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McLaren 720S GT3. The company has taken its GT racing operation in-house and it has big plans for customer sport. Turn to page 74 for more

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The inconvenient truth

Why you should not believe everything you're told at the race track

Post truth society, which is the current paradigm, both in the United States and the UK, and is rapidly gaining ground around the world, is actually nothing new in motor racing, where both the racing teams and the drivers not so much indulge in it as wallow in it.

Teams do it when they sell a seat to the driver or the livery to a sponsor. Promises of hitherto unheard of performance from the racecar and team is the stock in trade of these dream sellers. For, let's face it, it is not easy to prise multiples of million dollars, euros or pounds from anybody by just giving them the facts.

Drawing offices also extrapolate the simulations and wind tunnel analysis to Himalayan levels. All this is well understood in the business, and falls squarely into the cognitive dissonance bin. Let's call it Olympic (insert synonym for lying here) and move on to other examples.

Test of truth

Of course, there are the other, more premeditated, varieties. Like winter testing, where denser, crisper cool air will pump up the horsepower and produce more downforce, which will flatter the racecar's performance. Much softer tyre compounds can be run without melting and all the parties involved are rather complicit in this.

The leading teams are prevaricating in a rather different fashion, running say, with boost turned down, or with full tanks, or the harder compound, or with aero trimmed down to lessen performance – hiding the potential to lull other teams as to their effectiveness.

So the two varieties converge, the lipstick on a pig to entice prospective sponsors to sign on the dotted line, hand in hand with the luscious hottie wearing loose cardigans, glasses and hair pulled up in a bun to camouflage her appeal. By now these ploys are so well known and blatant that one would assume the intended victims must be aware, and that they accept the act of mendacity for reasons of their own.

All is fair in love, war and sponsorship hunting, but to reach really mega heights of deceit you must turn to the drivers. I have often been scathing about their IQ levels, as just the fact that they will strap themselves into the contraptions they race is proof enough of the low level of that, but in the 21st century, all their actions are followed by umpteen GoPros, GPS and multiple channels that record every creak, twitch and groan of the car, gearbox engine and tyres. Yet they still come in and tell porkie pies about what goes on.

Engineers nowadays are like the Old Testament God, seeing all and forgiving nothing. They might not necessarily say so to the offender's face, but opprobrium can drip corrosively from the engineering reports. Engineers also tend to have higher literary skills than drivers, so properly phrased scathing judgements can just whizz over the drivers' heads unnoticed.

Alternative facts

My pet peeve is the drivers that will corner you after the session and play over and over again the on-board recording video to prove whatever deranged excuse they have for not performing or why they have clouted another car, the Armco

The shady world of winter testing, where sometimes not everything is quite as clear-cut as the stopwatch and the data seem to suggest

or any other wayward object – I have never had a driver actually say the Armco has jumped out and bit him, but probably only because even they realize that this is stretching 'post-truth' just a little too far. You can only push the envelope so far before it becomes ludicrous, except if you are a politician or, say, the President.

The 18th century philosopher David Hume argued that facts belonged in a separate category from 'necessary truths'. It is necessarily true, for example, that all the angles of a triangle add up to two right angles. This is fundamental to engineering, the laws of physics being what they are. Wishful thinking simply will not keep a bridge up or generate more grip on a racecar.

Facts, on the contrary, are contingent rather than necessary. That is, facts could be otherwise. They are a body of knowledge that is accepted at a given time, but they can be modified in the light of new knowledge. For example, in the 1500s it was a given that the earth was the centre of the universe, but subsequent examination of the details proved otherwise. But at the time there were all sorts of work-arounds that fitted the theory and gave some sort of predictability to astronomical calculations, thus 'validating' the 'facts'.

The writer Joseph Conrad was a sceptic who believed that the human world was fuelled by illusions. We can actually be fairly sure of this – just examine what you thought a decade ago and what you think now. If you haven't changed your views quite a bit then either you are uninformed or just not very perceptive.

Just in case engineers are now sitting back and basking in the warm glow of 'I told you so', they should also consider their habit of having a pet assumption and then cherry picking the data to fit it. Nobody is immune to this, and I will assume my own faults here.

True lies

It takes a lot of will power to actually detach oneself from the subject and really be objective. Peer pressure, the time stress of coming up with a solution before the next session and the need to soothe your driver, that very fragile animal, can lead you to cry 'Eureka, there is the problem!', come up with a credible measure and have it blur into the haze of changed track conditions, driver motivation or that old reliable chestnut, the tyre pressures or temperatures were not correct, so it cannot be absolutely refuted in hindsight. That said, the other teams are going through the same process, and will be doing similar things.

Technically you could say it is not intentional, thus it is not actually a lie as such, just what's become known recently as an 'alternative fact', clearing engineers from the charge of intentionality. But remember, truth (or physics) will always win out. Good luck with that.

Race engineers should also consider their habit of having a pet assumption and then cherry picking the data to fit it

A game of Charade

A visit to a legendary old grand prix track sparks memories of F1's dangerous past

There can be very few places as quiet and inactive as a village in central France on an early-autumn Sunday mid-afternoon. Taking my time quaffing a beer, sitting outside the only bar open in Saint-Remy-sur-Durolle, there wasn't even any interest to be piqued in the occasional vehicle that ran gently through the centre. Not so many years ago, there would have been a distinctly national identity to them – the inevitable Citroen 2CV and elegant DS 'Dix-Neuf', rugged Peugeots and the ubiquitous Renault R5. If one was lucky, maybe a farmer had defiantly clung to a Traction-Avant Citroen, or there was the local boy-racer's raucous old Renault-Gordini.

Now, of course, it's almost all Euro-boxes, barely distinguishable one from another. Had there been anyone around, my 911 'Whaletail' might have created a little attention amongst all this drudgery, but there wasn't. At least it gave me something to look forward to, tackling some cross-country winding roads on the way home.

Lap of the gods

Apart from the Auvergne being a superb region of France, the reason for making this fairly lengthy trip was the 60th celebration of racing cars (and bikes) at Clermont-Ferrand, a circuit also known as Charade. Sir Stirling Moss apparently described it as the most beautiful track in the world. It was my first and probably my last opportunity to see it, as it is threatened by housing development, so I had to go.

Despite being billed as 'Charade Heroes', in truth the event was a little underwhelming, mainly consisting of on-track demonstrations. It always pains me to see a racing car not being driven at least a little in anger, especially with Jacques Laffite and Henri Pescarolo behind the wheel.

Fortunately, affable Ligier boss Jacques Nicolet had assisted by presenting the 'Ligier Saga', which brought together a selection of the French manufacturer's racing and road cars, including F1 cars of the '70's and '80s. This included the Lafitte/Patrick Depailler JS11, a design headed by the late Gerard Ducarouge, who I was fortunate to count as a friend. It is definitely one of the best-looking F1 cars of its generation, highlighted by the evocative blue and white Gitanes 'Gypsy Woman' livery. However, more examples of F1 and other formula cars that were raced at this magnificent Nurburgring-like circuit, built in the foothills of an extinct volcano, as well as those who conceived and drove them, would have been welcome.

It was once an immensely-challenging French Grand Prix venue. Over 8km long with 51 bends, combined with considerable elevation changes and little in the way of run-off amid imposing scenery; a drivers' circuit most certainly. Wonderful also for spectators, able to look down from close natural vantage points all around the track. Due to the celebration aspect plus the gorgeous weather, there was a very healthy crowd. It's incredible that such a track should become just part of history, although in truth it has been for some time when it comes to major international motor races. Financial issues, not least I'm sure the huge cost in bringing up-to-date safety features to the venue, as well as the infrastructure and access roads required, killed off Clermont-Ferrand for grand prix or prototype racing. Fortuitously, lower-level racing continued, along with historic series that visited in order for their participants to get a taste of real adrenaline.

Nico Rosberg samples a Mercedes W196 at Goodwood. Just how many of the current F1 drivers would have agreed to race cars like this in period?

Risky business

While enjoying my beer, I recalled how I have been disappointed at hearing the first words of some of today's F1 drivers privileged to be let loose in a mid-1950s Mercedes W196. These revolved around the lack of safety features, rather than the joy of piloting a gismo-free pure racing car with a hair-raising exhaust note, a lusty atmospheric engine and skinny tyres requiring sensitive throttle and steering control. This led to me pondering, not for the first time, if one was able to time-travel to the past, how many of the current crop of Formula 1 drivers would have been willing to race in grand prix cars of the 1950s and 1960s?

Have a go heroes?

Kevin Magnussen would be a shoe-in for sure, having frequently spoken of – and displayed – his willingness to flirt with disaster, and no doubt Max Verstappen, whose absolute self-confidence and ability might encourage him to believe he is immortal. I suspect Lewis Hamilton's real racer instincts would have swayed him to do so, also Fernando Alonso who has often stated his desire for more 'elemental' competition. Definitely Kimi Raikkonen, who has oft-times expressed his admiration for James Hunt and the high-risk racing of that period. Maybe Romain Grosjean, with his unrestrained passion and Sergio Perez, who demonstrates little fear of crashes (even if most of them are with his team mate). Of the remainder, I don't know.

Sebastian Vettel is a also a natural racer, but probably wouldn't have survived long due to his great speed compromised by lapses of judgement. Cars and circuits of the past were not at all forgiving of errors. It would be interesting to pose the question to every incumbent of this year's Formula 1 seats (although they might not all tell the truth).

Racing drivers today, cocooned in composites and benefiting from technology in all aspects of their fantastic machinery, are much more clinical in their approach to risk and their profession than their seat-of-the-pants forebears.

Should anyone argue that these days nobody sensible would consider anything beyond just sitting in a McLaren of even 20 years ago, let alone a Ferrari or Mercedes of the '50s, there are a few highly-skilled historic series drivers who still race such fragile cars flat out, despite having an awareness of the hazards involved.

Are they heroes? Maybe. Clearly, passion, maybe ego, and just rising to the challenge have outweighed their personal safety concerns. It is to our benefit that this is so. It's a pity that Charade won't echo to the sounds of their engines any longer, or see the Gypsy Woman.

I've been disappointed when hearing the first words of some of today's F1 drivers after they've been let loose in a mid-1950s Mercedes W196

Clash of cultures

At long last GT500 and DTM look set to converge, but there still remain some significant technical and philosophical differences to sort out before Class 1 is rubber stamped. The big question is, could these prove insurmountable?

By SAMUEL COLLINS

Nissan's GT-R is a mainstay of Japan's hugely popular Super GT category. Talks to bring the GT500 class fully in line with the DTM regulations are now at an advanced stage

'There is a basic and fundamental difference between the business and operational models of Super GT and DTM'

In retrospect, Super GT's 2017 season finale at Twin Ring Motegi pointed to a bright year ahead in 2018 for the Japanese series. The Nismo run Motul Autech Nissan GT-R dominated the GT500 category, with a lap record in qualifying, fastest lap and the race win.

This was the first time that year that Lexus had looked truly beaten. The LC500 had dominated thus far, but the Motegi race proved that the others had closed the gap. 'When we built the LC500 our target was very clear, build the best car and we did that,' says Yoji Nagai, general manager, TRD Motor Sports Development. 'Some of the advantages we got with it we kept for only one year. In 2018 Nissan and Honda closed the gap. This year it has been really close between all three manufacturers.'

But it is Honda that seems to have gained the most in 2018. The engineers at HRD in Sakura City, Tochigi, have struggled to get the most out of the current GT500 regulations since they were introduced back in 2014, but in 2018 they seem to have found something of a sweet spot with the NSX GT.

'Honda gained a lot of engine performance and made aerodynamic gains too,' Nagai says. 'I'm not sure about Nissan, but they did have some engine improvements. Last year at the final race Nismo had a new engine and the Michelin tyres worked well. We improved both

The Lexus LC500 was the class of the field in 2017, but both Nissan and Honda have fought back this year. There is a worry that these cars are now too quick for some tracks

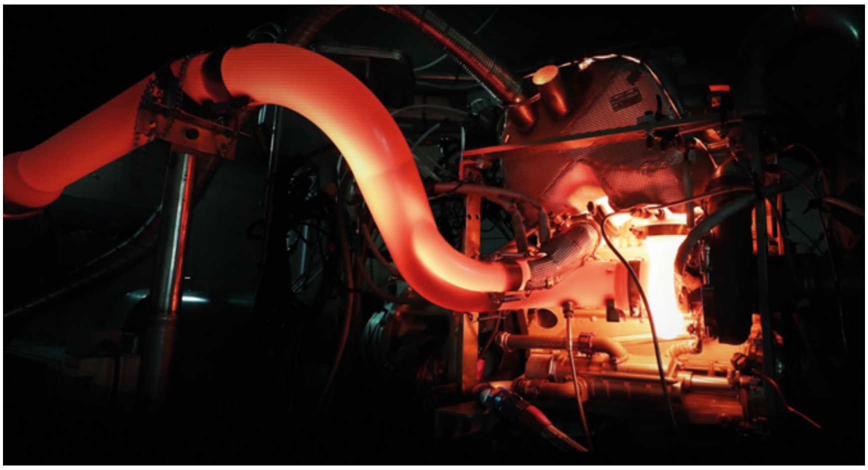
engine and aerodynamic parts, but to be honest the scope for improvement with the aero was not that big with the 2017 regulations [which have remained the same in 2018]. But on the engine side we made big improvements.'

Super power

GT500 uses 2-litre, turbo, 4-cylinder engines featuring direct injection. The combustion technology is very similar to that used in F1 and rumours have been rife throughout 2018 that all three manufacturers are using pre-chamber ignition systems, although none of them will confirm this. But it is clear that the engine performance has increased significantly since these engines were introduced and outputs in the 670-700bhp range are rumoured.

'The easy answer I can give is that we have improved by about 100bhp since these engines were introduced in 2014,' Nagai says. 'In terms of how [we have done this] it is still a difficult topic. There has been a lot of talk about using a pre-chamber ignition system on this engine, and on that we have not admitted it, but we have also not denied it. But that is a very interesting technology for the future. While we do not directly transfer technologies to the production car development as we here at TRD are only tasked with making racing cars, our information and knowledge is passed to the production car department. I believe lean burning high compression ratio engines have a real relevance for production. That is why we changed to the NRE [Nippon Race Engine] regulations, to promote efficiency'

This increase in performance has implications for the series, however, as the speed of the GT500 cars threatens to outgrow some of Japan's circuits. 'The number, quality and pace of the cars is increasing and the tyres are always improving,' Masaaki Bandoh, president of Super GT's promoter, GTA, says. 'As a result we are a bit concerned about safety at some tracks, especially the shorter ones like Sugo and Okayama. So we are hoping that the facilities will be upgraded slightly in line with the increasing speeds. We want to keep the racing quality as it is and not change the actual racing. I think this season the series has been both good and stable. We have a lot of spectators and I think the fundamental base of the Super GT series is very good, the format simply works. We have 45 cars which is good, and more are joining the series.'



Both Nissan and Toyota are thought to have developed pre-chamber ignition systems in their engines this season, although neither will confirm this. The NRE power units are reckoned to be producing 670 to 700bhp

Masaaki Bandoh (right) is president of GTA, the company that is responsible for promoting Super GT

Restricted by the rules HRD (Honda Racing Development) engineers only made subtle changes to the NSX for 2018, such as lowering the intercooler for a better centre of gravity. But the increased competitiveness of the Honda has created problems for GTA. When it introduced the current NSX to GT500 Honda's management insisted on having a mid-engined car, which required a bespoke monocoque and not the single spec design used by the other two GT500 manufacturers, and in the DTM. GTA allowed the NSX to compete under specific regulations based on the GT500/DTM chassis regulations.

'This year Honda has been very quick,' Bandoh says. 'As the car is a midship layout it

races under a specific balance of performance and this was set after the first two races of 2017, then adjusted after the first two races of 2018. The reason for this is that we wanted to see how it ran on different types of track [Okayama and Fuji]. Because the performance had improved so much we adjusted its BoP during the season. The car is still very competitive, however.'

Class action

The NSX actually made the 2017 Super GT finale at Motegi notable for another reason. It joined a special session where one car from each car maker in GT500 and DTM took to the track together. Honda had declined to send a car to a similar event in Germany a few weeks earlier.

In 2012 it was announced that GT500 and DTM would work together to create a common rulebook for both classes, and since then the rules of both have evolved toward Class 1, as this unified class will be known. Honda's participation in the joint demo session at Motegi was a major step toward Class 1 actually happening. That said, the Honda still remains something of a barrier to this happening at all, too.

'In 2019 we will have two joint races with both DTM and GT500, one in Japan, one in Germany, but we have to discuss the rules still,' Bandoh says. 'Class 1 regulations are only for front-engined cars, not mid-engine, but we are discussing with ITR [DTM's promoter] about running the two races as 'Class 1 plus-alpha', rather than pure Class 1, which would mean that the NSX can compete. In 2020 we will run the joint races with full Class 1 regulations. This means that the mid-engined Honda cannot participate in the joint events with DTM.

'When we announced this plan for full Class 1 regulations for the joint races in 2020 Honda's response was to say that it would make continued participation in Super GT difficult as it does not have a front-engined car,' Bandoh adds. 'They said that if the joint events only allowed front-engined cars then Honda would end its participation in Super GT at the end of 2019. This situation is not viable for us, Super GT is a Japanese championship, we need Toyota, Nissan and Honda, all of them. So right now we are discussing a solution with ITR.'

The proposal from GTA is likely to push for the NSX to be allowed to compete under a special balance of performance, as it does in Super GT. However, this may not be required if information coming out of various technical suppliers in Japan is accurate. Engineers from HRD are thought to have developed a front-engined version of the NSX-GT in great secrecy, and without official approval. This Class 1 compliant NSX is reported to have already been given a secret shakedown run, and it's said it will roll out in public during a Bridgestone tyre test at the end of the season.

Engineers from HRD are thought to have developed a front-engined version of the NSX-GT in great secrecy

Out of step

While DTM plans to run to the full Class 1 regulations in 2019, Super GT will wait until 2020 to introduce the new chassis rules to GT500, and even then it is unlikely to fully adopt them. 'We will have what we call the five per cent rule, that means that the engine and some other parts of the car will not be completely fixed and we will have some scope for development,' Nagai says. 'The exact details of what is included is currently being discussed. With the aerodynamic package, right now it's just a study. The rules are not fixed, and we don't know what areas will be different and free. So we have to create rules specifically for GT500, beyond the base of Class 1.'

What seems likely is that the main common parts will be the chassis, gearbox, monocoque, impact structures, floor and splitter, as is the case today, but in addition the side panels – currently an area of great aerodynamic development each year – and the suspension components will all be identical. This has not gone down especially well with some Japanese engineers. 'The Germans want to fix everything, and not allow development. I really don't understand why they want the same engine, same suspension and same tyre, everything the same. It is hard for us to understand,' Nagai says.

The engines which will be used in Class 1 have been an issue for some time. It was agreed back in 2012 that DTM would adopt the Japanese style 2-litre in-line 4-cylinder units, but the German series has delayed their introduction more than once, and will only finally use them in 2019. In the meantime the Japanese manufacturers have been developing their engines since 2014, giving them a significant advantage. But even with the exact engine format agreed there are still differences between the demands of the two series. In Class 1 the advanced combustion techniques used in GT500 will be outlawed, though they may well remain in GT500. This is all part of what is really a philosophical difference between the two championships.

'DTM want at least a three-year freeze on engine development, but even an annual freeze is difficult for us,' Bandoh says. 'There is

DTM and GT500 will hold some joint races in 2019 but there is no plan to run a Class 1 series. Absent from this picture is Honda and also Aston Martin, which is to join DTM next year

There are concerns that the mid-engined Honda NSX GT may not be able to compete in Class 1

a basic and fundamental difference between the business and operational models of Super GT and DTM. For the German car makers DTM is purely a marketing and commercial activity, but in Japan GT500 is funded by the R&D departments of each manufacturer. There is a huge difference in culture. In Germany the manufacturers pay for everything, the running costs, development costs, drivers. In Super GT the manufacturers build and develop the cars but private teams run them [with a couple of exceptions such as Nismo], the team has its own budget which is entirely separate, and that funds the costs. If you were to restrict development you would take away a huge chunk of budget [which comes from the manufacturers] and then GT500 and Japanese participation in Class 1 would not be viable.'

Waiting in the wings

However, while a simplification of the GT500 engine regulations is not popular with the Japanese R&D departments funding their development, Nagai reveals that the relatively high cost of the units also put off some other manufacturers. 'When we started working on these engine rules, we all met as manufacturers and discussed what was needed,' he says. 'It was, of course, Honda, Nissan, Toyota, but also Mazda, Suzuki and Subaru with some small tuners coming along, too. The others wanted to do it but they felt the budget was too high – the engineers wanted to do it but the budget was not there. I think the NRE is a big success, being a compact powerful unit and lightweight makes it really useful, it is very good for cars like single seaters too [it's used in Super Formula].'

Another area of uncertainty surrounding the Class 1 regulations is the suspension layout. The intention is that Class 1 will use the DTM's 2019 specification parts, but there is significant doubt about whether the components will be up to the demands of GT500 and endurance racing.

'The regulations do not let us make big modifications in terms of the chassis, so there is not a big gain in the suspension,' Nagai says. 'But we use it for tuning to suit the tyres. However, with Class 1 the suspension is fixed, the same for everyone. Right now we can make adjustments, even with the basic set-up [there are] things we can do with the Class 1 car, but the Super GT tyre performance is much higher than the DTM tyre performance, so we need to see about that.'

During 2019 GTA will ask the three GT500 manufacturers to test the DTM suspension to see if it is suitable for use in Super GT. 'The suspension rules are not decided,' Bandoh says. 'The idea is that we run the same suspension exactly as DTM, but first we need to run it in testing. Our tyres have much higher grip, our engines have more power, so we have to test the suspension. The Germans say it will be fine, but we have still to be convinced.'

Finding solutions

In terms of the technical regulations then, it seems like there are many details which remain uncertain, but this does not blunt Bandoh's determination to see Class 1 finally become a reality rather than simply a concept. 'There are a lot of problems and issues to get around, but we are very keen to work through them all. I don't expect it to be straightforward, but we will find solutions,' he says.

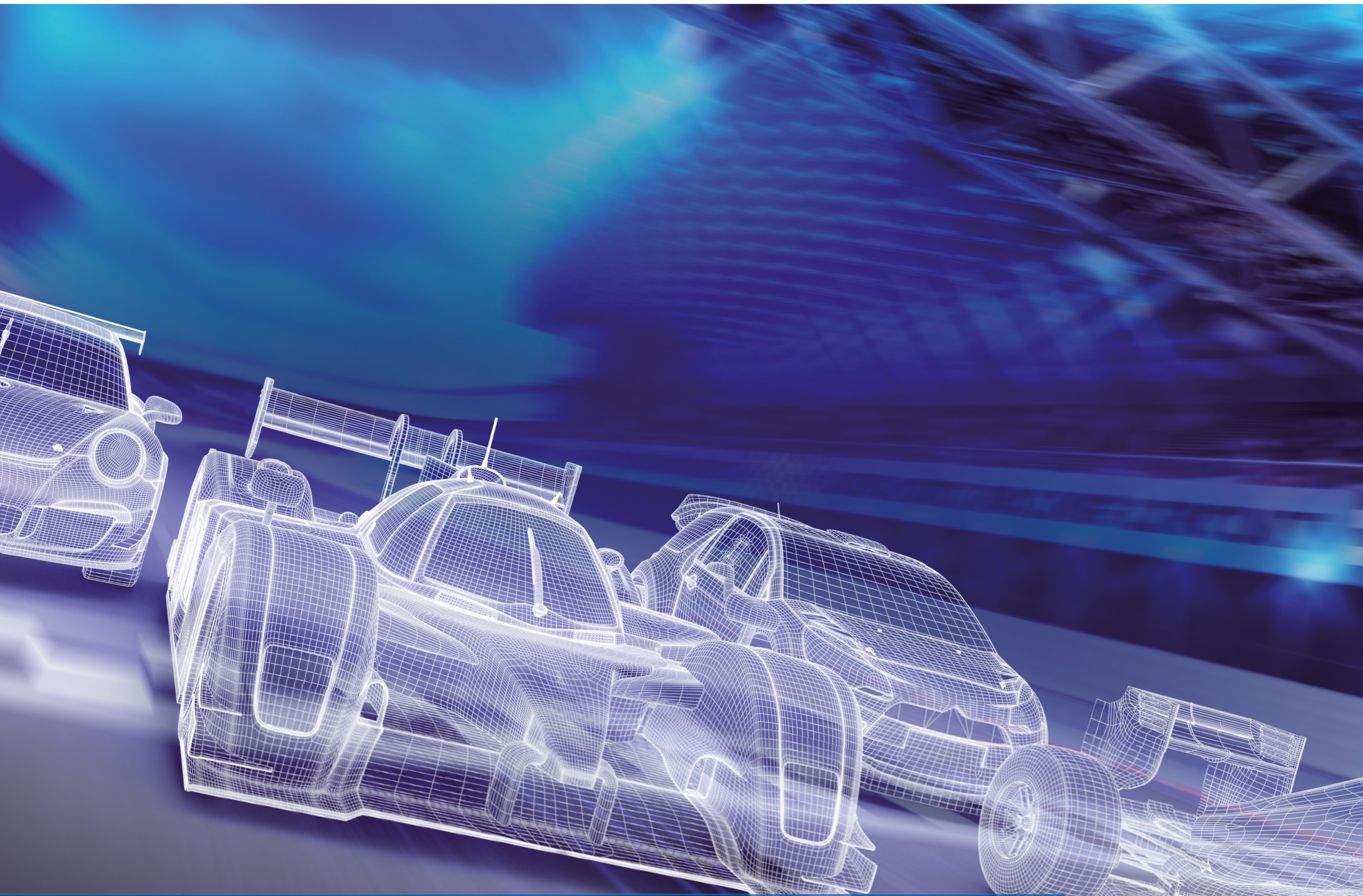
As well as the ongoing negotiations about the rules GTA and ITR will need to work out details of two joint races set to take place in 2019. 'The joint races are still under discussion, dates and locations are not decided,' Bandoh says. 'But I think at least one will be before the final Super GT race at Motegi, so we will fly 15 cars to Germany. The best date for us is when F1 and WEC are in Japan as there is no Super GT then. Then the Germans will fly the DTM cars to Japan in November. But for us it is new as we have never flown the cars and equipment to a race before; we use ships for races overseas. So now we are working with DHL to find ways to do it in the most cost effective way possible.'

The races would also need to be scheduled to give the GT500 teams enough time to

The Japanese manufacturers have been developing their engines since 2014, giving them a significant advantage over those in the DTM

GT500 suspension. Class 1 may use a spec suspension designed for DTM cars

The GT500 tub, made by Toray Composites, is dimensionally identical to that used in the DTM



convert their racecars from the more potent Super GT specification to the full Class 1 trim, which is likely to involve changing the engines, suspension and the bodywork.

Separate entities

A common misconception about Class 1 is that it will become a single championship absorbing both Super GT and DTM, like a 21st century ITC, but that is apparently not the aim – at least not in the short term. 'What I would like to see is that the two series stay separate, DTM and Super GT, they are different,' Bandoh says. 'What I would also like to see though is a special series of races each year, two races in Asia, two in Europe, and perhaps two in the Americas, this would be a world touring car championship.

'The competing cars would be the top three scoring cars from each manufacturer in GT500 and DTM,' Bandoh adds. 'So you would have Aston Martin, Audi, BMW, Nissan, Lexus, Honda; 18 cars. Those world championship races would run from November to March. I have discussed this with the FIA already in May, but Jean Todt did not agree with the concept, he did not want any sort of qualification system for a world championship. I think he is wrong, so we may just do this anyway and show that it works, and maybe the FIA will change their mind.'

The Class 1 concept seems like it could well work, if all the technical details can finally be fully agreed on. And if it does happen then its creators are keen for it to spread. 'We are now discussing with ITR to have a new agreement which runs to the end of 2030,' Bandoh says. 'That would allow teams, manufacturers, everyone, to make medium and long term plans. During this time if any other promoter or series wants to use these cars or rules, then GTA has the rights across Asia, and ITR in Europe.'

Bandoh also has a wider vision for Super GT's role in the international motor racing world, and is already in discussions about a number of collaborations with other series. 'You know if a major sportscar series comes to Japan;

The huge GT300 field is set to grow further while there have also been hints that it might feature a hydrogen-powered racecar in the future

A common misconception about Class 1 is that it will become a single championship absorbing both Super GT and DTM

Blancpain, the WEC, Asian Le Mans, we want to be involved' he says. 'Imagine how much bigger the crowds would be at the WEC event at Fuji Speedway if GT500 was there. A GT500 race shared with WEC would be interesting, from the time of 12.00 to 14.00 would be Super GT, then 14.30 to 20.30 would be WEC time, its an idea we will put to the ACO.'

Alternative fuels

GTA's plans do not stop at building Super GT into a major force in international motorsport, Bandoh is also working with manufacturers to try to bring about a shift in terms of alternative fuel usage in Japan. 'We need to think about the future, specifically hydrogen as an automotive fuel. We need to demonstrate to the spectators that the environment is important, and that hydrogen is a safe solution,' he says.

While many in the west associate hydrogen with the Hindenburg disaster, in Japan the association is rather more recent and harder to get past. 'There is a national government scheme about promoting hydrogen cars and we are working with them,' Bandoh says. 'But there is a significant problem. People in Japan believe that hydrogen cars are extremely dangerous, this is as a result of the accident at Fukushima Dai Ichii. When this was announced it was described [accurately] as a hydrogen explosion. It does not translate directly to English, but the term used for at least one of the explosions at Fukushima is also used in a way to describe the way the engine of a hydrogen fuelled car works. Now, as a result of this, Japanese people associate hydrogen cars with Fukushima, and this is difficult to get past. The government did not really explain things well.'

While a Toyota Mirai GT300 may seem far fetched Bandoh makes it clear that hydrogen and maybe other alternative fuels have a key role to play in the future of Super GT. 'They did do a racing version of the Mirai and demonstrated it at Fuji speedway,' he says. 'We have done demonstrations with Hydrogen buses and we have had a demonstration of a hydrogen fuel tank's safety. But it is the future clearly and maybe you will see something interesting with the Mother Chassis [see box out] in GT300 not too far in the future, too.'

Mother of invention

Super GT's secondary category often gets overlooked despite the fact that it is far more popular in terms of the amount of racecars competing. Its regulations allow for three different types of car, FIA GT3, JAF GT300 and Mother Chassis. The latter uses a single make composite monocoque from Dome along with an off-the-shelf kit of parts allowing private teams to develop a front- or mid-engined car around them. At its heart is an unbranded 4.5-litre V8 engine. However, the supply of this engine has dried up and the series is now looking for a supplier of a new low cost, lightweight engine capable of producing around 450bhp.

Meanwhile, in JAF GT300 a rule change has been introduced which forces all cars to run their engines in the same location as the production cars they are based on (already a rule in GT3 and Mother Chassis). This has essentially outlawed the popular Toyota Prius, built by the small apr team in Atsugi, Japan with some works backing, as it has a mid- mounted Toyota LMP1 V8. But the team is thought to be now working on another version of the Prius which will have a front-mounted engine sourced from the Lexus RCF GT3.

The apr Toyota Prius that races in the JAF GT300 class has fallen foul of a regulation change that calls for engines to be in production car locations, which means it can no longer use its mid-mounted LMP1 V8

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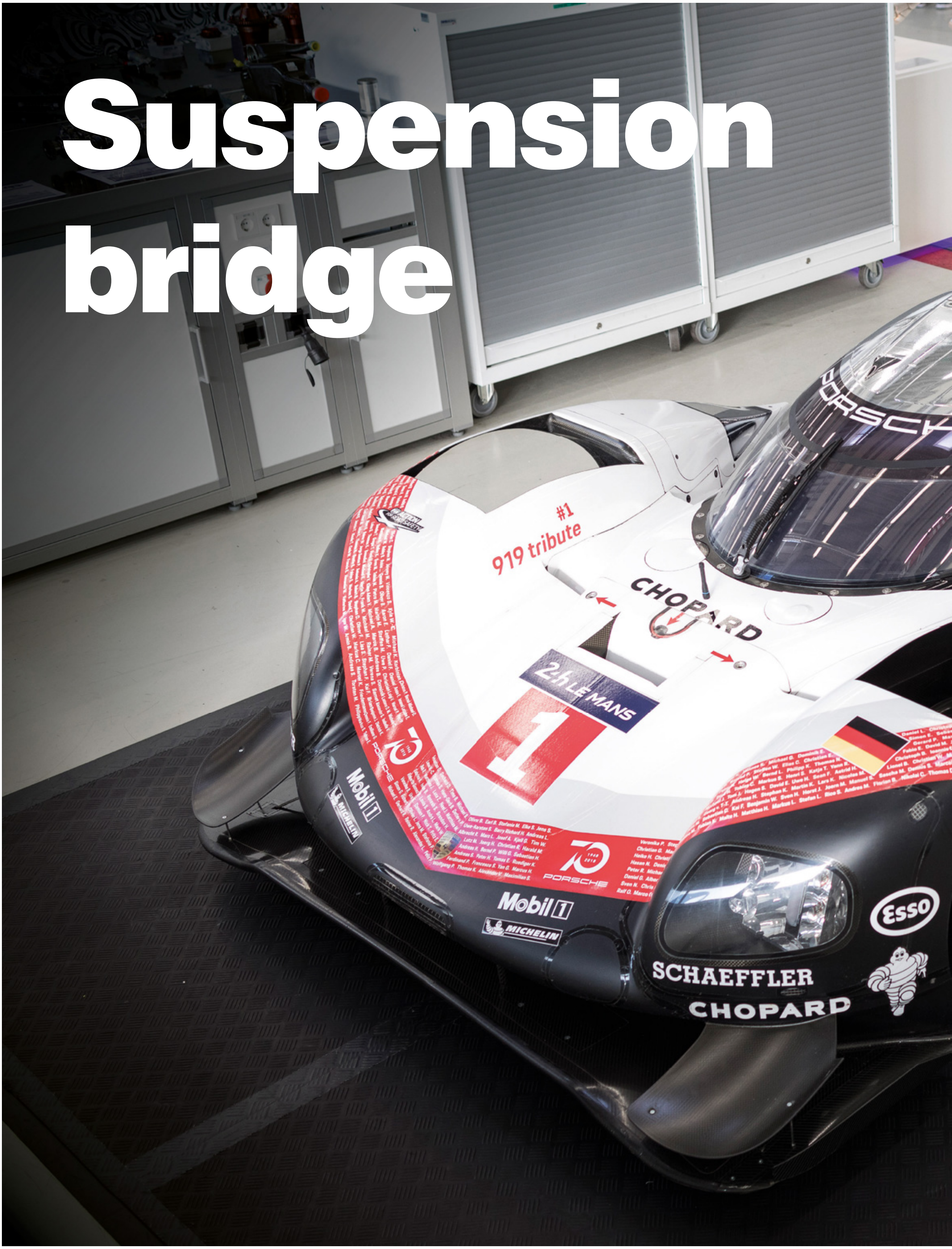
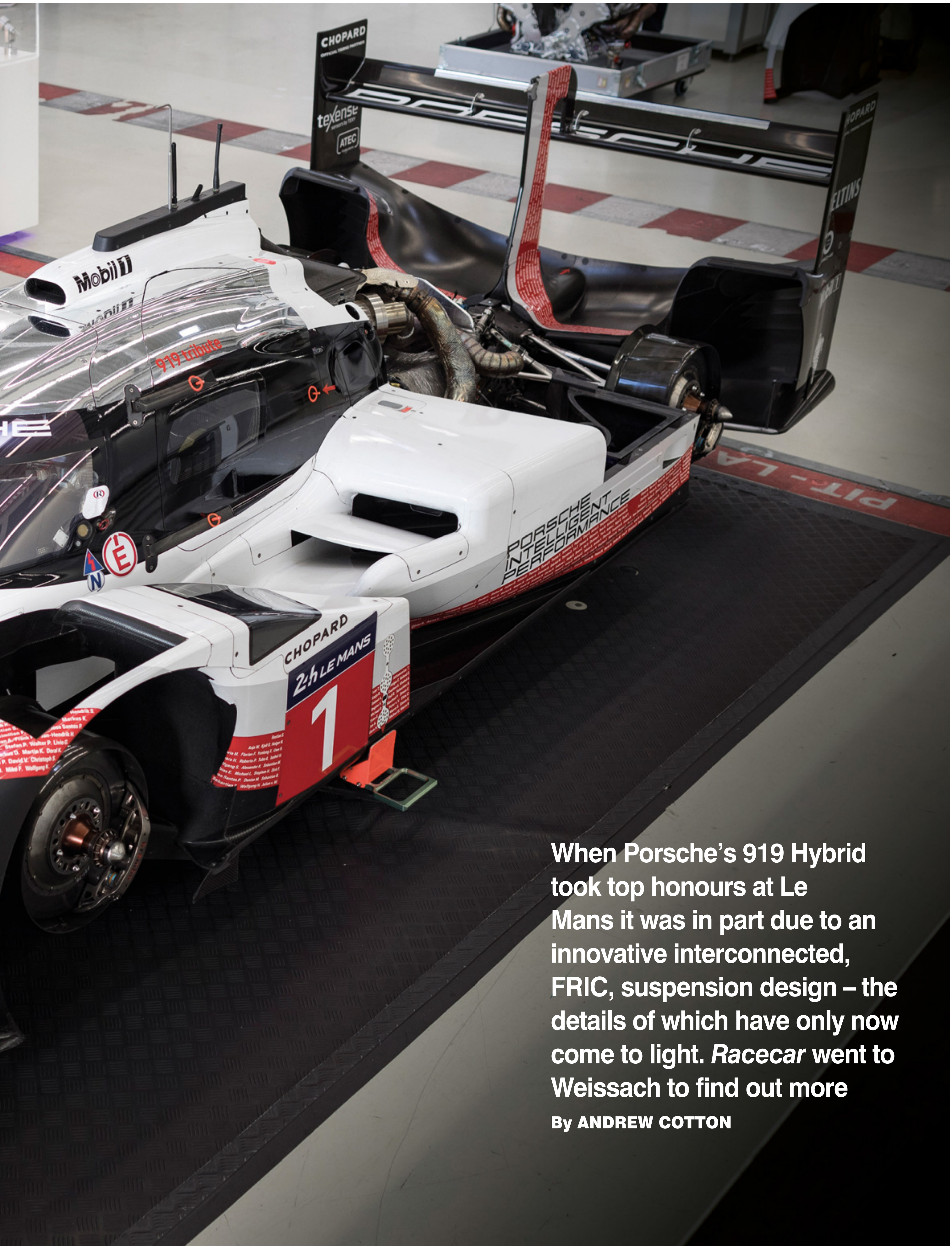
Suspension bridge





When Porsche's 919 Hybrid took top honours at Le Mans it was in part due to an innovative interconnected, FRIC, suspension design – the details of which have only now come to light. *Racecar* went to Weissach to find out more

By ANDREW COTTON

When the regulations for the new LMP1 hybrid category were released for 2014 the rules around the suspension system were extremely open. Adjustments forbidden from inside the cockpit included springs, shocks and anti-roll bars, an anti-intrusion bar had to be fitted at the base of the front suspension wishbones if these were potentially dangerous to a driver's legs, and there were some loose regulations surrounding materials and basic design parameters. Active suspension was banned elsewhere in the regulations, but otherwise the key word when it came to the suspension was 'free'. That left the manufacturer teams with plenty of options; including FRIC, which was later banned in F1.

Balance of power

The cars were balanced according to the maximum potential of the technology; the gasoline cars from Porsche and Toyota were balanced together according to the best performing of the two, while Audi campaigned a diesel alone. The k-factor allowed for the extra weight of the diesel engine compared to the lightweight gasoline engines. In year one, none of the manufacturers managed to make it in to the top 8MJ category; Porsche and Toyota raced in 6MJ, Audi in the 2MJ category.

The cars weighed 870kg regardless of which hybrid system they were using. Only the non-ERS cars from a non-manufacturer raced lighter, at 850kg. The FIA did not expect that manufacturers would be able to hit 8MJ so quickly, but by year two Porsche had stepped up, Toyota joining it a year later.

This was one of the most talked-about suspension systems since the Peugeot 908 HDi FAP

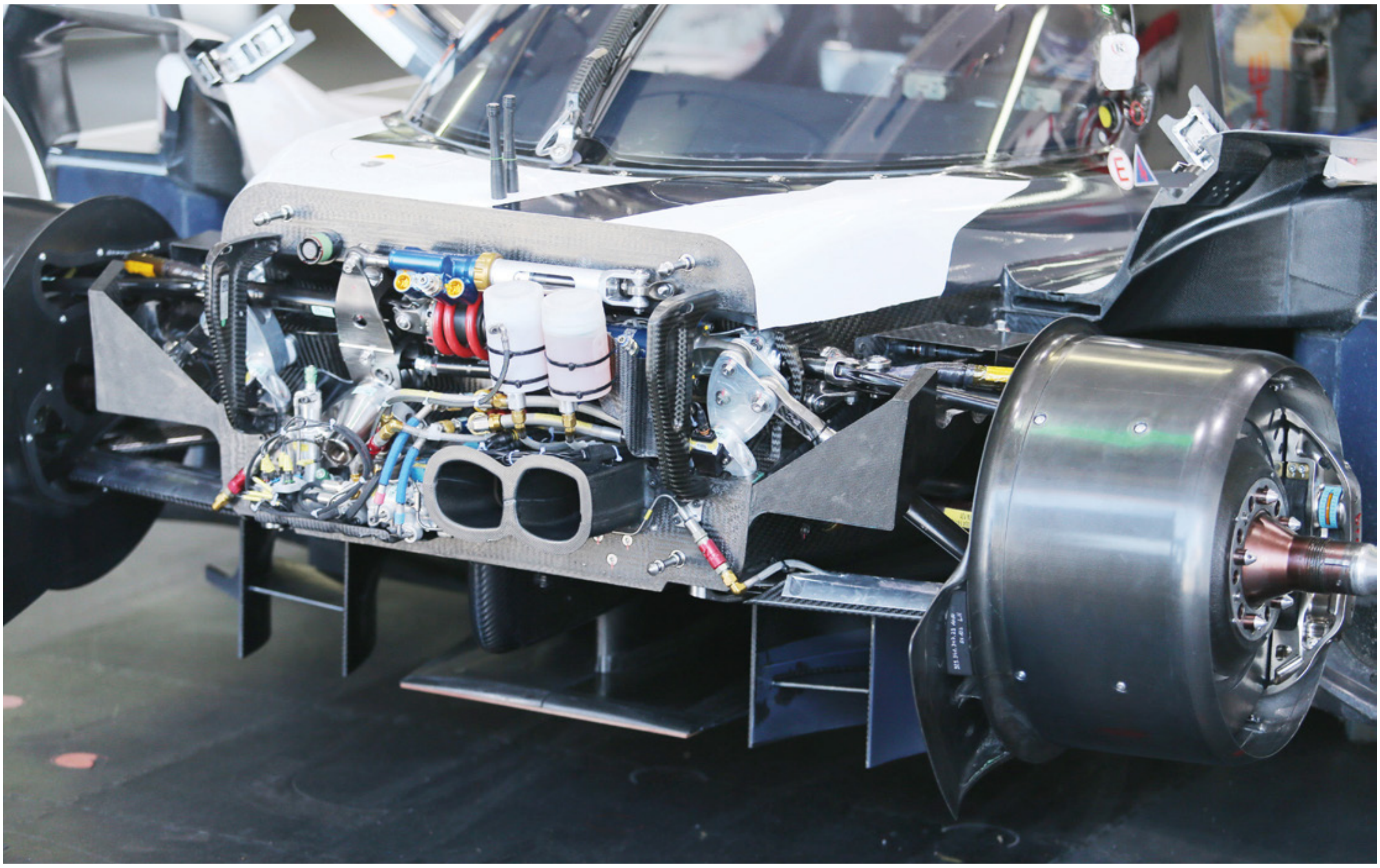
The battle between the manufacturers was extraordinary; not only on the engine front, but also the hybrid systems. And, then of course, there was the suspension.

With such freedom in the technical regulations it was actually a surprise when Porsche first showed drawings of its new 919 Hybrid in 2013 as one of the first things that was noticeable was the standard spring on the front suspension. It seemed unlikely that this would be in a prototype that would take the brand back into world championship racing against the might of Audi and Toyota, but Porsche confirmed that this was the case. Yet by the time the car turned up at the first round of the 2014 season, and the first spy pictures of the front suspension were published, it was clear that the standard spring concept had been abandoned.

In its place was one of the most talked-about suspension systems since the Peugeot 908 HDi FAP, a car that had handled very well. And the Porsche team was so secretive about its system that it was clear that something unusual was going on.

Unlike Peugeot, which actually just had a good set-up, Porsche had separated the heave and roll function from each other, allowing more adjustability into its system, and this also had the potential to give the car a more stable aero platform and therefore help its performance on track.

Below: Front suspension system on the Porsche separated roll and heave with mechanical rockers. This differed from the rear set-up due to reduced space in the nose



Porsche had separated the heave and roll function from each other in the 919's suspension, allowing more adjustability into the system

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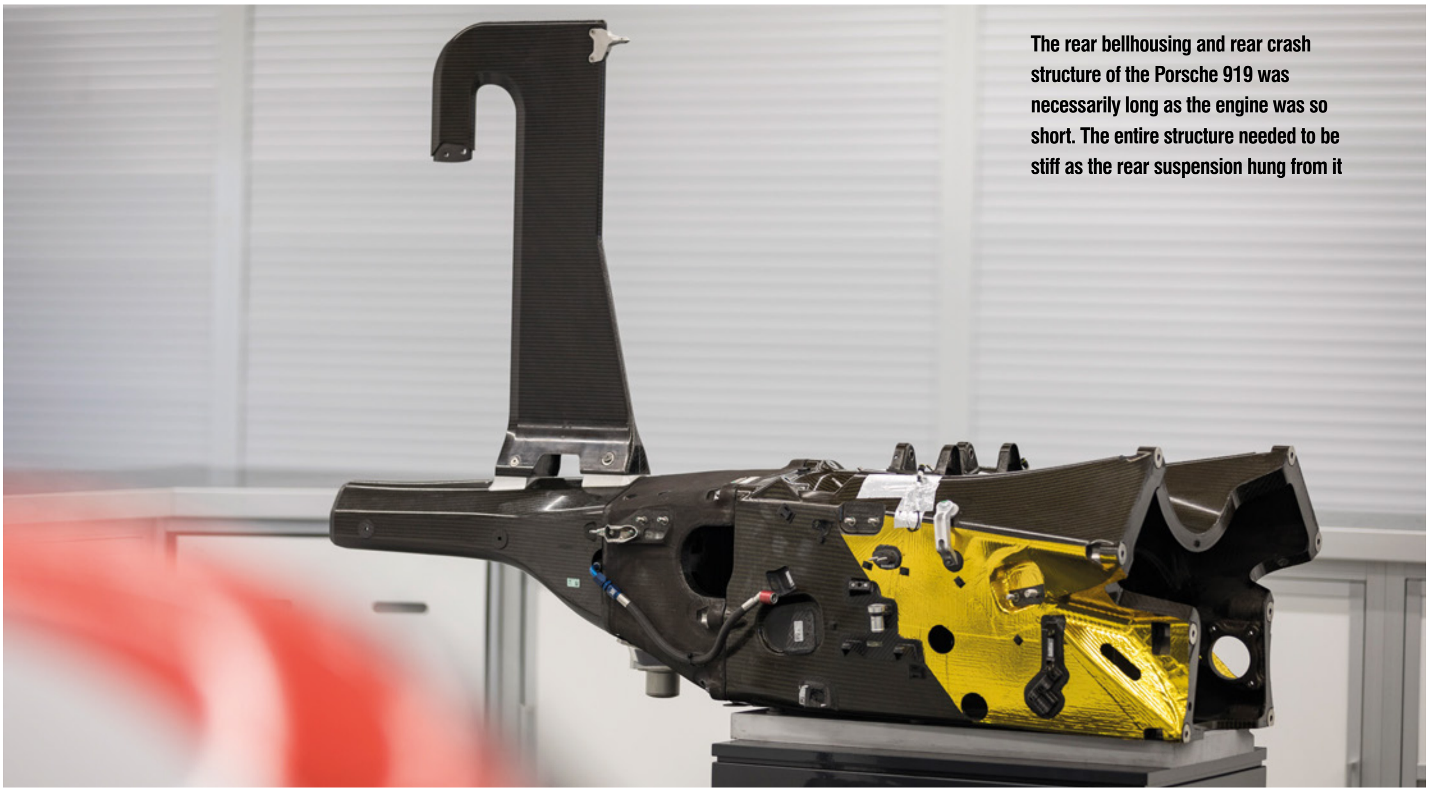


The rear bellhousing and rear crash structure of the Porsche 919 was necessarily long as the engine was so short. The entire structure needed to be stiff as the rear suspension hung from it

This was a relatively simple concept, one that has since been adopted by Formula Student teams in their cars, but to make it work effectively took some intensive development. By the time the Porsche 919 project had finished in 2017, the team had developed and introduced its FRIC (front to rear interconnected) system and had finally perfected it. What it hadn't perfected was the warp control; a system, incidentally, that Nissan had intended to use on its LMP1 programme in 2015, but ultimately it was designed out of the chassis.

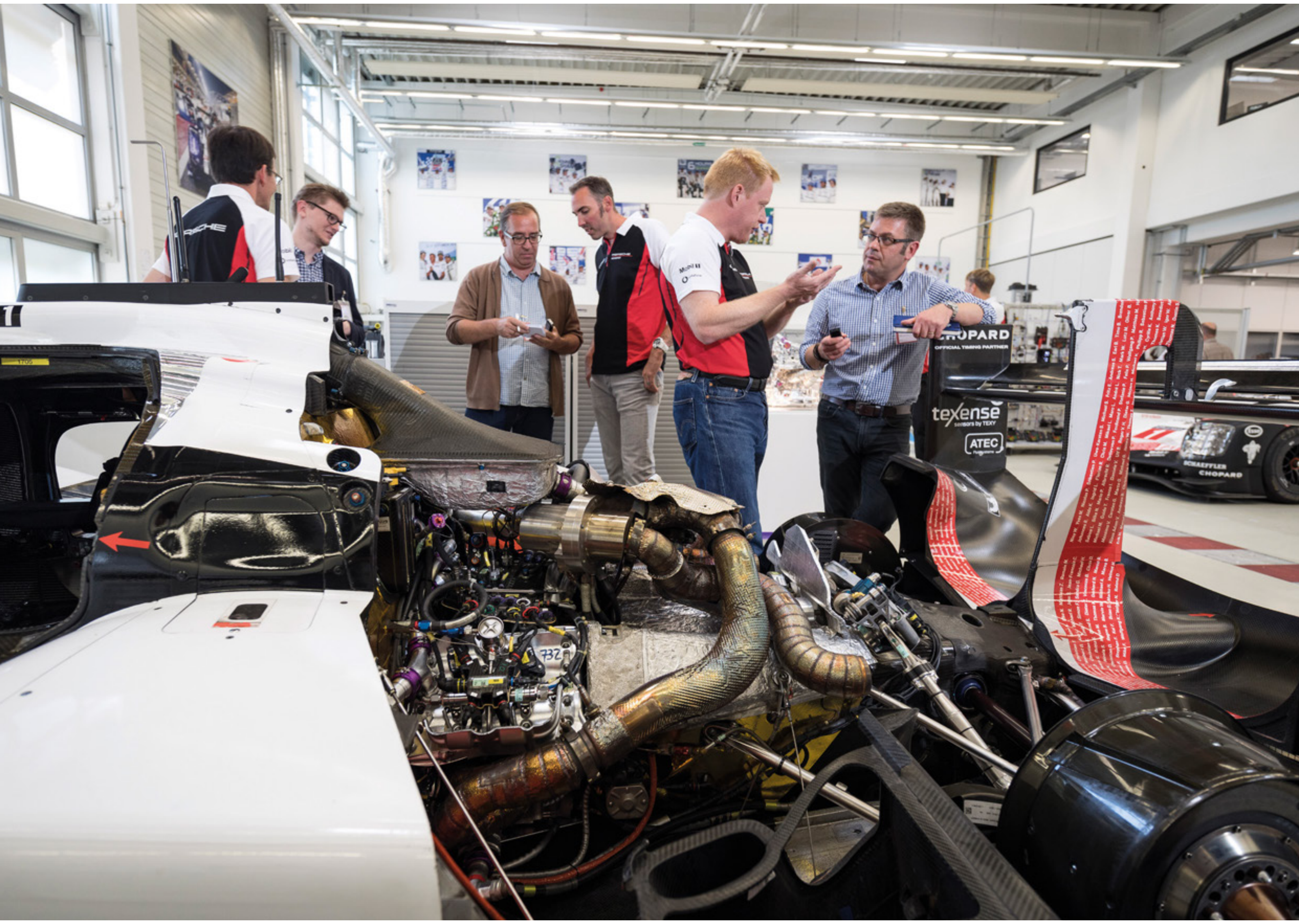
Nissan's system was mechanical and lightweight, but Porsche's warp control never made it to the final prototype as it was, apparently, rather large, ungainly and heavy. It was also considered not necessary for a circuit application as the modern race tracks on which the prototypes race are pretty much flat – warp control allows the suspension to follow the road more closely, with bumps, kerb strikes and so on better accommodated. The resultant weight and packaging issues outweighed the potential performance benefits of the device and thus the team did not pursue the concept further.

For the heave and roll function the process was entirely mechanical and relatively simple

Left: Georg von Tardy, senior engineer at Porsche, led the design team on many elements of the 919's suspension system

Heave and roll

For the heave and roll function the process was entirely mechanical and relatively simple in design and implementation. 'The pushrods connect to the rocker which is conventional motorsport,' explains Dr Georg von Tardy, senior engineer for Porsche, who led the suspension development team on items such as brakes, pedals, hub design and steering. 'What happens is that when



Porsche's 919 was the only LMP1 car to feature an exhaust energy recovery system, this was fed through the single turbocharger that sat on top of the 2-litre V4 engine

the car goes down under aero load, the rocker is working normally. We also have a spring element in parallel acting only on the vertical load on both sides, and then we have one which is installed diagonally so it connects to the upper side on one side to the lower side on the other and they work together. It is not active. If I have a rolling movement from side to side it is coming 100 per cent onto the other damper.'

Decoupling

That meant Porsche could control the stiffness and damping separately, for both heave and roll. Where the car could be softer in roll, or in heave, it could be tuned better than with an anti-roll bar, which caters for roll. 'Here, since we have all 100 per cent decoupling, we can do one or the other; that is the whole idea behind it,' says Tardy.

The front axle was a bit more complicated due to the constraints of space. Even though the rear suspension was limited by the rise of the diffuser under the floor, the front was more compact thanks in part to a front KERS.

'Here we have two rockers and we have one element between them,' says Tardy. 'That's working for the heave. But in parallel we have an intermediate see-saw element that is controlled from the outside and leads to the bottom and the top. When both move in the same direction it just performs the same and inside the middle elements there is a small rocker so it is a different mechanical system to decouple it, but the principle is the same as seen on the rear axle. At the front we did not have the space to use the diagonal alignment.'

The car was initially not launched with the FRIC system; that was introduced later, as two loops were needed to integrate it into the original racecar concept, a less than trivial exercise. 'The front and rear use a similar system in that it is a hydraulic linkage front to rear pitch link system,' says Tardy. 'We have a hydraulic cylinder acting on a spring, so the spring with the static load of the car will produce something like 70bar pressure in a hydraulic system. It is a bit like a spring in a hydraulic cylinder and we have hydraulic lines that go all the way to the front where we have a bigger cylinder that has less movement.'

On the level

The system was developed to minimise the front ride height variation throughout the lap to fundamentally maximise the aerodynamic performance of the racecar over that lap. Using a hydraulic line from

'In the lateral direction we use a mechanical link and in the longitudinal direction, where we have low frequencies, we use a hydraulic system'

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front to rear left a degree of latency in the system that had to be dialled out.

'With such a long hydraulic line there is a big damping factor and that means we can only control lower frequencies such as 3Hz, 2Hz or 0.5Hz as we would normally want because turns don't come that fast,' explains Tardy. 'In the lateral direction we use a mechanical link and in the longitudinal direction where we have low frequencies we use a hydraulic system.'

It is worth reminding ourselves here that Toyota developed a FRIC system too, and that it continues to run with such a system. That gives it the performance advantage over the privateers, who have yet to develop such a system in their ORECA, BR Engineering and Ginetta cars. These cars are, in year one, supposed to run at the same speed as the factory cars that have had more than six years of development, including the suspension systems. That has led to some frightening handling characteristics, with cars that work very much on the edge of performance with traditional suspension systems in the 900kg racers. But can these teams develop FRIC systems cost effectively?

'There are many different piston diameters and that means you need a very good whole car simulation to get it stable'

Porsche 919 Hybrid Evo

For the 2015 season Porsche introduced a new battery that was smaller and lighter than the previous incarnation, and was able to store enough energy that the team was able to move into the 8MJ hybrid system. Cooling was improved and the power was eventually limited by the FIA to 300kW per release in a bid to keep hybrid power boost under some kind of control.

The 'Evo' was a chance to show what could be produced by the last version of the power unit without redesign. While the aero was developed, the powertrain simply had the constraints of the regulations removed from it. That turned the car into one that would have been able to compete in the 11MJ category around the lap at Spa, with an increase of 50 per cent more power running through the system than was ever raced, although it has to be remembered that this was for only one lap, rather than a 24-hour race distance. 'The boosting power increased up to 340kW in the Evo,' says hybrid development engineer Jens Maurer. 'The hardware was the same as the WEC, and the engine too, only squeezing out what we could.'

The seriously impressive part of the Evo is the power from the engine, boosted from 517bhp to 720bhp from the 2-litre V4 turbocharged powerplant. Add to that a massive power boost from the hybrid system and the gross power rises to 1160bhp, almost one-third more than when it last raced. The hybrid development was stark, starting with the 6MJ category in 2014 and rising to the 8MJ top class in 2015 thanks to development of the battery, inverter and e-motors.

No holds barred

'We designed it to do 8MJ, and especially in Le Mans, but in the EoT table Le Mans was a factor of 1, and the others were 1.55, and this we were not able to do,' says Maurer. 'That was also the decision, to do the first year the safe way in Le Mans, and not push it to the limit. We developed a new e-motor, inverter and the battery, so we were confident to run in the 8MJ class. The motor was nearly the same from the beginning in terms of size and weight, but we increased the power, and later it was limited to 300kW, but in the recuperation we gained.'

Porsche's Exhaust ERS system was unique to the team, although it only worked at full boost pressure which meant that tracks with short straights would not allow for much recuperation from this system. That explains why Le Mans could have seen the car run in the 8MJ class. 'First you build up the boost pressure, then you start to recuperate,' says Maurer.

One criticism of the regulations was that the battery cell technology is not relevant to production cars, but Maurer believes that enough crossover of technology has happened under the 919 programme to make it worthwhile. 'You need a big amount of money to develop these cells, or you have a bigger and heavier battery,' he says.

The seriously impressive part of the Evo is the power from the 2-litre V4 turbocharged engine, which is boosted from 517bhp to 720bhp

'The pitfalls are that when you have to balance the rear and the front we do not over- or under-compensate, so there are many different piston diameters, and that means you need a very good whole car simulation to get it stable,' Tardy says. 'Then you also run into frequency problems, a feature of the Audi particularly from model year '16 where they bounced all the way down the straight. You need somebody to look after the damping systems and take out high frequencies. I would say that every damping supplier would be able to produce and supply parts, but the ratios needed between front and rear depends on how well the cars are able to use this simulation, but [just] on the track you cannot do it.'

'If you bought an LMP1 racecar then it would definitely be more difficult to optimise the use of such a system'

That would mean that the cars would need extensive CFD and wind tunnel work to perfect such a system. Yet the ORECA, for example, is based on the design campaigned by the Rebellion team in 2014, so still to the current regulations, but overweight in the first place, and designed before even Porsche perfected its FRIC system.

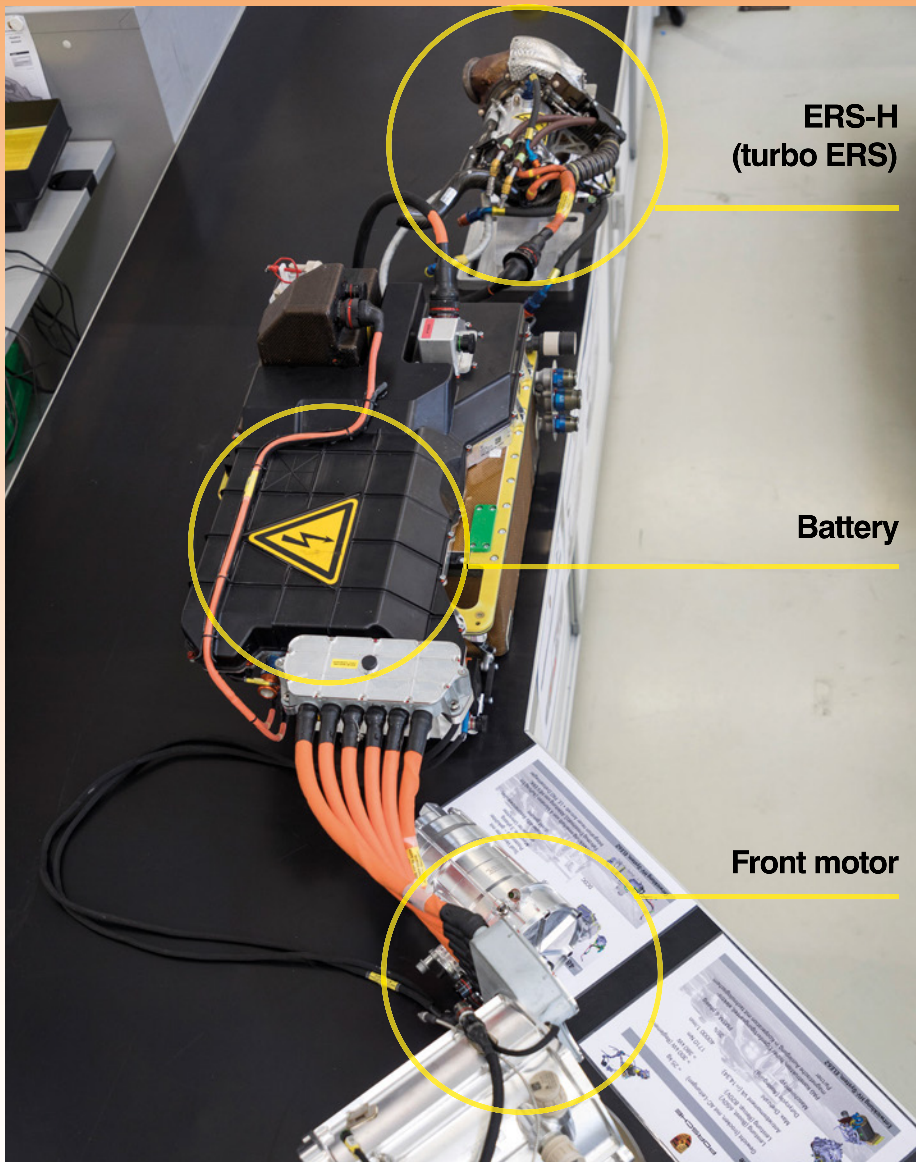
'You have to find the right ratios such as how much to bring the front axle up and how it interlinks with the driving dynamics,'

'If the regulations were different in Le Mans, that you were allowed to run more power and energy through the system, then you design the battery differently, but it was by regulation that the cells developed in this direction.

'You can still use the cell connection, the cooling, the e-motor, the magnets, the concept, the electronics, the chips and so on in a road car, but you cannot copy this system directly to a road car,' Maurer adds. 'The turbo technology would be difficult because you normally only use this turbine when you turn the boost pressure up to the maximum, and often you are not running at maximum pressure in a road car with the wastegate open.'

Meanwhile, Porsche has taken its e-motor and inverter technology forward into its Formula E programme. It doesn't currently have an opportunity to do its own batteries in the series, but that could come later.

The Evo version of the 919 set lap records at Spa and the Nurburgring running outside WEC spec



Porsche's hybrid system was heavily developed throughout the programme. It had a lighter battery – designed by Porsche with cells built by A123 – was more powerful and, without the constraint of regulations, over a single lap at Spa it could store 11MJ

The wind tunnel model of the 919. Porsche used its own wind tunnel in Weissach for aero development, which continued right up to when the project ended abruptly in 2017

While the Audi was nimble, the Porsche was renowned among the drivers for being more robust, and the results seemed to prove this

says Tardy. 'You can narrow the range of options if you know the range where you go, and [if] you have two or three different pistons and characteristics involved you will find your way pretty fast. Since it is a passive system you are not allowed to interact with it from the outside and it has to be stable in any condition.

'A comprehensive understanding of the car is required to extract the most out of the system,' Tardy adds. 'Since we designed and developed the entire car ourselves this process was fairly easy for us. If you buy a car it would definitely be more difficult to optimise the use of such a system.'

Porsche ran two programmes in the WEC; GTE and LMP1. As it was pitted against sister firm Audi in the top class it was only a matter of time before one of these would be dropped, and LMP1 was especially vulnerable

New horizons

While the Audi was nimble, the Porsche was renowned among the drivers for being more robust. Ultimately, this Porsche was not the fastest in many conditions, but it was very often the most effective.

Toyota may have produced faster cars in some years, Audi in others, but it was always the Porsche that held together and delivered the results. With that in mind, it was a shame to see the cars stripped bare and with nowhere else to go at Weissach. This exercise in suspension development was a case of 'how fast can you afford to go?' And so, it seems, it is still the case at Toyota. For the new regulations in 2020, it must either reject such extreme systems, or its domination will continue into the next era, leaving the privateers still wanting for pace against this highly developed suspension system.

Porsche's team, meanwhile, is moving on to different challenges, notably developing the powertrain for the Formula E racecar that the manufacturer hopes will be more relevant to the future of production cars.

Porsche's LMP sportscar racing operation is currently in the process of being trimmed from 260 to a more manageable number for Formula E for the 2020/21 season, so there is as yet no crossover of minds from the Taycan electric road car programme to the electric single seater series. But there will certainly will be some crossover in the other direction in the future, as Porsche continues to spread its learning from motor racing through its production car range.

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Taking adVantage

The new chassis is, says Aston Martin, twice as stiff as the old car, which helps in all areas

When it came to replacing its successful GT3 car Aston Martin needed to look only as far as its current GTE contender for inspiration – but that was just the start of the story for the all-new Vantage

By ANDREW COTTON

It's enjoyed seven successful years with the V12-powered Vantage GT3, but now Aston Martin Racing (AMR) has introduced a new version of the Vantage model, and it is a significant step for the British manufacturer. It's also significant for GT3, as along with new cars from both Porsche and McLaren, this is the third new GT3 model introduced this year, highlighting the strength of the category.

The rise of GT3 racing since the Vantage V12 first raced in 2012, when the Blancpain Series was in its infancy and there was no global GT3 racing platform, has indeed been extraordinary. There are now more than 1500 current spec GT3 cars racing around the world.

Back in 2012 the so-called convergence talks between the GTE and GT3 categories was not under consideration, of course, but they have had an impact on this new car. These talks were about allowing common components to be used between the factory racing programmes of GTE and the customer racing GT3s, but this was opposed by GT3 founder Stephane Ratel, as he could see the price of his GT3 cars rising as more expensive technology was introduced into them. It was a threat to his GT3 business, and so he nixed the idea. But the main obstacle to convergence was that GTE manufacturers wanted to use race engines in GT3, and GT3 manufacturers wanted to use production-based engines in GTE. No agreement could be found.

Shared values

Manufacturers went away and tried again, and produced a list of components that could be shared between the two cars, including the chassis, but not the engine, which remains a separate development programme. Incidentally, GTE cars are still balanced using air restrictors and now also by controlling turbo boost pressures, aping GT3, which is also balanced by the shape of the torque curve.

With the new Vantage, Aston Martin has taken advantage of this new convergence agreement, maintaining chassis commonality, as well as major items such as the Xtrac transverse gearbox, electronics, suspension and brakes. There are small differences, of course; the brakes for the customer car require ABS, and the software package from Cosworth is not as advanced as it is in the GTE, but there is more to this than reducing development time. 'GTE is small volumes,' says Aston Martin Racing (Prodrive) technical director Dan Sayers. 'If we can tie on GT3 quantities, it makes everything easier, including stock control and customers swapping between the two specs. The [gearbox] is an expensive component, and if we have more in our pool, it makes serviceability much easier, and we can rotate better for rebuilds.'

Testing has already begun, and it's raced in the VLN, while cars have been put in the hands of trusted amateurs to gain feedback before final sign off. Focus has been on making the car more drivable, a common need identified by all the manufacturers who clearly realise that the current breed of GT3 is now beyond the amateur driver. Even in professional hands an easier car to drive reduces the possibility of mistakes, and can improve tyre wear.

Stiffer chassis

The Aston Martin design team has carried over the lightweight aluminium chassis from the production car, as used in the GTE car launched late last year, moving away from the modular layout of the old car – which enabled easier fixing after major crashes. The new chassis is, says Aston Martin, twice as stiff as the old car, which helps in all areas. 'They are quite close,' says Sayers of the GTE and GT3 cars. 'With the numbers that we are producing they have to be, for economies of scale. Chassis-wise there are a lot of common components. The big differences are bodywork, to comply with the GT committee and the GT regulations that are quite different, and the engine. The rest is pretty common between the two cars. The brakes are common, but there is ABS on the GT3, obviously, but hardware-wise that is still the same.'

New safety regulations have to be incorporated into the car. These include the latest seat, fixed to the chassis rather than on sliding runners for different driver sizes (with an adjustable pedal box), the latest harnesses, and energy-absorbent foam in the driver's door. The new GT3 cars also have anti-intrusion panels along the length of the driver's door. Aston's is

QUICK SPEC: Aston Martin Vantage GT3

Chassis
Lightweight aluminium chassis; steel FIA spec roll cage

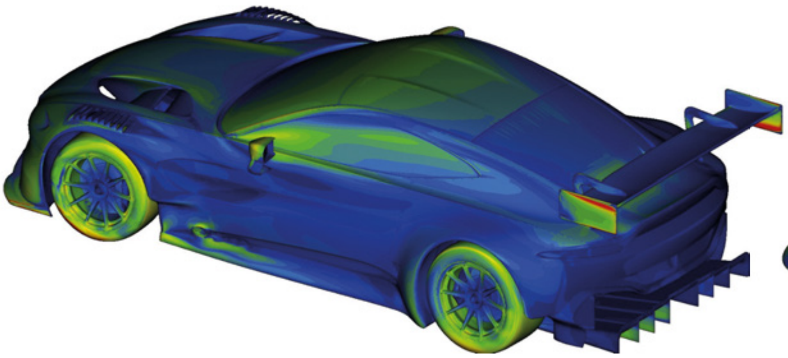
Engine
AMG turbocharged 4-litre V8; Borg Warner turbos

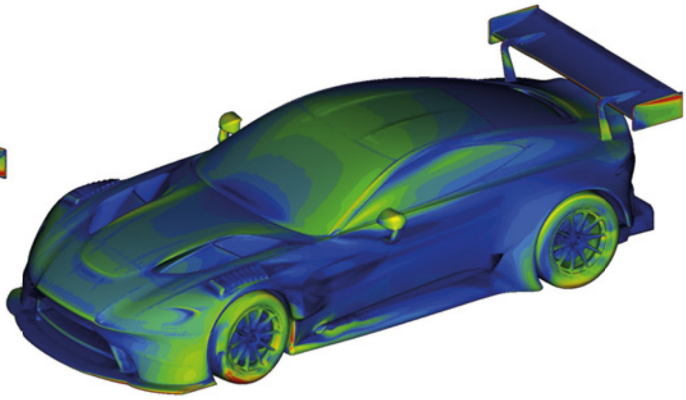
Transmission
Rear wheel drive with traction control;
Xtrac 6-speed sequential gearbox

Suspension
Double wishbone front and rear; Ohlins dampers

Brakes
Alcon with ABS

One of the big advances over the old car has been in the aero





The way the rear wing works with the diffuser and splitter has been the focus of the aero development

fixed to the chassis, and the team has plans to introduce that feature to its GTE. 'No one wants to scrimp on safety, but it does bump the price of the cars up,' says Sayers. 'For GT4, you want to put them in, but the cost cap hasn't moved, and the safety elements push the cost up a few thousand each time. That is a struggle, but I think that we have done a reasonable job so far.'

Turbo power

The new car features the Mercedes AMG 4-litre V8 turbo, as in the GTE car. Clearly, the changes to it are far smaller, but it still required work to make it competitive. 'It is the same base engine, but it is more production-based,' says Sayers. 'We still have the same turbos as GTE, because of the boost levels that you have to run, but the hardware is basically the base engine with a dry sump on it. There has been no machining of the heads, different valves or anything like that; it is production. To compete in the market place you have to keep things as cost effective as you can.'

This is a more modern engine than the outgoing version, and Prodrive has had less to do to it to make it competitive, helping to reduce the costs while increased service mileage is also on the cards. 'Previously we have been between 6-7000km for engines, and we need to get that well beyond 10,000. We have a 30-hour test, and we can't see any reason why we cannot improve that considerably,' Sayers says.

One of the striking features of the GTE version of the car is the lack of space in the engine bay, leaving little room to work. Prodrive figured that with cars so reliable and effectively performance balanced, any drama during the race will be catastrophic to the end result anyway, and to a certain extent the same is true in GT3. 'If you look at any GT3 race now, a huge number make it through without a problem and you cannot afford to have a problem at all, be it your brakes wearing out quickly, or more quickly than you would expect for a 24-hour race, bodywork damage or whatever,' says Sayers. 'I think the main parts are relatively straightforward to change, so quick release

The GT3 recently made its race debut in a VLN round on the Nurburgring Nordschleife, where it performed very well indeed

pads, so that brake changes are relatively quick, even though a lot of sporting regulations are changing to remove the importance of changing quickly.' Indeed, technical pit stops were introduced into the Spa 24 hours this year to combat expensive quick-fit solutions, and that reduces the pressure on the teams to do the brakes in less than one minute.

Aerodynamics

One of the big advances over the old car has been in the aero. The new chassis has forced a major change, but the team was already aware of the old car's deficiencies and has addressed them. Using lessons learned from the GTE programme, and adapting to the new regulations, it says that this car is far more efficient. 'The relationship between the splitter and the diffuser is quite different,' explains Sayers. 'The diffuser is smaller due to the regulations, so the wing does more than the GTE wing. It is more powerful, so has to balance out.'

The aero has been developed in CFD, and will be mapped in the Sauber wind tunnel as the FIA moves away from the sole reliance on the Ladoux test facility in France. 'We are targeting homologation by January 1, but that is going to be tough,' admits Sayers. 'The aero tests will be in November, and if there are any changes required, it doesn't give you much time to sign off and validate your components. The engine test and wind tunnel are instead of Ladoux. We are not anticipating going there. I think there will be validation tests between all three to make sure that [this new approach] is viable. There is a bit of flux at the moment.'

The front wheel arch design is pretty similar to the GTE car, Aston says, directing the airflow more effectively and efficiently to help improve the downforce. The design team has paid for this

'To compete in the GT3 market place you have to keep things as cost effective as you can'

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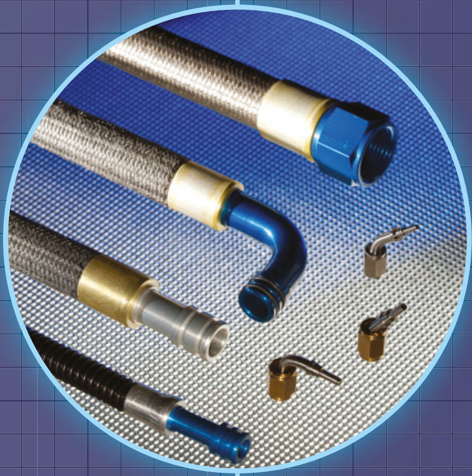

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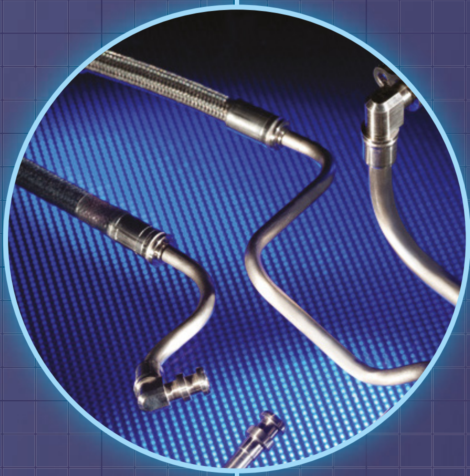

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a little with some extra drag, but says that their design should be able to hit the 270-280km/h (168-174mph) V-max target, which is another area where the old car struggled.

Prodrive has carried over the Alcon brakes from the GTE, because of the improvements in performance it's found there.

The tyre choices are pretty much the Pirelli D2 around the world, now, as the major GT racing series adopt the SRO's GT balance of performance, although series such as the VLN still have open tyre choice. This is a major change from the Michelin tyres on the GTE car, but there is enough adjustability already designed into the suspension that it does

'If you give the amateur drivers confidence, that is where the lap time comes from'

not require a big change of hardware. The relationship with Ohlins continues, although the dampers are at a lower spec than GTE.

'Historically our car has been good on its tyres, but that comes from being easy to drive, so there are no lock ups even without the ABS [in GTE],' says Sayers. 'With the am [amateur] driver you can get seconds out of them per lap if you have a car that is easy to drive. It has to be nice to drive for the am, and that is what we focus on, which is a slight challenge because the base car comes from a GTE. It has to be nice to drive, gearshifts have to be nice, nothing unsettled, and if you give them confidence, that is where the lap time comes from.

'The old car has been renowned for being easy to drive,' Sayers adds. 'It just goes to show how long they can be around for, and that is the advantage of BoP, to have a seven year old car. It does work, and our philosophy was right then, and is right this time. So, easy to drive, and for a sensible period. That is key.'

Although downforce gains have meant a small drag penalty AMR says new GT3 has better straightline speed than old car

Update kit

The car can be adapted to run in either the GT3 or the GTE configuration, although the complete update kit is slightly larger than had been anticipated. The adaptation is pretty much dampers, bodywork and engine, and it also costs more than had been anticipated.

The team plans to sell 40 to 50 cars over the next four years, and up to 150 GT4s (see box out). Prodrive is not, says Sayers, geared up to produce 70 cars per year and so the numbers are limited. The minimum requirement is to sell 20 cars in the first two years, a move designed to prevent 'specials' being produced. This, says Aston Martin, should not be a problem.

The cost of the car is £425,000 (€483,000), which is high to mid-range for a GT3, but Aston Martin hopes that, with reliability, serviceability, speed and comfort, the car will sell well in what is a very competitive market.

Wheels of 4-tune

Housed in a corner of the workshop when *Racecar* visited the Prodrive facility was Aston Martin's new GT4 model, engine out after validation tests, but otherwise pretty much ready for action. The car is far more production based than the GT3, and therefore the differences between it and the GTE are also far greater.

The lightweight, stiff chassis has been used once again, but there the similarities pretty much end. 'The chassis stiffness is so much better, but we have a production transmission in there, and it is being calibrated through specialist software for track use,' says Sayers. 'It is a stock engine, and we are using the production turbos due to cost. We have included the standard safety features, so the door foam and so on, and an ATL fuel cell, same as the others, but this is not a bag tank. This is a plastic spun tank, so more cost effective but the same standards. There are completely different suspension mountings, but the sub frames are all production.

'We had to change the rear suspension because you cannot package the brake and suspension components in an 18-inch wheel,' Sayers adds. 'The production cars are going to larger wheels, the suspension fills the void, and then you put an 18-inch rim on, it doesn't go in, so we had to change the kinematics. It is a production steering rack, calibrated for race use. The aero has been done in-house. The previous car struggled for downforce everywhere and it has been around for seven years. V-max was always quite good on this car because there was not much downforce, but now we have added downforce, yet it is still quite efficient because it is not full width and doesn't have all the aero features [of the GT3 car] so we don't envisage any issues there. Again, with the engine you have all the power on tap, which is the benefit of the turbocharged engines.

'There is even more headroom [performance development potential], and that is what we have built into all these racecars,' Sayers says. 'You have to build that in, so you have to take a judgement call on the mass of the vehicle, so if they decide to make it lighter [when balancing the performance] then there is scope to do that.'

The car uses Bosch electronics, mainly due to engine transmission interface and calibration, which is not straightforward. It also features an adjustable pedal box, as do the GTE and GT3 cars.

The brakes are by Alcon and Aston Martin Racing believes that this racecar should be good out of the box, due to the development that has already taken place on the GTE and GT3 versions of the car that it has been able to carry over to the GT4.

The new Aston Martin GT4 benefits from the same lightweight chassis as the GTE and GT3 but makes use of far more production parts


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Safe and sound

The introduction of the Halo this year was aesthetically, technically and philosophically controversial, yet it's already saved one F1 driver from serious injury or possibly worse. But it's only when you see the level of technology that goes into its manufacture that you realise why it's so effective

By GEMMA HATTON

The controversies surrounding F1's Halo have simmered down since the safety device protected Charles Leclerc when Fernando Alonso's car was launched over the top of his cockpit at this year's Belgium GP, and it's easy to see why.

'When you watch the video frame by frame you can see the McLaren's suspension was broken by the contact with the Halo, so with our data and that knowledge we have estimated it took a 56kN load, about half of what the test load is,' FIA race director Charlie Whiting has said of the incident. 'It stood up really well and there was no distortion of the Halo. Sauber took it off the car after the crash and thoroughly checked it but there were no cracks and no buckling.'

So now that the Halo has proved itself, it's time to unearth the technology behind this device; a piece of kit which can withstand 15 times the static load of a Formula 1 car and the hit of a 20Kg wheel at 225km/h.

The Halo has proved its worth in recent accidents. The secret to this device being able to withstand the static load of 15 times a Formula 1 car lies within its hi-tech manufacturing process

The FIA has been investigating additional frontal protection devices since 2011, ranging from a full canopy to having roll bar-like devices ahead of the car. From these early design iterations, three were pursued and developed to try and meet the initial design target of deflecting a wheel at 225km/h.

These were the Halo, the Shield and the Aeroscreen. We are now all familiar with the three-pronged tubular titanium structure of the Halo; the shield is effectively a windscreen made from transparent polycarbonate, while the Aeroscreen hybrid consists of structural carbon and transparent polycarbonate.

The Halo effect

To determine how effective each of these devices were in protecting the driver the FIA developed an array of safety tests. The R&D campaign involved extensive full-scale dynamic testing, conducted at RAF Bentwaters. The final tests for evaluating the chassis and attachment points include applying a load of 125kN vertically downward and rearwards followed by a load of 125kN sideways and rearwards.

In addition to this, prototypes of all three were tested on real cars, with Red Bull running the Aeroscreen during the Russian Grand Prix meeting back in 2016, while all the other Formula 1 teams tested the Halo in 2016 and Ferrari tested the Shield at Silverstone in 2017. The screen solutions were extremely promising but required further R&D to optimise the optical performance and minimise reflection, particularly during night races.

Further FIA investigations also looked into past accidents, simulating the scenarios with the Halo fitted to see whether having this would have changed the outcome of these events. Out of the case studies analysed, the vast majority showed that the Halo would have reduced the amount and severity of driver injuries, while the remaining scenarios had a neutral effect.

After this intense and long investigation, the FIA concluded that the Halo solution offered the most frontal protection for the driver. However, across the pond, IndyCar has been developing a different solution in the form of a screen – similar to the shield tested by Ferrari. This sparked a heated debate between motorsport

Out of the case studies analysed, the vast majority showed that the Halo would have reduced the severity of the driver's injuries

The alternatives to Halo were the Aeroscreen (left) and Shield. These might look nicer, but neither could withstand the impact of a 20kg wheel at 225km/h quite as well as the Halo

To ensure the titanium maintains its high performance throughout the bending process the bend speed needs to be relatively slow and consistent

enthusiasts worldwide as IndyCar's screen is undoubtedly more aesthetically pleasing. But the question remains; is it safer?

'We do work closely with our friends in the USA, you have seen what they have been testing, but what we have seen with the accident in Spa is that kind of thing would not have been nearly as effective, it would probably only offer about 10 per cent of the protection that Halo offers,' Whiting says. 'So we will be talking with the IndyCar guys about that as I think that there are lessons we can both learn.'

Deflecting debris

This supports the theory that both devices are actually designed to offer slightly different types of protection. The brutal impact tests for Formula 1's Halo illustrate how this structure needs to withstand huge loads, whether that be a barrier, wheel or another racecar. Whereas, the screen arguably protects the driver from smaller loads such as debris. However, the FIA claims that, statistically, the Halo does still protect the driver from small debris, but the nature of having a screen surrounding the cockpit provides fuller coverage.

The impacts of smaller debris can also be minimised in other ways, such as improving helmet safety, something which was done immediately after Felipe Massa's 2009 accident in Hungary, where a 833g spring from a car in front hit the top of his visor, leaving him with a serious head injury. More recently the FIA has worked with the helmet makers to integrate this protection into the helmet. A new version of FIA8860 was finalised in 2018 and the new helmets will be mandated in F1 and F2 in 2019.

IndyCar also has different demands in terms of the driver's view to think about. 'In terms of visibility, on circuits that are relatively flat, the Halo does not overly limit it, but on circuits such as Spa, visibility could be a bit more challenging,' says Daniel Chilcott, managing director of SST, which supplies Formula 1 and Formula E teams with the Halo. 'I think IndyCar are not so keen on the Halo because it will visually impair where the driver is looking to go on the oval tracks, which is probably why they are exploring the screen concept more.'

Sturdy structure

Today, the Halo is on the F1 and F2 grids and will debut in Formula E in December. As it continues to filter down to other championships and therefore improve the safety of drivers in all formulae, it is time to accept the Halo and appreciate that one day it may save lives. But

The Halo is actually made up of five parts. These are two bent tubes, the V-transition and two rear mounts, all of which have to be welded together to form the device

This titanium structure, weighing only 7kg, needs to withstand the weight of two African elephants

to do that, this titanium structure, weighing only 7kg, needs to withstand the weight of two African elephants, and the secret to its success lies with the way it's manufactured.

'The key elements of the Halo are the front section at the centre which is called the "V transition" and then there is the tube around the cockpit and also the rear mounts,' explains Chilcott. 'The tube is effectively a titanium bar, Grade 5 6AL4V, and because a non-standard tube was selected we had to gun drill the bar and then turn the outer diameter before it could be bent. In our early designs we actually bent one piece of tube the full 180 degrees because we felt that was the best and most elegant solution. However, we found that because of the tolerances required between the rear mounts and the main Halo structure, a single piece didn't allow any ability for adjustment. So, it is actually made from two tube sections that are welded together.'

Tube bending

To ensure the titanium maintains its high performance throughout the bending process, the speed needs to be relatively slow and consistent. 'The only reason we are able to do that is because we use a fully electric tube bending machine,' says Chilcott. 'It applies the same amount of torque throughout the process, achieving a proportional bend. Whereas a hydraulic machine may not be able to apply a consistent load, leading to breakages.'

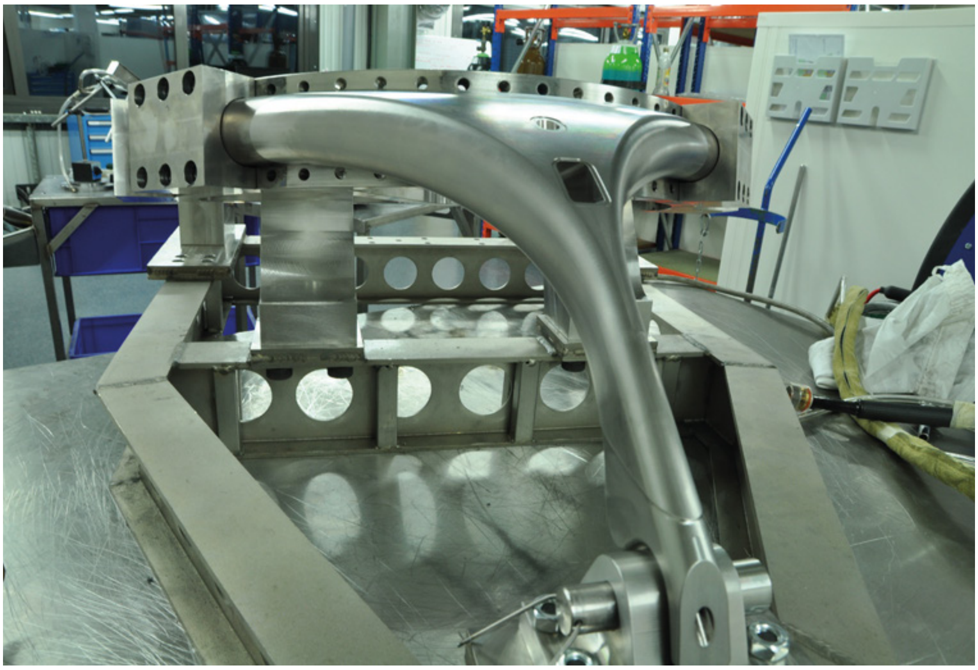
SST did investigate the application of hot bending. But heating the titanium oxidises the surface which consequently has to be removed and so to avoid this cold bending was chosen despite the fact that the tube has to be bent over a much longer period of time. There is also the issue of spring-back, so the tubes are actually bent further than they need to be, so that they relax-back into the desired position.

The V transition along with the rear mounts are machined from titanium billet using a Mazak 3- and 5-axis milling machine, with the complexity and size of the V transition taking at least 40 hours to machine. Once the two tube sections have been bent and welded together, this join is allowed to cool and settle before being welded to the V transition.

'Titanium is actually quite a difficult material to work with, so when you are welding it, you need to shield it in a particular way,' explains Chilcott. 'We have developed a bespoke shroud technique, that we weld the parts within using a unique gas mix to ensure that the welds do not oxidise in any way, because this can change the properties of the weld.'

Final process

Once the tubes have been welded together, and then welded to the V transition, the rear mounts are then welded to the structure. The final manufacturing process is where the whole assembly is placed into another 5-axis milling machine where the part is machined to tolerance. 'The final machining process is critical because throughout manufacture the structure is heated which can lead to distortion and therefore affect the tolerance,' says Chilcott. 'The tolerance across the bolt-holes in the rear feet is 100 microns, which is a challenge on what is ultimately a fabricated structure. We address that by securing the Halo by the 'nose' and finish machine the rear mounts, and without this final process the Halo wouldn't fit to the chassis.'



Here the Halo is attached to an assembly fixture; this helps to maintain the accuracy of the device during its manufacture

A 5-axis milling machine is used to achieve the complex shape of the V transition. This intricate process usually takes around 40 hours to complete

Every Halo manufacturer has had to design and refine their processes to guarantee that the bolted interface at the rear mounts, as well as the front, meets the FIA's requirements. The Formula 1 teams themselves then use metallic inserts which they have to bond into the chassis, as well as compensators within the attachments to secure the Halo into place.

Many believe the Halo is made from carbon fibre, but although carbon fibre is strong it isn't able to deal with impacts very well. But Formula 1 teams do wrap the titanium structure in carbon fibre which allows for aerodynamic fairings to be bonded to it.

Aero fairings

To compensate for the obvious aerodynamic losses of the Halo, particularly into the airbox, the FIA permitted teams a 20mm volume of freedom in which they could develop fairings. At the beginning of the season some diverse solutions were seen, but now most teams have converged towards a one- or two-tier winglet-like fairing that sits on top of the main structure.

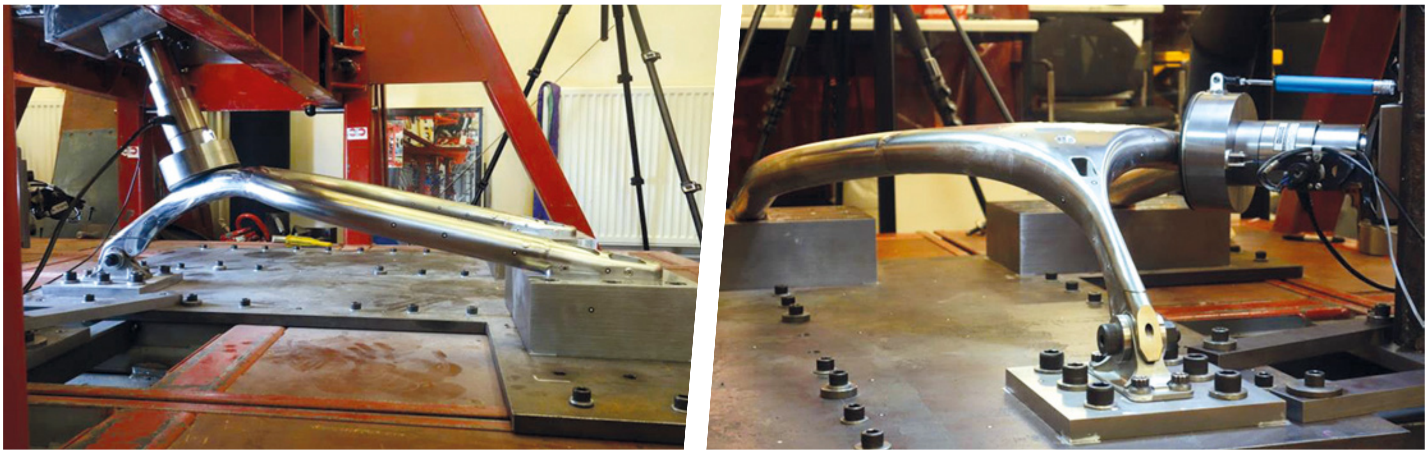
'When we were forming the Halo regulations, we agreed that fairings would be allowed so teams could try and adapt the aerodynamic influence as well as improving aesthetics and that's what every team has got,' says James Key, technical director at Scuderia Toro Rosso. 'You could have things forward of the Halo which influence the way it is behaving compared to now, but I don't think it's going to be a massive development. Because it's so visible everyone assumes it's a massive part of the car, but it's not the most influential.'

Aside from the aerodynamics, the Halo's weight has been another major factor. The FIA specified that manufacturers had to build the Halo to a weight between 6.85kg to 7.05kg. However, taking into account the adapters, as well as the increased strength required from the monocoque to pass the crash safety tests, and the additional weight increase in the chassis is estimated to be 12 to 13kg.

'That is one of the benefits of our Halo, because our design comes in at the bottom end of that tolerance window,' explains Chilcott. 'F1 teams are looking for every bit of weight saving and because the Halo is quite high up in the car,

Below: There's complex science behind bending titanium tubes. To achieve a proportional bend an electric bending machine is used, as this can apply more consistent loads than a hydraulic machine

Although carbon fibre is strong it isn't able to deal with impacts very well



Cranfield Impact Centre conducts the two static tests on the Halo; both involve impacts of 125kN. The test above right, with the load coming from the side, is the more difficult to pass

reducing its weight by a few grams can actually bring quite a major benefit to them.'

Once each Halo manufacturer has manufactured its design, the next challenge is to ensure it passes the load requirements of FIA8869-2018 and if not, to refine it until it does. Similar to how roll hoop testing is conducted, the Halo is first secured to a rig at the Cranfield Impact Centre where it undergoes two static impact tests so that the strength of the structure alone can be investigated. Once passed, the Halo suppliers become FIA approved.

When a Formula 1 team purchases its chosen design, the Halo is once again tested, only this time it is secured to the chassis in the factory and there must be 'no failure of any part of the survival cell or of any attachment between the structure and the survival cell'.

'We are the only test house that has been currently FIA approved to crash test the Halo,' says Jim Watson, engineering manager at Cranfield Impact Centre. 'The Halo testing consists of two static tests. For the first test, the load comes from above at an angle of 22.5-degrees and that is the more straightforward of the tests to do. The more difficult one is where the load comes in from the side. Both tests reach 125kN and then the load comes off, so we don't test the ultimate strength of the part, only to the required load specified in the regulations.'

Teething problems

Although it has only taken a few prototypes for each manufacture to pass these tests, there have been some minor failures that have had to be refined. These included small cracks near the welds, as the heat treatment made the titanium near the joints more brittle, and also failures surrounding the rear mounts which led to the distance between the weld and the bolt hole being extended for increased strength.

'The welding of the titanium has been the biggest challenge of all,' Watson says. 'Some of the prototypes had become too distorted through the heat treatment process and so they didn't conform to the size of the FIA standard. Therefore, we had to try and push them back into shape, but of course that can induce internal stresses.'

In addition to the titanium Halos in F1, F2 and now Formula E, we will also see the Halo being adopted in Formula 3, Formula 4, Super Formula and in any new single seater category hereafter. However, to control costs in F3 and F4, the Halos are made of steel rather than titanium. The FIA partnered with Crawford in USA and Tatuus in Italy to develop the steel version. The final weight is 13.5kg, almost twice the weight of the titanium variant.

'From a metallic standpoint, titanium is probably the ideal material for the Halo,' says Chilcott. 'If you went 100 per cent carbon composite, it would most definitely be lighter and you could probably modify the layup to have the strength to deflect a tyre or heavy object, but even with the use of less brittle fibres there is the risk that it could shatter. Because of that, I feel that there will always need to be some metallic element to the Halo, and because it is so high up in the car titanium will always be the material of choice.'

'The Halo device is the most thoroughly researched project we have ever done'

Note the aero fairing on the top of the Halo

The next step

Despite developing the Halo to be the strongest part of the car, as well as reaching a solution that is now widely accepted, and more importantly has proved itself, the FIA is still pushing to develop the next Halo. 'We have what we call Halo IV coming along, it's a long project but it's looking like we will introduce it in 2021,' Whiting says. 'There are a few candidate designs but needless to say we need to make sure that they work, that is by far the most important factor. We are trying to make it more aesthetically pleasing but that is not the predominant reason for doing it. Right now we're looking to have something that is both stronger and lighter as well as improving visibility for the driver. Improving safety remains the priority but aesthetics will be important with the 2021 car so we will include the new Halo in this research. The Halo project is the most thoroughly researched project we have ever done, it is a massively complex piece of research.'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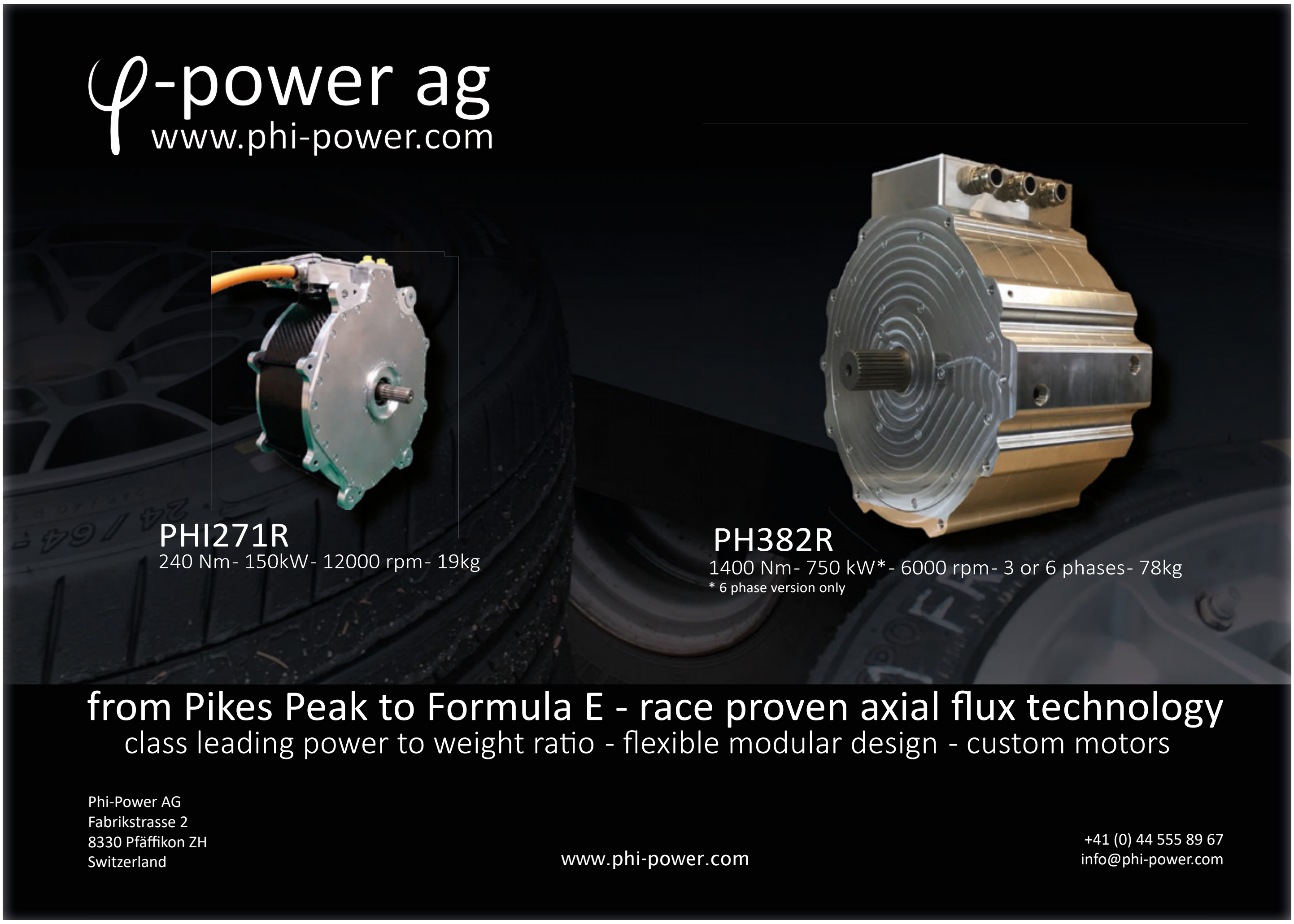
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The car that never was

The Caterham CT06 never saw action, indeed it was never even built, but once-secret design documents detailing its inception offer an intriguing insight into the thought processes underpinning a modern F1 car build

By SAMUEL COLLINS

In the final press conference of Formula 1 team bosses during the 2014 season there was an unfamiliar face. Finbarr O'Connell had previously had nothing to do with motor racing at all, but at the Abu Dhabi Grand Prix that year he found himself, essentially, the boss of the Caterham Formula 1 team.

O'Connell had been appointed joint administrator after the team collapsed financially in highly unusual circumstances involving a Romanian management team and the potential entry of a new team called Forza Rossa. The Irishman was tasked with keeping the team going until a buyer could be found and part of that process was to enter the Abu Dhabi Grand Prix and serve as team principal. Asked then about the team's future O'Connell was optimistic, but he admitted that the team's collapse had seen the development of the 2015 racecar fall behind schedule. 'As regards the car, my engineering team tell me that it's not hugely advanced but that if a purchaser comes along now, it will race in the championship next year,' he told the assembled media. Weeks later, however, it was announced that if Caterham were to continue in Formula 1 it would use an updated version of its 2014 car, the CT05, rather than build a brand new design.

But internal documents have come to light that reveal that the design of the 2015 Caterham was more advanced than O'Connell made out. Indeed, had the team not collapsed in the second half of the 2014 season it would likely have made it on to the 2015 grid and may well have been good enough to regain the crucial 10th position in the constructors' championship from the struggling Manor-Marussia team (which did run a modified 2014 car in 2015).

Just before the 2014 Malaysian Grand Prix in late March Mark Smith, the technical director at Caterham, sat down with a small group of engineers to discuss the plan for the team's 2015 car. The group talked through the overall car concept and objectives for the 2015 design, and the target was clear: beat Manor-Marussia and finish 10th in the championship.

In order to achieve that goal those at the meeting came to a number of conclusions about the concept of the CT06. Only one race of the new 2014 technical regulations had taken place and it was already clear that the

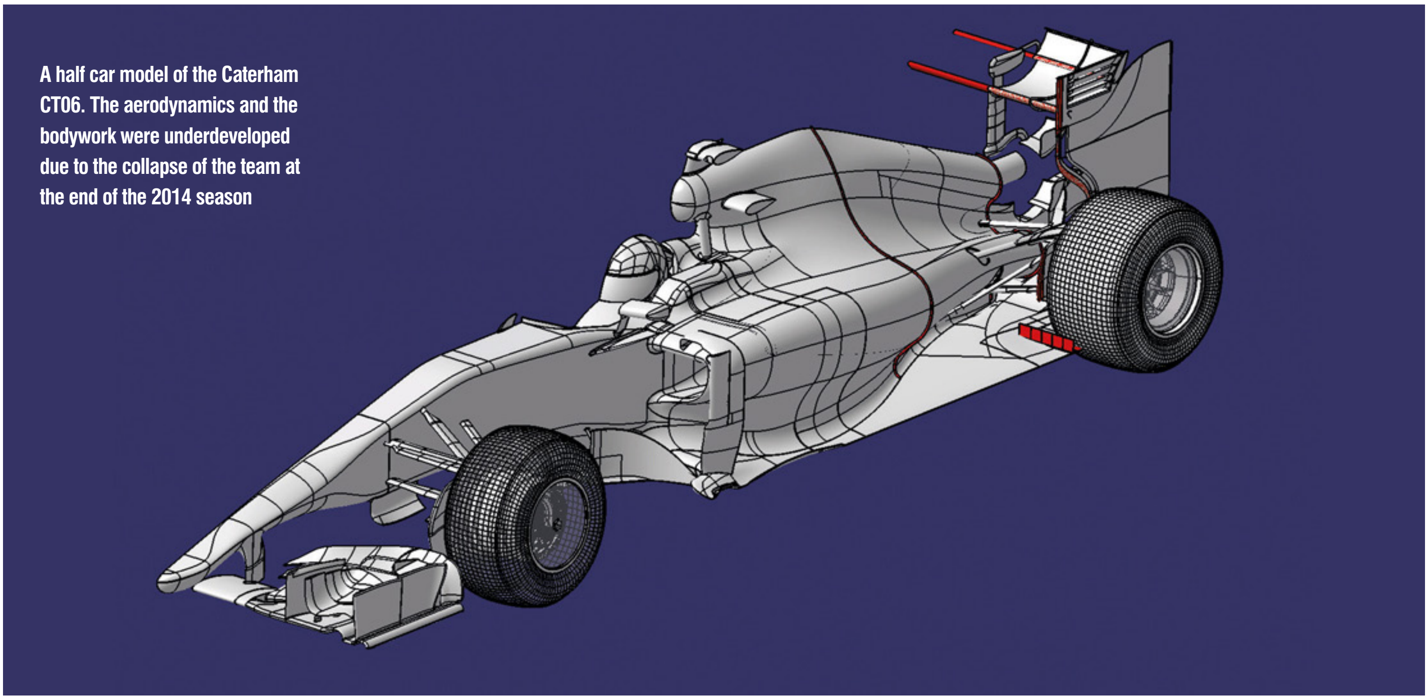
distinctive-looking Caterham CT05 would not be a competitive proposition. Yet despite this the group agreed that its successor would follow a similar concept, but with a number of key refinements and improvements.

The CT06 was to feature a shorter chassis than the CT05, and would be fitted with the latest specification Renault RS35 power unit. Red Bull Technology would supply the team with a transmission based on the unit fitted to the race winning 2014 Red Bull RB10, which featured a composite casing along with Xtrac internals. The rear impact structure would be carried over from the CT05 as the team saw no advantage in designing a new version.

Using the Red Bull gearbox limited Caterham in some elements of the rear end layout of the CT06, as it would have to utilise the same inboard suspension pick up points as the Red Bull RB10. The car would also feature a longer, bespoke, bell-housing to allow a new exhaust layout to be used. With the pick-up points defined by the RB10 casing the Caterham would have also adopted an outer rear suspension layout similar to the Red Bull, with the driveshaft passing through the suspension legs. This so called 'z-bone' layout was an option the team felt was heavier, but it also believed it offered significant aerodynamic gains.

At the front of the car the engineers in the meeting were unsure of whether the CT06 should retain the pullrod front suspension layout used on the CT05 for aerodynamic reasons. Only Caterham and Ferrari used this layout in 2014, and after further consideration it was decided to use a more conventional

Caterham decided that the CT05's successor would follow a similar concept, but with a number of key refinements and improvements



A half car model of the Caterham CT06. The aerodynamics and the bodywork were underdeveloped due to the collapse of the team at the end of the 2014 season

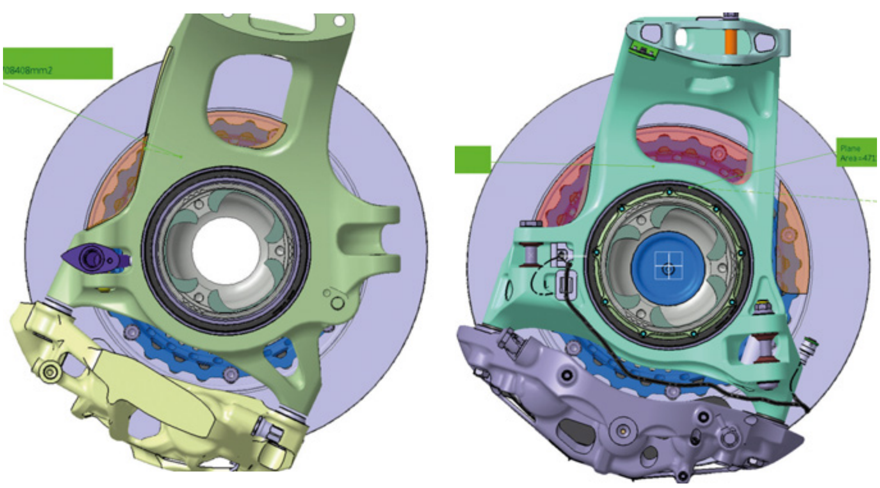
Using the Red Bull gearbox limited Caterham with some elements of the rear end layout of the CT06

pushrod layout on the CT06. It was felt that the potential aerodynamic gains with the CT05 layout were outweighed by other negative factors such as the high weight of the system. Interestingly, Ferrari persevered with the pullrod front end concept through 2015 but also decided to abandon it at the end of year.

At the front end of the car double unequal length wishbones would be flexure mounted and the outboard suspension would feature a high track rod. The pushrod would mount to the upright with adjustability fore and aft to give set-up options in terms of jacking. Inboard, the suspension featured a torsion bar front heave spring, a U-shaped anti roll bar, roll dampers, heave damper (with bump rubber) and a Cambridge inerter. The fitment of the inerter would have been something of a departure for the team as it did not use one on the CT05.

Rear view

At the rear the layout would have pullrod actuated torsion bars. The team had no option on this as a result of the mounting points on the RB10 gearbox casing. The wishbones were not parallel and would feature a slight forward sweep. Inboard there was an anti roll bar (with low, medium and high rising rates), side dampers, a rear centre damper with coil over spring and an inerter. Flexures would not



Although it was said towards the end of 2014 that little work had been done on the CT06 some aspects of the design were quite advanced. Detail differences between rear uprights are shown: CT05 left and CT06 right

TECH SPEC: Caterham CT06

Chassis
Moulded carbon fibre monocoque

Power Unit
Renault RS35 turbocharged 90-degree 1.6-litre V6; assisted with kinetic and heat ERS, aluminium cylinder block. Integrated hybrid energy recovery via electrical motor generator units, by Renault Sport. Valves: 24 (4 per cylinder). Bore: 80mm. Stroke: 53mm. Crank height: 90mm. Length: 480mm. Injection: Bosch direct fuel injection, limited to 500bar. Total horsepower: approximately 600hp (ICE) + 160hp (ERS)

Suspension:
Front: double wishbone, pushrod actuated torsion bars with Penske dampers. **Rear:** double wishbone, pullrod actuated torsion bars with Penske dampers

Steering
Power assisted rack and pinion

Transmission
Gearbox: Red Bull Technology with Xtrac internals; Clutch: AP Racing; Driveshafts: Pankl

Brakes
Carbon/carbon, Brembo calipers.

Cooling system
PWR

Exhaust
Inconel by SS Tube Technology

Telemetry
McLaren Electronics

Seat belts
Schroth Racing

Steering wheel
Caterham

Driver's seat:
Caterham; Carbon fibre shell

Wheels:
OZ Magnesium alloy

Fuel system
ATL fuel cell with Magneti Marelli low pressure fuel pump, Bosch lift pump.

Fuel
Total

Lubricants
Elf

Dimensions:
Front track: 1800mm (max). **Rear track:** 1800mm (max). **Wheel base:** 3475mm. **Chassis length:** 2250mm. **Overall Length:** More than 5000mm. **Overall Height:** 950mm. **Weight:** 700.96kg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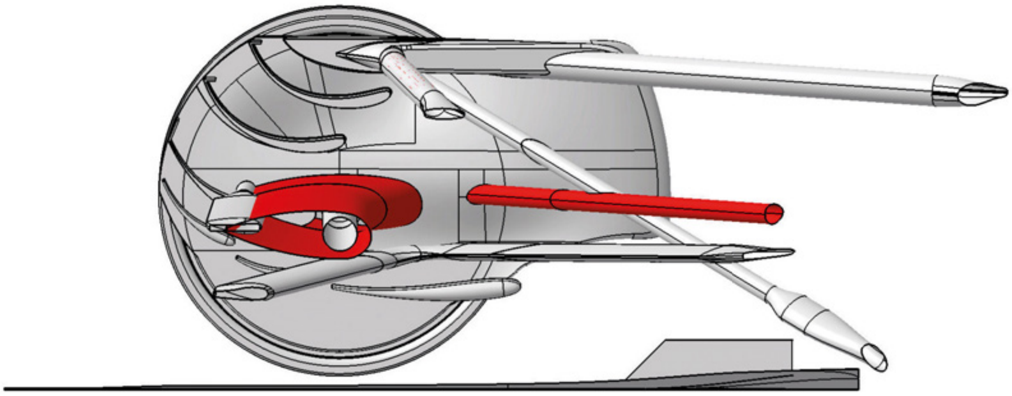
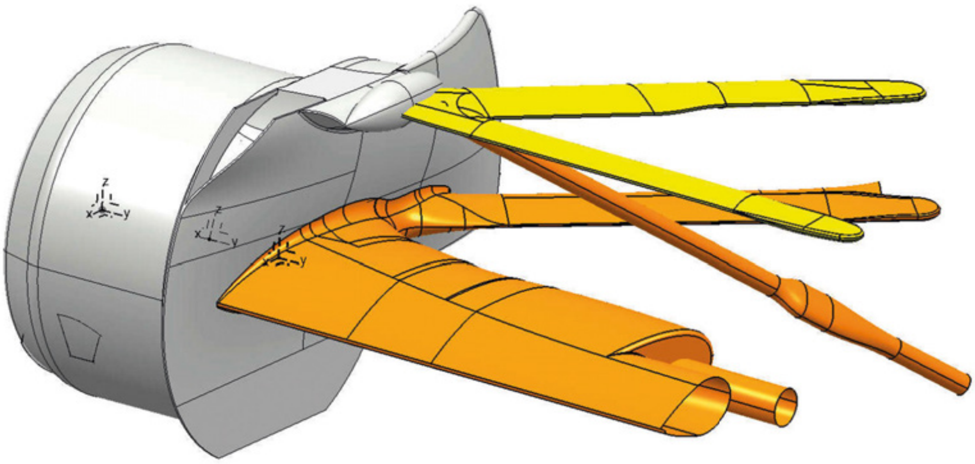


The rear suspension layout, showing the driveshaft and pullrod positions. This was the same as used on the Red Bull in 2015. It would have been a heavier solution to the approach used on the CT05 but might have brought some aero benefits



Rear suspension was to feature pullrods and wishbones that would have a slight forward sweep, and would not be parallel

be used as pickup points so that the operating window of the suspension could be maximised and the impact on droop travel minimised.

A quick levelling device was fitted to the Caterham CT05 which allowed the racecar to maintain its ride height in the ideal window for performance as fuel load decreased during the grands prix. A revised version of this was to be fitted to the CT06, and it was hoped this would have offered a significant improvement in the pitch stiffness of the car.

As a result of the switch from pullrod to pushrod front suspension, the front upright on the CT06 would have been all-new but the rear uprights would be an evolution of the concept used on the CT05. The improvements made largely for reasons of weight reduction and improving aerodynamic performance around the brake cooling. An all new brake calliper from Brembo would also have been used.

Further development

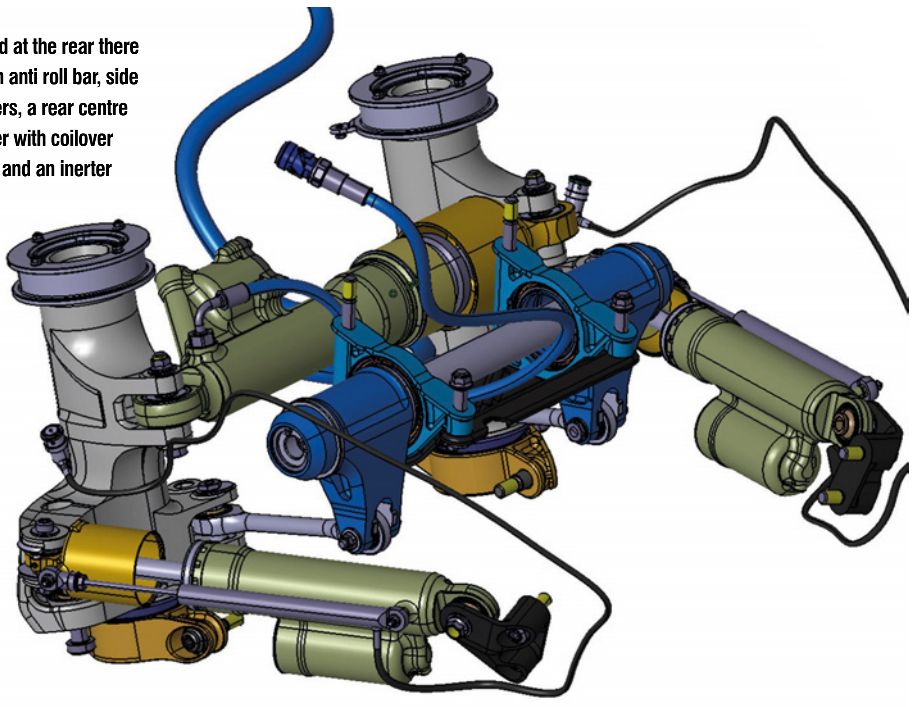
As the development continued the details of the project were further defined by a wider group at the team's factory in Leafield, headed by chief designer Lewis Butler. A major aim for the CT06 was weight reduction over the CT05, despite the fact that the technical regulations featured a minimum weight increase for the 2015 season.

In 2014 the minimum weight was set at 691kg, but for the 2015 season that was to be raised to 702kg. The CT05 tipped the scales at 689kg, while the CT06 was projected to weigh 701kg, with a theoretical 80kg driver. While that actually represented an overall weight increase over the 2014 car, much of this gain was beyond the control of the Caterham team.

This was because the team could only directly influence about half of the weight of the car, as that was the amount of the design it was responsible for, and 351kg of the CT06's total weight would have been made up of the driver, mandatory parts or parts the team bought in, such as the power unit, wheels and transmission. This left a 349kg target weight for the components it could control, 17kg lower than for the same parts weighed on the 2014 car (for a thorough break-down of the car's weight see box out page 50).

A number of areas were investigated which offered a weight saving, though. One engineer who had recently looked over the design of the Airbus A380 noted that 30 per cent of its hydraulic lines were made from carbon fibre, and that the same approach might offer an additional weight saving for the CT06. It is not clear if this was pursued further.

Inboard at the rear there was an anti roll bar, side dampers, a rear centre damper with coilover spring and an inerter



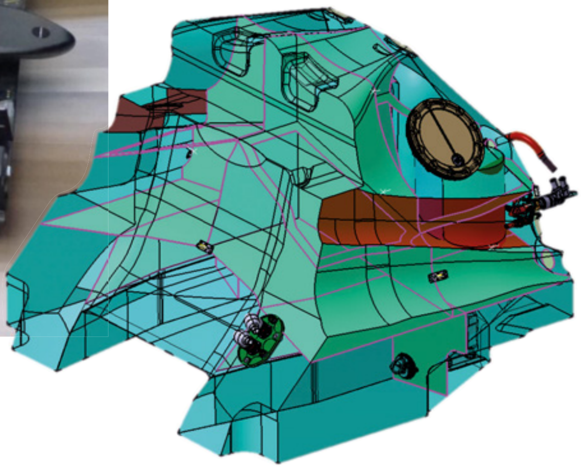
A major aim for the CT06 was weight reduction over Caterham's previous car

Weighty issues

Because the team was not entirely certain of its driver line up early in the season it deliberately overestimated driver weight to be 80kg, though if it had used the same drivers as the team started the 2014 season with, Marcus

Left: The wind tunnel model gives an idea as to how the CT06 would have looked. The front end treatment is, aesthetically at least, a vast improvement over the CT05

Below: ATL cell would have been capable of holding 109kg of fuel. Under this the energy store for the PU was to be mounted, its casing taking some chassis loads



Caterham CT06 weight break-down

Driver: 75kg-80kg
Nose: 7.37kg
Monocoque: 99.912kg
Front wing: 14.45kg
Rear wing: 6.1kg
ERS header tank and fluid: 1.1kg
Removable bodywork: 5.78kg
Floor: 26.802kg
Front wheels and tyres: 16.9kg
Front brake calliper: 1.578kg (each)
Front brake pads: 0.8kg (front and rear)
Front brake ducts: 5kg
Inboard front suspension components: 3.158kg
Outboard front suspension (including upright): 13.580kg (each side)
Inboard rear suspension components: 10.93kg
Outboard rear suspension (including upright): 15.254kg
Rear wheel and tyre: 20kg
Coolers: 32.09kg
Gearbox: 52.2kg
Driveshafts: 2.047kg (each)
Clutch: 1.1kg
Brake system (less callipers and friction material): 1.394kg
Pedals and cylinders: 3.92kg
Steering rack: 1.57kg
Steering column: 0.7kg
Steering wheel: 1.573kg
Fuel system: 12.5kg
Driver seat: 2.47kg
Cockpit padding: 1.19kg
Seat belts: 0.815kg
Fire extinguisher: 2kg
Power unit: (total 135.62kg)
Selected PU component weights:
ICE: 85.5kg
Turbo: 9.52kg
Wastegate: 0.88kg
Engine wiring loom and sensors: 3.5kg
MGU-K: 16.2kg
MGU-H: 8.4kg
Control unit for MGU-H: 4.8kg
Control unit for MGU-K: 3.5kg
ERS cooling pump: 0.75kg
Energy store: 29.95kg
Exhaust system: 14.509kg

Ericsson and Kamui Kobayashi, then the CT06 would have had to have carried 1.5kg (Ericsson) and 10.5kg (Kobayashi) in the front wing to meet the minimum weight and stay within the mandated weight distribution window.

The resulting weight distribution would be 45.40 per cent front and 54.60 per cent rear, which would mean that there would be 318.26kg on the front axle and 382.69kg on the rear. In 2015 the technical regulations mandated a minimum front axle weight of 319kg at the front and 376kg at the rear, but when the fictional 80kg driver was replaced with the team's real drivers (and the associated front wing ballast mentioned above) the car moved fully within the regulatory limits.

Weight saving was also part of the objective for the chassis of the CT06, and the monocoque would be slightly lighter than that of the CT05. In terms of shape the leading edge of the cockpit would be slightly lower in order to improve driver visibility and the tub would feature a narrower upper section but a larger lower section behind the driver's seat in comparison to the 2014 model. This volume would contain a fuel cell from ATL capable of holding 109kg of fuel. Under the fuel cell the energy store of the Renault RS35 power unit was mounted and its casing would have taken at least some chassis loads.

For 2015 Renault had developed a lighter energy store with slightly fewer cells, and this was not the only change to its power unit for

Today the CT06 wind tunnel model sits forgotten and locked away in a store room at the TMG facility in Cologne

It was very clear early in 2014 that the CT06's predecessor (the CT05, above) was not going to be competitive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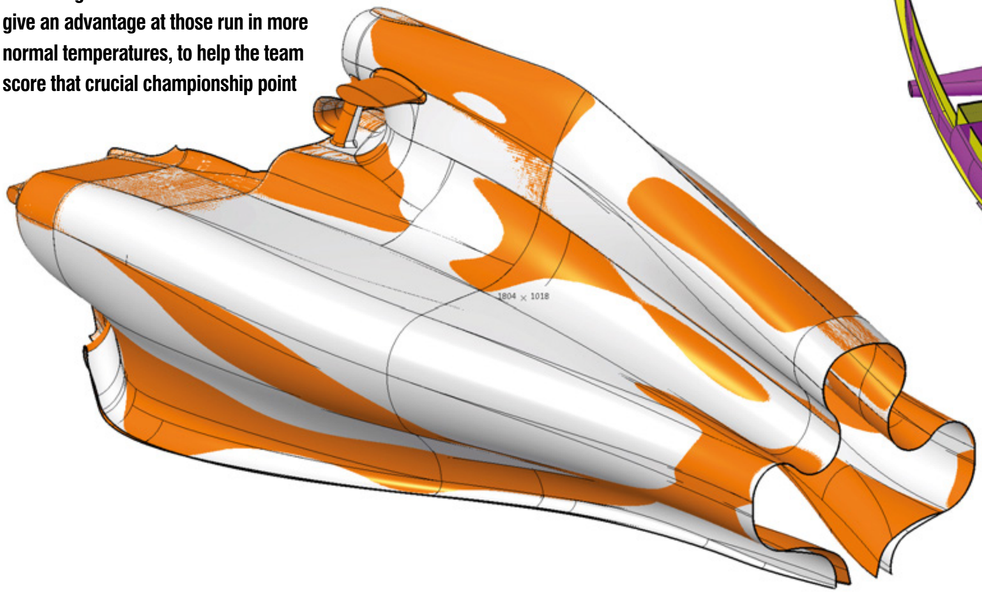
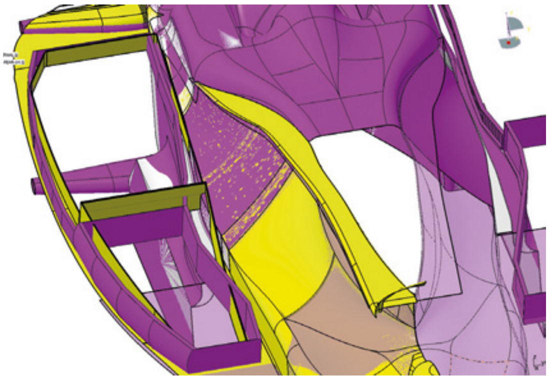


Rear bodywork would have been tighter than on the CT05 and may have been deliberately under-cooled, sacrificing races in hot conditions to give an advantage at those run in more normal temperatures, to help the team score that crucial championship point



Above: For aerodynamic reasons the charge air coolers were to be moved rearwards. The opportunity to do this came after a decision was taken to use exhaust primaries 150mm longer than those on the CT05 to improve engine performance

that season. The plenum on the 1.6-litre V6 IC engine would move forward by 35mm, while the turbine and compressor – both mounted at the rear of the engine block – would be moved 36mm rearward compared to the RS34 of 2014. This was done in order to provide a more axial air flow to the compressor.

Renault suggested to the designers of the CT06 that the car should use exhaust primaries 150mm longer than those used on the CT05 to improve engine performance, something which would have the added benefit of allowing the charge air coolers to be mounted further rearward, something the team wanted to do for aerodynamic reasons. This relocation of the turbocharger and the longer primaries were another major reason that the CT06 would have required a bespoke bell-housing, which was to have either been made from titanium or carbon fibre (but it is not clear if a final decision was ever made on this).

Aerodynamics

With the major internal parts laid out attention turned to the car's aerodynamics. Despite announcing plans for its own wind tunnel, Caterham never got around to building it and instead relied on the well proven 60 per cent scale tunnels at TMG in Cologne. The CT05 was developed at the same facility but work on that project was curtailed in the summer of 2014 in favour of the CT06. Certainly some runs were completed with the CT06 at Cologne but not nearly as many as planned as by that time the team was facing a very uncertain future. However, the one known picture of the CT06 in the TMG working section (page 50) reveals a number of the car's external design details.

One of the few technical rule changes for the 2015 season related to the design of the noses of the cars. In 2014 the front crash structures were exposed as teams tried to get as much air under the nose as possible, resulting in what at the time were described by some as an 'Ann Summers' style design (some far less polite names were more common). These new rules saw much wider front impact structures employed as well as a more gradual gradient on the nose itself and the front of the chassis.

On the CT06 the Caterham engineers decided to mount the nose as high as possible within the rules and came up with a fairly elegant design, as can be seen in the pictures on these pages. Beyond that the design of the bodywork was largely conventional but it did feature a much tighter rear end than the CT05. To achieve this the team had to relocate a number of coolers to the centreline of the racecar and then feed them from small ducts mounted behind the driver's head. The charge air coolers would be mounted further rearward than they were on the CT05.

Caterham decided to mount the nose as high as possible within the rules and it came up with a fairly elegant design

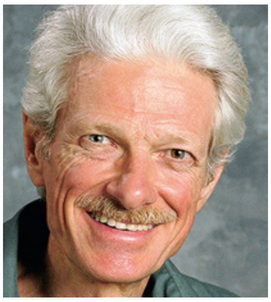
It all sounds well thought out. But by the time serious work started in the wind tunnel the team had changed hands. Airline tycoon Tony Fernandes had lost patience with the poor results of the CT05. After an exciting race-long battle with one of the two Caterhams in Monaco, Manor scored its first ever world championship points with a ninth place, a feat that Caterham had never achieved, and to regain 10th position in the constructors' championship the CT05 would have to not only have to match but beat Manor, and finish higher than ninth.

This was a highly unlikely scenario. So, with the prospect of losing millions of euros of prize money, Fernandes decided to sell up. What was referred to at the time as a 'Swiss consortium' took over the team and installed Colin Kolles as team boss, but rumours of financial trouble were confirmed when shortly before the 2014 Japanese Grand Prix bailiffs arrived at Caterham's factory and seized a number of assets due to a range of unpaid debts.

Game over

Around this time the final details of the CT06's mechanical design were being finalised with accelerometer positions being defined and the final range of suspension spring and bar options being selected. These were the last decisions to be made in the CT06 development process; aerodynamic work was thought to have stopped some time earlier due to bills to TMG going unpaid. No more work on the CT06 would ever be done. Just after the Russian Grand Prix the work at the factory stopped and the staff were sent home. Aside from that final grand prix with O'Connell in charge, and where crowd-funding paid the bills, the Caterham Formula 1 team was no more.

Today the CT06 wind tunnel model sits forgotten and locked away in a store room at TMG in Cologne, the Leafield factory has been stripped out and is abandoned, and many of the key staff involved in the creation of the car's design can now be found at other teams. The Caterham CT06 is likely to be another one of those motor racing 'what ifs', and sadly barely a footnote in the history books.



The real truth about roll centres and jacking forces

Our technical consultant takes the opportunity to respond to criticism

Q Are you aware of Bob Bolles' article in the February 2018 issue of *Circle Track*? He says he came up with an experiment that disproved what you say about roll centres and jacking forces. He also says that you approved the apparatus he used. Yet I do not see any indication in your writings that you have changed your views?

THE CONSULTANT

A The article referred to is called *The Truth Comes Out*. Here I will summarise the article's assertions, and comment on them. I do know Bob Bolles. I could have taken this matter up with him more privately. However, he did not extend to me the courtesy of letting me know in advance about what he published; he did not allow me to vet the article for accuracy regarding the assertions in it that involve me and my opinions, or the events surrounding his apparatus and experiments, or write a response; and the article contains serious errors and omissions, which, when corrected, completely change the story and the conclusions to be drawn. Moreover, these incorrect statements and omissions concern the scientific expertise that is my stock in trade as a consultant, and they appeared in a publication that has (or had) considerable circulation. Therefore, for me to reply in a similarly public manner is both appropriate and professionally necessary.

Here are the article's main assertions:

1. I say that geometric roll resistance in independent suspensions comes entirely from jacking forces induced independently in the right and left suspensions.

2. I say that therefore the whole concept of roll centres is useless and can be ignored.

3. I say that in all cases, the magnitude of the geometric roll moment depends not only on the magnitude of total ground plane force but also its right/left wheel distribution.

4. Bolles built an apparatus that simulates an independent suspension. The geometry can be adjusted. The apparatus allows controlled loads simulating cornering forces to be applied. The apparatus then rolls as an actual car would, and the angle can be measured with an angle finder. I looked at pictures he sent me and agreed that the apparatus modelled an actual half-car in a substantially valid manner.

Suspension simulation rig. Note buckets filled with shot and the skateboard wheels that take the place of tyre contact patches

5. Using geometry that was statically symmetrical and was representative of typical short and long arm stock car front suspension, Bolles applied combinations of simulated ground plane forces which had equal total magnitude but differing right/left distribution. The roll angle did not vary significantly. This, he says, disproved my thinking.

6. Using the force line intersection as a roll centre is valid, but only its height matters.

7. A car will be 'balanced' if front and rear half-car models generate matching roll angles.

The response

Number 1 is correct. I say that. Anybody who says that geometric roll moment in an independent suspension derives from anything other than jacking forces induced in the right and left suspensions needs to have a plausible explanation of where any other component might come from. I've not heard one.

Number 2 is incorrect. Some people have been dismissing the whole notion of roll centres at least since the 1980s, but I don't. I say the concept of a roll centre is useful if applied correctly, as a concise expression of the relationship between lateral force and geometric roll moment, and as part of a modelling method that doesn't require an engineering degree and the use of MATLAB. I have come up with a graphical method of assigning roll centre height, which I call the resolution line method. This method produces, for all cases, a roll centre height assignment that is correct in the sense that lateral force acting through the linkage, times roll centre height, equals geometric roll moment, and this agrees with geometric roll moment as calculated by the method of multiplying the vector difference of the two jacking forces by half the track. The method does require a right/left lateral force distribution, assumed if not otherwise known, as an input.

Number 3 is almost correct. I say that left/right distribution of the ground plane force affects the roll moment to whatever extent the jacking coefficients of the right and left suspensions differ, in the condition being modelled – and in most cases they do differ at least a little, dynamically. If the jacking coefficients are exactly identical, left/right lateral force distribution has no direct effect on geometric roll moment or, accordingly,

Some have been dismissing the notion of roll centres since the 1980s

Bolles' shortcut roll angle analysis will not work with a Porsche 911

on roll centre height correctly assigned. If the jacking coefficients differ slightly, right/left lateral force distribution has a slight effect on geometric roll moment. If the jacking coefficients differ markedly, left/right force distribution can have a considerable effect on geometric roll moment. I also say that even when the jacking coefficients are equal, right/left lateral force distribution affects total wheel pair jacking force, which is the vector sum of the two jacking forces. This can indirectly affect roll moment, as it affects dynamic ride height.

Number 4 is mostly correct and a picture of the apparatus is shown on the previous page. Other than the digital angle finder, the device is entirely mechanical. The buckets are used to hold measured weights of bird shot. A fish scale is used to measure their weight before hanging them. The apparatus simulates a left turn if we're looking at it from the driver's seat, or a right turn if we're looking at it from the front of the car. The right side in the picture is toward the outside of the turn. The skateboard wheels simulate the tyre contact patches.

The 'ground plane' is at the skateboard wheel axle centres. The left-most bucket acts through a string running over a pulley and pulls the left 'contact patch' to the left, exerting a force simulating the inside tyre lateral force. The middle bucket does the same for the outside tyre. The right-most bucket pulls down on the sprung mass and simulates the sprung weight of the half-car, acting on a point just below the angle finder that simulates the sprung mass cg. Also acting at that point is a horizontal string to the anchor structure at the right. That simulates the inertial or centrifugal force acting rightward on the sprung mass.

The only change I would make to the apparatus would be to hang the sprung mass from the 'contact patches'

So when the buckets pull on the 'contact patches', those points then move to the left a bit, and the model rolls. The springs are simulated by two tension coil springs acting on the lower control arms, attached to structures resembling feet on the sprung mass.

The only change I'd make to the apparatus would be to hang the sprung mass from the 'contact patches' rather than the control arms, so that the motion ratio on the springs wouldn't change when the geometry is adjusted, and the wheel rate would remain constant. Also, the 2x4 planks supporting the whole thing have about three-quarter inch of sag, so the skateboard wheels aren't quite rolling on horizontal surfaces. But I do agree that the apparatus provides a sufficiently valid model for the purposes at hand.

The first part of number 5 is true, but the second is false. For the geometry Bolles tested, where lateral force distribution had only a small effect on measured roll angle, my thinking would not predict a different result and is therefore not disproved. Bolles misunderstood my theory and methodology and consequently misunderstood what it would predict.

Jacking coefficients

But that's not the end of the story. When Bolles got that result he emailed me and told me. I then proceeded to explain to him that I would only predict a significant difference in roll angle if roll created a significant difference in jacking coefficients. This does happen with many statically symmetrical suspensions, including strut suspensions, trailing arm suspensions, and SLA suspensions with Mitchell indices far from one. K&C tests of actual cars with such suspensions, when rolled, have shown variation in geometric roll moment when right/left ground plane force distribution varies. With the proportions of Bolles' apparatus and the settings he used, the jacking coefficients are statically identical and also the Mitchell index is close to one, so the jacking coefficients remained very similar with roll.

The apparatus can produce significantly differing jacking coefficients, but only by adjusting it to be statically asymmetrical.

Bolles then did experiments with his apparatus adjusted so the right and left jacking coefficients are different statically, as they are in the picture, and he did get results confirming my prediction that the roll angle would be affected by right/left lateral force distribution.

This all occurred early in 2015. In May of that year, Bolles hauled his apparatus from Florida up to Morse Measurements in Salisbury, North Carolina, and we spent the better part of a day doing a series of experiments with it together. Again, the results confirmed that when the jacking coefficients are unequal, lateral force distribution does affect the roll moment. Despite the curvature of the 2x4s, the uncertainties in determining the front view instant centres by low-tech measurement, and the fact that we didn't calibrate the angle finder, I was able to predict the measured roll angle for every setting within less than a 20 per cent error, and the pattern of the results was exactly as I predicted. Bolles does not mention any of this, and this information utterly changes the conclusions to be drawn from the experiments. Are we to suppose that he forgot that any of this happened?

Number 6 is incorrect. It is true that only the height of the roll centre matters, but taking the force line intersection (the so-called kinematic roll centre) as the roll centre is not correct and there are many situations where using the height of the force line intersection for this value dramatically wrongly predicts geometric roll moment. There are also cases where the force lines are parallel and consequently there is no force line intersection.

Number 7 is also incorrect. I have addressed this repeatedly in the past, including last month (RCE V28N11). Bolles' shortcut 'roll angle analysis method' gets you approximately in the ballpark, provided that the car has 50/50 weight distribution and equal tyre sizes, or has the rubber distributed proportionately to the weight, and provided there are no other factors influencing understeer gradient such as aerodynamics, off-tracking, differential/locker/spool action, use of a large portion of drive wheel traction for propulsion, etc. For any other situation, notably where the car is nose-heavy or tail-heavy and has equal tyre sizes – and there are many such cases – it leads you in a wrong direction. In such cases, the heavy end goes through the fence first unless you give the light end disproportionately great roll resistance and load transfer.

There were actually some other assertions in the article that I would also take issue with, but here I am confining myself to those that relate to the soundness of my thinking on jacking forces and roll centres.

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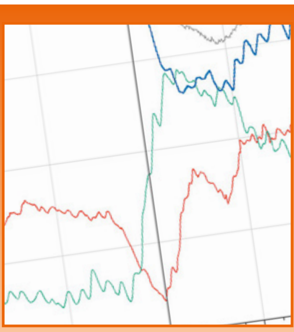


Databytes gives you essential insights to help you to improve your data analysis skills each month, as Cosworth's electronics engineers share tips and tweaks learned from years of experience with data systems

How electronic systems in a racecar communicate

Get on the bus with our introduction to Ethernet, CAN and LIN

Ethernet communication is used to drive the current range of Cosworth auxiliary displays including the Carbon Wheel (below) and CDU 4 display (top). RLU (left) is mainly for gathering channel data

Many electronic systems are working together in modern motor racing. From GT to formula cars, these controllers have many ways of communicating including CAN, LIN and Ethernet.

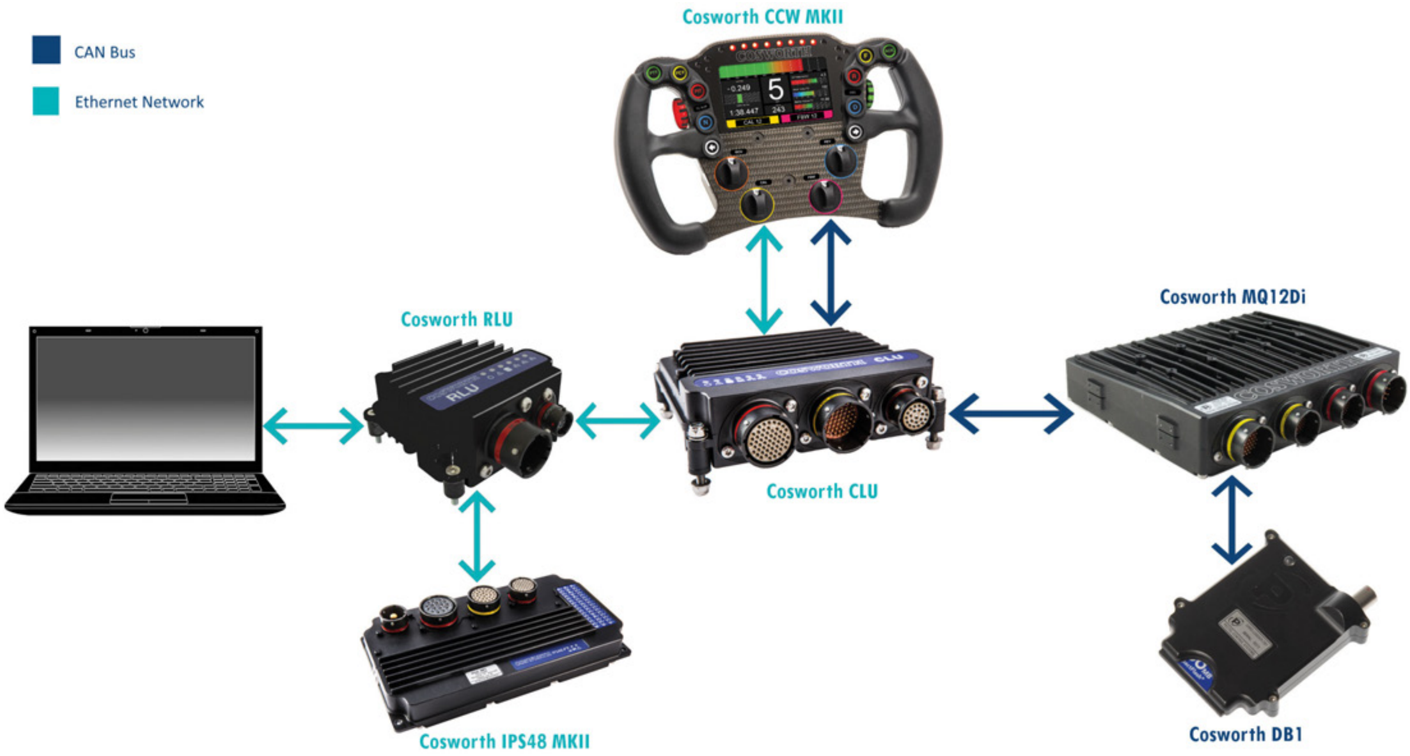
Each of these network types have different benefits and limitations, so choosing the correct one for each application is very important.

Ethernet

Motorsport Ethernet communication is most commonly used for transmitting information to and from the racecar, sending configurations to ECUs or receiving telemetry data from an onboard data logger.

Most modern installations use one Ethernet connection for the engine controller connection and another for connecting to the car's chassis system. Using a Cosworth system, we can also add an RLU (Removable Logger Unit) to these networks, which will gather channel data over Ethernet and log it to a removable USB drive. Ethernet is also the communication that is used to drive the current range of auxiliary displays including the Cosworth Carbon Wheel, and CDU 4.3 and 7-inch displays.

Most modern installations use one Ethernet connection for the engine controller and then another for connecting to the racecar's chassis system



This illustrates how Ethernet and CAN networks work within an LMP2 prototype. Ethernet is often used for transmitting information to and from the racecar

CAN

CAN (Controller Area Network) is used throughout the automotive and motorsport industries. Sensor values and switch status are transferred across the CAN network along with status information, from battery voltage to rpm and wheel speeds.

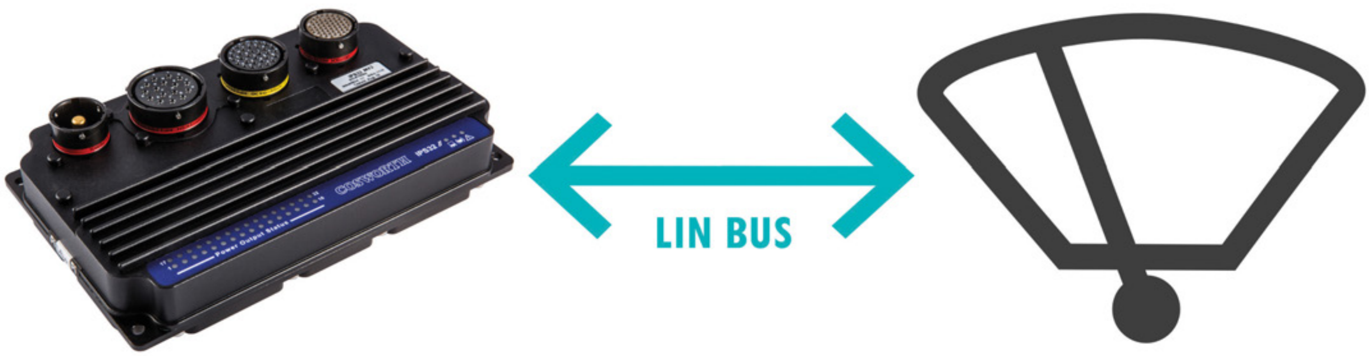
A CAN network consists of two wires, CAN high and CAN low. A device transmits information by sending inverse signals on each wire which minimises the chance of phantom signals and interference. Standard CAN architecture uses an unaddressed '64-bit' packet structure, meaning any device on the bus can see any message from any transmission, allowing it to be decoded by multiple recipients.

LIN

LIN is a low-cost alternative to CAN as it is a one wire network where packets are sent from the master and only acknowledged by slaves. In many applications Cosworth power controllers and data loggers use fully configurable LIN control to drive smart alternators, window wipers and air conditioning units.

The Local Interconnect Network (LIN) structure consists of one master device which controls one or more slaves by sending out commands and requesting feedback, addressing each slave individually. Many low bandwidth ancillary devices, such as window wipers, cockpit fans and alternators, use LIN for both control and feedback from a master device.

By using these three network types to create a fully interconnected car it allows for more effective debugging of issues and monitoring of both engine and chassis parameters. Cosworth power controllers, data logger and ECUs allow for fully configurable communication for all three systems, allowing for total integration and maximum compatibility.



LIN is a low cost alternative to CAN. Many low bandwidth ancillary devices, such as window wipers, use this system

The LIN structure consists of one master device which controls one or more slaves by sending out commands and requesting feedback

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Uplifting tales: ride height tweaks on an F1 Tyrrell

How would ride height adjustments affect the aero of a 1983 F1 car?

Flat bottoms became mandatory in Formula 1 back in 1983, when the FIA's ban on ground effect sidepods featuring profiled undersides came into force. Some of the designs for the new era, such as the Tyrrell 012 we are examining here, the Brabham BT52 and others, virtually abandoned sidepods altogether. Meanwhile, the Ferrari and the Renault, which took first and second in that year's constructors' championship, retained long sidepods.

Clearly, and to be fair this is looking back with what we know now, at this early stage there was little understanding of the potential of a flat floor. So would altering the ride heights of our Tyrrell test car make any difference to the aerodynamic numbers? We decided to find out.

Tyrrell 012 in the MIRA full-scale wind tunnel. This 1983 grand prix car currently races in FIA Masters Historic F1

Balance matters

First, let's backtrack slightly to get up to date on the Tyrrell's baseline numbers and where we got to in our previous two instalments. As delivered to the wind tunnel, and as run in the previous weekend's Silverstone Classic FIA Masters Historic F1 event, the car exhibited quite high drag that was very similar to other non-current Formula 1 cars we have tested in MIRA. It also had quite modest total downforce but a very similar figure to the 1983 Arrows A6 we tested in 2007. Where the Tyrrell differed markedly from the Arrows was in its downforce balance, with roughly 20 per cent front on the Tyrrell compared to nearly 41 on the Arrows.

Last month we focussed on the effects of increasing front wing angle, and found that at the peak downforce front wing angle the car's balance had changed to around 34 per cent front. This, on the face of it, seemed more like a good balance figure. However, given that the car had just been raced with a lower wing angle, one that produced the 20 per cent front wind tunnel figure, if we assume the car was balanced on track, then this implied that the fixed floor wind tunnel was underestimating front downforce by as much as 40 per cent. Clearly the rear wing would be essentially unaffected by the tunnel's fixed floor, so the rearward bias could well have been over-estimated.

However, such a large difference between the aerodynamic balance on track versus balance in the wind tunnel is more likely to be a particular idiosyncrasy of a single seater reliant almost solely on its wings for downforce generation. Any form of downforce-inducing underbody whose centre of pressure was between the front and rear wheels would tend to mitigate this difference, even over a fixed floor that underestimated underbody downforce.

In 1983 there was little understanding of the potential of a flat floor

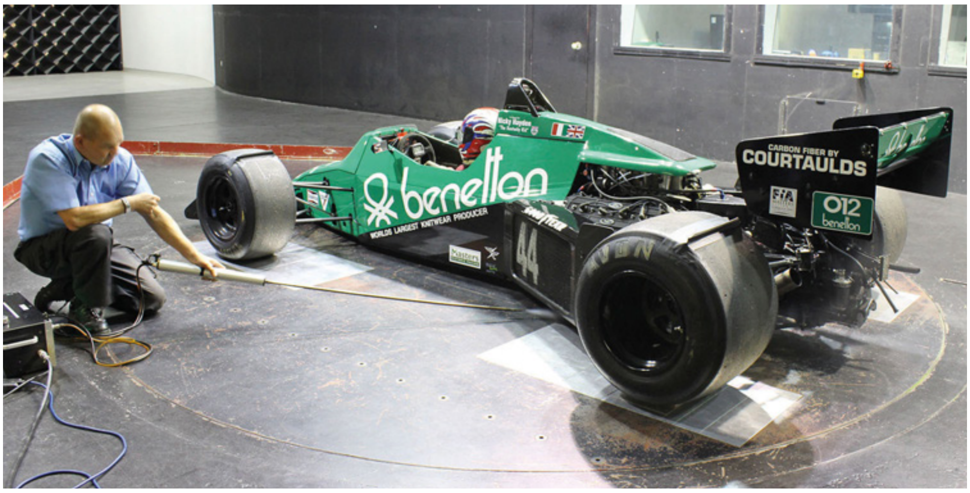
A range of aerodynamic balance options were available via front wing adjustments

Back up

So, with only a relatively small area of underbody, what effect would changes to ride height have on the Tyrrell? Two increases to rear ride height were made by adding shims under the tyres, initially 12mm then an additional

Table 1: The effects of rear ride height increases

RRH change	CD	-CL	-CLfront	-CLrear	%front	-L/D
0	0.836	0.736	0.253	0.484	34.3%	0.880
+12mm	0.850	0.758	0.255	0.503	33.6%	0.892
+17mm	0.851	0.764	0.253	0.512	33.0%	0.898



The Tyrrell's small underbody does generate some downforce

Was the increase in the chassis angle, and hence the rear wing angle, responsible for the rear downforce increase we saw?

Raising the rear ride height of the racecar did produce some modest changes to the aerodynamic parameters

5mm, and the results are shown in **Table 1**. Note that the front wing was at, or very close to, its peak angle in these runs.

There were, then, some useful gains achieved through these rear ride height increases, the biggest of which was a 5.8 per cent increase in rear downforce at the highest ride height, compared to the lowest. This came at the expense of a 1.8 per cent drag increase, so it was a reasonably efficient gain at 3.2:1 in downforce to drag terms. There was no change to front downforce even though increasing the rear ride height would have brought the front wing slightly closer to the ground and increased its angle a little. But, as mentioned, it was already at its peak angle.

Was the increase in chassis angle, and hence the rear wing angle, responsible for the rear downforce increase? In our first instalment on the Tyrrell we saw that a three-degree change of rear wing angle produced a 0.040 increase in the –CLrear value, or 0.013 per degree in that part of the angle range. The 0.028 increase in -CLrear achieved through a 17mm rear ride height change, equating to 0.37-degree angle change, represented 0.076 per degree, which was well in excess of the response to rear wing angle change alone. So the conclusion must be that the small floor area of the Tyrrell, with its very modest diffuser after the rear axle line extending back to in line with the rear of the rear tyres, was nevertheless still contributing some downforce, and that contribution increased with more rake.

Front down

The Tyrrell was set up to allow the front ride height to settle 13mm below its static ride height once it has reached speeds of 85mph plus. At 80mph in the wind tunnel it was evident that the car was not settling very much. This may have been partly due to friction within the suspension, which was not being 'worked' by running over track irregularities, and it was probably also due to the reduced front downforce resulting from the tunnel's fixed floor, as discussed above. So a final run was made with the front ride height adjusted via the suspension down to its normal high speed position; the rear ride height was 12mm above static ride height. Results are shown in **Table 2**.

Table 2: The effects of reducing front ride height

FRH change	CD	-CL	-CLfront	-CLrear	%front	-L/D
0	0.845	0.753	0.250	0.503	33.2%	0.891
-13mm	0.851	0.792	0.263	0.529	33.2%	0.931

This adjustment obviously made a reasonably significant improvement, achieving the best total downforce (-CL) and efficiency (-L/D) figures of the session. Drag increased by just six counts or 0.7 per cent but total downforce increased by 39 counts or 5.2 per cent. The downforce at each end increased by exactly the same percentage, so there was no balance change whatsoever.

That front downforce increase was interesting, showing that the front wing could still produce gains from closer ground proximity even though it was at its peak downforce angle at the higher static front ride height. Had time been available a full angle sweep at this lower ground clearance might have shown the downforce peak to be at a slightly lower angle. The rear downforce gains were probably down to the same mechanisms that brought similar gains when rear ride height was increased.

Racecar Engineering's thanks to Martin Adams (the Tyrrell's owner), Nigel Rees at GSD Racedyn and Martin Stretton and Russell Sheppard at Martin Stretton Racing.

CONTACT

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

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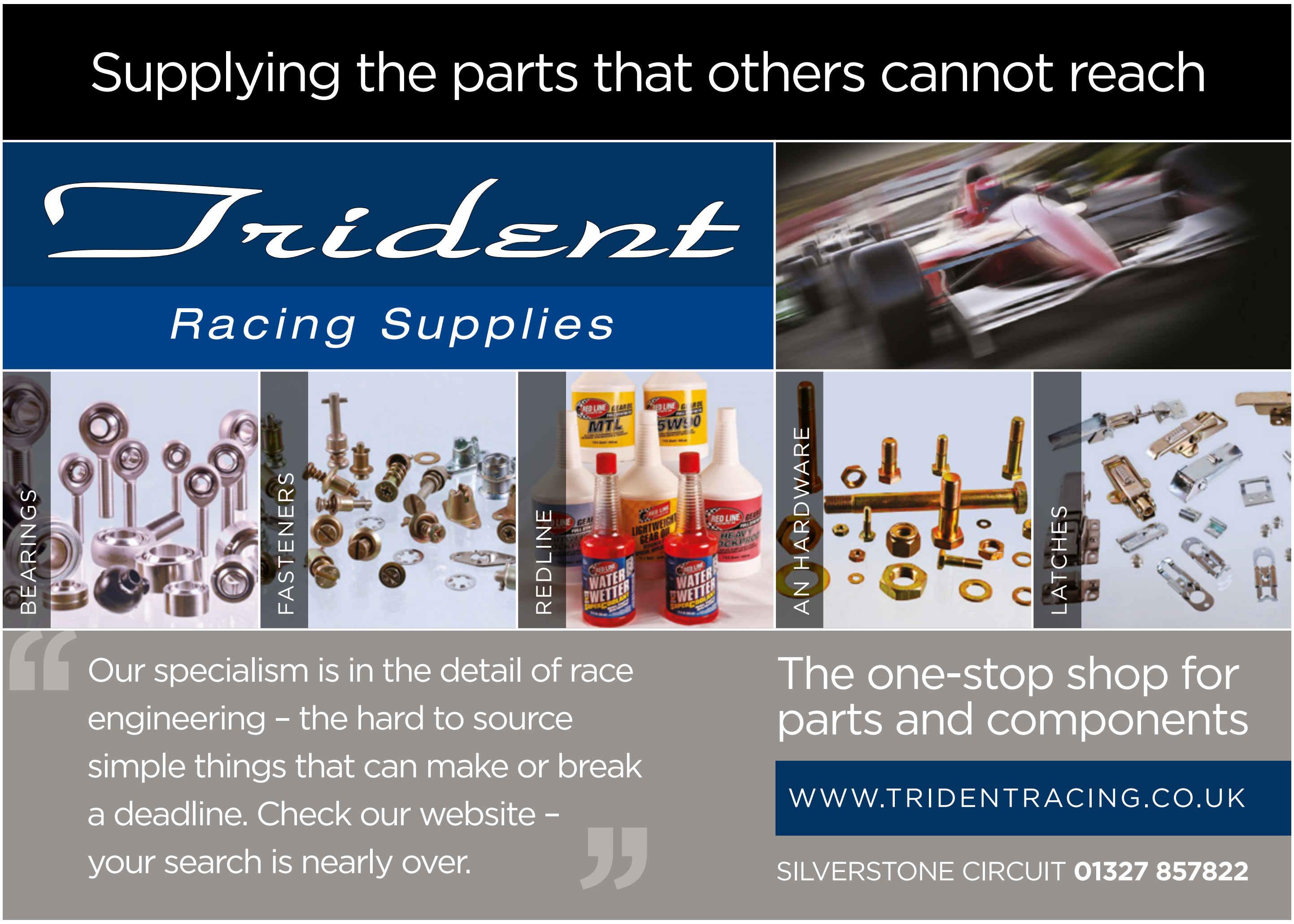
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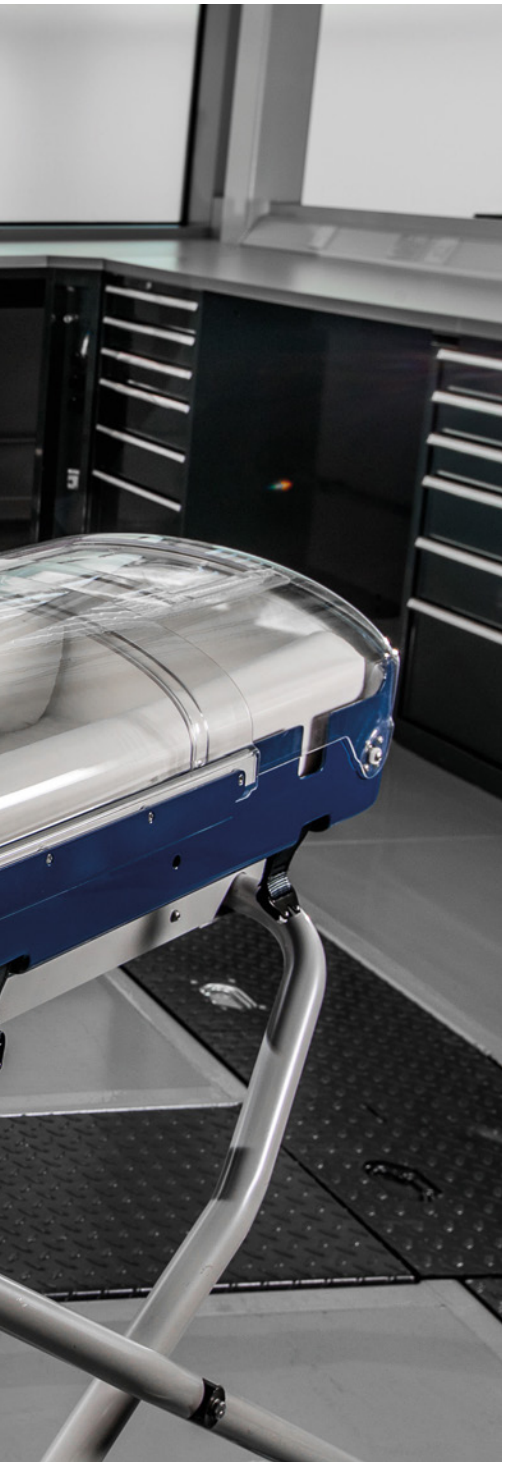
The same technologies used to develop the safety cell for Formula 1 drivers has also been used to design an emergency transportation device for new born babies; the Babypod 20

Beyond F1

Formula 1 technology does not need to be confined to race tracks, as the work Williams Advanced Engineering has carried out on electric road car projects, baby healthcare and even supermarket fridges, surely illustrates

By GEMMA HATTON



In a time when scientists are declaring that rising global temperatures will cause worldwide destruction, it's fair to question the environmental-friendliness of motorsport. After all, unthinkable amounts of resources are invested into an industry which is ultimately about making cars go faster in order to provide entertainment.

However, to achieve a quicker lap time you either need to have more grip, more talent or less weight. All of which ultimately boil down to efficiency. A racecar is set up to translate the available power into maximum grip at the wheels; a driver's inputs are tuned to be smooth to minimise energy loss and find the shortest route around the track, while lower mass requires less energy to move. Therefore, motorsport's relentless urge to win is actually developing techniques and technologies which maximise the distance covered for every drop of fuel or watt of electricity. In other words, improving energy efficiency.

This is proved by the fantastic achievements made while developing F1's V6 engines, which now run at more than 47 per cent thermal efficiency compared to the 29 per cent achieved with the previous V8s. Despite this increase in efficiency and the 100kg/hr restricted fuel flow rate, the amount of power produced is record-breaking. 'The last time we saw these levels of power in Formula 1 was back in 2005, with a V10 that guzzled fuel at a whopping 194kg/hr. To halve the fuel flow rate for the same amount of power is quite something,' said Andy Cowell, managing director at Mercedes AMG High Performance Powertrains, last year.

This is excellent news for those with a green conscience, but it is all pretty useless if motorsport doesn't share these revelations outside of its racing bubble. This is where companies such as Williams Advanced Engineering come in, as they become the ideal platform to integrate these motorsport derived innovations into other industries, and to help solve more broader problems.

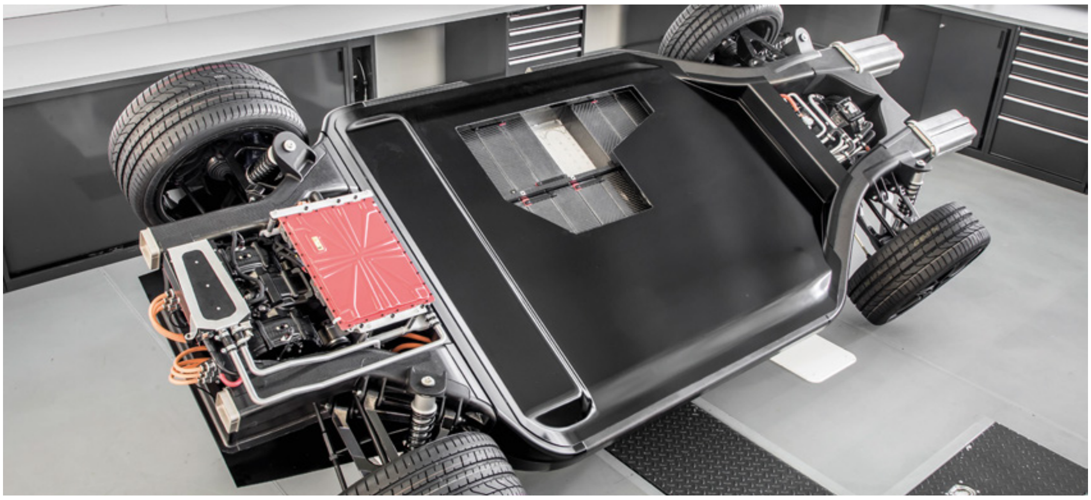
Widening horizons

'Williams identified that it wanted to take the occasional activity of special projects that the team completed in addition to F1 and make a separate entity that manages that work,' says Paul McNamara, technical director at Williams Advanced Engineering for the last five years. 'We have progressively built upon that concept of a separate company that uses F1 technology and applies it into other industries. There are two aspects as to why we exist, the first is because of the facilities we have access to, such as the wind tunnels, the carbon shops, machine shops, computational arrays and test facilities, all of which are in place because of the F1 team. The second is our capabilities, because we have expertise in aerodynamics, light weighting and electrification, the latter which came out of our original F1 KERS programme where we had to build up a team to deliver a battery, controller and inverter before the 2014 regulation change.'

Motorsport's advances are pretty useless if they are not shared outside of the racing bubble

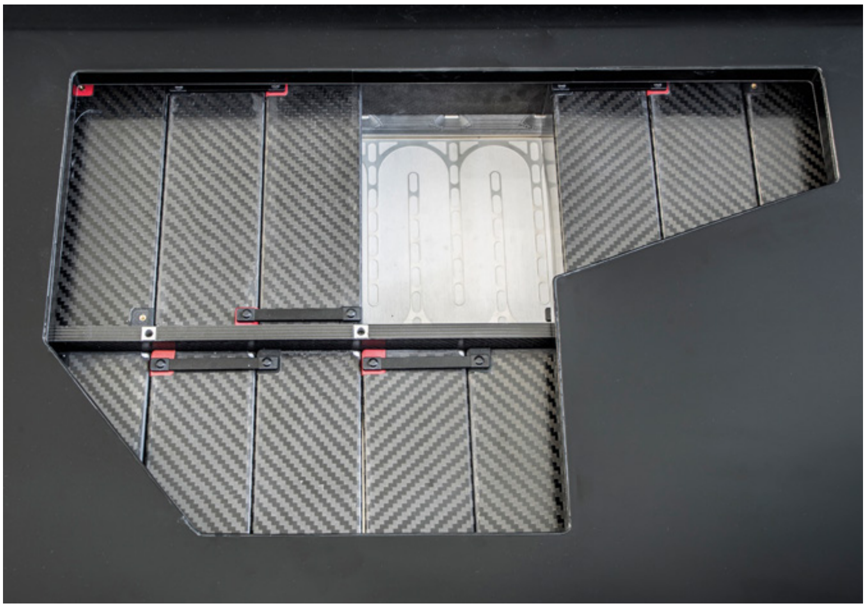
Electrification is really where Williams Advanced Engineering found its niche. After developing the F1 KERS system it then worked on the Jaguar C-X75 hybrid supercar, which was targeted to achieve the performance of a Bugatti Veyron, the emissions of a Toyota Prius and the electric range of a Chevrolet Volt, all within 18 months. The success of this really put the company on the map, which helped it to secure the tender for supplying the batteries for seasons 1 to 4 of Formula E, and for the Electric Rallycross Championship, set to start in 2021.

'This allowed us to build up our battery manufacturing capability to achieve reasonable volumes as well as provide support to the



Williams Advanced Engineering has designed a starter platform for electric vehicles. It features three patented technologies derived from F1, including carbon fibre folding techniques, innovative cooling strategies and carbon fibre wishbones

The FW-EVX uses Williams' Racetrak TM tech to produce carbon fibre wishbones using unidirectional fibres in precise locations. These are 40 per cent lighter than those forged from aluminium



Williams Advanced Engineering's 223TM is a carbon composite folding technique which is used to secure each of the 38 modules within the battery pack of the FW-EVX platform, giving it increased structural rigidity

'In this high-performance industry there are not many companies that can actually build a battery and supply it in low volume'

track and data analysis to review, maintain and also update the batteries each season,' says McNamara. 'With that foundation we were then able to develop batteries for low volume road car projects and it quickly became clear to us that in this high-performance industry there are not many companies that can actually build a battery and supply it in low volume. So, we decided to fill that gap in the market.'

Batteries included

One project that arguably incorporates the most F1 expertise is the FW-EVX platform designed to give car manufacturers a head start when developing an electric vehicle. This adaptable four- or two-wheel drive platform has a usable energy capacity of 80kWh, a New European Driving Cycle (NEDC) range of 343 miles and combines three patented F1-derived technologies; the 223TM composite folding technique, Racetrak TM carbon fibre wishbones and an innovative cooling system.

The battery pack is made up of 38 modules, with each module containing 10 lithium ion pouch cells that are wrapped in carbon fibre boxes using 223TM. This is where an engineered hinge is embedded within a single composite preform, so that the 3D structure can be created from 2D material and can therefore be folded where needed. This ensures that the battery pack has enough structural rigidity to help the chassis pass the side impact tests, which is often difficult for a layout such as the FW-EVX.

To help with this even further, the cooling system is actually part of the crash structure, because the cooling rails that run through the sills are designed to crush in sideways. These water channels are cooled from air flowing from the front of the chassis through integrated radiators, making sure both the battery modules and the power electronics operate at their optimum temperature.

'The FW-EVX also utilises our Racetrak TM technology which allows us to use unidirectional fibres in very precise locations within the structure to make an efficient and low cost type of carbon fibre,' says McNamara. Carbon fibre wishbones can be press-formed into shape in under 90 seconds and weigh 40 per cent less than forged aluminium wishbones.

'We think that light-weighting and electrification go together because by and large you are bringing into the situation a heavier system to provide your energy storage and traction,' McNamara adds. 'Therefore, weight has to be removed elsewhere so light-weighting the structure of the car as well as the battery casing is extremely beneficial to performance.'

This light-weighting philosophy, along with expertise in crash structures, has been essential to the success of modern F1 teams as the FIA continues to tighten the safety regulations and the teams continue to exploit performance. This has led to the development of advanced carbon fibre driver safety cells, which have now been carried over to the healthcare industry to help save the lives of new-born babies.

'We are very proud of projects such as Babypod 20,' says McNamara. 'This is where we designed a carbon fibre lightweight transportation device that is manufactured using our Formula 1 facilities. We also incorporated an effective retention system using standard retention clips so that the device can be secured into an ambulance safely. This device was then impact tested to check the intrusion levels and our design can now withstand 20*g* of impact during a crash as opposed to the previous design which could withstand 10*g*. Overall, we could make the Babypod 20 lighter and stronger than you can get elsewhere because of all the innovation that has gone into F1 over recent years.'

Babypod 20 was developed together with Williams Advanced Engineering's technical partner, Advanced Healthcare Technology (AHT) and workshops were held with nurses ↳

'We were able to make the Babypod 20 lighter and stronger because of all the innovation that has gone into Formula 1 over recent years'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from several hospitals to gauge the specific requirements. The device has a plastic cover which slides out of the way, allowing easier access to the baby. This new design also avoids the use of heavy incubators which not only require electricity but also dedicated vehicles. The Babypod 20 can now attach to any transport stretcher whether that be on a trolley, an ambulance, a car or even a helicopter. The Babypod is now used in intensive care ambulances and some hospitals in the UK, including Great Ormond Street Hospital.

Technology transfer

'Projects like this show that technology has a much broader relevance then we initially think,' says McNamara. 'In a similar vein to [Monty Python's] "what did the Romans ever do for us?", what did Formula 1 ever do for us? We have set up our Foresight Williams Technology EIS fund because there are a lot of small start-up companies that have some great ideas but need investment and technical expertise to gain traction and people's interest. Formula 1 has a key role to play in that because if you have had Formula 1 engineers help to develop your product then you are likely to get a lot more interest in your sales pitch.'

Another project where Williams Advanced Engineering has utilised F1 capabilities to improve efficiency is the Aerofoil. Based on the aerofoil shapes you find on the rear wings of Formula 1 cars, this aerofoil has been specifically adapted for supermarket fridges. It was developed in partnership with Cheshire-based Aerofoil Energy Ltd. The device attaches to the front of each refrigerator shelf and its aerodynamic profile channels cold air from the top to the bottom of the fridge, preventing it from spilling out into the aisle. This can save up to 30 per cent of a supermarket's energy costs, reduce CO_2 emissions, while it means you no longer have to wear a coat in the chilled section anymore, as this device also increases aisle temperatures by at least 4degC.

Supermarket sweep

One of the major UK supermarkets, Sainsbury's, is rolling this product out across its 1400 stores, which will reduce energy consumption by 44 million kWh, which is equivalent to the energy of 320 million kettles boiled. Asda is now onboard, too, while several US stores are also keen, as the device improves produce shelf life and therefore reduces food waste.

'There is an air curtain coming down from a grid at the top of the fridge, and as the airflow descends down, there is suction through another grid at the bottom,' explains McNamara. 'The flow also goes down the back of the fridge as well, so the split is around 70 per cent of the airflow coming out of the top grid falls down the front of the fridge, while the other 30 per cent travels behind the back of the shelves. When you analyse the CFD, the flow stays laminar at the front until about a third of the way down, where it becomes turbulent and starts to tumble. The aerofoils we have designed have a slight angle to their aerodynamic profile which keeps the flow hooked towards the aerofoil on the next shelf, as it travels downwards and therefore stays laminar. There is a small area of turbulence towards the bottom of the fridge, but a certain amount of that is being caught by the suction of the lower grid.'

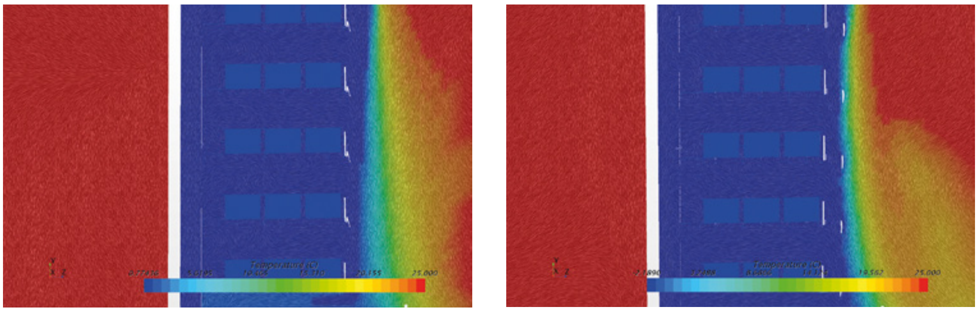
In motorsport, engineers start off designing for maximum performance, and then usually have to realign their designs to suit the

The Aerofoil device attaches to the front of each refrigerator shelf and its aerodynamic profile channels cold air from the top to the bottom of the fridge, preventing it from spilling out into the aisle

The cooling system of the FW-EVX is actually part of the crash structure as the cooling rails run through the sills, which means they will crush in sideways in the event of an impact

Originally inspired by Formula 1 rear wings, Williams Advanced Engineering has developed the Aerofoil to attach to the front of the shelves of open-front supermarket fridges. The device ensures that the fridge's airflow remains laminar while it can also reduce the energy consumption by 30 per cent. These are currently being rolled out in stores across the UK

regulations, and it is similar in the wider industry, as each has its own limitations. 'We did a lot of studies on all the different variants and we looked at the benefit of increasing the gap between the aerofoil and the shelf as you move down the fridge but that benefit wasn't enough to warrant the complexity of different designs that each supermarket would need to stock,' says McNamara. 'A surprising amount of engineering went into the attachment as well because it needs to be retrofittable, so you can't just approach it with a drill because all the swarf can create issues at the bottom of the fridge.'



A side-on CFD temperature slice of the refrigerator without the Aerofoil (left) and with it (right). Note how turbulent cool air from the fridge spills out into the aisle without the Aerofoil, but with the device the onset of turbulence is much lower down

F1 know-how

The advanced development of the aerofoil, and therefore its success, was only possible because Williams Advanced Engineering tapped into its CFD and experimental aerodynamic expertise gained from F1. In fact, it is this close relationship between Williams Advanced Engineering and F1 which is the real secret to the success of such projects and of such a company. Williams Advanced Engineering is now more than 250 people strong, but because the F1 side runs the wind tunnels and majority of the test facilities, up to 100 people from the F1 team can be involved with Williams Advanced Engineering projects at any one time.

'Williams Advanced Engineering to my mind is indivisible from the Formula 1 team, it is all part of one group,' McNamara says. 'Williams have a Formula 1 team, and an advanced engineering company. In fact, because we are utilising the wind tunnels, machine shops, simulators and test equipment for our projects the Formula 1 facilities perform a lot of work for us and therefore Williams gain benefit directly from the fact that the two co-exist. We want to show people that F1 technologies have a real-world relevance and can benefit different businesses in different ways.'

New business model

While Williams Advanced Engineering is growing strongly, the Williams F1 team has struggled on the track this season. However, the success of Williams Advanced Engineering reaching outside its comfort zone and in to other industries is bound to be a huge support to its F1 sister, and may be part of the reason for the F1 team's continued investment and optimism. With the recent demise of Caterham, Manor Racing and Force India's dip into administration this year, it is clear that funding an F1 team outside of the big three is unsustainable in F1's current format. Is this the reason behind McLaren's sister company McLaren Applied Technologies (MAT)? Or why Red Bull now has its Advanced Technologies division? Or will these side-companies simply provide the holding pen for engineering talent when the 2021 budget caps come into force?

Whatever the reason, the expertise gained by the thousands of Formula 1 engineers that design the most efficient racecars on the planet is a hugely untapped resource, and a resource that can bring great benefit to every other sector. Many would feel more content knowing that the brains behind F1 are also being used to improve the facilities in our hospitals, help the energy efficiency of transport, and design the armoured vehicles for our armies.

'Williams Advanced Engineering is to my mind indivisible from the Williams Formula 1 team, it is all part of the one group'

Woking awakening

The stunning 720S GT3 is at the heart of McLaren's customer racing programme

With the GT racing division now brought in-house the full might of McLaren is about to hit the world of customer sport. *Racecar* visited its new HQ to get the inside line on its present intentions and future plans

By ANDREW COTTON

McLaren has had a hard time of it recently and it is clear that there are some points that need to be addressed over the next few months. Target number one is to hit its sales targets of 4700 road cars, and the company says that it is on target to achieve this. Target number two is to sort out its Formula 1 team, which has had a shocking time of it in that highly public domain. The third and final target is to sort the GT racing division, which is going through an acrimonious split with Chris Niarchos, who developed the GT3 cars through his company CRS. This divorce procedure has now finished up in the high court in the UK.

That the split will happen is inevitable, although the details of the final judgement have yet to be revealed at the time of writing. But, to service the company's existing GT3 customers and to prepare the GT4 programme, McLaren has kick-started its own GT racing division in Woking, down the road from the impressive McLaren Technical Centre.

Home grown

This is a new Unit 1, and not the same Unit 1 which was once the base for the Formula 1 team. There, the spirit of Ron Dennis still lingers, with the now famously coloured floor tiles, as well as more tangible evidence of his time there

McLaren 720S GT3

The GT3 has been developed with gentleman drivers in mind and it is said to be a user-friendly racecar

The new GT3 McLaren has already been testing in professional hands, and in the hands of customers. The company intended that the car is easier to drive for the gentleman driver, and has trusted these drivers in the car early in the development stage.

The GT3 features the Mono Cell from the production version of the McLaren 720S, which is mated to the M840T 4-litre V8 engine. The car is sold at £440,000, which is a relatively high price for a GT3 car, but certainly not as expensive as the Ferrari 488.

The car also features lightweight body panels, a bespoke splitter, floor assembly and dive planes. A new electronic shift actuator increases shift speed, usability and reliability, while a Salisbury-type limited slip differential is fitted, as are cockpit-adjustable traction control and driver aids. The driver seat is fixed, in line with the FIA regulations.

TECH SPEC: McLaren 720S GT3

Chassis
McLaren carbon fibre MonoCage II, FIA approved roll cage

Engine
Motorsport-prepared M840T, 4-litre twin-turbo V8, 3994cc

Transmission
6-speed sequential motorsport gearbox

Suspension
Adjustable dampers with coilover springs, front and rear

Drivetrain layout
Longitudinal mid-engined; rear-wheel drive

Bodywork
Bespoke lightweight carbon fibre/composite body panels

Aerodynamics
Bespoke front splitter and floor assembly, dive planes, GT3-specification rear wing

Driver seat and harness
Winged head-rest seat (FIA approved); 6-point race harness

Dimensions
Length: 4664mm. Width: 2040mm. Wheelbase: 2696mm. Overhang, front/rear: 1155mm/813mm. Axle body width, front/rear: 2040mm/2040mm. Track, front/rear: 1745mm/1716mm

– his toothbrush still resides in his old office. But while that building might be historic, it is a world away from this new facility.

This new assembly plant is on an industrial estate on the outskirts of Woking, and while the company is still unpacking boxes, it is also still expanding. Currently, the GT3 and GT4 racecars, along with the company's 'Pure' experience, are housed in one unit, but the plan is to extend to a second unit, and bring all of the 83 workers under these two roofs. Beyond that the plan is to expand the workforce to more than 100 by the end of Q1 in 2019. And also to deliver a small number of GT3 cars to targeted customers around the world.

Limited edition

'We are going to sell this [the GT3 car, see the top of this page] in limited numbers, and that is a conscious decision, because we have to think of customer ownership experience, that enjoyment of ownership, which comes from a concerted and focussed effort from McLaren,' says Dan Walmsley, motorsport director at McLaren Automotive. 'In year one, we do have a maximum number, which is not a large number, but we will hit 20 [sales] in two years as demanded by regulation.'

The key thing is, the company does not want to give a number and then fall short of it and be deemed a failure. 'McLaren is there to operate as a business and we have regulation obligations to the FIA,' continues Walmsley. 'Our business case is to supply 20 cars in the first two years, but the key now is, we are trying to deploy the cars into the right championships with the right teams in the right circumstances.'

Starting up the division from scratch has required some serious planning and investment in facilities and machines ahead of the facility going online mid-2018. 'We are starting from a compromised position, we have had a difficult 18 months, bringing the division in-house, assemble a team, build the processes, develop a product, and we have launched a global retailer network for motorsport products,' Walmsley says. 'It is not a question of learning to walk before you can run. We are running, but we don't want to sprint and fall on our face. We want to maintain a high-quality pace.'

The new GT3 car, based on the 720S, is the first to be developed by the McLaren Automotive team, and it has an unusual build structure. The cars are assembled in their own bays, a stark contrast to higher volume suppliers that take the car around the factory to for assembly. This, says Walmsley, means that the space can be used more efficiently.

'We are trying to deploy the GT3 cars into the right championships, with the right teams, in the right circumstances'

General assembly

The company intends to produce the GT3 and GT4 cars from the same assembly unit, and expects to produce around 120 racecars per year. The build time of a GT4 car will be around 12 days, having started its life on the production line. Having advanced as far as it can go, the GT3 car will turn left, coming to McLaren Motorsport Division (MMD) as this requires 95 per cent unique parts, while the GT4 car turns right and goes straight to the paint shop before coming to MMD for final assembly.

When *Racecar* visited the Woking workshop the bays were all full as the company prepared for an event in Bahrain, as well as getting cars ready for delivery in early 2019.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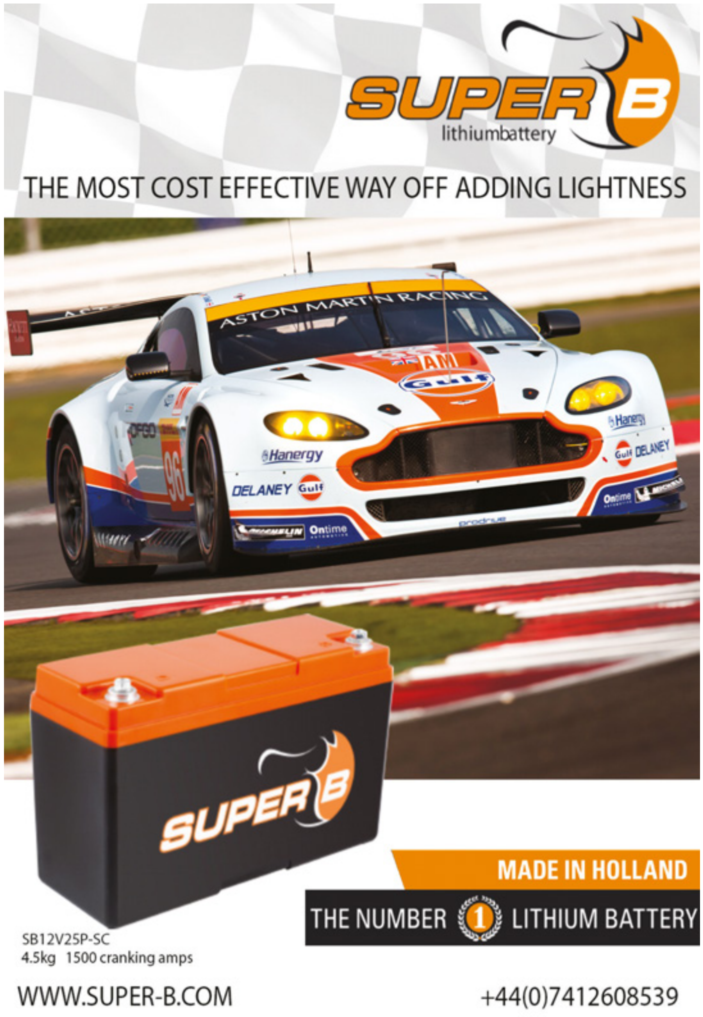
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The McLaren Motorsport Division builds up its GT cars in race bays at its pristine new Woking base

The GT3 car sat in a bay of its own, stripped down and being prepped for the FIA's Balance of Performance (BoP) testing. It has yet (at time of writing) to complete the testing, which is new this year and no longer uses the Michelin Ladoux facility in southern France. Now the engines run on the dyno first, and then the bodywork is taken to the Sauber wind tunnel in Switzerland before going on to the SRO's BoP tests in Paul Ricard early in 2019. McLaren is confident that its car will be competitive from the start, even under the BoP process.

'The BoP will slow the car down, but the laws of physics will allow a car with a low centre of gravity, with the right geometry and right tyre and handling characteristics, to shine,' says Walmsley. 'The target is to have the two prototypes running, this one will get through the homologation process, it has done the FIA dyno test. They dyno the engine, and the car will go to the wind tunnel, so shut gaps and flush are as they should be and the car is presented in the right way. It is getting ready and coming on well. We are in pretty good shape.'

Global market

As mentioned above, McLaren is under obligation to hit a sales target of 20 GT3 cars in the first two years, and to do that it has to win races. However, there is a world to sell to, with a proliferation of GT3 series including the Pirelli World Challenge and IMSA's GTD classes in the US, Blancpain Sprint and Endurance Series in Europe, coupled with a wealth of national series including the British, French and German series, and the Asian Le Mans Series and Australian GT Championship. There is also the opportunity for manufacturers to race in the Intercontinental GT series, which is global and has one race on each of five continents. But servicing teams in this sort of arena is no easy task.

'Our road car product is born on the track and it would be a nonsense to not be out there competing against other OEMs'

Currently McLaren has 86 retail centres and is planning to upgrade at least 12 of them to also accommodate the motorsport division. Using the McLaren brand, there will also be access to finance, legal and commercial experts around the world, and 24/7 support for its race teams. It is this, says Walmsley that will improve the customer experience.

'The motorsport retailer network gives us the geographic outposts that we are looking for as well; seven in North America, one in the Middle East, two in Asia Pacific, two in Europe, one in the UK that's not here [Woking] and another in central Europe,' Walmsley says. 'In 18 months we want to extend that to between 12 and 18, which will give us the global coverage. That allows us to engage our retailers in what we are doing. We have engaged with some top quality outfits that have motorsport experience, and we are racing with customers already, and we have opportunity to geographically locate spare parts, have technical expertise in region, and man a phone day and night.'

Customer service

This is the key to the future; if the customers are not happy with the service, or car, then the division will fail. Right now, with the high court decision pending and a settlement to be found, there is little anyone can do to predict the future, but McLaren is optimistic. 'The key thing for us, we exist [as] McLaren Motorsport Division and we are here as a marketing function for McLaren,' says Walmsley. 'It is undeniable that our road car product is born on the track, and it would be a nonsense to not be out on track competing against other OEMs.'

Regardless of the outcome of the court case then, McLaren says that its customer racing division is very much still in business.

Currently McLaren has 86 retail centres and it's planning to upgrade at least 12 of these to accommodate the motorsport division

The true cost of logging on

Our chassis simulation expert explains why data logging is not only a necessary skill for all race engineers, but it is also a good deal cheaper than you might have been led to believe

By DANNY NOWLAN

Data logging is valuable at every level and a modest initial investment will pay dividends in the end. GP3 racecar pictured

A question that comes up from time to time is, from a chassis perspective, what data logging channels do you actually need? It's a question I get asked on average once every two years. And it is actually a very important question.

But before we get on to that, I've some good news: in order to get the data you will need to engineer a racecar it won't cost you the earth. Actually, it's a huge misconception that abounds in this business that in order to engineer a racecar properly you need to spend a king's ransom on data acquisition. Not only is this categorically false, it's also a misconception that can cause issues later on in an engineer's career.

Categories such as Formula 4 have been created as the new nursery for drivers to learn their craft. As they progress up the ranks, if they are not data literate then they don't stand a chance. Any driver worth their salt must have the ability to review the data and to understand it.

But this doesn't apply only to drivers. It also applies to young engineers and mechanics; they need to know what to look for in the data so they can engineer the racecar, too. As someone who has been in the trenches as a race and data engineer I can testify that this is one of the first skills you must learn. This is why F4, F3 and Formula Renault cars must always run data logging with the appropriate sensors, for not to do so will have terrible consequences as drivers, engineers and mechanics progress through the ranks. It also looks completely ridiculous when club racecars and games like iRacing, rFactor and Project Cars have more data logging than a professional formula car.

The great news is that the core of what you need to log on a racecar can be distilled down to just 17 channels. The other good news is that these channels are presented in **Table 1**.

Table 1 isn't just based on text book theory. What you see outlined here is the basis of the ChassisSim monster file and the engine channels that are the first port of call for any engine diagnostic you should be looking at when the car is initially downloaded. Also, brake pressure channels are essential for driving coaching and monitoring the health of the braking system. Logging gear position is also a good thing, but to be honest you can infer this from data.

I've also added the vertical *g* sensor and GPS channel because recently I have found this invaluable for completing circuit models that take into account camber and track undulation.

Reverse gear

The first point to be raised is that this information can also be used to reverse engineer the aerodynamics of the car. I have discussed this on many occasions but allow me to present a quick recap. Every damper pot on the car is a load cell, and that spring force is given by **Equation 1**.

It is assumed the zero of the spring function is when the car is on the ground. In most cases the spring function, *k*, is a spring rate. If bump rubbers are used the spring function, *k*, can be easily deduced by a look-up table. But if you are fortunate enough to have strain gauges fitted to the racecar, then all the hard work in **Equation 1** has been done for you.

Now the spring force has been determined we need to determine tyre deflection. In the absence of laser ride height sensors; the tyre deflection is given by **Equation 2**.

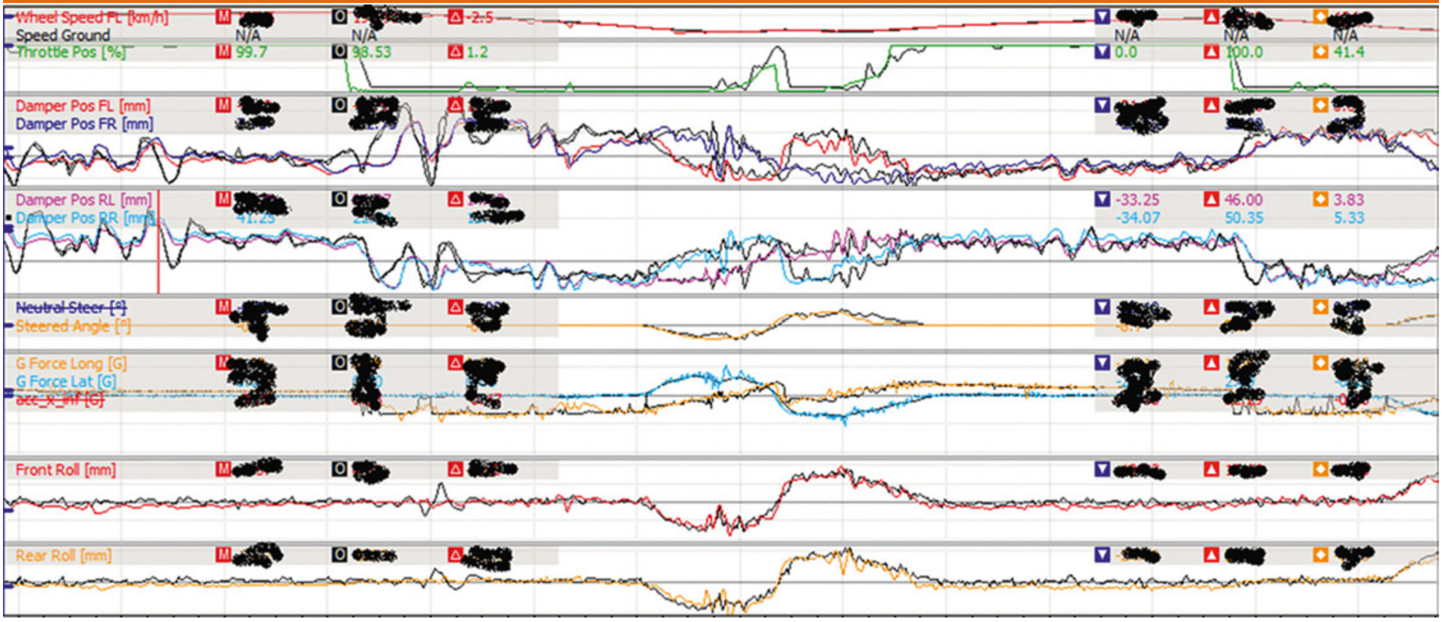
This is where things can get a bit tricky. As we know, tyre spring rate is a function of wheel speed, tyre pressure and camber. However, to get started I would suggest you use a single approximate figure. While not strictly accurate, it will form a basis on which to get going and you can add a more complex analysis later. Also, in

Table 1: Core channels you will need to log

Channel	Role	Frequency
Engine RPM	Engine/chassis	50Hz
Engine temp	Engine	10Hz
Oil pressure	Engine	10Hz
Lateral acceleration	Chassis	200Hz
Vehicle speed	Chassis	50Hz
In-line acceleration	Chassis	200Hz
Vertical acceleration	Chassis	200Hz
Steering	Chassis	50Hz
Throttle	Engine/chassis	50Hz
Front brake pressure	Chassis	50Hz
Rear brake pressure	Chassis	50Hz
Gear position sensor	Chassis	10Hz
Damper position FL	Chassis	200Hz
Damper position FR	Chassis	200Hz
Damper position RL	Chassis	200Hz
Damper position RR	Chassis	200Hz
GPS altitude	Chassis	10Hz

F3, F4 and Formula Renault cars should always run data logging with the appropriate sensors, for not to do so will have terrible consequences for the engineers and mechanics as they progress through the ranks

Figure 1: Example of correlation for a V8 Supercar on a street circuit



my experience, if the appropriate value of *kt* is chosen this can actually get you very close.

Once the deflection of the tyre is known the user can deduce how much the corner of the racecar compresses under this load. This deflection can be worked out with **Equation 3**.

The convention for the car corners is at the discretion of the user. The convention that I use is as follows: 1 is the left front, 2 is the right front, 3 is the left rear and 4 is the right rear.

Once the user has deduced the corner deflections, the ride heights can then be calculated. The front and rear ride heights *rhf* (front) and *rhr* (rear) are given by **Equation 4**.

These can be either drop heights or ride heights from the floor. The choice is really up to the end user and whether they want to clarify the aeromap by either drop or floor heights.

Now that we have clarified the ride heights and forces for this particular point the aerodynamic forces that are associated with this point are given by **Equation 5**.

I have presented on multiple occasions a Formula 3 hand calculation example of this. But what I have just presented is the basis of the ChassisSim aero modelling toolbox.

The other thing you can do with the data presented in **Table 1** is to use it to reverse engineer the tyre model of the car. You can do this by doing a whole bunch of track replays and changing the tyre model to minimise the differences between actual and simulated *g*. What I have just described is the basis of the ChassisSim tyre force modelling toolbox and the results of this are presented in **Figure 1**. As always, actual data is coloured and simulated

EQUATIONS

EQUATION 1

$$F_S = \left(k(x_s) + c(\dot{x}_s)\right) \cdot MR$$

Where

F_S = force of the spring damper unit at the wheel
x_s and $\dot{x}_s$ = movement and velocity of the spring
k = spring rate or function
c = damper rate or damper function specified at the damper
MR = motion ratio of the spring expressed as damper/wheel movement

EQUATION 2

$$w_m = \frac{F_S}{k_t}$$

Where

k_t = spring rate of the tyre
w_m = wheel movement

EQUATION 3

$$d_i = \frac{x_{s_i}}{MR} + w_{m_i}$$

Where

d_i = compression of the corner of the car for corner i
x_{s_i} = the spring deflection for corner i
w_{m_i} = the wheel movement for corner i

EQUATION 4

$$rh_f = rh_{f0} - \frac{d_1 + d_2}{2}$$

$$rh_r = rh_{r0} - \frac{d_3 + d_4}{2}$$

Where

rh_{f0} and rh_{r0} = initial ride heights

EQUATION 5

$$C_L A = \frac{\sum_{i=1}^{4} F_{s_i}}{\frac{1}{2} \cdot \rho \cdot V^2}$$

$$C_D A = \frac{\frac{T(rpm) \cdot gr}{r_t} - m_t a_x}{\frac{1}{2} \cdot \rho \cdot V^2}$$

$$awf = \frac{\sum_{i=1}^{2} F_{s_i} + \frac{m_t a_x h}{wb}}{\sum_{i=1}^{4} F_{s_i}}$$

Where

$C_L A$ (sometimes referred to as C_Z) $C_D A$ (sometimes referred to as C_x) = the lift and drag coefficients
awf = the factor of downforce on the front
a_x = in-line acceleration
$T(rpm)$ = engine torque in Nm
gr = gear ratio (in terms of torque multiplication from engine to gearbox)
r_t = rolling radius of the tyre

is black. The first channel is speed, the second trace is throttle, the third and fourth traces are dampers and the fifth trace is steering. The moral of the story is all this was generated using only the items provided in **Table 1**. It did not require a $100,000 data logging suite.

Also, you can readily create a circuit model with a car fitted with the channels outlined in **Table 1**. Firstly, the lateral acceleration you can deduce from the curvature file, which describes the path the vehicle takes, as in **Equation 6**. This is one of the best kept secrets of data analysis. The road surface profile can be reverse engineered from the dampers (ChassisSim bump profile modelling is an excellent case in point).

You can also reverse engineer the road camber from the vertical *g* accelerometer and GPS data. It is actually a spin off of **Equation 6**. Here we just sub *az* (vertical acceleration) for *ay* and look at the vertical curvature from the road surface provided by the GPS altitude. We then simply compare this to the normal curvature calculated from *az* and the difference is the road camber. That's how straightforward it is.

Logged and loaded

However, the real question you want the answer to here is what is the price? The quick answer is; not as exorbitant as you might think. Let me present two options you can go with. One will be Motec, the other Magneti Marelli. The breakdown of prices in Australian dollars is presented in **Table 2, a** and **b** (100 Australian dollars is around £54 or US$71, at the time of writing).

Whichever choice of supplier you take the investment will come in under $10,000. This will cover you for everything you will need. This is also the Rolls Royce option. There are other systems like AIM that can get you going for a lower price, and I would invite Cosworth electronics to put in its own costings. Bottom line, CAMS (Confederation of Australian Motor Sport) is capping the cost of Formula 4 at $170,000 and a rolling chassis will cost you somewhere in the order of $60,000. In the grand scheme of things this is not going to break the bank, then.

Think of this another way. A cost of $10,000 would cover you for a couple of days of testing – before you all say this figure is too high, add in flights, accommodation and food for driver, engineer and two mechanics, as well as the cost of running the car. But you pay this expense once, and all this testing becomes much more valuable.

Data blast

What we have just covered is the bare bones of getting you going. But what's involved in taking this 'over the top', so you have everything that you could possibly need, is illustrated in **Table 3**.

All the channels listed in **Table 3** will give you everything you need to not just race engineer the car but also to develop it. Let's take this opportunity to break this list down.

Firstly, laser right heights and the suspension loads complement the damper pots quite nicely. The suspension loads, also known as strains, complement the damper pots and this combined with the suspension movement will allow you to nail down the tyre spring rates.

I could have also added laser right heights left and right here but you can nail that down with two laser right heights at the front and one at the rear. However, a word of warning here; laser ride height sensors and strains are a bit like fish and chips and romantic movies. When they work they are fantastic, when they don't work, they are awful. So choose wisely.

The tyre temperature sensors allow you to nail down what the tyre is doing. The internal and surface temperature reveals what is truly going on with the tyre. It is why I put so much trouble and effort into incorporating this into the ChassisSim tyre model. You can get these items from bf1systems. Also, its tyre pressure monitoring systems are essential items if you have a racecar that is worth serious money.

Lastly, yaw rate will finish the picture. This will allow you to determine what is going on with sideways velocity and it nails down that all-important picture of the stability index.

In terms of finances, all this isn't as outrageous as you might think, either. Talking in Australian dollars again, the strains and laser ride heights will set you back about $1000 each and the tyre temperature monitoring will set you back $5000. A good yaw rate sensor is about $1000. So if you tack that on to the complete expenditure of $10,000 for the basics, to go silly will cost you another $13,000, so $23,000. Given that a GT3 racecar is these days in the six-figure territory the true question that needs to be asked is: why wouldn't you spend the money?

Logging off

In summing up, not only is data logging essential, but you only really need a handful of channels and it is also certainly not as expensive as you might think. The reason it is essential is that the combination of channels will allow you to reverse engineer parameters on the car and it is a perfect complement to tools such as ChassisSim. The combination of these tools will allow you not to just understand the racecar, but extract it's maximum performance. Combined with the competitive pricing, all this makes data logging a wholly necessary tool.

EQUATIONS

EQUATION 6

$$iR = \frac{1}{R} = cv\_sign \cdot 127.008 \cdot \frac{a_y}{V^2}$$

Where

iR = curvature (1/m)

a_y = lateral acceleration (g)

V = vehicle speed (km/h)

cv_sign = sign of corner (+1 for a_y being positive for a right hand turn, -1 for a left hand turn)

Table 3: Extra data channels

Channel	Role	Frequency
Pitot speed	Chassis	50Hz
Suspension load front left	Chassis	200Hz
Suspension load front right	Chassis	200Hz
Suspension load rear left	Chassis	200Hz
Suspension load rear right	Chassis	200Hz
Front laser ride height	Chassis	200Hz
Rear laser ride height	Chassis	200Hz
Internal tyre temp front left	Chassis	10Hz
Internal tyre temp front right	Chassis	10Hz
Internal tyre temp rear left	Chassis	10Hz
Internal tyre temp rear right	Chassis	10Hz
External tyre temp front left	Chassis	50Hz
External tyre temp front right	Chassis	50Hz
External tyre temp rear left	Chassis	50Hz
External tyre temp rear right	Chassis	50Hz
Yaw rate sensor	Chassis	50Hz
GPS altitude	Chassis	10Hz

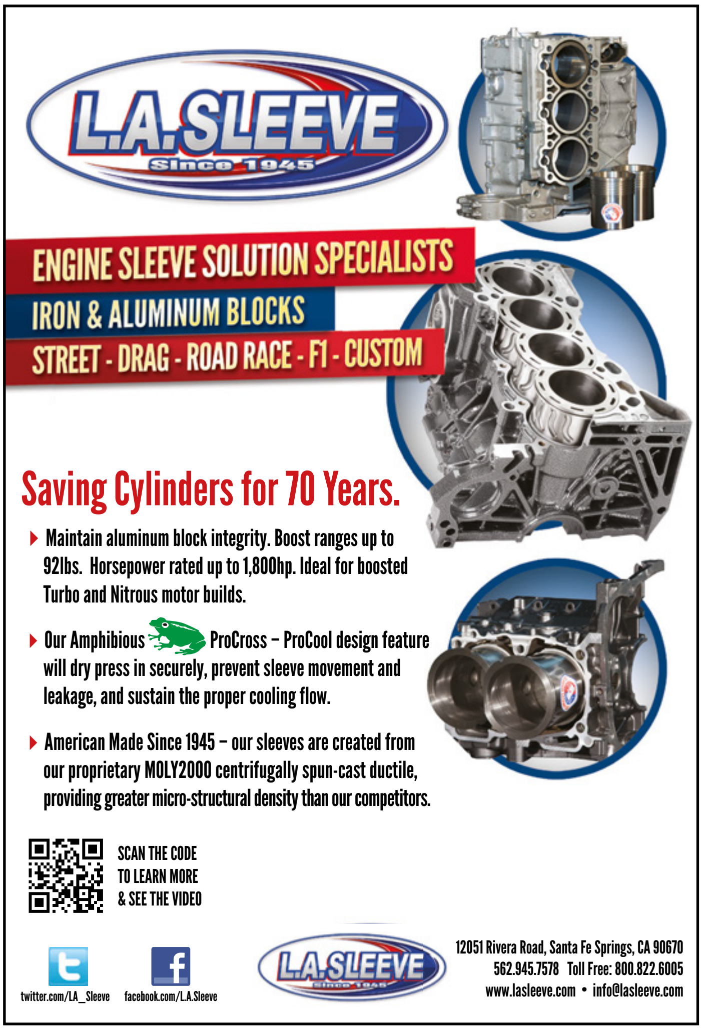
Table 2a: Breakdown of prices for data logging; Motec option

Item	Price
Motec ADL 3	$5000
Three-axis accelerometer	$1200
Damper pots	$400
Steering sensor	$200
Throttle sensor	$200
Temp sensor	$200
Pressure sensor	$400
Brake pressure sensor	$197.50
GPS package	$400

Table 2b: Magneti Marelli option *(courtesy Competition Systems Australia)*

Item	Price
Magneti Marelli DDU310 Dash Logger	$5350
Three-axis accelerometer	$395
Damper pots	$450
Steering sensor	$225
Throttle sensor	$127.50
Temp sensor	$65
Pressure sensor	$185
Brake pressure sensor	$197.50
GPS package	$1150

Not only is data logging essential, but you only really need a handful of channels and it is not as expensive as you think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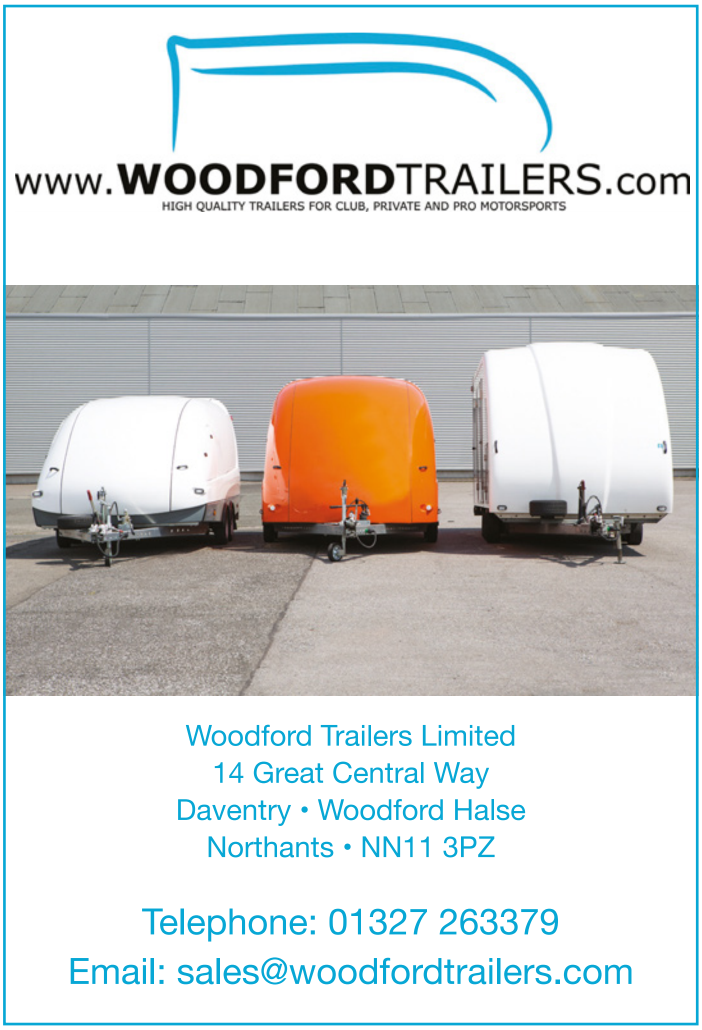
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High performance

Could the drug scandals that have rocked other major sports also hit motor racing? And are there really banned substances that might help drivers, engineers and mechanics, perform better?

By SAMUEL COLLINS

Drugs
and their uses

Brain drugs:	Modafinil, Ritalin, Adderall, Tacrine. Some of these can enhance cognitive function, memory and attention span.
Blood doping:	Erythropoietin (EPO). The US Air Force has experimented with blood doping to improve the performance of fighter pilots, while Australian special forces have admitted using blood doping to improve alertness and endurance.
Steroids:	To increase muscle mass.
Stimulants:	Amphetamines, ephedrine, methylhexaneamine. All have been found to have been in use in motorsport at some point.

Motor racing has always been about finding an edge, or, as Mark Donohue famously put it, gaining that 'unfair advantage'. From the earliest days of the sport almost every part of a competition car has been optimised, developed and pushed as far as the rules allow, and at times beyond. Modern technology and ever tighter technical regulations make gains harder to find, so even the smallest things can make a big difference. This has seen at least some attention shifting to what is perhaps the trickiest and most flawed component of all, the driver.

In the last three or four decades the importance of driver fitness has increased significantly and continuously, today all serious professional drivers have strict training regimes, specialised diets and experts in human performance working with them almost constantly. In many ways this is no different to other major sports, where athletes are as fine tuned as possible for the requirement of their discipline, but, like motorsport engineers pushing beyond the regulations with car design, in many sports competitors have also pushed beyond the rules with their bodies to find that unfair advantage.

Stirling Moss, Mille Miglia 1955. Moss has admitted that he took drugs to help keep him awake on rallies

Cycle of shame

Most notably the use of performance enhancing drugs has dogged cycling for decades, especially in the wake of the 'Festina Affair' and the revelations relating to Floyd Landis and Lance Armstrong. Two-wheeled human-powered sport is not alone, the Olympics has seen a large number of doping scandals in recent times, while the 2018 soccer World Cup had very prominent anti-doping controls, too.

Motorsport has not been entirely immune to this, most notably World Superbike rider Noriyuki Haga was hit with a ban in 2000 for using ephedrine, a stimulant which can also aid with weight loss. Haga claimed that the substance entered his system as a result of him taking a health supplement, but the ban was upheld by the FIM after appeal.

This was not the first time that motorsport competitors had tested positive for using the substance. In 1995 two Formula 1 drivers, Rubens Barrichello and Max Papis, also tested positive for ephedrine, though they claimed that they did know it was a

Today the FIA follows the World Anti-Doping Association regulations closely

Although there's no major drug problem in racing the FIA has tightened up its testing regime in recent years

banned substance and it was in their system as a result of being part of a cold and flu remedy both were taking at the time.

Professor Sid Watkins, who was then the Formula 1 medical delegate, claimed that both drivers were 'totally ignorant that the medicine they were taking contained a banned substance', and he went on to say that it would be better if Formula 1 did not utilise the IOC banned substances list as this was not specifically designed for it. Neither driver was penalised.

Things have changed a lot since then. Today the FIA follows the World Anti-Doping Association (WADA) regulations closely, having become a signatory in 2000. However, some in the sport still do not feel that this is worthwhile. They believe that there are no substances which could offer a competitive advantage in racing. But this sentiment is simply incorrect.

Unfair advantage

'Although not as physically demanding as some sports, human performance in motorsport is important and it can be significantly enhanced by drugs and prohibited methods. Therefore the risk of doping in motorsport is a factor which must be considered to ensure fair and safe competition,' the FIA's head of anti-doping, Prisca Mauriello, says. 'There are drugs which, for instance, can help you concentrate or be focussed for longer, there are others which can reduce your stress level too, so in terms of motorsport there are, absolutely, substances which can help improve performance.'

Doping for performance enhancement is actually nothing new in motor racing and drivers in the 1950s such as Juan-Manuel Fangio and Sir Stirling Moss used substances to boost performance. 'I used to take drugs, not when racing, but on rallies, it was the norm,' Moss told the *New York Times*. 'They weren't considered drugs at the time. The whole drugs thing only came in as sportsmen and women began using them to enhance their bodies. You would take amphetamines, Benzedrine or Dexedrine, purely to keep you awake. I'm not sure what was in the ones Fangio gave me for the 1955 Mille Miglia, but certainly today they would have been a banned substance.'

Largely as a result of developments in other sports the use of banned substances has become increasingly sophisticated, especially in recent years, and notably the FIA has increased its anti-doping activity significantly in the last two years – though this is because, it says, it is increasing the number of series it actively monitors.

'That increase is primarily due to the increase in the number of international championships being monitored,' Mauriello says. 'However, the total number of tests per year has remained on a similar level since 2011. This total consists of testing conducted on-event, between events and off-season.'

The FIA maintains what it calls its 'testing pool', a list of drivers from various championships who it tests periodically. 'Typically we conduct up to 130 tests per year, of which around 100 are during competition,' Mauriello says. 'The total number

Drugs like Adderall and Ritalin could allow a driver to have better levels of concentration for longer, which is why they have been used in e-sports; while simulator drivers might also be tempted to use them

'Human performance in motorsport is important and it can be significantly enhanced by drugs and prohibited methods'

of drivers tested will be somewhat less, as drivers may be tested multiple times in the same season. As the scope of the FIA testing is limited to international competition, the monitoring carried out by local authorities at national level is not taken into account in this data. It is also possible for national authorities to conduct their own testing during international events.'

Random tests

Drivers in the testing pool need to notify the FIA of their whereabouts at all times, so that they can be called on to give a sample at any time. This is not particularly popular with many drivers, but it is something which is common to all professional sports which comply with the WADA regulations.

It's been said that this testing in F1 is predictable; always just before pre-season testing in Barcelona, and on the Saturday at Spa, but Mauriello denies this is the case. 'Actually this year the tests were not in Barcelona so it's not that predictable,' he says. 'The FIA aims to test the drivers in the testing pool at least once a year, but the national authorities can also test them whenever they want. So if a driver is living in Monaco he can be tested out of competition by the Monaco sporting authorities. So the drivers can never be certain when or where they will be tested, it could be the FIA or another organisation.'

With 130 tests per year that gives some indication of the size of the testing pool, taking in all the drivers in Formula 1 and F2 as well as the manufacturer entries in the World Rally Championship and WEC. 'It might change soon but we focus on the main categories, Formula 1 and the WRC,' Mauriello says. 'But if there is any suspicion about a particular driver the FIA can add them to the testing pool. That means even if the driver is competing at a lower level they could still be part of the testing pool. But really we are focussed on the main categories because that is where the money is, and to date that has mainly been F1 and the WRC. It's the professional drivers.'

It is worth noting that drivers both in and out of the testing pool can still be tested at any point by their own national authorities, so this is not the limit of drug testing in the sport.

But the sport does not only consist of drivers, there's the whole team, with staff at the factory, on the pit wall and in the pit crew all contributing directly to the outcome of the race. Because of this NASCAR takes something of a different approach, randomly testing drivers and crew members under its substance abuse policy. It is able to do so as it requires all crew members at the track to be licenced, as well as the race drivers. Currently the FIA does not licence team members so this is somewhat out of its jurisdiction.

'We do not yet have a plan to roll out testing to mechanics or engineers,' Mauriello says. 'Right now the WADA code only concerns the drivers and their direct 'support personnel', the parents or the physio, for example. A team doctor could be guilty of assisting a driver in doping, for example, but we would not ask them for a urine sample. Those people are not linked to the FIA with a licence and we are not currently looking at something like that for the pit crews.'

NASCAR randomly tests its race drivers and crew members under its substance abuse policy

Smart drugs

But what sorts of drugs might be used in motorsport? There has been a well documented rise in the misuse of so called 'smart drugs' in professional e-sports which for some time went un-policed. This is noteworthy, as some of the skills utilised in e-sports are directly applicable to motor racing.

The FIA anti-doping procedure

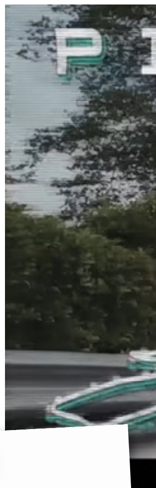
The test procedure typically applied by the FIA can be summarised in the following steps. The FIA selects the driver to be tested (in most cases prior to the event) who are then notified by the chaperone that they are required to report to the Doping Control Station for testing. The chaperone then stays with the driver until he or she can report to the Doping Control Station. When the driver does this they then provides two urine samples in the presence of the Doping Control Officer, and the specific gravity of the samples are measured.

The driver then seals the samples in the presence of the Doping Control Officer and the Doping Control Form is completed by the Doping Control Officer and the driver. The Doping Control Officer then sends the two samples to a laboratory accredited by the World Anti-Doping Agency (WADA) for analysis. The analysis of the samples is conducted by this WADA accredited laboratory and the results are available within a few weeks after the sample collection.

In the case of a negative result, no communication with the driver is necessary. In the case of a positive result, the driver is notified once the FIA has been informed. However, it can take several months before a sanction is decided. If the case is appealed, the decision of the Court of Arbitration for Sport can require up to one year. According to the WADA Code, all anti-doping rule violations and the associated sanctions must be published. Sanctions applied are then valid for all categories of sport which are governed by federations who are signatories of the WADA Code.

Adderall and Ritalin were in relatively widespread use in some e-sports, and these drugs essentially speed up brain activity. Aderall lasts for four to six hours while Ritalin is active for two to three hours. If used in motor racing they could in theory allow a driver to have better levels of concentration for longer. While both drugs are on the banned substances list they can be used in the sport without breaching the regulations with the use of a Therapeutic Usage Exemption (TUE), as these drugs are regularly prescribed for the treatment of ADHD (Attention Deficit Hyperactivity Disorder).

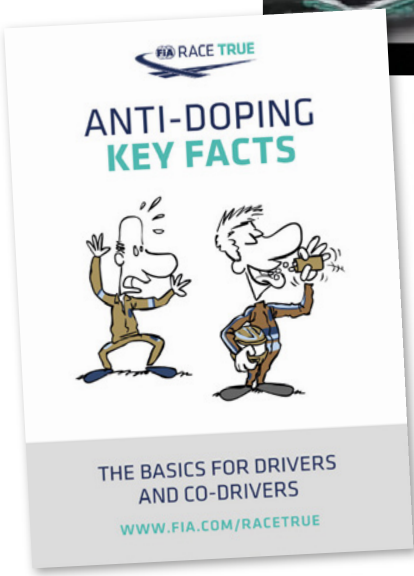
'If a driver is required to use a prohibited substance or method, for example in case of illness or a condition that requires them to take particular medication, they must first request a Therapeutic Use Exemption,' Mauriello says. 'When competing at national level, the driver must refer to the national anti-doping organisation in the country in which their licence was issued. If they participate in international competition, the FIA is the entity which should receive the request. In some cases TUEs issued at national level can be recognised by the FIA for participation in international competition. Considering the total number of competitors at international level, the usage of TUEs remains quite limited in motorsport.'



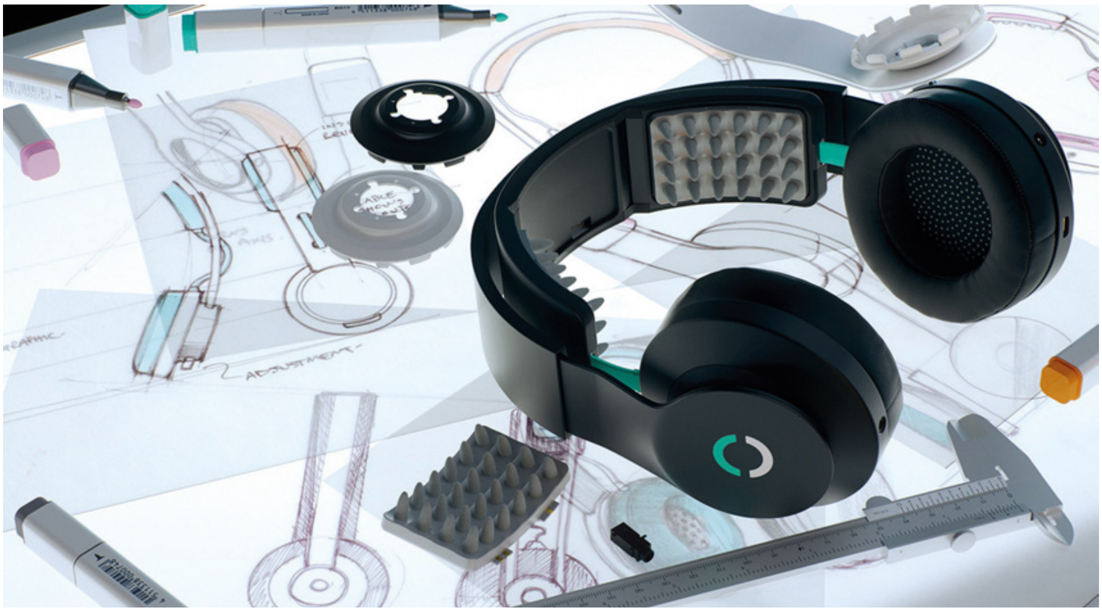
Brain doping

The increasing complexity of competition cars in major international championships has potentially added to the temptation for some drivers to use performance enhancing substances just to be able to maintain their performance level consistently rather than it dropping off through fatigue. So called 'brain doping' is one emerging area of the human performance enhancement industry, some of it is reliant on drugs, while other technologies are now also being experimented with.

Some years ago it was claimed that the use of Tacrine was widespread in Formula 1, largely to allow drivers to learn circuits faster, though this claim was never fully investigated as the drug was not (and is not) on the banned substances list. The best known smart drug, Modafinil, does appear on the banned list. It is a drug originally created to tackle narcolepsy,



Right: Halo Sport has developed headphones which incorporate transcranial direct-current stimulation pads. A mild electric current is applied to the brain through the pads



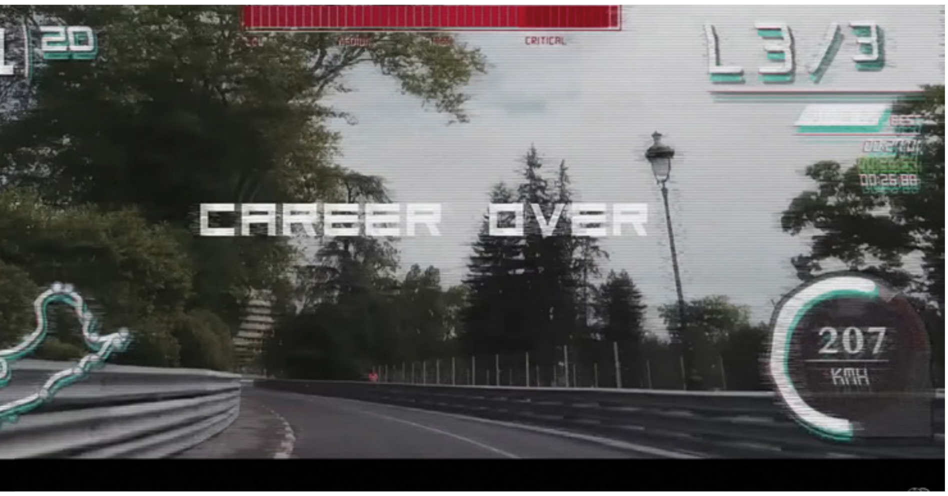
Below: Adderall can be used in sport without breaching the regulations with the help of a Therapeutic Usage Exemption (TUE), as it is often prescribed for the treatment of ADHD

but which has also been used as a so called 'brain booster.' The popularity of the drug for use in situations requiring a high level of mental capacity is clear from a quick online search, which results in many blog posts and claims of beneficial effects in professional and academic life. It seems these claims are not without merit. 'What emerged was that the longer and more complex the task tested, the more consistently modafinil conferred cognitive benefits,' a study by Dr Ruairidh Battleday and Dr Anna-Katharine Brem from the University of Oxford and Harvard Medical School found in 2015. 'Modafinil made no difference to working memory, or flexibility of thought, but did improve decision-making and planning.' Studies of so called nootropics such as Modafinil are ongoing, but the drug is easy to acquire online and is reportedly used by up to 15 per cent of students at some universities. The potential of such drugs being used in the drawing offices and engineering departments of major racing teams cannot be overlooked.

However, other techniques for improving mental capacity are also being experimented with in sports, and one in particular will never show up in any drug test – electrical stimulation of the brain. Transcranial direct-current stimulation (TDCS) sees a mild electric current applied to the brain via pads affixed to the scalp, and this is claimed to have improved the performance of athletes in winter sports. Literature from Halo Sports, a company which designs and manufactures off the shelf TDCS equipment, states that tests conducted by the US Ski and Snowboard team showed improvements of up to 13 per cent. A separate study undertaken by the University of Kent found that TDCS also reduced the perception of fatigue.

Just say no

While all the above is possible in racing, in the here and now the FIA is concentrating on its testing regime, and also on trying to educate teams and drivers about the risks and consequences of doping in the sport. 'We already met with the team managers in Formula 1 and the medical teams, and it is one of the aspects we will focus on in the coming months,' Mauriello says. 'E-sports and simulators are more and more common, so maybe we can use education to discourage these drivers. Education is something we want to focus on more and more.'



Above: A central theme of the FIA's Race True campaign is to inform drivers of the potential implications if they are found to be doping

The FIA's promotional anti-doping video focusses on recreational drugs, which have actually resulted in more bans than performance-enhancing substances

This is actually already a key part of the FIA's anti-doping activity, with the Race True campaign to educate drivers and others in the sport about doping. An e-learning course forms part of this and a glossy promotional video has been uploaded on Youtube which is focussed purely on recreational drug use. It has been viewed 1500 times. The reason for this focus on recreational drugs is that this is what has proven to be an issue in the past, with a number of drivers caught with banned (but not performance enhancing) substances in their system in recent years. 'While there have not been a lot of violations of the anti-doping rules in motorsport over the years, when it has happened it has, at least recently, been to do with recreational drugs,' Mauriello says. 'I think as the FIA we really want to avoid drivers being caught because they were not aware of the rules. If they are really cheating then we want to catch them, but it would be a pity if a teenager has a joint and gets caught, and his career is ruined. That is why we are trying to inform them.'

Risky business

Another aspect of the anti-doping education is to highlight the risks of using performance enhancing substances, with some sobering messages from other sports. 'You see that ex-cyclists have often had heart issues young, and we know that is from doping,' Mauriello says. 'They are the most common side effects seen in sport. Doping presents real risks to health, most commonly heart damage or hormonal disorders.'

Then there's the more immediate pain a drugs transgressor has to bear. 'In addition to the disqualification of the driver and the forfeiting of points and prizes, sanctions typically result in a ban of two or four years and in more extreme cases these are applied for life. Depending on the case, support personnel associated with the driver can also be sanctioned if they played a role in the anti-doping rule violation.'

'Apart from the obvious health risks, doping in motorsport is also a serious safety issue as a driver can endanger not only himself but also the other competitors, or officials and spectators'

Motorsport has a strange attitude toward cheating, with famous technical cheats like Smokey Yunick being lauded. NASCAR even has a collection of illegal parts in its Hall of Fame, highlighting the innovative ways in which its teams have broken the rules over the years. With this attitude would a driver who was caught doping really suffer from the same stigma competitors face in other sports?

Mauriello thinks that it is important that they should. 'Apart from the obvious health risks, doping is also a serious safety issue as a driver can endanger not only himself but also other competitors, officials or spectators,' he says. 'For this reason the FIA considers the fight against doping as both a sporting and a safety issue. You simply don't know how a driver who is under the influence of drugs will drive. Yes, doping is cheating, but it is also a danger, and that driver could cause an accident and kill someone. The sport cannot accept that. It is not just cheating it is dangerous, more than in any other sport.'

Interview – Gene Stefanyshyn

The stock market

How do you sell NASCAR in regions where Formula 1 is king? *Racecar* spoke to the man who has been given this very task

By MIKE BRESLIN

NASCAR

'A beautiful thing for the Cup Series would be to have a racer from Europe, from China, from South America'

For better or for worse, some things have been very successful in crossing the Atlantic – Coca Cola, Hollywood movies and McDonald's – while some others never seem to quite make it. American football is a very good example of the latter, for while it's often secured a foothold in Europe, it's never really taken off. The same could be said of NASCAR.

There have been many attempts to bring NASCAR style racing to Europe and the UK – Eurocar of the 1990s and ASCAR of the 2000s to name two – but while they did okay at a certain level they never really became truly established. The NASCAR Whelen Euro Series is different, though, chiefly because it *really is* NASCAR. And if you judge it on entry level alone, always a good indicator, then you would have to say it's looking pretty healthy – there were 73 cars entered for its three divisions at its most recent event, at time of writing, at Hockenheim.

Yet although it's been active since 2009 it's still decidedly low key from a European perspective, and while the Brands Hatch round attracts 45,000 spectators, a very decent attendance these days, most are probably there for the American car show it's a part of. Raising the series profile is then one of the challenges facing Gene Stefanyshyn, who recently took on the responsibility for NASCAR's international efforts as its senior vice president and chief international officer.

Global outlook

Stefanyshyn has been working at NASCAR since 2013 and before that he was involved in the automotive industry across the world, so he has the global outlook a post like this requires. His new role chiefly involves looking after the three existing international series – Whelen Euro Series, NASCAR Pinty's Series (Canada), and the NASCAR Toyota Series (Mexico) – while also exploring how NASCAR might expand into new markets.

'Now I'm getting more into the detail of trying to understand the racing series outside of the US; I'm getting my head around Europe, Mexico and Canada, just to see what we've got there,' Stefanyshyn says. 'If you look at Europe, I think we are starting to get some traction there. There seems to be a good appetite for NASCAR's stock car type of racing.'

Yet one thing Europe is not short of is race series, while NASCAR has plenty of categories, too. So what does it actually want from its international series? 'We're not looking for an F1 type of model where we go right around the world,' Stefanyshyn says. 'What we would really like to do is build a regional racing series in Europe, and we'd also like to build one in South America, and also Asia. The long term vision would be to have a string of series, and you could crown a champion in each of those, and then have a kind of world championships with the top drivers from each of these series.'

But this would be in no way a rival to the main NASCAR series, the Cup. 'We would want to elevate each of the regional series to the highest extent possible, but in every sport there's one league that's considered the premier league,' Stefanyshyn says. 'But I think this would be an aspiration for some of these drivers. A beautiful thing, for the Cup Series, would be to have a racer from Europe, from China, from South America, like in other sports. We have a lot of that in [ice] hockey with the NHL. Its premier league is all in North America, but 40 per cent of the players now are from Europe. It improves the quality of the sport, but it also begins to get an international following. That type of thing would be very, very good for us.'

Regional differences

This sort of approach has worked to a certain extent in Mexico, with Daniel Suarez graduating to NASCAR's big time. But the question is, is Suarez as big a name in Mexico as Sergio Perez? Probably not. And that's the biggest challenge; motorsport cultures are different the world over.

'It is a different scene, it's more and more F1, and the same in South America, particularly in Brazil,' Stefanyshyn says. 'But we do believe that there is interest, we see pockets of interest in our type of racing. But we have to be careful. We would not just say in Europe, for example, we're going to do all ovals. We would need to have a healthy mix of road course and ovals because there is this history, there is this culture, and you just can't ignore it. So I think we are trying to keep something that people like and are familiar with, a road course, but also beginning to introduce oval racing, it is a transition.

'One of the challenges you have, say if you go to China and you want to start NASCAR racing there, is that the tracks are predominantly road courses,' Stefanyshyn adds. 'So what you would do is try to put together a portfolio of road courses first, and then try and create some ovals. You have to take what you have got and then evolve it over time.'

NASCAR's Whelen Euro Series was watched by around 45,000 American car fans at Brands Hatch this season

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The mention of China is no surprise, many sports and businesses are looking there for expansion as it's a huge market. 'Our focus at the moment is how we grow in Europe.' Stefanyshyn says. 'But we're also looking at how to get into other areas of the world. The two big spots are Asia, and getting into Asia really you have got to go through China, and we're also looking for a footprint in South America. We've not created any deals or anything like that, but we are looking at both.'

But NASCAR is picking its battles wisely, so countries where there are entrenched touring car cultures will probably be avoided, Australia being the prime example. 'The racing down there is fabulous,' Stefanyshyn says. 'But given the size of the market, I don't think it can handle more than one series.'

OEM involvement

One thing the Supercars series has is a strong link to the road car scene in Australia, but in many markets outside the US NASCAR simply does not have this sort of link, chiefly because its cars are unashamedly American in style. For instance, the Euro Series cars are branded as Chevrolets, Fords and Toyotas, though they all use a 450bhp V8 Chevrolet engine, and the chassis concept – although optimised for the different demands of the European circuits – is US stock car through and through. Which raises a question: will this present a barrier when it comes to manufacturer involvement?

'I think that's another area we need to work on,' Stefanyshyn says. 'As part of this, as we try to go international, it is trying to give the OEMs a better global footprint for demonstrating their product. And we also want to get some sponsors who are global natured and work across the various regions. And that's one of the goals. We're in a phase now where we haven't really exploited that to the full … In Europe, what do you want to see? Do you want to see your Vauxhalls, or whatever?'

But some would argue that Vauxhalls are truly at home in the BTCC or TCR. 'That's a question we have got to ask ourselves,' Stefanyshyn says. 'Is Europe going to embrace the Americana, or is it going to go more unique?'

But before that there's the matter of selling what's there already. 'In Europe there hasn't been a lot put out from a marketing and communications perspective, and we need to look at how we can do more of that,' Stefanyshyn says. But that's the thing about crossing the Atlantic; it's a long voyage.

RACE MOVES

Racecar's **Simon McBeath** has called time on his driving career – but readers will be glad to know, not his writing career. McBeath has campaigned a Swift SC92 Formula Ford 1600 in speed hillclimbing events in recent years, a discipline he first became involved in back in 1977. Over the years he's driven a wide variety of racecars on the hills, encompassing everything from modified production saloon cars to Formula 1 V8-propelled Pilbeams and Goulds. His Swift, as featured in Aerobytes, has now been sold.

Former F2 and F3000 team boss **Bob Salisbury** has died at the age of 74. Salisbury started his career in motorsport as a mechanic and went on to become an accomplished race driver before setting up Bob Salisbury Racing, which competed in Formula 2 and other series, in the '70s. His Formula 3000 team, Bob Salisbury Engineering, was born after a stint working as chief engineer at Paul Stewart Racing in the same category. The company still exists, now specialising in show cars and simulators.

Former F1 team manager and well-known motorsport tyre engineer **Bert Baldwin** has died at the age of 88. Baldwin worked with Goodyear in the early '70s before becoming the team manager at the Shadow F1 operation. He went on to help Yokohama with its racing programmes in both the US and Europe, and was more recently involved in the same company's WTCC tyre supply deal.

CJ O'Donnell is to step down from his post as chief marketing officer at Hulman Motorsport, the owner of the IndyCar Series and the Indianapolis Motor Speedway, at the end of this year. Since his arrival in November of 2013 O'Donnell's team has contributed to a 23 per cent growth in IndyCar TV viewership. He has also overseen a renewed emphasis on its digital marketing and fan engagement.

IndyCar outfit Rahal Letterman Lanigan Racing has signed up veteran race engineer **Allen McDonald** as its senior development engineer in what has been described as a multi-year deal. McDonald, who joins RLL from Ed Carpenter Racing, has chalked up two IndyCar championships and a brace of Indianapolis 500 victories while working either as a race engineer or a technical director in the series.

Matt McCall, the crew chief on the No.1 Chip Ganassi Racing Chevrolet in the NASCAR Cup series, was fined $10,000 after a lug nut was found to be improperly secured on the racecar at post-race inspection at the Charlotte Motor Speedway road course ('roval') race in late September.

Bob Jane, a hugely influential figure in Australian motorsport, has died at the age of 88 after a long battle with cancer. Jane was a successful racecar driver, winning four Australian Touring Car titles while also notching up four Bathurst victories. On top of that he also made a fortune through his tyre business, owned and developed the Calder Park circuit, and sponsored racecars and teams at every level.

Historic racer **Andy Dee-Crowne** has been appointed chief executive officer of the Historic Sports Car Club, succeeding **Grahame White**, who was the Club's CEO for more than two decades. The latter will now be moving to a consultancy role within the HSCC. Dee-Crowne, who starts in the post in January, has had experience as an MSA-licensed clerk of the course.

After a tight finish in the Pirtek Pit Stop Challenge – a season long competition between car crews in Australian Supercars – Shell V-Power Racing team owner Roger Penske split the A$20,000 (US$14,000) prize with **Brad Jones** (the boss of Brad Jones Racing) after the Bathurst-held final.

Andy Palmer, president and group chief executive of Aston Martin, has announced plans to set up the Palmer Foundation, a privately-funded programme to create industrial apprenticeship opportunities for young people in the UK. Palmer, who began his own automotive career as an apprentice, has undertaken to fund the scheme. The details of the Palmer Foundation are to be announced later this year.

Marketing guru Phelps takes on the NASCAR president role

Marketing expert Steve Phelps is NASCAR's new president, having taken over from Brent Dewar, who has stepped down from the position to take on a senior consultant and advisory role within the organisation.

Phelps was previously NASCAR's chief global sales and marketing officer and is said to have been a driving force behind the Cup's Monster Energy title sponsorship deal. Before joining NASCAR he worked at the National Football League (NFL). He will report to current NASCAR chairman and CEO Jim France.

Steve Phelps is NASCAR's new president. He previously headed the organisation's global marketing operation

'We couldn't be more thrilled to have Steve Phelps as our leader,' France said. 'His passion for NASCAR and proven ability to work with our partners has been unparalleled over the years. We thank Brent for his service and leadership to our sport. His energy and vision have been of tremendous benefit to our employees and our industry.'

Phelps said: 'As a life-long fan of NASCAR, the opportunity to provide league-wide leadership is something I am looking forward to. I am confident that the strong team of leaders here at NASCAR and across the industry will accelerate the necessary changes to grow the sport and engage our passionate fans.'

Dewar joined NASCAR in 2013, serving first as chief operating officer and then president. 'It has been a privilege to serve this sport these past five years,' he said. 'NASCAR is a close-knit family and I have been blessed to be part of a great team and industry, working collaboratively to deliver great racing for our fans. I am looking forward to continuing to work with the industry.'

Mercedes chairman Zetsche to be replaced by former F1 engine boss

Dieter Zetsche, the chairman of Daimler AG and Mercedes-Benz, the parent company of the multiple-championship winning Mercedes F1 squad, is to step down from the post in May of next year.

Zetsche, who often attends grands prix, will be replaced by Ola Kallenius, who as a Swede is the first non-German to be appointed to head the German car giant.

After taking some time off Zetsche is set to return to the marque in 2021, when he will become the chairman of the supervisory board of Daimler.

Daimler has said that the change is because of 'challenges presented by the transformation of the automotive industry'.

Kallenius is well known in the Formula 1 paddock, and in the past he has headed up the High Performance Powertrains engine division in Brixworth.

Mercedes team principal Toto Wolff has said that he does not think the changes will affect the way the Formula 1 team operates. 'Ola as the new CEO provides stability for our F1 project,' he said.

Zetsche has been the head of Mercedes-Benz Cars since 2006 as well as a member of the company's board since 1998. He is a trained engineer and he first joined Mercedes in 1976, initially working in the research department.

Kallenius was first involved with Mercedes in 1993 and has been a member of the Board of Management at Daimler AG since 2015. As well as holding numerous roles within the Mercedes group he was also executive director, operations, at McLaren Automotive in 2003.

Dieter Zetsche is to step down from his role as chairman of Mercedes in May of next year

RACE MOVES – continued

The HWA Racelab Formula E team, which represents Mercedes' first foray into the electric series before the full works effort in Season 6 (2019/20), will have HWA AG CEO and former Mercedes DTM boss **Ulrich Fritz** as its team principal, and **Lucas di Grassi's** former engineer at Formula E team Abt Audi, **Franco Chiocchetti**, as its head of Formula E operations. Most of the personel for the team will be moving over from the HWA-run Mercedes DTM programme, which came to end at the end of this season.

NASCAR Cup Series crew chief **Adam Stevens** was fined $10,000 after the Joe Gibbs Racing (JGR) Toyota he tends was found to be running with an improperly secured lug nut at the Richmond Raceway playoff round of NASCAR's top level championship. Meanwhile, NASCAR Xfinity Series crew chief **Jason Ratcliff**, who also tends a JGR Toyota, was fined $5000 for the same rules infraction, also at Richmond.

Former Porsche motorsport chief engineer **Peter Tutzer** has joined the management team at Automobili Pininfarina, which is in the process of developing an electric hypercar. Tutzer, who has also worked at Pagani and Bugatti, is now senior technical engineer at the firm. Meanwhile, **Christian Jung** has joined as chief technical officer. Jung has worked at BMW and Porsche in the past, and more recently at EV maker Faraday Future.

Dave Rogers has returned to his role as crew chief on the No.19 Joe Gibbs Racing (JGR) NASCAR Cup Series car, replacing **Scott Graves**, who has left the organisation. Rogers, who was replaced by Graves on the **Daniel Suarez** car last year, has been working as the technical director for JGR's Xfinity operation this season.

Legendary F1 designer **Adrian Newey**, former grand prix driver **David Coulthard**, and vastly experienced Formula 1 team manager **Dave Ryan**, have all backed the new W Series, a female-only single seater championship which is to start next year. All three will act as judges to help select entries for the free-to-enter championship. **Catherine Bond Muir** has been named as chief executive officer.

From the end of this season **Chad Knaus** will no longer be the crew chief for seven-time NASCAR Cup champion **Jimmie Johnson**, bringing to an end the longest-running crew chief/driver pairing in the series – they have worked together since Johnson joined Hendrick Motorsports back in 2002. Knaus is moving to Hendrick's **William Byron**-driven car next season, replacing **Darian Grubb**, who has been promoted to technical director.

Kevin Meendering, who is currently Elliott Sadler's crew chief in the JR Motorsports NASCAR Xfinity team, is to move to the Hendrick Motorsports Cup operation next year, where he will replace **Chad Knaus** (see above) as the crew chief on **Jimmie Johnson's** car.

Kevin Mills, the boss of crack Formula Ford outfit Kevin Mills Racing, made a return to the cockpit at Castle Combe recently in a bid to help boost grid numbers for the circuit's struggling FF1600 championship.

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Double trouble

Why the industry must act now to deal with Vnuk and prepare for Brexit

From 1 April next year business will change across the European Union, our most important export market and easily the most influential to our future. I thought I would share some thoughts on what lies ahead.

The Vnuk insurance problem remains unresolved and could still close down all European and UK motorsport following a vote in December of the EU Parliament and the Council of EU Member States. Despite over 4000 responses to its last review demanding that it amends the wording so allowing motorsport to continue, the European Commission has ignored this. The new text could still make motorsport illegal. Its Motorsport Insurance Directive (MID) proposes substantial changes to insurance including a compulsory requirement for unlimited liability cover for vehicle-to-vehicle damage and person-to-person injury. It requires this cover for any motor vehicles on any land of any kind, anywhere, and this is not simply focused on 'in traffic only'.

Red flag

An unintended consequence is that all motorsport vehicles, competitors, circuits and events will be subject to this. Yet the specialist motorsport insurers have told the EC that none will offer such insurance due to the high risk of claims and lack of claims history from which to calculate premiums. Without insurance, all motorsport will become illegal, and the police will be required to close down an event as it will be an illegal activity.

This is not fantasy, and neither is it scaremongering. It is the single largest threat to our sport or industry in many decades. We must persuade our European MEPs, and respective ministers, to secure changes to the proposed MID text to allow motorsport to continue.

For over three years, on behalf of its members and the European motorsport industry, the Motorsport Industry Association (MIA) has fought to secure a change to the text. We have just launched a link to a focussed, multi-lingual site www.the-mia.com/VNUK which explains just how this might happen and what action is needed.

We want every *Racecar* reader to spread this link far and wide across the EU, to customers, competitors, suppliers and all motorsport fans. The site has a template letter to send to local MEPs, all contacts are listed, along with the ministers in all national governments who need to be influenced by our arguments.

Collateral damage

It is important our replies demonstrate to these key people the economic damage which will be inflicted. No question, the most persuasive argument is the damage to businesses, events and the employees involved in motorsport across the EU, which number well over a hundred thousand. The MIA is asking for everyone involved in motorsport, at any level, to act now and share this site with all your EU-based friends in order to stop this grave threat. All we are asking is that the MID text is changed so that this insurance requirement does not apply to motorsport in any way before they vote on it in December.

Could this become an illegal activity? There is a clear and present danger that all motorsport in Europe might have to cease as a result of the EU's Vnuk legislation

Dealing with Europe in this way is just one example of how things are going to change from 1 April, after which the UK no longer has access to the European Parliament. Some may say this is a good thing, but businesses will have to expect to come to terms with many changes.

This period of change will last for many years as the UK has to become accustomed to working with our friends in the European Union in a different way. We will have to find new ways to supply and service companies under their rules, not ours. But I am confident that motorsport businesses, as always, will adapt, survive and prosper, and also handle the increased costs which will undoubtedly be a part of all this.

With less than six months to go, every business should set aside time to study its contracts with EU suppliers and customers. Ask all of them, even in the UK, whether they, in turn, have resolved post-April changes. Some companies have already organised storage space in the EU with their closest customers to activate if necessary in the first quarter of 2019. Others have studied their contracts very closely and begun any re-negotiations to maintain trade in either direction. Of course, until we know what is agreed between the various governments, it is difficult to be exact in our preparation. But to do nothing is not an option.

There is plenty of advice available through professional companies and government offices, as well as at the MIA. All are happy to offer this advice. Early planning and preparation are essential. In particular, focus on how the free movement of goods and services can be maintained when supporting motorsport events taking place in the EU each weekend, these require temporary movement of goods and people across the various borders. Just one aspect of our business and sport that could cause companies serious problems.

Some may recall the days of carnets and import deposits, which were necessary many years ago. Discuss such issues with good shipping agents and distribution companies to find out how to overcome them, but expect all to cost time and money. The sooner you discuss this with professionals the sooner you will be ready to take action and the better prepared you will be.

Call to arms

Finally, the MIA plans to hold a substantial workshop on Brexit and Motorsport at the Autosport International Show in Birmingham in January, so keep your eyes on our website for news of this. The discussions and advice available will help in your preparations and, by then, we will know more of what to expect. My immediate call, however, is please go to www.the-mia.com/VNUK right now and save our jobs and businesses in motorsport. Don't let us lose this battle.

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What is wrong with GTE?

GTE is the highest form of GT racing, with Corvette, Porsche, Aston Martin, Ferrari and Ford all fighting for victory. The balance of performance formula works well, with the cars built to tight regulations, and the standards are high. There were more than 50 professional drivers at Le Mans in that category alone, and few could find a weak link anywhere. Ultimately the Le Mans race was nullified by the regulations, but there are other issues with the category that will come to a head soon.

The warning signs are there; Lamborghini and McLaren have both stopped their GTE development at a late stage, claiming that they want to see where the regulations are going. There are no new regulations on the horizon as far as I could see, but then with a bit of thought, and some interviews, it is clear why they took this decision. Ford will stop its GTE programme at the end of 2019 (or perhaps at Le Mans 2020 thanks to the WEC's new schedule), and there is no replacement model (though it might become involved in DPi).

Corvette has produced a mid-engine GT car that it is expected to run at the Petit Le Mans in October, 2019, and Porsche has produced a new GTE which apparently is normally aspirated, contrary to reports already published. Aston Martin's new GTE car was launched this year, but there are question marks over Ferrari's commitment, with Risi Competizione's participation looking in doubt for 2019 in the US, and AF Corse running effectively customer programmes with factory support. It's a far cry from BMW, which has the company's sporting director at most races. Aston doesn't have a US programme, although apparently it tried hard to get one this year.

The WEC has, apparently, been putting pressure on Corvette to race in its series, and the word on the street is that there has been a threat of non-homologation of the car if there is no WEC programme. Corvette says it has heard the rumour, but hasn't been contacted by the FIA with such a threat, and there are legal ramifications should the FIA choose this route. Regardless of this, Corvette does not have a global programme, but then it is not a global product. GM is, clearly, and it could be that Corvette is the halo brand that will attract new customers to all of its products. That's the hope when the 'Vettes race in the WEC in Shanghai in November.

Talking to manufacturers at Road Atlanta, the issue is that the level of these GTE cars is now so high that perhaps other manufacturers are wondering what would be the point of stepping in. The stable rules structure means that strategy, tyres, engineering excellence and so on is at a level where it would be a tough ask for a new manufacturer to compete. Yet although the category is stable for now, in three years it will need an overhaul, and here, too, is an issue.

Convergence is one matter, but actually another fly in the ointment is what happens with LMP1, and the 2020 regulations. The FIA is pushing a 'hypercar' concept, which is no such thing in reality. This will be a prototype chassis, with styling from manufacturers and a BoP that will include such tools as success ballast. It is, essentially, the DPi format, but with hybrid technology. But it's the road car styling that is causing the mischief. If these are the highest performing, and the best promoted, GT-style cars, what does the GTE (GTLM in the US) become? The second highest performing GT class? If so, then does that justify the costs?

Clearly not, so then we start to look at the GT3 platform, and all that entails. It seems that the rule books are starting to become more professional, and the GT manufacturers clearly have one eye on the future regulations. Cheaper cars, mass volume, a technical rule book, and with a clear place as a second category. There are some big personalities that have to put aside their differences to sort this out but, say the manufacturers, this should not be a huge challenge. With the FIA and ACO, IMSA and Stephane Ratel, four entities have to protect their interests and right now they have found ways to do so, but the market may force them to go down a particular route, or risk fragmenting altogether.

If the 'hypercar' LMP1 is to be the highest performing GT-style concept, what does GTE become?

What I did hear in Atlanta was an interesting point, more particularly to do with Class 1 and the DTM than anything else. I asked one manufacturer if they wouldn't just kill off DTM and concentrate on a more global series. 'Which DTM vision should be killed off?' was the response. That of the FIA (which has the World Touring Car Championship to consider), or that of Gerhard Berger who is looking at Class 1 with the Japanese (see page 8)? There is, said this representative, no clear vision of the future, or of how it should really look.

Oddly enough, his counterpart at another manufacturer said exactly the same thing about GTE. There is no clear vision between LMP1, GTE and GT3 and the separation of the classes. Maybe we are missing something here; we are not involved in technical working groups or commissions, after all, but from where I am sitting, and after talking to involved parties, the future seems unecessarily foggy.

ANDREW COTTON Editor

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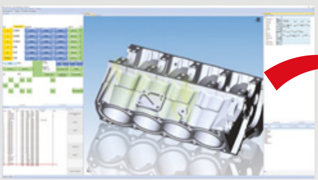

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