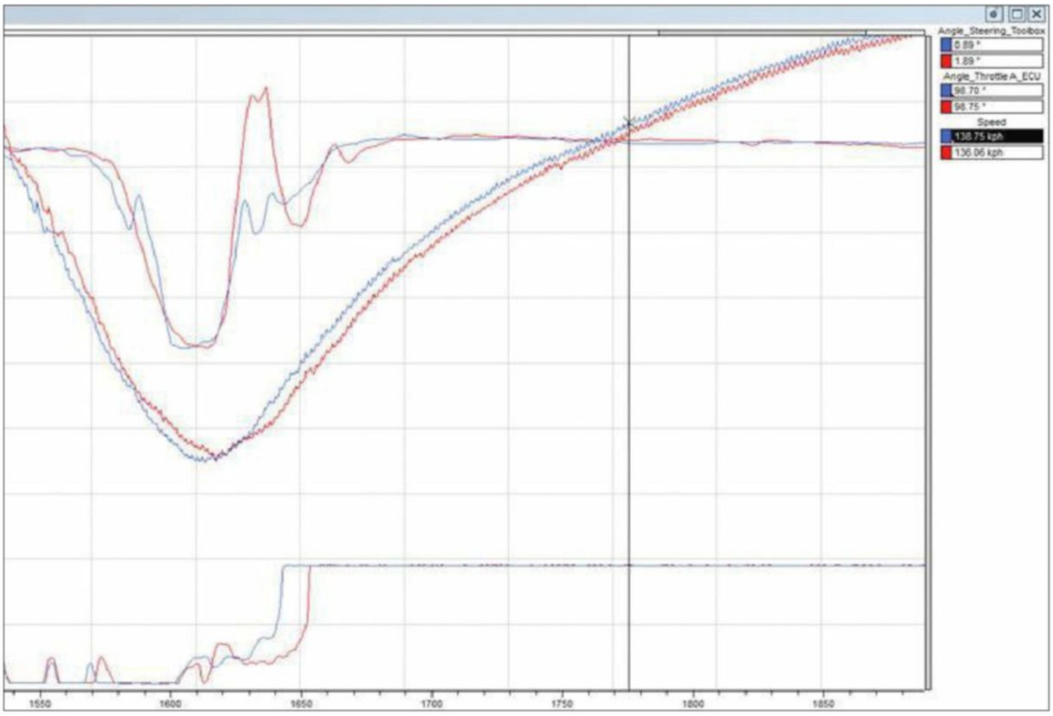

Figure 3: Comparing the overall car speed of the lap against another lap, without as much wheelspin, in blue. You can see how big the difference is by the time the car has accelerated down the next straight. Wheelspin clearly saps speed

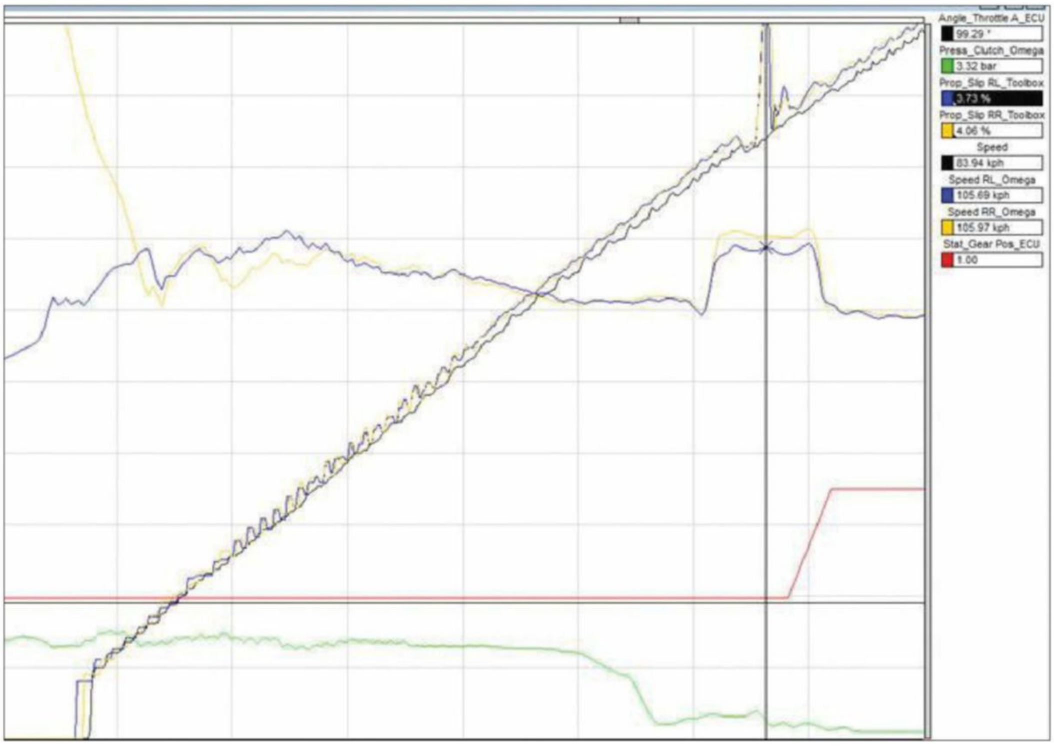

Figure 4: The start of a race. You can see that there is a small amount of wheelspin off the line as the blue and yellow wheel speed traces are slightly above the overall (black) car speed trace. There's also wheelspin during gearchanges

Wheelspin at starts

One other key area where wheelspin is present is in standing race starts. This is the situation when the car is accelerating the most and at full power. It is easy for the power and torque whilst in a low gear to overcome the grip that the tyres can provide. Many drivers have very different styles when it comes to starting. Some hold full throttle and modulate the clutch, others tend to hold the clutch more and modulate the throttle, and some use a combination of both. Either way, the aim is to provide as much power to the wheels as possible, whilst maintaining the grip.

Figure 4 is a race start. You can see that there is a small amount of wheelspin off the line as the blue and yellow wheel speed traces are slightly above the overall black car speed trace. Also shown is the corresponding wheel slip channels as mentioned in previous wheel speed articles, showing the ratio of individual wheel speed to car speed.

Here you can see that we have a small amount of slip, between two and four per cent. This is actually a good thing, as generally tyres operate at their optimum with a small percentage of slip. It can be seen that there is some more notable wheelspin during the gear change from first to second, suggesting that some small improvements might be made here.

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Reducing drag on a Swift Formula Ford

We use flow visualisation to find the draggy bits on an FF1600

Woody Allen is reputed to have said he lived in New York because he didn't trust air he couldn't see. Maybe that city has improved its pollution levels since then, but with his throwaway line Allen (presumably) unwittingly hit upon a problem for anyone wanting to visualise how the air moves around a racecar: we need to make it visible so we can see where it flows. And if we can do that we can then develop a better understanding of how we might be able to influence things to improve aerodynamic performance.

Our new mini-series then goes back to basics in more than one respect, for the subject of our latest session at the MIRA full-scale wind tunnel is a Swift SC92F Kent-engined Formula Ford. This particular example has been used by your writer for his hillclimbing forays in the past couple of seasons, but apart from the timing strut on the nose it is representative of pre-1994 Kent engine FFs worldwide. While except for the wider sidepods that house lateral intrusion structures on later FFs, it's not too far away in overall aerodynamic concept from *any* Formula Ford. Which is to say, with no downforce generation permitted in the rules, the only thing you can do aerodynamically speaking is to make sure drag is kept to a minimum.

Formula Ford designers had been chipping away at frontal area and looking for sleekness – for which read 'drag coefficient' – for 25 years by the time this 1992 Swift was built. The question is then, did they leave anything on the table that's still to be found?

For once, our quest will not be about chasing downforce and aerodynamic balance, but instead in identifying where there are sources of drag that we might be able to do something about. So we started our wind tunnel session by taking a close look at the flows around the car and over its external surfaces with the MIRA smoke plume and trusty wool tufts (any section of track or private road where you can run your car at a reasonable speed alongside a chase car with photographer installed will of course also enable effective wool tufting trials to be carried out).

The first task after installing the car was to affix trip strips to the tyres. These are to better simulate the flow separation that occurs on a rotating wheel, given that the MIRA wind tunnel's floor is stationary and the test car's wheels are, thus, non-rotating. Historical research found that positioning half-inch

For once our quest will not be about chasing downforce and balance

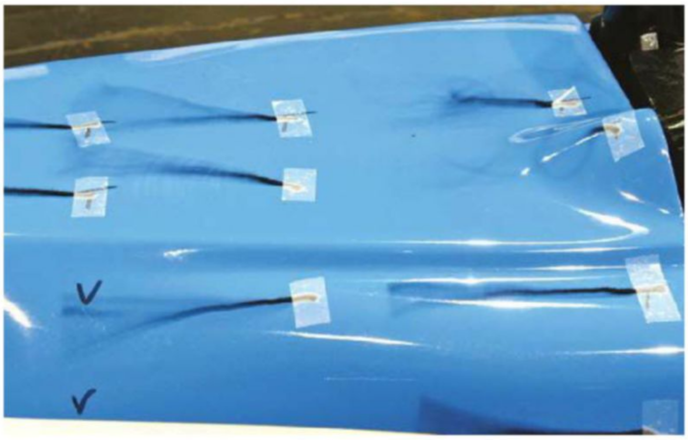
There is no downforce on the writer's Swift SC92F so the focus was on identifying drag sources. Note trip strips on tyres which simulate the flow separation on a rotating wheel

The smoke plume revealed that, usefully, the front wheel wakes partially impinged on the rear wheels, which would help reduce drag caused by the rear wheels and tyres

Wake from the mirrors was quite pronounced and these will certainly be causing drag

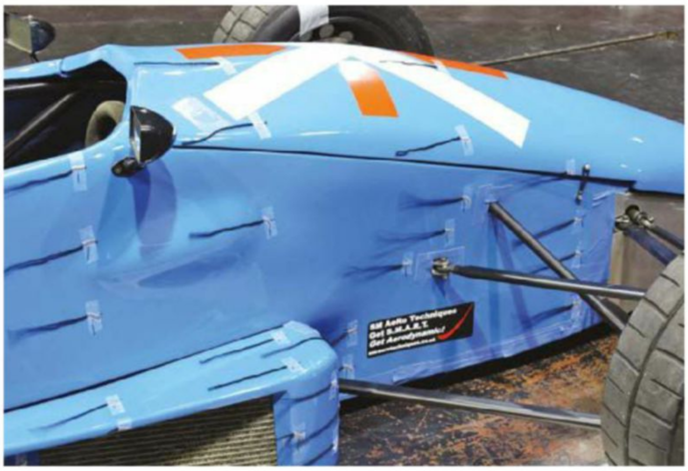
Flow down the rear of the engine cover was not fully attached; this could also add drag

The roll hoop clearly has an effect on the airflow but as a safety device it cannot really be altered. But could changes to the bodywork around the hoop help with reducing the drag?



Note the unsteadiness revealed by the almost invisible wool tuft immediately aft of the near leg of the roll hoop (centre right of the picture). Bodywork mods could help here

The exhaust headers and the regulation-spec silencer will also be adding unwanted drag



Upper centre wool tufts show the front suspension mounting brackets were disruptive

(12.5mm) tapered Gurneys just aft of the tops of the tyres on open wheel cars produced flows (and results) more akin to what is found when the wheels are rotating. In our May 2008 (RCE V18 N5) edition we examined the effect of trip strips on a then current Spectrum Formula Ford and found that they actually reduced the drag of the car by about one per cent. It was felt this extra step towards realism was important enough to include in our current study as we were probably going to be looking at quite small percentage changes.

The MIRA team positioned the trip strips so that their top edges were aligned horizontally with the top of the tyres. Of course there's nothing that can be done about the drag of the wheels and tyres, which are both controlled items. Suffice to say that, usefully, the wakes of the front wheels seemed to impinge on the rear wheels, which would at least reduce the drag the rear wheels might otherwise cause.

Rear view mirrors are not normally mandatory wear in hillclimbing, but the category's Pre-'94 FF class requires adherence to the original formula regulations in this and other respects. The picture on p57 shows the extent of the mirror's wake. So what, if anything, could be done to reduce their drag, given that their minimum area is specified?

The smoke plume passing over the driver's head shows a reasonably clear passage for the airflow over the centre of the engine cover. However, where the engine cover turns from roughly horizontal down towards the rear there appears to be too sharp an angle change because the plume was not remaining fully attached. Does this mean the engine cover needs re-shaping, or could some other means of improving flow attachment be applied? See, for example, *Research on Aerodynamic Drag Reduction by Vortex Generators,* by Masaru Koike, Tsunehisa Nagayoshi and Naoki Hamamot (which is published by Mitsubishi Motors and is available online).

The roll hoop is not something that can be altered but it clearly has an effect on the airflow. Bodywork maximum height is 900mm from the ground and the roll hoop top is 930mm. The wool tufts in centre right of the photograph at the top right of this page suggest fairings around the sections below 900mm could well bring some benefit.

The exposed exhaust system is also obviously disrupting the airflow along the left side of the car. Would a deflector or fairing ahead of the exhaust have a net benefit?

The suspension links may only be manufactured in round or oval tubing, but would fairings to ease flow around the mounts adjacent to the body help? The wool tufts in the centre of the bottom-right image suggest this (along with a better panel fit) might be an improvement. These, and other questions, will be answered in the next two issues.

The exposed exhaust system is obviously disrupting airflow along the left side of the car

CONTACT

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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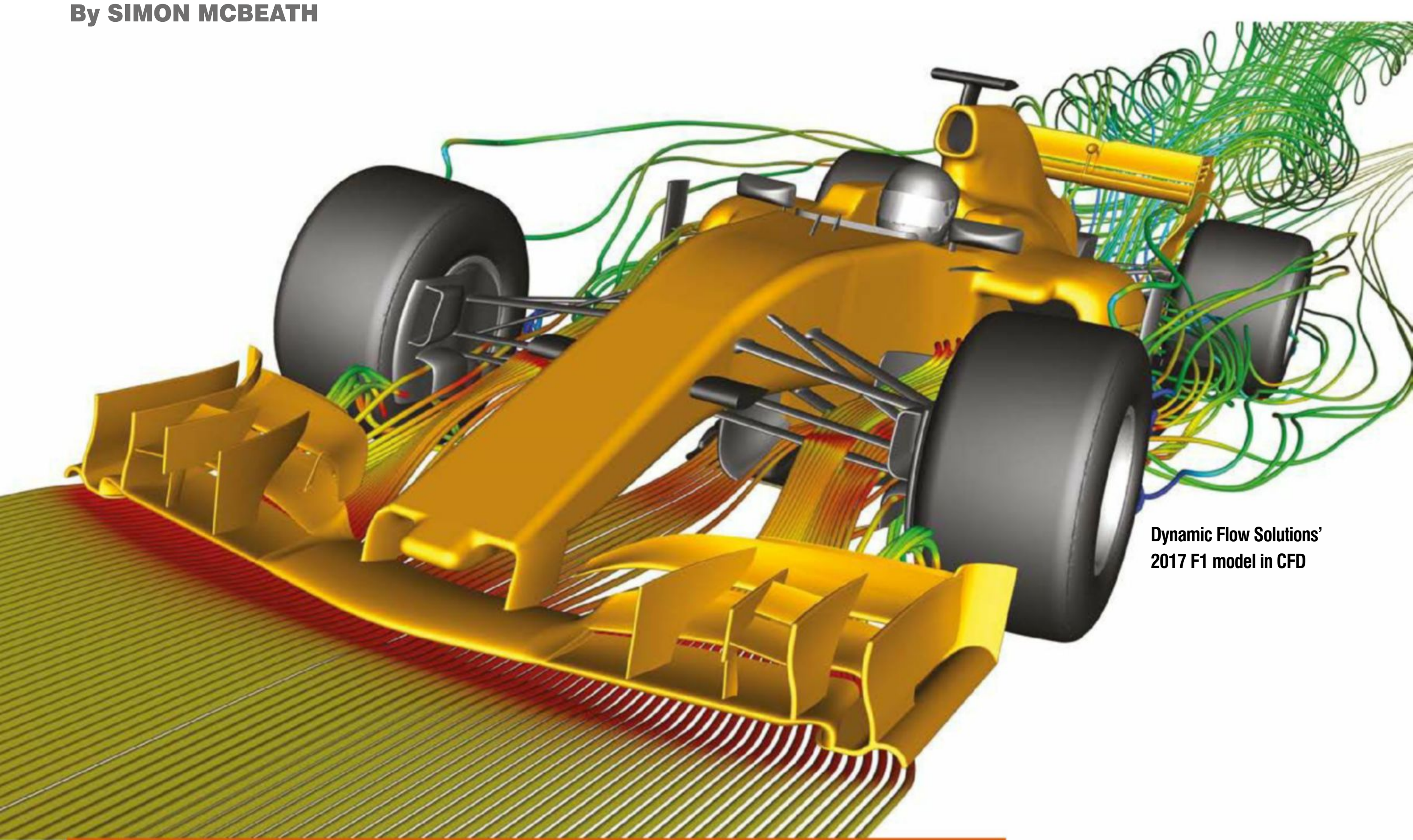
The force awakens

We continue our CFD studies on F1 models with our first in-depth look at what the 2017 higher downforce regulations might bring

By SIMON MCBEATH



Dynamic Flow Solutions' 2017 F1 model in CFD

Table 1: The key changes to the 2017 Formula 1 regulations

		2016	2017
Width	Overall	1800mm	2000mm
Front Wing	Wing Endplates	1650mm span	1800mm span, swept plan view shape (12.5deg), 200mm further forwards at tip. Simplified endplate legality
Rear Wing	Top wing Endplates	750mm wide, 950mm high, main element chord 200mm, overall chord 350mm. Rectangular endplate	950mm wide, 800mm high; main element chord 250mm, overall chord 350mm, mounted 150mm further aft. Swept back endplate in side view and 'tucked' in front view, smaller by virtue of lower max height
Floor	Step plane Reference plane Diffuser	1400 max width; 1300mm min width; Edge radii <50mm constant. Starts 330mm behind front axle. 125mm high, 1000mm wide, starts at rear axle.	1600 max width; 1400mm min width; Edge radii <100mm variable. Starts 430mm behind front axle. 175mm high, 1050 mm wide, starts 175mm ahead of rear axle.
Bodywork	Width Sidepods Bargeboards	1400mm max width No constraint Big exclusion zone behind front wheels	1600mm max width Swept leading edge allowed in top view Reduced exclusions zone allowing for longer, taller bargeboards
Suspension	Legs	+/- 5 degrees profile incidence	+/- 10 degrees profile incidence
Tyres	Front Rear	245mm wide tread 325mm wide tread	305mm wide tread (up 24.5%) 405mm wide tread (up 24.6%)
Weight		702kg max weight	722kg max weight + tyres (45.4% on the front)

With the 2016 season heading towards its conclusion the Formula 1 teams are now focusing on the design and the development of their 2017 racecars. Indeed, many will have had groups labouring away on this well before the rules were set in stone, as far as this was possible. The development race is on and opportunities exist for the ingenious to gain at least a temporary advantage.

Mysterious to some is the underlying remit for the 2017 rules shake up: to achieve faster lap times than the previous rules permitted. Just when you had got used to periodic regulatory resets to rein in performance generally for safety reasons, such as for 2014 to name the most recent example, along comes the governing body to mandate a significant performance

New-for-2017 regulations seem to have forgotten Formula 1's overtaking problem. This year's Spanish GP once again showed that, even with the DRS, it's hard to pass in F1

hike. Furthermore, there appeared to be only fleeting reference to a topic close to many peoples' hearts, and one that *Racecar Engineering* has been periodically studying for the past 18 months, and that's the difficulty of overtaking (except through the use of artificial aids).

Regular readers may have seen our features on various Formula 1 concepts devised and run through CFD by Miqdad Ali (MA), director of Dynamic Flow Solutions, as we investigated the aerodynamic issues of different aero concepts in the drafting situation. But it seems the topic was given rather cursory attention by the governing body with a statement to the effect that the 2017 rules were 'not to make overtaking any harder'. Let's avoid any phrases containing the words 'sand' and 'head' and, instead of pondering why the FIA has done (or not done) what it has, try to analyse the effect that the 2017 aerodynamics might have on the FIA's sought-after performance increase.

All the major and many subsidiary downforce-inducing components have come in for attention, but the picture is far from straightforward, as we shall see. **Table 1** summarises the principal changes, including some that are related to performance if not directly related to aerodynamics. See also **CAD 1** to **4** showing comparisons between our 2016 and 2017 models. (The eagle-eyed will spot that our 2017 sidepod does not have a swept leading edge, but be assured it does fall within the dimensional limits of article 3.8.7 of the 2017 rules).

In essence the major changes, to try to achieve the stated aim of five-second faster lap times, are the significantly bigger tyres and aerodynamic upgrades intended to generate more downforce. Questions at this point centre on how much of the required lap time decrease will come from the tyres and how much from the aerodynamics. Frontal area of the bodywork has been increased, and that plus the bigger tyres will see higher drag values, at the very least to begin with, so simplistically the lap time gains will need to come from cornering, including corner entry and exit phases. Mitigating factors include the 2.85 per cent increase in weight, which will adversely affect all aspects of performance except perhaps maximum speed. If we accept that the 100kg of fuel onboard at the start of a race is worth around three to five seconds per lap, that extra 20kg could add up to one second to lap times. And if the 24-plus per cent gain in tyre width equates to an equivalent amount of extra mechanical grip then it looks like this is where the greatest emphasis is being placed. In which case, how much extra downforce is expected? Let's examine the main changes in turn.

Width

Overall width has been increased by 11 per cent, increasing track and, therefore, mechanical grip potential. And with the increase in body width between the front and rear wheels, even if the sidepods themselves do not grow, there will be a significant increase in the frontal area. The bigger tyres will probably see the drag coefficient increase as well.

So although corner exit speeds will be higher in 2017, end of straight speeds (DRS unaided) may not be much different to 2016.

Front wing

The span of the front wing has increased by nine per cent, but take into account the 12.5deg back-swept styling of the wing and we have a total of 11.7 per cent greater area. However, the centre of the wing is further forwards than previously. And, crucially, the 500mm wide central 'neutral profile' section of the front wing remains the same width, so all of the area increase is in the heavily loaded sections, which will mean the downforce increase will be bigger than a simple area comparison might suggest. However, for this potential to be usable the car will need to be aerodynamically balanced, so the floor and especially rear wing must earn their keep too.

Rear wing

The changes to the rear wing comprise some gains and one significant loss with respect to its downforce potential. It is 26.7 per cent wider with the same chord which ought simplistically to enable 26.7 per cent extra downforce, and with greater efficiency as the aspect ratio (span/chord) has increased by the same percentage. However, by mounting it 150mm lower the rear wing will be in less energetic air and this will take away performance; but how much? Two other factors mitigate against this loss of performance though; the wing will overhang by another 150mm behind the rear axle, thus increasing the leverage felt at the rear wheels; and the reduced height should increase the wing's interaction with the (taller) diffuser. Other changes are an increase in main element chord, which ought to make the main element-to-flap chord ratio more optimal, and an endplate that is not as tall, but this should not make much difference because the endplates are connected to the diffuser (albeit we have seen much complexity in this region). So it's hard to judge how the rear wing will perform compared to this year's.

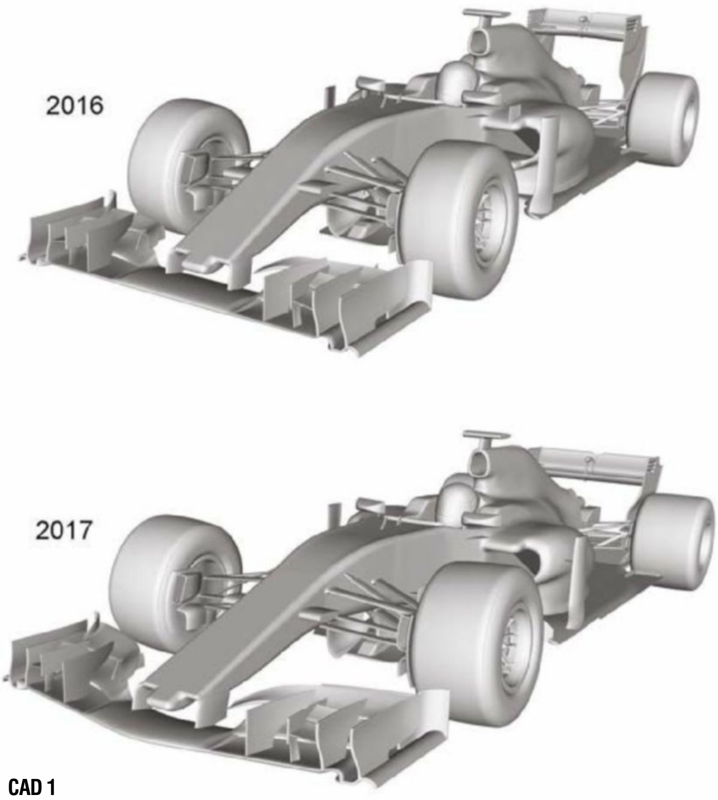
Floor and diffuser

Although the stepped floor is 200mm wider, the central floor on the reference plane starts further behind the front wheels than previously, and the overall length of the floor will be dependent on what wheelbase the teams elect to use. The diffuser volume has been increased by up to 120.5 per cent (using length multiplied by half the height by the width as a simple metric), and although still small it will be the primary mechanism for the increase in underbody generated downforce. The increased freedoms with respect to bargeboards will also be used to help with downforce from the forward floor, and the above-mentioned closer proximity of the rear wing will slightly strengthen the interaction with the diffuser to the benefit of floor downforce. However, the wakes and other effects of the much bigger tyres will detract from floor and diffuser performance, so again the picture is far from straightforward.

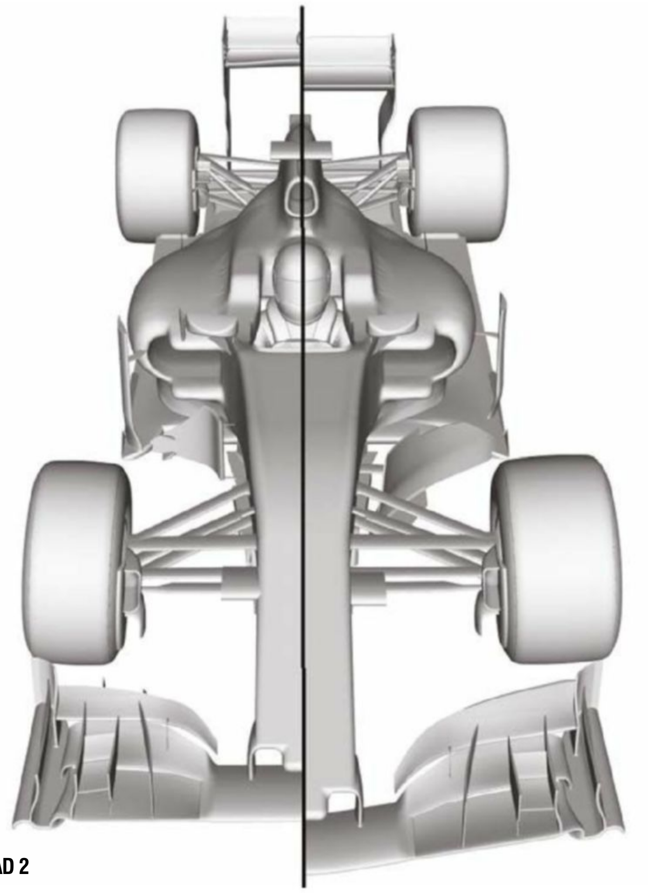
Downforce predictions

More than one Formula 1 expert stated when the regulations were published that downforce increases of around 25 per cent should be expected on the 2017 cars. However, in an interview in September 2016 Pat Symonds, the chief technical officer at Williams was rather more

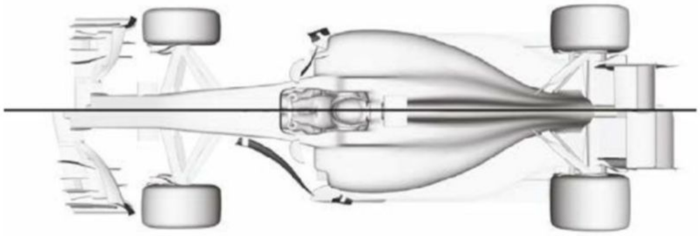
Mysterious to some is the underlying remit for the 2017 Formula 1 rules shake up: to achieve faster lap times than the previous rules permitted



CAD 1



CAD 2



CAD 3

Our 2017 F1 model featured the aero changes set out in the regulations. Perspective makes the centre of the 2017 front wing (right of image CAD 2) look lower, but it's not

circumspect, saying that 'the 2017 cars do have a bit more downforce' which seems to fall short of the 25 per cent value. In October, however, he was quoted as saying 'the gains we are making on aerodynamics on next year's car are just staggering', which may simply refer to the number of gains made, or to their magnitude; you can take your pick on that one!

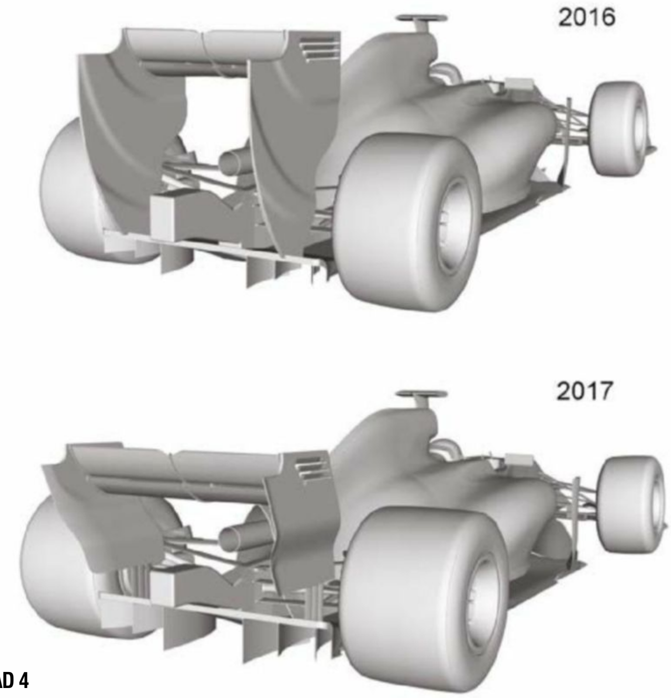
The foregoing discussions would imply that the total gain will be very dependent on what the car's floor can achieve. The front wing may be capable of substantial gains but unless the rear wing can generate around the same gain to preserve a similar balance (assuming the floor's overall centre of pressure is somewhere near the centre of gravity) then it may not be possible to utilise the wings' full potential. In that scenario, unless the floor generates significantly more downforce we could only be looking at a modest overall increase. On the other hand, if the floor's contribution rises significantly, that figure could be higher, but to gain 25 per cent overall would need a *big* increase in floor downforce. Getting big increases with the right balance will not be easy.

Simulations

In our previous Formula 1 CFD simulations MA had initially constructed a CAD model to 2013 regulations, which served as our baseline model in previous articles wherein we evaluated our own potential concepts for 2017.

However, in order to put the data on a model to the FIA's 2017 regulations into better perspective it was also necessary to construct a 2016 rules model, otherwise our comparisons would have little meaning. The time involved in the double dose of CAD meant that we have just been able to take a first look-see at the 2016 and 2017 models, a situation analogous perhaps to what would have happened in the F1 teams' CFD departments when they too ran their first models to the latest regulations. So the data in **Table 2**, comparing our 2013, '16 and '17 models, is on non-optimised versions in the latter two cases, but importantly all the data are at comparable balance levels. With the mandatory Formula 1 front to rear weight distribution of just over 45 per cent on the front, an optimised aerodynamic balance would see around 45 per cent of the total downforce on the front. In these cases the first iteration of the 2016 and 2017 models saw 49 to 50 per cent front, so the data for the 2013 model at that same balance level was also used for our comparisons.

It's noteworthy what a significant decrease there was in downforce from the 2013 rules model to the 2016 rules model as we ran them here. The regulations for 2014 (to 2016 as



CAD 4


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Table 2: The basic aerodynamic parameters on our FIA rules Formula 1 models

	CD	-CL	-L/D
2013	1.17	3.94	3.36
2016	0.87	2.84	3.27
2017	1.20	3.91	3.26

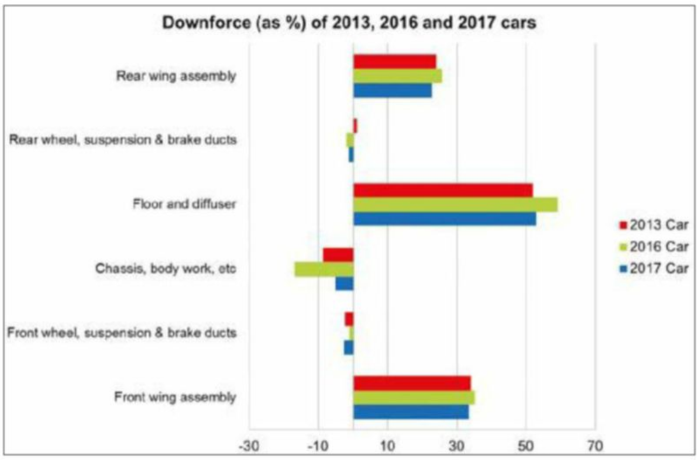

Figure 1: This shows the downforce contributions from the major component groups that make up the 2013, 2016 and 2017 *Racecar Engineering* Formula 1 car models

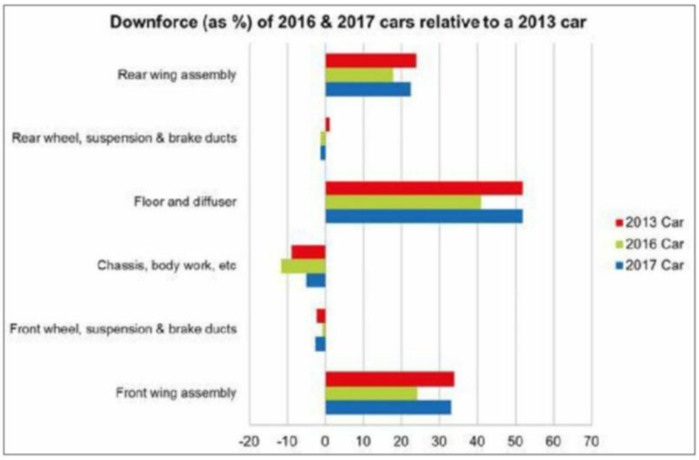

Figure 3: The downforce contributions adjusted relative to the 2013 Formula 1 car model to help show more clearly how each of the component groups changed

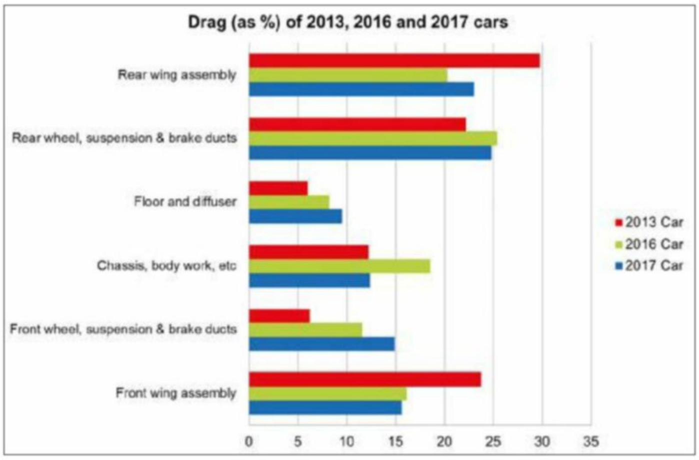

Figure 2: Drag contributions from the major component groups on the three racecars

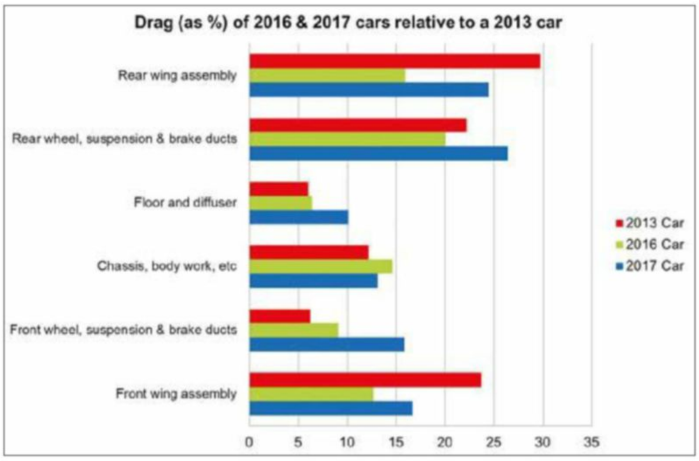

Figure 4: Here the drag contributions are adjusted relative to the 2013 Formula 1 model to help illustrate more clearly how each of the component groups changed

More than one Formula 1expert stated that downforce increases of around 25 per cent should be expected on the 2017 cars

it transpired) included the narrower front wing, which had previously been 1800mm wide (as it will be again in 2017), but the height of the nose was also lowered, which would have had a negative impact on underbody generated downforce.

Furthermore, the rear wing was less potent in the 2014 to 2016 regulations, which required a balance adjustment that would have lost further total downforce.

So, although our 2016 rules model was not optimised, nor was our 2017 model at this stage. As the data here is presented at a comparable balance level, we can see that the difference from the 2016 to the 2017 car was also pretty significant. Total downforce was up by over 37 per cent in this comparison, which is actually in excess of even the optimistic predictions cited earlier. We must take into account that neither of the models was balanced, and that if the 2017 model has to shed front downforce in order to find the correct balance, the increase over the 2016 model's downforce level may be somewhat less. But it does appear that most of the aero performance of the pre-2014 cars will be easily recovered, and no doubt constant development will see that go on to new levels.

MA made the following comments on these first runs: 'From the numbers we have [in **Table 2**], the downforce loss from 2013 to 2016 was around 28 per cent and the downforce gain from 2016 to 2017 was 37.6 per cent – these were just by making the geometry changes without optimising the cars. However, it is also possible that the 2016 model could claw back most of the lost downforce and the 2017 model is already close to its peak potential. In that case the 37.6 per cent figure could be a lot less when optimised models are compared, but this is still a good indicator of the 2017 car's potential. The same could be said about drag figures too. I have a feeling the 2016 model needs more work compared to the 2017 one, and the delta would have been more like 25 per cent to 30 per cent at this stage if the 2016 car was a bit better. If the numbers for the 2016 car were, say, 10 per cent better, realistic and easily possible with some work, making the numbers more like CL = -3.12 and CD = 0.96 with the L/D constant, the downforce delta between 2016 and 2017 would have been 25 per cent

Total downforce was up by over 37 per cent in this comparison, which is actually in excess of even the more optimistic predictions

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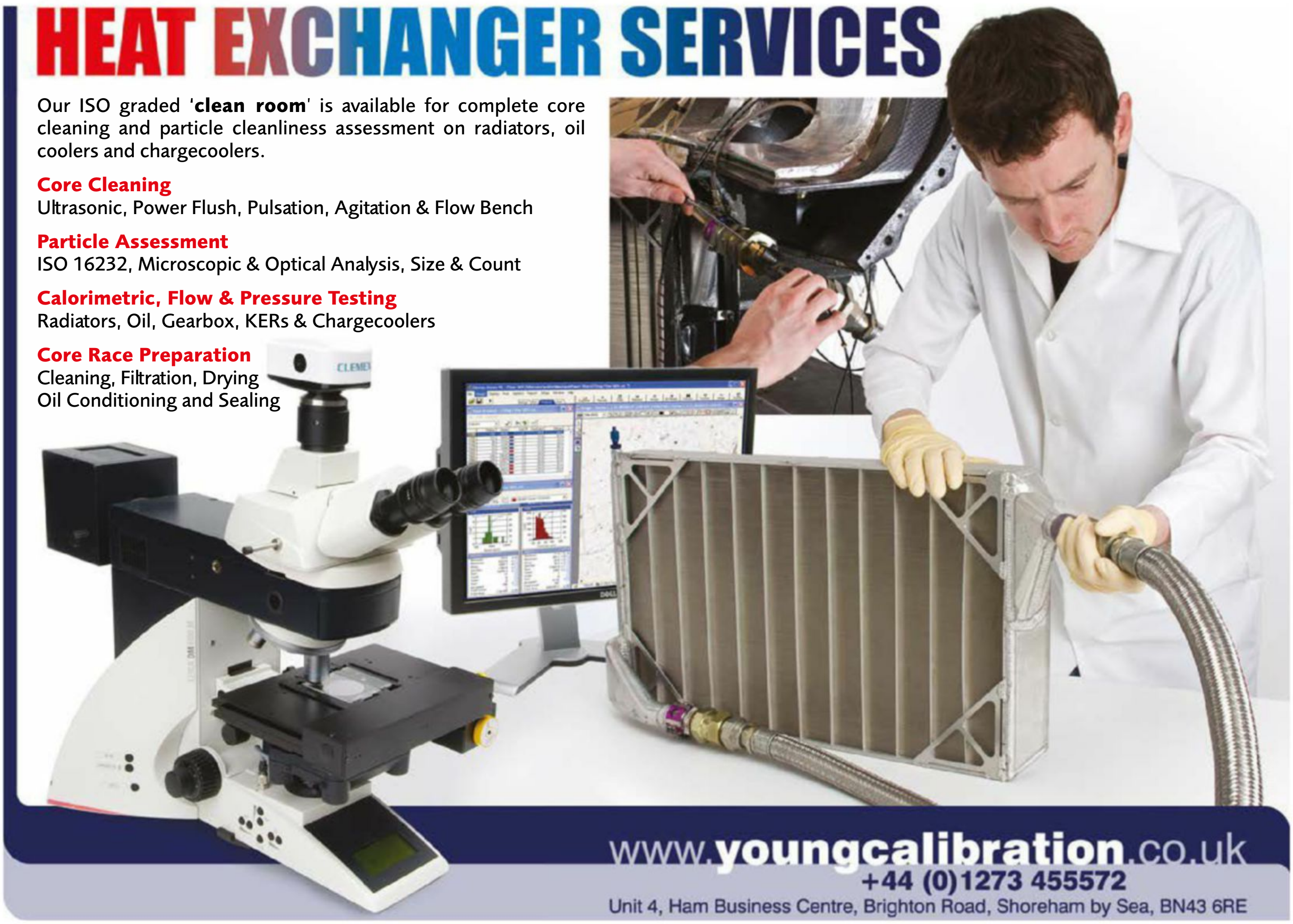

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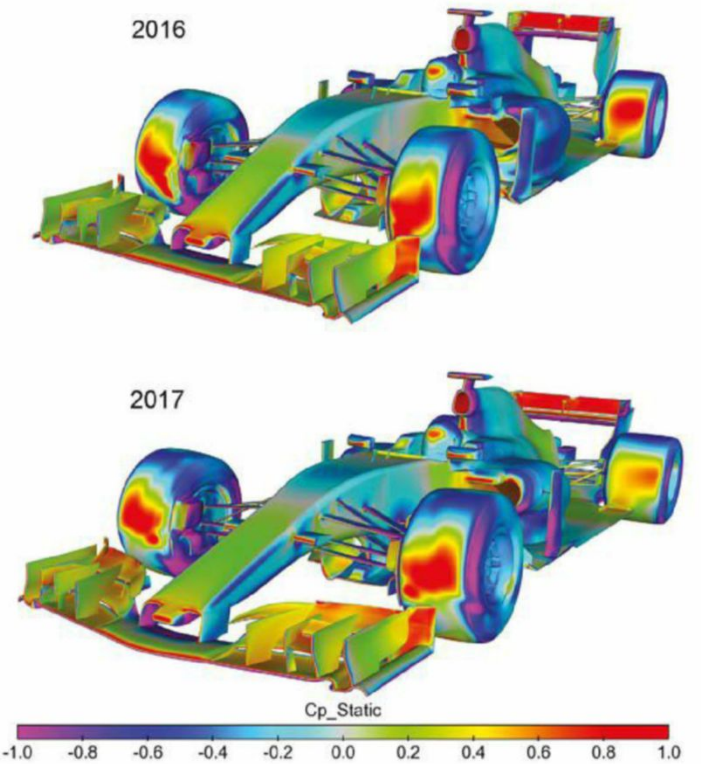

Figure 5: Surface pressures on '16 and '17 cars show minor differences from this angle

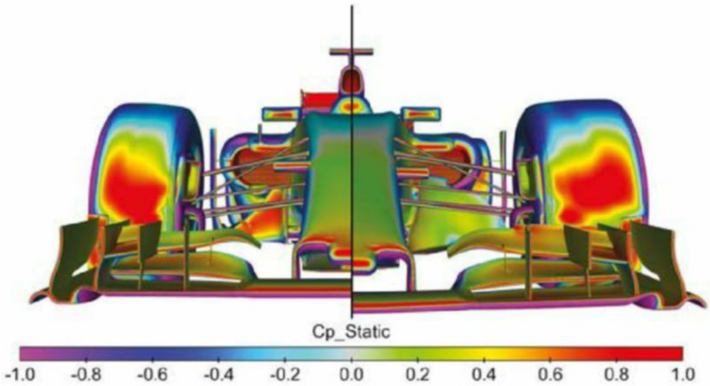

Figure 6: The static pressures viewed from head on show some differences

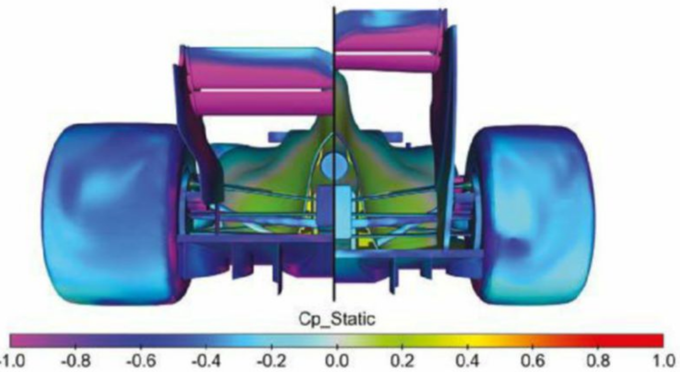

Figure 7: Viewed from behind it is possible to see the lower pressures in the 2017 racecar's diffuser (to the left of the image) and also on the back of its rear tyre

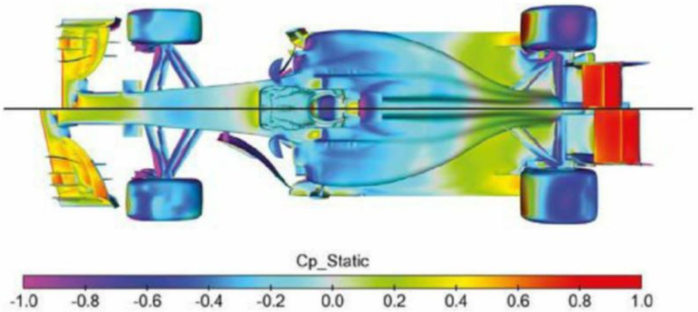

Figure 8: From above small local differences in surface pressures are visible

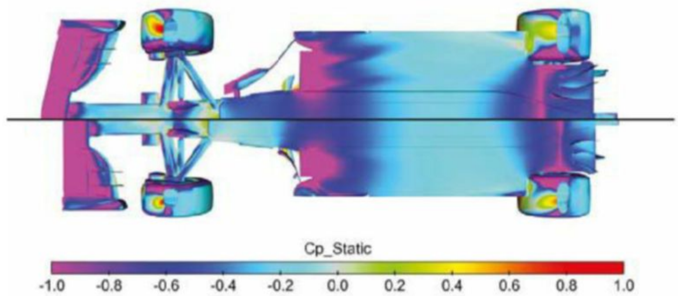

Figure 9: Differences in surface pressures on underside were evident. The 2017 car (top) makes more underbody downforce and front downforce is made further forwards

and that would be in line with some of the predictions quoted in the press.'

Component contribution

So it would appear that the 2017 rules model developed quite a lot more downforce than the 2016 rules model. Where did this come from? As ever, CFD enables a breakdown in the contributions from each major component group, and **Figure 1** and **Figure 2** show from whence the force contributions of our three models come. Of the three major downforce inducing component groups, the front wing contributed roughly similar proportions of each car's total downforce. However, applying these proportionate values to the models' overall downforce values it is apparent that the 2017 model's front wing produced almost a third more downforce than the narrower 2016 front wing. This was well in excess of the proportionate increase in even the heavily loaded wing area discussed earlier, which goes to prove once again that simplistic assumptions can be foolhardy.

The floor and diffuser produced, in this first iteration of the 2017 model, around 53 per cent of the model's total downforce whereas the floor and diffuser of the 2016 car generated almost 60 per cent of the total. However, applying these proportions to the total, again it's apparent that the 2017 floor and diffuser actually generated around 24 per cent more downforce than the 2016 one.

The rear wing comparison shows us that the 2017 rear wing produced a smaller proportion of the total than did the 2016 rear wing, but once again, applying the proportion to the total we see that the 2017 rear wing actually gave around 17 per cent more downforce than the 2016 wing, and as the 2017 wing is further aft then it will be applying more leverage again at the tyre contacts.

So downforce increases occurred on all three major downforce producers, and there was also less lift from the chassis and body. But the front wing seemed to fare better than the rear wing; hence balance was too far forwards at this early stage.

As far as drag sources go, the relative contribution from the front wheel/suspension etc. can be seen to have increased on the 2017 model, and although the rear wheel/suspension group's relative contribution was slightly less than the 2016's, when multiplied by the total drag it had in fact increased markedly. All of the downforce and drag comparisons are made clearer in **Figure 3** and **Figure 4**, which show the contributions relative to the 2013 Formula 1 car model.

Looking at the comparative static pressure plots in **Figures 5** to **9**, the surface pressure distributions show relatively minor differences between the 2016 and 17 models until one looks underneath (as illustrated in

Downforce increases occurred on all three major downforce producers, and there was also less lift from the chassis and body


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It seems the new rules will generate a significant hike in downforce

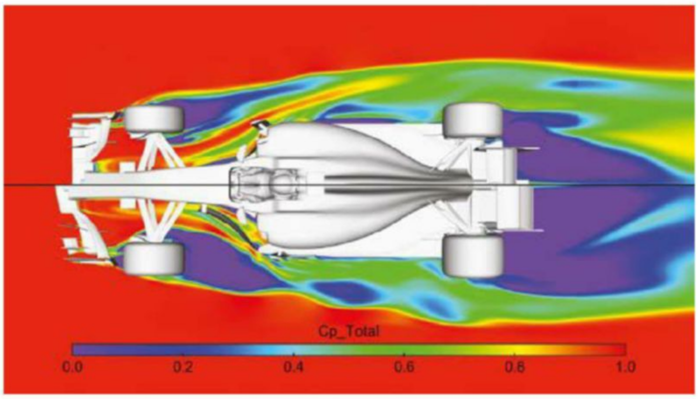

Figure 10: Total pressure slice 100mm above the ground plane shows the larger wheel wakes of the 2017 car (on the bottom of the image) relative to the 2016 racecar

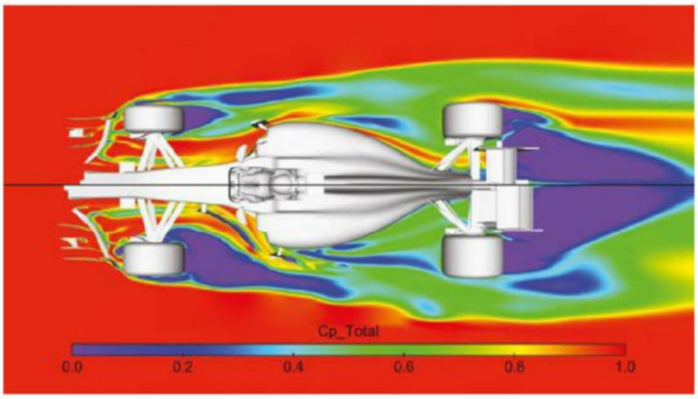

Figure 11: Total pressure slice 200mm above the ground again shows the larger wheel wakes that are expected to be generated as a result of the 2017 regulation package

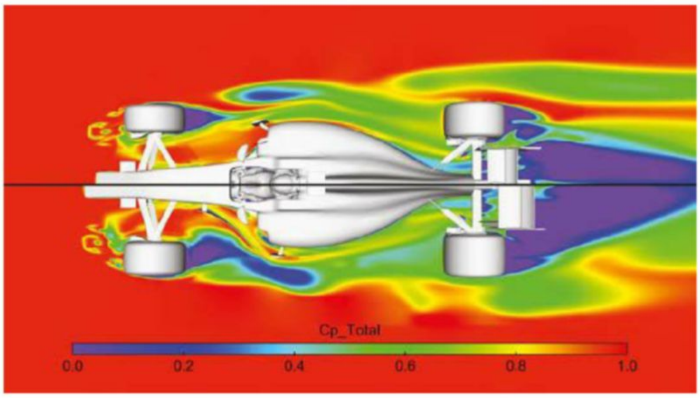

Figure 12: Total pressure slice 300mm above ground with 2016 car at top of image

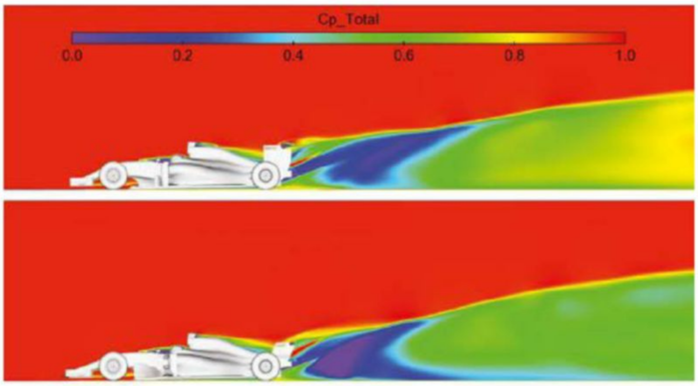

Figure 13: The total pressure slice on the symmetry plane, highlighting the wakes of the 2016 (top) and the 2017 models. It does not look like overtaking will be easier in 2017

Figure 9). Starting at the front, the 2017 front wing obviously develops its downforce further forwards.

Moving aft, although the 'tea tray' splitter starts 100mm further behind the front axle on the 2017 car, there is clearly lower pressure on its underside than on the 2016 model. In the forward floor there is slightly more widespread low pressure on the 2017 model, with notable 'spikes' resulting from vortices; and of course the floor is 200mm wider so this low pressure is spread over more area.

Moving further aft again, the diffuser transition is more forwards on the 2017 Formula 1 car and the suction peak is more pronounced and extends further forwards from the transition. On top of this the pressures in the 2017 F1 car's diffuser are generally lower too.

It would appear then that the 2017 rules will generate a significant hike in downforce, and lap times should indeed be faster during the 2017 F1 season. But what effects will the new aerodynamic package have on following cars? In the next stage of our studies MA will once again conduct a set of two-car simulations in line astern at different separations.

Overtaking potential

For now though, take a look at **Figures 10** to **13** which use total pressure slices to highlight aspects of the wake structures of the 2017 model compared to the 2016 model. Remember from earlier in this piece we mentioned that the remit to the rule writers was to not make it any more difficult for cars to overtake in 2017, and then judge for yourself if the wakes of the 2017 model look better, similar or worse than the 2016 model's in this respect.

MA commented that at this early stage there are aspects of the 2017 model that will benefit from optimisation, including the bargeboard and other turning vanes, which among other things will enable the front tyre wake to be better managed. But it is hard to see that much could be done with the rear tyre wakes, and it seems likely that there will be significant loss of downforce on a following racecar with what is probably going to be a larger, dirtier wake.

A key issue, though, will be what happens to the aero balance of following cars. One of MA's most successful configurations was showcased in February 2016 (RCE V26 N2). This was a modification of a 2013 car with a bigger diffuser and lower, less cambered rear wing (echoes in the 2017 rules perhaps?) and while it obviously lost downforce when following, there was negligible balance shift at any separation.

This is felt to be important because the loss of downforce on a following car will not be accompanied by the usual terminal aerodynamic understeer, and that ought at least to make following somewhat easier.

Will the FIA's 2017 Formula 1 aerodynamic package bring this same benefit? We will see …

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Dynamic Flow Solutions Ltd is an aerodynamics consultancy led by director Miqdad Ali, ex-MIRA aerodynamicist, who has performed design, development, simulation and test work at all levels of professional motorsport from junior formula cars to World and British touring cars, Le Mans prototypes, up through to F1 and Land Speed Record cars.

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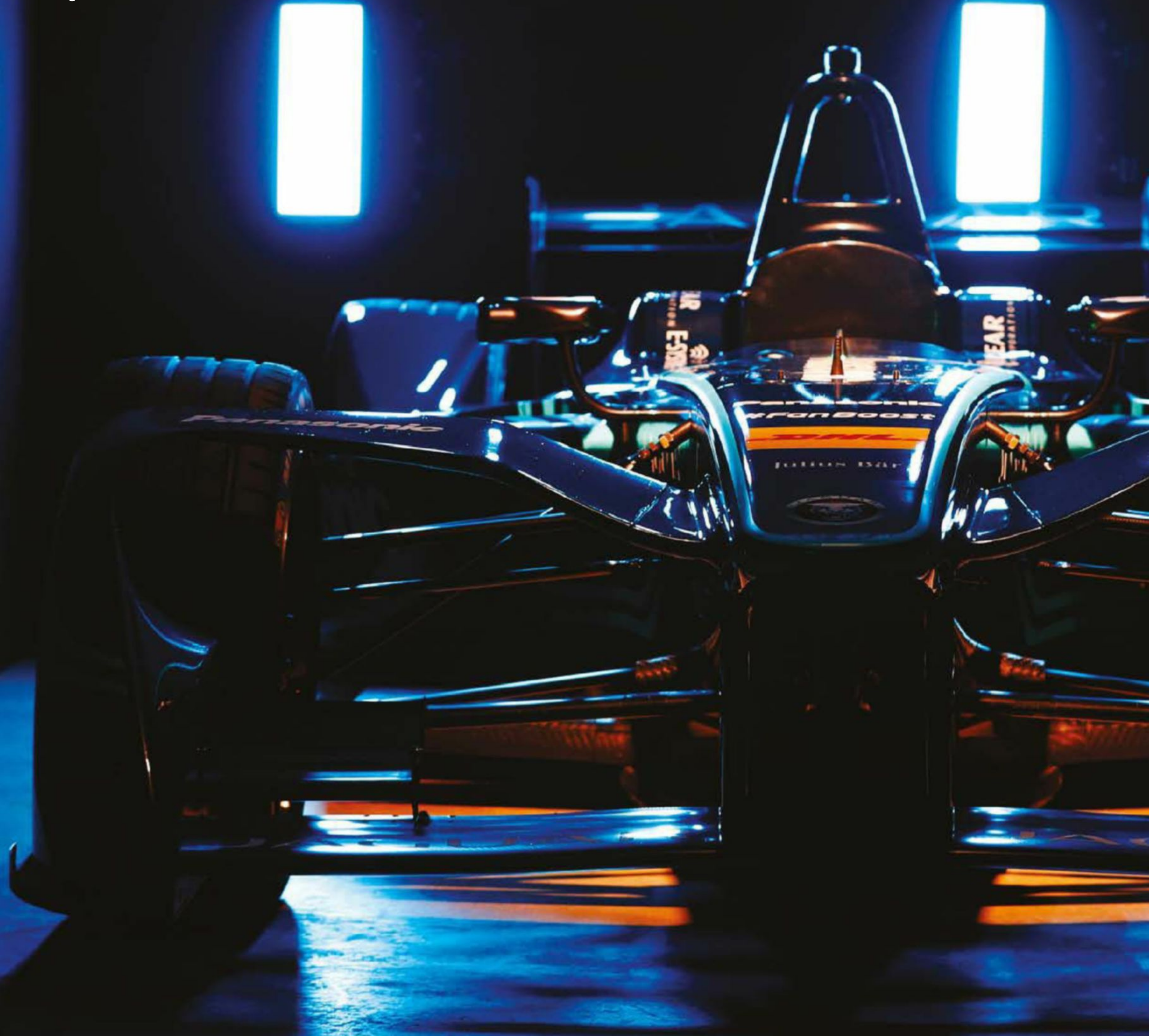
Batteries included

With hybridisation and electrification buzz-words in modern motorsport the role of the battery has changed significantly. *Racecar* spoke to those in the know about the positives and negatives of battery development

By LEIGH O'GORMAN



'In an ideal world you would like to cool the battery inside the cells, but that's a difficult task'

I n a sport that has previously celebrated brute engine power and sleek and astonishing aerodynamic prowess, the introduction of hybrid power units in F1 and LMP1 has now forced attention upon batteries, too. Add to that the creation of Formula E in recent years and the growing quest to achieve electric land speed records, and the technological shift within motorsport becomes even more obvious.

In this feature examining the current state and the future of battery technology, *Racecar* gathered the opinions of John Stamford (head of electronics, Mercedes Benz HPE); Yusuke Hasegawa (head of Honda's F1 programme); Thomas Laudenbach (head of Electronics and Energy Systems, Audi Sport); Paul McNamara (technical director, Williams Advanced Engineering); and Giorgio Rizzoni (director and professor of Electrical and Computer Engineering at Ohio State University).

Lithium-ion

To begin with, there's little doubt that lithium-ion stands as the most prolific form of battery chemistry now in use. Put simply, these batteries operate when lithium ions sweep from negative to positive electrodes and back again when charging, while electrodes and an electrolyte form the structure of a lithium-ion cell, allowing for electrical mobility.

The relative simplicity and reliability of the compound has ensured it has become the dominant technology, especially when taking into account the mass market of home electronics. McNamara, at Williams, which has developed and currently supplies the battery for Formula E, says: 'Lithium-ion is a sort of default. There are a fair few subtleties around that, but basically whether it is in your laptop or your phone or pretty much anything, it is the most effective chemistry for the specific energy storage.' He balances this by saying: 'There is trade off within a given chemistry, which is the amount you want to store versus the amount of power you want to take out.'

Yet lithium-ion batteries also enjoy an increasingly significant role in motorsport and, according to Laudenbach, there are numerous advantages compared to other technologies in the field. 'If you compare it with super-capacitors, a Lithium-Ion battery has a larger energy content. This is an advantage if you run in a higher energy class. The energetic storing capacity, the power and weight of Lithium-Ion technology based cells is quite good,' Laudenbach says.

Rizzoni agrees, to an extent, with the Audi man. He is a veteran of designing landspeed record attempts alongside his students at Ohio State University. Its latest effort, the Venturi Buckeye Bullet 3, broke electric landspeed records in 2015. In running the all-electric VBB-3, Rizzoni and his team opted for lithium-ion phosphate cells due to their excellent behaviour under extreme temperatures and also their ability to lend themselves very well to extreme power output, where the cathode material can be enriched with a little extra carbon, ensuring very little resistance while increasing the deliverance of very high currents. However, Rizzoni also believes that lithium-ion does have its limitations. 'The drawback of lithium-ion phosphate cells and the reason why you don't see them used too much in production vehicles – if you look at the plug-in hybrids or the electric vehicles that are in production today, they don't use that chemistry, they tend to use transition metal oxide batteries like lithium-manganese oxide (LMO) or nickel-manganese oxide chemistries. Those chemistries have much better energy storage capabilities and they also have a higher voltage, so lithium-ion phosphate cells would be about 3.3 volts when fully charged, whereas an LMO cell could be as much as 3.7 volts.' He adds that higher voltage proved better, because fewer cells are necessary. 'In our case the focus was safety, temperature, performance and the ability to deliver really high current, so power was the constraint and in that sense we have done quite well.'

Rizzoni also points to a constant path of progress being made by materials for cathodes, anodes and electrolytes as key to the continued development of lithium-ion batteries; but acknowledges: 'We're still talking about the same basic lithium battery, but with better materials if you will. Improvements are taking place rapidly and the costs of these batteries is also dropping – the lithium battery as we know it today continues to improve in all directions.'

Hasegawa also acknowledges that due to the nature of the Lithium-ion battery there is always a concern over the chance of a fire, or thermal runaway, and that it is also in the nature of the battery to deteriorate over time or with multiple uses. 'There are also severe restrictions on climate control and electric usage conditions,' says the Honda F1 man. Laudenbach adds: 'The biggest disadvantage of Lithium-Ion is that it's classified as a dangerous good when it comes to transport, whereas [supercapacitators] or a flywheel are not dangerous goods, because there is no energy left in the system when discharged.'

The hard cell

For all its positives and negatives, McNamara feels that one needs to consider the balance of type of usage, reliability and performance expectations when analysing the potential of battery cells. 'Williams are not a cell chemist; we are experts in understanding it, we do cell level tests here so that we can work out what the thermal characteristics and the electrical characteristics of the cell is, so that we can work out the design of the cooling and the

'Experience has got to be gained before it goes into consumer products and we in motorsport are usually at the front end of that'

retention system for it. If you want to take out a lot of power from the cell, the way you end up designing it, with its dimensions and ability to cool, means that you store slightly less energy and the other way around. So when you are selecting a particular chemistry in the lithium-ion family and how a particular design house for the cell is made up dimensionally, you have to look at the power-to-energy trade off.'

Williams use pouch cells in Formula E. 'They are continually producing year-on-year better and better chemistries as well as looking at the interaction of the chemistry with the way it is stored,' McNamara says. 'They push those boundaries; we get data from them as to where they've gone with that and to what extent we can make use of that within the cell.'

Whereas Rizzoni and his team are free to design their energy storage units to their own vision, the designs of Stamford, Hasegawa, Laudenbach and McNamara all operate to a regulated output cap of some kind, whether that be over the course of one lap, three laps or an entire race distance.

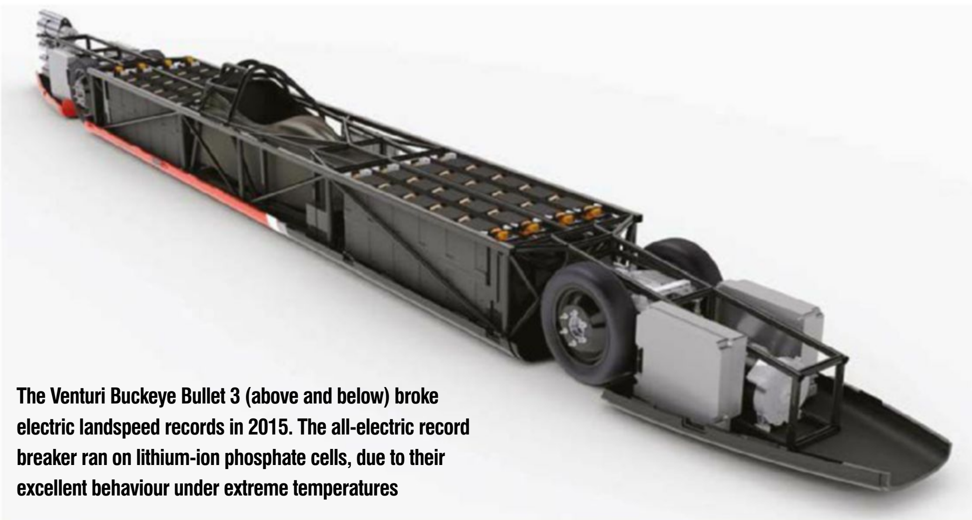
Power density

Despite the artificial regulatory ceiling in F1, Mercedes HPE's John Stamford is keen to emphasise progression that is still being made. 'The progression from KERS to where we are now with ERS is about increasing that power and bringing it up to a very healthy energy density number, while trying to get the reliability and increase efficiency to try and minimise the losses in the systems,' he says, adding: 'The regulations limit us to 4MJ, but I anticipate with the current technology of batteries, there is approximately double that amount of energy that could be available. We do keep an eye on up-and-coming technologies for potential future use and certainly if the regulations are enhanced going forward, then new technologies will be required.'

This began back in F1's short-lived KERS experiment in the late 2000s. 'We took the best road car lithium-ion cells and focused very heavily on increasing the power density for the KERS application,' Stamford says. 'We managed to increase the power density by a factor of around 10 back in 2009 and since the 2014 ERS introduction, we've also needed to further increase that power density and at the same time more than double the energy density of the batteries. The progression from KERS to where we are now with ERS was about increasing power capability and bringing the cells up to a level where they can store sufficient energy, whilst also improving reliability and efficiency. Improving the cells' efficiency in common with the rest of the powertrain tends to be beneficial in all areas.'

McNamara also foresees developments in the technology surrounding the Formula E battery. Originally designed to have an in-race nominal power release of 130kW, the series increased this to 170kW for season two. 'I think we, and the series, have generally accepted that we are at about the limit. The max level of 200kW has always been there, but we are talking about squeezing that up by another 10 per cent over the next couple of years as well,' he says.

Lithium-ion is not the sole battery chemistry available to regulators and manufacturers – it's just that it is the most prolific at *this* time.



The Venturi Buckeye Bullet 3 (above and below) broke electric landspeed records in 2015. The all-electric record breaker ran on lithium-ion phosphate cells, due to their excellent behaviour under extreme temperatures

Demonstrated attributes of differing battery technologies

	Maturity	Battery performance (pack level)				
		Specific Energy (Wh/kg)	Energy Density (Wh/l)	Power (W/kg)	Current Life (cycles)	Abuse Tolerance
Lithium-ion (current status)	Pack	50-80	100-150	500-750	>5000	Meets SAE J2929
Lithium-ion (future generations)	Cell 20Ah+	155	205	800	~500+	Not known
Lithium metal-polymer (solid)	Cell 10Ah+	150	250	<100	~1000	Flammability and volatility
Lithium metal/Sulphur	Cell (Lab)	250-400	180-250	<100	~100	Concern
Lithium metal/Air	Lab Devices	400-600 (approx)	200 (approx)	Poor	Not known	Concern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Burgeoning compounds such as lithium metal sulphur and lithium metal air (amongst many others) and also high energy density solid-state battery chemistries are in development.

However, despite the interest in these compounds in the academic world, there is much to be done if they are to break into the marketplace, as Stamford explains. 'At the moment, lithium-sulphur and lithium air don't possess the power capability that lithium-ion cells have today, although they are developing in terms of energy density, so the biggest issue with some of those newer technologies is probably their power capability. But, as they are being continually enhanced and developed, we keep a watchful eye on them for the future.'

'We managed to increase power density by a factor of around 10 in 2009'

Chemistry set

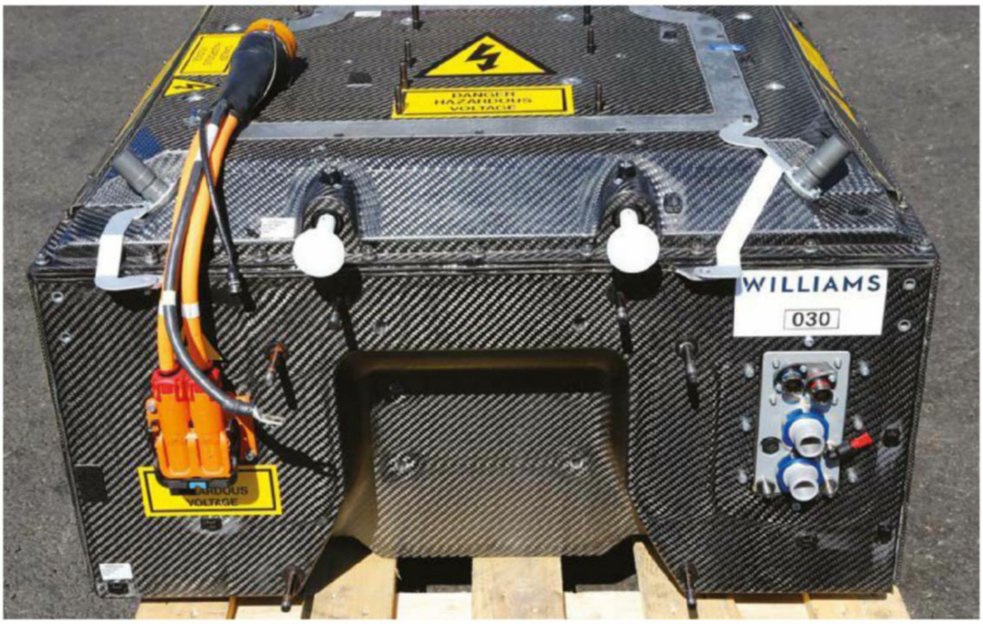
Rizzoni keenly follows the development of newer chemistries, but he says that mass-market penetration may be many years away and adds that the likes of lithium metal polymer and solid polymer electrolyte are at the cell level, with much work to do. Lithium metal sulphur and lithium metal air are still, according to the US Department of Energy, laboratory grade devices. 'They're not even commercial grade cells in shape, they are what we call button cells or coin cells,' Rizzoni says. 'They are small experiments that you do in a laboratory that really don't store enough energy or deliver enough power to be useful for anything except a science experiment. We are talking about laboratory grade prototypes; not something that is anywhere near commercialisation yet, so my forecast is that for the next five years we will continue to see improvements in the existing chemistries and materials – improvements that will be substantial, but I don't think that we are going to see new battery chemistries commercially available. They are too far from that.'

McNamara agrees with Rizzoni. However, he is also keen to press home how crucial it is for motorsport to look beyond its immediate boundaries. 'There are a lot of people researching cells and we've done work here on some of those cells, but they have got to reach a certain stage of industrialisation, which means we can use lots of them reliably and with the same quality before we can take them on board, so even in motorsport, we need a certain amount of industrialisation. If you are going to put a product out there, you have got to be sure that it is going to be reliable.

'In Formula E, we produce 44 batteries. We monitor them throughout the season and we put safety systems around them, so we are generally at the front end for consumer products, even though we do have the additional challenge of scale. Our batteries are big, 320kg things, but generally we would be the testing ground for new chemistries.

'People are going to see this stuff on airplanes, their cars in their daily lives, so it has got to be good in terms of its thermal performance and that it's not going to spontaneously combust [or] overheat,' McNamara adds. 'All of this stuff has got to be done and experience has got to be gained before it goes into consumer products and we in motorsport are usually at the front end of that.'

Laudenbach, however, questions whether the direction of development for these chemistries will truly best serve the requirements of motorsport. 'The question is: If those new solutions aim for this goal, will there be an advantage for us at all? We are primarily interested in power density, not energy density,' he says, but adds: 'Probably we will be able to develop solutions based on these new technologies for our demands in motorsport.'



The current Formula E battery pack is made by Williams Advanced Engineering. Williams produces 44 batteries for FE each season. Each battery pack weighs some 320kg so it accounts for a fair portion of the overall weight of the Formula E racecar

For season five of Formula E McLaren Applied Technologies is to take over the battery supply. Its challenge will be to double the energy storage for approximately the same mass, so that FE can complete a full race distance without a racecar swap

Packing power

In motorsport environments, competitors need to look beyond the chemistries involved when adapting batteries to the machines and developing an appropriate energy storage system. Knowing also that the type of package that hosts the cells is robust, is crucial.

Cylindrical cells are the most commonly available commercially, but other packing solutions, such as pouch and prismatic cells are becoming more prominent within motorsport. Rizzoni explains: 'Cylindrical cells

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'At the present time, lithium-sulphur and lithium-air do not possess the power capability that lithium-ion cells have'

are more robust, so in terms of ruggedness, the cylindrical cell is preferable. But the problem with cylindrical cells is that even if you use the larger format, you need a lot of them, because their energy storage capacity is limited by the package size. Also, from a packaging perspective, you are putting these cylinders next to each other and there are a lot of air gaps in between them. On the one hand, that may be favourable for air-cooling purposes, but from a packaging perspective, cylindrical cells are really not desirable.'

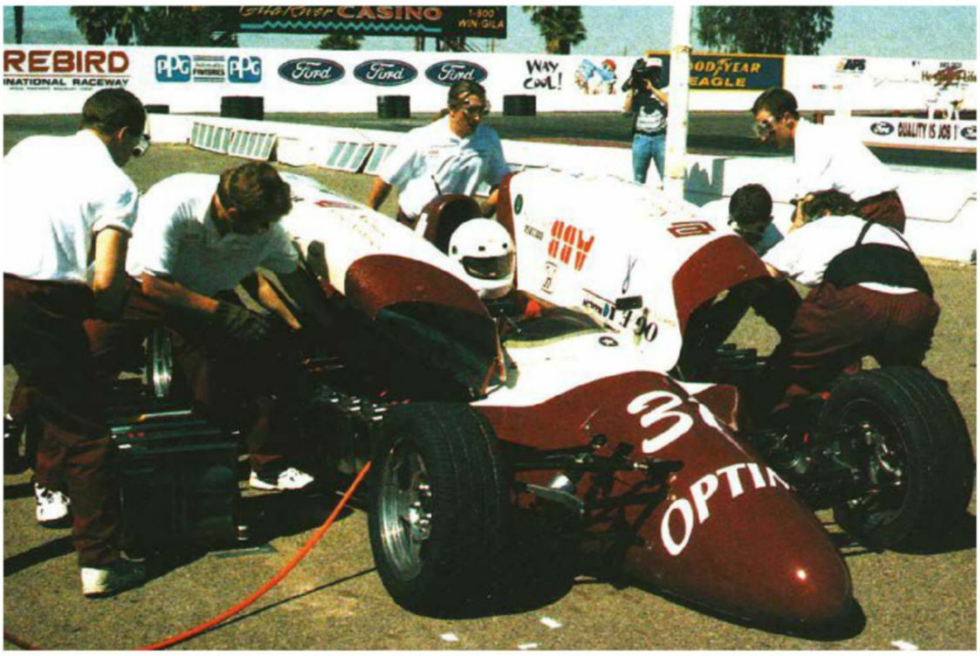
'Pouch cells on the other hand have the very same profile,' Rizzoni says. 'You basically take these long sheets of electrodes, electrolyte materials and current carriers like aluminium and copper, and you fold them up like an accordion, making a very compact package.'

But there are drawbacks to pouch cells, as due to the soft, layered construction, it is susceptible to bending and distorting. 'You typically have to package them into a box, so that is one of the challenges,' Rizzoni says.

Prismatic cells fall somewhere in between cylindrical and pouch cells in terms of construction. Similar to a squashed cylindrical cell, a prismatic cell enjoys a rectangular cross section that is reminiscent of a thin box.

Rizzoni says: 'It's configured like a spiral. So you take this cylindrical cell and turn them into a profile that can be compressed into a prismatic shape. Prismatic cells are not as thin as pouch cells and are much more rugged, because of the enclosure around the cell material. Prismatic cells may well be in a setting where you require a certain amount of ruggedness, with good packaging characteristics.'

The ETH Zurich Formula Student car makes use of two lithium polymer cells with high energy and power density. The balance between power density and energy density is a matter of much debate in electric vehicle development circles



A Formula Lightning pit stop – for a planned battery replacement – back in 1997. This US-based series, which was ahead of its time in many ways, was all about managing the life in the battery pack so as to have enough juice to race to the finish

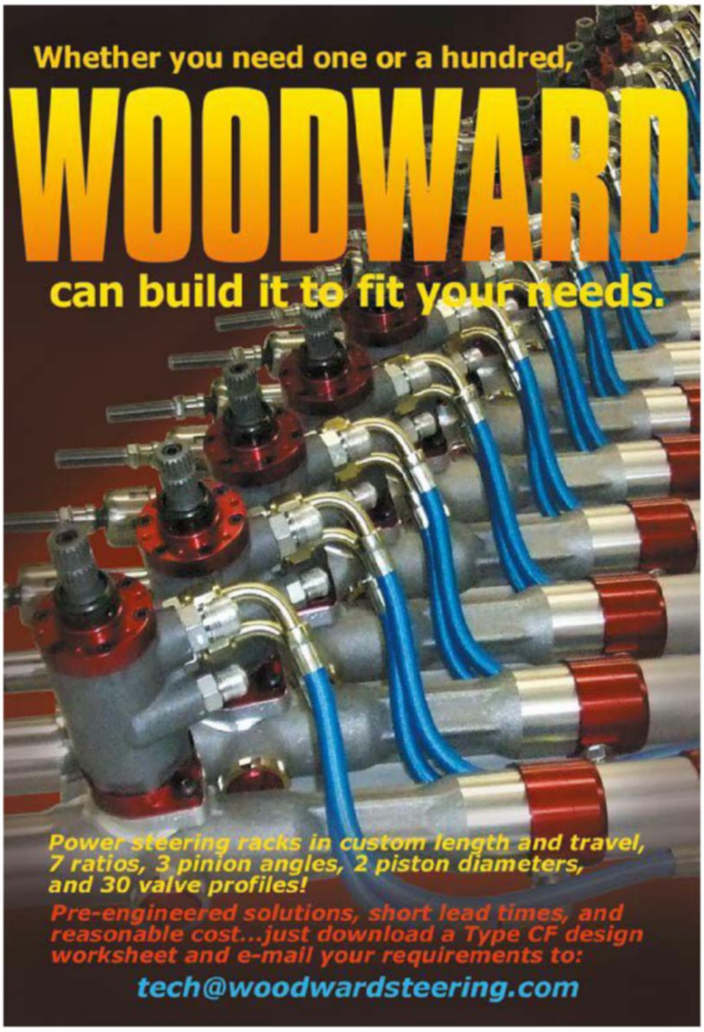
Material benefits

There is now more consideration being given to research in to lighter materials for battery units, while also attempting to increase energy storage and output at a given level. This is a crucial field for Formula E, which is aiming to eliminate mid-race car swaps by the start of season five (2018/19). Such development would require double the energy storage capabilities of the battery without doubling the mass and, McNamara says, this will be no easy feat. 'The challenge is out there now for organisations like us [indeed, the task has recently been given to McLaren Applied Technologies, which won the FIA's tender to supply FE from season five] and we are researching at the moment how can we have double the energy storage for approximately the same mass. That's done in two ways. We look for more advanced chemistries, because the chemistry in FE batteries at the moment is now in its third season, so we can get at a cell level a useful increase in the kilowatt hours p/kg number.'

The other way is working on the peripherals around the battery, which is key to reducing excess weight from the unit. 'The battery is the cells plus the buzz bars, the control system and the casing, so that in Formula E is about 40 per cent of the weight of the battery, so if we can knock weight out of that, it is another way we can do it,' McNamara says.

Power or energy?

There are also wider implications, as Rizzoni envisages this progress dripping down into the automotive industry, but the direction any given manufacturer will take is unlikely to be uniform. 'What you want to accomplish is to have the best possible power density and energy density – so kilowatts p/kg and kilowatt hour p/kg – so in theory you would like to have batteries that give you as much power density and energy



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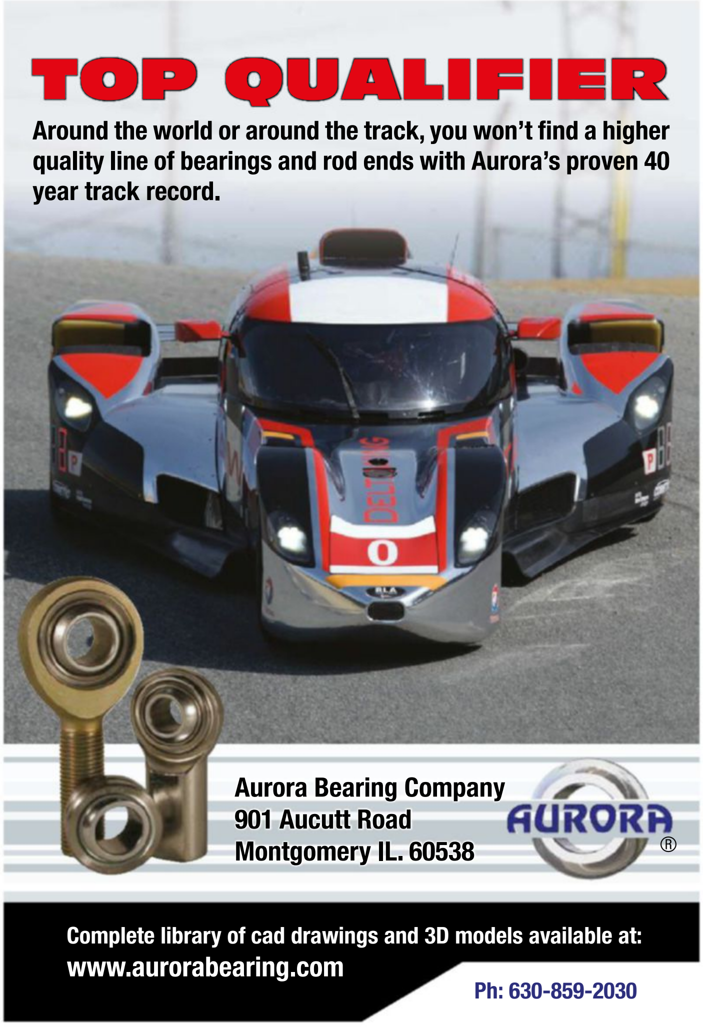

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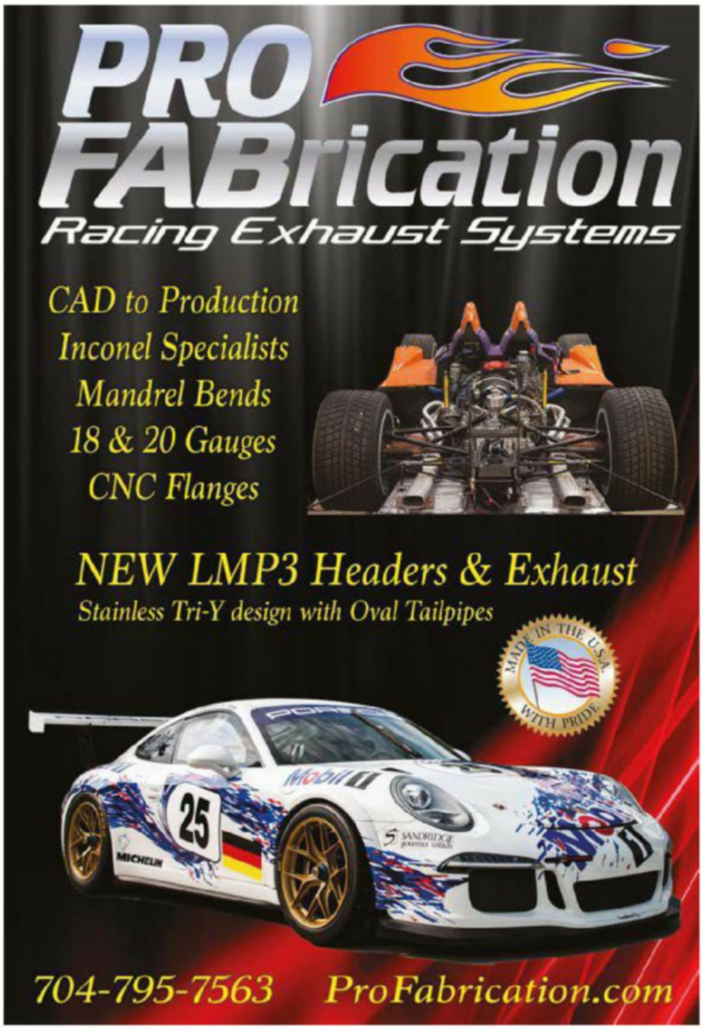

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'The biggest disadvantage with lithium-ion is it is classified as a dangerous good when it comes to transporting it'

The Porsche 919 Hybrid LMP1 car packs bespoke A123 Systems cells located in the cockpit. With a need for better power density in sports prototypes, rather than energy density, some have questioned its relevance to developing road car EV tech

The 2009 Mercedes F1 battery pack used cylindrical cells derived from a production car. These cells are the most commonly available technology, but other packaging solutions, such as pouch and prismatic, are becoming more prominent in racing

density as possible. If you are a manufacturer and you're thinking about a production vehicle, it depends,' Rizzoni says. 'If the production vehicle is a straight hybrid, no plug-in capabilities, then you will privilege power – you want a small battery pack that will deliver a lot of power. If you have a plug-in hybrid vehicle, then you want the compromise between power and energy, and energy becomes important because you would like your vehicle to have some electric range. If you had a pure battery electric vehicle, then energy would be the most important thing because energy is range and that is what you want in battery electric vehicles.

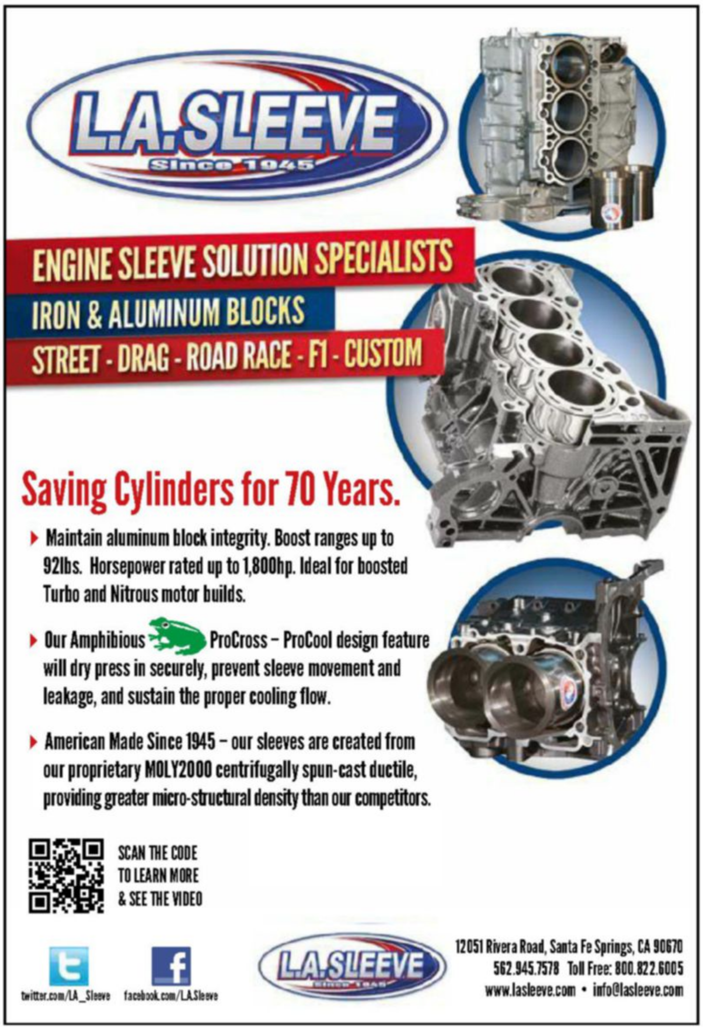
'I look at the F1 KERS and it is a case where you really privilege power, because you are doing very high power, high current rate in and out every time you use KERS,' Rizzoni adds. 'When you are looking at FE, you still need to have a certain amount of energy, so there's your compromise between energy and power, which shifts toward energy a bit more, because you do want to have range. Energy is much more important for road racing applications.'

Formula Lightning

During the mid-90s, Rizzoni served as faculty advisor to Ohio State University's Formula Lightning team – an electric open-wheel project that won three ABB National Championships. It was far from straightforward, for the team or the driver. 'Our driver had very precise instructions and some interesting electronics to make sure that we would not use any more charge than needed,' Rizzoni says. 'So we worked miracles to try and manage the energy content of the battery pack, because otherwise what happens is for the last couple of laps when you would really like to defend your position, or gain a position, the battery starts going soft.'

Crucially, the development of batteries that potentially produce more power, while also increasing their storage capacity, introduces numerous challenges for chassis designers, too, as cooling and bodywork dimensions gain significance, as McNamara explains. 'We've had to completely redesign the thermal strategy for the battery, so at the moment on the FE cars, we have got a thermal skin that is essentially taking heat from the top and the bottom of the cells and for season five, it needs something that is taking [more] heat from all around the cell.' It is a situation that has required a lot of innovative thinking, for while more cooling is required; the package also needs to be lighter.

It is an approach that McNamara admits may require a rethink of the Formula E car as a whole. Currently, the battery of the car acts as a structural member with the engine, gearbox and inverter and for McNamara it's not the most



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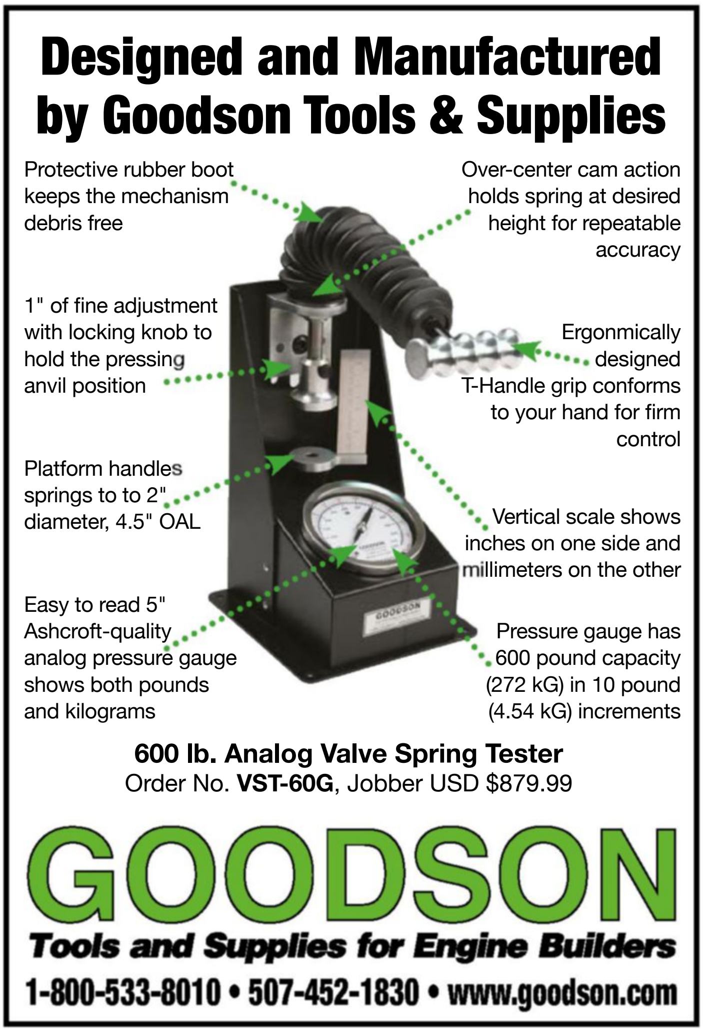

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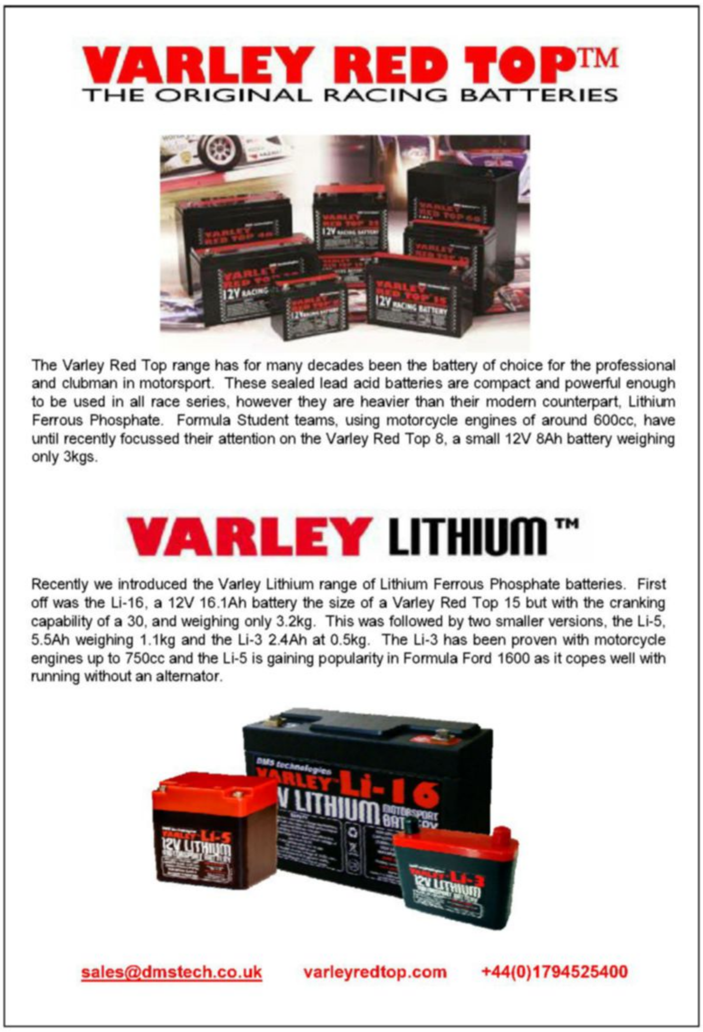

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'If you compare it with super-capacitors, a lithium-ion battery has a larger energy content'

efficient solution. 'It would be more efficient to have that car carrying that structure at the back and the battery plugging into it, so that's another area of development in discussion.'

Audi's Laudenbach takes this a step further. 'In an ideal world, you would like to cool the battery inside the cells, but that's a difficult task.'

Trickle charge

Of those we talked to, most believed that while it's unlikely we will see huge changes in chemistries in the coming decade, one cannot ignore improvements in existing chemistries. Also, while there is no doubt the breed of road-going technology may improve because of the ongoing battery development in the motorsport industry, there is still some way to go before this transfers significantly to the general automotive world.

As far as road cars go, according to McNamara until the range of electric cars improves, the size of the market could remain small. 'The main difficulty is range. The range is anywhere between 150 and 250 miles depending on who you talk to. That's clearly not an acceptable range for people with the recharging infrastructure and recharging time that exists. If you transition that number so that it is 250 to 350, you suddenly reach tipping point where these cars are practical for most.

'In Formula E, we have this pioneering all-electric series,' McNamara adds. 'I see that will start to trickle down, so maybe you could have an electric saloon car racing series or touring cars series … I'm reasonably confident that with normal engineering and scientific progression, we will over the next decade or so get to products that are practical for people to have and have a very wide user acceptance.'

Stamford says: 'I think the short-term developments in batteries will be smaller incremental changes. I anticipate the next major developments will centre around increasing battery voltage. That change will increase both the power and energy available from a particular battery style. I think we could see those developments coming in the next few years. It's a compromise between power, energy, mass, volume and efficiency of the battery pack, so it's trading all those things off to find an optimum solution. The volume the cells take up is also critical to the car layout.'

Hasegawa, meanwhile, considers the nature of cooling could also be the feature that directs battery development, but while the air cooling ducts or the water-cooling radiator may increase in size, he adds that 'we do not think that the exterior of the battery will change extremely due to capacity. The cooling process within the battery must improve, therefore ancillary parts will evolve'.

The future?

Audi's Laudenbach believes that there are still significant improvements to come from battery suppliers, but adds that the goals of road car developers differ significantly from the needs of motorsport. 'The suppliers might target for higher energy density in road cars, but we want higher power density in LMP1 racecars, so it's not an easy subject if new technologies are developed for road cars. Only in the mid-term or long-term, the basic technology might deviate from today's solutions.'

Rizzoni is reluctant to commit to how he believes the technology will develop. 'I think we have reached a stage with this technology where it is still not fully mature, but it is quite reliable and well understood and it will be with us for quite some time. If you are asking 'what comes next?', I'm not ready to make a leap and say that any step change or really dramatic change has been demonstrated yet.'

In the past battery technology may not have had the most obvious impact on the motorsport world, but as chemistries and packaging continue to develop, it's not inconceivable that big changes will come from this direction in the future.


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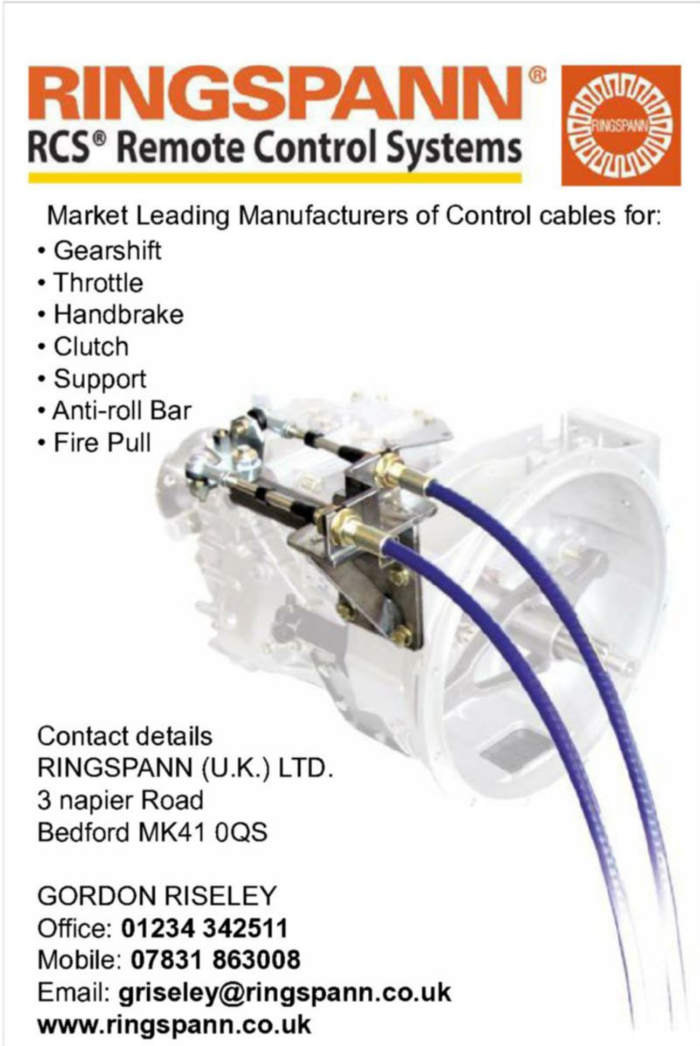
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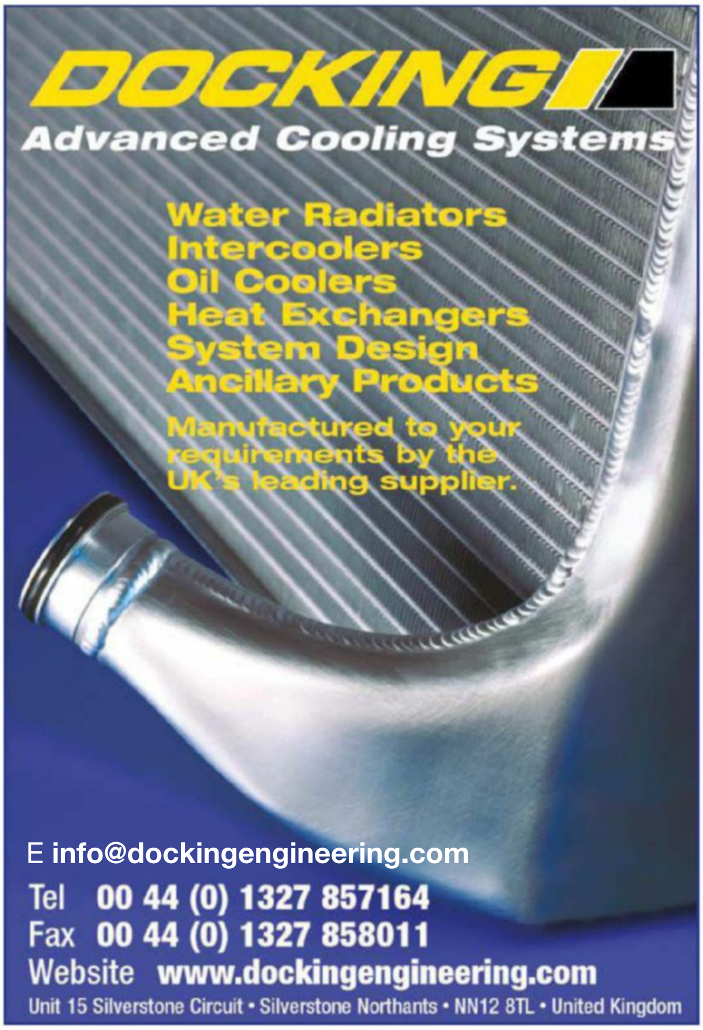
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The sum of all things

There's not only still a place for pencil and paper calculations in modern motor racing but they are also vitally important, as *Racecar's* resident number cruncher demonstrates

By DANNY NOWLAN

Hand calculations can give you a very good approximation of the figures you should expect for downforce on a Formula 3 car

One of the signatures of these articles is my use of formula and hand calculations to articulate an engineering point. This ability to mathematically show what you are saying is a core engineering skill. It is why over the last two years I've written a number of pieces about it, because this is a skill that has been dangerously atrophying over the last two decades. This is what we'll be discussing in this article.

The ability to do hand calcs is one of the definitive characteristics of being an engineer, and in this regard we are now at crisis point. On a micro level I've been recruiting again for interns, and I am shell-shocked at what I am finding. However, on a macro level this lack of ability to do hand calculations is now making its presence well and truly felt, too.

If we wind the clocks back 45 plus years, the SR-71 Blackbird was designed by 35 engineers with slide rules and drawing boards. We also went to the moon on computers less powerful than an iPhone. But if we fast forward to the present day you only have to look at the delays and cost blow outs in projects such as the A-380 airliner and F-35 Joint strike fighter to know something is very seriously amiss.

The reason we got here was the over-riding view that emerged in the mid 1990s that Computer Aided Engineering tools could replace traditional calculation techniques. On one level that was correct because you will never be able to hand calculate the downforce on an F1 car totally, or resolve the stresses on a carbon fibre monocoque to within one per cent purely by using pen and paper and a calculator.

The important lesson that was lost along the way is that hand calculations allow you to quickly approximate what to expect

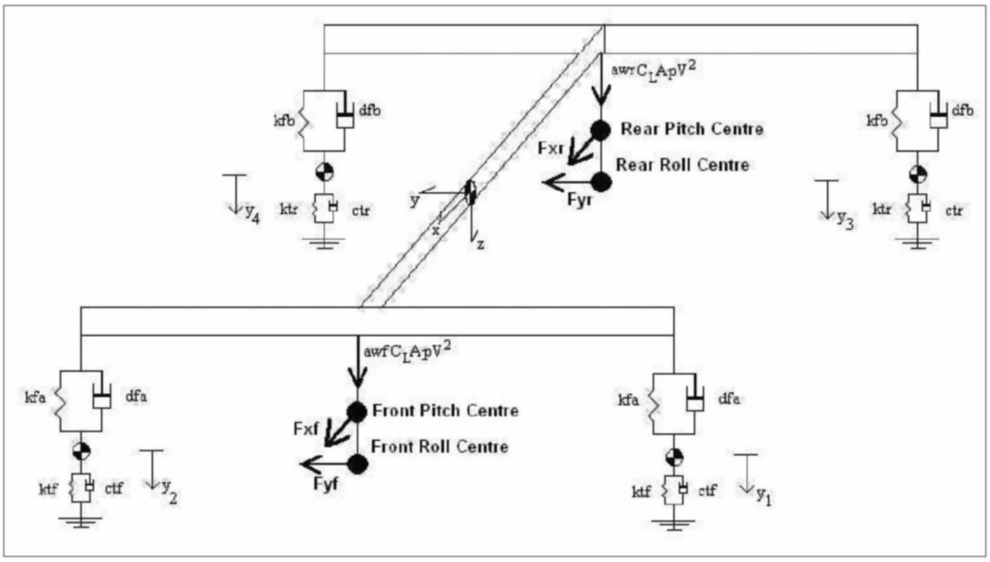

Figure 1: Once again the trusty beam pogo stick model of the racecar makes an excellent starting point for our discussion

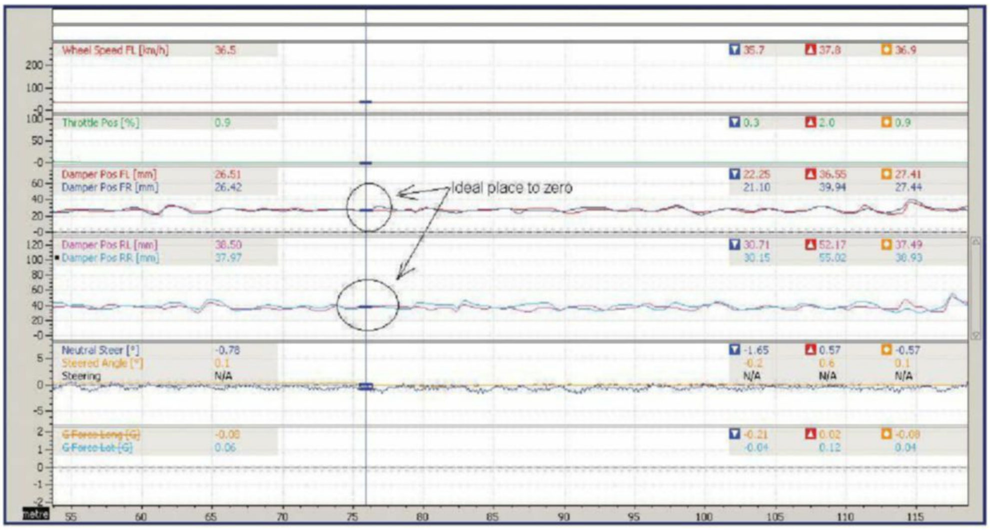

Figure 2: This shows the ideal place to zero the dampers to give a very good measure of the zero convention

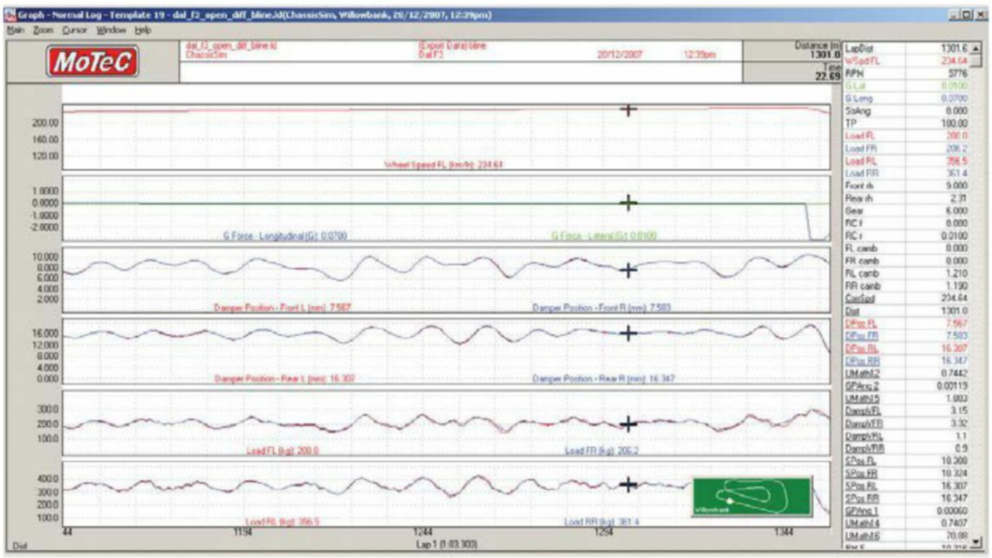

Figure 3: This shows the point from where to start the hand calculation for the aero; it's usually on the longest straight

But the important lesson lost along the way is that hand calculations allow you to quickly approximate what to expect.

The loss of this core skill put an ever increasing reliance on CAE tools, so you have a generation of engineers who have lost awareness of what the numbers are and where they come from. This is a very dangerous oversight, and it needs to be addressed.

First principles

Yet the good news is this is something that can be easily addressed, and I will illustrate via an example here. You'll see for yourself that when working from first principles and applying some simple maths you can get a very close approximation of what to expect. However, more importantly, if you master this skill it will give you a sixth sense of what to expect, too. A case in point was the legendary aeronautical engineer Clarence 'Kelly' Johnson, who could look at an aerospace structure and tell you what the pressure distribution would be to within a couple of tenths of a psi.

The first example I'll discuss is hand calculating downforce. I realise this is an example that I repeat *ad nauseam* but I am still astounded at the number of race engineers that can't do this. This is derived from the force balance of the beam pogo stick model of the racecar. This is shown in **Figure 1**.

If you have a racecar with downforce being applied to it a free body diagram will readily reveal that the sum of the forces on the springs will equate to the downforce. For open wheelers this doesn't take into account any wheel lift. However, it is still more than sufficient to calculate pitch sensitivity and ground clearance. Look at it another way, when you start running CLA north of two you ignore this information at your peril.

Ground zero

To kick this discussion off we need to talk about the zeroing conventions. The best procedure to do this is to look at the data and zero the dampers on the ground or apply an offset as the car comes out of the pits. A very good procedure to follow to do this is illustrated in **Figure 2**. As can be seen the dampers are level and this will give us a very good measure of the zero condition.

The next step in the process is to identify where to perform the aero calculation. The best place to take the numbers for this calculation is either the fastest point on the circuit or the longest straight. The thing that takes priority here is the car going in a straight line with

What we are talking about here is simple high school level mathematics, yet this can tell you a great deal about what the racecar is actually doing

EQUATIONS

EQUATION 1

$$FtDownforce = MR_f \cdot k_f \cdot (FL\_Damp + FR\_Damp$$
$$= 0.9 * 140.1 * (10 + 10)$$
$$= 2521.8N$$
$$RrDownforce = MR_r \cdot k_r \cdot (RL\_Damp + RR\_Damp$$
$$= 0.8 * 140.1 * (15 + 15)$$
$$= 3362.4N$$
$$C_L A = \frac{FtDownforce + RrDownforce}{0.5 * 1.225 * (220/3.6)^2}$$
$$= 2.57$$
$$AeroBal = 100 \cdot \left(\frac{FtDownforce + \frac{mt \cdot g \cdot a_x \cdot h}{wb}}{FtDownforce + RrDownforce} \right)$$
$$= 100 \cdot \left(\frac{2521.8 + \frac{500 \cdot 9.8 \cdot 0 \cdot 0.3}{2.6}}{2521.8 + 3362.4} \right)$$
$$= 42.9\%$$
$$C_D A = \frac{gr * T / r_t - m_t \cdot g \cdot a_x}{0.5 * 1.225 * (220/3.6)^2}$$
$$= \frac{3 * 200/0.28 - 550 \cdot 9.8 \cdot 0}{0.5 * 1.225 * (220/3.6)^2}$$
$$= 0.937$$

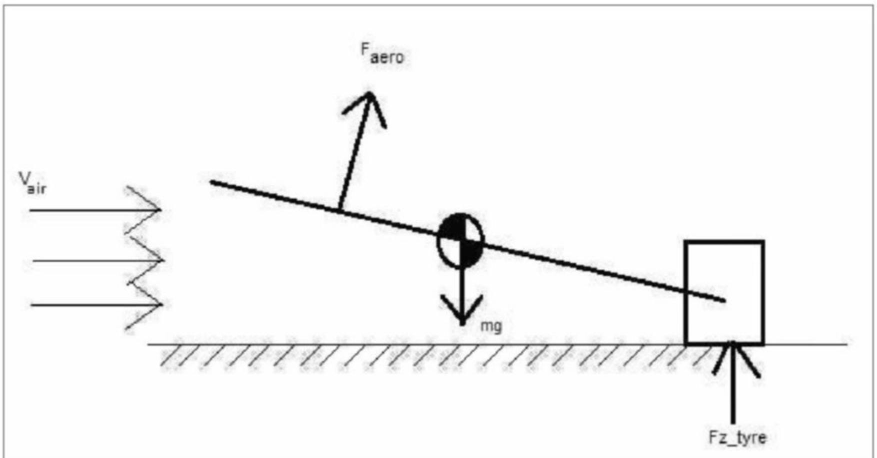

Figure 4: This free body diagram analysis graphically summarises an aerodynamic roll-over scenario

Table 1: Sample values for an aero hand calculation of a Formula 3 car

Item	Quantity
Front Motion Ratio	0.9
Rear Motion Ratio	0.8
FL Damper/FR Damper	10mm/10mm
RL Damper/RR Damper	15mm/15mm
Front spring	140.1N/mm (800lbf/in)
Front spring	140.1 N/mm (800lbf/in)
Torque at RPM	200Nm
Rolling tyre radius	0.28m
ax	0g
Vx	220km/h
Gear ratio value	3
mt	500kg
h	0.3m
wb	2.6m

minimum lateral acceleration. An ideal point to take it from is shown in **Figure 3**.

It is also wise to filter the data as well. I like to take a low pass frequency filter of about 1Hz. That said, I still like looking at the raw data because it gives me an idea of what the car is doing. Once these points have been established the next thing is to calculate the downforce. The best way to illustrate this is by example, such as a Formula 3 car; as shown in **Table 1**. Here all motion ratios are damper on wheel, and the gear ratio is engine/wheel velocity, and for simplicity I've omitted bump rubbers. Crunching the numbers we see **Equation 1**.

As can be seen, what we are talking about here is simple high school level mathematics, yet this can tell you a great deal about what the racecar is actually doing.

Roll playing

The next example I'd like to talk about is one of the most extraordinary technical discussions I have seen over the last three years. It was actually extraordinary for all the wrong reasons, and illustrated the lack of ability to do hand calculations as well as a lack of knowledge of engineering first principles. It centred on a discussion of an aerodynamic induced roll-over of a racecar. This is a problem that plagues modern sports prototypes. Anyway, this discussion tried to apply this to an FSAE car; and you should have seen the encouragement given to do detailed CFD studies of this scenario. I forwarded it on to colleagues of mine who were aerodynamicists in various senior categories and they where stunned in disbelief at what they where reading.

To discuss why this discussion was so off the mark it would be wise to do some rough

EQUATIONS

EQUATION 2

$$F_{aero} = \left(\tfrac{1}{2}\right)\cdot\rho\cdot V^2\cdot C_L\cdot A$$
$$= 0.5\cdot 1.225\cdot V^2\cdot 5\cdot\left(\frac{5\pi}{180}\right)\cdot 10$$
$$= 2.67\cdot V^2$$

EQUATION 3

$$M = F_{aero}\cdot\frac{3}{4}\cdot t - m\cdot g\cdot\frac{1}{2}\cdot t = t\cdot\left(F_{aero}\cdot\frac{3}{4} - m\cdot g\cdot\frac{1}{2}\right)$$

EQUATION 4

$$F_{aero}\cdot\frac{3}{4} = m\cdot g\cdot\frac{1}{2}$$
$$V^2 = \frac{2}{3}\cdot\frac{mg}{2.67}$$
$$V = \sqrt{\frac{2}{3}\cdot\frac{mg}{2.67}}$$
$$V = \sqrt{\frac{2}{3}\cdot\frac{1000*9.8}{2.67}}$$
$$V = 49.467m/s = 180km/h$$

EQUATION 5

$$F_{aero} = \left(\tfrac{1}{2}\right)\cdot\rho\cdot V^2\cdot C_L\cdot A$$
$$= 0.5\cdot 1.225\cdot V^2\cdot 5\cdot\left(\frac{5\pi}{180}\right)\cdot 2$$
$$= 0.534\cdot V^2$$

EQUATION 6

$$V = \sqrt{\frac{2}{3}\cdot\frac{mg}{2.67}}$$
$$V = \sqrt{\frac{2}{3}\cdot\frac{250*9.8}{0.534}}$$
$$V = 55.3m/s = 199km/h$$

If the aerodynamic moment exceeds the moment produced by the racecar's weight then the car will flip over

approximations to the mechanisms of what occurs in an aerodynamic induced roll over. What happens is that a car gets sideways at speed, the aerodynamic downforce reduces, it hits a bump, the underbody gets exposed to the open airflow, and the car cartwheels.

Believe it or not we can actually put some basic numbers to this to see whether we have a problem or not. This situation is summarised in the free body diagram shown in **Figure 4**.

Flip side

To keep this discussion simple I'm going to assume the car has gone sideways, so it isn't producing any downforce. As we can see in **Figure 4** we have two major forces in play.

The first is the lift being produced by the underbody as a result of being exposed at an angle to the airflow. This will be applied at the quarter chord. This is what is going to roll us over. The thing that is keeping us in check is the weight of the car. What we need to do is to take moments about the tyre that is still on the ground. If the aerodynamic moment exceeds the moment produced by the racecar's weight then it will flip over.

The trick here is to come up with an approximation for the aero forces, and it's actually a lot easier than you think. Our goal right now is not to try and predict the roll-over moment. We just want to see whether we have a problem that needs to be dealt with.

To that end we can look at some typical C_L *vs* angle of attack plots of an aerofoil to get some ballpark numbers. As rough as this may seem, in this roll-over situation this is pretty much what we are dealing with. In terms of some rough $dC_L/d\alpha$ numbers (α being in radians) 2π is an okay place to start from. Since this is a non ideal aerofoil let's approximate $dC_L/d\alpha$ at five. To further flesh this out let's assume we've hit a bump and the angle of attack is, say, five degrees. Given a typical underbody area of a sportscar of approximately $10m^2$, the aero forces we are going to generate will be given by **Equation 2**.

Let's assume the car width is 2m and the car weight is 1000kg. Taking moments about the tyre we then see **Equation 3**.

We are going to have problems when **Equation 3** is equal to 0. But by putting **Equation 2** into **Equation 3** and solving for the zero condition we see **Equation 4**.

Table 2: FSAE car figures

Parameter	Qty
Total mass	250kg
Width	1.5m
Floor Area	$2m^2$

FSAE application

So what all this tells us is that at 180km/h we are prone to aero induced roll-over. In reality it is a little bit more than that (usually about 220 to 240km/h in most circumstances). However, as a ballpark figure this indicates that this is a situation we need to consider quite seriously.

Let's now see what these numbers look like for an FSAE car. Using the same aero figures as the sports prototype (which may I say is giving the aero roll over scenario a considerable benefit of the doubt) we have the numbers for a FSAE car, as shown in **Table 2.**

So reviewing **Equation 2**, for the FSAE car, we have **Equation 5**. Plugging this into our analysis for **Equation 4** we see **Equation 6**.

What this means is that we can expect to see an aero roll-over situation for an FSAE car at approximately 200km/h. Given that an FSAE car is limited to approximately 110km/h it would be impossible for this to happen.

I should also add that in sideways view a FSAE car has all the aerodynamic attributes of a brick, so if we really wanted to get aggressive with this analysis the predicted roll-over speed would go up quite significantly.

However, by using first principles and some basic mathematical analysis we've shown why this discussion was so utterly ridiculous. Personally, I'm quite amazed that this subject got any oxygen in the first place.

Correlating data

Another case study of how to use hand calculations is with what happens when your simulated and actual data do not correlate. A couple of years ago I had a touring car

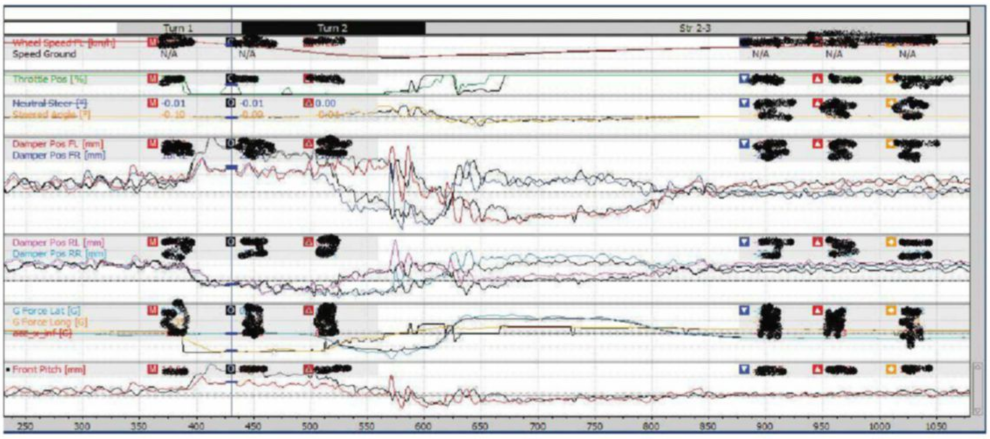

Figure 5: The pitch data for this touring car did not quite correlate correctly. Hand calculations helped enormously here

Table 3: Touring car paramaters

Variable	Value
Front Motion Ratio (Damper/Wheel)	0.63
Front spring rate	123N/mm
Front braking force	1224.5kgf
Rear braking force	885kgf
Front pitch centre	50mm
Rear pitch centre	180mm
c.g height	0.43m
Wheelbase	2.794m

customer who couldn't get their front pitch data to correlate, as illustrated in **Figure 5**. As always actual data is coloured, simulated is black. As can be seen the correlation is very good with the exception of the braking.

Most people at this point simply throw their hands up in the air and say the simulation is a waste of money. This is where hand calculations can be a valuable tool to lighting the way as to what is actually going on.

Sanity check

The great thing about hand calculating is it's a very powerful way of highlighting what the problem is. One of the variables that ChassisSim returns is the applied longitudinal forces and pitch centres. What this means is you can sanity check the numbers you are getting back from your simulation results. While I can't give you specifics on this particular example let me walk you through how you would do it. Firstly, let's look at some parameters for an equivalent touring car that are presented in **Table 3**.

We are now in a position to hand calculate what the expected pitch should be. Crunching the numbers we see **Equation 7**.

So calculating what we should expect to see at the damper, it can be shown as **Equation 8.**

When this was calculated on the actual racecar it was found the simulated data was behaving as it should. This is an instant red flag that something was not right here, and it clearly illustrates the power of using both computer aided engineering tools and hand calculations together.

Plane speaking

However, the ultimate power of hand calculation is they are the ultimate engineering BS detector. A perfect case in point here is the maximum claimed speed of the F-35 Joint Strike Fighter. Air Force chiefs all over the Western world and the aeroplane's manufacturer, Lockheed Martin, have all claimed the F-35 can hit Mach 1.6 at altitudes greater than 30,000ft.

But here is a critical question to be asked. Can it do it where it counts, in a straight line?

EQUATIONS

EQUATION 7

$$LT_{SM} = \frac{F_{BF}\cdot(h - pc_f) + F_{BR}\cdot(h - pc_r)}{wb}$$

$$= \frac{9.8*1224.5\cdot(0.43 - 50e-3) + 9.8*885\cdot(0.44 - 180e-3)}{2.794}$$

$$= 2408N$$

EQUATION 8

$$\partial Damp\_ft = \frac{0.5*LT_{SM}}{k_f \cdot MR_f} = \frac{0.5\cdot 2408}{122.6\cdot 0.63} = 15.6mm$$

EQUATION 9

$$\frac{dV}{dt} = \frac{T - 0.5\cdot\rho\cdot V^2\cdot C_D A}{m_t}$$

Here we have,

V = Aircraft velocity (m/s)
t = time (s)
P = Air density (kg/m^3)
CD = Co-efficient of drag
A = Aircraft wing area (m^2)
T = Engine thrust (N)
m_t = Aircraft weight (kg)

EQUATION 10

$$dt = \frac{m_t \cdot dV}{T - 0.5\cdot\rho\cdot V^2\cdot C_D A}$$

$$\int \frac{dV}{a^2 - V^2} = \frac{\tanh^{-1}\left(\frac{V}{a}\right)}{a}$$

$$a = \sqrt{\frac{T}{0.5\cdot\rho\cdot C_D A}}$$

This can actually be readily shown using hand calculations. The first step is to solve for velocity *vs* time for the differential equation that describes aircraft straight and level performance, as shown in **Equation 9**.

When you do a bit of manipulation **Equation 10** is the identity you'll be solving.

The next bit of information you will need is flight performance. This comes courtesy of the US Department of Defence. In 2011 the F-35A's transonic acceleration performance from Mach 0.8 to Mach 1.2 was downgraded to 63s. This was at 30,000 ft International Standard Atmosphere conditions.

So, all you need to do is curve fit what you get from solving **Equation 9** and **10** to this performance specification. You can then use this to solve for the CD . Then the max speed will pop out in the wash. I'll let the results speak for themselves. However, don't take my word for it, I welcome you to do the analysis yourself. Also, this will be an optimistic analysis.

Summing up

In closing, being able to do engineering hand calculations is a vital skill that all engineers need to possess. While it is a skill that is atrophying, the great news is that recovering this isn't that hard. It's just a matter of re-learning your basics and being methodical and patient. However, the pay off, as we can see with all of these examples presented here, is invaluable. More crucially, it gives you that necessary edge you need when you need to design the racecar, and more importantly, use it in the heat of battle.

This example clearly illustrates the power of using both computer aided engineering tools and hand calculations together

Teams not ruling out franchise system in F1

Formula 1 team bosses have said that they might welcome some sort of franchise arrangement in the sport.

Talk of a franchise system, or even a shareholding offer to the teams, was sparked in the immediate aftermath of Liberty Media's announcement in September that it was to buy Formula 1. In its statement the US media giant said the teams are to be 'given the opportunity to participate in the investment in Formula 1', although it did not go in to further details. It is, however, involved with franchises with its sporting interests in the US.

F1 team bosses have now said that, in principal, they are not opposed to the idea. Bob Fernley, deputy team principal at Force India, said: 'I think something that is giving Formula 1 stability, more importantly I think something that is anchoring the teams into Formula 1 – because it takes four or five years to build a team and whilst owners do come and go, the teams tend to be the same teams being transferred. I think it would be very, very good for the teams to have that stability and that security going forward.

'I think franchising is a different view for Formula 1 and it is one that we should look at very positively,' Fernley added.

But McLaren's racing director Eric Boullier said that while he agreed it would be a good thing in principal, he would need to see more details. 'It's difficult to have a strong opinion at this stage, just based on the word 'franchise'. We need to see the details of what they want to achieve. [But] I think yes, what Bob [Fernley] said is true.'

Speaking at the time of the announcement of the Liberty deal Red Bull team principal Christian Horner said he was in favour of the teams having a bigger stake in the sport, whether that was as part of a franchise system or as shareholders: 'I think it's a sensible thing. I think the teams are key stakeholders in Formula 1; without the teams there is no Formula 1. I think for the teams to take a minority shareholding would make sense and to offer it to all the teams under the same terms would make total sense,' Horner said.

The ongoing Liberty takeover of Formula 1 could see teams racing to secure places as franchise holders

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Mercedes eyes up Formula E for season five of electric series

Mercedes has secured a Formula E entry for the 2018/19 season, signing an agreement that gives it the right to race in Formula E from the electric racecar series' fifth season.

Formula E intends to switch to single-car races in 2018/19, and is likely to expand from 10 teams to 12, and one of those slots is now reserved for Mercedes.

Toto Wolff, Mercedes motorsport boss, said of the deal: 'We have been watching the growth of Formula E with great interest. At the current time, we are looking at all the options available in the future of motor racing, and we are very pleased with an agreement that secures us an opportunity to enter the series in season five.

'Electrification will play a major role in the future of the automotive industry – racing has always been a technology research and development platform for the motor industry, and this will make Formula E very relevant in the future,' Wolff added.

Mercedes is the latest in a string of manufacturers attracted to FE. Jaguar made its debut in the 2016/17 season opener in Hong Kong recently, while BMW is now in an engineering partnership with the Andretti Formula E outfit – with the possibility of a fully-fledged factory entry from 2018/19. Audi has already upped its involvement in the Abt team for the current campaign and will make it part of its works motorsport programme from 2017/18. Renault, DS and Mahindra are also already involved in the series.

Such has been the interest in FE that its CEO, Alejandro Agag, has said that a new entry – presumably the 12th team – would need to pay a fee of €25m if it wanted to be a part of the series.

Meanwhile, McLaren Applied Technologies (MAT) has won the right to supply the Formula E battery from the 2018/19 season, and has been tasked with developing it to the point that Formula E can do away with its mid-race car swaps.

Current battery supplier Williams Advanced Engineering was among the applicants for the tender for the new FE battery, as were Porsche and Red Bull Technologies, it is believed.

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Mercedes motorsport boss Toto Wolff believes that Formula E will gain wider relevance in future seasons

Mercedes Formula 1 team posts a £22m loss for 2015

The Mercedes Formula 1 operation has posted a post-tax loss of £22.3m for 2015, although the now three-time constructors' championship winning outfit's financial results were actually a marked improvement over the previous year.

Mercedes, which is officially called Mercedes-Benz Grand Prix Ltd, posted losses of £76.1m for 2014, but in 2015 it whittled that down by a cool £53.8m. The team also states in the financial report for 2015 that the results were 'within the pre-defined parameters set by the shareholders'.

The company has also reported an increase in turnover of £66.3m for the period in question, which it says: 'Resulted from higher sponsorship revenue and increased income from the commercial rights holder flowing from improved on-track performance in 2014.'

Operating costs also went up during the period by £8.1m, a figure which Mercedes puts down to 'inflationary increases in salary costs'. Staff costs were reported as £78.4m. The workforce at Mercedes' Brackley base also increased over the period, from 765 to 807. Broken down further, this was an increase from 688 to 717 in the design, manufacturing and engineering part of the company, and from 77 to 90 in administration.

The strategic report published within the accounts, which was signed off by Mercedes motorsport boss Toto Wolff, said that the team is confident of achieving better financial results in the near future, due to its dominant performance on the track in recent seasons.

'The agreement with the commercial rights holder has provisions for significantly increased revenue flows based on sporting performance, which will now be triggered from 2016 onwards as a result of the team's performances in 2014 and 2015,' the reports says. 'The future outlook for sponsorship revenues is also very promising. The company was very pleased to add a number of new significant sponsorship partners during 2015 and the prospect of further additions in 2016 and beyond are looking promising.'

The report also touched upon the ongoing quest for cost control within the sport as a whole. 'The company remains committed to achieving cost reduction in F1 in a fair and transparent way

The Mercedes team clinched the Formula 1 constructors' crown at Suzuka in October – it has also posted reduced losses for last year

and is confident that arrangements can be put in place for all teams to reduce the overall cost of participation in F1, without distracting from the sporting and competitive attraction,' it says.

Mercedes tied up its third consecutive Formula 1 constructors' world championship at the Japanese Grand Prix in October.

Haymarket motorsport titles bought by US media firm

In a move that looks set to massively shake up the motorsport media market, Haymarket Media Group has agreed to sell its motorsport brands, which include *Autosport*, *F1 Racing*, *Motorsport News* and LAT photographic, to US-based Motorsport Network.

The sale will mean that Motorsport Network, the Miami-based owner of *Motorsport.com*, will also take over the Autosport International Show and Autosport Engineering.

The deal includes a commitment to keep on around 70 Haymarket employees, who will now transfer to Motorsport Network along with the titles and their related businesses.

Zak Brown, chairman of Motorsport Network, said of the deal: 'This milestone in acquiring the businesses that Haymarket has grown over decades will be recognised by everyone in the industry as a mark of our intent. All that is best about Autosport and its sister businesses will be preserved.

'Supported with investment and aligned with our dynamic organisational culture and high-speed growth that is attracting younger demographics to motorsport, the fusion of these two organisations presents tantalising opportunities for our staff and our clients alike,' Brown said.

'This acquisition is part of a broader consolidation strategy and is aligned with a series of significant changes we're witnessing across the motorsport landscape,' Brown added.

Haymarket Media Group CEO Kevin Costello said: 'Motor racing has formed part of the Haymarket portfolio for almost half a century and the company has nurtured these businesses from their origins to be global category leaders. However, we are reassured that the Motorsport Network are the right people to be custodians of these businesses for the next stage of their investment and development.'

The Autosport International Show has been sold to Motorsport Network, along with Haymarket's well-known motorsport titles

SEEN: Audi RS 3 TCR LMS

Audi has unveiled its latest customer sport product in the shape of an RS 3 racecar developed to the TCR regulations. Audi Sport will start delivering the first Audi RS 3 LMS cars to customers this December. The purchase price is €129,000 (plus VAT). In TCR trim, the proven 4-cylinder 2-litre Audi TFSI engine delivers 330bhp. The safety package includes an FIA-standard safety fuel tank, a racing safety cell, PS3 safety seat, and a rescue hatch in the roof similar to the one used on the Audi R8 LMS GT car.

Chris Reinke, head of Audi Sport customer racing, said: 'The TCR market has even larger potential than that of the GT3 category. In 2016, there were 10 TCR series with races in 18 countries, and more and more series are being added.

'With the TCR version of the RS 3 we're also reaching countries where no GT3 races are held. The costs for a TCR racecar are very low. As a result, we are going to win new customers for Audi Sport as well. In terms of support and parts supply, they will benefit from the experiences we have been gathering with the Audi R8 LMS since 2009, which our GT3 customers have now come to appreciate.'

McLaren denies Apple buyout reports

McLaren has denied it is in $1bn talks with technology giant Apple, which were said to centre around supposed plans the iPhone and Mac maker had for producing an electric car.

The story surfaced in the UK newspaper *The Daily Telegraph*, which said Apple intended to buy McLaren Technology, the group that includes the Formula 1 team, as part of its EV plan. But this was swiftly denied by McLaren.

McLaren Automotive, which was supposedly of most interest to Apple, said there had been no contact whatsoever, its global communications and PR director Wayne Bruce telling *Racecar*: 'Our intention is to remain fiercely independent.' He added that the company will also not diversify its range in any way. 'Our business is supercars today, and our future is supercars,' he said.

McLaren supercars parked outside Woking's McLaren Technology Centre – the concern has denied it's in buyout talks with Apple

Meanwhile, McLaren Automotive has brought together its bespoke design division, McLaren Special Operations (MSO), with McLaren Motorsport under a new management structure.

The new department is headed by Ansar Ali, who takes on the post of managing director and will report to Jolyon Nash, executive director – Global Sales and Marketing.

Ali joined McLaren Automotive in March of 2016 as motorsports director, tasked with developing the sporting side of the business. Since his arrival McLaren Automotive has launched the 570S GT4 and 570S Sprint models into the motorsport market.

Nash said: 'The joining of McLaren Special Operations and Motorsport brings together the two areas of the company that design and deliver low-volume, highly bespoke offerings to their respective customers. And the integration of that new department into the Global Sales and Marketing function is a logical step, combining all of the revenue-generating areas of the business under one umbrella. I am confident that in taking this step, both MSO and Motorsport will make an even more significant contribution to the long-term future of McLaren Automotive.'

IN BRIEF

Formula 3 wind tunnel ban

Amongst changes to the sporting regulations of the FIA Formula 3 European Championship, aimed at improving 'the value proposition for drivers and teams', is a ban on wind tunnel testing, the FIA has announced. Meanwhile, there is also to be a prize money pool of €500,000 which is to be split between drivers and teams, with a portion of this earmarked for rookies. Drivers will now also be able to compete in four seasons of Euro F3, one more than the previous three-year limit.

Rebellion quits LMP1

Crack World Endurance Championship privateer team Rebellion Racing is stepping down from the top level prototype class next season. The Anglo-Swiss squad, which has won the privateer laurels for the past four seasons, now intends to mothball its pair of ORECA-built Rebellion R-One chassis and will campaign one of the new generation LMP2 cars, although it has yet to confirm which one. Part of the reason for the decision is that the new cars are expected to be almost as quick as the privateer LMP1 cars next year. At the time of writing Rebellion's decision leaves the ByKolles operation as the only team with an LMP1 privateer programme planned for 2017.

SEEN: Hyundai i20 WRC 2017

Hyundai has shown off an interim version of its 2017 World Rally Championship challenger. The car, based on the three-door Hyundai i20, has been developed to meet the WRC's new 2017 technical regulations. Hyundai Motorsport has an extensive testing programme lined up in the final part of 2016 in order to further evolve the car ahead of its debut at the Monte Carlo Rally in January.

WRC regulations for the 2017 season offer teams more power – an increase to 380bhp – more downforce, an electronic active central diff, and a longer and wider vehicle platform.

Hyundai team principal Michel Nandan said: 'The 2017 WRC regulations have allowed all teams to start from a blank page, which has offered us an exciting engineering challenge. The changes will raise the level of entertainment in WRC on stages around the world with wider and more powerful cars. We have been putting our experience from two full seasons of WRC into practice, as we aim to build on our successful 2016 campaign. The 2017 car started testing in April with initial work centred on engine and powertrain testing. More recently, we have looked at suspension, differential and aero. There will be some small evolutions on both chassis and engine later this year. We look forward to revealing the final version later this year.'

Prodrive Australia expands with new performance division

Prodrive Racing (Australia) is developing its business to include a performance arm which will be known as Tickford – the historic automotive brand which has links to Prodrive both in the UK and Australia.

Tickford last operated as a business in Australia in 2001, before being taken over by UK automotive and motorsport engineering giant, Prodrive, which then created Ford Performance Vehicles (FPV) from the Tickford business and at the same time set-up Ford Performance Racing (FPR), which is the former name of the Prodrive Racing Supercars team.

Prodrive Racing (Australia) and Tickford CEO Tim Edwards said: 'The choice of Tickford for the name of our automotive aftermarket business was a natural one for us based on our ownership history. We are the direct descendants of Tickford's previous operations in Australia so it makes sense for us to bring the brand back. The nature of the business is very similar to Tickford of the past – a focus on high-quality engineering and a passion for performance vehicles.'

Prodrive Racing (Australia) managing director Rod Nash said: 'Our race team is at the forefront of vehicle engineering and innovation and within it are disciplined and successful engineers and marketers due to their years of success on and off the race track … Tickford will bring its own strengths and ideas to the group. To me, it is a great addition to the Australian automotive engineering scene.'

INTERVIEW – Adrian Campos

Spanish steps

The grand prix driver turned multiple single seater team owner talks spec formulae, the future of GP2, and how he's helping race engineering careers in Spain

By MIKE BRESLIN

XPB

'My opinion is that it is a good decision to postpone the introduction of the new GP2 car'

When Spaniard Adrian Campos was a grand prix driver, in 1987 and 1988 with the Minardi team, Formula 1 was not a big sport in his native country. Now, thanks to the exploits of one Fernando Alonso, F1 is very big indeed in Spain. As Campos says: 'Fernando changed everything; every Monday after the race, at the bar taking coffee, people spoke about the football still, but also about Formula 1.'

But Campos is responsible for F1's rise in popularity in Spain himself in one respect, as in his second racing career as a team owner it was his organisation, Campos Racing, that launched Alonso on to the single seater stage back in 1999, in Spain's Nissan-backed Euro Open series (the forerunner to WSR/FR3.5).

Then, in 2010, Campos actually even looked set to join Alonso in Formula 1, this time as a team owner: 'There were places for four teams,' Campos says. 'I sold the GP2 team to Alejandro Agag; and the GP3 and Formula 3 team were also sold. I started to work towards the entry in to Formula 1, first as Campos Meta 1, then Hispania, then HRT. I was the founder. But my partners did not think in the same way as me and so I sold my shares and left the project.' HRT went on to compete in Formula 1 until the end of 2012.

Once his part in the F1 venture had come to an end Campos was left to start all over again with Campos Racing, beginning with Auto GP in 2011. Six years on and Campos Racing has grown into an impressive operation, with programmes in EuroFormula Open, Formula E (with Mahindra), GP3 and GP2, the latter actually coming about because of Formula E. 'For me it was difficult to come back to GP2. But in 2013 Bruno Michel [GP2 boss] called me and said "you have to take back your team in GP2 because Alejandro [Agag] is now the owner of Formula E. The team is still based in Valencia and it is the same people, and you have to take it back". I obviously have to be very thankful for the rest of my life to Bruno Michel, because he gave me the opportunity to come back to GP2.'

GP2 chassis stability

Campos is also happy with the way Michel runs the series, and fully backs the decision of the GP2 boss to put off the introduction of the formula's new chassis until 2018 – it was originally scheduled to come in next year. 'The first thing is the economic situation. To change the car for GP3 [which was changed this year], it has been difficult to work with a new car, with new investment. In my opinion Bruno Michel saw that the teams were struggling when changing the GP3 car. Because most of the teams that are in GP2 are also in GP3, two consecutive years with new investments in the cars would be even more difficult for the teams. My opinion is that it is a good decision to postpone the introduction of the new GP2 car. With the economic situation now it is difficult to find drivers with the budget, so this is good for the championship.'

Yet this will mean cars designed for 2011 will go in to yet another season, and as they were based upon F1 designs of 2010, they have started to look dated. But Campos says that is not important. 'The only important thing is to have the same for everybody. But also, wait one year. Formula 1 will be completely new in 2017. Probably the new car for GP2 will be more like the new Formula 1 and not the old Formula 1. So to wait one year is good, because we have to wait and see what's happening in Formula 1, and then make the best car for GP2.'

Level playing field

Having 'the same for everybody' is vital, Campos believes, and he has a good reason for holding the view that spec formulas are actually a very good thing. 'When I was a driver there were different cars competing in championships. I remember when I did the German Formula 3 Championship [1985], I finished third, and the winner was the only one driving a Martini, which was Volker Weidler. All of us others were in Ralts. We could only fight for second place! In GP2 or GP3 it is much better; to have all cars the same. Then it depends on the work of the team and how the driver develops the racecar.'

As a former driver it's understandable that Campos might want as level a playing field as possible for the drivers who are now his customers. But it is not just driving careers that are developed at Campos Racing and the organisation has linked up with Rey Juan Carlos University in Madrid to create an interesting, and effective, post-graduate training initiative for

Campos Racing mechanics and engineers work in one category only, whether that's GP2 (pictured), GP3, EuroFormula or Formula E

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young engineers and mechanics. 'Every year we run a masters [course] for engineers and for mechanics, called Motorsport Specialist Technician. Normally 20 to 25 people will work with us for six months and then we open the door for four of these to work and be paid in our team,' Campos says.

'But 80 per cent of all of them find work in racing car classes or motorbike championships. So, it's good for the students and good for us. For us it is a way to find the best engineers, and also to find the ones who merit the chance to work in this world. For me, every year it give us the possibility to find new work for new engineers, and in this way we know who will work well with us, too; so it's important for both sides.'

Concentrated effort

With four racing programmes and three sites – two in Valencia, one in Barcelona – there is certainly plenty of opportunity for a broad experience at Campos Racing, but the organisation is careful not to spread the close to 90-strong workforce too thinly, and specialisation is the order of the day. 'We don't have people working in two championships; everyone has his responsibility. The easiest way for the team is to see the calendars and to say; okay, that engineer can work in this, this, or this. This mechanic can do this, this and this. But when you do that, it are a lot of races, people become tired, people don't think in the right way and in the end you are doing things in the wrong way. So I took the decision that if we do three championships, or four championships, no one except for me goes to all the races. No one in Campos Racing is doing two championships. This way it costs more, but it is more serious, is more honest to our customers – which at the end of the day are the drivers. We are giving our best, and one engineer must think only of one car, one mechanic must think of his car during the season, and nothing more.'

In the future the engineers and mechanics at Campos Racing could find themselves in the World Endurance Championship – Campos says he has his eye on it, but only if the right partner comes along – but what about another crack at Formula 1? 'I think Formula 1 is for manufacturers now,' he says. 'For us we have to be humble, have our dreams, and try to do our best and be very thankful to have the opportunity to work in a sport that is our passion every year.' After 35 years working in motorsport, you have to say, that's a pretty good attitude to have.

RACE MOVES

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James Allison, the former Ferrari technical director who left the Scuderia earlier this year, has decided against returning to Renault, a move that would have meant a fourth spell for Allison at the Enstone-based team. He was approached by Renault about returning to the fold in June. Allison was technical director at Enstone between 2009 and 2013.

Jean-Baptiste Pinton has replaced **Damien Clermont** as the chief administrative officer at the FIA. Pinton, who joined the FIA at the beginning of July, is now responsible for the strategic direction of the FIA Support Services and coordinates the everyday administrative and financial activities of the organisation. He reports directly to the FIA president, **Jean Todt**.

Todd Parrot has taken over the crew chief duties on the No.95 NASCAR Sprint Cup car run by Circle Sport-Leavine Family Racing, replacing **Dave Winston** in the post. Winston is now working as a race engineer at the same organisation. Parrott has more than 20 years of experience in the Sprint Cup and won the title with driver **Dale Jarrett** back in 1999.

NASCAR Camping World Truck Series crew chief **Gere Kennon** was fined $6000 and placed on probation until the end of the year after the No.8 NEMCO Motorsports, John Hunter Nemechek-driven, truck he tends was found to be under the minimum ride height during a post-race inspection at the New Hampshire Motor Speedway round of the third-tier NASCAR championship.

The media centre at the Mount Panorama circuit – the venue for the Bathurst 1000 Australian Supercars series showpiece event – has been officially named the Bill Tuckey Media Centre, in honour of the Australian motoring and motorsport journalist who died earlier this year. Tuckey was also an author, writing 32 books including *The History of the Great Race at Bathurst*.

Brock Yates, motorsport journalist, Cannonball Run creator and screenwriter has died. The long-time editor of *Car and Driver* magazine created the first Cannonball Baker Sea-to-Shining-Sea Memorial Trophy Dash in 1971, to protest against the then new 55mph national speed limit in the US, with Yates and **Dan Gurney** winning in a Ferrari 365 GTB/4 Daytona. Five more Cannonball runs took place between 1971 and 1979.

Dave Eden has taken on the new role of global motorsport brand and communications manager at McLaren Automotive, with the responsibility for overseeing the PR activities for the growing McLaren involvement in global GT racing. Eden joined McLaren Automotive in early 2012.

Former racecar driver and Cal Club board member **Scooter Patrick** has died. Patrick started racing in 1956 and went on to compete at the Le Mans 24 Hours. He won numerous national championships and races in the US, including the last official Can-Am race.

Former Holden Racing Team (HRT) race engineer **Alistair McVean** has taken on the newly created role of head of engineering at rival Australian Supercars outfit Erebus Motorsport. He will also replace Erebus general manager **Barry Ryan** as driver **David Reynolds**' race engineer on the No.9 Holden Commodore. McVean stopped working for the Walkinshaw Racing-operated HRT team in May of this year.

The former head of the renowned Horton/Holmatro Safety Team, **Lon Bromley**, has died after a boating accident in Oregon. From the late 1980s until 2007, Bromley headed the safety team for what is now IndyCar at all CART and then Champcar races and he played a vital part in saving **Alex Zanardi's** life following his accident at the Lauzitzring in Germany in 2001.

Motorsport marketing guru quits the CSM group

Zak Brown has announced that he is to step down as CEO of the CSM sports marketing and entertainment group.

Brown founded Just Marketing International group in 1995, which became the world's largest motorsport marketing agency, before being acquired by CSM, a division of Chime Communications, in 2013.

The former professional racing driver, who competed in the British F3 Championship and Indy lights during the 1990s, said of his decision to quit the organisation: 'I feel privileged to have been part of an extraordinary team during my tenure. I'm satisfied that we have achieved what I set out to do, from the successful integration of JMI into CSM through to preparing a strong business for a successful future.'

There has been speculation that Brown is now set to join Liberty Media's new Formula 1 management team, and he has admitted that his future does indeed lie in motorsport. 'I will take this experience forward to my next chapter in the arena I know best, motorsport,' he said.

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Zak Brown has left CSM – could he now find himself in a management position with Liberty Media in F1?

Brown has a good record on the commercial side of F1, particularly when it comes to bringing blue chip sponsors in to the sport. These have included Johnnie Walker with McLaren, Martini with Williams, UPS with Ferrari, and UBS with the Formula 1 Group itself.

It is widely believed that new F1 chairman Chase Carey is currently seeking to make new management appointments and he has spoken openly of 'putting the right team in place' to work alongside the existing management of Bernie Ecclestone and his team at FOM.

F1 teams will recruit in face of possible calendar expansion

Formula 1 team bosses have revealed they are seriously looking at hiring more people to deal with the extra workload an expanded calendar would bring.

The F1 season is currently over 21 grands prix, but the sport's new owner, Liberty Media, has made it known that it would like to see more races. With this in mind F1 bosses are now looking at rotating staff, and also at bringing in more people.

Eric Boullier, racing director at McLaren, said: 'I think we are at the limit already so if there would be more races, we would have to have a rotating system with staff. And no, we don't have reserve people back in the factory so that means we would have to hire some people.'

Toro Rosso team principal Franz Tost agreed: 'I think that 20 or 21 races is quite a good number and if additional races come on to the calendar we also would have to think of a rotating system to bring in more people, because otherwise it's difficult to handle everything. But if we have more races, we also have more income and therefore it shouldn't be a problem.'

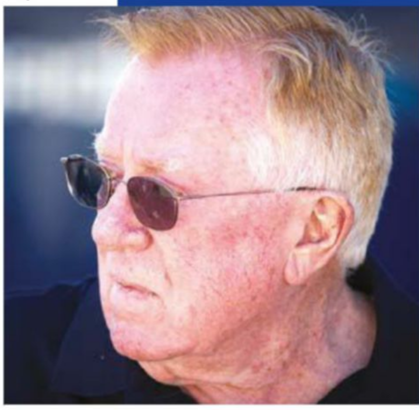
Force India deputy team principal Bob Fernley said: 'We would need to increase the personnel significantly to be able to bring in reserves.'

But Manor's racing director Dave Ryan thought that it might also depend on the future format of grands prix: 'I guess it depends what the package is. Maybe they are two-day events, maybe it's a different format. Until we know what they really are asking for or what they're thinking of, it may be that it works or not. We just have to wait and see,' he said.

With more races on the cards hard-pressed Formula 1 team personnel could be rotated admit team bosses

RACE MOVES – continued

XPB



Racecar constructor and American Le Mans Series founder **Don Panoz** was honoured for his 20 years in the racing industry at a special ceremony held in Georgia in October. Panoz, whose business career started in the pharmaceutical industry, has been responsible for the striking sports prototype cars that have carried his name, while he has also taken on the responsibility for a number of circuits during his two decades of involvement in the motorsport business.

Curt Cavin has been appointed vice president of communications for the IndyCar Series. The former *Indianapolis Star* sportswriter has covered motorsport for almost 30 years and will now lead the series' public relations, media relations and digital media efforts, in collaboration with **Mike Kitchel** (director of communications) and **Brian Simpson** (IndyCar digital/social media manager).

Bob Armstrong, the former competitions manager at the British Racing and Sports Car Club (BRSCC), has died at the age of 69. Armstrong was first appointed competitions manager at the club in 1988 and he played a role in starting many of the series and formulae that are now integral parts of the UK motor racing scene.

Luke Spalding, a talented 18-year old Australian race driver, has lost his battle with cancer. **Matt Chapman**, Spalding's race engineer, said of the former Australian F3 driver, who more recently was competing in the V8 Utes Racing Series: 'Luke lived to race. There have been times when he has had surgery and then less than a week later was racing at the national level. He has been an inspiration to a large portion of Australian motorsport.'

Tim Keene has joined IMSA outfit Michael Shank Racing as its general manager. Next season the Ohio-based team will move from the prototype classes to GTD, running a two-car programme for Acura Motorsports. Keene most recently worked as team manager at DeltaWing Racing.

IndyCar race engineer **Jeremy Milless** has left **Ed Carpenter** Racing, where he engineered the car of **Josef Newgarden**. He will now tend **Alexander Rossi's** car at Andretti Autosport.

Former Chip Ganassi IndyCar race engineer **Eric Bretzman**, who clinched multiple IndyCar championships and an Indy 500 win during a 12-year spell engineering **Scott Dixon**, has left the team to take up the post of technical director at rival outfit Andretti Autosport.

Craig Hampson has left IndyCar outfit Andretti Autosport to take up a position as race engineer to **Sebastien Bourdais** at Dale Coyne Racing (DCR). Olivier Boisson is also set to join DCR, where he will be in charge of damper development. **Michael Cannon** is to engineer DCR's second car. Both Hampson and Boisson previously worked with Bourdais at Newman/Haas during the Frenchman's run of four consecutive championship wins from 2004 to 2007.

Kyle Brannan, who joined Dale Coyne Racing (DCR) in 2016 to engineer its second car, has now left the team to take up a post as engineer on one of the Tequila Patron ESM Ligier-Nissan DPIs in IMSA next season.

◆ 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 email with your information to **Mike Breslin at mike@bresmedia.co.uk**

AUTOSPORT INTERNATIONAL ENGINEERING SHOW 2017 IN ASSOCIATION WITH Racecar engineering

Best in show

As the big event draws ever closer we preview some of the very finest hi-tech motorsport products you will find on display at the Autosport International Show in January

Racelogic
(Hall 7, Stand 7535)

Racelogic's latest camera system, the VBOX Video HD2, which is designed to be simple, yet powerful enough to be used at the highest levels of motorsport, is sure to attract many to the company's stand at the NEC in Birmingham.

One notable feature of this product is the lifetime support provided free of charge by Racelogic. The Video cameras are designed in-house and make use of the latest Sony Exmor HD sensor, which gives superb colour reproduction and great night sensitivity, Racelogic says.

They are also small, waterproof, and come with a 3m cable allowing remote mounting. Racelogic says this is its most rugged video recorder yet, with high grade motorsport connectors and a super-capacitor power back-up system.

The real-time graphics engine produces full colour HD graphics showing speed, g-force, lap-times, track maps and sensor data. These are overlaid onto the main video picture in real time (not using software afterwards). The internal 10Hz GPS engine recognises the track you are driving from a built-in database of over 450 circuits and automatically configures the track-map and lap-timing.

The VBOX HD2 will start recording automatically, whenever you go above 15km/h. This means that the memory card doesn't get filled up when the car is stationary. This also stops the creation of lots of small files whenever the GPS signal is affected by being in a garage or close to a building. The VBOX HD2 continuously buffers up to 30s of video before the car starts moving. But the moment the racecar goes above 15km/h, this video pre-buffer is then written out to the memory card.
www.vboxmotorsport.co.uk.

Bosch
(Hall 9, Stand E475)

The Bosch MS 7.4 engine control unit manages petrol engines with up to 12 cylinders. It features a powerful digital processing core with floating point arithmetic and a high-end FPGA for ultimate performance and flexibility.

The MS 7.4 also utilises a software development process based on MATLAB/Simulink, which significantly speeds up algorithm development by using automatic code and documentation generation. Custom functions can be generated quickly and easily. The flexible hardware design allows the MS 7.4 to support complex or unusual engine or chassis configurations. It is optimised for low and high pressure injection, it has a data logger included, and optional combustion chamber pressure determination.
www.bosch-motorsport.de

Willans
Hall 9, Stand E58)

Willans announced some time ago that it is now manufacturing FIA FT3 approved fuel bladders.

Its latest range of W301 Kevlar-based fuel bladders use Kevlar-woven fibre material to give the required strength – it is much lighter than Nylon as well as conforming very well to unusual shapes and tight radius corners.

Willans has invested in the latest custom-designed CNC machinery and CAD/CAM software to allow for a quick turnaround from initial design to the cut material ready for fabrication. The company claims that it can create a bladder from an old tank, a CAD drawing, or a simple sketch. It is also able to create nut rings and fill-plates to industry standards or to customer specification.
www.willans.com

Magneti Marelli

Magneti Marelli intends to unveil its full Formula E powertrain at the PMW show in Cologne in November 2016, before then bringing this exciting new technology to the Autosport International extravaganza in January of next year.

Magneti Marelli Motorsport's work on safety issues will also be showcased, with its High Speed Camera, a product it has developed with the FIA to improve the passive safety of Formula 1 cockpits.

Despite its small size, this device records at 400 frames per second, a frame rate crucial for race directors to analyse the dynamic of crashes.

The famous Italian company will also be showing off a new kit designed for GT cars, including the brand-new dashboard FBO. This device is more than a high-resolution colour screen – it is a complete hub of extensions for the driver and the team, Magneti Marelli claims.
www.magnetimarelli.com

Powerflex

(Hall 9, Stand E890)

Another company to look out for at ASI is Powerflex. It will be showing off its technical developments for the Mini Generation One, including the R50, R52 and R53 models.

A range of new geometry-adjusting products have been developed to improve handling, making them ideally suited to the faster driver, and for track and racecars.

The PFF5-101G offers an additional two degrees of caster and is aimed at offering greater precision with improved geometry for people wanting the very best from their Mini.

This new part, which is fitted to the rear of the front wishbone, has a hard anodised aluminium outer shell with one of Powerflex's 'unique' low friction polyurethane centre bushes. The poly/alu combination creates a low-friction-rotating bush reducing the forces acting on the arm. Lower arm deflection has been decreased by reducing the compliant material within the aluminium shell. Additional caster angle will give more negative camber when cornering, meaning improved tyre to road contact.

The results are improved geometry when turning, giving additional grip, steering control and feel, with less movement in the arm under cornering and braking, Powerflex tells us. **www.powerflex.co.uk .**

AUTOSPORT INTERNATIONAL

12-15 JANUARY 2017

OPENING TIMES:

Saturday: 9:00am to 6:00pm
Sunday: 9:00am to 6:00pm

TRADE TICKETS

TRADE	Advance price	Door price
Adult	£28	£30
MSA members	£23	£25
BRSCC members	Free	Free

Tickets do not include access to LAA (Live Action Arena), which is sold separately at £11 (advance and on-site)
Each ticket includes a Trade Directory (value £10), collectable on the day.

STUDENTS

Ticket type	Trade days (12 and 13 January)	Public days (14 and 15 January)
Student 1 day entry pass	£28	-
Student 1 day entry pass + LAA	£33	-
Tutor 1 day entry pass	£28	-
Tutor 1 day entry pass + LAA	£33	-

How to book

Trade Days.
To register visit www.autosportinternational.com
or call 0844 335 1109
(BRSCC Members should contact the BRSCC directly)

CONSUMER TICKETS

	Adult	Child (6-15yrs)
Standard	£35pp	£23pp

An exciting 2017 season kicks off at ASI

The off-season in racing now seems to be February, when the track action is temporarily suspended as teams undergo final preparations for a new racing season, and August, when an enforced 'down tools' period in Formula 1 has spread throughout the sport.

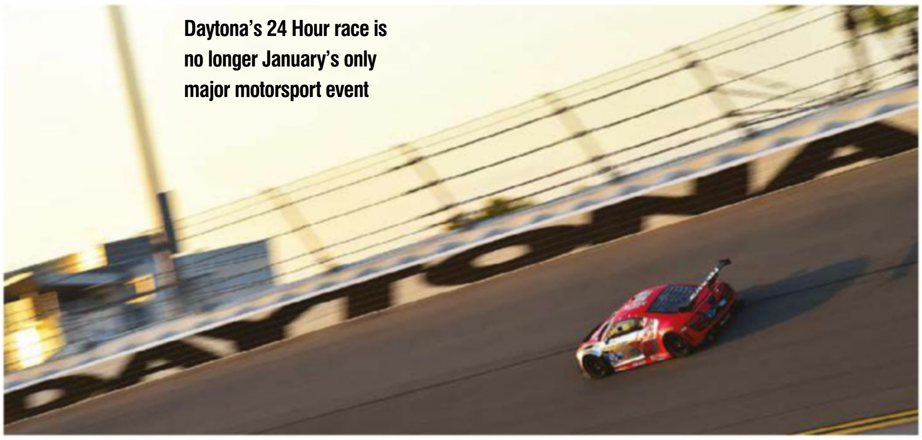
But it used to be that freelancers would get to October, and wonder what we were going to do for four months. The Autosport International Show, traditionally held in January, was the place to go and meet up with fellow temporarily unemployed personnel, in the hope that one would bump into an employed member of the racing community, and generally to find out what was going on.

It was a good place to finalise deals for the coming season, to come up with new ideas, and for journalists it was an excellent place to find stories to fill the pages of magazines around the world that were crying out for material.

The show has not changed, even though the racing scene has. With new markets opening up around the world, racing in January is now commonplace and not only limited to the Daytona 24 hours at the end of the month. The Dubai 24 hours also takes place early in January, as does the pre-race test for Daytona, at which all the new DPI cars will be running. Despite this, the Autosport International Show retains its place as the place to start the season, with the latest technology on show, and also with the calibre of personnel in attendance, many looking to do business.

The talk this year will undoubtedly be what is happening in the near and mid-term future. This month in *Racecar Engineering*, we feature the 2017 F1 regulations, the new tyres and the new aero packages and these are sure to be topics of discussion in Birmingham in January. The DIL drivers have already given their verdict on the new F1 cars; the cars feel slower but will be seconds quicker. Will we see better racing in Formula 1? Who will have solved the tyre issue better on the grid, and who will have stolen the early advantage? And what of the future of the DTM and the WEC? And how will the suppliers look to meet the new demands they face? Motorsport launches and interviews are common at the show, too.

For more than a quarter of a century, *Racecar Engineering* and the Autosport Engineering Show have gone hand in hand. And, there is plenty of reason for us to do so in the long term future too.
Andrew Cotton, editor



Daytona's 24 Hour race is no longer January's only major motorsport event

Racecar engineering
The International Journal of Motorsport Technology

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Subscription rates
UK £71.40 (12 issues)
USA $174 (12 issues)
ROW £90 (12 issues)

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News distribution
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Tel +44 (0) 20 7429 4000
Fax +44 (0) 20 7429 4001
Email info@seymour.co.uk

Printed by William Gibbons
Printed in England
ISSN No 0961-1096
USPS No 007-969

THE CHELSEA MAGAZINE COMPANY LTD

Independent publishing company of the year 2015

www.racecar-engineering.com

Losing control of control

The word 'control', according to the Oxford English Dictionary, means the power to influence or direct people's behaviour or the course of events. It has positive connotations when applied to oneself; to exercise control is to stop one running out of it. However, when it is applied to others, we come up with all sorts of reasoning why, but ultimately it leads to stopping another person from doing what they want, or need, to do.

At the World Endurance Championship race at Fuji, it was hard to have a conversation in the paddock without someone talking about control. It actually became a sport within itself, trying to have a conversation without the other party bringing something up about the subject.

Cost control was a key topic of conversation, with LMP1 dropping to two bodykits and four sets of tyres in 2017, while it was also concerned with three ERS introduced in 2018 as per my last column. Attracting a new manufacturer requires a demonstrably clear cost control system. Controlling performance through Balance of Performance is a continual topic – that weekend Aston Martin was watching the refuelling speeds of the Ferrari as they should be controlled to be the same as the other competitors. Meanwhile, Ferrari was watching the performance of the Aston Martin which qualified both drivers on the same tyres, setting fifth and sixth fastest times despite a smaller air restrictor and a larger Gurney to keep the Vantage in check. Each measure is designed to stifle spending, and therefore competition to the extent that a competitor will eventually not see the need to try. If they don't try, they will get some sort of help, while those who do try see their efforts thwarted. It is the antithesis of racing, and the basis for turning the sport into a business.

There is a lament among engineers that racing is not what it used to be

This has been going on for some time, and is a creeping cancer that has spread alarmingly. When Mark Webber announced his retirement from racing altogether, he echoed similar sentiments to those uttered by Fernando Alonso about driving in the modern era: less fuel, less aero, fewer tyres, what the hell are we doing here?

Cost control is simply another way of saying that the return on investment isn't enough. Instead of pushing the promotional opportunities more, generating better sponsorship and a television package that gives the competitors something to sell, there is instead a drive to reduce expenditure. While this may mean another challenge for the engineers, it also stifles R&D, simply because there is less money to invest. Fewer companies now will sign off an investigation by an engineering team without knowing what the outcome will be. But by the very nature of an investigation, no one knows what the result will be, otherwise one wouldn't require an investigation in the first place.

Any engineer has to work with what they have and the skill remains to make the most of it, but increasingly there is a lament among the established engineers that racing is not what it used to be. Pandering to the lowest common denominator behind the wheel, the gentleman driver, the professionals have been left with paddle shifting, ABS, traction control, fixed pit stop times, control tyres. Defining what is a professional and an amateur is the next stage to control the spending and the opportunity for the amateur driver, and so came the driver grading system. A law of unintended consequence if ever there was one.

I have written before that there is not enough competition, not enough edge between competing teams, drivers, manufacturers and series. Drivers are told to keep their aggression in check, manufacturers are told that they need to save money. Series demand that technical regulations are tightened to prevent unnecessary expenditure. In GTE Pro, for example, performance is balanced according to the entire car package, including the tyre performance, meaning that an interesting tyre war that looms large in the category between Dunlop and Michelin is being stifled and may be killed off entirely.

As for the new LMP2 regulations, the decision to limit the number of chassis makers to just four on the grounds of creating a sustainable business for these companies may be about to come back on the FIA with bells on. Manufacturers such as Wolf, Dome and BR have been cast to the weeds in terms of racecar construction for the category, and each had a car ready to go for the 2017 season. The four that are left, Ligier, ORECA, Riley Multimatic and Dallara now have a monopoly and, if they work together, can have the organising bodies over a barrel. For racing teams, they can buy a car for €495,000 and go racing, but the cost of the spare parts will fail to achieve the targeted 35 per cent reduction in costs.

Money in motor racing is tight, and so while fighting for a share a series is looking inwardly to make the money it can gather go as far as possible. This makes logical sense on the surface, but it is time that the series take responsibility for better marketing and return on investment. No business can survive long-term with austerity measures in place. At some point the financial brakes have to be released to allow innovation again. In racing there is no sign of that happening.

ANDREW COTTON Editor


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