EXCLUSIVE! FIA president Mohammed Ben Sulayem on motorsport's future

UK £5.95 / US $14.50
July 2022 / Vol 32 No 7

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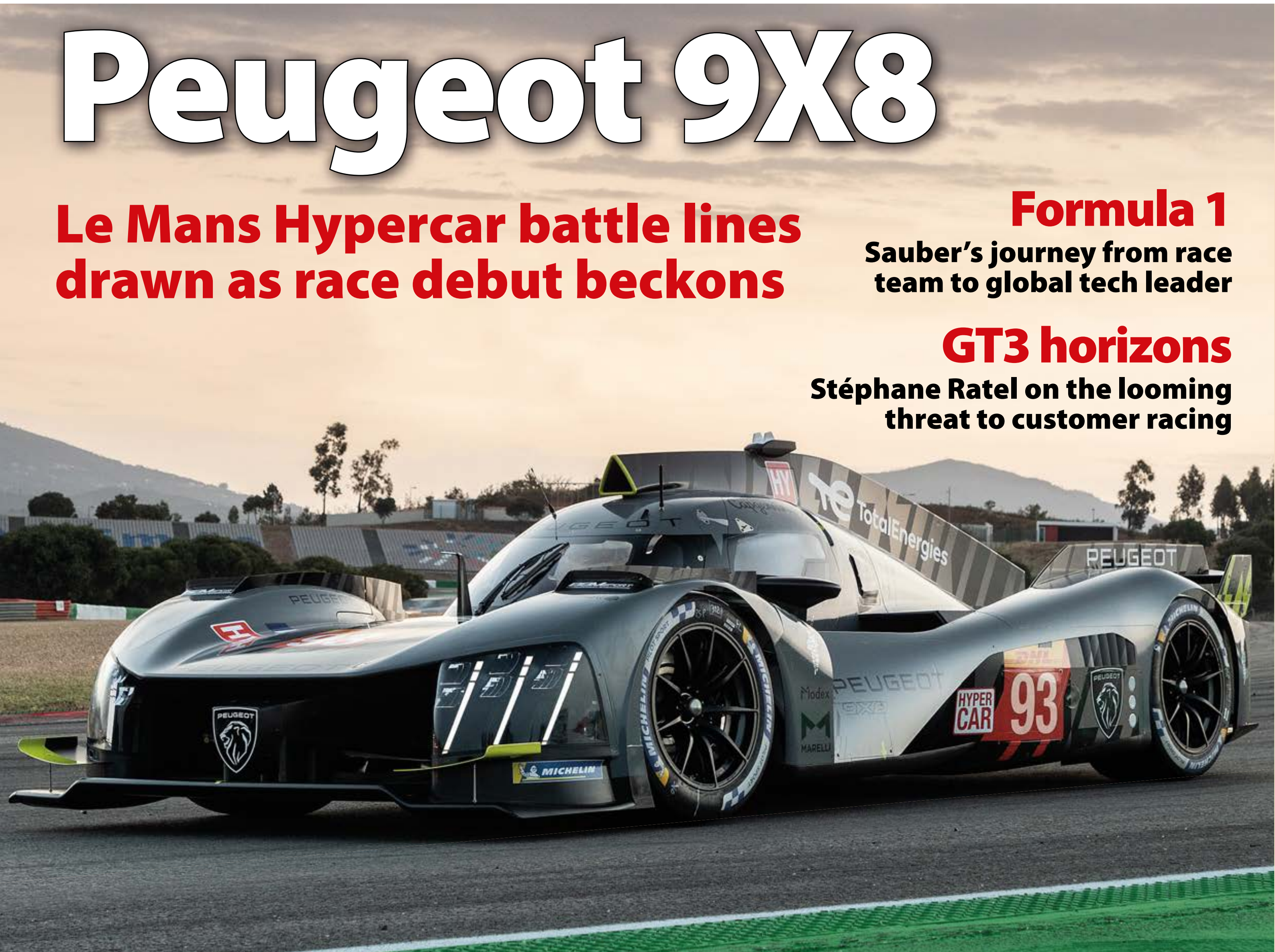

Peugeot 9X8

Le Mans Hypercar battle lines drawn as race debut beckons

Formula 1

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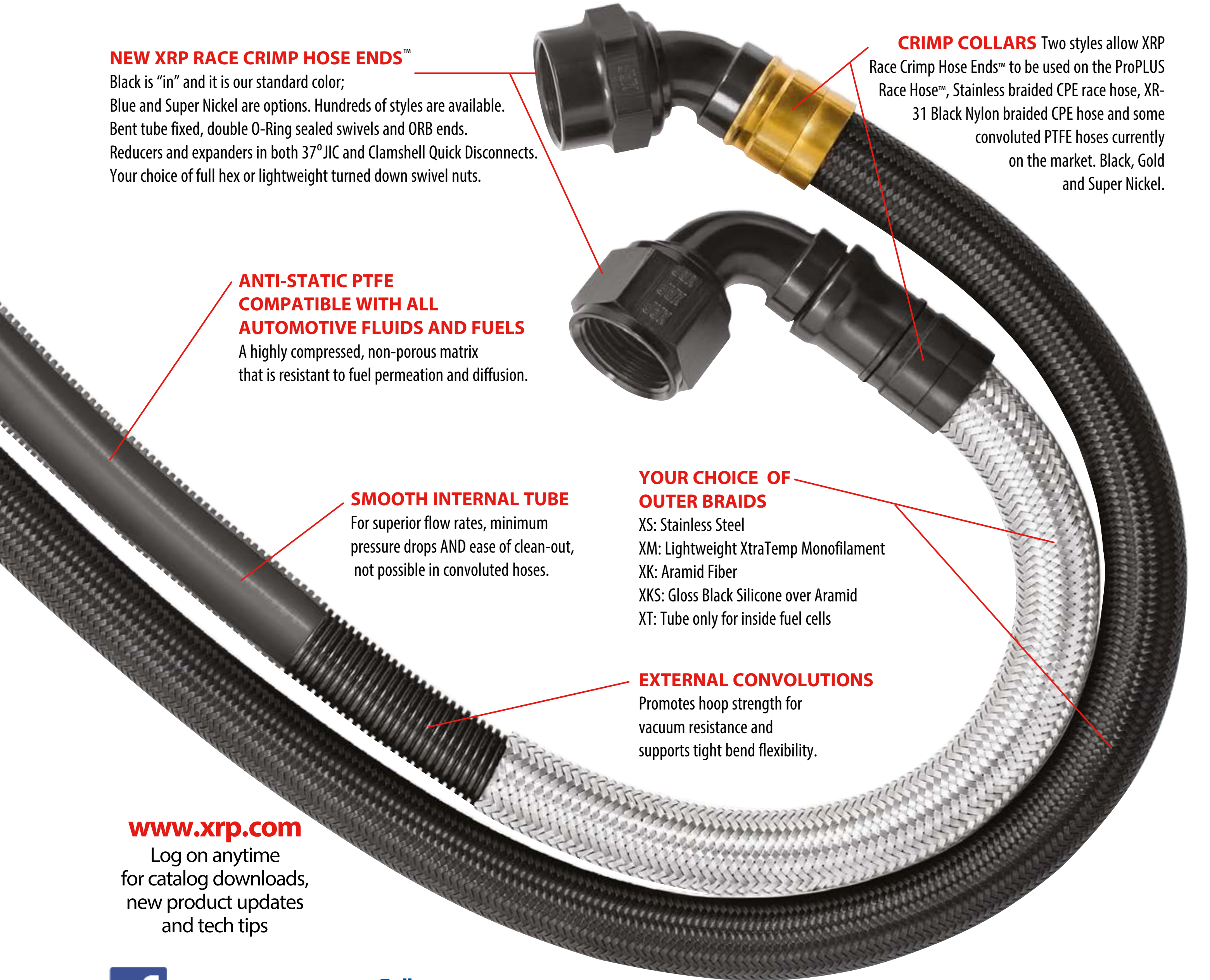

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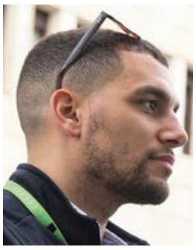
The WRC event in Portugal this year celebrated 50 years of the World Rally Championship. Shown is Sebastien Ogier in the Toyota Gazoo Racing WRT in Porto on May 19

Jaanus Ree



The weight of the VW

How powerful OEMs exert influence over racing

Formula 1 is set to maintain its DI V6 turbo hybrid power units for the foreseeable future. However, after extensive discussions with the current and some intent OEMs, the next generation, set to arrive in 2026, will contain some crucial recipe changes. One of the most significant is eliminating the e-Turbo-style heat energy recovery system (H-ERS).

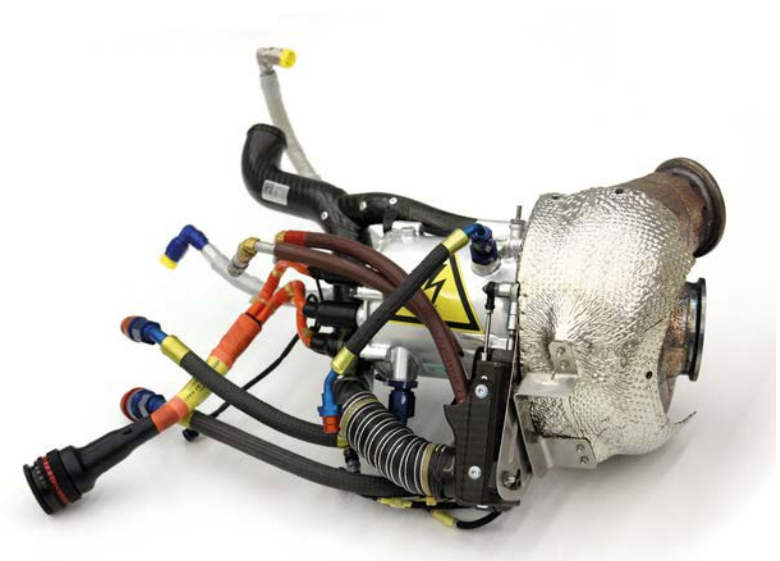
The H-ERS is a motor-generator unit mounted on the turbocharger shaft of a Formula 1 internal combustion engine. The unit converts heat energy from exhaust gases into electrical energy. This is then used to power the car's electrical driveline (either charging the battery or directly deployed to the kinetic energy recovery unit) to boost the power unit's performance. It's arguably the most significant performance differentiating system onboard the power unit.

Party politics

Understanding how this primary performance driver has been eliminated from the regulations is about understanding the parties interested in entering in 2026 – namely Volkswagen Group

The Volkswagen Group's Porsche Motorsport arm has kept a careful watch on Formula 1's power unit evolution for over a decade, and even developed a current-spec V6 before scrapping its Formula 1 entry evaluation programme. The reason Porsche did that was because it didn't agree with the aforementioned H-ERS system, feeling it was hugely expensive to develop and had little road car relevance.

So, it began discussions with Formula 1 about scrapping the e-Turbo-style H-ERS and running the DI V6 turbo power unit either without an H-ERS at all, or using a version it had developed in its 2014-2017 WEC campaign – specifically, the one found on the turbocharged, 2.1-litre, 9R9 V4 engine that powered Porsche's three time Le Mans-winning 919 LMP1 hybrid Prototype.



Stewart Mitchell

Porsche Motorsport's 35kW post wastegate-mounted H-ERS from the turbocharged, 2.1-litre, 9R9 V4 engine that powered its three time Le Mans-winning 919 LMP1 hybrid Prototype

Porsche recognised Formula 1 and LMP1 had one fundamental similarity – they were both fuel flow-limited formulae – which meant to be powerful, they had to be very efficient. Fuel flow has been the overarching limitation on the performance of F1 hybrid and Prototype engines since 2014 but, where Formula 1 insisted on using petrol-fuelled, direct injection, 1.6-litre V6 turbos married to an H-ERS on the turbo shaft, Prototype power units had relatively few restrictions placed upon them.

People – especially in the mainstream media – often talk in awe of the efficiency of today's Formula 1 power units. Yet they still only demonstrate what is possible within a type of power unit the FIA prescribed. The relative freedom in exploiting a given fuel allocation seen in LMP1 saw some interesting innovations.

Design features

A key design feature of the 9R9 engine is its 35kW post wastegate-mounted H-ERS. Located in series with the turbocharger, it uses only wastegated exhaust gas to drive the MGU. The turbocharger is conventional and never receives any input from the electric motor element, while H-ERS torque load control is done with a variable turbine. Constantly changing the positions of the variable veins keeps the H-ERS engaged to ensure it is in the most efficient region for harvesting at all times.

As such, the 9R9 engine still operates as a regular ICE if you take away the H-ERS. It is so efficient that there is less than a 0.1 per cent difference in engine power output between regular wastegating compared to the H-ERS in full harvesting mode, and it can switch between those two modes very quickly.

Dynamic response

The 9R9 H-ERS configuration means the turbocharger energy to the engine is almost constant without the increased load from the Formula 1-style e-Turbo H-ERS. Although less dynamically responsive than the Formula 1 solution, Porsche's solution is far more appropriate for road car applications. It could even be retro fitted to existing turbocharged ICEs.

The 9R9 is a standalone engine in the hybrid 919 chassis, with a front axle electrical drive system making for a parallel four-wheel-drive system with H-ERS charging for range extension – a solution far more akin to what OEMs could potentilly utilise on their road cars.

Additionally, Formula 1 is considering front axle energy recovery in the framework of the 2026 powertrain rules, though talks about whether it will ever use front driveline deployment are understood to currently be ongoing.

Formula E, on the other hand, is adopting a front axle driveline recovery system this year with its Gen3 cars. It, too, will evaluate how the front axle recovery system operating in racing conditions will work, and whether it could introduce deployment in future seasons.

The fact that these technologies are even on the table, and the e-Turbo-style H-ERS is off, shows how hugely influential OEMs like the Volkswagen Group are to Formula 1, as its technical staff consider their desires.

Porsche Motorsport has kept a careful watch on Formula 1's power unit evolution

Blowing in the wing

Peugeot is set to make its debut in the World Endurance Championship at Monza in July with its new 9X8 that has been undergoing extensive testing. Technical director, Olivier Jansonnie, brings us up to date

By ANDREW COTTON

Peugeot has presented the final version of its Le Mans contender, the 9X8, after five months and more than 10,000kms of testing. At the launch in Portimao, Portugal in May, the French company confirmed it expects the homologation process for its extraordinary car to be complete in time for the debut race in the FIA WEC at Monza in July.

The car is different from the 'teaser' car that was launched in July 2021 in that it has been brought into line with the technical regulations, although one key area remains – there is no downforce-generating rear wing.

The technical team behind it has now confirmed the single adjustable aerodynamic device will be at the front of the car, similar to the Glickenhaus 007C, rather than at the rear. Technical director, Olivier Jansonnie, confirmed that the option to have a front adjustable device was decided early on and no adjustment to the plan was considered.

Since the car was first revealed, there have been some major changes to technical aspects of the regulations that have had a seismic effect on the car, not least the adjustment in tyre size for all new cars coming in 2023. Although this will not apply to Peugeot, it will leave the French car an outlier on the grid.

One other change was the introduction of a cockpit-adjustable anti-roll bar, which has proved more complicated than expected, so that has not yet been integrated into the car.

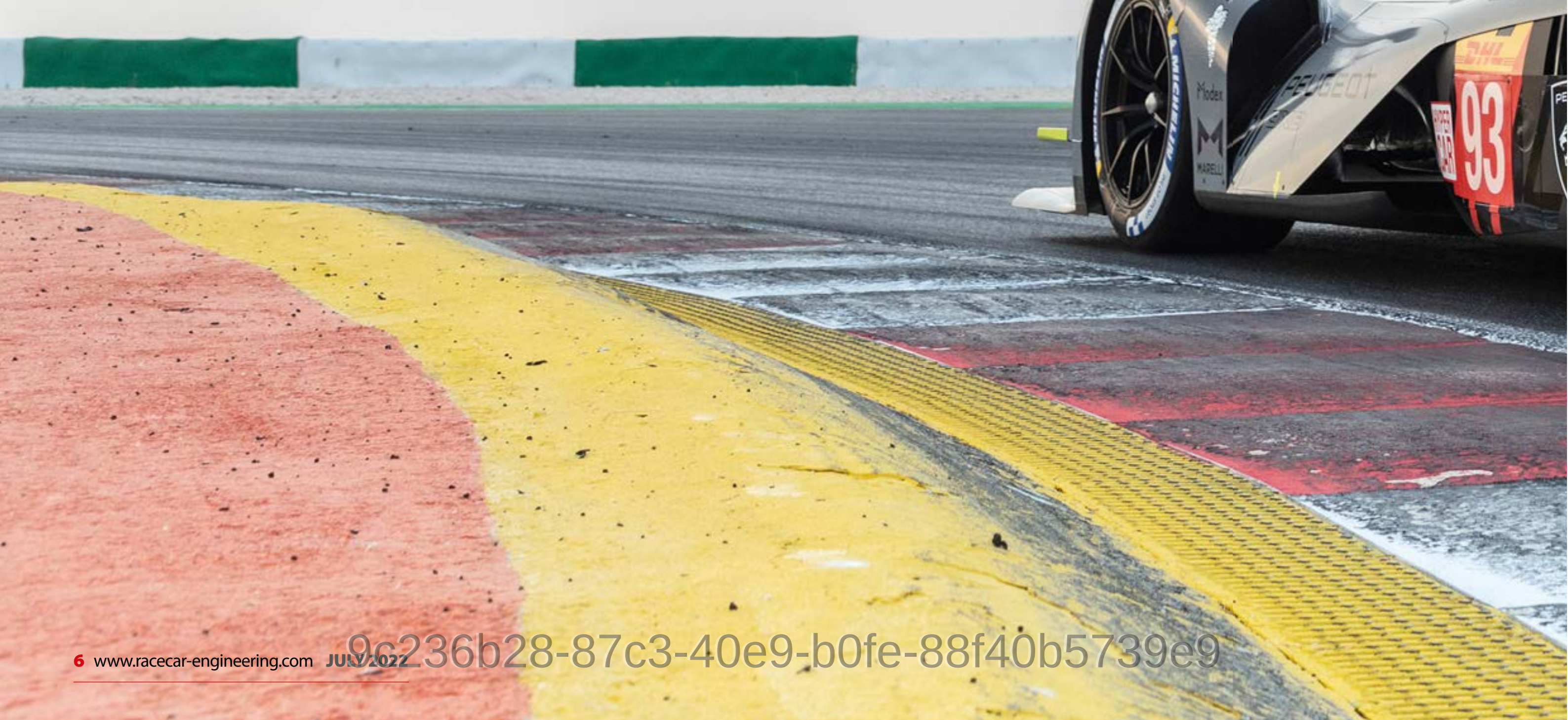
Talking points

One of the major talking points of the 9X8 is, of course, its aerodynamics, and much discussion has been held over whether the French car will run without a rear wing, yet still be competitive in the various temperature ranges, or track conditions.

Peugeot says it has now finalised the design of its car, with non-downforce generating rear winglets and a focus on an adjustable front device. According to the technical team, that combination opens up a wider window of adjustment for the car.

'The classic way of doing it is that you can adjust your rear downforce [with a rear wing], but the way that we do it you will balance the front and the rear together,' says Jansonnie. 'The purpose of this device is to change the aero balance, because you need to adapt for different drivers, tracks and conditions.'

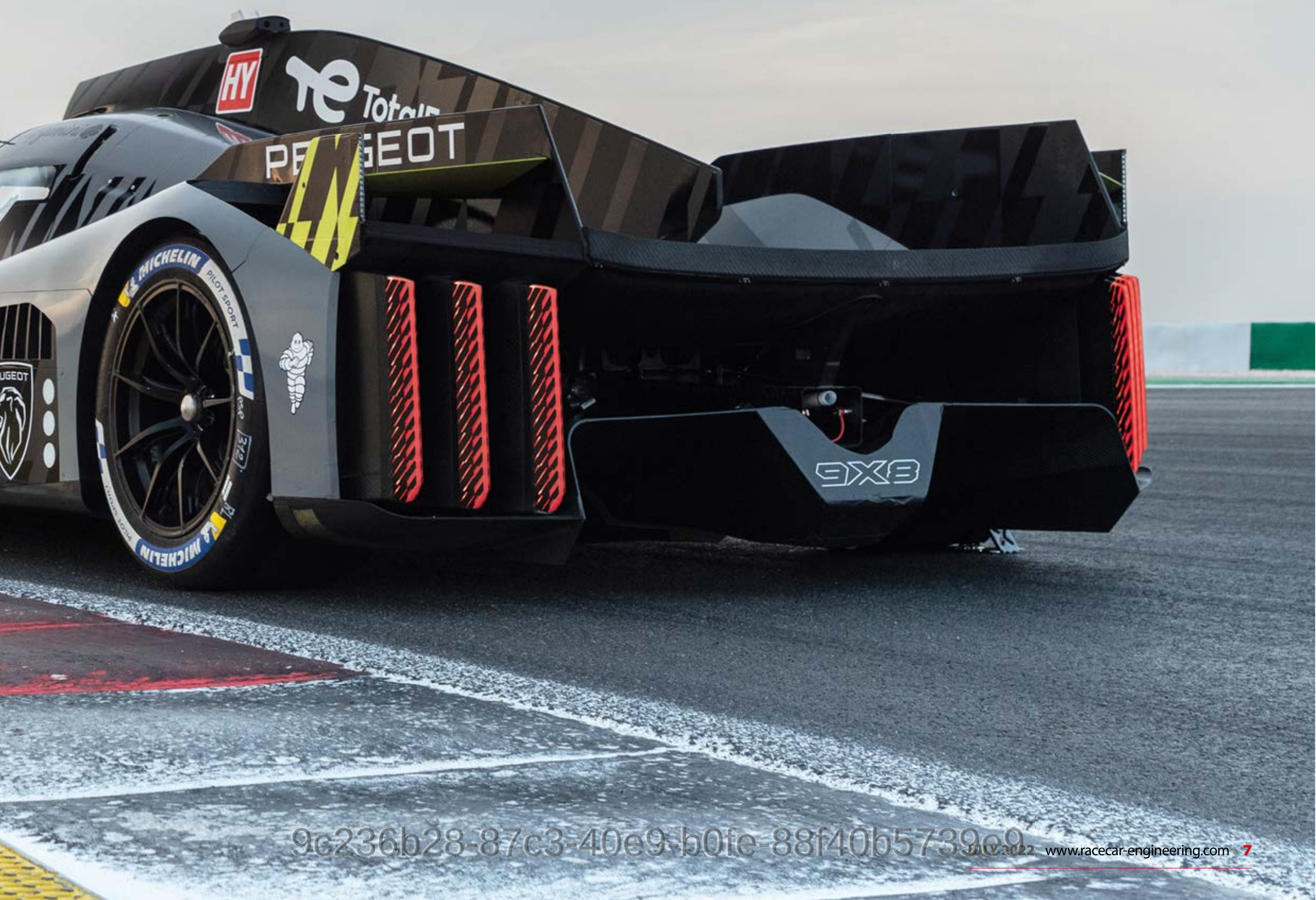
Peugeot's previous Le Mans 908 diesel programme was cancelled in January 2012 due to financial constraints on the company at the time, and so it never competed in a round of the WEC, which started that year. The experience of running the very high downforce hybrid cars was therefore missed and, says Jansonnie, is a loss to the team.



With only a single adjustable aerodynamic device allowed by regulation, Peugeot Sport opted to fit one at the front, saying it gives a wider window of adjustment than a traditional rear wing

'The classic way of doing it is that you can adjust your rear downforce, but the way that we do it you will balance the front and the rear together'

Olivier Jansonnie, WEC technical director at Peugeot Sport



Testing at Portimao in May gave the team the opportunity to run the car in hot temperatures for the first time, putting under pressure its cooling concept, as well as Michelin's tyre

'We had to be a bit more cautious, because the experience we have is more limited than the others, so we had to take a range of adjustments that was a bit big. That is why we chose this concept, because the range of adjustment is bigger than just a wing, but you still have to still stay within the performance window [set by the regulations].

'We spent quite a lot of time on it. We felt that it was easier to get a big adjustment of balance in a very tiny window.'

The team does not, for example, have an accurate aero map for Fuji or Bahrain, hence the need for that wide range of adjustment.

Performance windows

The homologation for the unusual aerodynamics has not been simple, admits Peugeot. Although the basic downforce levels prescribed by the regulations were relatively easy to hit, a lot of work was needed to keep the car in line with the performance windows set by the FIA and the ACO.

These windows, which set downforce and drag maximum and minimum levels, are narrow, and the range of aerodynamic adjustment of the car, including rake angle, wing adjustment and ride height, must keep it within them at all times.

'When you go to the wind tunnel, what you are trying to achieve is actually very difficult,' says Jansonnie. 'The window is tiny, and we repeated [our tests] quite a lot, privately, before homologation.

'It is difficult to be right in the middle of the box, which is where we wanted to be, so we have increased drag since the beginning, and there are many items on the car that show we have increased [it].' One noticeable part is a Gurney flap on the rear deck.

One of the key performance parameters of the car is weight distribution, and it is obviously biased towards the front. That was one of the original design targets, and one of the reasons why Peugeot was not able to change its tyre size to the 29/34 configuration used by its competitors, including Toyota.

Originally, the tyre size plan was to use the same size all round, and this was selected by Toyota in the first iteration of the GR010 that raced in 2021. However, LMDh convergence meant that a four-wheel-drive car would have to compete with a two-wheel-drive car in the same class, and have the same chance to compete. To make that work, they would need to restrict the advantage of 4WD in all conditions.The idea was then to have all cars competing on narrower front, wider rear tyres,

'We chose this concept, because the range of adjustment is bigger than [with] just a wing, but you still have to still stay within the performance window'

Olivier Jansonnie

A rear Gurney flap was added to help increase drag, necessary to put the 9X8 in the required performance window before racing starts

The Peugeot will compete in the WEC wearing numbers 93 and 94

Fences around the wheelarches were added late in the process to try to meet stability criteria in the event of yaw

Marelli collaboration

Peugeot Sport has signed a multi-year partnership with Marelli, a leading global automotive supplier with extensive expertise in the field of motorsports and high-performance technologies. This crucial technological partnership is based on the development of the most efficient electric solution to match the extreme performance requirements of the hybrid powertrain system on the 9X8 Hypercar.

Specifically, Marelli is providing the engineering and supply of the bespoke, high-performance electric motor and silicon carbide-based inverter that are part of the front axle electric traction system. The focus of the development is to maximise efficiency and reliability in the system, while adapting the motor and inverter technology to make effective use of the weight and volume allocated by the team.

'We are excited by this new collaboration with Peugeot Sport,' said Riccardo De Filippi, head of Marelli Motorsport. 'We already have a long and glorious tradition of collaboration with them in the history of endurance racing, and we both share a great heritage and technical tradition in motorsport competitions.

'Once more we put all our competences together to push the performance of such a unique and extreme car to the limit in a sustainable way, with the adoption of the most advanced Marelli electric powertrain technology.'

The car has been designed with the clear concept of running as much weight distribution forward as possible, and everything is connected to that

and Toyota made that switch in the 2022 version of the GR010. This was coupled with a change to the deployment speed of the ERS, but Peugeot was not able to accommodate that same change before it made its debut.

'We had the discussion with them about a year ago, during the summer of 2021, when the regulation changed,' admits Jansonnie. 'We considered changing the tyre sizes, but it would have been complete chaos in our schedule and our budget. The car has been designed with the clear concept of running as much weight distribution forward as possible, and everything is connected to that – the lack of a rear wing, the packaging of the car, it is very coherent, and that implies running the larger fronts.

'We made a proposal to try to increase the rear tyre size and keep our front tyre size, which would have been an increase in performance, but that was rejected at the time. Then, a few months later, the FIA and the ACO came back with the proposal to re-open the homologation for 29/34 tyre sizes for LMH, so we had to consider it. We put everything in balance, we discussed it deeply with Michelin, we ran simulations for between six and eight weeks, and finally had to decide not to change anything.'

There were rumours floating around that Peugeot would need to homologate a completely different car, and changing the car to suit the new tyre size was the only option that made sense. However, as this car is not yet homologated, an evo is not on the cards for now, although there is some consideration to upgrading the car, but that's normal following an intensive testing programme.

'The more you test the more you have a list of things that you would have done differently,' says Jansonnie. 'You also know that you cannot do it for now. It would be suicide due to the short time. It is better to [continue with] the concept that you have, but starting again from a clean sheet of paper we would do it differently. In parallel, we have a list, and if we have the chance to do another car, or an upgrade, we would do that.

'We will use our jokers certainly, but it is not clear that we will use them next year. It is a balance of bringing a small package in six months or a year, or a bigger package in 18 months. Since you are only given the chance to do one evo per cycle, you had better have the right target and the right strategy.'

Retaining the different tyre size to now every other Prototype on the grid means it will be harder to balance the car, and Peugeot has already cautioned the BoP adjusters.

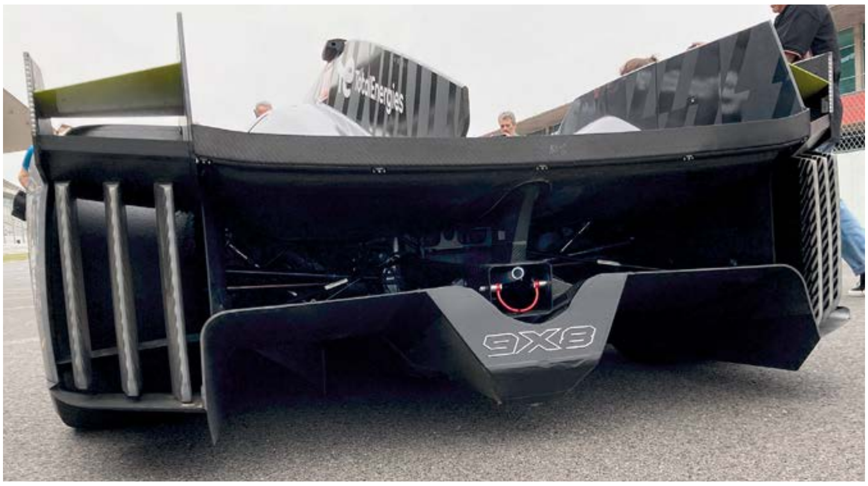
'I am thinking that as we kept for architecture reasons 31/31 we could still use our four-wheel drive, and I trust FIA and ACO to take that into account in the balance of performance,' says Jean-Marc Finot, Senior VP, Stellantis Motorsport. 'In this regulation, we think it is mandatory that BoP is rigorous and the outcome is of calculation purely engineering measuring, without any surprise and subjective tuning.'

The FIA, ACO and IMSA have decoupled the cornering and acceleration phases of the performance, and so the braking and mid-corner performance would be largely in favour of a larger front tyre. However, Peugeot was not able to change its concept at the late stage that such a proposal was made.

Roll with it

One item that the team did have to include, though, was the cockpit-adjustable anti-roll bar. Legal in the LMDh rule set from the start, the organising bodies tried to bring the concepts as close together as possible to help with performance balancing.

'In the end, the decision was to allow it for everyone, rather than ban it,' says Jansonnie.



Strong Peugeot styling cues from current models have been retained, particularly around the front and rear lights

'It was not our choice, and so we have to re-design this and integrate it into the car.' That is not the work of a moment. While the change might look minor from a regulation standpoint, it's a major change in the suspension design that was already tightly housed in a slim-fit bodywork.

'Frankly, that is something we would have preferred not to get. We found out quite late in the convergence process that it was part of the homologation between LMH and LMDh. It used to be forbidden in the LMH regulations, so our car was designed without and integrating it can be quite tricky.

'We will do it before the end of the year, but probably not for the first race. It should be an advantage [in terms of performance], so somehow we have to find a solution, but it's not easy when the car is already designed.'

Speed limits

One final element of the so-called 'convergence' between the LMDh and LMH rule sets was the minimum speed of the cars where the ERS could be activated. For the first two races of the 2022 season, Toyota has only been able to deploy its hybrid system above 190km/h, but Peugeot does not believe that will be an issue when it races in the series later this season.

'This is not a regulation change,' notes Jansonnie. 'The change is that the ERS deployment speed has been set as a parameter of the Balance of Performance. Then, the fact that this became 190km/h for Toyota at Sebring and Spa is a BoP adjustment. If we follow the calculations and simulations agreed with the FIA, the ACO and all the other manufacturers, normally we should have a lower deployment [speed].'

The change in activation speed of the ERS is to negate the advantage of four-wheel drive, but not in overall performance. The power output of the Prototypes is capped at 500kW, be it entirely from the ICE, or from a combination of 300kW from the ICE plus a maximum of 200kW from the hybrid system.

'We had all the simulation groups, and data and simulation was shared between the manufacturers, and there was different ways of approaching the issue,' says Jansonnie. 'One of the issues was that four-wheel-drive cars have an advantage when grip goes down. We were less penalised than a two-wheel-drive car. Then [if] the start of the race is dry and the end wet, the balance is completely wrong. That is down to the nature of the cars, and two different kinds of car that compete together, whatever the grip.

'One way to achieve [parity] is to ensure four-wheel drive does not give an advantage at all. That decision has been taken. The four-wheel-drive car manufacturers were not really in favour of this. What is interesting, though, is that the simulation was showing very clearly that tyre size and tyre dimension mean [deployment] speed is different.'

If this sounds complicated, it is. But there was no option to remove 4WD cars as, by regulation, an LMH hybrid *must* be four-wheel drive. With the front hybrid system advantage mitigated, then, it means teams have to pay for development of a complex part for no real gain, *and* carry around ballast at the front. They are certainly hoping the success of the WEC replays their investment.

The reduction in the effect of front hybrid performance is what helped Toyota make the decision to go with the narrower front tyre this year. However, Peugeot was hardly complementary about the decision.

'The ERS deployment speed has been set as a parameter of the Balance of Performance'

Olivier Jansonnie

Digital design

Prior to taking to the track for its pre-homologation test sessions, Peugeot's 9X8 Hypercar began life as a 51.1GB digital project, made up of 15,267 files stored on a hard drive.

Peugeot Sport's teams spent two years modelling and simulating the Hypercar, utilising both existing software – adapted where necessary to suit the project's specific requirements – and computer programs developed entirely in house.

'One of our strengths is being able to create the tools ourselves to shape the design of the components we need,' explains Francois Coudrain, powertrain director at Peugeot Sport.

'Thanks to our software, we can envisage a wide range of dimensions, shapes and materials, and work on the weight of the car in line with the technical regulations.

'As with the choice of the base concept, being able to take a purely digital approach to trialling systems and components allows us to assess a large number of potential solutions, which would be impossible to achieve in the real world.

'Digital technology and the calibre of our simulation tools enabled us to gauge the interaction between different components and systems, meaning we were already familiar with the theoretical performance and behaviour of the car before testing it for real.'

Close relationship

As a case in point, the Peugeot 9X8 incorporates a triple electrical system (900V battery, plus 48V and 12V components) and digital technology enabled Peugeot Sport's engineers to fully understand its electro-magnetic environment and work on the optimal dimensions for its wiring harnesses. In order to minimise the risk of interference, it was necessary to create a close relationship between the physical components and the software. In this way, the team established that it was better to use smaller wiring harnesses in 48V than in 12V, which simultaneously saves space and weight, while improving the compatibility between the physical harnesses and the calculators / computers.

Other parts, sourced off-the-shelf from Stellantis Sport, or derived from mass-market product, sometimes work very well. Certain 48V motors in the 9X8, for example, come directly from drones.

Digital simulations also allow for customisation, such as deciding what material to use around the exhaust outlets. Here, simulations revealed the carbon bodywork needed protection, or to be replaced with aluminium or titanium. Initially highlighted for attention in the design brief, this was corroborated during the simulation phase and then again in the first real-life test session.

Following its digital development, the hard drive containing all the technical data of the Peugeot 9X8 provided the basis for the creation of a full-scale wind tunnel model and, subsequently, a physical racecar, the ongoing development of which is currently taking place on track.

'If you choose the same tyres as the LMDh, you end up with two-wheel-drive cars, or at least, cosmetically four-wheel drive but practically two-wheel drive, and we made a different choice,' says Jansonnie.

Finot added to the argument: 'If we had the 29/34 tyres, the use of front-wheel drive is very difficult to justify because you have the same potential as a two-wheel-drive car.

'If you have the same potential as a two-wheel-drive car you cannot be surprised not to use your front axle. As we are promoting and developing our skills in electrified powertrain, it was also mandatory to develop the electrified powertrain.

'While LMDh seems easy, you just have to take a car from the shelf, and throw inside the internal combustion engine. What kind of story are you telling? What could I tell to the customers, to my board, if I say yes I am very proud of developing an internal combustion engine? It is not the trend currently. For you [the media] it is an opportunity because you have much more story telling on a car such as this one than if I was telling you I bought a car from ORECA, Ligier, Multimatic or Dallara and I put in an ICE engine from a road legal car.'

Electronic headache

While the mechanical elements of the car are under development, it's the electronics that have caused the biggest headache, not only the complexity of running a four-wheel-drive system, but also the Balance of Performance elements. These include a method of monitoring the car's power output, which has to work with the systems already on board.

'The cars are very complex on the systems side,' confirms Jansonnie. 'They are less expensive than the old LMP1 cars, but they are still four-wheel drive, hybrid, high-voltage systems that are complicated. The BoP adds an extra layer of complexity to that.

'The first step was to get the systems to work together. They are connected, and we are almost there. Then we have had some mechanical reliability issues, as you would expect on any new car, but nothing dramatic, and nothing we cannot solve.'

One of the elements the team encountered was the battery. Teamed with Saft, a subsidiary of TotalEnergies, cell technology and engineering support was outsourced, but the packaging of the battery within the monocoque, narrow by choice of the Peugeot designers, was complicated by the fact that, by regulation, the battery sits below the fuel tank.

'We pushed the packaging, and that is not easy to manage,' admits Jansonnie. 'Even if the battery capacity is not huge, you still have 200kW of power, which requires a number of cells. And with the cells under the fuel tank, and without a wide monocoque, that was not easy.

'In that respect, we have been very happy with the results of the crash tests for the battery and the car, which were passed first time and without issue.'

Testing has so far only taken place in cooler, winter temperatures, so the team has not had the opportunity to conduct much hot weather running, but it remains confident in its cooling packages. It's only issue in that respect was various components leaking, but otherwise it is happy with its solutions.

External challenges

That's not to say the test programme didn't have its challenges. One of the key areas of concern in the run up to the race debut has been supply chain issues, though that has affected everyone in the industry. But for a team that has been developing a new car, that has made life especially difficult.

'There was a shortage of electronic components, but aluminium is very difficult to get, as is resin for carbon fibre. We are a bit better off now than we were a few months ago, because the tooling for the bodywork is now done and we are producing parts, but we put in a lot of effort to secure materials up front.

'In the last 20 years of building racecars, this is the most difficult time I have ever seen. There is a huge impact on price when things become rare, but a specific phase of the project is first tooling, and from October 2021 to January 2022 was the most critical phase.'

So, the car has now undergone extensive testing, is set to be homologated before its race in July, and will then start to collect race data ready for the big race, the centenary of the 24 Hours of Le Mans in 2023.

'We have been very happy with the results of the crash tests for the battery and the car, which were passed first time'

Olivier Jansonnie

Driver's eye view: Paul di Resta

'The rear wing is the adjustable thing to get performance out of a car and give you a direction in set-up quickly. This [Peugeot solution] is not that. You are allowed one adjustable aero device, for balance, which is an important thing, [and the Peugeot's is at the front] but when you are in the car you don't *feel* the difference. When I first drove the car, the biggest thing for me was the difference compared to a P2, and I understand having followed a Hypercar how hard they are to drive. They are very complex cars, and are going to take a lot to get your head around. But as long as it produces great racing, it should be good.

'We haven't got into much set-up yet. We are going through different scans of roll bars, dampers, and all the things like that, and we don't even know where on the scale we are.

Never having driven a 4WD car before, the complex, and largely unknown Hypercar presents a challenge

'Every time the car leaves the garage it is learning. We are trying to build this database and simulation package that gives us the global [view] when we get to a race track and set it up. We are not even at the point of saying that this is optimised running. We are gathering information from all the variations we have and seeing if we have enough scope on how stiff something is, or how soft we need to go. We need to have all the stuff in the toolbox for when you need it, and we are not there yet.

'The other thing is that [the Portimao test early in May] is the first time we ran the car in proper heat, and you are on the upper scale of what Michelin brings as a tyre. That is another learning curve, compared to what we were running in January. You start closing things up and you get more downforce. You then need to make sure it's where you need to be, and if you have enough brake temperature.

'Even then, you don't know [where you are] until you see against other cars, and they start pegging you back or giving you more freedom. You try comparing this to the WEC race that was here last year, but the rules have changed for energy deployment, the weight is different and the track surface was new close to the race. It is juggling to try to get a reference. When it all stops in the race, will we have enough?

'You are in this window, and you need to be able to use what you have got. It is then whether you can in reality run that, through ride height variation and compliance.

'I have never driven a four-wheel-drive racecar, so you have to bring that in, too. The management of that is coming from front axle braking, so that is all the different maps, and the feeling you get from that.

'You are right at the beginning, so you cannot go into this promising the world. The biggest thing you can say is that they released the concept car, and they have not changed much. There is some architecture change for homologation, and it is what it is going to deliver on track that matters.

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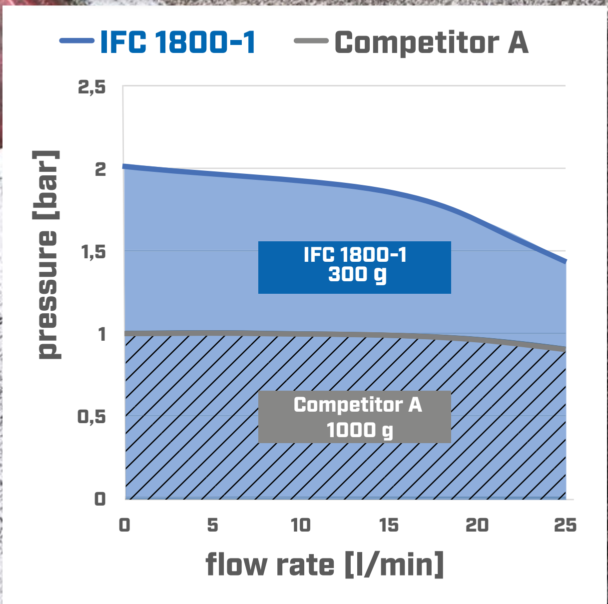

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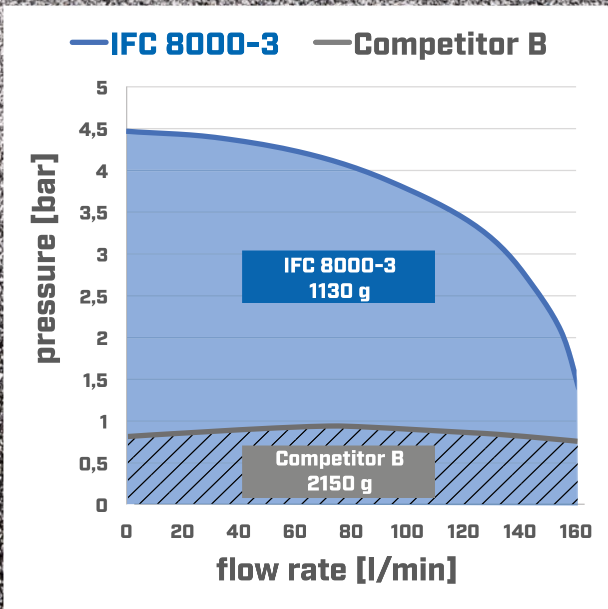

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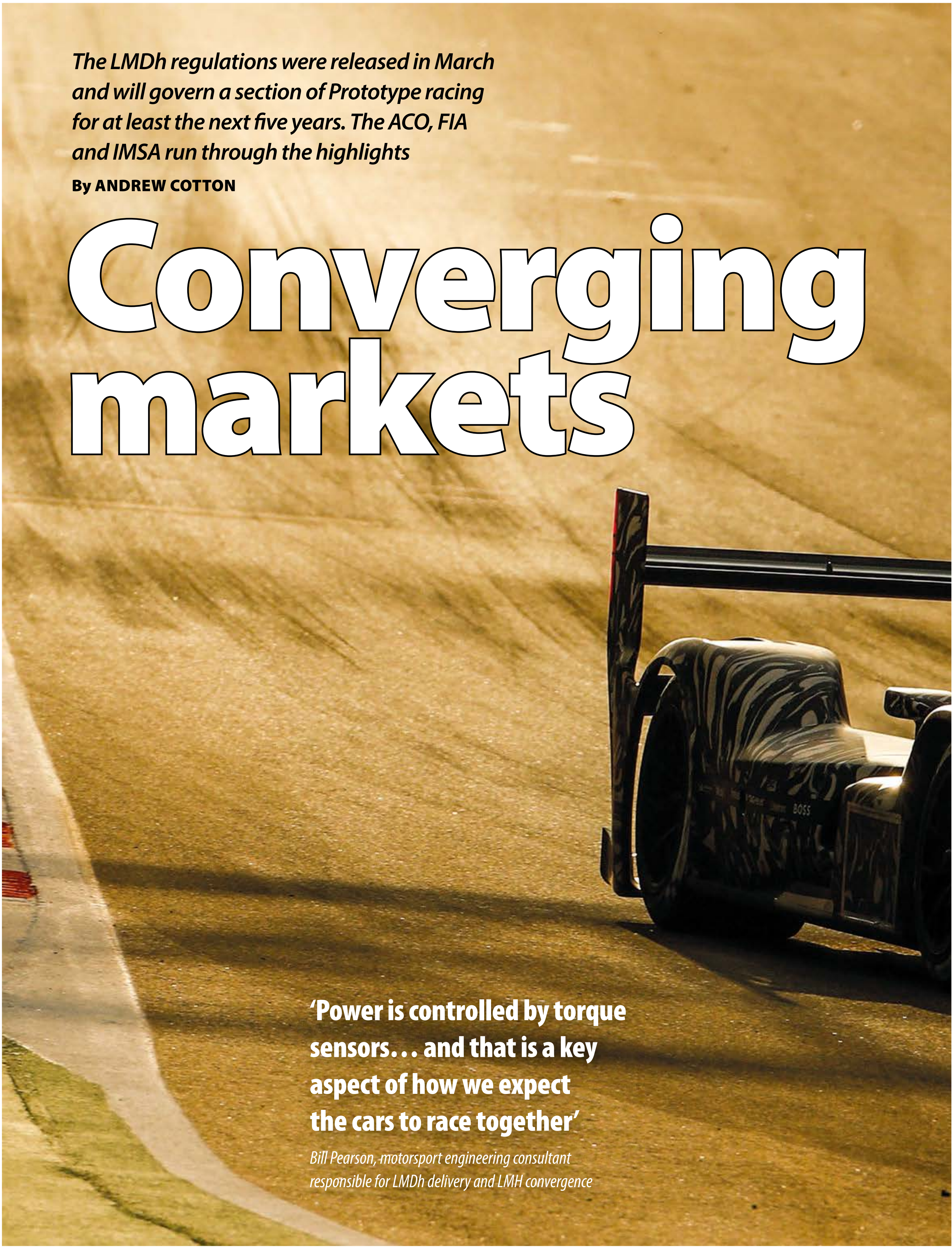
The LMDh regulations were released in March and will govern a section of Prototype racing for at least the next five years. The ACO, FIA and IMSA run through the highlights

By ANDREW COTTON

Converging markets



'Power is controlled by torque sensors… and that is a key aspect of how we expect the cars to race together'

Bill Pearson, motorsport engineering consultant responsible for LMDh delivery and LMH convergence

The regulations for the top class at Le Mans have been finalised as the ACO, FIA and IMSA published the LMDh rule set at the end of March. These regulations, based on IMSA's philosophy of low-cost Prototype racing, sit alongside the LMH rules that were designed by the FIA and ACO, and together they form the top class, named Hypercar, in the World Endurance Championship, and GTP in IMSA.

While the LMH regulations have been public for a long time, allowing Toyota and Glickenhaus to race in the WEC in 2021, the LMDh regulations have taken a little longer to finalise. The teams and manufacturers have had a version of them since September 2020, but the process of bringing the two rule sets together has been complicated.

The highlights of the LMDh regulations have been known for some time. They are essentially a chassis from one of four constructors – Dallara, Multimatic, Ligier and ORECA. They build the 'spine' of the car, including the monocoque, suspension, and brakes. This spine will be used to form the LMP2 cars of the future.

British companies Xtrac and Williams Advanced Engineering provide the gearbox and battery elements of the hybrid system respectively, while Bosch provides the MGUs for the cars.Each LMDh car will carry the same specification gearbox and hybrid system.

Manufacturers take the homologated chassis from their chosen constructor, and introduce their own engine, cooling packages and bodywork. The aerodynamics, power and weight (1030kg minimum) are all lined up to be performance balanced against the LMH cars.

So far, the manufacturer split between the two routes to the top Prototype class are pretty even. Taking the ground-up design route for LMH are Toyota, Peugeot, Ferrari and Glickenhaus, while taking the LMDh route are Cadillac, BMW, Acura, Lamborghini and Porsche. The idea is for each of them to have equal opportunity to win races and championships, be they the FIA World Endurance Championship or IMSA WeatherTech Sportscar series.

Performance windows

The method of bringing together the LMH and LMDh rule sets relies on the performance windows. These govern aerodynamic efficiency, power, weight and torque in the design phase of the car. While the initial numbers are relatively easy to hit in terms of performance levels, the windows are extremely small, and require a high level of accuracy in terms of car operation, but also in terms of measurement from the governing bodies.

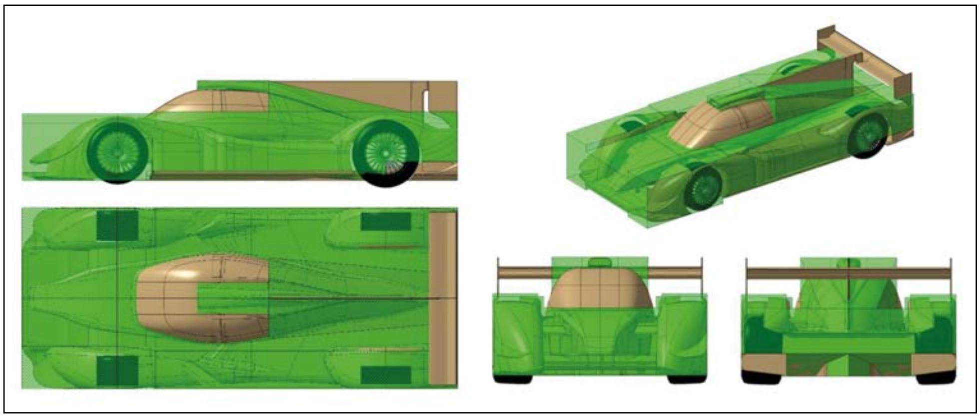
Wind tunnel data from two separate tunnels is used to map the cars and, while weight is stipulated, power and torque are measured on dynos.

The idea of performance windows was started in GT racing. These bring the cars broadly into line with each other in the design and development stage, and then performance balancing in race conditions helps make the final adjustments to bring parity across the class.

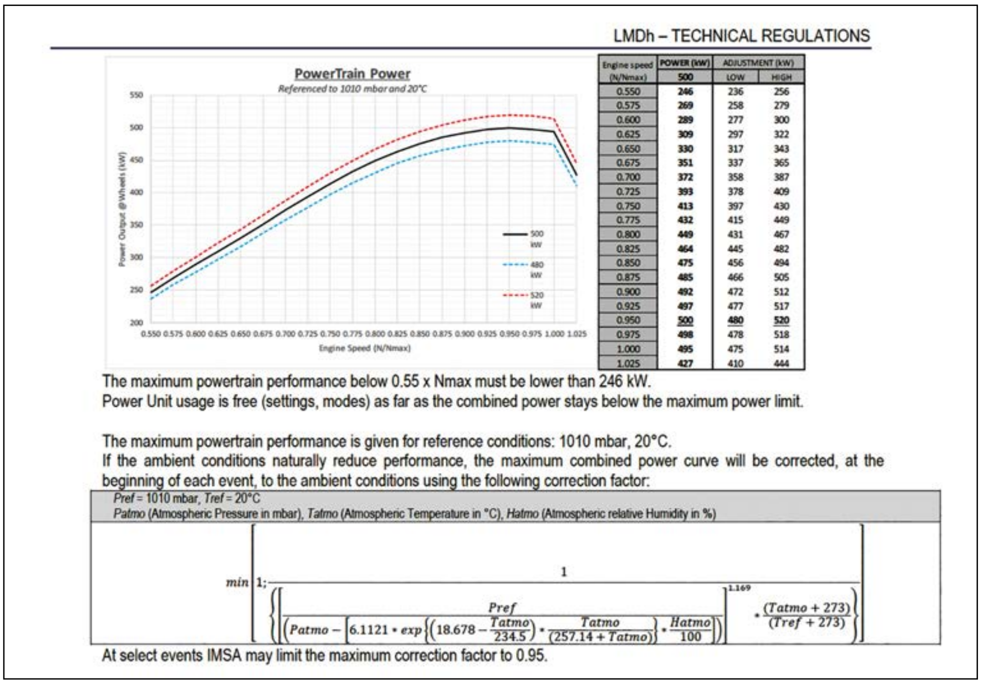
However, while the GT3 cars have very different architecture, not least in terms of engine location and minimum weight of the production car, the Prototypes are a lot closer in concept.

'The GT3 performance windows are quite a lot bigger than what we are doing with LMDh and LMH,' says Bill Pearson, motorsport engineering consultant responsible for LMDh delivery and LMH convergence. 'The target windows the manufacturers are working with are really very small. Power is controlled by torque sensors, which the GT3 cars do not work with, and that is a key aspect of how we expect the cars to race together.

'There has been a big focus on raceability and having cars equivalent out of the box, and we will still have that process, but rather than having to rely on big swings of BoP, big requirements of mass and power, the fundamental building blocks of mass and power are already going to be aligned for all the cars.'



Performance windows were put in place early on, and aerodynamic efficiency mapped using data from two separate wind tunnels



LMDh – TECHNICAL REGULATIONS

Engine speed (N/Nmax)	POWER (kW)	ADJUSTMENT (kW)	
	500	LOW	HIGH
0.550	246	236	256
0.575	269	258	279
0.600	289	277	300
0.625	309	297	322
0.650	330	317	343
0.675	351	337	365
0.700	372	358	387
0.725	393	378	409
0.750	413	397	430
0.775	432	415	449
0.800	449	431	467
0.825	464	445	482
0.850	475	456	494
0.875	485	466	505
0.900	492	472	512
0.925	497	477	517
0.950	500	480	520
0.975	498	478	518
1.000	495	475	514
1.025	427	410	444

The maximum powertrain performance below 0.55 x Nmax must be lower than 246 kW.
Power Unit usage is free (settings, modes) as far as the combined power stays below the maximum power limit.

The maximum powertrain performance is given for reference conditions: 1010 mbar, 20°C.
If the ambient conditions naturally reduce performance, the maximum combined power curve will be corrected, at the beginning of each event, to the ambient conditions using the following correction factor:

Pref = 1010 mbar, *Tref* = 20°C
Patmo (Atmospheric Pressure in mbar), *Tatmo* (Atmospheric Temperature in °C), *Hatmo* (Atmospheric relative Humidity in %)

$$min\left[1;\frac{1}{\left\{\left[\frac{Pref}{\left(Patmo-\left[6.1121\cdot exp\left\{\left(18.678-\frac{Tatmo}{234.5}\right)\cdot\frac{Tatmo}{(257.14+Tatmo)}\right\}\cdot\frac{Hatmo}{100}\right]\right)}\right]^{1.169}\cdot\frac{(Tatmo+273)}{(Tref+273)}\right\}}\right]$$

At select events IMSA may limit the maximum correction factor to 0.95.

The power and torque windows are extremely small, but using torque meters to measure the cars' output is helping achieve parity

Torque meters

While the aero windows are small, it is the adoption of torque meters that has really given the governing bodies the confidence to accurately map the power output of the engine. No longer are they relying on air restrictors to balance the cars, now they are looking at power output at the driveshaft.

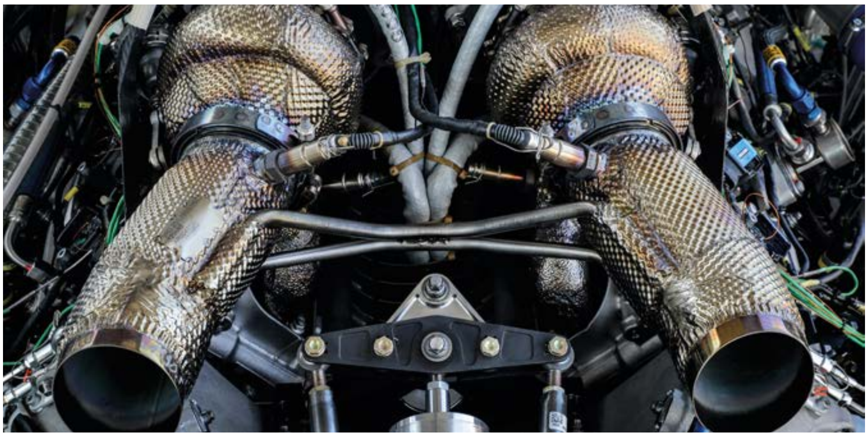
'There is an aerodynamic window for GTE, which is already smaller than a GT3 window, but [for LMDh] it really is a small dot on what we are used to seeing in GT3,' says the ACO's competition director, Thierry Bouvet.

'The performance window in GT3 is big, and nothing to compare to LMH and LMDh. In terms of power, the really good thing is the torque meter. Just imagine that the engine is a black box. We were policing the input of the engine to try to reach something on the output. Now we are not even going to the output of the engine, but the output of the gearbox, so taking into account gearbox efficiency, too. We are 100 per cent sure of getting what we want to get.'

This accuracy was not enough to bring in manufacturers though. They wanted to be sure of having the chance to race equally on every circuit, so needed the flexibility of BoP.

'The first set of LMH regulations had such small performance windows, and this was not attracting the manufacturers,' confirms Bouvet, 'so the day we said we will do BoP this opened the door to manufacturers.

No longer are they relying on air restrictors to balance the cars, now they are looking at power output at the driveshaft



Engine power figures are measured at the gearbox output, so transmission efficiency is no longer a key element

British company, Xtrac, will supply the gearbox to all LMDh Prototypes

'Weight, power and torque is captured. We have second order parameters that can make a difference and, if you don't do a BoP on that on homologated cars, then you are stuck.'

For IMSA, which has run its top prototype DPi cars on this philosophy for many years, BoP has been a necessary evil to keep the manufacturers and fans happy with close racing. While it has been the source of many column inches as teams complain that their rival has an unfair advantage, it is the only way the governing bodies could separate out budget and performance.

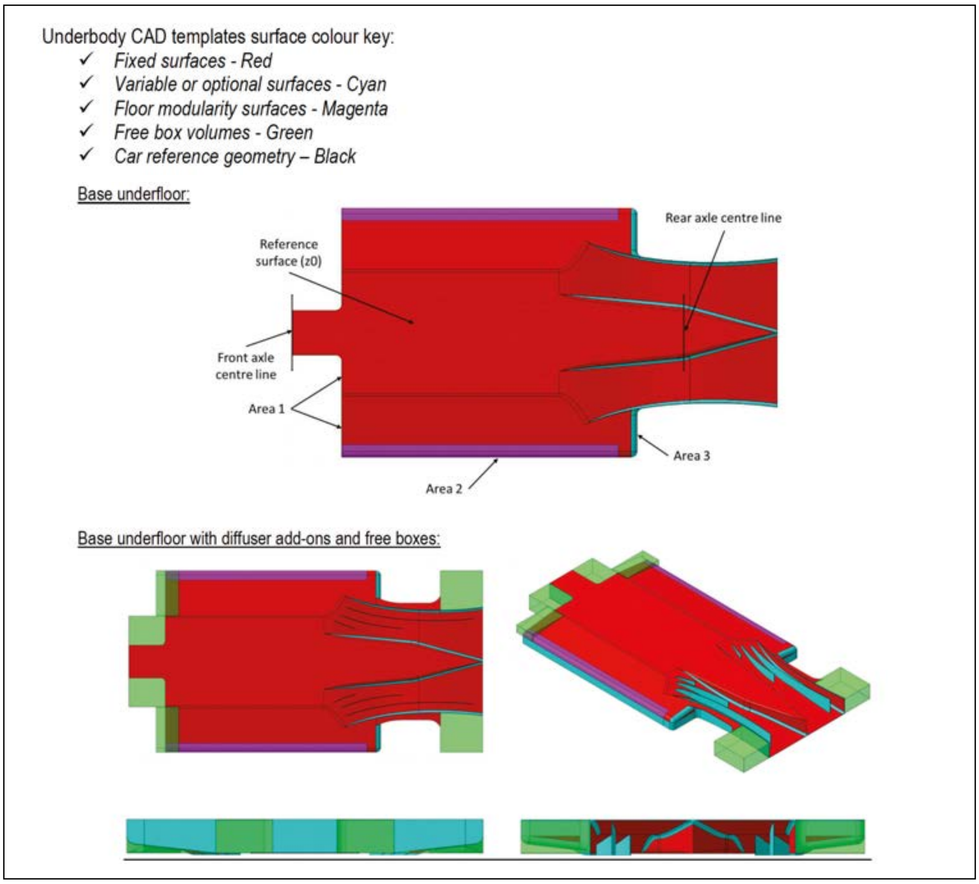
Clear statements

'The purpose of BoP is to dis-incentivise big manufacturer development programmes to get the edge in performance,' says IMSA's vice president, competition, Simon Hodgson. 'We have made some pretty clear statements to the manufacturers associated with convergence, which will be that every manufacturer will have an equal opportunity to win at every track, and the opportunity to win championships and races in both WEC and IMSA competition.

'Certainly, some manufacturers will arrive better prepared than others, and we have the responsibility to manage the competition appropriately.

'As we have seen from IMSA competition, we can go from the same event at the same track back to another event at the same track a week later and have a different result. We are talking about the same cars at the same track with the same BoP having a different result.

'The goal for both platforms is to achieve technical convergence and resultant performance. The goal here is for BoP not to be the main focus of the championship, but let the teams and manufacturers generate the result they deserve, but again on a competitive and as equal as possible playing field.'



LMDh high-downforce floor design has taken inspiration from LMP2, but with a clear eye on limiting excessive development cost

In order to allow the manufacturers to style the bodies properly, downforce had to be guaranteed, and stable. The LMDh regulations tread a careful path between the cost of developing a high-performance floor, and creating something worthwhile.

Downforce generation

'There is obviously a difference in the way the regulations are written between the two classes, and it is also clear that the LMDh floor has taken inspiration from the LMP2 floor,' says Pearson. 'It is along that idea of stable, simple, easy-to-find downforce on those cars.

'We have a comprehensive test session planned for each car where we go and make sure the performance we get from those cars is well understood, whether it is an LMDh or LMH'

Bill Pearson, motorsport engineering consultant

In a further bid to achieve parity between the two categories, LMH cars will have a more powerful floor design than LMDh cars, and a comprehensive test programme is planned to quantify this

Yes, the LMHs have a different set of regulations for the underfloor region, and we can all see what is going on in other series.

'Floor downforce, and how it behaves, is interesting. We have a comprehensive test session planned for each car where we make sure the performance is well understood, whether it's an LMDh or LMH, and make sure the key headline performance parameters are balanced between the two cars.'

That said, the LMH cars will have a more powerful floor than the LMDh cars.

'What we did is use for LMDh the performance of LMH,' says Bouvet. 'That was a good starting point. Together with the FIA, what we had in mind first and foremost was a performance window where the manufacturers could bring their stylisation on the car, and I think we have achieved that target when you look at the Peugeot.

'So really, the driving factor was stylisation, not performance. Manufacturers are racing for the fans, and the fans like to recognise some of their brand items on track. LMP1 was a great time, but the identity of the brands was a lot less compared to Hypercar, we believe.

'We have a process we follow with each manufacturer, to make sure the stylisation is strong enough and the engineers are not pushing the performance.'

Safety advances

When the LMP2 cars were first introduced in 2017, they were a step change in performance compared to the previous generation. They were small, powerful and quick, in order to reasonably share track space with the 1000bhp LMP1 cars. However, they will be replaced for the 2025 season with the spine of the LMDh cars, homologated bodywork from the chassis constructor and a standard engine.

Porsche has designed its chassis for build by Multimatic, and the Canadian company now must create an LMP2 design out it. By contrast, ORECA, Dallara and Ligier started work on their customer-focussed LMP2 'spines' before signing a manufacturer partner.

Six years on from the initial LMP2 design, the FIA has taken the chance to improve safety.

Comment: Doug Campling, head of motorsport at Williams Advance Engineering

There were initially rumours of delays to the hybrid system that will form the backbone of the LMDh rule set, but they have been denied by the suppliers. Porsche has led the testing for the LMDh hybrid system and is on such an aggressive development path that suppliers have been racing to keep up. The system is now running regularly on track, with Porsche completing more than 10,000km of testing since the first roll out, not all of it in full spec, but latest running is with a complete hybrid system.

WAE's pouch cell is a high power, state-of-the-art unit with 200kW+ potential

'I think it's fair to say that Porsche's schedule was very aggressively ahead of all the hybrid partners, with the exception of Xtrac,' says Williams Advanced Engineering's head of motorsport, Doug Campling. 'Trying to keep up with Porsche is one of those double-edged things. Keeping up has been a challenge, but Porsche has really kept a momentum to the project.

'Hats off to Bosch because, although I don't want to undersell the battery, the BMS is so important for the integration of all of that within the ECU on the vehicle, the software is just such a big deal.

'The battery was allowed to be a clean sheet design. The performance parameters of the battery changed over the period since we originally started working with IMSA on DPi 2.0, pre-LMDh and LMH. With how the convergence conversations went back and forth, we had to be reasonably flexible. Things kind of got tied down in the press release at Le Mans and, from there on in, we knew what we had to hit, and could tie the design down.

'It is a pouch cell, with super high C-rate, high power. I guess it's back to F1 KERS and ERS style. The differences between a hybrid battery and an EV battery are profound, but it is a cell manufacturer we are familiar with. We go back to Gen 1 FE and, before that, Williams F1 hybrid was pouch design as well.

'Cells have moved on, F1 has moved on. The KERS we supplied to Marussia could do 3000km on a good day. Here we aspire to be properly cost effective, which means good mileage, and that means a full season, including Le Mans, although manufacturers will always want new parts for Le Mans.

'This is a system that has a very high power capability, absolutely in parallel to LMH. How that is deployed is dependent upon regulation and the competitors' choice. The system can do north of 200kW potential, though I think LMDh won't use that level of deployment, but near to those levels in regen'.

'It is state of the art.

'This is not a mild hybrid, it's got real guts to it, but we will have to wait and see how the regulations and manufacturers choose to use it.'

'Together with the FIA, what we had in mind first and foremost was to bring a performance window where the manufacturers could bring their stylisation on the car'

Thierry Bouvet, competition director at the ACO

Porsche has led testing of the class' hybrid system from the front, stretching suppliers but keeping up a level of momentum that has allowed it to complete over 10000km of running already

The cars, which will be slower than the DPis, have already proven to be safe, but side impact protection is now a major focus for governing bodies.

'For the safety standards, we don't consider the speed, more the energy of the impact, which is the main parameter in this,' says the FIA's director of sport and Touring Cars, Marek Narawecki.

'From the FIA point of view, standards are evolving. It is a bit different to the approach to single seaters for closed-cockpit cars. There were some areas of improvement, but we rely on the standards that have been already set for the category. The intention is to keep this as a reference and have improvements, as mentioned, for side impact.

'The intrusion of suspension parts into the cockpit, this was the purpose of the panels and strengthening the sides.'

Cockpit size has also been increased.

'Knowing there would be LMP2 attached to it, that is the reason we went in the spine direction,' says Bouvet. 'The focus was for manufacturers to design a cost-efficient car. Obviously, there is a price in LMDh regulation [for] the spine, so that is to give a framework for manufacturers. We did that in collaboration with the chassis constructors, looking at the current generation of LMP2.'

The spine is, by regulation, limited to €345,000 (approx. $364,270) and the sum part prices forming the spine must not be more than 140 per cent of its selling price. The price of bodywork, dampers, wheels and brake systems are limited in a bid to make the cars cost effective for customers in LMP2 at a later date. However, a shortage of spare parts is leading constructors to warn that they may need to increase this basic cost, but that is open to discussion.

'Obviously we made [the chassis] thinking of LMP2, as well as LMDh. We made the survival cell wider in terms of habitability, which could be tricky from the current LMP2 version,' continues Bouvet. 'We wanted a wider driver area for the new generation.

'Crash testing is done with our colleagues from the FIA. We are always learning with experience, and where do we stand to improve safety. We had the opportunity to make the side panel stronger on the LMDh, for example, so we took that opportunity.'

Long-term stability

One of the main issues that has arisen recently is the shortage of materials to create cars. While none of the manufacturers coming to the series in 2022 or 2023 have admitted to concerns about bringing their cars to the track, it is something the organisers have considered.

'It has never been more important to be able to communicate with the stakeholder partners, be they manufacturers or tyre

'One of the big initiatives in wanting to create convergence is trying to get stability, trying to give a long-term vision for the platform'

Simon Hodgson vice president, competition at IMSA

suppliers,' says Hodgson. 'There is so much changing in the world, one of the big initiatives in wanting convergence is to get stability, trying to give a long-term vision for the platform, and that is why some elements of convergence have taken as long as they have.

'We had to take into consideration so much of the different chassis constructors, the manufacturers, their programmes, needing to make the technical changes. We are on a timeline, but we have trodden carefully to fully evaluate what makes the difference in performance and make some solid, educated decisions that we firmly believe we are not going to have to back up from.

'It has been a major process, and will continue to be as the world changes around us, that we try to maintain stability.'

The rules are now set, the cars are in build and testing, and Daytona in January will see the LMDh cars take to competition in anger for the first time.

Commitment to LMP2

At Le Mans in 2021, the ACO confirmed its commitment to the LMP2 class, effectively sending a torpedo into the side of the plans of LMDh manufacturers to flood the Prototype market in Europe and Asia with their products.

It was a welcome announcement, not only for the chassis constructors, but also for the teams. LMP2 will be a non-hybrid version of LMDh, and the development costs will be largely soaked up by the manufacturers involved.

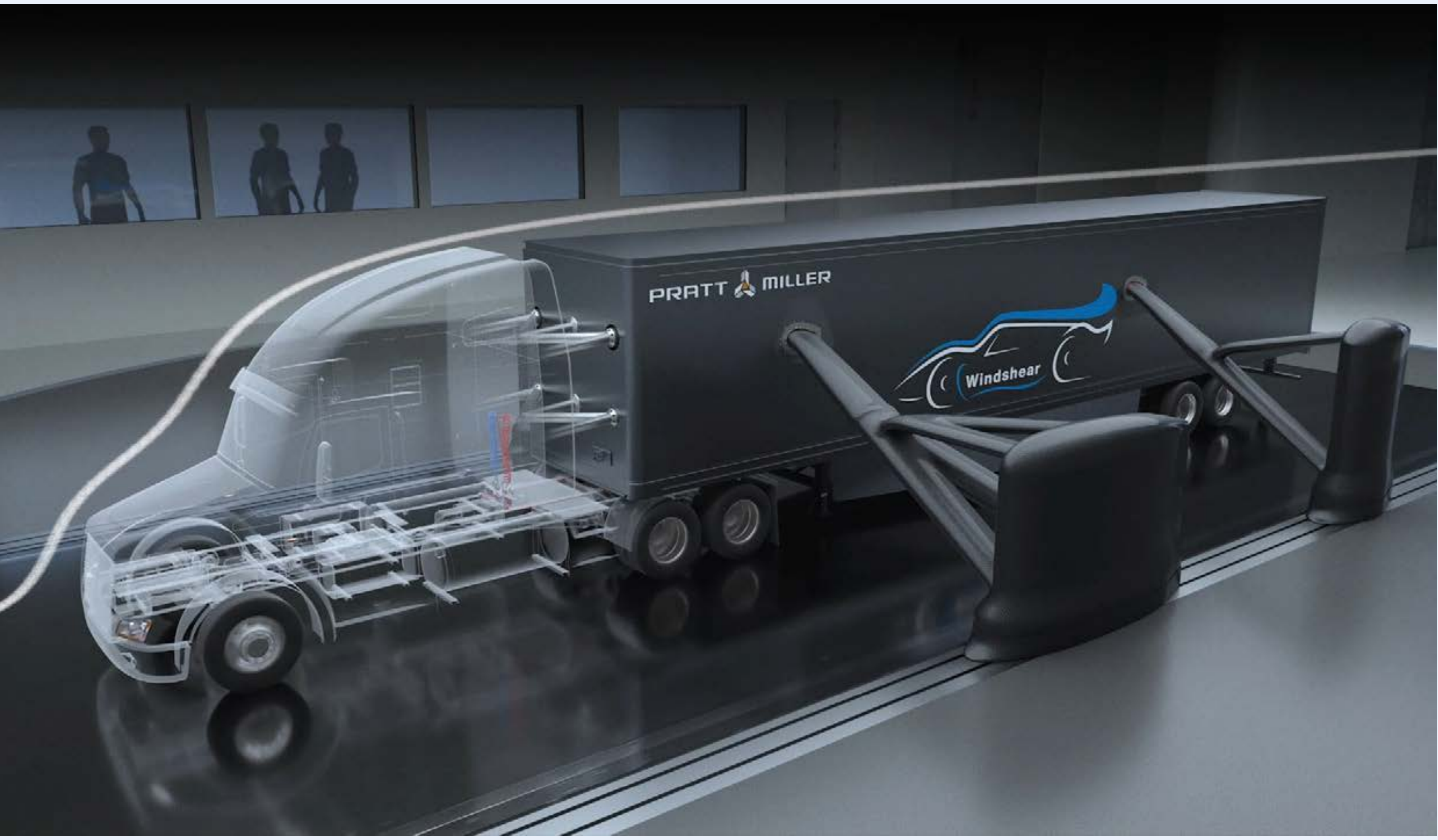
'As far as the ACO is concerned, I strongly believe the LMP2 class is an important part of endurance racing, and endurance has always been a share between manufacturers and privateers. That balance is important for us, and we need to keep it because we never know what will happen,' says Thierry Bouvet.

For IMSA, which has also seen high interest in its LMP2 class, there is also a commitment. 'We have worked pretty hard over the last two years to ignite interest from European teams, which is available for all to see in the car count at Daytona,' says Simon Hodgson. 'That took quite some investment on our part. We have strong relationships with each of the four constructor partners, and a big part of LMDh is looking at the future of what LMP2 will be.'

The LMP2 class will be cost capped, though constructors are concerned that with the current worldwide shortage of materials, and a bidding war around normally standard parts, they may have to put up the price of their cars.

'None of us have visibility when [the war] will stop, but with LMP2 we are working on the next generation,' concludes Bouvet. 'It is cost driven, and we are trying our best to calm down the increase. It is also linked to the more professional teams you have, the more expensive it will be, even with a small car, so we are trying to focus on that.'

A big part of the process has been allowing manufacturers to bring styling to the class for fan appeal. This is the Cadillac Racing LMDh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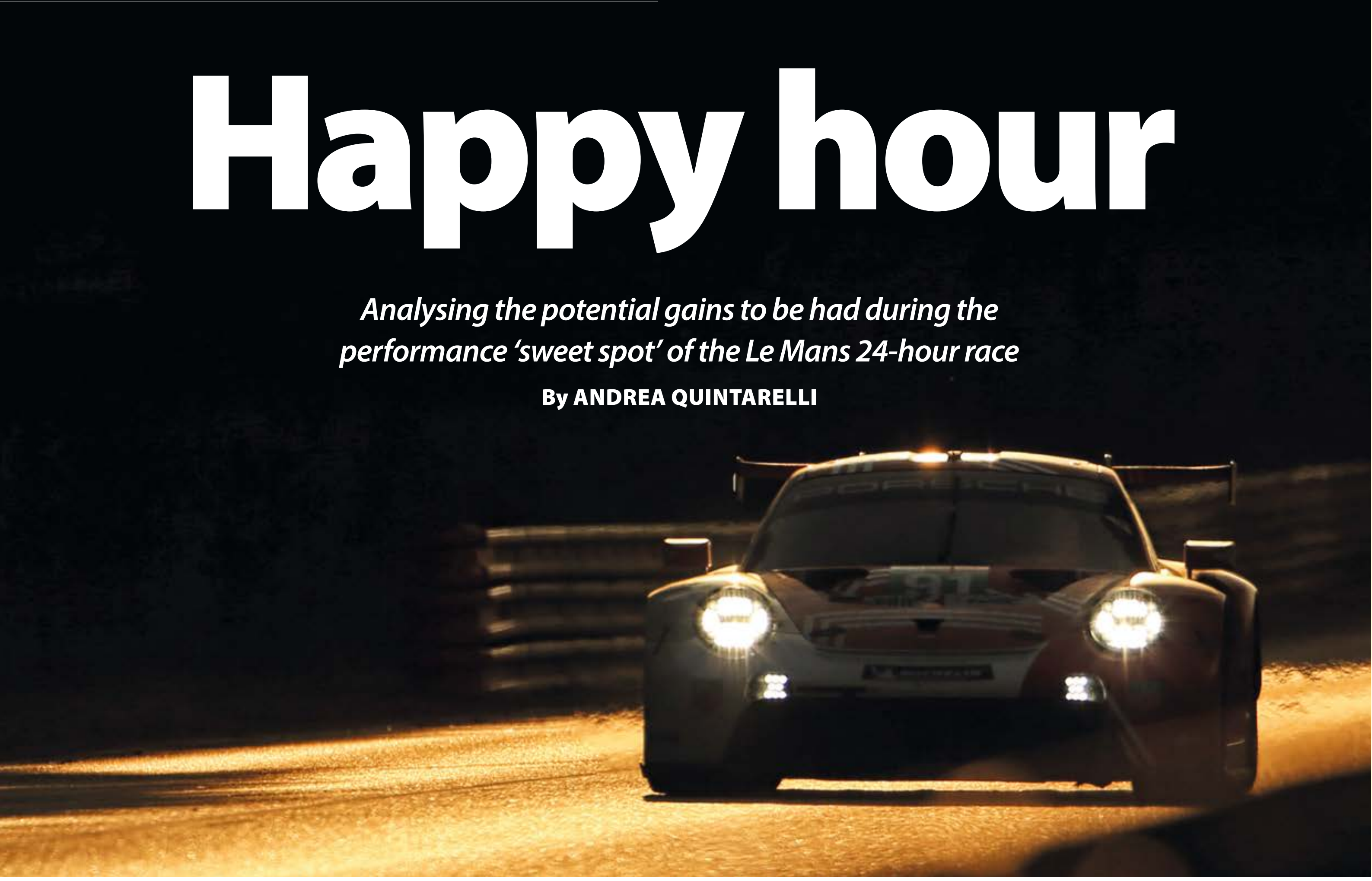


Happy hour

Analysing the potential gains to be had during the performance 'sweet spot' of the Le Mans 24-hour race

By ANDREA QUINTARELLI

The 24 Hours of Le Mans is one of the most exciting and demanding races in motorsport history. It catches the attention of millions of fans around the world, and fascinates experienced professionals due to the very special challenges it poses.

From an engineering perspective, beside the complex task of building a car reliable and safe enough to be driven at the limit for 24 consecutive hours, yet still capable of competitive performance at the more conventional tracks and events that are part of endurance championships around the world, there are a number of human and physical challenges the teams working on track need to overcome.

For starters, driver crews normally include three or more drivers, with different driving styles and preferences in terms of set-up. In some classes, at least one of them is normally not a professional driver either, so the teams must find the best compromises to enable the best possible average performance across the whole race.

Then there's the track itself, which has a layout unique in today's motorsport scene. The combination of a permanent circuit and open street sections include very long straights, separated by a mix of slow corners and extremely fast sections, such as Indianapolis or the Porsche Curves. At 13.6kms, the circuit is also very long, nearly twice the distance of Spa Francorchamps, the longest track on the Formula 1 calendar.

Top class cars operate at full throttle for more than 80 per cent of each lap, with top speeds in excess of 330km/h (205mph) and lateral acceleration peaks over 3.5*g*.

To complicate things further still, both track and weather conditions can change dramatically over a 24-hour period. Even in the lucky event of not having any rain during the race – an unusual situation at Le Mans – ambient conditions vary enormously between day and night, which have a significant impact on tyre, car and driver performance.

This means variables like tyre choice, driver rotation, stint length and set-up decisions can make a huge difference to how a team performs over the duration of the race. Even without considering technical troubles, a car with a slightly lower potential than another over a single lap can easily be lapped more than once at Le Mans.

Special moments

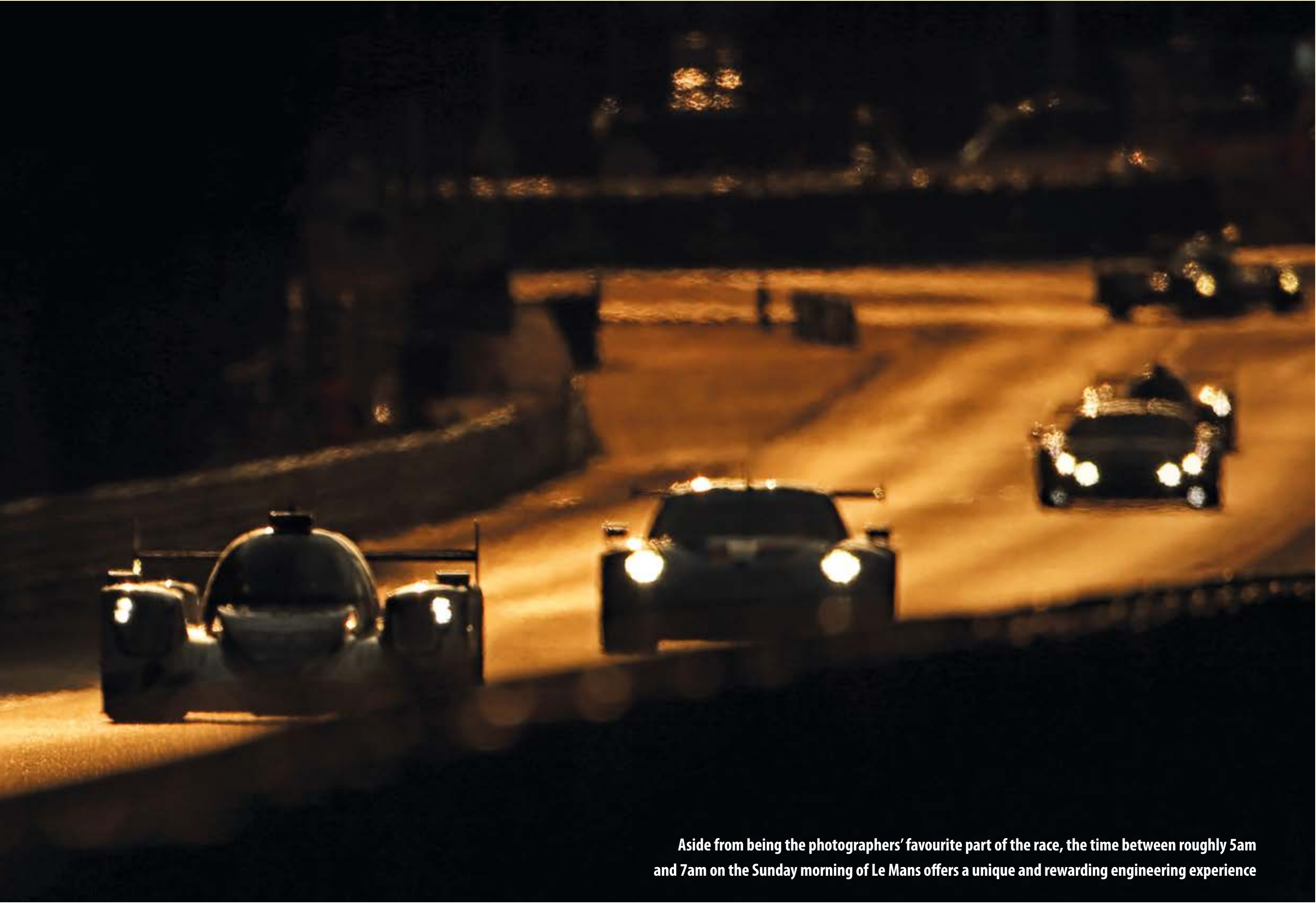
During the 24 Hours of Le Mans there are many special moments, but the start and finish of the race are two inevitable highlights, while some very emotive impressions can be experienced when night falls on the Saturday evening. Similarly, at sunrise on Sunday.

These two latter moments are also particularly interesting from an engineering perspective, because they represent the two zeniths of transition regarding track and ambient conditions. As night comes, temperature drops, visibility reduces and both drivers and engineers have to adapt their targets accordingly.

At sunrise, on the other hand, besides offering improved visibility for the drivers and wonderful picture opportunities for photographers, performance picks up again. This is the time many call 'happy hour', because it is the phase of the race when the cars perform best and, coupled with less traffic on circuit due to the inevitable retirements overnight, has historically often produced the quickest lap times of the race.

Traditionally, happy hour occurs roughly between 5 and 7am on Sunday morning, with sunrise occurring around 6am at Le Mans in June. Last year, however, was an

The cooler ambient conditions lead to a higher air density that influences two crucial parameters linked to car performance



Aside from being the photographers' favourite part of the race, the time between roughly 5am and 7am on the Sunday morning of Le Mans offers a unique and rewarding engineering experience

XPB

anomaly as the race was held in September due to the Covid pandemic, and the sun rose later, around 7.40am. That year, happy hour could probably be better identified as the window between 6.30 and 8.30am.

Figure 1 contains data relative to five recent editions of the 24 Hours of Le Mans, showing examples of cars achieving their best lap times during these happy hour phases.

In 2011, Audi won the race against all odds, with a single car of the three entered by the German manufacturer surviving and overcoming strong opposition from Peugeot (see the wonderful documentary, *Truth in 24 II: Every Second Counts*, for the full story). The winning crew achieved the best lap of the race during the happy hour, producing a faster time than in qualifying.

Porsche won in 2015, after returning to the French classic the previous year following a long absence. The winning crew, with F1 driver, Nico Hulkenberg, at the wheel, achieved its best lap early in the morning, as did the winning LMP2 car that year.

The rest of the table shows how other cars achieved their fastest laps immediately before or after sunrise and, incidentally, either won their class or finished in the first positions.

During happy hour, temperatures are still low, compared to the warmest hours of the race, which normally occur shortly after the start (usually around 3pm, local time). The cooler ambient conditions lead to a higher air density that influences two crucial parameters linked to car performance: engine power and aerodynamic forces.

Engines benefit from a higher air density because a greater amount of oxygen enters the combustion chambers for a given volume of air / fuel mixture, and this improves the combustion process.

Aerodynamic forces, on the other hand, are directly proportional to air density, meaning a change in this parameter is reflected by a change of the same magnitude in downforce and drag.

Moreover, a dry track in this phase of the race will have a high grip level because of the rubber that has been laid down during the first portion of the competition.

These factors all combine to produce substantial growth in car performance potential compared to the opening stints. How great the improvement is depends, of course, on weather conditions and how the early stages of the race have evolved.

In this article, we will analyse how big that performance gain in happy hour could potentially be, taking into account weather information from the last three editions of the 24 Hours of Le Mans – 2018, 2019 and 2020 – and also using some lap time simulation runs.

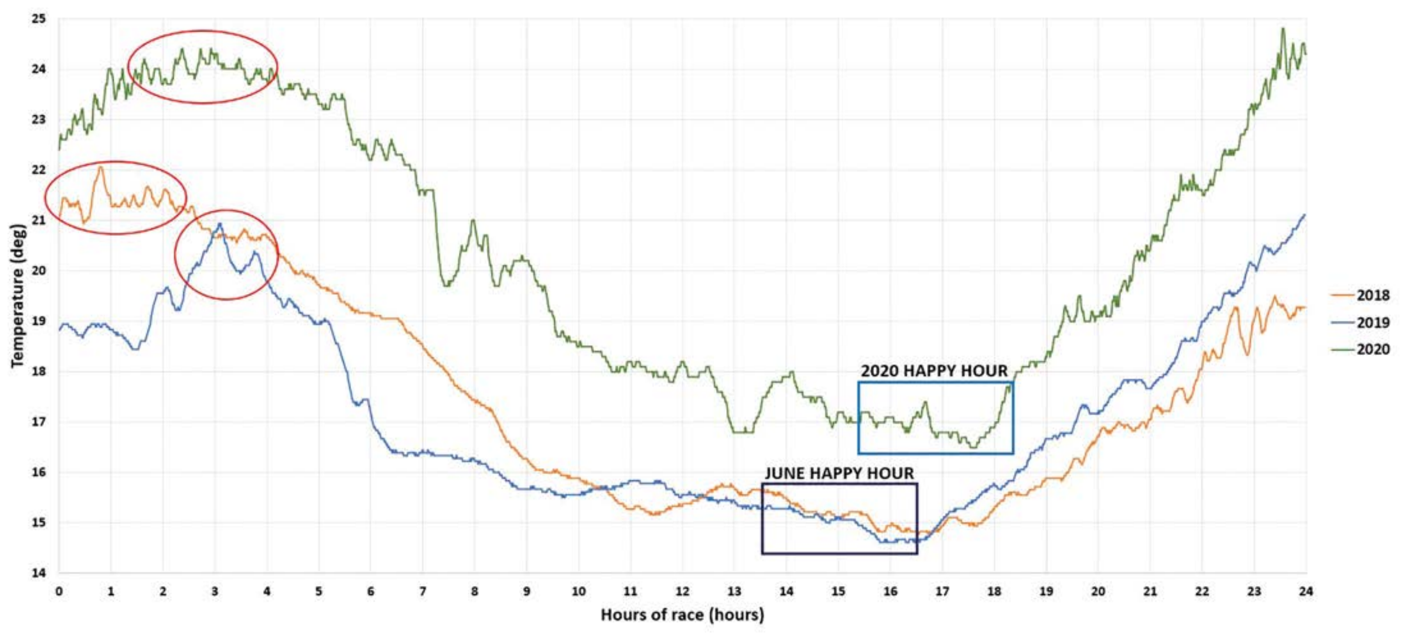
Fig 1: Overview of the best laps achieved by different cars during various editions of Le Mans

Edition	Race n.	Car	Best Lap Time	Class	End pos (class)	Time	notes
2011	2	Audi R18	3'25.289	LMP1	1	7:08 AM	car best lap
	9	Peugeot 908	3'26.298	LMP1	2	7:01 AM	car best lap
2015	19	Porsche 919	3'18.596	LMP1	1	5:27 AM	car best lap
	38	Gibson 015S	3'36.679	LMP2	2	7:34 AM	car best lap
2017	38	Oreca 07	3'28.632	LMP2	1	6:20 AM	car best lap
	37	Oreca 07	3'29.418	LMP2	4	7:31 AM	car best lap
	35	Oreca 07	3'30.551	LMP2	2	8:22 AM	car best lap
	35	Oreca 07	3'30.691	LMP2	2	5:35 AM	car 2nd best lap
2018	36	Oreca 07	3'28.610	LMP2	1	6:52 AM	car best lap
	32	Ligier JSP217	3'28.661	LMP2	3	6:56 AM	car best lap
2020	38	Oreca 07	3'30.452	LMP2	2	6:59 AM	car best lap

Air conditions

The first thing to consider is how much air conditions differ between a certain, reference moment during the race and the happy hour phase. For this study, the reference point we have chosen is the warmest time during the

Fig 2: Temperature evolution during 2018, 2019 and 2020 editions of 24 Hours of Le Mans



first half of the race, which typically occurs on the Saturday afternoon. The evolution of air temperature during the three editions of the race under scrutiny are shown in **Figure 2**.

The red circled areas highlight the highest temperature achieved each year. In 2019 and 2020, the warmest temperature was recorded around the third hour of the race, while in 2018 it was reached at the end of the first hour. It is interesting to note here how the 2020 race was, on average, the warmest of the three, due to it being held later in the year than usual because of the pandemic.

The happy hour can therefore be identified as the time approximately between the 14th and 16th hours for editions held in June, and a bit later, between the 16th and 18th hours, in 2020.

Beside temperature, air humidity and pressure also change during the race, and these both exert an influence on engine and aerodynamic performance.

Figure 3 summarises the values that have been taken into account for this study. For the happy hour phase, an average over the two-hour window of time mentioned has been considered.

The influence temperature, humidity and pressure have on air density is relatively easy to quantify. Based on air density, a correction factor for the aerodynamic forces has then been applied, while the whole power / torque curve has been shifted by an amount computed using SAE references for aspirated engines. This is a similar approach to that used by engineers when testing motors at the dynamometric bench, in order to normalise measured power to a standard set of ambient conditions.

For this article, the effect each year's happy hour conditions have in terms of performance, compared to the reference baseline, were then evaluated by running lap time simulations.

The correction factors to engine power and aerodynamic forces have been applied as a relative, multiplication factor on top of the simulation tool's built-in baseline.

The initial results obtained without any correction have been just used to get a feeling of the magnitude of performance change one could expect during happy hour, in relative terms.

The reader should keep in mind that the overall effects shown must be considered an upper limit of how much more performance a car could gain. This does not necessarily translate to a real driver being able to explore all of this potential.

In a simulation environment, the effects of complex phenomena such as tyre wear, traffic, driving approach, fuel saving measures and even the ideal operating window of a particular tyre compound choice cannot easily be reproduced. For all these reasons, it is a sensible approach to focus on the *relative* changes in performance with respect to a reference lap, because a relative delta can more easily be applied to understand what the new performance could be, following a change in boundary conditions.

Lap time simulation

The vehicle model used for this study refers to a 2020-specification LMP2 car, fitted with the Le Mans body kit, which offers lower drag and downforce compared to the sprint one. Even in this low-drag configuration, LMP2 vehicles still exhibit high levels of downforce.

In 2020, the minimum weight for these cars was 930kg, without driver and fuel, so considering a total weight of 1030kg could be a good picture of qualifying running conditions, while a 1050kg overall mass could be representative of mid-stint status. The car's normally aspirated, V8 engine produces about 600bhp and the gearbox has six forward gears.

This vehicle model, configured with a reference set-up, has been run on a virtual representation of Le Mans circuit, using a lap time simulation tool the author coded.

Beside the effects of ambient conditions, a 'rubbering in' grip improvement over the whole circuit of two per cent has also been accounted for. Again note, this approach does not consider explicitly any thermal aspects with regards to tyre grip, and is simply based on the assumption that all track and tyre-related effects can be roughly depicted by increasing track grip with a factor equal to 1.02.

Considering the simplified approach employed for this investigation, this amount of change in track friction coefficient seems reasonable, according to a number of experienced vehicle dynamics

Fig 3: Ambient condition values used for the performance study

Edition	Temp [°C]		Hum [%]		Press [hPa]	
	Ref	Happy Hour	Ref	Happy Hour	Ref	Happy Hour
2018	22	15.1	53	73.5	1008.9	1011.9
2019	20.9	15.2	55	83.2	1010.36	1013.3
2020	24	16.8	78	93.9	1003.5	1005.05

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engineers and tyre specialists *Racecar Engineering* consulted about this aspect.

To summarise, the following are the changes considered to represent the happy hour phase of the race:

- **Engine power / torque curve.** The whole curve was scaled up employing the multiplier calculated according to methods proposed in SAE papers for aspirated engines.
- **Aerodynamic downforce and drag.** The change in air density was assumed to have an effect on the whole downforce and drag aeromaps, without affecting the aerodynamic balance one.
- **Track grip.** To account for the effects of track rubbering on grip, track friction coefficient has been increased by two per cent.

Fig 4: Simulation results summary table

Run	Mass [kg]	Grip Fact [-]	Air cond. Correction	Lap Time [sec]	Delta [sec]	Rel Delta [%]
Run 1 - Base Qual	1030	STD	-	**203.763**	-	-
Run 2	1030	STD	Happy Hour 2018	202.842	0.921	**0.452**
Run 3	1030	+2%	Happy Hour 2018	201.886	1.877	**0.921**
Run 5	1030	STD	Happy Hour 2019	203.108	0.655	**0.321**
Run 6	1030	+2%	Happy Hour 2019	202.121	1.642	**0.806**
Run 7	1030	STD	Happy Hour 2020	202.783	0.98	**0.481**
Run 8	1030	+2%	Happy Hour 2020	201.792	1.971	**0.967**
Run 9 - Base Race	1050	STD	-	**204.678**	-	-
Run 10	1050	STD	Happy Hour 2018	203.744	0.934	**0.456**
Run 11	1050	+2%	Happy Hour 2018	202.755	1.923	**0.940**
Run 12	1050	STD	Happy Hour 2019	204.004	0.674	**0.329**
Run 13	1050	+2%	Happy Hour 2019	203.01	1.668	**0.815**
Run 14	1050	STD	Happy Hour 2020	203.672	1.006	**0.492**
Run 15	1050	+2%	Happy Hour 2020	202.653	2.025	**0.989**

Car settings have always been kept the same, with the aim of simulating what would happen when running the same set-up in different ambient and track conditions.

Simulation results

The first simulation run, with the car set-up in base configuration and a 'qualifying' fuel load, produced a lap time of 3m23.763s. That compares decently (with a deviation below 0.4 per cent) to the 2020 LMP2 car's pole position lap time of 3m24.528s.

Adding 20kg of fuel and assuming this does not change the static mass distribution, led to a lap time of 3m24.678s. These two lap times will be used as our references for the rest of this analysis.

Comparing these two runs also offers an interesting insight into the effect on performance 20kg of additional mass has at Le Mans. With this vehicle model, it equates to about 0.9s, or 0.45 per cent.

Taking these two reference runs as the starting point, **Figure 4** shows how lap times improve with the ambient and grip changes experienced during happy hour.

It is clear that the performance improvement produced by weather-related parameters is greater, although the 2020 set of conditions produced the biggest delta, despite the race being held in September.

Also, both grip and weather-related performance deltas are greater with a higher vehicle mass. This is probably related to the car operating in grip-limited conditions for a longer time over a lap, therefore benefiting more from higher downforce and a greater track friction coefficient, while also profiting more from the increase in engine power during acceleration phases.

This approach does not consider explicitly any thermal aspects with regards to tyre grip

Also interesting to note is the effect a sole track grip correction of two per cent has, which seems to produce roughly a 0.5 per cent improvement (about one second) in lap times.

Figures 5 and **6** show a comparison between the baseline run (shown in red) with a mass of 1030kg, and the best overall run (shown in green), which considered the 2020 happy hour set of conditions and produced a lap time of 3m21.792s.

Fig 5: Logged results of baseline (red) and Run 8 (green). From the top down: speed trace, front ride height, rear ride height and compare time

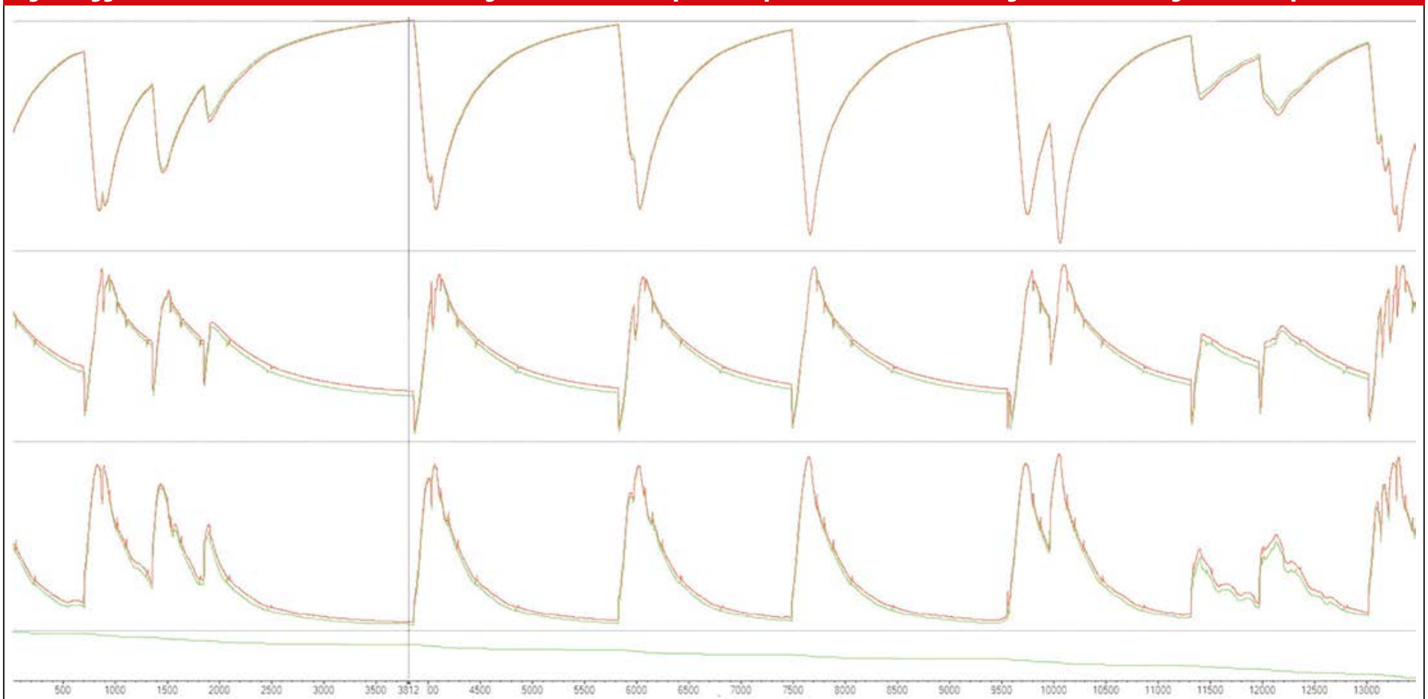

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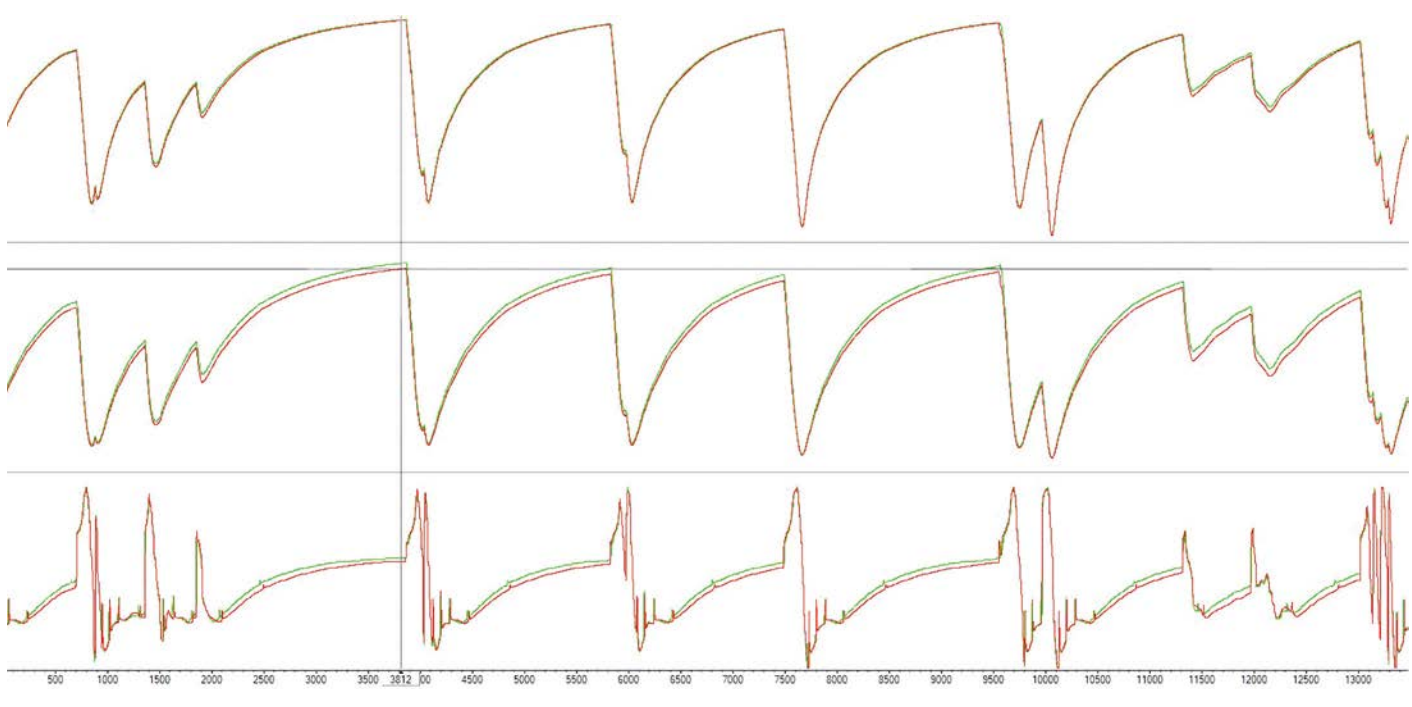
Fig 6: Logged results of baseline (red) and Run 8 (green). From the top down: speed trace, overall vertical load and aerodynamic balance



Again, the reader should focus on the relative improvement with respect to the baseline (about 0.97 per cent) more than on pure lap times, as these have been calculated under very ideal assumptions.

The horizontal axis represents the travelled distance, so **Figure 5** shows, from the top down, the traces relative to car speed, front ride height, rear ride height and the compare time. That tells us which run is faster, and by how much, at each point of the track.

In **Figure 6**, starting from the top, the reader can again see car speed, but also the overall vertical load acting on the car (assuming a constant mass, that is a basic representation of overall downforce) and aerodynamic balance.

The first thing to notice is how, and where, Run 8 performance differs from the baseline. Top speed is very similar for the two runs, so the main performance gain builds up in corners, thanks to the higher downforce and track grip available, and in the first portion of each straight / full-throttle section of the track.

Besides this, these two sets of plots are intrinsically linked. **Figure 5** highlights how front and rear ride heights are actually lower in Run 8, compared to the baseline. The reason for this is the greater air density experienced during Run 8, where the downforce acting on the car at a certain speed also increased, increasing suspension travel and tyre deflection. This initiates a chain reaction: more downforce means lower ride heights; lower ride heights mean the car operating at a different point on the aeromap where the downforce coefficient is likely higher, leading to even higher downforce than if it were operating at the same ride heights as in the first run, but simply at higher speed.

Besides this, the aerodynamic balance also changes because the ride heights are different. This can be seen in the last trace in **Figure 6**. At nearly every point on track, downforce distribution between the two axles is different and, most of the time, it moves toward the front in Run 8. Straight sections are less interesting in this respect, but a difference in balance can

The main performance gain builds up in corners, thanks to the higher downforce and track grip available, and in the first portion of each straight / full-throttle section of the track

also be seen in corners, especially higher speed ones, where the downforce is higher and its effect on ride heights greater.

The key message here is that, without changing the car's set-up, the behaviour and balance of a high-downforce LMP can alter due to the effects of a temporary change in air density and cornering speeds. In Run 8, the car has a higher performance potential and operates in a different performance window to that of the baseline run.

XPB

Photos: XPB

Clean sheet approach

***Racecar** secures an exclusive interview with the new FIA president and asks about his vision for the federation, and motorsport's future*

By DIETER RENCKEN

There's no doubt Mohammed Ben Sulayem has endured a turbulent introduction to the FIA presidency. Elected on 17 December, less than a week after the debacle that was the Abu Dhabi Grand Prix, as replacement for Jean Todt who had reached both age (75) and term (three) limits, Ben Sulayem's prime task was to institute the enquiry announced by the outgoing president into the events of the F1 season finale.

Having won the vote by 62 per cent to the 36 per cent (with a two per cent abstention factor) garnered for ex-deputy president for sport, Graham Stoker, his incoming administration faced the devil's alternative: given the divisiveness of the matter, they would be damned either way in the court of fan opinion.

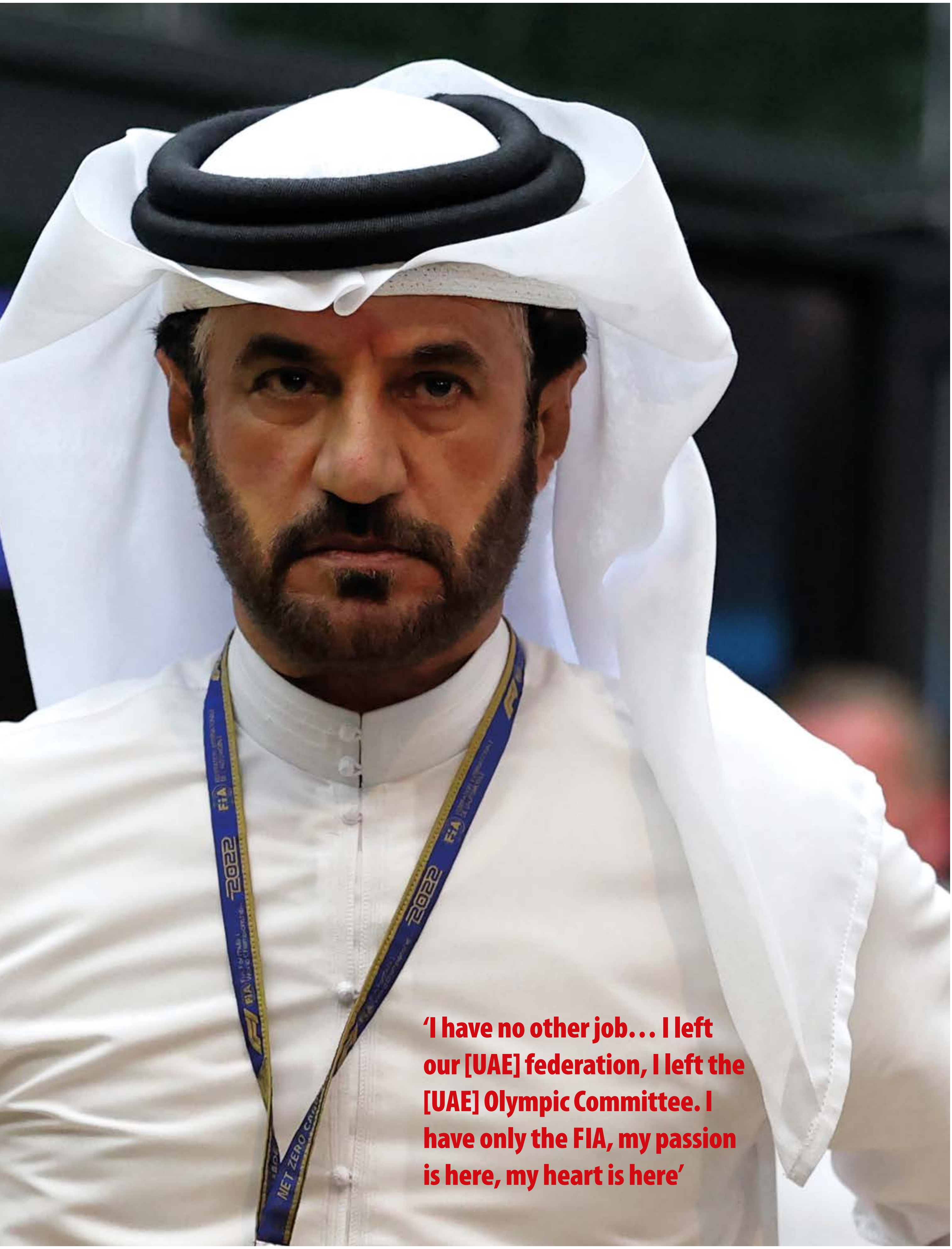
Compounding the situation was the thorny question of sanctioning Lewis Hamilton for boycotting the prizegiving gala, as required by protocol.

Then, within the first 100 days, MBS, as he is referred to informally, and his cabinet discovered the FIA was staring a €25m annual deficit squarely in the face. A month later, he is staring Lewis Hamilton down over the latter's very public refusal to comply with the sport's jewellery regulations.

Inheritance tax

'I inherited a lot of things,' he exclusively tells *Racecar Engineering* during the Miami Grand Prix in the first full-length media interview he has granted since taking office, stressing, 'But I will not run away. I have to confront them to go forward.'

We're sitting in MBS's makeshift office in the race control tower overlooking the Miami circuit, but his USA sojourn is not restricted to matters F1.



'I have no other job… I left our [UAE] federation, I left the [UAE] Olympic Committee. I have only the FIA, my passion is here, my heart is here'

Strong on cultural change [MBS] intends appointing an equality and diversity officer to ensure all demographic groups are properly represented and enjoy equal opportunities


In the first months of Ben Sulayem's tenure, he has made great efforts to meet major players in motorsport around the world, including F1, NASCAR, WRC and IndyCar, as well as visiting manufacturers and attending significant sporting events. It has been a punishing schedule

He has visited Indianapolis and met with circuit and legendary team owner, Roger Penske, plus visited the France family of NASCAR fame and also taken in a tour of the hallowed Daytona Speedway.

The FIA president's post-Miami schedule is equally punishing. Between a raft of internal strategy sessions and regional sporting and mobility club meetings, he is slated to visit Ferrari in Maranello, Porsche and Mercedes in Stuttgart, the WRC's 50th anniversary celebrations in Portugal and the Spanish Grand Prix. A week later, it is Monaco Grand Prix time.

These are no flesh-pressing sessions, but genuine attempts at gauging where the FIA currently stands in the eyes of its major stakeholders. MBS admits it's all a far cry from winning Middle East rally titles – 14 in all, scored via 61 victories – and running the UAE touring and motorsport federations, and fully accepts that the FIA presidency is not just about *ad hoc* trips to Paris.

'It's part of the job, and I'm a fast learner,' he says, the accompanying smile leaving no doubts that speed flows through his veins.

Indeed, there is no job description for the role, nor are there university degrees in FIA presidency, so he learns on the job, very publicly at that.

As the first elected non-European FIA president in its 117-year history, MBS is obviously strong on cultural change, and intends appointing an equality and diversity officer to ensure all demographic groups are properly represented and enjoy equal opportunities.

Lofty ambitions

His team's 'FIA for Members' election manifesto set a high bar, and clearly the Arab billionaire who owns the world's largest fleet of (21) Mercedes 600 classics, in addition to Ferraris Enzo, F40 and F50, and an assortment of McLarens, Porsches and Mercedes AMGs, has lofty ambitions for the federation. He does not, for example, believe the Abu Dhabi Grand Prix report went far enough.

'I don't think what's [being instituted] for [a revised] race control is a cure,' he says earnestly, clearly stung that the controversial events occurred on his home patch. 'We put a bandage for the time being in the aftermath of Abu Dhabi.'

As example, he cites the decision to appoint two alternating race directors rather than relying on the single individual – the contentious Michael Masi, who has headed back to his native Australia – as had hitherto been the case. 'We have Niels [Wittich] and Eduardo [de Freitas]. They are good, but what if something happens to either of them?

'Niels had Covid [in the run-up to Miami's race] and thankfully he's healthy and strong, but the pinnacle of motorsport should not rely on one person, it should run automatically. The Federation should not run because of me, but the whole team. This is something I'm looking into. It is doable, but takes hard, smart work'

Masi settled with the FIA but, given his experience and knowledge of F1, word is that he remains on the roster and could well be

Mohammed Ben Sulayem

Education:
Bachelor's degree in Business, American University in Washington DC, USA, and Ulster University, UK

Sporting career:
14-time FIA Middle East Rally Champion; won 61 international events as a driver (1983-2002)

Hobbies, interests and charities:
Patron of a wide range of charities and ambassador for road safety in the UAE; supports motorsport officials' and young drivers' education, training and research to promote motorsport safety; supporter of classic vehicle movement and automotive heritage

FIA history:
Vice president for sport and member of the World Motor Sport Council (2008-2013, re-elected 2017); founding member and chairman of FIA Region I; vice president for Automobile Mobility and Tourism (2013-2017); member of Innovation Fund Steering Committee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recalled at some stage, though that would surely cause ripples in the sport. Either way, Masi was effectively found not guilty during the investigation into Abu Dhabi, so there is no legal impediment to his return to duty.

Controversial as a Masi recall would be, it is also a clear signal that MBS is not prepared to bend to outside influences, unless they contribute to the overall wellbeing of the FIA, its member clubs and the governing body's sporting properties. Equally, the virtual race control MBS instituted post-Abu Dhabi will trickle down to other series in time.

Unlike FIFA in the world of football / soccer, the FIA is not charged with regulating a single global sport, instead being responsible for all things four wheeled, whether F1, Rally, Sports and Touring Cars or tourism, mobility and road safety. As such, the FIA's orbit does not revolve only around motorsport, pointing to potential disconnects between the objectives of commercial rights holders such as Liberty Media (F1) and ACO (WEC) and FIA member club interests.

Tough talk

F1 alone is a $2bn business, with Liberty aiming even higher, but, crucially, is owned and regulated by the FIA, which was paid a flat fee of $313m for the 100-year rights in 1998, plus an annual regulatory fee. On the flipside, the FIA is a non-profit organisation with annual revenues of $150m, of which around $60m is derived from F1, and a projected deficit of $25m this year. See the financial tightrope facing him?

'The operating losses will completely overwhelm the FIA's resources in the next five years if allowed to continue,' he wrote to member club presidents after 100 days in office. 'We need to make tough decisions in our portfolio, and in the way the organisation is structured and works.'

The first sign of such toughness was his refusal to agree to three additional sprint races, as proposed by F1 during a recent commission vote. Where F1 and the FIA traditionally voted as block, Ben Sulayem demanded further details on the financial and operational implications of sprints on organising clubs and officials. The vote was subsequently delayed, much to the chagrin of Liberty, who realised it merely manages F1. The FIA owns it. It was a loud wake-up call, and one has the distinct feeling it won't be the last time the alarm call shrills loudly.

'What could I do but ask for more details?' says MBS. 'Officials and marshals, many are club members, and we have a duty of care. I did not say no more sprint races, I left the door open, but only if we understand the implications. I owe it to the clubs.'

Significantly, MBS is the first FIA president to be elected from club ranks in 30 years, Mosley and Todt having been parachuted in from outside activities. To achieve their objectives, Ben Sulayem and deputy president for sport, Robert Reid, the 2001 WRC champion co-driver, plan to ensure FIA championships leave legacies wherever they compete.

University challenge

'We are not a circus, to go to a country and do something, then leave without an impression or a legacy. It is not right,' MBS says earnestly, adding that the FIA University will be expanded to include sporting disciplines.

'The [FIA] University, which [previously] we only had for mobility, we have it now for sport. I would like to see it include engineering, too'

'The university, which [previously] we only had for mobility, we have it now for sport. I would like to see it include engineering, too. Not everyone is going to be a champion, not everyone is going to be a Formula 1 or WRC champion, but there are people who can be involved in the motorsport society when it comes to education, when it comes to engineering.

'That's something I really would like to see. There are people in the world that have the talent but do not have the opportunity. This is where we have to go, to give them the opportunity to come into motorsport in terms of education, in terms of driving, in terms of being involved in motorsport.'

The same education process will be applied to medical delegates and stewarding. All recruiting within the FIA is now primarily open to club members, says MBS, adding that internal training courses are offered to those who show potential.

'We talk about an improvement or growing motorsport, but we have to go to [the clubs] first and offer something to them.'

Double or quits

Apart from a heavy emphasis on grass roots and regional motorsport development and diversity initiatives, the MBS manifesto prioritises a doubling in global motorsport participation within four years, enhanced value for clubs from international series, and intensified lobbying for motorsport at political level (see sidebar on p38).

'If you look at China, it has a population of 1.4 billion. The same in India. So that's 2.8 billion in those two countries, but just 8000 competition licence holders between them. Then look at Finland. A population of six million and 8000 competition licences. It's not right, and the reason is cost, cost, cost.'

As an example, MBS cites karting and Cross Car, the latter effectively a grass roots off-road karting discipline. 'If we want to grow motorsport, we have to go and listen to the clubs. Motorsport is too expensive. I mean, who can afford €275,000 [per year] for his son or daughter at the age of 10 or 12?

'Do we want the sport to be only for the elite? I don't mind, the elite has to be there, but we should not forget our members. The blueprint is to go to Africa, South America, India, Asia, China and let them do a kart

After the controversial end to the Abu Dhabi Grand Prix, one of the president's first jobs was to implement an enquiry into the decisions made by race control that led to Max Verstappen winning the race, and the 2021 F1 Championship

The winning racing coolers

Setrab, a wholly owned subsidiary of Yinlun, itself a leading global manufacturer of cooling products for automotive, aerospace, and industrial applications, designs and manufactures custom aluminium radiators, heat exchangers and oil coolers for high-performance, premium vehicle manufacturers from its headquarters in Malmo, Sweden, and its manufacturing facility in Karlino, Poland.

To meet increasing demand, and exceed expected automotive quality standards, a second production facility in Karlino is due to open its doors early in 2023. Boasting 10,000m^2 of production space, the state-of-the-art facility will be an impressive addition to the region.

Founded in 1968, Setrab started as an importer of various race-related products to the Scandinavian market. Following successful supply of oil coolers to production models being manufactured by Saab and Volvo, it was decided to set up its own production facility in 1979. This led to the company supplying products to a wide range of high-performance car manufacturers, including Ferrari, Lamborghini and Rolls-Royce, to name just a few. Since that time, many more premium vehicle manufacturers have chosen, and continue to use, Setrab cooling products.

Setrab customers have come to expect the best. From initial contact and concept, through CAD-based design and prototyping to production, delivery and after sales product support, the customer can be assured that their expectations will be met, if not surpassed, every step along the way.

The manufacturing process centres on the Nocolok brazing process (controlled atmosphere brazing), which has been used since 1979. There are also a number of fin and tubular machines employed to enable optimum cooler design.

From premium brand production cars to bespoke motorsport solutions and aerospace, Setrab is a leader in cooler technology

Following manufacture, every single Setrab cooler is leak and pressure tested in an automated helium-based system.

Setrab operates a unified management system for quality, environment and workplace, and the system has been certified in accordance with the requirements of IATF 16949 and ISO 14001 standards.

Based on the reputation of Setrab coolers, motorsport teams all around the world choose to fit Setrab PROLINE oil coolers and intercoolers to their vehicles. After spending a lot of time, effort and money preparing their vehicles and getting them to the track, they want to be sure that components fitted will perform under pressure and give the reliability required to help them achieve their goals.

Motorsport specific

The PROLINE range of products are designed and manufactured in the Setrab production facilities to the same quality standards, and go through the same performance testing process, as all the company's OEM products. The difference is the PROLINE range has been designed specifically for the motorsport market so, whether it is a motorcycle, car or truck you race, you can be sure you will find a high performing product that will match your own performance and fitment demands.

Details and information on the full PROLINE range can be found on the Setrab company website at www.setrab.com/products/proline and is available to buy through Setrab's vast global distribution network.

From its headquarters in Sweden, Setrab runs a state-of-the-art production facility in Poland, with a new site opening in 2023

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Tel. +46 (0)40 15 80 60
Email: info-oilcoolers@setrab.com
www.setrab.com

Ben Sulayem has made a point of meeting with teams and manufacturers, seen here with Michael Andretti in Miami

themselves, providing they follow the safety rules [and] follow the specifications.

'Nine years ago, we started with Cross Car and the target was €8500, but it's now €25,000. It's just not right.'

He illustrates the point by referencing Indian engine manufacturer, Hero, which was prepared to donate 80 engines, but the offer was declined as the power units were not homologated for the series.

'That will change.'

Ditto off-roading. 'There is a truck Robbie Gordon does for $37,000 and you can go and do cross country with it. They are homologated [locally] and they are safe. Then we say you have to pay another maybe $37,000 to homologate it for the FIA… and then we allow the two cars to race under an FIA licence, but one can score points and the other not.'

Cue a vigorous shake of the head.

Future direction

FIA presidents generally set the direction for both future world motoring and global motorsport but, ironically, their first years are spent implementing the policies of their predecessors. Todt, for example, oversaw various regulation changes as framed under his predecessor, Max Mosley, who signed the 2010-2012 Concorde Agreement and ratified 2014's hybrid formula before stepping aside.

Only during his second and third four-year terms could Todt impose his visions, many of which – such as F1's 'new era' regulations, WEC's Hypercar framework and hybrids – have now become MBS's responsibility. I put it to him, then, that FIA structures lack continuity. That he could be voted out of office by 2025, leaving his successor to oversee the regulation changes currently being drafted for 2026 onwards.

His response is that the recruitment of a full-time, heavyweight, FIA CEO 'to provide an integrated and aligned approach' is currently in process via international headhunters, and should introduce an element of stability. This would free him up to act as global ambassador for the full motoring spectrum, while providing the continuity the federation so clearly needs.

Asked for his vision of motorsport in the future, MBS trots out the standard lines about increased electrification elements and the need for sustainability, but believes oil companies, many of whom have sent out mixed messages about 'clean fuels', should be technically and commercially involved in developing energy solutions for the formula.

'This is what we are now trying to work as the FIA with them. Our commitment to certain championships will always be there, but we also have to find a way that we are not just a reactive federation.

'There are people who want [to be associated] with our brand in a different way, in a respected way. These companies have been dealing with us to support us in development and R&D,' following up with an apology for not being able to name the brands due to confidentiality clauses.

'One thing [we have] is a good relationship with Liberty top boss, Greg Maffei, [F1 chairman] Chase Carey and [F1 CEO] Stefano Domenicali. Together we can only improve the sport, and to improve the sport we must be all together. It's a marriage.

'Motorsport is too expensive. I mean, who can afford €275,000 [per year] for his son or daughter at the age of 10 or 12?'

FIA deputy president for sport, Robert Reid, on…

F1 / Le Mans clashes:
'One of the challenges we have is that the FIA doesn't have autonomy over calendars, so WEC works in the way that all the championships bar F1 works, whereby promoters propose a calendar and then it's up to the FIA to accept or not that calendar. So it's down to a bit of negotiation, but I would certainly be very supportive of there not being a clash.'

F1 political power:
'It's a situation we've inherited. It's something I know the president is very keen to ensure that the FIA has visibility over. The way the Formula 1 commission is set up gives the FIA the opportunity to decide not to support… I was going to say block, but delay support on certain things.'

Governments driving future technologies:
'If you look at our manifesto, one of the tag lines was a global voice for sport and mobility. We need to ensure that sport has a seat at the table of voices in the debate, and not just in Europe. The US, Asia, China, and Europe are probably the areas of most potential influence. We want to bring sport and mobility closer together, look at the synergies.'

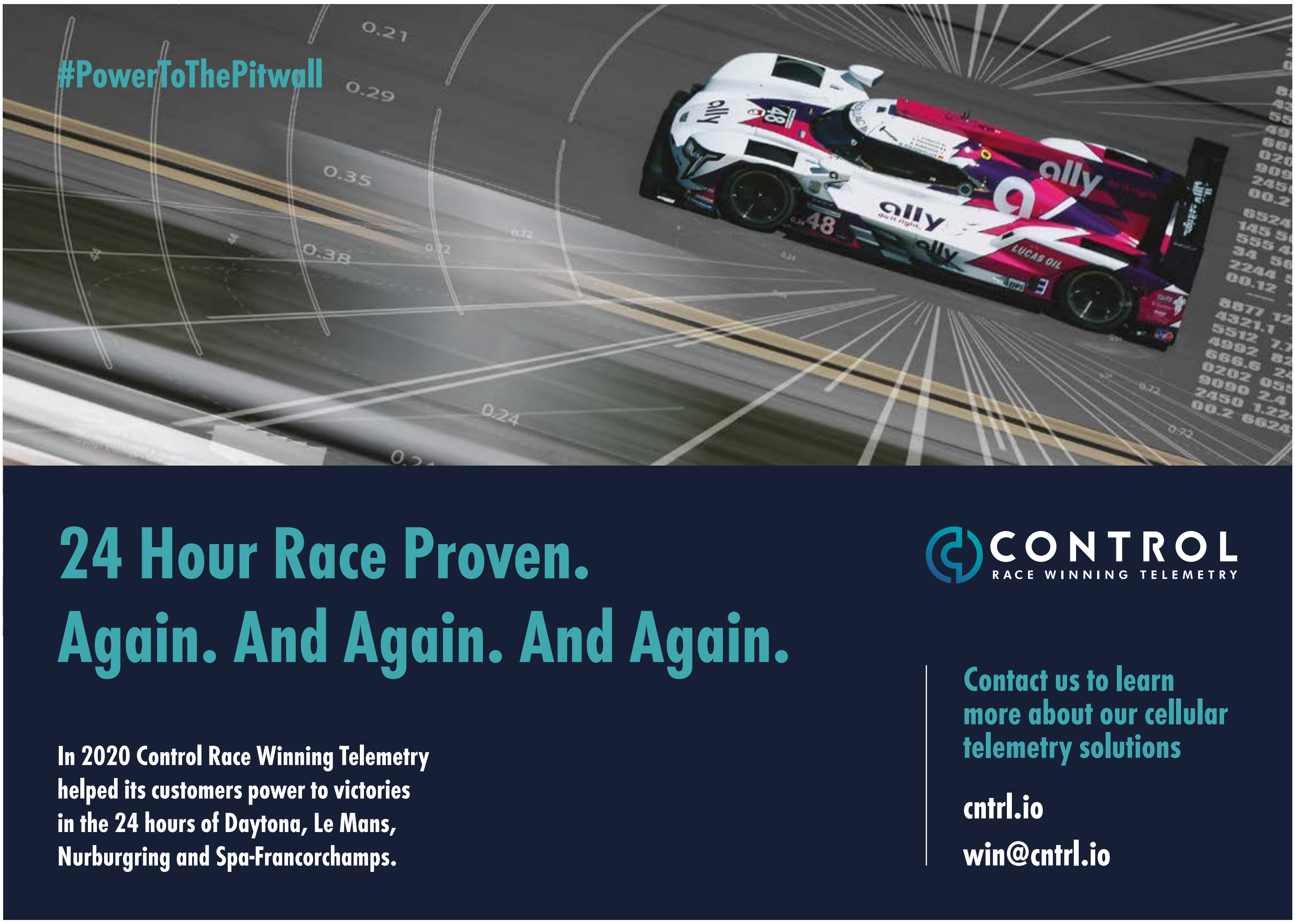
Hi-tech driving high cost:
'It's not a new problem. New technologies are exacerbating the problem, but there's also opportunity. Look at OEMs. They're struggling to work out what the future is, as is motorsport. But we have many disciplines and can provide different solutions that encompass the broad range of technologies that [OEMs] will use going forward.'

'So far, things are going well. It's challenging, I have to admit, and I never expected less than this. But it's a long way still to go. We have to be up to delivering for the new generation, and we have to update our rules accordingly.'

Although that comment refers specifically to F1, it can equally be applied across the whole sporting spectrum. He and Reid are taking their time in understanding where the FIA and the federation's various championships stand and how they fit into the global motorsport landscape, hence all the travel across the globe. Only once they have all the facts at their disposal will they make their decisive moves.

That Mohammed Ben Sulayem takes the FIA presidency extremely seriously is evident from his sacrifices since acceding to global motoring's top job.

'I am a motorsport person, but of course mobility is equally important for me,' he says earnestly. 'I have no other job, I have no xyz. I left our [UAE] federation, I left the [UAE] Olympic Committee. I have only the FIA, my passion is here, my heart is here.'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Pump action

How a former GT racer has found a winning formula for developing high-end motorsport fuel pumps and systems

By MIKE BRESLIN

Many involved in motorsport will be familiar with the name Rob Schirle. For quite a while he was a very capable driver, competing successfully in karting and then excelling in one-make championships in the UK in the early 1990s, before graduating to international GT racing and Le Mans. He was also a well-known team boss, his Cirtek outfit at the forefront of GT competition for a number of years.

These days, though, you will not see his name so often in the motor racing press, yet Schirle is probably more involved in motorsport now than he's ever been.

Name any top-line motorsport discipline and the chances are Schirle's Protec fuel systems concern has some involvement in it. Indeed, its products are found in WRC, NASCAR, IndyCar, WEC, F2, F3 and Formula 1 (where they are chiefly employed in pumping the fuel from the cars), while the company equips the majority of fuel cell / system manufacturers.

It also supplies numerous manufacturer motorsport departments, including Porsche, VAG, Hyundai and Subaru. And then there's the high-performance road cars, supercars and hypercars, not to mention powerboats, drag bikes and even tractor pulling machines.

Bresmedia

While Schirle is more at home in a lab coat than Nomex these days, the products his Protec concern manufacture see action in a very wide range of racecars and motorsport disciplines

XPB

Before he became a market leader in fuel pump technology, Rob Schirle was a successful racer, seen here sharing this Lister Storm with Ian Donaldson and Gregor Fisken at the 2004 Spa 24 Hours

I asked myself at that time, what hasn't changed on a racecar for many years?

To put it another way, Protec is pretty much involved in everything to do with motorsport.

But how does someone go from being a team boss to a businessman and engineer, developing and marketing fuel pumps and systems?

'Running the team meant I had plenty of contacts within the industry, and also plenty of experience working and running systems,' says Schirle. 'I think that was a really good grounding for some of the stuff I'm doing now.

'But how Protec came about was that I lost my father [Hans Schirle] and so took a year out and thought about what I was going to do. So it was a clean sheet of paper. What did I think could be done better, looking back on all my experience with the team? I literally started from the front of the car and worked back to the rear, and I seemed to keep coming back to the fuel system, especially the fuel pump.

'I also asked myself at that time, what hasn't changed on a racecar for many years?

'I also asked Adrian Newey, because Adrian and I were both racing in historics then, and he said the same thing – the fuel pump.

'The Bosch 044 pump had been around for a long time, and nobody had improved on it. I thought, well, I'm onto something here. At the time I didn't really understand how the pump worked, and I didn't understand how to design a pump, I just thought we had to be able to make something better if it hadn't been improved in all that time.

'So, that was my first task, and it proved to be quite an interesting experience.'

Talking point

Fuel pumps have become quite a talking point in motorsport recently, because of the issues that hit Red Bull in the Bahrain Grand Prix. This highlighted not only their importance, but also their complexity, though that should not be surprising, given the work they are asked to do.

In essence, this is taking the fuel from the cell and sending it to the fuel metering system. But it must be delivered at exactly the right pressure for the whole range of engine speeds and loadings, while the car's attitudes while it is cornering, accelerating and braking also need to be considered. It must do this without leaks in the system and without allowing air in, while always keeping the fuel at the required temperature.

Designing and manufacturing a fuel pump, or fuel system, is quite a challenge then.

And it has become even more so in recent times, with the introduction of biofuels, such as ethanol, which have created a range of new problems for fuel system manufacturers to address. For example, ethanol can eat away at the metal parts of a fuel pump's motor, eventually causing them to fail. With an increased use of biofuels in motorsport looming on the horizon when Schirle was setting up the company in 2010, it was clear that addressing this issue was a priority.

'I started to look into the change of fuels, and the demands the use of EFI and everything else were requiring, and I saw there was a massive hole in the market,' recalls Schirle. 'I could see the gradual movement towards ethanol-based fuels, and an increase in toluene and benzene coming into fuels, so we concentrated on brushless motor technology to begin with, as this is a way to counter the issues the newer fuels can cause.

'Brushless motors have other advantages, too. They are more efficient, they are lighter, and you generally get more bang for your buck. You've also got no brushes to wear out.'

Early work

The company's first work was with NASCAR, during the series' switch from carburettors to fuel injection. Schirle helped design the new system, alongside NHRA fuel pump guru, Sid Waterman, and after that it launched its 340 pump into the wider market.

'That was our first big break,' says Schirle. 'We designed the 340 as a replacement for the Walbro 255, and we've now sold around 100,000 of these pumps. It was one of the biggest sellers that [fuel system provider] Aeromotive have ever had. And it's still a core product now. It basically just completely changed the marketplace within a year.

We concentrated on brushless motor technology to begin with, as this is a way to counter the issues the newer fuels can cause

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Protec's Cobra pump is the Burton-on-Trent firm's flagship product

Bresmedia

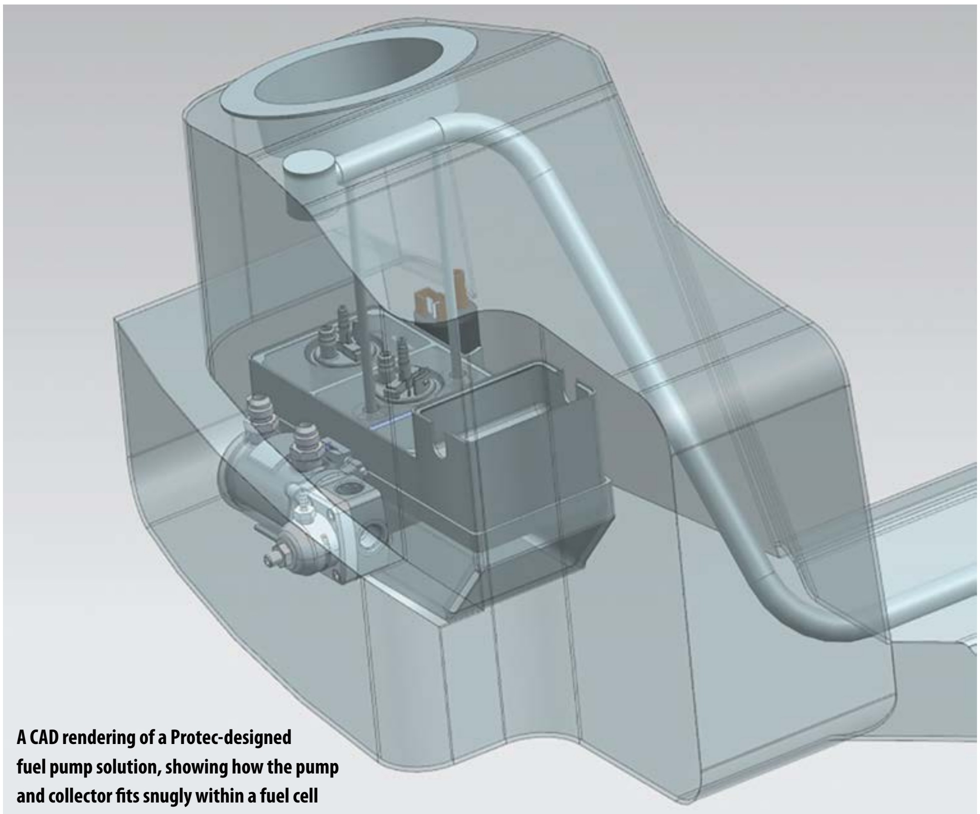
These delightful little screw pumps, which Schirle describes as 'mini superchargers', are at the heart of the Cobra pump

'That put us on the map, and gave us funds to develop the brushless range. And, within the market at least, we became well known.'

From there, the company has gone from strength to strength but, despite all its high-level success, is no smoked glass atrium packed with art installations sort of concern. Rather, it's run from a nondescript unit on an industrial estate in Burton-on-Trent, UK, usefully close to Donington Park.

What's more, there are no production lines, just a clean room-type space that seems more laboratory than factory, where the pumps and pump assemblies are expertly built by a key member of staff, Mark Heaton, the assembly builder. Before coming to Protec, Heaton worked at Premier Fuel Systems, with which the firm works closely, for around 20 years. He pieces together components made offsite by trusted suppliers with some now 3D printed in-house, assembling pump systems that will typically include a power source, level sensor, filter and regulator, all designed to fit snugly into a fuel cell.

Other members of the team at Protec include Andy Green, who designs the products on CAD, and Liza Wong, who runs the office and the shipping operation. There are a couple of other people involved in day-to-day activities, as well as motorsport engineering students, currently including Green's brother, Kris, who will often help with the testing. Schirle's wife, Mandy, is an integral part of the business, too.



Protec

A CAD rendering of a Protec-designed fuel pump solution, showing how the pump and collector fits snugly within a fuel cell

Fighting talk

It's a small team, but Schirle would have it no other way. 'It's almost fighting expansion, in a way,' he says. 'We don't want to expand, we want to stay niche and focused.'

This is partly down to keeping a firm grip on quality control, but Schirle also feels comfortable with the size of the business, its location, and the sector he is working in.

'I think this is what Great Britain does best. And motorsport in particular. We have a huge pool of small firms like this. It is very much a specialist industry, that's for sure.'

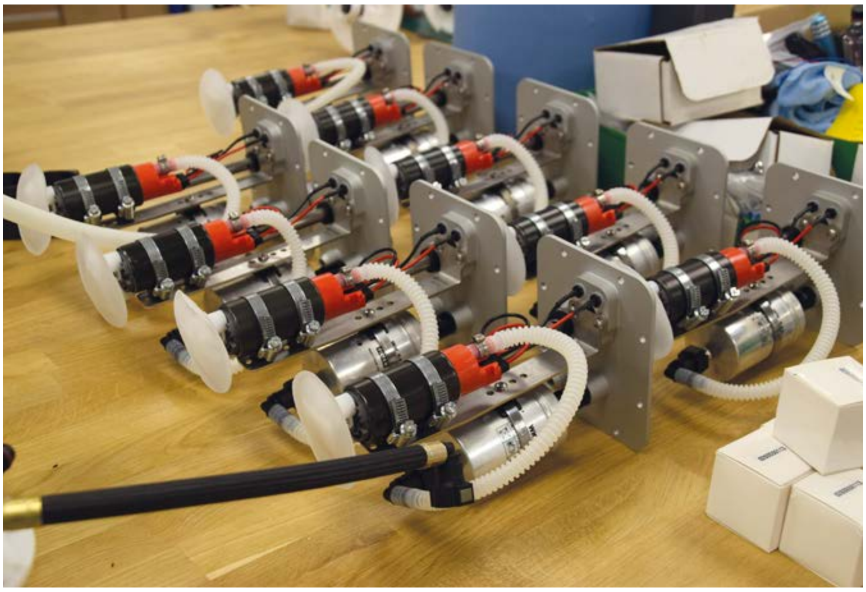
It's also very much a specialist product, as Schirle readily admits, though he insists there is much more to fuel pumps than people sometimes realise.

'What I find strange is, when you say, "I do fuel pumps", people think it's quite a boring little thing. But when you get into it, it's not boring at all, and with some of the stuff we're doing here we're really pushing the boundaries of what's possible, and we always want to do that.'

Breaking ground

The main way Protec is doing that right now is by embracing some game-changing technology, which has partly arisen from the groundbreaking approach the firm took from the start, which is to supply individual components when required, rather than just complete replacement fuel pumps. Now, with the onset of additive manufacturing, this has gone a step further.

'We're the first to launch commercially, 3D printing into the fuel market,' says Schirle.



Though it is undoubtedly its core market, the company is not just about motorsport. These pump assemblies have been produced for the Aston Martin (and Brough Superior) AMB 001 limited edition motorcycle project

Assembly builder, Mark Heaton, is responsible for meticulously piecing together the Protec pumps and systems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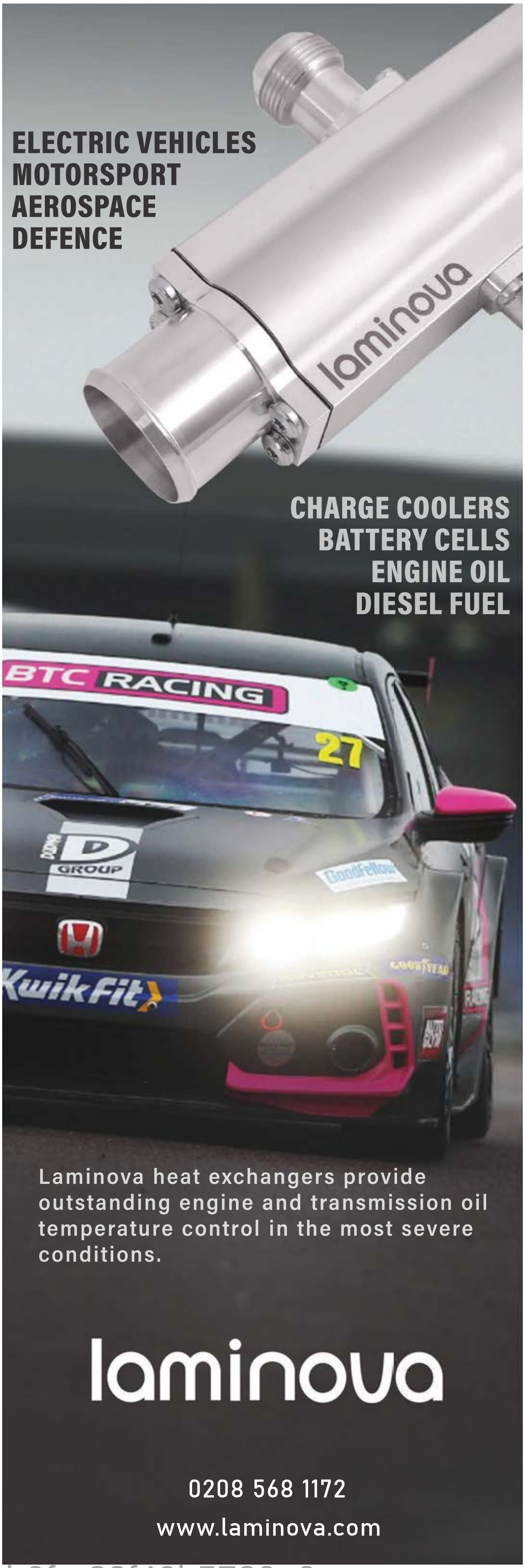
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'We've partnered with Spanish company, BCN3D, to do it, and one of the reasons for partnering up with a printer manufacturer is because for these parts, the G code [the commands for the printer], the slicing and the material must be 100 per cent right.

'We've also partnered with Italian firm, Filoalfa, which supplies the filament [the printing material].'

Now, in the corner of the workshop there sits an Epsilon W27, one of three 3D printing machines in which Protec has invested.

An array of completed fuel pump assemblies ready to be delivered to another successful UK motorsport business, Radical Sportscars

Print technology

'It means we've got the ability to just print what we want for a specific application, and it is also changing the way we look at the design of fuel systems,' says Schirle. 'I think what we're doing on the 3D printing side could get quite big quite quickly. What I envisage is that we have people signed up to the system, and we then make it easy, and make it repeatable, for them.

'It's a massive benefit to us, and to our customers. Instead of having to send off for what can be quite a bulky item, customers can just stock the pumps, and then they can print the rest themselves. All they've got to do is buy the machine from the manufacturer [which, at around £6000 (approx. $7350), is relatively cheap] – and they can also use that machine for anything else they want to do – and then we send them the G code and they can print out the part anywhere in the world.'

Manufacturing products this way can work out much cheaper, too.

'Whereas it used to cost us x amount to make an aluminium bush, for example, we can now do it in house and it costs a fraction of what the aluminium did, but it still does exactly the same job. And you're only printing the material you use, so there's no waste.'

Epsilon W27 3D printing machine. Additive manufacturing technology is revolutionising the way Protec can service its customers and design its products

However, there are limitations, as Schirle explains. 'It's that understanding of *what* you can print, because you can't print everything. Safety is obviously paramount to us, and at the moment I don't see having 3D printing on the pressure side of this, but maybe that will come in the future. I think injection moulding for an aluminium part is currently better there. But again, the design advantages of this means we can, for instance, print things out just to get proof of concept, and that's a good thing. We may print something, and then think actually, it's good, but we're going to make it in billet.'

But the principles behind designing a fuel pump remain the same, even with 3D printing to help.

'It's about efficiency,' notes Schirle. 'Reducing the heat to make the system efficient. Often, the first thing we talk through with a customer is the pressures. Because pressures vs flow, there's a massive difference. As the pressure goes up, the flow will come down. And in some instances, you'll get pressures up to 10 and 11bar, which is really quite high.

'I think that's where our pumps score. In fact, we're confident our brushless Cobra pumps give the most amount of output for flow with the least amount of amperage, for higher pressures.'

Go with the flow

It's also important to remember that, however good the pump is, it will only be as good as the system it is part of. 'You can put the best pump in the world into a bad system and, if the filter isn't rated accordingly, or the regulator, you can create massive problems.

Things I learned when I was building kart engines, those fundamental basics, are still applied here today

Some of these pumps flow so much fuel that if you haven't got a filter, or regulator, strong enough to bypass, or to flow, then all you're going to do is create a lot of amp draw, the pump head pressure will go up dramatically and the rest of the system can't cope with it. It's that overall understanding of the flow and volumes involved that is vitally important.'

Of equal importance to Protec is quality control. All pumps are tested on the company's array of flow rigs using Flowrite fluid (made by leading fuel injector supplier, ASNU, another company Protec works closely with).

'Flowrite gives us the same specific gravity as fuel, but without the flammability,' explains Schirle. 'And every single pump we make gets tested here before it leaves the factory. That's something we're very rigid with.'

There are quality checks on product aesthetics, too. Even if a part is destined to spend its life tucked away in a fuel cell, neat engineering intricacies and smart finishes are at the core of all Protec's products.

'I want people, when they pick something up of ours, whatever that product may be, to think that somebody has really thought about that, how it looks. I think that's really important,' says Schirle.

This approach probably comes from all those years running racecars but, even before he reached the car stage of his racing career, Schirle believes he learnt many things that are still put to good use today.

'It's amazing, but things I learned when I was building kart engines, those fundamental basics, are still applied here today. When balancing the motors that go in the Cobra pumps, I still use a knife edge, and we *do* still balance the motors, because we understand the benefits. If you balance a motor really finely, it will run smoother, and those basic facts are core to everything we design.'

The last straw

Yet for all the motorsport background, and the undoubted benefits it brings, much of the development at Protec is about seeing what's currently available in OEM, and then adapting it for motorsport and performance applications. A great example of this is the syphon jet Protec has developed.

To explain, one of the toughest tasks a fuel system faces is dealing with surge – the fuel sloshing around in the cell during hard cornering, acceleration or braking – which can move it away from the pick-up, meaning the pump will potentially just suck in air. Scavenge pumps are often used to counter this, but Protec's syphon technology, which works a little like a drinking straw, albeit with much more advanced fluid dynamics, has proved it is possible to do away with the need for lots of scavenge pumps.

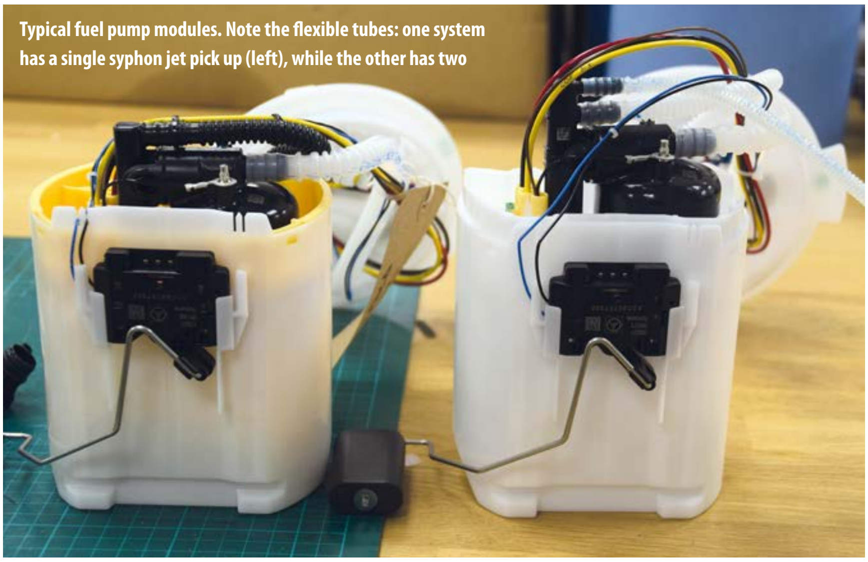
If it uses less power, it's better. It's more efficient

'Basically, we've taken the best OEM system, and made it useable for motorsport,' says Schirle. 'It collects fuel from one side of the cell, or from a corner, and moves it to the collector area. It's a very efficient way of making sure the fuel is always where you want it, and that's key in a fuel system. It means there's not such a need for additional lift pumps, while it also doesn't need electric power, as it pulls the fuel without power [300 litres per hour, in fact].

'It's very simple and very clever, with the fuel passing through a Bernoulli system that creates a negative pressure, which then sucks more fuel in.'

Fuel pump assemblies incorporating syphon jets are just one product among many supplied by Protec. The company also sells full fuel systems, fuel cells and all the components associated with fuel, from filter socks through brackets, valves and couplings. But pumps remain the focus.

The evolution of an in-tank fuel collector, from cardboard prototype through iterations of 3D printed versions to the final design on the right



Typical fuel pump modules. Note the flexible tubes: one system has a single syphon jet pick up (left), while the other has two

'The number of pumps we make each year just seems to increase all the time,' says Schirle. 'We supply a lot of different companies, but we're pulling back a little bit from having other company names on our product now. We don't want to do so much customer-branded stuff now Protec is a stronger brand, so a lot of our product has the Protec name on it.'

Staying ahead

New technology that might bear that brand name soon includes, 'controllers that are CAN bus, so fully integrated, and will accept PWM [pulse width modulation, which helps keep the amperage low in brushless motors]. They've got diagnostics built in. That's something that will be coming out next year. So, it's just staying ahead, and just watching for little changes.'

But what about the big changes? What will a fuel pump company do in a world of electric cars and electric racing?

'They still need to cool the battery packs,' says Schirle. 'And, when you think about it, we've got a pump that would only draw about one and a half to two amps. With an electric vehicle, if you've got a heavy amperage motor, or pump, or heater, or anything, it's taking from that core source of energy. So, if you've got a pump that can move the coolant around but only use one and a half amps, it's a better solution than a pump that uses five or 10 amps.

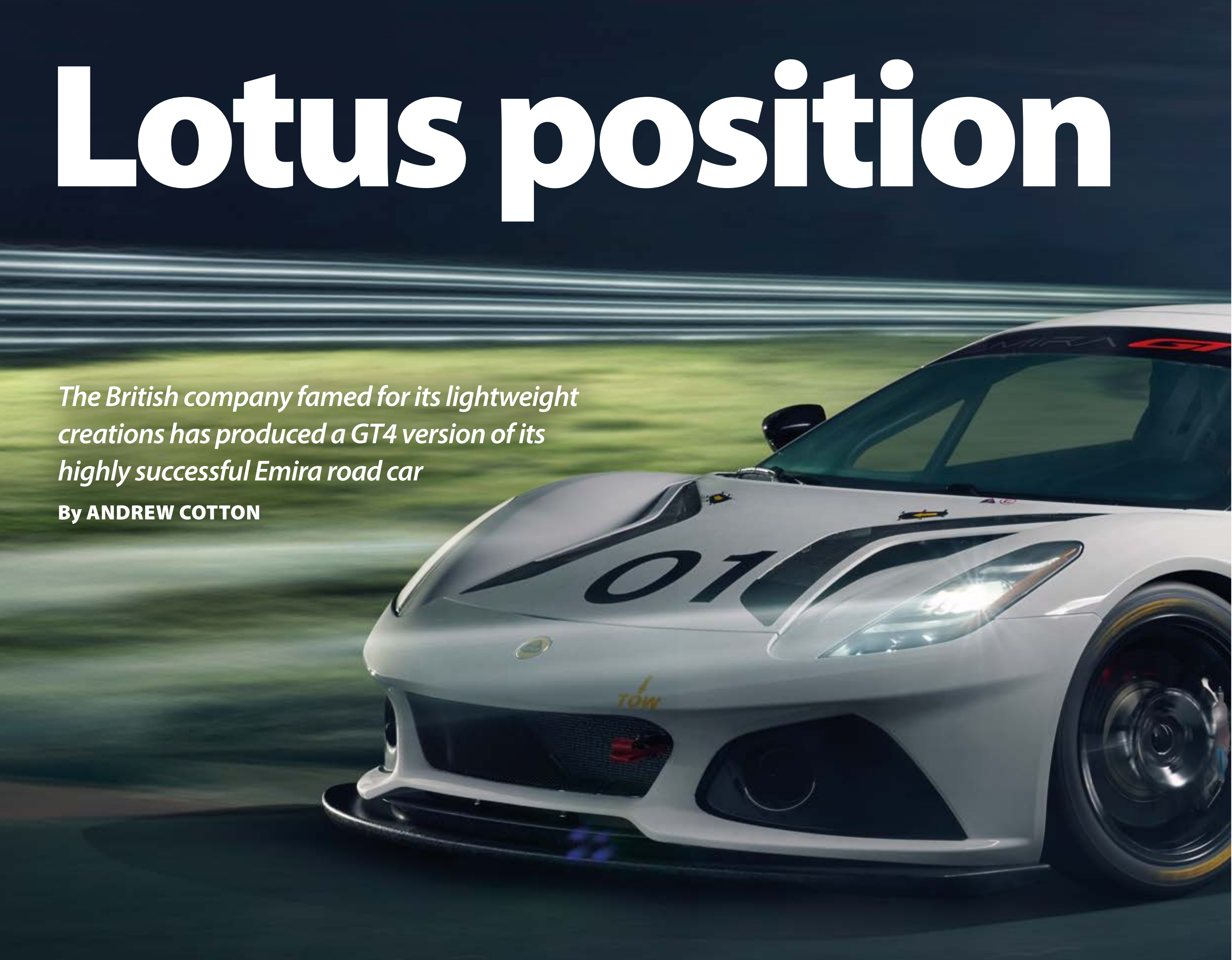
'There are always ways for us to supply our technology because our brushless motors don't care what they drive. It could be an impeller for a water pump, it could be an impeller for a dyno pump, or for a 1000bhp car. If it uses less power, it's better. It's more efficient.'

Of course, the future is not just electric, and it seems likely synthetic fuels will also play a large part, especially in motorsport.

'That's something we keep at the forefront of our minds,' Schirle says. 'In fact, we're in discussions with synthetic fuel companies now. We know who's developing it, and we want to be able to test it, and do material tests, both for our own benefit with the pump, but also with Premier Fuel Systems. They want to test the material for the bladders, because it has a knock-on effect for not just the pump, but everything you use in a fuel system: the hose, the regulators, the diaphragms, *everything* can be affected by a new type of fuel.'

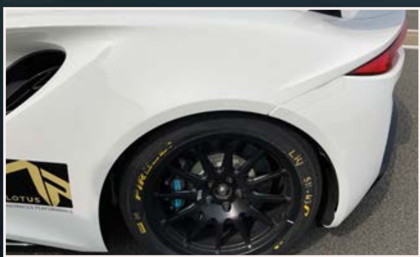
Fuel pump design and manufacture is clearly far from 'boring'. It's about keeping ahead of the competition, and abreast of technology. Which, when you think about it, is exactly what Rob Schirle was doing when he was a race driver and a team boss. Maybe some things don't change so very much, after all?

Lotus position



The British company famed for its lightweight creations has produced a GT4 version of its highly successful Emira road car

By ANDREW COTTON



The road car on which the racer is based is already a potent package, and Lotus has chosen the heavier minimum weight option for GT4 in order to utilise the wider tyres available

Following an announcement in September 2021 that it would build a racing version of its Emira road car, Lotus launched the new GT4 contender at its headquarters in Norfolk, UK in May this year. The car follows on from the extremely successful Evora in the same category and, consequently, the order book is already full, and the car is sold out for the first year of production.

The GT4 class has been growing rapidly in recent years, and is now a permanent fixture in national race series such as the British, French, Asian and US GT series, as well as internationally with the GT4 European Series. With full grids, the category is rapidly becoming an attractive proposition for manufacturers of all sizes.

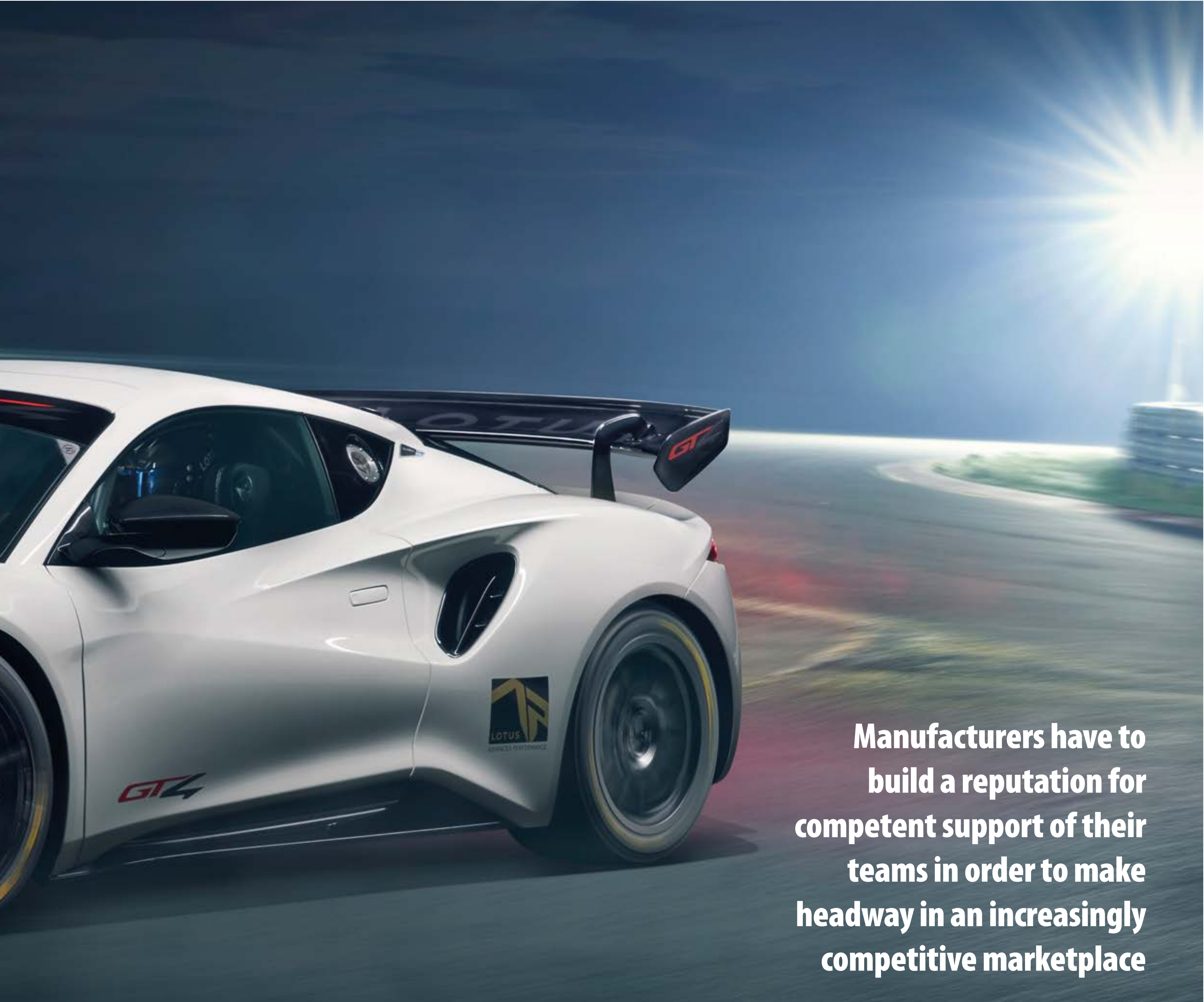
The class provides a stepping stone from Touring Cars and one-make series into GT racing. Professional drivers are increasingly being employed as driver coaches in the category, while new drivers are able to make a name for themselves before they step up into GT3 competition.

That means there is a fast turnover of drivers in the class, so manufacturers have to build a reputation for competent support of their teams in order to make headway in an increasingly competitive marketplace.

The Emira is the first new model from the Lotus Advanced Performance division, a bespoke vehicle and experimental sector of the business launched earlier this year. The project has been a collaboration between Lotus and the RML Group, and Lotus is hoping for a similar run of success as it had with the Evora GT4, which won multiple races and championships, including the British GT, Dubai 24 hours and European GT racing.

Power upgrade

The starting point for the project was the Emira road car, powered by a 3.5-litre, supercharged V6 engine that produces



Manufacturers have to build a reputation for competent support of their teams in order to make headway in an increasingly competitive marketplace

Car uses largely production body panels for cost of running purposes, but benefits from a new bonnet, floor / splitter, brake cooling ducts and a dynamic adjustable rear wing

around 400bhp. Provided by Toyota, the engine has been upgraded to GT4 power and reliability levels, which required changes to the valves, camshafts and to the supercharger itself.

'We start with a 3.5-litre V6 and, when you supercharge that, you have an element of inefficiency when you start to push,' says former British GT champion, Gavan Kershaw, one of the test drivers on the project and who was heavily involved in the car's development. 'You want to do an hour on 100 litres of fuel, and the less we stress the supercharger, the colder the temperatures going in, so less cooling packs required.

'We wanted robustness so it wasn't always on the limit, and also to make it easier to drive.'

The engine sits transversely in the chassis, which leads to certain limitations on cooling and choice of gearboxes, and is one of the main reasons why Lotus has not confirmed a step up to the GT2 category in the near future.

While GTE and GT3 cars share similar architecture other than the engine, the same can be said for GT4 and GT2, the latter having more power.

'Going up to a new class needs a lot of [additional] torque and power,' confirms Kershaw. 'Our engine is transverse, and not many are like that, they are longitudinal, so it's easier [for them] to find gearboxes and heat management.

'When we went to Le Mans with the Evora, it took Cosworth and us a lot of time and pain to get through some of the natural barriers of a transverse car.'

Back on reliability, the engine and gearbox are lifed for around 10,000km in a bid to keep maintenance costs for the car as low as possible.

Heavy weight

Surprisingly for a Lotus design, the company had a choice of weight limit for the car, and went for the heavier option.

Cars competing in GT4 can race at either 1100kg maximum weight on smaller tyres, or a 1300kg minimum on wider rubber, and Lotus has opted for the second option.

'The tyre development is done around the slightly heavier car and wider rubber, so if you go light you might finish up with a tyre that is not fully tuned for the car,' says Kershaw. 'For durability, it has to be really quick for an hour. There is nothing worse than jumping into a car after 30 minutes and the rear tyres are gone.'

The reason for the lightweight category was less to do with the OEMs and more to do with the one-off specials that could be built for the category. The organising bodies preferred to limit the performance of these cars in order to protect the business models of the bigger OEMs that entered the category.

'We were told they were happy with their rules and regulations, happy with the manufacturers it was attracting, happy with the OEMs, so small niche cars coming in super lightweights – the KTMs and so on – hurt it for other manufacturers,' explains Kershaw. 'They have robust series around the world, so they said if you want to come and play, you can do that, but the rules are tight, you can find the innovations somewhere else.'

Lotus Emira GT4 tech spec and target performance data

Engine	Toyota V6 2GR-FE; dry sump oiling; MoTeC engine management
Cubic capacity	3456cc
Power	400bhp*
RPM	7200*
Supercharger	Harrop TVS 1900
Transmission	Xtrac six-speed sequential with paddle-shift actuation and LSD
Fuel tank capacity	96-litre, FIA FT3-approved, with dry brake filler
Electronics	MoTeC dashboard with data logging; motorsport wiring harness
Suspension	Double wishbone front and rear; two-way adjustable Öhlins TTx dampers; front and rear anti-roll bars
Brakes	Competition specification brake system; Bosch adjustable motorsport ABS
Tyres	Pirelli GT4 265/645-18 (front) and 305/680-18 (rear)
Safety equipment	FIA-homologated six-point rollcage; FIA-compliant, HANS-approved seat with six-point harness; electronic fire extinguisher system / isolator switches
Dimensions	Length: 4410mm; height: 1290mm; track: 1636mm
Weight / mass	1300kg* without fluids
Body	Extruded and bonded aluminium chassis with composite panels
Wheels	Forged aluminium
Price	From £165,000 (approx. $204,725) (excluding taxes and delivery)
	**Subject to Balance of Performance*

One of the advantages of turning to the higher weight is that production body panels can be used, which leads to a wealth of available spare parts at reasonable cost. However, the rule does not apply to all of them.

The car features a new bonnet, a new floor, including an efficient splitter, and of course an adjustable rear wing. Cooling to the brakes has also been improved through ducts cut into the bodywork, but overall, the car produces more downforce and less drag than its roadgoing counterpart.

Bespoke parts

'The large percentage of change to the production car is to do with safety,' says Kershaw. 'Fuel tanks, rollcages, seats and dashboard are all bespoke for the car. For the really big hardware, such as the gearbox, we have gone for Xtrac.

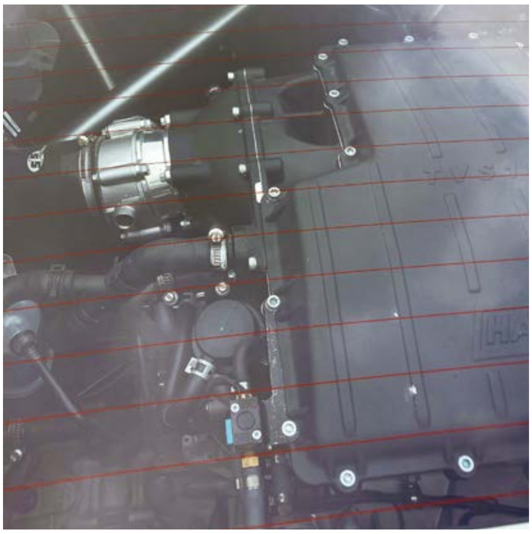
'We have also thrown away the engine mounts, so the engine is solidly mounted, and then made other upgrades to the brakes and dampers.'

One of the advantages of going for the larger wheel size is that the brakes can be sized more appropriately. The car uses a competition brake from Bosch, with ABS, while its TTx dampers are by Öhlins. The chassis also features front and rear anti-roll bars.

Nevertheless, it remains an entry-level GT car, so the front and rear subframes completely unbolt from the tub, making it relatively easy to work on, and to repair.

'Even if you get hit hard in the front, if you haven't touched the tub, it is front subframe, radiator pack and whatever cosmetic panels are there. Same at the rear,' explains Kershaw. 'A steel subframe protects the engine, and then the main tub. Even the rollcage unbolts. It's all modular in its design.

'If you look back at the Elise, it's double wishbones, coilovers and anti-roll bars, and then really that progressed. It's all part of our variable architecture methodology.



Power comes from a modified version of the road car's transverse, 3.5-litre, supercharged V6, while the sequential gearbox is from Xtrac

Overall, the car produces more downforce and less drag than its roadgoing counterpart

You have a central tub and can then grow the car wider or narrower from there. The Emira is different to the Evora in that it is wider, so the occupants sit further apart. The wheelbase is the same, but the subframes are different, so you can turn the car into a totally different product.'

Testing has been ongoing and extensive, to the point that the team is experimenting with different Balance of Performance parameters to see how it will perform.

'You try in testing to see how the extra ride height and ballast affects it, but if BoP doesn't get you that way, they just take 500rpm off, so what's the point? You just go along with it.'

Testing took place through the winter, and then the team decamped to Portimao for some hot-weather running. Happy with progress so far, Lotus aims to fulfil customer orders for the Emira GT4 during 2022, before increasing production for 2023 in line with global demand.

The GT4 cars are built by Lotus Advanced Performance, a new division of the company set up this year to focus on bespoke and experimental products

Pedal power

Racecar *examines the latest advances in brake-by-wire technology*

By LAWRENCE BUTCHER

For over a century, the basics of braking a racecar have remained essentially unchanged, albeit subject to phenomenal refinement.

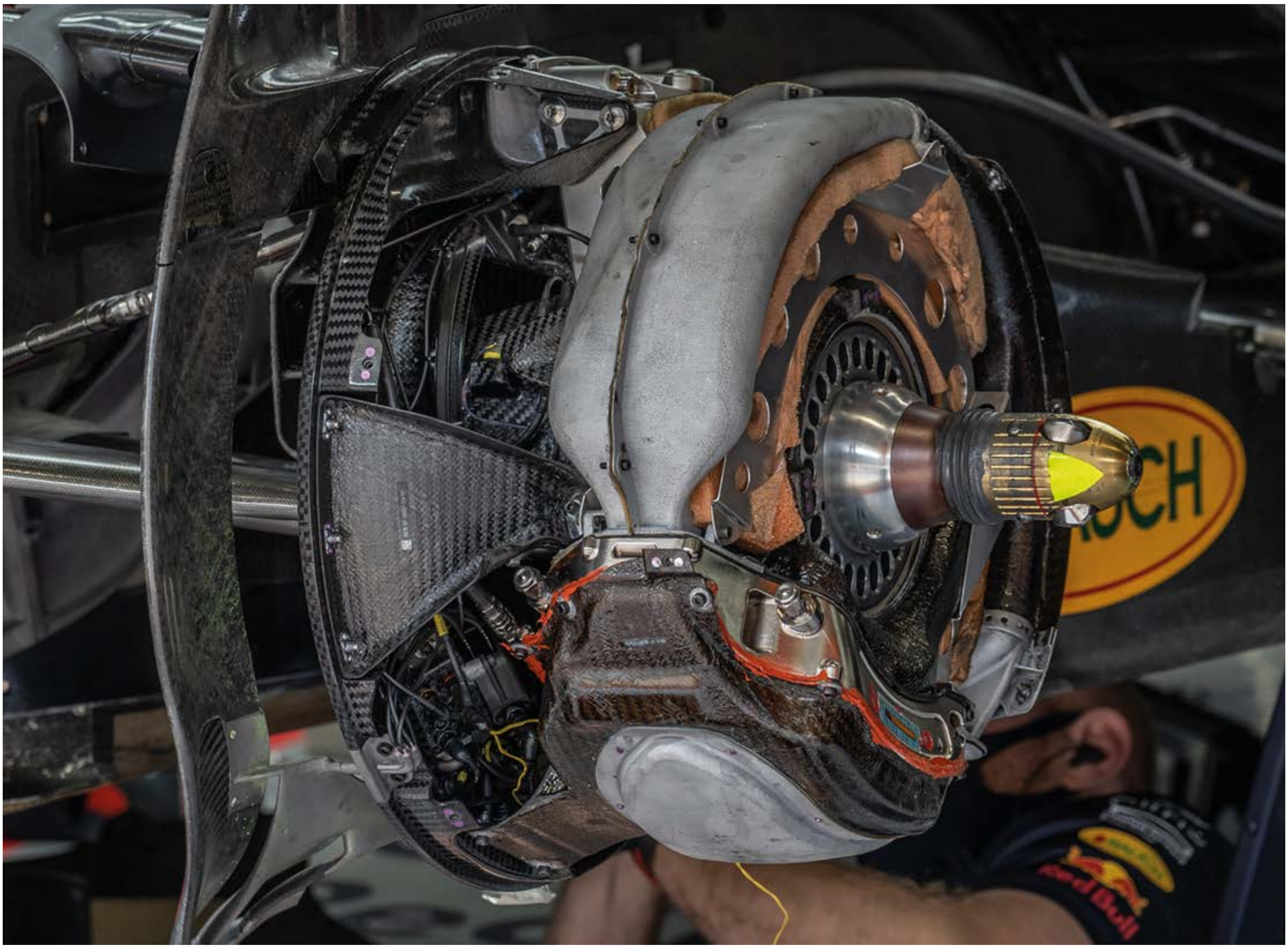
When Fred Duesenberg took the first leap and fitted hydraulic brakes supplied by Malcolm Loughead (better known as Lockheed) to his 1914 Indy racer, the mould was set. From then on, the pinnacle of brake technology would still rely on a similar hydraulic circuit with a cylinder attached to a pedal at one end, actuating cylinders in either drums or discs at the other. The link between driver's foot and braking force was a mechanically direct one, with the addition of functions such as anti-lock brakes (ABS) in production cars and some racing settings only arriving towards the end of the 20th century.

However, the appearance of hybrid and full EV racing machines means in some situations this is no longer the case.

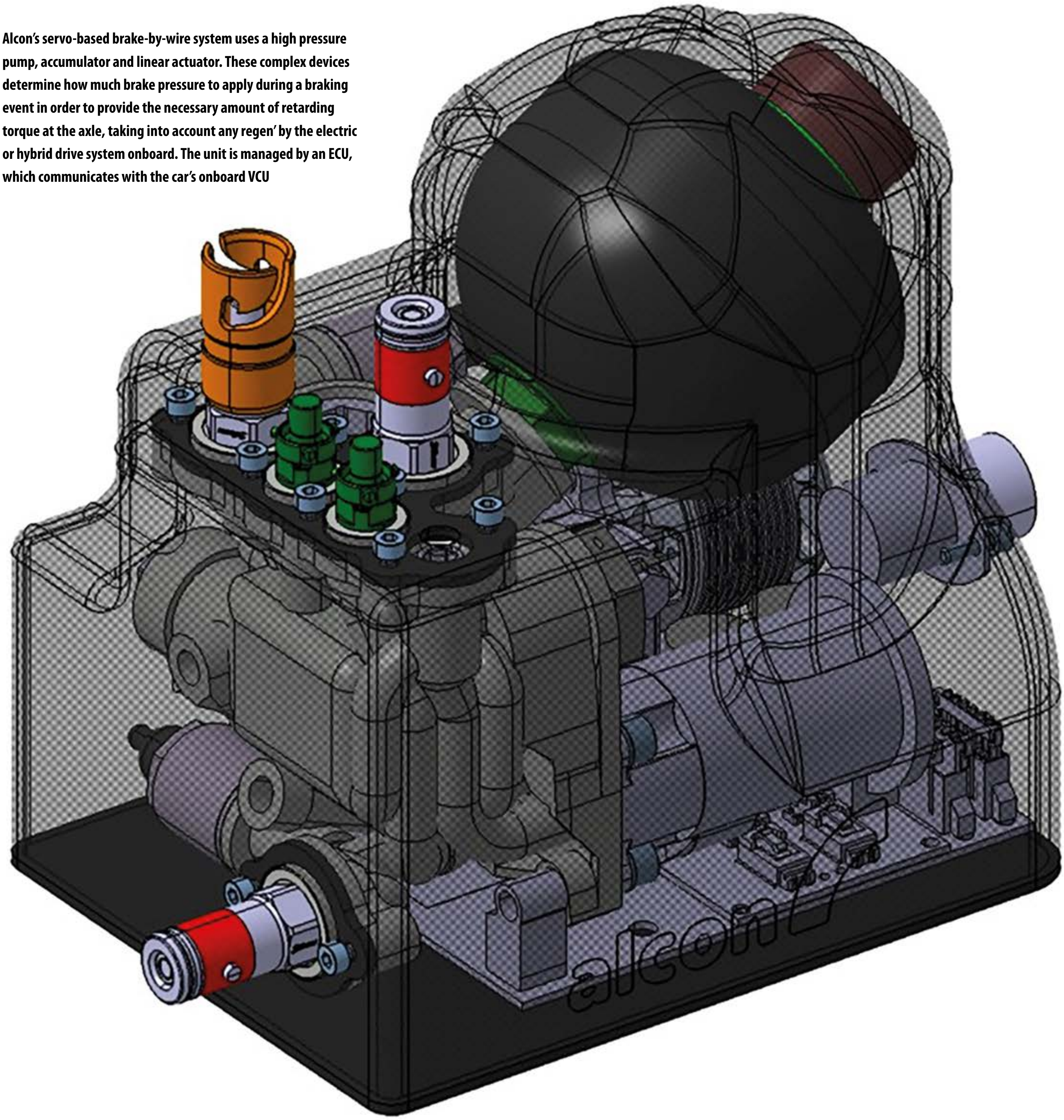
Electric motor generators now contribute to slowing a vehicle as they recover energy and, to ensure braking is consistent, regardless of energy regeneration level, the contribution of the driver and mechanical brakes needs to be modulated. Enter the concept of brake-by-wire (BBW) technology.

The basic precept of BBW is simple, but putting it into practice is complex. All the term means is that rather than the displacement of the brake pedal being directly proportional to fluid displacement in the brake caliper, an electronically-actuated system determines how much brake pressure to apply in order to provide the required braking torque at the axle once the contribution of energy regeneration by the hybrid or electric drive is taken into account.

BBW began to come to the fore around 2014, with the arrival of the latest hybrid powertrains in Formula 1 and an



For over a century, hydraulic braking systems remained largely unchanged, but technology is now moving apace. This is the Mercedes F1 team testing a new design of brake duct at Barcelona 2022



Alcon's servo-based brake-by-wire system uses a high pressure pump, accumulator and linear actuator. These complex devices determine how much brake pressure to apply during a braking event in order to provide the necessary amount of retarding torque at the axle, taking into account any regen' by the electric or hybrid drive system onboard. The unit is managed by an ECU, which communicates with the car's onboard VCU

Rather than the displacement of the brake pedal being directly proportional to fluid displacement in the brake caliper, an electronically-actuated system determines how much brake pressure to apply

increase in potency of those deployed in the WEC. Though Formula E also launched that year, teams in the all-electric series would not be permitted to run BBW until 2018, prior to which, braking force was fixed (save for traditional bias adjustment) with regen' at pre-set levels.

Pressure modulation

The early systems used in F1 relied on modulation of the brake pressure at the rear axle using a valve controlled by the standard ECU. When the driver hit the brakes, the ECU would determine how much regen' was needed and bleed off pressure to the rear brakes to balance the braking force. The rules forbade entirely disconnected systems by specifying that a direct hydraulic link must be retained between the master cylinder and rear calipers, while also stating that only a single hydraulic circuit was permitted.

Using fast acting valves, similar to those used in gearshift systems, pressure at the rear caliper can be controlled very quickly, in theory ensuring the driver has the same braking feel, regardless of the amount of energy being recovered. Managing this effect is a complicated process and many factors, such as the state of charge of the battery, the desired charge rate and the amount of energy

Berlin, German-based company, LSP Innovative Automotive Systems, provides its IBSe system to the majority of teams on the Formula E grid, and is a world leader in brake-by-wire technology

already recovered on a lap (which can be limited by rules), all need to be considered.

In the early days, it was clear that not all teams mastered the subtlety of control needed, and it would be a few years before everyone had a handle on BBW.

As one F1 engineer observed at that time, 'It's key to the mapping and brake set up that when the driver comes off the brakes there is no residual force that may give a little bit of instability, or a lock up. Some drivers are very, very sensitive to this.

'We can model the brakes on the simulator, but they are not straightforward as there is a thermal effect. The amount of stopping power the brakes have depends on the temperature of the brake, so that's an input we need to understand.' We will return to this last point in due course.

Decoupled systems

As technology evolved, so did the various rules governing BBW. Decoupled systems that completely remove the hydraulic connection between the pedal and calipers can now be used in both F1 and Formula E (though a back up hydraulic circuit is still maintained). These can best be referred to as powered brake systems, where either a pump or electrically-actuated piston provides hydraulic pressure to the caliper. When the driver pushes the brake pedal, either a pressure or position sensor sends a signal to a control unit, which then determines the balance between mechanical and regen' braking.

One issue decoupling the brakes from the pedal creates is a loss of 'feel' for the driver. If traditional front wheel brakes are still used, these can provide the required feedback to the driver's foot. But if a fully decoupled system is employed, working on both axles, a pedal force simulator will often be employed, either in the form of a heavy spring or a hydraulic cylinder acting against a spring medium connected to the pedal, giving the driver force feedback.

As Ollie Jackson from brake system supplier Alcon, which provides BBW systems into Formula E and other series notes, there are different approaches to actuating the BBW system, each with their own pros and cons: 'There are a few different concepts around. Some are servo-based, like ours, and some use a linear actuator – basically a ball screw-driven master cylinder.'

In his opinion, a servo-based approach has greater potential for higher flow rates

When the driver pushes the brake pedal, either a pressure or position sensor sends a signal to a control unit, which then determines the balance between mechanical and regen' braking

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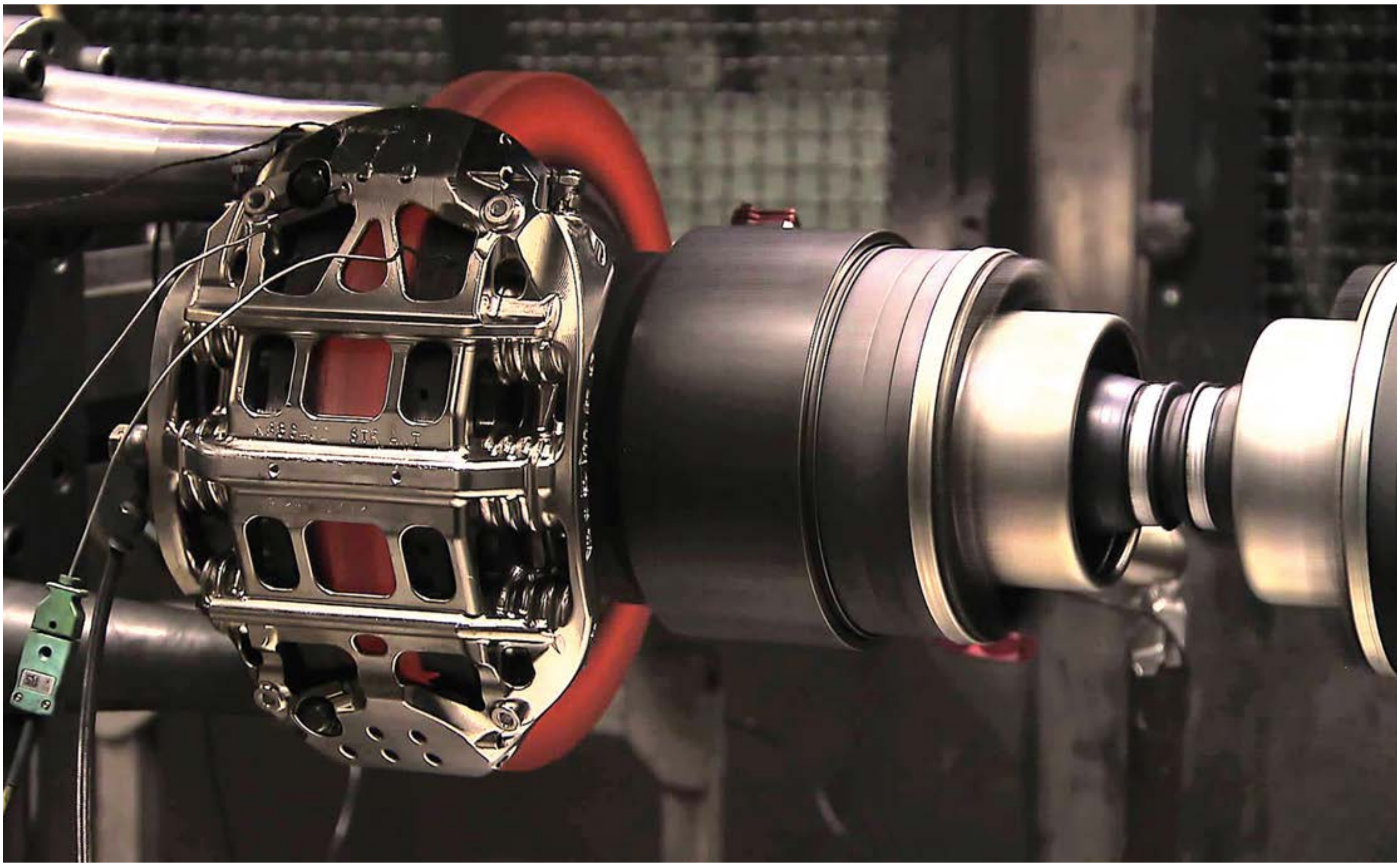


Achieving consistency in driver feel is crucial, so brake suppliers work with teams to develop friction maps to understand the precise behaviour of their systems. A brake dyno is invaluable here

and higher pressures, meaning they can react to inputs more rapidly. However, he admits that other systems tend to be simpler.

'We've chosen our system because it has the most flexibility going forwards for all the other things Alcon does outside of motorsport. Our system is like a little hydraulic power pack that runs purely on brake fluid. It consists of a high-pressure pump and accumulator with a servo valve to meter out high-pressure brake fluid from the accumulator into the circuit.'

The main role of the hydraulic components is to ensure a precise brake pressure can be applied rapidly and consistently. In Alcon's case, this is achieved using a pressurised accumulator that provides high-pressure fluid on demand, rather than relying on the rapid movement of a piston in a cylinder to generate line pressure. The unit itself is managed by an internal ECU, which communicates with a car's overall vehicle control unit to balance mechanical braking and regen' forces.

Depending on the application, the balancing of the mechanical and regen' braking effort will be the responsibility of either the BBW ECU or the VCU (vehicle control unit). According to Jackson, with most of the systems Alcon supplies to teams, the BBW ECU is responsible for this process, while the VCU tells the BBW controller how much regen' is available and is then told how much will be used.

The BBW system is therefore entirely responsible for controlling braking torque.

Jackson says teams tend to prefer this approach as it removes the need for them to come up with their own complex brake control algorithms and makes integration more straightforward.

Driver sensitivity

While the idea of balancing the action of the brake calipers against the level of regen' at each braking event may seem simple, it is anything but. Good drivers are very sensitive to even minute changes in the feeling of a car under braking, and any variation can reduce their confidence and cost lap time.

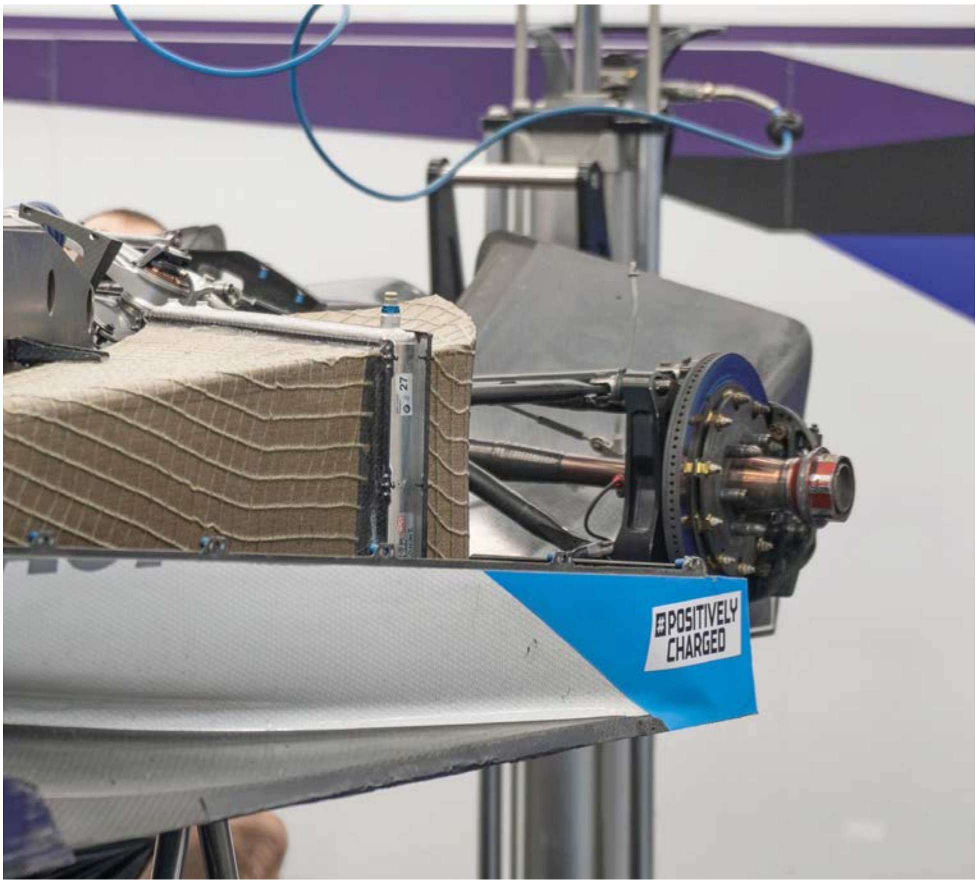
'Working out the regen' torque is relatively trivial,' says Jackson. However, while calculating the required level of brake torque is also straightforward, ensuring this translates to actual torque at the axle is a different matter. The torque applied for a given pressure at the caliper pistons is a constantly moving target throughout not just a race, but each braking event varies depending on many factors, including the specifics of the brake pad and disc material, the rotational speed of the disc and the temperature of the pads and disc. A good driver will be sensitive to these changes, varying pedal pressure as needed, and so with a BBW system they need to be accounted for in the mapping of the system to retain consistency.

'The key to making BBW systems work well is to have a good friction map of your friction couple on whichever axle you're braking'

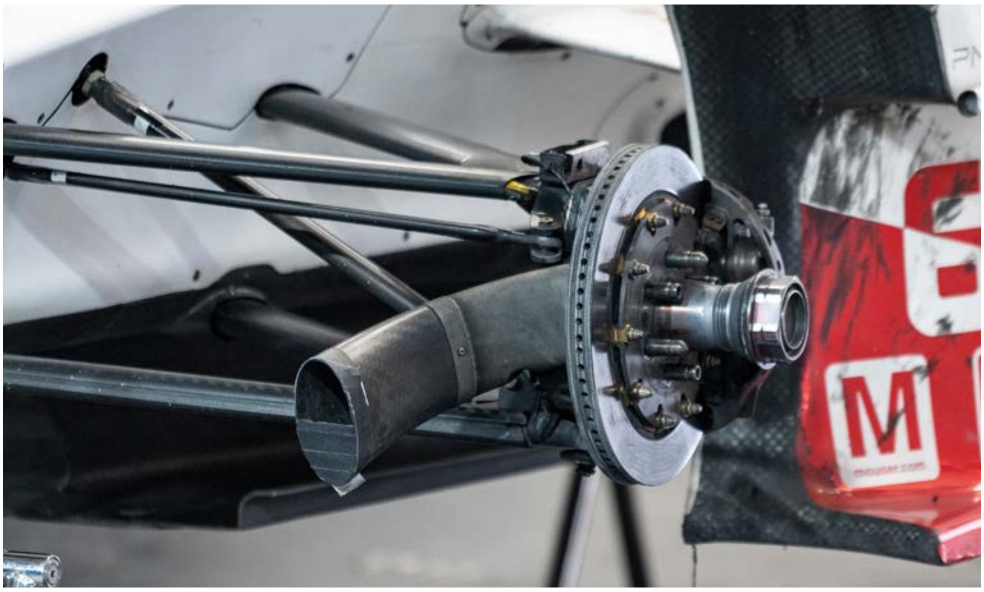
David Hamblin, managing director at AP Racing

'There's a lot of things that will change the Mu at that moment in time [when the pad grips the disc],' outlines David Hamblin, MD of long-time motorsport brake and clutch supplier, AP Racing. 'Being able to predict that accurately allows you to have the best brake blend between friction brake and motor brake, so we do a lot of work with teams on friction maps, getting the friction curve to be benign in terms of what it's trying to achieve.'

Jackson agrees. 'The ultimate consistency you can achieve is if you know the friction behaviour of the system and can then create a good enough model,' he says. 'If you can do that, then you can create a much more predictable and effective braking system for a fully decoupled set up. And you end up being able to really fine tune the torque control of the brakes vs the regen'.'



Since 2018, BBW technology has been allowed in Formula E, and cars in the series now feature entirely decoupled braking systems


For safety, a mechanical braking system must still be employed in order that cars can be stopped in the event of an electrical failure

'The ultimate consistency you can achieve is if you know the friction behaviour of the system and can then create a good enough model'

Ollie Jackson, development engineer at Alcon Components

Both AP and Alcon have in-house dynos for testing brake systems, and these have proved invaluable in the development of BBW control. 'With our newest dyno, we can drive the motor like a KERS, giving the ability to motor brake, based on simulation or lap data,' says Hamblin.

'The key to making BBW systems work well is to have a good friction map of your friction couple on whichever axle you're braking, because the least stable part of a brake system is the friction level between the pad and the disc.'

He also points out that pad wear, and the effect this has on fluid displacement of the system, also needs to be accounted for in the mapping of a BBW system.

Failure detection

Most rule sets require BBW systems to have fully mechanical redundancy built in, so that if the brake-by-wire system fails, the driver is not left without any braking effort. If there is an ERS failure, it can be a race-ending event as teams can size the mechanical brakes smaller, thanks to their reduced role under normal operating conditions. If no regen' is taking place, the brakes will be subject to a much higher duty cycle than they are designed to survive, and braking performance becomes marginal at best. This is a problem that has been faced by teams in both F1 and the WEC in recent years.

Jackson highlights that the BBW control system is critical in detecting any such failures and responding to them in a timely fashion.

'There's a lot of background work before you even build the first system to work out that detection, redundancy, measurement and to have the mitigations in place. With our system, if there's failure detected, it just reverts to passive mode. Obviously, you then lose regen' because if you have passive braking and regen', it can easily lock the wheels.'

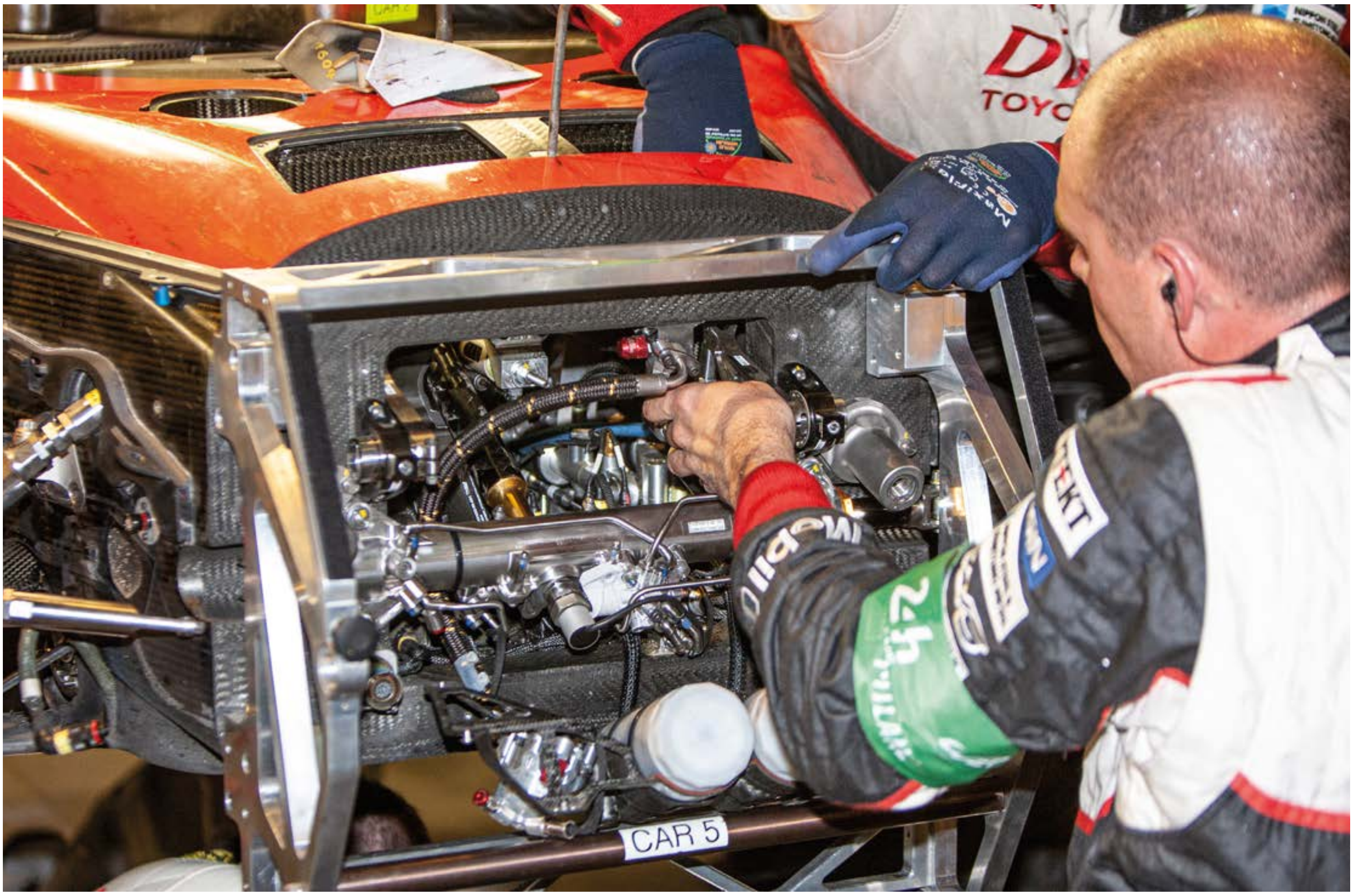
Caliper design

One interesting aspect AP's Hamblin notes is that due to the lack of direct connection in a decoupled BBW system, the caliper doesn't necessarily need to be as stiff as in a conventional braking set up.

'The brake by wire doesn't really care if the caliper is flexible or not. Now, it can't be too flexible, to the extent you have too much fluid displacement, but a fully decoupled system changes things for the driver because they're not connected to the brake system.'

The stiffness of the caliper is important to brake feel because it is essentially a c-shaped part, with the pistons mounted at either end of the c. When the brakes are applied, the force of the pistons pushing against the disc tries to open up the caliper, meaning some of the force being applied by the driver at the pedal is wasted through the deflection of the caliper body. This deflection both reduces the efficiency of the driver's brake applications, while also potentially creating a 'soft' or inconsistent pedal feel.

The caliper will also deflect due to the twisting force exerted as the friction level between the pads and discs begins to increase. As this happens, the pistons are pushed back into the bores and brake fluid displaced, meaning the driver needs to release the pedal pressure to account for this, otherwise the brakes will lock.



One of the big challenges in developing BBW systems is retaining braking 'feel' for drivers and this is a combination of sensor technology and materials used in the design of the caliper

By making the caliper body as stiff as possible, the effects of this flex on the feel and performance of the braking system can be minimised. The result is the driver has a more precise feel from the brakes.

However, for a brake-by-wire system, none of this really matters as the system will simply apply pressure to hit a set braking torque target. Theoretically, then, calipers controlled by BBW can be slimmed down compared to a conventional system.

The future

Despite all these advances in technology, BBW is still far from commonplace in racing. Drivers in the WRC, for example, which recently introduced potent hybrid systems, have to physically balance their braking effort to take into account energy regeneration.

As Jackson points out, current systems are highly optimised, but also expensive.

'I think that going forwards, the big step change will be people pushing the cost down and making it a more mainstream application. Because ultimately, what you're competing with is battery capacity.'

Effective brake by wire means greater energy regeneration is possible and smaller, more power dense battery packs can be used. However, with the current price of systems (and batteries) it is more cost effective to simply add more battery capacity than introduce the complication of brake by wire. 'What we're looking at really is to try and maintain the performance but keep reducing the cost,' says Jackson. 'We've gone straight in right at the top so, in terms of performance and the systems we produce, they're pretty high value.'

Undoubtedly, BBW will increase in prominence within racing, as well as in the production car world, as hybrids become the norm and the transition to EVs continues. In other words, it is a technology every race engineer will soon have to become accustomed to.

'Going forwards, the big step change will be people pushing the cost down and making it a more mainstream application'

Ollie Jackson, development engineer at Alcon Components

LSP's IBSe 9 module is a complete BBW system, and includes a pedal feel simulator and hydraulic fall back mode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From a privateer race team to one of the biggest players in the industry, Racecar *charts the evolution of Sauber's engineering groups*

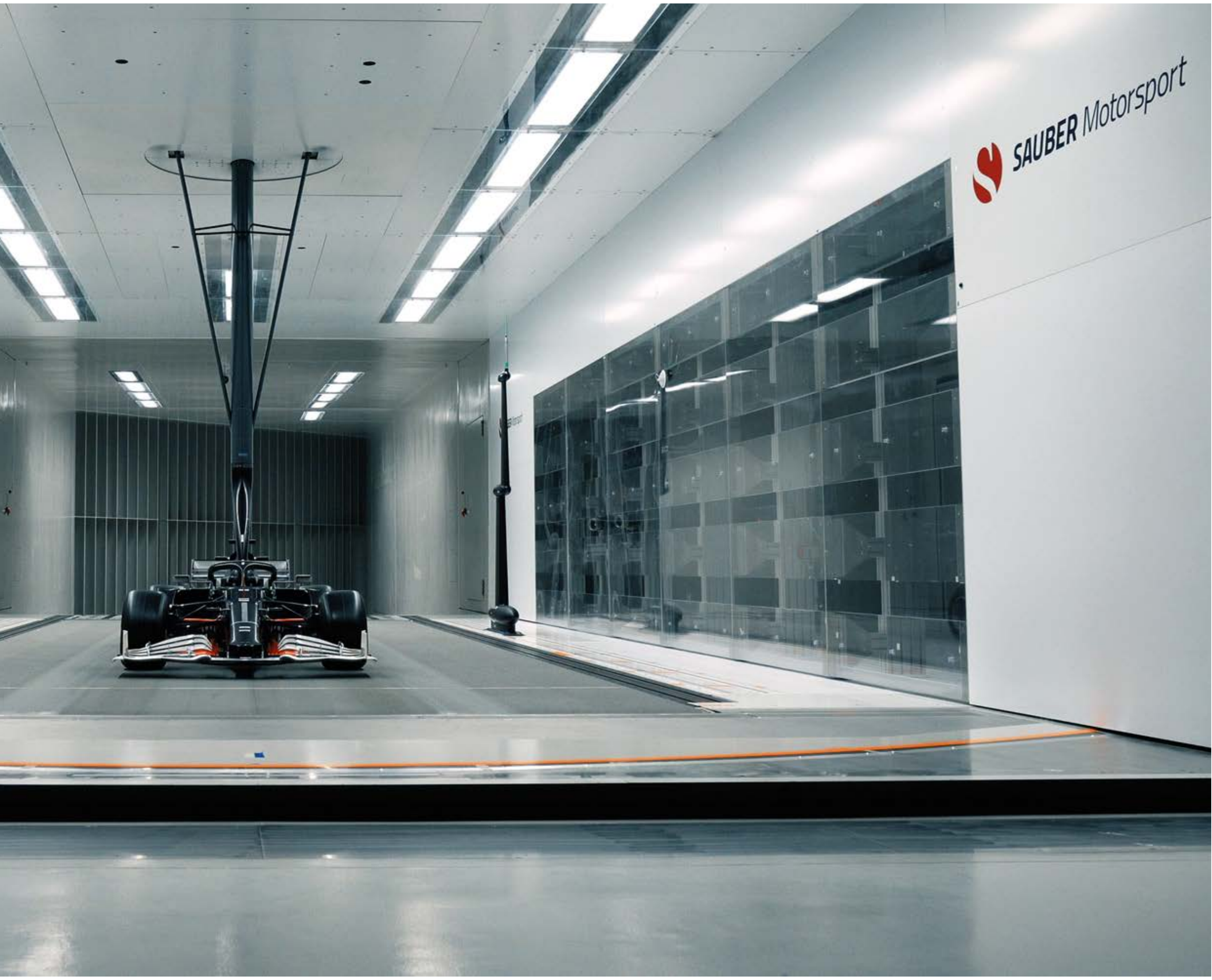
By STEWART MITCHELL

Sauber's wind tunnel is one of the best known and widely used of its type in motorsport today. This impressive facility now forms part of the newly formed Sauber Technologies

Axel Kruse, CEO of Sauber Technologies

'We've been pushing AM very hard because we recognise its potential for supply of the wind tunnel testing components and realising our designs in the real world before they go to final manufacture'

Axel Kruse, CEO at Sauber Technologies



Forward thinking

Leveraging a Formula 1 team's engineering expertise and DevOps capabilities for other applications is nothing new. Teams up and down the grid have formed race team partner firms to sell their services to outside organisations for many years. However, this part of Formula 1 has evolved significantly over the past couple of years to accommodate the cost cap regulations and keep the staff's amassed engineering expertise in house.

The Alfa Romeo Formula 1 team is run by Sauber Motorsport, part of the Sauber Group based in Hinwil, Switzerland. The start of 2022 saw the birth of Sauber Technologies, a new company devoted to bringing Sauber's engineering innovation and Formula 1 mindset to businesses worldwide. Sauber Technologies incorporates Sauber Engineering and Sauber Aerodynamics, which have both been around for a while, strengthening their capabilities for customers across a broad range of industries.

'In the past, we had three entities in the company: the motorsport pillar, aerodynamics and engineering,' explains Axel Kruse, CEO of Sauber Technologies. 'The engineering, which is the base of the Sauber Technologies group, came from our recognition of us having an excellent product in engineering expertise and being very strong in additive manufacturing (AM).

'We've been pushing AM very hard because we recognise its potential for supply of the wind tunnel testing components and realising our designs in the real world before they go to final manufacture. With the introduction of the budget cap, it made sense to merge the aerodynamic and engineering capabilities as they are hand in hand. So, we created the Sauber Technologies arm of our company.'

There and back

The evolution of the Sauber Group started in 1970 when Swiss businessman, Peter Sauber, founded Sauber Motorsport. After various stints in a multitude of racing disciplines, from hillclimbing through to Sportscars, the team entered Formula 1 in 1993. After failing to make much of an impression as an independent outfit, Sauber sold the team to BMW in 2005. It then competed as BMW Sauber from 2006 to 2009, scoring one victory.

Then, when BMW pulled out of Formula 1 at the end of the 2009 season, Peter Sauber bought his old team back again, and it was granted a 2010 entry.

The BMW Sauber project had resulted in a substantial increase in competitiveness for the team. Third party engineering work was always a strong pillar for Sauber, but its reliance on engineering output increased with the withdrawal of BMW's funding. Today, Sauber Technologies is its own entity, entirely dedicated to third party business, though one of its biggest customers is Sauber Motorsport (currently the Orlen Alfa Romeo Formula 1 team).

Within the Technologies arm, the company has finite element analysis (FEA) and computational fluid dynamics (CFD) capacity, milling and other subtractive manufacturing solutions, additive manufacturing (AM) capability and wind tunnel services, able to run from full-size cars down to 50 per cent scale models.

Clear vision

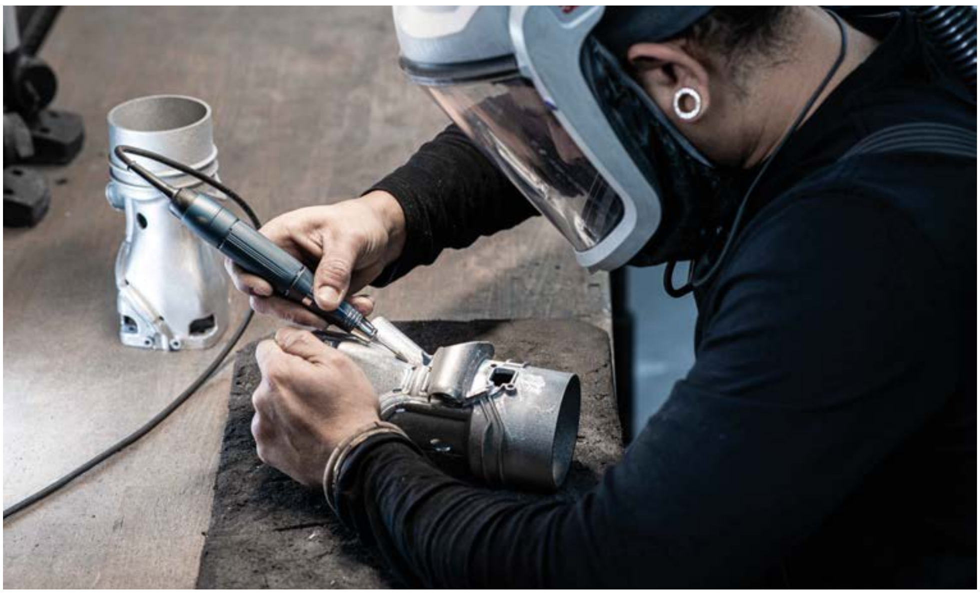
'With this capability, alongside our consulting within those areas, we can support companies with a clear vision who want to execute their programme from taking a blank sheet of paper and ideas to full production,' explains Kruse.

Sauber Technologies' additive manufacturing capability was born out of the high demand for test parts to be made quickly and accurately. When BMW bought the Formula 1 team, it brought with it a significant budget. The Sauber Group management therefore put together a plan for team to improve efficiency across all its operations. Part of that drive was to stop outsourcing the production of wind tunnel components. That desire saw Sauber build up its additive manufacturing department internally, initially for plastic parts for Sauber Motorsport produced via stereolithography (SLA) and selective laser sintering (SLS) techniques.

'Early on in our additive manufacturing journey, we discovered some parts on the full-scale car we wanted to print, but the material was not available in the quality we needed,' notes Kruse. 'For example, for the Monaco GP, you need the front brake ducts to have the maximum ducting because of the high number of braking zones and the low flow field velocity through the front braking system. But you only need this configuration for that race once a year.

Additive Industries' modular and scalable MetalFAB1 system, designed for integrated and automated production with metal powder bed fusion technology using four lasers

After an AM part is manufactured and processed, it is laser scanned and compared to the original CAD file to ensure no discrepancies



Often, additive manufactured parts will be hand finished by operators with subtle surface techniques used on external aspects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'In the past, we built Monaco GP brake ducts from virgin carbon fibre. The process included positive and negative laminating followed by milling, and then you have six sets for the two cars for that weekend. The design would evolve for the following year, so the tooling would be a waste. We wanted to print them because it's a one off, but we had to find a material temperature resistant enough to do that. So we developed our own.'

The company's proprietary HiPAC SLS material was the result. It is based on a carbon-reinforced polyamide 12 and offers high mechanical properties and dimensional stability, with low water absorption compared to other polyamides, making it barely affected by moisture.

Outside of the niche Monaco brake duct application, Sauber saw a market demand for such a material in different applications.

'So, we ramped up the plastic AM capacity to supply the needs of the Formula 1 applications [wind tunnel testing and some additional parts on the car] and third-party market demand,' Kruse explains. 'We bought six SLA and six SLS machines to cope with the demand as it came in.'

Material composition

With Sauber an early adopter of the then new AM techniques within the Formula 1 fraternity, it also pioneered material composition, alongside powdered material manufacture. The powdered material evolution has been rapid, although many of the exotic materials used to exploit performance in high-end industries are banned in Formula 1.

On the plastic AM side, Kruse says there's always something new coming. For example, Sauber Technologies is currently doing a lot of work with carbon fibre-reinforced PA12 material. The reason is that it's so versatile, and engineers can manipulate its composition to fulfil a wide range of different demands.

Its most significant strength is its high-temperature stability when compared to other AM plastics – up to 170degC.

The fibre orientation cannot be stipulated in manufacturing fibre-reinforced polymers produced using current AM. That means engineers cannot optimise the internal structure for the number of fibres and load directions the part will experience during operation. However, the part's shape can be designed to be more optimised for the application, thanks to the almost limitless construction freedom of AM. That means some of the strength lost from the lack of fibre orientation in the material structure can be compensated for by good design.

'After many trials, you learn what is the right number of fibres over that part,' explains Kruse. 'Everywhere across the part has the same density of fibres, and so the same strength, because you can't orientate them.'

Metal AM

Soon after the plastic AM side of the business took off, Sauber began investigating the potential of metal additive manufacturing. At the time, the technology was immature, and a lot of expertise was required to make parts successfully using this technique. Consequently, Sauber decided it needed a partner for this venture, which it found in Dutch firm Additive Industries. Today, they are a principal partner to Sauber Technologies, providing a series of metal AM technologies, including the machines and the software to produce metal AM components. Finding a partner in Additive Industries also saw the company install four metal printers to print titanium, specially strengthened aluminium and stainless steel.

Metal AM machines work with a vast array of powdered materials, so improving the performance of AM-produced parts is down to the laser parameters and environment around the part during production.

'We are focusing on the metals useable for Formula 1 in metal AM and exploiting what we know for third party business,' notes Kruse. 'Formula 1 wants to keep a stable bill of materials. The management does not want a situation where things like beryllium are used again, and the costs ramp up. They have a strict catalogue of what is available to use, so there's little point in exploring anything else outside those specified materials.

'Metal AM was a huge shift in capabilities for the Formula 1 application as a vast number of components on the car could now be printed'
Axel Kruse

'Metal AM was a huge shift in capabilities for the Formula 1 application as a vast number of components on the car could now be printed.

'This was a massive milestone for the technology and us as a supplier of these elements, but there was still a steep learning curve to climb. Early on, there was quite a disparity between the performance of an additive manufactured part compared to a part subtractive manufactured from a billet of material. To further optimise the AM components, we needed to develop our design approach for manufacture with AM in mind. Our technology and FEA programming has evolved to the point where we are designing in a completely different type of way to accommodate the potential of AM.'

Additive manufacturing has a series of positive knock-on effects outside of the lack of material waste and the potential to optimise shapes stemming from the freedom in design it offers. It allows users to reduce considerably the number of milling machine cutters required, and the produced parts are often lighter, so cheaper to transport. Engineers can also now achieve integrated features with four or five functions within one AM component, rather than producing several parts from subtractive manufacturing that go together into an assembly. As such, part count on a given system can be reduced, meaning storage departments can reduce their capacity, too.

Finally, lead times for AM components are significantly less than other manufacturing techniques.

Techniques for AM

When the part is being layered during the AM process, the first layer will heat cycle more than the top layer if the build chamber environment isn't properly managed. Making sure the heat distribution is even throughout the part, therefore, so there's no additional stress placed upon the first layers compared to the top layers is critical for part performance when it goes into service.

Titanium additive manufacturing is a major development for Sauber Technologies. Here's a post-turbine exhaust part for a contemporary turbocharged, 1.6-litre, V6 Formula 1 engine


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'We've worked very hard to develop working practices for AM throughout this journey,' remarks Kruse. 'Working out what the right chamber and build platform temperature should be when you start is critical to how the layers bond during construction. And this process is different from material to material. We print several millimetres before the formation of the main structure begins because we cut the part off the build platform, and this support structure will take the heat away from the part and into the platform.

'If you are building a complex structure, any overhanging or long lateral forms must be supported by structures underneath them. We design the manufacturing process so the machine prints these support structures, and they have several roles. Their primary function is accurately mechanically supporting the part, but they must also effectively draw heat away from the component body, and also need to easily break away, or grind away, from the main feature in post-processing.'

The secondary and tertiary roles are more intensive in engineering than mechanical handling. 'We carry out in-depth finite element analysis and simulation to identify how the part's mechanical and thermal stress comes out through the support structure, and ensure when we cut it out that it's not going to damage the part,' continues Kruse. 'Proprietary design techniques are used to ensure the heat from the build follows a given support structure path away from the part body better than through the part itself. We simulate this in the design programme we use: where the support structure contacts the part, where the heat goes, where the mechanical forces go, and the interface between the support structure and the part is defined extremely accurately. Then we will optimise that to ensure the part can go into service as soon as possible after the build.

'Additionally, using the build platform most efficiently is critical, because the money you're spending is mostly machine running time. So, you have a platform size with several parts and different structures, which should not interfere with all the others. Yes, this is the tricky thing.'

Engineering consultancy

Despite the manufacturing side of Sauber Technologies being a significant element of the business, the largest growth area for the company has been in engineering consulting. In the beginning, the consulting arm was around 30 per cent of the output, and now it's over 50 per cent, with far more customers.

'The engineering, consulting and project management is growing very fast,' says Kruse. 'Very often, these projects are combined with the AM technology or wind tunnel facility, making our company a one-stop shop for all the required parts of a project.'

Of the consulting side of things, Kruse says the competitive edge for the engineering side of the Technologies group is its design for AM capabilities.

'I think it's a big move, especially when talking with the designers, because they often think in structures they know. But when designing for AM, you must come from the other side, focusing only on what is necessary for the specification of the part, not thinking about what it should look like. This is a different type of thinking. It's also a lot of learning to give the designer confidence that we can do that.

'In Formula 1, speed of learning is everything, and we have a very high learning curve. To maximise this, we have dedicated programmes on the AM machines to do pre-development for the Formula 1 team, including testing. We have invested a lot of money in test facilities and equipment to carry out tensile strength tests and finished part tolerancing to verify the material and its properties.

'We have invested a lot of money in test facilities and equipment to carry out tensile strength tests and finished part tolerancing to verify the [AM] material and its properties'

Axel Kruse

'Because the AM techniques we use have a powder bed and are created by melting that powder in layers, you must make sure everything is consistent from top to bottom, and you have to test it. When we started, the testing methodology for this technology was not available. We had to develop it ourselves.'

Wind tunnel

Perhaps the most well-known part of the Sauber Technologies group is its wind tunnel facility. It boasts cutting-edge technology for all relevant aspects: wind speed, size of the test section, rolling road, model motion system and data collection. The tunnel has a maximum tube diameter of 9.4m and is designed as a closed circuit, measuring 141m in length (without the test section). The overall weight of all the steel

Sauber Technologies has invested heavily in AM technology in recent times. Shown here is its four stereolithography (SLA) polymer additive manufacturing machines

elements, plus the fan housing, comes to 480 tonnes. The single-stage axial fan with carbon rotor blades is state of the art.

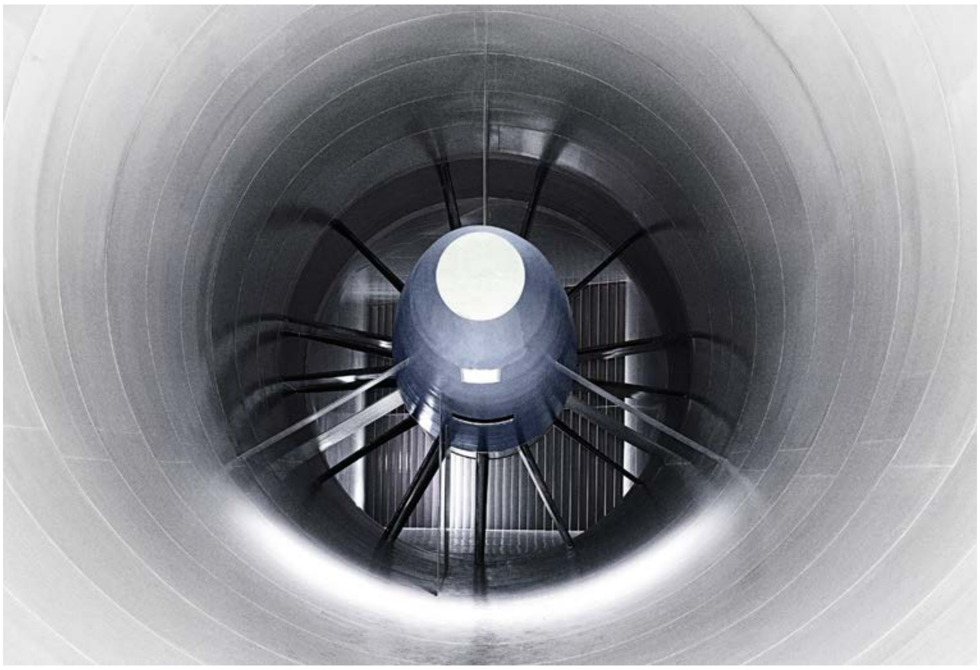
At the heart of the wind tunnel is the test section. It is generously proportioned to provide representative racing conditions for precise results. Testing with a full-scale racecar is possible and consequently it is used by many third-party clients.

However, current regulations ban full-scale testing in Formula 1 and some other racing series, so F1 exclusively uses 60 per cent scale models for wind tunnel testing work.

The entire measuring platform can be rotated in the Sauber Technologies tunnel to allow test models to be exposed to the airstream – at anything up to 288km/h – at an angle of up to 10 degrees. The platform features a rotating steel belt that runs in sync with the airflow to simulate the relative motion between the vehicle and road, and has load cells mounted underneath to measure wheel loads. This gives a more accurate picture of the dynamics and includes the influence of the rotating wheels, enabling engineers to measure aerodynamic loads in different states.

'We put a lot of emphasis on the tunnel facility to develop it to a very high standard,' remarks Kruse. 'We pride ourselves in being state of the art. This has really developed our relationship with the FIA and its racing championships. The tunnel size means we can prepare full-scale testing, ideal for understanding real world behaviour. We can also do all the BoP testing and validation with real cars, and we have always had an open mind to having third party business here.

'As a supplement to wind tunnel development, or as a substitute for complex tests in which engineers can try out many possibilities and options, CFD is the solution for working out results quickly and efficiently. We operate a computer centre in the wind tunnel facility, which allows us to perform numerous calculations in a short time. In addition to efficiency, the correlation between software and reality is also a major focus of our work.'



The wind tunnel's single-stage axial fan with carbon rotor blades can power the air speed up to 288km/h and uses 3000kW at full load

Unconventional thinking

The high standard of correlation, combined with the precise and flexible testing options, make the Sauber wind tunnel the most used of its kind in the world. Kruse explains why: 'In Formula 1, the boundary conditions are always changing. This calls for unconventional thinking to gain a competitive advantage. To support this process, we have developed a series of complex measurement and control systems and integrated them into our wind tunnel environment.

'In Formula 1, the boundary conditions are always changing. This calls for unconventional thinking to gain a competitive advantage'

Axel Kruse

'We have also designed flow switches controlled by changes in air velocity and developed many other mechanical and fluid-based testing systems.'

Naturally, the wind tunnel testing protocol changes depending on application, too. 'You can run full scale, high sophistication and development rates for things like Le Mans Prototype with tyre, suspension and powertrain measurement active,' explains Kruse, 'but sometimes it doesn't make sense to instrument everything to the nth degree. So, you design the testing environment to gather all the necessary information.

'For standard equipment, or GT-type racing, especially those running under BoP, LMP levels of instrumentation are not needed.'

It's clear that the Sauber Technologies arm of the Sauber Group does not still, which is why it continues to grow. And with it, so does the Orlen Alfa Romeo Formula 1 team's performance on track. That's not a coincidence, but the result of a dedicated engineering operation with state-of-the-art facilities that leverages the extensive talents of its crew. That's where the competitive advantage lies these days.

At over 141m in length and with a maximum tube diameter of 9.4m, the Sauber wind tunnel is a colossal structure, capable of accepting full-scale vehicles as well as the 60 per cent scale models required by current F1 regulations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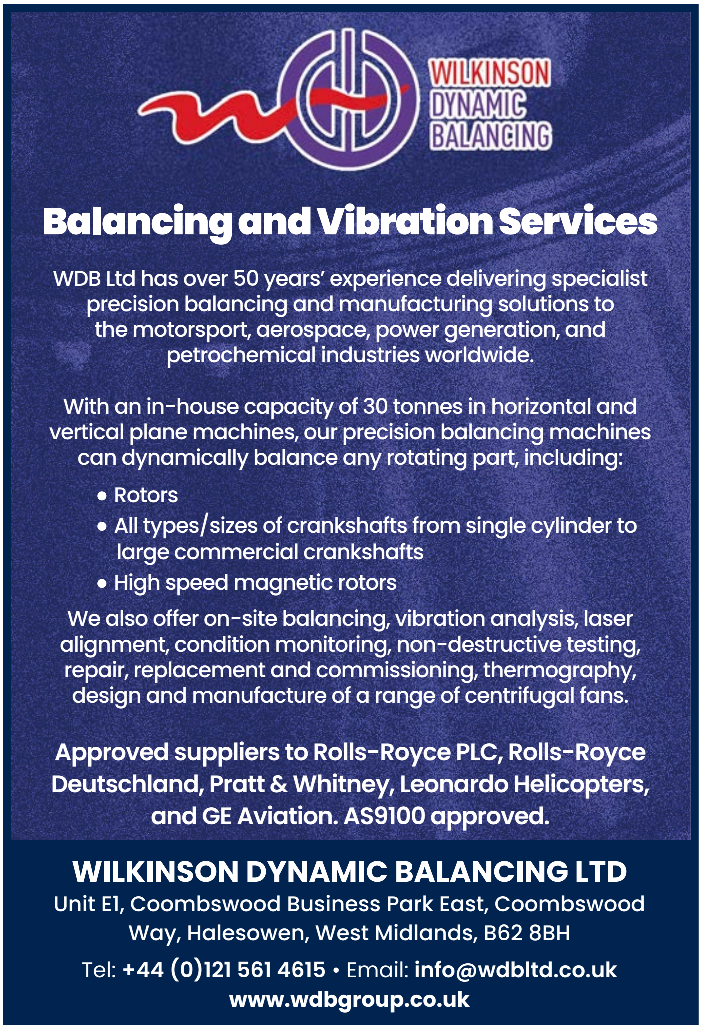
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Curvature ball

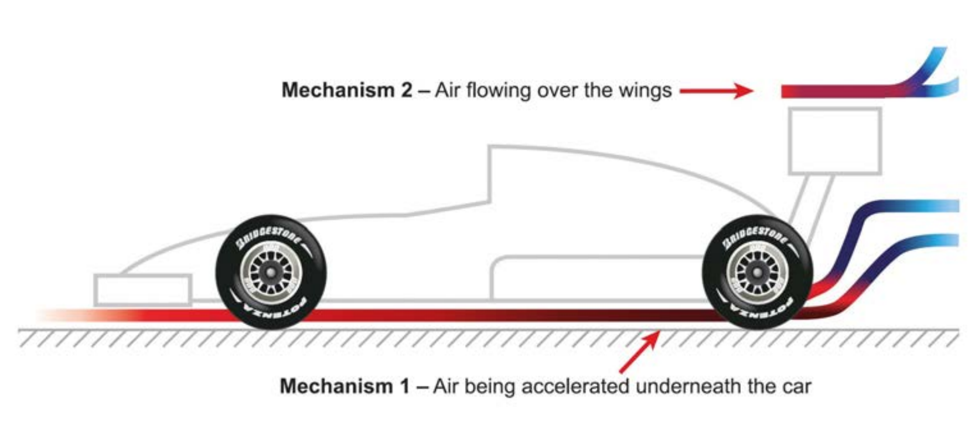
Revisiting the subject of aeromap curve fitting

By DANNY NOWLAN

I wrote an article about 10 years ago about using a technique called aeromap surface fitting to create a ride height sensitive aeromap. This has gone on to form a ChassisSim staple in formulae as diverse as V8 Supercars, Sportscars and high-downforce open wheelers, but is not without its traps for new players in the game. How to overcome this will be the focus of this article.

To set the scene, we need to briefly discuss how downforce is generated. The two processes are illustrated in **Figure 1**.

Fig 1: The two principal mechanisms of downforce generation

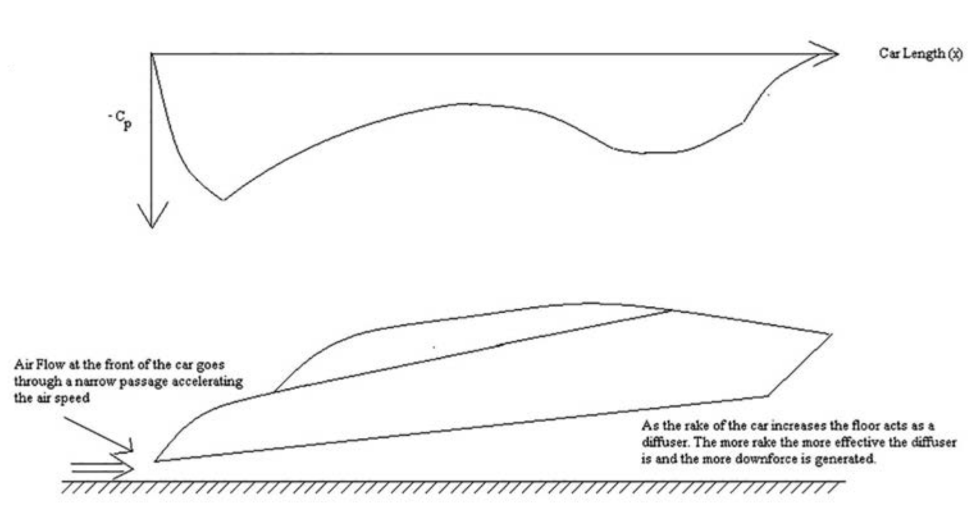


The first of the two main methods of downforce generation is airflow directed underneath the car. This accelerates the air and, following Bernoulli's Theorem, the resulting pressure drop creates downforce.

The second mechanism is air flowing over the wings, which can be nominally calculated using references such as *Theory of Wing Sections* by Abbott and Von Doenhoff and 3D airflow theory. However, the car's proximity to the ground can also affect the flow of the floor. To prevent any confusion, I should also add here that the car's floor is often referred to as its underwing.

The first mechanism of downforce generation dictates what the aeromap looks like. To better illustrate this, consider **Figure 2**.

Fig 2: Mechanism of downforce flow generation



While I appreciate **Figure 2** isn't going to win any awards for aesthetics, it does illustrate what to look for in an aeromap. As we can see, as the front of the car becomes lower, this creates a narrow channel that accelerates the air because it is so close to the ground. This accentuates the Cp drop that we see in the plot above our car.

There is a limit, however. That limit is the boundary layer on the underwing of the car and the ground, which will effectively choke the floor. But we can clearly see that the lower we go, the more downforce we generate. And, of course, it has an optimum position.

Raise and flow

The next step in the downforce generation process is to return the airflow underneath the car to the mainstream velocity of the current air speed of the car. By adding more rake, or raising the rear of the car, we effectively turn the whole floor into a diffuser. The more rake we add, the more downforce we generate. Simple.

The price you pay for it, however, is it creates drag, and the two Cp peaks move forward, creating more front downforce, too. Naturally, it is not a free lunch. For as you add more rake, you effectively need less floor to return the flow back to mainstream speed, so there will be a peak value of rear ride height where peak downforce is generated, and it is usually closely associated with the front ride height you're running.

It is these two mechanisms of front and rear ride height accelerating and decelerating airflow underneath the car that leads to ride height sensitivity. In the open wheeler and Sportscar case, this is further accentuated by the presence of front wings and diffusers.

The same thing also applies for under-body tunnels. If anything, these optimise the Cp vs car length distribution, but the same principles apply.

The limit is the boundary layer on the underwing of the car and the ground, which will effectively choke the floor

By adding more rake, or raising the rear of the car, we effectively turn the whole floor into a diffuser

So, from what we have just covered, we can surmise the following approximation:

- Downforce and drag have an optimum value associated with front ride height.
- Optimum downforce and drag are usually associated with a peak value of rear ride height.

Now we know what we are looking for, how do we put numbers to this? This is described by **equation 1**.

$$\begin{aligned} C_L A_{peak} &= c_1 - c_2 \cdot (x - c_3)^2 \\ a &= a_1 - a_2 \cdot (x - a_3)^2 \qquad (1) \\ rh\_r\_peak &= r_1 - r_2 \cdot (x - r_3)^2 \\ C_L A &= C_L A_{peak} - a \cdot (y - rh\_r\_peak)^2 \end{aligned}$$

Where,

$C_L A_{peak}$	= peak CLA value for a given front ride height
a	= inflection, or how much the rear ride height effects CLA changes
rh_r_peak	= rear ride height at which optimum CLA is produced
x	= front ride height
y	= rear ride height
c_1-c_3	= constant terms for determining CLApeak
a_1-a_3	= constant terms for determining a
r_1-r_3	= constant terms for determining rh_r_peak

What we have done in **equation 1** is put mathematical form to the methods of downforce generation we discussed at the beginning of this article. What **equation 1** therefore tells us is that for a given front ride height CLA (downforce) or CDA (drag) or aero balance, this can be approximated by a quadratic function (I have chosen to use a quadratic function here because they are simple to work with and allow a function to vary without going crazy).

What this particular function says is that for a given front ride height, downforce / drag / aero balance has a peak value that is obtained at an optimum ride height, rh_r_peak. The way this drops off from the peak value is controlled by the term a.

The sub terms of **equation 1**, CLApeak, a and rh_r_peak, are effectively functions of front height. This represents the physics of downforce generation, represented here by a quadratic function.

Peak value

In each of these equations, the first term (subscript 1) is the peak value of the function, the second term is how the function value curves around and the third term is the value of front ride height where the function value peaks.

To put this into perspective, let's look at some actual numbers. Those for a typical F3 downforce CLA map are presented in **Table 1**.

Table 1: Typical downforce approximation for CLA of a Formula 3 car

Parameter	Value
c1	3.225
c2	2.5e2
c3	-0.03
a1	470
a2	2e6
a3	0.015
r1	0.0255
r2	81.5
r3	0.007

The first things to notice about the numbers in **Table 1** is that the peak CLA is greater than what we would expect to see in the typical ride height envelope the car would run in. This is perfectly normal because for this aeromap the downforce kept on increasing as the ride height dropped. This is a good example of why you should be wary of initial results, though, because to generate this peak downforce, the front wing would have to be buried 30mm below ground level!

The numbers associated with the a term are also very interesting. What they tell us is as the front ride height goes up, the downforce will drop quite substantially.

The r1-r3 terms also make for interesting reading. What these tell us is that a front ride height of 7mm gives us a ride height peak of 25.5mm. This is invaluable set-up information because, not only does it tell us where to run the car, it also tells us what we need to examine in further testing.

Sanity check

In short, **equation 1** and the numbers in **Table 1** give us the necessary language to describe an aeromap. This is important because it allows us to sanity check the numbers provided by a racecar manufacturer, and also gives us the ability to look at the results and sort the good data points from the bad when reviewing track data.

The power of all this is it gives us the ability to inform our intuition and look with a level of certainty at the results we have generated from aero testing or the track and put some hard numbers to our aeromaps. Using this, we can divine the set-up information we require.

In layman's terms, what we are doing here is taking a ride height map for downforce, drag and aero balance and breaking it down into a series of front ride height slices, which are a function of rear ride height. This is illustrated in **Figure 3**.

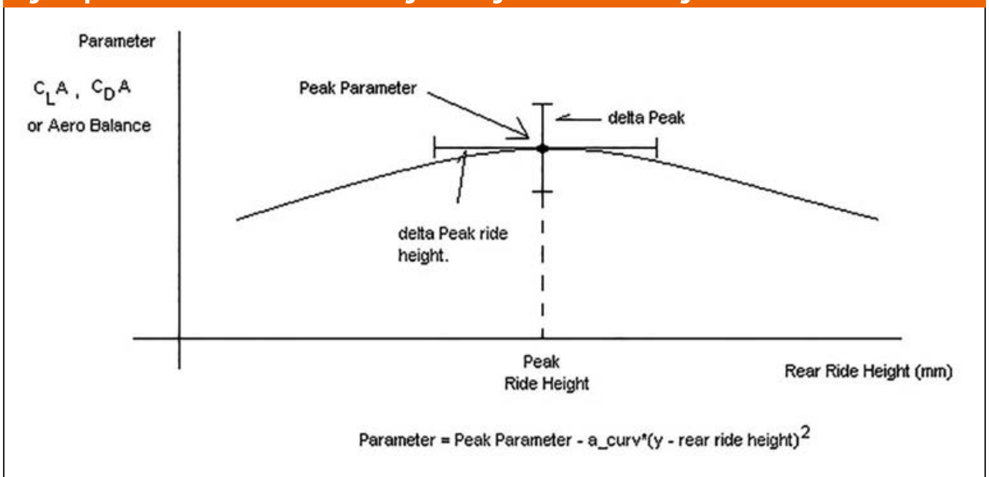
From a mathematical perspective, what we discussed in **equation 1** can be succinctly summarised by **equation 2**.

$$C_L A = C_L A_{PEAK} - a \cdot (y - rh\_r_{peak})^2 \qquad (2)$$

Where,

$C_L A$	= current CLA value for a given front ride height
$C_L A_{PEAK}$	= peak value of CLA
A	= curvature value
Rh_rpeak	= peak values of rear ride height
y	= current rear ride height

Fig 3: A plot of downforce vs rear ride height for a given front ride height



So, what we are doing with the aeromap is breaking it down into a bunch of front ride height slivers dictated by **equation 2**.

To reiterate, the reason we are using the formulation in **equation 2** is twofold. Firstly, the quadratic equation is the workhorse of curve fitting where you have a distinct minima and maxima. Secondly, this is a simple approach. From a conceptual level you have to try very hard to screw this up.

Better guidance

That said, when I first postulated this curve fit a decade ago, I was most remiss in not providing better guidance, particularly when it came to the curvature value. Where I came unstuck on this was when doing a job earlier this year on a low-downforce car. With the initial values of curvature set to 300, the results where far from ideal. This is shown in **Figure 4**.

You'll note the ride heights in **Figure 4** have been redacted due to confidentiality. Overall, the results weren't atrocious, but at the extremes, particularly at low ride heights, the CLA numbers drop of a cliff, and this just didn't add up with actual data.

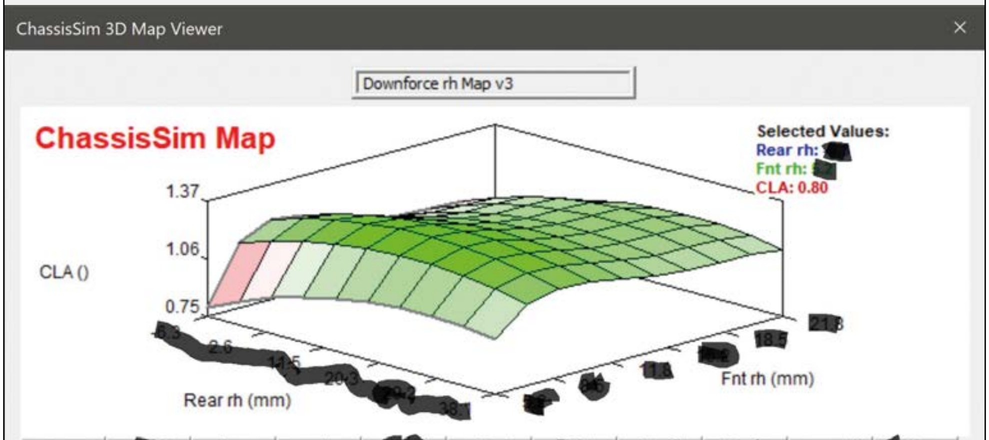
When the curvature values where revised to a value of 50, with a delta search of +/- 10, it became a radically different story. This is shown in **Figure 5**.

As can be seen, apart from the anomaly at the end (where we don't have a lot of data) the variation is now a lot more measured and believable. It also looks like something that would make sense. The anomaly at the end can easily be edited out, but it goes to show how you should take data fits as a guide, not as a definitive answer. These are curve fits and, by their very definition, won't nail it everywhere, but will get you into the ballpark (we're talking 80-90 per cent). You can then use your data to fine tune from there.

What this discussion also clearly shows is that key to nailing this method is ensuring your initial curvature value is correct. Your tell tale sign is how crazy the variation is. If the numbers start looking silly, like CLA and CDA of -1 or aero balances of -50 per cent, you drop the curvature numbers to suit. The rear ride height, delta CLA and CDA and aero balance values will all then play their part.

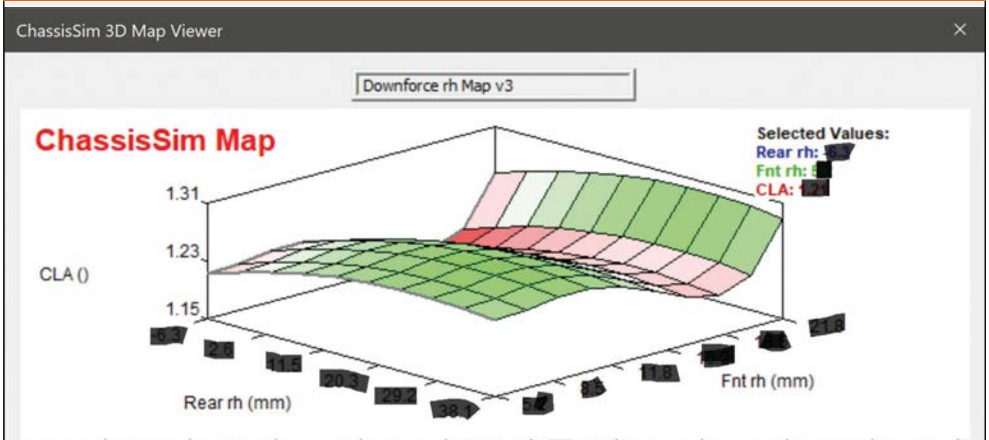
For interested readers wishing to go into this in greater detail, there is a tutorial on this very subject on the ChassisSim blog here: **https://www.chassissim.com/modelling-aeromaps-using-aero-surface-fitting-revisited/**

Figure 4: Initial ride height map with curvature set at 300



[redacted]	[redacted]									
[redacted]	0.799	1.10	1.18	1.16	1.09	1.04	1.02	1.01	1.01	0.93
	0.88	1.16	1.23	1.21	1.15	1.10	1.08	1.08	1.07	1.00
	0.94	1.20	1.27	1.25	1.20	1.15	1.13	1.12	1.12	1.05
	0.99	1.23	1.30	1.28	1.23	1.18	1.16	1.16	1.16	1.10
	1.03	1.25	1.31	1.30	1.25	1.21	1.19	1.19	1.18	1.13
	1.06	1.26	1.32	1.30	1.26	1.22	1.20	1.20	1.20	1.15
	1.07	1.26	1.31	1.30	1.26	1.22	1.20	1.20	1.20	1.16
	1.07	1.25	1.29	1.28	1.25	1.21	1.19	1.19	1.19	1.16
	1.06	1.22	1.26	1.25	1.22	1.19	1.17	1.17	1.16	1.14
	1.04	1.18	1.22	1.21	1.18	1.15	1.14	1.13	1.13	1.11

Fig 5: Aeromap surface fit with curvature now set at 50



[redacted]	[redacted]									
[redacted]	1.214	1.22	1.22	1.22	1.21	1.20	1.18	1.17	1.18	1.25
	1.23	1.23	1.24	1.24	1.23	1.21	1.19	1.18	1.20	1.26
	1.24	1.24	1.25	1.25	1.24	1.22	1.20	1.19	1.21	1.27
	1.25	1.25	1.26	1.26	1.25	1.23	1.21	1.20	1.22	1.28
	1.26	1.26	1.26	1.26	1.26	1.24	1.22	1.21	1.23	1.29
	1.26	1.26	1.27	1.27	1.26	1.24	1.22	1.21	1.23	1.29
	1.26	1.27	1.27	1.27	1.26	1.25	1.23	1.22	1.23	1.30
	1.26	1.27	1.27	1.27	1.26	1.25	1.23	1.22	1.23	1.30
	1.26	1.26	1.27	1.27	1.26	1.24	1.22	1.21	1.23	1.29
	1.26	1.26	1.26	1.26	1.25	1.24	1.22	1.21	1.23	1.29

These are curve fits and, by their very definition, won't nail it everywhere, but will get you into the ballpark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High fibre motorsport

The new Cayman Clubsport racer brings sustainable body panels and Porsche's electric vehicle technologies to the GT4 grid, with the hope of a one-make race series in the future

Porsche has started to test the components of its Mission R concept in a 718 Cayman GT4, says the German manufacturer.

The all-wheel-drive 718 Cayman GT4 Clubsport will use the entire electric motor and battery technology from the Mission R, with a maximum output of 735kW. The company has trialled the technology in simulation and achieved 450kW of power for 30 minutes, the duration of a Carrera Cup race.

'We are very excited about the response because a one-make cup with electric racecars would be an important addition to our existing customer racing programme,' says Matthias Scholz, GT racing vehicle project manager.

The car is 14cm wider than the 718 Cayman GT4, which allows the car to run wider wheels, and the bodywork is made of natural fibre composite materials, with the production intended to generate fewer emissions than that of comparable synthetic materials.

The car will make its public debut at the Goodwood Festival of Speed, held in the UK between 23-26 June this year.

The world's nastiest 911?

Ken Block has released his latest 'Hoonicorn' creation, this time based on a Porsche 911, with the intention of competing for overall victory at the Pikes Peak Hillclimb at the end of June.

The Porsche SVRSR is a one-off, mid-engine, all-wheel-drive competition car that was designed specifically for the Hillclimb and built by BBi Autosport, in partnership with Mobil. It weighs in at just 1000kg, is said to produce 1400bhp and features a GPS height-adjusted suspension system based on telemetry gained from the previous year's event.

'The Hoonipegasus is an absolute dream come true type of build,' said the founder of BBi Autosport, Betim Berisha. 'It just doesn't get any more mental from a tech, power, aero and visual standpoint.

'The original version of the car came from a long-time friend of mine, Joe Scarbo of Scarbo Performance, nearly a decade ago. We then teamed up with our most talented engineers and designers, threw the book out the window, and took an unconventional path. We are building the world's nastiest 911.'

Block's brutal-looking racer bears a resemblance to a Porsche 911, but is a one-off competition machine, built specifically to contest Pikes Peak

Green light for Lambo

Lamborghini has confirmed it will build an LMDh car to compete in the top class of endurance racing, bringing an end to speculation that has surrounded the manufacturer for many months.

The programme, which will see its competition debut in 2024, is expected to encompass the World Endurance Championship, including Le Mans, and the IMSA WeatherTech Sportscar Series that includes the 24 Hours of Daytona and 12 Hours of Sebring.

The company has long stated its ambition to go ahead with the project, but needed board approval from the VAG Group, which also owns Porsche and Audi. The former is leading the technical development on its own LMDh car, while the latter had its project 'paused' (or cancelled, according to paddock rumour) as it changes it focus to electric racing.

Lamborghini's programme will likely see the chassis built by Ligier, one of the four options open to manufacturers in LMDh and the only one without a factory partnership already.

Lamborghini is also expected to build its own engine for the project, although remains tight lipped on capacity or configuration. Company insiders only say the engine will be completely new, and that preparation work is advanced already. The rumour mill suggests the engine will form the basis of Lamborghini's new supercar, although that has not been confirmed.

Much of the delay to the confirmation of the project is because of financing within the Volkswagen Group, and it is understood that private funding has been secured for the racing project.

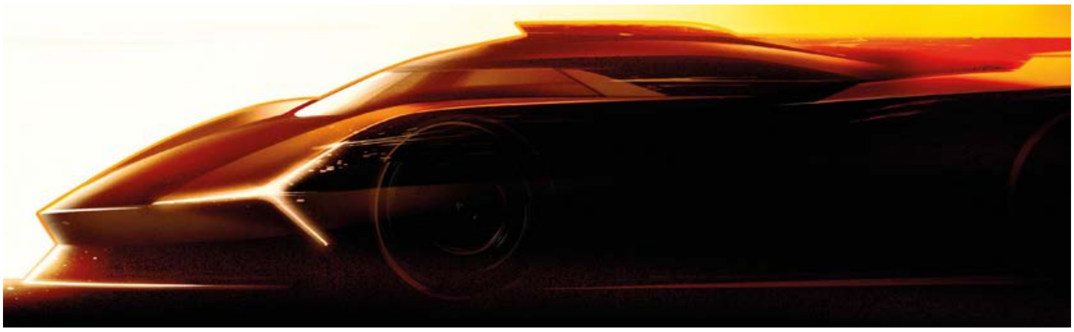
The car is likely to be run by the Iron Lynx / Prema team that is already competing in the WEC in the LMP2 category.

'I am absolutely delighted that Lamborghini will be taking the next step in our motorsport journey, the step into LMDh and the top level of Sportscar racing,' said Lamborghini's head of motorsport, Giorgio Sanna.

'LMDh will play a special role in Lamborghini's motorsport strategy, giving us the unique opportunity to expand our customer racing activities to new platforms and enforce our long-term partnership with customer teams and drivers.'

It is the first time Lamborghini will go for the overall win at Le Mans, having competed for many years with its Countach and Diablo models.

The project is expected to hit the track for testing late in 2023, although it is thought unlikely that it will be at the 24 Hours of Daytona race in January 2024, due to the delays in making final decisions.



A rival LMDh car from the VAG stable will make things very interesting on the grid at Le Mans, though we may have to wait a few years to find out

McLaren joins E to excite and entertain

McLaren Racing has confirmed it will compete in the Formula E series at the start of the Gen3 era. The McLaren Formula E Team will be formed through the acquisition of the Mercedes-EQ Formula E Team, and the transfer is expected to be completed later this year.

Ian James, team principal of the Mercedes team, will continue in his role to enable a smooth transition as the series heads into the new season.

'McLaren Racing always seeks to compete against the best, and on the leading edge of technology, providing our fans, partners and people with new ways to be excited, entertained and inspired,' said Zak Brown, McLaren Racing CEO.

'Formula E, like all our racing series, fulfils all those criteria. I firmly believe that Formula E will give McLaren Racing a competitive advantage through greater understanding of EV racing, while providing a point of difference to our fans, partners and people, and continuing to drive us along our sustainability pathway.'

The deal means that, despite withdrawing from the series at the end of this season, Mercedes' operation will continue racing.

The McLaren Formula E Team, the outfit formerly known as the Mercedes-EQ Formula E Team

IN BRIEF

Bosch has extended its relationship with the **Extreme E** series as the official power tool supplier for Season 2. The German brand will provide equipment to service Extreme E's electric SUV, the Odyssey 21.

The **IMSA** organisation has continued its deal with **Radio Show Limited** to provide commentary on all IMSA series, including the WeatherTech Sportscar Championship, IMSA Michelin Pilot Challenge, Prototype Challenge and other single-make series, including the Mazda MX5 Cup and Lamborghini Super Trofeo North America. Commentary is broadcast on the public address system, IMSA.com, Radiolemans.com and SiriusXM Radio.

Porsche has teamed up with **Avalanche Andretti**, the team founded by American racing driver, **Michael Andretti**, in the Formula E championship to form the company's first customer team for the 99X cars. The collaboration was announced before the Berlin round in May.

The **Indy 500** went ahead with a new marshalling system featuring LED panels strategically placed around the Indianapolis Motor Speedway. The EM Motorsport Marshalling System is activated with a push of a button by corner workers, and is in addition to the traditional flags. IndyCar is the first North American-based sanctioning body to use the EM system.

Royalty descended on gearbox manufacturer **Xtrac** as the **Princess Royal** met recipients of the Princess Royal Training Award at the factory. The visit followed the presentation of the 2021 award to 46 businesses at a special ceremony in London, of which Xtrac was one.

'Having twice received the Princess Royal Training Award, we were delighted to accommodate this visit following the recent official opening of our new apprenticeship academy,' said Adrian Moore, CEO of Xtrac.

'We warmly welcomed her gracious comments about the hard work we put into our apprenticeship and graduate training schemes, and that we should be justly proud of our successes and achievements.'

Interview – Stéphane Ratel

Open door policy

The godfather of GT3 racing talks of the class going to Le Mans in 2024, and what recent changes mean for his international and domestic race series in the future

BY ANDREW COTTON

The GT3 class started in 2006 and has since become the premier GT category in the world, with both national and international racing series adopting the format, and manufacturers creating customer racing divisions to support those racing in the class.

It has become big business, yet the rule set is owned by the FIA, not by the man who has become synonymous with the series, Stéphane Ratel.

The Frenchman has based much of his business on the class for more than ten years, but the FIA has steadily spread the category to other series, including the DTM, and in 2024 to the World Endurance Championship. Consequently, Ratel believes there are potential problems arising in the near future.

The Frenchman sat down at Imola in May with the editor to discuss his concerns for how the category is evolving.

'It is true that GT3 is definitely drifting,' says Ratel. 'We have maintained all along a real balance between sales and marketing return, which is wonderful in GT3. Manufacturers have customer racing departments, they have to sell cars to balance their development cost, and all the GT manufacturers we have in the paddock came with the prime objective of customer racing. They sell many cars, balance their cost and marketing in various countries and can use it when it suits them.'

Pro-am approach

'IMSA taking it to a pro series, DTM, and in some way also Le Mans, could be a disturbance. Even though Le Mans has come with the right approach of pro-am, I'm not entirely sure all the manufacturers will understand the spirit of pro-am, and will leave it entirely to their teams to find someone to finance it. That means you could have the best am[ateur] being paid more than the professionals.

'Nevertheless, even if that has an influence on the system, it is better than going pro at Le Mans, because that would have replaced GTE with GT3 and caused the same effect, which would have been the kiss of death in GT3.'

All the GT manufacturers we have in the paddock came with the prime objective of customer racing

SRO / Dirk Bogaerts Photography

Stéphane Ratel developed GT3 into a world business for all stakeholders, but never owned the regulation set. That was the property of the FIA and now his influence on the category is waning

SRO / Patrick Hecq Photography

BMW's legendary M3 was consistently refused entry into GT3 on the basis it was a saloon, not a sports car, so the canny German manufacturer entered its M4 coupé instead, and the FIA welcomed it

New manufacturers arriving into the category are normally celebrated, but Ford's announcement at Daytona that it will come with the Mustang has not been met with much enthusiasm from either Ratel, or some of the rival manufacturers. Ratel admits he missed the threat of the Mustang when it was being discussed in the meetings, and missed the boat on objecting to the project, which is why he now cannot stop it.

Ratel's position in GT racing was traditionally that he had final say on what could and could not be classed as a GT car, and he was instrumental in stopping the Ford GT from becoming a GT3 car, and Porsche not turning its mid-engine GTE car into a GT3. However, the manufacturers wanted more clarity, and worked with the FIA to create a stable rule set and technical regulations they could work to. The result is it's now a tick-box exercise, and Ratel is concerned that *anyone* can now build a car that complies, and there is no mechanism to stop extreme models coming.

The definition of GT

'If you go back in history, first with the Bentley, which was not a sports car, but the prestige of having Bentley meant we opened the door,' says Ratel. 'The problem is, what is the definition of GT? The Bentley was a sports car, GT a two-seater supercar, but when it arrived it became something else.

'We always refused the [BMW] M3 because it was a four-door touring car. Then they changed the name, wisely, saying the M3 was the sedan and M4 is the coupé. On that basis, the car is not a four door, it is a two door, so we can come.

'There, at that point, the FIA should probably have said no, it is still not a GT, but there they went. Now you have the Mustang, which is not only a two-door coupé, but a two-door coupé with a base model that is $28,000.

'The Mustang situation has just proven all the weaknesses of the way the FIA operates. In terms of the [base] price of the car, which was a key element that the commission put at €100,000 (approx. $105,250), that *de facto* would have outlawed the M4. But we had the Bentley, then the BMW, now the Mustang. What is next? The flood gates are open.

'Now, if you are any manufacturer who has a two-door coupé, you have a category to go to Le Mans, Bathurst, Spa, Nürburgring, DTM… Why wouldn't you do a GT3, since GT3 is no longer a GT? It is now anything with two doors, and you have a lot of cars with two doors.'

The fans, [the FIA] believe, will want to see Ford vs GM in the same class, and they don't care about the base model

It's a thought, but not one that holds much water with those running the series who welcome the Ford, to compete with the Corvette C8R that is currently in production for 2024. The two will face each other in IMSA, as well as the GT World Challenge America, and few in the US are concerned about the purity of the GT3 category. The fans, they believe, will want to see Ford vs GM in the same class, and they don't care about the base model.

Market influence

'Until recently, SRO was controlling about 70 per cent of the GT3 cars running in our events,' admits Ratel. 'If I said to a manufacturer, whatever you do, we will not accept you – and I said that a number of times – I was effectively killing the project. Now we are in a situation where our influence on the GT3 market [is less].

'Although we are doing well, because everyone is doing GT3, what we say doesn't matter any more. These cars are out, what will happen will happen, we will go with the flow, we will not resist.'

As a sweetener, Ford has indicated it will do the Intercontinental GT Challenge, the SRO's series that encourages manufacturers to support teams in their local territories (Australia at Bathurst, Europe at Spa, the US at Indianapolis, Asia in Suzuka and a growing African market at Kyalami) with factory drivers and a low level of technical support.

'We have larger manufacturers with more widely sold models coming to GT3 and we will see the effect of it,' says Ratel. 'We will go with the flow and see where it leads us.

'The most important thing is that we have a safety valve, which is GT2. If the whole thing becomes too expensive, or the technical evolution of the car is too high, what is important is to have something else.'

During the arguments surrounding the Mustang, Ratel made a proposal to split GT into two groups – sedan and GT. It didn't go down well with the manufacturers, or with the series organisers involved in shaping the GT3 regulations with the FIA, as it was too radical for them. They said it would have broken up the class and was not necessary, but Ratel disagrees.

Group therapy

'If you give 20 Matchbox models to a kid, they will put the muscle cars in one group, and all the others are sports cars. You can divide them quite easily into two groups, say we have the same regulations and let the promoters decide if they want to run them both, or just one or the other. There will be enough manufacturers to have a GT3 more touring car-orientated, DTM type, and another that is more sports cars.

'Now manufacturers like Ferrari and Lamborghini, they have Formula 1, Le Mans Hypercar, which is the sports car image, and then their super successful trophies. The moment you have a Mustang [in competition with] a Ferrari, it would not be shocking if the top [management] at Ferrari [stop the programme].

'The value in the stock market of the [Ferrari] brand is huge because of its image, and they have to protect that. They can say we are in Le Mans, with Hypercar, we are in Formula 1 and for the product we have the Challenge. Why do we have this being beaten by a Mustang?

'It is a risk we cannot deny, because the day you lose Ferrari, that's the end of the game in GT. We must be aware of that, but now it is too late. We are all a bit responsible because we saw it coming but were not careful enough. Now it is drifting toward touring cars mixing with sports cars, so let's see.'

Having accepted defeat on the Mustang argument and the separation of the GT-class cars, will Ratel try to block the Ford competing in his series?

'You cannot pick and choose,' he admits. 'If you have GT3, if you are an FIA promoter – and I am one of those – the reality is the FIA has homologated the cars and we have to live with it. I am not going to say that I will take

SRO / Dirk Bogaerts Photography

It was the Bentley that started the rot, but the prestige of the brand weighed heavily in that decision

If you give 20 Matchbox models to a kid, they will put the muscle cars in one group, and all the others are sports cars

the cars in America and don't take them in Europe. If next year [a team owner] comes to me and says he is going to run the Ford, am I going to tell him no?

'They are my client, they own the championship in some way, so they will come and we will have to deal with it. If we then lose Ferrari and Lamborghini, cars we don't want to lose, because they don't get anything here other than lose their image, thank god I have another baby that is ready, that is going to grow. That platform is built now.

'You see GT4 with young drivers doing well, so you have the up and coming drivers there. Then they come to where the best of the best are, while the more ageing clients go to GT2.

'GT2 is more cost effective, the cars are spectacular, and we want more diversity through constructors such as Brabham.

'So, if GT3 does has trouble, GT2 will be there.'

The day you lose Ferrari, that's the end of the game in GT

SRO / Kevin Pecks

To retain an air of exclusivity, one of the key ingredients of the GT3 concept was that roadgoing versions of the cars competing had to cost upwards of €100,000. You can buy a Mustang for $28,000…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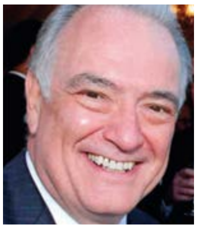

Constant change

Covid may now be under control, but a challenging future still awaits

What happened?! We were told this would be a period of renewal for UK industry and the wider economy, following the pandemic, and we would all emerge stronger than ever. Services and products of the motorsport industry are undoubtedly in great demand, but we need agility and determination to overcome a further set of extreme challenges.

We should expect hard work and constant change. Our main asset is our people, who are motivated by winning in a challenge-led environment. Competition is in the blood of motorsport businesses, so by utilising these skills our future is sound.

Motorsport Valley could benefit from recent plans from government. The chancellor confirms its focus is innovation, boosting spending on research and development and the new Advanced Research and Invention Agency (ARIA). Its strategy will be to protect and build world-leading industries in which the UK is strong, which should include motorsport.

Accelerated by the Formula 1 cost cap, many in the supply chain are securing business for their innovations from a wide range of sectors – aerospace, defence, rail and marine, amongst others. These are exciting times, full of potential opportunities everywhere.

Future power

Automotive has been the backbone of motorsport since its inception, but this link is diminishing as mainstream OEMs focus solely on one future power source – batteries. In the face of that, it's good to see the high performance mobility sector embracing alternative solutions, such as sustainable fuels, but increasingly, efficient internal combustion power units may offer even more exciting opportunities.

Porsche announced that, from next year, its many global motorsport programmes and Porsche driving centres will use sustainable fuels produced at its South American plant. We can expect others to follow suit, so accelerating interest in and popularity of sustainable fuels. Motorsport can lead in the development and use of such fuels.

XPB

Many of the top racing series, including Formula 1 and the World Endurance Championship, have switched to biofuels with the aim of reducing the sport's carbon impact

Once the full life cycle of battery power is fully understood by politicians, from mining and transporting rare materials through to the disposal of billions of batteries, sustainable fuels could get the green light. The Formula 1 group plans to use sustainable fuels in the next few years and, with the increasing popularity of F1 globally, this will influence consumers, too.

We are witnessing a significant change of direction in other areas, too. Motorsport primary sponsorships are moving from automotive brands to an array of alternative service sectors. The days when automotive brands would come and go, leaving teams in financial disarray, is over. The new breadth of consumer interest and brands will provide a more secure base in the long run.

Inflation is going to be with us for the next few years – some predict 10 per cent inflation by this year end, or even higher. Increased costs of gas and oil will be a powerful issue in this, but it is unlikely it will turn into another recession.

Post-Covid personal savings are said to be at a record high, so borrowing has reduced, spending has been suppressed and there are a great many job vacancies.

History shows that to survive in these times, you cannot afford to be slow in changing your prices, and should expect the same approach from your suppliers. Strict cash control and caution, particularly when setting credit limits, is absolutely essential. Companies should be light on their feet and agile, particularly in the pursuit of bad debts, in order to stay ahead of your targets.

Sadly, the unacceptable behaviour of Russia in recent months will affect us for some time. We all hope this stops soon, but sanctions on Russia and its suppliers present an additional challenge.

Nearly six years after the referendum, Brexit remains a headache for many businesses, who clearly need a new trading relationship with the EU, and fast. A recent IoD survey found that 45 per cent of internationally trading UK SMEs now export less to the EU than five years ago, while 31 per cent import less from the EU.

Despite these negatives, growth in demand for motorsport here and overseas is at unprecedented levels. The increase in popularity of Formula 1 encompasses many areas of society, and potential technology customers and suppliers have been contacting the MIA to be introduced to members and other race series. We are seeing similar interest and success in endurance, Touring Cars and rallying as well.

Chasing success

Chasing new revenues is the way to secure a future for motorsport companies. We cannot afford to sit and wait for circumstances to change. Customers are already booking to visit CTS2022, our new October Show at Silverstone, to find out more about the unique capabilities of motorsport. The show is attracting business visitors from across Europe and the USA who will place orders for delivery in the first quarter of 2023.

The MIA hold many B2B events, as all need to meet face to face with customers and suppliers, to generate new revenues. These popular networks are essential to get our industry moving in the right direction. Whether by working with the MIA, or other trade organisations, I urge all readers to make contact with people in the sector and explore collaborations to bring mutual success. We all know success in motorsport relies on teamwork, so contact the MIA team at info@the-mia.com if you need help. We exist to serve the motorsport industry, so please take advantage of our services.

For more information on the MIA, look up www.the-mia.com, or make contact directly via info@the-mia.com

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PIT CREW

Editor
Andrew Cotton
@RacecarEd
Email andrew.cotton@chelseamagazines.com

Deputy editor
Stewart Mitchell
@RacecarEngineer
Email stewart.mitchell@chelseamagazines.com

Sub editor
Mike Pye

Art editor
Barbara Stanley

Technical consultant
Peter Wright

Contributors
Mike Breslin, Lawrence Butcher, Danny Nowlan, Andrea Quintarelli, Dieter Rencken

Photography
James Moy

Group sales director Catherine Chapman
Email catherine.chapman@chelseamagazines.com

Head of sales operations Jodie Green
Email jodie.green@chelseamagazines.com

Advertisement manager Lauren Mills
Tel +44 (0) 20 7349 3796
Email lauren.mills@chelseamagazines.com

Marketing executive Eleanor English
Email eleanor.english@chelseamagazines.com

Publisher Simon Temlett
Managing director James Dobson
Chairman Paul Dobson

Editorial and advertising
Racecar Engineering, Chelsea Magazine Company, Jubilee House, 2 Jubilee Place, London, SW3 3TQ
Tel +44 (0) 20 7349 3700

Subscriptions
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Email: racecarengineering@subscription.co.uk
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Subscription rates
UK (12 issues) £84
Europe (12 issues) £100/€120
ROW (12 issues) £120/USD$165
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News distribution
Seymour International Ltd, 2 East Poultry Avenue, London EC1A 9PT
Tel +44 (0) 20 7429 4000
Fax +44 (0) 20 7429 4001
Email info@seymour.co.uk

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

THE CHELSEA MAGAZINE COMPANY LTD
www.racecar-engineering.com

Battle of wills

Why so much is hanging in the Balance (of Performance)

It was never going to be an easy marriage, but the rules of engagement appear to be clearer now than ever before as the FIA, ACO and IMSA seek to balance two-wheel-drive cars with four-wheel-drive ones and give each equal chance of victory.

The manufacturers building LMDh cars, on an homologated chassis and supplying engine and aero, are working together to deliver a competitive and reliable package in time for the Daytona 24 hours in January 2023. The LMH manufacturers, meanwhile, have given up significant performance to make the marriage work, which will allow them to race around the world, including in the United States, with their cars unchanged.

Juicy carrot

It's a big, juicy carrot on the end of a short stick, but bringing the concepts together has not been easy or straightforward, and nor have the LMH manufacturers been particularly happy about the way the negotiations have panned out as they have been forced to effectively nullify their front-mounted hybrid system, which by regulation they have to have.

Consequently, at the launch of the Peugeot 9X8, some grenades were thrown that highlighted the level of pressure they had been under.

The issue is not necessarily one of balancing the two concepts in outright performance, that will be sorted by the Balance of Performance. More pressing is the rather more complicated argument of what happens in a low-grip scenario, where four-wheel-drive is *always* an advantage.

'In this regulation, we think it is mandatory that BoP is rigorous and the outcome is of calculation purely engineering without any surprise and subjective tuning,' said Jean-Marc Finot, Senior VP of Stellantis Motorsport. That was quite an eye-opening statement. What else would BoP be, than an engineering-based calculation? Perhaps his comment comes because temperatures and track conditions vary wildly throughout a 24-hour race.

To allow for the extra weight of the front-mounted hybrid system and management of power delivery, the LMH hybrids were given wider front tyres. However, in the convergence, they were asked to go narrower front, wider rear tyre. This didn't work at all for Peugeot, although the team did consider the idea in the spirit of fairness, but had to dismiss it. It wasn't only a matter of time and budget. Going to a narrower front tyre could be to change the whole wingless concept of the car.

Finot's comments, in our feature on the 9X8 launch, took aim at those choosing the LMDh rule set, which is largely based on the engine and styling cues. That's not what Peugeot is selling or developing, and his argument is what's the point in producing an IC engine at this stage?

The answer, clearly, is that it's supposed to be cheaper to develop, encourage more manufacturers to join on a platform that does not cost what Toyota, Ferrari and Peugeot choose to spend, create variety in terms of identification and put pure racing at the heart of the regulation. However, for those developing LMH cars, it's easy to see why technical development is so important.

The real zinger in Finot's argument is that Toyota has the same size tyre this year as LMDh, and so can expect to have the same performance disadvantage as LMDh when compared to the Peugeot with the wider fronts. It's clearly in everyone's interests, other than Peugeot, that all cars run on the same size tyres.

> **It's a risky strategy to base your business model primarily on motor manufacturers**

Ferrari will compete on the narrower fronts and wider rears as its car won't race until 2023. There is clearly pressure on Peugeot to change its idea, and Peugeot is resisting.

In other areas of political intrigue comes the reason why ByKolles and Glickenhaus don't have their cars accepted into the WEC and IMSA respectively. The former claims to have rights to use the Vanwall name, the latter is not considered a big enough volume manufacturer. But at what stage do the governing bodies' responsibilities stop?

Superficial relationship

Given that Rebellion had TVR plastered all over its LMP1 car, and could not explain why, I don't understand this need for a superficial relationship with a volume manufacturer. Worse, to decide if a manufacturer is worthy of partnering with a team that *wants* to race in the series. Surely, if a car is built to the technical regulations, and capable of being performance balanced, it should be accepted.

The reason is because we are on the cusp of a golden age in terms of entries. As one observer put it, we are looking at gold for 2023, platinum for 2024, and what happens for 2025? Will it remain platinum, or slip back again, perhaps to silver? Either way, it's a risky strategy to base your business model primarily on motor manufacturers, whose primary concern is to sell cars, not to go racing.

ANDREW COTTON Editor