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McLaren MP4-30

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Porsche wins Le Mans

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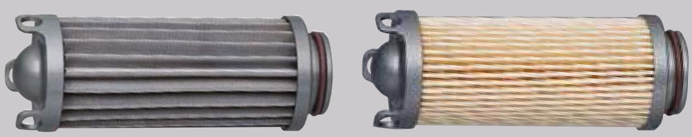

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Safety fast

How aerospace pioneers helped racecar designers to build safer cars

To be absolutely honest, racing's golden age was somewhat less than 24-carat, as it involved at least a brace of drivers departing this hallowed Earth and joining the 'choir invisible' every year. It was rough out there and the cars were not that safe. 'It was a great race. No one got killed,' Juan Manuel Fangio said of the 1958 Italian Grand Prix.

Car design did not take ergonomics, biology and biomedical science much in consideration, nor was there any work done on the structures or other safety features around the track. At Eau Rouge straw bales on the outside of the corner did a great job of protecting the old rock face, but not so much the drivers.

These days, ecological conscious people at places like Nurburgring, Oulton Park, Monza, Rouen or Hockenheim would raise a huge outcry about the dangers to the trees being damaged by wayward cars.

Some glimmers of safety were coming into the sport, with seatbelts for example. But a whole gaggle of drivers didn't like them, strapping the belts up under the seat and preferring to be thrown out of the car rather than stay for the barbecue that usually ensued. Masten Gregory made a name for himself by standing up on the seat of the car heading for a crash so as to be thrown clear. In fact, he did it enough times to class it as a technique.

As Gregory said of his exploits in a Silverstone sportscar race in 1958, where he had lost control of his Lister Jaguar: 'I stood up on the seat and stepped over the side. The car hit the bank and wiped out. I landed on the grass, I hurt my shoulder. It was paralysed for a while, but relatively little happened to me, really. Afterwards I started thinking about it, I wondered if I had done the intelligent thing. Actually, of course, I had certainly done the right thing, because I was alive.'

At about this time serious work was being done in the US by Aero Medical Laboratory of the Wright Air Development Centre, to improve safety in aircraft crashes. Aircraft had been using belts for some time due to the different constraints of three-dimensional manoeuvring; after all, keeping the pilot in when inverted is a bit of a priority to ensure the success of the manoeuvre.

As far back as 1945, service personnel realised the need for a comprehensive and controlled series of studies. This led to fundamental concepts that could apply to better safeguard aircraft occupants during a crash. The initial phase of the programme was to develop equipment and instrumentation so aircraft crashes might be simulated, and to study the strength factors of seats and harnesses. Human tolerance to the deceleration encountered in simulated aircraft crashes could also be simulated.

So what could be survived? Textbooks of the day put 18*g* as the limit of human tolerance, but was that really the limit? And if it wasn't, could there be a way to protect a pilot during a high-speed crash? Deceleration tests would go a long way in answering these questions, and so that became a John Paul Stapp, of rocket sled fame, research project.

The first run on the rocket sled took place on 30 April 1947 with ballast. The sled ran off the tracks. The first human run took place the following December. Instrumentation on all the early runs was in the developmental stage, and it was not until August 1948 that it was adequate to begin recording. By August 1948, 16 human runs had completed, all in the backward-facing position.

Textbooks of the day put 18*g* as the limit of human tolerance

XPB

In the old days a crash like this could be fatal, unless the driver jumped clear!

Forward-facing runs started in August 1949. Most of the earlier tests ran to compare the standard Air Force harnesses with a series of modified harnesses. This was to determine which type gave the best protection to the pilot.

By June 8, 1951, a total of 74 human runs had been made on the decelerator, 19 with the subjects in the backward position, and 55 with them in the forward position.

Stapp is credited with being the populariser, as well as of the author of the final form of the principle known as Murphy's Law: 'Anything that can go wrong, will go wrong.' Stapp is also credited with creating Stapp's Law, during his work on this project. This 'law' states: 'The universal aptitude for ineptitude makes any human accomplishment an incredible miracle.' He would fit in very well in the world of motor racing.

By riding the decelerator sled himself, in his 29th and last ride at Holloman, New Mexico, Stapp demonstrated that a human could withstand at least 46.2*g*. (In the forward position, with adequate harnessing). This is the highest known acceleration voluntarily encountered by a human.

Also, Stapp reached a speed of 632mph, which broke the land speed record. This made him the fastest man on Earth. Stapp believed that the tolerance of humans to acceleration had not yet been reached in tests. He believed it is much greater than thought possible.

As a result of Stapp's findings, the acceleration requirement for fighter seats was increased considerably up to 32*g* (310 m/s^2). His work showed that a pilot could walk away from crashes when properly protected by harnesses if the seat does not break loose.

Having established the human tolerance it became obvious that the frail spaceframes of racecars needed some improvement, and that designing for crash strength and preventing intrusion into the survival cell could increase the survival ratio of drivers.

On the chassis side mandatory crash testing brought a new level of survivability, to the point that drivers and teams are quite blase about crashes, and the thought of coming back from the race in a pine coffin is quite absent from their minds. The loss of Senna in another freak accident accelerated the push for safety, for, as it was with Jim Clark, it brought home the fact that if it could happen to them, it could happen to lesser mortals.

Danger is still out there though, for it is difficult to foresee all possible scenarios when a fast object departs from the intended line, as Dr Peter Neumann originally said: 'Complex systems break in complex ways.'

There will always be Black Swan freak accidents that give bleak results, just as long as we run 100m/sec human manufactured objects driven by fallible testosterone driven humans. But the survival rate today is much higher, an improvement on the past. After all, extinction should not be the sanction for exceeding the limits.


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Thankless task

For team owners, LMP2 means all P1's effort and very little glory, yet still they do it

With the Le Mans 24 Hours just completed, it may be worth reflecting on what's involved in being an LMP2 team owner. Unlike LMP1 which is – successfully – aimed at attracting big manufacturer participation and their specific commercial and technological benefits, LMP2 entrants are typically enthusiasts, trying to make a living out of what they love (or those who don't know what else they could do).

Some aspire to graduate to LMP1, but without manufacturer support this is impossible to do with any likelihood of success. I guess there is a sneaking hope among most owners that displaying dominant performances might attract the attention of a major automaker looking to come in, but not having the infrastructure or confidence to set up its own race team. After all, ORECA with Toyota, Joest with Audi and RML with Nissan's Garage 56 project are a few examples of such 'marriages', some of course being more successful than others. Presumably this must be at least part of the reason why Rebellion and Team ByKolles (always a bit mysterious, this one) bother to run in LMP1 as privateers, other than to be perceived as playing with the big boys. Now that there are 11 manufacturer cars on the Le Mans grid, what possibility can there be of any worthwhile result, even in exceptional circumstances?

XPB

It can be hard work running a P2 team but getting to race at Le Mans can be reward in itself

Business model

The 15 LMP2 teams present at Le Mans largely exist due to a mixture of multiple team sponsorship deals, few of them being really big money, and pay drivers. There are very wealthy individuals who will support a team, or even set one up, mainly to provide a drive for themselves in an environment in which they have control. This is beneficial for professional drivers who get paid for co-driving and coaching the rich man and elevating the overall performance of the team. Every other outfit of course would relish the opportunity of running three top-line professionals, but this ain't gonna happen.

Without a long-term benefactor, running an LMP2 racing team is a precarious existence which is why they frequently change hands as well as names. A number of them come and go, and rather sadly there are those which disappear altogether. Because generally people lose a lot of money through debts unpaid, assets are sold off cheaply and employees put out-of-work. Commitments are not able to be honoured and ambitions remain unfulfilled. While there are teams that are over-optimistic from the start in their budgeting and financial sources, much of the funding shortfall usually comes from a failure of sponsors (team's or driver's) and investors to meet their obligations. It never fails to puzzle me why companies and individuals go through all the business of negotiating and coming to agreement on their contribution and then fail to deliver even the first payment. Is it misplaced enthusiasm that soon cools when the bank transfer is required, some kind of ego-trip in kidding along serious people meanwhile enjoying the glamour part of racing, or just sheer dreaming? There is of course opportunism – I might say fraudulent misrepresentation – by drivers who know from the outset that they don't have the full backing that they promise. They reckon that by the time the money dries up the team will be so committed that it will continue to run them, encouraged by further promises of new backing.

Without a benefactor, running an LMP2 team is a precarious existence

So why not sue, assuming that a contract has been put in place? It does happen, but resorting to the legal system while trying just to survive may not be practical. It also costs money of course, can require huge amounts of management time and a successful resolution might take many months, even years. Often, the guilty party will throw up a smokescreen of defence, alleging poor performance, equipment shortfall, blah blah, to get off the hook. Consequently there is a temptation for teams to just cut their losses and tighten their belts and move on. Such shenanigans are not limited to LMP2 racing of course, they exist at all levels of motorsport, but it does explain some of the shifting sands that occur. Maybe there is a case for the ACO to assist by banning any sponsor or driver from participating in their events (the WEC as a whole and also the ELMS and TUSCC) if they're proven to have wilfully defaulted on a financial commitment. This would be far from simple and could introduce a number of legal complications, but 'bringing the sport into disrepute' is a powerful tool that could be utilised. Such a penalty would surely discourage the less honest to think again before trying deliberate scams.

Second class

Given that LMP2 will always be overshadowed by LMP1 in the WEC unless some disastrous development occurs, one might say stick to the ELMS then, in which LMP2 is the headline class. There is nothing wrong in that view, except that the cachet – to sponsors, drivers and the teams themselves – in competing in a World Championship and the inevitable lure of the famous Le Mans 24 hours often makes it essential to follow this more expensive route. There is also nothing wrong either in teams staying with LMP2 without any pretensions to moving up to LMP1, just enjoying a good level of international competition and competing on some of the best circuits in the World with beautifully-engineered racing cars and a professional structure. There is also scope for a degree of innovation within the regulations. This will be more so if the ACO and the FIA would stay with the current multiple chassis and engine formula instead of changing to four-only chassis types and a fixed engine specification.

Now that LMP2 cars demonstrate the reliability once badly lacking in endurance events, the reward measured in exultation and pride in reaching the podium against all the effort and stress expended can be similar to the overall event winners', even if the headlines don't reflect this.

Shrink wrapped

McLaren's 'size zero' MP4-30 has failed to shine this year, but as a packaging exercise it's a seriously impressive piece of kit, as *Racecar* discovered

By SAM COLLINS

The return of the once all-conquering McLaren-Honda partnership has proved disappointing thus far, with just one lowly points finish in the first seven races, and numerous high profile retirements

McLaren has a clear mission in Formula 1, as anyone who is treated to a tour of the team's facility on the outskirts of Woking, England is told. It is a simple goal, to win every race in a single F1 World Championship season, a feat that has never been achieved by any team in the history of F1. Back in 1988, McLaren came closest, winning every race bar one. At the time the team was the dominant force in grand prix racing and this was due, at least in part, to its partnership with Honda. In more recent times McLaren has struggled to find good form; it has not won a race since 2012, let alone a world championship, but then the new engine regulations introduced at the start of 2014 allowed the partnership that brought so much success in the 1988 season to be rekindled.

Honda came onboard for 2015, one year into the new power unit formula, which meant that while other teams could enjoy a period of relative stability as the regulations changed little for chassis or engines between 2014 and 2015, McLaren had a serious challenge on its hands.

'The most significant change for us was the transition from a Mercedes power unit to a Honda power unit,' Tim Goss, McLaren Racing's technical director says. 'With Mercedes we had a customer relationship, the power unit was developed specifically for the Mercedes chassis, and we just had to package what we were given. With Honda, we are back to works team status, so from the outset we had the opportunity to shape the power unit and all of its ancillaries in exactly the way we wanted, so we could fit it around the philosophy we had had for the car.'

That switch to works team status with Honda resulted in the two organisations working together to make the MP4-30 as integrated as possible, something McLaren had not managed to do with Mercedes. An example of this is the fuel and lubricants used by the team. While McLaren has a long-standing partnership with Mobil 1, the Mercedes power unit was developed around Petronas products. But the new Honda would be developed around the team's preferred fluids.

As is always the case with modern Formula 1 cars, design work on the MP4-30 started even before the MP4-29 had even run on track for the first time, and working closely with Honda a number of objectives were set. 'We knew we had to push really hard in terms of packaging but at the same time had to ensure that we were

'Neither McLaren nor Honda will be satisfied until we are back at the front'

getting as much as possible from the power unit in terms of performance, and that leads to balances and trades,' Goss says.

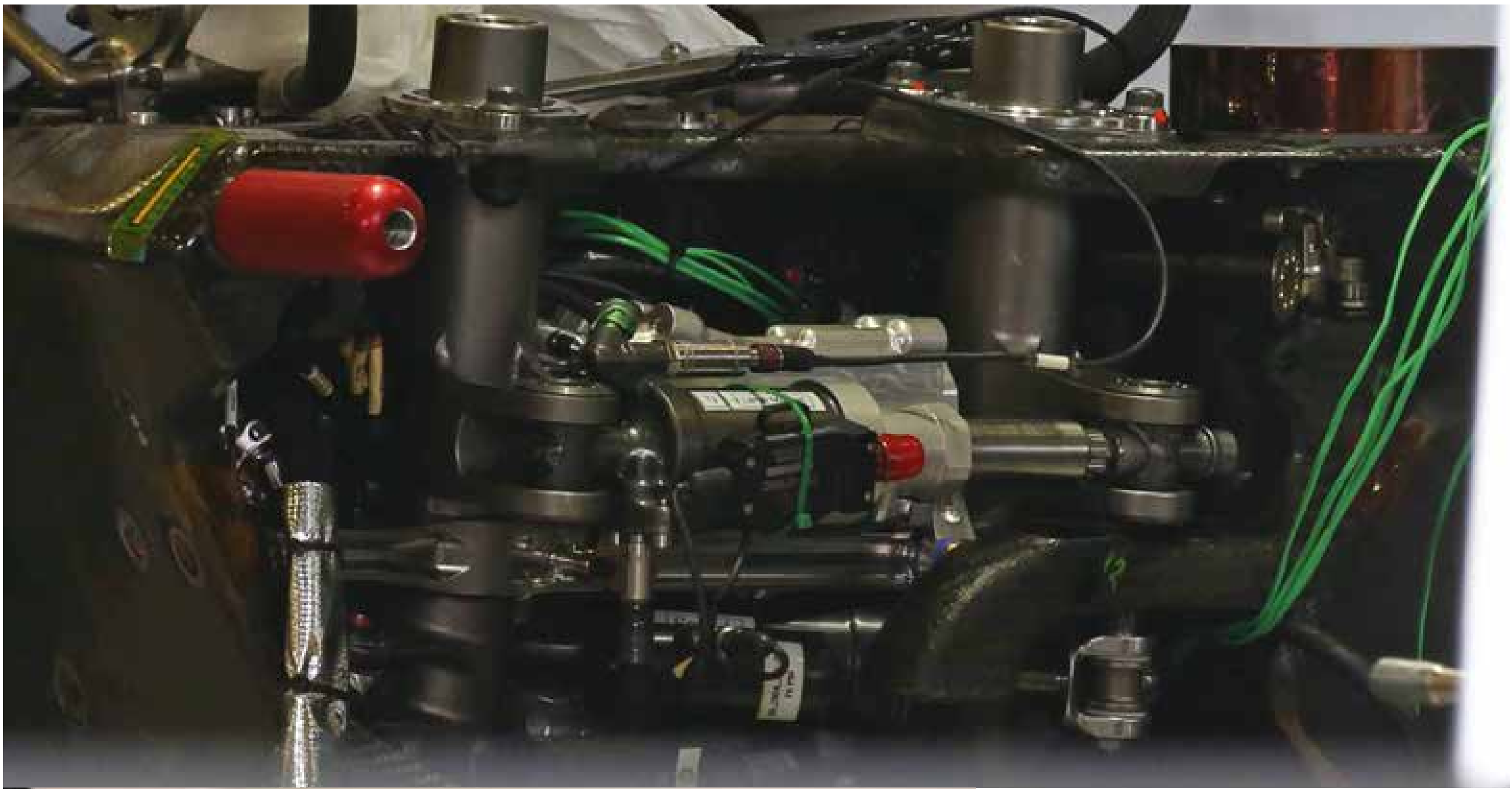
Compromises

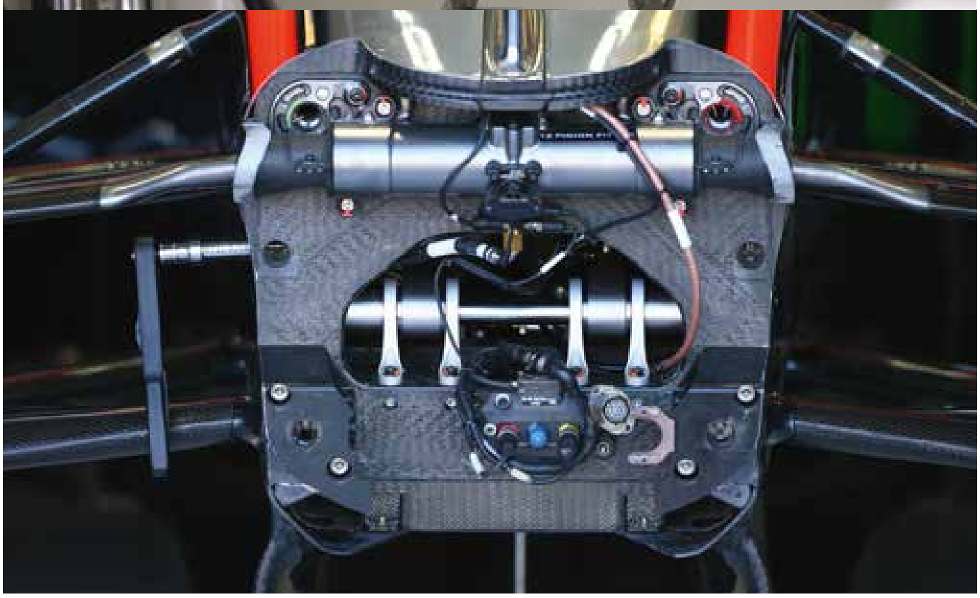
To get a better understanding of the trade offs and for Honda to gain more experience of modern Formula 1, McLaren built a special one-off car to test both the prototype power unit and also to help make decisions on certain compromises. The McLaren MP4-29H tested only twice, once at Silverstone and once at Abu Dhabi, and has since gone into storage.

'That car provided us with a massive amount of learning and gave us a head start on getting ourselves and Honda something that had both performance and ran well,' Goss says. 'Even though the car did not do a huge amount of mileage it was still a huge success for both us and Honda. It was quite difficult for us to achieve it at the time, as we were still pushing with the MP4-29, trying to get the best out of that. The design team were working on not only the mule car but also in parallel on the MP4-30, so it was quite a stretch on the organisation, but it was a step we had to take.'

The current Formula 1 technical regulations essentially freeze power unit design from their first homologation right up to 2020, so any weakness in a design concept can get locked in if discovered too late. 'Principally because of the way the regulations are written now, once you homologate the power unit you are only allowed a certain number of tokens to update the engine annually, but overall what you homologate you are going to have to live with for years to come, so we put intense effort into that and working out what was needed in terms of packaging and deciding where those trades needed to come,' Goss explains.

Indeed the MP4-29H did highlight a number of issues with the original plan for the MP4-30 and as a result some changes were made. One thing that was immediately noticeable was the design of the car's cooling system. The MP4-29H featured additional cooling slats on the left hand sidepod and, while not legal to race, they revealed that there was a change of concept to come on the MP4-30. On the MP4-29, the radiators were mounted longitudinally in the sidepods of the car (the only Mercedes-powered design to adopt this layout) but on the MP4-29H those large longitudinal radiators had gone. It was the first sign of the most distinctive feature





Top: A glimpse inside the bell housing of the MP40-30, where vertical torsion bars connect with horizontal dampers. Note Reventec sensor mounted on the damper casing. All of this has to be shielded from a 1000-degree turbine just a mm away **Middle:** Gearbox, rear suspension and rear brake assembly. Note the calliper at the base of the disc (disc removed here). The gearbox was redesigned to accommodate Honda's power unit while rear suspension was also substantially reworked **Above:** The front bulkhead of the MP4-30 shows how the steering rack has been moved from a very low position on last year's MP4-29 to a much higher position on this year's racecar, so much so in fact that the torsion bars are barely visible

of the MP4-30, which has led to it becoming known as the 'size zero racecar'.

'There is a huge challenge with this breed of F1 car, which is to get enough cooling without it costing you in terms of the overall bulk and weight of the car,' Goss says. 'In 2014 a lot of the teams came up with novel solutions for the radiator area on the car, we had quite a novel solution on the MP4-29, but a year on we have learned a lot more about the size of coolers we actually need and have found better ways of getting the air mass through them. On the MP4-30 we adopted a more conventional cooler layout with two angled cores sitting either side of the chassis. The chassis has been kept reasonably narrow and quite long in order to give the space we need to fit the required area.'

The layout sees the car fitted with a water/oil radiator in the left hand sidepod while the charge air cooler is mounted in the right hand pod, both fed by the ducts on the front of the sidepods. On the spine of the car there are two additional coolers fed by the roll hoop duct (separated from the flow for combustion air by a small vane). The smaller of these two coolers is for the transmission while the larger cooler is for the energy recovery system (ERS).

'The reason it is there is the result of us talking every opportunity to find space on the car without detracting from the theme of keeping the sidepod area as tight as possible,' explains Goss. 'If we had those coolers in the sidepod it would just make them bigger.'

The demand for such a tight rear end comes from the aerodynamic department at McLaren, which has dominated much of the car's overall design, and not just in terms of surfaces. Although based at the team's Woking base the

aerodynamicists spend a lot of time in Cologne, Germany, where they work in the TMG wind tunnels with a 60 per cent scale model.

'Our packaging concept for this car came about from some themes that we were developing around the end of 2014, and that set a clear direction for the design team,' says Goss. 'Once that was defined everyone knew what had to be achieved in terms of internal wetted surfaces for the car within that space, and trying not to water down that concept in any area.'

Tight fit

This 'size zero' concept led to many mechanical components on the car being changed, especially at the rear, which externally does not appear large enough to even accommodate the power unit and transmission. 'Some people say that there is no Honda power unit, or that it only has a 600cc engine,' Yasuhisa Arai of Honda jokes. But the reality is that there has been significant work on the sub systems housed in this area.

'We took a very different direction in terms of the rear of the car and the rear suspension layout,' Goss says. 'That offered the opportunity to do the much, much tighter packaging the concept demanded and that was the theme for the MP4-30, to push the packaging and the base architecture of the car very hard.'

The rear suspension remains a double wishbone layout with pull-rod actuated dampers, the whole system picking up on the carbon fibre transmission casing. But in detail the design is actually quite different to that of the 2014 car. 'Both the front and rear suspension layouts were driven mainly by aerodynamic

Top: The 'size zero' concept is evident at the rear of the car where there have been many changes from MP4-29, although rear suspension remains a double wishbone layout with pull-rod actuated dampers, all picking up on transmission casing
Above: Packaging the cooling has been a major challenge with the MP4-30. There is a water/oil radiator in the left-hand sidepod while the charge air cooler is situated in the right-hand pod. Both are fed by ducts on leading edge of sidepods

requirements,' Goss admits. 'What you have to do is trade off those aerodynamic requirements against those of vehicle dynamics, structural integrity and weight. A recent theme has been to raise the rear lower wishbone higher and higher and put it in line with the driveshaft, even shrouding the driveshaft in it. If you looked at that purely in terms of vehicle dynamics and the compliance of the rear suspension you would not do it. If you work hard enough at the detail of the upright design, suspension leg design and transmission casing, usually you can get the structural performance to meet the requirements there and the losses in terms of tyres and vehicle dynamics are not significant.'

Despite speculation that some of the cars in F1 this season have moved away from conventional rear suspension systems using some of the lessons of the hydraulically interconnected systems used early in 2014

'The theme was to push the packaging of the car very hard'

and in previous seasons, according to Goss the McLaren's layout still features both torsion bars and dampers, though both are very hard to see as they are mounted inside the bell housing at the front of the transmission, one of the most complex areas in the current cars.

'It's one of the things that makes these modern F1 cars so challenging, just trying to get a tightly packaged car to work when you have some quite tricky physical problems to deal with,' says Goss. 'You have a very hot turbine in the region of 1000degC; only a few millimetres behind that you have the damper which you are trying to keep quite cool. There are torsion bar dampers, anti-roll bars, there are also some hydraulic system components, servo valves and wiring harnesses. All of those things need protection from the heat from the turbine.'

The leading edge of the transmission on the MP4-30 not only had to accommodate the systems mentioned but it also had to mate to the rear of the Honda RA615H, which when the MP4-30 was in the final phases of design had still not been fully defined. With the MP4-29H only running on track towards the end of the 2014 season the final design of the gearbox would have to be signed off, built and crash tested in just a few weeks, as the MP4-30 was due to shake down at Jerez, Spain at the end of January.

As a result the MP4-29H had to use an MP4-29A transmission casing adapted to accommodate the Honda V6, something that was likely not that straightforward, due to the original design being based on that of the very compact Mercedes power unit with its split turbo layout. 'We could not define the MP4-30 transmission in time for it to be used on the MP4-29H because we would have had to make too many top level decisions too early on in the project. It made more sense to adapt what we had,' says Goss. But for the MP4-30 the plan had always been to use a new design.

Coolers on spine of car are fed through the roll hoop duct, with a small vane in place to separate the flow of the air for the engine. The coolers are for the transmission and the energy recovery system

Front brake. McLaren is the only team on F1 grid to use Akebono callipers. Front axle is hollow to influence flow structures

Gear change

'When changing power unit manufacturer you need to have a bit of a rethink in that area,' Goss says. 'We changed the transmission between the 29A and the 30A for several reasons. There are differences in the rear face of the engine that meant that to get the packaging right we had to do a new casing. We changed the layout of the inboard rear suspension to allow us to tighten up the packaging for the 'size zero' concept and we also changed the wheelbase slightly, again to get the overall wheelbase and weight distribution right.

'For a new a car project like this you have to put down some milestones, the general layout of the engine, the power unit and where we would put the MGU-K, MGU-H, the turbine. Honda had to make those decisions at roughly the same time we had to make decisions on the transmission, so we just worked really closely together on the total package.'

With the rules remaining largely stable going into the 2016 season, and the Honda power unit concept likely to remain dimensionally similar at the rear of the V6 engine, MP4-30's transmission may carry over into the car's successor, something McLaren's engineering director Jonathan Neale predicted in *Racecar Engineering* last year (see RCE V24 N9). 'Looking ahead to MP4-31 there is rules stability and if we choose to continue with the themes at the rear end of the car the transmission can mostly be very similar or be a mild evolution,' he said.

Cosmetic headache

At the front end of the car the designers did not have to worry too much about accommodating the new power unit, but here there was the impact of one of the few chassis rule changes introduced between 2014 and 2015 to think about. After it became clear that recent F1 cars were deeply ugly the FIA decided to take action and re-word the regulations relating to front impact structures and chassis height.

'If you look at the rules there was nothing dramatic, just a few of what at first appeared to be minor changes, but they turned out to be quite significant,' Goss says. 'For example the change to the nose regulations on the outside looks like a relatively nondescript change, but it has a subtle but important impact on the flow structures around the front of the car. That was something we had to consider when we were looking at how to design the MP4-30, and what the objectives of that design were.'

The McLaren features a long and wide nose protruding beyond the leading edge of the front wing, breaking from the current trend (seen on cars like the Red Bull, Mercedes and Lotus) of short stubby noses with their tips almost behind the trailing edge of the wing. The nose shape itself is defined by work in CFD and at the wind tunnel but the new regulations have also reduced the space available on the front bulkhead for housing key components. 'Packaging the inboard front suspension, steering rack, pedals and master cylinders is always quite a tight job on a modern F1 car,' Goss admits. 'It's tighter on this car, but it was not a much bigger challenge than normal.'

Aerodynamic requirements led to the biggest design changes at the front when compared to the 2014 design. 'We changed the front suspension inboard layout on the MP4-30 so you will see that the steering rack has been raised, it was reasonably low on the MP4-29, and now it is quite high. That led to the inboard suspension layout being changed fundamentally,' Goss reveals.

Looking at the front bulkhead, the torsion bars are now partially obscured by the high mounted rack, something that would seem to reduce the serviceability of the car. 'Year on year the mechanics find it harder; I guess we will have to find mechanics with smaller hands,' Goss jokes. It is a problem not unique to Formula 1. Some years ago when the Dome S102 LMP1 was introduced, the Pescarolo sportscar team found that only one Japanese engineer from Dome and one French female mechanic had hands small enough to make a certain adjustment on the front of the car. This was again due to tight packaging introduced to achieve aerodynamic requirements.

Shortly after the start of the Formula1 season the MP4-30 received an aerodynamic update which included an inlet duct on the base of the nose and twin outlets on the top of the chassis, linked by a pair of pipes mounted on the front bulkhead, this follows the trend of cars such as the Red Bull, which have utilised such solutions for some years.

'Designing the aerodynamics on an F1 car is a lot about extracting load from high quality air. At the front of the car you have lots of clean high quality flow, you have to try to extract the most efficient downforce from that,' Goss explains. 'The purpose of the duct on the noses is to take some flow that could be detrimental on one area and route it to an area where it would create less of a penalty. It's exactly the same on the other cars too.'

Poor results

The races so far in the 2015 season have clearly been something of a struggle for the McLaren MP4-30, and much of that blame has been laid at Honda's door, but comments apparently made by the team's drivers also suggest that the car lacks downforce. Goss will not be drawn into too much discussion into the reasons for the car's poor results to date, preferring to look forwards. 'I don't think any Formula 1 team is ever satisfied with downforce, grip or power. It's our daily job to pick holes in everything we are doing and we know that we have got work to do on the car, and Honda knows that it has work to do on the engine, but we are all working incredibly hard to get back to the front. McLaren is here to win races and championships, so is Honda. Neither of us will be satisfied until we are back at the front. We know where the strengths and weaknesses of the car are now, and we know how we have to attack, and so does Honda.'

It is worth noting that when Honda returned to Formula 1 back in the 1983 its initial performance with the Spirit team, and later Williams, was not great. But five years later the only thing that stopped McLaren-Honda from achieving their goal of winning every race was an errant Williams-Judd taking out the leading car. It is hard to believe that it will take McLaren-Honda as long to reach such a performance level again, and take the fight to the now dominant Mercedes team.

'We have learned a lot more about the size of coolers we actually need'

Changes in chassis regulations to banish ugly noses caused McLaren some packaging issues. Original Nose was long and wide and protruded from leading edge of front wing, but the team introduced this all-new nose for the Austrian Grand Prix

McLaren is one of a number of teams to do a lot of work on front wheel design in order to optimise flow around front of car

Power struggle

It's been more 'power of nightmares' than 'power of dreams' since Honda returned to F1 with McLaren this season. But just what has gone wrong?

By SAM COLLINS

'The 2008 and 2009 Formula 1 hybrid system experience was very useful'

Honda's return to Formula 1 was announced with great bravado. In these very pages Yasuhisa Arai, the man tasked with bringing the famous Japanese marque back to grand prix racing, revealed that he expected that the McLaren MP4-30s using the RA615H power unit would be at the front of the grid from the start of the season.

However, since Arai made the claim (RCEV24N12) it's fair to say that things have not quite turned out the way he envisaged, and a quick scan of the results of the first half of the 2015 Formula 1 season provides a harsh reality check. The statistics show that the Honda power unit has seriously under-performed. In fact, the reliability of the McLaren-Honda, the only car using the RA615H has been woeful, and the performance of the cars has not been much better.

It's not all been bad, though, and there are signs of improvement. At Monaco the MP4-30 scored its first points of the year with an eighth place and the car's outright pace has progressively improved. But still, it's clear that things have not really gone the way Honda, and many in racing, expected. So what's gone wrong?

'We lacked time,' Arai admits now. 'We started work on the power unit in May 2013, at that time we had nothing, no drawings, no parts, no concept, but we fired up the V6 engine for the first time in the Autumn of 2013.' This early test was not reported in the media, though some sources in Japan suggest that the first mono-cylinder work began as long ago as October 2012, when the *Racecar Engineering* website broke the news of Honda's return to F1.

The move to a new turbocharged, downsized engine formula based on efficiency was one of the key attractions that lured Honda back into grand prix racing after it quit the sport at the end of the 2008 season. It had already designed, built and tested a mild hybrid Formula 1 car as part of the re-introduction of hybrid systems into F1 in 2009. The unraced Honda RA109 F1 car is widely said to

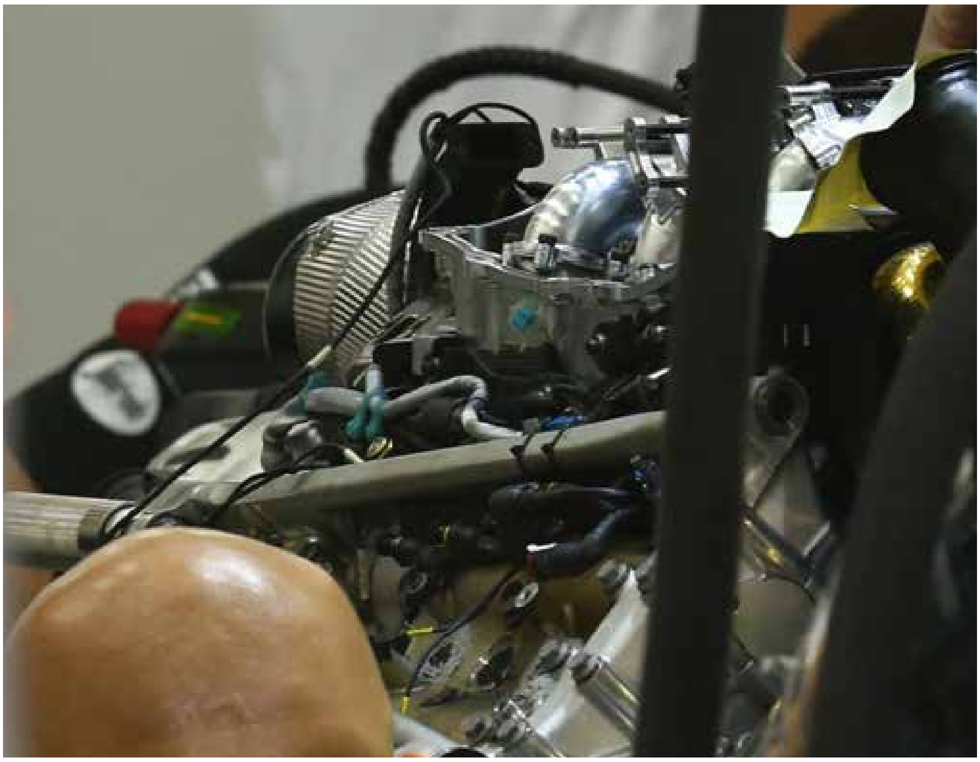
Main picture: Honda's RA615H has proved disappointing thus far in Formula 1, but many in the paddock believe it has potential. It features a Birmann type exhaust layout, which can give much better gas flow to the turbine and allows for better energy recovery from the MGU-H. **Below:** Honda was attracted back into F1 by the new engine rules which call for 1.6-litre hybrid power units. The V6 engine itself has its roots in other Honda projects

have been rebranded as the title winning Brawn BGP001, but in reality it was a very distinct design with a unique energy storage layout, mounting the batteries in front of and under the legs of the driver, while all of Honda's rivals mounted the energy store below or behind the fuel cell.

This project and the technologies used in it laid the foundations for a new Honda hybrid system for motor racing, but its evolution saw Honda engineers taking advantage of the firm's wide motorsport involvement, too. 'The 2008 and 2009 Formula 1 system experience was very useful in this project,' Arai says. 'I think that hybrid system was really, really good for that time with the high RPM engines and the energy storage layout that they had proposed. The Honda design had good control systems too. Then there was the GT300 hybrid system used on the CR-Z, it was made by Zytek in England but the design was all done by Honda; the motor layout and transmission was all Honda. We used a lot of the lessons from the third era F1 system on that, then the lessons from developing the GT300 system on the track were very helpful in the creation of the current MGU design.'

The V6 engine itself also has its roots in existing high performance Honda projects, with the firm having developed power units for Super Formula, GT500, WTCC and LMP2 (the latter ICE also being used in the GT300 CR-Z). 'We took the basic understanding of the technology of this engine from the GT500 NRE engine [a 2-litre in-line four], the direct injection, turbocharging, small displacement all of those things. The combustion chamber from that was an especially helpful starting point for the F1 V6 as it is very similar. The WTCC engine is quite different because of the restrictions on boost pressure in that class and that means it has a different combustion concept, but the overall architecture and concept was also helpful in terms of knowledge', Arai reveals.

Once the overall layout of the Honda power unit was defined the first physical prototypes could



In this image the ducting to the intercooler, mounted in the right hand side pod of this year's McLaren MP4-30, can be seen. The pipe coated in the gold-coloured heat shield appears to be there to supply the air from the compressor to the intercooler

At the start of the 2015 season the RA615H featured a machined aluminium plenum, unique in Formula 1, but this was simply for reliability purposes and Honda has now reverted back to this composite plenum, as included in original design

Almost immediately the Honda engineers realised the challenge that they faced

be made and tested at the Japanese marque's secretive R&D facility near Utsonomiya, Japan.

'The early test bench running was literally just to confirm the very basic concept,' Arai continues. 'From there we did a lot of development, and finally in Silverstone and Abu Dhabi we used an old McLaren chassis to confirm the whole system.' That 'old' McLaren chassis was in fact a 2014 MP4-29 adapted to accommodate the new Honda power unit. Officially the car was called the McLaren MP4-29H 1x1, the 1x1 referring to the prototype Honda power unit used in the car.

Tim Goss, McLaren Racing technical director explains: 'The MP4-29H was a mule car to prove out some of the systems. While Honda has experience in hybrid power units, this current breed of F1 engines is unlike anything anyone has come across before, so Honda needed a platform to test those systems. Most of the key decisions on power unit and car layout had been taken, we had not fully refined everything. We took an early version of the power unit and installed it into the MP4-29 with the primary objective of proving out some of the systems before we fully designed the MP4-30A.'

Early tests

Goss Continues: 'Given that the MP4-29 was designed around the Mercedes power unit and we had since created something very different, it was not just an easy case of bolting it in. But we took the chassis and adapted the rear bulkhead. We took a MP4-29 gearbox casing and with some small modifications managed to adapt that for the differences in the rear face of the engine and bell-housing.'

The test mule was fitted with additional cooling ducts on one of its side pods, a solution not legal under the 2015 rules but as the car was merely for testing it did not matter. 'The packaging of the systems was not optimal but that was not the idea, it was to try out some of the systems,' Goss says.

The first test of the Honda power unit on track took place at Silverstone in the late Autumn of 2014 under a cloak of secrecy. But as is always the case with 'private' tests at such venues, details began to leak almost as soon as McLaren booked its track time. The test runs of the MP4-29H test car were part promotional and part shakedown, and almost immediately the Honda engineers realised the challenge that they faced. 'That was literally a test to see if the hybrid system and V6 were all working together, really that was a lot to do with control system checks,' Arai says. 'It was very complex to get it all working with MGU-H, MGU-K, ES, all of those things. We wanted to make sure these things all worked together properly.'

The Honda engineers, and indeed some of those from McLaren, expected that it would take to the track and turn a good number of laps at a decent speed, but the spy videos of the car showed that is was rather limping round

'Everyone wants to know about our compressor, but I cannot tell you much'

the course. 'We had so many electrical issues, it all went wrong, strange things like the wiring harness connectivity problems and things like that. There were issues with the control boards, when you got one working the other ones would fail, the communication between the systems was very difficult, but those were important lessons for the future,' Arai says.

The MP4-29H was then shipped to Abu Dhabi for a public test along with the rest of the Formula 1 field. Here things took a further turn for the worse. This was meant to be the first proper outing for the new power unit. As the McLaren engineers attempted to fire up the car nothing happened. After a long systems check the problem was found and the MP4-29H left the garage for a couple of installation laps, but an issue with the car's onboard electronic systems was giving incorrect fuelling data, causing it to stop on track.

On the second day of the test another mystery electrical problem stopped the car from going on track in the morning, then in the afternoon it managed an installation lap, but at the next attempt at a run the electronics again caused the power unit to shut down. After this McLaren decided to call it a day and return to England.

'That power unit was quite different to the one we have now, after those events we changed a lot of parts between the MP4-29H experimental car and what you see on the final power unit. The lessons we learned allowed us to redesign some of the areas of the MP4-30A to make things work better,' Arai says.

The numbers

The final power unit was homologated early in 2015, and its official name was revealed: the Honda RA615H (RA for 'racing automobile'). As with all current specification F1 engines the design is a hybrid power unit featuring a 1590cc-1600cc (the exact capacity has not been disclosed) turbocharged V6 engine using direct injection and mated to a pair of electric motor generator units. Much of the engine's overall architecture is defined by the regulations, which dictate the cylinder bank angle (90 degrees), the diameter of the bore (80mm), the crankshaft centre-line, and the minimum weight of the whole power unit at 145kg.

But there is still scope for much variation, particularly in terms of the design of the turbocharger and the hybrid system. On the RA615H the MGU-K is mounted on the left hand side of the crankcase under the exhaust manifold while the MGU-H is mounted in the V of the engine. The turbine is mounted at the rear of the engine while details of the design and location of the compressor have yet to be revealed – Honda engineers remain tight lipped on the subject: 'Everyone wants to know about our compressor, but I cannot tell you much. We tried to make a good compact layout, it's a core part of the concept,' Arai says.

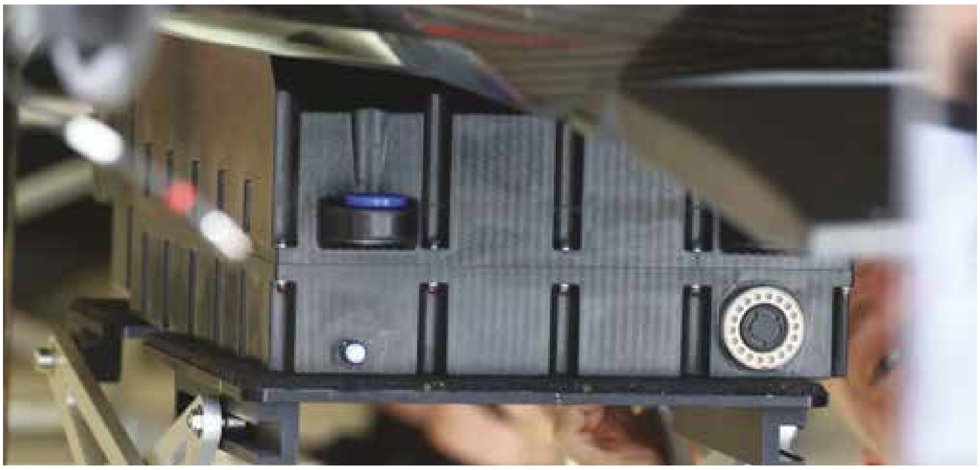
It is likely that the compressor concept has closely followed the split concept seen on the Mercedes V6. Another cue from the Mercedes PU106A is the use of the log type exhausts seen on the German marque's 2014 power unit, but dropped for the 2015 version (RCE V25N7). This solution uses gas dynamic rectifiers in the exhaust manifold which basically ensure that the exhaust gas pulses are directed to the turbine in the most effective way, meaning that the MGU-H can recover significantly more energy from the exhaust gasses at the turbine than is possible with a more conventional exhaust manifold. It is also notably smaller than a conventional design. 'It's a compromise with the aerodynamics, that's the main reason we did that,' Arai explains. 'We discussed the layout with McLaren, to find the most efficient way to design the complete car. A big exhaust system is easy to get good horsepower, but it's heavy and takes up a big volume. It can also lead to heat rejection issues, and its not very good in terms of the turbocharger performance to have such a big layout, we need a tight and tiny exhaust system.'

Winter woes

With the layout finalised and the RA615H installed in the back of the new McLaren MP4-30A the Honda's first proper test would come at Jerez, but again things did not go according to plan and the car struggled to lap anywhere near the pace of its rivals and spent much of its time in the garage. There were operational failures as well as technical failures during the test, including one occasion when the V6 was fired up without enough oil in it. 'There we had the first proper shakedown, but there were many unexpected issues in the winter tests and we lost a lot of track time. We did not have enough time to fully test everything,' Arai admits.

That lack of time on track was clearly one of the biggest problems in the development of the RA615H, and many people have suggested that Honda perhaps should have developed its own power unit test bed, something Ferrari did back in 2013 in order to get more experience of running its F1 engine.

'Many people have asked about installing the RA615H into a Dallara Super Formula chassis,' Arai says. 'But you need space for the batteries, other electrical parts, which that car does not have. It's really not very easy to do in reality. The GT500 chassis was possible as it is bigger but again it would have been too much of a job to install it into the car, so we decided not to do that, it was too difficult to do.'



Above: The battery pack on the McLaren, with FIA seals, temperature strips and high-power connectors. This unit is mounted at the base of the MP4-30 chassis

Right: The McLaren MP4-29H test mule ran with additional ducting on the left-hand sidepod during early testing of the RA615H power unit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In all of the pre-season tests the McLaren Honda would frequently stop on track, and it was a trait that would continue right through the first half of the season with ten retirements (including two failures to start the race at all) in the first eight races. There were rumours that the only way that the Honda engine could be made to last the race was to run it at a reduced performance level, and even then technical failures were a regular occurrence.

But Arai claims that these rumours are simply not true: 'I have heard these stories but they are not true, we always use 100 per cent horsepower, but during those early races there were some small issues, many of them were related to heat. But we [had] already fixed those problems ahead of Barcelona, though now we still find many small troubles race by race.'

It's true that the performance of the McLaren-Honda has noticeably improved as the season has gone on, and this is largely related to the performance of the Honda power unit. It progressed enough for McLaren to secure its first points of the year with an eighth place finish at Monaco. 'We are now improving every race, improving horsepower, better drivability' Arai enthuses. 'I think it is a great success story, but we have still not been on the podium, that is the next goal.'

Upgrade tokens

As part of that process Honda has used up two of the nine in-season performance upgrade tokens that it has been given to ensure parity with the other three manufacturers, who had 32 update tokens at the start of the season to use on their 2014 power units.

Beyond those tokens the only changes that can be made to a power unit are on the grounds of cost, safety or reliability, and Honda has made significant changes for the latter reason. This was particularly noticeable at the Spanish Grand Prix where the V6 engine was fitted with a new plenum. At the start of the season the RA615H uniquely featured a machined aluminium plenum, but that was in essence a reliability fix in itself, a result of some of the test failings.

'Barcelona was not really a new specification power unit, we originally tried to use a composite upper section of the plenum, but there were some failures in testing with cracking and poor sealing, so for the first races we used an aluminium component for reliability. Now we have the composite part back as we have improved the manufacturing so it does not fail, but it is exactly the same design really. It was not a big update, it was just returning to the original design,' Arai explains.

As the lower section still remains in aluminium it seems likely that there are more upgrades coming in this area. 'We are developing many new parts for the PU, but we don't have the complete plan yet to use the tokens and which tokens to use. But there is some new technology coming on the power unit, though, and you will see the impact when it is on the car,' Arai adds.

Honda is adamant that it is in Formula 1 for the long haul, but it goes without saying that it needs to improve its performance very quickly. That said, there is a feeling among some in the Formula 1 paddock that the RA615H has yet to come close to showing its full potential, and that the concept could prove to be very potent indeed in the future. With seven performance tokens left to spend Honda could still move back to the front of the grid before long. Watch this space…

Honda's mystery new facility

To support its Formula 1 campaign Honda built a new facility in Milton Keynes, England to house its staff and test power units. Shared with Mugen Euro, the Mugen Technical Centre houses a number of dyno cells and offices, allowing both Honda and Mugen to conduct R&D work in Europe in conjunction with Honda's vast new R&D facility in Sakura City, Japan.

In early 2015 Honda filed a planning application in England to allow it to construct a large new facility behind the existing Mugen Technical Centre. The plans state that the new building will allow Honda to expand its operation in Formula 1 and allow it to develop new technologies in the UK. 'At present, Honda's power units are solely used by the McLaren-Honda race team, but it is intended that they will become a key provider for multiple Formula 1 teams,' the document states. 'As a result it requires the new facility to not only service that demand but also conduct research and development in Europe.'

Development plan

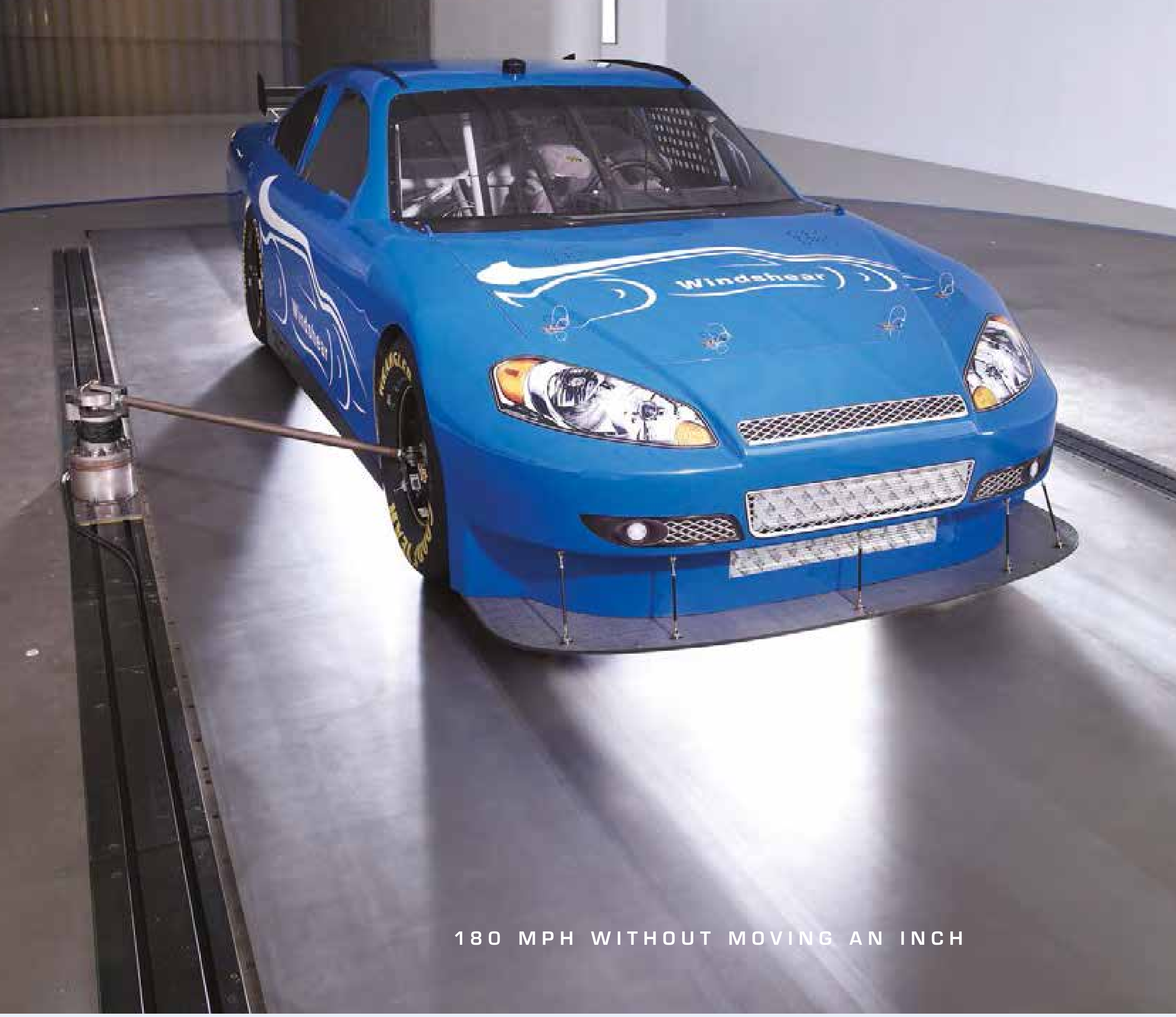
The plans for the new building includes a number of CAD work stations, meeting rooms, truck bays, a machine shop, a staff canteen and a gym. Additionally a large area of the facility has been set aside for energy recovery system development. The ERS room is located next to a workshop containing small-scale engineering workshop equipment such as lathe, milling machine, pillar drill and CNC machining centres. While the ERS R&D area will feature MGU dynos and other battery and electrical diagnostic equipment. 'The research and development specifically taking place is into state-of-the-art hybrid power technologies for Formula 1 racing cars, and this technology will filter into production vehicles,' the planning document continues. 'The key to this growth is research and development of the technology and the proposal is a crucial element of this. It will provide significant employment opportunities for specialist engineers and support staff and will act as a further endorsement for Milton Keynes as a centre for cutting-edge engineering. The facility will initially generate approximately 35 full-time jobs, which will be a mixture of highly-skilled engineering positions and support staff. By 2018 it is expected the facility will directly employ approximately 65 staff with significant knock-on employment benefits both locally and nationally.'

Honda has filed plans to enlarge the Mugen Technical Centre in Milton Keynes

The site for the new building has been acquired from the UK's state owned railway company, and was previously used as a storage area for track maintenance. However, Honda denies that there are any immediate plans to recruit new staff and that the new facility is simply needed because it has run out of space in the Mugen building. 'Really this is just a warehouse to store our ERS, nothing more,' Arai insists. 'The Mugen Technical Centre is tiny, we don't have any storage there. We use an old shipping container round the back of the building to store the ERS at the moment and it's not very good. So we need a bigger warehouse, we also need somewhere to keep the new motorhome. The current office is not good for trucks to come into either.'

New Honda teams

As for supplying multiple teams, Arai is very clear and re-iterates the comments he made to *Racecar Engineering* at the 2014 Japanese Grand Prix: 'We would like to have more than one team to supply, but right now nobody has come to me to ask for a power unit next year. Maybe now we have some points they will ask, I hope they do. If someone said to us, "give us a power unit", we have to consider it. FOM and FIA tell us that all power unit suppliers should supply multiple teams but the first year was a very difficult situation for us. Years two and year three we must think about it, but we have had no interest. Perhaps it's because we have not had any good results yet?'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Le Mans in depth

The story behind Porsche's historic Le Mans win in words and numbers

By PAUL TRUSWELL and ANDREW COTTON

Porsche recorded its 17th victory at Le Mans when Nico Hulkenberg, Nick Tandy and Earl Bamber crossed the line ahead of the field in their 2-litre, V4 turbo hybrid Porsche 919. They finished a lap ahead of their team mates, Mark Webber, Brendon Hartley and Timo Bernhard, with Audi, the pre-race favourite on the race pace it had shown earlier in the year, well beaten in third.

The positions may not have changed much over the course of the 24 hours, but the reason for Porsche's emphatic victory came during the night. While the track rubbered in and the conditions suited the 919, the competition from Audi simply wilted away.

'What happened is that the conditions went our way,' said Porsche's technical director Alex Hitzinger. 'The track rubbered in and the temperatures dropped, but I don't know why the Audis were not faster. I expected them to be much faster during the night, and I don't know why they were not. The engine performance gets better in the cooler temperatures, it is not huge but it is a bit better. The biggest surprise for me was that the Audi was slow.'

Audi personnel confirmed that the time lost was in sector two, the sector that includes the long Mulsanne Straight and its two chicanes. It is a sector of power and acceleration, and Porsche had both in abundance. Audi, on the other hand, saw its pace drop noticeably after midnight. That pointed to one of a number of things; engine performance, hybrid performance, tyre performance, or a problem with the fuel flow. The pace of the Audis picked up again on Sunday morning, suggesting that there was no problem with the engine or the hybrid system in the number 7 car that eventually trailed home in third. That left the fuel and tyres as the likely solutions although Shell insisted that it was not down to its diesel.

Attention first turned to the fuel flow meter, as it is here that Audi has had problems in the past. At Spa in 2014 the Le Mans spec car was slow, and the fuel flow meter readings were blamed. At Le Mans in 2015, the team, the only one to be running a diesel engine, apparently experienced a similar occurrence.

A new fuel flow sensor was introduced for the 2015 season for the gasoline-powered cars. The fuel flow sensor in the diesel Audi R18 does run hotter than a gasoline powered car – so hot in fact that the R18 has an extra cooling duct to direct air flow over it. The Audi also runs three sensors, compared to a gasoline-powered car's two; one for measurement, the other as a back up. For the diesel, it has a flow sensor and a return sensor in addition to the back up, and the fuel flow measurement is calculated between the two. This can lead it to be more susceptible to variations in fuel temperature and, on occasion, air temperature too.

Flow rate

The other issue, of course, is tyres. A drop in temperature helps a car that is harder on its tyres as they cool faster. That put Porsche in a good position during the night, although air temperature dropped by two degrees, from 21degC to 19degC. Another issue with the tyres is the lift and coast function, which had affected Audi throughout 2014. Lifting and coasting means less energy put into the tyres than under heavy braking, which means cooler temperatures in the tyres, and that affects cornering and acceleration. Any reduction in ability to accelerate hard out of a corner leads to a drop in speed all the way down the straight. If the Audi arrived at Tertre Rouge with reduced heat in its tyres and had to wait to apply power, it would carry that deficit to the first chicane, while Porsche would benefit.

All of that meant that the Audis struggled during the night and by the time happy hour came, when the air temperature is cool and the track temperature hot and rubbered in at dawn, the race was already settled in Porsche's favour.

That is not to take anything away from Porsche's victory in the Le Mans 24 hours, which was achieved remarkably simply – by sticking

‘The track rubbered in and the temperatures dropped, but I don’t know why the Audis were not faster. I expected them to be much faster during the night’

Porsche took a famous victory at this year’s Le Mans: its first since 1998 and 17th since it started racking up victories at Le Sarthe back in 1970

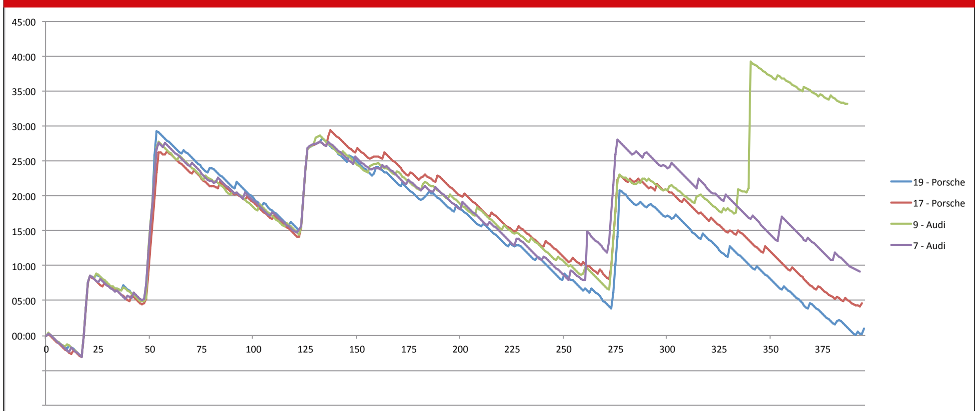
The number 7 Audi, which was driven by last year's winning crew, lost seven minutes in the pits having its rear bodywork replaced after it had started to flap. This was possibly because of unpredicted pressures on the underside of the R18

Race time spent in pits

No.	Car	No. of stops	Total time in pits
1	Toyota	29	43m 42.7s
2	Toyota	30	35m 10.2s
7	Audi	32	42m 09.3s
8	Audi	31	38m 01.5s
9	Audi	30	52m 32.5s
17	Porsche	30*	29m 42.0s*
18	Porsche	30	31m 39.9s
19	Porsche	30	34m 15.3s

includes stop/go penalty

Gaps between leading cars during course of race



The accident was spectacular, the car spearing across the track and into the barriers, which required a lengthy repair under the safety car

to the first three rules of endurance racing: be quick on the track, minimise time spent in the pits and stay out of trouble. The first of these was hardly a surprise. Since re-entering the World Endurance Championship in 2014, the Porsche 919 Hybrid, with its turbocharged 2-litre V4 engine and lithium-ion batteries, has had speed in abundance. The three cars from Weissach took the top three places on the grid with ease, improving by nearly five seconds on last year's pole position time.

By putting less fuel into the cars at each stop, Porsche was also able to spend less time in the pits during the race than any of its rivals, as the table shows. To a large extent, this was due to Porsche's strategy of pitting for fuel after every 13 laps, which meant that at most of its stops Porsche added almost five litres less fuel than Audi or Toyota, providing 1m30s of an advantage by the end of the race.

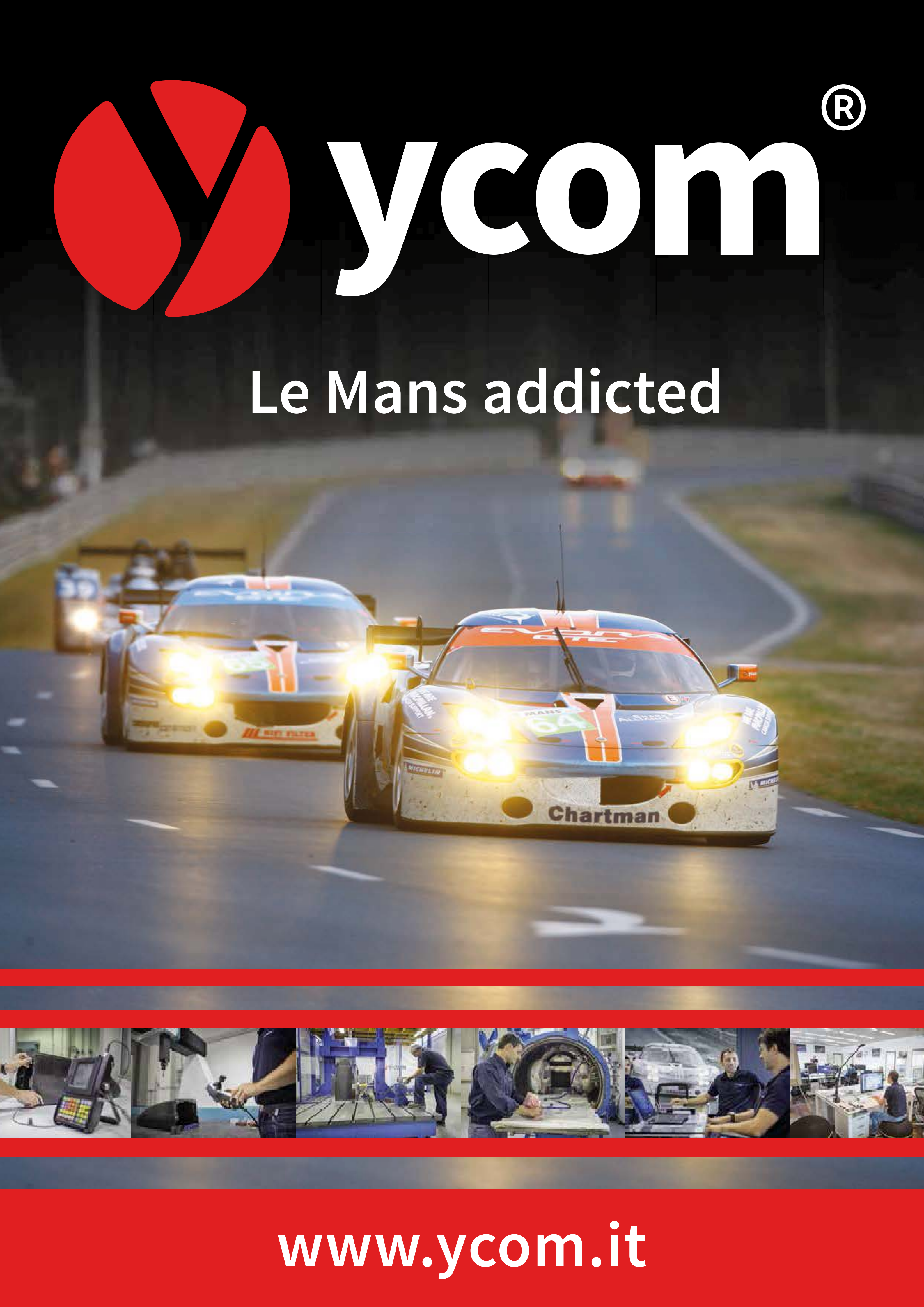
As for staying out of trouble; that really was the distinguishing factor between the three Porsches. The red car, driven by Mark Webber, Brendon Hartley and Timo Bernhard, suffered a one-minute stop-and-go penalty for a yellow flag infringement, while the black one, in the hands of Marc Lieb, Romain Dumas and Neel Jani, had a couple of off-track excursions at Mulsanne corner due to brake problems. It was only the winning white number 19 car that had a trouble-free run.

Long distance

The distance covered – 395 laps represents 5383kms – was the second-furthest distance ever covered at Le Mans, and but for four safety car periods neutralising the race for more than two hours, and numerous 'slow zones', then surely the distance record would have been beaten by a substantial margin.

In the eyes of many, Audi started the race as favourites, and – as the table of lap times shows – they were quick on the track. They rather failed on the other two golden rules though. The number 7 car, with last year's winners Benoit Treluyer, Marcel Fassler and Andre Lotterer driving, lost nearly seven minutes in the pits having rear bodywork replaced after a failure on the track. The number 8 car, driven by Lucas di Grassi, Oliver Jarvis and Loic Duval, lost time in an awkward-looking shunt less than three hours into the race, when a slow zone procedure caused confusion just before Indianapolis. Duval was warned that there was a slow zone at that area of the track when he started the lap, but when he reached Mulsanne Corner, he was told that the track was clear. Marshalling confirmed this; the flags waving were green, but his display still lit up yellow for the caution. He arrived at full speed among a group of slow moving GTE cars and tried to squeeze past, but he just clipped the AF Corse GTE Ferrari.

The resultant accident saw the car spearing across the track and into the barriers, which required a lengthy repair under the safety car.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Toyota struggled to match the speed of its German rivals. Its best times three or four seconds off those posted by Audi and Porsche. The best placed Toyota, No2 car of Alex Wurz, Stephane Sarrazin and Mike Conway, finished 6th, eight laps down

The number 17 Porsche in its evocative red livery led in the early stages of the race but then incurred a penalty for a yellow flag infringement. It showed good pace throughout the race, though, and posted the quickest lap time of all the Porsches

Race lap times

No.	Car	Best Lap	Average Best 20%	Top Speed
1	Toyota	3m 20.896s	3m 23.103s	336km/h
2	Toyota	3m 22.633s	3m 24.157s	337km/h
7	Audi	3m 17.475s	3m 19.839s	342km/h
8	Audi	3m 17.831s	3m 20.259s	346km/h
9	Audi	3m 17.647s	3m 20.993s	343km/h
17	Porsche	3m 18.186s	3m 20.609s	340km/h
18	Porsche	3m 18.917s	3m 20.731s	339km/h
19	Porsche	3m 18.596s	3m 20.040s	340km/h

Porsche's biggest worry was to understand and manage the tyre loading

The Audi required new bodywork but was underway in less than seven minutes.

The number 9 car looked for a time like the biggest threat to the Porsches, in the hands of Felipe Albuquerque, Marco Bonanomi and Rene Rast, but suffered in the second half of the race with intermittent hybrid energy delivery problems, first reducing its pace, and later leading to remedial work being required to the front suspension.

The graph (p26) shows the gaps between the leading cars over the course of the race, plotted against a notional 'average lap time', calculated by dividing 24 hours by 395 laps. The crucial phase of the race was during the night in the period from lap 126 (just after 11pm) until about lap 250 (6.20am). Mercifully, the safety car did not appear during this period, although there were various slow zones which had a significant impact on the average lap times.

Quick stints

The graph clearly shows, though, that the blue line (Porsche no. 19) emerges in the lead (closest to the x-axis) from lap 160 onwards. The table showing the comparison of Tandy's stints (p30) shows how this was worth more than a minute over Lotterer in the Audi over the course of a three-hour stint.

On lap 261, Marcel Fassler brought the number 7 Audi into the pits, rear bodywork flapping; most likely caused by unusual and unpredicted pressures on the underside. This left Hulkenberg (now back in the Porsche) a clear lead of 2m15s over Rene Rast in the best of the Audis. By now though, Rast was unable to use the full power of the Audi's hybrid unit, and fell away following the final safety car period between 7.39am and 8.10am.

Given Porsche's known speed over a single lap, it is fascinating to see how the team made its strategic decisions to maximise its advantages. It was surprising that at no time did the team attempt more than 13 laps (with any of the three cars) between refuelling stops, except when safety car periods slowed the pace sufficiently to allow them to extend their stints. There is no doubt that this was a strategic choice, since the fuel flow mandated by the regulations requires the cars running in the up to 8MJ class to have enough fuel for 14 laps.

Tyre worries

As a consequence, not only were Porsche's pit stops quicker, sometimes by five seconds, but also they had greater flexibility to manage the tyre wear. Following the six-hour race at Spa-Francorchamps, Porsche's biggest worry was to understand and manage the tyre loading, so that the cars could manage to complete two hours' running on a single set, as required by Le Mans regulations. In the early stages, there was no doubt Porsche was playing things cautiously, refuelling every 13 laps and changing tyres after three stints – which is 39 laps.

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While the Porsche was quicker at night, the Audi was as quick in daylight hours, although it was hindered by a variety of issues. The Porsche was also very quick when accelerating out of the slow zones, which might have made all the difference

Tandy's lap time comparison

	From lap	From Time	To lap	To Time	No of laps	Best	Average of best 20%
Night-time laps							
Tandy	146	00:17	197	03:15	52	3m 18.674s	3m 20.137s
Lotterer	149	00:28	199	03:31	52	3m 20.739s	3m 21.351s
Bernhard	137	23:48	188	02:47	52	3m 19.755s	3m 20.915s
Sunday morning laps							
	From lap	From Time	To lap	To Time	No of laps	Best	Average of best 20%
Tandy	277	08:10	329	11:10	53	3m 18.695s	3m 19.560s
Fassler	253	06:31	314	10:25	54	3m 18.532s	3m 19.287s
Lotterer	315	10:30	353	12:40	39	3m 17.475s	3m 18.670s
Webber	241	05:51	294	09:12	54	3m 19.543s	3m 20.796s
Bernhard	295	09:16	346	12:12	52	3m 18.186s	3m 19.728s

Night analysis between 23:40 and 04:00

		Average Lap Time*	Best Lap Time
7	Audi	3m 29.507s	3m 20.565s
8	Audi	3m 30.722s	3m 20.445s
9	Audi	3m 30.131s	3m 20.515s
17	Porsche	3m 29.207s	3m 18.938s
18	Porsche	3m 33.165s	3m 18.917s
19	Porsche	3m 28.899s	3m 18.674s

**includes slow zones and pit stops.*

The Porsches were doing an outstanding job between midnight and 4am … [when] there was evidence that the white car was quicker than the other Porsches

There was a decision taken early to test the tyres over a quadruple stint with Nick Tandy in the number 19 car, but a safety car meant that he completed only one stint on the tyres. To leave him in for the full quadruple would have put him beyond the maximum driving time permitted in one stint.

Porsche stuck to the three-stint strategy until well into the eighth hour; Mark Webber in the number 17 car being the first to stay out for a fourth stint on the same set of tyres, whereas Audi had been doing four stints from the very start of the race. In fact, the fourth-placed number 8 Audi completed the race on just eight of the 12 sets of tyres permitted.

Sunday morning

Undoubtedly, the reduced temperatures of the night-time contributed to Porsche's decision to extend their stints, but even when the sun rose on Sunday morning, the wear was sufficiently light for them to continue to quadruple stint the tyres. Perhaps it was a significant factor that the temperatures on Sunday never rose above 25degC, whereas on Saturday afternoon they had peaked at 30degC, and dropped below 25degC only after 11pm.

At Audi, consideration was given to letting the drivers five-stint the tyres; particularly as the driving time would have allowed it. But there was always the risk of further safety car interventions extending the stints; furthermore, the additional stress on the tyre sidewalls due to the amount of downforce, camber and pressures introduced additional risk, even if the wear was within the necessary tolerances.

The second table (left) which shows Tandy's lap times during the daylight hours on Sunday morning is less flattering. Not to say that he did not do a good job – indeed he was still faster than Webber – but during what traditionally is the happy hour, when lap times tumble, the Porsches were no faster than the Audis. Part of the explanation here is that the lead that Porsche had built up by this stage was simply big enough to make it unnecessary to push to the absolute limit.

Nissan woes

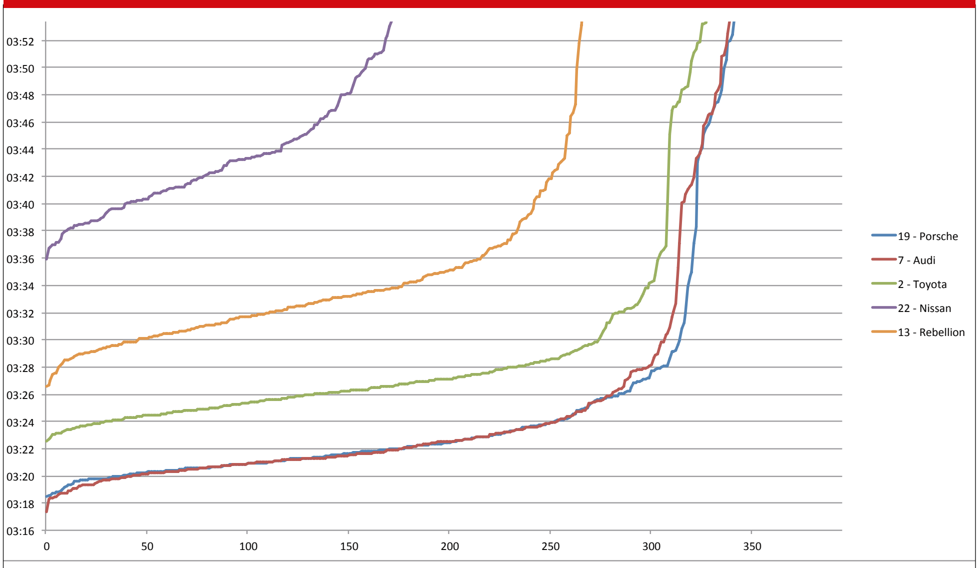
Contrast this with the table showing the lap times at night, which shows how the Porsches were doing an outstanding job between midnight and 4am (perhaps with the exception of Jani, who was spending a lot of time in the gravel at Mulsanne corner as the team battled with brake wear). During this night-time period, notice though that there is evidence that the white Porsche was quicker than the other Porsches, as well as being quicker than the Audis. (Note that the average lap times in this table include various slow zones and also pit stop times, which is why the averages are higher than in other tables).

Thus far, we have concentrated only on the battle for the overall lead of the race. Where

Audi came into Le Mans 2015 as firm favourite but relatively slow pace during the night running proved to be its undoing

Nissan struggled badly and while the GT-R LM hit some performance targets some say the future of the project is in doubt

Rising lap time graph



were Toyota and Nissan? Given that Nissan had been forced to miss the two opening races in the WEC, and bearing in mind the way that expectations were being set before the Test Day in May, it was no real surprise to see them struggling behind the rest of the LMP1 runners.

However, although the three GT-R LMs continued to improve throughout the event, there is certainly a mountain to climb before the unusual front-wheel-drive cars arrive back at Le Mans next year. The rising lap time graph is a good way of comparing cars from different manufacturers. Instead of viewing the lap times chronologically, this graph shows all lap times in ascending order. Thus, the fastest laps appear at the left-hand end of the x-axis and the slowest laps at the right-hand end. In fact, due to the scale of the y-axis, the slowest laps of all are not shown, as they disappear off the top of the graph.

Toyota slow

This graph can also be used to see how far off the pace Toyota was. Before the race, Pascal Vasselon was talking in terms of the two Toyotas being two seconds per lap behind, explaining that would mean that his cars, the class of the field last year in outright pace, would be lapped before half distance. He was being optimistic; the cars were more than four seconds slower per lap on average, and the better-placed car, driven by Alex Wurz, Stephane Sarrazin and Mike Conway, finished the race eight laps behind the winning Porsche.

Analysis of the various sector times suggest that the Toyotas were losing out around five per cent through the Porsche Curves, whereas down the Mulsanne straight, the cars were only one or two per cent slower. The conclusion is that while the Audis and Porsches are able to use their additional power to increase downforce, the Toyotas were relatively underpowered and being forced to run less downforce in order not to lose too much on the straights that comprise so much of the Le Mans circuit.

GT-R LM uncertainty

Toyota is already talking of a major redesign, including the possibility of a move to a turbocharged engine for next season. Nissan do not have that luxury, however, and indeed the team is waiting to learn its fate – will it continue next year or not? It achieved its performance targets in all areas other than lap time, 10 seconds off what was promised, and that is a major concern for the future of the project.

In terms of best lap, the cars are nine per cent behind Audi and Porsche. However, note the steeper gradient of the Nissan's line in the Rising lap times graph. The area between the lines provides the time difference between Nissan and their rivals, so a steeper line means that the faster laps are less repeatable for Nissan than for the rest. Half of the laps that the number 22 Nissan completed were more than

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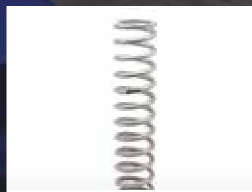

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Nismo has a huge amount of development to do in the next 12 months

four per cent slower than the car's best time. Only 30 per cent of the laps completed by the number 7 Audi and the number 19 Porsche were more than four per cent slower.

During the race, the best Nissan time was a second faster than in qualifying. That may sound impressive, but Audi was 2.4s faster in the race than in qualifying and Toyota was 2.7s faster! The Nismo team has a huge amount of development to do in the next 12 months.

One final observation on the rising lap time graph: the lines for the Lotterer/Treluyer/Fassler Audi and the Tandy/Hulkenberg/Bamber Porsche lie on top of each other for a large amount of their length. However, the Audi's top 20 lap times are clearly quicker. The Porsche's advantage lies in the lap times beyond the best 280. These are almost certainly those laps that are influenced by slow zones – they are too quick to be pit stop laps, and too slow to be flying laps. The acceleration of the Porsche out of the slow zones has probably played a part in their ability to win the race. A number of the night laps during Tandy's night-time stint were while slow zones were in operation. Circumstantial evidence perhaps, and with the various problems experienced by the Audis, not enough to make a difference to the outcome; but certainly one more thing for Audi to think about if they are going to have a chance to take the trophy back. This year, though, Porsche's dominance was impressive – and complete.

GTE: Lone Corvette picks up the pieces

The race in the GTE class rarely fails to disappoint, and the class of 2015 provided as strong a race as ever. Ahead of the race it seemed like the Aston Martin V8 Vantage would carry off the spoils: they were superior in performance, had equal fuel consumption and had the advantage of numbers. Over at Corvette Racing, one of their C7.Rs was damaged beyond repair during qualifying when Jan Magnussen crashed as he suffered a mechanical failure, the team claiming that it was throttle-related as the car was recovered from the Porsche Curves.

The race was between three Aston Martins, two AF Corse Ferraris and a solitary Corvette. The two Manthey Porsches were more than a second and a half slower than the Astons in qualifying and were left hoping for a race of attrition – or rain – to give them the opportunity to pick up the pieces. It was the Porsche of Patrick Pilet that was the first retirement, and although the other car featured in the top three, it too fell back in the late stages.

Aston Martin started Le Mans as firm favourite for GTE honours and one of them led the field in the early stages of the race, but the AMR cars were then beset with problems

In terms of outright race pace, the Danish-crewed Aston Martin Vantage of Nikki Thiim, Marco Sorensen and Christoffer Nygaard was half a second quicker than the rest of the field on average lap times and led early on until power steering problems intervened and forced the car to pit for lengthy repairs.

Aston out

The sister AMR car, driven by Richie Stanaway, Fernando Rees and Alex Macdowall, was roughly the same, in average lap times, as the remaining Corvette of Oliver Gavin, Tommy Milner and Jordan Taylor and the AF Corse Ferrari driven by Gianmaria Bruni, Toni Vilander and Giancarlo Fisichella, before it crashed out.

For some reason, the Aston driven by Rob Bell, Darren Turner and Stefan Mucke could not match the pace, not of the other two Astons, nor of the Ferrari or Corvette. Worse still, it had engine failure before midnight and retired. Prior to that it had been 4km/h slower through the speed trap on the Mulsanne straight.

A disastrous weekend for Aston Martin was completed as both their cars in the GTE-Am class were crashed: the number 96 by Roald Goethe in the 17th hour of the race, and the number 98 car by Paul Dalla Lana with less than an hour remaining.

With the Aston Martins and Porsches out of the running, the GTE-Pro race was thus left as a battle between the AF Corse Ferrari and the GM Corvette. Both had had short delays earlier in the race, the Ferrari making up time by double-stinting the tyres. Both were able to complete 14 laps on a single tank of fuel, and by the sixth round of pit stops, the Corvette was double-stinting its tyres too. However, the Ferrari was still spending less time in the pits; before gearbox gremlins struck it had spent 1m30s less time in the pits than the Corvette.

Unfortunately for AF Corse, half-an-hour was lost making repairs, leaving the other AF Corse 458 of Davide Rigon, Olivier Beretta and James Calado to take second place ahead of the recovering Gimmi Bruni.

PHOTOGRAPHY BY XPB

Corvette had a bad start to its 2015 Le Mans losing one car after it crashed in qualifying but the surviving 'Vette showed pace and hung on to win an attrition-hit GTE


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Boosting up

Rebellion's switch from Toyota to AER power for the 2015 season meant much work to do and very little time to do it

By ANDREW COTTON

When Toyota announced at the tail end of the 2014 season that it would not continue with its customer engine programme, it was bad news for the British-run Rebellion team. It then spent the winter searching for a replacement for its Toyota power, but in reality there was only ever one solution: the turbocharged AER LMP1 engine.

There was nothing wrong with the engine choice, but the prospect of adapting what the team already had to run with a turbo compared to a normally aspirated engine meant a huge amount of design work for the ORECA team, which built the car, and not much time to do it. The target for the French manufacturer was to retain as much of the existing chassis as possible while adapting it to the turbo engine.

'The time frame was quite hard on this project because the green light was at the end of February to run with the new engine installation,' says ORECA's chief designer, Christophe Guibbal. 'We ran for the first time at the end of May.'

With such a late decision on the engine, and safe in the knowledge that the likelihood was a change of direction, the design team wasn't able to work on the car during the off-season, which meant added time pressure once the decisions were made.

Compromises had to be made to install the engine, including locating it in the same place as the V8 so that the location against the chassis was in the right position, and that meant the centre of gravity was higher than it needed to be. However, keeping the engine in the same place also meant that the gearbox casing and rear suspension could be carried over from the 2014 car, and no changes needed to be made to the underfloor aerodynamics, which was a further cost-saving for the team.

'When we started the Rebellion project we optimised the design for the monocoque around the Toyota engine and not around the turbo,' said Guibbal. 'There was a lot of work to integrate the turbo engine. Cooling is a big challenge, and within that, one of the challenges was to change the minimum that we could for the external bodywork. We didn't have the time to put the engine in the car, and optimise the aero.

'We could have put the engine lower, but we have the turbo intercooler and a lot of water pipes because the water cooling is a lot more complex than the Toyota. In the Toyota we had only one radiator for water, and here we have two, one in either side, and we are a little heavier than compared to the Toyota.'

The base weight of the car has gone up by around 25kg compared to the Toyota solution, simply because of the increased cooling required for the turbo engine.

With all the work going on at the rear of the car, there was little time to do anything at the front, and that was not the design aim of the team anyway. The splitter, wheel arches and floor area around the front were all untouched from the 2014 design, despite the better understanding of the Michelin rubber, which is still an adaptation of the LMP1 hybrid front tyre.

The design team wasn't able to work on the car during the off season

Successful debut

The tub is the same as last year, but the sidepods were adapted to integrate the radiator duct and increase the mass flow inside the duct. As a consequence, the team had to change the engine cover and the air inlet through the airbox. 'This kind of engine needs a big inlet,' says Guibbal.

'We kept the same external parts of the gearbox, but we changed the ratios to cope with the demands of the new engine. Keeping the external parts meant that we didn't change the suspension layout. We have put new dampers in one of these cars, but we kept the same key points of the suspension.' One of the suspension solutions was PKM, the other Multimatic, and the team tested both during practice and qualifying on Wednesday and Thursday at Le Mans.

Other changes in the car were relatively minor. 'We changed the bell housing, and kept the suspension points in the same place so there is no big difference for the alternator,' confirms Guibbal. 'We have a big difference in terms of electrical loom because the management system is quite different. We changed the clutch [to Sachs] because the two engines don't have the same power.'

The Rebellion had a sterling race, finishing first and second in the LMP1 privateer class. However, there is a lot of work to do ahead of the next race at the Nürburgring at the end of August.

Life Racing

The Rebellion team has benefited from a new electronics system from Life Racing in the 2015 version of the R-One. With a four-inch dash screen that is programmable by the team for the driver, the new system also featured a USB port that allowed for hot-swapping, and instant data for the engineers in the pits. 'It means that we have gigabytes of data to analyse, even if you don't have time during a race pit stop to download the data,' says Life Racing engineer Jason English. 'If the pit stop is short for whatever reason, you may not be able to download the data, but changing a memory stick can easily and quickly be done.'

The memory stick records 1000hz per channel, providing the team with plenty of data on which it can make strategy calls, particularly around fuel consumption. The system uses bespoke software developed by Life Racing. 'Because of the Direct Injection AER engine and the way that the fuel metering is done, we can work out how and where to save fuel and know the output of the engine in a given rev-range,' says English.

Main picture: The AER-engined Rebellion went well at Le Mans, winning LMP1 privateer class
Left: Installing AER's turbocharged lump was the obvious solution once Toyota engine became unavailable at the end of 2014, but adapting it was not the work of a moment
Above: Meeting the cooling demands of the new engine while not compromising the aero was a major challenge for the design team while the turbocharged engine also required a bigger inlet

BR-ave new world

The work of Le Mans-winning Peugeot designer Paolo Catone, the BR-01 LMP2 could be the first in a string of LM prototypes from the Russian firm

By MARKUS EBERHARDT

With new LMP2 regulations, that will limit the number of chassis suppliers coming into force in 2017, the debut of the BR-01 chassis could be one of the last for a new P2 car for years, as other suppliers hold off until a decision is made as to who will be the four chosen chassis manufacturers.

Run by the Russian SMP team, the BR-01 made its race debut in the European Le Mans Series at Imola in May, after both financial and supply chain problems delayed the first public running planned for the WEC pre-season test at Paul Ricard in March.

Designed by the respected Paolo Catone, who penned the Peugeot 908s, much was expected of the car. Catone started work on it in February 2014, and worked with experienced suppliers that enabled him to take the idea forward quickly. His main target was a high performance with great aero stability and good driveability, which would help the gentlemen drivers.

In contrast to the existing chassis suppliers, this car was built exclusively to the LMP2 regulations, rather than, for example, the Dome S103 that was originally conceived as an LMP1. This makes it impossible for the car to ever run as an LMP1, which means an all-new design should SMP decide to make the switch to the higher category at a later date.

After the basic layout was done in CAD and the first evaluations made in CFD, a 40 per cent model was built and put into the rolling road Fondmetal wind tunnel in Sant' Agata Bolognese in May. A further eight wind tunnel sessions followed between May and December to allow the team to finalise its design.

Aero details

'The work on the aerodynamics changed a lot compared to the Peugeot 908,' said Catone. 'You work a lot more on the details as they bring more performance than changes to the general shape of the car. For example, we tested only two different rear covers and maybe three or four sidepod designs as the differences were only very minor.'

While the rear of the car received limited attention, it was the sensitive front that took up most of the tunnel time, with a multitude of variations on the nose, and the splitter, affecting flow over and through the entire car. 'We tried nine different nose concepts with narrow low and narrow high noses, wide low and wide high noses, squared and more rounded designs,' confirms Catone. The team also tested no fewer than 19 front splitter variations, with the final version including turning vanes on the underside and two 'ramps' with changeable angle for different downforce configurations on either side of the nose for added efficiency. The whole front splitter was much less pitch sensitive, which helped the overall handling and balance of the car. 'We did a lot of work on more minor parts, such as turning vanes or flow conditioners as they made the difference,' says Catone. 'What you see as the final car is just a consequence of wind tunnel results.'

The final design features high front wheel arches to direct the air around them rather than over them, as is common in current LMP models. However, the bodywork flows into the rear arches, in contrast to many rivals that make more of a feature of the transition. The low nose and low rear deck are also key to the aero efficiency. The sidepods have a large undercut for the best possible free airflow coming from the splitter. Four shuttered turning vanes were added as legal panels in this area, shaped to support the airflow to the rear and back under

The front splitter is much less pitch sensitive, which helped handling

'You work a lot more on the details as they bring more performance'

There was much detail design work undertaken on the BR-01 nose

the car to enhance the rear diffuser. As with the Dome design, the roof of the car has received attention to lower it as far as possible while still retaining the height of the LMP2 regulations. The cockpit canopy features quite a steep and short windscreen, and two 'blisters' on top of the rear roll cage to keep the engine cover as low as possible.

But one of the most striking elements of the BR-01 is hidden by panels between the nose and the front wheel arches. The inner face of the front fender is fitted with a vertical slit. Part of the air coming from the front is blown via this vertical slit into the wheel arch to help the flow of the rotating wheel. There is an interaction with the large vent of the front wheel arches on the back of the car.

The monocoque, built by ARS Tech in Italy, consists of aluminium honeycomb with carbon fibre skins, moulded as a single piece with three internal elements. The front and rear suspension consists of machined aluminium uprights supplied by Pankl with double steel wishbones by Breda. Steel pushrods and rocker arms operate the conventional coil/damper layout with an additional third damper element at the front and at the rear.

The Nissan 4.5-litre VKE-45 V8 sits in a monocoque of aluminium honeycomb with carbon fibre skins, built by ARS Tech

Car has been designed to lower the roof as much as possible within limits of the LMP2 regs with a steep, short windscreen

Late start

The car is powered, as is most of the LMP2 field, by the Nissan 4.5 litre VKE-45 Nissan V8, mated with a Hewland TLS 6-speeed sequential gearbox with a magnesium case that is developed by BR in conjunction with Hewland.

The final build of the car was supposed to be completed in October, but the sanctions placed on the Russian state after the Ukraine crisis caused problems with the flow of money, and so the first car was not finished until February. As mentioned, the first test was missed in March, but by April the team had put some serious miles on the car, completing a 1000km test at Barcelona and 6880km at Paul Ricard at the end of the month before its race debut in Italy in May.

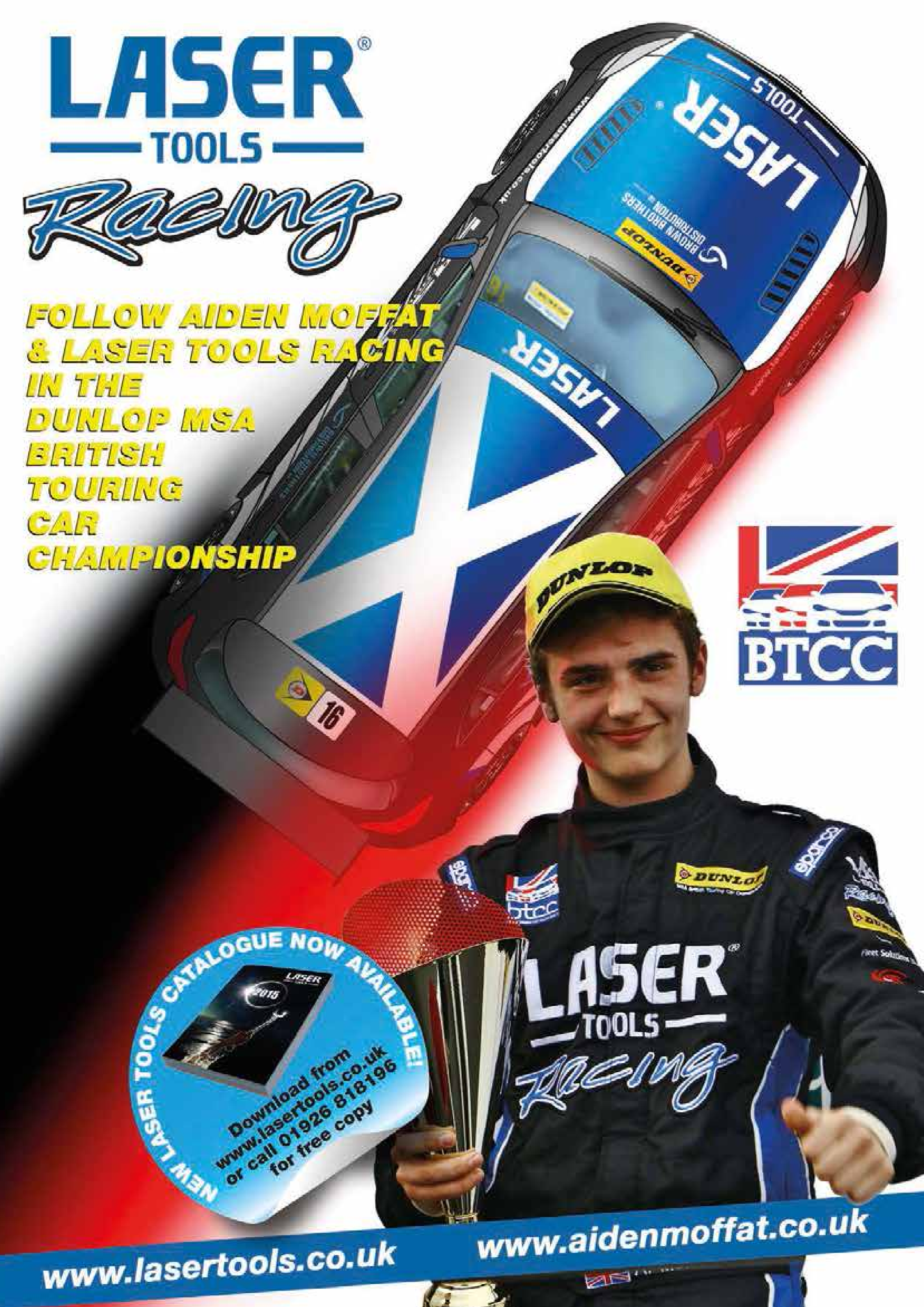
'We have designed the car purely around the LMP2 regulations, a difference to nearly all the other manufacturers, and we have also had a close look at the costs,' says Catone. 'We are able to produce the cars at a given price. Maybe we will not earn the money back through sales, but we will also not make a loss, although the development costs are not included in the selling price!'

Solid performance

The cars ran at the Le Mans test day and produced a solid, if unspectacular result. 'We still have a lot of work on the adjustment of the car, and I know we are a step away from our main rivals, but we are working on getting closer and I am sure we will reach the performance figures that I have promised my customers,' said Catone.

As far as the race was concerned, not only did it perform well during the race week, qualifying just over four seconds off pole around the 13.629km circuit, but it was also classified as a finisher after a long and gruelling race.

BR (for Boris Ratenberg, owner of SMP Racing) Engineering has confirmed that it will submit a bid to be one of the four chassis manufacturers for 2017, although it is believed to be an outside bet for selection. 'I confirm that BR-01 is the first chassis design built by BR Engineering,' says Benjamin Durand, managing director of SMP Racing. 'It is, and always has been, the company's intention to keep on developing the activities and we will design and develop new cars in the near future. We are now studying all of the potential options, including LMP1 and LMP3.'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By DON TAYLOR

While this summer's movie theatre screens will be filled with comic book superheroes, such as Batman and the Fantastic Four, battling it out by using their various powers to show superiority, there's another such contest starting to take place in the world of motorsport. In this case, that slightly grubby but loveable, homely hero, Internal Combustion, is being challenged by a new force, Electric Power. It's a bit like Electro taking on Spiderman, but hopefully without the same collateral damage. It's not happening everywhere right now, though, just on those battlefields where this precocious new challenger can shine.

One venue that suits a head-to-head contest is Pikes Peak. Its annual competition was first held in 1916, run over a limited distance (12.42 miles), with 156 turns, and ending at the 14,110ft summit of the mountain. The fabled hillclimb tests hard acceleration, handling, and power units not running out of breath.

The overall crowned winner may come from any class and the ruling Pikes Peak International Hill Climb (PPIHC) sanctioning body welcomes all sorts of vehicles, with a minimum of technical rules and limits (beyond the basic safety requirements). Indeed, the PPIHC actually encourages innovation, such as when it added an electric vehicle class back in 1981.

Now, after some rather rapid developments in performance, the electric powered competitors are even talking of winning the event overall one day soon. Note that in the motorcycle group, the quickest two-wheeler in 2013 was a Lightning electric bike.

Electric dreams

Giving the EV contingent extra encouragement were last year's overall results, in which EVs placed second, third, and fourth, with the runner-up just three seconds behind Romain Dumas' run of 9m5s in his turbocharged, petrol powered Norma. However, ultimate Pikes Peak record holder Sebastian Loeb needn't worry, yet.

An in-house built carbon fibre body covers the chassis, while Pikes Peak is all about low average speeds and plenty of corners, so aero philosophy tends to be based on adding plenty of wing

Now the electric powered competitors are talking of winning the event overall

His spectacular record of 8m14s, set in 2013, will stand for some time. But to win the event, you don't need to break his record; you just need to beat the fastest ICE powered cars, and the other modified EVs entered (see box out).

And, as always, you will need to beat the mountain, with its own supernatural powers. Very often race day can be beautifully sunny on the starting line at 9390ft elevation, and rainy, blustery, even snowy, at the chequered flag, waved at nearly a mile higher.

Competitiveness in this event is split between the abilities of the car, where all-wheel-drive can be a benefit, and the driver, where experience is valued, having someone behind the wheel who knows what is lurking around those next 156 corners.

Entering a new vehicle in this year's Pikes Peak was a Latvia-based company: Drive eO, a hi-tech firm founded in 2011, that uses racing as its calling card. Its racing projects have all been led by Kristaps Dambis, an automotive engineer. He explains: 'Drive eO's electric racecars are technology demonstrators to showcase our engineering capabilities. The flagship product is our electric motor controller, and we want the eO PP03 [2015 Pikes Peak-entered] car to help us with getting this product to the market. As a result of our demo projects, we get enquiries for supply of electric drivetrains as well as complete prototype car builds.' Dambis admits that the automotive industry in Latvia is pretty much non-existent. 'But we are good for niche and hi-tech products and services, and there is currently a lot of EU support available for development of environmentally friendly technologies. Once you prove your worth at events like Dakar or Pikes Peak, there is really no difference as to where you're based. It is the product that matters and we are quite proud that our electric motor controllers are indeed a class leading product.'

Dambis and the Drive eO team are not rookies in competing at Pikes Peak. Last year they ran a modified Tesla roadster, the

The battery packs sit either side of the driver between the front and rear wheels, saddlebag style, in these hermetically sealed and electrically isolated aluminium containers. The battery pack is capable of full discharge in eight minutes

Cooling is a major concern and the Drive eO PP03 requires a flow rate of dielectric fluid of some 15 litres per second for each of its six electric motors. The tube-frame chassis is quite straightforward, and has been designed and built in Latvia

Electrical grid

There were other electric challengers at this year's Pikes Peak, including event legend, Nouhiro (monster) Tajima, who teamed up with Rimac to enter a 1.2mW EV racer, while Rhys was not the only Millen in an electric vehicle, either, as there was a TRD (US) entered Toyota RAV4, driven by Ryan Millen, his younger brother. The TRD race prepared RAV4 EV was entered in the Electric Production class for the second time. 'Compared to last year, we have made some changes to the roll cage based on having a bit more time to build this year's car. Last year, the car was built in two weeks,' says TRD VP Steve Wickham. 'Otherwise it's the same specification as 2014, with coil over shocks, Toyota genuine accessory TRD 19in wheel and tyre package, TRD big brake kit, lowered ride height, and a full NASCAR carbon safety seat system borrowed from one of our Cup cars. Due to the rules we can't modify the powertrain so it's complete stock giving approximately 170hp (120kW) and 270ftlb, regardless of altitude.'

Wickham continues: 'The thermal management in the car is really capable straight from the factory; we had no issues last year running wide open for most of the climb. In fact the car was the most maintenance-free racecar I have ever been involved with. All we did last year was plug the car in every night after the practice runs and do a quick safety check. With the 42 kW/h battery we have no range anxiety and could easily do the race distance two or even three times over, at race speeds.'

production EV based on a Lotus platform. That was preceded in 2013 by their ground-up build, sports-coupe, the eO PP01. And before that, they ran a hybrid car in the Dakar Rally. And now, with a new car, the eO PP03, they are taking what they learned, and boldly declaring that they have a chance to win overall. 'We want to become the first overall winner with an electric vehicle,' said Dambis.

As the Pikes Peak Electric Modified class has no limits on battery energy capacity, numbers of motors, etc. Drive eO is bringing in the big guns, stuffing the car with lots of power, and for Pikes Peak it put it in the hands of a legendary winner of the event, Rhys Millen.

Serious power

Twenty-time Pikes Peak veteran, multi-time class winner, and 2012 Champion, Rhys Millen has historically designed and built his own cars for the Pikes Peak challenge. His latest was a converted Daytona Prototype, re-fitted with a turbocharged, Hyundai engine (see RCE V23N9 for details). He finished second only to Sebastian Loeb's factory Peugeot effort that year. Although this will be his first time in an electric vehicle, the New Zealand transplant has proven he is not afraid of adapting to new vehicles. He does it all the time in his other job as stunt driver for advertising, TV, and action movies such as *Fast and Furious*.

The eO PP03, is armed with 1.0MgW of peak power, or 1367hp, which is equivalent to the muscle of about 300 golf carts lashed together. Previous Pikes Peak electrics have been less than half of that, in the 450-500kW range.

All four wheels will be driven, turned by six (yes six), electric motors. The off-the-shelf, YASA-400 motors are 'triple stacked' at each axle, liquid cooled, and are rated at 170kW peak each. Such power does not come without waste heat generated, requiring a flow rate of dielectric fluid at 15 litres per minute for cooling each motor. The biggest challenge for the team was rotor alignment on the splined output shaft, and syncing the controls to each.

High voltage

The motor output is fed into a Sadev SP03 limited-slip differential, with a ratio 3.875, with no need for a multi-ratio transmission. The power reaches the ground through the 320/710 R18 Hankook tyres, front and rear.

Drive eO assembles the twin battery packs, which contain 2646 individually tested and matched lithium ion cells, giving a system voltage of 720 V DC and 49kWh energy content. They wind up in hermetically sealed and electrically isolated aluminium containers weighing 345kg in total. The battery pack is capable of full discharge in eight minutes, with no need for any liquid cooling.

To control this leaping-with-lightning-bolts power level from the batteries to the motors, and to convert it from DC to AC, Drive eO has

‘Latvia is good for niche and hi-tech products and services’

designed its own controller/inverter units. Dambis says: ‘The six controllers are arranged as one master and five slaves. Communication takes place via a dedicated CAN network at 1 Mbit/s.’ Unlike the batteries, the controllers do need cooling, which is provided at a 10 litre per minute flow rate through each controller.

The chassis is pretty straightforward; a tube-frame design constructed in Latvia, laid out to package the electric motors, controllers, and batteries. The global motorsport supply chain has been tapped to provide standard chassis components, such as the Eibach springs, Sachs dampers, AP Racing brakes, and Woodward rack and pinion steering, which is electrically assisted with a DC Electronics motor. Suspension is double wishbone, with push-rods all around.

The two battery packs sit to either side of the driver, between the front and rear wheels, down low, saddlebag style. The chassis also accommodates the hardware for the two cooling systems for motors and controllers, with one radiator for dielectric fluid, and another for water.

Refined yet simple

An in-house fabricated, open cockpit, composite carbon fibre body covers the chassis. Major assists to aerodynamic downforce come from the front and rear mounted wings. With top speeds at Pikes Peak only occasionally touching 150mph, drag concerns take a backseat to keeping the car nailed in the numerous 60-100 mph corners.

Driving the car for the first time a few weeks before the big event, Millen’s impressions were positive: ‘This was a very unique experience. The design, build quality and layout of the Drive eO PP03 unlimited electric car is refined yet simple. There are no wheel speed sensors, no traction control, no active differentials and that’s okay with me.’

In its chassis, the PP03 has a lot of built-in adjustability for tuning, which will play into a key strength of Millen’s, his skill in setting up a car: ‘[This is] something I have become very familiar with, most recently in setting up our winning rallycross cars. The biggest difference comes in the form of torque demand delivery, basically, the balancing of front and rear torque.

‘By requesting less torque delivery to the front wheels I was able to reduce power-on understeer and front wheel spin to a very neutral more conventional chassis balance,’ Millen explained. ‘The fact that after day one we were already making differential setting changes, shock and spring changes, shows me the potential this vehicle might be capable of this year.’ All that remains is for the super heroes to do their stuff …

The suspension is double wishbone with pull-rods all-round. At the sharp end the eO PP03 features Sachs dampers, Eibach springs and electrically-assisted Woodward rack and pinion steering. Brakes are by AP Racing with vented steel discs

All four wheels are driven by six electric motors, the off-the-shelf YASA-400s triple-stacked in the car at the front and rear axles. The output from the motors is fed to the BBS wheels and R18 Hankook tyres via Sadev SP03 limited-slip differential

TECH SPEC

Drive eO PP03, Electric Pikes Peak Car

Manufacturer: Drive eO, Ogresgala Pagasts, Latvia

Powertrain: pure electric
Motors: YASA-400 **Number of motors:** 6
Maximum power: 170 kW each, at 720 v
Maximum revs: 7500rpm
Batteries: 2646 lithium ion pouch cells
Controller/Inverters: Drive eO
Top Speed: 250kp/h
Transmission: direct drive
Differentials: Sadev SP03 limited slip axle differentials F&R, ratio 3.875

Chassis
Frame: welded steel tube
Bodywork: carbon composite

Suspension/brakes/steering
Suspension: double wishbones and pushrod/rocker arm actuation at all corners
Uprights: aluminium, CNC from billet
Springs: coil over dampers; Eibach springs
Dampers: Sachs 4-way adjustable dampers
Brakes: AP Racing, hydraulic double circuit brake system with one piece light alloy callipers
Brake discs: vented steel
Diameter (front): 355 mm
Diameter (rear): 320 mm
Wheels: BBS Motorsport 3-piece aluminium: 18in x 13in
Tyres: Hankook 320/710 R18 slicks
Steering: Woodard rack and pinion, DC Electronics electric assist motor

Dimensions
Length: 4445mm
Width: 2000mm (with wings)
Height: 1150mm at roll cage
Wheelbase: 2800mm
Wings: adjustable Reverie two element wings – width: 1800 mm front and 2000 mm rear
Weight: 1150kg – 52/48 front/rear


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Fab' 5

Skoda's new Fabia R5 rally challenger will face stiff opposition on the stages while it also needs to live up to the success of its S2000 predecessor. We trace its development

By CHRIS EYRE

Skoda recently revealed its latest challenger in the burgeoning production-based 1.6 litre turbocharged WRC2 'R5' category, its Fabia R5. Sitting beneath the headline WRC rally car class, R5 is the forced-induction capacity-downsized successor to S2000, currently dominated by M-Sport's Ford Fiesta, as well as Peugeot's 208 T16 and the similar Citroen DS3.

Mirroring Volkswagen's Polo R WRC sister marque approach, the Skoda joins the party after an ominous length of private testing relative to M-Sport and PSA's offerings prior to launch. As Dr. Frank Welsch, Member of the Board of Management for Technical Development at Skoda commented: 'To be able to compete with rivals from around the world on the rally tracks, a car needs to be at the top of its game technically.'

There is also the challenge to continue the Fabia success story to think about. Since 2009

The first 2011 Polo R WRC 'Zero car' test mule was essentially a re-clothed Fabia

just under 100 S2000 Fabias were built and the normally-aspirated car won almost 50 national and international titles around the world, making it Skoda's most successful rally car, in part due to the company's successful customer programme. And then, of course, VW Motorsport's Andreas Mikkelsen became the first back-to-back Intercontinental Rally Challenge champion driving for Skoda UK Motorsport in 2011 and 2012.

One of the most noteworthy challenges with designing an R5 rally car, as opposed to a WRC car, are the regulation component price caps to stop the category soaring out of control, coupled with restricted re-homologation options. With a target price of €180,000, several iterations of design compromise are often required to produce within budget.

A first 1.6 turbo-engined S2000 Fabia chassis mule was seen testing at the end of July 2013 and a similar mule ran as a course car a year later on Rally Bohemia. Homologated on 1 April, the Fabia was duly unveiled after a 15-month, 10,000km gestation period near the Skoda headquarters in Mlada Boleslav. Development test locations included Czech Republic, Austria, Germany, Italy, France, Greece, Spain and Finland. Czech Jan Kopecky, Finn and European champion Esapekka Lappi, Belgian Freddy Loix and multiple Austrian champion Raimund Baumschlager were all on the development team.

The evolution of the species shows that the first 2011 Polo R WRC 'Zero car' test mule was essentially a re-clothed Fabia S2000. Volkswagen then extensively re-engineered it to create its WRC car, with all the additional headroom of the FIA WRC regulations. So wholesale reverse engineering shortcuts were out of the question for the customer-orientated Fabia R5. Regulated engines, transmissions and suspension specifications apart. Welsch confirmed VAG Group collaboration: 'Naturally we drew on the [Polo R WRC] world champion's knowledge when developing the Fabia R5,' he said, although a Skoda release went further: 'The development process took advantage of synergies within the Volkswagen group – after all, Volkswagen has won the World Rally Championship for the last two years and once again holds a commanding lead in the series this year.' Ales Rada, chief engineer at Skoda Motorsport, added: 'Consultations between engineers of both [rally] teams were part of the development activities during the Skoda R5 development project.'

At 1230kg in rally trim, up 30kgs from its predecessor, the production Fabia is based on a mixture of the PQ26 platform, used by the facelifted Mk5 Volkswagen Polo, and the MQB platform, utilised by seven Volkswagen Group models. Rally bodyshells are prepared in the Czech Republic at Skoda, with TIG welding outlawed where WRC regs otherwise permit it, a continuation of cost-capped MIG welding traced as far back as FIA Rally Super 1600.

The Fabia R5 sports a small hydraulically-controlled clutch between the front and rear axle which is engaged when the handbrake is pulled; the aim of this is to disconnect the front and rear axles when the brake is applied in the tighter turns

Like sister firm VW, Skoda uses Sachs dampers, although it says spec is very different from WRC

Under the bonnet, clearly the most significant difference between the outgoing S2000 and the R5 Fabias is the 2-litre naturally aspirated petrol engine giving way to a 1.6 litre turbo engine, which must be a production-based engine, permitted to be sourced from a different model in the manufacturer's range. Skoda chief engine development engineer, Pavel Hlavacek, confirmed the base engine's origin: 'EA 888 Generation 3 1.8T 132 kW [from a] VW Lamando'. This is a four-door China-sold coupe similar in size to a Jetta. The turbocharger must be from a production road car, under the price cap with no variable geometry or exotic materials and Skoda has chosen the IHI unit from the high performance 2-litre Audi S3. A bespoke crankshaft was chosen, rather than production origin, and is therefore subject to a minimum weight of 12kg, Skoda clearly opting not to risk issues with the final torque outputs. Regulations permit the engine to be mounted 25mm forwards, upwards or 15mm backwards, and Skoda confirms a maximum permitted 25-degree engine rearward inclination.

R5 FIA regulations also require the use of standard parts for items such as the radiator and intercooler. Skoda engineers say they've delved into the Seat Ibiza Cupra R parts bin. It was a real challenge to force enough air in to meet operating temperature targets, as Rada described: 'The front part of the car is really challenging just because only standard cores for cooler and intercooler can be used but as well by the fact that area of the bumper/bonnet opening is limited by rules.'

Hlavacek said: 'The development of [the] engine for Skoda Fabia R5 car was fully under control of the Skoda company and Motorsport Department, supported by the Engine Department of Skoda´s Development Centre.' Controlled by a Magnetti Marelli ECU, adapted by Skoda to meet its own requirements, the R5 regulations stipulate a maximum compression ratio of 10.5:1, turbo boost limited to 2.5bar via an FIA pop off boost control system and rev-band capped at 7500rpm. Disclosed output is 275bhp and 310lb.ft at 4700rpm. Those who have seen it go say torque looks impressive and the gearing appears lengthened to suit.

Gearing up

The transmission is the new-for-2015 R5 offering from Xtrac, a five-speed sequential transmission – as opposed to six for the normally aspirated S2000 predecessor – with four-wheel-drive and a 'theoretical' torque split of 50:50. Rada adds: 'There is a small clutch between front and rear axle which is controlled hydraulically by [the] handbrake. This clutch just disconnects the front and rear axle when the driver uses the handbrake to lock the rear wheels.'

Designed specifically for R5 turbocharged cars up to 1600cc, the 'box is Xtrac's FIA regulation interpretation for the category. Its technical director, Adrian Moore, said: 'We've optimised the P1202 transmission to meet the FIA's weight, durability and cost targets. It incorporates Xtrac's well proven plate differentials, and the gear-change mechanism is the latest overlapping type on all five gears, giving a fast, accurate and very precise manual gearshift.' Casings are made from high strength L169 aluminium alloy, sand cast to the regulation minimum wall thickness of 5.5mm, using a material normally specified for critical aerospace applications.

The development process took advantage of synergies within the Volkswagen group

Unconventional

The McPherson strut suspension uses ZF Sachs shock absorbers. Skoda took advantage of the considerable experience and knowledge of Volkswagen Motorsport and Sachs in the WRC, where the Polo is hugely impressive over rough terrain and bumps. However, Rada cautioned that: 'It is almost impossible to compare [the Polo WRC Sachs dampers] with the customer oriented solution prescribed for R5.'

Flying in the face of rally convention, one of the most intriguing outwardly-visible aspects of the car is the front McPherson strut design position, with the front strut lower pickup point mounted behind the hub. Looking back, the oft-seen S2000-bodied R5 test mules had this new configuration too.

For the best part of a decade WRC and S2000 cars have had the front strut positioned forward of the driveshaft. M-Sport Ford was one of the first to do this with the 2006 Focus WRC, and they followed this with the Fiestas, just as Skoda did with the Fabia S2000, the damper angle for which then translated to the Polo WRC. Mounting a strut forward of the driveshaft allows increased damper stroke, at the potential cost of airflow around the brakes, particularly when remote damper canisters are located at the bottom of the upright. Downside is the strut has increased bending loads and stem friction.

So, did Skoda consider moving the R5 calliper behind the hub instead, as per Polo R WRC? 'In the phase of the car concept definition we considered a lot of aspects which have an influence on the car performance,' Rada says. 'One of the most important issues was to have a reliable and efficient brake system even in hot conditions. The calliper position

It was a real challenge to force enough air in to meet operating temperature targets

There's not much scope for aerodynamic innovation in R5 but there are some VW Polo WRC cues on the Fabia, such as the wheel arch shape. The rear wing is the result of CFD optimisation

is not restricted by regulation. In the phase of concept definition it is necessary to evaluate a lot of aspects in the package of the car. The ball joint geometry is not so different. We had to evaluate the kinematic characteristics of the car, decide what will be the wheel travel front and rear for gravel and tarmac, analyse the capacity for the brake cooling etc. After analysis of all of those parameters we decided on this concept of the front strut. We are not the only one with this configuration. The same system is used by Porsche on one of their 4x4 models.'

Suspension travel

So Skoda is suitably discrete about the exact rationale. Compromising suspension travel seems inconceivable unless deemed to be in surplus. Clearly the R5 struts now articulate more directly in the plane of the suspension, reducing frictional losses. Anecdotes from its WRC2 Portugal debut suggest it has ample travel for an R5-class car.

Related to this, an R5 regulation forces the headlamp assembly to remain in the original position and unmodified. As with the Fiesta, Peugeot 208 and Citroen DS3, this taxed the minds of the Skoda designers as far back as 2013 when it came to establishing available front suspension travel where, unlike in WRC, it becomes a headache.

This magazine previously noted that PSA had to work around the issue (REV23N11) and it was an area the Czech concern was also working on a solution towards. The finished product has an undisclosed suspension travel, but Skoda confirmed: 'This was really not easy and without the support of FIA and other competitors to slightly modify the rules to reach a technical compromise we would not be able to finish the rally car.' So a deal has been brokered.

Two strut types are allowed in the FIA R5 regulations. Skoda confirms its front and rear hubs are the same, visible from the damper angles seen, side on.

Scope for R5 aero is fairly limited. Some translation design cues appear in evidence from the Polo WRC square-topped and backed wheel arches. The upper front wing forward facing 'dive plane' ramps aren't as pronounced, while Skoda discloses that: 'The rear wing design and position is a result of our CFD optimisation of this part giving requested values for downforce and drag.' This notably rear-set rear wing position shows an evolution in aero thinking and balance.

To ignite the customer programme, Skoda is taking the fight to the WRC2 competition at the highest level, head-to-head with its rivals in a clear effort to demonstrate the car's potential. Debuting on the Rally Sumava Klatovy in late April, Asia-Pacific Champion Jan Kopecky won in convincing fashion, setting fastest times on every stage and beating Bryan Bouffier's Citroen DS3 R5 by over a minute and a half. A successful start.

The next big hurdle came on WRC Portugal, with Finland's Esapekka Lappi and Swede Pontus Tidemand finishing second and third where Nasser Al-Attiyah took victory ahead of the two Skodas, albeit in an RRC-spec Fiesta, not an R5. A further victory for Kopecky on the Cesky Krumlov domestic event cemented progress, while obstacles and accidents on the second Italy WRC round saw a promising start and then a third podium spot salvaged.

Eschewing the European Rally Championship, having won it for three years in succession, the Fabia R5 will continue to compete in selected European rounds of the World Rally Championship. Jan Kopecky meanwhile competes in the Czech Rally Championship where he will face older 2-litre World Rally Cars, now eligible following rule changes. Tidemand will also be in action in the Asia-Pacific Championship, where Skoda aims to gain a foothold for what is a core China market. On the China Longyou Rally, he may line his Skoda up against Prodrive's bang up to date 2.0-litre turbocharged FAW-Volkswagen Golf SCRC (REV25N1), which will provide inter-marque intrigue, for otherwise Volkswagen group policy is generally not to compete in the same series. In 2014 Chris Atkinson's Golf won that contest convincingly, finishing five minutes ahead of Kopecky in the S2000 Fabia.

Skoda says it has no plans to create a WRC car, just as Volkswagen has no plans to make a Polo R5 (or indeed to sell its World Rally Cars). The two campaigns can thus co-exist in different rally categories where they meet on the European WRC events.

State of play

With the next big WRC2 test closer to home ground in Poland in early July, there are around 10 Fabias built as this feature is written. Skoda hopes to sell 15 to 20 cars into the privateer market during 2015, with Raimund Baumschlager having already taken an allocation. German driver Mark Wallenwein has received his, Pedro Meireles' car has been delivered to Portugal, and Freddy Loix's car is readied for Ypres as this was written. Umberto Scandola, the former Italian champion, has just taken delivery too. The balance to date is made up of the main works-run cars and a test car.

Pre-roll out, Michal Hrabanek, played down the team's WRC2 ambitions for 2015, noting the not-insignificant challenge and asserting that experience over success is the priority. With pace nevertheless to prove, four solid finishes from four events sees the silverware collection starting well, but arguably its World event capability has yet to fully emerge.

While M-Sport's Fiesta has stolen a huge march on the R5 market with more than 100 cars sold in less than two years, and PSA endure some growing pains with their cars, the Skoda looks so far to be reliable and the aim will be to progressively show how competitive it can be. Just like their S2000.

Let's see if it can follow that …

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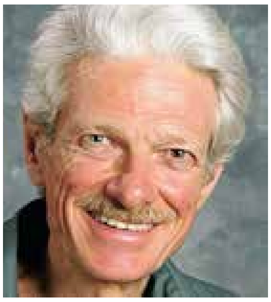

Formula SAE differential differences

A look at some of the many types of diff now available

Question

There seems to be a bewilderingly wide variety of differentials used in FSAE. What are the pros and cons of each type?

The consultant says

I have at least some experience with the following options, in chain-drive FSAE cars:

1. **Worm gear diff (Quaife, Zexel)**
2. **Clutch pack diff (Drexler)**
3. **Viscous diff (adapted from Mazda Miata)**
4. **Face cam diff (Suretrac, which is from a Honda ATV)**
5. **Spool**

The problem with the worm gear design is that it doesn't provide much locking effect when the inside rear wheel is very lightly loaded. This can be helped by preloading the gears, but the preload is highly wear-sensitive. The result is that when cornering near the limit, the car cannot be throttle steered; the inside wheel spins.

The Drexler comes preloaded. When the preload is right, the car can put enough torque through the diff to get some further locking, even with the inside wheel very light. There is, however, an inevitable compromise between torque transfer when it's needed and the tendency of the preload to produce understeer. In the 2015 UNC Charlotte FSAE car, the team found it best to reduce preload torque to about half the value the unit had as supplied.

It should be noted that this was a very light single-cylinder car with 10in wheels. The car, with driver, is around 500lbs, compared to more like 650lbs for a typical 4-cylinder car. The tyres have about 18in outside diameter, versus about 21 for a typical 13in tyre. This means that for a similar effect on car behaviour, that car would theoretically need the preload reduced by a factor of (18/21)(500/650), or to about 2/3 as much, compared to a 4-cylinder car on 13s. The amount of preload reduction actually used was the result of cut-and-try.

The team also had a car with an adapted Mazda Miata (MX5) viscous LSD. This type of diff has the advantage of having negligible locking torque when there is little speed difference, and still generating locking torque when one wheel spins, even if the wheel that's spinning is transmitting very little torque. It is entirely velocity sensitive.

The UNCC car with the viscous didn't perform as well as hoped. I attribute this to two factors. First, there was no way to adjust the aggressiveness of the viscous unit. Second, the team insisted on using traction control. The viscous unit works by allowing some wheelspin but generating a locking torque roughly proportional to the square of the amount of wheelspin, and also related somewhat to temperature. When the engine management won't allow any significant wheelspin, the viscous diff can't work as intended. According to the students responsible for tuning the ECM, the abruptness of traction control intervention could be adjusted, but the trigger point, in terms of slip value where intervention began, could not.

The face cam unit remains a bit of a mystery to me, even after reading an SAE paper about. It appears to me to be a kind of soft locker, rather than a true differential. That is, it will allow one wheel but not both to either overrun or underrun the carrier, and the average of the two output shaft speeds will not necessarily equal the carrier speed. The paper does not include information relating locking torque to input or output torque. The team used this unit because it seemed promising, was able to put some power down with one wheel very light, and was available at a much lower price than a Drexler. I am not sure what degree of success the team had with this unit, but they went to a Drexler for the next car.

There was no way to control the aggressiveness of the unit, and the team insisted on traction control

One car had a spool. A car with a spool requires a driver who can deal with its properties. Drivers with karting experience tend to be good candidates. This particular car never was developed to the point where it was reliable. One problem was that it kept breaking driveshafts. I still think somebody should try a locker – either a face dog locker like a Detroit locker, or a roller clutch locker like the Weismann. I would appreciate hearing from anybody who is aware of anything like either of these being tried in FSAE.

Drexler manufactures a clutch pack differential that comes preloaded; Charlotte FSAE team reduced preload by half

Mumford set-up

Can a three-link design work on a Mumford-Mallock set-up?

Question

All the photos I've seen of example cars with a Mumford/Mallock set-up, all four link. You mentioned two trailing links at each end of axle with other requisite provisions regarding roll and wedge in braking (right side to bracket welded to rear housing and rotating birdcage on left carrying left brake caliper; with other description of instant centres of both link pairs at or near axle height; longitudinal location of both IC's same, etc.).

Can a three link (two lower and single upper) be configured for the Mumford *and* provide for roll and wedge considerations?

The consultant says

Any longitudinal locating mechanism can be used with any lateral locating mechanism, provided of course that nothing hits anything else and you don't run any joints out of travel. So yes, you can use three longitudinal links rather than four. With three links, the system will operate bind-free with any link angles.

The main reason for using the Mumford linkage is a lower rear roll centre

With four links, the two on each side have to be equal-length and parallel unless there is at least one birdcage, or compliance in the system, as from rubber bushings.

Regardless of the lateral locating mechanism, a simple three-link system can provide zero roll and wedge change in braking or under power, but not both from the same geometry. The fundamental problem is that driveshaft torque is present under power but not under braking. But the choice of lateral locating mechanism does not affect this.

The usual approach is to either not attempt any compensation for driveshaft torque, or split the difference and provide partial compensation and accept a bit of wedge change in braking. Further help can be had from the fact that an offset top link will level out some when the rear suspension extends.

Still, we cannot get perfect operation from such a simple system. It is best to provide some way for braking forces to be reacted differently from propulsion forces. There are many possible ways to do this, but all of them involve more complexity than just having three trailing links.

The main reason for using the Mumford linkage is that it can provide a lower rear roll centre than other options, for a given set of packaging constraints. The main reason for wanting the low roll center is that we will then be using more elastic roll resistance at the rear, other things being equal. The reason we want more rear elastic roll resistance is that this diminishes the wedge changes we get when the longitudinal locating linkage cannot compensate for driveshaft torque and also react braking forces symmetrically.

So, a really good longitudinal linkage works just fine with a Mumford linkage for lateral location, but at least potentially, it eliminates the main reason for using the Mumford.

One might then ask: if a builder doesn't want to try to design a longitudinal linkage that compensates for driveshaft torque without creating a roll moment in braking, or just can't figure out how to, or is prevented under the rules – is it better to go with a three-link or a parallel four-link? I'd go with the three-link, unless there's some structural or packaging issue that makes it impractical. With a four-link, either we have no anti-squat or anti-lift, or we have roll steer, or we have compliant bushings in the system. With a three-link, we can have any anti-squat and anti-lift we want, with very little roll steer, and still use rod ends throughout with no bind.

How important is compensating for driveshaft torque, and how much does it help to have more elastic roll resistance at the rear? We can get some idea with a quick calculation. Suppose we have a 2000lb car and the rear tyres are propelling it with 1000lbs of thrust. This would represent something like the limit of traction for a front-engined car on street tyres. Suppose that the rear roll centre is about at axle height and the front is near ground level. For roughly equal amounts of load transfer at front and rear, the front suspension will then have around 80% of the elastic roll resistance. If the tyres have a radius of a 1ft, and the car has a 4:1 axle ratio, the driveshaft torque is 250lb.ft. If the front suspension reacts 80% of that, and the track is 5ft, the load change at the front wheels is 250lb.ft times 80%, divided by 5ft, or 40lbs. The right front and left rear gain 40lbs of load each, and the other two wheels lose 40lbs each. The change in crossweight is then 80lbs, or 4%.

If the rear roll centre is nearly as low as the front one, so that the rear has 50% of the elastic roll resistance, the load transfer at the front is only 25lbs and the crossweight changes by 50lbs, or 2.5%. In other words, by using a Mumford and a stiff anti-roll bar at the rear rather than a Panhard bar at axle height, we can reduce torque wedge by somewhere between a quarter and a half. This is a worthwhile improvement, but not as good as having linkage that compensates for driveshaft torque.

Nismo brakes

Last month we considered the very unusual front-drive Nissan Le Mans car. I mentioned that it would be interesting to see if they could keep front brakes in it.

Evidently the designers were well aware of the issue, and they have addressed it by fitting brakes (at least on the front) that can be quickly changed in a pit stop. The rotor and caliper can be quickly swapped out, without even the need to re-bleed. There's a good interview with Chief Engineer Zack Eakin on Jay Leno's Garage at https://www.youtube.com/watch?v=fw_2N3tGMEg.

See p24 to see how Nissan got on at Le Mans.

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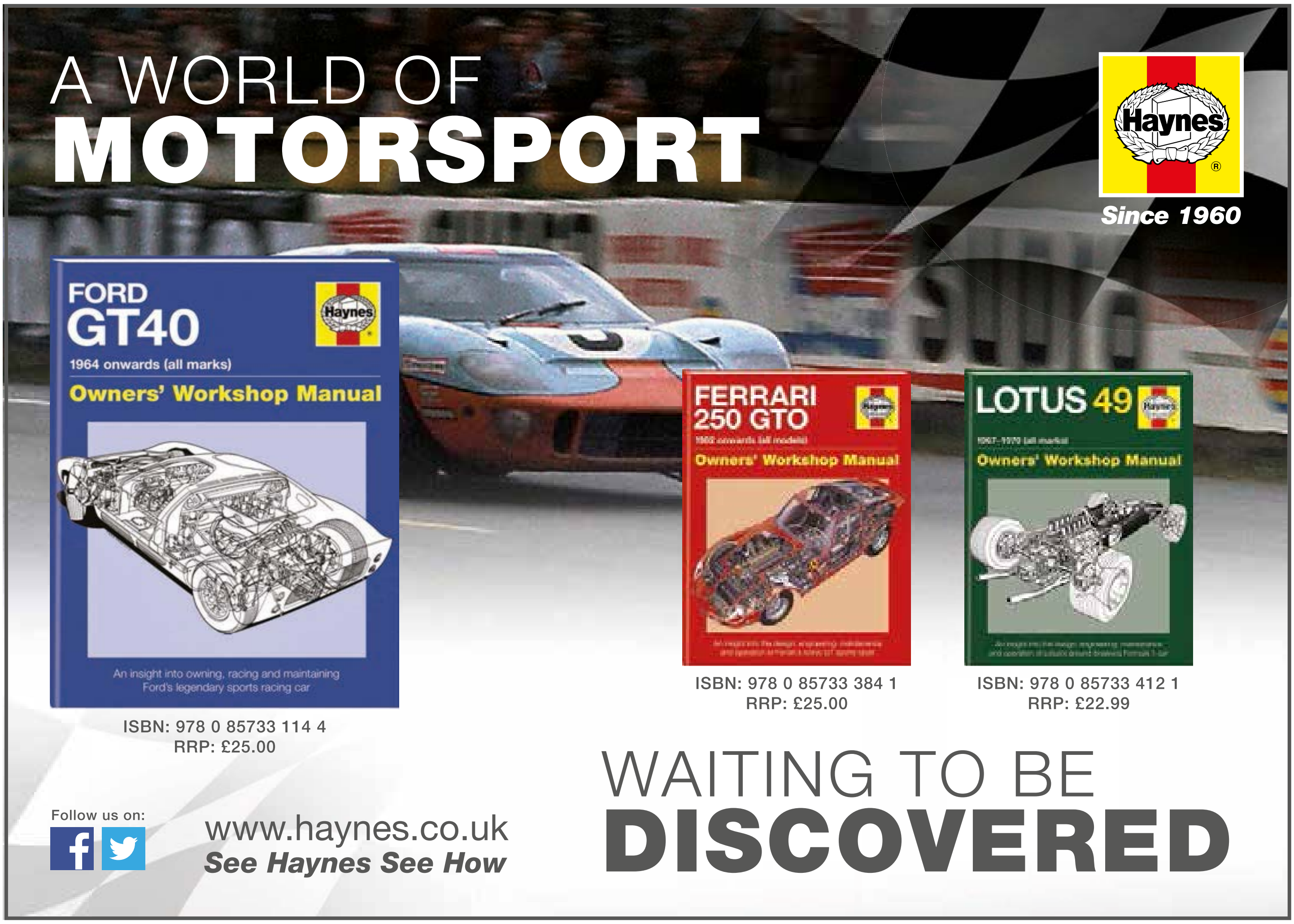
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Front-engined club racers examined

We look at the aerodynamics of popular Clubmans sports cars

Never mind the Nissan GT-R LM, the Clubmans category has provided an arena for front-engine sports racing cars since 1965, albeit with rear-wheel-drive, of course! And if you were to ask anybody to name a Clubmans manufacturer, chances are the first name to come to mind would be Mallock. Starting with the Mk 1 in 1958 under founder the late Major Arthur Mallock, the first car designated for Clubmans in 1965 was the Mk 5. The company, run these days by Arthur's son Richard, has now reached Mk 36. Our trio of Mallocks represent some of the most popular models still running; the Mk 18B first appeared in 1977 (this one being the ex- Barry Foley 'Catchpole' car for those with fond memories of his cartoons); the Mk 28B was a 1990 car, and the second Mk 28 had been clad in bodywork based on the Mk 36, and therefore represented the current era.

Briefly, the 'classic' Mk 18B featured the archetypal full width shovel nose, cycle-type front wheel covers, enveloping rear bodywork and a full width, high-mounted single element rear wing. The Mk 28B followed in much the same vein but the lines appear to flow a little better. It was longer, mainly because it was originally powered by a longer engine, and featured a rear diffuser, absent on the Mk 18B. The Mk 36 was distinctive in having all-enveloping bodywork rather than a separate nose and 'mudguards', and again had a rear diffuser connected to the long, flat underbody and a lower mounted rear wing.

Bringing these cars to the wind tunnel was an opportunity to address some fundamental questions about the configurations in which Mallocks and their like have been run over the years, and to see how they responded to configuration changes. It was also a good chance to see how they compared aerodynamically with other sports racing cars we had previously tested, and of course to see how the aerodynamics of this one marque had evolved over time.

We'll start this month with the classic Mk 18B model and look first at the baseline 'as delivered' data. **Table 1** shows the coefficients at approximately 60mph and 80mph.

Fundamentally, the car generated moderate drag and downforce, although most of the downforce was at the rear with only around 9-10 per cent at the front, so in this guise the car would have significant aerodynamic understeer in anything other than slow corners. With a static weight distribution of perhaps 45 per cent front with driver aboard, a preferred aerodynamic balance would see nearer 40 per cent of the total downforce on the front. Of passing interest was the slight rearwards shift in balance as air speed was increased, this thought to be most likely down to increased flow attachment on forward, upper surfaces (maybe the mudguards?) as speed was ramped up, leading to a relatively bigger positive lift increment at the higher speed. Had the car generated more front downforce then this effect may not have been so apparent.

Nose jobs

For years Mallocks have had what have been referred to as 'Low' and 'High' downforce noses, the former being convex in side profile, like the one on the Mk 18B baseline configuration, and the latter being more concave in shape. What would the data say? **Table 2** shows the coefficients and balance data compared to baseline at 80mph.

The 1977 Mk 18B, the ex-Barry Foley 'Catchpole' car, with full width shovel nose

The 1990-spec Mallock Mk 28B is somewhat longer and features a rear diffuser

Mallock Mk 28 with Mk 36-style bodywork; a modern take on the 50-year-old formula

Table 1 – baseline coefficients and balance on the Mallock Mk 18B

	CD	-CL	-CLfront	-CLrear	%front	-L/D
60mph	0.510	0.652	0.065	0.587	10.0%	1.281
80mph	0.508	0.644	0.059	0.586	9.2%	1.268

If you asked anyone to name a Clubmans manufacturer, chances are they would say Mallock

The Mk 18B sporting its high downforce nose with its sharp concave cross section

The inner and outer nose Gurneys on the Mk 18B, with the inner at 'low' height

Table 2 – 'High' and 'Low' downforce nose comparisons on the Mallock Mk 18B, with the difference (Δ or delta value) in counts (1 count = a coefficient change of 0.001)

	CD	-CL	-CLfront	-CLrear	%front	-L/D
'Low' Df	0.508	0.644	0.059	0.586	9.2%	1.268
'High' Df	0.529	0.793	0.287	0.506	36.2%	1.499
Δ, counts	+21	+149	+228	-80	+27.0%	+231

Table 3 – the changes, in counts, arising from nose Gurneys

	ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear	Δ%front	Δ-L/D
Outer	+2	+36	+48	-14	+6.5%	+65
Inner	+27	+51	+62	-9	+7.4%	+28
Inner, shorter	+15	+39	+45	-5	+5.4%	+39

Table 4 – coefficients and balance data with the high downforce nose compared to the low downforce nose plus outer and tall inner Gurneys

	CD	-CL	-CLfront	-CLrear	%front	-L/D
High Df	0.529	0.793	0.287	0.506	36.2%	1.499
LowDf++	0.537	0.731	0.169	0.563	23.1%	1.361
Δ, counts	+8	-62	-118	+57	-13.1%	-138

Outer nose Gurneys modified the flow over the front of the Mallock's 'mudguards'

Most of the downforce on the Mk 18B was at the rear

The first conclusion, then, is that the 'High' downforce nose really did generate more downforce than the 'Low' downforce nose! Furthermore the car's 'per cent front' value was quite close to being well balanced with this simple change of nose shape, and with the rear wing setting employed at this point. Clearly some downforce was lost at the rear wheels by fitting the high downforce nose. This may simply have been down to the cantilever effect of the nose's overhang taking some load off the rear wheels, but we can't rule out an aerodynamic effect because what would undoubtedly be an increase in 'upwash' from the high downforce nose would have affected how the airflow encountered the rear wing. Drag also increased by around four per cent, but efficiency (-L/D) increased by over 18 per cent.

By way of contrast, a sequence of modifications was made to the low downforce nose so that the incremental changes could be measured. First a set of 38mm (1.5in) high tabs, or Gurneys if you prefer, was attached to the top, outer sections of the nose cone. Next, a set of Gurneys approximately 50mm (2in) tall were attached to the top of the nose just inboard of the higher, outer sections. These 'inner nose Gurneys' were then adjusted to about half height (25mm). **Table 3** shows the incremental changes brought about by each change.

The outer Gurneys were really quite efficient, and the fact that the drag increase was so small could be partly attributed to improvements to the flow over the front of the mudguards, as the image above demonstrate. The taller inner Gurneys were much less efficient, although were evidently quite effective balance adjusters. The shorter inner Gurneys were much more efficient than the taller versions as supplements to the outer Gurneys.

A comparison between the data with the high downforce nose and that with the low downforce nose with additional Gurneys is shown in **Table 4.** Although the nose Gurneys would clearly have their uses, **Table 4** puts into perspective how effective the high downforce nose was in comparison. It produced considerably more front downforce for less drag, as well as a more balanced 'per cent front' figure than did the modifications to the low downforce nose, and gave rise to a much better efficiency (-L/D) figure.

Next month we will explore further configuration changes to the Mk 18B as well as taking a first look at the Mk 28B.

Racecar Engineering's thanks to James Kmieciak, Orex Competition and owner/drivers Chris and Morris Hart and Chris Lake for providing the cars for this

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Back lash

Could the seating positions in some competition cars be responsible for a spate of recent spine injuries?

By PETER WRIGHT

Anthony Davidson prepares to enter an MRI scanner. He is in his race seat, which is fixed into the position it was in when he was injured in a crash at Le Mans in a Toyota LMP1 back in 2012

It is a fact of life in the world of safety, especially as applied to automobiles, both road and track, that as one problem is solved, others appear that may have been hidden by the fatal nature of the original problem. A case in point is air bags and seat belts. Once these became widely used, fatalities in frontal impacts reduced significantly, but lower limb injuries caused by structural intrusion into the footwell, appeared to increase. They were always there in severe and fatal accidents, but were masked by the other devasting injuries. Yet the long-term disabilities caused by lower leg injuries can have a social and health cost that is of the same order as a fatality, and so the next task for the safety engineer is to solve these new, exposed problems.

Spine injuries

In motorsport, Frontal Head Restraints (e.g. HANS), headrests, and racing nets have almost banished serious and fatal injuries due to basilar skull fractures and cervical fractures, in impacts from all angles. Massively strong CFRP monocoques, optimised tubular frames, and roll cage reinforced production car shells have helped to prevent intrusion injuries in all but the most severe impacts. But with survival rates significantly higher than in the past and particularly pre-1994, one injury type that is starting to emerge in a variety of forms is spinal injury. Depending on the nature of the impact causing the injury and the severity and location of the injury itself, this can be anything from back pain to quadriplegia, and can be fatal if the paralysis affects breathing.

Spinal injuries have occured in all types of competition cars: single-seaters, LMP two-seaters, GT, touring cars, rally and off-road cars. In circuit racing they tend to be a consequence of impact into barriers or other cars; in rally and off-road they also include injuries due to heavy landings following a jump. Recently there has been a focus on LMP cars following Kazuki Nakajima's accident at Spa in the Toyota, when he hit the back of an Audi driven by Oliver Jarvis. This follows on from Anthony Davidson's accident at Le Mans in 2012, also in a Toyota, and Guillaume Moreau's LMP2 accident in Le Mans testing the same year.

FIA action

Following Davidson's accident, the FIA Institute entered into collaboration with the Toyota Motor Company, Japan, to research the causes and potential solutions to his injuries, using their FEA model of the human body: THUMS (Total Human Model for Safety). THUMS has been developed over 20 years and is acknowledged as being the industry standard, widely used by automobile manufacturers and academic research laboratories. An initial report on the programme has appeared in the FIA magazine Auto, issue 07 (www.fia.com).

Because this programme is ongoing and is necessarily subject to confidentiality due to the involvement of personal medical data, I am not going to describe this work in detail. Instead I am going to attempt to outline the fundamental problem that leads to these injuries, and identify the implications for racing car design. I am not a doctor and sometimes have problems with fully understanding the excellent team of medics who work with the FIA, due to the fact that they so often speak in Latin! Many years ago, my Latin teacher wrote on a piece of work I handed in: 'Where have you spent your life so far? In an incubator?' I gave up Latin at the first opportunity.

Fortunately however, the problem is primarily an engineering one, or more specifically, biomechanical, and so I will try and make it understandable to non-medical readers of *Racecar Engineering*. The potential solutions involve the laws of physics (forces, accelerations, stresses, moments, and so on), which engineers readily understand.

The spinal column is a stack of segments of bone (vertebrae) interleaved with soft fibro-cartilage (intervertebral discs) and held together with ligaments. It has evolved into the current curved shape since our species rose up onto two legs and stopped hanging about in trees. It is able to sustain limited compressive

Fortunately this problem is primarily an engineering one

loads provided it is in its correct shape. Bend it and try and pick up a heavy weight, and some part, most probably a disc, is likely to fail. Hence the advice: 'Keep a straight back, and bend knees to pick up something heavy.' If the spine does not carry the load centrally, the muscles and ligaments will compensate and they will also become strained, whilst simultaneously increasing the net load on each vertebral body.

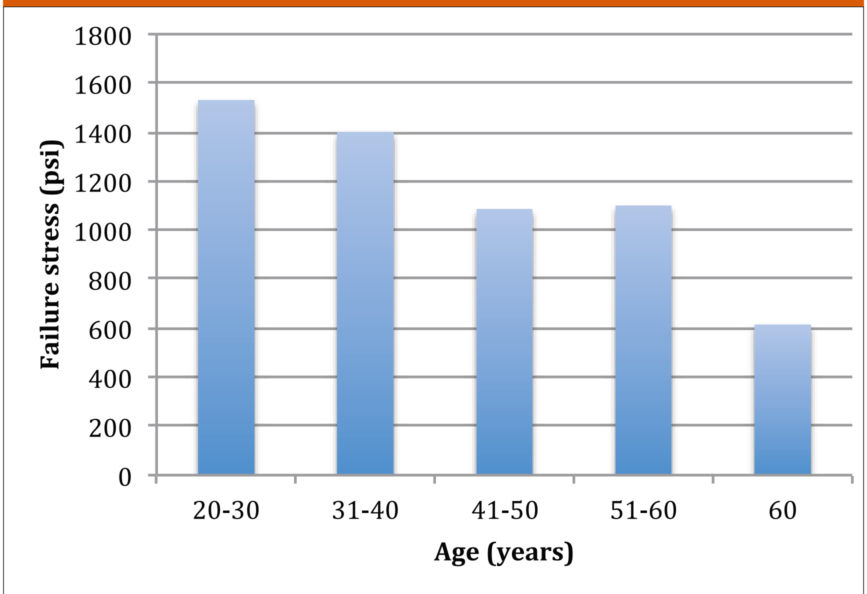
Anthony Davidson's X-ray after his 2012 crash at Le Mans showing how close a fractured vertebra came to his spinal chord. Davidson climbed from his car unaided. When Nakajima had his accident he was instructed to stay put.

Modern racecars are built with safety in mind as much as performance, but is there a hidden danger lurking in the cockpit?

Table: 1. Strength of vertebrae (T8-L5), and g-loads sustainable for a 75kg human

Vertebra	Max failure (N)	Min failure (N)	% body mass	Max g	Min g
T8	6400	5400	33	24.9	20.8
T9	7200	6100	37	25.0	21.0
T10	8000	6600	40	25.7	21.0
T11	8600	7200	44	25.1	20.8
T12	9000	6900	47	24.5	18.6
L1	9000	7200	50	23.0	18.2
L2	9900	8000	53	23.9	19.1
L3	11000	9000	56	25.2	20.4
L4	12000	9000	58	24.3	19.7
L5	12100	10000	60	25.7	21.2

Figure 1: Average failure stress of 223 vertebrae, L1-L5.



The seating positions in most competition cars are quite inappropriate

The problem stems from the engineering of the spinal column. Like a masonry column, made up of blocks or bricks, it will take high compressive load but only low tension loads. Hence if it is bent, part is subjected to tension which it cannot sustain; not only is bending strength compromised, but any compressive loads are concentrated and the local peak stresses may cause the masonry to fail in compression.

In accidents the spinal column may be subjected to loads, in compression or tension, and bending moments, or a combination of the two. Only if it is in the most tolerant posture is it best able to sustain these loads without injury.

Spinal gap

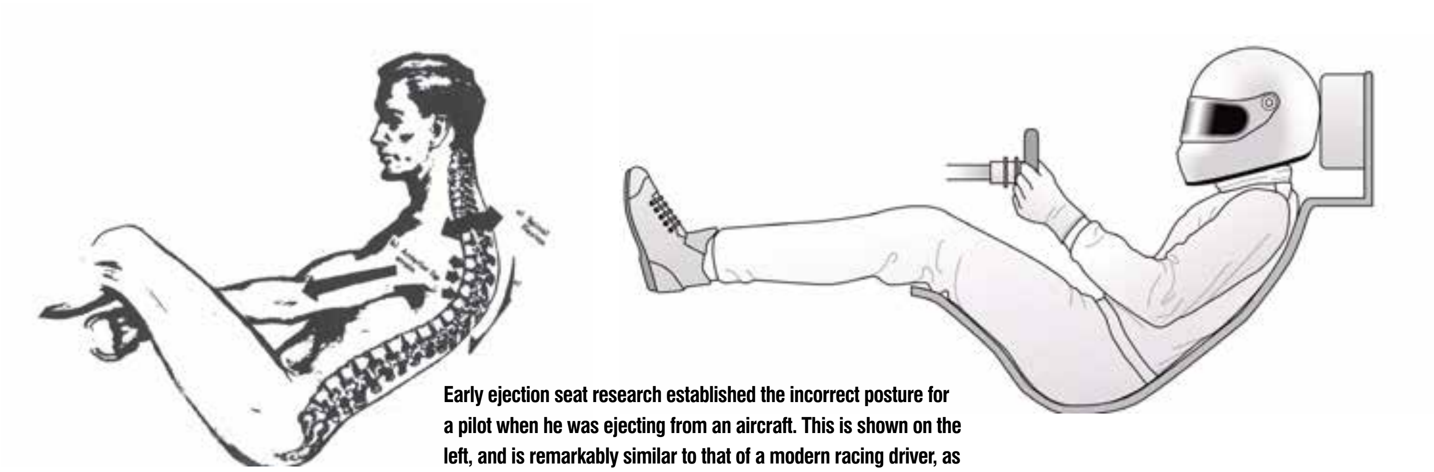
There are three compression load paths in the spine. The load distribution in each will depend on the nature of the loading (pure compression and/or bending) and on the curvature of the spine. The Facet Joints are bony parts of each vertebra that engage through low friction pads with the adjoining vertebra. They are strong in compression, but can sustain no tension loads other than via the connecting tissues and muscles, and a gap will develop between them as the spine is bent forward. At this point, the entire compression load is carried by the middle and anterior columns, and the disc that separates the vertebrae. The more the bending of the spine, then the greater the load on the anterior column.

If the compressive loads, or more specifically, the local compressive stresses exceed the strength of the bone material, failure will occur. This type of bone failure, and disc damage, are not in themselves life-threatening, but through the middle of each vertebra passes the spinal-cord, the bundle of nerves that pass vitally important messages to and from the brain to other parts of the body. If a bone fragment is displaced and impinges and damages the spinal cord, paralysis of muscle functions served below that point is very likely.

The problem that most often occurs in a motorsport accident is when the spine of the seated driver (and/or the co-driver in rallying and off-road events) is subjected to an impact load through the seat pan, in a rearward and/or upward direction, and the strength of one or more vertebrae is exceeded. There is a separate class of impact, notably rear impacts, that can also injure the spine, but they are more complex and so I will deal with them separately.

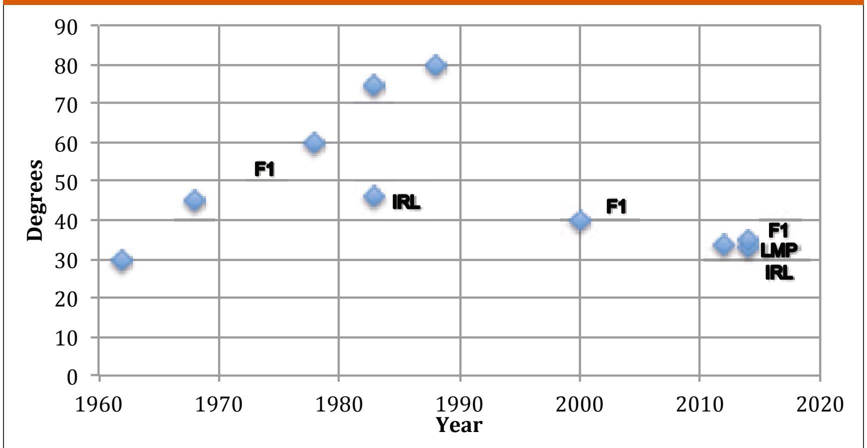
Ejection seat research

There was intensive research into spinal injuries due to seat pan accelerations during the development of the aircraft ejection seat. Study of this work provides a very comprehensive background for what we need to know: the injury mechanisms; critical factors; and how to maximise avoidance of injury. Interestingly, it appears that racing car designers have not



Early ejection seat research established the incorrect posture for a pilot when he was ejecting from an aircraft. This is shown on the left, and is remarkably similar to that of a modern racing driver, as the diagram on the right (courtesy of John Rigby) clearly illustrates

Fig 2: Seat inclination history



studied this work, as the seating positions in most competition cars, especially circuit cars, are quite inappropriate for minimising the potential for injury.

Ejection seat design and development started in the early 1940s, in Germany. By the mid '40s the systems had been developed to such an extent that it was possible to eject the pilot without injuring him. Post-war the UK ejection seat company Martin Baker Ltd initiated a comprehensive programme of engineering development and human response testing.

In the late '40s, the USA also undertook a major R&D effort to determine how to safely eject a pilot clear from a jet aircraft. A definitive paper on the subject was written in 1967 by US Air Force Captain John H Henzel, entitled: *The Human Spinal Column and Upward Ejection Acceleration: An Appraisal of Biodynamic Implications*. In this he states: 'Design and material properties of the normal vertebral column are sufficiently constant that when structural characteristics are defined and acceleration profiles known, prediction of failure may be made.' That very much sounds like an engineering statement to me. The paper identifies three critical issues: 1: The biomechanical characteristics of the vertebrae making up the spinal column. 2: The magnitude and characteristics of the acceleration pulse. 3: The posture of the seat occupant.

The first of these looks at the maximum acceleration the spine will withstand under ideal conditions. The second considers the effect of the rate of onset of that acceleration on the maximum value, while the third investigates how the shape of the spine reduces the peak acceleration that it is able to withstand without injury.

The paper analyses data on vertebral strengths from a number of sources and arrives at probability of failure for a given acceleration load (*g*) along the spinal column. This is based on the maximum and minimum compression failure load of the vertebra tested, and the body mass supported by that vertebra. The figures for T8 to L5 (the 8th Thoracic vertebra to the 5th Lumbar vertabra) are shown in Table 1. This indicates that there is a minimum strength around T12 to L1, which statistically is where the majority of ejection seat injuries occurred. This is also generally true for motorsport spinal injuries in frontal and vertical impacts.

More worrying (particularly for those of us who are over 60 years) is the data that indicates that there is a significant fall off of vertebral strength with age (Figure 1). The most severe reduction occurs over the age of 60.

It was this data that led the developers of early ejection seats to limit the acceleration to 18*g* (thus limiting the compressive load in the critical T12 to L1 vertebrae to under 7000 N). However, early tests still resulted in spinal injuries below 15*g*, as the catapult used generated an extremely rapid initial acceleration rate of over 1000*g*/second. Once it was realised that spinal injuries were not only a function of peak acceleration, but also the rate of onset of acceleration, it was established that 18-20*g* could be tolerated provided the rate of onset of acceleration did not exceed 250-300*g*/second. With cartridges, and later rockets, to accelerate the seats, the acceleration profile could be accurately tuned to minimise the potential for injury.

Straight talking

Earlier ejection seats were fired by the pilot reaching down between his thighs and pulling up a firing handle. However, this put his spine into a forward curved posture, the worst for sustaining vertical compressive loads.

It soon became clear that restraining the pilot into the ideal, straight-backed posture prior to ejection made his spine much more tolerant to acceleration loads. Pulling a face blind down to initiate an ejection sequence not only ensured correct posture, but also protected the pilot from windblast at high speeds. Once fast jet pilots adopted helmets and visors, this latter advantage was no longer relevant, and initiation was returned to a seat pan mounted handle. However, a powered shoulder harness retraction system was fitted, fired early in the injection sequence in order to pull the occupant's shoulders back into the correct posture for ejection. Development of the firing gun and rockets permitted significantly 'softer' acceleration, but sustained sufficient thrust to ensure a high ejection velocity to separate the seat from the aircraft.

One injury type that is starting to emerge in a variety of forms is spinal injury

Boffins have been looking into the science of ejection seats since the Second World War and by studying its development we might be able to limit spinal injuries in motorsport

Armed with this 50+ year old information on the essential parameters for subjecting a seated human to acceleration along the axis of the spine, we can now apply the three basic principles to the driver of a modern racing car. A survey of seat inclination in circuit racing (F1, IRL, and LMP) is shown in Figure 2. This starts with the Lotus T25 in 1962, where Colin Chapman laid Jim Clark down at 30-degree to the horizontal. He was able to do this due to the relatively short, small capacity V8 engine, and by packaging the fuel in pannier tanks. Over the subsequent years, following the much safer Lotus T79 arrangement of a single, central fuel tank between the engine and the driver, and regulation changes to ensure that the driver's feet were behind the front axle centreline, seat angles had to become steeper, culminating in the 75-80-degree angles of the fuel-thirsty turbo cars of the late 1980s.

Refuelling, as used in CART and IRL, F1 from 1982-2009, and LMP permitted a smaller tank. This, combined with a trend away from long V12 and V10 engines towards shorter V8s and V6s has allowed the driver to be reclined back down to around 35-degrees. This is now the norm. The problem is that, if the driver is reclined to 35 degrees whilst retaining the ideal posture as defined by aircraft ejection principles, he will be looking at the sky. Drivers are encouraged to look forward, just over their steering wheel and to do so brings the head and shoulders forward and curves the spine. Raising the legs to allow a high nose also rotates the pelvis, inducing curvature into the lower spine. Foamed-in-place seat construction techniques ensure this posture is locked in. This is the worst possible configuration of the spine to sustain acceleration along its axis.

A female IRL driver was escaping injuries her male colleagues were suffering

The crash pulse causing injury in the majority of cases of frontal/vertical impacts is generated either by a vertical input during a frontal crash (e.g. Nakajima's Toyota running into the back of the Audi) or by a heavy landing (e.g. Davidson at Le Mans, or World Rally Championship and Desert Raid cars). This landing nearly always occurs while the car has forward velocity and so generates a longitudinal deceleration due to friction as the underside of the car hits the road.

Taking hits

Consider a simple acceleration pulse where during 5*g* braking the car hits the kerb with the underfloor plank. It generates 10*g* vertically and 10*g* longitudinally to give a total of 15*g* longitudinal acceleration (this assumes that the braking is unaffected). The resultant acceleration is an 18*g* vector, at 34 degrees to the horizontal – aligned almost exactly with the seat back and the curved axis of the driver's spine. An acceleration rise rate of over 1000*g*/second in this sort of impact with a very stiff plank is not unusual. Pure longitudinal and lateral impacts involve much softer structures – e.g. barriers, and front, rear and side impact structures – and so acceleration rise rates are much lower.

Because of the acceleration rise rate of vertical impacts, and the curved spine, one would expect injuries to one or more vertebrae, in spite of the peak *g* being within ejection seat determined limits. This impact scenario is not that excessive in racing. If the car takes off and lands heavily, as often happens when one car runs into the open rear wheel of another, or the car takes off aerodynamically as happened in Davidson's case, or in rallying and off-road racing where the road profile causes the car to take off, the vertical acceleration pulse can be much greater.

Rally and off-road cars tend to benefit from a fairly upright seating position, but the co-driver is often crouched forward over his notes, with his spine bent. It is significant that it is more often the co-driver who suffers in this sort of impact.

The above shows just how likely a driver in a modern racing car with a reclined seat is to suffer a spinal injury if there is a vertical component to the impact pulse. The issue is compounded if the longitudinal component is of sufficient magnitude and duration to cause the driver's shoulders to move forward against the restraint harness while his pelvis is restrained by the crotch straps and the seat pan kick-up. Seat pan kick-ups have become quite pronounced since the pedals were raised to allow high noses. If there is a concurrent vertical impact a short time after the longitudinal component starts, his spine will have become even more bent, with most of the curvature likely to occur around the transition from the thoracic spine to the lumbar spine, below the ribcage: i.e. T12 to L1.

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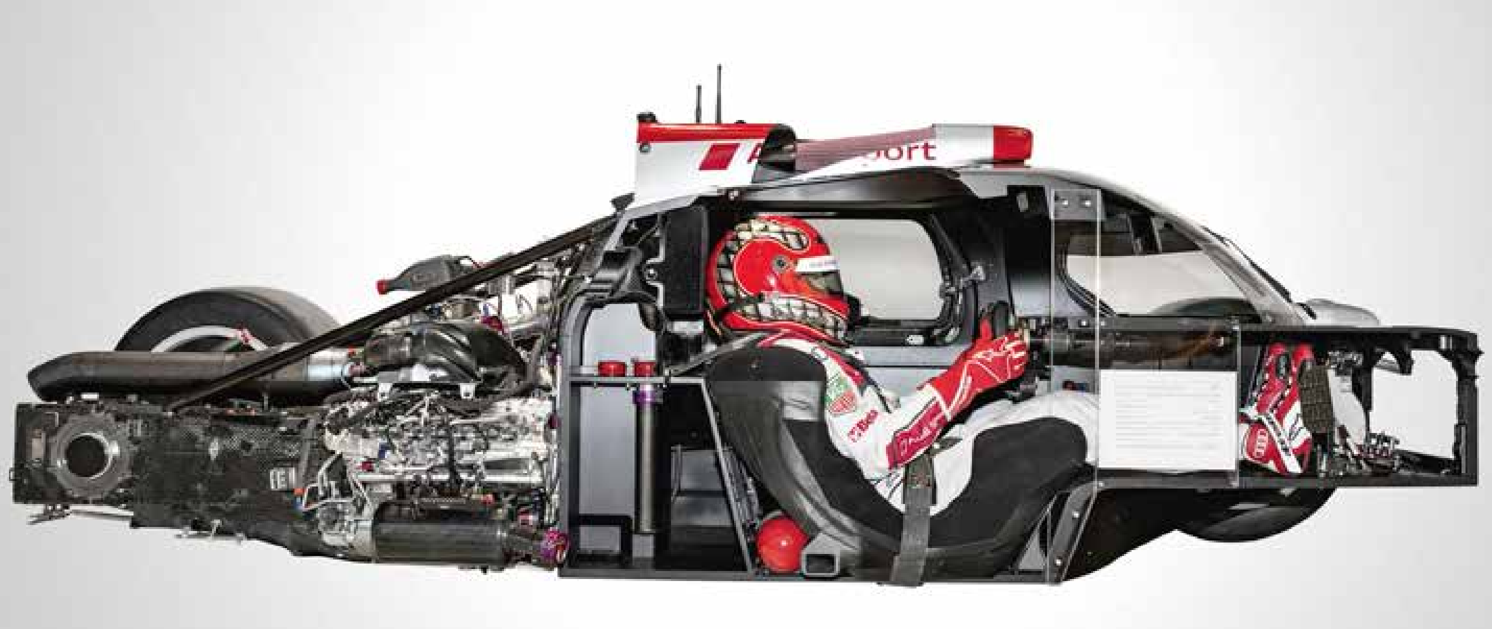


Seat pan kick ups are a notable feature of modern raised-nose racecars, but they can bring a vertical pulse to the crash force, which could have serious consequences for the driver's spine

Rear impacts are somewhat more complex and do not require a vertical component to cause spinal injury. A longitudinal rearward acceleration – fairly common in wall impacts on the high-speed ovals – causes the whole body of the driver plus the mass of his legs to move rearwards. Because of the reclined seat, the torso will ramp up the seat, restrained only by the shoulder belts. This will load the curved spine causing lower back injuries. If the helmet is embedded in the headrest and thus locked to it, cervical spine (neck) injuries may also occur. Dr Terry Trammell has carried out valuable research into the effects of this type of accident for the IRL (*Spine Fractures In Drivers Of Open-Wheeled Open Cockpit Race Cars, Aspetar Sports Medical Journal –Terry Trammell and Kathy Flint*), and as a result a series of measures have been implemented in IndyCar, bringing about a significant reduction in injuries.

Pelvic thrust

One of the most fascinating and key findings was that a female IndyCar driver was escaping injury in rear impacts her male colleagues were suffering. Dr Trammell realised that: 'This can be accomplished by creating a pelvic 'bucket' that fits to the pelvis and adding a prominence that promotes normal lumbar lordosis. These factors combine to reduce the compressive loads on the thoracic and thoracolumbar vertebra and the fracture risk is mitigated. The pelvic bucket is most easily accomplished in a driver with a broader pelvis and gluteal contour (norm in female drivers). The seat material cladding should deform and allow the pelvis to 'sink in' to the seatback, like a baseball into a catcher's mitt, but not 'bottom out' (as happens when you catch a baseball and it stings your hand through the glove).'

For the last 50 years or so crash testing has used Anthropomorphic Test Devices (ATD), more commonly known as dummies, e.g. Hybrid III and THOR, and HyGe sleds to simulate the dynamics of humans and to measure critical biomechanical loads during impacts. Used by the automobile industry originally for restraint system and airbag development, some parts of the dummies do not simulate the represented parts of the human anatomy adequately for reclined seating positions and six point restraints. This has compromised research into spinal injuries, although Hybrid III has performed a sterling job in the development of head and neck restraint systems e.g. HANS, rally car seats, and racing nets. However, fortunately Toyota has invested over the past 20 years in the development of THUMS.

The developers of early ejection seats limited acceleration to 18*g*

Rule of THUMS

THUMS is a 20-million element FEA model of the human body complete with skeleton and all internal organs and systems, whose biomechanical characteristics and injury criteria are known. Seat, restraint systems and protective equipment can be structurally included in the model and the whole subjected to a specified crash pulse.

Outputs include dynamic motion, loads and stresses, pressures etc., to enable the causation of injuries, and systems to mitigate them to be studied. Requiring significant computing power (10,000 CPUs, and 24 hours to complete just 150ms of a crash), THUMS is now the industry standard for mathematical models of humans in automotive crashes. The FIA Institute is working with Toyota to apply THUMS to racing car crashes and spinal injuries in particular.

It is too early to predict the outcome of this collaborative research and development, or to predict regulations to alleviate the problem. However, areas that will be looked at closely include: determination of injury mechanisms; seat back inclination; restraint system characteristics and geometry; seat geometry; impact attenuating foam seat inserts; compliant/energy absorbing seat mountings; impact attenuating systems in the floor of the car; and harness pre-tensioning.

It is already clear from the above analysis that one of the most significant parameters to affect the likelihood of spinal injury, whether in a longitudinal/vertical or a rear impact, is the inclination of the seat back. Varying over the years from 30 degrees to 80 degrees, the pressure to lie the driver down comes from the aerodynamicist, although there is some influence from CG height.

Regulating this critical parameter, whether for single seaters or two seaters would be equal for all. However, such a drastic step would have a large effect on the configuration and look of racing cars, and so a sound scientific basis must be established before doing so.

If it just so happened that fans could see more of the driver and what he was doing while driving the car, so much the better!

Acknowlegements: This article was inspired by work carried out by Dr Michael Henderson and Dr Terry Trammel.

Industrial strife

Racecar's regular boffin throws out the usual formulas and equations to tell us why he thinks the motorsport industry is in serious jeopardy

By DANNY NOWLAN

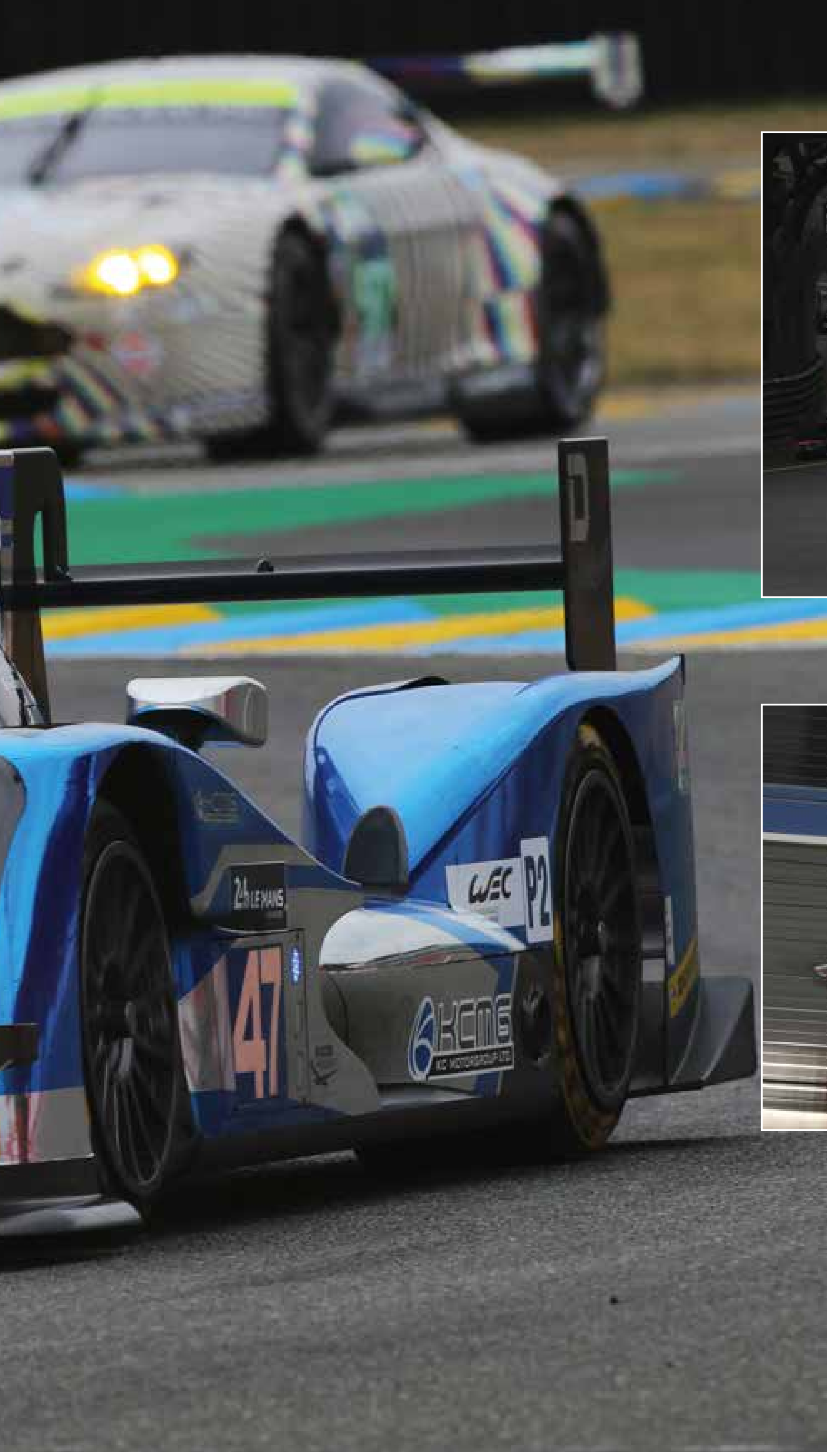
Could the ACO's plan to limit LMP2 to just four manufacturers from 2017 be the last nail in the coffin for some racecar constructors?

It is very rare for me to write about industry-based matters as opposed to vehicle dynamics. The primary reason for this is that I am still utterly appalled at the misconceptions about vehicle dynamics I actually see out there. Consequently this is where my attention tends to be focussed. But sometimes there are other issues to dwell on, such as what I see as the erosion of the motorsport industrial base, which is putting the whole industry at risk. Something needs to be said. This is also a very rare article for me in that it won't feature a single formula …

The motivation for this piece came from a recent discussion I had with my UK dealer, Mike Pilbeam of Pilbeam Racing Designs. He was telling me about the ACO's plans for LMP2, which will limit the number of LMP2 constructors to four. My immediate reaction was something that can't be put into print. Suffice to say a torrent of sharp, colourful language ensued. Given that sportscar prototypes remain the last bastion of innovation and freedom in our sport this could very well be the last nail in the coffin for budding racecar manufacturers seeking to progress up the ladder.

I now believe the erosion of motorsport's industrial base, aided and abetted by the cancer of the single spec formula, has put the whole industry in serious trouble. I intend to give you a brief outline here of how we got ourselves into this mess, and some suggestions about how we get out of it. For make no mistake, if we don't act now motorsport will degenerate into club racing, rich guy racing, and a handful of elite formulae that will be on shaky ground.

First things first, the millisecond you make a category spec it limits the number of players in the market. Bottom line, if you don't get the



PHOTOGRAPHY BY XPB

With GP2 teams spending somewhere between £2m and £4m for a season of racing it's nonsense to maintain that spec racing is cheaper than open competition says our man Nowlan

Spec or one-make motor racing is not just a European phenomenon. It has been a part of IndyCar, the highest level of single seater racing in the United States, for some years

As costs where climbing in the mid 1990s the motorsport regulatory bodies panicked

contract you are in serious trouble. Look at the decline in the number of racecar manufacturers. If we wind the clock back 20 years there was Reynard, Lola, March, Ralt and a host of other manufacturers. Now you can list racecar manufacturers on your fingertips.

Closed shop

But the most insidious thing of all is it turns motorsport into a closed shop. With the spec formula it becomes virtually impossible for a budding racecar manufacturers to evolve. Let me quote one of Mike Pilbeam's clients, Greg Mills, who has been striving to establish a South African team to take to Le Mans: 'As you are aware, it has been my long-term ambition to take an African team to Le Mans, as a practical sign, fundamentally, of what is possible from our continent. I have learnt many lessons over the last 36 months, not least of the widening gap between the top end of motorsport and the rump of competitors who passionately feed this system with talent, following and money. The ladder, which once enabled those at the bottom to reach the top, is at least badly damaged, if not broken, including for requirements of extreme finance, technology, and regulation. Little wonder the stands at most of our race-tracks are empty.'

The other consequence of this is the quality of the products that are now on offer. Data logging is a very good case in point. When I started in this business you had your choice of good quality loggers you could fit to your racecar. It also forced all the companies like Motec, Pi Research (sorry I really should call them Cosworth electronics but old habits die hard) and Marelli to be on their game. In the spec formula world you are stuck with what you

Nowlan maintains that the skill base of engineers (not this chap, obviously) has been downgraded over the years thanks to spec racing and they often no longer have the ability to figure things out

Ralt is just one of the great racing car manufacturers that is no longer with us thanks largely to the arrival of more spec formulae. Pictured is Ayrton Senna at the wheel of a West Surrey Racing RT3 in 1983

have. If you don't believe me go to a F3 round, find the data engineers and buy them a few drinks and start to ask them what the genuinely think of the electronics and software they have to deal with.

Yet the single spec formula mentality and the tight controlling of technical regulations has had two unintended consequences. The first consequence is that rather than controlling costs it's actually made things more expensive. I remember spending some time with Dave Williams on the MultiMatic rig in Thetford in the UK in mid 2008. For the uninitiated Dave was the father of Lotus's F1 active suspension. He is also one of the sharpest minds you'll deal with in this business. He made the point that when you tighten the regulations you will always spend more money. Bottom line you need to spend a lot more money and more engineering effort to figure out how to make a front wing flex by, say, 4mm instead of 2mm, and then pass a ridiculous load test that will gain you half a tenth. Compare this to, say, spending a week or two brainstorming a hydraulic actuated third spring that is worth 0.5s per lap. Don't believe me? Cost it out.

Also consider these case studies. In IndyCar in the golden era of CART and ChampCar, Penske and Chip Ganassi Racing ruled the roost. That being said they had a lot of other good operations that could keep them awfully honest. Fast-forward the tape to now and Penske and Chip Ganassi Racing still dominate the single spec incarnation of IndyCar. Also GP2 is another case in point. In 1995, the last season of the technical free era of F3000, your operating budget per car was about £600,000. Now the operating budget of a typical GP2 team is in the order £2m to £4m. So the assertion that single spec or tight technical regulations save costs is simply untenable.

However, the second and more frightening consequence has been the degrading of the skill base of engineers and their ability to figure stuff out. While not trying to over-romanticise the motorsport landscape 30 years ago, you basically got a box of bits and it was up to you to figure out how to run it. Sure, you had unlimited testing, but a lot of hard thinking was required. Now you get a spec racecar, a set-up sheet and all you have to do is spanner check it to get it running. Also, because of limits on testing you don't have any wiggle room to screw up. The consequence of this is you no longer have any room to experiment or think creatively.

Skills gap

Let me give you an example of this that is very close to home. The most skilled ChassisSim users (with a few exceptions) are those who learnt their trade in the pre spec open formula era. When something goes wrong they will usually double check their work and then I'll get an email saying what I did wrong. They will also assess something on its technical merit as opposed to reputation and bells and whistles. One of the most frightening things I am seeing with younger engineers is the inability to follow basic instructions, and then when things go wrong they will throw their toys out of the pram. Sure, a lot of this is cultural but given they can't test and everything is handed to them on a platter in the current spec formula this is exacerbating an already very bad situation.

The reason we got into this mess is that as costs where climbing in the mid 1990s the motorsport regulatory bodies panicked. A lot of this was fuelled by the resident techno hysteria that exists in motorsport. It's always been there just burbling underneath the surface. Don't believe me? Rock up at a motorsport event and mention traction control to a scrutineer and see what happens. Also, for grins, rock up at a typical junior formula round with a laptop display with a fancy 3D display with source code visible underneath and then try to explain to the punters in technical detail why this is a good idea. With this sort of a backdrop you are not going to be making informed decisions.

Yet the most ridiculous thing about all this is that this situation is actually quite fixable.

Need for speed

The first thing to fix this mess is that we in motorsport need to embrace what we are good at – and that is going fast. One of the things that infuriates me about this business is when I hear people talk about improving the show. When I hear this I know things are lost. Make no mistake folks, the show is a consequence, not your primary goal. Let me illustrate with some examples. Thousands don't turn up to the Isle of Man in summer to see a bunch of mopeds going through Ballegary at 80km/h. Nor do they turn up to Bathurst every October to see a bunch of sedans cruising the mountain at 60km/h. If you

The spec formula mentality has actually made things more expensive

Should senior racing formulae assist the junior formulae when it comes to clinching crucial TV rights? Our man argues that this could help the smaller teams to find sponsorship which in turn could will help secure the industry at its grass roots

let the engineers and drivers go fast the results and the show will take care of themselves.

Also, the other thing that motorsport is brilliant at is that we are the ultimate Research and Development environment for the automotive industry. Disc brakes, the use of aero aids and many other features pioneered in racing have found their way on to road cars. The reason for this is we need to push our equipment to the edge and it's amazing what you learn in the process. This gives road car manufacturers a vested interest for being involved in motorsport and not just when it suits them. We are losing this at our peril.

Informed thinking

Let me also just state there is a place for technical oversight, but it must be informed. A direct example of this is the ACO banning composite material for suspension elements. Since carbon fibre doesn't deform elastically if you get a hit, the last thing you need is a fatigue based catastrophic failure heading down the Mulsanne Straight. It was actually a very good and informed call by the ACO, and we need more of this. In that regard I'm very excited to see what is happening behind the scenes in NASCAR and it is also why people such as Will Phillips and Scott Raymond are vital assets for IndyCar and IMSA respectively.

The direct action that can be taken right now to start to fix this mess is to start doing away with spec equipment and move it to a price base. For example, rather than having to buy this car and these ancillaries, cap the price of said components. For example, I'll talk rough numbers, but a cap on the tub cost at $70,000, a data logger say at $10,000, A set of dampers at $5000, an engine at $50,000 and so on. Then have specific and clear guidelines about what you can do with the bodywork and powertrain. This is going to have two immediate impacts. Firstly it lets multiple manufacturers in to the game, and it will make the drivers and engineers think about what they are doing. The other thing is to reintroduce testing on a limited basis. It may not fix the problems but it gets the ball rolling.

On top of this the senior formula have to assist the junior formula with regards to television rights. TV is the lifeblood of any sport and motorsport in particular. If you start giving the junior formula such as F4 and F3 serious air-time then the race teams have a firm business case to seek sponsorship. It means they can select drivers on talent as opposed to how rich dads are. This is vital for rebooting the industry.

In closing, the erosion of the industrial base of motorsport is one of the most serious threats to this business, but it can be fixed. Along our current trajectory we are staring at a closed shop, a disastrous slide in quality that ultimately dooms motorsport to irrelevancy and a race to the bottom. The great news is that this can be fixed by embracing what we are good at, and that is going fast, and with that we can take concrete action to get the ball rolling. The bottom line is, if we want this industry to have a future we don't have a choice. Action needs to be taken. Now!

When you tighten the regulations you will always spend more money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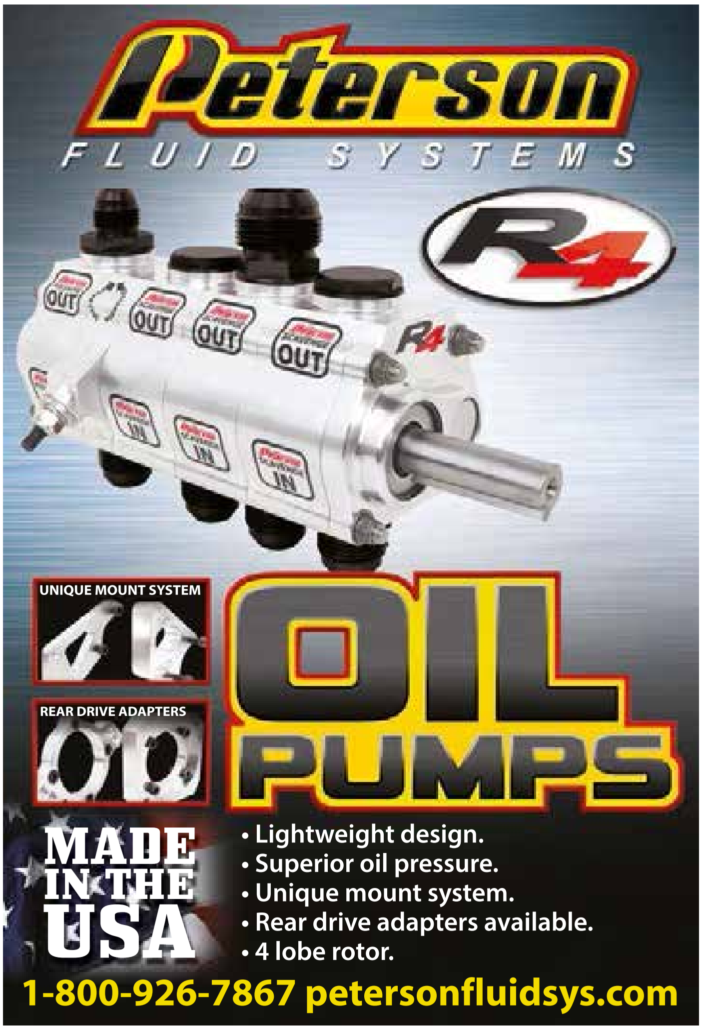
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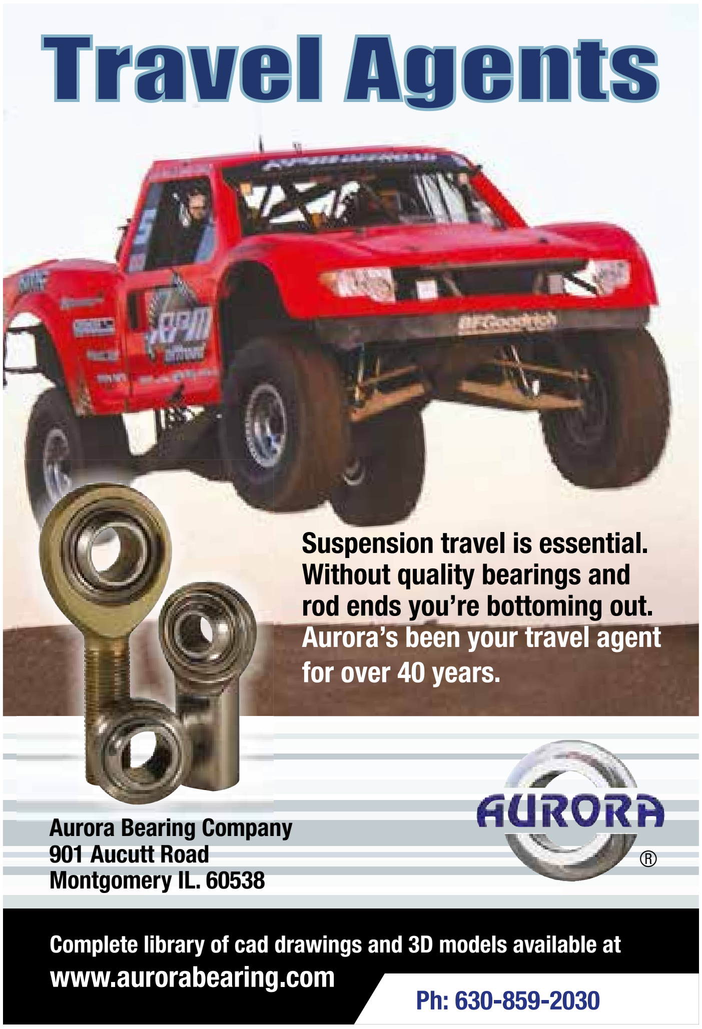
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Belt up and sit tight

A new wonder material that's previously been used in bullet proof vests is now being put to work in Formula 1 seat belts

By PHILLIP WELTRAUM

There is no such thing as a minimum weight limit in the production car business but, on the grounds of cost saving, motor racing has just such limits to avoid teams developing new and costly materials. Yet, while this regulation may have been made with the very best of intentions, teams still spend millions of pounds, Euros and dollars shaving grams from components in a bid to be able to place the ballast inside the car at the most opportune of places.

Seat belts can hardly be considered to be the heaviest of components, yet manufacturer OMP has switched to using the material Dyneema for its new range of harnesses. The material is used by the New York police in its bullet-proof vests – 13,000 of them will eventually be issued – while Shell uses it in the cables for mooring and towing its oil drilling platforms.

The material is light weight, extremely resistant and flexible and perfect for motor racing although, as a new material, it needed extra testing by the FIA, including exposure to UV light, humidity and resistance testing before it could be homologated for racing.

The webbing of the Formula 1 belt has a special weave that provides the correct elongation properties for the belt. Belts are designed to hold the driver in place in the event of an accident, but also to extend to reduce the possibility of an injury due to a sudden stop. During the FIA impact tests with a deceleration of 30*g*, a polyester webbing allowed the dummy to move 250mm. With a Dyneema belt the dummy moved just 130mm. It is already lighter than its predecessor, a 10 per cent reduction in weight, but the ultimate strength of the belt has increased to 3000kg for the 2in webbing, an eight per cent increase.

Belts are tailor-made to each individual driver to ensure that there is no extra material in the car than is necessary.

'We designed dedicated metallic parts to use with Dyneema webbing, made with the best materials available (titanium alloy grade5, magnesium alloy, aluminium alloy 7075) and using innovative production process such as forging, machining, additive manufacturing,' says Matteo Repetto, technical manager at OMP.

The white stuff

'The softness and resistance of Dyneema allows us to redesign some parts of the belts like the crotch strap,' Repetto adds. 'And we also introduced a new patented design for lap straps that makes belts lighter and comfortable. Completing the design process with rapid prototyping allowed us to respect the very short delivery time-line the F1 market has.'

Dyneema yarn is a high molecular weight polyethylene and this is why it's so light. Its strength is due to the production process that is owned by it's maker, DSM.

OMP supplies some of the leading Formula 1 teams, and its belts are easily identified because they're white, as Dyneema cannot be dyed. The company is now looking to introduce the fabric into other series, including TCR, which follows much of the F1 schedule.

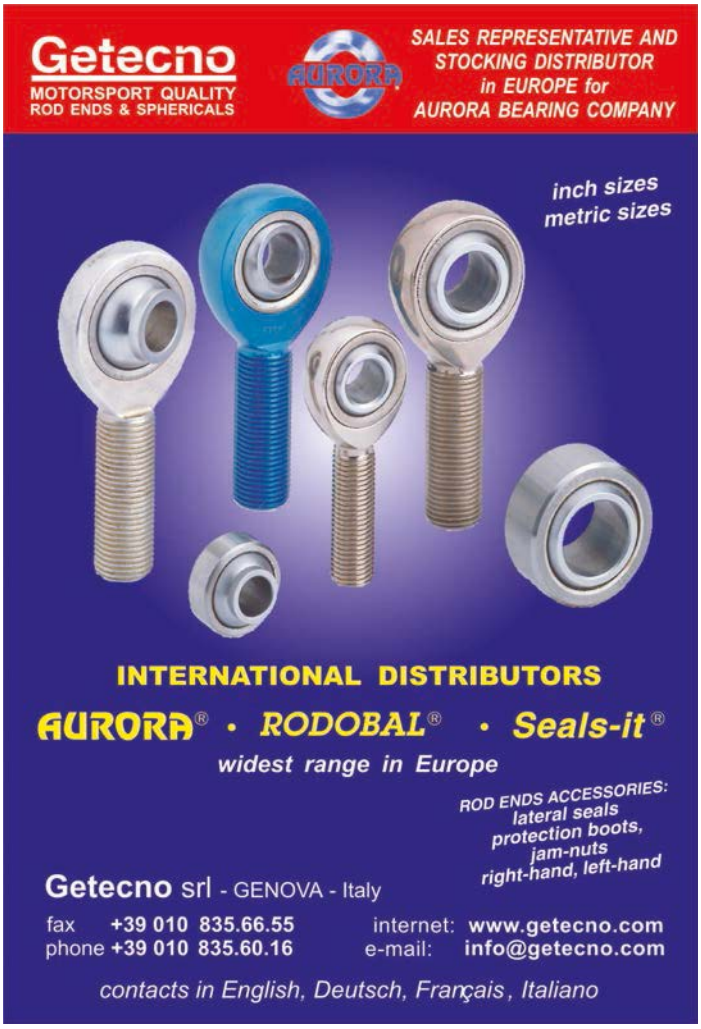
Comparison between Dyneema and other HP fibres

	Dyneema	Aramid	Carbon	PET HT
Density (g/cm3)	0,97	1,44	1,8	1,38
Tenacity(g/den)	max 45	20–28	17–22	8-9
Modulus (g/den	<1200	500	> 1000	50–100
Stretch (%)	2,5	3-4	1,3	15

OMP has started to use the light weight product Dyneema in its race harnesses. The wonder material cannot be dyed, so it's easily identifiable by its raw white appearance. Because of the properties of Dyneema, OMP has been able to redesign its belts and it says they are now more comfortable for the drivers

F1 belts are designed to hold a driver in place in the event of an accident, but also to give a little to reduce the possibility of an injury due to a sudden stop

Belts are tailor made for each driver, ensuring no excess material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New GTE for 2016

In a bid to distance GTE from the blossoming GT3, the ACO has announced new regulations that call for lighter, more powerful cars

By SAM COLLINS

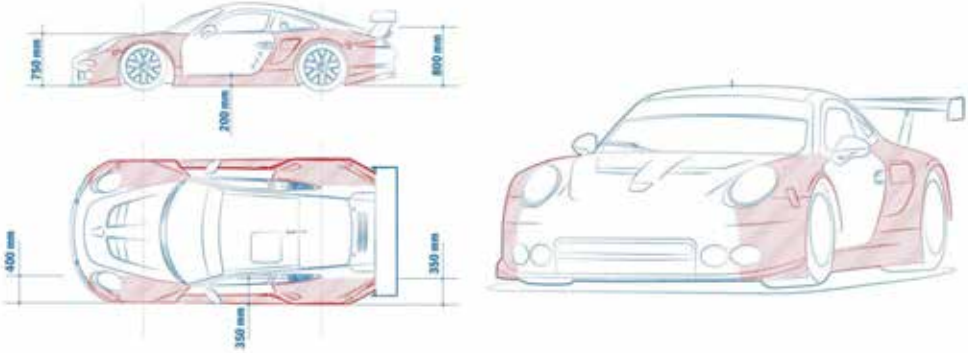
Ford's new GT is the first car built to the new GTE regulations, which is to be introduced into Pro competition in the Le Mans 24 Hours, WEC, Asian LMS and the European LMS from the start of next season

The top class of GT racing at Le Mans, LM GTE, is set for a substantial performance boost to differentiate it from the popular GT3 class, resulting in lighter cars with more powerful engines. During the official ACO press conference ahead of the Le Mans 24 Hours details of the uprated category were revealed by Pierre Fillon, president of the ACO.

'Two years ago the ACO and the FIA started work on convergence of LM GTE and GT3 cars,' Fillon said. 'We understood that the LM GTE manufacturers were not ready to take this step, even though a good number of innovations discussed in these working groups have helped us to optimise our regulations.

'LM GTE must more than ever be the premium category of GT racing. These are real high performance racecars which allow top professionals and the best gentlemen drivers to show what they can do behind the wheel. LM GTE is and will be the most prestigious setting for the most beautiful GTs.'

The new rules see the performance box concept from GT3 adopted, governing maximum and minimum weights and maximum and minimum engine performance both on a sliding scale. Currently all GTE cars have a flat minimum weight of 1245kg (though this is adjusted in the BoP process), but under the new rules a car's minimum weight will be linked directly to the engine power, starting at 1225kg for a car with around 357kW and rising to 1245kg for a car with 366kW. The approximate maximum output in GTE at the moment is about 355kW.



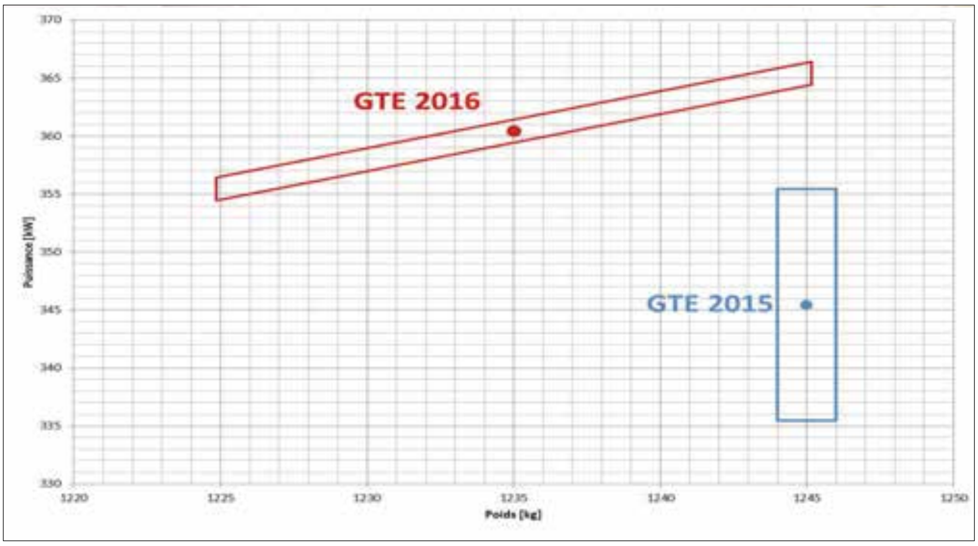
Manufacturers involved in GTE are to be given more freedom when it comes to aerodynamic modifications, with much more scope for work across the car (some of the areas shown in red). But there will also have to be an escape hatch in the roof

This all represents one of the key factors of the new rules, cars that are around 10kg lighter and around 15kW more powerful. Engine performance, though, will still be governed using air restrictors, as it was felt that using torque sensors on the driveshafts would prove too difficult. The ACO feels that this approach allows a simpler and less expensive implementation of technical regulations, which the class will still retain.

These technical regulations will also allow additional aerodynamic freedoms for the cars' bodywork in free development boxes, including the front and rear fenders, bonnet, splitter, and rear bodywork behind the rear wheels and rear diffuser. This will move the cars closer in aerodynamic concept, and indeed overall concept, to JAF GT300 cars such as the Subaru BRZ, and potentially even allow such cars to race at Le Mans.

Overall the new rules will see the number of waivers used by cars racing in the class reduced drastically, currently some cars like the SRT Viper require a waiver to run a smaller capacity engine than is used in the production car as

This will move the cars closer in aerodynamic concept, and indeed overall concept, to JAF GT300 cars such as the Subaru BRZ



A schematic to show the GTE performances boxes for 2015 and 2016. The GT3 cars will race in the GTD category in the US and there has to be a clear performance difference between the two in favour of GTE. These performance boxes are key

GTE currently has a 4-litre maximum (the Viper's 'smaller' engine is still eight litres, however).

In an attempt to cut costs cars built to the new rules will be homologated for three years, in theory the design would be frozen for the whole period though in practice it seems that this may not be rigidly stuck to.

With more open rules and fewer waivers the ACO has claimed that it will enforce the remaining technical regulations much more harshly than it has done in the past. It hopes that these changes will make the class far more attractive to manufacturers, and potentially allows the adaptation of GT3 chassis.

There will also be a number of safety upgrades on the cars, including the addition of roof hatches to help driver extraction in the event of accidents, and rear impact structures may also be mandated.

The final technical regulations have yet to be published and there are a number of unanswered questions, including the provision for hybrid powertrains to be used. It's known that some manufacturers want to race hybrid cars such as the new Honda NSX in GTE, but so far they have been prevented from doing so.

Ford is the first manufacturer to openly commit to competing in the upgraded class with its new GT, while Corvette, Ferrari and Porsche are known to be developing cars with all likely to at least test before the end of 2015.

Phased introduction

These technical regulations for Grand Touring cars will be applicable for the Le Mans 24 Hours, the FIA World Endurance Championship and all the Le Mans Series (Asian Le Mans Series, European Le Mans Series and the Tudor United SportsCar Championship) and will come into force on 1st January 2016 (though they have yet to be passed by the FIA World Council).

The distinction between LM GTE Pro and LM GTE Am will be retained. In the 2016 season the new upgraded GTE cars will only contest the Pro class in the WEC, alongside existing GTE cars, while the Am class will only be open to existing GTE models.

In 2017 the Pro class will be exclusively contested by the new cars, which will also begin to be phased into Am class. Additionally, the new designs will begin to appear in both classes in the Asian Le Mans Series and the European Le Mans Series. By 2018 all GTE cars will be built to the new rules.

Wings and things

During the official pre-race test day both the Audi R18s and Porsche 919s ran with interesting two-part rear wing end plates, which feature shaped and angled leading edges. Additionally the Porsche design also features a three dimensional outer section. When first spotted there were mutterings that the designs were 'clearly illegal' and 'I don't see any way that they can comply with the rules'.

There was controversy over the trick end plates run by Porsche and Audi at Le Mans

Looking at the end plates in question and comparing them to article 3.6.2 of the 2015 LMP1 technical regulations it does actually seem that, indeed, both the Audi and Porsche designs are illegal. 3.6.2 states that the end plates must have a minimum constant thickness of 10mm, must have edges rounded with a minimum constant radius of 5mm, the surfaces shall be flat and parallel to the vertical plane passing through the longitudinal centre-line of the car, and that apart from the fixations to the bodywork permitted above, no bodywork elements must be attached on to the end plates. Two part end plates are specifically allowed.

It is clear that some parts of both the Porsche and Audi designs are not flat and parallel to the centre-line of the car (vertical plane). So how is this legal? Well, according to Chris Reinke, head of the LMP programme at Audi Sport, the leading edges are in fact not end plates at all. 'If you look closely you will see that those parts are not attached, they are bodywork and so not part of the end plate at all,' he said.

Questioned legality

But even this is hard to fathom, as the rules (3.4.1) clearly state that 'All bodywork behind the rear axle centreline and more than 200mm above the reference plane must form a smooth, continuous, unbroken surface without cuts, and be visible from above the car with the rear wing removed.' Both Porsche and Audi insist that if you look really closely it is possible to see that the design complies with this rule, too. The designs do indeed seem to comply with the letter of the rules, although certainly not the spirit of them.

That said, a close inspection of the Audi end plate from above shows that actually the end plate has an overlapped section with the 'bodywork' forward part. With the 'bodywork' removed the exposed leading edge of the end plate would not be 'flat and parallel' as it would clearly be stepped.

An Audi Sport source admitted to *Racecar Engineering* that the solution was not legal in detail but overall it is acceptable. 'Because of the way we made it you can say that it is not legal, we could remake it to be legal and it would not change the external shape of it or the aero effect at all, so we said to the ACO that it is not logical to change it just for this as it makes no difference, now it is homologated and everyone accepts it,' the source said.

Rear wing and rear bodywork design is a particularly touchy subject for LMP1 manufacturers after Porsche was found to have moveable bodywork at last year's test, and Toyota's rotating wing was exposed during the race but then deemed legal (though it was later banned).

Nissan and Toyota are not using the design on their wings, and a paddock rumour claims that the reason that both Porsche and Audi have the concept is that staff have gone from one firm and moved to the other, taking information with them. But it is not clear which brand thought of it first.

Ford confirms 2016 Le Mans, WEC and TUSCC assault for its new GT

Ford is to return to Le Mans with its new GT in an attempt to heighten the profile of its new Ford Performance group

Ford has announced that it's to enter its new GT in the Le Mans 24 hours in 2016, as well as the WEC and United SportsCars, in what it says is an attempt to further boost sales in its burgeoning new performance cars division.

The Multimatic-built Ford GT racecar will compete in the GTE class at Le Mans in 2016, when both the production car and racecar come on-stream – a neat bit of marketing synergy for the Blue Oval as next year marks the 50th anniversary of Ford's GT40 placing 1-2-3 at the 1966 24 Hours. Ford went on to repeat its victory at Le Mans in 1967, 1968 and 1969.

Ford's GT will also run the full 2016 schedules of the World Endurance Championship and Tudor United SportsCar Championship, making its competition debut in January 2016 at the Daytona 24 hours.

The Ford teams in each championship will be operated by Chip Ganassi Racing with Felix Sabates (CGRFS), and the WEC and TUSCC GT teams both intend to compete with a two-car effort at Le Mans, meaning four Fords in total.

The motor giant tells us the Ford GT will serve as the 'pinnacle product' of the new Ford Performance group. Ford is set to deliver more than 12 new performance vehicles by 2020, and the performance segment is a growing business, it says. The Ford Performance line-up includes Ford GT, Focus RS, F-150 Raptor, Shelby GT350 and Shelby GT350R, Focus ST and Fiesta ST.

Bill Ford, executive chairman of the Ford Motor Company, said of the company's return to Le Mans: 'When the GT40 competed at Le Mans in the 1960s, Henry Ford II sought to prove Ford could beat endurance racing's most legendary manufacturers. We are still extremely proud of having won this iconic race four times in a row, and that same spirit that drove the innovation behind the first Ford GT still drives us today.'

A1GP fleet to race again in new South African winter series

The Ferrari-engined racecars that competed in the final season of A1GP six years ago have finally been sold and they will now form the basis of a new race series in South Africa.

AFRIX Motorsport is the company behind the purchase of the Lola-built cars and it plans to run them in a four-event series in South Africa during the European and north American winter of 2015/16, before moving on to an expanded calendar for 2016/17, which could include rounds in other African countries.

The people behind AFRIX hope to attract drivers looking for seat time during the off season, something that has worked successfully for MRF Challenge in India and the Toyota Racing Series in New Zealand in recent years.

AFRIX has bought all 21 cars, plus their 4.5-litre Ferrari/Maserati direct-injection V8 engines and a sizeable spares package, all of which has now been shipped to South Africa. However, the sale of the fleet did not include the electronics to run the engines because the Magnetti Marelli ECUs and steering wheels were returned to Italy when A1GP went into administration in 2009. AFRIX says it is currently working on a way to resolve this problem.

The company has also said that it expects that the cars will be centrally run from its Johannesburg base, although it has not ruled out the possibility of inviting European teams to South Africa during the off season in Europe to run the cars.

AFRIX is headed by successful South African racer Alan Eve, while Neville Johnson and Greg Canny are also involved in the company.

It's been suggested that AFRIX paid around £1.5m for the package of cars, engines and spares, which it bought from freight company Delivered on Time.

Ferrari-motivated A1 GP racecars will now see action in South Africa

XPB

Ginetta in bid to win LMP2 chassis building rights

Ginetta has thrown its hat into the ring for the right to be one of the four permitted LMP2 manufacturers from 2017 onwards.

The British sportscar maker, which has already produced an LMP3 car for this season, says it has started work on a P2 coupe project and that it has approached the Automobile Club de l'Oeust (ACO) – the body behind Le Mans and the WEC – to state its interest.

The ACO intends to limit the amount of LMP2 producing companies to four in an attempt to cut down on costs. The limit is set to be enforced from 2017 until 2020. Manufacturers desiring to be among the chosen four were to express an interest by June 10.

Those chosen to produce P2 cars will have a ready market for their wares in the WEC, European Le Mans Series, Tudor United SportsCar Championship and the Asian Le Mans Series.

Ginetta, with the help of seasoned racecar maker Juno which it acquired in 2014, was the first manufacturer to make an LMP3 car and its design team has now started work building a modified version of its P3 chassis in order to explore the feasibility of the P2 project.

The Ginetta-Nissan LMP3 has been crash-tested to the same standards as that of an LMP1 car, therefore the British marque says it has all the relevant data ready to apply to the next stage of prototype development.

Ginetta Chairman Lawrence Tomlinson said: 'Ginetta are committed to offering a genuine motorsport ladder for our customers, and LMP2 would further extend our current career options.

'We have been producing race-winning GT cars for a number of years now, and have a reputation for delivering in large numbers and against tight deadlines,' Tomlinson added. 'We've learnt an incredible amount from our LMP3 car, and it forms a great basis upon which to build an LMP2 car, which we believe we could do very well given the resources we already have.'

Onroak, BR Engineering, HPD, ORECA and Pilbeam are thought to be the other racecar producers hoping to clinch a permit to manufacture LMP2 cars.

Ginetta says its LMP3 will provide a good basis for LMP2 project

Ginetta has previous history with LMP2, entering a Ginetta-badged Zytek in the Le Mans 24 Hours in 2010.

V8 Supercars set for top billing at all-new Kuala Lumpur street race

Australia's premier motorsport category, V8 Supercars, has signed an agreement to stage a round of its championship at an all-new street circuit in the Malaysian capital of Kuala Lumpur.

V8 Supercars has raced in Asia just once before, at Shanghai in 2005, while its last event away from its heartland of Australia and New Zealand was in 2013, when it raced at US GP venue Austin.

The four-year agreement should see the thundering V8s shake the city streets in KL from next year until 2019, while as an appetiser before the first race five V8 Supercars are to stage a demo run in the city in August.

Kuala Lumpur, which also has the Sepang F1 venue on its doorstep, is to call the event the KL City Grand Prix. The FIA-approved 3.2km 16-corner circuit is to make use of the city's most famous streets and will also pass well-known landmarks such as the Petronas Towers.

While V8S is set to top the bill there will also be international GT racing on the card.

James Warburton, CEO of V8S, said of the deal: 'We are absolutely delighted to begin this partnership with the KL City Grand Prix and be the first international racing series to participate at this spectacular event.

'With a TV audience of hundreds of millions worldwide the KL City Grand Prix will be shining the spotlight squarely on the world's best touring car championship in one of the world's greatest cities.' Warburton added that the KL location was perfect for V8S: 'Having four championship races in Kuala Lumpur until 2019, in close reach of Australia and in a similar time zone for our fans are key ingredients. We would envisage that many fans would make their way to Kuala Lumpur to watch us race live on what will be one of the world's most spectacular street tracks,' he said.


XPB

Petronas Towers will provide a stunning backdrop when V8 Supercars top the bill in Kuala Lumpur

IN BRIEF

Marlboro extends

It's been reported that Marlboro has extended its sponsorship deal with Ferrari although, possibly because of the controversial nature of the deal, there was no official announcement from either party. Ferrari is no longer actually allowed to display the Marlboro livery, however it does carry a red and white square on the engine cover that hints at a cigarette packet. Philip Morris, the company that owns the Marlboro brand, confirmed that the agreement had indeed been extended beyond 2015. Marlboro is thought to spend over $100m a year on its F1 involvement. Current Ferrari team boss Maurizio Arrivabene was previously an executive at Marlboro.

Infiniti ends

Infiniti has pulled the plug on the manufacturer support it gave to British Touring Car Championship (BTCC) outfit Support our Paras Racing, after the Parachute Regiment affiliated team suffered a disappointing start to the season. It is understood the Nissan luxury brand supplied the team with its Infiniti Q50 body shells and also contributed to the build cost under the initial agreement, but did not extend its involvement beyond that.

Tripled 8

The V8 Supercars grid is to expand to 26 cars after a new Racing Entitlements Contract (REC) was sold to Triple Eight Race Engineering. This means the team, which races as Red Bull Racing Australia, will now run three cars. James Warburton, V8S CEO, said: 'The bid process was extremely competitive amongst the bidders. It is testament to the great health and growth of the sport at all levels that a number of parties wanted the opportunity to join the championship from next year.' He also said there would be no more new teams until the start of the 2017 season.

MSV unveils all-new and faster Formula 4 racecar

Motor Sport Vision (MSV) has unveiled its new-for-2016 Formula 4 car, which is set to make its debut in the 2015 winter series at the end of this year.

The spec of the Tatuus-Cosworth MSV F4-016, which will replace the current RFR (Ralph Firman Racing) spaceframe design, is set to lift the performance of the BRDC F4 so that it will be significantly quicker than the car it replaces, those cars racing in other FIA F4 championships, and its MSA Formula UK rival, MSV tells us.

In a clear move to distance the BRDC F4 car from the 15-year-old driver-compliant FIA F4 (with its 160bhp limit), the F4-016 sports a new Cosworth 230bhp 4-cylinder normally aspirated engine together with a Sadev 6-speed paddle-shift gearbox with LSD, AP 4 pot front brakes, Pirelli tyres and a higher downforce aerodynamics package.

MSV boss and BRDC F4 founder Jonathan Palmer said: 'MSV's original RFR car uses a steel tube chassis and a 185bhp Ford Duratec engine. Our new F4 single-seater has the highly acclaimed Tatuus FIA F4 composite chassis as its core, but with substantial evolution by MSV to produce an outstanding new racing car that has much increased performance compared with both the BRDC F4 and FIA F4 machines.'

The new aero package includes the addition of secondary flaps on both front and rear wings together with a composite rear diffuser which results in a total increase in aerodynamic downforce of 81 per cent, and an efficiency improvement of 47 per cent compared with the FIA F4 specification car. Despite the additional power and downforce the weight of the new Tatuus-Cosworth MSV F4 car, less driver, is just 495kg, compared with 515kg for the current BRDC car and 540kg for the MSA Formula Mygale.

Budgets for 2016 BRDC F4 are expected to be between £90,000 and £135,000. They are currently in the £80,000 to £120,000 area with the RFR car – both ranges depend on team and testing packages.

CAUGHT

The Abt-run Formula E car of Lucas di Grassi was stripped of its victory in the Berlin ePriz at Tempelhof after the electric racecar was found to be running with a modified front wing and wheel faring. FE stewards said that changes had been made in three key areas, relating to the internal reinforcement of the front wheel farings, the sealing of holes in the front wing, and modifications made to the front flap and gurney. Abt said that the infringements were the result of repairs to damaged parts rather than an attempt to improve car performance.
PENALTY: disqualification

Kevyn Rebolledo, a crew chief on the No.40 Dodge in the NASCAR Xfinity Series, has been placed on probation until the end of the year, while the car's owner-driver, Derek White, has been docked 15 points in the drivers' and owners' championship, after the racecar was discovered to be running with improperly secured ballast at Talladega.
PENALTY: 15 points

NASCAR Truck Series crew chief Joe Shear Jr has been fined $6000 and placed on NASCAR probation until the end of the year after the JR Motorsports Chevrolet he tends was found to be running too low at post race inspection at the Charlotte round of the series. Team owner Dale Earnhardt Jr was docked 10 owners' championship points as a result of the infraction.
FINE: $6000
PENALTY: 10 points

NASCAR Xfinity crew chief Gary Cogswell has been fined $15,000 and placed on NASCAR probation until the end of the year after the No.4 JD Motorsports Chevrolet he tends was found to be running with improperly fixed ballast at the Iowa Speedway round of the series. Car chief Charles Kent was also put on probation until the end of the year.
FINE: $15,000

NASCAR Xfinity crew chief John Monsam has been fined $15,000, suspended from one race, and placed on probation until the end of the year, after an improperly attached weight fell from the No.97 Obaika Racing Chevrolet he tends at the Dover round of the series. Car chief David Jones also has to miss one race, while driver Peyton Sellers and owner Victor Obaika both lost 15 points in the drivers' and owners' standings.
FINE: $15,000
PENALTY: 15 points

Nick Harrison, the crew chief on the No.33 NASCAR Xfinity Series Chevrolet, has been fined $7500 and placed on probation until the end of the year after the Richard Childress Racing-run car he is responsible for was found to be running too low at the rear at Dover International Speedway. Car owner Richard Childress was docked 10 owner points for the infringement.
FINE: $7500
PENALTY: 10 points

Human waste to fuel Le Mans racecar

Gerard Welter's WR Racing team will occupy Garage 56 at Le Mans – reserved for innovative projects – in 2017, with a car powered by an engine that runs on biomethane, which includes human waste.

We're told that biomethane is a CH4 biogas produced by re-using waste, which comes from different sources – including household, animal, agricultural and industrial waste.

Wind tunnel testing has already been completed on the car, and the monocoque and tooling are in the process of being developed, as is the 1600cc 3-cylinder 450bhp powerplant. The chassis will comply with the 2014 LMP1 technical regulations.

A cryogenic tank will be integrated into the chassis and filled with biomethane liquid. According to the ACO, enough human waste is produced over the Le Mans 24-hour meeting to power two cars.

Meanwhile, the Garage 56 entry for 2016 has also been announced. This will be for quadruple amputee Frederic Sausset, who is planning to drive a specially-adapted Morgan LMP2 chassis under the Sausset Racing Team 41 banner.

Sausset, who lost his limbs in 2012 after a bacterial infection, has started racing a Ligier in the VdV endurance series this year. He has now gained the support of Audi, which has supplied an Audi S3 turbo engine to power his CN Ligier JS53 EVO, and will provide an endurance version of its DTM 4.0-litre V8 for the Garage 56 venture.

Sausset (46) operates the pedals with special controls under his thighs, while he steers with a prosthetic limb attached to his right arm.

The announcement of both projects puts paid to rumours that BMW was to use Garage 56 within the next two years to debut fuel cell technology ahead of a full LMP1 programme.

Famous Formula 1 names involved in TVR comeback

British sportscar maker TVR is to resume production, with legendary F1 designer Gordon Murray behind the design of its new model and motorsport engine builder Cosworth providing the power unit.

TVR has revealed few details about the new car but it is known it will follow the Murray philosophy of lightweight design –1100kg being mentioned – while it will also stay true to the traditional TVR DNA of front engine with rear-wheel-drive and a manual transmission, powered by a normally aspirated, dry-sumped, V8 engine – the latter developed by Cosworth.

Les Edgar, the computer games mogul who took over TVR in 2013 and is now its chairman, said of the new car: 'We know that a new TVR has to be better than just good – it has to be outstanding. From the outset we only wanted to work with the best partners in the business, and both Gordon Murray's and Cosworth's track records within motorsport and high performance car design and engineering speaks for themselves. Gordon Murray Design and Cosworth are the perfect partners for TVR and together we will deliver a truly exceptional new car.'

The new model will go on sale in 2017 and TVR says the cars will be completely produced in a new UK factory.

Edgar has also told the media that the company is keen to return to Le Mans at some time in the future with a GT car based on the new production model. The company's previous assaults at Le Sarthe came in 2003 and 2005 (with the Racesports team) and 2004 (with Chamberlain-Synergy).

Bruce Wood, Cosworth's technical director, said: 'We are proud to see Cosworth's industry-leading engineering at the heart of the revived TVR brand. Our team has been working closely with TVR and Gordon Murray Design to develop a powertrain solution that perfectly complements the exceptional performance characteristics of the new car. It's an exciting project and one which well suits Cosworth's engineering expertise.'

XPB

TVR could return to GT racing and Le Mans with new Gordon Murray-designed car (pictured is Tuscan T400R back in 2005)

SEEN: Ligier JSP3

Onroak launched its new Ligier LMP3 car at Le Mans. It also revealed that it has already sold four of the new JSP3s, which it says should all be on track and competing by the end of the year. As with all LMP3 cars the Ligier packs a Nissan VK50 5.0-litre normally aspirated V8, generating around 420bhp and supplied by ORECA, while power is put down via an Xtrac 6-speed sequential gearbox.

IN BRIEF

Culture clash

Cars from the Japanese Super GT category and the German DTM will go head to head in two standalone events in 2017 and 2018. The news, covered in RCE V24N12, comes after the two series introduced new 'Class One' regulations which will give them a common technical package from 2017. Both share DNA when it comes to chassis and aerodynamics. The first year of the new rules package will now culminate with a race in Japan in late 2017 which will see DTM cars going up against Super GT racers. Germany will host a similar race the following year.

Racing aerodynamic know-how helps to slash truck drag figures

Motorsport engineering specialist Wirth Research has been granted a patent for a key component in a revolutionary race-inspired aerodynamic device for trucks.

The WR Aerokit, which was launched earlier this year, is said to deliver measurable drag reduction, as much as 33 per cent for a vehicle previously not fitted with another aero kit and 10 per cent for a truck with other kits, Wirth claims.

Wirth Research started the development of the WR AeroKit in 2010 in a bid to use its core motorsport experience and capability to enhance the aerodynamics of HGVs (Heavy Goods Vehicles). The company used detailed Computational Fluid Dynamics (CFD) analysis to understand the designs and air flow modifications required to reduce the aerodynamic drag of big trucks.

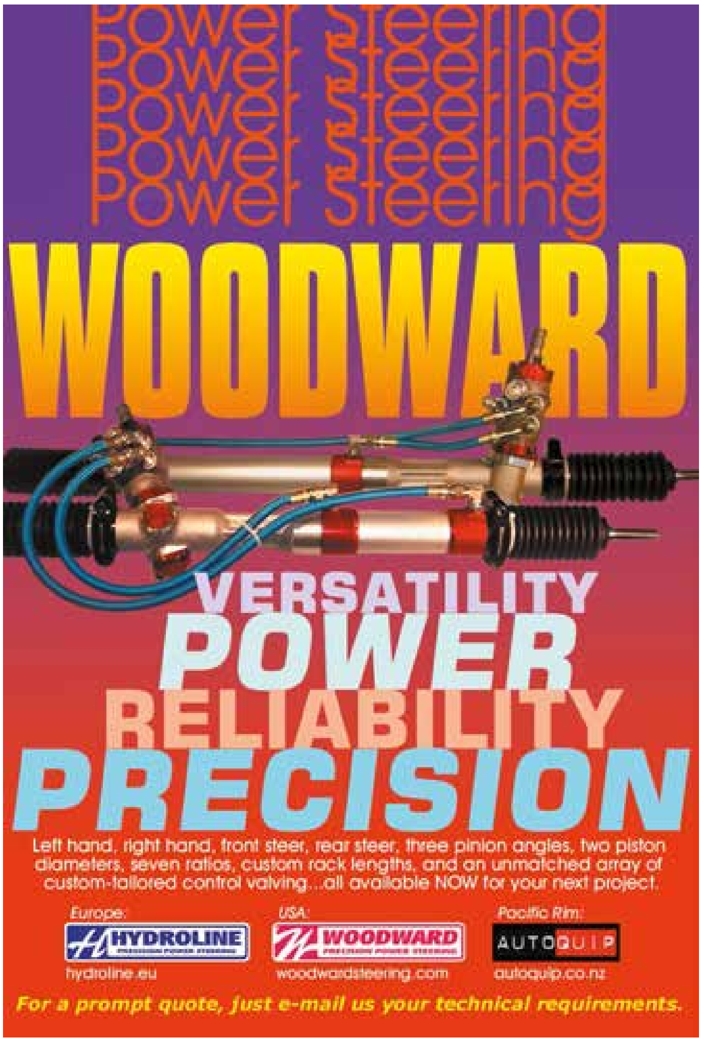
The resulting AeroKit is a set of components from Wirth Research that can be tailored to each type of vehicle and includes in-house designed roof and chin spoilers, bumper turning vanes and trailer kits.

The bumper turning vanes – for which Wirth has been awarded the patent – are the most noticeable crossover of motorsport technology to the WR AeroKits. The purpose of these vanes is to act in a similar way to components seen on the front end of F1, IndyCar and WEC racecars, Wirth tells us. In generating a vortex along the side of the vehicle they narrow the wake envelope of the truck, thereby reducing aerodynamic drag.

Well-known UK haulage company Eddie Stobart has been the first logistics firm to adopt the new technology.

Nick Wirth, president of Wirth Research, said: 'In many ways, enhancing the drag performance of HGVs is the ultimate aerodynamic challenge.'

Haul of fame: Wirth has helped Eddie Stobart to cut down drag on its trucks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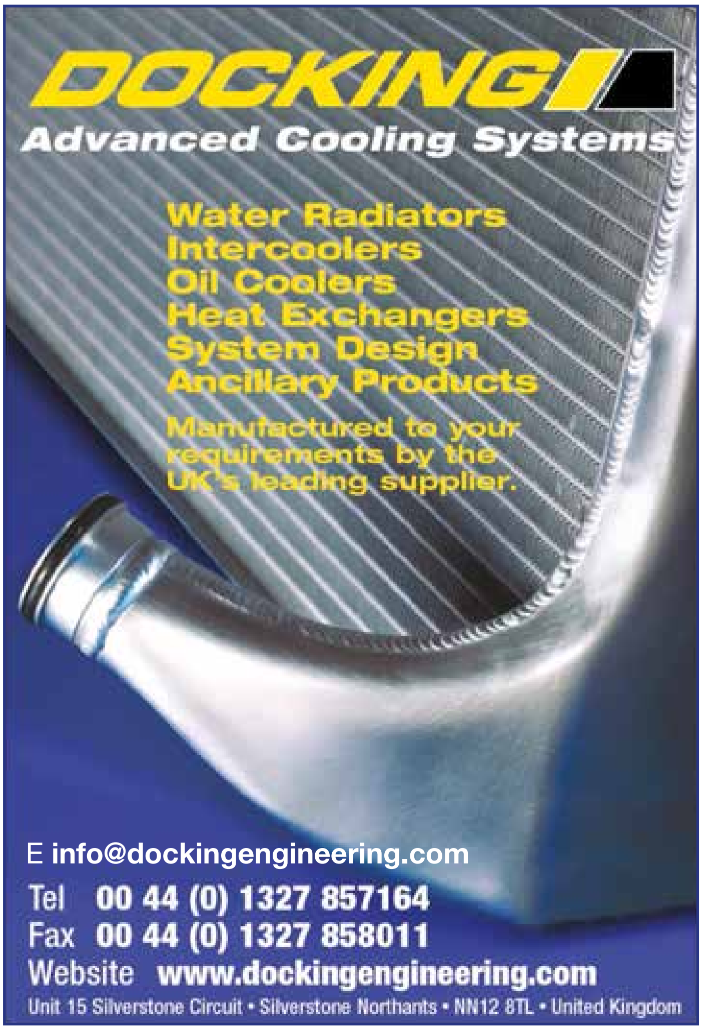
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INTERVIEW – Patrick Allen

On the right track

Silverstone's new managing director has brought a new philosophy to the British GP venue – but just how do you change the culture at such a historic circuit?

By MIKE BRESLIN

'I would define the business by the core competences that exist, not the tarmac'

What has Silverstone in common with a supermarket? More than you might think. Or so says Patrick Allen, managing director of Silverstone Circuits Ltd (SCL). Allen, who has been in charge at the British GP venue since the start of the year, has little in the way of a motorsport background – though as a youngster he did some motorcycle racing and rallying – but he does have a very successful record in business including, as you might have guessed, retail. Indeed, as executive director of marketing for the Co-operative Group he helped take its brand value from £147m to £2.2bn in just three years.

So, back to that opening question: surely a race track is quite different to a supermarket? 'I don't think it is different actually, Silverstone's a retail business,' says Allen, adding that like other retail businesses it has more to offer than just one product. 'If you define Silverstone as the product, you've got the track and you put cars on it, it limits your ability to sweat the asset. If you think about what our team do – and they're brilliant at it – it's putting on events, motorsport events. But it could easily be rock concerts or everything else, because the core competence is getting people around the place, ticketing, traffic management, catering, etc. And I would define the business by the core competences that exist, not the tarmac.'

Customer focus

And, just as it is at supermarkets, for Allen the customer must always come first, an attitude he says he is now bringing to SCL, which runs the circuit on behalf of its owner the British Racing Drivers' Club (BRDC). 'I think I bring a customer focus. To do that you need people to come here, and you need to understand them and have an empathy with them, and provide great value for money. That's my focus, changing the culture if you like. I'm looking at the whole business, not just discreet events in it. And that's what a retailing vision looks like as opposed to somebody who's just mad keen on motorsport.'

But that does not mean forgetting the major crowd-puller, of course. 'We make money out of Formula 1. We've got one of the better contracts of all the [F1 hosting] circuits, we just need to look at how we leverage the F1 event into other things, which we've not done in the past. If you just look at F1 as one event, albeit a very big event, and then that's finished and you go on to the next one, you lose the opportunity to gain the synergies from holding such a prestigious sporting event.'

Examples of this are manifold, Allen says. 'If you want to do a driving experience, where do you want to do it? On some airfield, or where Lewis Hamilton has won a grand prix? Or if you want to hold a conference, you can have it at a serviced office, or would you rather have it at the home of the F1 race? Therefore we need to look at how it's a premium product, we need to position it as such, and start to leverage that.'

But to leverage on the grand prix the fans need to be coming through the gates in the first place, which means making the flagship event more attractive. On that score Allen is not so sure of the show F1 puts on at the moment, contrasting some recent grands prix with Silverstone's pulsating WEC season opener. But there is a more fundamental issue at work here. To watch F1 costs money, too much for most. And this is where the retailer in Allen got to work straight away. 'We're making it great value for money for customers coming in to the site. We did our £120 for the weekend general admission ticket, which went down very well, we sold over 3200 tickets within 30 minutes, and the £99 ticket, which was prior to that and was Sunday only, that sold out in 22 minutes.'

Of course, £99 is a lot of money to some, but then it's no secret that it costs a great deal to host a grand prix. Exactly how much Allen is unable to tell us – the contract with FOM states the fee must remain undisclosed. 'We've done a deal, got one of the better ones. It's a long contract [until 2026] and we've just got to make the most of it,' he says.

Bigger crowds

And making the most of it means packing the venue and the campsites to create a busy atmosphere at the track. 'Generally speaking we are going to have more people in the ground paying less money, but the volume makes up for the margin erosion that you would have had if you'd just charged higher prices. Now the last thing I want, and I'm sure the last thing Bernie Ecclestone wants, is empty grandstands on TV, where viewers are looking and thinking, "well this is not much of a spectacle".'

XPB

It's not just about spectators coming to the F1 race; there's also businesses to consider. If you think of Motorsport Valley as a solar system, then Silverstone is its sun, and motorsport businesses want to be there. Yet much of the business development land is no longer in the circuit's hands, thanks to a deal with commercial property developer MPEC, which paid £32m for a 999-year lease of Silverstone Industrial Estate in 2013. This helped the BRDC to pay off loans from Lloyds Bank and Northamptonshire County Council for alterations to the track layout in 2010 and the completion of the £27m 'Wing' pits development in 2011.

Yet even with the loss of the space, the resultant development is good news for the circuit, Allen insists. 'We have a very good working relationship with MPEC, and the more people that are coming to the Innovation Park as they develop it, that's good for us, as it's more conferencing, it's more banqueting, it introduces more people to the circuit.'

New priorities

The sale of the business park and the hiring of Allen marked something of a change in direction for the BRDC. For some years there had been attempts to secure investment, usually from the Middle East, and on at least two occasions Silverstone came close to being sold on. That, however, is now no longer a priority. 'They tried to do it a couple of times, but they never got over the finish line. The circuit might have suffered slightly from that, because anything of that nature is a distraction, clearly. What's great now about the BRDC is that they are now fully focussed on making it the circuit that it should be, and not selling it.'

Part of the thinking behind chasing that investment was to start a huge building programme, including hotels, new grandstands and a heritage centre, so has this now been shelved? 'We are still progressing those. A heritage centre is something that the BRDC feels is important and again it generates even more visitors who are not just here for racing, it's another hook for people to come here. Ultimately, we want people to say, "Let's go to Silverstone this weekend." "Why, what's on?" "I don't know, but there will be something on and it will be great value for money, so let's just head off and go there." So it's a destination venue as opposed to just a motor racing venue.'

Silverstone has seen massive development over the past few years now it's time to 'sweat the asset' says its new MD

RACE MOVES

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Mercedes motorsport boss **Toto Wolff** has unloaded his large stake in HWA, the company that runs works Mercedes racecars in the DTM. Wolff bought his 49 per cent shareholding in 1999. HWA founder and chairman **Hans Werner Aufrecht** has increased his share in the organisation as a result of Wolff selling his stake, HWA has confirmed.

NASCAR Sprint Cup crew chief **Rodney Childers** has signed a multi-year contract extension with Stewart-Haas Racing (SHR). The longevity of the deal has not been disclosed, though Childers did remark that 'it's a long time'. Childers moved from Michael Waltrip Racing to join SHR at the end of 2014.

Fortec Motorsport has signed up **Trevor Foster** as its Formula 3 team manager. Foster moves over from the company's now defunct GT squad and replaces F3 stalwart **Bruce Jenkins** in the role, the latter having now left Fortec. Foster was previously involved with the Fortec F3 operation back in 1995.

The JRM Group has appointed **Jason King** as its new managing director. King steps up from his previous position of operations director. JRM is a motorsport preparation and advanced engineering specialist, well-known for its technical partnerships with manufacturers such as Nissan and Subaru.

JRM (see above) has also announced that **Andy Blackwell** has taken on the position of supply chain manager, while **Ryan Wallace** has become manufacturing manager. Both men have been promoted from within JRM.

Drew Furlong is now chief operating officer for the BARC (British Automobile Racing Club) Group. Furlong (48) takes up his new position after 22 years at the British Racing and Sports Car Club (BRSCC), most recently in the role of competitions director. He will be based at the BARC's Thruxton HQ.

Daniel Jang, a pit crew member at IndyCar outfit Dale Coyne Racing, suffered a broken ankle at the Indianapolis 500 when all three of the Dale Coyne-run cars were involved in a coming together in the pit lane during the 99th running of the classic event.

NASCAR has announced its 2016 Hall of Fame class, a five-person list comprising mostly drivers but also including **O Bruton Smith**, the executive chairman of Speedway Motorsports Inc., which owns race tracks across the United States. Smith, who started out in racing as a promoter, was responsible for the building of the Charlotte Motor Speedway.

Harold Brasington has won the Landmark Award for Outstanding Contributions to NASCAR. Brasington, a South Carolina businessman, was a supporter of NASCAR in its early days and was responsible for the building of the Darlington Raceway, NASCAR's first superspeedway, in 1950.

IndyCar team owner **Sarah Fisher** has announced plans for a 60,000sqft indoor karting facility near the base of CFH Racing – the outfit she co-owns with **Ed Carpenter** and **Wink Hartman** – on Main Street in Speedway, Indiana. Speedway Indoor Karting is set to open in April 2016.

Heidi Winterbourne has joined vintage and classic rally organiser Rally Round where she will be the company's rally coordinator. Winterbourne is well-known in the classic and long distance rallying world, in which she has been involved for nearly 20 years.

John Sprinzel, the founder of the Speedwell tuning concern, is now the patron of the HRDC (Historic Racing Drivers' Club) Academy, a new series for A30 and A35 historic racing saloons that's to start this year – Speedwell was largely responsible for the success these cars enjoyed on the race tracks in the late '50s.

Manor F1 team snaps up former Mercedes tech chief

Bob Bell, the former technical director at the Mercedes Formula 1 team, has now joined Manor as a consultant.

Bell's signing is part of a concerted effort by Manor-Marussia, which was rescued from administration at the beginning of the year, to beef up its technical staff. This has also seen Manor sign Luca Furbatto and Gianluca Pisanello in recent weeks.

XPB

Former Mercedes technical boss Bob Bell is now at the Manor-Marussia operation

Bell has previously worked at McLaren, Benetton, Jordan and Renault, and most-recently at Mercedes for three and a half years up until November 2014.

Furbatto has taken on the role of head of design. He previously held the position of chief designer with Toro Rosso and before this worked at McLaren for close to 10 years.

Pisanello has filled the post of chief engineer. He worked as head of engineering operations at the Caterham team, while he was also at Toyota before it withdrew from F1 in 2009.

John Booth, team principal at Manor, said: 'We're delighted to welcome Bob, Luca, and Gianluca to the team. It's been a dramatic but rewarding start to our 2015 season, and we're only now able to settle into more of a rhythm, allowing us to look to the future. Our focus this season is to rebuild the foundations of the team and develop our internal capabilities.

'As ever in Formula 1, we rely on the experience, tenacity and drive of our colleagues, so we're delighted to welcome our new teammates,' Booth added. 'Each of them brings a huge amount of experience from within the sport, adding further dimensions to our existing technical and engineering capability. Whilst we seek to optimise our performance during the remainder of the 2015 season, we can also turn our attention to the next exciting chapter in our story – 2016 and beyond.'

OBITUARY

Well-respected Australian driver, engineer and racecar constructor Frank Matich has died at the age of 80.

While Matich made his name as a fast driver – at one point in the mid '60s Lotus, Brabham and Rob Walker all offered him drives which he turned down, preferring to stay in Australia – he also had a huge talent for race engineering.

Unable to afford new machinery he built his own sports racers in the '60s, the first of these being the hugely successful Matich SR3 and SR4, with which he cleaned up in Australia before fielding them in the US in CanAm – although the 5-litre Matich SR4 was never really a match for McLaren's dominant 7-litre cars.

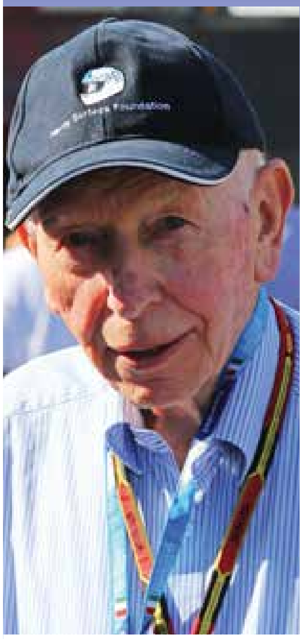
Ironically, Matich then hooked up with Bruce McLaren in the late '60s to develop the McLaren M10 into a Formula 5000 winner in Australia and, when he returned to the US in 1971, there as well. He later developed his own Matich F5000, the A50, which went on to dominate on the Australian national scene.

Driving his own creations Matich won the non-championship Australian and New Zealand Grands Prix, and the Australian Drivers' Championship.

Matich retired from racing in 1974, though he still acted as an agent for Bell Helmets and Goodyear race tyres, while his company branched out into solar energy and other non-motorsport engineering projects.

Frank Matich 1935-2015

RACE MOVES – continued



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Former F1 and multiple motorcycling world champ' **John Surtees** (above) is to buy the Buckmore Park kart track in Kent from **Bill Sisley**. Sisley will continue as a consultant for the company while **Chris Pullman** will join **Mike Griffiths** as joint managing director.

Kirsty Andrew, who has previously worked at Cosworth and Williams Advanced Engineering, has also taken up a position at the Millbrook test facility (see above). Andrew has been appointed general manager special vehicles.

Jill Gregory, who oversees NASCAR's Industry Services department, has now also assumed leadership of NASCAR Marketing. Gregory replaced **Kim Brink**, who has moved on to become chief operating officer of Global Team Ford, the WPP-owned group of agencies dedicated to Ford.

The **Team Penske** pit crew that services the Helio Castroneves-driven IndyCar won the 2015 TAG Heuer Pit Stop Challenge during Carb Day at Indianapolis. The Penske crew clocked 12.561 seconds, while its Chip Ganassi rival (Charlie Kimball's crew) was the nearest challenger with a time of 13.017 seconds. Penske has now won the event a record 15 times.

Ferrari's sporting director, **Massimo Rivola**, was back at work with the Scuderia at Monaco after missing the previous grand prix in Spain, where his absence sparked rumours that he had been suspended or even sacked.

NASCAR Sprint Cup team Michael Waltrip Racing has switched its crew chiefs, with **Brian Pattie** moving from the No.15 Toyota driven by **Clint Bowyer** to the No.55 Toyota of **David Ragan**. **Billy Scott** moves in the other direction, from No.55 to No.15.

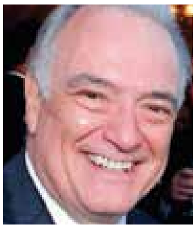
Arnaud Boulanger, the former motorsport director at Renault Sport Technologies, has taken up the position of chief operating officer (test and engineering) at the Millbrook vehicle testing facility.

According to reports in the Italian media Hollywood legend **Robert De Niro** has been lined up to play Enzo Ferrari in an upcoming film of the famed sports and racecar builder's life. Shot as a docudrama it is to be produced by **Gianni Bozzacchi** and De Niro's own production company TriBeCa Film.

Williams Formula 1 team co-founder and former technical director **Patrick Head** has been awarded with a knighthood in the Queen's 2015 Birthday Honours list. Head helped fellow knight **Sir Frank Williams** establish the team as a once dominant force in Formula 1, first as the outfit's designer in the 1970s before becoming technical director overseeing the engineering department in 1986.

◆ Moving to a great new job in motorsport and want the world to know about it? Or has your motorsport company recently taken on an exciting new prospect. Then email with your information to **Mike Breslin at mike@bresmedia.co.uk**


HEWLAND
ENGINEERING LIMITED
Congratulations to SMP Racing for a strong first showing at Le Mans 2015



Packing the stands

The industry needs more fans to be watching the sport, says our business guru

Currently, £280m is being spent in the USA by just one race track to 'improve the fans' experience'. Check out this unprecedented project on www.daytonarising.com and be amazed. It's clear that USA motorsport leaders are rising to the challenge of bringing back the fans. They fully appreciate their critical value to their future business plans.

There are many new opportunities in non-motorsport sectors, but commercial motorsport remains at the core of our industry, and it's this that relies on fans paying to attend races or watch on TV. We need to increase the size of this audience to attract more income from sponsors, which in turn pays industry for the engineering solutions which 'make the car go faster'. In the long term, fewer fans mean less income – simple.

It would be easy to be deluded into thinking UK motorsport is in good shape with regard to popularity. In just one week of July, Goodwood, Formula E and the British Grand Prix attracted some 400,000 paying fans. But we all know this occurs in only one week of the year; what happens to those fans for the remainder of the year? British Touring Car Championship does a great job, attracting over 30,000 from time to time, and is the most pro-active series at making sure entertainment comes first. Close racing is 'artificially assisted' by switching grid places, or holding a draw to decide them. Is this pure racing, or just great entertainment? I am sure it's the latter, and the better for it – it certainly attracts audiences, sponsors and plenty of business.

NASCAR action

The USA model takes quick action, as the primary motorsport series and most major race tracks are controlled by the France motorsport family. For three generations they have learnt how to make money out of motorsport and also that to protect that income they must keep their fans entertained. I'm sure the $400m investment they are making in their Daytona International Speedway will be mirrored at others which they own across the USA and this will force their major opposition to do the same. They are turning a family visit to their race track into one full of entertainment to rival other sports stadiums in the USA, hosting baseball, basketball, and football. They are right to do so.

But, I ask, who will be responsible for bringing fans back to racing in the UK and Europe? Is it the circuit owner, the series promoter, or the governing body under the FIA? If it is any of these, there doesn't seem much urgency from any of them to counteract the clearly declining numbers, as fans desert motorsport for other forms of modern entertainment.

In partnership with UK government, I am leading the MIA to develop a Business Growth Strategy for our UK-based industry for the next five years, with a vision of motorsport in 10 years' time. I would welcome your contributions and ideas – just email me on info@the-mia.com.

The MIA's Business Growth Strategy for Motorsport will be severely restricted if we face a declining fan base which, in turn, reduces sponsorship income to fund our industry. We need to attract the attention of those who can make a difference and encourage them to, collectively, wake up to the challenge and agree a plan to provide more entertainment to attract fans in the next decade. Those fans increasingly demand more from their sports entertainment – as every day goes by, more competition for motorsport emerges and we need urgent action.

As every day goes by, more competition for motorsport emerges

XPB

NASCAR knows that to fill the grandstands it needs to entertain the race fans

This led me to think about the future of motorsport beyond the next 10 years. With autonomous, emission-free transport for urban dwellers (and most of us will be living in cities in the next decade or two), where does motorsport fit? A declining number of young people are learning to drive or buying a car, instead choosing to use improving public transport systems to get them around their home city as they simply can't afford to insure or run a car – evidenced by them more than ever before having to live with their parents until well into their 30s. This major change in the profile of people who enjoy driving is happening now, and will affect our business future.

Autonomous vehicles for city dwellers is far closer to a reality than we imagine – you will see pods in action in Milton Keynes in 2017. Pollution in cities throughout the UK, and the world, is rapidly reaching crisis levels and soon governments are bound to move to protect their voters, and will choose cars as the demon. They will either ban cars from city centres or increase taxes to such a level that we are forced onto public transport, and then eventually, to use only emission-free transport.

Will this change over the next 20 years be as bad for motorsport as it seems? For many years ahead, people will buy cars for enjoyment outside of cities where the roads will be less crowded. There will be more centres for driving entertainment, whether race tracks or private clubs with de-luxe facilities as are appearing in the USA, Europe and Japan.

Real racing

Commercial motorsport could then focus on delivering real racing entertainment to fans without the pressure, as of today, to be relevant to the technology of urban transport. This is the current dichotomy where full blooded, powerful racecars as at Le Mans have to justify their technology as being relevant to a driving population that is increasingly restricted in their enjoyment of driving at speed and with power. The ordinary car they use is becoming more sophisticated and autonomous, by the month, where the need to be 'a skilful driver' is being overtaken by automatic systems.

Motorsport would become a really popular sports entertainment on its own merit, enjoyed by many as an alternative to the drab existence of autonomous transport in the cities. When you witness the immediate popularity of the new forms of rallycross, made for TV with jumps, crashes and fast-changing action, you can see there is a future for motorsport entertainment.

Let me know your own views which I need for our Growth Strategy. I'm sure many of you have a clear vision of the future and I would like you to share it with me. Please do check out the MIA website – www.the-mia.com and attend the events where we discuss our future – you would be very welcome.

Facebook debate

Provoked by the current trend of FSAE teams staging elaborate and seemingly expensive launches, we asked on our Facebook page is Formula SAE/Formula Student getting out of control in terms of costs or are the rules too stable? Is the best engineering winning or simply the biggest budget?'

This seemingly innocuous question provoked an ongoing debate. To read the full debate or to join in visit www.facebook.com/RacecarEngineering

Julian Hakkinen: I think the concepts have converged a bit over the last years (10in rims, single cylinder/4WD electric, as much aero as the rules allow), so therefore I think the overall costs for a car have not changed too much in recent seasons. Looking at FSAE Michigan, the performance of the University of Florida showed that you don't need the most fancy car to place on the podium, and get close to winning. Budget is not everything. Yes you can get yourself some nice unnecessary parts but that won't give you too much performance. Only in the electric class, I think, you cannot win if your budget is quite limited.

Some parts are really expensive and you cannot get them sponsored, so you have a big disadvantage, that you probably are not able to make up with best engineering against teams like Delft, Zurich, Stuttgart or Karlsruhe.

Daz Wiese: I personally think the engineering rules are fine, as they promote innovative ideas. But how many of the cars are actually designed and built by the students these days? There should be a cost cap or containment, with harsh penalties if any of the teams are found guilty of not adhering to it.

Robin Bailes: I think FSAE Michigan proved you do not need a large budget to be competitive. Gator Motorsports (Florida) were second in both Design and Endurance, finishing third overall. Comparing them to TU Graz, who finished less than 20 points ahead of them overall (finishing first), the budget difference is huge. Formula Student is more about the people involved, way more so than anything else, if you don't have the right people, you could have a budget of £1m, you still wouldn't win the competition.

Soren 'Kage' Kaae: The rules of Formula Student have been too stable for a long time. Especially engine regulations. Why have a maximum displacement and a restrictor? The only people who gain from this are those who sell spare parts for R1's and CB600RR's.

Pat Clarke: FS was started to complete the education of young engineers with an interesting practical project. It was to be an educational engineering competition with a motorsport theme, not the motorsport event it has mostly become. Part of the challenge set for teams is to raise funding and clearly some teams are better than others.

What the event really needs to get it back towards the original intent is to readdress the points split between the static and dynamic events. Clearly, an engineering design competition that awards less than 1/6 of the available points to design is one of the issues. If FSAE is a design comp', surely the designs should be assessed against their design criteria (with cost an important factor). If we are supposed to be preparing young engineers for industry (as the original intent) then Industry needs cost savvy engineers and project managers, not race engineers and drivers.

Charlie Kniffin: It would definitely be worth paying more attention to manufacturing and cost effectiveness during Design judging. Either that, or maybe revamp the cost of the event to make it better reflect real world cost. I'm working for a major jet engine manufacturer and some of the stuff I see teams putting on cars is just so unrealistic in the real world at this time. I think it is a great way to get exposure to the technology, but it won't be hitting the automotive world for quite some time. There needs to be more of a trade off when it comes to putting these massively expensive parts on the car (the five figure electric motors being another example).

I'll also add that my team (UCONN) placed 19th this year with a very basic car: spaceframe, 4 cylinder, no aero. And that is with finishing dead last in skid-pad and no prep at all for Business. So I guess there are two sides to this argument. There are certainly some exorbitant parts going on to some of these cars, but going by the Gators and from what I have seen from my team you can go basic and still do well.

To meet and see the cars of some of the top British Formula Student teams visit the 2016 Autosport International show, where there is a section dedicated to universities and colleges involved in the motorsport industry

Useful information

Ticket prices:

- **Trade tickets – £28**
- **MSA members – £23 (available later in the year)**
- **BRSCC members – free (available later in the year). Members will need to contact the BRSCC for tickets**
- **Live Action Arena – £11**

How to book –
www.autosportinternational.com/trade
or call 0844 335 1109

Stand rates
AUTOSPORT INTERNATIONAL & PERFORMANCE CAR SHOW

- **Shell scheme – £345 per m² plus VAT**
- **Space only – £320 per m² plus VAT**

AUTOSPORT ENGINEERING
Turnkey shell scheme package: fully equipped 6m² stand package including shell scheme walling, carpet, power socket, strip light, nameboard and a table and chairs.

- **6m (3x2) – £2425 plus VAT**
- **9m (3x3) – £3638 plus VAT**
- **Space only – £320 per m² plus VAT**

The shell scheme price includes a modern attractive shell scheme system with fascia board. All stands include carpet, cleaning, free stand listing in the official show guide and a hotlink on the Autosport International website.

University of Florida, Gator Motorsports, showed at FSAE Michigan that you don't necessarily need a huge budget to be successful, coming second in Design and Endurance and finishing third overall. Some also say raising the budget is a part of the challenge when it comes to student engineering competitions like FSAE

Pit equipment
Portable clubman race scales

B-G Racing is now offering a lower cost and fully portable scale system that incorporates all of the features required to carry out a professional chassis set-up to race standards.

The control pad displays readings from the four corner weights, the cross weights and percentages all at once, and it also has the ability to calculate the vehicle's centre of gravity.

The control pad also has a low power consumption level with a rechargeable battery life of 40 hours, and it includes the option to save vehicle set-ups for future reference. A protective carry case is also provided to protect and transport the control pad, heavy-duty flexible cables and mains power adaptor.

www.bg-racing.co.uk

Fuel storage
Keeping fuel cool

Most paddocks and pit areas require fuel to be stored outside. However, doing so exposes your expensive investment to the summer sun.

This exposure heats the can, which shortens the life of the fuel, degrading the performance potential. Also, cooler fuel can bring its own small performance advantage.

A new reflective fuel cover from DEI has been designed to keep fuel temperatures stable and extend the pot life of expensive race fuels. Its maker hopes that it will end the need to stuff cans under blankets, or move them around all day to avoid the sun. The DEI covers are designed to easily slip over the standard five-gallon metal cans that many race fuels come in.

www.designengineering.com

Plumbing
Red hose

Red Horse Performance has released a new range of crimp style hose ends, called the 7000 series. CNC cut from 6061 T6 aluminium, the crimp style hose ends assemble in a matter of seconds with the aid of a crimping machine.

RHP claims that its double Viton O-Ring seals provide leak-free performance when used with a wide range of racing fuels and fluids. RHP crimp-style AN Hose Ends are engineered for use with RHP 200, 205, 230, and 235 series hoses. For high performance race applications, Red Horse recommends using the 205 and 235 series e85 compatible hoses.

redhorseperformance.com

Components
Stay well adjusted

QA1 has released a new four-way adjustable damper which features independent rebound and compression adjustments at both low and high shock speeds.

It is designed to offer club to mid level competitors the ability to fine tune their suspension for low shock speed situations, such as corner entry and exit, and high shock speed situations, such as hitting bumps or kerbs.

Featuring an aluminium body, the coil-over Quad Adjust shock has two rebound adjustment knobs for high and low shock speeds. The two compression adjustment knobs are located on the attached reservoir body and also adjust both high and low shock speeds. All four knobs offer independent adjustability. The shock and reservoir are connected with a PTFE lined braided steel hose that swivels four directions on the bodies for flexible mounting. Also, a Schrader valve on the reservoir allows for on-the-fly gas pressure adjustments.

qa1.net

Components
Hit the loud pedal

Designed to complement Tilton's current generation 600-Series aluminium overhung and firewall-mount pedal assemblies, Tilton's 600-Series throttle pedal mounts on to the existing under-dash framework used for the brake and clutch pedal assembly, enabling customers to have a matched set of clutch, brake and throttle pedals.

It can also be used with previous generation Tilton 600-Series pedal assemblies.

The throttle pedal is designed to accept Tilton's throttle linkage kits, which are available with either mechanical linkage or drive-by-wire systems. A steel extension arm kit, designed for attaching throttle cables in mid- and rear-engine cars, is also available.

The new pedal features a lightweight and rigid forged aluminium pedal arm and frame, and provides a range of motion of approximately 30 degrees.

As with Tilton's current generation 600-Series aluminium overhung and firewall-mount pedal assemblies, the new design allows for a variety of pedal pad configurations, with lateral, vertical and angular adjustments available. It also features built-in throttle stops for both pedal directions. An optional grip-tape pedal pad overlay is included.

Tiltonracing.com

Rumour has it…

The paddock was alive with gossip at Le Mans, with stories jumping up like fleas on a rug.

But as secrets go, Ford's announcement of its return to Le Mans in 2016 was one of the worst in the history of poorly kept secrets. This rumour became a fact more than a year ago. Bill Ford is clearly passionate about returning to endurance racing, and in 2016 two cars will race in the TUSCC, two in the World Endurance Championship and, if all the invitations are issued, four will race at Le Mans next year.

This last does rather bring into question the grid numbers at Le Mans, particularly given the other rumours in the paddock. The ACO will build more garages for 2017, but that still means only 60 cars, and the places are limited. What was Garage 56 (and now presumably will be Garage 61) has been awarded for the next two years, to a driver with no limbs in 2016 and to a car that is powered by bio-methane in 2017 (see Business).

It was the 2017 announcement that really caught the eye. This means BMW's plans to enter the LMP1 arena through the Garage 56 door will either happen in 2018, or the company will launch directly into the LMP1 category, possibly as early as 2017. Running with hydrogen fuel cell technology would require a change in the regulations, but rival manufacturers are not against changing the rules to accommodate them – if it is important to develop this technology, then Le Mans is the place to do it.

> **There was a lot of chatter about the Nissan programme at Le Mans**

Speaking of unusual programmes, there was a lot of chatter about the Nissan programme and its performance at Le Mans. The bald facts make for uncomfortable reading for the company; only one of the cars qualified within 110 per cent of the pole time, and as many of the drivers had not qualified, the cars started behind the LMP2 grid. During the race, the predicted brake problems meant multiple changes for all cars, gearbox internals were changed on all cars, each had a suspension failure and two of the three retired. The one that made it to the end had not completed enough laps to be classified. Was this reason enough to throw the project in the bin? Many in the media were quite prepared to suggest Nissan should do just that. However, this project and its concept has been well covered by this magazine. The figures make sense, the GT-R LM can work, but there is a long development path to follow for the car before it will be competitive.

Each delay in delivery of a component, each resultant compromise that had to be made, had a knock-on effect on lap time and reliability for the GT-R LMs and it was relatively simple to establish how the Nissans finished up where they did. In my opinion, there's a need for fundamental changes to the way the team operates. I still don't think, for example, that basing the programme in Indianapolis, with no direct flights to the UK and knee-deep in snow for much of the winter, is the right decision if the team is to work with British suppliers.

Should the programme be cancelled, how would the Renault/Nissan alliance save face? That was another topic for discussion. Clearly the company believes in Le Mans or it wouldn't have invested such sums of money building up the Nissan programme. After qualifying, the rumour did the rounds that a mid-engine car would have to be built, and that it could run in the LMP1 category under the Alpine banner. Carlos Ghosn was thought to be turning up at Le Mans and, with a sell-out crowd and the French President, Francois Hollande, there, it would make sense.

It didn't happen. During the race, the Nissan GT-R LMs achieved every performance target set for them other than the 3m26s lap time. That may be enough to kill off the programme, but if it is given another year, it will certainly be better and may meet the company's expectations of being faster than the customer LMP1s. It may not win the race overall, but management is currently in meetings to discuss how to take the project forward over a longer term.

There were also rumours of another manufacturer joining BMW in the LMP1 class. It wasn't Peugeot – Bruno Famin was at the Le Mans test and said that the current cost of competing was too high. However, if the rumour of a further manufacturer is true, what does that mean for the customer teams? LMP1 would then comprise Audi, Toyota, Porsche, BMW, Nissan (or Renault), plus one other as a manufacturer team. It would then field Rebellion, Kolles, and perhaps some refugees from the LMP2 category, which is introducing new regulations and limiting the number of suppliers in 2017. Zytek for one might step up to P1, as might Dome.

GTE Pro would consist of Aston Martin, Corvette, Ferrari, Porsche and Ford. GTE Am and LMP2 would be squeezed out, a particular problem as the P2 class is the ACO's global prototype category and GTE-Am perfectly fits the bill for allowing the gentleman driver, on which the foundations of the event were built, to race.

If these rumours are true, the ACO might need to build some more garages. But then, they are just rumours …

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