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Why Toyota still holds all the aces in the WEC

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The secrets behind F1 2018's surprise package

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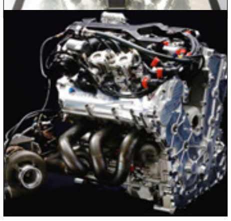
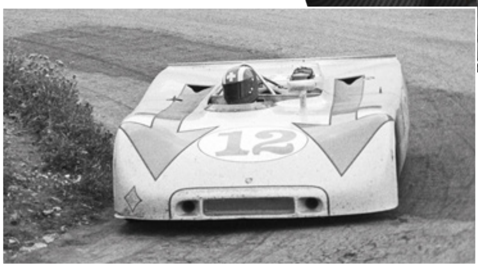
The four-way engine war that will shape Le Mans





Porsche 908/3 008
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The oval office
How NASCAR R&D is using aero to spice up the show

Seven-post rigs
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About 1 1/8" diameter, they fit everywhere and they do the job right for so many applications! 2 sets of O-Rings for a variety of racing fluids. Choose from 10, 20, 40, 60, 75, 100, or 120 micron screens to suit all needs.

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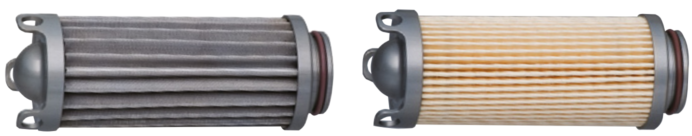

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The Haas VF-18 has been the surprise package of the 2018 Formula 1 season thus far, and it's not all thanks to Ferrari. Turn to page 24 to find out more

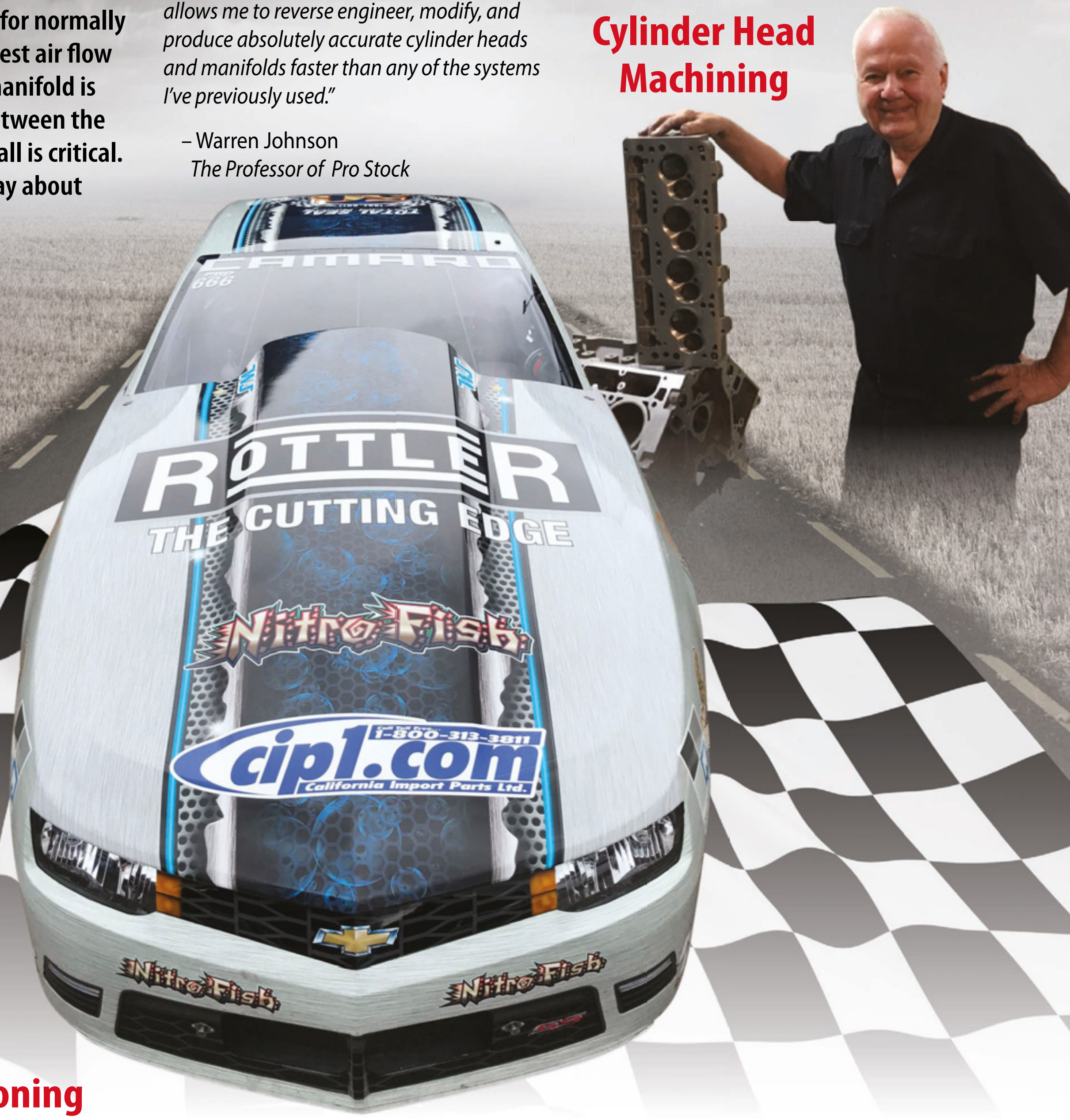
Hear from the Experts!

Pro Stock drag race engines are the pinnacle of engineering for normally aspirated engines. The best air flow through the ports and manifold is critical. A perfect seal between the rings and the cylinder wall is critical. Hear what the experts say about their Rottler machines:

"The Rottler P69 with its advanced software allows me to reverse engineer, modify, and produce absolutely accurate cylinder heads and manifolds faster than any of the systems I've previously used."

– Warren Johnson
The Professor of Pro Stock

Rottler CNC Cylinder Head Machining



Rottler CNC Engine Block Honing

"We have spent countless hours using the Rottler CNC Vertical Honing Machine in the hunt for the proper surface finishes required to achieve perfect ring seal.

Until recently we have been limited to using vitrified or diamond abrasives.

The vitrified stones gave us nice clean cuts and make it easy to hit the target surface finish numbers but consumable costs are much higher compared to diamond stones.

Diamonds can create better bore geometry and give extremely long life but the surface finish is nowhere near as clean a cut and we see lots of debris and burnishing of cylinder surface.

After testing CBN abrasives from Ed Kiebler of Rottler, I was amazed at the surface texture, we now have the best of both worlds.

We have an abrasive with extremely long life and a surface finish that is as good as or better than the vitrified delivered. Little to no debris, no burnishing and almost thread like consistency in the valleys.

We've examined these different abrasives and the surface textures they leave under high power microscope and the results are consistently the same. CBN honing stones are a real game changer."

– Keith Jones, Total Seal Piston Rings

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Race against time

History shows that racing is very often a product of the age in which it exists

Politics have always influenced motorsport, sometimes conspicuously. In the 1930s motor racing was turned into a national symbol by Germany. Which shows that no one can escape the time in which they live, least of all sportsmen or the teams who employ them.

The Nazi regime's support of Mercedes and Auto Union brought forth the juggernaut that dominated in the 1930s, with small scale manufacturers running on frugal budgets falling behind in a literal arms race, this only being stopped by the war. As an added bonus for the companies who were involved there were lucrative contracts, helpful financing and slave labour to man their factories, admitted to and apologised by them since. But blaming the present companies for the previous sins of the company several decades ago is simply not logical.

The previous management of F1 displayed an authoritarian mind-set, which got several things done to the satisfaction of the participants, even as they were being manipulated and exploited. As they say, everyone has their price, but most people don't know their real value. The question now is what Liberty's American approach to running a major sports franchise will lead to. It's possible it will be guided by the same national ethos that prevails in the US, much like what Germany did for the sport in the 1930s, operating under its own imperatives.

Red light

Running a brothel is a profession which requires a similar skill set to that needed to run F1 racing, in the sense that it caters to the public's desires, is shady and also because they attract unsavoury characters, plus the handling of egos both of drivers and team owners, much like handling temperamental courtesans or notorious customers.

Success breeds celebrity, which bring in the fans to follow them, so a circular process ensues, much as vampires in modern times avoiding going for the jugular but patronising the local blood-bank, it causes less unrest, keeps the public happy and brings in profits. Suspension of disbelief helps, and is sometimes required to follow soap operas, or films, for the spectators, but not in business. Racecars are less works of art than of commerce nowadays, for that very reason.

The crowds are there to see tales of derring-do combat between the heroes, not to know the intricacies of the regulations, which are prostituted and crafted to do service to the demands of manufacturers' marketing requirements.

A fractal view of the current situation in racing shows that the problems you have in a macro sense replicate themselves in any segment you examine. Teams get bigger, you need more equipment. Costs spiral, what a surprise! Well if you are in competition you will use every means possible to improve your chances, and privateers need a truckload of ingenuity to beat deep-pocketed manufacturers.

Money talks

Let us be under no illusions that having the means to iterate your solutions until they succeed will eventually tilt the field towards the well financed, as the odds are that they will still be there while the others shipwreck on the shores of finance. Long-term outcomes are predictable, but when did that stop people from acting for short-term gains?

Supposedly independent racing for professionals and gentlemen drivers, if successful, ends up being a classic case of false flag operations when the drivers, engineers and financing end up being a surrogate for the constructors. We all know that, but keep on pretending it is *sport*.

Why does this happen? Firstly, because people tend to be selective ethicists. The other side's friend has a beer, thus he is a 'drunkard'; your side's friend downs a bottle of scotch a day, he is a 'fun-lover', and he is on our team. Secondly, as soon as any activity starts attracting spectators, otherwise known as 'cash-fodder', there will be operators in all domains waiting to profit from it.

And what could be the overweening factor is that those in control do not want change, they are comfortable as it is, unless the cash cow suddenly dries up or dies on them. When you are a publicly owned company you also have fiduciary responsibility to maximise your profits, which leads again to short-termism. There is an opportunity to change the paradigm under new management and it will be interesting to see how American corporativism will blend into, or clash, with what is a pretty much British environment in F1.

There is a point where relativism will not solve the underlying problem, but that applies to any other social interaction. Human nature is the same in any epoch, and most of what happens is well known and understood. It is euphemised by words and phrases like *gamesmanship*, *culture* and *status quo*, but underlying it all means more of the same methods. We know that all are using semantic masking and cognitive dissonance to obscure the real goals, namely to win and reap the rewards of the system.

Alright, let the participants run their sport and cut out those who are selling the product to the public. If you have no skin in the game you should not be in a position to decide how it's played. There was a precedent, in Champ Car racing, and we saw how that turned out even though the reason for the association was to ensure the profitability, fairness and survival of the championship. Personal objectives and biases won out over the group interest.

MERCEDES ARCHIVE

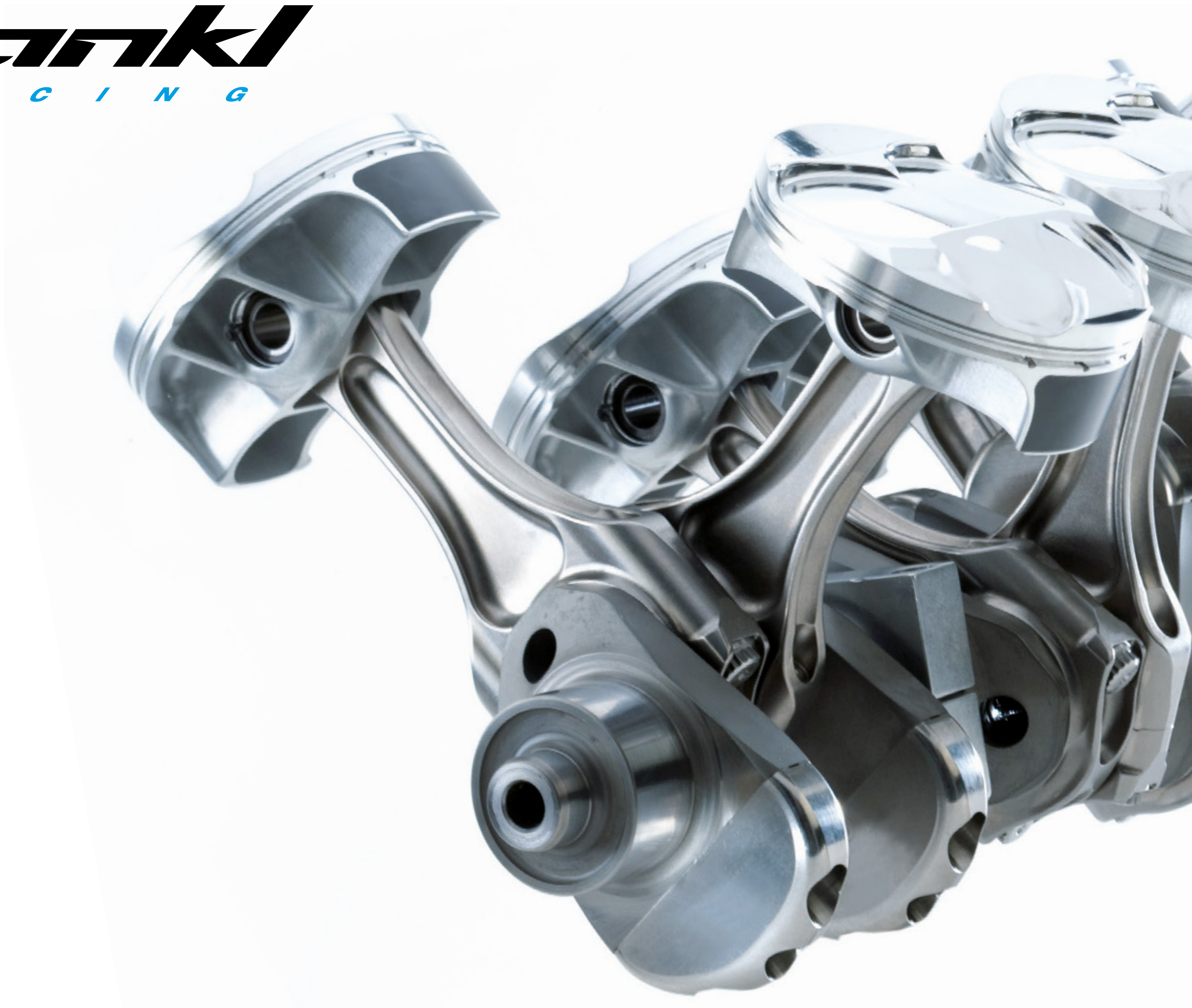
The Mercedes W154 reminds us that grand prix racing has often been shaped by the politics of the time. So what now for Formula 1?

Realpolitik

We will find *pure* sportsmen in the voluntary marshals, some team members and surprisingly even in the press, who are not just objective reporters of what happens but passionate believers in the long term viability of motor racing. The others have reasons of their own to defend their interests or illusions, much as in the rest of life, so it is in everybody's interest to be objective and all work together to keep the golden goose alive, no matter what their personal objectives are.

Probably the biggest irony is that World War Two was billed as the fight to defeat fascism by the west. Now Germany is the paragon of ethics, democracy and humanism, and the leader of the western world is to the right of Attila the Hun. So never underestimate the power of very stupid people in very large groups, and never forget that life goes on. Now let's go racing.

The previous management of F1 did display an authoritarian mind-set, which got several things done to the satisfaction of the participants



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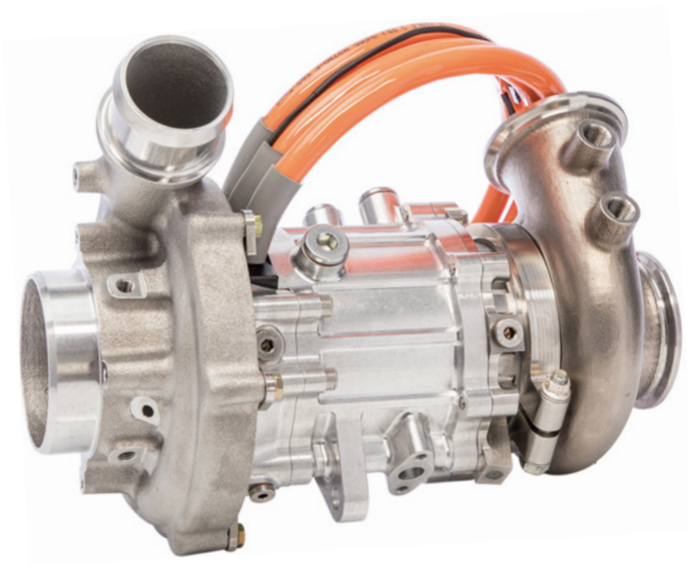

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History lessons

The hidden dangers that could be lurking in some historic racecars

Historic motor racing is undoubtedly a hugely important sector of our sport and business across the globe. Observe the huge grids at major events all over the world.

Audi and Mercedes spend a great deal of money preserving and even re-creating the awe-inspiring pre-war days of the Silver Arrows. Clearly, both of these mega-corporations, dedicated to the most advanced road vehicles of the future, believe in the benefits that this display of impressive past engineering and long-serving commitment to motorsport brings to their present-day marketing.

Away from the high-profile spectaculars, countless racecars dating from the earliest days compete all year round in as large a spread of motorised competition as can be imagined. This contributes significant opportunities for training and employment in the renovation, preparation and operation of almost every type of vehicle that can be raced. In the upper echelons, serious money is available and gets spent. For many an established engine supplier the relatively short life between rebuilds of old-style motors is in sharp contrast to the 10,000km frequently mandated by modern racing championships, and is what keeps their businesses viable.

Historic racing also enables some to compete on the lower rungs who could not otherwise afford to, as well as providing a 'seat-of-the-pants' and intuitive driving experience which is becoming increasingly rare in contemporary racers.

Feel the noise

It's great for spectators and media viewers, too. How else can they experience the visual and aural treats of a supercharged straight-8 Alfetta, a ground-shaking Can Am V8, a howling Ferrari V12 and the ubiquitous Ford-Cosworth DFV, plus so many, many more? In an era of mind-swamping uniformity and blandness, historic motorsport is a much-needed refreshment to the senses.

Inevitably, there is a potential downside. On the face of it, driver safety in these racecars is generally as far removed from what is acceptable in current racing machinery as can be imagined. In order to maintain the attraction and purpose of historic racing, it is neither desirable nor practicable to change this to any great degree. The addition of rollover hoops has long been permissible but they so spoil the look of the racecars – a parallel here to the Halo now blighting Formula 1 cars?

Risky business

Given all the above, and the fact that often (with some very notable exceptions) the seats are occupied by drivers with significantly more money than they have – let's face it – talent, it's perhaps surprising that serious injuries and even fatalities are relatively rare. During the times when these cars were raced by professionals, severe trauma and deaths were fairly frequent. Some of the explanations for this are obvious. Older drivers, who have the money, represent much of the historic entry base and they are doubtless less inclined to push it to the limit. The latest in fire-resistant gear and HANS devices certainly contributes.

Meanwhile, circuit safety with energy-absorbing barriers and wide run-offs has improved by a country mile; and marshals and medics are highly-trained now, and the resuscitation equipment and practices much more advanced.

In the highly successful F1 Masters, the quality and preparation of the cars is sometimes better than when they were the latest and greatest. And herein lies the key. Along with applying serious scrutineering standards, entry to this championship includes mandatory requirements for component validation, among other safety measures. In other series and events, scrutineering in the main is quite rigorous and many of the racecars are prepared by professional outfits with facilities and working practices far superior to those previously employed when these same cars were raced.

Big grids bear testimony to historic racing's popularity, but are all those involved aware of the possible perils of competing with an old racecar?

However, I have no doubt that outside of the 'big-time' historics some competitors are blissfully unaware of the need to take into account certain basic factors. For instance, thoroughbred racecars were not designed or constructed to last for umpteen years, particularly so when performance improvements such as stickier tyres, subtle aero and suspension tweaks and more powerful engines have been incorporated. Then there's aluminium, as used in monocoques, which can become brittle and develop cracks, especially around rivet holes and highly-stressed mounting points.

Steel components such as tubeframe chassis, suspension and steering links, driveshafts and so on tend to rust from the inside and often cannot be easily spotted. Also, magnesium alloy, copiously used for wheels, suspension uprights, gearbox casings and bellhousings, corrodes inconspicuously. A shelf-life of seven years was an accepted norm at the time when most were produced. Some still running might be over 40 years old. On top of all this, old racecars may have been poorly repaired at some stage after crash damage and/or modified in unprofessional ways.

Fortunately, due to lack of design tools such as FEA most older racecars were over-engineered, which helps to avoid some of the perils above. But the heavier and more powerful the car, and/or those built down to a low minimum-weight regulation like F1 machines, the more likely it is that disastrous failures can occur. I'll wager that when severe historic racing crashes occur not involving another competitor, there is a strong likelihood of a component breakage being the cause.

Safety drive

But to be more positive, regular crack-testing based on usage and time is not so very expensive. Happily, availability of many parts is much wider than ever and, due to state-of-the-art manufacturing, not necessarily mega-expensive. A fund of knowledge exists to support these historic racers. So the opportunity for many to keep enjoying what can be described as the most exciting and raw motor racing there is should continue well into the future. Thankfully.

Steel components such as tubeframe chassis, suspension and steering links, tend to rust from the inside and often this cannot be easily spotted

Gibson's 4.5-litre V8 is an evolution of its proven LMP2 unit and it is the most widely used privateer engine

Power struggle

There are four very different engines, each with their own distinct technical philosophy, powering the new breed of privateer LMP1 entries. The question is, which will have the edge at Le Mans?

By GEMMA HATTON

With Toyota the only remaining LMP1 manufacturer the 2018/19 WEC season presents the best opportunity ever for a privateer team to not only claim that final podium spot at Le Mans, but potentially the victory too. It's hardly surprising then, with eight privateer entries, the hunger for the Le Mans podium has triggered an engineering war, with the development of the LMP1 engine the most significant battle. But with four different concepts ranging from naturally aspirated 4.5-litre V8s to 3.4-litre V6 turbos, who has got it right, and who has got it wrong?

In terms of design, the regulations for LMP1 privateer, or non-hybrid, engines are in motorsport terms relatively free. Unsurprisingly, they have to be four-stroke petrol engines with reciprocating pistons and must only have two inlet and two exhaust valves per cylinder. But aside from some more detailed constraints, the engine dimensions, fuel injection pressure and air induction configuration are all free, which is the polar opposite to F1. As would be expected, this has led to a variety of concepts, with no two engine manufacturers converging on the same solution.

The regulations for LMP1 privateer or non-hybrid engines are, in motorsport terms, relatively free

Four sight

The most popular choice of engine on the LMP1 privateer grid is the Gibson GL458, which powers both Rebellion ORECA R13 cars and Dragonspeed's BR Engineering entry. This naturally aspirated, port injected, 4.5-litre V8 is an evolution of Gibson's proven LMP2 engine, which has its roots as far back as Formula Renault 3.5. The GK428 baseline unit supplies the entire LMP2 grid in WEC, ELMS and various teams in the IMSA championship.

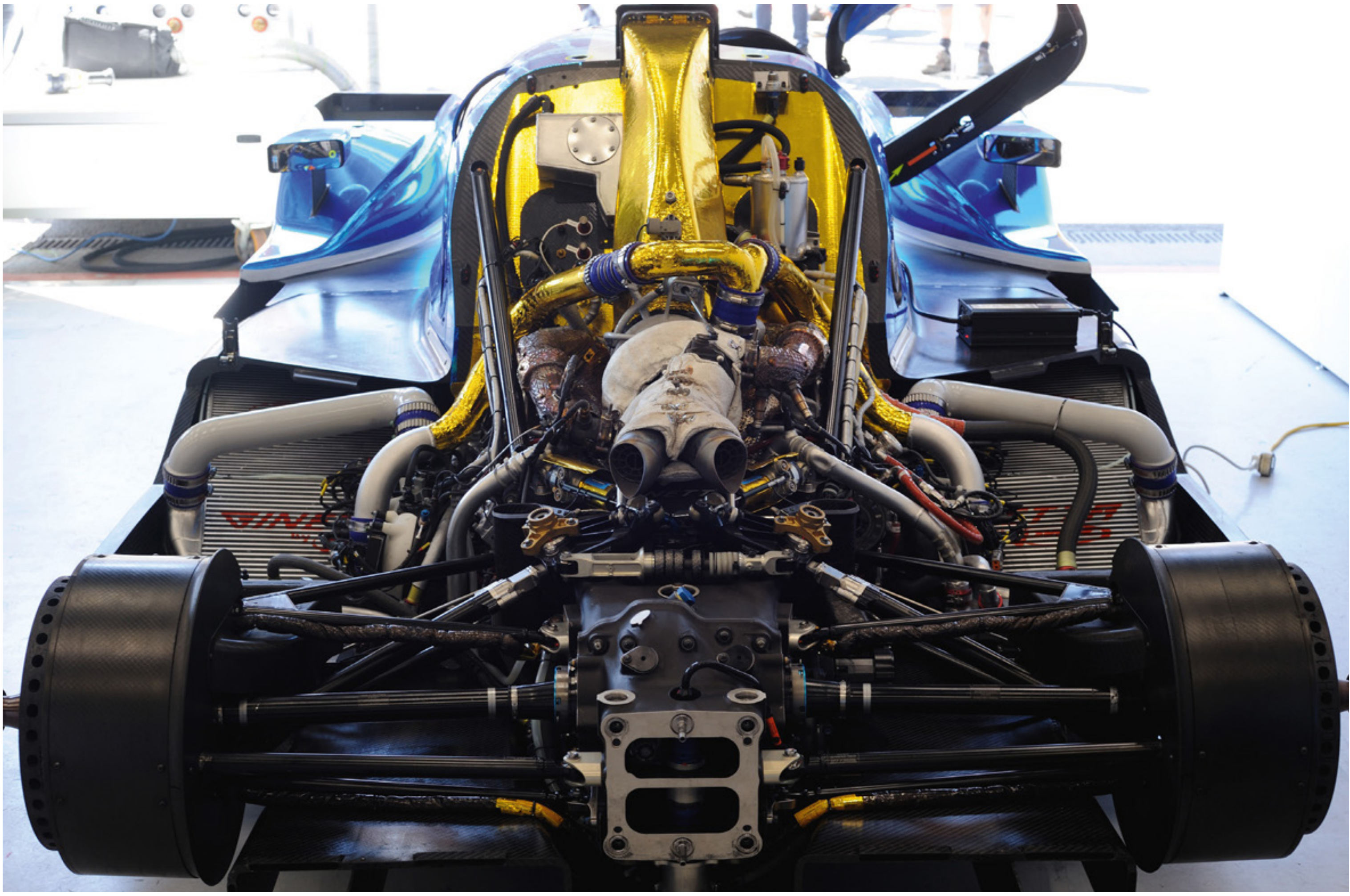
Next up is the Mecachrome 3.4-litre turbocharged V6 which features in both the Ginetta cars run by CEFC TRSM Racing. The V634P1 engine has been adapted from Mecachrome's Formula 2 V6, replacing the original port injection philosophy with direct injection to optimise performance for the fuel flow restrictions of LMP1 – details of this engine can be found in our V28N3 (March) issue.

Then there is the AER P60B twin turbocharged V6 direct injection engine, which is based on the original P60 concept that was last raced in the WEC back in 2016. Since then AER has developed this V6 into the P60B derivative, which will power both the BR Engineering cars run by SMP Racing.

The fourth engine is that run by the ByKolles team, which will continue to race with the 3-litre twin-turbocharged V6 powerplant developed by NISMO. Having competed with this engine during the European rounds of last year's WEC, the unit, as well as its installation within the car, is well known, allowing the team and NISMO to focus on reliability for the 2018/19 season.

Lean machines

Despite the rather open regulations leading to a variety of different concepts, each engine manufacturer has still had to cope with one major challenge of competing in LMP1; the fuel flow restriction. At the time of writing this was limited to 110kg/h for both naturally aspirated and turbocharged concepts, compared to 80.2kg/h for Toyota's hybrid. The optimum method of achieving maximum power with a fuel flow limit is to extract the most amount of energy possible out of every droplet of fuel. This has required the manufacturers to run lean or even stoichiometric mixtures, which is the ideal air to fuel ratio that ensures all the fuel burns with no excess air. Consequently, this has led to the redesign of internal components and the integration of innovative techniques to improve that all important combustion efficiency.



Mecachrome's VP634P1 engine is a 3.4-litre turbocharged V6 based on its F2 powerplant. It's the chosen engine for the Ginettas run by CEFC TRSM Racing (*Copyright David Lord*)

'LMP1 is a totally different proposition to LMP2, really,' says John Manchester, operations director at Gibson Technology. 'One of the big challenges of LMP1 is dealing with the fuel flow restrictions, and as such there's an enormous amount of work required to ensure the engine is able to run within that fuel constraint, which places high levels of thermal stress on the components within the engine because it is running so lean. We're reaching lambda targets now which we would not have believed possible a few years ago, and which are incredible for a race engine. Yet it has still got to perform at a competitive level, and for 24 hours.'

Gibson has opted for port injection rather than the direct injection systems usually seen in fuel flow restricted formulas. This is because, with both of its contracts finalised as late as January this year, it had to carry over the port injection used with its naturally aspirated LMP2 baseline engine. Despite this, Gibson feels it has developed a solution that is competitive in terms of fuel targets and efficiencies. The other manufacturers have all incorporated direct injection within their engines.

The optimum method of achieving maximum power with a fuel flow limit is to extract the most amount of energy possible out of every droplet of fuel

Direct approach

Bruno Engelric, managing director of Mecachrome Motorsport, says of this: 'To optimise performance with this fuel flow restriction you need to guarantee that each droplet of fuel is burned with the maximum amount of air and this is best achieved with direct injection. This really impacts the combustion chamber geometry as well as the cam profiles and all the surrounding components. We have selected Bosch as a partner and have worked with them on this redesign and also on defining the control strategy. This gives the driver the possibility to switch to different maps to have the optimum performance for the fuel limitation and we have seen a big improvement in efficiency so far.'

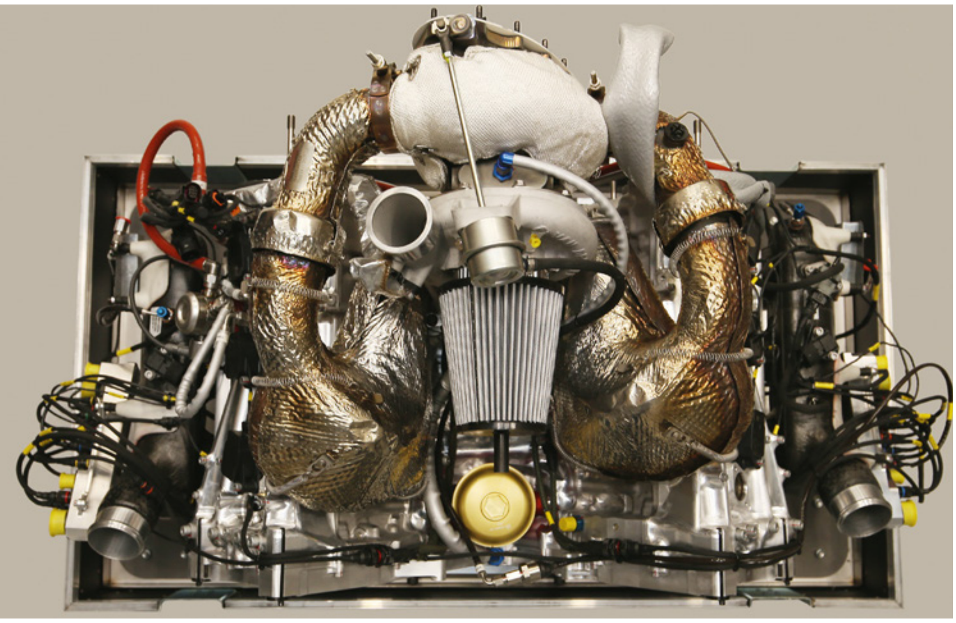
But direct injection achieves a great deal more than just improving efficiency, as Mark Ellis, technical director at AER explains. 'GDI [Gasoline Direct Injection] allows a number of benefits. For example, it improves the charge cooling, the mixture distribution within the cylinder, and you are able to target the fuel spray interaction more accurately. This improves the homogeneity of the charge and allows more precise control of the fuel added each cycle. This not only brings benefits to the combustion efficiency and BSFC [Brake Specific Fuel Consumption], but also driveability, torque response and traction control.'

Natural aspirations

AER's original P60 (the baseline concept of the P60B) was designed from a clean sheet of paper, with the specific intention of exploiting the fuel flow restrictions of LMP1. With the other manufacturers, except for Gibson, all adapting their power units to incorporate direct injection, it might be fair to suggest that this is arguably the optimum solution, particularly when combined with a turbocharger. However, the turbo is yet another area of diversity, especially for Gibson which has stuck with the naturally aspirated philosophy it's utilised in LMP2.

'We are the only naturally aspirated engine in LMP1 but we feel we are going to be competitive,' Manchester says. 'We were keen to continue using the naturally aspirated V8 LMP2 engine and with both contracts finalised so

This season's twin turbo P60B engine from AER is based on the company's original P60 concept, which was last used in the WEC back in 2016 and was specifically designed to exploit the fuel flow restrictions of LMP1



To optimise performance with a fuel flow limit each fuel droplet needs to burn with the maximum amount of air – running lean. Mecachrome (engine above) believes that direct injection is the best way to achieve this

late, the time constraints and the work required meant that the LMP2 engine would be a very good baseline to develop the LMP1 engine from. Although outwardly the GL458 shows some similarities to the LMP2 engine, it is a very different engine internally, with approximately 40 to 50 per cent of the internal parts all new, so it is effectively almost a new engine.'

Gibson's upgrade

Gibson's redesign focused on the rotating parts, developing new crankshafts, conrods, pistons, liners and the valvetrain with new materials to reduce weight whilst improving performance. All of which were a consequence of the required increase in capacity from the 4.2-litre LMP2 engine to 4.5-litre for LMP1. There has also been a major reduction in weight, with the GL458 now weighing less than its LMP2 variant, most of which was achieved through machining features, materials and replacing cast parts with machined versions due to the increased capabilities of modern machining processes. The carried over components include the cylinder head, block and lower crankcase castings developed by Grainger and Worrall, but these were also extensively modified.

Mounting views

The biggest advantage the Gibson GL458 has is that it shares the same mounting points as its LMP2 cousin. Therefore, the installation was a much easier task, especially for Rebellion whose ORECA chassis has already been adapted for the structural requirements of the Gibson, having run it in P2 last year. This allowed ORECA to focus on the aerodynamic performance of the car because the engine and its performance in the ORECA 07 chassis was a known quantity.

'We wanted to run a naturally aspirated engine and decided to go with the Gibson because the external dimensions of their LMP1 engine are the same as their LMP2 engine,' says Bart Hayden, team manager at Rebellion Racing.

'For a privateer team to be able to fund a hybrid car using current technology would be very difficult indeed'

'This meant that the installation was pretty straightforward because the only difference is the internals of the engine. Also, we were given the green light on this project quite late last year so, in the time-scale we had, it was much easier to get this engine in than anything else.'

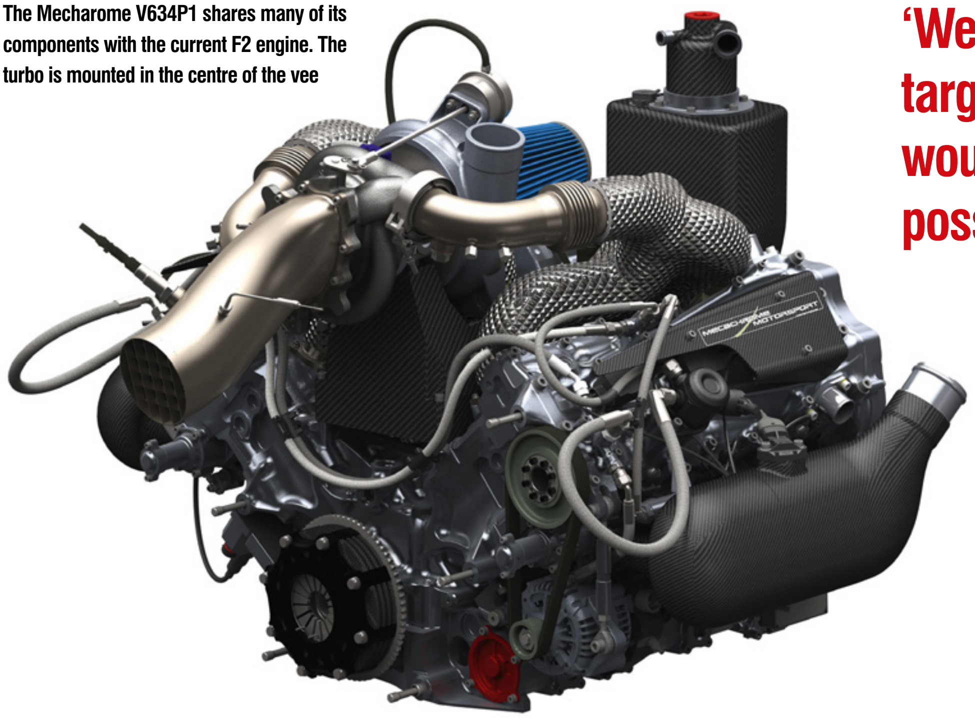
Unlike Gibson, all the other engines on the grid feature turbochargers, with AER and NISMO running two. 'For the fuel consumption and driveability requirements of LMP1, the path we've taken is to use two small turbochargers working off the two banks of the engine. Both turbos are low in the car which is good for packaging and the centre of gravity,' says Andrew Saunders, engineering manager at AER. 'Other suppliers have gone for single turbos and I imagine that is to do with legacy. AER ran LMP1 engines as far back as 2006, in the V8 configuration with twin turbochargers, and we've taken the knowledge learnt from there to develop the P60 engine, and now the P60B.'

Future boost

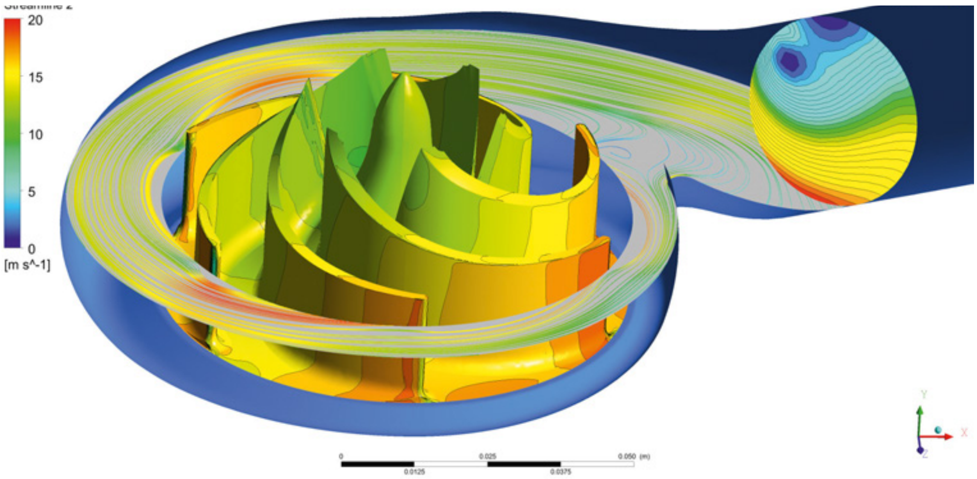
The use of turbochargers for this LMP1 non-hybrid category looks to be a competitive solution not only for this current era of prototype racing, but also for the future. Recent discussions surrounding the proposed 2020 rule changes highlight that the turbocharged engines may be well suited to the new rules, particularly if the FIA and ACO decide to make the privateer class go hybrid.

'There are various solutions of incorporating hybrid technology that have been discussed, but for what is currently proposed, the P60B is well suited so we're optimistic that the P60B will be competitive within this future rule framework, only requiring very minor changes,' says Ellis. 'The turbochargers as well as the advanced combustion system that we have specifically developed to optimise the fuel flow restriction makes it a potentially good choice. [Also] as incorporating a hybrid system often puts additional pressures on the installation into the racecar, the P60B has compact packaging and low mass, so it is ideal to be combined alongside a hybrid system.'

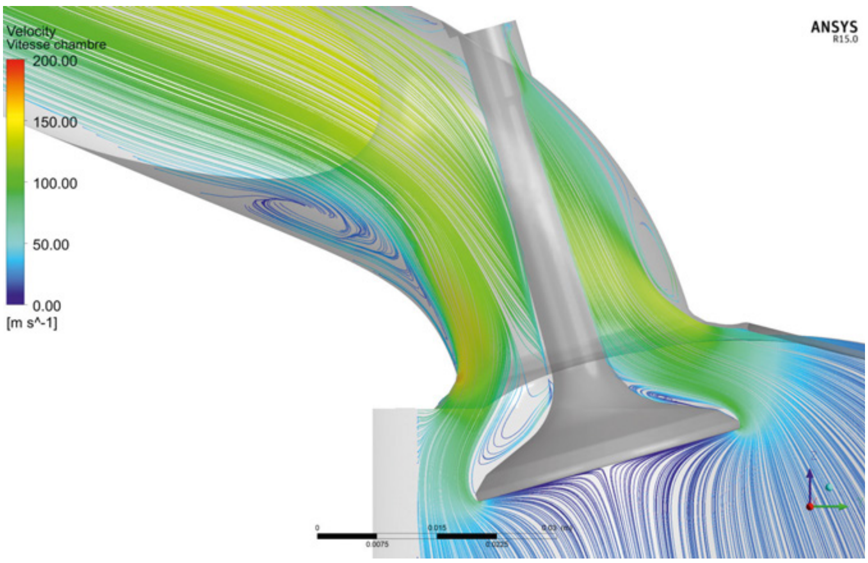
AER is not the only manufacturer looking ahead; Mecachrome also claims it is hybrid-ready should the regulations sway that way. 'We have already made some developments with regard to a hybrid package,' says Engelric. 'We were contracted by the marine division



The Mecharome V634P1 shares many of its components with the current F2 engine. The turbo is mounted in the centre of the vee



This shows the velocity streamlines swirling about within the water pump turbine of the Mecachrome powerplant



The LMP1 fuel limit has forced the engine manufacturers involved in the privateer class to design the combustion chamber, injection strategies, valve geometries and inlet and outlet ports to maximise the amount of air burnt with the fuel. This image shows velocity distribution during exhaust valve opening

'We're reaching lambda targets now which we would not have believed possible a few years ago'

of an industrial company located in Dubai to develop a hybrid powertrain for a yacht. So we have prepared our team to jump into this hybrid world, because I believe that's the direction that the ACO and FIA will choose to go in the future and our LMP1 engine is a good base to evolve into a hybrid powertrain package.'

Cost questions

A potential move to hybrid powertrains for privateers opens up a rather large can of worms in terms of costs. It could go against the whole point of the privateer category, where the participants do not benefit from manufacturer support. This would suggest then, if hybrid is the future, it would most likely come in the form of standardised hybrid parts – similar to the current 2021 proposals for Formula 1.

'As a manufacturer it would be nice to still be competitive with a naturally aspirated engine because I think people like this type of engine compared to turbochargers,' says Manchester. 'But it will really depend on how the regulations go and if we feel we can't be competitive with a naturally aspirated engine then of course we would have to look into new technologies.

'We could produce a hybrid system as we have done this in the past and so have a large amount of expertise in this area, but one of the main problems are the costs that this can generate,' Manchester adds. 'For a privateer team to be able to fund a hybrid car using current technology would be very difficult indeed.'

Consistency call

There is no question that defining new regulations for any motorsport category is a turbulent process. However, the engine is arguably the biggest investment for privateer teams and requires the longest development time. Therefore, to ensure the survival of these teams the rules not only need to be clear, but also consistent year on year.

'When you make new rules, the only thing you can be certain of is that you will please nobody,' says Engelric. 'So don't try to do something too smart because in the end nobody will be pleased. The most important thing when defining the rules is to keep them for a minimum time of four to six years. If you do that, you show the competitors who want to enter that they have a chance to invest in the sport and get their money back through publicity or marketing. If you change the rules every year, in the end, no one wants to invest so you're using what's available, old packages

'In our opinion it is quite reasonable that a turbocharged engine, with its better efficiency, should maintain an advantage'

that have just been refreshed in one way or another. You are then not innovating new technologies. The only way to do that is to guarantee stable rules. The WEC really has a big potential to attract companies and big investors into the sport and I'm sure these would come with stable rules.'

A prime example of this is the Equivalence of Technology (EoT) used this year (for more on this see page 16). This aims to somehow quantify a gap between the LMP1 hybrid and non-hybrids, whilst maintaining the difference between LMP1 and LMP2, all in an effort to try and artificially create more competitive racing.

As you can imagine, trying to get all the teams to agree on just how big this gap should be has been a difficult process. But further complications arise in the LMP1 non-hybrid category, with the vastly different engine configurations used leading to further advantages. Therefore does this also need to be equalised through regulation?

'Turbocharged engines do have an inherent BSFC efficiency advantage over a naturally aspirated engine but should that be borne out with track performance?' questions Ellis. 'It's possible in the future that there will be an EoT adjustment, in the same way the hybrid LMP1 cars have an advantage over non-hybrid LMP1 cars. In our opinion it's reasonable that a turbocharged engine, with its better efficiency, should maintain an advantage.'

The Gibson (above) is the only naturally aspirated unit. Mecachrome has opted for single turbos, while AER and NISMO use a twin turbocharger layout. The Gibson is also the only one of the four to use port injection rather than direct injection

Balancing act

The current EoT table, in Appendix B, assigns the naturally aspirated and turbocharged engines into different columns, yet the values of the EoT parameters are the same for both. Does this mean there was the initial intention to equalise the different engines and, if so, why was this not finalised and will this happen in the near future? If the FIA and ACO do decide to incorporate further changes then, once again, the rules are not stable, damaging the business case of competing in the WEC for suppliers.

'Unfortunately, we are being penalised by the regulations today because we decided to go into endurance last year, before the EoT showed up at the end of the year,' says Engelric. 'If we had known this EoT would have been applied, we would have probably changed the direction taken with this engine. I don't consider that to be the best in endurance racing today you have to extract the last horsepower. Should we invest to achieve better engine performance when we know that in the end the EoT will kill this advantage that we have developed? We are not in racing just to race, we are doing it as a business, and when you invest money you have to have a return on that investment.'

With Toyota the only P1 manufacturer there's a spot on the Le Mans podium up for grabs for privateer teams like Rebellion

Transitional phase

Engelric concludes: 'We understand that we are in a transitional phase at the moment, but hopefully the arrival of the new 2020 regulations will cater for the privateer teams with, also, reasonable budgets, over at least a five-year period for stability. On the technical side I anticipate that it will head in the direction of hybrid units, but the regulations need to be clearly defined with a maximum power output, energy per lap and weight of the system to avoid budgets getting out of control.'

In the meantime there's the small matter of this year's Le Mans to think about, and it will be fascinating to see which engine clinches that third spot on the podium – or maybe even better should the Toyotas falter.

First among equals

The EoT system was originally devised to give different technology concepts an equal chance to win in LMP1 – so why is it now being used to hand an advantage to hybrids? *Racecar* investigates

By ANDREW COTTON

When the hybrid regulations were introduced into the World Endurance Championship in 2014 at their heart was the Equivalence of Technology (EoT), an appendix in the form of a table that was based on scientific calculations to allow petrol and diesel cars to be balanced, and for small, medium and high power hybrid systems to also be balanced.

The idea was not to balance the cars, or teams, but to take the best from each concept, and accept that the others should be able to do the same job. Therefore, it was an equivalence of *technology*, rather than of performance, and it seemed to work rather well.

However, from the outset, that EoT title was immediately misleading. There was actually an *in*-equivalence built into the system, with those teams reaching the 8MJ top class of hybrid system receiving a slightly skewed advantage. The idea was to encourage the manufacturers to hit that target and gain a competitive advantage for doing so. The FIA/ACO did not anticipate that Porsche and Toyota would be able to arrive at that 8MJ target in year two, but they did, leaving Audi to catch up with its diesel.

Level pegging

Once Audi withdrew from the WEC in 2016 there were only the gasoline-powered cars from Toyota and Porsche left, and so the Appendix B table, which outlined the EoT, was effectively redundant. Both cars were running in the 8MJ class, and only the ByKolles and Rebellion teams were running to the non-hybrid column of the rules. There was no possibility of the private teams competing with the major manufacturers and their enormous testing and simulation

Toyota dominated the first round of the 2018/19 WEC at Spa and was able to cruise to the flag under team orders. It's hoped this won't be repeated at Le Mans

When Porsche withdrew at the end of the 2017 season, suddenly the EoT came back into the frame

capability, and so there was a separate class for privateers. But once Porsche withdrew at the end of 2017, suddenly the EoT came back into the frame, and it required a lot of tinkering.

From the original engineers that included Alex Hitzinger (Porsche), Ricardo Divila (Nissan), Ulrich Baretzky (Audi) and Pascal Vasselon (Toyota), along with Bernard Niclot of the FIA, only Vasselon was left. At the FIA Gilles Simon took over from Niclot. At the ACO Thierry Bouvet is still in charge, while Denis Chevrier has left.

This new team also faced a new issue, in that the EoT now needed a further imbalance in order to bring the non-hybrid cars into the same performance window as hybrids. Toyota hardly developed its TS050 between 2017 and 2018, concentrating on battery technology and the removal of the air conditioning system for cooling it, and so brought to the circuit essentially the same racecar. The FIA and ACO therefore used this as the reference, and then tried to balance up the privateer LMP1 cars to give them a chance to compete.

Promoting privates

'The EoT is here to achieve the targets that the endurance commission have set,' says the ACO's sporting director, Vincent Beaumesnil. 'We have two different cars with two different technical rules. We have the hybrid, so this is the reference car for performance as it is nearly the same as last year. The issue is that the others have new cars. We have never seen them on track before, [they have] new engines, new teams, everything is new, and it is private teams, so the technical ability is good, but a factory team has more.

'When we say that we want to bring these people back into the game and make them competitive, then in the rules we have to give them an advantage,' Beaumesnil adds. 'They have a lighter car, more power from the ICE because they have more fuel, more aero with a bigger diffuser, lower splitter, different end-plates. All of this is a gift that we make to bring them into the game, but when you do that you have to make sure that it doesn't result in them being artificially more competitive through these gifts that we have made.'

The performance target set by the FIA Endurance Commission is to allow hybrid to still be an advantageous technology, while also allowing the private cars from BR Engineering (Dallara), Ginetta and ORECA to compete, and therefore justify the costs associated with running an LMP1 car. These are not insignificant costs, either; to compete in the 2018/19 WEC season, the outlay for a two-car team

Rebellion's ORECAs were the closest of the non-hybrid runners to Toyota, despite their limited mileage prior to the race. Toyota had racked up 25,000km of testing as it prepared for the WEC

No.7 was the faster of the two Toyotas in qualifying but an administrative error put it a lap behind at the start. Yet it still finished in second, a full two laps clear of the chasing pack

with factory support is more than €870,000, including the deposit for the Total fuel.

The 2018 EoT targeted, therefore, a technical imbalance for the hybrid and non-hybrid cars, based on the 13.6km Le Mans circuit. The targets are that, for the best average of 20 per cent of theoretical green flag laps in the race, the non-hybrid lap times are more than half a second adrift of the hybrid cars, that the hybrid cars complete one lap more per stint, and that they refuel five seconds faster than the non-hybrids.

'Clearly, I don't believe that by this you take the people out of the game to win at Le Mans, but we need to have this margin to ensure that it's not an unfair advantage,' says Beaumesnil. 'The endurance commission ask that we promote hybrid. So, we need to show that the performance is close, there is a small gap, and a hybrid car has better economy. But, a hybrid can do 14 laps, and we have taken out three laps in order to close the gap to the privateers. They are going to put around 35kg [of fuel] in at each pit stop while the others put in almost double. In the end, there will be five seconds in the refuelling time [due to the different refuelling restrictor sizes]. It should be more than this in reality. We wanted to have this gap for people to understand that they put less fuel in the car, and they have better fuel economy.

'The reality is that a hybrid car will have almost half the fuel consumption compared to a non-hybrid car,' Beaumesnil adds. 'People need to understand that. We could not reduce this to zero, or the hybrid message is destroyed.'

The number crunch

But did they get the sums right? At Spa, the opening round of the WEC in May, we had our first chance to see. The No.8 Toyota started from pole position with a gap of 1.463s over the second placed Rebellion (the No.7 Toyota was actually faster, but an admin error surrounding the fuel flow meter meant that it had its times cancelled and it started from the pit lane, and one lap down). Could anything be read into this time? Clearly not, as Stephane Sarrazin stopped his BR1 early in the session, bringing out a red flag, and later Pietro Fittipaldi crashed his BR1 at Raidillon, causing another red flag.

This meant that the heat cycle of the tyres was hardly optimal; Rebellion's Neel Jani had to complete almost an entire lap at 80km/h returning to the pits, by which time his Michelins were clearly confused as to what they were supposed to be doing.

Come the race things were at least representative. Track temperature started at 21degC and rose to 32degC around three-quarter distance, finishing at 28degC. Air temperature fluctuated between 20 and almost 23degC and it was dry throughout.

The No.8 Toyota started from pole, but needed a rear wing change as driver Fernando Alonso complained of an aero imbalance. Under new regulations, this change of rear wing can be completed at the same time as refuelling and so Toyota took the chance to work on the car while it was being replenished, without a time penalty. However, that imbalance returned at the end of the race, allowing the recovering sister car (No.7) of Mike Conway to close up to within half a second before the final pit stop. That completed the recovery drive; both hybrids finished two laps clear of the non-hybrid cars, one pegged back by the safety cars mid-race, the other helped by those same safety cars.

Going with the flow

At Spa, compared to the same race in 2017, the only change to Toyota was a reduction in max fuel flow, down from 80.2kg/h to 80kg/h, and a reduction in petrol per stint, from 44.1kg to 35.1kg. For the non-hybrids, they had a decrease in maximum petrol energy, from 116MJ/lap to 106.4MJ/lap, although the non-turbo engines required a lift off the throttle to avoid using more fuel than was permitted per lap. Non-

The performance target set by the FIA Endurance Commission is to allow hybrid to still be an advantageous technology

Spa WEC LMP1 laps

Pos.	No.	Car	Laps	Best Lap		Average best laps (20 per cent of green)		Average best laps (60 per cent of all)		Top speed (km/h)
1	8	Toyota Hybrid	163	1m 57.805s	0.31%	1m 58.965s	0.27%	1m 59.918s	0.21%	321
2	7	Toyota Hybrid	163	1m 57.442s	0.00%	1m 58.642s	0.00%	1m 59.669s	0.00%	318
3	1	Rebellion-Gibson	161	1m 59.027s	1.35%	2m 00.146s	1.27%	2m 01.397s	1.44%	317
4	3	Rebellion-Gibson	161	1m 58.820s	1.17%	1m 59.985s	1.13%	2m 01.711s	1.71%	319
5	4	ENSO CLM-Nismo	158	2m 01.768s	3.68%	2m 03.147s	3.80%	2m 04.138s	3.73%	316
6	11	BR1-AER	158	2m 01.991s	3.87%	2m 02.961s	3.64%	2m 04.165s	3.76%	323


brembo

‘The reality is that a hybrid LMP1 car will have almost half the fuel consumption compared to a non-hybrid LMP1 car’

hybrids also had a reduction in petrol flow, from 115kg/h to 110kg/h, and saw petrol per stint drop from 53.2kg to 47.1kg.

What of the performance, then? The No.7 Toyota set a fastest lap of 1m57.442s, more than 1.1 per cent better than the fastest non-hybrid car, the No.3 Rebellion ORECA of Mathias Beche, Thomas Laurent and Gustavo Menezes, which set a one-off fastest lap of 1m58.820s. However, the EoT is more concerned with the best average 20 per cent of green flag laps, and here the gap is slightly reduced. Again, the No.7 Toyota was the fastest, with an average of 1m58.642s, compared to the No.8 at 1m58.965s. The No.3 Rebellion was 1.13 per cent slower, with a 1m59.985s, the No.1, 2m00.146s. This, clearly, is more than the targeted half second gap between hybrid and non-hybrid.

A point to note is that the No.7 Toyota was fastest in sector 1, including the long Kemmel Straight, while No.8 was fastest in the final sector, including the run from Stavelot to the start/finish. The Rebellions were comparatively fast through the second sector, even though all were running low downforce. Top speeds indicate that the Rebellion was down on the Toyota and the BR cars, too, so we will have to see how far Rebellion can trim its car at Le Mans.

The EoT now limits the amount of fuel available for a racecar during a stint, which helps to limit the distance that a car can travel. Under green flag conditions at Spa, that allowed for 19 laps for a hybrid car and 17 laps for a non-hybrid car. At Le Mans, the hybrid cars will do 11 laps, the non-hybrid 10 laps. These are green flag laps; a slow zone will increase mileage.

Ginetta’s G60-LT-P1 remains an unknown quantity having failed to complete a competitive lap at the Spa round of the WEC

Pit stop times

Another topic to look at is the pit stop times. The non-hybrids are supposed to be five seconds slower in refuelling, but both Rebellions spent significantly more time in the pits. The winning car spent 8m18.195s in the pits during the six-hour race, compared to the sister car that spent 7m33.666s, including 10 extra seconds in the final pit stop, presumably as part of the team

Spa WEC LMP1 pit stops

Pos.	No.	Car	No. of stops	Total pit time	Stop 1	Stop 2	Stop 3	Stop 4	Stop 5	Stop 6	Stop 7	Stop 8	Stop 9	Stop 10
1	8	Toyota TS050 Hybrid	9	8m 18.195s	54.492	54.801	01:03.729	01:02.659	49.822	56.348	56.615	01:00.894	38.835	
2	7	Toyota TS050 Hybrid	8	7m 33.666s	56.057	55.586	01:01.134	59.288	58.547	55.851	58.458	48.745		
3	1	Rebellion R13 Gibson	9	11m 03.019s	01:04.267	59.099	01:03.889	01:15.411	01:03.743	02:39.663	01:14.543	47.883	54.521	
4	3	Rebellion R13 Gibson	9	9m 59.952s	01:06.822	01:24.481	01:06.256	01:07.147	01:06.254	01:05.299	01:09.911	01:06.121	47.661	
5	4	ENSO CLM P1/01 Nismo	10	10m 44.408s	01:26.183	56.675	01:27.632	35.169	01:07.273	01:06.157	01:05.912	01:09.552	01:06.553	43.302
6	11	BR Engineering BR1 AER	10	12m 06.839s	43.400	01:06.060	01:08.658	02:00.668	01:07.020	01:36.988	01:12.076	01:23.725	01:12.793	35.451

Spa WEC LMP1 stints

Pos.	No.	Car	No of stints	Laps longest stint	Laps longest green stint	Laps stint one*	Laps stint two	Laps stint three	Laps stint four	Laps stint five	Laps stint six	Laps stint seven	Laps stint eight	Laps stint nine	Laps stint ten	Laps stint eleven
1	8	Toyota TS050 Hybrid	10	20	19	18	16	20	19	1	19	19	19	20	12	
2	7	Toyota TS050 Hybrid	9	21	19	20	13	20	19	19	19	19	21	13		
3	1	Rebellion R13 Gibson	10	19	17	18	16	19	18	17	17	17	9	19	11	
4	3	Rebellion R13 Gibson	10	18	17	17	18	24	7	17	17	14	19	17	7	
5	4	ENSO CLM P1/01 Nismo	11	19	17	18	15	19	9	9	16	17	17	18	17	2
6	11	BR Engineering BR1 AER	11	22	17	4	17	22	9	18	17	16	17	20	16	2

Formation lap not included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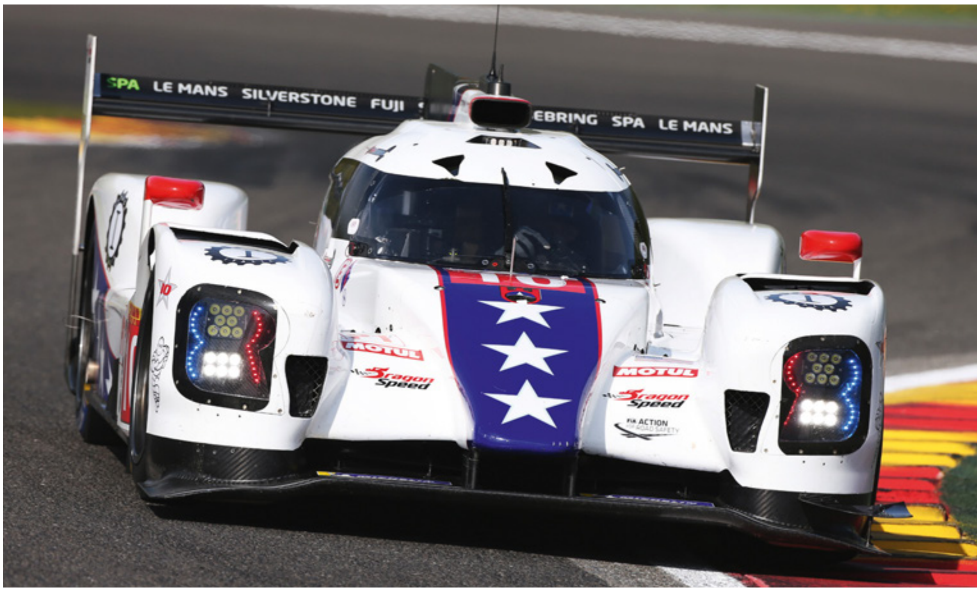
Teams should spend a few extra seconds in the pits strapping drivers in



BR Engineering had a tough start to the season with the Dragonspeed car crashing in qualifying and SMP having a car take to the air at Raidillon. FIA investigations into the circumstances of the latter accident were ongoing at the time of writing

orders that were enforced to ensure that the two TS050s did not race each other on track and maintained position to the chequered flag. The No.7 car had one fewer stop, eight compared to nine for the sister car, and both Rebellions.

By comparison, the best Rebellion spent 9m59s in the pits, but leaked time at every stop. 'Headmaster's report would read; could do better,' said team manager Bart Hayden. One of the issues that affected it was the change in regulation regarding tyre changes during refuelling, and how it subsequently worked the driver change assist; having to change the pit stop routine with the mechanic coming in from the other side to the previous approach to get out of the way of the tyre changer.

Belt and braces

According to one estimate, it takes 26s to change driver, 23s to refuel, and the tyre change is the fastest part of the stop. When Kazuki Nakajima exited the pits he was immediately on the radio complaining of an issue between his legs, according to the team. He made a quick pit stop, of 49s from pit in to pit out, to have the belts 'adjusted.' There's no reason to think this was anything more than that, an adjustment, but it does point to the fact that pressure will be on when it comes to strapping drivers in, and this is not really something that should be rushed. Maybe teams should simply spend a few extra seconds in the pits strapping their drivers in, as the penalty for not doing it properly could be catastrophic at Le Mans.

'Now the tyre allocation is defined by the rules and we have all the data,' says Beaumesnil. 'We don't need anymore to have this long pit stop, and three guys not moving for 30 seconds, and one gun. We needed to think about the quality of the show for the fans, promote action and [make it] attractive for television, so that has to form part of the decisions that we make.'

LMP2 threat?

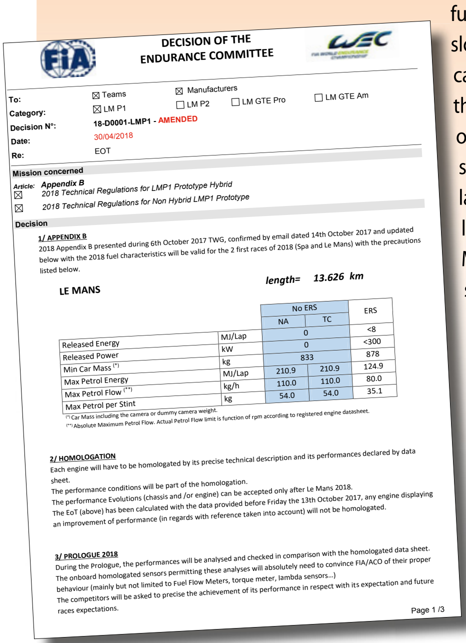
Tyre allocation at Le Mans is 28 for practice, qualifying and warm up, 48 for the race for both hybrid and non-hybrid LMP1 cars. Interestingly, for LMP2 cars, they have two extra sets for the race, 56 tyres in total. Given that they will be closer in pace, it could be that an LMP2 car is up with the LMP1s in the first half of the race.

Post Le Mans, a new Appendix B will be issued. This will be calculated for the LMP1 non-hybrid cars on the basis of the performance of the best cars of each engine technology (normally aspirated and turbocharged), and the analysis of Brake Specific Fuel Consumption of engines. It will take into account the average particularity of WEC tracks, with a formula slightly more weighted than in 2017 towards hybrid, to maintain its advantage.

Statement of intent

In the run up to the opening round of the WEC there was much discussion over how much of a 'gift' had been given to the non-hybrid cars. Mid-race, and one engineer concluded: 'We look stupid, the amount of time that we spent discussing this issue.'

A document circulated to teams prior to the race featured a new EoT and an explanation of various issues that may arise.



DECISION OF THE ENDURANCE COMMITTEE

To:	☒ Teams	☒ Manufacturers		
Category:	☒ LM P1	☐ LM P2	☐ LM GTE Pro	☐ LM GTE Am
Decision N°:	18-D0001-LMP1 - AMENDED			
Date:	30/04/2018			
Re:	EOT			

Mission concerned

Article: ***Appendix B***

☒ *2018 Technical Regulations for LMP1 Prototype Hybrid*

☒ *2018 Technical Regulations for Non Hybrid LMP1 Prototype*

Decision

1/ APPENDIX B

2018 Appendix B presented during 6th October 2017 TWG, confirmed by email dated 14th October 2017 and updated below with the 2018 fuel characteristics will be valid for the 2 first races of 2018 (Spa and Le Mans) with the precautions listed below.

LE MANS *length= 13.626 km*

		No ERS		ERS
		NA	TC	
Released Energy	MJ/Lap	0		<8
Released Power	kW	0		<300
Min Car Mass (*)	kg	833		878
Max Petrol Energy	MJ/Lap	210.9	210.9	124.9
Max Petrol Flow (**)	kg/h	110.0	110.0	80.0
Max Petrol per Stint	kg	54.0	54.0	35.1

(*) Car Mass including the camera or dummy camera weight.
(**) Absolute Maximum Petrol Flow. Actual Petrol Flow limit is function of rpm according to registered engine datasheet.

2/ HOMOLOGATION

Each engine will have to be homologated by its precise technical description and its performances declared by data sheet.
The performance conditions will be part of the homologation.
The performance Evolutions (chassis and /or engine) can be accepted only after Le Mans 2018.
The EoT (above) has been calculated with the data provided before Friday the 13th October 2017, any engine displaying an improvement of performance (in regards with reference taken into account) will not be homologated.

3/ PROLOGUE 2018

During the Prologue, the performances will be analysed and checked in comparison with the homologated data sheet.
The onboard homologated sensors permitting these analyses will absolutely need to convince FIA/ACO of their proper behaviour (mainly but not limited to Fuel Flow Meters, torque meter, lambda sensors…)
The competitors will be asked to precise the achievement of its performance in respect with its expectation and future races expectations.

Page 1 /3

In this document issued before the Spa race the FIA implied that it would not hesitate to slow the non-hybrid cars if they proved to be too quick

In it the FIA threatened that it could adjust the performance of the non-hybrids by adding 20kg of ballast, reducing the maximum fuel flow and 'any other adjustments required if necessary.' The implication was that a non-hybrid would be slowed if it proved to be too fast.

'In terms of stint length, in any case, the maximum number of 'green' laps (without safety car, full course yellow, or slow zone (s) while the car is not in the pits – this is not depending on track conditions) should not exceed 11 laps for LMP1H and 10 laps for LMP1NH in Le Mans 2018…' read the statement. This led the privateer teams to run for their calculators.

In the race each managed to complete their maximum 17 laps, compared to 19 for Toyota.

However, there was a further threat to non-hybrid teams. 'If a LMP1NH car is faster than its expected performance relative to the best LMP1H or is not capable to provide proper data from the homologated sensors it will be subject to a penalty applicable during the race at steward's discretion. This penalty may consist in the reduction of fuel allocation for the remainder of the race.' At stewards' discretion, a stop/go penalty may be applied.

H-bomb

The statement continues: 'The performance of each LMP1H and LMP1NH will be calculated by doing the average of best 20 per cent theoretical lap times on a number of laps corresponding to 20 per cent of the race distance.' Anyone hiding performance would have a tough job keeping that under control. But the implication was clear; if the non-hybrid cars were too fast, they would be slowed. There was nothing in the document to suggest that, if they were too slow, they would have their speed increased.

These are new teams, with new racecars and new technology. The gap in performance at Le Mans should be closer, but is it within the range expected by the ACO, or will Toyota have an easy run to the chequered flag, able early on to protect a lap lead thanks to Appendix B, and team orders?

TECH SPEC

Haas VF-18

Chassis: Carbon fibre and honeycomb composite structure manufactured by Dallara.

Power unit: Ferrari 062 EVO, turbocharged 1.6-litre V6; direct injection; max speed 15,000rpm. MGU-H and MGU-K in a compounded layout.

Transmission: Ferrari servo-controlled hydraulic limited-slip differential; semi-automatic sequential and electronically-controlled gearbox with quickshift (eight gears, plus reverse).

Suspension: Ferrari double wishbone pushrod actuated (front) and pullrod actuated (rear) torsion bars with ZF Sachs dampers.

Steering: Ferrari.

Clutch: AP Racing.

Brake System: Carbon-carbon with Brembo 6-piston calipers.

Cockpit Instrumentation: Ferrari.

Seatbelts: Sabelt.

Wheels: OZ Racing.

Tyres: Pirelli P Zero.

Fuel Cell: ATL.

Weight: 733kg (including driver).

‘The first car was ultra conservative, the second less so, and this one even less so again’

This is only the third year that the Haas team has been competing in F1, yet as the European portion of the 2018 season began it found itself in sixth position in the constructors’ championship with one of its two cars a regular points finisher.

This strong performance, which began in winter testing, has prompted some to claim that the car is a mere copy of last year’s Ferrari. But Haas say this is far from the truth, and while it does source much of its car from the

American independence

If one team is punching above its weight in Formula 1 this season it's third-year outfit Haas. But is there more to the US car's impressive pace than just a huge dollop of Ferrari DNA? *Racecar* took a very close look at the VF-18 to find out

By SAM COLLINS

Compare and contrast: the Haas VF-18 is followed by the Ferrari SF71H. While the similarities are clear there is much that is different under the skin, Haas insists

Italian manufacturer – including its complete suspension system, power unit and transmission – the chassis and aerodynamic package is the work of a joint team of Dallara and Haas engineers, headed by Englishman Rob Taylor.

Cool concept

The VF-18, as the 2018 Haas is called, is different from its predecessor, the VF-17, in a number of ways, and this is most notable in the cooling system, which has been significantly revised. Like almost every car on the grid the Haas features a centreline cooling layout, which interestingly is something that did not feature on the 2017 Ferrari until the latter part of last season. For Haas this layout is partly for aerodynamic reasons, but also partly due to the design of the 2018 Ferrari gearbox.

'The addition of the centre cooler, to some extent, is a reaction to the basic model we have from our drivetrain supplier, and in other ways it is down to creating the best cooling layout,' Taylor says. 'This year the plumbing came out of the top of the gearbox rather than out of the side. We could have had the coolers in the side of the car, but the plumbing layout defined by the transmission suggested we do otherwise.'

This shift sees a set of coolers mounted above the gearbox bellhousing, fed by inlets on the roll hoop either side of the main engine air intake duct. 'What you have got above the gearbox is, strangely, the gearbox cooler,' says Taylor. 'It's not that alone, though, there is a

Relocating coolers to the centre of the VF-18 has allowed Haas to adopt the sidepod concept that was introduced by Ferrari in 2017

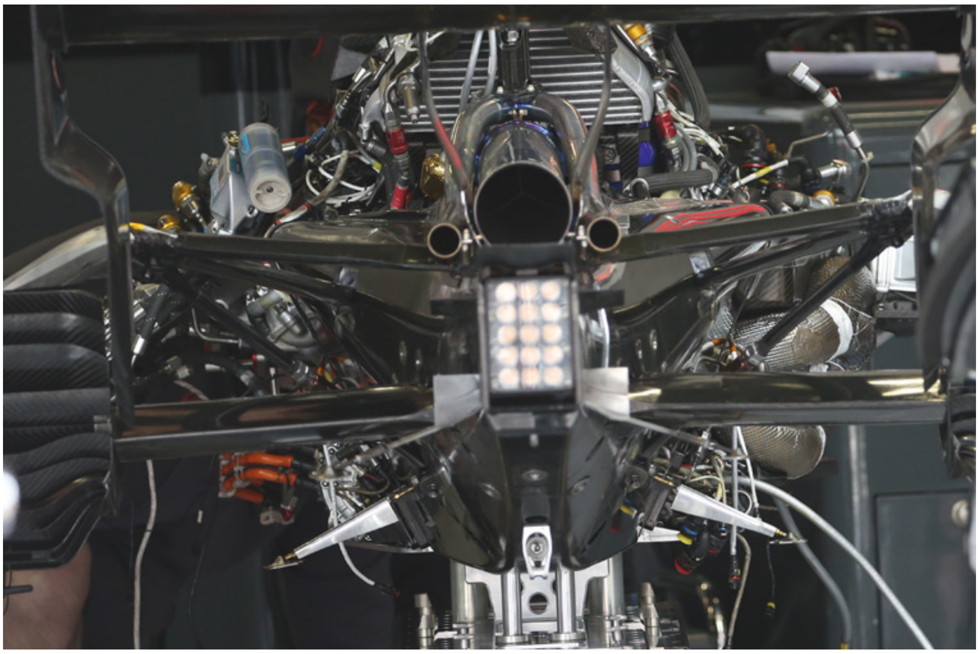
hydraulic cooler along with part of the MGU-K cooling system. A lot of that was to do with a symmetry of the system, so you move one thing to keep the two sides of the car symmetrical. Some of it is driven by a change of requirements, too, so we had to change our approach to the hydraulic cooler, for example. It is a tiny little cooler which you don't really want to tag on to the side of the car. So that is usually run on a duct on its own, but this year we have ended up with a gearbox cooler and a hydraulic cooler together, that is because we knew we were going to bleed air off the ears on the roll hoop, so it lets us be quite symmetrical and give us a good distribution of wealth really. The plumbing forced us one way, the temperature limit had an impact, too, so we thought that while we were making a duct in the engine cover we might as well put another cooler up there.'

While this approach of feeding coolers from the roll hoop is now almost universal in F1 it remains something of a compromise.' Of course it raises the centre of gravity, but there are a lot of choices we make in terms of packaging; things like minimising the width and elongating the coolers, letting us squash the coke bottle area at the rear of the car a bit more, for example,' Taylor says. 'You have to make these trade-offs, you would not out of choice put stuff with a lot of parasitic weight up there. Heat exchangers in themselves are not particularly a lightweight solution, but an air-to-liquid cooler looks quite dense and bulky but it is really just a lot of perforated aluminium. It's very thin aluminium as you need the heat transfer through it. As a compromise, it's not that bad.'

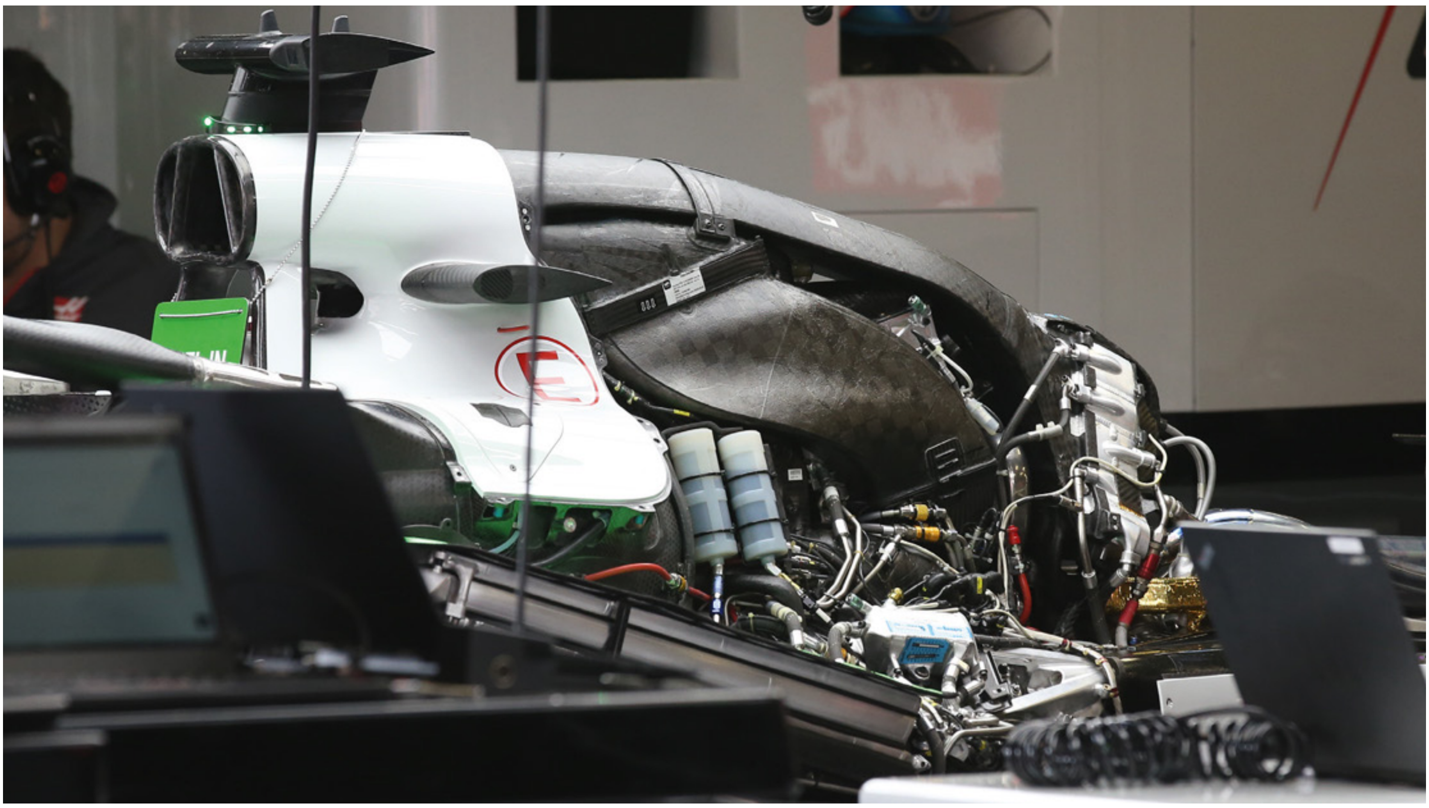
Game of clones

Relocating coolers to the centre of the car has allowed Haas to adopt the sidepod concept introduced by Ferrari in 2017 with a shorter pod, and a complex arrangement of parts to ensure it meets the technical regulations, as well as works well aerodynamically. Some teams who have not adopted this concept (notably Mercedes) have questioned the potential benefits of it.

'We run it; we believe it to be better,' Taylor says. 'But could I hand on heart tell you what that part of the package delivers? Probably not. It is buried in a pile of other aero testing results. We do a test and it delivers a result way above



The VF-18 uses Ferrari's composite transmission and its hybrid power unit. The centreline cooler can be clearly seen here



Haas is proud of its cooling package, although the extra cooler above the bellhousing does raise the centre of gravity. VF-18 retains the sideways V-shaped cooler layout of the VF-17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‘In terms of plumbing the car it is a lot nicer. I wouldn’t say it is more elegant, but it is just easier to use, a more thoughtful package’

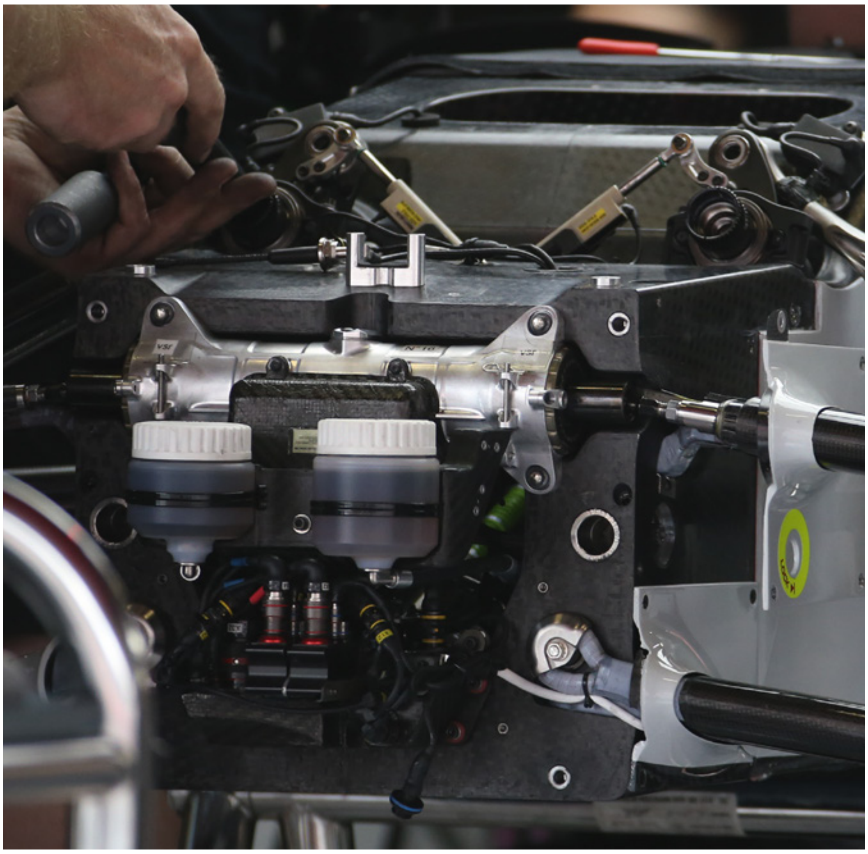
The Halo effect

The 2018 technical regulations give teams a 20mm area of freedom around the Halo and most have exploited this with stacks of winglets sited on the upper surface of the titanium structure. Haas, though, has gone its own way with an array of vortex generators on the upper and lower edge of the structure. However, in Barcelona the team did experiment with some winglets similar to the type used by its rivals.

‘It is a subtle aerodynamic area,’ Ron Taylor says. ‘With the vortex generators we were looking at wake structures. The winglets we tried in Barcelona were perhaps a little bit better performing in terms of car speed, but not as good in terms of wake, and our major concern was to do with wake on to the engine inlet. But it is all very subtle in terms of aerodynamic effect.’

The the upper and lower edges of the Halo structure on the VF-18 are adorned with arrays of vortex generators

At the Spanish GP Haas experimented with winglets on the Halo, an approach that’s employed by most of its F1 rivals



Front bulkhead. The suspension comes from Ferrari as does the braking system, but the tub is built by Dallara

the noise you get running in a wind tunnel, therefore it gets adopted. Then the guys who are responsible for it refine it, they do a lot of CFD work to find small gains. But truly we made the decisions at a fairly immature state of play, we chose to put that pod inlet on, looked at the implications and committed to it because it showed promise. But the implications then were that it could not then be taken off.’

Impact structure

One of the major challenges with introducing such a layout is that it requires the upper side impact structure to be relocated, something which is not only difficult but also has a weight penalty. ‘Moving those crash tubes was a key part of the chassis and it would be very difficult to reverse that,’ Taylor says. ‘We moved the upper crash tube, side impact structure, so the requirements of the chassis cockpit rim are increased so there is more weight in the cockpit rim to allow us to move the crash tube down. It’s all about the aerodynamic gains though.’

Indeed, the complexity of manufacturing this part of the car has proven to be something of a headache for Haas after a number of accidents has resulted in damage in that region. ‘What was once just a moulded component, the whole pod inlet which bonded on the side of the chassis was two pieces, this year it’s nine, I think,’ Taylor says. ‘You have to bond those all together then bond them on to the chassis.’

Under the bodywork the VF-18 retains the sideways V shaped cooler layout seen on the VF-16 and VF-17, something which was also a feature of the 2016 and 2017 Ferrari designs, but was then dropped for 2018. ‘We call it the ‘V-rad’ and we are fond of it,’ Taylor says. ‘It has its moments, it is a bit of a plumber’s nightmare, but it also has its advantages. We believe in it, and it’s good in terms of packaging.

‘You might not hear about cooling issues on our car, but it is one of the more challenging things in terms of designing and operating it,’ Taylor adds. ‘To balance the multiple cooling circuits, you need the cooling of the ERS and the intercoolers, engine, transmission and all the other bits, to all work together. Bearing in mind that they have quite different parameters and requirements and they deliver their energy to the coolant at different parts of the track, balancing all of those is bloody difficult. It’s very rare that we get it spot on first time out. For example, that centre cooler, I think we are on our third iteration, you might not be able to see it, but we are. The only way to tell is to look at the welds on the side, it is very subtle. It’s a triangular cooler with a lot of tubes, and we have redistributed those tubes from one circuit to another to re-balance the heat rejection.’

Neatly packaged

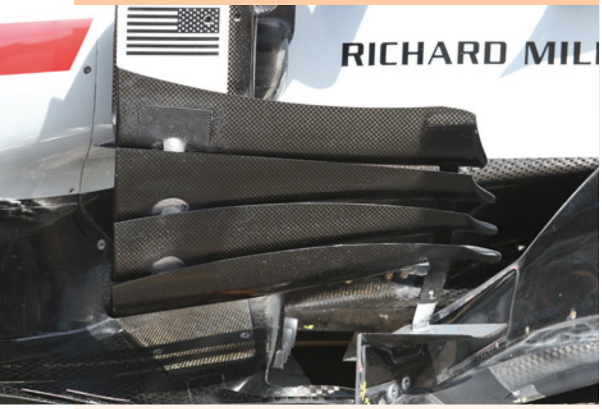
Despite the increased complexity of the cooling system overall, Taylor is particularly proud of its installation and functionality. ‘The integration of the car, when you peel the bodywork back and the various heat shields and other stuff, you see that the integration is really good. We have put more coolers in but the whole assembly is probably lighter. The guys in the design office

The nose of the VF-18 is largely carried over from the VF-17; though Haas has optimised it and it is now said to be lighter

Venetian blinds

Taylor highlights an array of components on the outer leading edge of the sidepods as the VF-18's weakest design element. 'While on the car there is nothing I can point to as the Achilles' heel, there are a few parts I think we could have done better,' he says. 'One thing I don't like is the 'Venetian blinds' in front of the sidepod entry, they are a little bit too complex for the benefit [they give]. They cause us a lot of structural issues, it's a lot of parts, with a lot of slots and features, but with a rather unhelpful load path.

'Aerodynamic things usually tend to be unhelpful in terms of their load paths and structural integrity, so you are always trying to balance the want of the aerodynamicists against the want of the stucture guys,' Taylor adds. 'On this component there is the linkage down to the bargeboard, and the load path that it carries. The aerodynamicists don't want the two aligned, but that means from a structural point of view you have an offset load there. It means you are putting the thing into bending rather than tension and compression. Sadly, there have been problems with that little Venetian blind thing, it has always been a casualty, and at other times it has been an innocent bystander as it is reasonably fragile. Whether they are the culprit or the bystander, they always end up getting hurt.'



The 'Venetian blind' aerodynamic arrangement that's situated at the front of the VF-18's sidepods is very complicated, while it is also quite easily damaged in the event of a racing incident

have done a really nice job there. It's not just how it works but in terms of plumbing the car it is a lot nicer, it's easier for the guys at the track to get all the Wiggins clips in place, it is easier to do the bleeding. In the garage it is easier to get the heating system on before you start the car. I would not say it is more elegant but it is just easier to use, a more thoughtful package.'

Weighty issues

With the cooling system raising the centre of gravity somewhat and the new sidepods increasing the overall weight of the chassis, the addition of the AFP-Halo and its inherent increase in mass meant that the overall weight of the VF-18 was a significant focus for the Haas organisation. That was not the only reason, either, Haas' reliance on Ferrari for its suspension and many other car components meant that the VF-18 would have to have an identical wheelbase to the 2018 Ferrari.

'We could change the wheelbase slightly, but to do it much would have meant not being able to use the Ferrari parts,' Taylor says. 'We are constantly concerned with what we are going to end up with because of the choices that are not available to us. That is one of the reasons to push on weight reduction, we don't know how much ballast we are going to need so we have to give ourselves as much freedom as we can.

'We are a bit more free within the window than we were in 2017,' Taylor adds. 'Integrating the Halo into the chassis structure was relatively straightforward in engineering terms. The tricky bit was trying to analyse the load case properly. The Halos ended up turning plastic every time they were loaded, so we ended up scrapping them every time we tested them, and because of it going plastic the distribution of loads as a result was a little unpredictable. We made ourselves a dummy chassis top and bought a Halo and tested it to destruction. We did a lot of physical testing and FE work. It's hard to put a number on it…because we were doing a lot of other things around that area as well, like moving the impact tube, its hard to tease out exactly what the weight increase [because of the Halo] is. Overall, though, the VF-18 is perhaps 3kg lighter in terms of the tub.'

Still learning

According to Taylor, one of the reasons for the weight saving is that Haas is still a new team, and it's still working out the very best way to go about doing things. 'It is down to the maturity of the product, this is the team's third car, the first car was ultra conservative, the second less so and this one even less so again,' he says. 'We are still on the steep bit of the learning curve, and there is more to come.'

An example of this is the roll hoop of the car, which externally looks significantly different to that used on the VF-17, but is really a gentle evolution. 'The aerodynamic wetted surface is quite different but the structure is not,' Taylor says. 'The top radius is a bit smaller but in principle the structural metallic component is an extremely close cousin to what was used in 2017. It is slightly lighter as a result of that growing maturity in the team, better analysis and a slightly different material, along with a different manufacturing technique. If you stuck them both on the table next to each other you would see that they are extremely similar.'

Taylor also highlights another area of the car which is very similar to the VF-17. 'The nose is another example in that it's a gentle improvement on last year, but it is so similar in terms of its shape and wetted surfaces,' he says. 'It is again a bit lighter but it is not one of the things we focussed on, we pushed hard on it in the first year, a bit in the second year, but for this car there were other structural things to focus on, like the cockpit rim, so we spent our analysis budget on those things instead.'

Haas continues to move up the field and its owner, Gene Haas, clearly hopes that he can replicate the success of his Stewart-Haas NASCAR operation, which won its first Cup series in its ninth year after entering the series. If the Formula 1 team continues its rate of improvement would it be too much to suggest that a similar timetable could well be realistic for it to win its first F1 championship?

'We are constantly concerned with what we are going to end up with, because of the choices that are not available to us'

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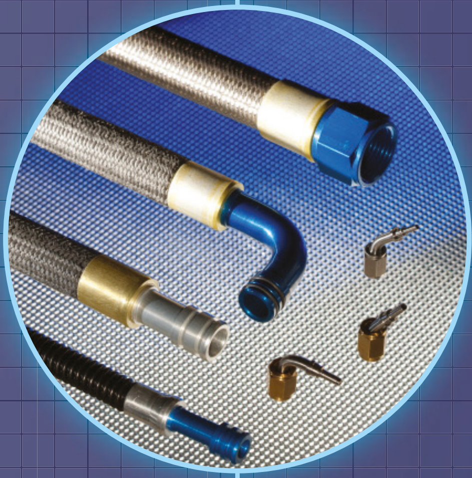

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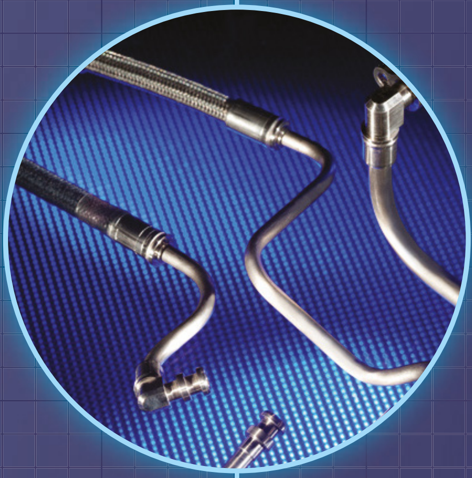

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The two-seater Formula 1 car is based on the Tyrrell 026 chassis from 1998. Mike Gascoyne's MGI Consultancy has been responsible for its recent upgrade

A tale of two seaters

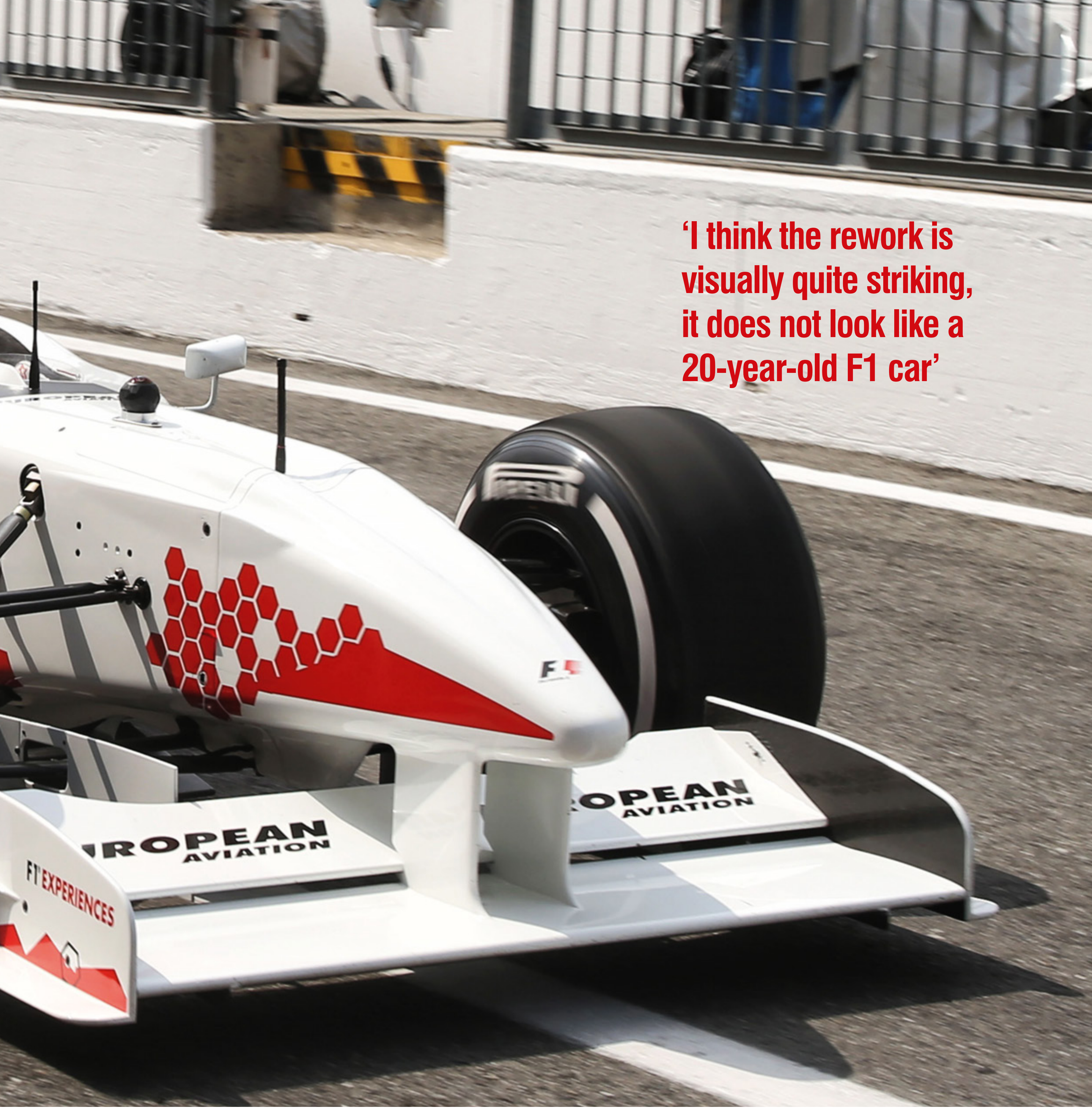
One of Liberty's more welcome initiatives has been the resurrection of the V10-packing F1 two-seater – Mike Gascoyne, the man behind the car's upgrade, spills the beans on this unique race engineering project

By SAM COLLINS

Formula 1's new owner, Liberty, has set out to improve the show and turn every race into a Super Bowl. As a part of this drive the paddock has become less sterile, content is posted on social media and media access has been greatly improved.

But one initiative is very much a case of bringing back something from the past. At a number of races through the season, a couple of times a day over the race weekend, the distinctive, and welcome, sound of a pair of 3-litre V10 engines dating back to 1999 will now be heard all around the circuit.

This is because Paul Stoddart's Minardi two-seater programme has been fully revived for the 2018 season, with VIPs, journalists, celebrities



'I think the rework is visually quite striking, it does not look like a 20-year-old F1 car'

and even paying customers taking part in what is now called the 'F1 Experience'.

However, the cars used are not really Minardis, they are actually based on the 1998 Tyrrell 026, designed by Harvey Poselthwaite and Mike Gascoyne. Stoddart acquired much of what was left of Tyrrell when British American Racing took the team's entry for the 1999 season. He then got a group of engineers to create a two-seater version of the racecar to help promote his European Aviation business. It was a very successful PR exercise, which towards the end actually included a number of Formula 1 two-seater races.

When Stoddart sold his team to Red Bull – it's now the Toro Rosso team – he kept the two-seaters at his facility in Ledbury, England. From time to time they would appear in promotional activities, such as at the Australian GP, but there was no real co-ordinated effort.

Take two

When Liberty took over F1 the two-seater programme was revived in a great hurry, with garage equipment and transporters purchased from the defunct Manor team. Two of the two-seaters were dusted off, given a new livery and rolled out on track. But despite the new stickers and shiny paint the cars looked distinctly dated, having not been updated in 18 years.

It was soon decided that they needed a facelift, and Stoddart engaged Mike Gascoyne's MGI consultancy to carry out the update – actually something of a case of coming full circle for that organisation. 'I was deputy technical director of the 1998 Tyrrell which this car is based on, so I designed the original,' Gascoyne says. 'My company, MGI, did all the update work on it for 2018 too. Interestingly, the two guys who designed the two-seater originally were James East and Sean Briscall, who now work for me at MGI and were involved with this.'

The result was seen for the first time at the 2018 Spanish Grand Prix, the cars featuring a distinctive, larger and more elaborate front wing and a 2018 style swept back rear wing. 'The objective was to make it look contemporary, like a 2018 Formula 1 car, which I think we have

‘This new car has been quite fun from an engineering point of view, as we have been playing with the set-up a lot more’

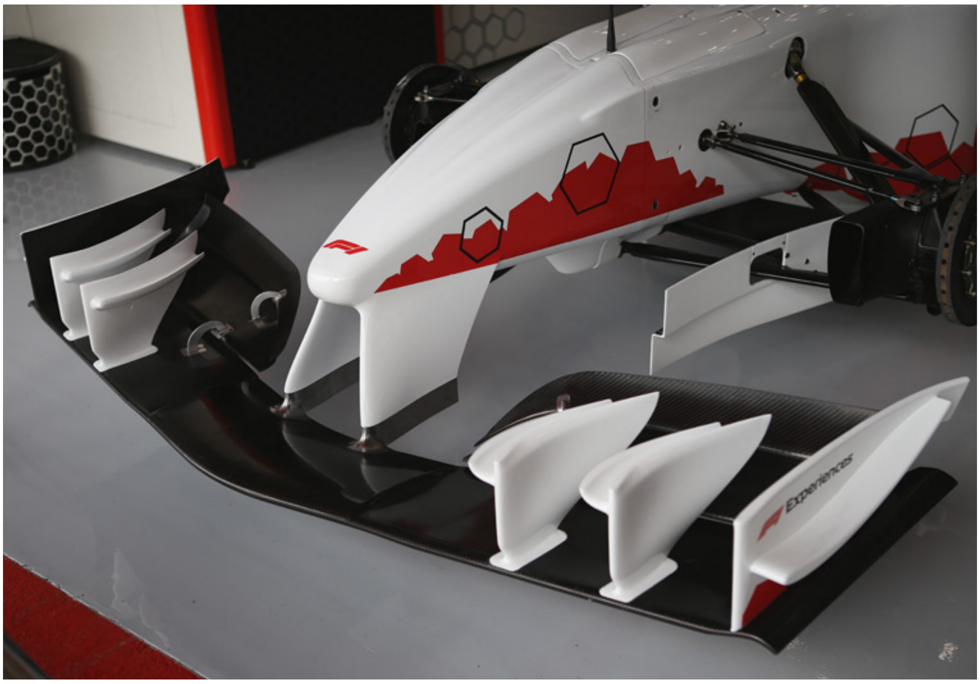
achieved,’ Gascoyne says. ‘I think the rework is visually quite striking, it does not look like a 20-year-old Formula 1 car, and from that point of view we are very pleased with it.’

Two into 1

Updating the aesthetics of the car has had a knock on in terms of the car’s aerodynamic performance, with an increase in downforce resulting from the new wings. ‘It is obviously a very different front wing, much wider with the neutral central section, that allows the diffuser to work much better and it improves the cooling,’ Gascoyne says. ‘So actually we have got a car with more downforce, better cooling and it’s better on its tyres. From the driver feedback point of view we are pleased as they say that there is a lot more grip. We were obviously not going to go to the wind tunnel and spend six months developing it. We laid it out in CAD and did some CFD on it, we also did CFD on the original package so we had a comparison.

‘One thing in that respect we are really proud of is that we are running the wing we predicted in CFD, with just one hole of adjustment for balance,’ Gascoyne adds. ‘We expected a slight understeer balance, which is a safe way to start, and we went up one hole and the car is now pretty neutral.’

But increasing grip and aerodynamic performance in general has little benefit for a car for which the sole purpose is showing a good time to whoever is in the back seat. ‘In some ways that is all kind of irrelevant, as they are quick enough for the passengers, but the drivers are happy with it, which from an engineering point of view is very good,’ Gascoyne says. ‘Part of making it a good experience for the passengers is to make the car easy for the drivers to drive, so they have the confidence in it and it is not twitchy. We are working at the track on the balance, and the priority is to give that good experience, and that comes from the driver being able to drive it.’

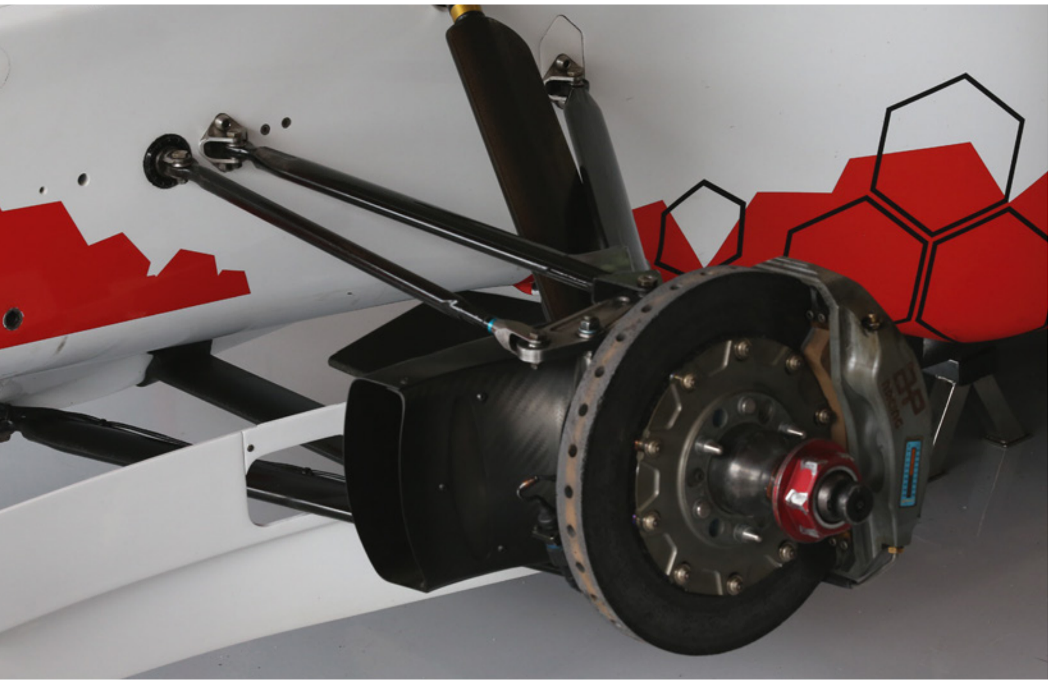


A modern style swept back front wing was introduced for aesthetic reasons but it’s also provided an increase in downforce

Uber-taxi

The updated car also has more scope for adjustment from track to track. While the two-seaters will not tackle Monaco they will have to run at low grip low speed tracks like the Hungaroring, and also at more high speed venues such as Spa and Monza.

‘In terms of changing track to track we would previously change the ratios to give the best end of straight speed, and the cars would typically run at maximum downforce,’ Gascoyne says. ‘Now, with the new aerodynamic package we will play with it a lot more and tune it from circuit to circuit. That makes it more interesting from a team point of view. We have been playing with the set-up, we found we could back off the rear wing a lot to improve straightline speed. This new car has been quite fun from an engineering point of view as we have been playing with the set-up a lot more.’



Carbon-carbon Hitco brakes are from the Tyrrell 026 base car. Wear is not an issue as the passenger rides are quite short

Ticket to ride

With a two-seater ride the centrepiece of a $27,500 (per person) Paddock Club package, a secondary aim was to increase the size of the passenger compartment of the car in order to be able to accommodate as many different sizes and shapes as possible, essentially maximising the potential customer base.

‘It’s a stretched version of the 026, the moulds had to be extended and new moulds made so it is a bespoke tub not a converted former racecar,’ Gascoyne says. ‘But in general terms it has the same rear end and the same front end as the 026. Behind the driver there is an additional bulkhead. So the passenger sits on what is the old rear bulkhead because the fuel system is essentially the same, and the rear bulkhead has not changed. The car is stretched

'The two-seater only runs very small fuel loads so even with two people aboard it is way lighter than a current F1 car'

from that bulkhead forwards. Then there is the seat back bulkhead for the driver and that is fully structural with a full roll over structure. The structure between the driver and passenger takes the full roll over test. This means that the passenger is really very well protected as he has the original roll hoop behind him and the additional structure in front.

'But when the original design was done in about 1999 it was pretty conservative in terms of the load criteria for the middle bulkhead,' Gascoyne adds. 'With advances in composites and FEA we have been able to take a lot of structure out of that bulkhead which does not compromise its ability to meet the structural requirements and pass the roll hoop tests. As building new tubs was not really commercially viable we have modified two of the original two-seater monocoques substantially to the new specification. We have been able to take out a lot of material and that has allowed us to increase the space for the passenger.'

Blast from the past

Mechanically, the car is much as it was when the two-seaters rolled for the first time almost two decades ago, something which actually has its advantages. 'The cars are very good in terms of serviceability and reliability, it has run for 20 years and not many cars can claim that,' Gascoyne says. 'From a design point of view it was very good to start with. Due to its age and life there are some clear advantages; it has steel suspension which is much easier to repair and replace. Tyrrell was a very good engineering company and this car is an example of that.

'In terms of weight the biggest increase is the passenger, so around 100kg more than it would have been when you factor in the additional size of the tub,' Gascoyne adds. 'But the car only runs very small fuel loads so even with two people aboard it is way lighter than a current car. The update has not increased the weight at all.'

The brakes have carried over directly from the Tyrrell 026. 'It has a full carbon-carbon brake package,' Gascoyne says. 'Tyrrell was the Hitco works team and to be honest we don't wear the brakes out much so we have a very good supply. The materials used in F1 have not changed too much, while the cooling has changed a lot that is not a big issue for us as we don't overheat brakes as we are not doing race distances. The update allows the drivers to brake a bit deeper with the downforce level, and while they hit the pedal a bit earlier than you would do in a 026 in race trim, they still hit it pretty hard. That is the thing that is most impressive for the passengers.'

A Formula 1 two-seater passenger ride can be purchased as part of a glitzy Paddock Club package, costing a cool $27,500

The European V10 powerplant started life as the Ford Cosworth VJ, the engine that propelled the Stewart-Ford in 1997/98

Perfect 10

Something which has not carried over from the Tyrrell 026 is the engine in the two-seaters. In 1998 the Tyrrells were fitted with the Ford Cosworth JD Zetec R, a 3-litre V10, but the two-seaters are fitted with a slightly different powerplant originally from the same company. The 'European V10' started life as the Ford Cosworth VJ, a 72-degreee V10 which shared its bore and stroke with the JD but was specifically developed for the Stewart-Ford team.

'Basically Paul acquired the rights to the engine, he can make new components to complete engines at his facility in Ledbury,' Gascoyne says. 'The engines all run on the original Pi electronics suite, but that is probably the next thing that would need to be updated, not because it lacks functionality but the funny thing is that you have to run on Windows 98 computers. The electronics system on the car may be old but it is built for a purpose and it does it well. You don't need telemetry, we are not racing, we are not looking for a competitive advantage. A lot of things a new system would give you are entirely irrelevant. It's already capable of running traction control, automatic upshifts, it has launch control, a hand clutch and a fly by wire throttle. It does everything you want it to do. There would be no increase in experience for the passenger by spending money to upgrade it, so we have not done that.'

The cars now look set to stay in F1, as the fan response has been very positive. Not least because of the sound of those V10s.


vehicleSpeed (kph)
4
201
fastestLap
1:49.379
lapTime
12.593
predictedLap
1:50.867
timeSlip
01.488


GPS-AG50

Back to the future

It's a vision of racing's future yet the Espera Sbarro Dilemme EV concept was designed and built using old-school tech and tools, all with the intention of equipping students with solid engineering skills. *Racecar* examines this most unusual piece of coursework

By SAM COLLINS

'We don't use CAD, instead everything is drawn on paper, measurements are made the traditional way and calculations are done without computers'

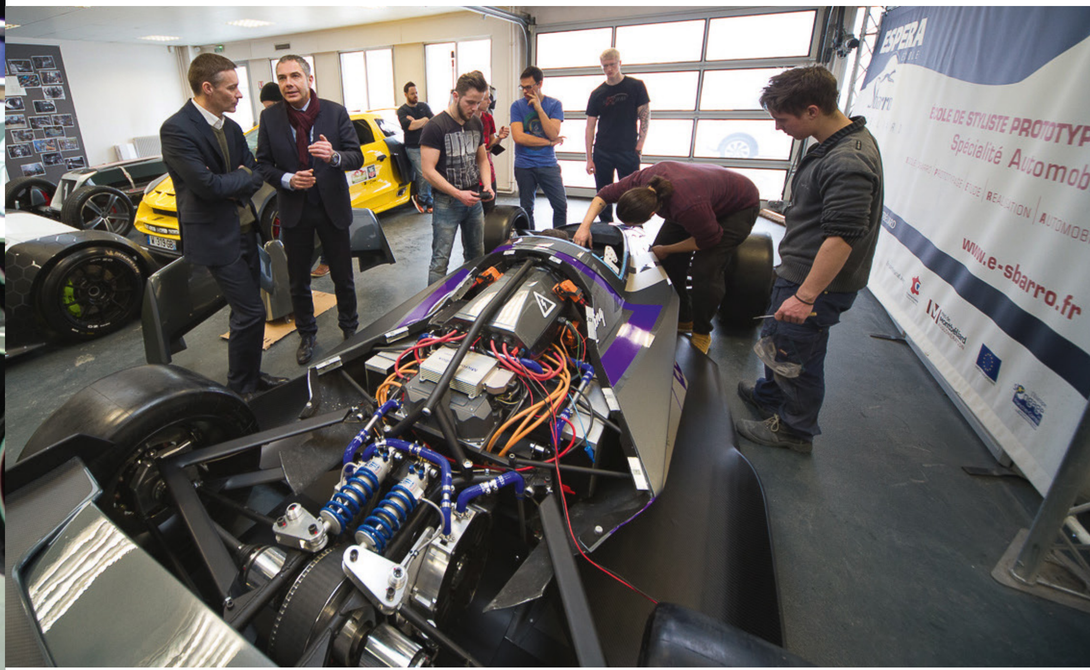
With the motorsport industry seemingly always looking to the future these days, the challenge for a concept is that it needs to be technologically innovative while also appearing futuristic and exciting. It's even more of a challenge if the car needs to be fully functional. One group of students from the west of France have met all these challenges head on with the Espera Sbarro Dilemme, a fully-operational electric racecar that wowed visitors at the Geneva Motor Show earlier this year.

Ecole Espera Sbarro was set up in partnership with Universite de Technologie de Belfort-Montbeliard by Swiss designer Franco Sbarro as an antidote to what he felt was an increasing homogenisation of automotive design as a result of corporate pressures and the rise of CAD. Each year the school takes on a group of students and teaches them the core skills required to not only design a car but to build one from scratch, too. This is then shown at the Geneva Motor Show in February.

'Our teachers at the school set the project, we have some restrictions set by the institution, but it's really only cost and being realistic, and beyond that we were pretty much free,' Moncef Bouroubi, a student at the school explained at the launch of the 2018 car.

'We were not associated with any particular brand so we are not constrained by that and each year the task set is a different type of car. Last year it was a retro racing car, the year before there was a hot rod,' Bouroubi adds. 'So the day

The Dilemme EV is a design exercise and its enclosed cockpit was part of the brief



Power comes from twin motors producing a maximum of 1500Nm of torque. The tubeframe chassis was built from scratch

It's a striking car and the students admit its aesthetics were of more importance than delivering a workable aerodynamic package

they announced the subject for 2018 there were a lot of rumours. We were wondering if it was a muscle car or a truck or something like that. Then I saw these racing slick tyres piled up and realised it would be a competition car, and I was so happy. They went on to explain to us that the car would have to be open wheel, futuristic, electric and have a closed cockpit.'

Class act

Unlike many of the concept cars on display at the Geneva Show the cars produced by the students from Montbeliard have to be fully operational, and they are all tested and run. In one case some years ago an alternatively powered rally car took part in the alternative energy version of the Monte Carlo Rally (Rallye Monte Carlo des Energies Nouvelles), though the 2018 car will only be track tested briefly.

'The idea is that we are not just making a car to look good on a stand at a motor show, we are also building a car which should work on track,' Bouroubi says. 'Instead of just sitting through lessons and reading textbooks we do things in practice, we go for it, that is the philosophy. We do still have traditional learning but the idea is to mix both things and apply what we are learning directly to a real car. Of course, the car has to look nice but it has to be realistic, it has to work, it has to be operational. We don't look to sell the cars, we don't usually put them into competition. The idea is simple, to learn. That gives us the tools personally to move forward in our careers and work on our own projects.'

Perhaps because the unconventional course is the only one of its type in the world it attracts students from a wide range of backgrounds, most of whom have no real knowledge of the automotive industry. 'My background was as an automation engineer, I had never worked on a car before. Then you get set this project and you have 62 days to deliver a completed car, that is a real challenge,' Bouroubi says.

Back to basics

Students with backgrounds in automation or other fields where digital technology is dominant get a real shock when they start the course. In most of the workshops there is barely a digital display to be seen, even in the design suites there are no computers. But for students

Each year the school takes on a group of students and teaches them the core skills required to not only design a car but also to build one

like Bouroubi this is actually quite refreshing. 'We don't do any simulation or anything like this, we have to do it all the old fashioned way, this is to ensure that we understand things from the first principles,' he says. 'We do not even use CAD. Instead everything is drawn on paper, measurements are made the traditional way, and calculations are done without using computers, too. We make wooden mock ups to check things. We sit down and calculate the suspension kinematics, for example, on paper.

'Even the tools we use are old fashioned,' Bouroubi adds. 'We don't use modern CNC or other computer controlled equipment, it is all manual. You have to do it all yourself, using your eye to know when to stop cutting, choosing the speed yourself, it really makes you understand the advantages of the modern equipment and what it can do. It's easy to make a 3D model in CAD, put it into a printer and a little while later your thing is made, doing it like this means you really have to understand what you are doing.'

Charged up

The Dilemme ('Dilemma' in French) is propelled by twin 100kW electric motors, producing a maximum of 1500Nm torque, packing a physically large battery. The car represents what the students see as the future of motor racing, but it was certainly a challenge to design and build this striking looking electric racer.

'The car weighs 960kg, and the batteries are the worst. They account for almost half the weight of the entire car, and take up a huge amount of space,' Bouroubi says. 'The chassis weighs 102kg, we are quite proud of the overall design. We went for the steel frame as we did not have the time or budget for a composite monocoque. Everything you see, [including] the tubular steel chassis is hand made, pretty much. The wheels, tyres, motors are bought in, but everything else has been done from scratch.

'We have done everything from the design to the final touches,' Bouroubi adds. 'There are 22 of us working on the project, half of us work on the mechanical engineering and the other half on the body and styling. Even the suspension system was all designed by us, and almost every component we also made. But we had the dampers and springs made to our specifications by an outside supplier.'

French flair

Understandably, much attention has been paid to the look of this racecar concept, which the students freely admit is really a styling exercise rather than a true aerodynamic package. 'It is that way because we had no facility to test the airflow until the car is built, and as we had heavy snow just as the car was finished we could not then do those tests,' Bouroubi says. 'We know the basics, so we stick to that, but obviously it's just a guess. You can see the wings and there is a big undercut on the side of the car, with the cooling for the motors included into that.'

One of the key design criteria set by the teachers was that this racecar had to be futuristic, they were apparently keen to see what young people thought the future of motor racing might look like, rather than the corporate-led design studies seen to date (such as those produced by Ferrari and McLaren). With this in mind it is interesting and ironic that the car has a number of styling cues reminiscent of older designs. 'Actually, we started by looking back at what had gone before, the 1990 Tyrrell Formula 1 car, for example, that was a beautiful car and a big inspiration,' Bouroubi says.

Closed cockpit

One feature of the car many have commented on was the fully enclosed cockpit, which gave the students a good insight into the challenges of this concept with regard to introducing it into single seater racecar designs. 'When you sit in the car the cockpit does have a bit of visual distortion with the curvature, only a little, but this screen was formed by us and it is not for impact protection,' Bouroubi says. 'When you are in the cockpit it is a little claustrophobic and it can get quite hot even sitting still. Actually, it's quite hard to get in and out of the cockpit with all the bodywork on the car.'

As the motorsport industry continues to try to work out what Formula 1 cars and others should look like in future, the Dilemme might put an alternative set of ideas into the mix. Meanwhile, most of the students who created it are now joining automotive companies to start their careers, so just perhaps it might actually turn out to be a clearer look to the future than other design studies seen to date.

TECH SPEC

Espera Sbarro Dilemme

Chassis: Tubular steel.

Body: Composite materials with front and rear wings, full canopy (no impact protection).

Motors: Twin Yasa 750 three-phase permanent magnet; 1500Nm torque (combined); total output 200kW.

Energy store: 114 CALB SE60 cells (Li-ion).

Transmission: Belt-drive; direct motor pair to differential.

Suspension: Two-way adjustable EMC SportShock2.

Brakes: D2 Racing calipers and ventilated steel discs; 6-piston (front) 4-piston (rear).

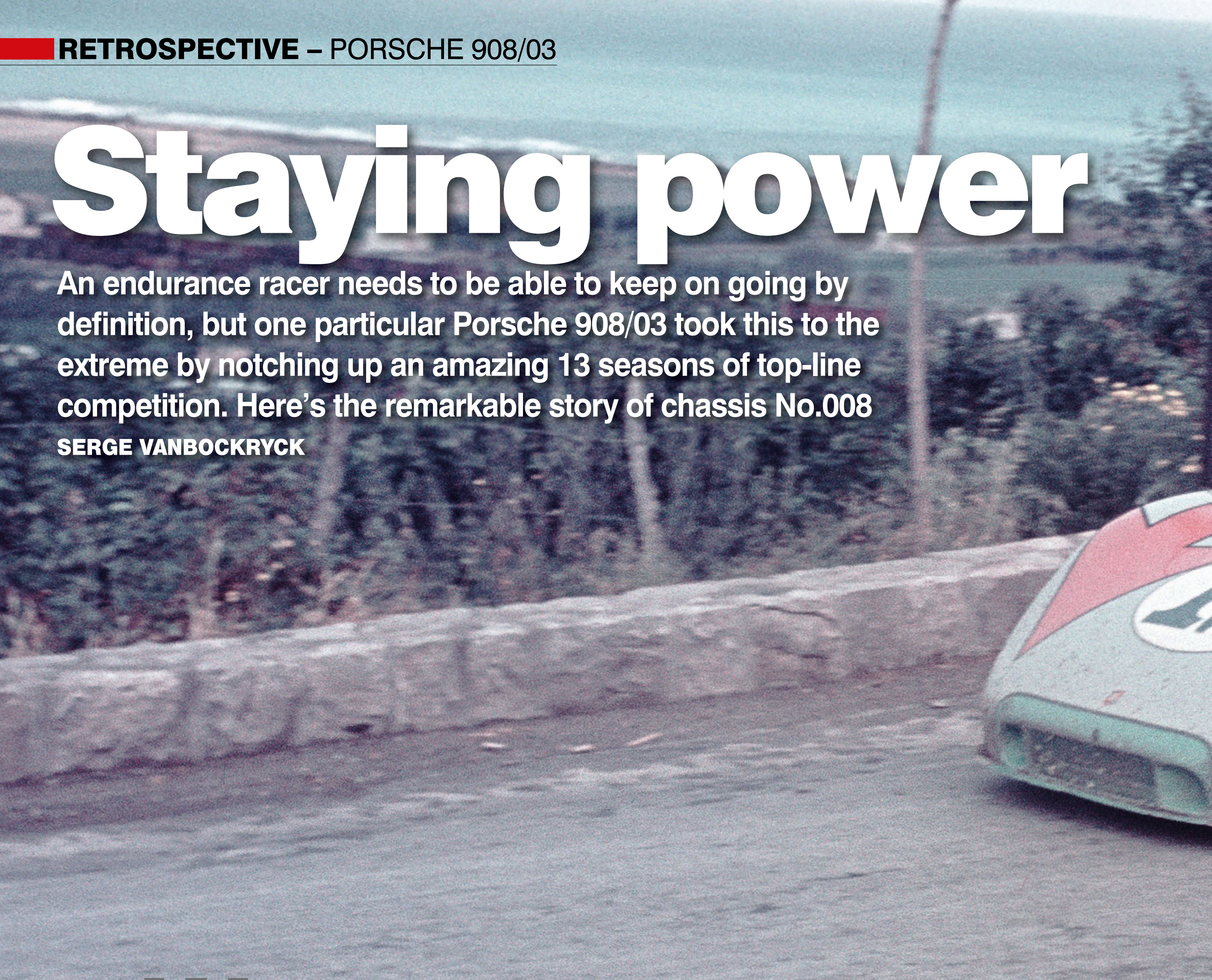
Wheels: OZ Ultraleggera centre-lock.

Tyres: Michelin slicks, 24/65-19 (front), 31/71-19 (rear).

Dimensions: Wheelbase, 3000mm; Width, 2000mm. Ride height, 100mm.

Weight: 950kg.

The students designed and fabricated most of the racecar's components themselves including suspension parts, except for dampers and springs which were produced to required specifications by outside suppliers



Staying power

An endurance racer needs to be able to keep on going by definition, but one particular Porsche 908/03 took this to the extreme by notching up an amazing 13 seasons of top-line competition. Here's the remarkable story of chassis No.008

SERGE VANBOCKRYCK

When 1969 came to an end Porsche's head of R&D and motorsport, Ferdinand Piech, defined the specification for the compact 908/03. He might have had high hopes for this car, but he certainly didn't have a 13-year career in mind for probably the most nimble Porsche since the Typ 909 hillclimb car. In fact, as far as Piech was concerned, the 908/03 didn't even have to be used for a full season, because he wanted it to do just two very specific events.

Following a comparison test with the 917, the decision was taken to use the 908/03 at the Targa Florio and the Nurburgring 1000kms. For the rest of the WCM (World Championship of Makes) season Porsche's interests would be looked after by a flotilla of the more powerful works-supported 917s, deemed unfit for the Italian and German classics, where less power and especially less weight was important. What was needed was a car that was as light and nimble as it could be, with short overhangs and a perfectly balanced weight distribution.

That car had already been created on paper in the summer of 1969, and carried the code number 908/69. It was supposed to have been the 1969 development of the 908/02, but as the 908/02 was still winning races, and since Porsche's motorsport policy had changed drastically over the summer in order to reduce costs, the update project had been shelved. For the 1970 season, however, with all the factory's remaining 908/02s sold to customers, the need for its successor made itself felt again.

A car is born

Piech had based the new car on the successful Typ 909 2-litre *Bergspyder*, which had all the ingredients he knew were needed to be successful at these two events. All that was required was the 908's 3-litre engine, and one would have the ideal car to beat the big 5-litre sportscars, including the 917. Piech managed to convince his uncle, Ferry Porsche, to put the 908/69 paper exercise into practice, thus giving birth to the Typ 908/03. In a way it was strange that this car carried the 908 type number, since apart from the engine and the wheelbase dimensions, it had little in common with its predecessors, the Typ 908 and Typ 908/02.

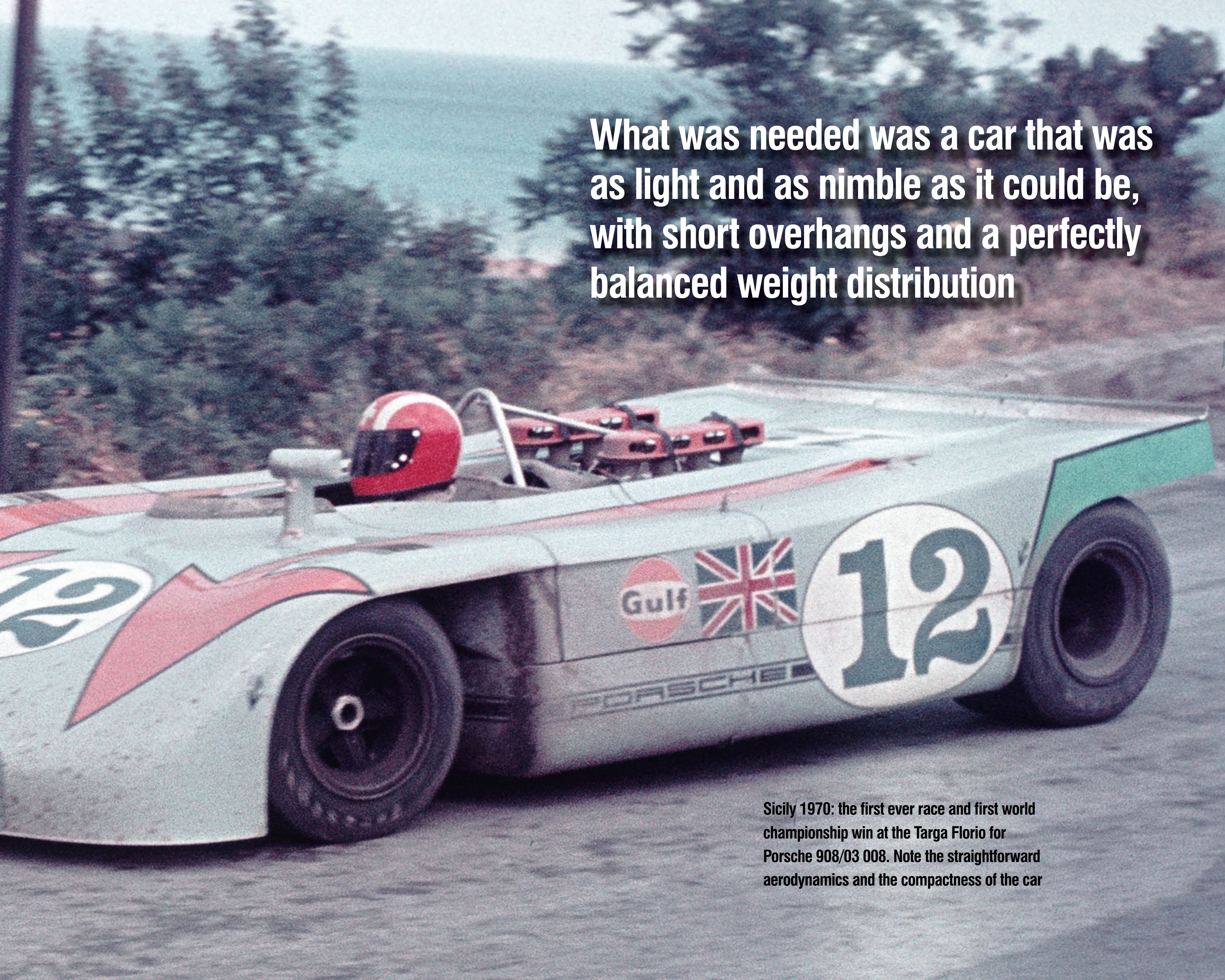
The Typ 908/03 had an all-new aluminium spaceframe chassis, with the driver's seat moved as far forward as possible without the driver actually sitting on the front axle. His feet were placed ahead of the front axle line, thus allowing for more room for the 380bhp flat-8 engine. The suspension was also new, while the gearbox was placed between the engine and the differential. Liberal use of magnesium and titanium kept the kerb weight at just 545kg (1201lb), which, given the engine produced some 100bhp less than the competition, still made it a very competitive proposition at specific circuits.

The body of the 908/03 was completely new and featured a blunt nose with no headlights (as the rules allowed, for daytime races), and a flat top surface in order to reduce drag and increase downforce. Weighing just 12kg, the foam-reinforced plastic body was nearly transparent when it wasn't painted. There was a minimal rear overhang, the body ending at almost the exact outer edge of the rear tyres, which were mounted on 13in rims all-round, 9.5in wide at the front and 14.5in at the rear. The extensive use of exotic materials, like titanium, contributed to the low weight. Two development cars were built, and after finalising the shape and forms, seven new cars were built for the two races.

Sicilian debut

The Porsche 908/03 made its debut in May 1970 in Sicily. Four cars were entered for the Targa Florio: three for John Wyer's JWAE Gulf team and one for Louise Piech's Porsche Salzburg team,

What was needed was a car that was as light and as nimble as it could be, with short overhangs and a perfectly balanced weight distribution



Sicily 1970: the first ever race and first world championship win at the Targa Florio for Porsche 908/03 008. Note the straightforward aerodynamics and the compactness of the car

with a fifth chassis present as a spare. The four cars wore striking liveries and were individually identified by playing-card symbols on the nose section, an idea of Porsche's new design guru Anatole Lapine, who knew his motorsport history since the Austro-Daimlers entered in the 1922 Targa Florio – and designed by Ferdinand Porsche – had been similarly decorated. The playing cards indicated even more the equal footing the JWAE and Salzburg teams were on, despite JWAE having the 'official contract'.

Star cast

The driver line-ups showed that, as always, Porsche meant business. Jo Siffert/Brian Redman (car No.12, chassis 908/03 008, diamonds), Bjorn Waldegard/Richard Attwood (No.36, chassis 908/03 011, spades) and Leo Kinnunen/ Pedro Rodriguez (No.40, chassis 908/03 009, clubs) were entered for JWAE, while Vic Elford/ Hans Herrmann (No.20, chassis 908/03 007, hearts) were entered by Salzburg. Almost as if to emphasise that Piech could do as he pleased with the Salzburg team, a 909 and a 917K were entered as T-cars for Elford and Herrmann. Porsche's main opposition, as usual, came from Ferrari and Alfa Romeo, the former with the big 5-litre 512S, the latter with the 3-litre T33/2.

In the lead after the first lap was Gerard Larrousse in a Martini Team 908/02 he shared with Rudi Lins. At half distance, though, it was the Ferrari of Nino Vaccarella and Ignazio Giunti leading from the Team AAW 908/02 of Gijs Van Lennep and Hans Laine. In the second half of the race Laine lost a wheel and the Ferrari drivers suffered what Elford had predicted from his test run in the 917K; fatigue. The 908/03s moved to the front with Redman leading till the finish, closely followed by Kinnunen, the latter setting the all-time lap record at 33m36s while taking second overall from the Ferrari on the last lap. Laine finished in fourth position with the third remaining 908/03 finishing in fifth.

Lords of the 'Ring

Four weeks later the little bombshells from Stuttgart reappeared for their second and last race of the year at the notorious Nurburgring Nordschleife. In those four weeks, the 908/03s had received bigger 15in wheels, the fronts also increasing in width to 11in to improve the turn-in, while the rears stayed at 13in. In qualifying Laine, who had heroically three-wheeled back to the pits at the Targa, was killed in an accident. At the end of the qualifying session Siffert had set pole in a record 7m43s, some 12 seconds faster than the year before with the 908/02. Rodriguez was the only other driver to set a time below the 7m45s mark, the two Salzburg 908/03s qualifying five and 14 seconds slower in third and fourth. Interestingly, the JWAE cars ran on Firestones, while the Salzburg cars were on Goodyears (though they still carried Firestone branding), which might explain the differences in times between these racecars.

Also noteworthy was the fact that Piech, for no apparent reason, had allocated the Targa-winning chassis 008 to his own outfit, giving Wyer chassis 010 instead. The fastest Alfa Romeo, driven by Rolf Stommelen, was some 17 seconds off the pace. With four 908/03s on the first four places of the starting grid, Porsche had proved its point, as had Piech.

Two out of two

The four 908/03s looked unbeatable, pulling away from the rest of the field from the start. But then Kinnunen crashed on his first lap after having taken over from Rodriguez, while Redman's engine started to die by mid-distance. But the race was still a walk in the park for the Salzburg entries with Elford/Kurt Ahrens winning by five minutes from Richard Attwood/ Hans Herrmann. The Porsche 908/03s 1970

When Porsche offered its 908/03s for sale Reinhold Joest snapped up chassis 008. It raced to fifth at the 1972 Watkins Glen 6 Hours in the hands of Joest himself and Mario Casoni

scoring card showed 100 per cent success, while the 917s cleaned up the remaining races of the season. The 908/03s were then mothballed and put away until the next Targa Florio.

Targa return

One year later the 908/03s reappeared in Sicily, now with 17in rear wheels and 917-style vertical fins on the engine cover to increase stability at high speeds. Brake discs were cross-drilled, not only to save unsprung weight but also to increase their effectiveness and reduce brake pad wear. The 1971 version weighed in at 565kgs, 20kg more than a year earlier, courtesy of a larger fire extinguisher and a full-width roll-over bar over the cockpit, as per the latest CSI (governing body) regulations on safety.

But despite all the improvements it was apparent in qualifying that the Porsches would not have things all their own way as they had done the year before. The three factory-entered Alfa Romeos T33/3 were quickest, the fastest 908/03 in qualifying being chassis 908/03 008, now entered by Hans-Dieter Dechent's Martini International Racing Team for Vic Elford and Gerard Larrousse; over one minute behind the fastest Alfa. In the race things were even worse with both JWAE Gulf entries, driven by Rodriguez and Redman, crashing out on the first lap. The Martini car lasted a little longer until a puncture damaged its suspension and forced the team to retire the car.

Two new cars were built for the Nurburgring 1000 kms two weeks later (chassis 012 and 013), but it appeared that the outside contractor building the chassis had made a manufacturing error, causing the chassis to crack. The new Ferrari 312PB of Jacky Ickx was quickest in qualifying, with the Targa-winning Alfa Romeo T33/3 of Rolf Stommelen lining up alongside the Ferrari. The four 908/03s qualified neatly grouped together, in third, fourth, fifth and sixth.

In the race the Jo Siffert/ Derek Bell car retired after just seven laps when the chassis broke. At the front the Alfa retired with a blown engine after 14 laps, while the Ferrari retired after 21 laps with a cracked cylinder head. Whereas Lady Luck had worked firmly against the Porsches in Sicily, she was certainly smiling at them in their home race, the three remaining 908/03s finishing in first, second and third, with only the Andrea de Adamich/Henri Pescarolo Alfa Romeo on the same lap in fourth. The rest of the quality field had been lapped at least twice.

The 1971 Nurburgring 1000 kms marked the end of the works-career of the Porsche 908/03, with three wins from four races; all three victories achieved with chassis 908/03 008.

Apart from the engine, and the wheelbase dimensions, it had little in common with its predecessors

Used car sales

Partly as a result of CEO Ferry Porsche's late 1971 decisions to get rid of all family members from the company management, as well as to drastically cut motorsport budgets, but also because the new rules for the World Manufacturers Championship required a minimum weight of 650kg for sportscars – thus taking away one of the main advantages of the 908/03 – the 1972 season became the first international sportscar season without any factory involvement from Porsche. In the absence of the factory team, Porsche's honour was to be defended by privateers and thus, in April 1972, the works 908/03s were sold off to privateer teams. Reinhold Joest was one of those team owners keen to buy a 908/03 and he cleverly bought the Targa Florio and Nurburgring winning chassis, 908/03 008.

In preparation for the 1972 season Joest rebuilt chassis 008 from the ground up, very much in the same way he would do with all his future Porsche prototypes. Technically the car stayed as it had finished the 1971 season, while cosmetically it was given the well-known powder blue and orange livery, but without actually being sponsored by Gulf. Joest planned on making the best possible use of his latest acquisition and entered the car in the World Championship for Makes as well as in the European Interserie Championship.

Air miles

At first the results were what might be expected with a now underpowered and overweight car, with some flashes of success, notably at Monza. But by the Watkins Glen 6 Hours in July Joest had picked up sponsorship from Lufthansa, which allowed him to fly the car back and forth across the Atlantic. This also enabled Joest to enter the non-championship Interlagos 500 kms in Brazil, which he promptly won from pole position. True, the entry list was an amalgam of mostly gentleman drivers in older sportscars interlaced with the odd professional, but he did beat Herbert Muller in a Ferrari 512M.

Joest's 1972 Interserie programme, however, yielded little in terms of results. Just like the CanAm series in North America, the Interserie championship had become the refuge for the big sportscars which had been ruled out of the World Championship and thus Porsche 917Ks and 917/10s, as well as Ferrari 512Ms and

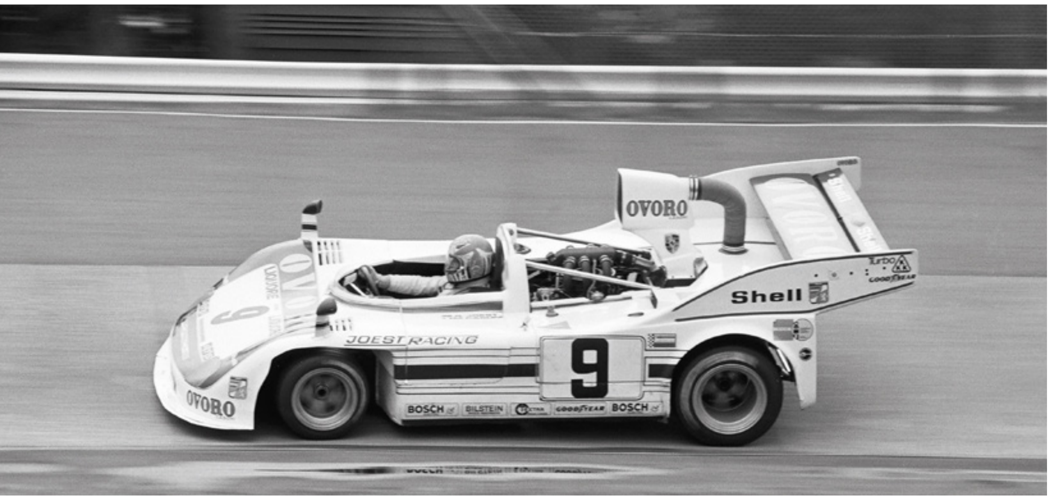
McLaren M8Fs ruled the roost. Joest's second place at the Nurburgring was an anomaly; a fourth place at Hockenheim and a sixth in Imola better reflected the real balance of power in the Interserie. The 1973 season could only be better.

Joest started 1973 trying to emulate Porsche's 1968 victory with the 908/02 at the WCM opener in Daytona, but chassis 008, driven by Joest, Mario Casoni and Paul Blancpain succumbed to gearbox issues. A fifth place was all Joest achieved with 008 at world championship level and the Interserie yielded just two thirds (Norisring and Misano), a fourth and a fifth place. It thus was with a certain sense of revenge that Joest entered his 908/03 in the Kyalami 9 Hours in South Africa. Sponsored by Audi, and co-driven by Porsche stalwart Herbert Muller, 008 faced stiff opposition from John Wyer's Gulf Mirage team, which had entered two of its Cosworth-engined M6s for Derek Bell/James Hunt and Mike Hailwood/Hughes de Fierlant. The Mirages duly outpaced the 908/03 by four seconds in qualifying, but Joest prevailed when the Brits hit mechanical issues and beat Bell/Hunt to victory by some 11 laps. Chassis 008 had found its winning ways again.

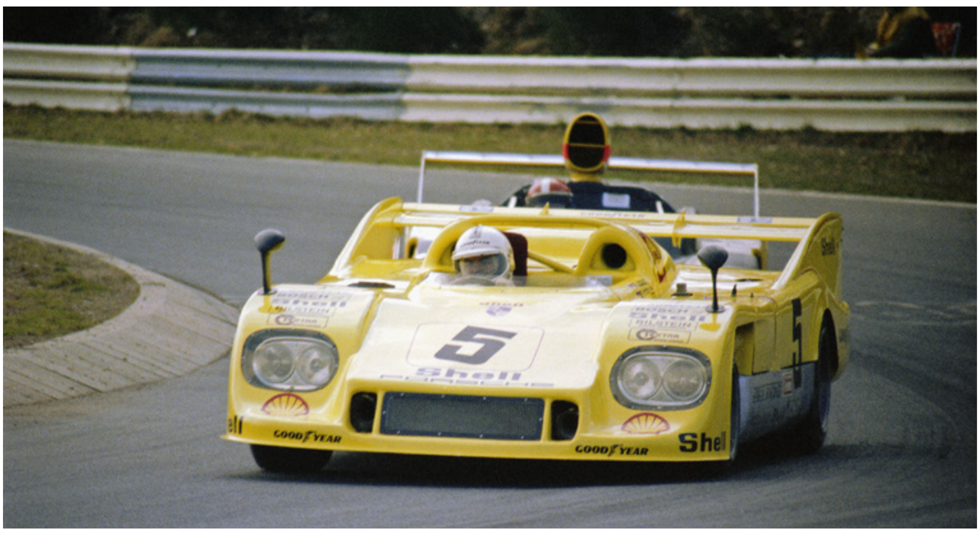
Weighing just 12kg, the foam-reinforced plastic body was nearly transparent when it wasn't painted

Power struggles

For 1974 Joest bought a second 908/03 (chassis 908/03 012) and competed in nearly all the rounds of the world championship. But the lack of power made itself felt now more than ever and he and regular partner Casoni usually finished in the second half of the top 10, while most races were won by the unbeatable works Matra-Simca MS670Cs. A fourth place at the Paul Ricard 750 kms would be the highlight of the German team's season. While the car in itself was still good enough, the normally-aspirated powerplant was getting long in the tooth.



For the 1975 season selected 908/03 owners were sold the 2.1-litre F6 turbo engine from the previous year's works 911 Carrera RSR. Because of the extra power 008 was given a 917/10 engine deck and rear wing to provide more downforce



Porsche built the 936 as a works entry for the 1976 World Sportscar Championship but it was Joest and 908/03 chassis 008 that won the first round at the Nurburgring. Note the new 917/30 body and the headlights, which are from an NSU road car

For the 1975 season, Porsche – again not having a factory programme that year – agreed to sell selected 908/03 owners the Typ 911/78 2142cc turbocharged engine from the previous year's Carrera RSR Turbo. Three cars were thus equipped over the winter, despite the factory warning the owners that the original 908/03 transaxle might have difficulty coping with the extra power: Joest's chassis 908/03 008 (his second car kept the normally-aspirated engine), Herman Dannesberger's Martini-sponsored and Interserie-bound 908/03 006 and chassis 908/03 013 of Spanish Porsche importer, Ben Heiderich. The rear frame of these 908/03s was reinforced at the factory while the brakes, driveshafts and part of the suspension were borrowed from the 917/10. The original Typ 910 gearbox was deemed strong enough to cope with the 500bhp, especially since the Typ 915 'box of the 1974 Carrera RSR had been that car's Achilles heel, but a gearbox oil cooler was added.

Getting a grip

Equipped with the engine cover and rear wing from the 917 to produce enough aerodynamic grip, the Typ 908/03 Turbo – or 908/04, as it was unofficially dubbed – made its debut in Mugello under the watchful eye of Norbert Singer who over winter had been in charge of the upgrade programme. Driving one of the Martini Racing 908/03s, Van Lennep and Muller finished in third behind the winning, also turbocharged, Alpine-Renault A441 of former Porsche driver Gerard Larrousse, and Jean-Pierre Jabouille, and the Willi Kauhsen-entered WKRT Alfa Romeo T33TT12 of Arturo Merzario and Jacky Ickx. Joest's 008, sporting a home-made overhead air scoop and entered under the Scuderia Nettuno Ovoro banner in deference to the sponsorship Casoni had brought, retired with a blown turbo.

At the car's second outing in Dijon, 008 finished second overall, as it would at the next round in Monza. Another podium finish at the Enna-Pergusa 1000 kms by the Joest team was followed by a third place at the Nurburgring by the Martini entry of Muller and Kinnunen. For Le Mans Joest used his normally-aspirated chassis 012, which was a safer bet than the turbo, as confirmed by the fourth place overall. Double-0 Eight was back on duty at the Osterreichring where it finished on the podium. That and a fourth place at Watkins Glen were enough for Porsche to finish runner-up behind the near unbeatable Alfa Romeos in the 1975 World Manufacturers Championship.

Six appeal

For 1976, there were two FIA world championships, one for Manufacturers (WMC) and one for Sports Cars (WSCC). The manufacturers' championship was open to road car-based Group 4 and Group 5 cars such as the Porsche 934 and 935, while the sportscar championship was open to Group 6 prototype cars. The Porsche factory team produced the

936, a 'parts bin special', but it was not to be sold to customers, thus the company's usual clients stuck to their 908/03s. In fact, it was thanks to Joest's 908/03 008 that Porsche claimed its very first Group 6 win in the opening round of the WSCC, when Joest won the Nurburgring 300km after Rolf Stommelen's factory 936 hit problems.

Yellow fever

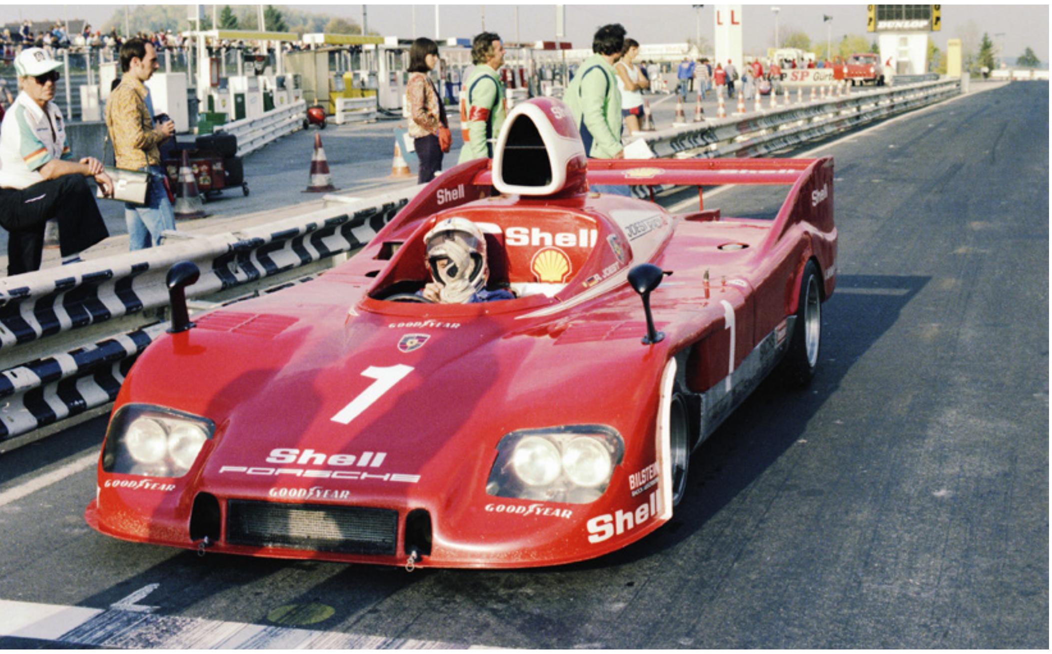
By now the 008 was equipped with the full bodywork of the CanAm 917/30, painted in bright yellow and equipped with headlights borrowed from an NSU 1000 TTS road car. The big airbox had gone, since the CSI's rules stipulated that a sportscar could not be higher than 92cm, thus fresh air for the air-to-air intercooler was fed through an airbox located on the left of the driver's head, inside the roll hoop. It wasn't the most elegant looking car, but it was a winner of yet another world championship event. Chassis 908/03 008 would continue to be the 936's unofficial wingman throughout the 1976 WSCC season, usually with Joest and Ernst Kraus sharing the duties.

Chassis 908/03 008 would continue to be the 936's wingman throughout the 1976 WSCC season

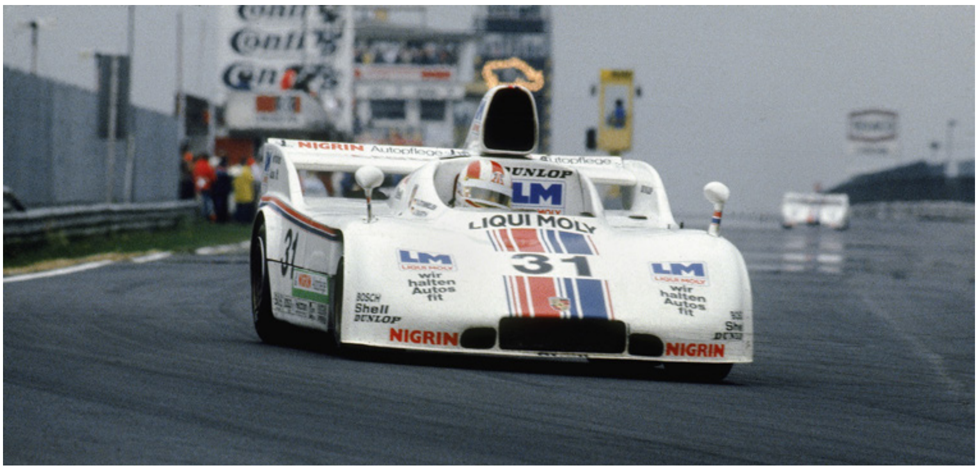
With Renault playing the French card when it came to respecting the technical regulations (it had presented its cars with wings and airboxes way too high and wheels too wide, then played dumb and subsequently refused to do anything about it) the Porsches, too, were allowed to run a high airbox and much higher rear wing, as otherwise the WSCC would have collapsed.

Thus 908/03 008's bodywork further evolved to look like the works 936, with the bright yellow paint now changed for fire truck red. But before that umpteenth change Joest had installed a normally-aspirated F8 for Le Mans (and taken off the rear wing) and let Ernst Kraus and Porsche works test driver Gunther Steckkonig finish in seventh overall, while Joest himself shared a works 936 with Jurgen Barth.

In 1977 Joest and 008 were less lucky. Driving with Claude Haldi and Brett Lunger, he entered only two rounds of the WSCC, both times retiring with engine failures, while the Interserie netted just two podium finishes.



Joest upgraded his 908/03 continuously throughout 1976 and by the end of the season it was quite hard to tell the difference between his car and a 936. At the Nurburgring (pictured) Joest won from pole position, the car now running a higher airbox



Rolf Stommelen on his way to victory at the 1980 Nurburgring 1000 kms, where he shared the racecar with Jurgen Barth. This was chassis 008's third world championship win on the Nordschleife – the car had always been well suited to the 'Ring

Plastic surgery

The following year the WSCC was cancelled, as had been expected, but the good news was that it would be replaced by a five-round European Sportscar Championship. Joest, meanwhile, had further developed his 908/03 and had given it a 936-inspired bodywork made by Design Plastic, the same company which one year later would become known the world over for developing the bodywork of the Kremer Porsche 935 K3. Joest's 908/03 Turbo now looked like a shortened 936/77. He finished in second overall at the opening race of the ESC at the Nurburgring behind the Osella of Giorgio Francia, but then went on to win at Monza, Vallelunga and the Salzburgring to claim the European title. Clearly on a roll, Joest and 008 also added the European Interserie title to their tally, with wins at the Colmar-Berg test track, the Ulm airfield and the Nurburgring.

And the success story of the 908/03 Turbo just continued. In 1979 FISA allowed Group 6 cars to compete in the WMC, albeit without the possibility to score points. For Joest this was the incentive needed to once again extend the career of 908/03 008. He put a powerful 630bhp, twin-turbo Typ 935/73 engine from the 936/78 in the back, and at the first opportunity, the Dijon 6 Hours, Joest, Volkert Merl and Mario Ketterer obliterated the hitherto untouchable 935 brigade by four laps. At the Brands Hatch 6 Hours, Joest and Merl again won, beating Le Mans winners Klaus Ludwig and the Kremer brothers and their 935 K3. In the Interserie, too, Joest and 008 struck hard almost wherever they raced, winning at the Nurburgring, at Ulm, Hockenheim and Kassel-Calden.

The 'Ring cycle

One year on, in 1980, a feeling of deja-vu could be forgiven when looking at the results sheet of the Nurburgring 1000 kms. Once again, Joest's Equipe Liqui Moly had beaten Porsche Kremer Racing, this time Jurgen Barth and Rolf Stommelen driving the 908/03 Turbo and finishing ahead of John Fitzpatrick, Dick Barbour and Axel Plankenhorn in their 935 K3/80.

Unfortunately the 908/03 Turbo's long world championship career would dramatically come to an end at the 1981 Nurburgring 1000kms, where Joest and Sigi Brunn had both entered similar cars. Brunn had bought the ex-Evertz 908/03 013 and upgraded it with the same twin turbo engine Joest ran, calling his car a 908/03-81. At the previous world championship round,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The Porsche 908/03 Turbo's long world championship career would dramatically come to an end at the 1981 Nurburgring 1000 kms

Eleven years after its debut 908/03 008 made its last world championship appearance at the 1981 Nurburgring 1000 kms. Jurgen Barth and Volkert Merl finished the shortened race in sixth place. In total this remarkable racecar won 43 races

The business end of the last evolution of 008. The 630bhp twin-turbocharger Typ 935/73 engine made the 908/03 a difficult car to beat at any level. Its final full campaign was in the DRM series in 1982, then a safe haven for obsolete Group 6 cars

The unexpected encore. Wearing Reinhold Joest's helmet Jurgen Barth was a very last minute entry into the 1983 AVUS DRM event. After this, its 155th race, 908/03 008 was restored and technically back-dated to its Nurburgring-spec of 1970

the Silverstone 6 Hours, Brunn had finished in third together with Eddie Jordan. At the next round in Germany, Brunn entered the car for himself and Herbert Muller, but a freak accident cost the life of Muller and ended the race prematurely, at the same time ending the 908's world championship success story, 12 years after it had begun. Barth and Merl salvaged sixth place, but the real international farewell for 008, and indeed for the Typ 908/03, came at the Kyalami 9 Hours where Barth, Brunn and Jean-Michel Martin finished in second overall.

End of the road

With the advent of Group C in international sportscar racing in 1982, the German DRM championship offered a safe haven for now obsolete Group 6 cars. Gentleman driver Volkert Merl had enjoyed his runs in 908/03 008 the previous season and asked Joest to prepare the car for him for the DRM and the Interserie championships. After the season finale at the Nurburgring, and after 12 seasons of racing, with 154 races and 43 victories (of which six were world championship races), Joest mothballed Porsche 908/03, chassis 008, in his workshops in Absteinach; a possible restoration to its 1970s glory in the back of his mind.

But before it would come to that, sportscar fans would unexpectedly see 908/03 008 in action one last time. For the third round of the 1983 DRM at the Berlin AVUS street course only 10 cars had made it to the city. This was the minimum for the race to count towards the championship, so any mishaps in practice or qualifying would turn the event into a point-less affair. But in the final qualifying session Klaus Ludwig had blown his engine and the team had to put in an all-nighter to get things fixed.

Fortunately there was an 11th car sitting in the paddock: Joest's Porsche 908/03 Turbo, chassis 008. Quite why Joest had brought the car to the event was anybody's guess. Joest asked Jurgen Barth to get in the 908/03 and start the race from the back, without even having done a single lap in practice, qualifying or even in the race morning warm-up. In fact, Barth had never even raced at the AVUS before! Since Barth was in Berlin in his capacity of Porsche's head of customer sport he hadn't brought his overalls nor his helmet and thus had to wear Joest's old suit and head gear. Chassis 008's very last race unfortunately ended with a DNF after just four laps when the transmission broke.

At the turn of the century, Joest restored 908/03 008 back to its 1970 Nurburgring winning specification. Together with 908/03 012 it is still part of his extensive collection of very successful Porsche racecars.


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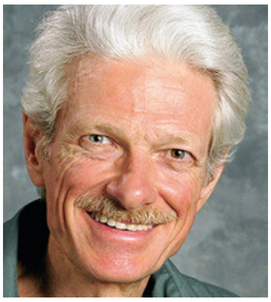

Beamed up: De Dion switch for a Lagonda

Is a rear suspension change the answer for our wayward classic?

When we left off last month, we were going to consider converting the 2.6 Lagonda road and track day car we've been discussing from swing axles to a De Dion system. My first thought was to use a 2in or slightly larger tube for the beam, and let it twist in roll and act as an anti-roll bar. This could bolt in, attaching to the same bolt circle as the rear legs of the stock suspension arms. Now you're updated, back to the discussion …

THE CONSULTANT

I now have a copy of the Donald Bastow book on WO Bentley (see V28N5). I see that Bentley later had a similar idea and developed a De Dion for the related Armstrong Siddeley 3-litre. This involved a complete redesign of the whole suspension, although changes to the frame were fairly minimal. So now I think I see a way to do this as a reversible retrofit.

THE QUESTIONER

I think it will be straightforward to join the two hub rear carriers with a tube across the car using the flange face to which the existing transverse suspension arms fit. What is not going to be so easy is to provide longitudinal location for the De Dion. The hub carrier is within the well of the wheel, so there is no simple way of running a locating arm forward from the front flange face of the hub carrier.

The X-frame is not very strong in the area where a longitudinal arm would be located. However, it may be possible to exploit the strength of the body sill, especially if beefed up.

THE CONSULTANT

I don't see any need to have pure trailing arms like the later Armstrong Siddeley De Dion design. I think the forward arms of the existing suspension will do just fine. I don't think they would be seeing substantially different loading from longitudinal forces than they do now. The existing torsion bars and their roll-compliant mount could also be retained.

The De Dion tube should then probably be tubular, rather than channel section. It would act as an anti-roll bar but would probably have a reasonable rate even if it were around two inches in diameter with perhaps $^{3}/_{16}$in wall. What diameter are the tapered tubes of the existing arms at the big end where they are welded to the flanged bungs?

For lateral location, I was thinking it would be possible to use a Watt linkage with a fairly small horizontal rocker bolted to the same pad that now carries the rear ball joints. Transverse links would be angled upward toward the wheels at around 10 degrees, somewhat like the rear arms are now.

Would it be possible to measure how much room there is vertically from the cross-member to the floor pan? And then from the parting line of the rear arm mount to the floor pan?

The 2.6 Lagonda's cousin, the 3-litre Armstrong Siddeley, was switched from swing axles to De Dion back in the 1950s

THE QUESTIONER

The tube outside diameter into the flange bungs is 2.25in. The eight flange bolts are on 3.375pcd. There will not be a problem with clearance to the floor pan as we will move the floor pan as necessary.

My initial thought had been that the original hub carrier could be used, but the more I look at it the more I think this will not be possible because the flange angles are wrong, and I think there must be a question of strength if the wheel loads are not fed through both flanges. It might be possible to modify the hub carrier, but it might distort with welding.

I do not have a figure for the vertical difference between the top of the cross-member and the wheel centre – I guess 3 to 4in, perhaps a bit more. But less if the tube goes over the central mounting.

THE CONSULTANT

I calculated what sort of roll stiffness we'd get if we just substituted a tube for the rear legs, leaving the front legs unchanged. The stiffness ends up being excessive, for any tube likely to be strong enough in bending. For a 2in tube with $^{3}/_{16}$ wall, the car would end up with a suspension roll gradient of a bit less than a

Bending loads at the hub carrier flanges should be similar to original

The solution offered here is similar to that used on the rear of the Mk1 VW Golf – well known for its excellent handling

degree per g. We probably want at least three degrees per g, unless the track day version of the car runs only on very smooth surfaces.

So the De Dion *beam* (probably the correct word for it if it's not really a tube) needs to have properties more like a channel section or a hat section. At the same time, to connect conveniently to the hub carriers it needs to be round. It might work to use a 2.50in tube with $^{1}/_{8}$in wall, which would slip over and weld on to stubs of the existing rear legs after cutting most of the leg off, with bends as needed for fit and clearance, and then mill a slot about $^{3}/_{8}$in wide through the front or back wall, leaving a C section. Roll stiffness could be varied by length of the slotted portion.

Thicker walls, more like $^{3}/_{16}$in, could also be used with a bit of hand work on the i.d. at the ends. Alternatively, a larger o.d. could be used, although finding the bending dies for odd o.ds could be problematic.

The beam definitely doesn't need to be straight, so adapting to the angles of the stubs shouldn't be a problem. Bending loads at the hub carrier flanges should be similar to original. The biggest bending loads come from lateral forces, and those should be the same at the flanges regardless of whether the rear flange connects to a leg that resists bending and is held at the ball or a beam that resists bending in the middle. With the stock suspension, longitudinal forces are resisted mainly as compression and tension loads in the legs, and these will be similar whether the rear legs are separate and connected to the frame or are replaced by a beam that is rigid in tension and compression and constrained laterally with respect to the frame.

The key to making a twist beam work, and also to survive, is to make it stiff in bending but relatively flexible in torsion

THE QUESTIONER

I have been assuming there has to be some sort of joint at the point where the forward legs meet the hub carrier, else how do you allow for one-wheel bump/rebound? Are you designing on the basis the De Dion tube bends?

THE CONSULTANT

Yes, I am proposing a design where the De Dion beam is intended to deform in roll – but twist, rather than bend. This is known as a twist beam, and it is a well-accepted idea. It is most often seen on rear suspensions of front-wheel drive cars, notably the original VW Golf, but there is no reason it can't be used with rear-wheel drive as well. In fact, to my knowledge the earliest example of it for a rear suspension was the De Dion system on the next Bentley design, the Armstrong Siddeley.

The Armstrong Siddeley De Dion beam twists about the same amount per degree of roll as would a De Dion beam with the stock Lagonda forward legs. Its trailing arms anchor further forward than the Lagonda front legs but also further outboard. The beam is a rolled channel section of ¼in stock with outside dimensions of 2.3in x 1.6in.

The key to making a twist beam work and survive is to make it stiff in bending but relatively flexible in torsion. A tube can work, but only if it twists very little and can be given adequate bending strength with a small enough diameter to obtain suitable roll resistance and outer fibre stress in the particular installation. I was thinking that maybe this would be so for the Lagonda due to the fact that the pick-up points for the front legs are fairly far inboard, but my calculations show that that is not the case. Therefore, the De Dion beam will have to have a more torsionally flexible cross section, as is usually the case with twist beams. Many kinds of sections will do this, including channel section as on the Armstrong Siddeley, Z section, angle or L section, I-beam section, T section, channel with outward flanges (hat section), channel with inward flanges (square C section), or the round C section that I'm suggesting.

The Armstrong Siddeley torsion bars do not have a roll-soft mounting to the frame, so the Lagonda would probably require more roll resistance from the De Dion beam than the Armstrong Siddeley, depending on the rest of the suspension system; 2.25in DOM tubing is readily available in .188in and .250in wall.

THE QUESTIONER

I do have one, quite practical, reservation about milling a slot in a round tube as this will, presumably, let in water that won't then be able to run out. Given that the track day car will be used most of the time as a road car, this does not sound like such a good idea.

THE CONSULTANT

Yes, probably we do want the beam to drain so it won't rust, although if we powder coat it and it has $^{1}/_{4}$in wall thickness maybe it's not such a worry. Either small drain holes through the bottom could be added, or the slot could be at the bottom.

It looks to me like the beam needs to be strongest in the YZ (transverse/vertical) plane rather than the XY (longitudinal/transverse) plane, so that's why I was thinking the slot should be through the front or rear, but it might be strong enough with the slot at the bottom. Half a 2.25in tube would be weaker than the Armstrong Siddeley's 2.3in by 1.6in channel, but two of those, which is approximately what we would have with the slot at the bottom, might be at least as strong, albeit a bit heavier. It should also be possible to make a channel beam by cutting one wall off a square or rectangular tube.

CONTACT

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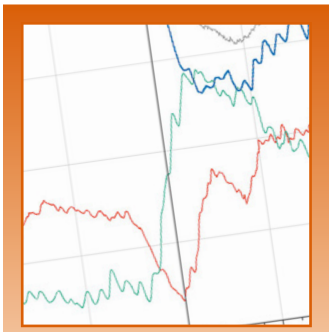


Databytes gives you essential insights to help you to improve your data analysis skills each month, as Cosworth's electronics engineers share tips and tweaks learned from years of experience with data systems

Pros and comms: telemetry explained

An insight into how the digital communications revolution has made its mark on the technology that drives racecar telemetry

In modern day endurance racing it's considered normal to receive a great deal of information directly from a racecar going around a track.

This hasn't always been the case, but it was obviously identified very early on that the more information that was available to the pit crew the better. The simplest form of communications between car/driver and the pits is the pit board and this is still used extensively as it a great back-up if radio communications fail and it also offers the driver a form of communication should they want peace and quiet to focus.

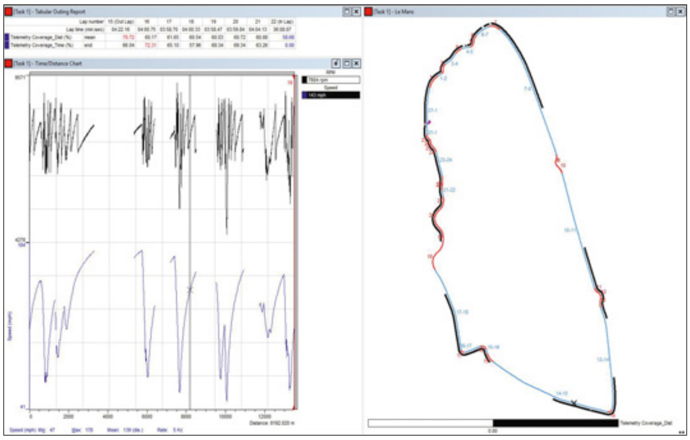
Radio times

Motorsport is very much a team sport and having telemetry allows the engineering and strategy team to work on their part without much need for the driver to supply them with information. This also means the drivers have a lot less to focus on, as the team can supply them with the information they need at any time.

Up until recently most telemetry solutions have been based on radios such as the Cosworth P192s and P900. These operate in a voice radio frequency range of 450-460 or 900-930Mhz depending on markets and licence restrictions. The main benefits of this type of system are that they are small and require minimal effort to set up and, depending on frequency licencing, can be used anywhere.

But there are two main downsides of these systems. One is throughput limitation. Maximum baud rate for these systems is 115kbps for the P900 and 19.2kbps for the P192s. With these restrictions in place the rate and number of channels is limited.

The other downside is coverage. A single antenna solution can only be expected to cover small circuits or parts of larger ones. Typical coverage at Le Mans is in the 20 to 40 per cent range, depending on installation. At the Nurburgring this would probably go down to below 10 per cent.



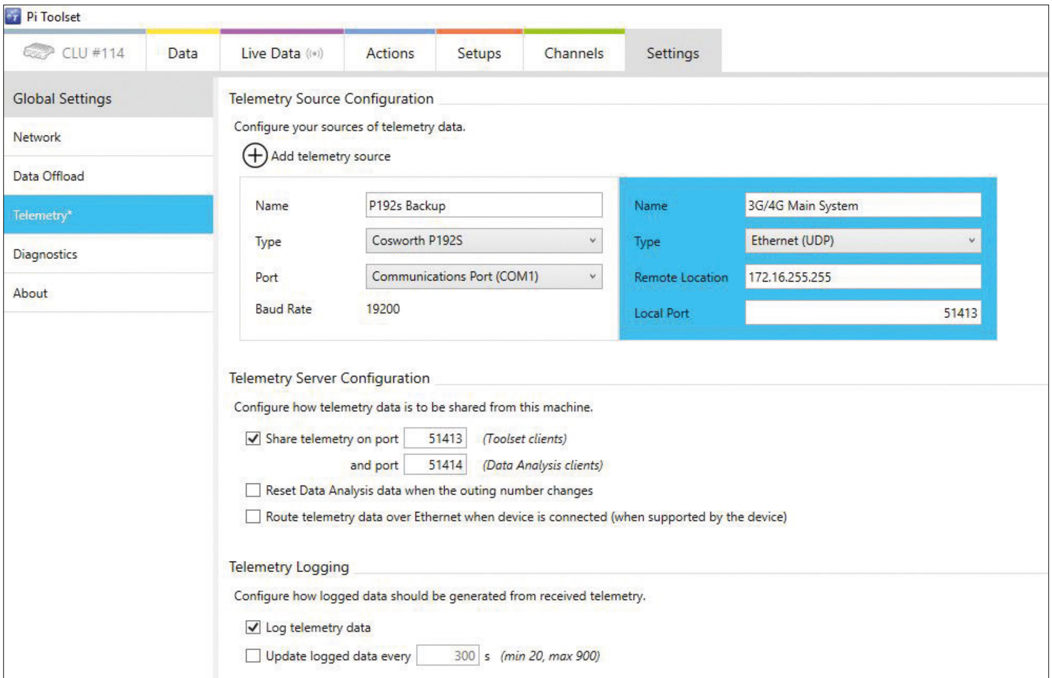
This shows how telemetry coverage can be viewed in different ways. The data traces have gaps where coverage is lost. The map shows clearly where the blind spots are, helping to decide where base stations should be located

A single antenna solution can only cover the smaller tracks

Setting up multiple receiving stations around the track would improve this, but the infrastructure would be very complex as all the stations would have to be linked and managed.

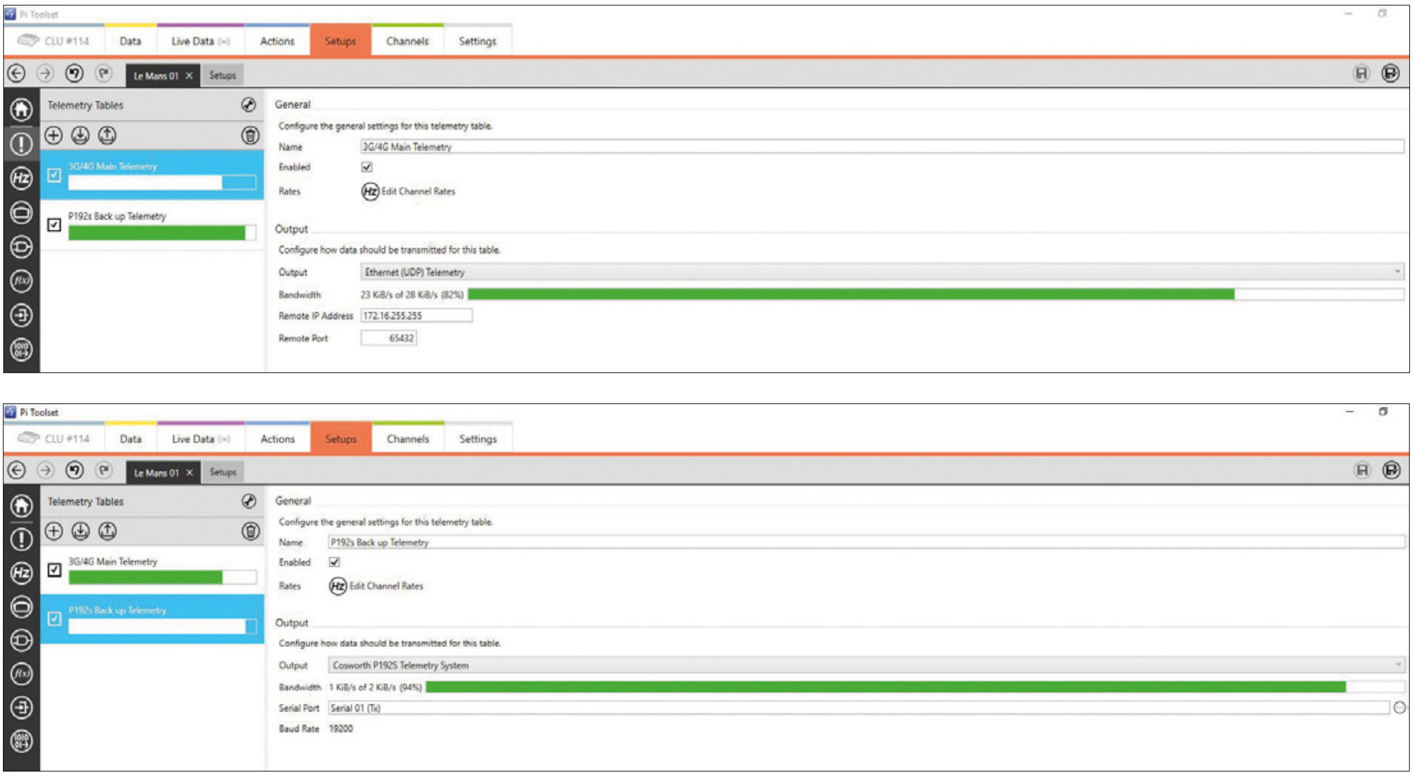
Mobile home

The latest developments in racing telemetry have predictably followed advances in mobile phone and wi-fi technology. 3G/4G radios are now widely used as they offer high bandwidth, are very small and require minimal set up at a track. The coverage can be very good, even at long circuits such as Le Mans and Nurburgring. There are still significant downsides, though. These systems use licence free mobile phone frequency bands which means they are entirely reliant on the mobile phone infrastructure and load. This means, for example, that a car with

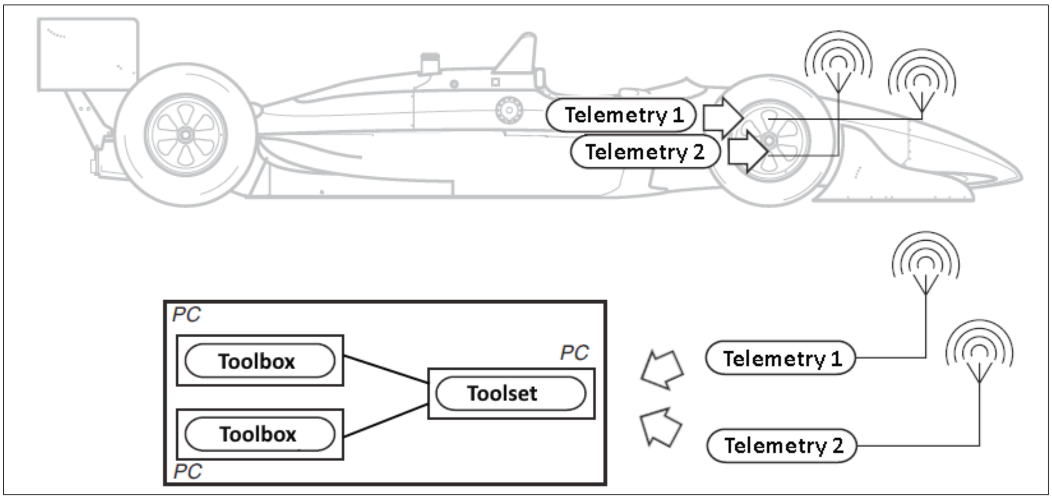


Using a radio based telemetry solution and a mobile phone based solution on the same car can solve a host of issues

Wi-Max has a much longer range and uses licenced frequencies



Here's a comparison of 3G/4G (top) *vs* 19.2kbps (bottom) serial bandwidth. Note the big difference in the bandwidth available from these two telemetry solutions



This simple schematic helps to illustrate the system architecture when two telemetry systems are working in tandem

this system is unlikely to have any telemetry for the first few hours of a popular race such as the Le Mans 24 hours or Nurburgring 24 hours, as most of the spectators will be using that same exact bandwidth.

Other solutions include standard Wi-Fi based systems in the 2.4 and 5GHz range which also do not require licences, but do not have as much loading issue as 3G/4G. Range is the biggest hurdle for this type of system, which means multiple sites must be set up around a circuit. Typically, between 12 and 30 sites are needed depending on tracks. All the sites must communicate on the same network, meaning the rigging and infrastructure to set these up is significant and only viable if a whole series or its organiser are involved.

Wi-Max is another technology which offers some advantages over the standard Wi-Fi based solutions. Wi-Max has a much longer range and uses licenced frequencies. The trackside infrastructure and management is still more than a single team would realistically want to deal with, so this system is again primarily used by entire series.

An example of this is IndyCar and the Cosworth Live-On-Air system. This uses Wi-Max base stations to communicate with all the cars on the grid. The system is fully managed and secured trackside so the teams just need to plug into a port in pit lane and they then receive data from their cars. It also allows information to be shared with the series organiser and television broadcast companies.

None of the above solutions is the ultimate one, they all have downsides which need managing. One of the things that has been identified as an easy improvement is the ability to have two or more broadcast systems on one car. An example of that is to use both a radio based telemetry solution as well as a mobile phone based one. The primary source is the 3G/4G solution with the radio one as back up. There's a good chance that most of the 3G/4G issues are seen near pit lane where usually there is the largest number of people and this is conversely where the radio solution is the strongest. It is then possible to let software choose the handover point and patch together the two streams for a near seamless transition.

New developments

Looking to the future there are interesting new technologies emerging and some already in place. Currently there's a machine-to-machine data network supported by mobile phone infrastructure which uses a different frequency than phones. This is primarily used for internet of things devices and still has a lot of bandwidth free. Meanwhile, 5G infrastructure has began taking shape and as soon as this comes on-line there will be possibilities for even more increased bandwidth.

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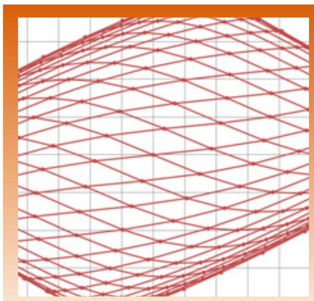

Slip Angle provides a summary of OptimumG's seminars

Characterising tracks for set-up solutions

OptimumG's Claude Rouelle explains why, and where, you might want to make use of an asymmetric set-up on your racecar

Having difficulties convincing someone to use more camber on the right-hand side than on the left for a counter-clockwise circuit; running higher tyre pressure on one side than the other; using different damper settings?

Looking at the number of left and right corners already gives you a good indication of the need to run an asymmetric set-up or not, but this is only part of the answer and more accurate track characterisation will help you to understand how much left to right set-up bias is required for a particular race track.

Track characterisation can be a very powerful tool. For any given circuit, evaluating the time that the car spends under acceleration, braking, lateral acceleration, or any combination of those can help you understand the characteristics of the circuit. This type of characterisation, together with the use of tyre metrics, helps decide the set-up.

There are many ways of characterising a race circuit. In this feature we will be explaining one particular method of doing so. This is making use of the GG diagram. We will be looking at vehicle accelerations and lap time to evaluate the track asymmetry.

This type of track characterisation, together with the use of tyre metrics, helps decide the set-up

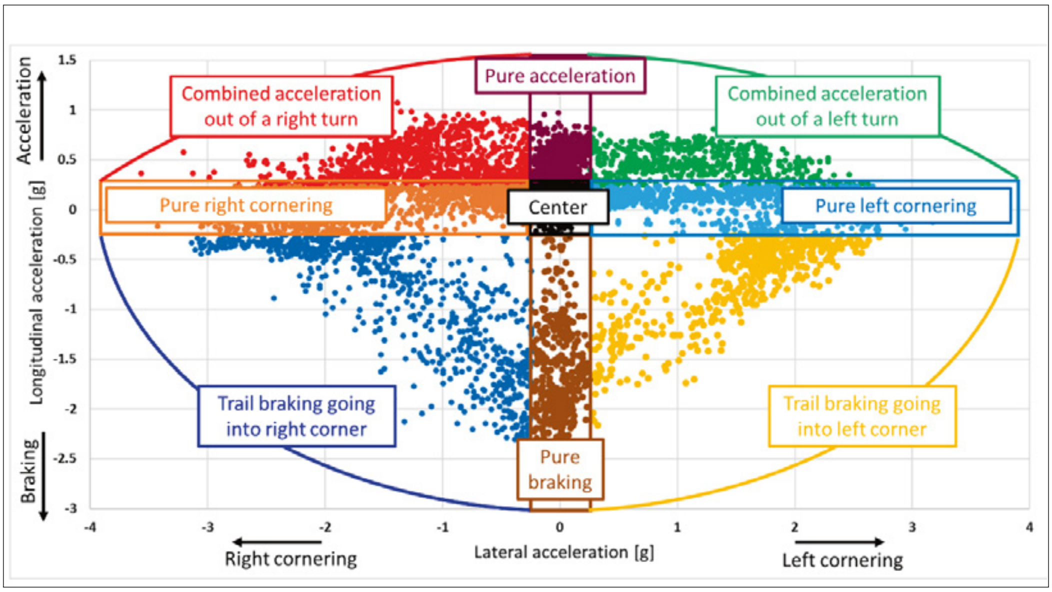

Figure 1: A GG diagram that's divided into the different car conditions is a fantastic way to characterise a race circuit

Table 1: The logic to create the different areas in the GG diagram ('Long G' is longitudinal acceleration, 'Lat G' is lateral acceleration)

Pure acceleration	Long G > 0.25G AND -0.25G < Lat G < 0.25G
Combined acceleration out of a left turn	Long G > 0.25G AND Lat G > 0.25G
Pure left cornering	Lat G > 0.25G AND -0.25G < Long G < 0.25G
Trail braking into left corner	Lat G > 0.25G AND Long G < -0.25G
Pure braking	Long G is < -0.25G AND -0.25G < Lat G < 0.25G
Trail braking going into right corner	Long G < -0.25G AND Lat G < -0.25G
Pure right cornering	Lat G is < -0.25G AND -0.25G < Long G < 0.25G
Combined acceleration out of a right turn	Long G > 0.25G AND Lat G < -0.25G
Centre	-0.25G < Long G < 0.25G AND -0.25G < Lat G < 0.25G

The GG diagram

To display a GG diagram, on the y-axis, we plot the longitudinal acceleration where a positive value means forward acceleration and a negative value means braking. On the x-axis, we plot the lateral acceleration where a negative value means a right-hand corner and a positive value means a left-hand corner. The GG diagram can be divided in many different ways, but we have chosen to divide it into nine areas for our example: pure acceleration; combined acceleration out of a right turn; pure right cornering; trail braking going into a right corner; pure braking; trail braking going into a left corner; pure left cornering; combined acceleration out of a left turn; centre of the GG diagram.

To split the GG diagram, first we need to create acceleration thresholds. To create the 'pure acceleration' boundaries shown in **Figure 1**, this is defined as when the longitudinal acceleration is greater than 0.25*g* and the lateral acceleration is between -0.25*g* and 0.25*g*. The math channel should return 1 or 'True' when the conditions are satisfied. The threshold value of 0.25*g* was chosen based on experience. Depending on the type of vehicle that we are analysing, the threshold will be different.

Table 1 summarises all of the necessary logic to create the remaining areas shown in **Figure 1**.

For each condition in **Table 1** a math channel is created in which we integrate the vehicle's speed only when the logic for this condition is satisfied. As a result, since we are integrating the speed, we obtain the total distance travelled along the lap under each condition individually.

An example of a MoTeC math channel to calculate the distance travelled under pure acceleration is as follows: *'integrate('Speed'[m/s], 'Pure acceleration'=1, range_change('Outings:Laps'))'.*

The same logic should be applied to obtain the distance travelled under all the other defined conditions by substituting 'pure acceleration' by the name used for the other logic channels (defining a condition/area) as shown in **Table 1**.

This same analysis can be done using time instead of distance. **Figure 2** shows the percentage of lap distance travelled in each area of the GG diagram around Le Mans.

By summing all the pure, combined, and trail braking in right cornering conditions, we can see that 30.83 per cent of the lap distance is right corners, while 16.58 per cent is left corners.

Lap distance histogram

With all the integrated sections, we can create percentages for each section. **Figure 3** shows a histogram at five different circuits: Silverstone, Spa, Le Mans, Imola, and Paul Ricard. The y-axis represents the percentage of the total distance that the vehicle travelled for that particular area. Each colour corresponds to the areas previously defined in **Table 1** and shown in **Figure 1** and **Figure 2**.

Based on the histogram, a few observations can be made: Imola has the highest percentage of pure acceleration as well as combined acceleration out of a left turn. Spa has the most distance travelled in pure left cornering. All have more distance in pure left cornering than in pure right cornering.

Figure 4 shows a histogram for the same five different circuits. The 'Left turn' is composed by combined acceleration out of a left turn, pure lateral acceleration, and trail braking into a left corner. 'Right turn' is the sum of the combined acceleration out of the right turn, trail braking into right corner acceleration, and pure right cornering. The y-axis represents the percentage of the total distance that the vehicle travelled for that particular area.

The first thing that we can observe is that Imola is the track in

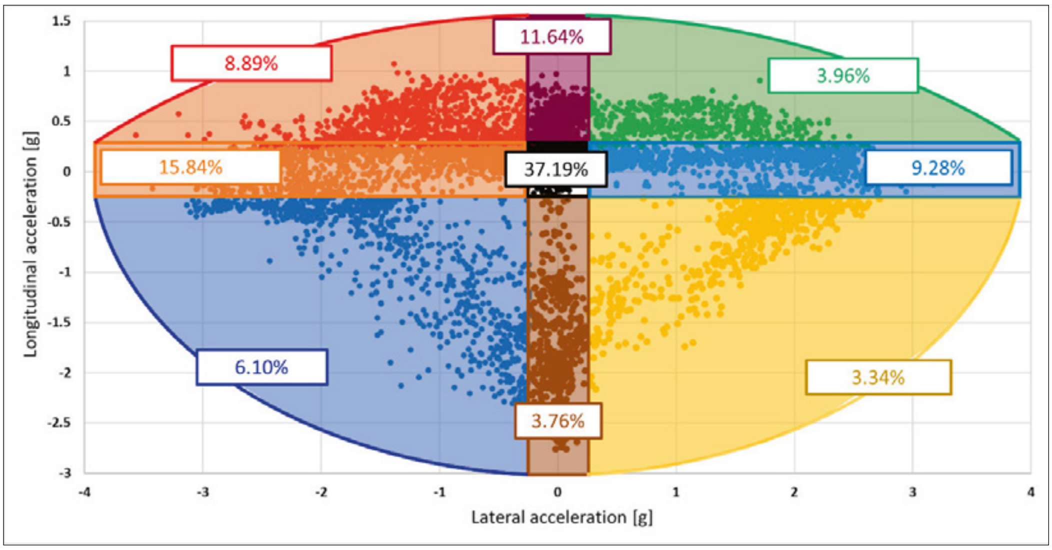

Figure 2: This shows the percentage of distance spent in each area of the GG diagram around the full Le Mans circuit

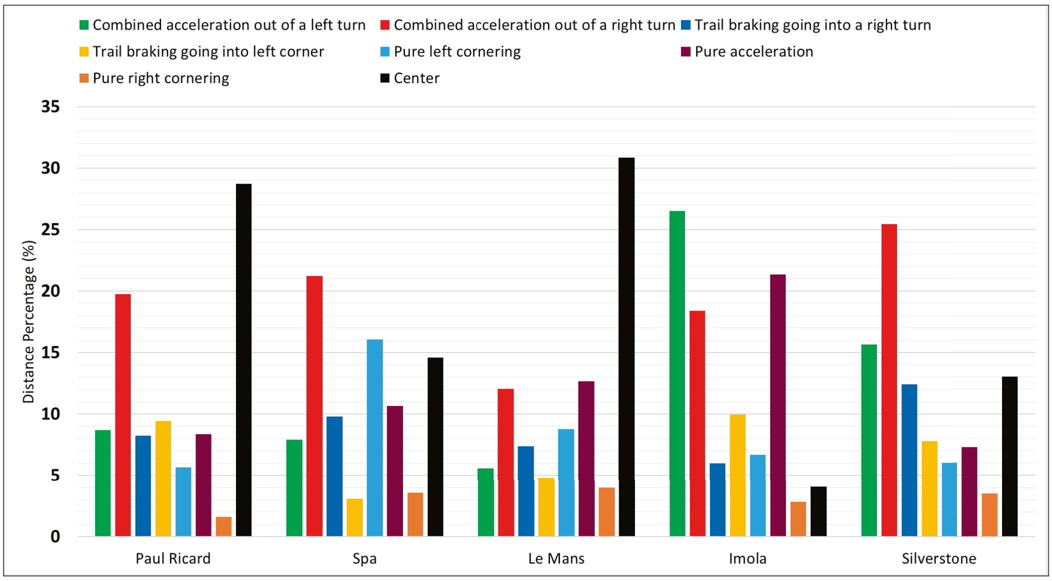

Figure 3: This histogram shows the percentage of distance spent in each condition at a variety of international tracks

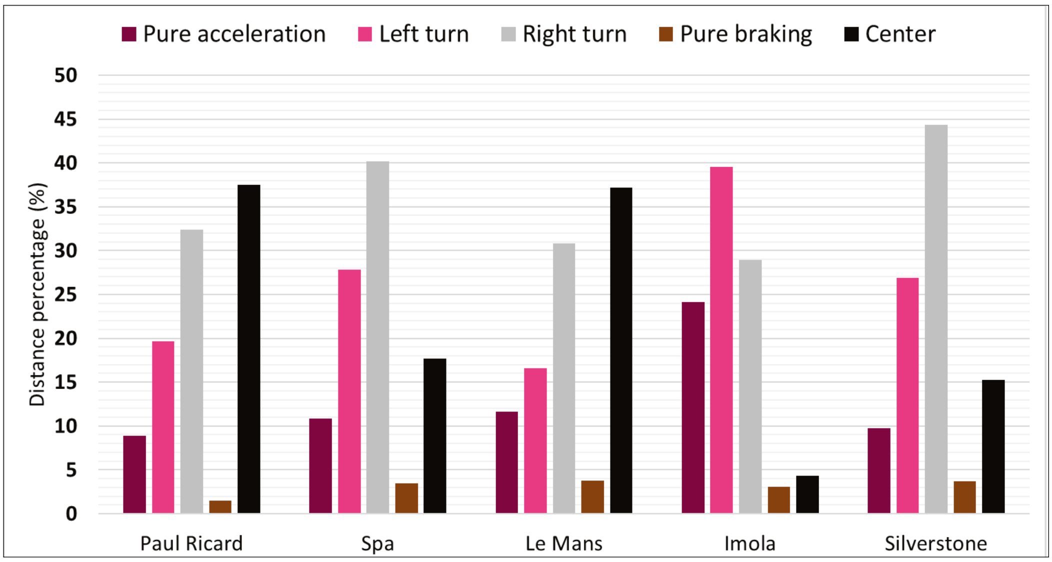

Figure 4: This shows the percentage of distance spent in each of the racecar conditions shown at the top of the chart

We can see that 30.83 per cent of the lap is right corners, while 16.58 per cent is left corners

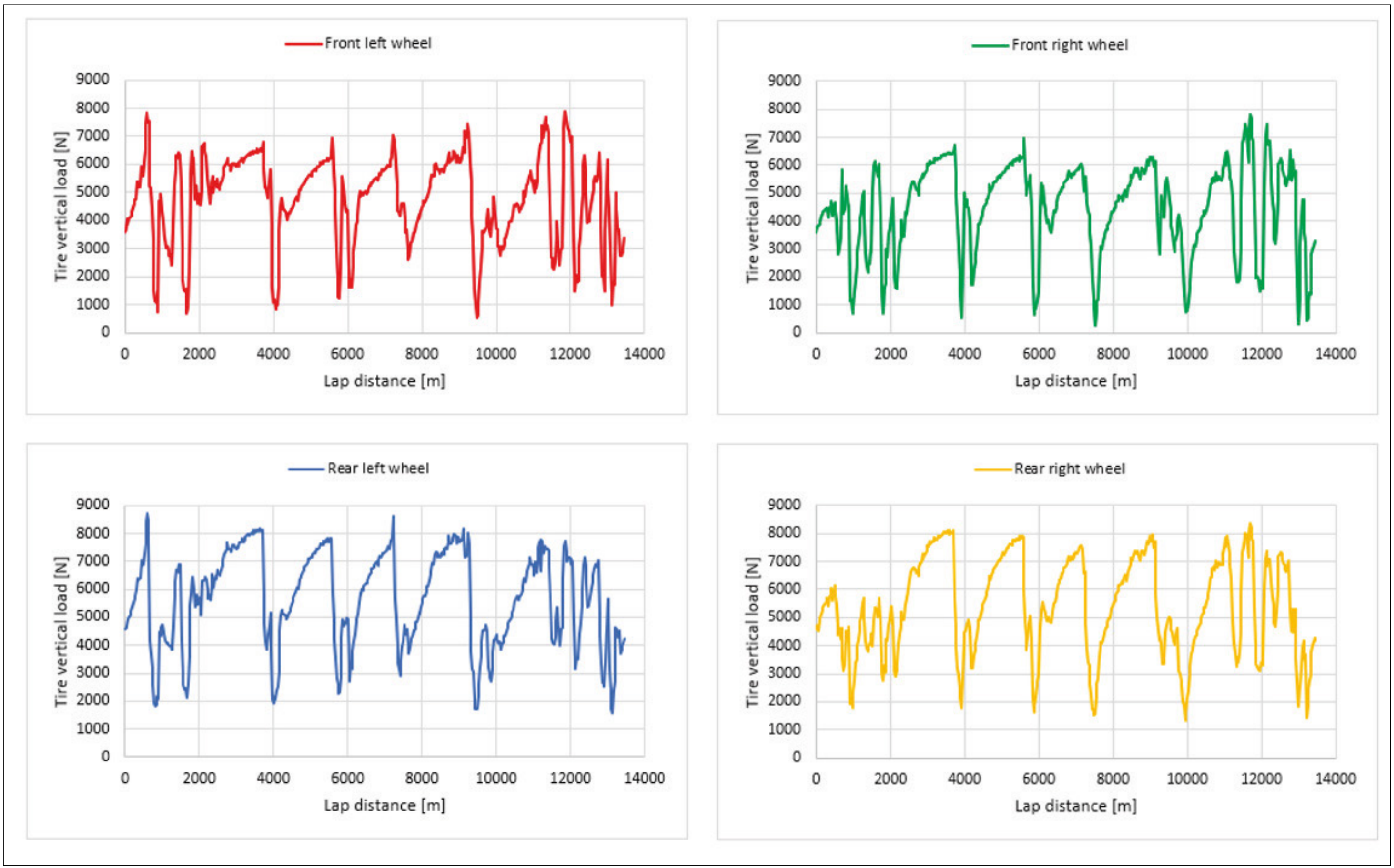

Figure 5: The tyre vertical load applied in each wheel along the track at Le Mans. This has been complied using the OptimumDynamics track replay feature

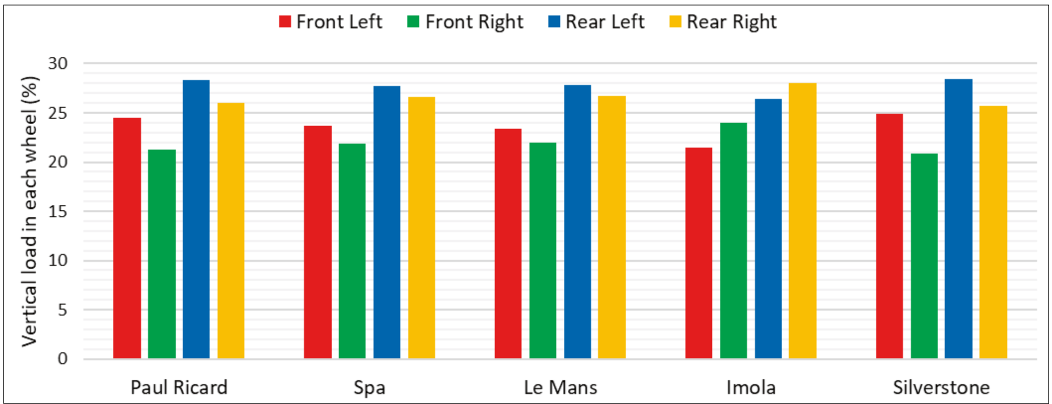

Figure 6: The percentage of tyre vertical load acting on each of the car's wheels through a lap of our example tracks

which more distance is covered in left-handed turns. We can observe that all circuits, except Imola, are more asymmetric to the right, because the racecar covers more distance in cornering to the right than it does to the left.

Besides looking at lateral asymmetry, we can also look at longitudinal asymmetry, the distance travelled in braking or acceleration. From the histogram, it's clear that the vehicle travelled more distance in pure acceleration than pure braking. Imola is the track that has the most percentage of distance travelled in the pure acceleration area.

Based on this conclusion, we can expect that for Paul Ricard, Spa, Le Mans, and Silverstone the left side will have the highest vertical loaded tyres. At Imola it will be the right.

Simulation

Using logged accelerations, speed, and steering wheel angle from the vehicle, we can run a simulation, where we reproduce a lap at the same track to analyse the vertical load for each tyre. **Figure 5** shows the vertical load, from simulation, in each of the tyres at Le Mans.

If we sum the vertical load from the simulation shown in **Figure 5**, along the lap, we can analyse the vertical load distribution between all tyres. The results, in percentage for each tyre, are shown in **Figure 6**.

As we have concluded above, **Figure 4** indicates that the car spends a higher lap distance under lateral acceleration to the right, except for Imola. Therefore, we expect that the left side of the car would be more loaded during the lap. This is confirmed by the simulation results displayed in **Figure 6**, where it is shown that the sum of the vertical load along the lap is higher for the left side, both front and rear, and in the case of Imola for the right side.

Corner weights

Looking at the dynamic cross weight also gives an indication of whether we should run with an asymmetrical static cross weight on the set-up pad to compensate for the dynamic cross weight for the circuit.

The cross weight is defined as the sum of the vertical front right and rear left wheel divided by the total sum of all vertical loads. From the vertical loads obtained from **Figure 5**, we can calculate the cross weight. By applying an average, we obtain the average dynamic cross weight for a lap **(Equation 1).**

On a given circuit we will put a little bit more cross weight on the

Besides the lateral asymmetry, we can also look at the longitudinal asymmetry, the distance travelled in braking or acceleration

Equation 1

$$cross\ weight = \frac{Fz_{FR} + Fz_{RL}}{Fz_{FL} + Fz_{FR} + Fz_{RL} + Fz_{RR}}$$

Where:

Fz_{FR} – front right, Fz_{FL} – front left, Fz_{RL} – rear left, Fz_{RR} – rear right

Table 2: Average cross weight along the tracks

Track	Cross weight (%)
Paul Ricard	49.53
Spa	49.45
Le Mans	49.82
Imola	50.56
Silverstone	49.35

diagonal that is less loaded along the race track (see **Table 2**). That would then help to preserve the tyres by avoiding putting an unnecessary load on them.

Conclusion

Splitting the GG diagram into eight areas can be useful to understand the amount of distance that a vehicle is spending in a particular area of the diagram. If we then integrate with respect to the distance of each of the areas that we previously defined, we can then quantify the percentage of distance that the vehicle spends in that area of the GG diagram.

This presents us with a way to understand the effort going through each tyre for different tracks. If we then sum the braking, acceleration and cornering for the left/right side we can have a quantifiable way of measuring the asymmetry of the track. The same can be done for pure acceleration and braking.

Using simulation we can then further understand how the asymmetry of the track affects the vehicle, for instance studying how the total vertical load distribution in each tyre changes from track to track, as shown.

These metrics can be generated from one or multiple laps, from qualifying or race laps. Depending on the data that is being used the results can differ slightly, but the most important thing is to use the same type of data for all race tracks to get a good reading of the delta between the circuits.

In this article we showed how to characterise a track, and why the set-up should be asymmetrical. This type of track characterisation and simulations are taught more in depth in OptimumG's data-driven seminars. In these we teach step by step how to process the data, interpret it, and draw conclusions. Based on these conclusions you can then choose the amount of camber, spring stiffness, damper set-ups, tyre pressures, etc. that you should be running on your car for a particular race track.

To find out much more about the OptimumG seminars' content and their dates, please visit the website at optimumg.com

The most important thing is to use the same type of data for all the tracks to get a good reading of the delta between the circuits

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Evaluating the aero on a BTCC racer

Is Team Hard's Volkswagen CC touring car as slippery as it looks?

Team Hard's VW CC was the quickest car on the track through the speed trap at the 2018 pre-season British Touring Car Championship (BTCC) test at Thruxton, the UK's fastest circuit. It topped out at 138.3mph (1.4mph up on the nearest rival), and set the quickest high speed sector times of the day. So it was going to be very interesting to see the baseline data in the MIRA full-scale wind tunnel in the very same configuration.

Renowned, highly experienced race engineer and designer Geoff Kingston had taken the technical lead at this team in late 2017, and had prepared for our wind tunnel session with a set of illuminating configuration changes to work our way through. Without further ado let's look at those baseline numbers, shown in **Table 1** in coefficient form.

Drag comparison

The low drag of the VW CC was immediately apparent, and compared favourably with the production car's drag coefficient, said to be around 0.29 (not the manufacturer's claim, by the way). Of more interest, though, how does this VW CC compare with other BTCC entries?

We have tested two other cars that conformed to the current NGTC technical regulations, and to make the comparisons valid **Table 2** shows the CD.A and CL.A values (coefficients multiplied by frontal area) giving values directly related to the aerodynamic forces at a given speed. The VW CC in BTCC trim produced 13 to 14 per cent less drag than the other two cars, while generating comparable total downforce. Hence its –L/D, or negative lift divided by drag (aerodynamic efficiency) figure was also significantly higher.

Another way of looking at drag is to calculate the power absorbed at a particular speed. With the writer's usual abominable mix of imperial and SI units, power in BHP, speed (V) in metres/second and area (A) in square metres: BHP absorbed = $(Cd \times A \times V^3) / 1225$.

So at 100mph, or 44.7m/s, in their respected baseline trims as tested, the BTCC VW CC absorbs 55.5bhp, whereas the Mercedes A Class absorbs 65bhp, which is a significant difference in a category where drag is said to be the dominant aerodynamic factor in achieving good lap times. We will return to this racecar's drag at various times during our forthcoming studies in subsequent issues of *Racecar*.

Setting up the Team Hard BTCC VW CC on the wind tunnel balance. The car has proved especially potent on fast circuits

Table 1: Baseline data on the BTCC VW CC

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Baseline	0.339	0.177	0.155	0.023	87.3%	0.522

Table 2: Baseline data for three different BTCC cars, all derived in the MIRA full-scale wind tunnel

	CD.A	-CL.A	-CLfront.A	-CLrear.A	%front	-L/D
VW CC	0.763	0.398	0.349	0.052	87.3%	0.522
Subaru Levorg	0.882	0.400	0.168	0.232	42.0%	0.454
Mercedes A Class	0.891	0.385	0.328	0.057	85.1%	0.431

Downforce and weight

The technical regulations in the BTCC are not intended to allow high downforce, and they have been kept to very modest levels. But the burning question is, are they significant in terms of generating extra grip? Let's look at the actual vertical forces on the VW CC and compare them to the car's weight.

In baseline configuration the VW CC's total downforce was measured at 500.3N at 100mph, or 51kg in the planet's gravitational field. 87.3 per cent was on the front axle and 12.7 per cent on the rear axle, amounting to 44.5kg front and 6.5kg rear. The car plus driver (less fuel or success ballast) weighs around 1350kg, split 61 per cent front, 39 per cent rear, or 823.5kg front, 526.5kg rear. So in relative terms, front downforce equated to 5.4 per cent of the weight on the front tyres, and rear downforce to 1.2 per cent of the weight on the rear tyres.

Downforce has been kept at very modest levels in the BTCC

The CC's curves did not flatter to deceive and it was shown to have a low drag coefficient

British Touring Car rear wings are not supposed to generate very much downforce

Removing the wing from the VW CC revealed the extent of the base road car's rear end lift


Renowned BTCC race engineer Geoff Kingston is the technical chief at Team Hard

Table 3: The effects of removing the rear wing

	CD	-CL	-CLfront	-CLrear	%front	-L/D
With wing	0.339	0.177	0.155	0.023	87.3%	0.522
No wing	0.331	0.036	0.195	-0.158	540.3%	0.109

Table 4: The effects of wing angle changes; angle measured in the centre

	CD	-CL	-CLfront	-CLrear	%front	-L/D
8deg nose up	0.340	0.170	0.156	0.014	91.7%	0.499
7deg nose up	0.339	0.177	0.155	0.023	87.3%	0.522
5.7deg nose up	0.343	0.189	0.151	0.039	79.8%	0.550
4deg nose up	0.344	0.201	0.147	0.054	73.0%	0.584

If we assume that the grip increase is directly proportional to the increase in vertical force felt by the tyres, then at 100mph front grip would improve by 5.4 per cent and rear grip by 1.2 per cent (compared to zero downforce or lift). And in a given radius of corner this, again simplistically, is related to the square of the potential speed around the corner. If the car was able to exploit that 5.4 per cent extra grip (ignoring the front to rear imbalance) then this would enable a 2.7 per cent increase in corner speed, to 102.7mph in this single point example. While it could be argued that this is irrelevant in a category where the cars are more or less equal, the exercise shows the value of even modest downforce levels.

Wing removal

A configuration change we had never previously tried in Aerobytes was removing the rear wing to see what effects it had, as shown in **Table 3**. Drag actually reduced very little, superficially implying that the wing wasn't contributing very much. But the changes to the downforce numbers suggest otherwise, and in fact the absence of the rear wing allowed a significant amount of positive lift to be felt at the rear tyres, shown here as a negative -CLrear value. The apparent increase in downforce at the front tyres would not be aerodynamic; rather, it would be due to the absence of the wing's mechanical leverage behind the rear axle which, when present, adds a lifting force at the front tyres. Rear end lift is a common trait of production cars, especially low drag ones, where the curvature of the roof to the rear screen sees a zone of reduced pressure.

Wing angles

We'll now look briefly at the results of a wing angle sweep, as shown in **Table 4**. The BTCC rules not only mandate the wing's location (via a regulator-run wind tunnel evaluation) but also stipulate the range of permitted angles, hence the limited range tested here. The responses were essentially linear. Drag changed by just over one per cent across the range, and front downforce changed by a modest nine counts, or 5.8 per cent. Actual rear downforce (at 100mph) ranged from 62.4N to 149.4N, or 6.4kg (1.2 per cent of rear axle weight) to 15.2kg (2.9 per cent of rear axle weight). The change in vertical force at the front tyres was even smaller, from five per cent to 5.3 per cent of the car's weight. Aerodynamic balance went from 92 per cent front to 73 per cent front, which sounds like a large change, but in this context basically represents an increase of just 9kg on the rear tyres at 100mph. It would be a sensitive driver who could feel that difference.

Next month we'll examine cooling drag, rake change and the effect of roll angle.

CONTACT

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

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PRIMARY DESIGNS

Access all areas

NASCAR R&D has not relented in its quest to improve safety and the quality of the racing in 2018 – as *Racecar* discovered when its director of aerodynamics, simulation and design gave us the inside line on new Cup and Truck developments

By ERIC JACUZZI

Removing the static ride height requirement means the cars at the superspeedways are low – extremely low

The 2018 NASCAR season is now over a third of the way through and NASCAR R&D has been busier than ever, with a focus on the top-tier Monster Energy NASCAR Cup Series (MENCS) and the NASCAR Camping World Truck Series (NCWTS). As always, the updates we make are aimed at reducing the costs, increasing the safety, and providing more excitement for the race fans.

Let's begin with the top series, MENCS. To improve the lift-off speeds at superspeedway events in the Cup, NASCAR wind tunnel tested and track tested removing static ride height requirements to reduce the rear ride heights of the cars. The new regulations were introduced this season for the Daytona 500. Wind tunnel testing showed a gain of approximately 25 per cent in lift-off speed by maintaining the car as close to the ground as possible during a spin, rather than lifting back up to the static ride height as it would in the past. However, as all changes in motorsport tend to do, it introduced a variety of new issues to contend with that were not immediately anticipated.

Low riders

Removing the static ride height requirement means the cars at superspeedways are low – extremely low. With the mandated 5in rear spoiler, the name of the game is hiding the spoiler behind the greenhouse. The first way this is achieved is by having the rear of the car as low as is possible based on the regulations. The limiting point at the rear of the car is the Panhard bar mount. Teams sought to maximise the mount height as much as possible to allow more ground clearance. This was anticipated to increase speeds by 3-4mph at Daytona, resulting in pack speeds approaching 202mph at the fabled superspeedway.

Between Daytona and Talladega there was a clarification to the rule that allowed some teams to build in more ground clearance and hence more rear travel, which resulted in pack speeds of 204mph in the first practice. A frightening incident occurred involving the No.1 car of Jamie McMurray, which suffered a left rear tyre failure along the backstretch. This caused it to veer abruptly left into the nose of Ryan Newman's No.31 Chevrolet. With the No.1 car being struck and pushed sideways it became airborne over the top of the No.31 and tumbled violently down the track. A decision was made to reduce the engine restrictor plate size in the interest of safety, reducing speeds by 3-4mph.

Skewed vision

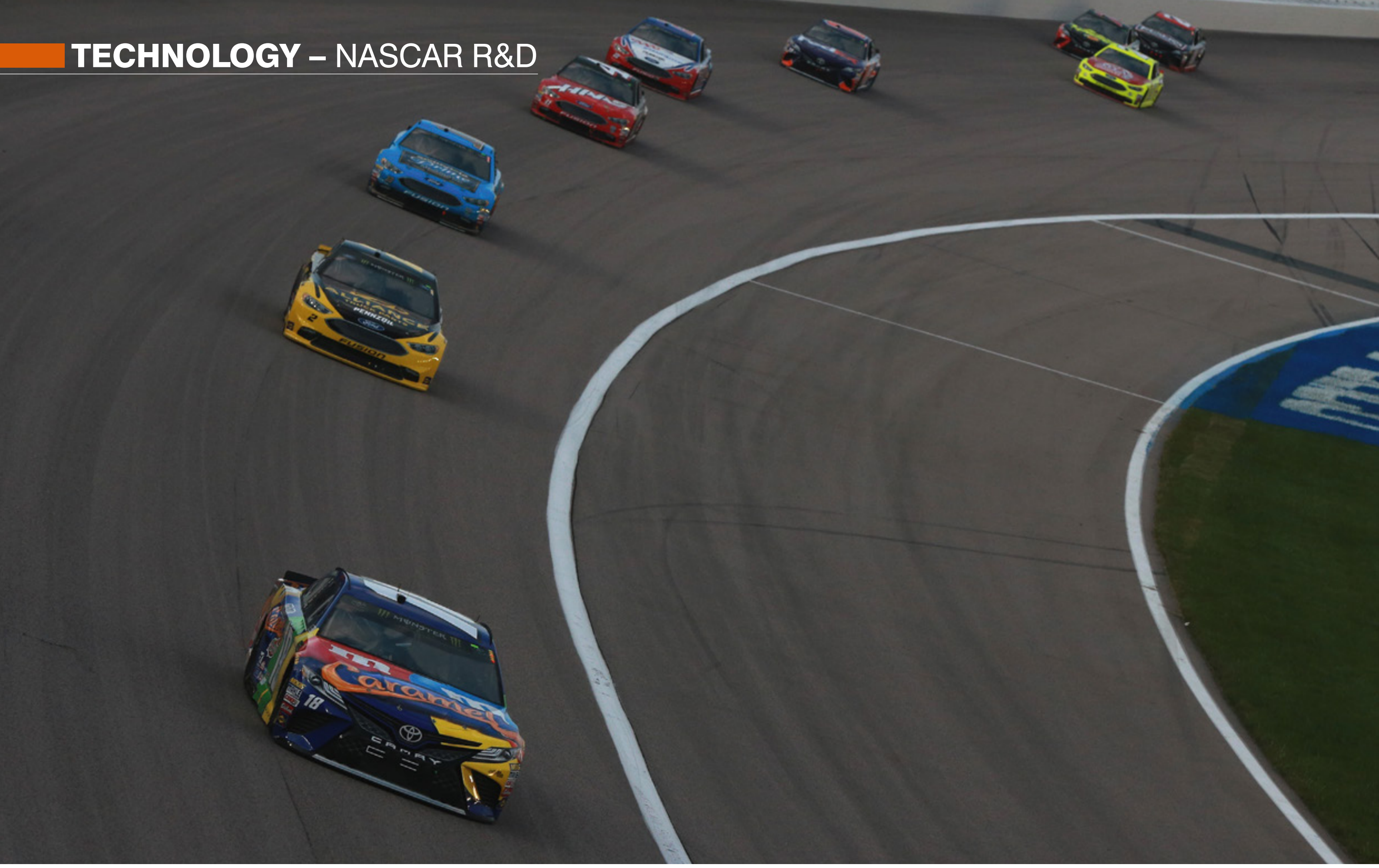
Another visual difference that occurred with the new regulations was the appearance of reverse skew, with the cars travelling down the straights with their rears shifted to the left. This was caused by the asymmetry of the bodies, which have the tail offset to the right to generate a positive yaw moment. This is a desirable characteristic at most tracks except superspeedways like Daytona and Talladega, where drag is the primary performance differentiator. Because the spoiler is centred on the tail, it is in effect shifted to the right of centreline on the car. Hiding the spoiler by yawing the car in a clockwise direction from the top proves to be the lowest drag configuration. Teams achieve this by varying the trailing arm lengths within the regulations and by the height difference between the Panhard bar points.

The optimal solution to this issue would be to remove the asymmetry from the body, but that will have to wait for the next generation of body for the Cup Series. In the meantime, NASCAR R&D is now investigating both increasing the size (and hence the drag) of the spoiler and potentially shifting more of the spoiler to the left of the car. This will force the optimum yaw angle of the racecar closer to zero degrees and should help reduce the skew of the bodies at superspeedways.

Xfinity and beyond

With the success of the NASCAR Xfinity Series (NXS) race at Indianapolis in 2017 and its expansion to Michigan and Pocono in 2018, it was only a matter of time before the package (see May 2017 issue, V27N5) was attempted with the top-tier Cup Series. In a bid to spice up the Monster Energy All Star Race at Charlotte Motor Speedway, NASCAR's worked with the industry to build consensus and agree to use the exhibition event as a testing ground.

With a $1m purse on the line, the All Star race provides a perfect opportunity for evaluating potential package changes in a non-points race environment. Innovations in the racing product have previously been tried



NASCAR is investigating increasing the size of the rear spoiler and shifting it to the left in a bid to eradicate the chassis skew Cup cars have been exhibiting out on track this season

out at the All Star Race, including double file restarts which are now commonplace. Charlotte is a challenging intermediate track that features 24 degrees of banking and a 1.5-mile overall length, making for high corner speeds.

All Star draft

After getting the green light, the NASCAR R&D team went to work to make the All Star Race package a reality. The key components to the original NXS Indy package, now known as the Drafting Package, included a significant increase in downforce and drag via a larger splitter and rear spoiler, reduced engine power, and enhanced slipstream performance through the use of NASCAR designed ducts in the front fascia, which have been dubbed 'aero ducts.'

The aero ducts improve the slipstream performance of the cars by anywhere from 25 to 40 per cent at various trailing distances, giving the trailing racecar a marked drag advantage and promoting passing. In the 2017 NXS race at Indy there were record passes for the lead and a thrilling 0.1 second margin of victory. More of the same is anticipated from the MENCS version at the All Star race (set to take place after *Racecar* went to press).

The All Star race provides a perfect opportunity for evaluating potential package changes in a non-points environment

With such a short time frame, NASCAR utilised its trusted CFD process to establish baseline car performance on the current 2018 aero rules package. Then the larger splitter and spoiler were added, and finally, the aero ducts. Models of each current Cup car were generated to assess the changes on each manufacturer.

Drag racing

Summarised in **Figure 1**, the results show that at close spacing (0 to ½ car lengths), the current low downforce package (blue) penalises the trailing car from a drag perspective, resulting in what is colloquially known as the 'drag bubble.' This means that as a trailing car approaches a leading car, it will push the leading car away through a combination of increased drag on the trailing car and a reduction in drag on the lead car caused by the presence of the trailing car.

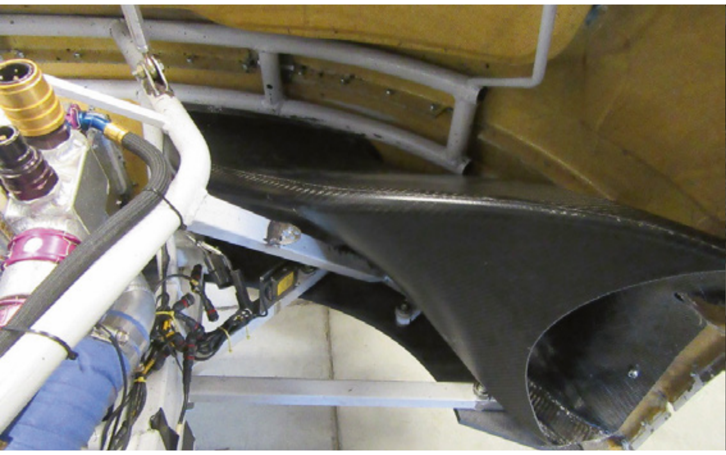
At spacings from a half-car length up to four car lengths, the trailing car enjoys a slight drag advantage. Adding the larger spoiler and splitter results in a greater drag advantage at most spacings, but concerning was the increase in the drag bubble at the half-car length location, which could work against the goal of increasing passing. This effect is due to the increased upwash and inwash behind the leading car because of the increased level of downforce, as well as the reduction in base pressure behind the lead car due to the presence of the trailing car. Adding the aero ducts not only increased the slipstream performance at each following distance, it also reduces the drag bubble at below the level of the low downforce package by widening the wake of the car.

The aero duct design was complicated by the unique front-end designs used by each of the three manufacturers in the Cup. A key consideration for manufacturer partners was for us not to negatively impact the aesthetics of the racecars while still achieving the increased slipstream performance. After evaluating several options for a common duct design, NASCAR ultimately decided to produce distinct sets of ducts for each of the manufacturers, which will make use of the manufacturer-specified brake ducts as an inlet for the aero ducts.

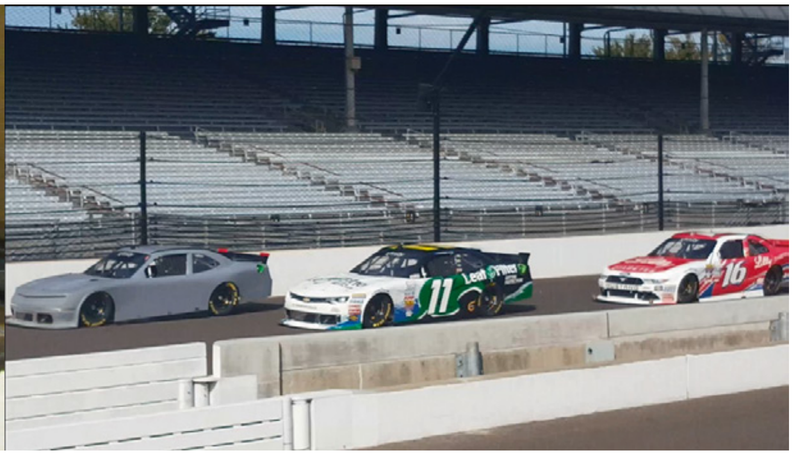
Perfect fit

As part of the body homologation process, each manufacturer specifies a location and design of brake ducts for their model. The design process for the aero ducts involved using a common section from the middle of the duct to the exit at the wheel opening, with a manufacturer-specific inlet and front duct section.

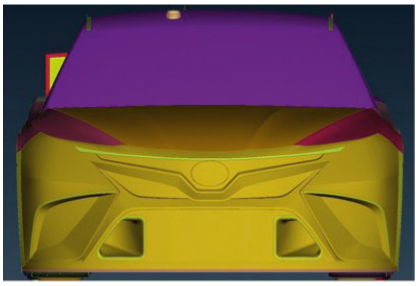
Cross-sectional areas of the manufacturer brake ducts were very close, but to alleviate performance differences from increased mass flow rate, the ducts intentionally feature a choke point of approximately 50 per cent of the inlet volume at the approximate mid-point of the duct. Variance in downforce and drag between manufacturers was well within an acceptable range, with the drag delta being nearly identical between makes.



A close up of the drag duct installed on the right hand side of an Xfinity Series stock car. Versions of these aero devices are now to be tested in the Cup series

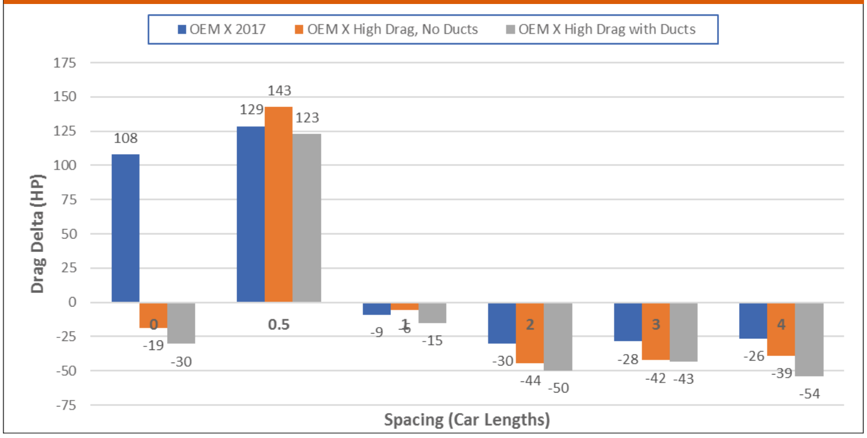


The Xfinity ducts were tested in a mock race at Indianapolis last year (above). The Cup aero ducts were set to be used for the first time at the non-points scoring All Star race at Charlotte



Toyota Camry Cup car CFD model with the aero duct inlet visible. This is also the brake duct inlet

Figure 1: Lead *vs* trail drag delta for Cup cars



Aero map average results indicate the ducts will add approximately 50lbf of downforce at 200mph, with the total All Star package having approximately 1200lbf of downforce and 300lbf of drag. With the engine restricted to 435bhp, lap simulation indicates that the qualifying speeds should be in the range of 160-165mph, with anticipated peak race speeds at 175mph. It is hoped that the reduced corner entry speed and the increase in downforce will widen the racing line at Charlotte Motor Speedway and offer up an exciting race for fans.

Pending the outcome of the Monster Energy All-Star Race, NASCAR and industry partners will evaluate the race and decide whether a broader implementation of the package is advisable for the 2019 Cup season. If there is consensus, NASCAR will work to certify the ducts as part of the aero package for each manufacturer to ensure parity for the 2019 season. While not an across-the-board race package, the MENCS drafting package could be realistically expected at some of the longer tracks on the calendar to deliver the kind of racing NASCAR fans have come to expect every weekend.

Truck Series

Talking of on-track excitement, often providing some of the best racing of the NASCAR weekend is the Camping World Truck Series. It holds a special place in the hearts of many die-hard NASCAR fans. As with all three major series, NASCAR has worked tirelessly to reduce costs in the NCWTS to ensure as many teams as possible can be competitive and healthy.

In an effort to reduce engine costs, NASCAR worked with Ilmor throughout 2017 and into early 2018 to introduce an optional engine, dubbed the NT-1. Engine costs can represent up to 50 per cent of truck team budgets, making it a significant incentive to reduce these costs and provide a more equitable playing field. With a low purchase price, robust tunability and a 1500-mile rebuild schedule, the engine has provided substantial savings to truck teams along the pit lane. Some estimates have put these savings at $400,000, which is a substantial sum for many teams in the field.

Balance of power

A key factor in developing the engine as a viable option in competition was to ensure that there would be parity of performance with the OEM engines already used in the series. This kicked off a co-operative effort between NASCAR and the three manufacturers to analyse the current crop of truck powerplants and come up with a tuning and gearing solution for the NT-1 that everyone could be happy with.

The NT-1 engine's characteristics necessitated a thorough investigation of gearing and calibrations across a variety of tracks. The NT-1 engine has a greater displacement than the OEM engines but has a lower rpm limit and greater torque earlier in the rpm band. Typically, manufacturer engines are targeted for an 8200rpm peak engine speed in races but are capable of up to 9000rpm without issue. The NT-1 engine has a soft redline of 7500rpm with a progressive limiter up to 7700rpm, where full spark cut occurs. This necessitates a rear gear difference between OEM and NT-1 trucks, aside from matching performance between two very different torque curves. The greater torque of the NT-1 at a lower rpm range meant full lap simulation analysis was required to ensure a level playing field.

To analyse parity of the engines NASCAR worked with engineering teams from Chevrolet, Ford, Toyota and Ilmor to perform independent simulations of several tracks on the NASCAR calendar that were representative of the various

Aero map average results indicate that fitting the ducts to the Cup cars will add approximately 50lbf of downforce at 200mph

The manufacturers have worked with NASCAR to make sure its NT-1 is on the same level as their own truck powerplants

The NT-1 engine has helped slash truck budgets by up to $400,000 in some cases, while the racing is still as close as ever

track types raced on. These included using Daytona as the superspeedway target, Charlotte to represent intermediate tracks, and Iowa to represent short tracks. Each engineering team, including NASCAR R&D using ChassisSim lap simulation software, provided results based on various calibrations and air restrictions for the NT-1 versus the current crop of manufacturer engines. The results were unanimous for superspeedways, with a 1.062in four-hole size restrictor using the lowest electronic power calibration. Each air restrictor size has been tuned to have a low-, mid- and high-power calibration that can be changed via updates to the ECU. For the intermediate and short tracks, all organisations landed on a 1.600in restrictor opening with the low-power calibration.

Another unique attribute of the NT-1 engine that had to be considered is its somewhat lower temperature tolerance when compared to the manufacturer engines. The current cooling layout of all vehicles in NASCAR features radiator cooling air emptying into the under-hood region, which directly impacts the downforce of the car. The ability to run less cooling airflow, and thus higher engine temperatures, means that the car can make greater downforce. The NT-1 engine is not quite as capable of running high temperatures as the manufacturer engines, so simulation work had to include both outright qualifying laps (with no cooling airflow) and race laps, with slightly reduced downforce for the surrogate NT-1 trucks in race trim.

Engine costs can represent up to 50 per cent of a NASCAR truck team's budget

Keep on trucking

Simulation results have correlated well with on-track performance, with manufacturer and NT-1 powered cars performing equitably. A major boost has been given to the midfield teams, who previously were racing used engines at a much higher cost and lower power level than the new NT-1 due to budgetary constraints. Additionally, the purchase or lease of the engine includes at-track support from Ilmor to address engine tuning and other typical engine issues.

NASCAR will continue to monitor the performance of the engines and adjust the calibrations as needed but, for now, the NT-1 is looking like a big win for the series, one that NASCAR could not have accomplished without the help of the OEM partners and Ilmor.

Rigged-out

Our two-part examination into shaker rigs continues with a look at the wide variety of hi-tech virtual and physical paraphernalia that's needed to make these amazing machines perform at their very best

By GEMMA HATTON

In last month's issue we delved into the fascinating world of shaker rigs, exploring the concepts behind them and looking at new innovations in the sector. This month we will be taking this a step further, venturing into the virtual dimension of rig testing, while also looking at the various measurement tools.

There are many questions to ask. With a F1 seven-post rig test logging approximately 100 signals at 1000HZ, just how is this amount of data measured, stored and managed? How can you synchronise seven actuators to move at mm-perfect displacements? How can you simulate tyre squash when the wheels are stationary? As ever, there is only one way to find out, and that is by talking to the experts.

At first glance seven-post rigs can be a bit of an anti-climax, as what you see is a car simply sitting on four metal plates that move up and down. But strip back the floor and underneath you will find a web of data acquisition points, along with complex hydraulic actuators to achieve the precise synchronisation and displacement of the wheelpans and aeroloaders.

Above 100mph, aerodynamic downforce has a major effect on the suspension. This is why in most motorsport applications three aeroloader actuators are added, with usually one at the front and two at the rear, along with the four wheelpan actuators at each corner. The wheelpan actuators drive displacement inputs into the wheels, emulating the bumps on a track, while the aeroloaders are attached to the chassis and simulate the overall effect of downforce by pulling down on the car. All these combine to create the seven 'posts' of the rig.

Double data

Rigs require two sets of sensors to capture the data. Firstly, there is a vast array of sensors on the car to accurately measure the reaction of the chassis, suspension and tyres, while another set of sensors is required on the rig to monitor the inputs and the rig's performance.

'On the car usually there will be pushrod loads, damper displacements, strain gauges measuring the drop-links for the rollbars and accelerometers on the wheel hubs and the body

A seven-post rig test on a GT car such as this Porsche can log up to 70 signals at 1000Hz. That amount of data requires clever control strategies and accurate sensor measurement

to measure pitch, heave and roll,' says Henri Kowalczyk, COO at Auto Research Centre. 'On the rig side, each wheelpan has a displacement sensor and accelerometer to know what the 'road' is doing as well as a load cell to measure the normal load that the car is seeing. For a seven-post rig, you then have the aeroloaders to worry about, which require displacement and velocity sensors in addition to load cells. You will also be measuring temperatures of the actuators and other rig performance parameters. In this way, you can tell from the input side what the rig is doing and from the output side what the car is doing.'

Some of the most crucial sensors are the load cells, used to measure the axial forces exerted by the actuators on both the corner posts and the aeroloaders. The wheelpan load cells mounted on the corner posts also feature inbuilt accelerometers, so that the dynamics of the displacement can be monitored.

Load cells

'The principles of a load cell design are quite generic although there are different types depending on application specific factors,' says Ian Papworth, applications engineer at Novatech Measurements Ltd. 'We use foil strain gauges that are either etched or deposited depending on the production process of the supplier. Effectively, a strain gauge consists of loops of very fine wire, only microns thick. These

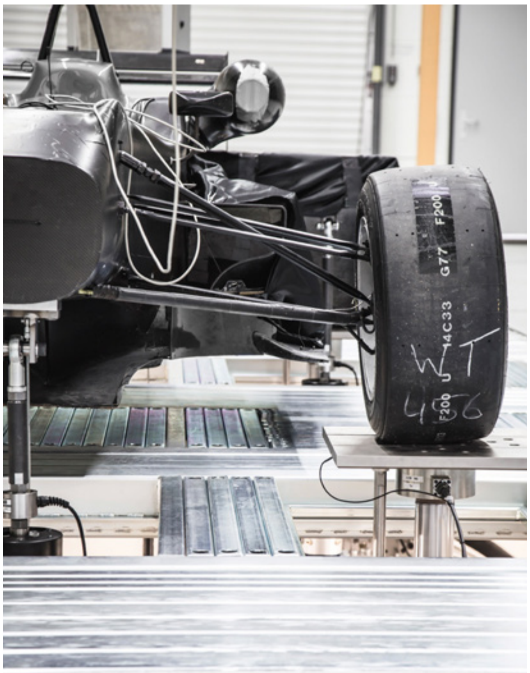
A Formula 1 seven-post rig test logs approximately 100 signals at 1000HZ, but just how is this amount of data measured, stored and managed?

Sensor table

Car	Rig	
	4 post Rig	7 Post Rig (additional channels)
4 x Hub accelerometers (FL, FR, RL, RR)	4 x Wheel actuator displacement (FL, FR, RL, RR)	3 x Chassis velocity transducer (near each aeroloader)
4 x Chassis accelerometers (FL, FR, RL, RR)	4 x Wheel contact load (FL, FR, RL, RR)	3 x Aeroloader velocity
4 x Damper displacements (FL, FR, RL, RR)	4 x Wheel actuator acceleration (FL, FR, RL, RR)	3 x Aeroloader displacement
2 x Damper temperature (FR, RR)		3 x Aeroloader load
Vertical body acceleration (positioned at cog)		Front ride height
Lateral body acceleration (positioned at cog)		Rear ride height
Longitudinal body acceleration (positioned at cog)		Air speed (from track data)
		Lateral acceleration (from track data)
		Longitudinal acceleration (from track data)

There are two sets of sensors required to run a rig test; those on the racecar and those on the rig itself. Additional channels are then required for seven-post tests and track replays

At each corner wheelpan actuators drive displacements into the wheels to simulate track inputs. There are also the three aeroloader actuators which emulate the effect of downforce; usually with one at the front and two at the rear, as seen here



There are normally two sorts of test conducted on seven-post rigs. These are sine sweeps and track replays. The former characterises the suspension at different frequencies and the latter analyses the vehicle's response to realistic track inputs

are attached to a metal structure, and when this structure deforms under load, it either stretches or compresses the wire grid, therefore changing its length and cross-sectional area. All the time this deflection is occurring, the resistance of the wire is changing. The foil strain gauges are wired up in a Wheatstone bridge and any change in resistance excites this bridge, forming a potential divide. The output signal is in the order of millivolts and is linearly proportional to the amount of load applied. Instrumentation is set up so that the calibrated output is displayed as an accurate force measurement.'

Wheatstone bridge

The Wheatstone bridge is a concept dating back as far as 1833. It converts small changes in resistance to a voltage signal. Typically, four resistive elements are connected in a diamond shape, with the resistance value of one element unknown and the other three known. From the output, this unknown variable can be determined through comparison with the other resistors. In the case of a load cell, the Wheatstone bridge is used in conjunction with the strain gauges described above, which replace all of the resistive elements and all have equal, known resistances. When a load is applied to the strain gauged structure and the wire deforms, either stretching or compressing, the resistance across the Wheatstone bridge is unbalanced, producing a voltage corresponding to the induced strain and therefore the applied load. The wire of these gauges are designed to work within their elastic limit, so the wire reverts back to its original shape once the load has been removed, rebalancing the Wheatstone bridge into the 'zero' condition.

'The trick when designing a load cell is making sure the way you design and fabricate the metal component is going to give you the correct amount of deflection and therefore output signal for the load,' Papworth says. 'If you get it wrong, you could end up with the wrong amount of deflection. Either the output signal will be too low, leading to a loss in resolution, or you can go the other way and make the metal component too soft so that it deflects too much. This is even worse as it potentially puts the material under huge amounts of stress leading to fatigue, cracking and even complete mechanical failure. Although simple in concept, load cells do require a certain amount of engineering know-how and expertise.'

Foil gauges

Novatech use foil strain gauges for four- and seven-post rig applications because they are the most stable and versatile, although the needs of many other industries to measure low forces at the highest resolution has opened up the potential for other load cell technologies to be utilised in the future. 'Piezoelectric devices are good for high frequency measurements and semiconductor gauges allow much more signal for the same mechanical deflection,' Papworth say. 'This could potentially increase the resolution beyond what foil strain gauges are capable of. But the technology that some companies are currently taking more seriously is fibre optics. They work almost like a radar gun where you measure the time taken for one pulse to travel down the fibre optic and bounce back. The strain element of the fibre optic wire can be attached to a material and, when deflected,

Four- and seven-post rigs tend to be adaptable and can be utilised to tune suspensions for pretty much any vehicle; whether it's a Formula Student (pictured) or a Formula 1 car

there will be a change in length of the section that the wave is propagating along so the return signal will be slightly out of phase. Fibre optics will come into their own in applications where large electromagnetic forces could severely effect the output of the load cell.'

Accurate inputs

The aim of a shaker rig is to simulate the effect of track inputs on the suspension, so the race teams can not only fully understand the characteristics of their particular suspension designs, but they can also experiment and tune the suspension to optimise their racecar's performance. To achieve accurate results, the inputs from the rig into the chassis have to be realistic, which is why the aeroloader actuators require the innovative 'compliant links' developed by Servotest, which we discussed last month. Furthermore, the drive file itself also has to be representative, and achieving this on a rig is quite a complex process.

Sine of the times

There are two main types of tests that are conducted on a shaker rig. The first is called a sine sweep. This is where the wheelpans are moved in a sine shaped movement. In this way the characteristics of the vehicle can be measured at each frequency, which is where the frequency of the wheelpan displacements gradually increases and the consequent performance of the racecar is measured.

Load cells are instrumental in measuring the displacement of the wheelpan and aeroloader actuators. They work by feeding back to the control system to achieve the precise control necessary to give realistic vehicle responses

The second type is a track replay. The first task before any form of track replay testing can be conducted is to generate a 'track file'. This contains the information on how to move the rig to match the car's suspension movements from the track. To do this the dynamics of the system need to be characterised by determining the frequency response function (FRF) or system matrix of the vehicle and rig combined as one system. This essentially measures the magnitude and phase of the outputs as a function of frequency compared to the inputs. These outputs are commonly shock potentiometers and pushrod load cells, while the inputs are the seven rig actuators.

'At the beginning of a track replay test, we have to develop the track file to replicate the

'The trick when designing a load cell is to make sure that the metal component is designed and then fabricated to give you the correct amount of deflection'

suspension movement from the track inputs,' says Christer Loow, engineering manager at Ohlins. 'We take the exact same sensors they use on the track and instead of recording them with the team's data acquisition system, we plug them into our data acquisition system. We then play random inputs for a few minutes, which moves the car randomly, and we measure the frequency response of the whole system.

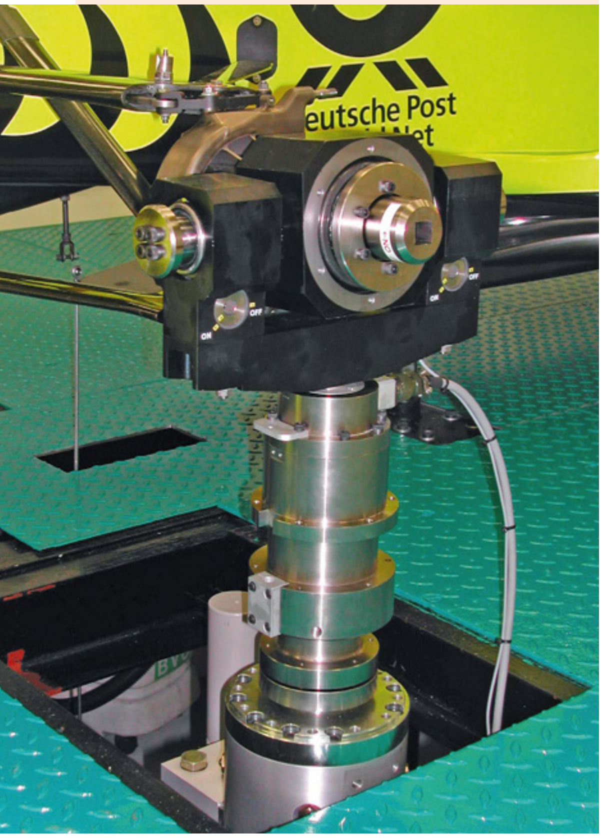
'So, for example, we measure the effect on the left front suspension if you push or pull with the three downforce actuators and bounce with the four wheelpan actuators. We can then use this data to develop a computer model of the vehicle and the rig together as one system. We then invert that model mathematically. The inverted model is used together with the data

Socket set

Perhaps the most important performance factor of any racecar are those four rubber circles at each corner. Tyres are unquestionably a black art to design, model and analyse. Yet despite this complexity, advances in reliable data capture, correlation studies, and the available computing power these days, are all contributing to improving the accuracy of tyre models.

On a rig the main aim is to achieve an accurate representation of the suspension response from track inputs. However, these displacements are induced by the wheelpan actuators into stationary wheels. So not only are these wheels not rotating, but the consequent squash of the rubber under aero load is also not considered, leading to unrepresentative suspension measurements when compared to those monitored at the track.

But there's a way around this, as the physical tyre on the rig can be replaced by a virtual model, a load *vs* displacement DSP Simulink model to be exact, also known as a 'socket'. This model is inserted into the control loop in the DSP so it can influence the control in real time, and it allows the characteristics of the tyre to be modelled relative to car velocity and downforce, whilst the actuators drive the inputs into the wheel spindles. 'The Socket is a black box with as many inputs and outputs and as much complexity as the engineer judges necessary to model the dynamics under scrutiny,' explains Vincent Besson, R&D engineer at Servotest. 'For example, the effect of tyre growth in a spinning wheel or the influence of DRS on downforce can be simulated, as well as banking effects and a lot more which the teams do not tell us about.'



Sockets are virtual tyre models that replace physical tyres on the rig. They are integrated within the control loop to simulate the effect of tyre growth, and of downforce, during rotation. The displacements are driven into the wheel spindles (above)

The control system allows the operation of each actuator as well as the synchronisation between them. Here a single Optostar fibre optic purple cable on the node box allows noise-immune digital data communication

from the shock potentiometers and pushrod load cell data collected at the race track to calculate how we should move our seven actuators on the rig to replicate the suspension movements from the track.'

Essentially, the race teams use track data to iterate through different parameters to try and figure out what inputs are needed on the rig to recreate the outputs they saw at the track. Once this track file has been refined, this becomes a constant input into the test and therefore any measurements captured during the test are real responses which should match those experienced at the track.

Synchronisation

Another key factor in running realistic tests on a shaker rig is the synchronisation between all the wheelpan and aeroloader actuators. 'For a four-post rig, the key is to control all four actuators to exert their specific correct inputs and at the same time. Otherwise you'll be putting inputs into the car that it is not seeing at the track,' says Kowalczyk. 'For example, if you're inputting a heave input where all four actuators are supposed to be travelling at the same time and there is a delay between the front and rear, then you'll actually end up inputting some pitch, which is not what you want.

'For a seven-post rig, it's a similar problem,' Kowalczyk adds. 'But those additional aeroloader actuators that simulate downforce have to move with the car, because they are attached to the chassis. It's easy to apply a force to a single actuator, but it becomes harder when the car is moving and you are trying to make sure all of the actuators are tuned.'

To operate each individual actuator, as well as precisely synchronise them all together, requires an advanced control system and each company has developed their unique control theory strategy. 'This is where the magic happens,' says Kowalczyk. 'The control system for a standard hydraulic actuator is a PID [Proportional Integral Derivative] controller for displacement. So for a single actuator to displace one inch at a certain frequency in a specified time, it is a reasonably straightforward process, it is just a PID loop which you are able to tune. The key for multiple actuators is to synchronise them and each company has their own special control theory that allows them to do slightly different things.

'Our seven-post rig is a Servotest unit and we have developed our control strategy to allow us to apply downforce that varies with ride height maps,' Kowalczyk adds. 'This means you can take wind tunnel data and simulate aerodynamic changes because the ride height is changing. One of the stages of the control system is the PID control and that's not straightforward, which is why everyone has their own recipes.'

Pulsar control

One of the most popular control systems is the Pulsar digital servo-controller from Servotest. Pulsar is a second-generation real-time control system that utilises industry standard USB

A key factor in running realistic tests on a shaker rig is the synchronisation between all the wheelpan and aeroloader actuators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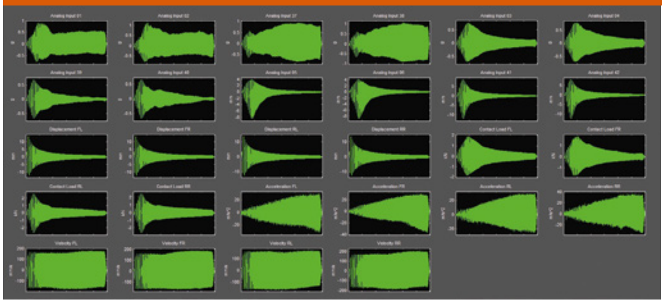
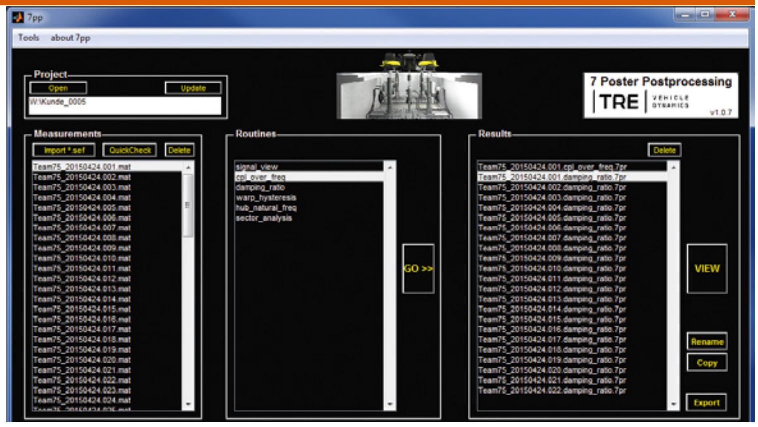
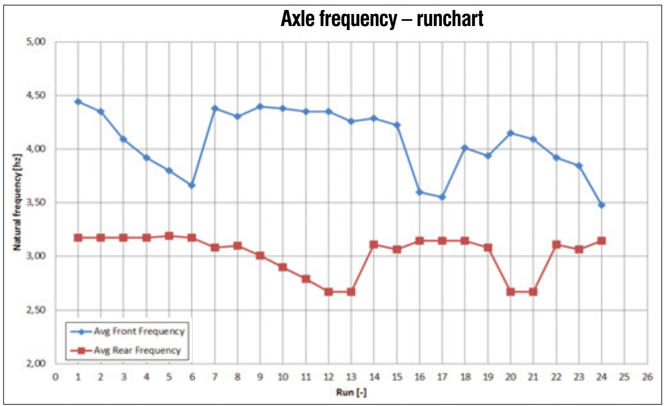
Control system data management method



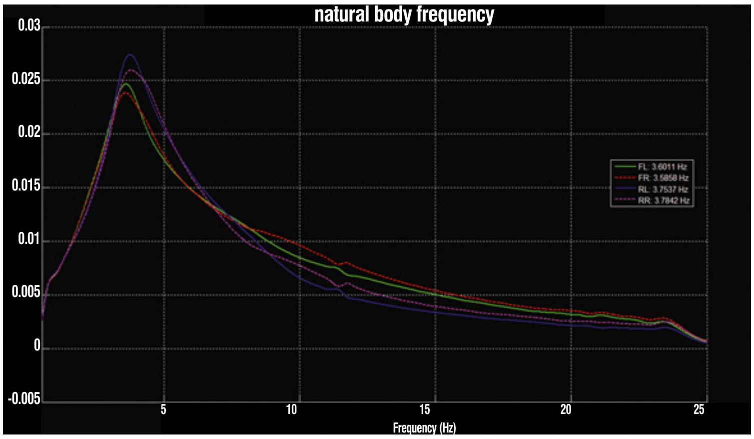
This is an excellent example of some of the inputs and sensor signals you can expect to see during a test on a top class seven-post rig, including live telemetry



Recorded data can be exported into Matlab or Excel and analysed by TRE's custom toolbox



This shows how a plot of the basic analysis parameters recorded in Excel helps to illustrate the influence and progress of set-up changes throughout the rig test



Graphs are automatically generated during post processing, with the displayed parameters depending on the customised code. Different companies tend to have their own approaches

'The ultimate set-up does not exist. It is always a compromise between a variety of performance related factors'

technology allowing for easy connection to any laptop or desktop PC. The new DSP within this controller is capable of 30 times the processing power compared to the older DCS2000 unit which means much more powerful control algorithms can be computed and implemented quicker. The Pulsar DSP also minimises gain and phase errors between the four wheelpans whilst ensuring robust control of the downforce actuators. Overall, all of these benefits mean that any set-up change on the racecar is fully reflected within the car's response, rather than the actuator response.

'We use the Servotest Pulsar system which is the main control system for the rig itself,' says Daniel Pfeiffer, who is the senior engineer at TRE GmbH. 'We also use our own TRE seven-post rig post processing toolbox which is very variable so the routines can be customised to fit the unique and specific needs of our customers. Essentially, all the rig and sensor signals are initially synchronised and logged via the Pulsar system and saved as a .sef file. This is then exported into Matlab or Excel format for further post processing using our own TRE toolbox and the raw data will then be handled and filtered differently, depending on the specified routines that we are using.'

'The benefit of Pulsar is it allows you to run all the complicated control mechanisms and loops such as the ride height maps and controlling the aeroloaders to be in sync with the car,' says Kowalczyk. 'There is also a lot of data coming in. We run some tests between 500-1000Hz so the control system has to be fast and do a lot of computation within that time, whilst continuing to log a lot of channels. You really need to eliminate the lag of all the inputs into the car, because the moment the actuators become out of sync then you are applying loads that the real car isn't seeing on the track, so the control system has to react fast.'

Translating data

Despite the monumental efforts and investments in technology and modelling to help deliver realistic results on shaker rigs, achieving representative suspension behaviour is by no means the last stage in the process. The final, and arguably most important task, is to translate the data and lessons learnt from the rig tests into useful results that the race engineer can implement at the race track.

'The ultimate set-up does not exist,' says Pfeiffer. 'It is always a compromise between a variety of performance related factors. Therefore, we provide our customers with a final set-up sheet which includes a list of various set-up options which are each specifically designed for a particular scenario. For example, we suggest optimum set-ups for changing weather conditions; fast tracks which require increased aero platform stability and slow tracks which focus on mechanical grip and traction. We also run set-up matrix tests where we sweep through a matrix of different set-up options such as damper settings to identify sweet spots for different performance parameters plus linear and non-linear effects on car performance. This provides the race engineer with a great guide for set-up work at the race track.'

Reality check

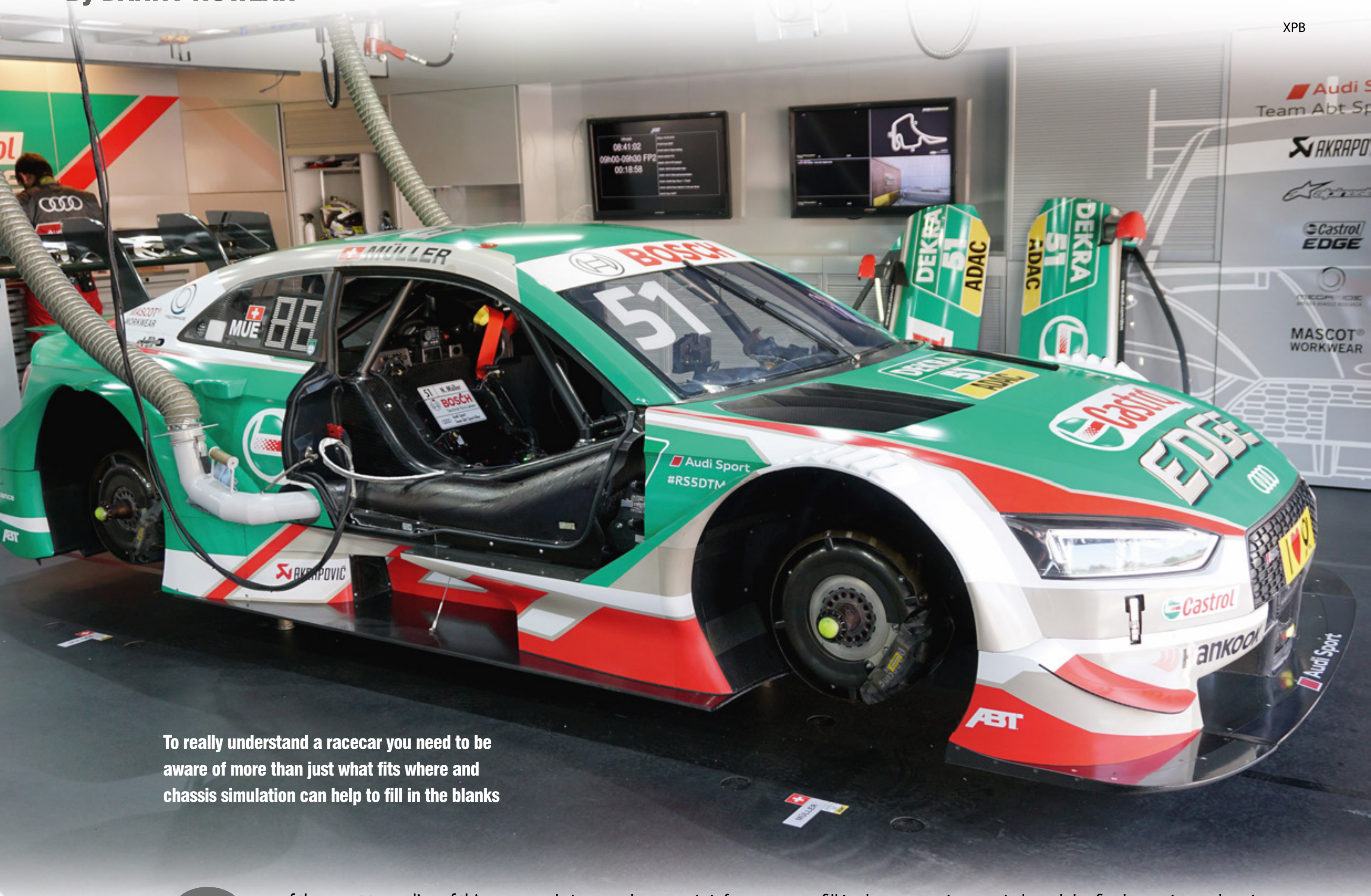
With track testing restrictions and the desire to win placing huge emphasis on arriving at a track with an already optimised racecar, seven-post rig testing is an essential tool for keeping one step ahead. But can future developments in shaker rig technology ever reach the accuracies required to replace track testing all together? Probably not, as no simulation ever fully matches reality. But one thing's for sure, rigs are continuing to edge closer to this.

The wages of sim

Our resident number cruncher explains why race engineers who don't make use of chassis simulation could be missing out on a gold-plated opportunity to fully understand their racecars

By DANNY NOWLAN

XPB



To really understand a racecar you need to be aware of more than just what fits where and chassis simulation can help to fill in the blanks

One of the great tragedies of this business is that many in the motorsport engineering fraternity actually don't understand the real worth of simulation. As the principal of ChassisSim Technologies I've seen this at first-hand. I have lost count of the number of prospective customers who just want a magic bullet, or those who get so wrapped up in the squiggly lines or the driver-in-the-loop rig graphics they actually miss the point entirely.

The key thing that simulation brings to the party is that nothing, and I mean nothing, will help you understand your car like simulation will. If you want to know the secret to being consistently quick you must know your car inside out. Once you know your racecar inside out making those key judgement calls in the heat of the action becomes easier. What simulation brings to the party is it forces you to fill in the blanks of what you don't know. That is where the pay-off is. In this piece we will be using some key case studies to illustrate why this is the case.

Correlation street

The first case study that I want to discuss is when the damper correlation doesn't add up. When this happens most motorsport engineers tend to throw their toys out of the pram and scream 'simulation is useless'. But what is actually happening is the simulation has simply told you something is not adding up. Consider the pitch correlation on an oval shown in **Figure 1**.

Figure1 has been taken from actual data so I've had to blank out scalings and data numbers, but let me walk you through the channels. The top trace is speed, the second trace is steering, the third trace is front pitch the fourth trace is rear pitch and the final trace is acceleration. By pitch what we mean is average of the left and right damper traces. In rough terms, what we are seeing here is that down the straights the correlation is fine but in the corners the simulated pitches, indicated by the black traces, diverge significantly. When most people see this they would throw their hands in the air and say the sim is rubbish. However, what you really have here is an aeromap that isn't performing as advertised. When you see something like this, then this is your signal to fix the aeromap.

Before we discuss how to fix **Figure 1** it would be wise for us to reflect on exactly what it is telling us. What **Figure 1** is telling us is that when the rear ride height drops below a certain value it actually stops producing downforce. This screams out at you when you see the simulated rear pitch keeps on going while the actual pitches level off. To young data engineers who are reading this, what we have just discussed should ring at you like an alarm bell. Typically, what is happening here is the rear diffuser is becoming choked and it's effectiveness at producing downforce has thus diminished.

What you have just seen with **Figure 1** is a prime example of simulation's pay-off. What the simulator has done here is it's allowed you to evaluate the veracity of the aeromap you have been supplied with. However, more importantly, when it doesn't add up the simulator has just told you where in the aeromap this doesn't add up, so that allows you to fix it. Therefore, this provides you with the bedrock of running set-up sweeps that actually mean something.

Pitch imperfect

The next example I want to discuss is again another correlation mismatch, in this case one which allows you to pinpoint what is going on with suspension geometry. A couple of years ago I had a touring car customer who couldn't get the front pitch data on the car to correlate. This situation is illustrated in **Figure 2**.

As always, actual data is coloured, simulated is black. As can be seen the correlation is very good with the exception of the braking. Again, many people at this point will simply throw their hands up in the air and say that simulation is a waste of money. Yet this is where the returned variables from simulation can actually shed considerable light on what is going on.

One of the variables that a simulation package like ChassisSim returns is the applied longitudinal forces and pitch centres. When you combine this with some basic hand calculations it becomes a very powerful tool to sanity check the numbers you are getting back from your simulation results. While I can't give you specifics on this particular example, let me walk you through how you go about doing this.

Sum stroke

Firstly, let's look at some parameters for an equivalent touring car. These are presented in **Table 1**. We are now in a position to hand calculate what the expected pitch should be. Crunching the numbers we see **Equation 1**.

So, calculating what we should expect to see at the damper is shown in **Equation 2**.

When this was calculated on the actual racecar it was found the simulated data was behaving as it should. This is an instant red flag that something is not right, and it shows you how simulation can shine a light on to something that is not adding up on the car, so you can then nail down what is going on.

The final case study I want to present is how the ChassisSim tyre force modelling toolbox was used to explore the set-up limitations for the World Time Attack Challenge tyre. In particular, is it worth increasing the downforce *ad infinitum*?

The answer is no, because the limiting factor with these cars is the tyres. This is especially the

Figure 1: Pitch correlation on an oval

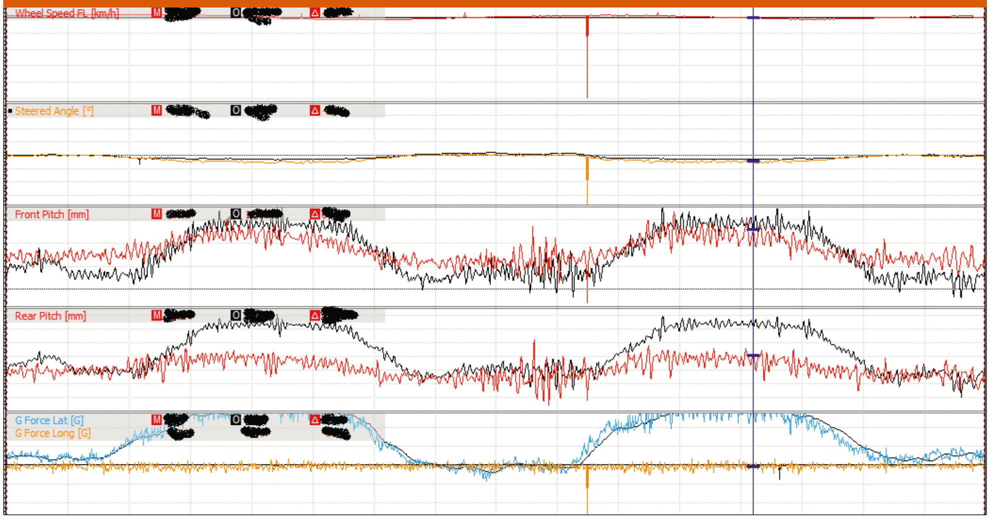


Figure 2: Touring car pitch data correlation

Table 1: Touring car parameters

Variable	Value
Front motion ratio (damper/wheel)	0.63
Front spring rate	123N/mm
Front braking force	1224.5kgf
Rear braking force	885kgf
Front pitch centre	50mm
Rear pitch centre	180mm
cg height	0.43m
Wheelbase	2.794m

Once you know your racecar inside out making those key judgement calls in the heat of battle becomes easier

Equations

EQUATION 1

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

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

$$= 2408N$$

Terms are:

LT_{SM} = Load transfer of the sprung mass (N)

F_{BF} = Front braking force that is applied (kgf)

F_{BR} = Rear braking force this is applied (kgf)

h = cg height (m)

pc_f = Front pitch centre (m)

pc_r = Rear pitch centre

wb = wheelbase (m)

k_f = Front spring rate (N/mm)

MR_f = Front motion ratio (damper/wheel)

EQUATION 2

$$\partial Damp\_ft = \frac{0.5*LT_{SM}}{k_f\cdot MR_f}$$

$$= \frac{0.5\cdot 2408}{122.6\cdot 0.63}$$

$$= 15.6mm$$

The two grey areas you will always have to deal with are tyres and aero

case in the pro class, where they barely stand up for a full flying lap. The reason for this is apparent from the results of the ChassisSim tyre force modelling toolbox, as presented in **Figure 3**.

Diminishing returns

The model presented in **Figure 3** was reverse engineered from race data. As can be seen here, once you start applying loads in excess of about 700 to 800kgf you get an ever decreasing return on the vertical load that is being applied.

This explains why you often see some very oddball results in this category. The most recent example of this was when a modified Honda Civic won the open class category last year. It might not have been running the most downforce out there, but with a kerb weight of 900kg it exploited the load properties of the time attack tyres quite nicely.

A common theme of all the case studies that we have discussed here is that while we haven't evaluated any lap times it has revealed much about the racecar. For example, in the first case study it was seen what happens when an aeromap doesn't behave as advertised and more importantly how you can fix it.

In the second case study, by looking at some pitch data that didn't correlate, we could use returned simulated data to sanity check what was going on with suspension geometry. This is invaluable as a sanity check just in case your logged data is leading you up the garden path.

Finally, in the third case study we were able to see how the results from the tyre force modelling toolbox can be a very useful tool when it comes to determining key design parameters (in this case weight) for the racecar.

Also, a follow-on subject to all this is that when you have done your job right correlation is a by-product and not the end result. Everything that we have discussed in these examples goes to the heart of what makes a racecar tick. In particular, to paraphrase my Australian Dealer Pat Cahill of Competition Systems, the two grey areas you will always deal with in vehicle dynamics is tyres and aero. As you dial the simulator in it reveals a great deal of information about what makes the car tick. So when something in the simulator doesn't correlate, rather then worrying about fudge factors the true question you need to ask is: what is it about the car model that I am missing or don't understand? If you answer that then the correlation takes care of itself and correlations such as those in **Figure 4** are the order of the day. As always actual is coloured and simulated is black, and I'll let **Figure 4** speak for itself.

On-track validation

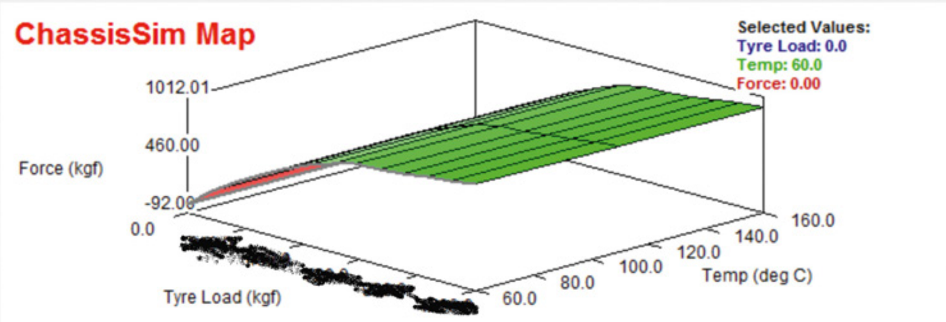
At this stage of the game it would be wise to talk about what you get from a wind tunnel and a tyre test rig. One of the biggest suck-you-ins I see in this business is when people see results from a wind tunnel or CFD, or they see results from a tyre test rig, then they treat these results as if it was an email from God almighty himself. This will ruffle a lot of feathers, but this is not the case. You need to treat a wind tunnel/tyre test rig as a dyno. It's a tool that tells you a lot of what goes on with the aero and the tyres, and for that it is worth its weight in gold. However, due to the different operating conditions you find yourself in from the rig to the track, the absolute values and some of the trends can be a different story. This is why on-track validation is absolutely essential and I speak from bitter experience on this one! To this end simulation is about to become your best friend.

In closing, the real pay-off with simulation isn't so much the squiggly lines it produces but the way it forces you to understand your racecar. The great Chinese military strategist Sun Tzu once said: 'If you know the enemy and know yourself, you need not fear the result of a hundred battles.' The motorsport corollary of this is if you want to be consistently quick you have to know your car inside out. As we have discussed with all our case studies simulation produces this understanding in spades. This is why, regardless of the level of racing you are involved in, you would be mad not to take full advantage of this powerful tool.

Figure 3: WTAC 2D tyre model from ChassisSim tyre force modelling toolbox

ChassisSim 3D Map Viewer

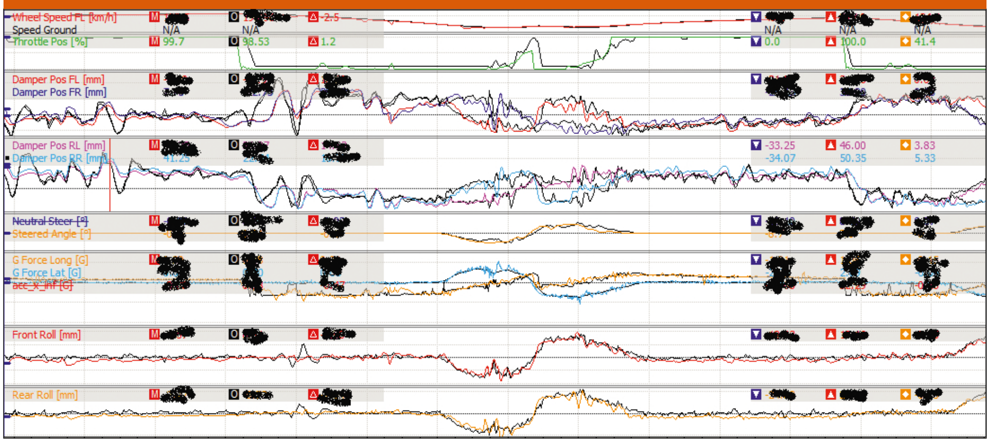
Tyre Force v3



	60.0	110.0	160.0
	0.000	0.00	0.00
	180.50	180.50	180.50
	327.90	327.85	327.80
	455.50	455.50	455.50
	569.90	569.90	569.90
	671.91	671.91	671.91
	755.51	755.51	755.51
	808.01	808.01	808.01
	812.01	812.01	812.01
	839.01	839.01	839.01
	866.01	866.01	866.01
	893.01	893.01	893.01
	920.01	920.01	920.01

OK | Cancel | Axes Properties/Calculator | Export text/Aero File | Import text file

Figure 4: ChassisSim correlation when you have done your job right



Clipped wings

With a view to improving overtaking in Formula 1 the FIA has announced aero changes for next season. Its F1 tech chiefs talked us through some of the details

The racing's been good at times in 2018 but there's still a problem with overtaking in F1, which is why the FIA's rushed through aero changes for 2019

During the Spanish GP weekend in May, Nikolas Tombazis, FIA F1 tech boss, and race director Charlie Whiting talked through the changes the Formula 1 Commission has introduced to improve overtaking in 2019. Later in the weekend the teams voted on the proposals, with a 50-50 result. FIA president Jean Todt has called the Commission's decision a 'miracle', and these aero changes are now set for next season.

Though there was scant detail as *Racecar* went to press it's known that the main thrust is to simplify the front wing and brake duct, and also to introduce a wider and deeper rear wing. Tombazis and Whiting also talked about changes to DRS when they addressed the press.

The aero changes will, say the FIA, increase the DRS effect by approximately 25 to 30 per cent

The outline target of the plan is to decrease lap time by around 1.5 seconds through the changes, particularly to the front wing, with the aim of increasing overtaking opportunities. There's also the possibility that further DRS zones will be introduced to shorter straights.

Done deal

Teams had been concerned that the FIA had not done enough research, and so were invited to investigate the proposals themselves by April 26. Their remarks had been fed into the current document, which in turn has been studied by the World Motorsport Council, the Strategy Group and the Formula 1 Commission.

'The dimensions have already been put down in a detailed wording,' said Tombazis. 'What was actually voted in the e-vote was a detailed wording. Now, what we have on Sunday [May 13] is a discussion with the teams in order to make sure that we cover any little loopholes or any little open points … Not in order to again put down whether we want it or not, or the particular substance, but rather the detail. I should think that after that discussion on Sunday then we will be able to make official the rule wording in detail. But the substance is already clear, the dimensions and everything.'

The aero change will, say the FIA, increase the DRS effect by approximately 25 to 30 per cent, in relation to the delta of the drag of the car when it opens the DRS under the new regulations when compared to 2018's DRS.

'The delta of speed of the following car will as a result be bigger by that amount,' says Tombazis. 'Hence the probability that [it] can then approach the front car will increase.'

DRS code

The increase in the number of DRS zones will depend on the circuit. A more difficult track on which to pass may see more zones, while a circuit on which overtaking is considered to be easier may see a reduction in the number of zones. For DRS to be most effective a driver has to get within four tenths of a car in front, which will be difficult on a shorter straight due to running less time in the slipstream. 'I think the main advantage to us will be that we will be able to make the DRS more effective on

The highly complex front wings are the chief focus of the aero changes. The end plates and the top profiles will be shorn of the winglets and vertical fins that are now common in F1

shorter straights,' said Whiting. 'At the moment we're trying to lengthen zones where we can, in places like Melbourne for example, maybe an extra zone in Canada. Those are the places that with the extra power from the DRS we should be able to make them work a bit better.'

The FIA was also keen to stress that this was a separate study compared to the more radical changes on the table for the next set of F1 regulations. 'There is work going ahead at Formula 1, with the collaboration of the FIA, for 2021, and this work is still ongoing and covers a lot of more complicated areas of the car, which need, frankly, quite a lot more work before we can define a regulation,' says Tombazis. 'These regulations for '19 were a [product] of some of the lessons learned already at Formula 1. They obviously had to be implementable for '19 and therefore they only covered specific areas of the car that are a bit more simple.

'The underlying lessons that we have learned, with Formula 1, about how cars perform in the wake of other cars etc. have been used, but let's say it's only a halfway house,' Tombazis adds. 'I don't want it to be confused with the work that is going on for '21, in the future, that is going to be more extensive and will have much more time for research.'

Long term, the FIA has plans to get rid of DRS altogether, when cars are able to follow each other and lose less front end grip than they do currently. 'We feel DRS is the right thing to have in the present state of things,' says Tombazis. 'For 2021 we hope that the cars will be much more able to follow each other closely and it would be a really nice outcome if we can severely decrease DRS in the future, or even eliminate it. But until we get in a position where we are comfortable enough with the wake performance and how cars can follow each other I think it's something that is … I would call a necessary evil perhaps at the moment.'

Frontal assault

The headline change for 2019 is the reduction in the complexity of the front wings, which are designed to push airflow around the car; hence they disrupt the wake behind it, too. 'The change of the wings for next year is not just the end plate,' said Tombazis. 'The end plate is significantly simplified, but all the top furniture – the little winglets that you can see, the various vertical fins and so on, which produce a range of vortices which are intended to control the front wheel wake – these are getting eliminated, and the wing profiles themselves have to follow certain rules which make them, let's say, simpler and hence less able to control the wheel wake. So, in our studies, that wheel wake is then what affects the rear car and losing control of that, we feel, is going to make a step improvement. I would also add that the way development is going in current racing, one of the key tasks of aerodynamicists in a Formula 1 team is to move the wheel wake further outboard for the benefit of their own car. The more outboard it is the less it affects the diffuser or the rear wing and they gain performance. So that is their key objective. That key objective is also bad for the following car. So, our expectation is that if we didn't do a rule change the next two years, '19 and '20, would be gradually getting worse. So, part of the rule change was also to stop that trend and make a step change. We feel that these performance characteristics would have actually been worse for '19 and '20 if we did nothing.'

On the level

The FIA is keen to avoid having to clarify the regulations at a future date should a team find an advantage with the new regulations, which is why it was in close discussions with all the Formula 1 teams and allowed them to vote on the changes in Barcelona. 'You may, of course, say that a team may have found something and did not say it in the meeting. But we feel we are covering the rules in a lot of detail, and hopefully with experience of previous years we can avoid that before next year – that is right now – to avoid this scenario,' says Tombazis. 'If something happened we would probably have to wait until 2020 to fix that – but I think that is, in my view, quite a low probability.'

'One of the key tasks of aerodynamicists in a Formula 1 team today is to move the wheel wake further outboard for the benefit of their own car'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Interview – Guy Lovett

Fuel for thought

Shell's motorsport technology boss tells us how its relationship with Ferrari in Formula 1 brings big benefits to both parties

By MIKE BRESLIN

'What we are in Formula 1 for is to demonstrate performance gains through fuels and lubricants, and that's not possible with a control fuel'

There are many types of partnership in Formula 1. The word – never 'sponsor' these days – encompasses everything from the team's toilet roll supplier and IT support to simple advertising on the racecar. But perhaps the purest of partnerships is the technical partnership, as exemplified with the role of oil companies. At Ferrari this is Shell, and that familiar *pectern* logo has certainly earned its prominent place on the SF71H's sidepod.

'Since 2014 almost a quarter – in fact, to be accurate, 23.3 per cent – of Ferrari's efficiency or performance gains to the power unit has been down to our fuels and oils,' says Guy Lovett, Shell Motorsport's technology manager. 'I'm really proud of that accomplishment. I think it's a powerful demonstration of how important fuel and oil is to performance in Formula 1.'

But this is not a one way street, and Shell would not be in the sport if it didn't get something out of it. 'First, it's about promoting the Shell brand through demonstrating our technical capabilities; having our pectern on the side of Ferrari's Formula 1 car is a really powerful way of demonstrating our technology,' Lovett says. 'But beyond that, and this is where my responsibilities really play out, it's about having the opportunity to innovate and develop and trial our latest fuel and lubricants in an unrivalled proving ground.'

With that in mind recent talk that Formula 1 might opt to use a control fuel at some point in the future has not been welcomed by Lovett. 'We're not in favour of Formula 1 going down the road of a controlled fuel supply, that's not what we're there for,' he says. 'What we are there for is to demonstrate performance gains through fuels and lubricants, and obviously that's not possible with a control fuel.'

Street cred

Knowledge transfer from the track to the street is clearly vital for Shell, then, and that's epitomised in the way the motorsport division works with the road-going R&D department at its Hamburg base. 'We sit in the same office and there are colleagues who are developing road applications working with us. The transfer of technology from track to road, and actually vice versa, is of fundamental importance to us,' Lovett says. 'There are a couple of areas where we try and focus this. Firstly, and most obviously, is in the chemistry, in the molecules, and then if the fuels and oils perform in motorsport then how can they be applied to the next generation of V-Power or Shell Helix. But also we're looking at how we can share methodologies and working practices from motorsport; how we're using modelling and simulation work; our screening and laboratory techniques and how can we include those in our road going R&D. Actually, that second avenue of technology transfer isn't quite as obvious, but it's almost more powerful than just trying to look at the molecules and the chemistry.'

So what is the methodology for developing a fuel for F1? 'In general we start with an idea,' Says Lovett. 'We do some initial laboratory blends at our facility in Hamburg, and we use those to feed into the modelling and simulation work, to get an initial read on performance, efficiency or a general assessment of the idea. We then progress to screening tests, again in our laboratories, or potentially with some of the experiments that Ferrari may conduct in Maranello.

'The next step would be single cylinder testing,' Lovett adds. 'Although it's a bit removed from how things might perform in the car itself it's a really useful way of seeing small differences. The level of accuracy of this test is really high. If things are looking good there we progress to the V6 in an engine dyno, and the next step is in the car, but the opportunity to test things on a track are incredibly limited, and that's why we put a lot of effort and emphasis higher up the development process.'

Oil drill

Shell prides itself on how close its F1 petrol is to road fuels – by regulation F1 fuel is around 99 per cent the same as pump fuel, but you can bet there's a lot that goes into that final one per cent – and the same goes for the lubricants. 'The building blocks that we use to put the oils together for Formula 1 are very similar to those we would use for road going oils, we just construct the formulation differently, and the end result is subtly different,' Lovett says. 'In road cars the ultimate issue is fuel economy and fuel efficiency, and one way to achieve that is to reduce the viscosity of the oil, to reduce friction in the engine. It's exactly what we try to do in F1, we're just exploiting that gain differently; we're reducing friction for power there.'

But the work does not end in the lab, and Shell has a highly visible presence at the track, too. 'A big element of the project

Shell says nearly 25 per cent of performance and efficiency gains on the Ferrari PU since 2014 has been down to its fuels and oils

XPB

we have with Ferrari is trackside,' Lovett says. 'We're at the track at every single race. We have a very dedicated, highly instrumented, laboratory that sits within Ferrari's garage, or within the technical truck at the European races. There are two main functions of the lab. One is to analyse the fuel for legality and quality, and the second is to analyse the lubricant, also for legality and quality, but also to look at the wear metals in the engine to help Ferrari monitor the health of the engine.'

Incidentally, Lovett says that as far as the oil burning situation goes – where excess lubricant was said to have been burnt as fuel in the cylinder – he welcomes the recent clarification from the governing body. 'From our perspective we always welcome clarification from the FIA, and we do work very closely with them on fuel regulations and specifications, and for them to come forward and bring more clarity around their regulations is always a good thing.'

Shelling out

But it's not all about F1, and Lovett oversees partnerships in a wide variety of series, including Hyundai in the WRC, BMW in WEC and DTM, Team Penske in NASCAR and IndyCar, and Ducati in MotoGP. 'Although there are a lot of similarities in terms of our working processes and our approach, the end formulations and the end result are quite different, because of the differing requirements, the different applications and the subtleties of the regulations,' he says. 'It's fascinating really.'

Yet while it might be a fascinating area to work in, listen to some and you might think the days of fossils fuels are numbered in motorsport. 'We are acutely aware of this and really trying to drive forward our contribution to the emissions issue,' Lovett says. 'Shell have made some quite significant investments over the last couple of years in terms of e-mobility; charging systems, and charging stations, and long may that continue. I think it's vital for our progress as a company to continue to move in that direction. I think for certain we've seen moves in that direction in motorsport; hybridisation in motorsport is rife. Look at a Formula 1 car now, it's one of the most advanced hybrid powertrains you could ever imagine. In that respect we are already well and truly active, and we will continue to move in that direction.'

Which means, so long as it's able to keep developing its products, the Shell logo is likely to remain on the sidepod of the Ferrari Formula 1 car for some time. An emblem of a true partnership, rather than just an advert.

RACE MOVES

XPB

Alain Prost is to leave the Renault e.dams Formula E team, where he was co-owner with **Jean-Paul Driot**, and will now concentrate on his special advisor role with Renault in Formula 1. Renault's sister firm Nissan is to take over from Renault in FE at e.dams when season five starts in the autumn. Driot now owns 100 per cent of the e.dams operation, he has confirmed.

Former Formula 1 driver and 2016 world champion **Nico Rosberg** has started his own driver development programme, recruiting two promising young karting talents as its first drivers. The Petronas-backed Rosberg Young Driver Academy has been set up in partnership with his former kart team boss from the 2000 and 2001 season, **Dino Chiesa**.

The former boss of the Manor Formula 1 team, **John Booth**, has confirmed that he has left Toro Rosso, where he had been director of racing since 2016, to fully concentrate on the Manor WEC squad's new LMP1 programme – although this was hit by cash flow issues in May, which forced the team to withdraw from the opening round at Spa before qualifying.

Bruin Beasley is now team manager at the Erebus Supercars operation in Australia. Beasley has been with Erebus in a commercial role since 2016, but he does have team management experience, having run his own team, Minda Motorsport, in other championships such as the Dunlop Super2 Series (a Supercars feeder category) and in Australian Formula Ford. The Erebus team says Beasley's promotion is to help reduce the workload on general manager **Barry Ryan** and crew chief **Dennis Huijser**.

Automotive and motorsport PR firm Prova has hired **Louise Smith** to fill a new role of creative services manager, while designer **Charlie Owen** has also joined the firm. The Midlands, UK-based agency, which has more than 20 people operating from its headquarters in Warwick, is currently busy building up its video capability and these appointments are said to reflect this aim.

Robbie Pierce, who sold his Impact Racing and MasterCraft Safety brands to Sparco last year, has now acquired San Diego-based Jimco Racing, one of the most successful manufacturers of off-road racing vehicles in the world. Jimco was founded in the mid-'70s and has since built over 500 Baja-style racecars and race trucks.

Sydney Davis Yagel is now senior manager of race operations at SCCA Pro Racing. Davis Yagel has spent the last decade managing HSR Houston events, while she has also been the Circuit of the Americas Motorsports Operation's marshal coordinator and race chair of the Houston and Louisiana Grand Prix with the SCCA.

Australian Supercars engineer **Romy Mayer** has become an ambassador for the Dare to be Different initiative, the scheme that was set up by **Susie Wolff** in 2016 with the aim of increasing female involvement in motorsport. Mayer relocated from Germany to work for the Red Bull Holden Racing Team in Supercars in 2015. She is now data engineer on **Jamie Whincup**'s car.

ARCA stock car team owner and former NASCAR racer **James Hylton** (83) was killed in a road crash in April. The accident happened when he was returning from an event at Talladega. Hylton started off as a mechanic before going on to make 602 starts at NASCAR's top level, winning two races. He carried on driving in ARCA events until he was 79. His son, **James Hylton Jr**, was also killed in the accident.

Former FIA man **Marcin Budkowski** attended a grand prix as executive director of Renault for the first time at the Azerbaijan race. Budkowski, the ex-head of the FIA's technical department, has been working for Renault since January but was not allowed to work on Formula 1 projects, or at its Enstone base, until the beginning of April.

Jorg Zander loses tech director role at Sauber

Jorg Zander has exited the Sauber Formula 1 team, where he was technical director, as the Swiss outfit restructures its tech management in the wake of a disappointing start to the season.

A Sauber statement issued just after the Azerbaijan GP, where ironically the Swiss team claimed its first points of the season, said that Zander would stop working for it immediately.

Jorg Zander is no longer the technical director at Sauber and the team is now restructuring its technical management structure

Frederic Vasseur, team principal at Sauber, will now oversee the work on 2018 upgrades and the beginning of the 2019 car's development until the team's 'new organisation' is announced.

Zander returned to Sauber – where he had been chief designer when the team was known as BMW between 2007 and 2008 – at the start of 2017, following the demise of the Audi LMP1 programme, where he was also technical director.

Before Audi he was deputy technical director at Brawn in 2009, when it won the world title in its only season, staying on when it became Mercedes. He had also worked for the same team through its Honda and BAR guises, while he also had a spell working at Williams.

Zander had recently made some high profile appointments himself, including the signing of former Toyota and Ferrari F1, and Audi LMP1, man Jan Monchaux as Sauber's new head of aerodynamics.

Sauber now uses current-spec Ferrari engines, rather than the 2016 power units used last season and its C37 carries Alfa Romero branding,.

Thanks to Charles Leclerc's sixth-place finish in Baku and 10th in Spain Sauber was ninth of the 10 teams in the constructors' championship at the time of writing.

Long-standing chief designer Ed Wood leaves Williams

Ed Wood, the chief designer at Williams, has now left the struggling Formula 1 team after 12 years in the position.

Wood joined the Grove outfit in 2006 from Prodrive, where he had worked on the Subaru WRC programme, and previous to that he had worked in Formula 1 with both the Ferrari and Renault teams.

Williams said of his departure: 'We can confirm that Ed Wood has decided to leave Williams for personal reasons.

The FW41 has proved a disappointment thus far this season and long-time chief designer Ed Wood has now left the Williams F1 operation

'As chief designer, Ed has been instrumental in many successes during his time with the Williams team, including the FW36 and FW37 cars which secured third place in the constructors' championship in 2014 and 2015, respectively.

'The team would like to express its gratitude to Ed for his hard work over the past 12 years; his experience, skill and passion for engineering has been a huge asset to Williams.'

Williams has recently been recruiting to bolster its technical team, having signed up Paddy Lowe from Mercedes as chief technical officer as well as Dirk de Beer, formerly of Ferrari, as head of aero last year. Ex-McLaren man Doug McKiernan was also recruited as chief engineer in 2017.

Wood's exit comes on the back of a disappointing start to the season for the team's FW41 chassis, and at the time of writing Williams is languishing in last place in the constructors' standings, with a mere four points to its name.

RACE MOVES – continued

XPB

Tim Goss is no longer chassis chief at McLaren. He had been one of three leaders of the Woking team's technical operation, alongside chief engineering officer **Matt Morris** and chief technical officer (aerodynamics) **Peter Prodromou**. Goss has worked at McLaren in key posts since 1990. At the time of writing it was not known whether he had taken on another role within the company.

The IndyCar community has rallied around Schmidt Peterson Motorsports truck driver **Eric Stewart** after his home burnt down. Stewart, a veteran of single seater racing in the States, lost everything he owned in the fire and many within the IndyCar paddock were swift to respond by paying in to a GoFundMe page set up to help him.

Margareta Mahlstedt has been appointed general manager, marketing, at Porsche Cars GB, succeeding **Ragnar Schulte**, who takes on a new position at Porsche AG in Stuttgart. Her new role includes not only overseeing all marketing operations but also the Porsche Experience Centre at Silverstone and the Porsche Carrera Cup Great Britain. Mahlstedt was formerly director of marketing at Porsche Canada.

Peter Horsman has succeeded **Barry Cannell** as chairman of the Historic Grand Prix Cars Association. Horsman is an active racer in HGPCA events where he has been a regular winner in his ex-Tony Shelly Lotus 18/21.

Tony Harper has been appointed director of the Faraday Battery Challenge, the UK government's £246m investment to help develop batteries. Harper, who was formerly Jaguar Land Rover's director of engineering research, started work at UK Research and Innovation, which oversees the initiative, in April.

NASCAR Cup Series car chiefs **David Bryant** (No.42 Chip Ganassi Racing Chevrolet) and **Austin Konetski** (No.88 Hendricks Motorsports Chevrolet) were each ejected from the Kansas Speedway round of the championship after the cars they look after failed pre-race inspection three times in a row.

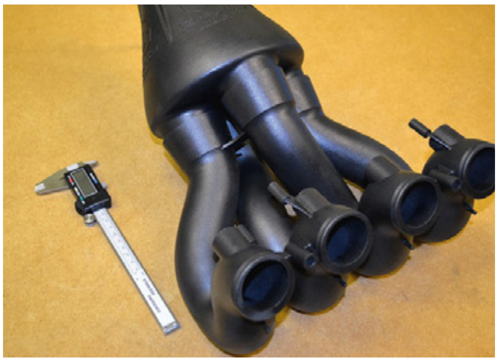
NASCAR Xfinity Series crew member **Lawrence Hayden** was arrested and charged with assault after the Dover International Speedway round of the series. He is alleged to have repeatedly punched his boss, JP Motorsports co-owner **Jerry Hattaway**, following an argument about his future employment. Hattaway sustained a broken jaw in the altercation. Hayden has now been indefinitely suspended from all NASCAR competition.

NASCAR crew chiefs **Mike Bugarewicz** (No.14 Stewart-Haas Racing Ford) and **Scott Graves** (No.19 Joe Gibbs Racing Toyota) were each fined $50,000 following failed inspections at the Dover International Speedway round of the series, where both cars were found to be running with rear window violations.

Billy Scott, the crew chief on the No.41 Stewart-Haas Racing entry in the NASCAR Cup Series, was fined $10,000 after the Ford he tends was found to be running with an improperly secured lug nut during post-race inspection at the Dover International Speedway round of the series.

◆ 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**

Additive manufacturing
Printed parts for prototypes



Graphite AM (GAM) is helping several LMP1 and LMP2 teams to reduce weight by 3D printing lightweight carbon filled SLS parts including plenums, intake systems, turbo pipes, baffles and brackets.

GAM's Carbon SLS offers the best strength-to-weight ratio of any 3D printed nylon, we're told. Parts are resistant to fuels, oils and also have high temperature resistance.

www.graphite-am.co.uk

Simulators
Making the Grade

VI-Grade has announced that Virtual Vehicle, which is a leading international research and development centre for both the automotive and the rail industries, has selected its newly developed static driving simulator.

The Static Simulator by VI-Grade is a professional solution which will allow Virtual Vehicle to bridge the gap between physical testing and simulation in automotive engineering, we're told.

The Static Simulator is based on the same VI-DriveSim software package used on the company's Compact Simulators and DiM Dynamic Simulators.

It is also said to be fully compatible with third-party software solutions.

www.vi-grade.com

Cockpit
In the hot seat

Racetech enjoys preferred seat supplier status with Aston Martin Racing (LMS GTE, GT3 and GT4 programmes), Porsche (RSR GTE) and Callaway Corvette (GT3) and this year there will be at least 11 Racetech-equipped cars on the grid for the Le Mans 24 hours.

The company has been specialising in the design, manufacture and marketing of closed cockpit racecar seats for over 20 years and it is an acknowledged world leader, thanks to innovations such as forced air induction and its patented back-mounting system, which means the seat can be bolted to a racecar's roll cage as well as the floor.

www.racetechseats.com

Sensors
Winning the space race

For over 40 years Chell has supplied electronic pressure scanners developed in NASA wind tunnels and packaged them for motorsport and flight data acquisition systems, providing the highest integrity aero data.

In recent years, the availability of very stable low-cost pressure sensors has allowed it to develop pressure scanners at much lower cost, yet having very nearly the same performance, it says.

It's nanoDAQ-LT is the result and, having been benchmarked by some of the leading F1 teams, it is now being developed further to provide convenient multi-channel packages for both model and on-board use.

The initial package provides16 channels with a configurable choice of absolute or differential measurement. Measurements are fully temperature compensated up to 90degC with no measurable thermal effects. Developments will include side-entry tubulations and no tubulations, allowing quick-disconnect plates to be incorporated into the user's features. Wireless data output will also soon be available.

All models have been tested in an IP67 environment and pressure channels are very robust with a high proof-pressure of 345kPa (50psig).

It's said to be easily configured through its embedded web server with CAN and Ethernet outputs – the Ethernet can be configured with IEEE1588 time stamping and data may also be configured for on-board averaging to improve data quality.

www.chell.co.uk

Electronics
Keeping connected

Souriau 8STA circular connectors from lane Electronics are designed for applications where performance, small size and light weight are key.

These are used extensively in motorsport, including engine control, communications and harnesses. As an assembling distributor Lane also supplies connectors with a wide range of accessories from HellermannTyton and Weald Electronics.

www.fclane.com

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The past and the curious

The 1968 Le Mans 24 hours was held in September rather than its customary date in June. The delay was due to civil unrest in France, but it had an impact on the racing too. For John Wyer, the delay was a particular problem as his fastest driver, Jacky Ickx, had broken his leg while driving for Ferrari in the Canadian Grand Prix the week before Le Mans, and Enzo Ferrari had signed Derek Bell to drive his F1 cars in the American and Mexican Grands Prix. He was banned from driving for Wyer at Le Mans, and Ferrari was not present in view of Enzo's protest against new regulations. That meant Pedro Rodriguez was signed to JW alongside Lucien Bianchi in place of Ickx, which was a shame for the Belgian as Rodriguez and Bianchi raced to victory in the Ford GT, taking a five-lap win at Le Mans.

According to the report in *Motoring News* the race was largely dry, save for four hours of teeming rain during the night (the cars raced longer in darkness due to the date change), which made life 'unpleasant' for the drivers. Two of the JW Fords stopped to change to dry tyres as their wet weather rubber was breaking up on a drying road, but Brian Muir slid into the sand bank at Mulsanne, before the Porsche 908s started to run into gearbox and alternator problems.

There was much at Le Mans in 1968 that can be related to Le Mans in 2018

As the Porsches continued to find trouble, into second overall slipped the privately entered Porsche 907 2.2-litre driven by Rico Steinemann and Dieter Spoerry, while the works 908 of Rolf Stommelen and Jochen Neerpasch finished third. It was a case of David versus Goliath; the Fords raced in the 5-litre category, for heavier Group 4 cars that had more power, while the lighter, more nimble Porsches raced in the 3-litre class. However, the Porsches were all in their first season, and so it was hardly surprising that they had issues on their way to the flag.

All of this can be related to Le Mans in 2018. As the FIA and ACO look to encourage F1 technology in powertrains at Le Mans, this was also a reason for the 3-litre prototype category in which Porsche raced in 1968. On track the similarities are equally as stark. The lighter, more nimble privateer LMP1 cars are also in their first season as was the 908, and therefore subject to reliability issues, but they are also on the back foot compared to the better funded and longer tested Toyotas.

Toyota's decision to continue means that this looks like a two-horse race but the Japanese manufacturer has proven that it will implement team orders. This is a shame as it would be logical to assume that, protecting the inevitable one-lap lead, racing between the two cars is halted, and from there it becomes a reliability run. This will excite no one.

The EoT between the privateers and manufacturers is clearly skewed in favour of the hybrids, but at Spa the privateers had their own dramas that made the gap look even bigger than it actually was. Simple things such as driver changes and pit stop choreography cost the privateer teams time in the pits, for example. Little could be read into qualifying after two red flags, the second due to Pietro Fittipaldi's accident. It's easy to be judgemental afterwards, but in my opinion, his leg injuries point towards LMP1 cars adopting Formula 1-style leg supports in the cockpit, which would lead to slower driver changes, and fly in the face of the ACO's decision this year to allow fuel and tyres to be completed at the same time. According to one LMP1 driver, a driver change takes around 26s, refuelling 23s, and tyres quicker than that. Look for errors in doing up lap belts this year as teams are forced to take risks to do it quickly.

Balancing the performance of the two prototype classes was easier to manage in the 1960s; the heavier cars had more power, the lighter cars less grunt, and the rest was left to reliability. Now, with modern technology and better reliability, the cars can be gapped at 0.5s/lap in the fastest 20 per cent of the laps, be refuelled five seconds faster than the privateers which makes a difference, and can go further on a tank of fuel thanks to the hybrid system.

However, reliability is still a factor. To win Le Mans, Toyota first has to beat the race itself, and it's found new and innovative ways of doing so and has spent months practising failure modes. When Alonso brought his McLaren F1 car back to the pit on just two wheels in Baku, Toyota looked on approvingly.

One small note; this year every single class, including LMP2, is performance balanced. LMP2 cars can have power reduced, weight increased and fuel capacity limited if one brand appears quicker than the others. GTE is famously performance balanced, in both Pro and Am classes, while the LMP1 cars are subject to balancing such as we have never seen before.

What to do, then? As in 1968, there are other classes to keep the thousands entertained, and not least is the GTE field. Aston Martin and BMW have brought new cars to the fight this year, while Ferrari has an evo kit, and says it has been penalised for it. At Spa, it was all about Ford and Porsche in GT, the Blue Oval coming out narrowly on top, but will the others come back into the frame at Le Mans, or will these two old foes be left to decide it between themselves, as they did 50 years ago?

ANDREW COTTON Editor


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