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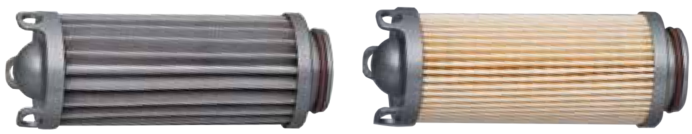

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Taking the nuts to Brazil

Recalling a time when getting to an event was as much an adventure as the race itself

Forty-six years ago there was an expedition to the darkest parts of the South American continent by a band of intrepid Brits, doing all the things people did in the comics such as *The Eagle*. It wasn't meant to be that way, but the combination of the idea of sending a gaggle of Brit Formula Ford racers on a 'Temporada' in Brazil with a sprinkling of South American drivers for local interest, sponsored by Ford of Brazil and British United Airways, coupled with the sheer size of the sub-continent, made for some interesting moments.

Emerson Fittipaldi had won the Formula Ford Championship by May 1969, in his first year in the UK, and both UK F3 championships by the end of it. TV company Rede Globo and Ford thought it would be a good idea to contact John Webb, then owner of Brands Hatch and a Formula Ford race organiser, to corral a suitable representative group of Formula Ford stalwarts and capitalise on this. British winter being what it is, it was not too difficult to find a group of racers and mechanics happy to escape from the snow, while the good prize money on offer might have helped a little, too.

Brazilian blend

As well as Emerson Fittipaldi some other future notable drivers took part in the series, many of whom would go on to make an impact on the sport at a higher level in other roles, too, such as Tom Walkinshaw; Vern Schuppan; Ian Ashley; and Tony Lanfranchi, as well as the winner of the first ever Formula Ford race, Ray Allen. These were also joined by the best drivers from Brazil.

Webb had a naive view of the Brazilian road network, and came up with an optimistic calendar for this race; starting at Rio on 1 February 1970, driving the Jeepsters provided by Ford (it had taken over Willys in Brazil) with trailers carrying the cars to Curitiba to race on the 8th after a 840km tow, then loading the racing cars on to car transporters to do the 3308km to Fortaleza (more on this later) for the 15th, whilst the drivers and crews drove the Jeepsters and trailers to Rio, before driving to Recife, and then Flying to Fortaleza.

After the race in Fortaleza they would then be driven back to Rio to race on the 22nd and on to Sao Paulo for the final race on March 1. Much to the surprise of me and the other locals, nobody in the organising group raised the least question about the timing and distances involved in this schedule.

The first race was in Rio de Janeiro, on the local track at Jacarepagua. The fact that the circuit was in between a couple of mountain ranges ensured that the race, held in February, would be in a 42degC, 100 per cent humidity environment.

Cars overheated, drivers overheated and even I – a local brought up in this sort of climate – was struggling a bit, as I had spent the European winter in the UK, losing my acclimatisation. But the sizzling weather did not deter the crowds, and there was a sizeable audience of 35,000 spectators for the start of the event – not bad for a Formula Ford race.

After that first race the adventure began in earnest, and the run down to Curitiba with the trailers in tow produced a list of wide-eyed tales – a few of the Jeepsters even turned up with bullet holes in them. As Brazil was still in the grip of a military dictatorship, the borders between states had checkpoints with armed military police, who did not take kindly to an unruly mob of Brits driving through at warp speed ignoring the barriers.

The rest of us awoke as we spun off into 5ft high prairie grass

That's quite a crowd for a Formula Ford race; many were attracted to Interlagos by the presence of Brazil's new hero Emerson Fittipaldi

Jeep thrills

The interesting part of the Temporada was really the slog up to Fortaleza. The teams had a somewhat easy ride, driving up to Rio with empty trailers, dropping them off at the track, then driving up to Recife 2305km away. The Rio-Bahia road went through several states, and one unforgettable stretch consisted of a dead straight line for 500km, uphill and downhill through uninhabited scrubland, most of this at night. Headlights being what they were in those days, this was a nerve-wracking flat out driving exercise, all the while the man at the wheel expecting the inevitable corner to loom out of the night, which entailed many driver changes as each of us cracked under the pressure.

The inevitable finally happened. With Ian Ashley at the wheel the rest of us awoke as we spun off into 5ft high prairie grass, which seemed to stretch for miles. Where was the road? Headlights masked by the grass left only one solution. Whilst one was left at the car blowing the horn at regular intervals, so he could be found again, all others fanned out in four directions until one stumbled upon the road.

The fuel stops in the middle of nowhere, at pumps where one wound the handle to fuel up in places where you also had horses tied to the railings, also enlivened the rest of the trip to Recife. Once there one gorged oneself on fresh lobsters, the local delicacy, until it was time to fly on to Fortaleza. Meanwhile, as the last third of the route was on dirt roads, the transporters struggled through, having to drive the equivalent of the distance from London to Cairo …

Behind bars

The mayor of Fortaleza, who had paid part of the costs to bring this circus to his town, was suspicious of all the boisterous young gringos living it up in a tropical beach town with no sign of their racing cars turning up by Saturday night. So he decided to take Webb into custody. The arrival of the transporters early Sunday morning, race day, solved that problem, but as the multi-lingual personage I had meanwhile been pressed into getting some of our band out of jail, as they had been sampling the rather downmarket fleshpots and in true Brits abroad fashion, raising considerable trouble as they did so.

The trip back was less troubled as we were all road-hardened by then, and by another miracle the transporters managed to get to Rio by the next Saturday morning. Another good race in Rio, followed by the final in Sao Paulo, with a massive crowd, and the *Torneio* being won by Emerson, which kept the spectators happy, meant the series was seen as a success. Then the cars were delivered to the port and shipped back to the UK.

The return of the Jeepsters was chaotic. They were parked higgledy-pigledy on kerbs around the hotel, though one was in a fountain in the nearby park, and several were missing altogether, their keys dropped off at hotel reception. A Ford Galaxy loaned to the organisers had also somehow disappeared in the melee. All of which attested to the fact that a good time was had by all.

Racing is not what it used to be …

Grand prize racing

Should winning a 'major' mean a double helping of world championship points?

I watched a fair amount of the Rolex Daytona 24 Hours race on IMSA's live website. Unlike the Le Mans 24 hours last year, I didn't wake up especially during the night nor miss out on proper meals to keep track of goings-on. Undoubtedly the absence of works LMP1 Audis, Toyotas and Porsches had a hand in this – these are remarkable machines to see in action – but I also found that the banked Florida track itself doesn't provide particularly exciting viewing. It presents a challenge for the drivers and engineers, but actually there are not many corners in the three-and-a-half mile lap, no classic fast bends, no elevation changes. Nonetheless, it provided some very good racing and remarkably close finishes.

Despite its' notorious low spectator attendance (possibly due to its proximity to NASCAR's standout Daytona 500, also in February) the race remains a special event, for a number of reasons apart from its long history, faithful sponsor Rolex and twice-round-the-clock challenge. It attracts a large and eclectic entry of cars and, especially, drivers. Where else is one likely to see LMP, NASCAR, Indycar, GT, Touring Car and ex-F1 drivers competing in the same 53-car event, along with amateurs? Taking place so early makes it traditionally the first big international race of the year. It is also notoriously tough, with 10 hours being run in darkness and frequent debris on the track among some of the hazards. Due to the debut of Ford's new GTLM car, with pleasing styling echoes of its iconic GT40 ancestor, this year's race gained additional media focus.

Standout events

Having become a bit fired-up from watching the goings-on, it got me thinking about other classic races and their place in global motorsport. Le Mans stands out above all, of course, along with the Nurburgring and Spa 24 hours. This is because there is something unique about them. All have history, some from the very early days of motor racing; they are extremely challenging circuits with frequently changing conditions where one has to really work for a win. The Bathurst 1000 is gaining a similar status. Also, although not, sadly, quite what it used to be, the Indianapolis 500 nevertheless remains a great race which is recognised the world over, more so in fact than the championship of which it is a part (IndyCar), and this event still has the potential to regain its glory days.

Classic races

In racing generally, I believe that there is an argument for placing more emphasis on individual races including those that make up a championship, not just on the championship *per se*. Of course, serious sport of any kind generally demands a person and/or team that can stand proudly on the rostrum by the final event and be proclaimed champion. It is just reward for determination and consistent competitiveness, with some special performances along the way. However, in motor racing – which we should remember first began with stand-alone endurance races – too often it seems qualifying rounds of a championship have become just another step on the way to the final result; they are not lauded for their own unique characteristics and supporting national culture. This needs to be worked upon, with social media playing its part. F3 has grasped this to some extent for a good many years now, with prestigious non-championship races such as F3 Masters and Macau. To a driver or team undergoing a bad year for reasons perhaps not of their own making, it gives an opportunity to hit the headlines and save a season, or even a career.

XPB

Winning the Monaco Grand Prix is a feather in the cap for any team and driver but should victory in this race and other 'classic' GPs be rewarded with double points?

Certain races in F1, such as Monaco, do have a particular status, but to me the traditions embodied in these grands prix are not always enough. They need reinforcing. I was among the majority who ridiculed the double points awarded to the final round in 2014 because of the risk that it could skew the championship result and destroy a season-long endeavour at the last gasp. However, there is an argument for awarding double points to a number of events, rather than just the final one, as it spreads the risk more fairly. I would advocate these special rounds (*Grands Prix Majeure*?) as being deserving of this added prestige by virtue of having been the most consistent in staging GPs over the years, consequently they possess a great history, are particularly challenging for car and driver and are well-established. As an indication, if someone was to ask me off the cuff who won a specific GP a couple of years ago I would more likely answer correctly if it was Spa than if it was Abu Dhabi; I venture that I wouldn't be alone in this. With 21 races now on the calendar, there is a real risk of them passing blandly in a bit of a blur. To Monaco therefore I would suggest adding the Belgian (Spa), Japanese (Suzuka), Italian (Monza) and British (Silverstone) GPs. Given that it's a driver's circuit and often provides a great race, Brazil's Interlagos could count as well.

Had the German GP not alternated between Hockenheim and the emasculated Nurburgring, then it would qualify, but these tracks are not worthy of their predecessor. That there is no French GP is a travesty, given this country's history with racing, but unfortunately it seems to be a case of *c'est la vie*.

Double-points races would introduce a degree of unpredictability throughout the season, as the championship lead could change dramatically to and fro. As with Daniel Ricciardo at Spa in 2014, it could also give added kudos as well as vital points to an unanticipated winner. Should any of the other GPs object to not having the same status, then the answer is that they have to earn their spurs. Maybe this would start ruling out, or at least altering, some of the characterless Tilke-dromes that currently blight the sport.

In motor racing, too often it now seems qualifying rounds of a championship have become just another step on the way to the final result

Honed to perfection

There were few surprises when this year's batch of Formula 1 cars broke cover at the first pre-season test – but some of the detailed development on show was very impressive

By SAM COLLINS

Formula 1 has now entered the third year of a rules cycle which began back in 2014 with the introduction of the then new 1.6-litre V6 turbocharged hybrid power units. That was probably the biggest year of change in the sport's modern era. In stark contrast to that is the 2016 F1 season, which is most remarkable for how few changes there actually are in the Formula 1 technical regulations.

This has resulted in some of the new cars being almost indistinguishable from their 2015 counterparts, something which became rapidly apparent during the first day of pre-season testing where 10 new designs were revealed in the space of about an hour.

The overriding trend on display was one of continuity: Red Bull, Renault, Williams and Force India's initial specifications bore striking resemblance to the 2015 versions, aside from a few livery changes. Sauber did not even bother bringing its new car to the opening test, though it was suggested by some that if the press release had simply claimed it was running the new car most in the media would have believed it.

'I'm often asked at this time of year what area of the new car I'm most pleased with,' Adrian Newey, chief technical officer at Red Bull Racing said. 'But with the stable regulations we have at the moment it is difficult to find any major new areas to exploit. This is a third-year car under a pretty restrictive set of regulations, but the guys have done a very good job of tidying things up. Therefore, what we

With many teams now starting work on the 2017 designs, the story of 2016 may be one of continuity, with the area of greatest technical change expected to be the power unit

have really tried to concentrate on with this car is getting a cohesive package for all the parts – the suspension, the chassis dynamics, the aerodynamics – so that they all work together in harmony.'

This trend toward what used to be known as 'legacy cars' in FSAE has been further exaggerated by an ongoing uncertainty over the shape of the next designs for many teams. Formula 1 (FOM and FIA) has announced on a number of occasions that in 2017 there is to be a major overhaul of the technical regulations – with the intention of creating a faster and more visually exciting class of car – most recently part way through the first 2016 test. Yet no rules have appeared as yet and there is growing uncertainty about whether the rules will change at all. This is a situation that has seen many, but not all, opt for consolidation of the current concepts rather than try to do much that is new.

Force India, for example, introduced a substantial upgrade to its VJM08 design halfway through the 2015 season. 'With the regulations likely to change for 2017, it didn't really seem like an efficient use of our resources to start from scratch on a project that would have such a limited lifetime', its technical director, Andrew Green, said at the VJM09's launch. 'We are happy with the direction we took last year, we think there is scope for further improvement so we made the decision to maximise the performance and potential of the current concept.'

All of this does not mean that the cars are exactly the same. Indeed the chassis rules


The Haas VF-16 (left) is the first of a new type of grand prix car built to exploit a rule change that means it is now possible to buy in most of the parts used on the car. The new American team has partnered with Ferrari to co-develop the VF-16 alongside the Ferrari SF16-H and the two share many components. Haas claims that the aerodynamic package is all its own work (compare and contrast above). Haas suffered a front wing failure on the first day of the Barcelona test but otherwise it was moderately pleased with its progress


The Haas exhaust (left) and the Ferrari exhaust. Monkey seat aside the treatment here seems very similar. Ferrari has worked hard on detail changes to the rear end of the SF16-H and it has also changed the layout of the components of is power unit in an effort to improve the packaging, and to shift the weight a little more towards the centre of the racecar

prevent any 2015 cars being raced in 2016. This is because, following the deaths of Jules Bianchi and Maria De Villota, attention turned to improving the head protection for the drivers, and for 2016 this area must be significantly larger. While the regulations state that cockpit sides must be 20mm higher, they also have to pass a much tougher crash test of 50kN, where in 2015 just 15kN was the standard.

'The chassis now has to take that five tonnes of load at that point, it's been a really big job for the people designing the chassis,' Paddy Lowe, executive director (technical) at Mercedes explained. 'It's a very significant load increase so it's a case of how do you achieve that with a minimum impact in terms of the weight and the aerodynamic influence.'

For some of the teams the larger cockpit protection sections were not the only challenge

But for some teams the larger cockpit protection sections were not the only challenge which they had to face in developing the chassis. As a direct result of perceived negativity from Red Bull about the performance of the Renault power unit in 2015, three of the cars on the 2016 grid have had to make very late decisions on power units. Red Bull Racing had been unable to secure a supply of power unit until it was agreed that it would continue with Renault, though rebadging the engine. Sister team Toro Rosso lost its Renault supply and is now using year-old Ferrari units, while Renault's reaction to the situation was to re-enter the sport as a full works team, even though the team (as Lotus) had already designed its car around the Mercedes power unit.

'It was super tricky to deal with that as we designed the car for the Mercedes PU, then made the switch very late,' Bob Bell, Renault F1's technical director said. 'That was a massive amount of work to change the chassis patterns, all the cooling system, and all the layout of the back of the car. It was an impressive bit of work by our designers just to get here.'

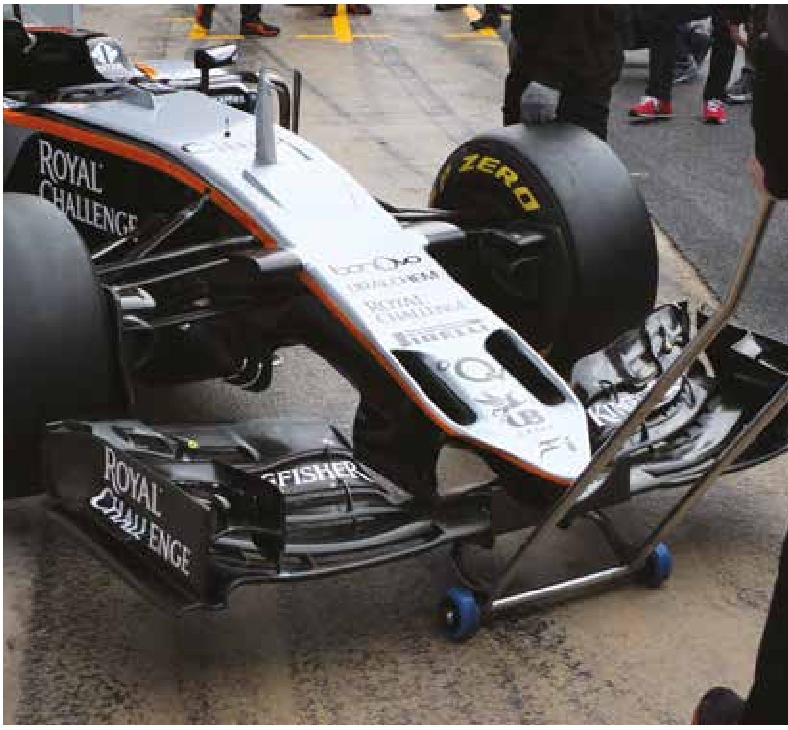
The difference between the Mercedes and Renault in terms of shape is substantial, not least because the Merc engine has its split turbo, which has the compressor and turbine at opposite ends of the block, while the Renault is conventional with the compressor and turbine mounted at the rear of the engine.

Technical Implications

Rob Marshall, who designed the Red Bull RB12, said of this challenge: 'If we were to put in a different unit, the car would have to have been different architecturally because the different units have different requirements in terms of installation; where compressors are, the size of batteries, it affects the length of the chassis.'

The change hit the design of some of the longest lead time items of the entire car, the

Mercedes and Toro Rosso have opted for very large air-boxes on their 2016 cars, a concept which Red Bull's Italian junior team has developed over recent years. 'It's an evolution of the cooling concept on the car, with lots of air which was going through the sidepod now going through the air-box,' Merc tech boss Paddy Lowe explained



Force India was so pleased with its 2015 updates and the upturn in pace that resulted from them that it decided to base its 2016 VJM09 on the '15 car, with its distinctive nostril nose. The team topped the timing sheets on occasions at Barcelona, which doesn't always tell the full story when it comes to race pace, but Force India is certainly one to watch

Mercedes and Toro Rosso have run with ducted noses in testing but during the opening day at Barcelona the Mercedes wing actually struggled to pass the FIA deflection tests

monocoque and the transmission. Renault's technical director, Nick Chester, said: 'Switching the transmission was not easy at all. We had made some changes for the '15 car, but that did not fit the exhausts for the '16 car. So we had to come up with a few solutions to get round that knowing that we could not produce new castings in time. This box is not what I would call cut and shut, but we have had to do it in a way that worked with the time we had.'

The overall aerodynamic design of the car is also hit by any change to the power unit, Marshall says: 'We looked at a number of power units and the requirements they had and as a result we looked at a number of different car concepts in parallel. It is a good exercise as it give us an idea of what the opposition is up to. Also, the cooling requirements for the different power units are different. As we have stayed with the same unit we understand the heat rejection requirements and, even though it was very late, we were confident of getting it right.'

Planning for change

Red Bull was in a somewhat better position than the Renault (Lotus) team in as much as it was planning to change power unit. It just did not know what it would change to. While ultimately this change was limited to the stickers on the bodywork, rather than the power unit itself, the uncertainty created some very real engineering challenges for Marshall and the team at Red Bull Racing. 'You can design everything up to the bellhousing and the back of the chassis and you can normally push the drop dead dates back a bit,' he explains. 'Splitting the tooling to give you an extra week on the bulkhead or getting the rest of the transmission spot on before defining the bellhousing it is not that tricky if you know it is coming. It is not all that long since we designed a car for Toro Rosso which used

The level of efficiency of the engines has risen through 2014 and 2015

Pirelli has brought out a new type of tyre for Formula 1 in 2016. The new concept features a thin operational layer and a lower-grip base level beneath it. It forces teams to pit before wear reaches a critical level, as it did a couple of times in 2015

Ferrari has abandoned pullrod front suspension and has returned to a pushrod layout. Also note new short and narrow nose

Higher cockpit sides are the main regulation change this year. These now have to pass a much tougher crash test of 50kN

a different engine; it was a manageable task with a different bulkhead.'

One of the biggest components which influences the design of current monocoques is one of the key power unit constituent parts; the energy store. And as a result of Red Bull's 2015 search for a new power unit partner Marshall was presented with the chance to get an understanding of the differences between each of the four currently in use. 'Some of the batteries have the control units packaged with the batteries and some have not. The regulations say that the battery must be inside the chassis but the control unit does not have to be,' he reveals. 'A manufacturer which has put both together means a larger volume in the tub, which reduces fuel volume, which then means you need to make the car a bit longer or a bit fatter. It's not a big deal, but if you designed your car around a small battery then had to fit a big one, then you would not have enough fuel.'

Battery technology is an area of rapid development in industry in general, and Formula 1 currently seems to be no different. 'There is a lot of development into the cells [to] get ones that heat up less and requires less cooling,' says Marshall. 'Trying to develop cells that degrade less with time is also important. The cell suppliers are working hard on that. The cells out there now are all fairly similar.'

PU development

However, battery technology is not the main focus for any of the current four power unit suppliers. Instead they are focussing on more traditional areas after an initial period of technological development when the current rules were introduced. 'In 2014 we went safe by using a battery with a bigger capacity than you would need at any race that year,' Remi Taffin, Renault's F1 engine technical director reveals. 'So in 2015 we used a slightly different technology and resized it a bit, but it's not pure gains now, it's all trade off things. We are on the tail of what is being done on road cars – there is a massive amount of work in that area. Nissan and Renault put a lot of resources into that and we share a lot with them. Where we are going to find the improvement for F1 is making lighter cells with a higher specific capacity but I don't think this is the big focus for the coming years in F1. We still have a lot more energy from the fuel than the ERS, so the best thing to focus on is the combustion. Now we [get to] the edge of the amount of recovery possible with the MGU, it is the ICE which is where the gains come.'

This is something borne out by others, as the level of efficiency of the combustion engines has risen substantially through 2014 and 2015, and with it much focus on the fuels used and specifically how they burn. 'We don't hit the 500bar fuel pressure limit at the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'We now have a nice clean pipe without any silencing points'

Top: Renault has returned to Formula 1 as a works team. Its new car, the RS16, is a mildly updated Lotus E23 **(above)** – the continuity between the two is very clear. But the change from Mercedes to Renault power has not been without its issues

The Manor MRT05 is the team's first new car for two years. It has almost nothing in common with the 2014 MR03, but does share a lot with the stillborn MNR1. This year the team has also switched to a Mercedes engine and Williams transmission

moment,' Taffin says. 'I guess it's going to be more if you have multiple injections and trick things like that, but so far we are not on that limit. We are already in that direction and we are getting closer and closer to a diesel engine in that respect.'

The second major change in the technical regulations for 2016 (the first being the cockpit regulations) is focussed on the power unit. As part of the ongoing and somewhat controversial attempt to make the current cars louder, the wastegate exit may not now be linked to the tail pipe and must have its own direct exit. 'The FIA undertook an interesting and thorough investigation to analyse noise in the tailpipe and investigate what could be done to increase noise without impacting performance or efficiency,' Mercedes HPP managing director Andy Cowell explains. 'What they spotted is that the wastegate fed into the tailpipe. So, when the wastegate is not open, it's a dead end. It then becomes a side branch resonator, effectively a silencer, on the tailpipe. That design has now been removed, so we are left with a nice clean pipe without any silencing points, which should improve the noise.'

Volume control

Following the FIA research the rule was adopted, and during running on the test bench a clear result was seen, according to Cowell. 'On the dyno we have seen a 4db increase in the peak sound level,' he says. 'We were at about 124db now we are about 128db, where the V8s were 129.5db. We are still working with the FIA on that. I think that it improves the quality of the sound, a bit of purer sound.'

However, there is some debate about how much difference the new wastegate exits really make. But Cowell says: 'As we continue to increase the performance of the engine you increase the exhaust pressure and that also creates more sound. I think with time it will get progressively louder whatever you do, but we are working on a new system too.'

Pat Symonds, chief technical officer at Williams, is clearly sceptical that the wastegate exits make any difference at all. 'I'm not sure it's much louder, it's very subjective. There is a 2015 car out there running at the moment and has anyone noticed the difference? I didn't,' he said.

Adrian Newey has his own theory as to why there was not a clear difference. 'I think the big difference will come in qualifying, during that session you run in a mode where you drain the battery and don't use the MGU-H for recovery, so that means the wastegate is open a bit more. It should be a bit louder in qualifying. In the race it depends on the strategies used.'

However, the rule still states that there must be at least one wastegate exit in addition to the main tailpipe. As these pipes

The new Haas VF-16 – VF stands for 'very first', we're told. While much has been made of the American team's tie-up with Ferrari there is also a great deal of Dallara know-how in this racecar

McLaren is one of a number of teams to run its rear wing support through the exhaust tailpipe, something pioneered by Toro Rosso in 2015. The team goes into its second season with the Honda power unit – the only outfit to use the Japanese engine

The exhaust on the Renault RS16. The jury is still out on whether changes to the exhaust system, which means that the wastegate must now have its own exit rather than using the tail-pipe, have actually improved the sound of the cars

The overall aerodynamic design of the car is also hit by any change of a power unit

are downstream of the turbine teams have freedom to lay out the exits as they see fit, and all but one of the 10 cars which turned up for the opening test used a twin exit layout. The exception is Renault, which is making use of just a single wastegate pipe. 'I think its all about packaging,' says Taffin. 'We went for a single wastegate because it is a little bit lighter. Its just about how you route them past things.'

A final note on the power units for 2016 is to do with the life expectancy of each of them. With 21 races on the calendar, each driver is allocated five power units which, averaged out, is a slightly lower life requirement than that which was in place last season. But the manufacturers are actually working on only using four units per driver, in case one of the 21 races currently on the calendar is cancelled and they are required to operate with four.

Looking ahead

'It is tempting to keep an engine back to use as a wildcard unit,' Cowell says. 'Maybe just for one race. Our plans were based on there being 20 races and four units, our targets are based on that, but with five and 21, it's possible that we could do a performance special, but we won't know if it's four or five until Melbourne.'

In reality the token system would probably prevent the Honda 'Suzuka Specials' of yesteryear, which were designed to last a single event, from returning this season, but with the token system removed in 2017 this could be a possibility next season.

Indeed with many of the Formula 1 teams now starting work – albeit in rather uncertain directions – on the 2017 designs, the story of 2016 may remain one of continuity, with the area of greatest technical change expected to be the power unit rather than the chassis.

The prospect of a brand new set of regulations for next year certainly excites Force India's Andrew Green: 'With new rules, it is a good reset for all teams and it gives us an opportunity to potentially take a lead on some of the bigger teams, at least in the short term. Everyone is back on the starting blocks – it's a new race and we are very excited.'

F1 front nose: Aerodynamic application for F1 wind tunnel.

The laps of the gods

A view from Olympus on F1's lack of real racing – and what might be done about it

Formula 1 seems to be in such a state of schizophrenia that everyone and anyone can offer *solutions* to what is fundamentally a lack of interest in the younger generation. In fact, it is not just the young; Gerhard Berger admitted that he falls asleep watching Formula 1 once he knows who will win, usually after the first few corners.

Rather than plunge headlong into this melee, I am going to ask you to momentarily suspend belief and imagine I am the God of Sport, residing on Mount Olympus. Imagine Zeus has just given me instructions to go and sort out F1, as he is sick of the whinging of mortals. The brief is to take no account of the politics or commercial self-interests, and on no account to form a committee or working group to decide what to do. Having observed motor racing over the last 100 or so years, and seen the highest level become the Formula 1 of today, he has become annoyed.

I do wonder what has become of the 'racing' in 'motor racing'. Given the brief to sort it out quickly, I would decide to concentrate on just this issue, as overtaking means uncertainty, and uncertainty means entertainment (us gods are good at broad, sweeping statements).

My first port of call would be to go and find Jabby Crombac, the late editor of *Sport Auto*, who attended all grands prix from 1955 until just before he died in 2005. He maintained, by hand, a rigorously accurate lap chart of each GP. In 1998 (yes, really, overtaking was a subject for debate 18 years ago) he undertook to use this database to calculate the number of changes of position in each GP, each year, as noted as the cars cross the start/finish line. This data was condensed down to an average number of such manoeuvres per year, as can be seen in the chart below.

Draft excluders

Certain features are immediately apparent. First; when the great slip-streaming circuits ceased to be used in the early 1970s, overtaking reduced by around 60 per cent from an average of 20 a race. Second, overtaking reached a minimum in the mid-1970s, and then nearly doubled again by the mid-1980s. Finally, from then on it fell steadily over the next decade to an absolute minimum of two to three per race.

Why? In the early 1970s, wing-generated downforce was being steadily developed, with drag less important, due to the absence of the very fast circuits. Overtaking reduced.

In the late 1970s, ground effect with skirts entered the arena and front wings shrunk, acting mainly as trim tabs. The overtaking then increased.

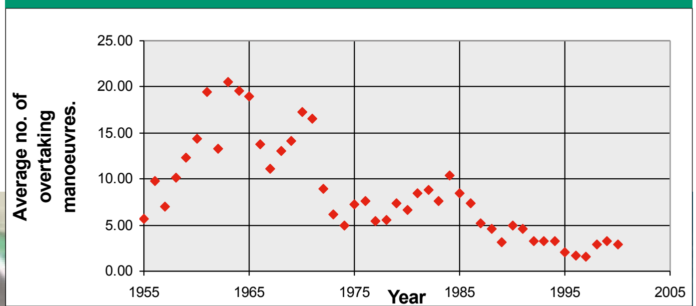
In 1981, sliding skirts were banned, though fought over until 1983 when flat bottoms were mandated. From that year on the front wing became the dominant aerodynamic feature on Formula 1 cars, and overtaking declined steadily. Plotting average overtaking manoeuvres/race against front wing downforce generates a clear trend, as seen on the chart on the following page.

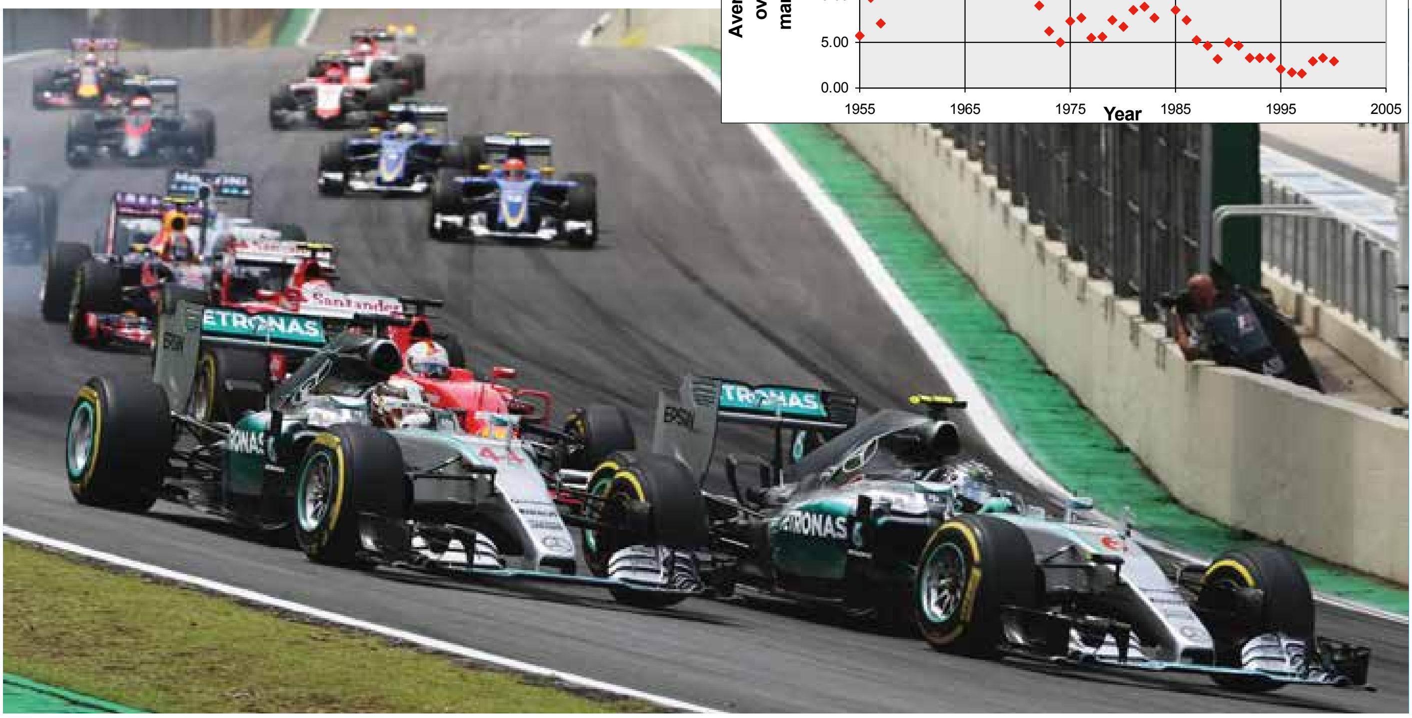
Unfortunately, Jabby's analysis was never extended to the present day, but we can probably predict what it would look like up until the time that DRS and Pirelli tyres reinstated overtaking.

Most people know that the front wings, elaborate multi-element devices, are the culprits, yet F1 itself is unable to do anything about them. Time for a thunderbolt then. Limit front wings drastically, controlled by size and number of elements – max one or two at the most. Then we should limit overall CLA to, say, 50 to 60 per cent of current values, or maybe even less.

The first can be regulated dimensionally, the second requires the measurement of downforce on track, normalised with pitot pressure, and limited

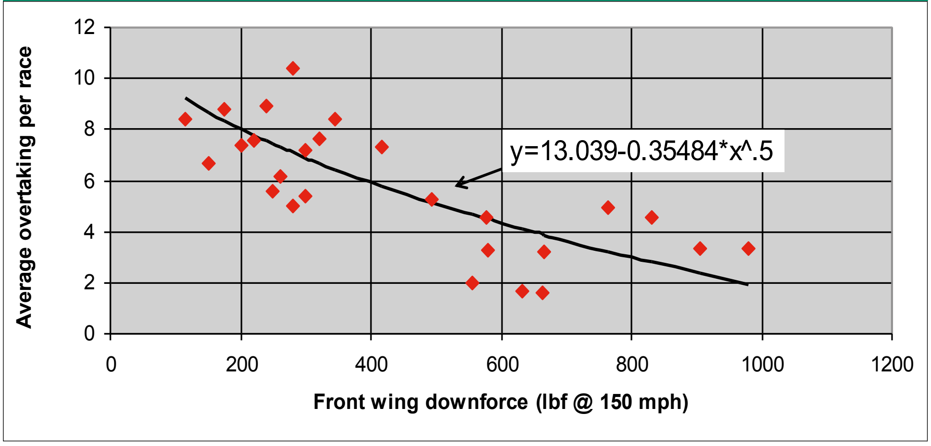
Average number of overtaking manoeuvres per race





Many believe F1 is not exciting these days beyond the cut and thrust of the first lap – but might there be a way to improve the racing by changing the aero regulations?

Average number of overtaking manoeuvres per race v front wing downforce (1972 - 1997)



to an FIA-monitored, never-exceed figure. All the teams have the means to measure downforce precisely, to a level where they are able to confirm or otherwise a driver's feeling that he has lost downforce, either due to damage or rubber blocking the front wing's flap slots. The FIA can have access to this data, and the teams would have to ensure that downforce never went over that CLA value.

Drag reduction

With freedom regarding the rest of the aerodynamics of the car, with the exception of no skirts and dimensional limitations such as rear wing width and overall height, the efforts of the hundreds of aerodynamicists would be re-focused onto: drag reduction at the CLA limit; minimising the effect of disturbances from the car in front in order to enable overtaking; and, inevitably, how to tune the aerodynamics to make it more difficult for the car behind to overtake.

The downforce and drag lap time sensitivity values of a Formula 1 car at a high downforce and tough-to-overtake circuit such as Barcelona, are in the ratio of around 4.3 to 1, downforce to drag. This means that the return in terms of lap time on aerodynamic research and development effort would be significantly less than at present, where the concentrated effort is on downforce, and so rich teams would have less of an advantage compared to the smaller teams.

This would focus the efforts of the aerodynamicists on to aero-efficiency, in much the same way the fuel flow regulation focuses the powertrain engineers on to thermal efficiency.

The reduction in downforce would allow larger, grippier tyres, and so the increase in overall lap time would be compensated for. Drivers complain about the heat degradation characteristics of the current Pirelli tyres, pushing for cars they can drive flat out until the tyres wear out. Drivers drive flat out in qualifying, and then line up in the order of speed. If they could then race flat out, the field would slowly stretch out, with no overtaking bar errors. What is the good of that?

Reducing the downforce, and hence the drag, which would be further reduced by aero R&D focusing on efficiency, will increase the top speeds and reduce grip under braking. Thus the area where the majority of overtakes are set up would be extended. Lap times will be increased to five to six seconds a lap by the reduced downforce, but some of this will be clawed back by reduced drag and increased mechanical grip, unleashed by the lower aerodynamic loads Why is lap time so important anyway? It is like 0-60mph times of supercars – only important on paper.

Strategy Working Group attempts to increase downforce have been thwarted by the inevitable response by Pirelli that the tyres will become harder and less grippy. So isn't it obvious that there is a need for us to go in the opposite direction?

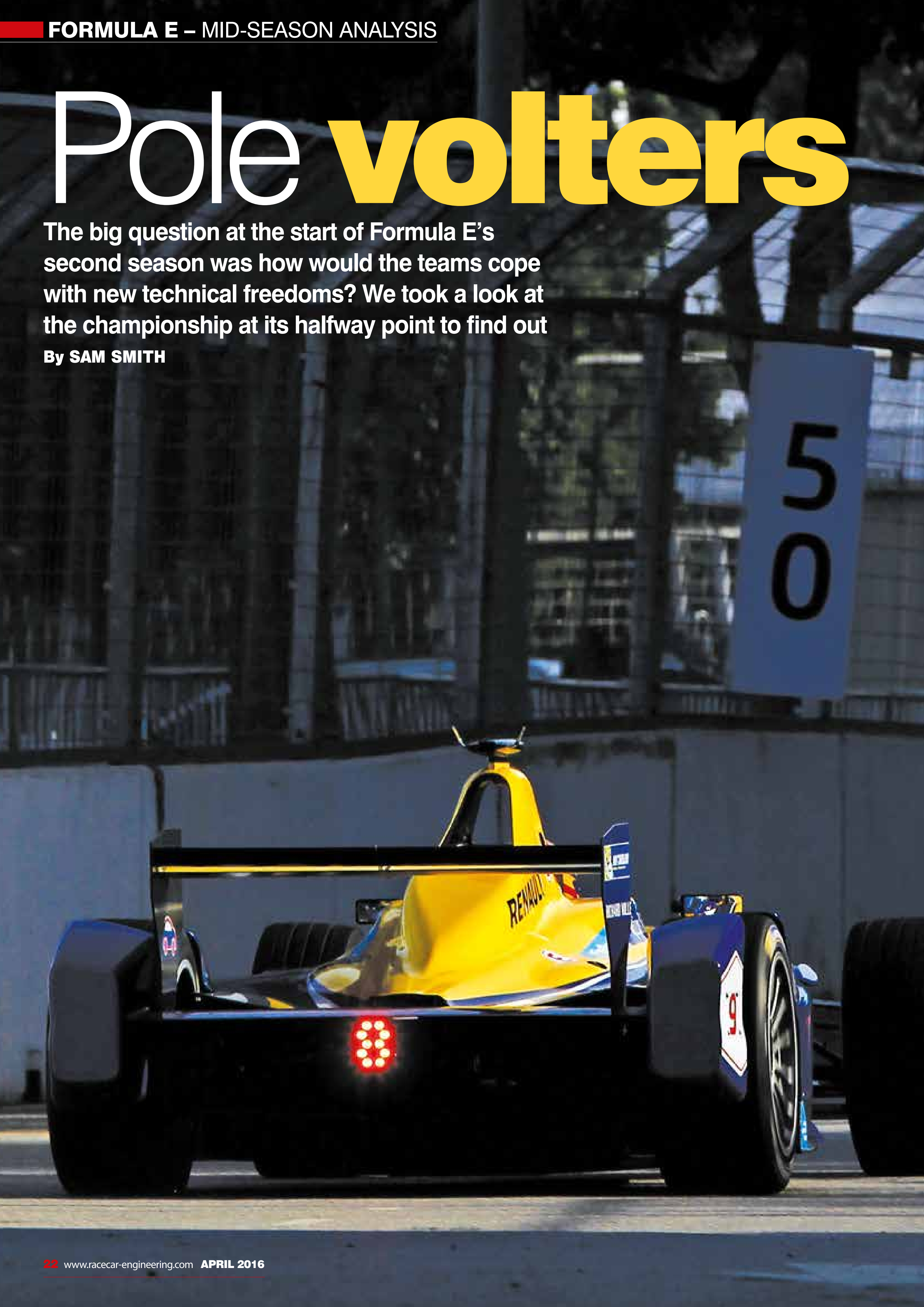
New direction

Reducing downforce and drag will take the pressure off the quest for more power. Current powertrains are 850-900cv, and teenagers can manage them. Does anyone really think another 200cv is going to sort the men from the boys? If powertrain changes are needed after three to four years, then I would ask the manufacturers what features they would like to change to make them more relevant to road cars and increase thermal efficiency. One day, when the bones of motorsport are being picked over, the engineering skills of the F1 manufacturers will be compared with those in WEC LMP1, and those achieving the greatest thermal efficiency will be declared the winners.

And that's it. The change towards a limited, reduced downforce would send Formula 1 in a whole new development direction. It would increase overtaking ability, make the cars more difficult to drive, prevent speeds escalating to the safety limits of the circuits, and yet be more relevant to road car technology.

Right, I wonder what Bacchus is up to …

Reducing downforce and drag will take the pressure off the quest for more power



Pole volters

The big question at the start of Formula E's second season was how would the teams cope with new technical freedoms? We took a look at the championship at its halfway point to find out

By SAM SMITH

The Renault e.dams team has starred thus far in the second season of Formula E. Its single-motor car has benefited from much chassis work, especially when it comes to shifting the centre of gravity forward in the racecar

Halfway in to the second season of the FIA Formula E Championship and the technical freedoms that were implemented from the all-electric series' technical road map have not proved to be troublesome – for now at least. Indeed, three different winners from the first four races seems to offer firm evidence that Formula E's CEO Alejandro Agag, the FIA, and the manufacturers now involved in the series have got it right. On top of this, both a single motor set-up powertrain (with e.dams and Abt) and a dual motor design (DS Virgin) have stood atop the podium.

So all seems well in FE at the time of writing. But pre-season there were significantly more questions than answers. The main one was whether or not the twin-motor choice would be too heavy for the existing Spark-derived chassis package. The regulations dictate that the teams have to run a mechanical differential that drives the rear axle. With this being packaged in the existing Dallara-built car, it was a tricky design test for the teams that opted for twin motors – DS Virgin and NEXTEV TCR.

The new powertrains – which include motors, inverters, gearbox and electronic packages – are of course the key points of interest in the second season of Formula E. However, weight reduction and vehicle dynamic honing have been just as important, and modifications on the rear suspension have seen a variety of solutions in packaging around the mandatory twin-wishbone, pushrod set-up of the current Spark-Renault SRT_01E.

Renault e.dams

The clear pacesetter so far is the Renault-backed e.dams operation, which boasts an enviable staff line-up of Alain Prost, Jean-Paul Driot and Renault Sport electronic systems wizard Vincent Gaillardot.

Renault e.dams hit the ground running in the Beijing (China) opener and totally dominated with its single motor, two-geared set-up. As revealed by *Racecar Engineering* in the October edition (V25N12), Zytek have supplied the motor and possibly the inverter too, while its two-speed gearing is developed by transmission specialist Sadev.

Development of the vehicle dynamics in conjunction with the new powertrain set-up has delivered another boost for the French squad. A healthy dose of carbon fibre casing in just about all departments rearward of the driver has also helped.

Highly developed Sachs dampers and the team's work on shifting the centre of gravity forward and reducing mass has also reaped significant dividends. However, the car is not infallible and at the Punta Del Este (Uruguay) and Buenos Aires (Argentina) rounds its knife edge set-up sent the team's drivers, Sebastien Buemi and Nicolas Prost, into spins at vital moments in qualifying and the race respectively.

The Putrajaya (Malaysia) race also saw problems with excessive temperatures causing software headaches, but Renault e.dams was just one of many teams to suffer such issues.

Abt Schaeffler Audi Sport

One of the pre-season favourites, the Abt team has probably been the most consistent and has accrued a significant amount of points, mainly through having one of the series' standout performers in the cockpit in the shape of Lucas Di Grassi.

Abt, working alongside Audi and Schaeffler, went with a single motor and three-geared solution. It appears that, like with the Renault e.dams team, the main step forward has been achieving a low centre of gravity in the Abt Schaeffler FE01. This has been achieved due to the team integrating the Schaeffler-derived motor and inverter in to one load, which thanks to some cute cabling packaging has reduced a substantial amount of weight.

Additionally, Abt has been creative with the bellhousing and has worked with Hewland to revise the gearbox itself, which houses much of the electronics. The chief issues which the Abt team is believed to have had were in summer testing, when inadequate cooling had to be revised slightly, but this now appears to have been solved.

Dragon Racing and Venturi

Venturi's tiny VM200 unit is the only motor – apart from the original season one unit run by Aguri and Andretti – that is used by two entities in Formula E. The decision by Dragon Racing to use Venturi power came relatively late in the day, after it decided against an original plan to continue with the season one Spark-Renault package back in June.

The Buenos Aires rounds apart, Dragon has comprehensively outperformed its motor provider, Venturi. Surprisingly Venturi and Dragon do not share a significant amount of development data, something which has baffled some staff members within both of the teams. Dragon's Loic Duval told *Racecar*: 'I don't see data or info coming across either way. But I would hope any significant positives or negatives that the engineers find were shared after the initial testing and running.'

Dragon Racing seemed to really hit its straps at Punta Del Este when Jerome D'Ambrosio claimed pole position and led the opening stages. Eventually finishing third, it catapulted the team to third position in the points standings. But this should be no surprise after the Jay Penske-fronted outfit outscored the Abt squad last season to finish runner-up.

The Venturi motor used by both teams has an expansive rev range and a serious amount of torque in its relatively conventional four-geared set-up. A modified Hewland gearbox was a conservative option for season two, but so far it has delivered.

Experienced engineer Nigel Beresford, who has

The main question was whether or not the twin-motor choice would be too heavy for the existing Spark-derived chassis package

'The way you work on these cars, it is a very small iterative process, and working with the drivers is key'

spent most of his successful career with the Penske organisation, is a major asset to the Dragon team. As it continues in what is likely to be a stepping stone season before it starts developing its own powertrain for season three – with an as yet unnamed technology partner – Beresford's influence is establishing the team as a consistent top six performer.

'The way you work on these cars, it is a very small iterative process, and working with the drivers is key,' Beresford said. 'You don't take big swings of change in the set-up, you just do small steps and getting in to the detail of these little changes has served us well so far in most races.'

Meanwhile, Venturi itself has been the real enigma of the FIA Formula E Championship so far. The Monegasque outfit went through a raft of engineering changes over the summer; most notably with talented EV engineer Nicholas Mauduit leaving, ironically for Dragon Racing, where he will manage its independent season three powertrain project.

Abt has integrated the Schaeffler-derived motor and inverter in to one load which, thanks to some clever cable packaging, has provided weight benefits. Cooling issues the Audi-backed team experienced in testing now appear to have been solved

Andretti was forced to abandon plans to race its new ATEC-01 car in season two and opted to use the season one powertrain, but the team has not stood still and has worked hard on damping, and perfecting new software packages

DS Virgin Racing

One of the two teams running a twin-motor set-up, the newly named DS Virgin outfit was the first to start testing the season two powertrain on track last May. Its outright spend may not be as much as Renault – initially anyway – but the team has significant support from the PSA group. This was evidenced in January with renowned Citroen engineer Xavier Mestelan joining the squad.

As revealed by *Racecar Engineering* in the October edition (V25N10), the DS Virgin team is using a pair of YASA 400 motors and a conventional mechanical differential. The two motors sit in a bellhousing and are connected to the battery safety unit, with another distinct case protecting the differential. The inverters are believed to be Sevcon-supplied, but the team would not confirm this.

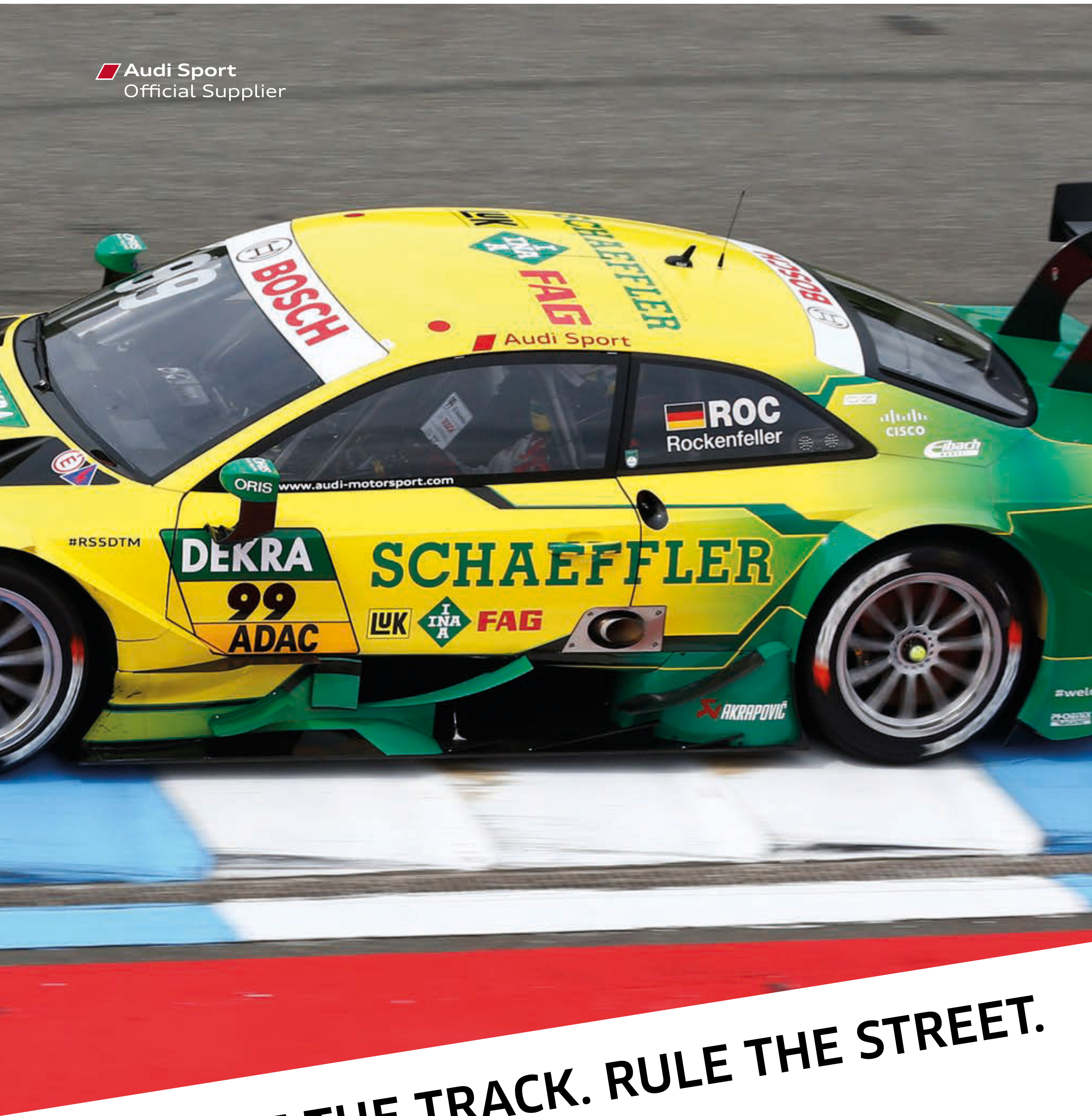
So far the Virgin DSV-01 challengers have evolved into decently paced cars. The start of the season was tough with both Sam Bird and Jean-Eric Vergne struggling with energy management, and a fortunate podium at Putrajaya preceded a difficult third round at Punta Del Este, when Vergne was compromised in qualifying by traffic, and Bird suffered a sudden and terminal battery problem.

However, the first race of 2016 saw a turnaround in fortunes as Bird triumphed magnificently in Buenos Aires. It was a stunning drive and the circumstances even seemed to slightly surprise team chief Alex Tai. 'This is a win which came from a lot of hard work from a really dedicated bunch of mechanics and engineers, so I'm delighted we won,' he said. 'The car we found so difficult to race in Beijing is exactly the same car we raced here because it is homologated. But what I will say is that through our hardworking engineering team and the injection of steroids that we have had from DS [we] have left no stone unturned and so we know that this effort has paid some great dividends in Buenos Aires.'

Mahindra Racing

Mahindra chose the relatively conservative path of a single and four-geared powertrain solution after a mediocre season one performance from the Indian manufacturing giant.

A close alliance with McLaren Electronics to run an updated version of the original motor has since paid off with a debut podium placing for Nick Heidfeld at Beijing. The former Sauber, Lotus and BMW Formula 1 driver has revelled in the lighter package this season. Mahindra also runs a clever 'Total Loss' pneumatic gear-shifting system using an air pressure reservoir that is topped up, which gives it enough capacity to



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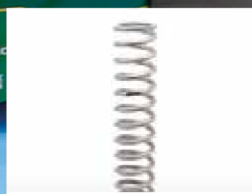

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Dragon Racing has made very good use of Venturi's compact VM200 motor and – at the time of writing – it had beaten the works Venturi operation at most of the season two races

operate the gear selection mechanism for an entire race distance.

Like many of the teams, Mahindra has gone aggressive on damper and software development in this second season.

NEXTEV TCR

Previously owned by the Team China concern of Steven Lu and Yu Liu, but now increasingly under the control of the ambitious automotive EV start-up company NEXTEV, this team is having a tough second season in Formula E.

The surprise package of season one, where it finished fourth in the teams' standings but also took Nelson Piquet Jnr to the inaugural drivers' title, the NEXTEV TCR outfit decided upon a twin-motor approach this time round.

Unlike DS Virgin, however, the all-round package has been troublesome. The main issue has been the team's choice to go with relatively large and heavy axial flux motors. Rinehart Motion Systems are believed to have supplied the inverters which are located atop the motors. These are similar products to those used in the Drayson Lola B12/69 LMP1 car, which set an electric speed record back in 2013.

The big problem so far for NEXTEV, which has scored only a handful of points with Piquet and teammate Oliver Turvey, is the weight of the powertrain. A spaceframe around the motors has increased the bulk at the rear and has contributed toward a car that's a serious handful for the two drivers.

It has improved slightly since the Beijing opener, where the chassis was twisting, but as former Ford CEO and now president of NEXTEV Martin Leach said, season two is now essentially a testing period for future campaigns. '[The remainder of] season two will be difficult because it is hard to changes things with the limitations to the Spark catalogue plus the homologation process,' Leach said. 'We are pushing on every area we can for the rest of season two and one of the areas we have invested in is a new driver in the loop simulator.' This is located at its technology partner Rational Motion's base within the Toyota Motorsport GmbH premises in Cologne.

The big problem so far for NEXTEV TCR, which has scored only a handful of points, is the weight of the powertrain

Andretti

The Andretti Formula E team was forced to put its initial ATEC-01 season two design on the backburner ahead of the start of season two, at least when it came to racing it anyway. The issues were addressed throughout the autumn and winter and Roger Griffiths, the technical director of the American squad, told *Racecar Engineering* in January that the design was back in business. 'There were two options that we had with the ATEC-01 going forwards. We could continue with the current homologation, which limits you to changes, but we chose to re-submit a new homologation which effectively makes it an all-new car.

'It gives us much more freedom to make wholesale changes to the packaging, the design of the motor or the design of the inverter,' continued Griffiths. 'Our intention is to see this project through and get it racing in season three. We will test it and start our 15 allocated test days, probably in the late spring.'

Andretti has worked hard on damping and perfecting new software packages and should be commended for reacting quickly to its harrowing summer, with the problems concerning the ATEC-01. *Racecar* understands that Andretti has significant plans for its season three programme, and that new technical partners will come on stream this summer.

Team Aguri

Team Aguri is fighting for season one powertrain honours with Andretti and at the time of writing – post Buenos Aires – the teams were parted by just a single point in the standings. The spicy rivalry between the two has been cranked up further by Andretti acquiring Aguri's former commercial partner – Amlin Insurance – for season two. But on the track the teams are similar, with really only one competitive car from each team showing so far – in the hands of Robin Frijns for Andretti and Antonio Felix Da Costa for Aguri.

Aguri has changed almost beyond recognition from season one. The majority of the engineering team was replaced ahead of the Punta Del Este round in December, the most notable change being the departure of former Jordan and Caterham engineer Gerry Hughes, who was instantly snapped up by NEXTEV.

On track, a two-bob part frustratingly cost Team Aguri a chance of victory on the streets of Buenos Aires, but with a major new commercial partner coming on-board in time for the Mexico City race, the team is certainly in a good position to grow for season three.


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Rear gunner

When the guns fell silent at the end of the war France put one of its weapons factories to another use – building the revolutionary yet flawed CTA Arsenal grand prix car

By WOUTER MELISSEN

A picture of a CTA Arsenal in action is a rare thing indeed – it never got beyond the start-line at its one and only GP back in 1947. This is Monaco in 2010

During the second half of the 1930s Mercedes-Benz and Auto Union showcased Germany's engineering capabilities by dominating grand prix racing. This was very much a matter of national pride at the time and the German government provided the majority of the funding, while other governments did the same in the hope that their teams could take the fight to the Silver Arrows.

For the Italian manufacturers, it proved too much, and they decided to focus on Voiturette racing, for smaller engined single seaters, towards the end of the 1930s. But the French government had not quite given up yet, and it offered a million franc prize for the French manufacturer that could beat the German cars in 1938. A Delahaye did manage to win two grands prix that season – including the Pau Grand Prix where a Mercedes-Benz W154 was actually beaten in a direct fight. But these wins proved to be the exceptions to the rule as the Silver Arrows continued their domination through to the outbreak of World War II.

After the war the victorious countries were keen to return to the race track and quickly erase the memory of Germany's dominance in the 1930s. Most event organisers decided to run their single seater events to the pre-war Voiturette regulations, as more of these type of racecars were readily available. These regulations limited supercharged engines to 1500cc, but naturally-aspirated engines up to 4500cc could also be used.

The decision to run Voiturettes particularly suited the Italians, as they could simply wheel

The design and construction of the frame was not unlike that of a fighter aeroplane fuselage of the day

In some respects the engine might be seen as a 1927 Delage straight-8 motor cut in half and stuck back together as a V8

The CTA Arsenal's engine used some 781 separate stud-bolts, and this remains one of the most distinctive features of the unit

out the Alfa Romeos and Maseratis that had been carefully hidden away during the war. Meanwhile, the British set about creating what would become the infamous BRM V16, while in France the government backed the development of a new racecar from scratch.

But this did not sit well with established manufacturers like Delahaye and Talbot Lago, which both had 4.5-litre engines available, as they were to be overlooked in favour of two establishments that had never built a racecar. The new French racer was to be designed at the Centre d'Etude Technique de l' Automobile et du Cycle (CTA) technical college, and built by the nearby Arsenal de l'Aeronautique in Chatillon; a manufacturer of military aircraft. Accordingly, the car was referred to as the CTA Arsenal.

The engine

While the students at the CTA were tasked with the actual design of the car, veteran engineer Albert Lory was hired to supervise the build project. He was best known for the all-conquering 1927 Delage grand prix car. This beautifully engineered machine was very quick but also highly complicated and its conception nearly bankrupted Delage. Conveniently, this Delage was powered by a 1.5-litre supercharged, straight-eight, which remained competitive well into the 1930s. This engine would form more than just the inspiration for the V8 eventually created. In fact, it almost seemed as if the Delage eight was cut in two halves and put together again as a V8. Indeed, some minor components were even interchangeable, like the rocker fingers and their

The car's gearbox and final drive unit. The transmission needed to be sturdy to handle the 330bhp produced by the Arsenal's hugely impressive 1500cc supercharged powerplant

The original components of the CTA Arsenal's front sliding block suspension – these caused problems when the car made its woeful historic racing debut

The chassis features two tall side sections plus three oval cross members to give it strength. There's an echo of 1930s aeronautical design thinking, unsurprising given the company's roots

The underside of the frame showing drilled sections, which were an attempt to cut down weight. The car also features a full-length belly pan to help reduce drag

bearing system and covers. Mounted on an aluminium crankcase at a 90-degree angle were two banks of four cylinders, while the blocks were cast in a single piece from iron to ensure the powerplants would be able to cope with the high combustion pressures.

Twin overhead camshafts were used, which were driven by gears mounted at the rear of the engine, and a flat-plane crankshaft was fitted, running on five main bearings. The V8's origins were immediately recognisable, due to the dozens of small studs and bolts used to construct it – a total of 781 separate stud-bolts were used. Leaving nothing to chance, each of the intake and exhaust ports was cooled by individual pipes.

Initially, the engine was equipped with a single Roots-type supercharger mounted at the front. In the configuration used the fuel and air were mixed by the carburettor first and then charged by the crankshaft driven blower. In this guise the compact V8 was rated at around 215bhp. During the development process a second supercharger was added. Whereas most twin-stage superchargers feature blowers of a different size to provide additional power on a broader rev-range, the CTA Arsenal was actually fitted with two identical examples, but they were running at different speeds. The superchargers were not driven by solid axles but featured centrifugal clutches to prevent damage caused by backfires during engine warm-up.

The project's nationalistic ambition to use only French parts prompted the engineers to fit a Solex twin-choke carburettor. Ironically, it was later discovered that the type used was actually built by the German subsidiary and its only other use was on the German WWII panzers, where six of them were fitted on the V12 tank engines. Regardless, the revised charge system worked very well and the V8's claimed output rose to 275bhp at 8000rpm. As it turned out this was a modest claim as during a recent dyno-test, a surviving engine produced in excess of 330bhp at around 5500rpm. For preservation reasons, the V8 was revved no higher, but it was certainly not at the peak of its power curve. This was very much a competitive figure compared to power claims from Alfa Romeo and Maserati in the same period – claims which were most likely slightly inflated, too.

Chassis

The CTA Arsenal's chassis was created from scratch. It was built around two boxed, sheet steel side-members. These relatively tall sections were spot-welded together, as were the three oval cross-members that reinforced the chassis. Beautifully drilled to reduce weight, these cross-members were fitted fore and aft of the engine and behind the cockpit. The design and construction of the frame was not unlike that of a fighter aeroplane fuselage of the day. This

After the war the victorious countries were keen to return to the race track and quickly erase the memory of Germany's pre-war dominance


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Although unconventional, this sliding block suspension did have a remarkably low unsprung mass, which should have improved handling

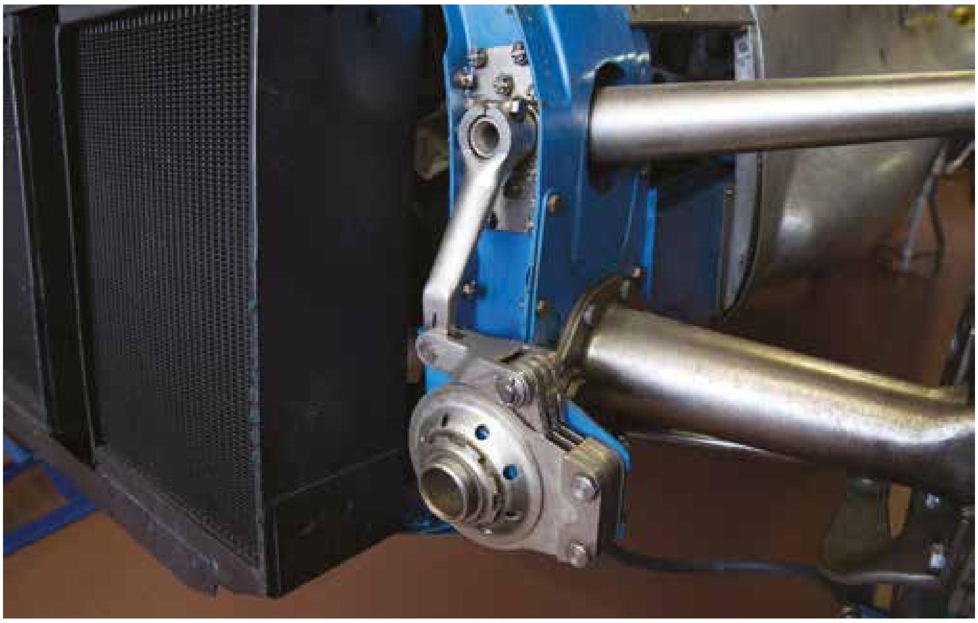
was no doubt the result of the military thought processes still at work at the CTA and, of course, at the Arsenal factory itself.

Due to its design and method of construction, the chassis of the CTA Arsenal would have probably not have been repairable after a substantial accident, unlike cars with the more conventional ladder or tubular frames used at the time. The engine was mounted at a 4-degree angle to allow the seat to be mounted slightly lower in the chassis while the exhaust manifold ran through holes cut in the chassis-rails. The car's 'fuselage' was completed by a tightly wrapped aluminium skin, which included a full-length belly-pan to create a very slippery design. To feed the thirsty engine, four separate tanks were fitted with a total capacity of 280 litres; a large one in the tail, a pair on either side of the driver, and one behind the dashboard.

Even more unconventional was the sliding-block suspension. On both ends of the chassis, solid axles were fitted with vertical uprights. The blocks on the uprights fitted in slots on the back of the drum brakes, which allowed the wheels to move up and down independently. At the front, a lever arm actuated a laterally mounted torsion bar. This was fitted inside a hollow shaft, which was connected to a friction damper at the front and a hydraulic damper at the end of the torsion bar. Throughout the engine and chassis, hundreds of roller-bearings were used but crucially they were not used where the torsion bar and its shaft rotate. As a result, there was considerable play in the suspension and the wheel travel – as much as a centimetre before the movement reached the hydraulic damper.

The rear suspension was of a similar design, but this featured transversely mounted torsion bars. Although unconventional, this sliding block suspension did have a remarkably low unsprung mass, which in theory should have improved the car's handling.

The modified front sliding blocks that are now fitted to the Arsenal. The blocks on the uprights fit in to slots on the back of the drum brakes, which allow the wheels to move up and down independently. It's a smart idea but it didn't quite work out



At the front a lever arm actuates a laterally mounted torsion bar. This is fitted inside a hollow shaft connected to a friction damper at the front and a hydraulic damper at the end of the torsion bar. Sadly there was too much play in this suspension

Troubled debut

By the summer of 1947 the first car was assembled in Chatillon, with plans to compete in the French Grand Prix at Lyon. Although barely tested, the CTA Arsenal was entered in the race with veteran French race driver Raymond Sommer at the wheel.

Compared to the dominant Alfa Romeos, the new French single seater was considerably taller and slightly heavier. That, however, was the least of Sommer's concerns as the unconventional suspension and relatively short wheelbase meant that the Frenchman struggled to keep the car running straight on the high-speed track. Despite these handling issues, and absolute lack of pace, the CTA Arsenal did line up for the race. Unfortunately, one of the driveshafts failed at the start, leaving Sommer stranded on the grid – the exact same thing would happen to him again when he debuted the BRM V16 at Silverstone a few years later. Initially undeterred by the embarrassing results, a second car was assembled and two entries were lodged for the 1948 French Grand Prix, due to be run at Reims. However, realising success was unlikely, the entry was scratched and the project was then abandoned.

Grand Prix success for France was not far away though, as the Talbot Lago T26 would go on to win both the French and Belgian Grands Prix in 1949, and, with a two-seater body, Le Mans a year later. This car used a wholly conventional chassis and a naturally aspirated engine that had been designed before the war. Compared to the supercharged cars, it was far more frugal and much lighter on its tyres.

It was actually Anthony Lago (of Talbot Lago) who bought the complete CTA Arsenal project. Some suggest that he was keen to see if he could make further improvements to the design for high-speed record runs. Another persistent

Perhaps students at a technical college associated with a military factory were not prime candidates to design a top level racing car

The original front sliding block suspension (above) as installed on the car when it run in 2010 Monaco Historic GP practice (below)

story is that he simply bought the cars and placed them in a corner of the factory to show his workers how it should not be done!

The car today

The car featured in the pictures here resides in Germany, where it has been restored by retired engineer Eckart Berg. Although he is the first to admit that the car was an absolute failure, he loves the beauty of its engineering. Perhaps not surprisingly, one of the previous cars in his stable was an earlier Delage GP racer that featured many of the same design attributes.

This CTA Arsenal is believed to be the second chassis – as there is no evidence of the damage the sheared driveshaft most likely would have caused. It was brought to Germany with an engine devoid of many internals. However, during the next few years Berg carefully assembled parts to rebuild the engine, and then he was given a chance to buy the only other engine known to have survived. Crucially, this V8 was complete, which helped move the rebuild along considerably.

Most likely never driven in anger, the CTA Arsenal was now completely original, down to the unpainted bodywork. By 2010 the car was back in full running order and, as had been the case back in 1947, it was entered for its first race, the Monaco Historic Grand Prix, with little or no testing. But it was driven in practice only, as the brakes were not working properly. Also, despite completing just a handful of laps, the sliding blocks were worn on both ends, which allowed for considerable camber changes in the corner.

As was the case back in the day, the first appearance of the CTA Arsenal lead to some scalding reviews, one British magazine concluding that the racecar would never have a chance of being even slightly competitive – when *Racecar* saw the car five years later Berg had that magazine clipping stuck to the chassis, as he continues to work to further sort its faults. Among the changes made was a revision of the sliding block suspension with sturdier components. The engine's still pretty good, though – on its most recent outing the prop shaft snapped on full throttle.

The CTA Arsenal has gone into history as one of grand prix racing's biggest failures, but why? Perhaps students at a technical college associated with a military factory were not prime candidates to design a top level racing car. Their ideas may have looked good on paper, but they lacked the knowledge and, crucially, the experience of how a racecar actually works in real life racing conditions.

What was certainly not at fault was the design of the engine, and it is a shame that it was never tried in a chassis that actually worked. However, it is wonderful that at least one complete car has survived – if only because we can admire the beautiful craftsmanship of its original builders.

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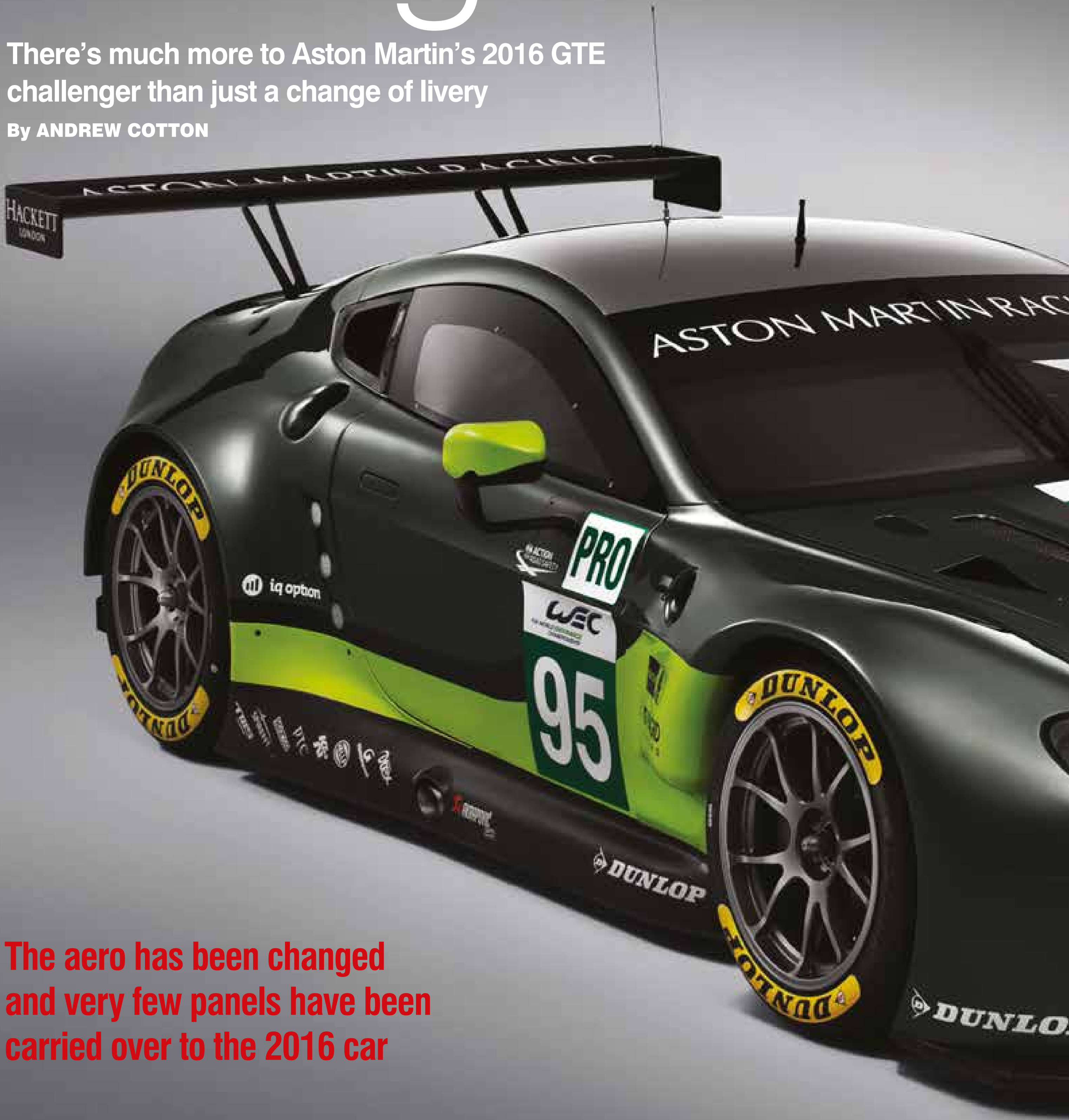
There's much more to Aston Martin's 2016 GTE challenger than just a change of livery

By **ANDREW COTTON**



The aero has been changed and very few panels have been carried over to the 2016 car

A new set of GTE regulations has opened the door to some radical looking designs, particularly from Ford with its GT, but also from Ferrari and BMW as detailed in last month's edition of *Racecar*. Mid-February, Aston Martin unveiled its new V8 Vantage, which looked decidedly understated compared to its rivals – a huge rear diffuser is the only unsubtle difference compared to the 2015 model. But in fact the aero has been radically altered, and different design targets surrounding drag reduction were set, and have been met.

There are also two key partner changes, with Aston Martin signing deals with both Dunlop and Total, each of which will supply bespoke products for the car not only in GTE, but also at the Nurburgring 24 hours.

Dunlop confirmed that, having completed the move of its racing operations from its British base to Germany, it is now ready to take on its rivals in a tyre war at the 24-hour event and will use Aston Martin to spearhead the attack. 'We spent a lot of time in Bahrain testing the ELMS tyre for Beechdean AMR and got good results,' says Aston Martin's technical director Dan Sayers. 'As discussions progressed, it seemed to be a sensible choice. The only way to win is to develop something specifically for our car. We have a great relationship with Dunlop already and we have been on the rig. To work with them is very different to how we have worked before.'

The relationship with Dunlop means that Aston Martin will move away from its customer deal with Michelin, which it clearly feels was not providing the best tyres for its front-engine car. At the launch, there was more than a hint that the team also believed that 2015 development of the Michelin tyres suited other cars better. 'It certainly had quite a different tyre to previous years,' confirms Sayers. 'The car is very light on its tyres, and double stinting was its thing, and last year the tyre degradation seemed extremely high. It seemed to go away from us and towards other manufacturers. When it is not in your hands it is difficult to control. With Dunlop it is down to them and us to make us win.'

Ride-height has been lowered once again, from 55mm to 50mm, and the team has switched to Bilstein dampers. 'Radiators are the same as last year, all the coolers are the same,' adds Sayers. 'Mechanically it is similar; the brakes have changed, differential has changed, and tyres obviously. There is a lot of learning to do there, and we are now part-way through that process.'

The aero has changed on the car, too, and very few body panels have been carried over to the 2016 Aston; just the bonnet, rear fender and bootlid. Gone is the flared floor beneath the doors, which Aston first introduced to house the exhaust pipes but which, in fact, dramatically increased the floor area, and therefore downforce. 'We haven't gone as wild on the aero and there are reasons for that,' says Sayers. 'We have targets that the FIA has set, and the drag is what we have to reduce. Other cars have the flared floors, but we have taken them off because it was more draggy. You get more downforce, but the efficiency wasn't so good. Everything is tailored towards drag reduction.'

Aston thriller

Aston Martin has developed the car in CFD in cooperation with partner TotalSim, the first time it has undertaken such a project. So much did Aston Martin rely on the figures that the new Vantage had only one run on an airfield before it went to the GTE Balance of Performance test in Ladoux in September.

'We work with TotalSim but this is the first time that we have run a project from start to finish on CFD and it is quite a high profile one, but we had a finite amount of time, which wasn't long, but that seems to be the key for CFD,' says Sayers. 'You can keep going, but you have to call time. We did one run at an airfield, and then we put it in to the Ladoux test. That

The huge diffuser is the most obvious change to the Vantage GTE, this to claw back downforce after a concerted effort to reduce drag; but it does sit in a highly vulnerable position

was a nervous time. Once you are there, they have to then balance it. We started in February or March, and we had to be in Ladoux in September, so we had to make parts in August. You could spend any amount of time perfecting anything, but you have to get into that window.'

One consequence of the reduced drag is that downforce has been compromised, and the team has had to heavily revise the underfloor aero to bring some back. That includes a huge rear diffuser that could become a target for competitors and lead to a series of replacements. 'We have had to focus so much on drag reduction that the diffuser is necessary to get the downforce levels and the correct balance,' says Sayers. 'We have got spares! There are a lot of changes to the flat floor compared to the previous car. We have worked hard to make it more efficient. The starting point for that compared to a Ford is very different. Each has their challenges, and ours is aerodynamic.

'We probably needed between seven to ten per cent reduction in drag, which is not insignificant so you can understand why we have tailored [the pacakge] towards drag reduction. We have suffered previously with top speed, and we have had to focus on that. The bonnet is the same, but fenders, bumper, splitter, sills, doors, diffuser, centre floor are all different; the rear wing is smaller and to the regulations,' Sayers adds.

Total commitment

The technical partnership with Total is also expected to bring a performance gain, and Aston Martin says that it was a 'positive decision' to move away from previous partner Gulf which also provided the team with its iconic blue and orange livery. 'Total will supply us engine oils, gearbox oils, greases for all the wheel bearings, the joints, but one of the exciting things is the track-side support, the analysis of oil at an event, although we haven't worked out how yet,' admits Sayers. 'At the end of every session they will be sampling all of the oils, making sure there are no surprises. You only have to look at Bahrain in 2013 when the championship should have been ours and we had a catastrophe [a rare issue with the engine]. In the lead up to that race we might have noticed it earlier and been able to act.

'We are also looking for more efficient oils, and even if we increase temperature and friction is reduced, [then that is good], as we are looking to reduce losses. They're gearing up for 100 per cent reliability and we can work on performance from there.'

Other changes to the car include driver visibility, with the door mirrors moved off the doors, a new dash layout and colour screen from Cosworth. The chassis has been upgraded to the latest safety regulations, meaning that the seat is bolted to the floor, but Aston has also gone for the option to bolt it to the roll cage at the rear, too. 'If you look at it makes a massive difference in an impact,' says Sayers. 'We have moved the mirrors off the doors so you can see the apex now, the rear camera we have had for a while, and we are looking at the anti-collision system from Bosch, but just with the drivers being able to see more they remark on what a change it is.' A hole in the roof, also as per new safety regulations, was incorporated within the existing roll cage. The carry over is clear; the car featured at the launch was the GTE-Am Le Mans winning chassis from 2015.

With Aston bringing a new aero concept, Dunlop tyres and the might of Total as a technical and commercial partner to the World Endurance Championship, these changes could see a dramatic turn in fortune for the British team. The Balance of Performance figures have not been released (at time of writing), and no doubt will be the topic of debate with such variables, but the team is more confident this year than it's been for a while.

'We probably needed between seven to ten per cent reduction in drag, which is not insignificant'

Northern light

Gibson Motorsport's latest Group CN car will be going up against some serious opposition in this year's V de V – but there's much to suggest the GH-20 might have the edge

By LEIGH O'GORMAN

Based in Middlesbrough in the north-east of England, Gibson Motorsport is a V de V prototype manufacturer with what might be described as a quiet history of success and achievement. But with the launch of its GH-20 earlier this year, the team may now be in a position to make a big splash in Group CN, and in the V de V series in particular.

Not to be confused with its LMP2 namesake, Gibson Motorsport was founded in the late-1970s by racing driver and designer Paul Gibson. After a time racing a Mallock, the Englishman began penning other innovative Clubmans and then Supersports cars. His early efforts were developed with independent suspension all-round, and some Formula 1-like aerodynamic thinking. Naming his creations Nemesis, after the goddess of revenge and retribution, Gibson would go on to claim the Supersports manufacturers' title on four occasions.

But as Supersports began to wane, Gibson turned his attention to designing front-engined Proto class Clubmans cars, with the assistance of current Toyota LMP1 aerodynamicist David McKenzie, beginning with the Nemesis K10 and K11 in the 2000s. With McKenzie as chief designer, Gibson then looked to FIA Group CN prototypes, eventually creating the Honda-powered GH-19, which also counted as McKenzie's final project for his university degree. When McKenzie moved on, Gibson then began to investigate the possibility of creating a new car for the CN Class, to replace the GH-19.

Designed in-house by a group headed by Teesside University graduates Thomas Fielding and James Wilson, the Gibson GH-20 is the subsequent creation, but as Fielding admits, the new car does owe a little to its predecessor. 'The GH-20 is an adaptation of the GH-19,' he says.

Yet although it's a development of the GH-19, the GH-20 has kept relatively few component parts from the previous machine, leaving Fielding and the team to heavily redesign certain elements of the car. 'Only 15 per cent of the component parts were carried over from the GH-19, which has meant an awful lot of redesign, particularly on the front suspension kinematics, as the Michelin V de V slick is a world apart from the Avon that the GH-19 was designed to use,' Fielding says.

The monocoque is a full carbon fibre tub. CN regulations prohibit the use of carbon fibre and/or Kevlar for the manufacture of bodywork, although rear wings and their supports made

Top left and above left: The GH-20 is a full carbon monocoque – with carbon bodywork in V de V trim. **Top right:** The car is powered by a 2-litre Honda K20 engine. This dry sumped unit produces 255bhp and revs to 8200rpm, which is the maximum revs in V de V. **Above right:** Because of its high downforce levels the car uses a clever third element front suspension system which is adjustable by using spring stiffness and single way damping but also with the use of an 'engagement gap'. Dampers are Ohlins TTX40 4-way adjustable

from composite materials are permitted. Carbon bodywork is allowed in V de V, though, and this is the main market for Gibson.

Crucial to the GH-20 design is Gibson's aggressive approach to its aero silhouette. The GH-20 enjoys a reasonably high lift-to-drag ratio, offering plenty of downforce compared to the induced drag; however, when questioned about this ratio Fielding remained tight-lipped.

Aero balance

Possessing an aerodynamic balance of between 40 to 52 per cent to the front, there is plenty of scope for a competitor to move the downforce from fore to aft in order to suit their particular feel. Crucially, a revised front splitter with second element, and a new rear wing, have improved airflow from the GH-19 design, and also lowered the amount of drag produced by the GH-20. Such a healthy balance and ratio allows the new machine to generate approximately 575kg of downforce at 100mph, with that increasing to over 700kg at 140mph. But If the aero balance of the GH-20 is something of a step forward, then the gains made in weight saving across the car are also quite significant.

Fielding said: 'The main area for saving weight was the bodywork; the GH-19 used E-Glass [woven glass fibre], however, a change in [V de V] regulations means the car saved one-third of the weight of the bodywork very easily indeed.' This is because carbon bodywork is now allowed in V de V and so the Gibson is available thus clothed for this championship.

Other weight reductions came about through redesign of components, and the redrawing of 85 per cent of the car gave Fielding and the crew plenty of scope. 'Through racing the GH-19, we learned which parts of the car were not stressed as much as was thought initially, and were therefore too heavy. Similarly we learnt where the failures where occurring and addressed those problems. The car is now comfortably at the minimum weight of 575kg.'

Powering the GH-20 is a standard Japanese-spec Honda K20 engine. However, as Fielding notes; 'certain things are allowed to be done to the engine to blueprint it.' With a regulated maximum rev-count of 8200rpm, the 2-litre K20 engine produces 255bhp. The unit uses a dry dump system and is mounted longitudinally.

The Gibson GH-20 also uses a Sadev SLR82-14 transaxle transmission unit. 'At the time of design Sadev offered the best package and this has so far proved to be a very good gearbox,' Fielding tells us.

Feilding also says that it was not possible to use a gearbox with the gear cluster at the back,

'Only 15 per cent of the component parts were carried over from the GH-19, which has meant an awful lot of redesign'

The GH-20 has good aero balance with around 40 to 52 per cent of downforce to the front of the car. A revised front splitter, with a second element, and a new rear wing have both improved airflow, when compared to the GH-19, and Gibson claims the car has a good drag to downforce ratio. Other improvements have come from weight savings across the car

TECH SPEC

Gibson GH-20 Group CN

Chassis:
Full carbon fibre monocoque FIA homologated to CN regs; bodywork is carbon where permitted, otherwise E-glass glass fibre

Engine:
Honda K20, mounted longitudinally in rear of car; dry sump; 255bhp; max rpm 8500 – as per V de V regulations

Suspension:
Double wishbone; pushrods and rockers; advanced front third element system with engagement control; Ohlins TTX40 four-way adjustable dampers

Transmission:
Sadev SLR82-14 transaxle with changeable ratios; Shiftec paddleshift with auto-blip for downchange.

EPAS:
Gibson Motorsport electronic power assisted steering

Safety:
FIA approved front crash structure and roll protection; FIA approved collapsible steering column; FIA approved bladder style fuel tank

Electronics:
Emtron KV-8 ECU; GEMS DA3 card logger; Gems LDS4 display in steering wheel; wide range of chassis sensors

Cockpit:
HP Electronik Membrane switch panel; Gibson Motorsport QR steering wheel

Brakes:
Tilton fully floating master cylinders and Brembo Euro RS calipers

Wheels:
Evocorse Lightweight
Front: 9 X 13in. Rear: 10.5 X 13in

Tyres:
V de V regulation Michelin slicks

as that would move weight back behind the car's rear axle centre-line.

While some of the redesign elements might appear straightforward, the reworking of the suspension posed a not unexpected problem, due to the increased loads at the front. 'Due to the significant levels of downforce, it is not possible to control the aerodynamic loads on the front axle of the car using corner springs,' Fielding says. 'This is an obvious problem, so the use of a third element has to be implemented.'

Where the GH-19 used a Penske SS9000 to control the aero platform, limitations forced Gibson to move in a different direction, with the team drawing up a mechanical system. In addition, the GH-20 also incorporates Ohlins TTX40 4-way adjustable dampers to help maintain a stable aero platform .

Third element

Fielding says: 'The use of a mechanical system was necessary in order to try and separate two-wheel from one-wheel bump scenarios. Its kinematics allows the car to find grip, like any other correctly sprung car in the corners, thanks to an engagement gap on the third element. The third element system is adjustable by means of not only spring stiffness and single way damping, but also by use of this engagement gap. For example, if the engagement gap is set at *X*mm thanks to the motion ratios of the components in relation to each other, it will take 2*X*mm of outer damper displacement before the third damper is exerted to any force, whereas it would only take *X*mm of displacement if both outer dampers where subject to it.'

Stopping power is provided by Brembo Euro RS brake calipers and Tilton master cylinders. While the mixing of brands works well on track, Fielding admits cost effective competition was also in mind when choosing suppliers. 'The mixing of the supplied parts is because they offer the best package. The Brembo calipers have been used on cars before the GH and work very well, the Tilton floating master cylinders have also been used before. Together the package is cost effective but also the best performance we could achieve.' Meanwhile, the GH-20 runs with EVO Corse lightweight wheels and Michelin radial slicks – the latter stipulated by V de V technical regulations.

Spark and ride

The electronics package was chosen for its reliability, ease of use and cost effectiveness, Fielding tells us: 'The hardware we have gone for is an Emtron KV8 ECU, Gems DA3 Card Logger, Gems LDS4 display, Shiftec paddleshift and paddle clutch. All of this hardware uses CAN and will work effortlessly together.' As part of the package the GH-20 boasts a comprehensive range of sensors, monitoring damper travel, pushrod load and laser ride height, as well as engine sensors.

The GH-20 has now passed its FIA crash test at Cranfield – a test which includes a high-speed frontal impact test, as well as a steering column collapsible test, and press tests to the roll hoops and monocoque – meaning it is now homologated and is ready to race.

But with opponents in the V de V fielding cars from the likes of Ligier, Wolf, Norma and Juno, Gibson knows it will have its work cut out if it is to win. However, Fielding is certainly confident: 'We believe that we have a sound engineering package. And one of the good things about motor racing over any other engineering business is that this can be demonstrated by passing the chequered flag more times in front of the competition.'

The new Gibson GH-20 generates approximately 575kg of downforce at 100mph, with that increasing to over 700kg at 140mph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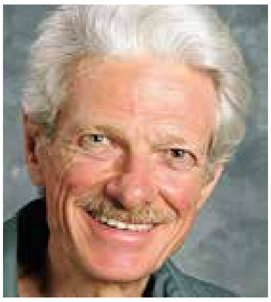

Sand blast: sorting a buggy for the road

Can a dune buggy be as much fun on asphalt as it is on dirt?

Question

I'm a fairly young mechanical engineer with an interest in motorsport. I built a Lotus 7 style car during my degree, using an MX-5 as a donor and making the necessary design modifications. I'm now working on a new design: a road-licensed buggy based on a Mazda 3 donor, with transverse mid-engine, relatively light weight – basically similar to the 1960s style Beach Buggies or perhaps the more modern Ariel Nomad.

In the course of this I've been trying to teach myself the fundamentals of suspension geometry and design. Though I feel like I have a handle on the basics from my work on the first car – castor, bump steer, camber gain, static roll centre placement, etc.

But I would be very interested to know what you consider the most important concepts in making a car with relatively soft, long-travel suspension handle predictably and enjoyably on bitumen, especially considering the rear weight bias which this vehicle will have. Outright speed and traction is obviously not the objective, rather I'm after something playful which can be thrown around without presenting any nasty behaviour.

The numbers are:
Tyres: 225/75/16 (approximately 30x10in)
Wheel travel: targeting 200mm bump/100mm droop on front and rear axles
Front: Double wishbones
Fabricated uprights, re-using the factory bolt-on hubs/spindle from a Mazda 3
Mechanical Trail: 30mm
Scrub Radius: 35mm
Caster: 5.5 degrees (adjustable)
Static camber 1-degree (adjustable)
Roll centre vertical: 157mm at 0 degrees roll. 154mm at 2.5 degrees roll
Roll centre horizontal: 100mm from centre-line at 2.5 degrees roll
Camber gain: 0.5 degrees per degree of roll
Rear: MacPherson strut
Static camber: 1 degree (adjustable)
Roll centre vertical: 146mm at 0 degrees roll. 142mm at 2.5 degrees roll
Roll centre horizontal: 200mm from centre-line at 2.5 degrees roll
Camber gain: 0.25 degrees per degree of roll

I am trying to stick with the MacPherson strut rear for simplicity/ease of fabrication, but I can see that it's quite compromised; camber gain is very low, and the roll centre moves across the car quite a bit. Do you have any suggestions about whether this path is worth pursuing, or will the handling simply be too compromised with this design for it to be a fun, playful car?

I'm also very interested in the effects of a roll centre moving *across* the car. What is the real-world outcome, especially if there is a disparity front to rear?

The consultant

One thing that jumps out at me immediately here is that the questioner plans on building a markedly tail-heavy car with equal size tyres at both ends. Unless there is some compelling reason to do that, I would advise following the usual practice in rear-engined buggies of making the rear tyres larger than the fronts.

Probably the most likely reason to use equal size tyres would be to have a single spare wheel that will fit any corner of the car. A common approach is to have the rear tyres wider than the fronts, but similar diameter, and use a front tyre for the spare. The car can then use that on the rear as well, temporarily, without creating undue wear on the diff. That matters a lot less with an open diff than with a limited slip. It is necessary to have room to carry the larger flat rear home, of course.

Within certain limits, an engine-over-drive-wheels car with equal size tyres can be made to handle decently by giving the light end a disproportionate share of the total roll resistance. The tyres at the light end are then less equally loaded when cornering, and the tyres at the heavy end are more equally loaded. This can give an acceptable understeer gradient – acceptably neutral cornering – up to the point where the inside wheel on the light end lifts. Beyond that point, the light end has 100 per cent load transfer and any further load transfer must occur at the heavy end.

This means that there is a relationship between the total load transfer the car will exhibit and how successfully we can compensate for having equal size tyres yet a lot of the weight on the driving wheels. We'd like the car to have low-grip tyres, a wide track, and a low centre of gravity. That will then allow

I would advise following the usual practice of making the rear tyres larger than the fronts

This month's question involves a dune buggy-style build project and how to make it a fun and safe drive on the asphalt

The Elite was just one early Lotus to feature a strut suspension at the back with a double A-arm suspension at the front

the largest percentage of weight to be on the drive wheels, while still giving decent handling with the equal size tyres.

The questioner's car apparently will have tyres optimised for dirt, with a high aspect ratio and therefore tall, compliant sidewalls. They will therefore probably have relatively low grip on pavement, with a gentle breakaway, occurring at a relatively large slip angle. They probably will also be relatively insensitive to camber. They will most likely prefer to be inclined into the turn a lot if possible, but their lateral force capability will not change abruptly with camber.

He does not say what the track width is going to be, but the use of Mazda 3 components, with wider wheels, would put the track somewhere around 60in, like most cars. The fact that the car is to be off-road capable and has 200mm of bump travel suggests that it must sit fairly high. I would caution that it is important that the suspension bottoms before any part of the frame or floor gets too close to the ground, and that the suspension bottoms gently, on good snubbers. The high ground clearance, and correspondingly high cg, work against us in trying to make a tail-heavy car corner neutrally with equal size tyres.

It's not too bad to have a strut suspension in back and double A-arm in front. Colin Chapman designed a number of successful cars that way in the '50s and '60s, including the original Lotus Elite and Elan. He even tried it on his last front-engined single seater, the Lotus 16 of 1958. He was so known for this that a MacPherson strut system used at the rear is commonly called a Chapman strut. Whether Chapman should be credited with its invention can be debated. Certainly Chapman was the first I know of to use strut suspension at the rear. However, Ford was using it at the front of passenger cars first. Chapman was pretty much just applying prior art to the rear of the car. But his designs did incorporate some features not seen in front suspensions. The Elite and the 16 used the driveshaft as the lower control arm, with just one additional diagonal trailing arm for toe and longitudinal location. Brakes were inboard. Later versions used separate lower control arms and outboard brakes.

Roll centre heights in the neighbourhood of six inches would be a bit high for a pure pavement car

In the Lotus designs, the strut was inclined more than is generally seen in front suspensions. That tends to provide more camber recovery in roll; the front view projected upper control arm has more inclination and the front view swing arm length is shorter, for a given lower arm configuration. The original Elite had the struts inclined at around 20 degrees. The Lotus 16 had them at around 30 degrees from vertical. Such inclinations can't be used in front suspensions because the front-view steering axis inclination becomes excessive.

Roll centre heights in the neighbourhood of six inches would be a bit high for a pure pavement car, especially on sticky tyres. They would cause the car to jack noticeably, although not really severely. On the tyres planned for this car, they are probably okay, but I wouldn't go any higher.

Long-time readers will be aware that I am not of the opinion that the roll centre concept should be dispensed with entirely, in favour of exclusive reliance on multi-body simulations that can only be done with computers. Nor am I of the opinion that the force line intersection, sometimes called the kinematic roll centre, is actually what should be taken as the roll centre. My opinion is that the concept of the roll centre is useful, provided that the roll centre is thought of not as a pin in a hole but rather as a roller in a vertical slot. The height of that notional roller is such that the portion of the lateral inertia force acting through the suspension linkage, times the roller height, equals the geometric roll or anti-roll moment.

Rock and roll

For cases where the force line intersection or kinematic roll centre is near the centre of the car, the height of that point will very nearly satisfy this requirement. For cases where the force line intersection is far to one side, the height of that point will generally not come anywhere near satisfying that requirement.

When the system has little geometric anti-roll (low roll centre), the force lines will be close to horizontal and close to parallel. In such a case, very small changes in force line slope, or jacking coefficient, will cause the force line intersection to laterally migrate wildly. It doesn't matter. With a higher roll centre, the same variation in jacking coefficient will create much smaller lateral migration of the intersection. That doesn't mean the system will behave better.

What does matter is how much the force line slopes, or jacking coefficients, themselves vary. That is what determines the variation in actual geometric roll resistance.

In that regard, strut suspensions are not very good. The jacking coefficient decreases a lot in bump and increases a lot in droop. The jacking coefficient of the outside wheel diminishes in roll and the jacking coefficient of the inside wheel increases. That's why the force line intersection migrates toward the inside wheel in roll.

Bottom line; double A-arms in front and struts in back are really not too bad at all. The rear loses and gains geometric roll resistance more than the front as ride height changes, but that is not really cause for alarm – just something to be aware of, particularly if you like to set the car up higher or lower for different applications.

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

Shifting perceptions on gear calibrations

Correctly relating the data to what is actually happening inside the gearbox will help you make sure your car's shifts are smooth and fast

It is becoming increasingly common for modern racecars to employ semi-automatic transmission. In paddleshift systems there are two switches on the steering wheel requesting up and downshifts independently. When the driver requests an upshift, the ECU will initiate a torque reversal, rotate the barrel and reapply engine torque – all inside a fraction of a second.

A correctly calibrated shift system can save precious milliseconds over the course of a lap. On the other hand, an incorrectly calibrated system can result in catastrophic damage to the gearbox. Here we will look at how to relate your data to what is actually happening inside the gearbox, along with some examples of common shifting characteristics.

It is important to consider what channels will be useful when analysing shift performance. Perhaps the most obvious is the direct driver input via the paddles. This will allow you to identify the start of either an up- or a downshift. It is possible that the driver believes a shift has been requested when in actual fact the button press was not seen by the ECU.

Whether you are using an electric, pneumatic, hydraulic, etc. shift system it is important to log the output signal that controls your actuator. This will allow you to see when the gearshift begins; mechanically, the actuator causes the barrel to rotate, moving the selector forks to disengage one gear and engage the next.

This leads on to possibly the most important channel to log when analysing shift performance. The barrel position shows how the gearbox transitions between gears as well as being key to identifying potential problems within the 'box before they result in damage. The voltage is directly proportional to the position of the barrel, a voltage range for each gear is programmed into the ECU to tell it what position to consider itself to be 'in gear'.

It is worth noting that barrel position and current gear are not to be confused. While the current gear is useful for many purposes, the barrel position logged at a fast rate is essential for analysing gear shifts. It is recommended that channels should be logged as fast as possible, ideally 1000Hz. The importance of fast logging is emphasised in the screen grab, **Figure 1**. The speed of the shift is so fast that it has been requested and completed before the driver has released the upshift paddle.

When the gearbox is loaded in the forward direction, a cut is required to reverse the engine torque and allow the gear to disengage. On the other hand, when the gearbox is loaded in the backwards direction, a blip is required. The blip and cut methods are most commonly associated with a downshift and upshift respectively, however, there are exceptions. For example, consider the driver requesting a downshift whilst accelerating (due to a need for more acceleration); a blip would be required. But for the purposes of this article, an upshift will be considered to require a cut and a downshift will be considered to require a blip.

An incorrectly calibrated shift system can result in catastrophic damage to the gearbox

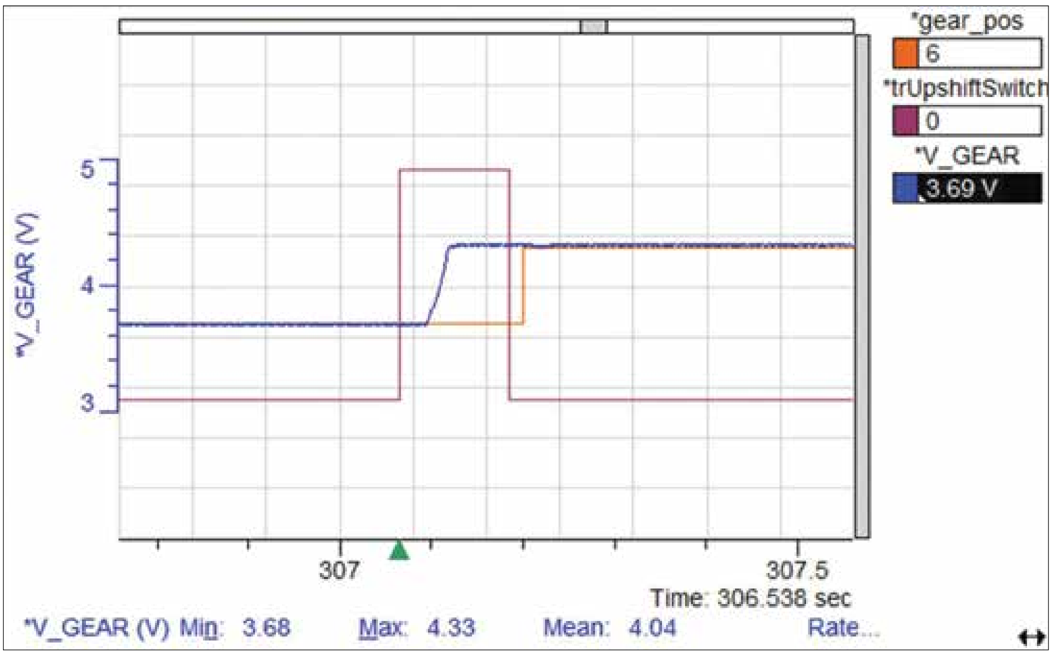

Fig 1: The speed of the shift is so fast that it has been requested and completed before the driver has released the upshift paddle

Transmission state

It is common that the ECU has a number of phases it goes through during the shift. For example, in an upshift, it is necessary to cut the engine torque before attempting to move the actuator. This allows the dogs to disengage before the barrel is moved. Another fundamental reason to consider this channel is that the ECU will use it to determine when the barrel has moved into the target gear therefore completing the

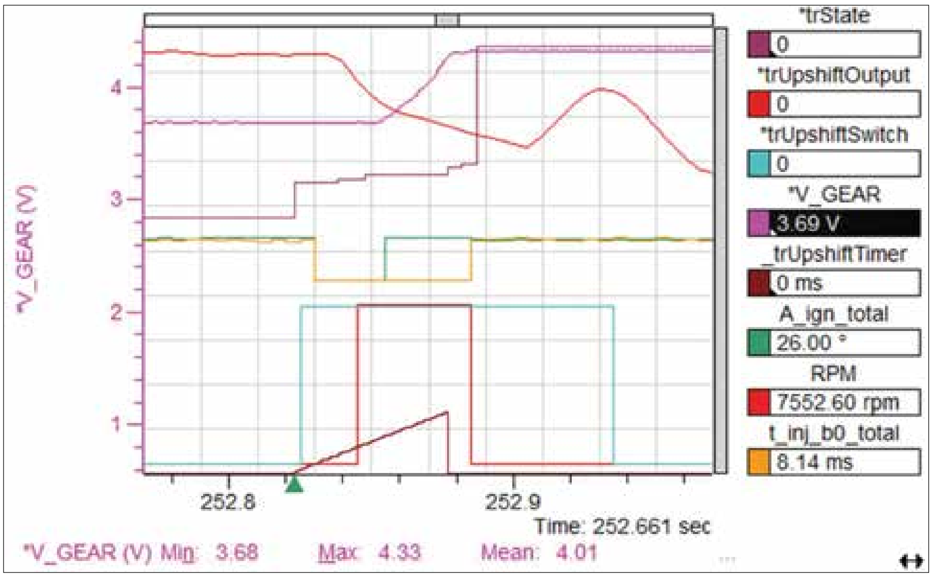

Fig 2: Ignition is cut causing torque reversal, output becomes active, and barrel rotates, moving to the next gear

	Lap number	0 (Out Lap)	1	2	3	4	5	6	7 (In Lap)
	Lap time (sec)	84.880	56.933	55.347	54.635	54.352	54.044	53.860	60.133
_trUpshiftTimer 1-2 (ms)	max	90	73	72	75	72	77	109	0
_trUpshiftTimer 2-3 (ms)	max	76	60	87	90	93	65	67	0
_trUpshiftTimer 3-4 (ms)	max	87	86	106	62	91	94	101	79
_trUpshiftTimer 4-5 (ms)	max	55	55	175	92	176	77	76	53
_trUpshiftTimer 5-6 (ms)	max	0	115	175	84	109	57	112	70
_trUpshiftTimer 6-7 (ms)	max	0	0	0	0	0	0	0	0
_trUpshiftTimer (ms)	max	90	115	175	92	176	94	112	79

Fig 3: Outing report can be generated to provide statistics about the average shift time per gear and other info

shift. It is key to log this channel in the data as it can help both diagnose faults and improve calibration.

Ramp out stages

When moving in a forward direction the torque needs to be cut in order to unload the engine and disengage the dogs before the barrel can rotate. The 'ramp out' stages allow for the user to initiate the ignition and/or fuel cut before entering the main cut phase, this allows for greater flexibility and tuning of the torque reversal timing and severity during a shift sequence.

The blip

The blip phase is used when the gearbox is rotating in a backward direction. This is achieved by momentarily opening the throttle to reverse the engine torque. A good example of where tuning is required would be under heavy braking, where a larger blip is required to unload the gears.

Main cut

The main cut is where the barrel is moved out of the current gear and into the next target gear. The time of the main cut is determined by the shift itself and it ends once the barrel position is measured to be within the 'in gear' tolerance. If the time of the main cut exceeds a user defined time a 'full power retry' is triggered and the shift is attempted again.

Ramp in stages

Once the barrel has moved in to the target gear the 'ramp in stages' allow power to be reapplied gradually. This can help prevent a jerking action on the gearbox, sometimes referred to as 'ringing'.

Wait ratchet return

Following the main cut (for a downshift) and the ramp in stages (for an upshift) the final phase in the transmission state waits for the actuator to return to its centre/rest position, thereby completing the shift sequence.

Gear Shift Analysis

Good Shift

As you would expect, a good shift is characterised by a smooth transition between gear positions. Consider **Figure 2**. The upshift is requested by the driver, the ignition is cut causing a torque reversal, the output becomes active and the barrel rotates moving to the next gear, completing the shift.

- **The shift is requested by the driver (trUpshiftSwitch). The trUpshiftTimer math channel begins measuring the time for the shift. Transmission state enters ramp out stage one (trState). Ignition (A_Ign_Total) and Injection (t_inj_b0_total) are cut to begin torque reversal.**
- **Transmission state progresses from ramp out stage one to ramp out stage two. The torque reversal is evidenced by the falling engine speed (RPM). Actuator output is switched on to move the barrel position (trUpshiftOutput).**
- **Transmission state enters the main cut, the barrel begins to move (V_GEAR) out of gear into the target gear. The fuel injection remains cut.**
- **The barrel reaches its 'in gear' position ending the main cut phase. Transmission state enters ramp in stages to reintroduce engine torque by reapplying fuel injection. Actuator output is switched off. The timer stops measuring the time of the shift at this point.**
- **The transmission awaits the actuator to return to its rest position. The shift is completed. Engine speed increases.**

This screenshot also shows the importance of logging rates. You can just see that trState appears to change before the driver has requested the shift (trUpshiftSwitch) and then the ignition (A_ign_total) and fuelling (t_inj_b0_total) is cut, and this is due to the logging rates. In reality all of these things happen at the same time.

Bad shift

Anything that is not characterised by a smooth transition can be considered a bad shift. However, it is important to be able to determine what could have caused it. Here you can make use of additional channels appropriate for your system such as actuator Current, Duty, Position (for electric systems) or Force Applied and Shaft Strain. Furthermore, you can make use of Math Channels, Software Events and Event Reports to identify points of interest in the data quickly (**Figure 3**).

- **A Math Channel has been created to calculate the time taken to complete shift, this has been implemented by measuring time difference between the different transmission states.**
- **A Software Event has been used to flag up the start of any new shift and also when any shift has taken longer than a user-defined length of time.**
- **An Outing Report is generated to provide useful statistics about the average shift time per gear, maximum shift time per gear per lap and any failed gearshifts.**

Next month we will explore how to characterise common issues that can be diagnosed using the data, as well as some more useful analysis techniques for assessing shift performance.

The blip phase is used when the gearbox is rotating in a backward direction

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Blanking apertures on an Aston Martin

In part two of our GT3 aero study it's time to slap on the race tape

This month we continue our studies of a British GT specification Aston Martin Vantage GT3, kindly provided by Aston Martin Racing, by blanking off some inlets and some outlets. It's worth mentioning that this particular racecar was being prepared for a private client, but was to exactly the same specification as the one that Beechdean AMR used to collect first and second places in the 2015 British GT Drivers' Championship.

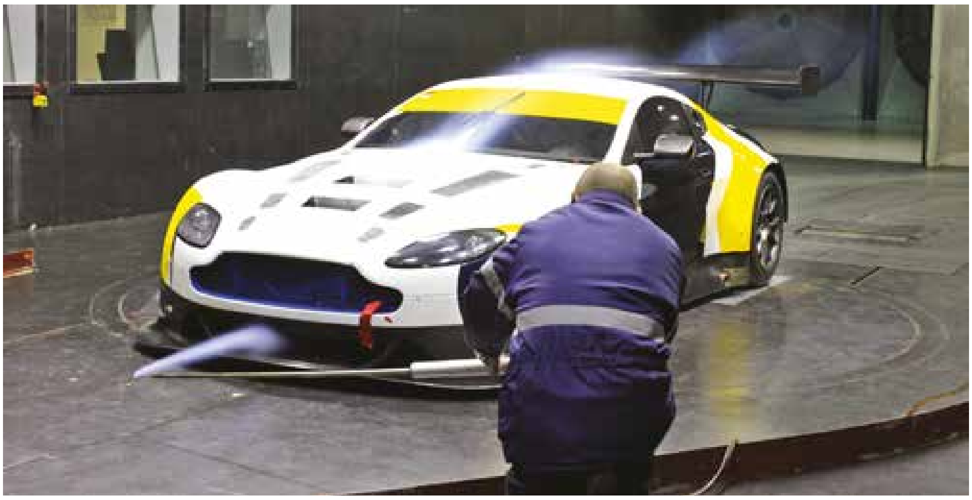
As in all mainstream GT race series, the aerodynamics are tightly controlled by the technical regulations, and British GT regulations require homologation of the key components. The principal downforce-inducing parts then are the front splitter, which features a raised central leading edge and a gently curving profile across the central section of its underside to form a front diffuser; and the large and quite aggressively-angled single element rear wing, which also featured a subtle twist across its span profile. Modest dive planes and the small standard rear spoiler are the only other obvious downforce-generating devices. Interestingly, the car does not have a flat underside feeding a conventional rear diffuser, this to lessen ride height sensitivity in the various worldwide race series, with different ride height regulations, that AMR supply.

We began last month with a look at the baseline numbers on the Aston Martin, and found that it had good downforce compared to the previous GT cars we have tested for Aerobytes. The quite aggressive deployment of the rear wing gave a fairly significant (and somewhat surprising, to this writer) rear-bias to the aerodynamic balance, although this was apparently not an issue with the drivers. The limited range of available wing adjustments was evaluated and produced the expected responses in the data.

Cooling ducts

The Aston Martin was equipped, as expected, with beautifully crafted, fully ducted cooling systems fed by the front grille apertures that exited through tandem apertures in the bonnet, and in the case of the brake cooling ducts, through the wheels. There were additional openings in the bonnet either side of the main cooling exits. The smoke plume highlighted some of the different airflow routes available (see pictures this page). We know from

The Aston Martin in the wind tunnel. Here the front upper aperture can be seen feeding the forward exit duct in the bonnet



The front, lower aperture fed the rear bonnet duct. The smoke plume was a great way to show the different airflow routes

The outer, upper aperture fed the brake cooling ducts. The Aston features beautifully crafted, fully ducted, cooling systems

Table 1 – the effects of taping over the front inlet apertures (positive changes to negative coefficients = more downforce)

	ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear	Δ%front	Δ-L/D
Change	-4.0%	+0.5%	-4.1%	+2.5%	-1.31%	+4.6%

We found that covering up the front wheel arch exits produced some interesting results

The airflow from the front wheel arch exits seemed to be low in energy while it was also not well organised, but it had both upstream and downstream effects

Table 2 – the effect of running with the front wheel arch exits open

	ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear	Δ%front	Δ-L/D
Change	+0.5%	+3.8%	+6.9%	+2.6%	+0.91%	+3.3%

previous experiments in the wind tunnel that if internal airflow, and especially that into the front compartment, is not carefully controlled, increments of drag and front lift can accrue. Given then that the Aston Martin was equipped with fully ducted internal systems, what would be the response in the data to taping over all the front apertures? And would this give an idea of 'cooling drag', that is, the drag from the cooling system alone?

Table 1 illustrates this by showing the changes in the aerodynamic parameters that occurred following the application of a few metres of race tape. The data is given as Δ or delta values, which are expressed as percentage changes to the coefficients.

The reduction in the drag coefficient was interesting. Hucho (**ref 1**) cites figures on production vehicles indicating that cooling drag fell in the range of 2.5 per cent to 15.0 per cent of total drag, with an average of around 7.5 per cent. Carr (**ref 2**) ran trials in the MIRA wind tunnel suggesting that a well-designed cooling system could offer cooling drag as low as 2.5 per cent. Given the power of a GT3 car and the size of the radiators required to maintain effective cooling, the comparison here with ordinary production cars of 30-plus years ago seems very reasonable.

The response of the lift coefficients was interesting if academic, given that the front apertures would never be closed off in this way. When the front apertures were blanked off, front downforce decreased and rear downforce increased. This implies that blanking off the front apertures caused an increase in mass flow over the upper surface of the car, which would have seen an increment of lift over the forward bonnet and possibly the roof, but the rear wing received greater mass flow and so created the extra rear downforce.

Front wheel arch exits

The Aston Martin featured large, rear-facing exits in its front wheel arches. These are generally understood to facilitate the relief of pressure build up within the arch, and also to enable greater mass flow to pass under the front splitter, as these exits provide an improved downstream escape route. Both these aspects are known to help with front downforce. However, the response of the Aston Martin to these exits being covered was thought-provoking, and another lesson in avoiding simplistic assumption. **Table 2** illustrates this, with the changes in the aerodynamic parameters shown with the exits open.

Opening up the front wheel apertures, relative to blanking them off, produced nearly four per cent more downforce for just 0.5 per cent more drag, so this was an efficient and quite useful increment of extra aerodynamic performance. Intriguingly, there were also downforce gains at the rear. As stated above, the reasons for the front end gains are reasonably intuitive. The reasons for the rear end gains are perhaps not quite so obvious, and one must assume they involved the front wheel arch exits increasing the mass flow to the rear of the car. The flow down the sides of the car may have been energised, which could have improved the flow to the outer sections of the rear wing, even though the smoke emerging from the exits appeared to show the flow to be fairly low in energy and quite disorganised. It should be noted that these numbers were measured with stationary floor and wheels; in the real world the effect of these wheel arch apertures may be greater.

Next month we'll look at the effects of changing ride heights, and the strategic deployment of even more race tape on the Aston Martin GT3 racecar.

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Racecar's thanks to Aston Martin Racing.

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In these pages he uses data from MIRA to discuss common aerodynamic issues faced by racecar engineers

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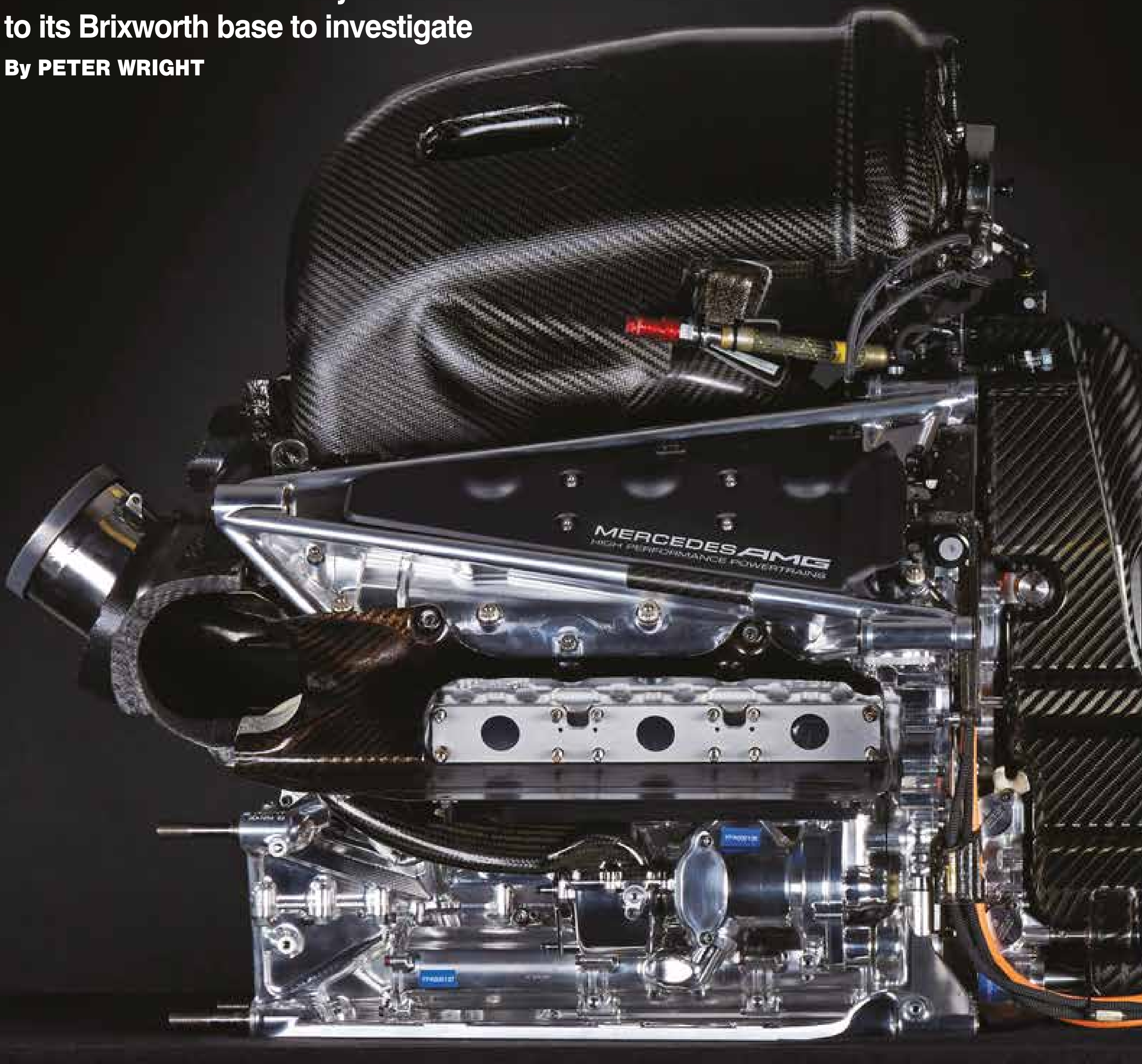
When the front apertures were blanked off, front downforce decreased and rear increased

Halfway to **impossible**

One hundred per cent thermal efficiency is simply impossible, but with its F1 power unit Mercedes HPP is halfway there – *Racecar* went to its Brixworth base to investigate

By PETER WRIGHT



In 2012 the FIA announced new powertrain regulations with two radical features: firstly it determined that power output was to be a function of thermal efficiency and energy recovery, and secondly it constrained the configuration of the system – IC engine, and energy recovery and storage – to align the technologies with those of the road car industry. For the first time in 64 years of Formula1, the technical objectives of the engineers in both disciplines were very nearly the same.

Since the first powertrains ran in early 2014, half the F1 paddock has been decrying these devices on the basis of: 'not noisy enough'; 'too complicated'; 'too expensive', and 'his is more powerful than mine; it's not fair!' All to be expected. The other half of the paddock has kept quiet, and this is the extraordinary thing. Instead of extolling their achievements in radically improving the thermal efficiency of an IC gasoline engine, and the power density of energy storage systems, power electronics and machines, they, being racing engineers, have kept their heads down looking for the next improvement and competitive advantage. A consequence of this is that the bath water, baby and all, very nearly got thrown out, with a reversion proposed to return to irrelevant, high-revving, fuel-guzzling powertrains.

Racing's relevance

The relevance of motorsport engineering to road cars has always been a debated topic, and never more so than with powertrains. The problem is that motorsport requires the maximum output within the regulatory constraints, regardless of cost, while road car engineering sets out to provide adequate output for minimum cost.

With a swept-volume engine regulation dominating throughout F1's history until 2014, power output has been the quest for RPM. Pneumatic valves are an example of an expensive F1 technology that removed a development constraint but had no road car relevance. An opposite example is GDI (gasoline direct injection) – present on the W196 Mercedes of 1954, which

From 2012, when HPP started work on the current powertrain, efficiency has risen from 29 per cent to nearly 50 per cent

revved to 10,000rpm, at that time twice the RPM of a high performance road car engine, such as the Jaguar XK. GDI did not return to racing until the late 1990s with the Audi R8. The engine for this produced its peak output at 6500rpm, while at the same time F1 engines, in particular the Mercedes engine which won the World Championship that year, turned at up to 18,000rpm, where GDI is not feasible. GDI is one of the technologies that has had a big influence on road cars, but was not possible to use in F1 until now, when it has been made central to the current F1 regulations.

As a prelude to the 2016 season, with two successive World Championships under the new regulations in the bag, Mercedes HPP decided it was time to tell the world what it had achieved to date, how it did it, and the relevance of the technologies developed to its passenger cars. No one is better placed to do this than Andy Cowell, managing director of Mercedes HPP, and the architect of this success.

Measuring efficiency

Cowell was at pains to ensure that what is meant by efficiency is correctly understood, which in an era of energy recovery and energy storage, is not always the case. True thermal efficiency is the ratio of the power delivered at the crankshaft to the power delivered to the engine as fuel. And 100 per cent is thermodynamically impossible. In F1's case, 100kg/hour of fuel is delivered at a peak rate equivalent to 1240kW or 1686PS. The crank power must not include any that derives its energy from an electrical storage system. Cowell then gave some interesting numbers, starting in 1876, the year that Karl Benz invented the automobile – see Table 1.

Pressed to be a little bit more specific about the thermal efficiency achieved today, based on the fact that through reverse engineering all his competitors will probably know the figure anyway, Cowell admitted, 'not far short of 50 per cent'. Halfway to impossible, then … (Table 2).

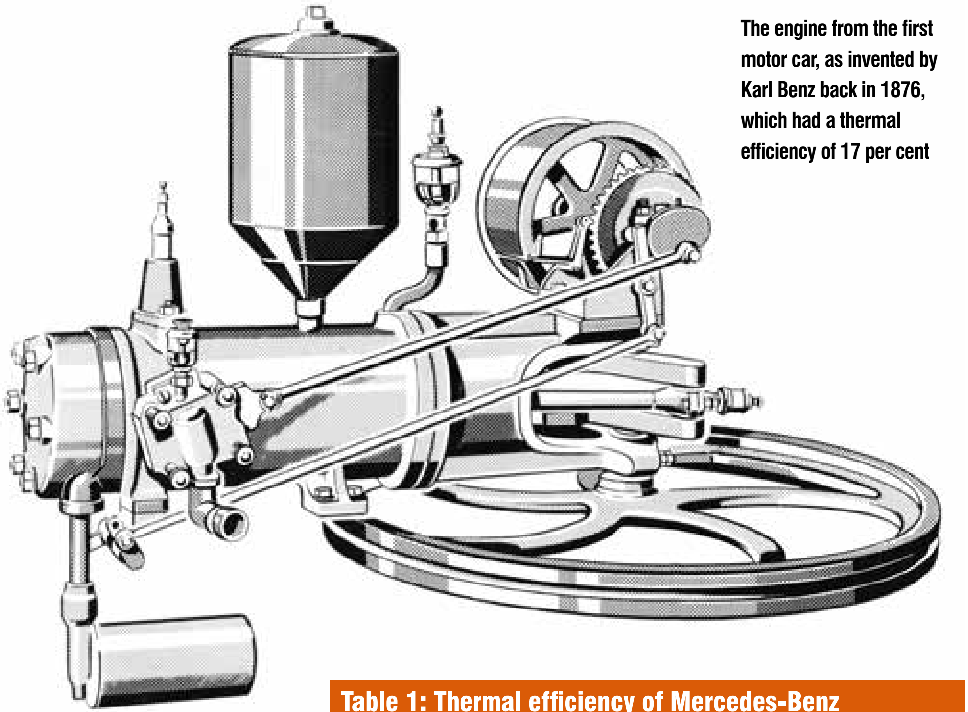
A one per cent gain in efficiency yields 18ps, so it is easy to see both why HPP is working so hard on efficiency, and why Cowell is somewhat cagey about exactly where they have got to. With additional energy sent to the MGU-K from the battery to top it up to its permitted maximum, there is at certain times greater than 900PS available to the driver at the flywheel.

Staggering development

In the 137 years since the inception of the IC engine, thermal efficiency has been improved from 17 per cent to 29 per cent, that is 0.00875 per cent per year. From 2012, when HPP started work on the current powertrain, efficiency has risen from 29 per cent to nearly 50 per cent, that is 5.25 per cent per year. This represents a staggering steepening of the development curve.

HPP made a fundamental decision when it heard KERS was to be introduced into F1 in 2009; that it would take on the responsibility for this technology, starting work on it in 2007 (Table 3).

Cowell stated that the specific power had been improved by a factor of 12, which would mean that the 'less than 20kg' might in fact be nearer to18kg, based on the firm figures supplied. This weight not only includes the battery itself, but also all the control electronics that monitor the Lithium Ion cells, and control the flow of electrical energy to and from the two MGU's (H and K) that form part of the powertrain. This latter computer performs a mere 43 trillion calculations in the



The engine from the first motor car, as invented by Karl Benz back in 1876, which had a thermal efficiency of 17 per cent

Table 1: Thermal efficiency of Mercedes-Benz automobile engines since its inception

Year	Engine configuration	Thermal Efficiency
1876	1-litre, 1-cylinder, NA	17 per cent
2013	2.4-litre, V8, NA	29 per cent
2015	1.6-litre, V6, turbo-compound	>45 per cent

Table 2: Performance of recent Mercedes Formula 1 powertrains

Year	Engine	Power	Fuel flow	Thermal Efficiency
2005	3-litre, V10, NA	900ps @ 18,000rpm	194kg/hr	27.5 per cent
2013	2.4-litre, V8, NA	725ps @ 18,000rpm	148kg/hr	29 per cent
2015	1.6-litre V6, t-c	750-840ps @ 10,500rpm	100kg/hr	45-50 per cent

Table 3: Mercedes-Benz HPP's work on KERS

Year	Weight (kg)	Power (kW)	One-way efficiency (%)	Power/Weight (kW/kg)
2007	107.0	60	39	0.56
2008	36.5	60	54	1.64
2009	25.3	60	70	2.57
2012	<24	120	80	>5.0
2015	<20	120	95	>6.0

course of a two-hour race. This level of number crunching is needed to manage the recovery and deployment of the energy between the MGUs and the battery, and to ensure that the race driver receives exactly, and repeatedly, the torque that he demands.

The first of these is supervised according to the strategy in use: *Friday practice*, *Qualifying*, *Race*, *Safety Car*, etc. The software learns and updates the strategy according to what is actually happening out on the track.

The second function reveals an interesting insight about the entertainment value of F1. Many perceive that F1 has become less spectacular, and that this can be corrected with more power – although why more grip is also being prescribed is currently beyond me. However, Cowell explained how HPP engineers spend a great deal of time tuning the torque delivery response to the drivers' desires, both on track and in the simulator. When the driver applies the throttle pedal he wants to receive the exact torque at the wheels he desires, and it must be exactly the same as last time. More can lead to loss of control; less to frustration.

In the days of port fuel injection, the fuel droplets 'made a couple of laps of the trumpets before disappearing down them,' says Cowell. Mixture distribution was somewhat haphazard, and the response of the engine to a given throttle opening was guesswork. GDI has solved much of this problem with predictable, repeatable fuelling of each cylinder. The throttle pedal is a torque demand, and the computer determines the actual throttle opening according to engine conditions at the time, compensating for RPM, turbo pressure, air temperature etc. If the IC engine cannot deliver the desired torque, then the MGU-K can draw energy from the battery and fill in any holes in the IC engine torque curve. Cowell stated that torque feedback from a sensor on the input shaft of the gearbox is not employed as 'that would look too much like traction control'.

This mastery of the mammoth torque of these powertrains has given the drivers better control than ever before, and has meant that talented young drivers can step up to F1 with ease. Spectacular it is not, and however much power the powertrains deliver, that era is gone.

But does Mercedes ever burn fuel solely to fill the energy store, under braking or mid corner, or for instance when the traction is limited? Cowell says that would be an inefficient use of fuel, to send the energy via the battery, but admitted it would be possible on circuits where the race allocation of fuel (100kg) is not needed, or when there is an extended safety car period and fuel is conserved.

Cowell spoke carefully and somewhat guardedly about how HPP had achieved these remarkable results starting in 2012, when the new regulations became firm. He gives much of the credit to four key groups within HPP: Performance Simulation, tasked with combustion, Dr Nigel McKinley, its team leader; Turbocharger Design (Pierre Godof, team leader); Hybrid Systems team (led by John Stamford); and the Software Development group, led by John Goodman.

Performance simulation

The first powertrain, the GB (the 2016 is the GF), weighed in at 262kg and would never have fitted in to a car. It did not feature the later engines' split turbo system, but gave the engineers the first validation of the combustion simulation work that is the cornerstone of HPP's R&D. Using moving-mesh CFD, essential where there are geometry changes, the Performance Simulation group ran hundreds of simulations in order to understand and optimise the synergy between: GDI; charge motion; compression efficiency; gas exchange; and combustion – including molecular-level modelling of fuels with a knock limit being the critical boundary. Results are then proven in a single cylinder research engine, and transferred to the latest spec of the V6 R&D engines.

At the start of the project, HPP found that there was virtually no turbocharging expertise in-house at Brixworth. Turning to parent company Daimler, it ended up talking to both the truck division of Mercedes-Benz and the helicopter gas turbine division of MTU. The truck business is driven by the costs of fuel, and so efficiency is paramount. Also, the power rating of big truck diesel engines is of the same order as the F1 powertrain, so learning from truck turbos is not as odd as it may seem.

Freeing up the size of the compressor by taking it out of the *V*, and mounting it at the front of the engine, with the MGU-H just

The Mercedes F Cell Roadster concept of 2009 (left) was a tribute to the very first car, the Benz Motorwagen (right). The roadster has an electric motor powered by a fuel cell. Mercedes-Benz HPP has now made concept car-like efficiency gains in the real world of F1

Mercedes HPP has achieved a thermal efficiency of close to 50 per cent with its F1 power unit. True thermal efficiency is the ratio of the power delivered at the crankshaft to the power delivered to the engine as fuel

behind it and the driveshaft extending back to the turbine at the rear, brought a number of benefits: 'When added together, they are worth the enormous effort needed to make it work – it was very hard,' says Cowell.

Inspecting the assembly indicates that the 125,000rpm rotating parts are monitored by a number of sensors to ensure that the bearings and shaft dynamics are always within limits. The 'cogging' of the electrical machine, combined with the exhaust pulses the turbine experiences, make for a highly 'excited' rotating assembly. At the front, the compressor inlet conditions are controlled by variable geometry inlet guide vanes, to maintain the surge margin when the throttle is closed. At the rear, variable geometry is not permitted on the turbine, and in fact is not required as the whole system is constant speed, controlled by the MGU-H. A wastegate, however, is required for safety, for instance when it is necessary to unload the turbine suddenly due to an electrical short, triggering the total disconnection of the high-voltage power electrical system. It is also sometimes useful to compensate for sudden load shifts during downchanges. It took 600 CFD simulations to arrive at the first design, and many containment burst tests to prove it, at £20,000 a test for the hardware alone. The large diameter compressor allows HPP to run the turbocharger below the maximum 125,000rpm at sea level, and to speed it up and continue to use the 100kg/hr fuel flow rate at altitude, for example at Mexico City, to maintain design power output.

The compressor wheel employs the same alloy as the pistons, an aluminium alloy still closely related to the piston alloy developed by Rolls Royce for the Schneider Trophy R-engine and the Merlin, 90 years ago. The double entry turbine wheel is a cast, high nickel inconel alloy; ceramics are not permitted. We did not get a chance to look at an exhaust system.

Inspection of the other IC engine components revealed parts that look similar to the V8 equivalent parts, although there were obviously many, many detailed differences. Much lower RPM has relieved the inertial loads, but the gas loads are way higher. The small V6 also needs some beefing up to maintain its structural stiffness as an integral part of the chassis, and this is particularly evident as a larger web at the base of the crankcase, and tubular structures above the cylinder heads.

Electrification

It is easy to overlook the development that has gone into the two electrical machines that are part of the powertrain. By their very nature they are densely packed cylinders of copper, steel laminations, and rare-earth magnets, with the smallest of air gaps and only sufficient free space for cooling fluid. Weight reduction only comes from reducing the size for a given power by increasing RPM. Both MGU-K and MGU-H seem to be around the same size, but HPP is neither releasing the power rating of the 125,000rpm MGU-H, nor the RPM of the 120kW MGU-K. From the sizes observed, it is unlikely that either is much under 10kg.

A 16ps/kg figure is, however, impressive compared to around 10ps/kg of the 900ps of the best V10s. The problem with automotive

The 125,000rpm rotating parts are monitored by a number of sensors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Above: The V6, which is smaller than the V8 which preceded it, needed some beefing up to maintain its structural stiffness as an integral part of the Mercedes chassis
Left: HPP spends a great deal of time tuning the torque delivery response to the drivers' desires, both on track and in the simulator, so they always know what's under their right foot

electrification is not the motor; rather it is the storage of the energy

Cowell stressed how hard HPP had worked on the efficiency of the whole power electrical system. The payoff is not just yielding more power, but less cooling of all elements of the system, which compromises the car's aerodynamics. Every aspect is studied to yield crumbs of performance, which add up to something useful. Aircraft wiring and connector systems are utilised. In aircraft power electric cables, copper is replaced with nickel-plated aluminium wires, which are half the weight for a given resistance. Running the system under full power and inspecting with thermal imaging cameras guides the engineers to hot areas where the losses are occurring. 'It is like the water and oil systems, you have to eradicate or ease every little restriction,' Cowell explains.

Yet while all's clearly very good at HPP now, in an ideal world what would HPP like to do to change the F1 powertrain regulations to yield greater efficiency? 'Maybe two less cylinders,' says Cowell. 'If it must be a V6, then 60-degree or 120-degree rather than 90-degree, for a sweeter sound. Larger capacity with less RPM would increase thermal efficiency. The fuel regulations are okay – a reasonable balance between energy density and knock.'

Tech transfer

Another hypothetical question: if Cowell was suddenly and unexpectedly transferred by Mercedes-Benz to design the next C-class powertrain, what would he take from HPP to incorporate into a middle of the range powertrain? After some thought, but still just about off the cuff, these are the features he puts forward: 400cc, 90-degree V-twin, with 200PS; electric turbocharger – but not exhaust energy recovery as this requires full throttle; an MGU-K integrated into the powertrain, with two energy recovery MGUs for each of the front wheels, giving 4WD when necessary; combustion know-how; lower RPM than the F1 internal combustion engine. 'The IC engine would effectively become a range extender with around 54 per cent efficiency,' he adds.

Cowell sees no future for the IC engine as a stand-alone powertrain. However, he did also admit that his vision would require clever production engineers to get the costs out without destroying the efficiency.

HPP has a total staff of around 500 at Brixworth, of which Cowell is the managing director. To have an engineer with total management control is unusual in F1, and this, plus the autonomy of Mercedes-Benz HPP, located in a different country to the parent company but close to the racing team, is a major contributor towards its success.

A number of other things impressed me as Cowell led a brief tour of the factory, during which he offered a number of insights, for instance: 'In general we don't employ F1 people. Instead we simply look for very good engineers.'

In the middle of the engineering office was the materials group. 'We tend not to believe the material performance as published by suppliers, so we do our own tests,' he said. 'Then, when something breaks, the materials engineers carry out a full forensic investigation. We have developed three or four alloys, unique to HPP, for the powertrain,' Cowell added.

Machine shop

The machine shop was the next stop. It is laid out in such a way that machine tools can be removed and replaced easily, as new technology comes through. This may be machine tools themselves or new powertrain technology requiring different processes. The machine tools are relatively lightly used, as Formula 1 components generally require light cuts, and so they maintain their value; HPP depreciates them over five years. Cowell said: 'We encourage a spirit of change in the machine shop, not a production mentality.'

Another point Cowell made related to the company's staff: 'The key to a happy workforce is to avoid annoying them with silly little things, like there not being enough parking.' But the workload is heavy: 'We are working 24/7 through January, February and March to build and test engines for testing and the early races, and yet we try to be flexible. We build about 100 engines a year, but we managed to get away with using only three engines for one driver last year. That is good, as it means we have a spare!'

Perhaps the single thing that struck me about how different HPP is from many other F1 outfits was the lack of trophies in the entrance foyer. The trophies, and there are many of them, are displayed around the factory, even in among the machine tools.

HPP is quietly confidant of what it is doing; that is, something that is quite remarkable in automotive engineering, and well worth telling the world about. It is halfway to impossible, and has no intention of stopping there.

'We've developed three or four alloys, unique to HPP, for the powertrain'


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Carbon dating

With many Formula 3 carbon chassis now getting a little long in the tooth should we be worried about the structural integrity of battle-scarred tubs? *Racecar* investigates

By LEIGH O'GORMAN

It could be said that some Formula 3 monocoques have quite a hard life, with eager drivers keen to impress and accidents like this hardly uncommon. But should an extension in the life of the current carbon chassis, many of which could now be in the thick of the action for eight years in total at least, be a cause for concern for those involved in the category?

In December, 2015, the World Motor Sport Council declared it would extend the life of the current Formula 3 chassis. It wanted to counter the rising costs of competing in the Single Seater Commission's flagship series, the European Formula 3 Championship, which is quite understandable. But this move has raised some interesting questions about the life cycle of carbon composite tubs, and whether they deteriorate with age, and the implications if this is indeed the case.

The current Formula 3 technical regulations came into being in 2012 and a large number of the existing chassis are about to enter into their fifth year of competition. Originally a new set of technical regulations was due to come into effect in 2018; however, that has now been pushed back until 2020. With the current cars set to run until the end of 2019, that would complete an eight-year cycle for these regulations. According to a WMSC release, a safety update kit will be rolled out in either 2017 or 2018 but details of this are not due to be discussed until this June's meeting of the WMSC.

Alongside its pan-European competition, the FIA is also hoping to encourage the re-growth of national Formula 3 championships, primarily to reinstate a rung on the single-seater ladder that will be able to cope with the projected large number of graduates from the numerous Formula 4 categories that have been launched in recent years.

It is believed that these new national Formula 3 competitions will utilise the same chassis regulations that exist in the European Championship, albeit with a cheaper detuned engine (similar to the situation in the current Euroformula Open regulations).

But is it feasible for carbon tubs to run for eight years or more without the structural integrity or performance degrading to the point where they might become susceptible to age-related fragility? This also brings into question whether the onus for this is on the teams, the chassis manufacturer, or the FIA to define when evaluation of the structural integrity of a tub at a microscopic level is required following a set number of miles, events, or amount of time.

Generally, monocoque chassis have an internal and external skin of carbon fibre, while the core is constructed of either Kevlar or an aluminium honeycomb. Thereafter the skins are bonded to the core, creating a sandwich construction. Although composite skins are

FIA-spec Formula 3 tubs need to go through brutal and thorough crash testing before they are approved. But beyond the damage caused in an accident, is there any cause to be concerned about general ageing?

With the current cars set to run until the end of 2019, that would complete an eight-year cycle for these regulations

Modern carbon composite monocoques are extremely tough while the teams tend to send them back to the manufacturer for examination at regular intervals; but there is currently no regulation to ensure this happens

Carbon tubs have an internal and external skin of carbon fibre and a core constructed of Kevlar or an aluminium honeycomb

flexible, the core is not, so when the external skin is hit – by gravel, debris, barriers, etc. – the outer skin flexes and returns to its original shape, but the honeycomb most likely will not.

The result of this action is a small gap between the external skin and the honeycomb. This gap is called a delamination, and it can also be caused by general fatigue. Over time, these delaminations can join, potentially causing the structure to fail. This type of damage may not show up on torsional testing and so would require ultrasonic testing, or X-ray.

As with all things in life, the properties of a carbon chassis will alter with time and use, but what impact does ageing have on performance and structural integrity, and how does one assess such a factor? As engineering and project manager at Dallara – by far the most popular car maker in Formula 3 for many years now – the subject of composite ageing is one that Jos Claes is becoming more and more familiar with. 'Ageing of composite structures still belongs largely to a very undiscovered world. We are actually spending quite some time researching exactly this area,' he says.

Tub thumpers

Following the WMSC release, Robert Maas – technical delegate of the European Formula 3 Championship – confirmed that: 'The ageing of monocoques with time is an active project for investigation.' However, he then went on to add that: 'The chassis manufacturer is able to decide with the help of different inspection methods whether a chassis is still suitable for competition use or not.'

Dallara agrees. It is more than three decades since it began using composite materials in tub construction, and for the Italian manufacturer it is a constantly evolving area, especially as the tubs of today are lighter and enormously stiffer compared to its early efforts. 'Our FEA/FEM and research department is continuously experimenting,' Claes says, and there is a belief that the ongoing research will go a long way to revealing the effects of structural performance over time. 'We will soon be in a better position to answer this. Of course, in cases were the car is built around a monocoque that has lost 10 or 20 per cent of its torsional stiffness, the car feels different, and differences will appear in the set-up used to get a similar balance and handling.'

The majority of examinations of carbon tubs are used to detect potential cracks and

Most damage to a tub is clearly visible and the teams learn where that damage is more likely to occur. Sometimes they will also make use of ultrasonic testing

This old tub has seen better days but it might still be in great shape. Dallara checked one well-used 20-year-old chassis and found it was fine. *Picture credit: Tristan Cliffe/Dallara F398.com*

other damage following an accident – a regular occurrence in lower categories as drivers learn the craft of racing, often by hitting things. But while ultrasonic testing and X-rays might be the way forward should there be questions about the structural integrity of a chassis, there are more straight-forward examinations that can be carried out before one chooses to go in at the deep end. 'Delamination is a rather rare problem these days, it is also easily detected; soft knocking will find the delaminated area. Basic inspection is purely visual; eventually we do ultrasonic [if] we think it needs it,' says Claes.

'While repairing, [we start by] cleaning the area and opening the skin to get a perfect view of the damage and the kind of repair needed,' Claes continues. 'Damage is mostly clearly visible. Even small cracks are quite easy to find.

'The areas where tubs get damaged are known by the teams, who look at the state of the tub all the time. Most damage is clearly visible from outside the inner or outer skin.'

Claes also stressed the importance of making sure the repairs are done well: 'Each composite structure that is damaged must at least be repaired to be as strong as it originally was. Most repaired areas become, if anything, rather stronger and slightly more heavy through repair. Basically, the same carbon fibres, and at least the same amount of layers, are installed.'

The majority of examinations of carbon tubs are to detect potential cracks and other damage following an accident or a significant off

With his extensive experience in the area and the knowledge that teams send cars for examination at fairly regular intervals, Claes is rather less concerned with the long-term structural composition of a carbon tub. 'There is no worry for the current generation of monocoques, as we occasionally inspect five- or 10-year-old tubs and find them in very good shape and extremely close to their original torsional stiffness,' he says.

Tough tub

Indeed, a few years ago, Dallara received a repair request that stretched even that time frame significantly. 'We had a request from a Brazilian team to repair a monocoque, a type F394. This car had been racing for nearly 20 years! Some of the tracks in Brazil are extremely fast and bumpy and have high kerb stones. There is no worse. We did repair the tub and for interest we measured the torsional stiffness. The repair itself had not much to contribute to the stiffness. The number we found was within a few per cent of what those tubs had when new, more than 20 years ago! This chassis had probably done more than 150,000km of racing in rather harsh conditions, and still it had lost near nothing of its original strength. This story illustrates the final good reason for composite structures, the longevity of its safety features. So, that today's cars will be used for eight seasons of 10,000km raises no safety questions.

'Today's monocoques stand very well the hard life in racing also over many years,' Claes continues. 'Monocoque constructions have continuously been improved both by more severe regulations and better material and also a better understanding of where and how to use the material.'

On the surface, there appears to be no immediate concerns regarding the status of long-life carbon tubs, then. But there is one pressing question: who exactly does take the responsibility for determining whether a chassis should be examined for structural issues due to high use? Initial investigations into this left one with the distinct impression that there is no outright entity responsible for monitoring the life cycle of a carbon tub that has been in competition for many years.

There is nothing in the FIA regulations to stipulate how long a chassis should be in active service before it is examined for structural integrity and, as far as is known, there does not appear to be an agreement between teams or chassis manufacturers that governs this aspect of chassis maintenance.

For Mick Kouros, head of engineering at F3 squad West-Tec, it is a point that has no definitive answer. 'That's a good question and it has never been defined. The teams take the view that it is in a team's best interest to maintain the structure 100 per cent to have the best performance. The teams don't have any agreement; they just know Dallara is the best place to send them.'

In the grand scheme of things, there should in theory be little to worry about, then. The teams should be – and of course usually are – actively working to maintain a high level of performance. And leaving a tub to age without conducting examinations is as good as taking a short-cut to finishing last.

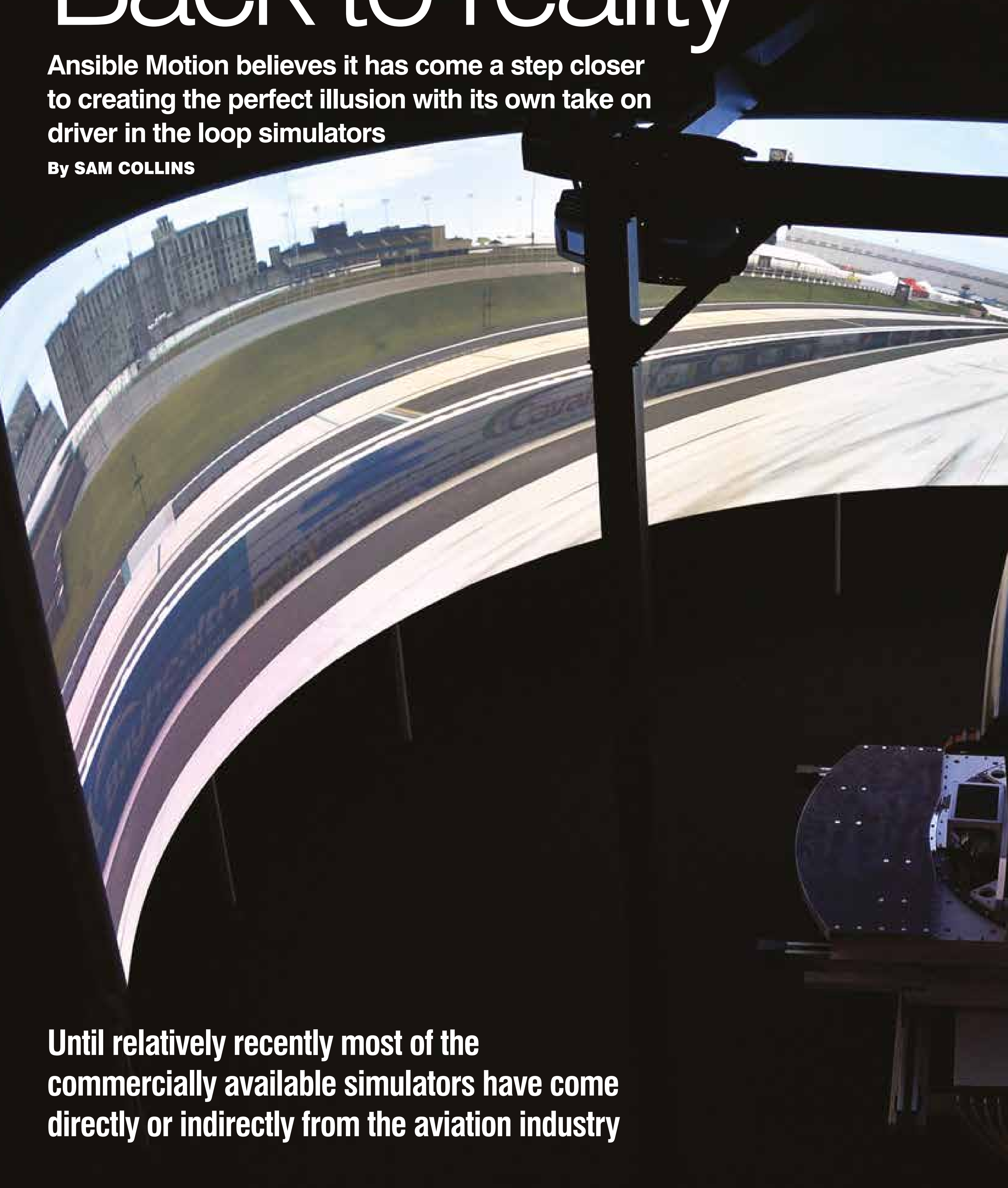
But while no one wishes to see an already expensive category rise further still in price, it might be a touch more reassuring if guidance for long term maintenance or examination of carbon composite tubs could be drawn up and placed within the regulations.

No team, driver, supplier or regulatory body wants the industry to walk into a dangerous situation that could have been prevented. Beyond the purely regulatory side of this, the examination of carbon composite structural integrity over a long period of time is something that may be revisited at a later date. It is certainly a subject worthy of continued research.

Back to reality

Ansible Motion believes it has come a step closer to creating the perfect illusion with its own take on driver in the loop simulators

By SAM COLLINS



Until relatively recently most of the commercially available simulators have come directly or indirectly from the aviation industry

Ford, which uses an Ansible Motion system at its Tech centre in North Carolina, has both NASCAR and GT cockpits to fix to its machine. This extra layer of realism is key when it comes to making drivers believe they are at the wheel of a racecar

When the new crop of grand prix cars took to the track for the first time during the pre-season tests at Barcelona many of the drivers already knew what to expect from the new designs. Most, if not all, of them had already driven their machines for countless laps in the virtual environment.

Of course, simulators are nothing new, they have been used in racing for years, and in aviation for almost a century, but the way they are being used by engineers in motorsport today is changing. They have now become a key tool in the car design and development process in Formula 1 and LMP1, and they are having a growing impact in classes such as GT500 and the NASCAR Sprint Cup.

However, until relatively recently most of the commercially available simulators have come directly or indirectly from the aviation industry. These had some inherent shortcomings when they were adapted for use with ground vehicles, though at first almost nobody noticed these, mainly because quite simply there was no alternative. Most of these issues are also not to do with hardware or even software functionality, rather they all relate to that flawed component; the human in the loop.

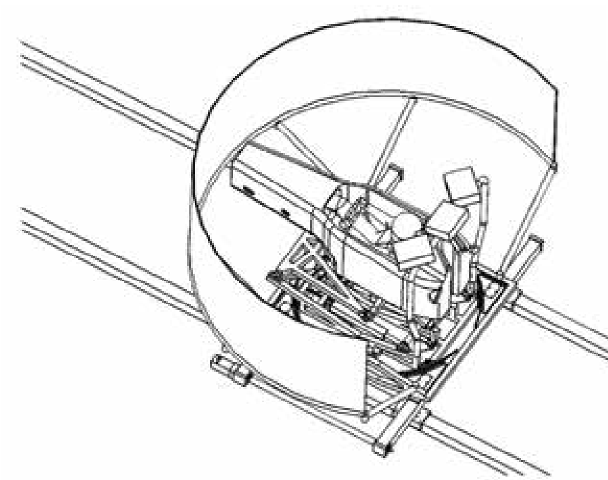
'Is it a simulation or a measurement that is closer to the truth? Is it better to trust objective representations of *reality*, or subjective feelings and perceptions about *reality*?' Ansible Motion's Phil Morse asks in a white paper published by the company in 2015. 'Such questions often bring into focus the human factor – that inescapable and mysterious combination of physiological and psychological elements that defines the total driving experience. Simply put, a Driver-in-the-Loop (DIL) simulator is a mechanism for creating an illusion for drivers. If the illusion is convincing – and a number of other characteristics are present – then we have the basis for a useful tool for human factors studies, vehicle engineering work, and/or fundamental research.'

Keeping it real

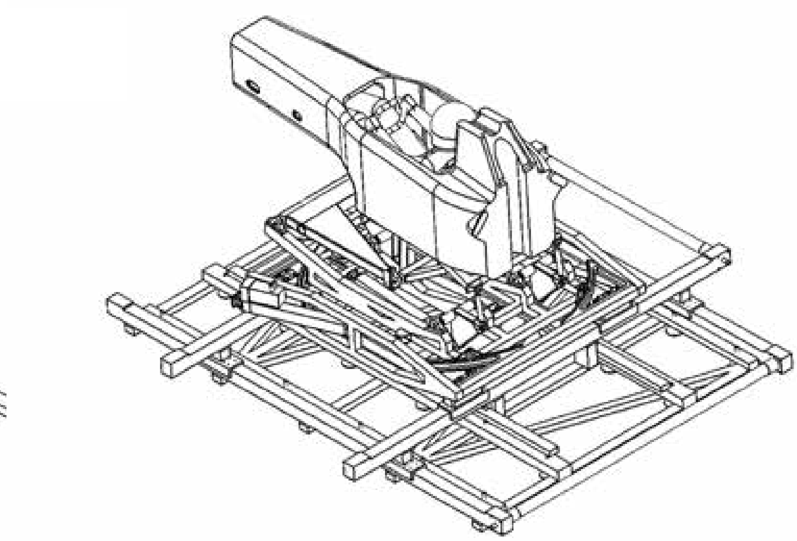
It is in the process of creating this illusion where many aerospace derived simulators struggle somewhat. If a driver's mind and body does not believe it is real then the feedback that both give will also not be real. The human reaction to motion is fairly well understood by those who study such things, and they call this the vestibular system. This organic system consists in essence of miniature, six-degree-of-freedom gyroscopes within the inner ears. Special organs within the vestibule, called the utricle and saccule organs, detect linear accelerations in three directions – vertical (which includes gravity), lateral (sway), and longitudinal (surge). In addition, three fluid filled semi-circular canals are oriented in three planes to sense yaw, pitch and roll. When a person's body is moved about, tiny hair cells in the vestibule and semi-circular canals stimulate the vestibular nerve, leaving the brain to interpret the nerve impulses resulting from simultaneous combinations of the six primary accelerations. The key to getting a simulator to work as intended is to have the whole of this system, in addition to the visual inputs, fooled into believing that everything it is encountering is real.

Most of the aviation derived systems are based on the Stewart platform concept. Having evolved into the modern hexapod concept these designs can trace their roots back to Dr Eric Gough in 1947. They tend to suffer from the limitation of size, range and mechanical performance. The mechanical lag on some products can be perceived by the driver and it shatters the illusion and can ruin technical feedback.

In the aviation world, which developed these simulators



Ansible Motion's patented design (above) goes some way towards addressing some of the problems associated with hexapod simulators, which are often based on aerospace units



At the heart of the Ansible simulator is a motion platform comprising linear slides which provide the surge and sway, and a rotary table which provides the yaw

The platform is designed to be inherently stiff while it also has a very low centre of gravity, which reduces the bending moments

The cockpit the race driver will sit in needs to feel as real as possible. Typically Formula 1 teams will fit a monocoque to the simulator. For extra realism there will be torque force on steering wheel and seat belts

this lag is not a factor, the pilots are used to controlling huge vehicles and seeing far-away objects. There are no objects close to the eyeline and no sudden change in direction. Even with the latest fighter jets, which change direction incredibly rapidly, the lag for the pilot is not an issue as they tend not to have advertising hoardings, kerbs and barriers passing within 10 metres. They also don't have to deal with bumps in the road or tyre adhesion.

Hexapod type simulators can also struggle with the range and type of motion experienced; as they are fully parallel six degrees of freedom machines all six actuators must move in order to create any motion, even just in one direction. This can mean that they have an inherently limited capability to create complex simultaneous movements such as those that might be experienced by a driver turning while braking while driving over kerbs. As a result engineers have tried to create workarounds such as hybrid systems with the hexapods being mounted on tracks or turntables, or as is the case with the Dallara simulator, they will have very long stroke hydraulic actuators. This can overcome the parallel movement limitations by adding more than six degrees of freedom to the system, but at the expense of increased complexity, cost, mass, actuator friction, and, of course, mechanical lag.

Control strategies

Another common approach is to add control strategies to protect the hexapod's limited motion space. Rather than controlling the hexapod or hybrid hexapod to merely return to centre, the controller actually winds up in a direction opposite to an anticipated command.

All this said, hexapods can indeed be used for automotive simulation work, and are still the most common type in use in motorsport.

Becoming aware of these issues some years ago, Kia Cammaerts, a former Ralt and Lotus F1 engineer, and Bob Stevens, another ex-Lotus man, decided to develop a new type of simulator specifically for use with ground vehicles. Rather than utilising the Stewart platform concept they came up with something completely new. 'In 2009, we had a vision for what an automotive style driving simulator should look like, and how it should behave. Being automotive engineers ourselves, we put it to paper,' Cammaerts says. 'We knew straight away that we had something unique, something that might serve as a useful tool for vehicle constructors. We now recognise that our vision formed the foundation of the world's first commercially available vehicle dynamics-capable driving simulator.'

And thus Ansible Motion was formed. Its first simulator featured a motion platform for use in a simulator comprising linear slides providing surge and sway, and a rotary table providing yaw. A payload carrying platform was mounted on the rotary table via three bell cranks to provide heave, pitch and roll. It looked

Aircraft pilots don't have to deal with bumps in the road or tyre adhesion

The simulators used in motorsport, which have evolved over the last few decades, range in size, complexity, capability and cost, and they can be broadly classified into three basic categories.

Entertainment Simulators

These systems are powered by powerful gaming PCs. Additionally, there are larger, commercial systems used for amusement parks, trade shows, and other events that feature mock-up vehicle cockpits, motion systems, and audio systems. Entertainment DIL simulators feature graphics centric software displaying a driving environment that responds to input received from driver devices (steering wheels, gearshifts, and pedals). The graphics can be state-of-the-art in terms of quality and photo-realism, and the applications enable players to simulate changing vehicles, environments (typically race tracks), simplified vehicle tuning parameters, and can even allow inter-connectivity with other 'live' drivers for the purposes of competing in virtual racing and driving competitions.

These systems are not designed for automotive engineering work, so they typically do not connect to sophisticated vehicle descriptions. However, they are often endorsed by professional racing drivers, as they can be useful for learning and practicing the racing lines around visually-realistic race tracks.

Human Factors DIL simulators play an important role for automotive manufacturers

Human Factors DIL

Unlike entertainment simulators, which are designed primarily for the enjoyment of the player/driver, Human Factors DIL simulators are designed to more closely simulate actual driving conditions of real vehicles and, as such, they are useful for vehicle manufacturers and engineering work. The emphasis is typically directed towards monitoring drivers rather than vehicle behaviours.

For example, automotive manufacturers might use a Human Factors DIL simulator to study human behaviour while driving a representative vehicle model in a dense traffic scenario containing some erratic fellow drivers. These systems are typically large and complex and they are generally built around hexapod motion systems. Graphics and image generation technologies usually emphasise flexibility in scenario modifications over photo-realism or visual latency reduction strategies. Scenes can be projected on to the interior of attached domes or in some cases on to large stand-alone screens. Some high profile installations can take up entire rooms or even buildings and capital costs can spill into the hundreds of millions of dollars.

But the potential for safety research alone can justify these enormous investments in Human Factors DIL simulator installations. Human Factors DIL simulators are useful and they play an important role for automotive manufacturers. As mentioned above, there are tangible benefits to placing real drivers into contact with sophisticated vehicle simulation models during the product development stage.

Entertainment simulators are a step up from games and are useful for learning circuits and for driver talent search schemes. Pictured is gamer turned race driver Jann Mardenborough

Human Factors DIL simulators are typically operated by road car manufacturers and they are designed to closely simulate actual road driving conditions. This one belongs to Lexus

Vehicle Dynamics DIL

These simulators represent the newest, emerging class of DIL simulation tools and, as the name implies, they are designed for a different category of DIL simulation. Like Human Factors DIL simulators, they are designed to closely simulate actual driving conditions of real vehicles and, as such, they are useful for vehicle manufacturers' engineering and product development work. However, unlike Human Factors DIL simulators, the emphasis for Vehicle Dynamics DIL simulators is typically directed towards measuring vehicle and driver performance rather than monitoring driver behaviours.

Vehicle Dynamics DIL simulators must connect to sophisticated vehicle simulation models in order to contribute to core vehicle development tasks that involve skilled drivers. Expert drivers must be able to interact in a highly realistic way in a 'virtual proving ground' manner, without being subjected to sensory violations, and they must be able to provide useful subjective feedback regarding vehicle behaviour and performance. As such, emphasis is often placed on real-time functionality of detailed sub-systems and application tool chains – systems that would not be the subject of scrutiny in typical Human Factors DIL simulations, such as tyre/surface modelling, steering wheel feedback tuning, cue tuning relative to vehicle simulation commands, and so on. In some cases, real vehicle cockpit components might be utilised, but for haptic (touch) immersion rather that ergonomic reasons.

Vehicle Dynamics DIL simulators are often connected in real-time with sophisticated vehicle subsystem models via Software-in-the-Loop (SIL) or mechanical Hardware-in-the-Loop test benches, and real engine control units (ECUs) via Hardware-in-the-Loop (HIL).

Simulator technology for motorsport applications is clearly not yet mature and the applications, tools and usage are still evolving fast

completely different to a hexapod and they patented the technology.

But the simulator is more than the mechanical components, says Cammaerts: 'One of our favourite quotes is: "The best way to predict the future is to invent it." The man who is credited with that quote, Alan Kay, also said that "people who are really serious about software should make their own hardware." I would be hard-pressed to find any statements that are better aligned with how we go about our business. Our technology has three layers of operation; the vision system, which comprises the screen and projectors; then the computer system, comprising a dozen PCs of different types performing different functions for the system and audio rack. And then there's the motion platform and cockpit.'

All of these layers combine to provide the required inputs and responses to create that illusion for the driver. 'The main parts of the system are the vehicle dynamics, which is where the calculations are made for the physics of the vehicle interacting with its environment,' says Cammaerts. 'That's typically a software solution, and it's connected to a graphics engine, which renders the view from the cockpit in a way that can be graphically corrected for the optical perspective that the driver would see in the real world environment within the simulator. On the other side of the vehicle dynamics, there are the cue filters which take the accelerations that the driver of the real car would be subject to and transforms them into a set of demands for the accelerations that the driver in the platform would be subjected to. Those demands are passed to the motion control system which energises the motors to cause the motion of the platform to reflect the acceleration demands we want to provide. This creates a realistic sense of motion for the driver.'

Honing the illusion

To enhance the virtual driving experience of its simulators, or in other word to make the illusion even better, Ansible Motion has developed a number of special systems. One example is its Helmet Loading System (HLS), a multiple degree-of-freedom electromechanical device that can inform a simulator driver about vehicle directional changes.

According to Ansible Motion, applied forces and displacements are contained within safe operating envelopes, and can also be tuned for different driver heights, positions, and personal preferences. 'The HLS provides safe, subtle cues that can be highly informative during certain classes of manoeuvres,' says Kia Cammaerts, Ansible Motion's technical director. 'We classify this as a supplemental cue, one that adds a useful enhancement layer on top of the primary motion cueing.'

The firm has already supplied the technology to some of its existing customers, it tells us.

Ansible Motion's Helmet Loading System is just one way the company is enhancing the experience for simulator drivers

Ground control

'There are another couple of components, Cammaerts adds. 'The terrain that the vehicle is passing over. That sits in between the graphics rendering and the vehicle physics. The vehicle physics has to pass the tyre models over a terrain surface that reflect the ground conditions that the graphics centre has to render, with the surface at the right height or you might seem to be driving through the ground, over or underneath. Typically the terrain is passed through the graphics pipeline first before being passed to the vehicle physics.'

The final layer of the system is the cockpit the driver sits in. This, too, needs to feel as real as possible. Typically F1 teams will fit a monocoque to the simulator in order to provide that real feel, while Ford, which uses an Ansible Motion system at its Tech Center in North Carolina, has both a NASCAR cockpit and a GT cockpit for its work. 'It is a big part of the system,' Cammaerts says. 'A part that provides feedback to the driver in terms of supplemental cues like torque or force on the steering wheel or seatbelt, and allows the driver to make demands of the vehicle model through steering position and pedal inputs. We can also provide additional cues to the driver like high frequency actuators on surfaces touched by the driver.'

The attention to detail on the Ansible Motion system is total, and its products are the result of a hugely detailed analysis of every component and how it operates. 'We started with the basics of the mechanical engineering of the system; load paths, compliances, bearing design. We looked to eliminate flexibility wherever we could and make it stiff enough, that is also part of the inherent design of the platform, which has a very low centre of gravity, and that reduces the bending moments, so it's from both the basic layout of the platform, the overall architecture and the detailed design.

'But that wasn't enough,' adds Cammaerts. 'Our first generation of motion control system used commercial off the shelf components and motion controllers. We used them at quite a high level so we gave top level commands saying "move like this" and we let them work out how to perform that movement. We then developed another generation of control system which was much closer to the metal, so to speak, for our hand-wheel control system. It needed a much higher control response and a much lower latency than the main vestibular systems, because your fingers are so sensitive when they're holding something.

'We then took that control system and extended it to the whole system. Now we have a control system where we still use commercial off-the-shelf motor drives for our servo electric motors, but we use them as very simple current controllers. All the intelligence is removed from the commercial components and placed under our control in software we write ourselves. That was an enormous effort, but it means that we have very low level control over what is happening. If there is a problem it means that we can fix it; if there is a problem we can often understand it – which can be a big problem with sealed systems. That improved our control response in terms of bandwidth and frequency response considerably.'

Synchronous motion

Cammearts continues: 'A positive by-product of the way we've designed it is it's never over-constrained, so every axis is always free to move independently of all the others. With our control strategy we send a move command to all six axes within microseconds of each other so we have highly synchronous motion. Having made that leap – it wasn't a leap a small company could easily do, but we had to start somewhere, and we're quite pleased with our early efforts – our new control system, where we took control of the design process and implementation, is so subtle it's almost not there.'

The Ansible Motion simulators have raised the bar in terms of creating the illusion for drivers, and they're now widely used in the automotive and motorsport world, but they are certainly not the only products on the market which provide a good level of immersion.

Simulator technology for motorsport is clearly not yet mature and the applications, tools and usage is evolving fast. Next month we will explore how cutting edge simulators are changing the way cars are developed.

Shockaholics

In response to requests from readers and colleagues alike *Racecar's* numbers man turns his attention to calculating damping ratios and figuring out wheel rates

By DANNY NOWLAN

Damper efficiency is vital to a racecar's performance, so it's extremely important that you get the numbers right

XPB

Over the last couple of months a number of readers and colleagues have been asking me questions about damping. In particular, questions to do with the mechanics of calculating wheel rates and damping ratios. This shows that people have been thinking about this, and that's great. However, what it has also shown me is that people have been missing some intermediate steps on how to calculate and use damping ratios and wheel rates, and this is what we'll be addressing here.

To kick off this discussion we first need to get our heads around what the difference is between a spring rate and a wheel rate. To illustrate, let's consider a spring/damper unit with a bell crank – **Figure 1.** The reason I have illustrated with a bell crank is to show the difference in the way the wheel moves and the way the damper moves. This is what is termed motion ratio, and this is what separates the spring rate from the wheel rate. The spring rate is the rate of the spring and damper measured at the damper. The wheel rate is the rate the tyre is going to see, and this is dictated by the motion ratio and spring rate.

To calculate wheel rate we first need to determine the motion ratio. To keep this discussion simple we will assume linear motion ratios and springs. We'll discuss non-linear motion ratios a little bit later. The motion ratio defines the relationship of damper to wheel movement, and we can define it as shown in **Equation 1**. This tells us that the motion ratio is simply the slope of damper movement *vs* wheel movement. So, if the wheel changes by, say, 15mm and the damper movement moves by 10mm, the motion ratio is that shown in **Equation 2**.

There will be some who will define the motion ratio as wheel and damper movement. I have always preferred to do it as damper on wheel, because it gives me a direct measure of the forces acting on the wheel.

Now that we know motion ratios the wheel rate can be readily calculated and is given by **Equation 3.** But Let's walk through an example of how to do this. Let's say we have a spring

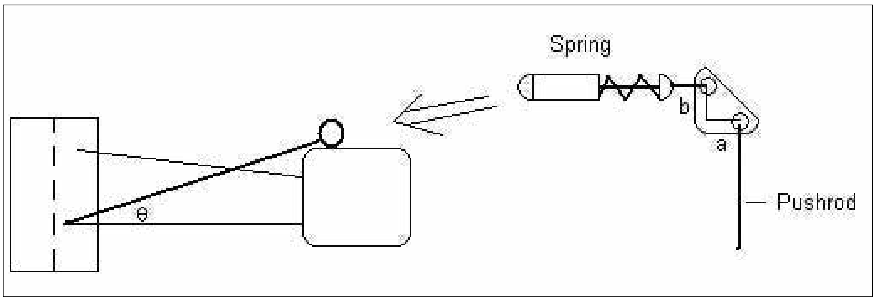


Figure 1: This helps to show the difference between the way a wheel moves and the way a damper moves

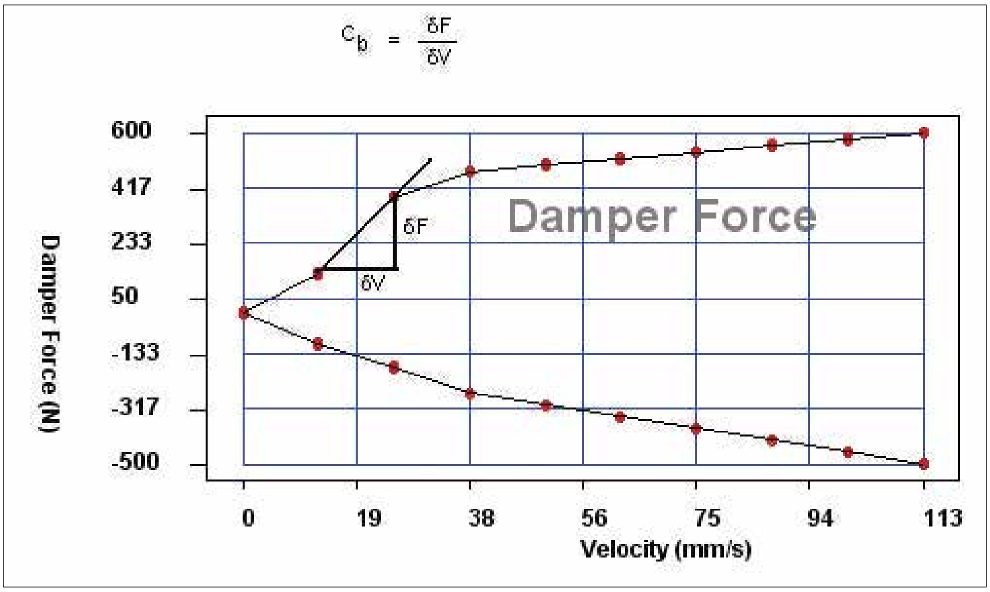


Figure 2: A peak force *vs* peak velocity curve for a damper – the critical thing is to be able to calculate the damping rate

EQUATIONS

EQUATION 1

$$MR = \frac{\partial Damper}{\partial Wheel}$$

EQUATION 2

$$MR = \frac{\partial Damper}{\partial Wheel} = \frac{10}{15} = 0.75$$

EQUATION 3

$$WR = MR^2 * SR$$

The terms of the equation here are:
WR= Wheel rate
MR= Motion ratio specified on damper on wheel.
SR= The spring rate at the damper.

EQUATION 4

$$WR = MR^2 * SR$$
$$= 0.75 * 0.75 * 140$$
$$= 78.75 N/mm$$

EQUATION 5

$$C = \frac{\partial Force}{\partial Velocity}$$

EQUATION 6

$$C = \frac{\partial Force}{\partial Velocity}$$
$$= \frac{410 - 141.5}{(25-10)*10^{-3}}$$
$$= 17900 N/m/s$$

When you calculate the damping ratios you're effectively looking at the damper's fingerprint

with a rate of 140 N/mm (about 800 lbf/in) with a motion ratio of 0.75. So the wheel rate is that which is given in **Equation 4**.

Remember, everything we do in this business is driven by working the tyre. What the wheel rate tells us is the spring rate the tyre is seeing. This is why it's so important to calculate this properly, and while this might seem trivial it is a vitally important skill.

Damper force

The next step is knowing how to read a damper force curve correctly. To illustrate this let's consider a typical force *vs* peak velocity curve, which is shown in **Figure 2**

You can be forgiven for a multitude of sins in damping, provided you read this right. The critical thing is to calculate the damping rate or the slope of this curve. This is the thing that counts in damping. The calculation of damping rate here is given in **Equation 5.**

Here *C* is the damping rate, ∂*Force* is the change in damping force, and ∂*Velocity* is the change in damping velocity. There are a couple of traps that I need to alert you to here. First, be tight on your units, so forces in N, and velocity in m/s. The damping rate unit is N/m/s. The second thing is calculate this moving forward on the damping curve, not backwards.

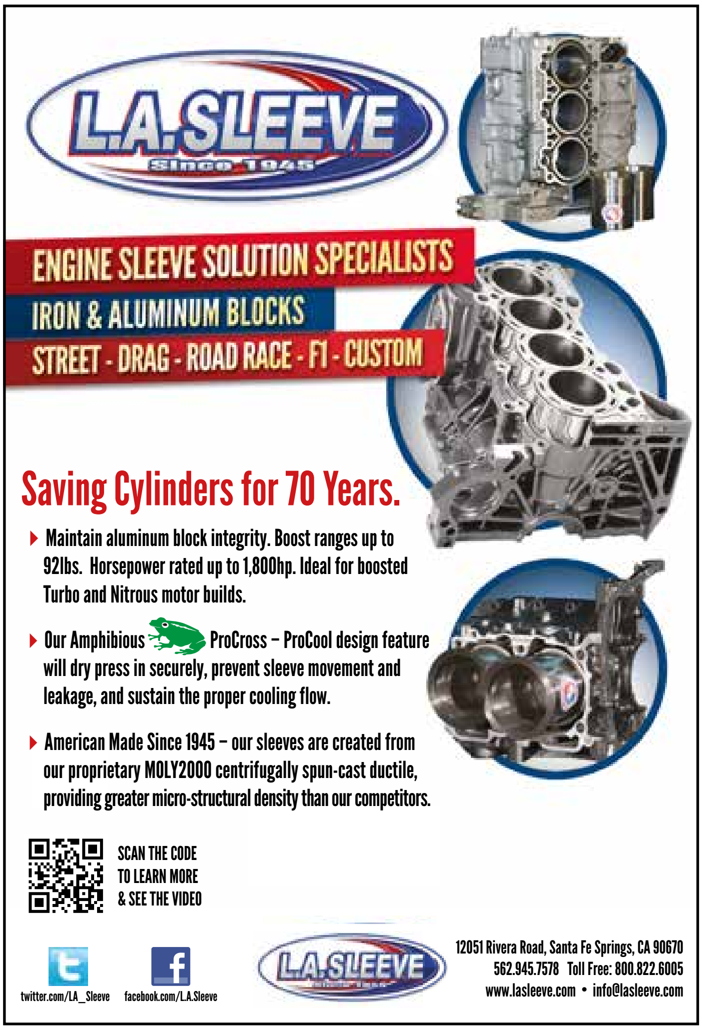
Now, using **Figure 2**, let's to do an example calculation and we will discuss what scale of numbers is to be expected. So, where we have illustrated our slope, the damping rate at this point is given in **Equation 6.**

I realise these numbers are a bit approximate, but what counts is the way in which we did it. We marched it forward and calculated the slope of the curve – that's all there is to it. The only trick was to multiply the damper readings by 10^{-3} which converts mm to m. Apart from that it's pretty simple stuff. In terms of some rough rules of thumb, rates in excess of 15000N/m/s usually are representative of low speed damping when we want body control. Rates of 2000 – 5000N/m/s apply to high speed damping, when we want to filter bumps out.

You might be thinking this is all well and good, but how do we tie this into a wheel rate? The answer is really quite simple. Remember **Equation 3** to convert spring rate to wheel rate? It's exactly the same for damper rate, and this is given in **Equation 7**. So, for our example with a Motion ratio of 0.75, the wheel damping rate is given in **Equation 8**.

Now that we know how to calculate both wheel spring rates and damping rates we can calculate damping ratios using the quarter car approximation. The quarter car approximation is shown in **Figure 3**. It is a very powerful tool to estimate what our damping rates should be and what spring rates we should be considering.

The trick here is to visualise the spring/damper unit at each corner of the car. While it isn't obviously the full story of what's going on with the car, it's a valuable building block to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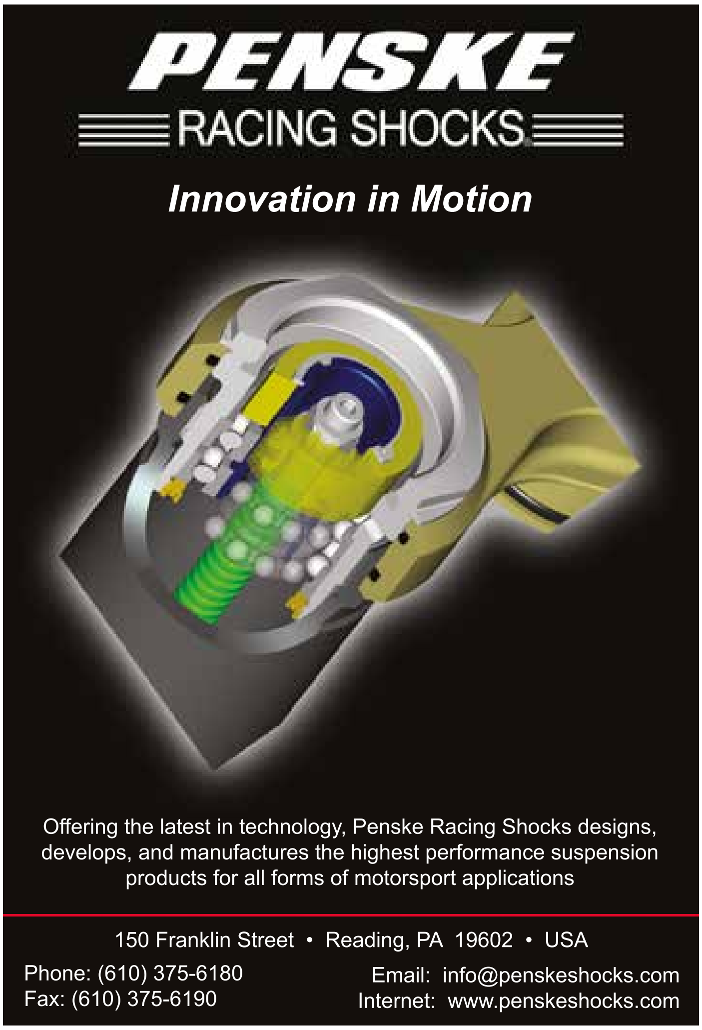
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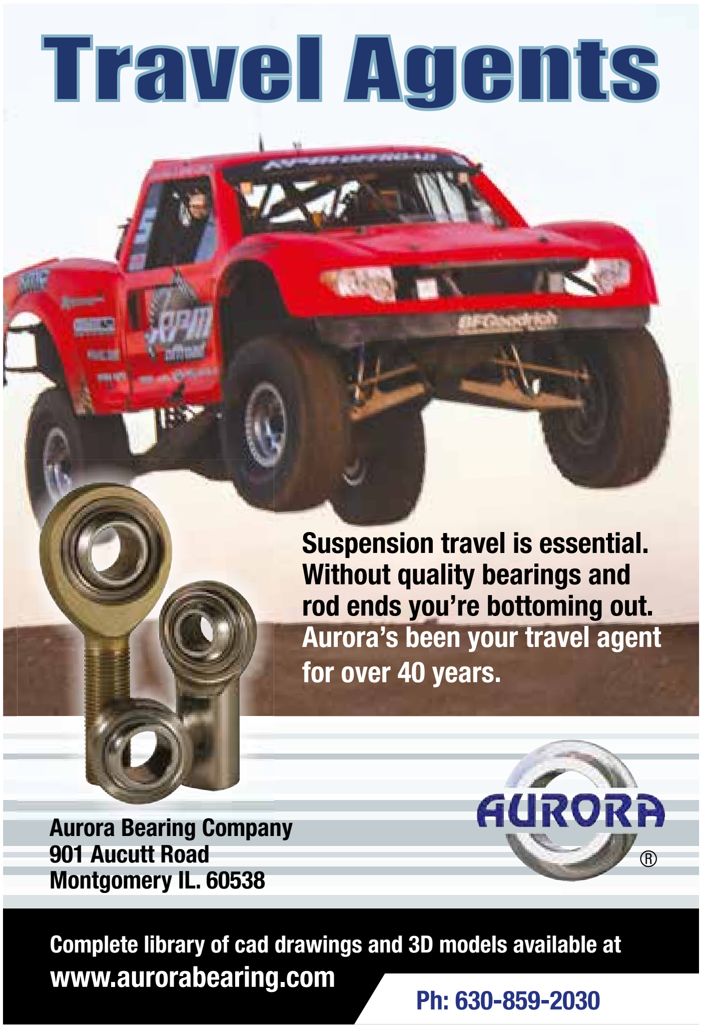
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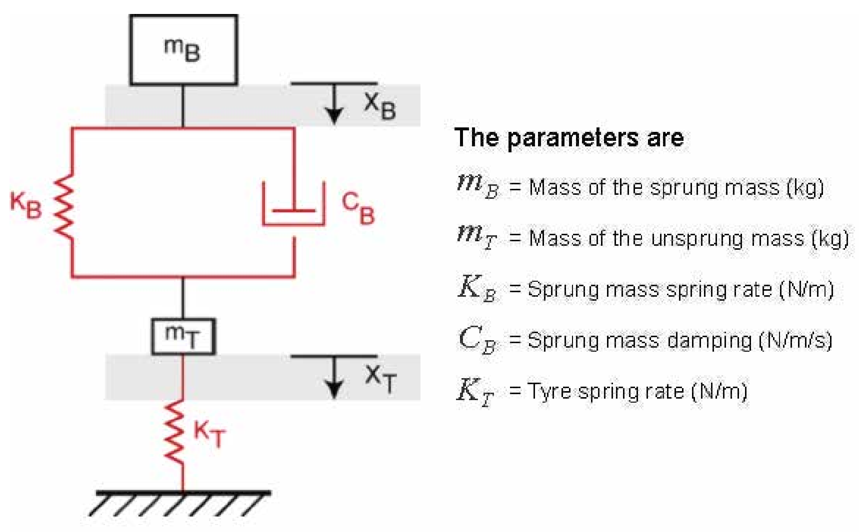

Figure 3: Quarter car approximation. The trick is to visualise the spring/damper unit at each corner of the car

EQUATIONS

EQUATION 7

$$C_{WHEEL} = MR^2 * C_{DAMP}$$

Here we have:

C_{WHEEL} = Damping rate the wheel sees
C_{DAMP} = Damping rate at the spring damper unit
MR = Motion ratio

EQUATION 8

$$C_{WHEEL} = MR^2 * C_{DAMP} = 0.75 * 0.75 * 17900 = 10070 N/m/s$$

EQUATION 9

$$\omega_0 = \sqrt{\frac{K_B}{m_B}}$$

EQUATION 10

$$C_B = 2 \cdot \omega_0 \cdot m_B \cdot \zeta$$

$$\zeta = \frac{C_B}{2 \cdot \omega_0 \cdot m_B}$$

Here the terms of the equation are:

K_b = Wheel rate of the spring (N/m)
C_b = Wheel damping rate of the spring (N/m/s)
m_b = Mass of the quarter car.
ω0 = Natural frequency (rad/s)
ζ = Damping ratio

EQUATION 11

$$K_B = MR^2 \cdot SR = 0.75 * 0.75 * 140 * 1000 = 78750$$

$$C_B = MR^2 \cdot C_{DAMP} == 0.75 * 0.75 * 17900 = 10070$$

$$\omega_0 = \sqrt{\frac{K_B}{m_b}} = \sqrt{\frac{78750}{125}} = 25.1 rad/s$$

$$\zeta = \frac{C_B}{2 \cdot \omega_0 \cdot m_b} = \frac{10070}{2 * 25.1 * 125} = 1.6$$

Table 1 – Rough outline to damping ratios

Damping ratio range:	What this applies to:
0.3 – 0.4	Ideal for filtering out bumps
0.5 – 1.0	This deals with body control
1.0 +	This deals with extreme body control/forcing temperature into the tyres

quantify the spring and damping characteristics. Mathematically the crux of the quarter car method is shown in **Equations 9 and 10**.

The power of the quarter car is that given a damping ratio, we can readily calculate the damping rate we want. Once we know the damping rates that we want, we can then turn to a damper builder and say 'this is the damping curve we want'. This is why this technique is so powerful.

So, using the spring and damping rates we discussed earlier, let's do a worked example. When we calculate this we need to ensure our spring rates are in N/m and our masses are in kg. I realise this causes considerable consternation to our friends in North America, but you'll hate me now and thank me later! Some rough rules of thumb to converting to N/m are: If the spring rate is in lbf/in, then multiply by 175.126. Or, if the rate is in N/mm, multiply by 1000.

So, for our example let us assume a quarter car mass of 125kg. Crunching the numbers we see the result in **Equation 11.**

Practical applications

At this point you might be thinking, this is great, but how do we use it? The answer is we use this in understanding what the damping ratio is telling us. This is going over some old material, now, but recall our damping guide – **Table 1.**

The damping ratio is showing what effect you want from your spring damper unit. Remember, high values of damping ratio tell you we want to control the body. Low values tell us we are trying to filter out bumps and/or keep the wheel in contact with the ground. Remember, when you calculate the damping ratios you're effectively looking at the damper's fingerprint.

Also, the damping ratio will vary throughout the velocity range of the damper. This is a consequence of what we discussed when calculating damper rates. Remember, damper rates will affect the damping ratio and this drives the behaviour of the damper. To illustrate this why don't we consider an example I presented a number of articles ago, where I calculated the damping ratios throughout the velocity range of **Figure 2.** In this case the motion ratio was 1, and the spring rate was 175N/mm or a 1000 lbf/in, and the quarter car mass was 157kg. The results are shown in **Table 2.**

Table 2 presents some enlightening insights in to what this damper is trying to do. First things first, the damping ratios from 0 tell me immediately this is a high downforce car. The high damping ratios are tell-tale signs of this. The high damping ratios immediately suggest that body control is paramount. Looking at the bump at 13mm/s the damping ratio jumps to 2.03. This indicates the damper engineer is trying to give some feel to the car, as well as load the tyres. Beyond this range the dampers blow off to a low ratio to allow the car to ride the bumps. In rebound from 13 – 25mm/s the damping ratio is 0.7. This tells me body control is still important.


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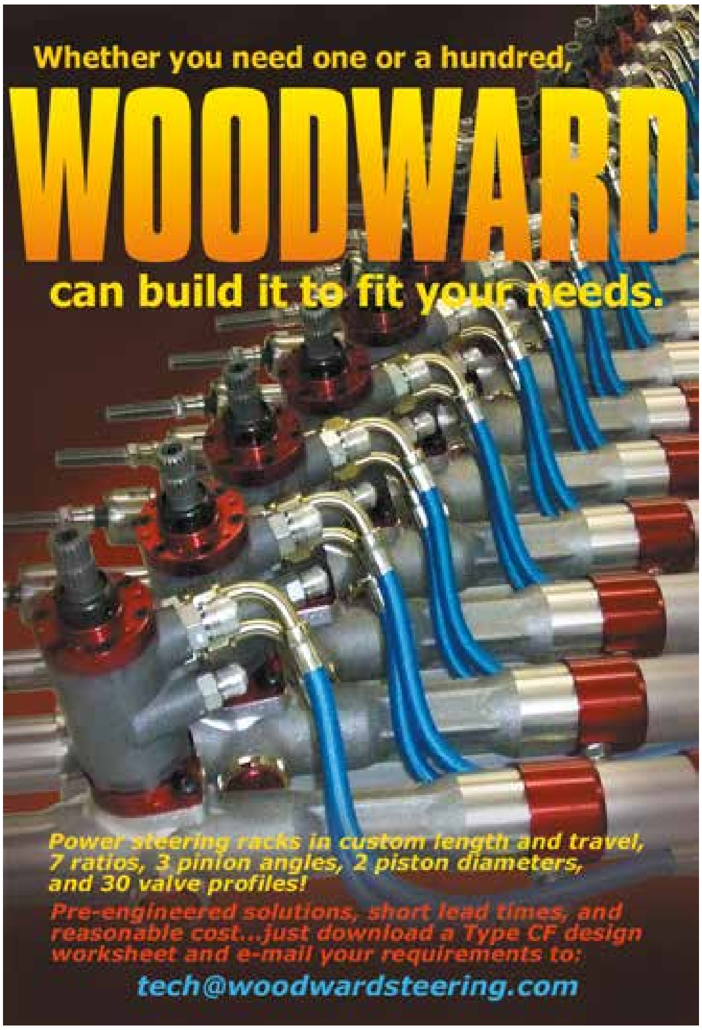
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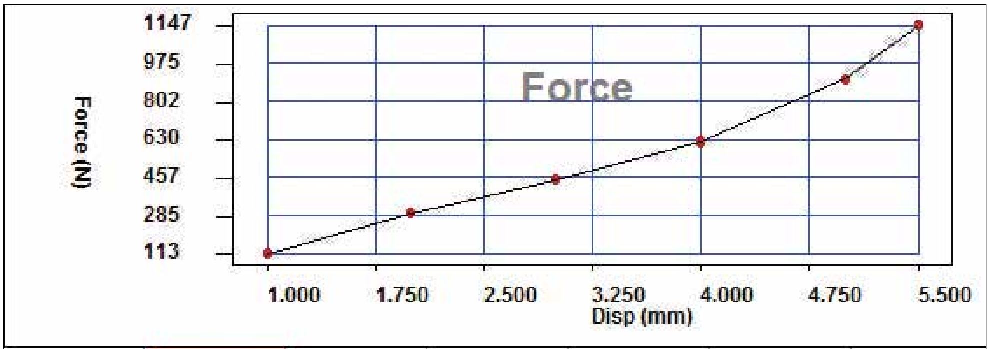
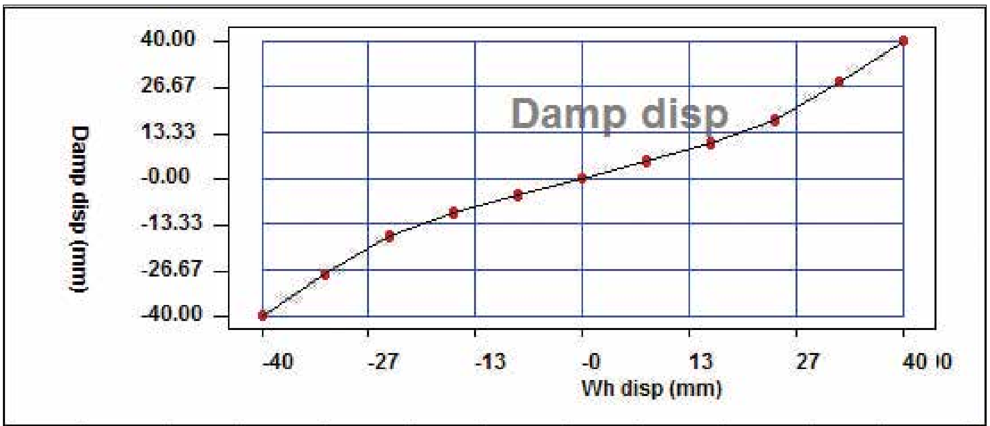
Table 2 – Damping ratios for damper presented in Figure 2

Velocity (mm/s)	Damping ratio in bump	Damping ratio in rebound
0	1.24	0.95
13	2.03	0.6
25	0.616	0.707
38	0.175	0.31
50	0.167	0.286
63	0.174	0.31



disp	1.000	2.000	3.000	4.000	5.000	5.500
Force	112.700	294.000	445.900	617.400	901.600	1147.000

Figure 4: Calculating the spring rate of a non-linear spring – which in this case is a bump rubber fitted on a racecar



Wh disp	-40.00	-32.00	-24.00	-16.00	-8.00	0.00	8.00	16.00	24.00	32.00	40.00
Damp disp	-40.00	-28.00	-17.00	-10.00	-5.00	0.00	5.00	10.00	17.00	28.00	40.00

Figure 5: Non-linear motion ratio. A motion ratio is the measuring of slope of damper movement over the wheel movement

EQUATIONS

EQUATION 12

$$SR_{BR} = \frac{901.6 - 617.4}{5 - 4} = 284.2N/mm$$

So the actual spring rate at the damper is,

EQUATION 13

$$\begin{aligned} SR &= SR_{BASE} + SR_{BR} \\ &= 140 + 284.2 \\ &= 424.2N/mm \end{aligned}$$

EQUATION 14

$$MR = \frac{17 - 10}{24 - 16} = 0.875$$

Low values tell us we're trying to filter out bumps and keep the wheel in contact with the ground

I encourage the reader to look at **Figure 2** and, using the example we have presented, to rework these numbers. A hint here: when calculating slopes in rebound use absolute values.

Non-linear springs

The next question that must be addressed is how to deal with non-linear springs and motion ratios. Again, this is actually a lot easier than you might at first think.

First let's deal with non-linear springs. You will encounter non-linear springs when you are using bump rubbers. All this means is the spring rate changes. That's it, and to calculate it is really easy. Let's consider the bump rubber that is illustrated in **Figure 4.**

Let's say this bump rubber is compressed by 4mm. Let's also say the base spring rate is 140N/mm. The spring rate of the bump rubber is then shown in **Equation 12.** So then, the actual spring rate at the damper is what we have in **Equation 13.**

I realise this is a bit of a trivial example, but nonetheless it illustrates how straightforward this is. All we need to do is march forward on the look-up table, calculate the slope, and that's how we get our spring rate. It goes without saying, if this was the only active spring rate we wouldn't need to add the other spring component.

Non-linear motion ratios

We also deal with non-linear motion ratios in a very similar way. Remember, at its core all a motion ratio is measuring is the slope of damper movement over wheel movement. Once you get your head around that you can calculate for any given situation. Let's consider the non-linear motion ratio characteristic that is presented in **Figure 5.**

So, let's just say we want to calculate the motion ratio at 10mm of damper displacement. Just like with the spring and damper all we need to do is to calculate the forward rate. The calculation for this is shown in **Equation 14.** It is as simple as that. In terms of units to calculate you can choose whatever units you want. Just be consistent when dividing.

The implications of these non-linearities are that when we encounter them the damping ratios are going to change. There is no need to be nervous about this. This just reflects the physical reality; the wheel rates or damping rates have changed and we need to deal with it. However, at least you have the language to describe what has happened.

In closing then, I trust this resolves the methodology of how to calculate wheel and damping rates and also answers the question on how to calculate damping ratios. As we have seen, this isn't hard, you just need to fill in the blanks. The next step I leave to you. It is time for you to go back into your set-up information and calculate this, and produce your own version of **Table 2** for various set-ups. Trust me, the results will be well worth it.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For the **record**

Those involved in Land Speed Record attempts are currently embroiled in a debate over the future of the discipline's regulations. *Racecar* brings you up to speed on the arguments

The Aussie Invader 5R has been designed to break the World Land Speed Record and the 1000mph barrier. Its team is one of three currently lining up to make a record attempt, the other two being the British Bloodhound effort and the North American Eagle outfit

Recently a debate has erupted in the world of Land Speed Record attempts over how this unique form of motorsport is governed. Led by North American Eagle team members, a new body called the World Land Speed Racing Association (WLSRA) has called for changes to improve the safety for all teams contesting outright records, and also for improvements in the timing system. It is worth noting that some of the current rules for world and international Land Speed Records date back to 1935, when Malcolm Campbell convinced the regulatory body to increase turnaround time from half an hour to one hour. The first two-way record was set by LG Hornsted in 1914. The first 15 records set were all measured in one direction.

Now the WLSRA is calling for the rules to change to require all vehicles to still make two runs, with an average of those two runs being the official time, but that the two runs can be made within 24 hours, and also that the runs can be made in any direction. The WLSRA has also suggested alternatives to the current timing systems – based on light beams – suggesting that certified GPS and GNSS technology can be used in addition to, or instead of, this.

Eagle's view

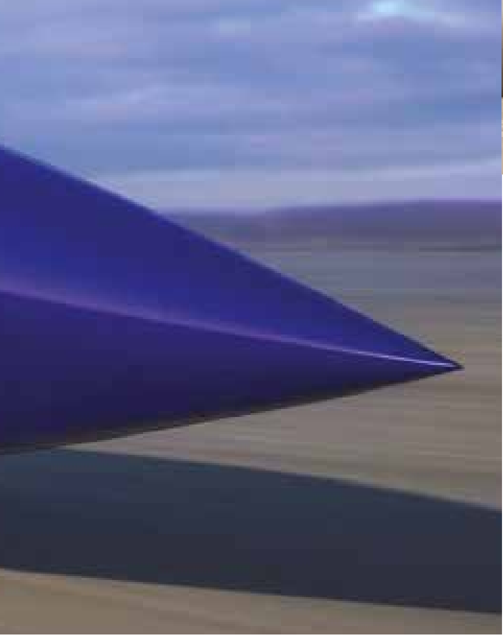
Ed Shadle; WLSRA and North American Eagle: 'Safety in running one of these unlimited class cars has always been a major concern to the drivers and crews ever since speeds started exceeding the 600mph region.

'We now need an urgent rule change for unlimited class vehicles to increase their tightly sanctioned turnaround time of one hour, which puts huge pressure on these race teams and is outdated and dangerous. The current FIA rules state that after a vehicle passes through the measured mile in one direction it must be rolling in the opposite direction within one hour and cover the same measured mile, the speeds in each direction are then averaged to determine if a new record has been set.

'One of the major problems with this rule is that a car like ours takes a lot more distance to stop than it does to get up to speed for the measured mile, as shutting off the engine of our car when we exit the measured mile would mean the driver would experience about 16*g*, so the car needs to be slowed gradually. We will probably be about seven miles down range, whereas it needs only three miles to get up to speed. The car then needs to be towed back to its new starting position (about four miles away) before it can be refuelled, re-oxidized (in our case), new braking chutes fitted, nitrogen banks recharged and a complete safety check carried out. The turnaround and tow back time to reach the new starting location can take 30 minutes alone, so the race crews need to invent ways to refuel and recharge our nitrogen supplies whilst the car is being towed. Scary stuff!"

'There is no disrespect toward other records from the past as they are all recognised by the sanctioning body of that record and would be recognised by WLSRA as well. Yes, there may

'We now need an urgent rule change for the unlimited class vehicles'



The Bloodhound project, which is set to make its attempt later this year, says its record car has been designed from the start to meet the challenges of the existing FIA LSR regulations

The debate's been sparked by Ed Shadle of the North American Eagle project (car above). He argues that the current one-hour turnaround before a second pass in the other direction could be a safety issue because of a lack of car inspection time

need some changes in the concept, but I think the basic idea has merit. Many people have talked about the various changes but nothing has been done about it. Even the idea of using Global Navigation Technology has been fought against by some. I installed the system on my Lakester at Bonneville and tested the accuracy against the timing clocks and found the GNT was more accurate than the clocks.

'We have also practised the one hour turnaround with the Eagle and were able to do it within 50 minutes. The downside is that inspection of important components of the vehicle has to be glossed over due to the time constraint. That, in my mind, is a compromise of safety. As for the two-way pass to nullify wind aided, that can actually be calculated into the formula if wanted or needed, as we now have the technology to do that.

'There are so many reasons why we should move forward on this rather than shove it under the table as has been done in the past.

'Spending $12,000 plus expenses to have the FIA come to your event, especially when it is a single vehicle event, really bites into the budget for the little guy. As Terry Nish put it, "a record is a record", and trying to nullify it due to nit-picking small details is contrary to the whole idea of record breaking. I threw the WLSRA idea out there to a few people in our sport, to see what response I would get.'

Following the release of Shadle's thoughts *RCE* also asked the wider LSR community for their thoughts on the proposals, and the responses sparked an interesting online debate.

Bloodhound's response

Wing Commander Andy Green; the RAF and the fastest man on Earth:

'The Bloodhound position is very simple. The FIA is the world governing body and, in order to set an outright World Land Speed Record, we are following the FIA rules.

'We would be very happy to take part in a discussion. However, please note that doesn't imply any support from Bloodhound for any proposed changes: we would engage with the FIA with an open mind. For interest, I don't believe a change of rules would have had any significant effect on Thrust SSC's record speeds. That car was built to meet the FIA requirements, so acceleration and deceleration distances were (by design) about the same. Bloodhound has been designed with the same requirements in mind, so a symmetrical track and a one-hour turn round are not limitations, just performance targets which we have built in from day one.'

More from Bloodhound

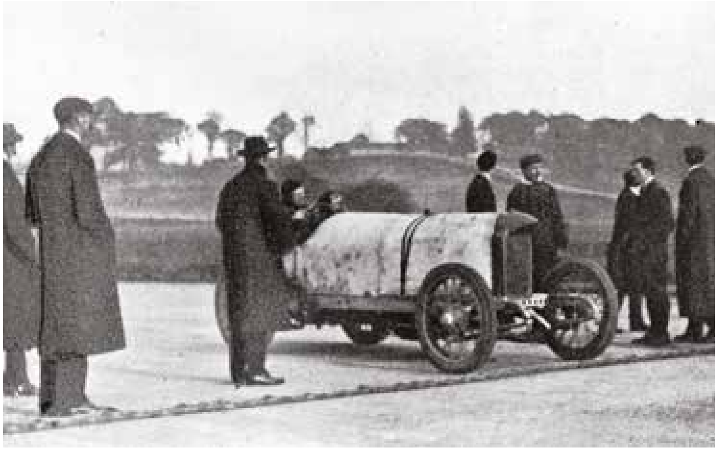
Ron Ayers, Thrust SSC designer, and Bloodhound SSC designer:

'I note with interest all of the proposals to change the regulations for WLSR records. If the FIA is approached with such proposals, I have little doubt that they would ask me, as co-designer of the existing WLS record holding vehicle, for my views on the matter. I have strong views and I am here giving you advanced warning of what my reply would be.

'Changes of regulation can invalidate existing designs and cause great additional expense and frustration to teams. Thus, rule changes should be made very infrequently, only when absolutely necessary, and definitely in consultation with existing teams.

'Starting and stopping in the same distance is a fundamental design requirement implicit in the rules. We achieved it with Thrust SSC and with Dieselmax, but purely because in each case the distance-matching was thought about from the very start of the design process. In the 21st century there is no excuse for getting it wrong, as modern computers enable a designer to create sophisticated performance programmes which will enable him to assess the effectiveness, and distance required, for each mode of propulsion and of chute/brake systems.

'As for changing the rules to having records from one run only, or runs on different days, or two runs in the same direction. The idea that two runs in opposite directions is unnecessary since modern tracks are horizontal is simply not good enough. Another reason for the second run in the reverse direction is to take account of prevailing wind. It is not well remembered that Thrust SSC set the record twice – look up the record books. On 25 September 1997, some three weeks before our supersonic record, Thrust SSC set a record of 714 mph. It so happens that on that day there was a strong wind blowing along track. I do not have the actual run speeds immediately to hand, but from memory I believe that the down-wind run was at around 730 mph while the reverse run was struggling to get up to 700 mph. Thus we could, quite inappropriately, have set a much



The Blitzen Benz record car of 1909 (above) was timed over a single run as it hit 126mph at Brooklands. The first two-way Land Speed Record was set five years later by LG Hornsted

Rule changes are nothing new in speed records: In 1935 Malcolm Campbell managed to convince the powers that be to change the turnaround from half an hour to an hour

higher single-run record on that day. Another reason for insisting on a return run soon after the first one is that this ensures that the vehicle's engineering is not so way-out as to need a complete rebuild/repair between runs.

'On the topic of allowing a longer turn-round time for better safety checks, condition-monitoring instrumentation is now commonplace in the aircraft industry and in F1 and, to an ever greater extent, on road cars. Why have record breakers not caught up? The cost of instruments is falling rapidly, and the much-heralded 'internet-of-things' is bringing the costs down ever further. Having identified the safety-critical items (e.g. bearing temperatures, oil condition, brake pad wear, high-stress components, etc.), these can be monitored and readings both displayed to the driver and radioed live to the run controller back at base who can call "abort" if necessary.

'So, you do not wait until turn-round before inspecting, you do it during the run. The recorded results from each run can then, at leisure and between pairs of runs, be studied in detail to further ensure that there are no incipient problems. This is the type of application where record breakers should be leading, not trailing. If any team lacks the expertise in some areas, they should involve a local university or technical college. I have yet to encounter an engineering education establishment that refuses the chance to become involved with an exciting engineering project – particularly if it is located near them.

'As an engineer with 66 years professional experience, I do not do short-cuts or easy options. It is the task of the FIA to specify the rules and maintain them over long periods as the standard to aim at. It is our job as professional engineers to meet those targets – not simplify the operational requirement for our own convenience, or bend the rules to match our own limitations. That equates to failure.

Suppose we tried it with athletics? What about putting a spring-board at the take-off point of the high-jump? How about a rocket-assisted javelin?

I suspect that my own views on this issue will not be universally popular, but now you know where I stand.

'Changes of regulation can invalidate existing designs and cause great additional expense and frustration to teams'

Invader's response

Mark Read, member of the Aussie Invader 5R team:

'We all highly respect Ron Ayers, and his opinions carry a lot of weight. However his reference to athletics and specifically the javelin, was quite interesting. In 1986 rules governing the javelin were changed, with the weight increasing to 800 grams (from 600 grams). This was partly to reduce the distance a javelin could be thrown in the 1986 Olympics. Javelin throws were commonly exceeding 100m and it was unsafe for spectators and competitors (as the javelin competition was held inside the running track). What has this to do with the unlimited WLSR? Sports evolve and rules change, you only have to look at F1.

'F1 was becoming a procession and cars were exceeding track conditions. We all know you have to attract an audience or a sport dies, F1 does it very well. Look at cycling, tennis, cricket and golf; all have gone through massive changes in equipment and formats to keep interest alive. Does that mean that Eddy Merckx or Jack Nicklaus is a lesser champion?

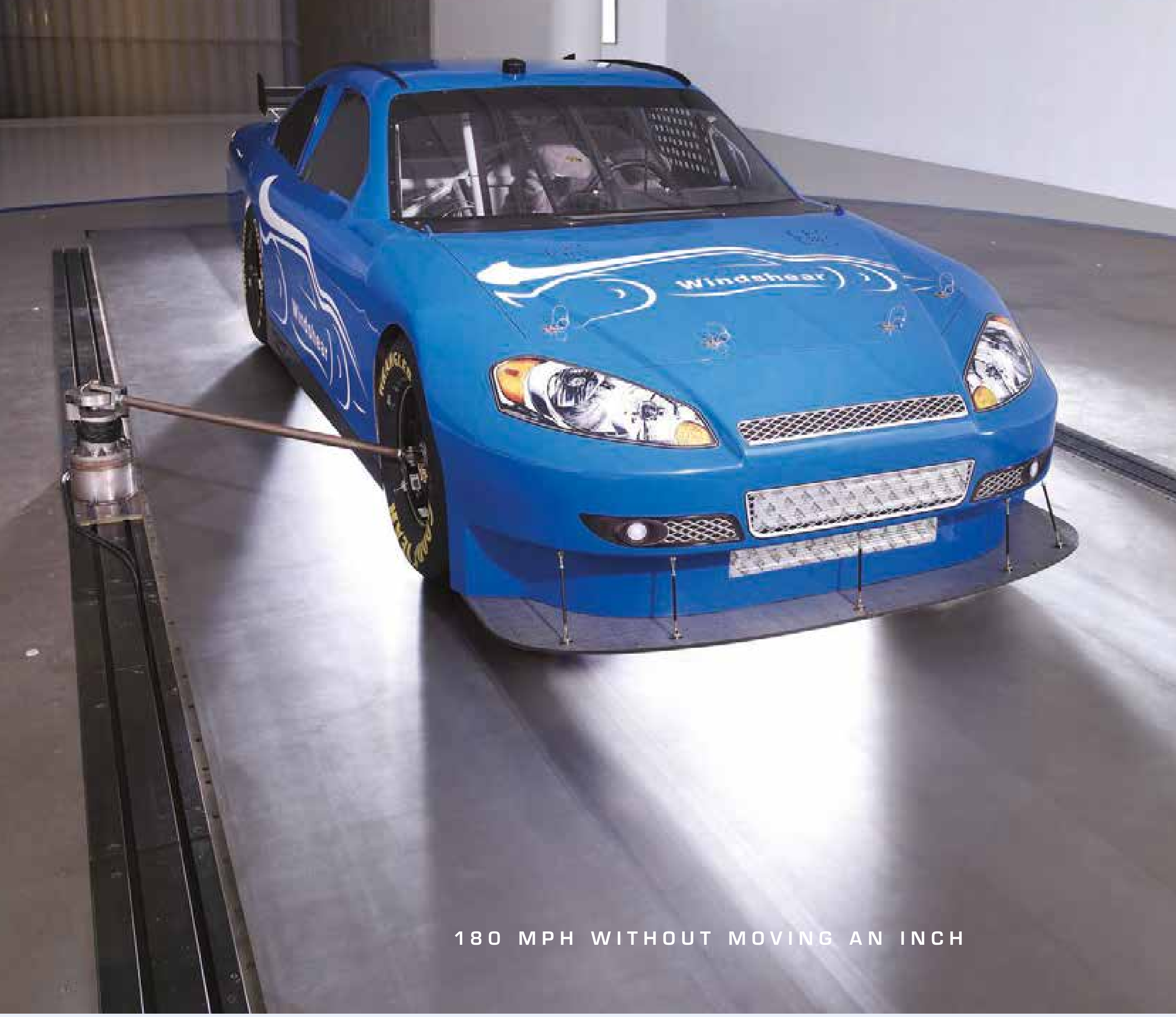
'Just to re-iterate this point, the SR71 Blackbird has held the record for the fastest air-breathing manned aircraft since 1976, no one seems to mind that it could operate at many tens of thousands of feet above other aircraft in a rarefied atmosphere, and this does not diminish from its achievements. We are talking about the *unlimited* record here, which by its very nature suggests pushing the boundaries of what is possible. We might need to bend some rules to do it, or change them!

'World Land Speed Records are attempted so infrequently that the spectator interest has diminished, and as we all know eyeballs is what sponsors are looking for (hats off to Bloodhound for its great achievement in exciting the next generation of budding engineers here). All the current teams have found it a very expensive business, building a car to break this record, and we need to attract sponsors. The last unlimited record was broken in '97; many young drivers and enthusiasts were not even born when that was attempted. Yet when records between Art Arfons and Craig Breedlove were changing hands month on month there was global interest.

'If this is about protecting a legacy or a set of rules that were created in a different time, then so be it. But as Andy Green stated in a 2013 Bloodhound newsletter, the turnaround time was increased from 30 minutes to one hour, probably for Malcolm Campbell to be able to change tyres between runs.

'I agree about having to complete two runs over the same measured mile, but maybe not the time it takes to allow those two runs to occur. Winds and weather can change in an instant, and as we know Donald Campbell waited two weeks for the right conditions to attempt his water speed record in 1964 at Dumbleyung, and then got about a 30 minute window where everything came together.

'An extension of one hour is not going to significantly change anything, but rushing and putting a man back in a car with a potential to do 1000mph is not the way to increase the safety of an already dangerous sport and give sponsors some comfort that their brand will not be associated with someone's preventable death. Now is the time to review the turnaround time, and for the sake of a sport that may become irrelevant to many, if another record is not attempted for 20 or 30 years after the current set of challengers.'


180 MPH WITHOUT MOVING AN INCH

Formula 3 entry deadline extended amid departure of stalwart teams

The entry deadline for the European Formula 3 Championship has been extended because of a drop in entries as some teams find it difficult to find drivers, which many claim is due to the dominance of the big-spending super teams.

On the original deadline of 15 Feb, just 24 entries had been received, and with a penalty of €21,000 for late entries it seemed unlikely that more would follow, so the deadline's been extended until mid-March.

To put this in perspective, Euro F3 has been riding high in recent years, with 35 cars in 2015, for example. But perhaps more important than grid numbers is the quality of the teams leaving the series.

These include F3 stalwarts such as Double R Racing – whose boss Anthony Hieatt has now confirmed it will concentrate on MSV F4 and MSA Formula – as well as Fortec Motorsport and Signature.

Another perennial on the F3 scene, West-Tec, is hanging on in the hope of attracting a driver, but its boss, Gavin Wills, has told *Racecar* that he believes the blame for the difficulties teams are having in finding drivers should be put on the technical regulations, which allows the very well-funded teams – namely Hitech Grand Prix, Prema Powerteam and Van Amersfoort Racing – to spend huge sums on aerodynamic development.

'The situation is that you have a number of extremely wealthy funders behind some current Formula 3 teams,' says Wills. 'And they are going to extraordinary lengths to try and find extra performance. To the point where Formula 3 cars are even sitting at Formula 1 teams' premises, while Formula 1 engineers pore over them to do development and find extra speed. And these teams have then done an extremely good job at convincing the market place – at convincing the drivers – that they simply will not be competitive unless they drive for a team like that, which is not true.

'What happens now is if the drivers can't get a place in one of these big funded teams – I mean you've got three teams that are owned by billionaires – then they don't look to get a drive elsewhere in the series, they look to a different series,' Wills said.

Currently a single-car budget for a season in the European Formula 3 Championship is around the €650,000 mark, but the richer teams can charge as much as €750,000, we're told – although they are thought to spend far in excess of this per car when it comes to racecar development.

European Formula 3 boasted huge grids in 2015 but numbers are down this season as some well-known teams elect to stay away

XPB

Bres says

As I write this I am informed that an F3 car is sitting in a well-known F1 team's factory, where it is being worked on by F1 engineers. But when you're a billionaire, and you own an F3 team, why not?

Problem is, with the advantage this is seen to buy, then other teams are going to suffer, as they simply can't compete with that level of spending. Also, there's another sad thing about this: look at the results in detail, and it can be seen that much of this is just perception. Poorer outfits can certainly still take the fight to the super teams.

It would be a shame to place more development restrictions on Formula 3, we love it for the relative tech freedom it has. But if wealthy backers insist on spending crazy money for tiny benefits, might this be the only way?

Mike Breslin

NASCAR Sprint Cup teams secure greater stake in the series

NASCAR has introduced a franchise-style 'Charter' system in its flagship Sprint Cup Series, with the aim of instilling long term stability while also giving teams a bigger say in how the series is run.

Teams have been pushing for some kind of franchise arrangement since the 1990s and the governing body has now granted 36 teams Charters which will last for nine years.

A Chartered team – which refers to a single entry rather than the organisation that runs it – is guaranteed a slot on the grid in Sprint Cup races. The maximum grid size has also been reduced this year, to 40 cars from 43 last season.

It's not just about guaranteeing entries, though, and the teams will also have a much bigger say in the way the Sprint Cup is run, with the setting up of a new Team Owner Council.

NASCAR says the system will mean that Chartered teams will be rewarded with more predictable revenue over the nine years of the agreement. It added: 'Along with improved financial certainty, the new framework is designed to increase the long-term market value of teams and provide the ability to plan farther ahead with existing, new and prospective partners.'

The Charters are also transferable, which will help to boost the long-term value of the individual Sprint Cup entries.

Rob Kauffmann, co-owner of Chip Ganassi Racing (which has Charters for its No.1 and No.42 cars), a man who has been instrumental in the negotiation of the deal from the teams' standpoint, said: 'The new Charter programme strengths each of our businesses individually and the team model as a whole, which is good for NASCAR, our fans, drivers, sponsors and the thousands of people who we employ.'

NASCAR CEO and chairman Brian France said: '[This] represents a landmark change to the business model of team ownership in NASCAR. The Charter agreements provide nine years of stability for NASCAR and the teams to focus on growth initiatives together with our track partners, auto manufacturers, drivers and sponsors.'

New Charter system will give Sprint Cup teams business stability and will allow them to have more say in the way the sport is run

Alfa 'must' consider return to Formula 1 says Ferrari president

Ferrari president Sergio Marchionne, who is also the CEO of Alfa Romeo parent company Fiat Chrysler, has said that Alfa needs to consider a return to F1 if it is to hit his ambitious sales targets for the brand.

Marchionne has said that he wants Alfa Romeo to boost its worldwide sales from the 74,000 units it shifted last year to 400,000 by 2018, and the fabled Italian marque is now investing €5bn in developing eight completely new models as part of this drive.

It has now emerged that part of that €5bn could be earmarked for an F1 assault for Alfa Romeo, which was a mainstay in grand prix racing before WWII and during the first years of the world championship in the 1950s, winning it in 1950 and 1951. It was last in F1 from 1979 to 1985, although it also supplied engines to the formula in the 1960s and 1970s.

A new Alfa F1 assault would most like be undertaken with some sort of technical tie-up with Ferrari, Marchionne has said – Enzo Ferrari actually ran the works Alfas in the 1930s.

Speaking to the Italian press Marchionne said: 'In order to re-establish itself as a sport brand, Alfa Romeo can and must consider the possibility of a return to race in Formula 1. How? Probably in a collaboration with Ferrari.'

Marchionne also said it would be unlikely that an Alfa Formula 1 effort would be just a branding exercise, with a current team taking on its name, but would probably be a full works operation. 'Alfa Romeo is able to make itself a chassis, and it is able to make engines,' he said.

However, he then added that it was also possible that Alfa could use Ferrari engines, saying that such a partnership was 'a classic example of a model to follow'.

As far as other motorsport is concerned, and specifically Le Mans, when asked if Alfa could get involved in a WEC LMP programme Marchionne said: 'I would really like to have it in Formula 1.'

Part of Formula 1's attraction would be the presence of Mercedes, as it's a stated aim of the marque to match its German rivals, such as Mercedes and BMW, in terms of sales.

Alfa Romeo logos were present on Ferrari equipment at some of last year's grands prix but could it be back in F1 in its own right?

MIA's Autosport Show initiative rakes in millions for UK industry

UK motorsport companies have reported in excess of £5m in expected additional export sales during 2016 on the back of January's Autosport International Show.

The multi-million pound figure comes from the Motorsport Industry Association, and specifically relates to the International Business Visitors Group it arranged and managed at the show.

This saw delegates from eight global markets attending meetings with UK companies over the course of three days. The potential business confirmed over that period adds up to more than £5m.

Supported by UK Trade and Investment (UKTI), the event provided a one-to-one meeting environment for UK companies to present to delegates from the motorsport, high-performance engineering, automotive, low carbon and energy-efficient sectors in USA, Germany, Austria, France, Italy, China, Australia and India.

Chris Aylett, CEO of the MIA, said: 'Motorsport is a £9bn UK industry, which employs more than 50,000 people across in excess of 4000 companies. Organisations in UK motorsport lead the world, with innovative skills, fast-response processes and a can-do attitude.

'It is, therefore, fantastic news that, in bringing together potential purchasers from across the globe, we have been able to generate potential for at least £5m in additional export business. Indeed, with a quarter of the UK's motorsport companies exporting more than 50 per cent of their sales, the opportunities for further growth are significant.'

Brian Ghidinelli, who is the CEO of US-based MotorsportReg, said: 'This was my first visit to Autosport International and it was an excellent event with exactly the right audience. The MIA arrangement was helpful, not just for logistics, but also for introductions and a general welcome to the UK and the UK industry.'

Much business was done at this year's ASI show; *Racecar Engineering* saw it as the ideal place to do business. Others clinched £5m in possible export deals

SEEN: Porsche 919 ICE

Porsche has released images of the internal combustion engine that sits at the heart of its Le Mans-winning 919 LMP1 racecar. The unit is a 2-litre V4 and the German marque tells us it is the most efficient combustion engine it has ever built.

IN BRIEF

Formula 4 for United Arab Emirates

The UAE has embraced the FIA Formula 4 concept, launching an all-new championship which will make use of the Tatuus-Abarth racecar that is already seeing service in the Italian and German F4 championships. The first season will be of 18 races over six events, to be held at Abu Dhabi's Yas Marina and the Dubai Autodrome, between October 2016 and March 2017. Only drivers holding a licence from within the FIA's Middle East and North Africa region will be eligible to score points in the series.

GM opens new race base for powerplant development

General Motors has opened the doors to its all-new GM Powertrain Performance and Racing Center – a state-of-the-art facility specifically designed for the company's race engine programmes.

The new, 111,420sq.ft facility is now connected to General Motors' Global Powertrain Engineering Center and is part of a $200m investment at the Pontiac, Michigan, factory.

The Center has been relocated from Wixom, Michigan, bringing together under one roof an additional team of nearly 100 engine builders, engineers and other support staff.

GM's Performance and Racing team is responsible for developing engines for NASCAR, NHRA, IndyCar, IMSA and other racing series.

'We race to win and learn,' said Dan Nicholson, vice president, General Motors Global Powertrain. 'This new facility offers unprecedented opportunities to connect our racing engineers and powertrain engineers, integrating their knowledge to give our racers an edge on the track and our customers better vehicles on the road.'

The new GM race engine centre is for all its motorsport activities, including its IndyCar involvement with Chevrolet (pictured)

Jim Campbell, GM US vice president of Performance Vehicles and Motorsports, said of the new facility: 'Chevrolet earned six manufacturer and five driver championships in 2015, and we are carrying that momentum into 2016. This new centre is a valuable tool in developing powertrains with the right combination of performance, durability and efficiency to help our drivers and teams win races and championships.'

The new facility incorporates the latest engine assembly, engine testing and calibration equipment, while the connected layouts of the engine assembly and testing areas are specially designed to help with workflow.

There are 10 all-new engine build bays – eight in the engine build room and two in the prep area to facilitate quicker transfer to dyno testing and other validation areas. Each 120sq.ft bay has access to an overhead crane for easy loading on the build stands. Builders will also use specialised tools such as programmable torque wrenches to help ensure consistency with the engines. There are also over 30 machining tools, including nine CNC machines, plus a 3D printer, and four state-of-the-art AVL engine dynamometer cells.

Half a million paid out in brake case

AP Racing has been awarded £570,660 in damages, costs and interest following a ruling that Alcon infringed the company's patent for one of its design concepts.

The case centred on the range of Radi-CAL calipers AP says it introduced and patented in 2007. It says this design was a step forward in brake caliper technology within the motorsport industry, and was used by teams in Formula 3, NASCAR and later in Formula 1. However, it also claimed that rival Alcon Components introduced a similar design in 2009.

Following an initial trial in 2012, and a subsequent hearing in the Court of Appeal in 2013, a ruling was made in January 2014 confirming that the patent was valid and infringed, allowing the UK-based company to pursue financial compensation and to stop Alcon manufacturing more of the calipers.

AP racing calipers: the company behind these components has successfully sued for a patent infringement that dates back to the late 2000s

AP Racing managing director, Charles Bolton, said: 'Innovation is vital for the development of new technology, and patent infringement is always an uncompetitive answer. The court's decision sends a clear message to the industry that the courts will not tolerate intellectual property infringement. AP Racing will always act to protect its intellectual property rights around the world, in order to safeguard our research and development work going forward.'

For its part, Alcon managing director Alistair Fergusson told *Racecar*: 'This has been quite a long-running legal case brought by AP Racing in 2011 claiming infringement of two patents by some Alcon calipers that were designed in 2008 before the patent applications were published, i.e. before we knew what AP was claiming it had invented. In fact, at trial, Alcon initially prevailed. It was able to challenge one patent to the extent that AP Racing abandoned it, and the other patent was ruled to be invalid. The ruling of invalidity was overturned when AP Racing lodged an appeal. We respect the court's judgement and will of course comply with its directions.'

Fergusson added: 'Our most recent OSCA calipers exhibit world leading stiffness-to-weight ratios – well in advance of our early optimised designs – and do not infringe the patent. We have launched 12 such new designs in the past two months alone, so AP's patent has next to no impact on our current design thinking.'

FV8 promoter bought by global media firm

Alesport Group, the Spanish company which owns and runs Formula V8 3.5 promoter RPM, had been acquired by media giant Dentsu Aegis.

Dentsu Aegis is a multi-national media and digital marketing company based in London, which itself is a wholly-owned subsidiary of Japanese media giant Dentsu.

Alesport was set up by Jaime Alguersuari Sr – father of former F1 driver Jaime Alguersuari – back in 1975. Alguersuari Sr will remain president of Alesport, and the sale is not thought to affect Formula V8 3.5 – which was previously known as FRenault 3.5, before Renault pulled the plug on its sponsorship last year.

Andre Andrade, CEO of Dentsu Aegis Network Iberia and SSA, said of the deal: 'We are delighted to welcome Alesport to our network. Alesport's strong reputation and extensive experience is the perfect addition to Dentsu Aegis Network, further strengthening our portfolio and talent pool in Spain and importantly, extending Alesport's reach internationally.

'I am confident that the expertise of Jaime Alguersuari and his management team will further complement and strengthen our global offering in the important remit of sports and event marketing,' Andrade added.

Alguersuari Sr said: 'In 1975, almost 41 years ago, I decided to devote my life to a dream project. It has been a wonderful journey, full of challenges and where hundreds of times the impossible was made possible.

'Collectively we produced a dream factory which attracted hundreds of talented collaborators. Today, I have the certainty that through incorporating our heritage, emotions and professionalism with Dentsu Aegis Network, the dream factory will continue to strengthen and flourish.'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INTERVIEW – Warren Scott

Down to business

The boss of crack BTCC outfit BMR spills the beans on the team's new Subaru deal – and just why it's developed a front-wheel-drive go-kart

By MIKE BRESLIN

'You get the knowledge and everything works well, in any kind of business'

Every now and then in the British Touring Car Championship (BTCC) a car comes along that really captures the imagination of the fans. Such as the Volvo 850 estate back in 1994, for instance, or the Rovers of the 1980s, or very possibly the Subaru Levorg Sports Tourer that's set to hit the tracks this year.

The Subaru programme is to be run by BMR, a relatively new outfit which sprang to prominence last season, almost bagging the title with its Volkswagen CCs. Its boss, Warren Scott, is also one of its drivers, but above all he's a businessman – and the word 'business' peppers any conversation you might have with him about his organisation. But it was as a frustrated bike racer that he came to the BTCC. 'I've been racing for many, many years, but not as a business so much really,' Scott says. 'I've been in the racing world for a long while, in motorbikes; starting in motocross, then in to road racing. But then injury forced me to stop doing that, and brought us into touring cars; and then there was an opportunity to set up a team as a business [in 2013].'

It was the introduction of the TOCA BTCC licences, which guarantee grid places and add value to teams, which really opened Scott's eyes to the potential of the series as a commercial enterprise. 'That was the opportunity for me,' he says. 'I believed in what Alan Gow [BTCC boss] was doing with the championship, I could see it getting better, and I could see it as a place where we could race and turn a profit.'

But a successful business needs the right people, and it is here that BMR has really excelled. As well as having renowned BTCC team manager Alan Cole on the pit wall it has also recruited Carl Faux (previously technical director at Triple Eight Racing) and Kevin Berry (who designed the championship-winning WSR-run rear-wheel-drive BMW 125i M Sport of 2014) on the design team. 'You get the knowledge and everything works well, in any kind of business, any kind of motorsport. If you have the right people it will run well,' Scott says.

Subaru approach

Which goes for the drivers, too. BMR has not relied on pay drivers, but as brought two of the best – Jason Plato and Colin Turkington – on board, in the belief that that's the way to attract the sponsorship that will help the operation to thrive as a business. 'It's all done through sponsorship,' says Scott. 'Obviously, when you have the drivers of the calibre we have, that makes that job a lot easier, because they're at the top of their game, and they're also good at playing the ambassador role in looking after these sponsors.'

Plato was actually also instrumental in chasing the Subaru deal, Scott tells us. 'Jason started it, probably six months ago. These things take some time to sort out, but Subaru have been absolutely fantastic, they were engaged very early on and have been working with us to make sure this deal comes together.'

What's interesting is that it was the car that was the initial attraction, not just the chance to work with a brand with a mighty motorsport heritage in the WRC – oh, and the BTCC car will not be blue with gold wheels, just in case you were wondering. The racecar is based upon the Japanese company's Levorg estate car. In street form it is 4wd, but for the BTCC – and thanks to much lobbying and then a rule change last year which allows 4wd base cars to run as 2wd – it is to be rear-wheel-drive. 'It's fantastic. It's got a great shape to it, it's got a lovely engine [Mountune is developing the boxer unit which will be unique in the BTCC and should bring a distinctive new sound], and a low centre of gravity; it's a proper touring car – a touring car on the road,' Scott says.

'The Subaru base was what first excited us, I think, that it's got a low centre of gravity and that engine. Subarus have always had a good aero package, too,' he adds. As for the decision to go rear-wheel-drive rather than the more common front-wheel-drive, Scott says: 'It's tight, which is better; front- or rear-wheel-drive – they both have their circuits.'

Tight on time

The team has been left with a short time-frame in which to compete its four racecars, but at the time of writing (mid-February) it was five days ahead of schedule with its build programme at its new 20,000sq.ft factory in Hertfordshire, partly thanks to the input of the car supplier. 'It's a Subaru UK effort, and they're putting all their weight behind it, they've made life very easy for us. They're making sure we have

everything we need, they understand our time pressures and they're fully supportive,' Scott says.

Scott hopes the three-year programme will cement his organisation's place at the pinnacle of the BTCC. But it's not all about touring cars, and the long term business plan has much to do with the ambitious driver development programme BMR has in place. With this in mind BMR is also running Ginetta Juniors and Renault Clios, all with an eye to enticing youngsters in to the organisation with the lure of a path to a drive in its top level BTCC outfit – it will also be running a team in GTs in the not too distant future, too, Scott tells us.

Reinventing the kart

One interesting by-product of the BMR driver development programme is its front-wheel-drive kart, which actually started life as a training aid for Scott himself, as he tried to come to terms with the complexities of driving a front-wheel-drive racecar – ironically its new BTCC car is rwd, but Scott says the kart will still be a valuable learning tool for young drivers. But does it really drive like a BTCC car? 'Yes, it's like a front-wheel-drive touring car, exactly the same,' Scott insists. 'We developed it because I hadn't done a lot of front-wheel-drive cars, and we wanted a cheaper way of testing for driver advancement. It turned out to be good fun, as fast as the rear-wheel-drive karts, and a completely different experience: you've got the castor, camber, toe-in, toe-out; it's all the different set-ups that you can put on a car, so it starts to train people early as to how to set up these racing vehicles. It's just different.

'The front-wheel-drive go-kart is going into production shortly, and we've also got our own four-stroke go-kart engine, which we're pushing,' Scott adds. 'I think we've got 16 lads signed up for our go-kart racing this year. We intend to offer them the opportunity to race through from cadet karting all the way to touring cars, or British GTs.'

It's all very ambitious, but then that's a hallmark of the team. When asked how he thinks the Subaru will perform this year, for example, Scott does not hesitate as he says: 'We intend to be vying for the championship at the last round. It might be a bit difficult, early on we'll have all the normal new car things to sort out, but with the quality of the engineers and the mechanics, and with the drivers, I think we'll be there or thereabouts.'

BMR is running the rear-wheel-drive Subaru Levorg estate in this year's British Touring Car Championship

RACE MOVES

XPB

Chris Dyer has returned to Formula 1 with Renault's new works effort, heading up the performance group at the team that until recently was known as Lotus. The former Ferrari race engineer, who tended the car of **Michael Schumacher** during the German's dominant 2003 and 2004 seasons, is to focus on race set-up and performance at the Enstone outfit.

Brandon Fry is to be **Max Chilton's** IndyCar race engineer at Chip Ganassi Racing. Fry previously worked on the now defunct Nissan LMP1 programme, which Chilton was also a part of. The move to CGR marks a return to IndyCars for Fry as he has previously worked with Conquest, Forsythe Racing, and Dale Coyne Racing.

Christopher Reinke is to switch roles at Audi Sport, moving from his post as boss of LMP to head up the customer racing department, where he replaces **Romolo Liebchen**. The move is seen as a promotion within Audi. At the time of writing there was no word on who would succeed Reinke as Audi's LMP chief.

Grant McPherson, a race engineer at crack V8 Supercars outfit Triple Eight Racing Australia, has switched from engineering the car of **Craig Lowndes** to that of incoming driver **Shane van Gisbergen**. Van Gisbergen will be McPherson's fourth driver in as many seasons, after he engineered **Mark Winterbottom** in 2014 and **Will Davison** from 2011 until 2013.

IndyCar and NASCAR team boss **Chip Ganassi** has been inducted into the US's Motorsports Hall of Fame. NASCAR team owner **Richard Childress** was also inducted into the Hall of Fame.

Graham Prew is the new head of motorsport sales at preparation and advanced engineering specialist the JRM Group. Prew, who joined JRM in August 2015, steps up from his previous position as the company's business development manager. He has worked in the motorsport industry for 24 years and has a wealth of commercial, operations and sales experience.

NASCAR broadcaster **Barney Hall** has died at the age of 83. Hall was one of the original members of the Motor Racing Network staff and was known as the 'Voice of MRN'. He was inducted into the National Motorsports Hall of Fame in 2007 and in 2012 joined former MRN colleague **Ken Squier** as the first recipients of the NASCAR Hall of Fame's Squier-Hall Award for NASCAR Media Excellence, to which they both gave their name.

Jim Llewellyn is the new public relations manager at the Sports Car Club of America (SCCA). Llewellyn has spent more than 20 years working in communications and has been an SCCA member for a decade. His past motorsport PR experience includes working in NASCAR. Last year he oversaw the public relations activities for the SCCA 'Track Night in America' event.

Kate Adamson has been appointed to the newly created role of safety director at the Motor Sports Association (MSA), the governing body for the sport in the UK, while **John Ryan** has taken on the post of technical director. Both are replacing **John Symes**, who had responsibility for each area but has now retired. Symes will remain at the MSA as a consultant in 2016.

Jock Clear has now started work at Ferrari, after having spent a year on 'gardening leave' following his departure from Mercedes, where he was **Lewis Hamilton's** performance engineer. His new role will be to oversee the race engineering operations at the Scuderia.

Former drag race star **Mike Dunn** is now president of US drag racing promoter the IHRA. Dunn, one of only four drivers to ever win 10 or more races in both Top Fuel dragsters and Funny Cars, retired from competitive driving in 2002, joining ESPN TV to cover the NHRA Drag Racing series, leaving at the end of last season.

V8S management changes

Australia's premier motorsport series, V8 Supercars, has announced changes to its senior management structure.

V8 Supercars CEO James Warburton said the restructuring is to help the series pursue further growth opportunities.

Commercial director Matt Braid has now been appointed managing director, focusing on the day-to-day operations of the series, while marketing director John Casey will move into a new role focusing on business development.

V8 Supercars boss James Warburton says changes in management will help grow series

Warburton will remain as CEO and Shane Howard will continue in his current role as chief operating officer.

Warburton said: '2015 was a great year for V8 Supercars with strong growth in crowds, TV ratings, and commercially. With the turnaround of the business complete, we now want to ensure that growth continues into the future against a backdrop of increasing competition from other sports and forms of entertainment.

'These changes allow me to focus on those strategic and growth opportunities as Matt [Braid] assumes greater responsibility for the day-to-day operations of the business. We have a strong and competitive sport and a growing fan base and now need to capitalise on the growth opportunities before us.'

Warburton added: 'This is an exciting time for the sport and all our participants, partners and fans and I believe there's never been a better time to be involved in V8 Supercars. I can't wait for the 2016 season to start, and look forward to a fantastic year ahead including our first championship event in Malaysia in August.'

Skills shortage sparks UK automotive recruitment crisis

Up to 5000 jobs in the UK automotive industry could be vacant due to a skills shortage affecting the sector, claims a new report published by the Automotive Council.

The report, which was developed by automotive industry consultants SMMT Industry Forum on behalf of the Automotive Industrial Partnership, surveyed a range of British-based firms, from vehicle manufacturers to component suppliers, to identify those areas of employment that are proving most difficult to recruit for.

Around 19 per cent of the unfilled vacancies cited in the report are identified as 'critical' and having a significant impact on company operations.

Of the top 10 job types for which recruitment is most difficult, the majority are in engineering – with the top two in-demand roles being design and production engineers. The knock-on effect, according to the report, is that companies are hiring temporary contractors and increasingly recruiting from abroad.

Jo Lopes says government and industry must tackle skills shortage

Jo Lopes, chairman of the Automotive Industrial Partnership and head of Technical Excellence, Jaguar Land Rover, said: 'These are very significant findings which present a valuable basis for government and industry to jointly tackle this issue head-on and ensure that the growth potential of the industry in the coming years is fulfilled. The Automotive Industrial Partnership has already made some important steps since its inception – including the introduction of a range of training programmes – and it will have a crucial role to play in addressing the skills challenge.'

The UK Government's skills minister, Nick Boles said that the government drive to encourage apprenticeships could help: 'The sector needs to maintain its high productivity and international competitiveness and address the required demand of skilled workforce, engineers and designers. That's why our apprenticeship reforms are putting employers in the driving seat, to help deliver the hi-tech, long-term skills our economy needs,'

RACE MOVES – continued

Former GT and single seater ace **Bas Leinders** has been appointed sporting manager at McLaren GT. As a driver Leinders enjoyed a successful career, including winning the German F3 Championship in 1998, while he was also a McLaren Formula 1 test and reserve driver. The Belgian has also been successful since opting to work on the other side of the pit wall – chalking up a victory at the 24 Hours of Spa in 2015 while working with Marc VDS.

Former Brabham F1 designer **Sergio Rinland** is now a technical adviser at the project which is trying to revive the once-great team – which is headed by **David Brabham**, son of team-founder **Sir Jack Brabham**. As well as Brabham, Rinland's F1 career also included stints at Williams, Benetton, Sauber and Arrows. More recently he has been focussing on his own engineering consultancy company, Astauto.

JD Gibbs has joined his father **Joe Gibbs** as co-chairman of Joe Gibbs Racing, with bother **Coy Gibbs** also joining the NASCAR team as vice-chairman/COO.

Carsten Schumacher, the CEO of the Nurburgring circuit, is stepping down. Schumacher has been in charge of a recent restructuring of the business at the fabled venue on behalf of the Nurburgring's current Russian owners.

Pat Fry has joined the Manor Formula 1 operation as an engineering consultant. Fry was director of engineering at Ferrari until the end of the 2014 season. He has also worked at Benetton and McLaren in an F1 career that stretches back to 1987.

Brian Wilson is now crew chief on the Team Penske NASCAR Xfinity Series No.22 Ford. Wilson moves from an engineering role within Penske's NASCAR set up.

Chris Heroy has joined the Richard Petty Motorsports NASCAR Sprint Cup operation to work as crew chief on the No.9 Ford. Heroy is a former Hendrick Motorsports engineer who has previous crew chief experience from his time at Chip Ganassi Racing. He replaces **Kevin 'Bono' Manion** at RPM.

Derek Perry has been appointed Chief executive officer of MRTC, a leading supplier of motorsport communications systems and equipment. Perry was previously sales director at SPA Design, and before that he worked as head of sales at Forward Composites.

SCCA Enterprises president and CEO **Erik Skirmants** has tendered his resignation, after more than 10 years in the position. Skirmants, a life-long SCCA member who joined the company in his current position in June of 2005, has overseen the build and servicing of the Spec Racer Ford and Formula Enterprises machines, both popular in SCCA Club Racing.

Jim Travers, a well-known mechanic, engine builder and race engineer who was something of a legend at Indianapolis – having been a part of **Bill Vukovich's** Indy 500 winning streak back in the 1950s – has died at the age of 95. Travers formed a hugely successful partnership with **Frank Coon**, the pair widely known as the 'Whiz Kids'.

◆ 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**

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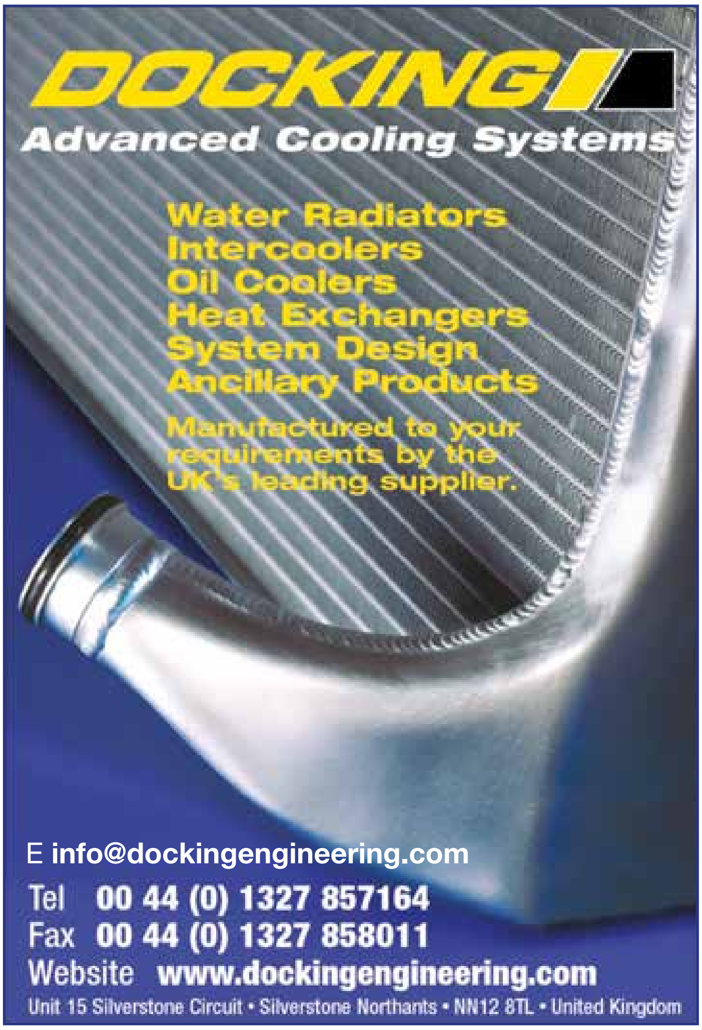

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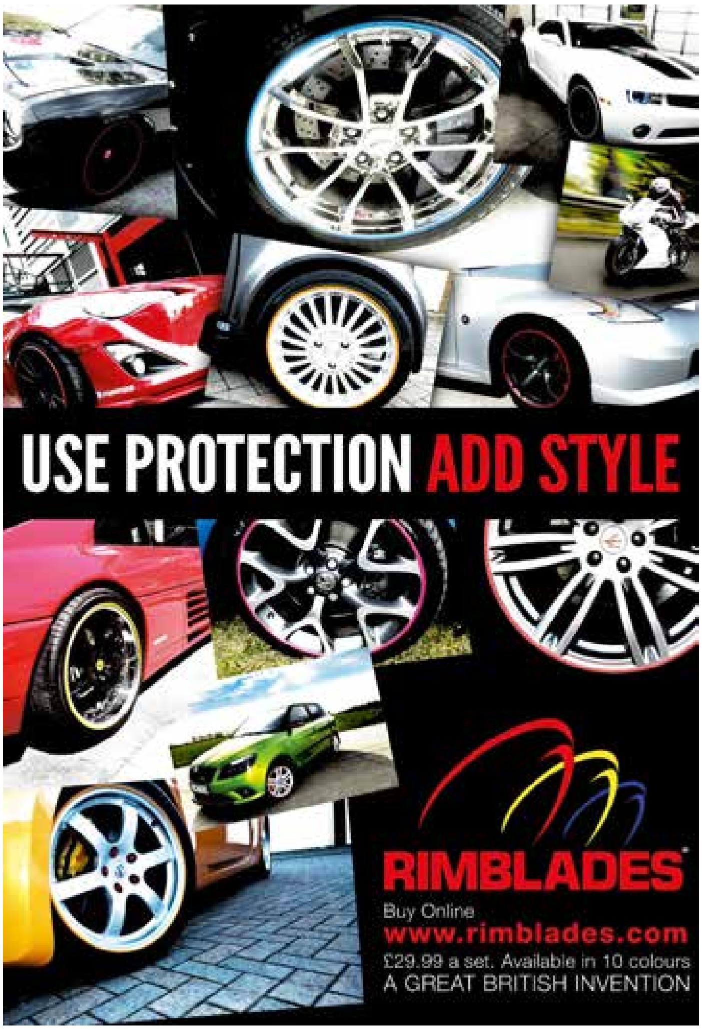

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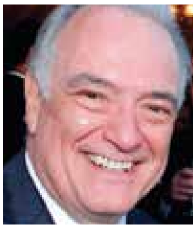


Weathering the storm

The industry needs to be prepared to meet some mighty challenges this year

With the trade shows behind us and the season ready to start, it's a good time to consider the year ahead and what might be in store for the motorsport industry.

At a macro-level, it looks to be a confusing year ahead with many potential dangers and pitfalls for business. The very low oil price is just one contributor towards volatile stock markets around the world; another is the significant reduction of the booming consumer market in China and its reduction in raw material needs. These factors create a seismic shift in the world economy. Whilst the US economy continues to improve, we see a most unusual election situation developing there, which will run throughout the year and create additional confusion and lack of future confidence.

We are also witnessing a complex situation in the European Union with a wide range of economic and political issues. In the UK, we face a referendum on whether to stay or leave the European Union, which will run throughout the summer so adding to instability.

On a global scale, we have the spectre of escalating military activity to combat the issue of ISIS, drawing in many national economies to support a resolution.

Wider world

What is the relevance of this to motorsport? The business of our global sport relies on the spending power of fans and their leisure time which attracts commercial sponsors who need access to these consumers. Any instability and lack of confidence in their economies and job prospects affects the market opportunity for motorsport. The effect of these wider issues should be borne in mind as we set forth on making our plans.

The MIA recently ran a snap-shot Business Survey of our membership and found that sales growth had continued strongly through the past two years and that the majority were confident of continuing growth in 2016 and 2017.

The survey confirmed that the international market, with the most potential for growth over the next three years, remains the USA, where sales to sportscars and GT racing and off-road activity, including rallycross, are set to grow substantially. And keep your eyes on IndyCar, as new technical regulations will open up opportunities for new suppliers later this year. The MIA will organise a Business Development Group visit to the USA in May, to meet NASCAR, Off-Road and IndyCar teams to which all are welcome.

We are also taking a business group to Italy in the spring to boost sales to this market and seek suppliers of top-class machining and engineering to supplement over-stretched UK businesses. Modena abounds in high quality, under-utilised, world-class machining companies, due to the relative decline of the domestic motorsport market in Italy, so this is the perfect time for UK companies to add to their supply base.

Free money

To my surprise, 60 per cent of UK motorsport companies have yet to claim an R&D Tax Credit from the British Government. This is free money, being a tax rebate, which gives a real competitive advantage and is enjoyed by many. To help *Racecar* readers take advantage, there is a new MIA Guidelines publication which answers many questions, freely available at www.the-mia.com.

Most survey respondents had unfulfilled staff vacancies indicating a weakness in the supply chain of skilled labour which may hold back business growth. So, in early March, the MIA organised the first Motorsport Jobs Fair at Silverstone, aiming to attract many job seekers to meet companies with vacancies, now or in the future. The Jobs Fair linked with the automotive industry which has thousands of vacancies right now, in the hope that between us, we can attract the skilled individuals we need.

The new US legislation will severely restrict the conversion of road cars for motorsport

Touring car racing remains a relatively strong and settled market for the motorsport industry around the world. Pictured is the BTCC at Silverstone

The Secretary of State for Business, Sajid Javid, visited the MIA Business Lounge at the Autosport International show, and spoke positively of the current Government's intention to support the growth of the UK motorsport industry. Our industry must maintain this connection with Javid and encourage him to deliver policies which benefit the UK industry. The MIA's created a connection for the industry with our national government which is the envy of most other motorsport countries, this is an advantage which should be maximised.

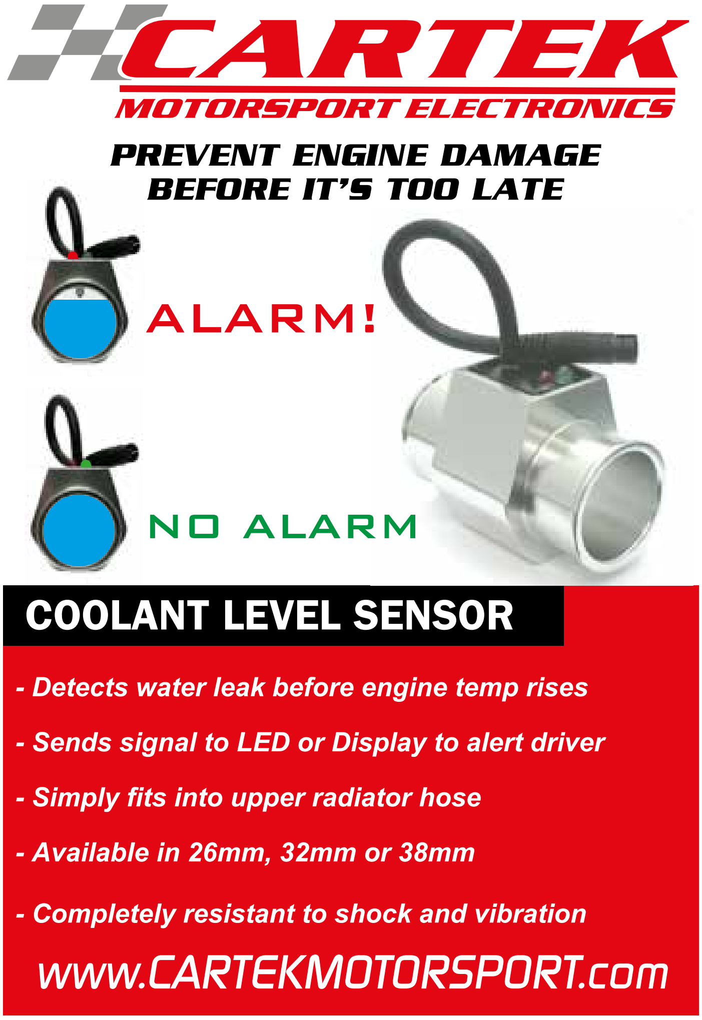
In the next two years we face quite a few 'government-related issues' in which our industry will become involved. For instance, the European Parliament has proposed a motor insurance action which, if left uncontested, will damage European motorsport. In the US, the Environmental Protection Agency has proposed legislation which, under the guise of emissions control, will severely restrict the conversion of road cars for motorsport. These issues must be resolved by the motorsport business community acting in unison, to press our case with governments collectively. Individual voices carry little weight in such matters.

Engineering heroes

At the Energy Efficient conference at the Autosport show, the suggestion from major motorsport engineering companies to use technology to entertain future audiences was really inspiring and is an exciting opportunity overlooked for too long. The data and knowledge secured from technology during races could be shared more openly with the audience, so stimulating those who enjoy the engineering behind motorsport, particularly young engineers. It would help to make engineers the heroes, alongside the drivers. This idea should be taken on board by race series and legislators. Most teams already capture performance data from their opposition, by fair means or foul. Little would be lost and probably a great deal gained, particularly by enthusing new fans to enjoy technology and engineering.

I was pleased to hear the commitment of the VW Group to maintain its motorsport budget, which is critical to hundreds of suppliers. It seems the F1 engine situation has been resolved, with Renault, Honda, Mercedes and Ferrari in line to support an increased number of teams. Again good news for the supply chain. Touring cars are holding a strong, settled, position around the world with growth in some developing markets, and this also applies to sportscars and GT.

So, despite my earlier comments of global political and economic uncertainty, I am sure the motorsport business community can look forward with confidence, but do check www.the-mia.com to see the business growth activities, open to all, which will help make your year a success.



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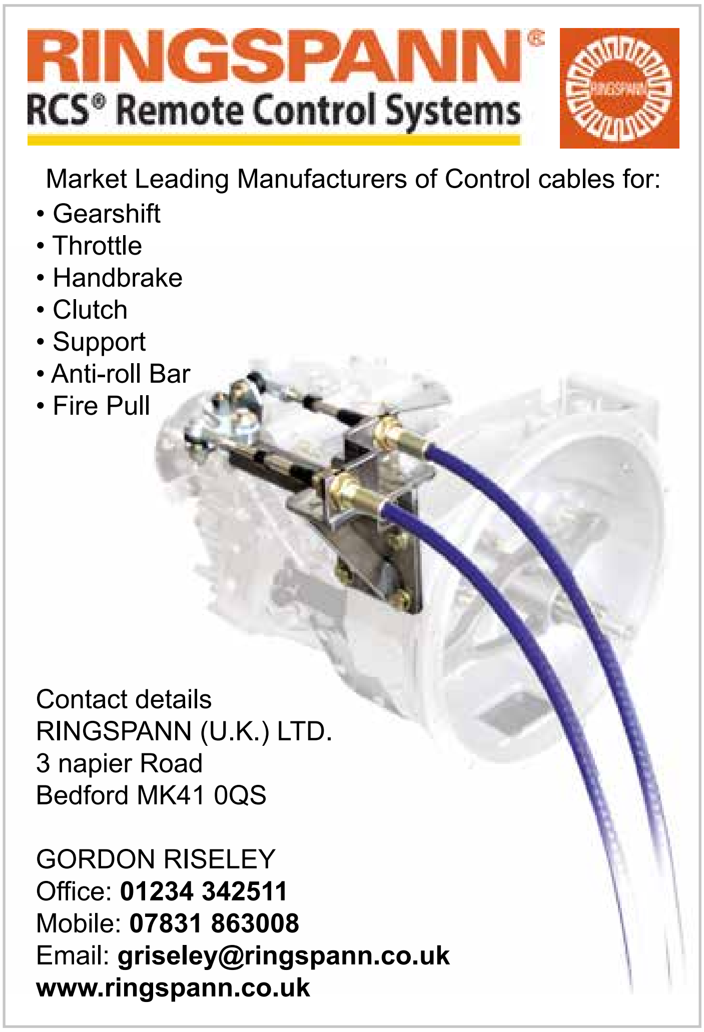

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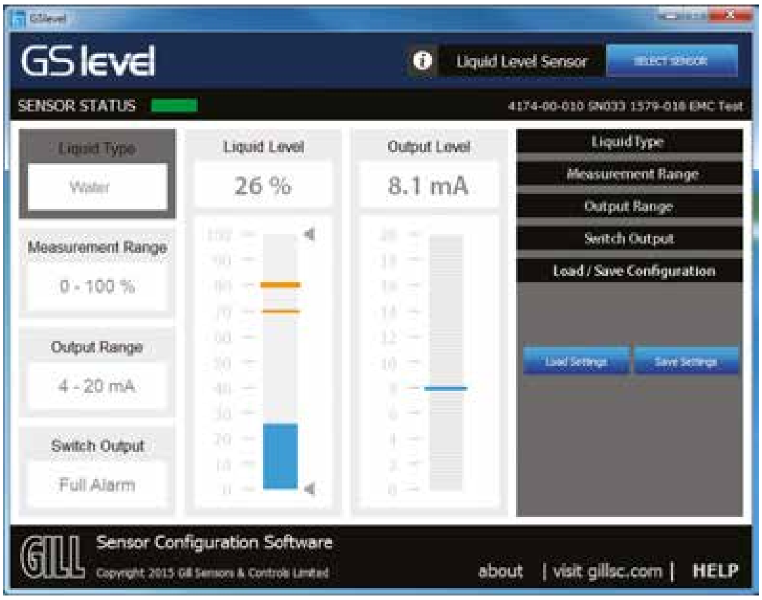


Gill Sensors has released a new generation of software for liquid level configuration. Developed to support the launch of its latest lightweight liquid level sensors, the GS level 4223, the software has been overhauled to provide what Gill claims to be a modern, simple to use and intuitive way of customising output settings, minimum and maximum levels, alarm switch level and hysteresis conditions.

Using feedback from its customers and user-experience, Gill aimed to develop the new software to streamline functionality and provide a user-friendly system, allowing its customers to gain quick analysis of the sensor's data.

One of the main benefits of the software is the ability for users to achieve a volumetric output via a new tank profiling feature, Gill tells us.

Users can programme the software using a configuration wizard or by uploading a CSV file to profile a cross section of the data to gain a volumetric output. Users can also set a secondary output using the open collector switch and set a hysteresis tolerance band at the desired level, so that the indicator only changes when that level is reached.

The software is downloadable from the Gill website, requires no programming, and connects using RS232 serial protocols.

gillsc.com

Measurement
Double bubble is no trouble

This new B-G Racing bubble gauge accurately measures from -6 to +6 degrees camber and from -4 to +12 degrees castor, displaying the readings very clearly on separate positive and negative vials.

A stepped design ensures all the vials are aligned to the hub centre line. The camber/castor gauge is machined from billet aluminium with a black anodised finish.

www.bg-racing.co.uk

Controls
Pedal to the metal

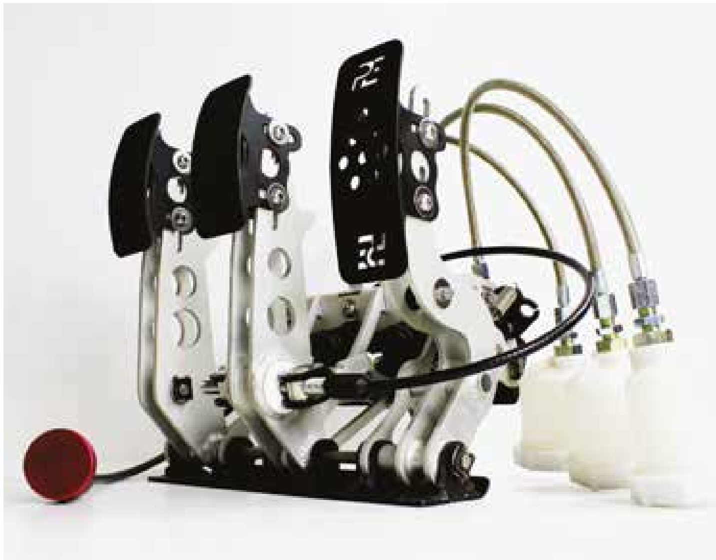
This brand new universal pedal box from PE Racing features an adjustable lightweight design utilising high strength alloy construction, an anodised finish, universal fitting using adjustable mounting feet, and adjustable pedals with maximised mechanical advantage, we're told.

The box also has built-in brake balance technology, and adjustable throttle linkage geometry.

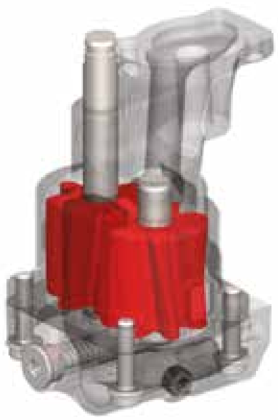
The kit comes complete with a throttle linkage system, remote brake bias adjuster cable, top quality motorsport master cylinders, top quality reservoirs, fittings and braided feed hoses. All this in one pedal assembly which weighs 2.02kg without master cylinders and 3.45kg with them.

Mounting is achieved via the adjustable feet at both ends, this feature aimed at spreading the loads over a much greater area of the foot-well, resulting in lower floor stresses, PE Racing claims.

peracing.com.au



Fluid transfer
Pumps with added bite



Melling has released an innovative new range of oil pumps, which it claims has major benefits over traditional internal gear pumps.

The company says its new Shark Tooth range is significantly smoother due to the use of new helical asymmetrical gears. This new gear design provides the engine with an improved flow of oil without the usual pulsing found in traditional gear pumps.

The reduction in the pressure ripple from the pump will also provide benefits to the distributor and camshaft drive, Melling says.

www.melling.com

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Belly flops to pit stops

Having to work through February, I was unable to join the family on the school half-term holiday and so contented myself with sitting at the computer during the day, and watching the television in the evening. A rather disappointing set of programmes on traditional channels led to an exploration of others, and I ended up at two favourites; *Impractical Jokers* on Comedy Central, and *The Jump* on Channel 4.

The first involves four friends setting each other embarrassing tasks and getting filmed doing them. It's funny in a very schoolboy-humour way. One of the tasks was to get Joe to interrupt a diving competition, and belly flop his way through it. The dramatic change in skin colour front compared to back was noted after about five dives. 'We should probably only make him do one more,' one of his friends said.

The Jump involves a group of celebrities taking part in winter sports. The series opened with the celebrities trying the Skeleton, a fearsome discipline. Unfortunately, the elimination round at the end of each programme, a ski jump onto an air-filled cushion, is almost redundant as the celebrities withdraw due to various injuries. A British Olympic gymnast had to have vertebrae fused after one accident, an Olympic swimmer dislocated her shoulder. An actress dislocated her elbow, an Olympic sprinter developed a hamstring issue. I started out wondering how the hell they got the idea past the lawyers, and finished up applauding them for being able to do so.

Why this as a topic this month? Well, it all links to the latest measures suggested to improve the F1 'show'. Television is presenting an open goal, and racing is reacting by discussing the optimum shape of the ball. The proposals laid out are, I am sure, based in logic, but from the outside I can't fathom it. A 'Driver of the Day' may get people voting, but how? Will the audience telephone a premium hotline and pay for the right to take part (ker-ching!), or will it be a free vote? Will there be the obligatory 15-second delay between 'and the winner is…' and announcing the recipient of the award? On a more important note; why do this in the first place? If you want the drivers to be heroes, unleash them to speak...

And now, in a bid to spice up Saturday, the most sensible qualifying system introduced to racing is about to be made vastly more complicated. There will be a careful eye on the clock; after seven minutes the slowest driver is eliminated. And, thereafter, every 90 seconds the same until the chequered flag. The commentators will have their work cut out as some drivers will be out on track with a shout of making the 90-second cut to start the lap, and others won't.

Somewhere along the line, Formula 1 has seemed to have lost sight of what sport actually is. In these pages Peter Wright explains how F1 could rescue itself aerodynamically, and we will in the coming months look at Formula 1's proposals for its next generation cars in greater detail. But I think F1 has some far more serious problems. The decision-making processes are taking F1 so far away from what it should be that I do start to wonder; what is the ultimate goal? VW has once again delivered its verdict on the category – that F1 is not stable enough to warrant the investment needed to succeed. Alfa Romeo on the other hand is looking to go in, although it could develop Ferrari's F1 technology to compete in the WEC.

We are a world away from the days where every penny earned was spent on the car. Ricardo Divila has been outspoken with his views regarding topiary outside the garage and five-star food available to guests of the team. The pits have become a place where Gucci is commonplace, rather than oil and grease. When a racing car is fired up in the pits the guests are forced out, their eyes streaming from the fumes, this is an unwelcome surprise for them. It shouldn't be.

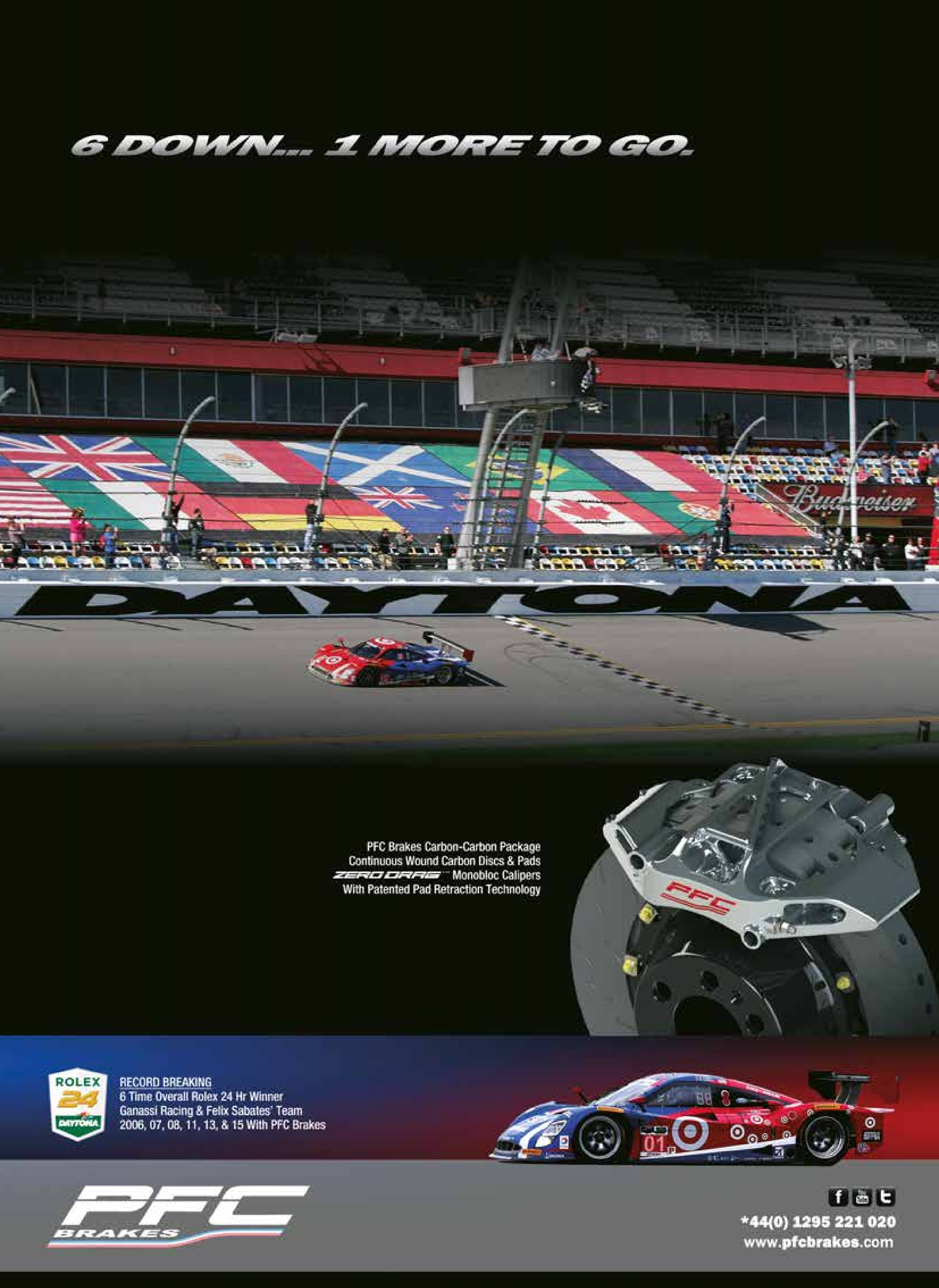
The pits have become a place where Gucci is commonplace, rather than oil and grease

There are huge technical advances that are being proven in motor racing, yet Formula 1 is not celebrating its successes. Instead, it appears to be focussing on the negatives. Actually, it seems to be focussing on the populist vote, rather than the sporting one. Its solution to dropping audience figures is to change the product, not to adapt to the way it is watched and embrace the internet, following NASCAR's model.

And, I believe that racing is missing the key factor; this could all be irrelevant in our lifetimes anyway. Driverless cars are going to go on trial in the UK, sooner rather than later. The rise of the machines won't stop at the UK or US borders. How manufacturers will market and sell cars will change dramatically as the Uber-style system takes over and our purchasing habits change from buying cars to hiring, or buying time in cars. At that point, what happens to the marketing element of racing? I reckon it will need to go back to the pure element of sport to survive.

We need to remember why motor racing started in the first place. One fella says to another; 'mine's faster than yours', and the race is on. It is simple, and we don't need to over-complicate the process. Appealing to the television audience, and then reaching that audience, is important to finance the technology, but I would argue that it is a secondary requirement, not a primary one.

ANDREW COTTON Editor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