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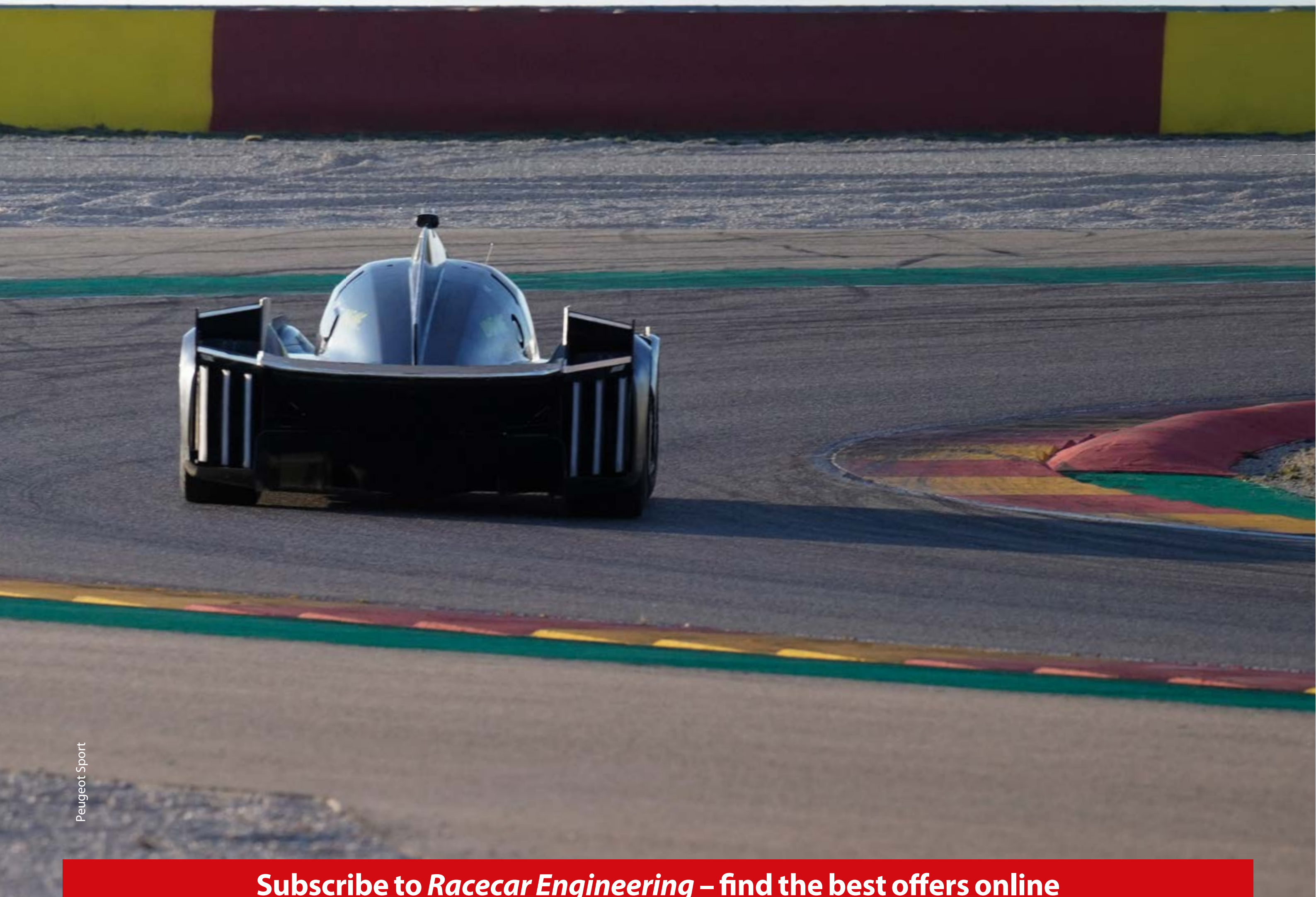
Below: The unusual Peugeot 9X8 Hypercar has been out testing, but the team needs to put in some competition laps at Spa in May if the car is to make the grid at Le Mans in June



Peugeot Sport

A different approach

Simulation is here to stay, and it's pleasing to see the young embracing it

I've race engineered since 2010 and each event, series and team have taught me new skills, but my time at Multimatic has so far been one of the biggest learning experiences.

Most of my career as a race engineer was at Audi Sport Team Joest, where there was a large element of trackside testing. I worked closely with simulation and performance engineers, but their day-to-day work, and the intricacies of their simulation tools, wasn't something of which I had first-hand knowledge. As the experts in their field, there wasn't a need to micro-manage, rather to provide guidance on where development should be focused.

Preparation process

Since coming to the Mazda DPi project, I was able to experience a different approach, one that is probably commonplace through multiple levels of racing and race series. And that was the use of the simulator as part of the preparation process for events.

This tool was not used extensively on the LMP1 for the simple reason that Audi Sport did not have one in house until the final two years of the project. Prior to that, limited use was made of a commercial one, but it's fidelity was compromised at times because the model wasn't constantly updated, correlated or cross checked against every test or race.

Multimatic has three simulators spread across its North American and UK facilities. Two are identical six-degree-of-freedom (DOF) systems, while the Detroit facility houses a nine DOF system. My main experience has been with the six DOF system in the UK and it has proved an invaluable tool for event preparation.

With a constantly maintained and correlated model, a two-day simulator session allows 40+ set-ups to be evaluated and four drivers to be brought up to speed before an event. This not only allows us to narrow down set-up parameters in advance of arriving at the track, but also to prep the team for expected changes and parts preparation. All of this helps in setting out test plans, priorities and dividing work between cars.

For the drivers, it's an opportunity to get laps under their belts and zone into the event.

The sessions quickly became an extension of the race week preparation. It was possible to test four or five damper options without downtime for physical changes or ambient differences. The reads were as clean as possible for the drivers, and gave a newbie like me a quick understanding of the Multimatic DSSV damper in action.

In a homologated series such as IMSA's DPi class, once the car is in a working window you need to look for all the small advantages you can find and exploit *everything* on the car to 100 per cent of its capability. By using a combination of simulation tools correlated with track testing, it was possible to evaluate multiple different parameters and further develop set-ups.

This has the huge advantage of creating a 'what if?' list that can be referred to at the track when specific car balance issues are identified. From the first test, I was impressed by how well the track reads correlated to the simulator.

Multimatic has three simulators in the UK and in the US which aid race week preparation

Admittedly, this level of correlation wasn't always perfect, and at one race in 2020 we did have to ignore the simulations and go back to old school engineering experience to make set-up changes. What was most notable doing this was that in past races, where the drivers felt we had given them a package that made the most of the car potential, the car wasn't quite as optimised.

Simulators and simulation are now easily accessible and used in almost level of motorsport, both for pre-race preparation and driver familiarisation. It might be seen as a less authentic form of engineering ability because there isn't the seat-of-the-pants engineering at the track, but that devalues what knowledge and engineering has been done in the background.

To develop a model takes a good understanding of vehicle dynamics fundamentals and an in-depth understanding of the software coding to troubleshoot issues. This is before any correlation and analysis work is started. Typically, performance engineers carry out this function and, with exposure to track testing, quickly gain a feel for sensitivity of changes and possibilities.

For many years, F1 has been driven down the simulation route with restrictions on track testing and limitations on development. The use of simulation and simulators to verify concepts has become an integral part of the racing process. Money that is saved from physical testing has been re-directed into simulation and this has driven the fidelity of software and models.

Engineering speak

Late last year I had the privilege of judging the four finalists in the Aston Martin Autosport BRDC Award for young drivers. All four were exceptional, but what astounded me more than anything was their knowledge and understanding of vehicle dynamics. They had either taught themselves the fundamentals or been guided by the teams they have worked with in F4 and F3. This will undoubtedly stand them in good stead for their future careers as it will help them work with engineers on car development and explain issues in engineering speak.

Asking some of the drivers, and their race engineers, why they were so knowledgeable at such a young age, it became apparent that with restrictions on team numbers and testing, the use of models and simulators has now become an integral part of their job.

The youngest driver had just turned 16 but spoke about simulators as a significant part of his preparation process for a race weekend, and felt that without it he was hugely disadvantaged because everyone was using these tools.

With the simulator developments that will come in the future, I'm excited to see how we will be preparing for races in the future.

Leena Gade is race engineer at Multimatic Engineering UK

With a constantly maintained and correlated model, a two-day simulator session allows 40+ set-ups to be evaluated and four drivers to be brought up to speed

Maximum *g*

Are we missing a simple method of controlling costs and increasing relevance?

Being a simple fellow, I favour simple solutions. So, to tear up a whole mass of aero and bodywork regulations in many racing categories, not just F1, how about a fundamental one that stipulates a maximum cornering *g* force appropriate to each?

Easily monitored in this digital and sensor-loaded age, and given a lower figure than is currently regularly achieved, the emphasis would turn from maximising downforce to minimising drag. Which, given today's environmental pressures, seems like a good thing. It would reduce energy consumption and take tyre development in a more beneficial direction. However, I must surely be missing something, otherwise it's obvious. To me. But then, I'm a simple fellow.

Major saving

Actually, I want to follow this idea through a little. Let's say, just for discussion and taking the extremes of F4 and F1, the limit might range from 2.0*g* to 4.0*g*. As well as the change in direction of aerodynamic development, it could be that teams would run the same level of downforce at every track in order not to exceed the set figure. Result: a major saving, at least in F1, by not having so many aerodynamic alternatives, which means reduced expenditure on multiple spares and tooling costs.

However, on some circuits – F1 at Monaco, for instance, where I suspect that, apart from the fabulous Swimming Pool 'piff / paff', a maximum *g* as suggested might never be reached – attaining highest downforce would still be favoured.

Still, if it's only one or two races affected, there nevertheless remains a cost saving. And with the introduction of budget caps in F1, this is a major issue, even for the top teams now.

What wouldn't be so great would be to see drivers and their engineers having to keep an eye on the *g* meter and backing off on fast bends to avoid a penalty. Or, more likely, a sensor linked to a PU function that would automatically reduce power. This could happen if engineers came to the conclusion that the benefits of high downforce regarding braking, traction and tyre degradation in the majority of corners on most tracks would still result in reduced overall lap time.

Regardless of this imposition on driver skills and commitment, it would eliminate the challenge that should be a key element in race driving. I suppose also stipulating a maximum braking *g* might help in countering this, and also assist with overtaking. Hmmm, it's starting to sound less simple than I first thought.

Such are the intricacies of rule making and the not always obvious knock-on effects of them. There is also the effective policing aspect. Friends of mine are very sceptical about the F1 budget cap. They contend that with technology developing as fast as it is, and some high-level cost items outside the cap, there are so many ways expenditure can be manipulated, especially for teams with major auto corporation backing. The FIA's accountants will have to really be on the ball to pick up any such deviousness, with severe penalties for significant breaches being the only effective deterrent.

It will be interesting to learn if any teams have been found guilty of overspend during 2021, the first year of implementation, as their year-end accounts are finalised and closely scrutinised.

XPB

The F1 cost cap appears to be working, but how long before all teams are on an equal footing?

Upping their game

Surprisingly, both Mercedes and Haas, albeit at opposite ends of the competitiveness range, actually upped their game towards the end of the season. Both have put this down to understanding their cars better as restrictions forced them to focus exclusively on extracting the optimum from what they had. Maybe there's a lesson to be learned from this?

I advocated long ago that in-season developments should be limited to maybe three opportunities only, as a means of reducing the resource advantages of the bigger teams. Because, like most in the business, I never thought a cost cap would happen. Now it has, and assuming it is being controlled effectively, it is achieving much more in levelling up the contest and reducing expenditure.

Therefore, with completely new designs it isn't a given that the two top teams will have it all their own way again in 2022. Mercedes had a much harder time last year than in previous seasons and failed to win the Drivers' Championship, I believe as a direct result of the cost cap denying the team the ability to throw money and resources at development.

Nonetheless, as with Red Bull, they still have a strong management and engineering structure. Despite denials, I suspect part of Toto Wolff's ongoing angst concerning the final race is driven by the realisation that taking risks on the design of the 2022 car to make improvements to the W12 to enable Hamilton to take the title again in 2021 have not worked out.

It may make 2022 more of a struggle, especially as winning the Constructors' Championship penalises them further. The team will now only be allowed reduced aero development time as part of the sliding scale introduced in 2021.

Red Bull's huge efforts may have a similar effect going forward, which could make Ferrari (at last) and McLaren potential threats regarding both championships. Alpine and the others still have a fair way to go, I expect, to have a genuine chance of grabbing the big trophies at year end, but there may be more surprises along the way.

PS Further to my previous column, it is pleasing to see that as part of the €80m investment to Spa-Francorchamps, Eau Rouge's run-offs are being modified to reduce the danger of cars bouncing back onto the track after crashing. The organisers and government deserve high praise for this commitment to motorsport's future at the track, though I hope the challenge of taking Eau Rouge 'flat' will be increased, not reduced as a result.

How about a fundamental [rule] that stipulates a maximum cornering *g* force?

Cap in hand

F1's cost cap has forced teams to take a long, hard look at every aspect of their business, but is the end result a fairer, more efficient operation?

By DIETER RENCKEN

Photos: XPB Images

Mercedes and Red Bull set the pace in 2021 with their two lead drivers, but how much will they be affected by a cost cap for the coming season and will that allow the rest of the field to close the performance gap?

Although F1's sporting and technical regulations were largely rolled over from the 2020 'Covid' season (around 60 per cent of the cars was carried over, although some of minor changes such as to floors and wings caused headaches) for practical and financial reasons, in 2021 F1 teams grappled with another variable, namely financial regulations – 'budget caps' in popular parlance – that were introduced after a protracted gestation.

Under consideration even before Liberty Media gained control of F1's rights in 2017, the budget cap restricts spend in performance-critical areas and is intended to level the playing field. Three main areas are targeted: car design and development, component manufacture, and testing and race operations. Spend in these areas was restricted to $145m (approx. £107m / €128m) in 2021, reducing by $5m (approx. £3.7m / €4.4m) per annum in 2022 and '23.

Ahead of the 2022 season, McLaren Racing CEO, Zak Brown, welcomed the reduction and glidepath. 'With the spending limit reducing to $140m this year and $135m next, the new financial regulations present us – and the sport as a whole – with a fairer framework to compete by reducing the inevitable advantage of the biggest spending and best resourced teams,' he said.

Exclusions to the cap are power units (at present), marketing / hospitality and team travel – to prevent cutbacks on standards of accommodation and flight classes – and car demonstrations and heritage (museum) operations. Crucially, despite drivers being major performance differentiators, their wages are also (currently) excluded from the cap, enabling better funded teams to gain distinct advantages in this quarter.

Equally, the top three salaries paid to team personnel are excluded, enabling wealthier outfits to recruit and retain top designers or strategists at the levels these command.

Still, the cap does go a way to redressing imbalances, although such are the facility and operational advantages accrued by major teams over the years that, according to AlphaTauri team boss, Franz Tost, momentum will carry them for three years, at least.

Kick in the Covid

A complicating factor is that introduction of the (then $175m) cap was timed to coincide with F1's 'new era' cars, planned for 2021. Teams would have open budgets during 2020 under which to design their new cars, while having headroom to spend on campaigning their outgoing designs. The cap would then kick in during the first year of operation for the new era cars. All was sweet, it seemed…

But then came Covid, forcing F1 to reduce the planned cap by $30m and simultaneously roll over 2020 cars on cost saving grounds.

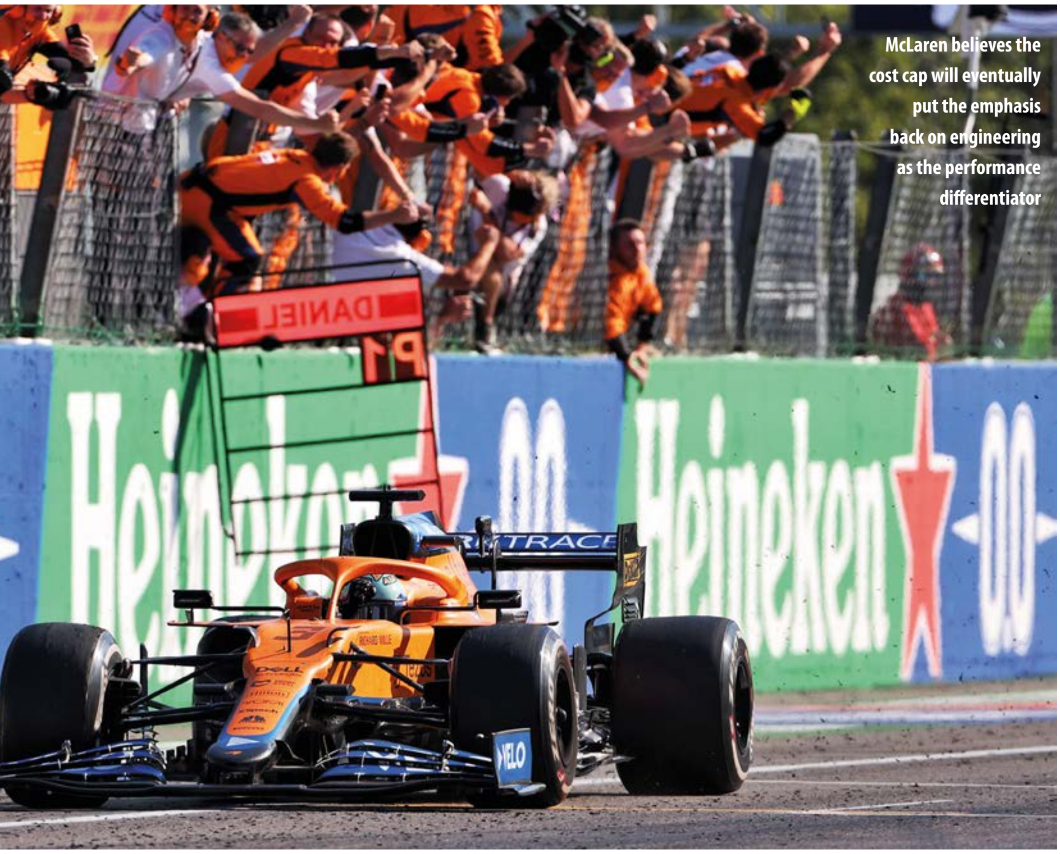
While these moves arguably saved various teams (and F1?) from bankruptcy, the bottom line is they immediately hurtled F1's plans for an orderly transition off the patio on the top floor of the FIA's building in Paris.

'[The revised] cap cannot be achieved without further significant sacrifices, especially in terms of human resources,' argued Ferrari team boss, Mattia Binotto, at the time. 'However, if the current situation puts the existence of some of our competitors in this sport in doubt, and make it necessary to revise certain cornerstones, then Ferrari would be open to it.'

'[The revised] cap cannot be achieved without further significant sacrifices, especially in terms of human resources'

Mattia Binotto, team principal at Ferrari F1

Overall, Ferrari says the cost cap has forced it to be more efficient, and to set higher targets for performance in all areas



McLaren believes the cost cap will eventually put the emphasis back on engineering as the performance differentiator

But, as always in F1, there's no gain without pain, as Binotto admits: 'With the financial regulations, we cut some of the development and cut parts of our organisation. When you've got a cap, you need to limit yourself.'

For example, Ferrari took an early decision to cease aerodynamic development of its 2021 car in April, bringing its final upgrade package to Silverstone in July after transferring various aerodynamicists to the 2022 car earlier in the year. Under a 'normal' budgetary regime the team would have pushed through much deeper into the season, possibly even to the final round.

That said, due to its internal values, Ferrari was fundamentally committed to reducing the human sacrifice where possible, with the benefit of also preserving its hard-won expertise, as Enrico Racca, Ferrari's chief of staff functions, points out: 'We first attacked any waste in production, especially to eliminate things we do several times because we were not able to succeed the first time.

'The team's head of chassis (engineering), Enrico Cardile, expands on that comment: 'This was the first way we tried to reach our target, and we improved our simulation instead of using physical materials.

'Of course, the budget cap is decreasing in the following years. We started on this path and we don't know exactly where it will lead in the end, but for the 2021 car we focused on what we have explained, and in 2022 we have plans to stay in the budget, while trying to preserve our know how.'

The introduction of the cap gave rise to perceptions that teams, particularly the better funded ones, were squandering money and needed to be saved from themselves, but Racca counters this. '[Controls] were in place, but the budget cap [forced] us to set higher targets with cost of performance to ensure that when we decide to improve, or to invest money in another direction, or a specific design or material, it is done for performance that we recognise the merit of, because now the [cost implication] is part of the performance,' he says.

McLaren technical director, James Key, believes it will take a certain amount of time for matters to settle in. 'There will be some mismatches in facilities and things for a little while but, as things begin to coalesce between the various teams, I think you'll begin to see much more of the performance engineering influence than we've been used to as a financial influence.'

Crash damage can be very costly, and at one point there was a suggestion of a compensation fund for innocent victims

A measure of how tightly the financial regulations impacted team operations was revealed during the Monaco Grand Prix, when Mercedes F1 CEO, Toto Wolff, admitted the team was unable to conduct wet tyre tests aimed at 2022's 18in tyre development due to budget constraints.

'We are trying to make the budget cap, which is not trivial, and we couldn't take the costs related to the tyre test and we wouldn't have been able to send our mechanics on such a long journey,' he said, adding the $1m costs in damage from Valtteri Bottas' Imola crash had tipped the balance.

Brown and Tost, though, believe the caps are still too generous, despite budgets for the majors tumbling by as much as 50 per cent, the latter telling *Racecar Engineering*: 'They are still too high. Teams just have to get used to [lower budgets].

Crash course

'It's a question of organisation, of management,' notes Tost. 'We were sitting together [in 2021] to plan for next year, and everything we could put into consideration we put in there, which means there should be no surprises because we know exactly how much money we have for car parts. That includes modifications, upgrades and so on.

'The only thing that could really cause problems are some very big accidents, expensive accidents, but we have some money on the side for this.'

To ensure employees grasped the full implications of the restrictions, teams staged internal training courses for staff at all levels to reinforce savings awareness in all areas. Still, considerable juggling was required to ensure maximum efficiencies, with savings in one area – for example, freight costs – benefiting car performance.

'In my specific area, the main impact is the freight,' explained McLaren executive director of racing, Andrea Stella. 'This is an operational element of going racing that's sometimes not in the spotlight, but actually is a considerable opportunity to generate savings and efficiency.

'I welcomed the push given by the budget cap, because we generated efficiency in the way we ship stuff around the world, and I'm pleased with the way we were able to do that.'

Unsaid was that the savings facilitated additional spend in car performance areas.

Key stresses that McLaren has also been more cautious with its materials selection process. 'There are some carbon fibres that are very expensive but very effective, and you sort of default to them knowing that your part will work as intended,' he said. '[Not doing that] adds a layer of workload and complexity onto material selections, but it's the right thing to do to reduce costs.'

According to various team sources, the cost of raw materials for a given car design are in the order of 10 per cent of the total, so substantially bigger cost savings are facilitated by simplifying the design of certain components, in turn reducing tooling requirements and manufacturing costs. Still, it is not a binary choice.

'The search for [better] material is a never ending area of development, both for performance and for financial saving,' confirms Ferrari's Cardile.

'I would not say we compromised our 2022 car by choosing cheaper materials. What we did is push for a more rational approach by challenging past assumptions, or challenging some choices we would have [made] in the past by going into deeper analysis to check if a certain material was really needed for a specific application.

'We now have another dimension that has to be taken into consideration,' he adds.

Sporting changes

This year's rules also include changes to the sporting regulations as part of F1's cost-saving ethos, including a reduction to three-day race weekends, meaning teams need to pack the same workload into one day less. This, too, has complicated the design task as the cars ideally need to be simpler to work on, in turn saving money.

'You want to have a car that is slightly easier to operate, so you don't find yourself up against time, or rushing, or having to complete the car in the morning,' Key says, 'which is never a healthy condition to be in because you end up missing other important aspects of the weekend if you're constantly flat out with your car.'

Having worked for a several independent teams before joining McLaren, Key has seen first hand the effects of cost restraints, noting, 'I've seen how much efficiency you can

Savings are being made in all areas, from material choice to freight to simplifying component design. But ultimately, for F1 to survive, it must retain its position at the top of the motorsport tree

With their eyes on the prize(s), both Mercedes and Red Bull pushed development of their 2021 cars to the absolute limit, no doubt spending every last dollar of their budgets in the process

'The only thing that could really cause problems are some very big accidents, expensive accidents, but we have some money on the side for this'
Franz Tost, team principal at AlphaTauri F1 team

gain by thinking in a different way, trying to extract maybe 80 per cent [performance] out of 30 per cent of the cost.

'There are definitely ways of working, which are kind of smart and to the point and prioritised and lean and kind of aggressive and agile. That's where you need to be under the cost cap.'

Nevertheless, it was all a balancing act, with Key admitting that restructuring the technical department to meet the cap was no easy task. 'We wanted the team to be internally recognisable, because it settled down into a rhythm of work with various groups operating very well together,' he said.

'So, we didn't go through a massive restructure in the way the team operates. We just looked at sensible directions. We needed to find efficiencies and found many. Disrupting the team would have been counter to our longer-term objectives.'

Alfa Romeo (Sauber) team principal, Fred Vasseur, agreed. 'Budget caps changed the mindset of F1, forcing the sport into efficiency mode.' he said. 'We have a [finite] budget and we have to make the best usage of [it].

'It's more the reality of business, back to the reality of life. You have to anticipate much more than before – what will be the impact of developments in terms of lap time? What issues could arise?

'Also, you can't launch parallel projects, you have to make a choice beforehand because you won't have resources for both.'

The French graduate motorsport engineer says it will be crucial for teams to make the right choices throughout *all* stages of their design phases as they will no longer be able to spend their ways out of wrong decisions.

'If a team takes the wrong way from the start [and] have to change some big component, this will penalise these teams for a very long period because they will need to spend a large part of the resources to change the monocoque, or the gearbox, for example, and [that will] take you to the limit of the cost cap,' continues Vasseur, adding that major components could be rolled over to the next season provided the regulations remain stable.

The big question, though, is how Mercedes and Red Bull – both of whom pushed development of their 2021 cars to the maximum for as long as they dared in their quests for both titles – will fare once F1's financial adjudication committee scours their respective accounts. While there are no suggestions that either team broke, or even bent, the rules, they surely ran extremely close to the limit.

'We tried to extend the life of components to cut down on frequency of replacements,' Red Bull chief engineer, Paul Monaghan, said in an exclusive interview with *Racecar Engineering*. 'We sought to curtail the number of large aerodynamic updates we could consider for the seasons.'

Close to the limit

Max Verstappen's Silverstone crash effectively lost Red Bull an entire car, and a second of that magnitude could well have cost the Dutchman's team two major upgrades, potentially torpedoing his title challenge. Indeed, teams have discussed 'crash compensation' for innocent victims of expensive incidents and, although talks went nowhere, that the topic was even tabled proves how close to the limit some teams are.

'We didn't want to spend money on just making spares replacements,' says Monaghan. 'We didn't want to spend money on making parts that were benign in terms of performance, and so by careful diligence and Friday running we were able to evaluate that we could make fewer components. So, a few pennies [saved there].'

There's no doubt the pinch was felt across the board, he says, with head count reductions and resource restrictions affecting design and development as much as research capability and manufacturing capacity. 'So, you try to minimise the effects of that.'

Financial adjudication

In terms of financial regulation, all teams are required to supply full documentation detailing all information pertaining to the operating year, as prescribed by the regulations, plus any declarations they may wish to table, by 19:00 CET 31 March of the subsequent year. In addition, the FIA reserves the right to impose spot checks at any point during the year.

All outsourced goods or services, whether obtained from another team or outside supplier, are subject to checks to ensure they are booked at 'notional values' to prevent teams from indirectly profiting from transfers from associated entities. So, for example, Red Bull could not supply sister team, AlphaTauri, with gearboxes for a dollar, or Mercedes have foundry work done at half price.

'There's quite a lot of checks going on,' Alpine executive director, Marcin Budkowski, told *Racecar Engineering* in Jeddah. 'We get regular visits from the FIA, regular requests for data and for information. Probably more than we expected, and at very short notice, including surprise visits to the factory. That's how it *should* be, though, and that's how it should be policed.'

The acid test will not be whatever outcomes arise from the adjudication process, but rather what penalties should be applied if teams are found in breach of any area of the financial regulations. Penalties range from reprimands through monetary fines and time penalties to race suspensions and even exclusion from the championship, with the nominated responsible executive(s) potentially in line for bans from the sport.

Crucially, though, no prescribed tariffs exist, as is the case with sporting and technical contraventions: breaches will be subject to penalties as above being handed down on a discretionary basis by the adjudication committee.

'The regulations don't specify what the penalty is for [a specific] breach,' says Budkowski. 'The reason they are not defined is that as soon as you define a penalty, teams start to calculate whether [a certain interpretation] is the right thing to do or not.' In other words, it's a deliberate decision to prevent teams trading lap time gains against the cost of specified penalties.

The million-dollar question remains, though: how low can Formula 1 actually go, having initially fought tooth and nail against any kind of budget cap, and then rolling over and accepting $175m before signing up for a pandemic-induced glidepath from $145m to $135 over three years?

The acid test will not be whatever outcomes arise from the adjudication process, but rather what penalties should be applied if teams are found in breach of any area of the financial regulations

Teams could, if they desperately need to, survive on $100m (approx. £73.7m / €88.2m), as Williams (and others) did recently. If all teams raced to such levels, it would hardly affect the competitive order. It might even tighten it. But would it still be the Formula 1 loved by millions of fans, and recognised globally as the pinnacle of motorsport?

Ultimately, market forces will decide whether fans vote with their feet, and whether broadcasters and circuits remain willing to shell out eyewatering sums for a parade of increasingly dumbed-down cars.

This is Formula 1's conundrum. Take budget caps too far, and the most capitalist sport on earth may well find itself paying the highest price for what, ironically, was intended as a saving spree.

In the interim, teams need to preserve sufficient budget to build and race their 2023 cars on another $5m less.

Red Bull was able to develop their 2021 challenger within the cost cap with intelligent planning. They sailed close to the financial wind, and one more crash might have scuppered their year


It's a new dawn,
It's a new day,
and we're Feeling GOOD.

Dominant force

Racecar ***gets the lowdown on the W12's season from Mercedes-AMG Petronas F1 technical director, Mike Elliott***

By STEWART MITCHELL

'To work within the regulations, you end up with something very complicated to achieve something that potentially could be done with a much more simplistic shape'

Mike Elliott, technical director at Mercedes-AMG Petronas F1 team

Mercedes AMG Petronas Formula 1 team

What can be said of the Mercedes Formula 1 teams' domination of the first hybrid era of Formula 1? Starting with the F1 W05 Hybrid in 2014 and culminating in the F1 W12 E-Performance in 2021, Mercedes Formula 1 cars have tallied an unsurpassable number of combined points every season since the dawn of the era, seeing it crowned Constructors' Champion eight years in a row.

The manufacturer's 2021 machine, the W12 E-Performance, was the most challenged by the opposition, mainly by Red Bull's RB16B, which won the highest number of races in 2021, but that wasn't enough to take the Constructors' title from Mercedes.

The 2021 season also marked the end of a generation of Formula 1, with a shift in technical regulations for the 2022 season and beyond, so teams had to decide when to stop development and shift focus to the '22 car instead.

'It's always harder to lead than it is to follow,' says Mercedes F1's Technical Director Mike Elliott. 'Our whole development strategy was unique because of this, and our approach throughout this era was, perhaps, less risky than our competitors because we wanted to maintain our lead rather than chase down our rivals. When you look at the string of championships we've had over the last eight years, to be able to carry that on so consistently is the bit I'm most proud of, and most impressed by in terms of what we've achieved.

'There have been several significant changes to the regulations throughout this era, 2017 and 2019, that could have caught us out and put us behind. But we prevailed in the end.'

The 2021 dilemma

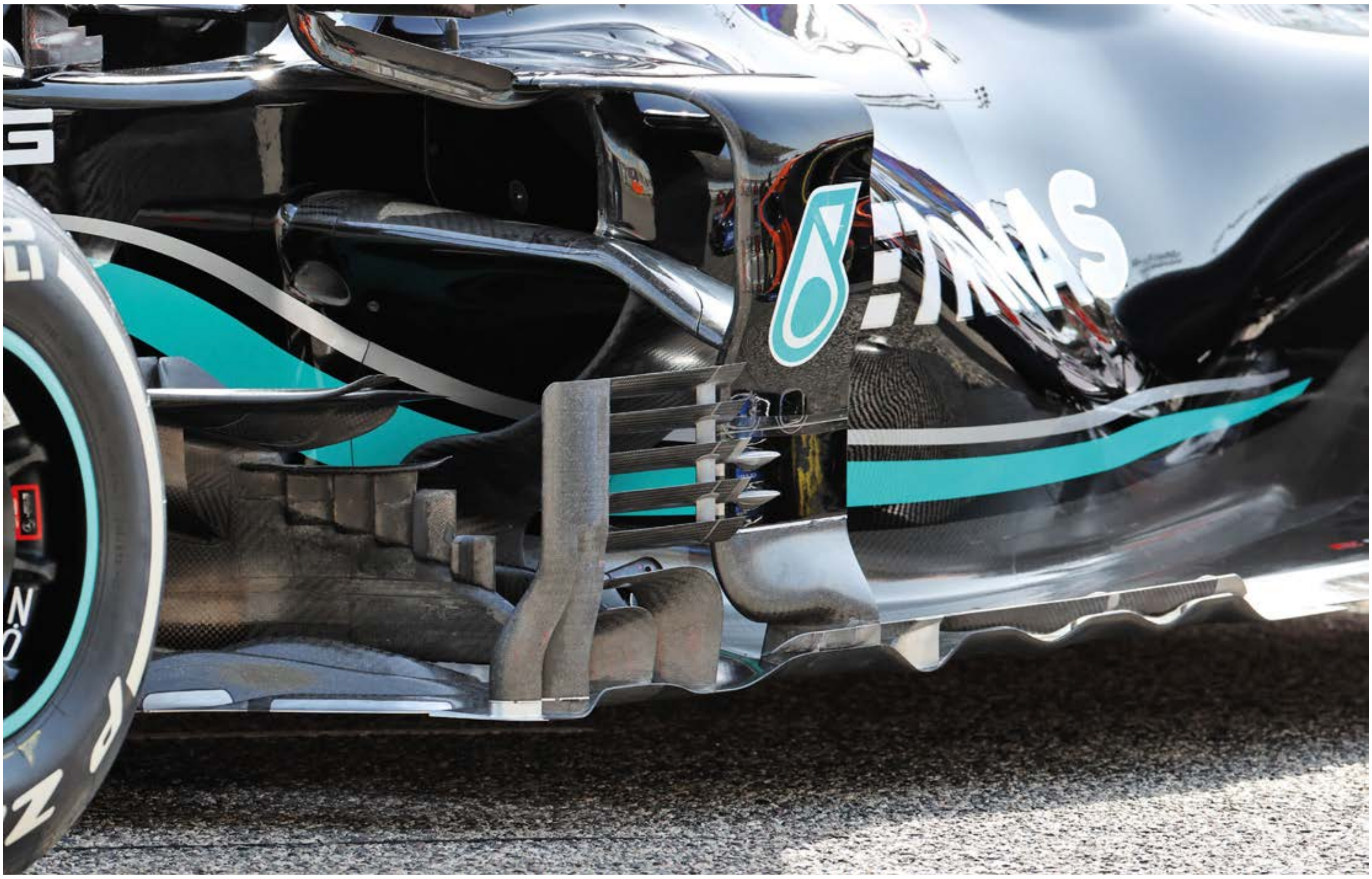
Entering the 2021 season, technical regulation changes, the cost cap, development strategy and resource management all played a huge role in teams' approach to the championship. Not least because it marked the end of a cycle of development under the outgoing regulation set. In the recent era, Mercedes has consistently loaded its development over the winter period, stopping car development early in the season to focus on the following season's car.

In 2021, this was particularly challenging as the W12 did not have the same advantage over the rest of the field as its predecessors. To stay ahead, that meant balancing in-season development of the W12 alongside pre-season development of the 2022 W13 car.

'When you're making that trade between working on the current year's car and following year's car, you know that every bit of effort you put into the current car will come with scant reward, whereas anything you put into next year's car can pay huge dividends,' explains Elliott.

'It's a brutal trade, and the 2021-2022 cycle was even more warlike because of the enormous 2022 package changes. We felt like we started this year on the back foot.'

The Mercedes-AMG Petronas Formula 1 team have been Constructors' Champions for every year since the hybrid era's inception. In 2021, it scored its eighth championship win in a row



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Early Mercedes AMG F1 W12 floor detail. The wavy outer edge of the front floor is an exit flow conditioner. The flow comes out sideways from underneath the floor at this unusual-looking feature, into a stream behind the bargeboard area. It then turns back towards the car and returns back in under the floor much further rearwards

As per all the cars on the 2021 Formula 1 grid, the Mercedes W12 E-Performance was somewhat of a carryover from its predecessor, the 2020 W11, but with some significant changes to coincide with the FIA's 10 per cent targeted reduction in downforce.

The drop in downforce came in the form of regulation changes that saw diagonal cut-outs in the floor ahead of the rear tyres, reducing the floor width at the trailing edge by 100mm on each side. Similarly, the height of the vertical strakes of the diffuser decreased by 50mm and the winglets mounted in the lower half of the rear brake duct reduced from 120mm to 80mm.

The effect of this was a profound change in the cars' ability to generate rear downforce, which the W12 relied on for performance.

Although it didn't appear so on paper, the aerodynamic regulation changes the FIA brought in ahead of 2021 were significant.

'The limitations in terms of what you could do structurally with the car, and the token system that allowed you to do bits and pieces, saw Red Bull take a bigger step on its 2021 car than we took,' concedes Elliott. 'When we were making W12 development decisions, around midway through racing the W11, we had a car with a significant advantage.

'Our strategy then was about trying to carry on that theme and extract more performance. Then we got the aerodynamic regulation changes that upset the apple cart as the die was already cast, and we'd already set the basis of what we were going to do with the overall car.

'The regulation changes were such a total hit to our car performance that our focus just became how can we correct that, and how do we get as much of that performance back?

'By the start of the 2021 season, we were in a similar position to where we were with the previous car in terms

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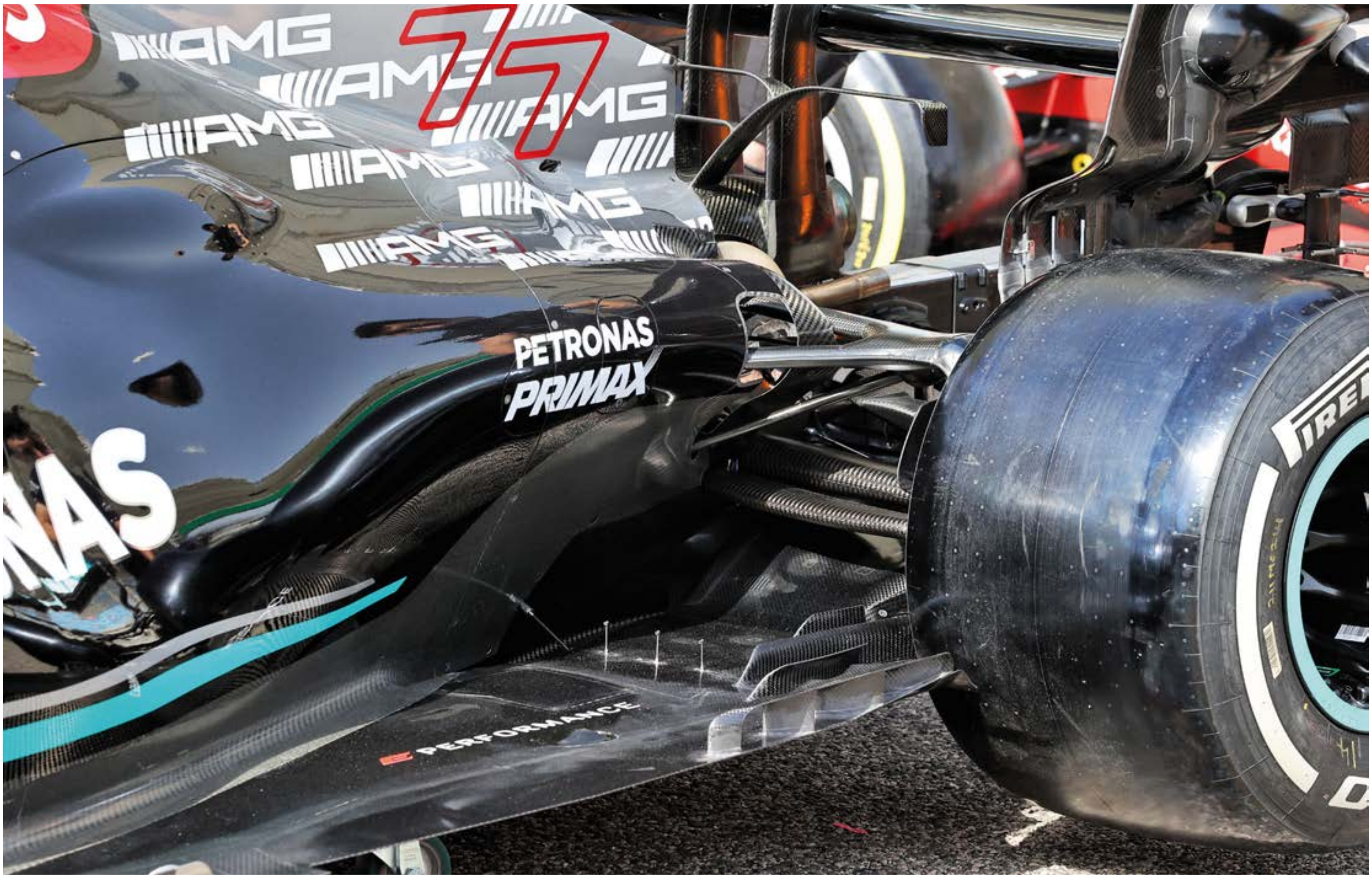
Red Bull Racing was Mercedes' biggest challenger throughout the 2021 season, the rival's high-rake philosophy RB16B seeming to have an advantage at some rounds of the championship



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FIA regulations cut away the floor in front of the rear tyres for 2021, which caused the floor edge losses to end up in the diffuser stream and become a dominant flow feature. To regain this, Mercedes didn't focus solely on local element detail, but on how all the flow structures fit together

of handling and balance, but less so regarding load, and therefore grip.'

Two-step change

The 2021 aerodynamic changes came in two steps, both pretty damaging to Mercedes. The team knew there would be a decent development slope early on, but the new regulations came late in the day, which saw Mercedes never actually use its two FIA-prescribed development tokens for the W12.

'With cars effectively locked down because of Covid, implementing the FIA token system meant most of the W11 architecture carried over, and we couldn't make significant structural changes,' says Elliott. 'This meant we had to develop the W12 from the base of the W11, which was designed to different regulations.

'The regulation changes were such a total hit to our car performance that our focus just became how can we correct that, and how do we get as much of that performance back?'

'We investigated how to recover the flow field towards what we had before [in the W11] as we knew that if we recovered that, we'd be able to recover some of the load. We also researched new opportunities in the 2021 set of regulations for a slightly different flow field.

'As we started to examine the losses created by the 2021 technical rule set, we discovered we were hit heavily at our rear ride height – the area where we'd had peak performance. Over time, it became clear that it hurt our car's design philosophy more so than it did the cars with a higher rake concept.'

Mercedes didn't have scope to shift completely away from its low-rake philosophy going into the 2021 season as the concept was integral to how the entire car's aerodynamics operate.

'You play the cards you've got,' says Elliott. 'We only had so many wind tunnel runs to turn the W11 into the W12, so we developed across the themes we understand. Learning an alternate philosophy was never an option, given the constraints we had in time and rules.

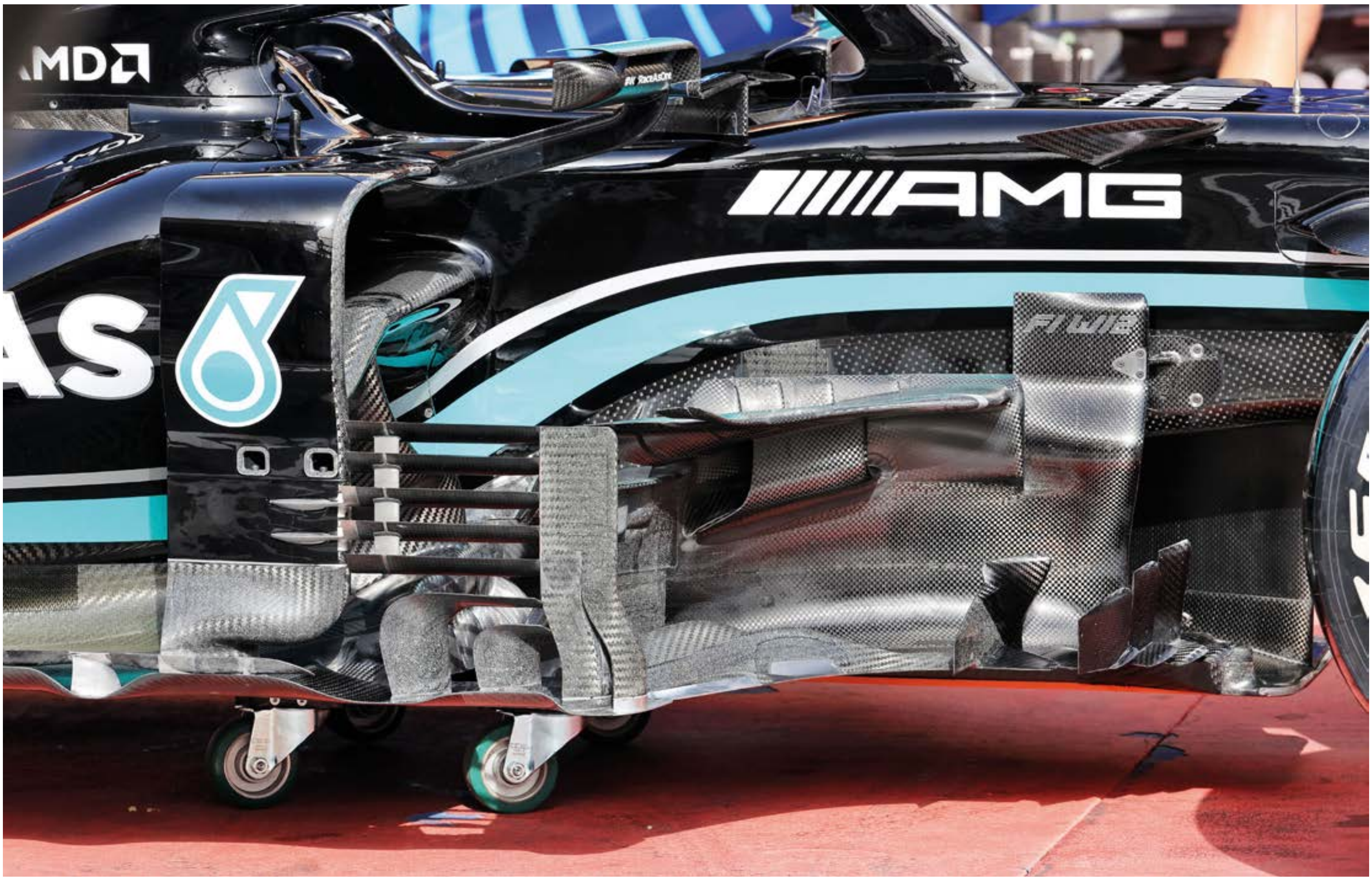
'It's fair to say that we have crept up on rear ride height over the past few seasons, though it's still nowhere near what some of the other teams have been doing. We simulated higher rear ride heights to see its effect on our car and discovered no benefit because we designed the rest of the car's concept for low rake.

'During the W12 development, we knew the rear end aero technical rule changes dominated the car regarding what we needed to do to recover performance. It was less of a philosophical discussion and more a case of saying, we've just taken this big hit, what are we going to do about it?'

Wavy floor

Early versions of the Mercedes W12 featured one of the most distinctive elements of the 2021 field – a wavy edge to the front half of the floor. This feature was one of the load-recovering devices introduced by the team, coinciding with the bargeboard and sidepod structures.

It has several functions, including out-washing the front tyre wake and creating and setting up flow structures under the floor, as Elliott explains: 'The wavy outer edge of the front floor is an exit flow condition. The flow comes out sideways from underneath the floor at this feature, into a stream behind the bargeboard area. It then turns back towards the car and comes back in under the floor much further rearwards.



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Early 2021 sidepod detail of the Mercedes W12, highlighting the now huge complexity of these aerodynamic structures

'The exit flow leaving this feature generates local load at the front of the floor without putting too much loss into the flow that may impact the car's rear flow fields.

'That floor design was an iteration in the process of trying to get the correct front floor loading, without damaging the aerodynamic performance rearward of that where we needed the most recovery.'

Regarding the rear floor, where the FIA rules had done the most significant damage to Mercedes' aerodynamic philosophy, Elliott says: 'There were two impacts here. The first from the reduction in floor area. Given a low-pressure zone under the floor and high-pressure above, the smaller the floor area, the less load it can create. The second is that the area in front of the rear tyre is susceptible to aerodynamic consequences of the varying rear tyre sidewall bulge and contact patch squirt [loss ejected by the tyre as it contacts the ground].

'These flow fields influence the diffuser downstream. So, when the FIA cut away the floor in front of the rear tyres, the floor edge losses end up in the diffuser stream and become a dominant flow feature.

'As for recovery, it's less about local element detail and more how it all fits together regarding what you're trying to achieve with the structures underneath the floor. Each part morphs together with the cake tin deflectors, the diffuser strakes and the diffuser sidewall. We worked on all those elements. The aerodynamicists had to work hard to investigate how to improve the control of those structures, and the result went some way to getting load back.'

Bargeboard loads

Having changed the side-impact structure from a high position in the W10 to a mid-height position in the W11, accepting the extra weight needed in the structure to meet the necessary stiffness requirements in that area, the feature remained for the W12. The primary driver for this design change initially was its influence on the flow to the back of the car.

'It goes in line with the bargeboards and what you want to do there,' says Elliott. 'The bargeboard has become a vastly complex structure that not only conditions flow and generates outwash of the front tyre wake, but has been designed to generate load in recent years.

'A few years ago, you would have said that the bargeboard's primary job was to condition the flow from the leading edge of the floor to the back of the car. However, in recent years, you can see that the architecture has become vastly more complex, with an intricate Venetian blind-shaped structure on the ground plane appearing on bargeboards of many of the cars up and down the grid.

Aerodynamic elasticity was a significant discussion throughout the 2021 Formula 1 season

'That generates a chunk of local load from those Venetian blind-shaped parts because we have a pressure delta over an area there. Bargeboard design has shifted the development in this space, balancing flow field control and the local load generation simultaneously.

'At no point, however, do you want to sacrifice the conditioning of the flow field behind the bargeboard, so we were sure to be accurate there.

'If we had just put a flat plate on the ground plane to reflect some of the high-pressure air in this region on top of that and direct low-pressure underneath it, it too would have generated local load. However, this would have put a significant loss into the flow field and damaged the aerodynamic performance of the rest of the car behind this structure.

'Additionally, the constraints in the regulations in the bargeboard region prevent teams from doing something that would be an ideal shape for this structure.

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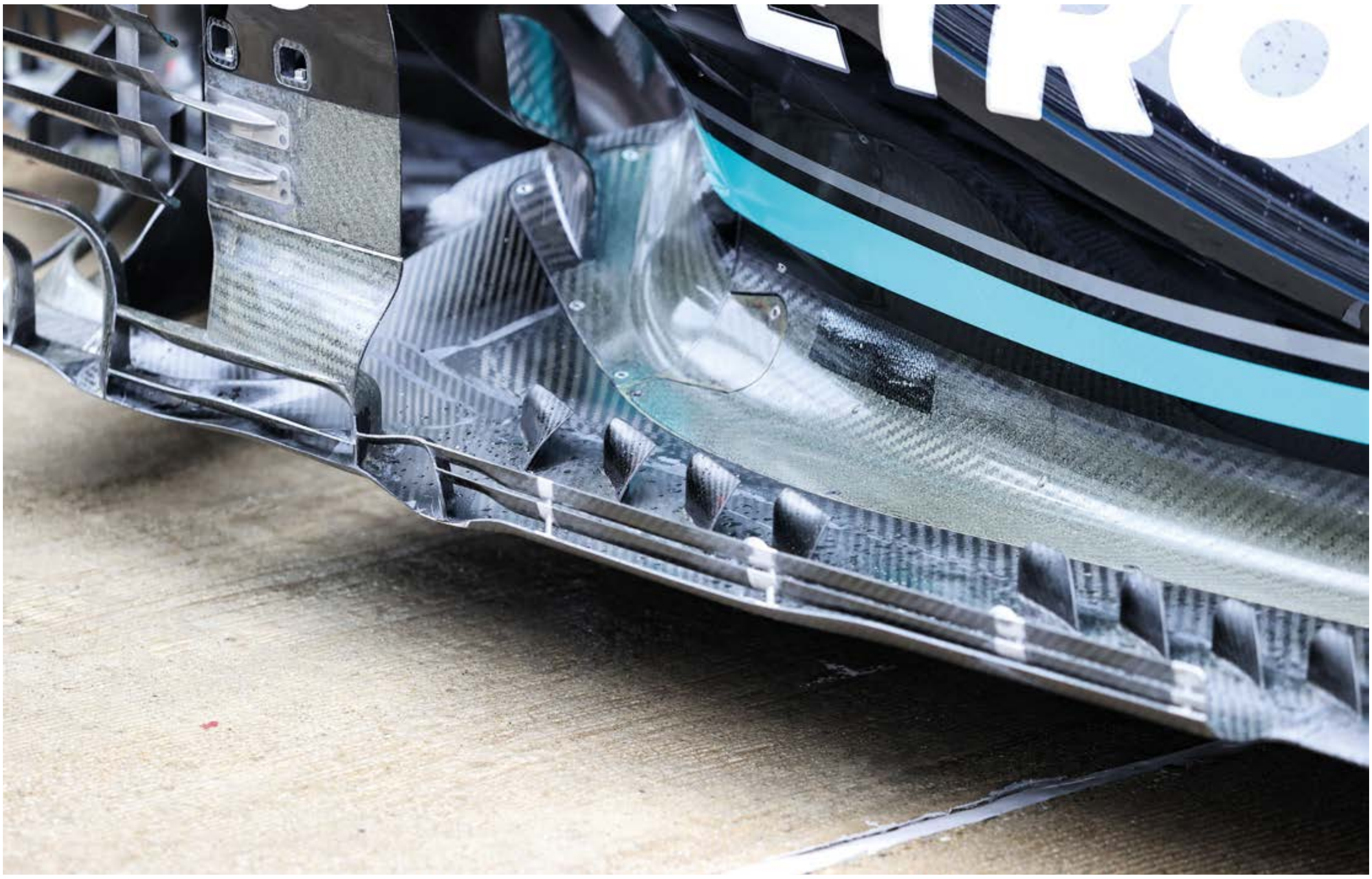

Later season floor detail saw the W12 sport larger Venetian blind-style strakes down the side of the car in a bid to generate more localised load in this area

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When it was suggested the front wing of the W12 was flexing more than it should, the FIA intervened. Datum point stickers and cameras monitor wing displacement during the investigation, but no further action was taken

So, to work within the regulations, you end up with something very complicated to achieve something that potentially could be done with a much more simplistic shape.

'Additionally, as the regulations have stayed broadly the same for a reasonable chunk of time, teams develop more complicated structures to keep finding performance.

'We were probably one of the earlier adopters of the very complicated bargeboard region with the Venetian blind-shaped solution, and others have done the same with the strake features in their sidepod leading edges.'

Aeroelasticity

Aerodynamic elasticity was a significant discussion throughout the 2021 Formula 1 season. The FIA put the Mercedes W12 wings under scrutiny after its wings were seen deflecting at high speed, potentially providing an aerodynamic advantage by reducing the drag on straights and returning aerodynamic load in the corners.

The rulebook accepts some wing deflection, both front and rear, allowing them to twist backwards to a given displacement from their static position. How far the wings were deflecting was looked at because it potentially offered those exploiting this somewhat grey area a significant change in the downforce, and therefore load, the wing generates at speed.

The FIA has a template for the wings and addresses the wing movement using cameras and datum points mounted to the wing surface. The phrase 'nothing can be infinitely stiff' was presented to the FIA by those under investigation on several occasions in response to allegations that wings on cars up and down the paddock were flexing too much.

Mercedes was one of the teams investigated, particularly with regards to the W12's front wing. 'It's not something we were trying to do deliberately,' says Elliott. 'There's a load test you have to pass, and it's pretty tough, and we passed that without any issue. When you look at the shape of the front wings, stopping them backing off under load is quite hard. If you wanted to stop them backing off completely, you'd end up having a huge main plane and junction between where the main plane goes into the Y250.

'The junction between the Y250 inboard and outboard is quite critical in terms of what it does for the flow field so, in terms of getting the aerodynamic shapes we want there, we compromise the structure quite a lot. You would end up with a horrendously heavy front wing to try and get it strong enough to stop backing off at all *and* get the aerodynamic shape you want.

'In our case, we will always try to design the wing to the load test required, which we did, and this will consequently give us some deflection under load. The backing off of the front wing wasn't aerodynamically something we wanted on the inboard end as the load went up.'

The load carrying sections of the front wing, which are the areas where pressure delta generates, are not very complicated. The complex element is the part managing the vortices that come off the Y250 and those that manage the front tyre wake. These are what were particularly analysed on the W12 after they were seen flexing back under load at the Baku GP, though the FIA took no further action to have them addressed.

Balancing act

Of course, there came a time in 2021 when Mercedes decided there would be no further development of the W12, and the focus and resources shifted to the W13. That happened at a predetermined point in the season, and the team knew that any advantage it had then would dwindle afterwards. The car's performance would therefore remain static for the remainder of the season, albeit with set-up changes tuned for each circuit.

Mercedes brought in the last W12 upgrade at the Silverstone round of the 2021 season, with wind tunnel testing stopping a month or two before that.

'There are descending wind tunnel runs available from last to first place in the championship title within the aerodynamic testing restrictions,' highlights Elliot. 'We knew we would be in a position where we'd given up a significant percentage of the runs compared to the teams who'd not scored so many points in 2020.

'As such, we had this double whammy of being in the 2021 championship fight, where pushing loads of runs into the W12 could have helped, but fewer runs available than anyone else. We didn't want to end up on the back foot for 2022 because, if we start that season poorly, we could be on the back foot for a long time.'

As it turned out, the gap between Red Bull and Mercedes in the remainder of the 2021 season was minimal, and the circuits, track conditions, temperatures and tyres all influenced the results.

'We didn't want to end up on the back foot for 2022 because, if we start that season poorly, we could be on the back foot for a long time'

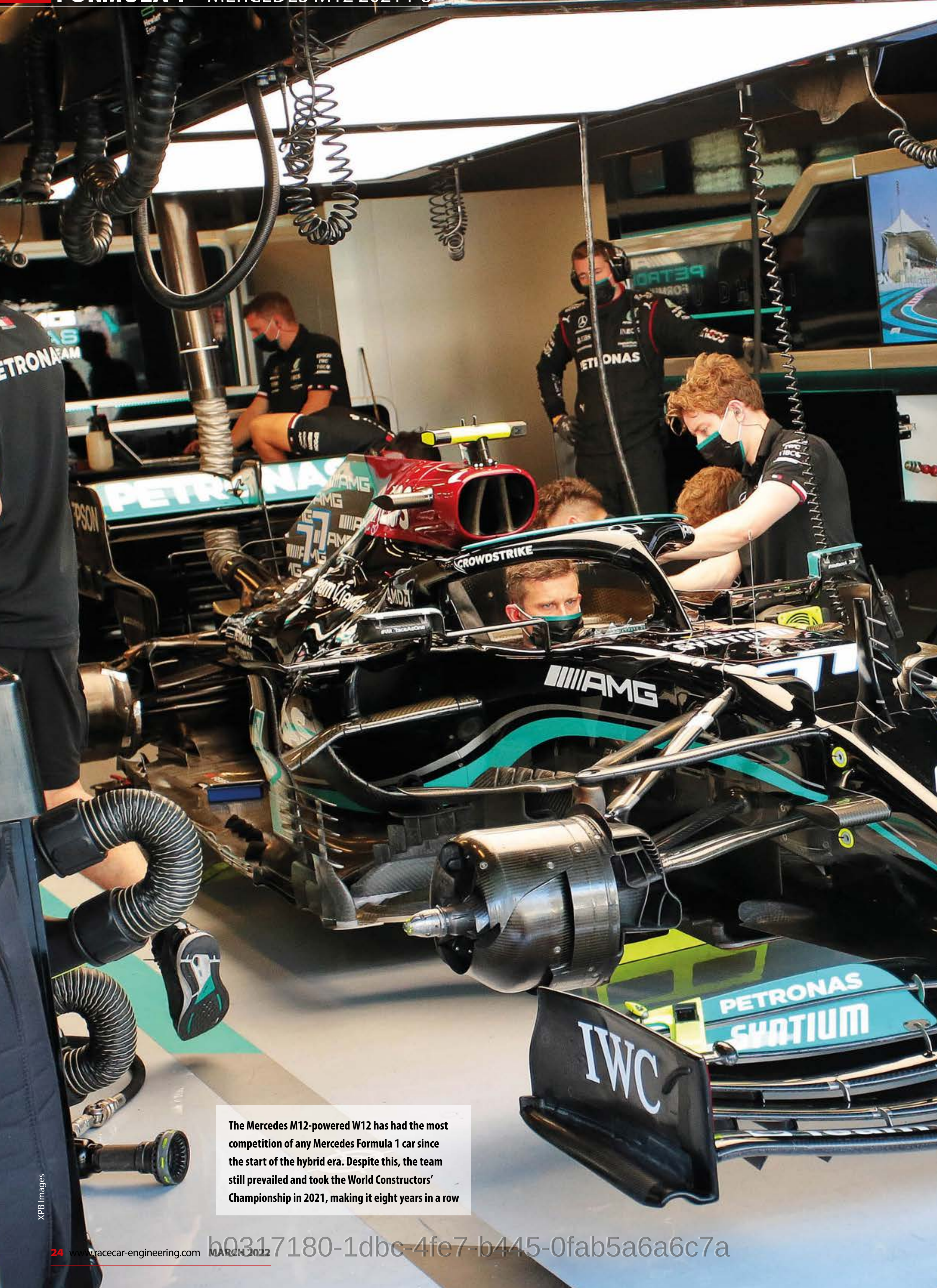
'At some points during the season, we were trying to predict where we'll be good and where we'll be bad, but we quickly realised that was a fruitless exercise,' admits Elliott. 'After the final updates were made at Silverstone, the development direction just became, how do we get the best out of this version of the W12 car? And then developed that in the virtual world and the driver-in-the-loop simulator.

'From there, we could say this is the right set-up and, if the track conditions evolve in a given direction, that involves us setting the car up in a certain way, and we'd likely move x, y and z.

'That is how we hedged our bets towards the end of the season, and turned up with a car we could optimise quickly on the Friday of a race weekend. The results of 2021 were what they were.'

Mercedes AMG Petronas Formula 1 team

The 2021 British GP was the last time Mercedes brought upgrades to the W12 to the track. After this point, the team's development effort shifted focus to the 2022 W13



The Mercedes M12-powered W12 has had the most competition of any Mercedes Formula 1 car since the start of the hybrid era. Despite this, the team still prevailed and took the World Constructors' Championship in 2021, making it eight years in a row

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Power house

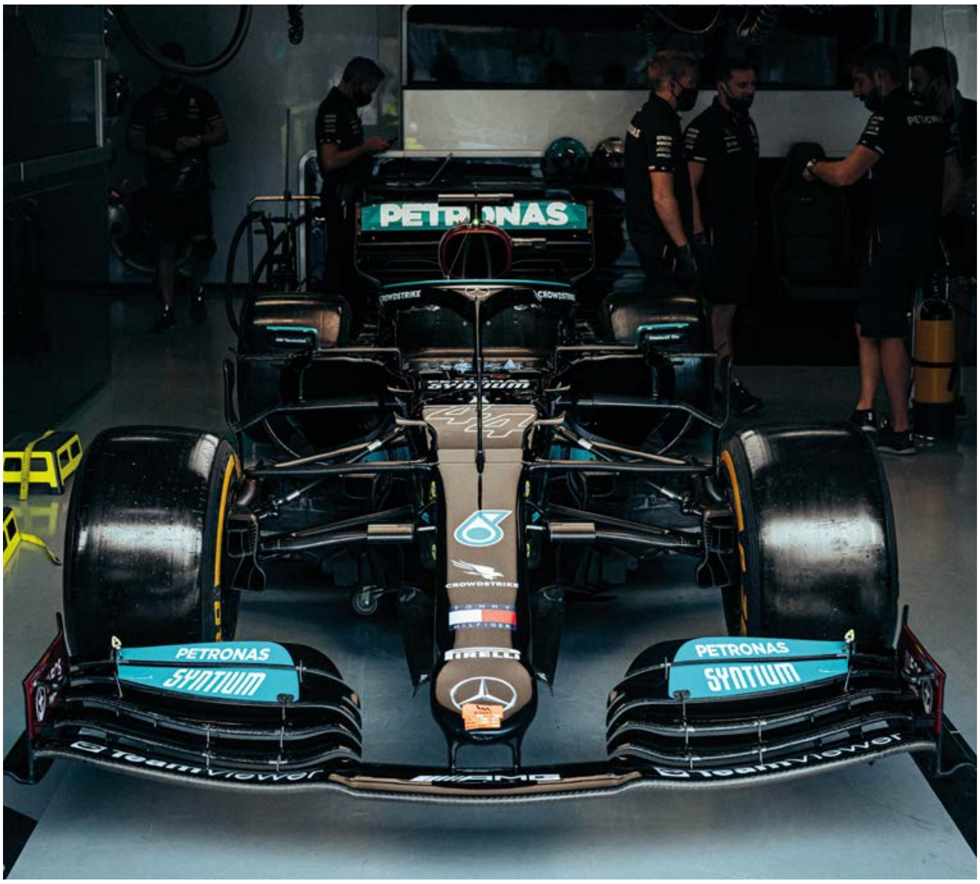
Racecar *asks managing director, Hywel Thomas, how Mercedes AMG High-Performance Powertrains approached engine development in the 2021 season*

By STEWART MITCHELL

Mercedes AMG High-Performance Powertrains (HPP) developed the M12 2021 Formula 1 power unit, chasing every possible improvement to deliver a step forward when it hit the track in all eight cars it powered during the 2021 season. Going into the eighth season of stable regulations, the power unit manufacturers understand the current hybrid engines, but rule stability also means it's increasingly challenging to unlock additional performance. Teams therefore need a highly focused approach.

According to Hywel Thomas, managing director of Mercedes HPP, ahead of the 2021 season Mercedes-AMG HPP identified three main areas on which to work: improving the efficiency; improving technology in the power unit and improving reliability, while also adding innovation into the racing power unit. That was particularly challenging because last season finished late. Hence, the winter development period was shorter than average and gave the teams less time to prepare, putting extra strain on the industry.

The hunt for performance was emphasised further by the 2021 technical regulation that permitted a single hardware performance specification, rather than allowing upgrades at different points throughout the season.



Mercedes

The M12 engine that powered the W12 is an evolution of Mercedes' hybrid technologies that it has brought to the track since 2014

Three's a crowd

There was also an increased production workload in the build up to the 2021 season, with McLaren joining the stable of Mercedes customer teams, That presented an extra challenge for engineers at the Brixworth, UK-based factory. The 2021 season marked the first time a Mercedes PU has powered a McLaren since 2014.

'A third customer team did put more pressure on the organisation,' admits Thomas. 'We needed to take more engines to winter testing and all the races, but we didn't want to freeze our designs any earlier because of that. So that put additional strain on the internal and external supply chains, as well as the build and test team to develop the design for as long as possible.

'What we gain is another group of chassis designers looking at the power unit, looking at how it works, how it's integrated into the car and how it's working with the rest of the package. We could add all those comments and ideas into the melting pot of the season, and all the subsequent seasons.'

The FIA introduced several unexpected restrictions to power unit development during 2020 in response to the Covid-19 pandemic. The 2020 / '21 winter period was therefore the first for Mercedes HPP working with the enforced reduction in dyno hours, alongside the singular performance specification for the hardware.

'It's similar to how wind tunnel usage has seen restrictions for several years, but we had to implement the restrictions with immediate effect for the dyno,' says Thomas. 'We then needed to decide earlier what projects to focus on because we couldn't afford to use precious dyno hours on ideas that end up not making it to the car.'

Reliability

Last season saw a form change for the Mercedes team, which appeared to not have the power advantage over its rivals compared to previous seasons. It suffered from reliability challenges too, in the lengthiest season of Formula 1 in the contemporary era. 'With 22 races on the calendar, it made the three power units per car for the season significantly harder to achieve,' highlights Thomas. 'It's a challenge to get the power units to survive so many races competitively, and then there are so few spares that you can use. It's a strategy game as to when to use them and when to take a penalty if you can't make it to the end of the season on three.'

Both Mercedes drivers suffered for this on several occasions in 2021, which saw both taking grid penalties at several tracks, coinciding with the rules for using more than the FIA-prescribed allocation of PU parts.

'What's not always clear is there is always power unit development going on in the background, and for us, in 2021, these were mostly addressing reliability challenges.

'We needed to decide earlier what projects to focus on because we couldn't afford to use precious dyno hours on ideas that end up not making it to the car'

Hywel Thomas, managing director at Mercedes HPP

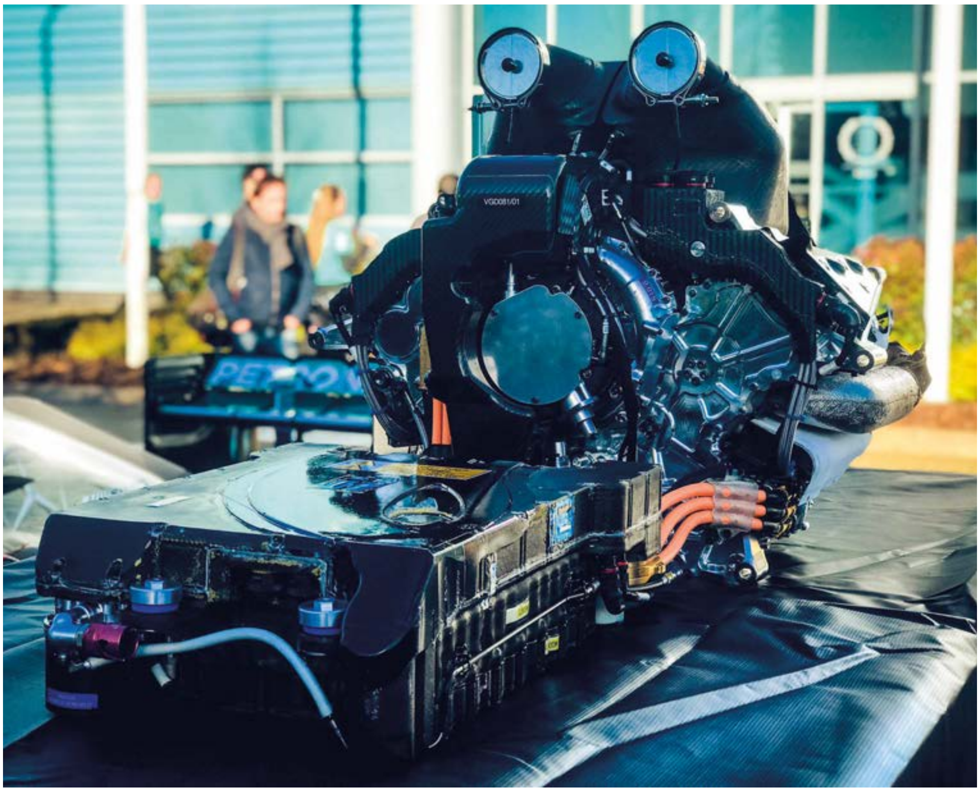
'Some of that is about damage limitation in the current specification, and other development is addressing reliability issues for an updated engine specification in 2022.

'We're nearly always managing something, and we are always trying to control what risk we are carrying, and what effect that will have on our ability to score points. We are always doing that trade and calculations.

'The nature of the challenges we encountered in 2021 and our calculations forced us to swap engines for fresh ones several times in the season. Overall, that provided a better point scoring opportunity as the risk of a terminal failure and, therefore, a non-point scoring race was too high.

'If you look at how the power units evolve as we increase the performance, and change how the power is used, and change some of

Mercedes



Example of a Mercedes HPP Formula 1 power unit. This version is from 2018

Mercedes

Mercedes HPP was careful not to change the packaging of the M12 too much so it didn't disturb the aerodynamics of the W12 chassis

the design and friction regimes, you'll see you're also going to change the load case. And we're not in a position where we run statistically significant numbers of engines so you can find out every nuance of a component's capabilities.

'You do your best over the off-season to do all your analysis and runs on the dyno to ensure none of those things catch you out, but occasionally they do.

'Additionally, if there's a distribution of the capabilities of a component, you might find, by some stroke of fortune, you prove your system with high-end versions of some components, and end up with something that perhaps is not so in the race pool. This is quality control that can catch you out.

'Also, from year to year, the issues change. You may be addressing a problem with a piston for two or three years, and probably get yourself to a position where you developed it to the point where you don't see it again. But then as you optimise one element, another may fall out of favour.'

Development strategy

In the early days of the hybrid regulations, the most significant proportion of research was allocated to electrical items. These were the newest features of the powertrain, and the most immature going into this regulation cycle. However, the regulations on the electrical side are now heavily prescribed with power, energy and weight allowances. Although teams continue to develop them for efficiency, the amount they've changed is less than the internal combustion engine technology onboard the cars.

'Although we continue to chip away at the ERS development, relative to where we were in 2014, the development here is not as big as the changes on the internal combustion engine, which is still freer in terms of regulations,' explains Thomas. 'The relative rate of lap time benefits you're seeing is mostly within the internal combustion engine development. Therefore, the resource allocation and the rate of change are mostly within this area.'

Formula 1 power unit manufacturers conduct energy audits for the power unit as a whole, considering the development and deployment of the internal combustion and electrical systems to understand what trade-offs can be made in each for the best lap time.

'You have a long list of quite small changes nowadays. It's fair to say there are more elements we are addressing in the internal combustion engine than in the electrical system within the list of small changes.

'We're doing incremental evolutions of parts all over and, as we further understand them, we find how we can take them further.'

Some elements baked into the architecture are challenging to address without a significant overhaul of the power unit, which could be a considerable risk. Notable features of the Mercedes power unit are somewhat permanent, with changes here potentially requiring a new chassis to accommodate the space needed for an alternative solution. These include using a split turbocharger, with the compressor at the front of the engine and the turbine at the back, and the use of liquid-to-air charge cooling methods.

Nothing is set in stone, though, as Thomas explains. 'We always investigate, design, simulate and test alternative solutions to optimise these power units as much as possible,' he says. 'We're not scared of having a look at all elements and checking we've made the right decisions either.

'Suppose we have developed down a particular route for several years. In that case, it might be tricky to make a complete u-turn, and we might not get the performance back straight away, but that wouldn't stop us having a look at it and considering whatever those changes might yield.

'We are finding little bits of performance in optimising subsystems, and perhaps going backwards a little bit to go forwards is not always a bad strategy.'

Intake system

Compared to its predecessor, the Mercedes AMG M12 E-Performance saw some significant changes to the intake design, with the inlet trumpets standing vertical instead of being angled into the combustion chamber. It has the potential effect of improving the gas exchange into the cylinder during the intake stroke and reducing the angle between the intake and exhaust valves, lowering the height of the combustion chamber ceiling. That forms part of a structure that made Mercedes have bigger inlet plenums that protruded much higher than those on the previous M11 engine.

'In terms of the changes we've made to the intake system design, those are physics-based,' explains Thomas. 'The reason we were doing it was because of the way this geometry aids engine breathing. We knew from when we first ran this on the dyno to prove the physics that it was the correct development direction.

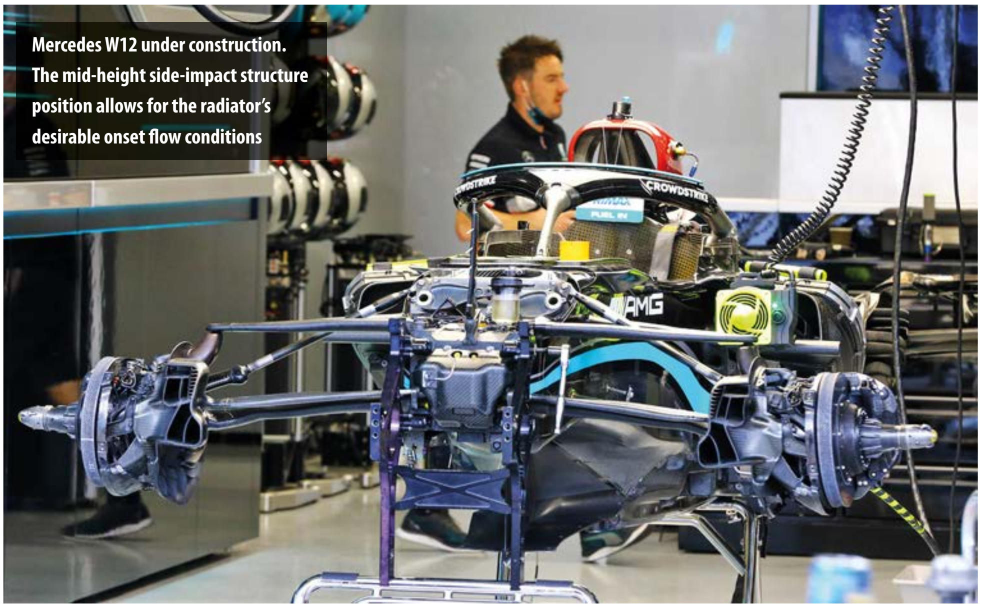
'But we quickly found that what we'd seen in the calculations and physical tests then became this rather large mechanical task to somehow package that in a way that worked with the full-scale racecar.

'At some point, though, there was no turning back. We could see an opportunity there for a benefit in lap time, so we set about the tough packaging challenge to realise it in the envelope we had to work in.

'It was straightforward to specify what we wanted to create in terms of geometry for the intake system, though doing that in a way that didn't compromise the car's aerodynamics was a challenging mechanical engineering problem. The compromise we reached there with regards to aerodynamics was minor. Still, the physics regarding the part being up high onboard a vehicle meant it added weight to the car where it was not ideal for vehicle performance.'

When Mercedes implemented its new intake solution for the M12 power unit, there were knock-on effects with combustion efficiency. Therefore, the post-combustion constituents and exhaust gas entropy for the MGU-H energy recovery system to exploit differ from the previous specification.

'When we've seen what we think will be an on-track performance benefit, what we're looking at is typically the change to the crankshaft power and the change to the MGU-H power,' says Thomas.



Mercedes W12 under construction. The mid-height side-impact structure position allows for the radiator's desirable onset flow conditions

XPB Images

Lap time performance

'We looked at that against a series of circuits and compared the lap time performance of the car, looking at its sensitivity in deployment, comparing the increase in crankshaft output from improved combustion efficiency vs the reduction in MGU-H recovery from exhaust gas entropy, and therefore deployment of the MGU-K throughout a stint. We did that for the whole race, we even did it for the whole season, and worked out if it is still a benefit.

'We then worked with the aerodynamics team to ensure the effect on the aero performance isn't detrimental with the new engine package, which for 2021 saw just a couple of bulges on the engine cover.'

'In terms of the changes we've made to the intake system design, those are physics-based'

XPB Images

A power unit change put Lewis Hamilton's Mercedes on the grid in last place for the Sprint race at the Brazilian GP. Hamilton finished fifth in the Sprint and went on to win the Grand Prix

The changes to the intake had the most significant impact on the way the car ran going into 2021. 'The calibration was a little bit immature at the start of the year in terms of its optimisation, exploiting the potential of the new intake systems and the knock-on effects for the rest of the power unit,' admits Thomas. 'That was the focus of this year: to get the most out of that hardware.'

Running the power unit

Teams use any number of control parameters to adjust the overall crankshaft output wherever they are on track. That can include combustion parameters such as ignition timing, injection timing and lambda, and the control parameters of the energy recovery systems that are either in or out of play at any time. By changing these parameters, the team can compromise between crankshaft output power from combustion and MGU-K deployment and MGU-H recovery under full throttle conditions. Depending on some sensitivities, a car might start the straight being driven primarily by the crankshaft power from combustion and perhaps not worrying too much about MGU-H recovery. But, by the end of the straight, as the lap time sensitivity to crankshaft output becomes less, the MGU-H energy recovery is progressively brought into application.

'The power unit is rarely sat in a static control parameter scenario,' explains Thomas. 'These control parameters constantly change throughout each sector of a circuit. The changes fit into one engine mode, which considers each lap to have the same parameters controlling the power unit at the same point on the track.'

Early in this hybrid regulation set, Formula 1 only implemented a maximum fuel limit on the car, rather than prescribing the amount of fuel required onboard at the start of the race. It meant there was a massive trade-off between the vehicle dynamics benefit of having less weight onboard vs the amount of power the cars could generate and the fuel consumption. Consequently, this rule set saw some radical fuel-saving strategies employed to finish the race, and engine modes that ran extremely lean.

The way teams approached power unit development and fuel consumption was very different from now, with the prescribed 110kg of fuel onboard each car as the starting lights go out. This is mainly because the power unit design to support the rule set with a maximum fuel load limit is different to one designed for a prescribed fuel load.

'When you had a maximum fuel limit, everyone has to go lean burn to make the most of it and there's a huge amount of lifting and coasting,' explains Thomas. 'Once we had a prescribed fuel load at the start of the race, it changed the game completely. The reward for being efficient isn't as large, but there is a reward for using the fuel wisely for the various recovery systems onboard the power unit.

'The fuel mass flow limit is still 100kg per hour so, if you convert that more efficiently to mechanical drive, you're still able to have the highest power at those positions in the circuit where you want the most power. It's just the case now that you don't get an additional benefit by also being able to carry less fuel.'

This shift in targets has been addressed by software controlling the power unit. The software strategies developed for the M12

'The calibration [of the new intake system] was a little bit immature at the start of the year in terms of its optimisation'

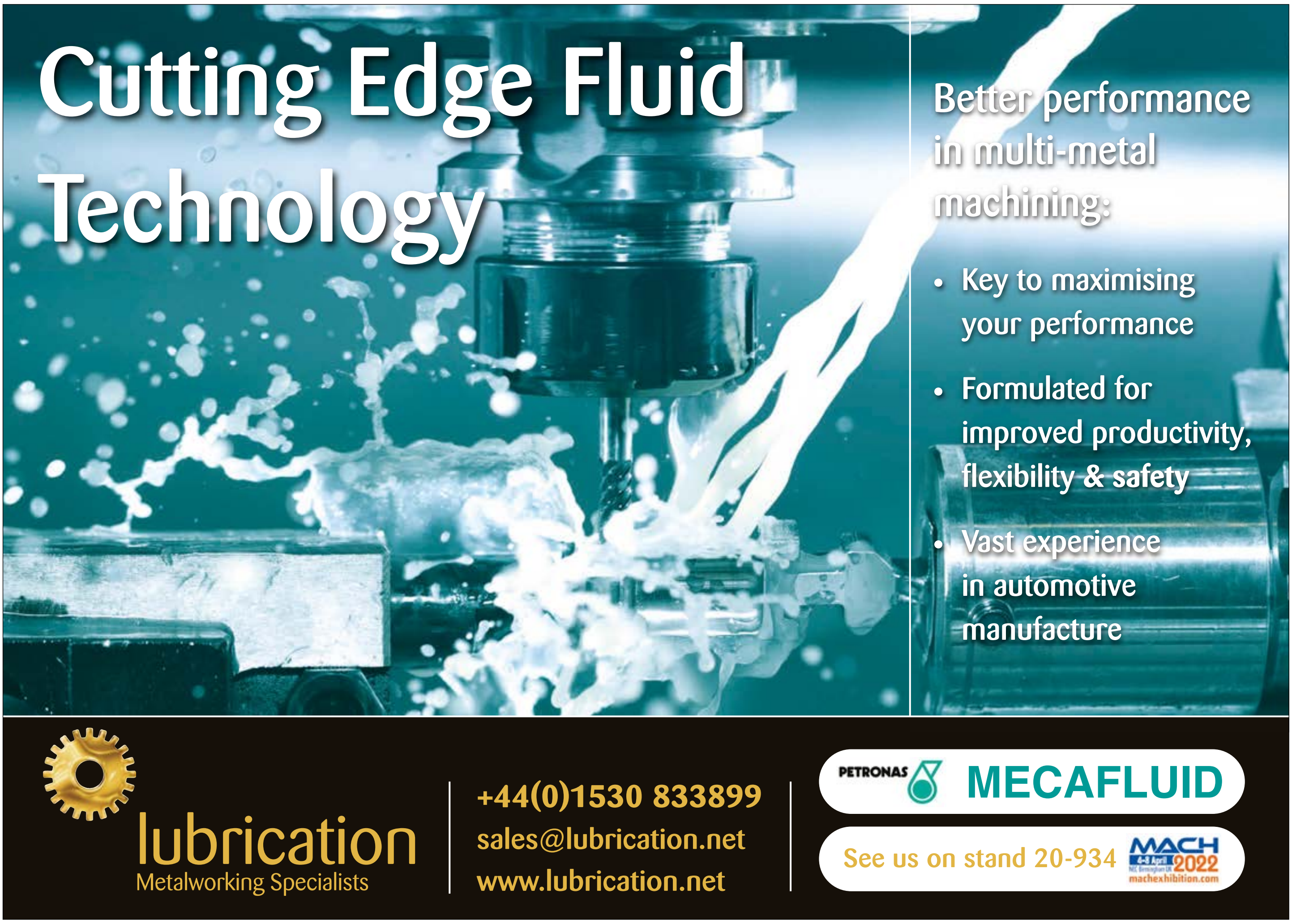
allow Mercedes to optimise these complex deployment and recovery modes that are constantly changing for each part of any given circuit. They have become more and more sophisticated as the sport has progressed during this regulation cycle.

'The software goes hand in hand with the hardware development in the power unit,' notes Thomas. 'There are instances where the target capabilities of the power unit cannot be achieved by hardware or software alone, and here the two work together to pick up the pitfalls in each one's capabilities.

'In the technology we have now, the software can enable many things. It's always been a very intertwined relationship, where sometimes development on the hardware opens a new area of development that software can only exploit. Other times, ideas will come from another direction, whereby the calibration team and the software team will desire a mechanical system to operate in a certain way to exploit the software to its potential. Each of these elements has come together to produce the M12 E-Performance power unit that powered us once again to a World Constructors' Championship title.'

In the low ambient pressure conditions of the Mexican Grand Prix, Mercedes seemed to be no match for the Honda-powered Red Bull racecars

XPB Images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Fourth dimension

French racecar constructor, Mygale, introduced its new Generation 2 Formula 4 at the PRI Show in Indianapolis, ready for competition this season

By ANDREW COTTON

The Formula 4 category, for entry-level racing drivers and engineers, has taken a huge step forward in terms of safety for its second-generation cars. Not only has front and rear crash protection been improved, but stronger cockpit safety criteria mean better side-impact protection, more secure seats and, most visually, the introduction of the Halo to protect the drivers' head.

It is a step that has been brought about following a series of high-profile accidents in single-seat racecars, including those of Billy Monger at Donington in 2017, Anthoine Hubert at Spa in 2019 and Romain Grosjean in Bahrain in 2020. The FIA took the data from the crashes and ensured that design work for all future single-seat cars reduces the risk of injury to the driver.

This generation of Formula 4 car is therefore longer, stronger, lighter and safer than the Generation 1 cars, yet has still been designed and developed to meet the strict cost criteria set by the FIA.

Mygale, the French manufacturer based in Magny Cours, showed its new car at the PRI Show at Indianapolis in late December 2021, with a view to it competing this season. Having revealed renders of the car early in 2021, the car has been testing around France throughout 2022 in preparation for a competition debut this season.

The MY21-F4 is powered by an ORECA-prepared, Renault-based, four-cylinder engine that produces between 160-180bhp depending on the weight of the car.

A raft of safety improvements mean the new car is longer, stronger, lighter and safer, as well as featuring a Halo for the first time for driver protection

Photos: Andrew Cotton, unless stated

By regulation, the pedals and the drivers' feet are now contained within a longer monocoque with an anti-intrusion panel at the front

Dominique Breugnot

A change to the regulations also allowed Mygale to make the chassis in one piece, rather than an upper and lower chassis bonded together

The Generation 2 car features four-piston calipers to improve stopping power, a new SADEV gearbox with gears that sit ahead of the rear axle of the car to improve rear safety, and has saved nearly 50kg over the Generation 1 car.

Chassis changes

Mygale decided to take a different approach this new generation of Formula 4 car. Instead of designing it as a one-make chassis to be sold around the world, they adopted the philosophy that it would find a home in open competition. That meant putting the car on a significant diet, while also improving the aerodynamics, brakes and construction techniques to improve safety.

The car is longer than the previous generation car by around 40cm, taking advantage of the regulations that have brought the pedals, and therefore the drivers' feet, inside the monocoque. 'After the Billy Monger accident, the cars changed massively,' explains Mygale's founder, Bertrand Decoster. 'With this front anti-intrusion panel, the monocoque is longer so the pedal box is now inside the monocoque, rather than outside, and there is no hole at the front.'

That extra protection for drivers' feet may seem obvious, but the unusual circumstances of Monger's accident caused a reflection on crash testing procedures.

'We normally crash into a wall at the front and rear,' says Decoster of the controlled test environment. 'Rarely do you have a front and rear crash fully aligned. Those pieces [in the design of the F4 car] are now aligned.'

An improved frontal protection comes courtesy of both the new anti-intrusion panel ahead of the pedals, but also a change in the rear crash structure at the back of the car. Gearbox manufacturer, SADEV, has changed the design of the 'box, putting the gears themselves ahead of the rear axle line of the car to avoid them becoming a factor in an accident. The result is a longer rear crash structure, which further helps with safety.

'With the old gearbox and the gears behind the axle it would not pass the crash test or the push test,' says Decoster. 'The length of the rear crash structure is massive. I would say from the rear it was the rear impact crash test that re-designed the rear suspension.'

Seat time

Side-impact protection has also been improved following the catastrophic accident for Anthoine Hubert, the Frenchman who was left side-on to traffic following an accident at the Raidillon at Spa in 2019. While the impact speed itself in that instance was unsurvivable, the FIA has taken steps to improve the safety for drivers, including specifying a space between the monocoque and driver's seat.

Not only that, but Mygale has produced three seats to accommodate different sizes of driver. Foam in the extractable seat can be no more than 50mm thick, meaning the driver must have better protection from the structure of the seat rather than foam.

Three seat size options are offered, and a space between the seat and monocoque improves side-impact protection

'Now we have three seats – small, medium and large,' says Decoster. 'And we have to prove to the FIA, which provided a CAD mannequin of small (1m50), medium and tall (1m95) that each driver is installed into the car properly.'

A change to the regulations also allowed Mygale to make the chassis in one piece, rather than an upper and lower chassis bonded together, as was the case with the Gen 1 car. That has been backed up by a carbon panel that now runs from the front of the monocoque to the rear, replacing the previous rather heavier material in the outgoing car. That change alone saved 20-25kg from the base weight of the car, and the overall weight is now just 500kg.

The most visual difference is the introduction of the Halo, now becoming commonplace in FIA single-seat cars following other accidents in which the device has proven its worth. Chiefly among these is Romain Grosjean's accident in Bahrain, where his Haas pierced the safety barrier, leaving a Halo-shaped dent in the upper part. Without the Halo it could potentially have been a different outcome for the Frenchman and was a further example of the effectiveness of the device. Since its introduction it has proven its worth in open cockpit racing so it was natural to include the device in the new F4.

The Halo fitted to the F4 car weighs 13kg, and is made of steel 4.5mm in thickness that can stand the push and impact tests specified by the FIA. It is also part of the monocoque, like the roll hoop, meaning the chassis itself cannot fail under pressure. Nor can the Halo.

Engine options

Mygale's chassis is also certified to run in regional Formula 3 series. The Formula 4 chassis is so strong that it will also serve for the more powerful 300bhp engine used in F3.

In F4 guise, the Mygale presented runs a Renault-based, 1.3-litre, turbocharged engine that has been under development and racing since 2018 and so is 'bulletproof', according to Decoster. In F3 guise, the engine is based on a larger capacity Honda unit to hit the power numbers required to be competitive in that field.

'It is not a big change from the road car, because that is the spirit of Formula 4, but it is a proper racing engine, with proper electronics from Magnetti Marelli,' notes Decoster. 'It is a very light engine with an aluminium block. The change from last year – and we used this in the French federation last year – was we changed the turbo. Before, you were losing power in a straight line, but now it is still pushing. It is a road car engine internally, but fully designed as a racecar engine.

'You have no choice but to go turbo. The regulations allow for a 2.0-litre engine, but the problem is that can give 160-180bhp.

1.3-litre, four-cylinder, turbocharged engine has been prepared by ORECA and produces between 160 and 180bhp, but the chassis has been built to take anything up to a 300bhp power unit for use in different global formulae

An all-new, and significantly lighter, SADEV gearbox has been designed specifically for the car, with the gear clusters sited ahead of the rear axle centreline to further improve driver safety in the case of a nose-to-tail accident

More than that can start to be very difficult. There is no more normally aspirated engine on the market [that can achieve that], and honestly these are very nice engines. In Europe, to find a normally aspirated engine now is pretty much impossible.'

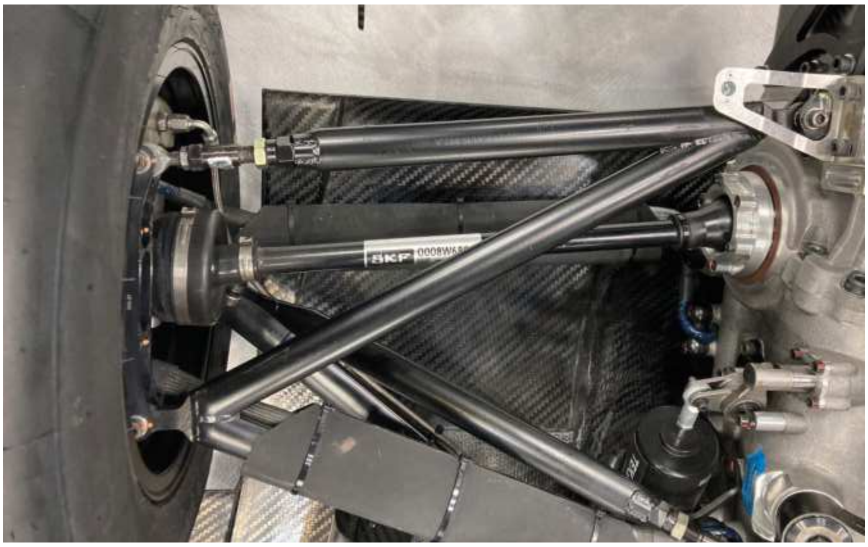
Aero development

One of the key areas of development was aerodynamics. New, lighter front wing end plates have been introduced, while the rear wing is inclined to the rear, helping with efficiency. Within the rear wing end plates, as is now becoming common, are rain lights, a further additional safety feature.

Both the front and rear wings are made from carbon fibre to help reduce weight.

Despite the increased frontal area compared to the Gen 1 cars, the Gen 2 has better efficiency with downforce largely unchanged. 'This car is between 1-2s quicker than the old car,' confirms Decoster.

Despite an increase in frontal area, overall efficiency is improved and downforce is similar to the Gen 1 chassis



The car's double wishbone rear suspension was re-designed to pass the new rear impact crash test

TECH SPEC: MYGALE MY21-F4

Chassis	• FIA-homologated carbon monocoque • Full length anti-intrusion side panels next to the driver and fuel tank • New standards for accommodating a range of driver sizes
Engine	• Four-cylinder engines homologated for FIA F4 • Power ranging from 160-180bhp, according to the FIA regulatory power-to-weight formula
Suspension	• Double wishbones with pushrods front and rear • Bump and rebound-adjustable dampers • New front anti-roll bar mounted inside monocoque, revised rear anti-roll bar mounted on bellhousing
Safety	• At latest FIA standards: front and rear impact absorbing structures; new front and side anti-intrusion panels; safety Halo; roll hoop; extractible seat; gap filler foam from seat to monocoque; head restraint; two-wheel tether cables per wheel; fire extinguisher; collapsible steering column; ADR at the latest FIA norms
Aerodynamics	• Single-element front wing adjustable by shims, new lighter end plates • New inclined rear end plates with rain lights • Upper wing with fishplate adjustment
Dimensions	• 4879mm x 1733mm x 1044mm
Wheels	• Front: 8 x 13in • Rear: 10 x 13in • EVO Corse rims • Tyre manufacturer according to championship choice
Brakes	• New monoblock, four-piston, motorsport calipers front and rear • New ventilated floating disc with aluminium bell
Transmission	• New SADEV gearbox with improved gear profiles • Full shift 1-N and N-Rev • ECU-controlled electrical gearshift
Fuel tank	• FIA FT3 specification, 45l • Filler and drain system with optional dry break connections

'We have seen that everywhere [we have been testing]. Through aero we have quite significantly increased the speed of the car. What we wanted was to give the best car possible [according] to the regulation.'

The degree to which a team of engineers can manage the set-up of the car depends on the series in which the car competes. The French federation, for example, has fixed the roll bar specification so, although you can adjust it, you cannot change it, while others allow for changes. The roll bar is also now mounted inside the monocoque.

Two-way adjustable dampers, coupled with the ability to change camber, caster and toe are pretty much the limit of what you can do within the regulations.

The braking system was also overhauled as it was considered one of the weaker points of the old car. A new, machined monoblock, four-piston motorsport caliper, with a new ventilated floating disc and aluminium shroud have all been introduced onto the new car.

'We spent a lot of time on the braking system, damper set-up and springs,' says Decoster. 'The target was to set a quick, basic, racing set-up for the car.'

At what cost?

Introducing these safety measures has come at a cost to Mygale. Due to the FIA's mandated cost cap, the constructor is unable to recover development costs through purchase price. It's a common theme among chassis constructors who have had to meet increased safety standards, while also keeping weight down and costs under regulated control. It has driven profit margin out of the chassis and left constructors considering their future.

Mygale is no different with the new F4 chassis price capped at €60,000 (approx. £50,200 / $68,150), the engine at €14,000 (approx. £11,700 / $15,900) with a maximum rebuild cost of €6,000 (approx. £5,000 / $6,800) after a minimum of 10,000km.

For F4, suspension variables are limited to rebound and bump settings, plus camber, caster and toe adjustability

The maximum cost per kilometre is calculated on a 30,000km basis at €0.87/km (approx. £0.73/km / $0.98/km).

This all makes sense for an entry-level series, except it's not what it costs to go racing.

'As a manufacturer, we have huge pressure on the price,' says Decoster. 'When you sell a car, it is one million euros of development, and there is no amortising of the cost. This is not the right approach; it is destroying the industry.

'Safety is important, of course, and you cannot say you won't increase the price of the car because of safety. The only thing we can do as a manufacturer is to do our job and be paid for it.

'As a manufacturer, I understand that there is pressure on price, and that it is important. What I cannot accept is there is no pressure on the racing price. At the end, what counts is the racing price.

'If you look at the European system, you have the French philosophy of the FFSA academy. We charge €115-120,000 (approx. £96,150-100,325 / $130,550-136,250) for the season. The FFSA decided a long time ago to ban the teams so, basically, they have the academy, a one-make team run by the French Federation, and they can control the costs.

'As a manufacturer, I understand that there is pressure on price… What I cannot accept is there is no pressure on the racing price. At the end, what counts is the racing price'

Bertrand Decoster, Mygale's founder

If you look at the British and Italian championships, you speak of €400-600,000 (approx. £334,425-501,650 / $454,275-681,425), which is ridiculous for these cars. That is where the big work should come.

'And that is just a starting point. €120,000 is a lot of money, but it is acceptable, and you can find some sponsors. At €400,000, you are out of the game.

'As a manufacturer, if everyone is playing the game then that is fair, but why should we as a manufacturer manage the cost when the money being spent is crazy? And the championships are struggling because of this. It has to be addressed.'

Evo tech

Racecar ***talks to ORECA's former technical director, David Floury, about how the constructor became the reference car for the LMP2 class***

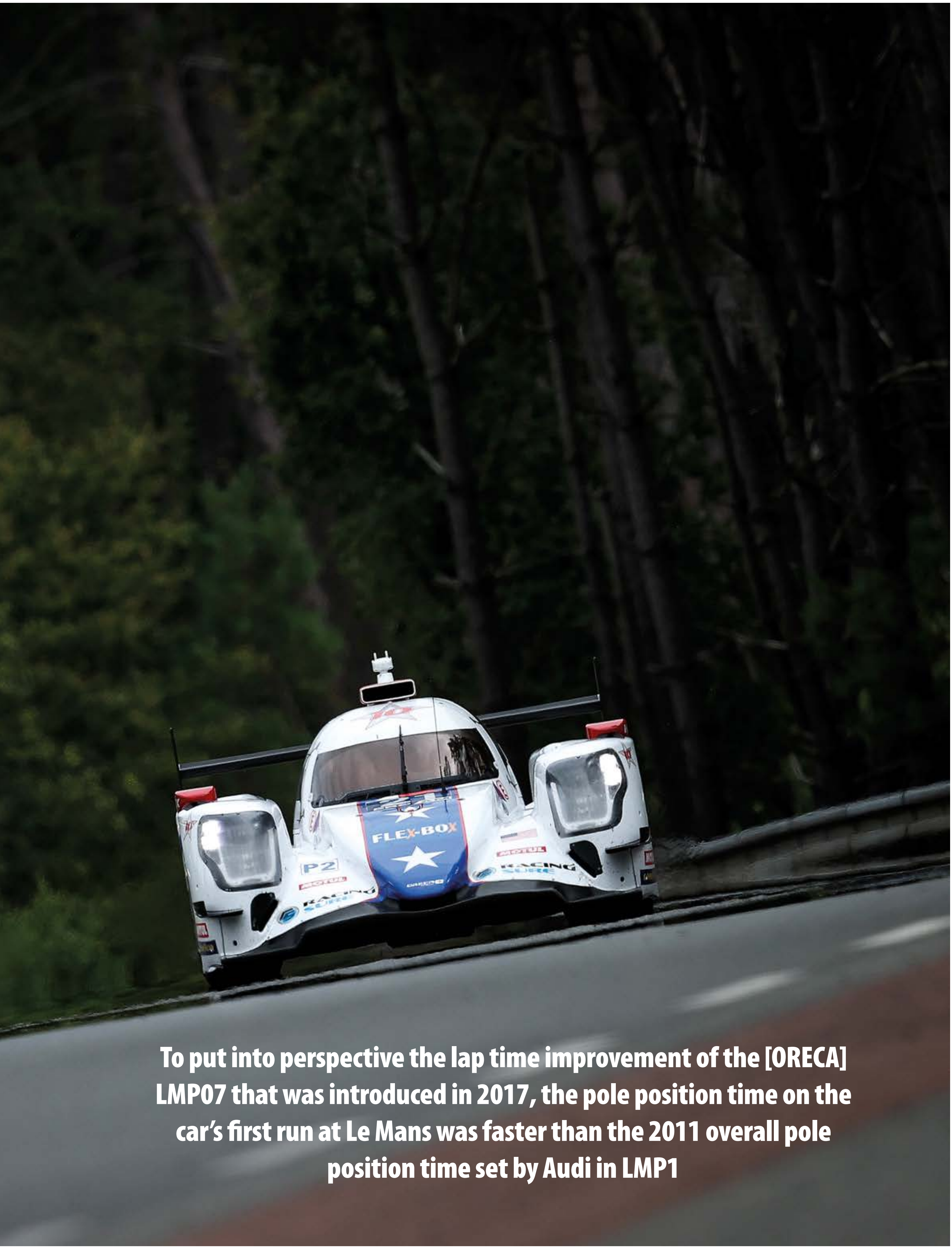
By ANDREA QUINTARELLI

Sportscar racing has gone through an evolution in 2021, with the ACO and FIA introducing the Hypercar category as the top class of the World Endurance Championship. In doing so, the top-class prototypes are slower by design than the old LMP1 cars, and that in turn has shifted attention onto the raw speed and reliability of the LMP2 machines.

LMP2 was designed for privateers, yet has seen such a huge improvement in performance over the past decade, that in professional hands the cars challenged Hypercars on certain circuits. Efforts have been made to slow the cars in 2021, and more restrictions are in place for 2022.

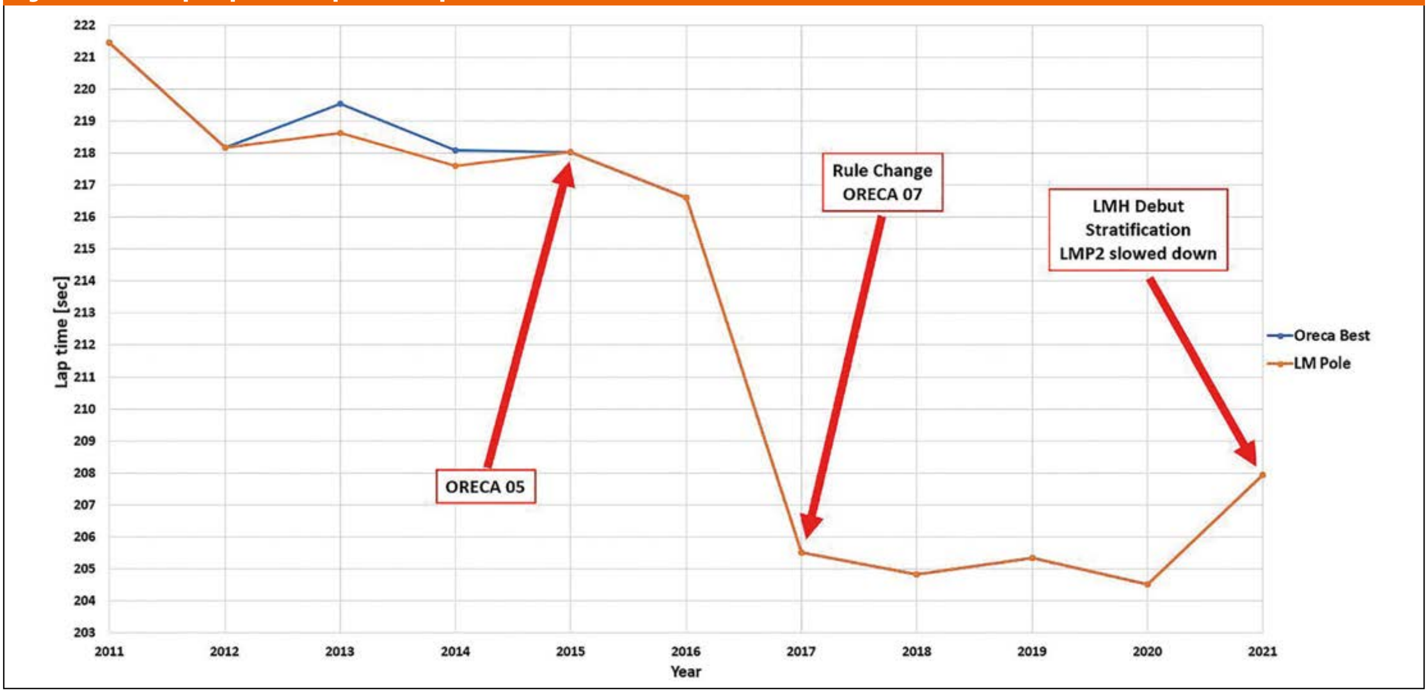
This current generation of LMP2 cars was introduced in 2017. Four chassis manufacturers were selected by the FIA to supply the category – ORECA, Dallara, Multimatic and Ligier. These chassis then formed the basis of the DPi cars that were the top class in IMSA. Dallara became the Cadillac, Multimatic the Mazda, Ligier underpinned the Nissan and ORECA the Acura.

The base LMP2 cars were homologated for five years, and one 'joker' package was permitted within that time. The ORECA LMP 07 chassis was taken as the benchmark for this joker package, and the other cars were balanced against it.



To put into perspective the lap time improvement of the [ORECA] LMP07 that was introduced in 2017, the pole position time on the car's first run at Le Mans was faster than the 2011 overall pole position time set by Audi in LMP1

Figure 1: Le Mans pole position lap time comparison between 2011 and 2021



However, for various reasons, the LMP2 class for the 2022 FIA WEC is solely the domain of the ORECA chassis. *Racecar Engineering* had the opportunity to sit down with David Floury, former technical director at ORECA at the formative time of the LMP 07, and who has now moved to TMG in Cologne to continue his role as race engineer for Toyota. He was involved in the design, development and track operation of some of the most successful LMP1 and LMP2 / DPi cars of the last 15 years, including the forerunners of the 07, namely the 03 and 05 designs.

The time frame we will follow for this article is between 2011, when the ORECA 03 set pole position time at Le Mans for the first time, and 2020, before the LMH rules were implemented, which directly led to the LMP2 cars being slowed in international and regional series. Within that time, the LMP2 cars have gone through major rule changes that have seen them develop into much faster cars.

ORECA's cars have been the reference in the LMP2 class for many years, and so it is apt we should focus on this example.

Besides the regulation changes, there has also been incredible optimisation and development on the cars, that in every area have improved lap times. **Figure 1** shows how Le Mans pole position lap time has evolved during this era.

ORECA has won all the pole positions at the French endurance classic since 2015 and even before that, the ORECA 03 had a 50 per cent strike rate, scoring pole in two of the four Le Mans it contested.

Poles apart

To put into perspective the lap time improvement of the LMP07 that was introduced in 2017, the pole position time on the car's first run at Le Mans was faster than the 2011 overall pole position time set by Audi in LMP1.

In absolute terms, comparing the LMP2 pole position time of 2011 with that of 2020 before the cars were artificially slowed to make way for Hypercar, we can see the times improved from 3m41.458s to 3m24.528s, a staggering difference of 16.9s.

Jackie Chan Racing, Nürburgring, 2017, the first season of the ORECA LMP07. Rule changes worked in favour of the car, making it much quicker at Le Mans, but ongoing development helped, too

> **'Overall, from regulation evolution, I would say the lap time gain at Le Mans is probably in the order of 6.5s'**
>
> *David Floury, former technical director at ORECA*

Also interesting to note is that between 2017 and 2020, performance in qualifying improved by a second, despite there being no update to the car, which shows the optimisation that has gone on since the car's introduction.

The latest LMP2 regulations state that cars cannot be modified for the whole homologation of the car, other than to balance the class, should a manufacturer fall behind in terms of performance. In this respect, as ORECA has always been the reference car (and the fastest), the constructor has not been allowed to update the car since its introduction. That has had the happy knock-on effect of teams not having to invest heavily in an upgrade package in five years.

The final point to make is that from the 2011 pole position time to 2017, when the new generation LMP2 cars were first introduced, there was a lap time improvement of 15.9s.

At that point, a major regulation change was introduced, which can be broken down into the following categories:

- Engine: the class switched from a free engine formula, with motors limited by air restrictor or turbo boost limitation to around 500bhp, to a commonly available Gibson engine with an output of around 600bhp.
- Weight: minimum weight limit was increased from 900kg to 933kg
- Dimensions: the maximum width reduced from 2000mm to 1900mm, while the overall length of the car went up from 4650mm to 4750mm.
- Aerodynamics: detail changes such as floor leading edge and increased wing dimensions led to a performance improvement, while other changes were focussed on safety, including holes over the wheels to reduce air pressure in the wheelarches.

So, how much of ORECA cars' lap time improvement is due to proper development work, and how much is related to the 2017 rule changes? 'The engine power increase explains a lap time gain at Le Mans of just under 7.5s per lap,' says Floury. 'The increase in car weight and reduction in width led to a lap time penalty of 1.6s and 0.6s per lap respectively. The effect of increasing car length [and wheelbase] are more difficult to quantify, but this surely improved corner entry stability and driver confidence.

'The impact of the aerodynamic regulation changes are also not easy to estimate as the rules changed over a longer time frame, and every time you work around new regulations you regain some of the induced penalty. Overall, from regulation evolution, I would say the lap time gain at Le Mans is probably in the order of 6.5s. The rest of the performance gain came by development, in every area of the car.'

Tyre development

Before 2021, the World Endurance Championship and the European Le Mans Series had Dunlop / Goodyear competing against Michelin in what were two of the few championships in the world where a choice of tyre was allowed. The manufacturers declared their specification of tyres and their rival was able to check tyres at random throughout the year to ensure they conformed.

In 2021, though, the rules were changed to a single tyre supplier, Goodyear, and the company was charged with the task of reducing performance by the rubber alone.

'Tyre development has enabled a big performance gain through the years,' says Floury. 'The competition has been quite tight between Michelin and Dunlop / Goodyear and we experienced very interesting seasons with intensive development on the tyre side.

'The rear tyres always kept the same size, but the front diameter increased. This has not contributed directly to more grip potential, but it has enabled a higher load capacity and consistency. We have taken this into account to set different targets in terms of weight distribution and aerodynamic balance.

'Through these years we have also learned a lot about how to optimise the tyres' working point and this pushed us to change our cars' architecture and evolve the weight distribution, aerodynamic balance, suspension geometry characteristics and suspension concepts.'

It is difficult to quantify quite how much tyre development could mean in terms of lap times as they have a very complex behaviour that depends heavily on ambient and track conditions, on tarmac, car set-up and design, as well as driving style.

Moreover, from year to year, tyre manufacturers may decide to focus their development effort on different areas, depending on the feedback provided by teams and racecar manufacturers. Sometimes tyre evolution is not aimed at pure, single lap performance, but rather at improving consistency or driveability.

With no 06 designation, the constructor's preceding car was the ORECA 05, seen here at Silverstone in 2016. Less powerful and shorter, but also lighter and wider, it was still a formidable racecar

From the start of our journey, the ORECA 03, which made its debut and set pole position at Le Mans in 2011. Developed from a Courage design, it was the last of ORECA's open top LMP2 cars

ORECA's first LMP2 car, the 03, had an open cockpit, in line with the standard approach used in the category at the time. Despite being successful, ORECA had to face some significant compromises. 'The ORECA 03 was an open car and employed a survival cell that had been designed by Courage, and which we inherited when we bought Courage Competition in 2007,' says Floury.

It's worth noting here the Courage monocoque was already relatively old when the ORECA 03 started racing in 2011.

'We switched to closed cars in 2015 with the ORECA 05, and the ORECA 07 uses the same survival cell as the ORECA 05 We designed their monocoque in house.'

Open and close

Switching to a closed cockpit brought many advantages, as Floury highlights: 'A closed car enabled multiple gains: aerodynamic efficiency, safety, stiffness and weight. The ORECA 07's survival cell is more than 25kg lighter than the 03.'

One of the most significant advantages, at least in part linked to designing a car around a closed cockpit, was the impact on aerodynamics.

'A closed cockpit brings a good step in terms of aerodynamic efficiency, and the new survival cell also enabled us to improve flow management under the monocoque and the internal flow. We could increase front-end aerodynamic performance quite significantly.'

Monocoque design also influences significantly suspension layouts, in particular on the front axle.

'On the 03, we were quite limited by the survival cell,' notes Floury. 'Once we introduced our own monocoque, we could review some of the suspension concepts, parameters and directions.

Figure 3: Breakdown of lap time improvement between 2011 and 2020, a total delta of 16.9 seconds. The total gain due to the 2017 regulation changes was about 6.5 seconds, largely attributable to an increase in engine power and aerodynamic development of the car

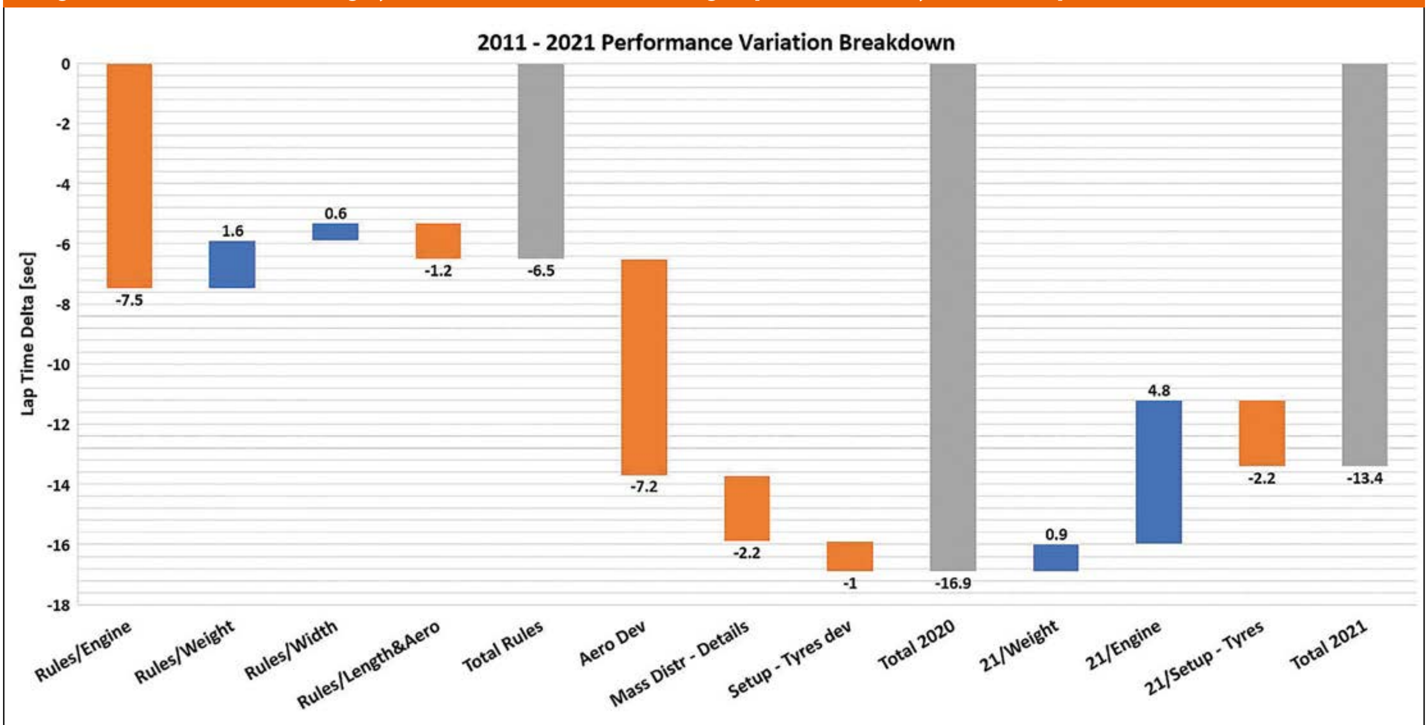


Figure 4: Comparison between ORECA 07 (top) and 05 (bottom) front end

'There is nothing fundamentally revolutionary on the suspension side. The regulations ban many advanced concepts, like FRICS (front-to-rear interconnection) or inerters anyway.

Suspension philosophy

'Still, our suspensions are designed to optimise tyre performance and are well integrated in the car's general concept and philosophy. We developed them to fit our vehicle's aerodynamics and architecture.'

Suspension is a critical tuning parameter. In very high downforce cars, such as a modern Le Mans Prototype. Beside playing a crucial role in ride height control (and, hence, downforce and aerodynamic balance), they also define dynamically how the tyres come into contact with the road and the way forces are exchanged, both in terms of direction and magnitude.

Quantifying their effects in terms of absolute performance is not easy because they are so closely linked to driver perception.

'We did a lot of simulation work to refine our suspensions parameters,' says Floury. 'We have developed specific dampers with PKM and our philosophy has been to define a base set-up that is easy to use for teams and drivers, with specific focus on amateur ones.' Indeed, it is important to ORECA that when an amateur driver is in the car, the performance remains consistent and as high as possible. To achieve this, the car must be predictable.

'We have a reduced number of options available as the testing time is limited during a race weekend, when you have three drivers sharing the same car. Normally, there is no time for big set-up changes,' explains the designer. 'So, we wanted to avoid the teams getting lost with too many set-up options.

'Obviously, this can be felt as a limitation for some teams, but I think it fitted quite well with the philosophy of this LMP2 generation.'

Another critical parameter for every racecar is weight. This is particularly important in classes where a minimum weight for the car alone is mandated as being underweight allows teams to use ballast as a tuning element, a very powerful set-up tool.

'We have always paid a lot of attention to weight and weight distribution,' says Floury. 'On the ORECA 07, we saved quite a lot of weight thanks to an extensive FEA [finite element analysis] programme. The car has to carry between 70 and 75kg of ballast to achieve the minimum homologation. This enables it to have a lower c of g, and for teams to tune the weight distribution to adapt to different tracks, tyres or conditions.

'Our baseline weight distribution has been carefully optimised to adapt to the tyre characteristics. We approached this differently to our competitors, and we are clearly using the tyres in a completely different way.'

'With more budget, we would have elected to develop our cars in the wind tunnel in parallel to the CFD'

Aero development

In a car with a high downforce and a sophisticated aerodynamics such as an LMP2, this area remains, together with the tyres, probably the strongest performance driver. This is also where ORECA's cars seem to outpace their competition.

'This is where we gained the most through the years,' explains Floury. 'The ORECA 07 [2017] has a 40 per cent higher aerodynamic efficiency than the 2011 03. This has been achieved by both reducing drag and increasing downforce.

'We also worked on the aero map shape and robustness of the aero concept in order to ensure a consistent performance throughout a race and a more user-friendly behaviour and handling. At Le Mans, the aerodynamic gains are worth around 7.2 seconds per lap and around 17kmh of top speed.' And that's on top of the 33km/h top speed difference between an ORECA 07 and 03.

Interestingly, none of the ORECA designs have undergone wind tunnel testing, all development work having been completed in CAD.

'Since 2009, all our cars have been developed using CFD only on the aerodynamics side, employing our in-house capabilities,' confirms Floury. 'We worked to improve our cars' performance, but we also considerably evolved our process and tools. We developed our own methodology and worked extensively on the correlation with track data. With more budget, we would have elected to develop our cars in the wind tunnel in parallel to the CFD. The two are indeed very complementary. But the cost cap in place in LMP2 pushes us to be as efficient as possible, and we therefore preferred to focus our effort on CFD and expand our in-house know how.'

'CFD, like the wind tunnel, is just a method that has his own strengths and weaknesses. Wind tunnel testing is also normally performed using a scale model and this is also an approximation. You need to know the limitations of your method and work accordingly. We have validated our CFD methods using both track and full-scale wind tunnel testing.

'Also, the data we provide to our teams are always checked against data logged during track testing, at the end of the development phase.'

This approach has allowed the French company to take different routes, compared to their competitors, and this paid dividends.

Conceptually, the 07 is very different all other current LMP2 cars. It is the only one to use a closed front aero concept, unlike the 05.

Working points

'All the other LMP2 are using a through flow between the splitter and the top shroud covering the upper wishbone,' explains Floury. 'They are following a trend that has been set in LMP1 in the last decade. But LMP2 regulations are less permissive than LMP1 ones in this area, and the working points are quite different. LMP1 rules were really pushing towards fuel efficiency. The

The Le Mans aero package is slightly more efficient than the sprint package and it reduces the drag level by around 15 per cent

ICE power out of the boost was low in LMP1 and you had to do fuel lifts at the end of straights, so this was pushing towards lower drag. The 2017 LMP2 rules lead to a different sweet spot, mainly because of an increased ICE power. So, we investigated both concepts, but it appeared to us that the closed concept was better suited to the LMP2 working point.

'Also, the aero concept on the side of the car, the way the bodywork geometry is treated around the exhaust outlet, and the rear wheelarch geometry, is really dictating the flow structure to the rear end. That has been a key feature in the development.'

Survival of the stiffest

Floury also underlines how carrying over the previous car's monocoque actually became an advantage: 'FIA and ACO regulated very early on in the 2017 LMP2 project the need to use a survival cell homologated to the 2014 LMP1 regulations. We built one according to this standard already for the ORECA 05, in 2015. Although we could have improved significantly from the existing survival cell [in weight reduction, aero performance, stiffness and packaging], it would have required a lot of resources.

'We decided that it was probably not the most efficient way to use these resources and therefore kept the existing survival cell and focussed our attention and energy on other topics, especially aerodynamics. This enabled a much more detailed work up and a lot of the performance gain produced by 07's aerodynamics comes from the details.

Another challenge for Le Mans Prototype cars is to suit a very special and fast circuit like Le Mans, as well as the more conventional tracks where sprint races for the WEC, ELMS or IMSA championships take place.

'The car has been developed for both HDF tracks, as well as Le Mans, even though the working points and targets are quite different. In LMP2, you could develop a specific aero package for the Le Mans race, but its price has been capped at €10,000 (approx. $11,350 / £8,350). So here as well, you must be very efficient.

'The Le Mans aero package is slightly more efficient than the sprint package and it reduces the drag level by around 15 per cent. We run extensive simulations on all tracks to precisely define our aerodynamic targets.'

Floury is also aware that this could have been the last platform where the search for performance was only limited by cost, making it a memorable engineering experience.

'It has been a very enjoyable project. From an engineering standpoint, it is probably also the last one for a period of time where we actually have freedom to search for performance in an open competition and try to beat our competitors on pure merit.

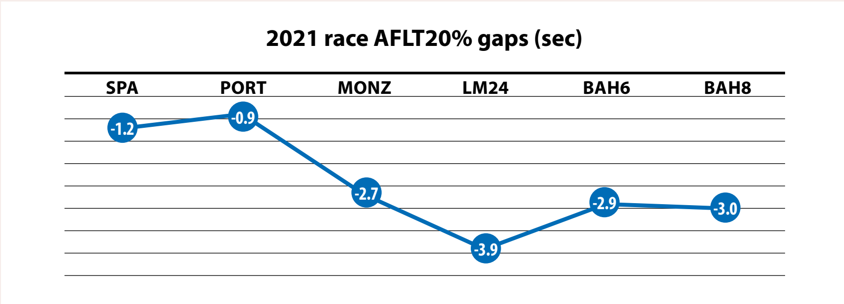
'Nowadays, most motorsport categories are becoming either one-make series or managed by a Balance of Performance system. If this is beneficial for the show and enables cost saving, it does not allow us to express, nor develop, engineering skills and know how.

'BoP is clearly not pushing you to be a better engineer, and in various categories there are successful cars that would never win on pure merit. That's a shame, but that's the way it is, and we have to live with it and adapt.'

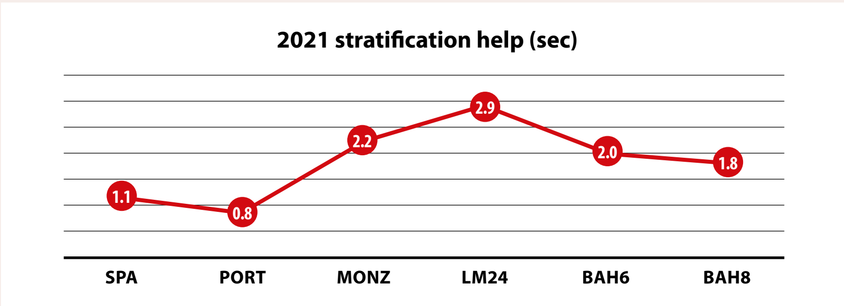
LMP2 2022

In order to reduce the performance of the LMP2 cars for the 2021 FIA WEC season, the FIA and ACO dropped power, minimised the aero options, and prescribed less performant tyres that Goodyear had to supply. Yet LMP2 cars were considered too fast (see table below) and Hypercar teams were unhappy. For the 2022 season, further restrictions have been introduced. These include:

- **For WEC and 24h of Le Mans**
  - **Further reduction of engine power by 8kW (including the effect of the 2022 fuel specification). The power reduction will be performed with an air inlet restrictor (at full throttle) developed and managed by Gibson.**
  - **The bodywork configuration will be:**
    - **Le Mans kit (as per 2021).**
    - **Removal of front dive plane.**
    - **Diffuser strakes shorten by 50mm, modified / produced by chassis constructor.**
    - **Addition of 10mm Gurney on rear flap to compensate aerodynamic balance**
  - **Reduction of fuel tank volume to 65 litres (the ACO / FIA are working with constructors to find a simple, mandatory method to implement such a change).**
  - **Adaptation of driving time (if need be) to be aligned with the onboard fuel volume.**



During the 2021 FIA WEC, the ACO / FIA used stratification helping factors (see table below). This meant that more performance was given to Hypercars by removing, for example, the penalty for altitude at circuits such as Spa. However, the FIA/ACO made it clear that this will not be possible from 2022 onwards as the cars already run at maximum power and at minimum weight. No more performance can be gained from changing the Hypercars which means that LMP2 has to slow.



For the European Le Mans Series, in which the LMP2 cars are the top class prototypes, teams are allowed to run a standard body kit, but the power reduction, fuel tank size and driving time will all follow the regulation changes of the World Championship in order to help teams with the costs for the season.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The C word

In 1982, Group C was unleashed on the Sportscar world. Despite some hiccups, it paved the way for much of motorsport as we know it

By SERGE VANBOCKRYCK

A menacing line up for the big battle: Porsche's trio of 956s posed for a family photo at the Weissach proving grounds shortly before the team left for Le Mans

Corporate archives Porsche AG

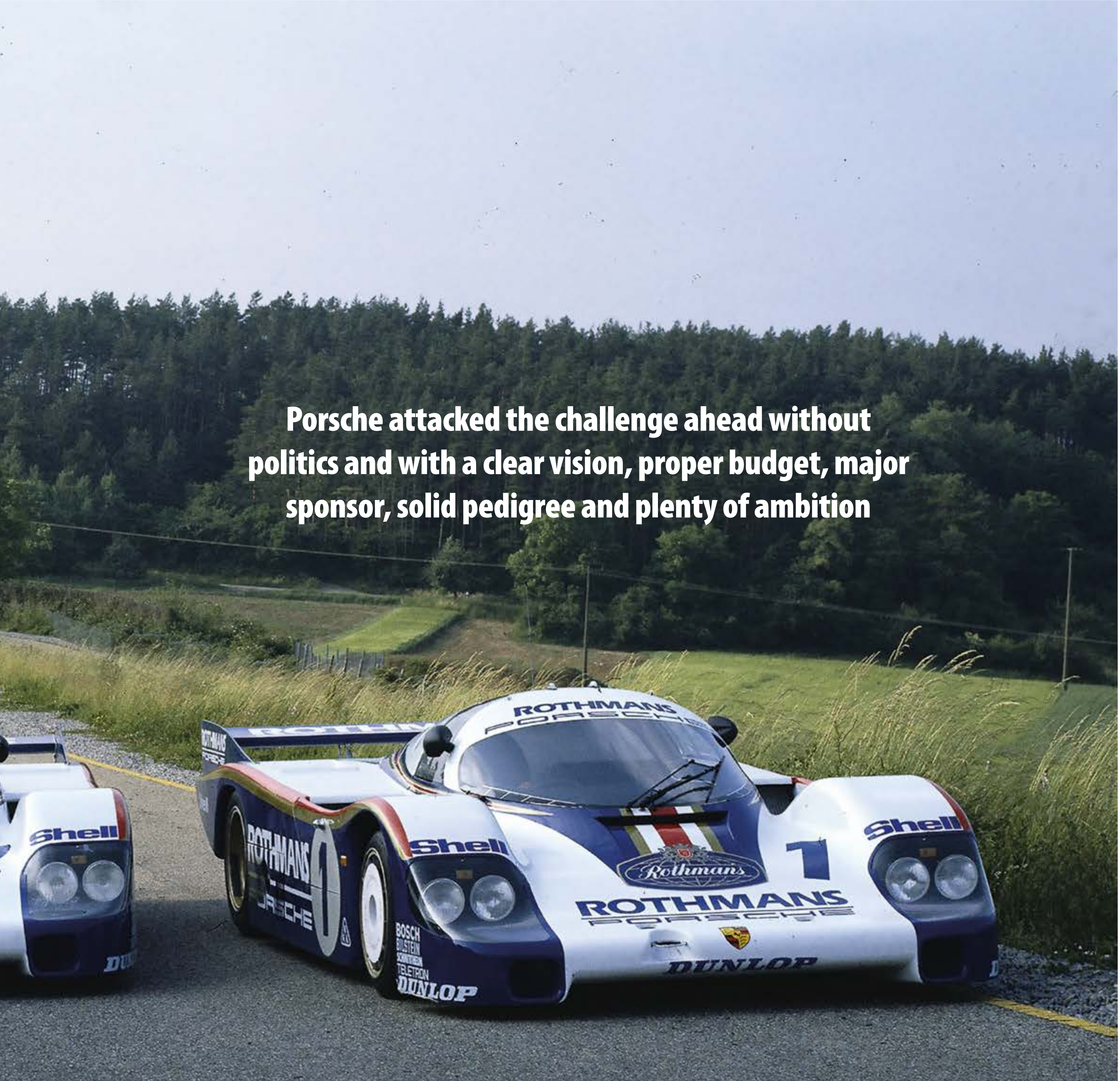
40 years ago, in 1982, the World Endurance Championship (WEC), and indeed global Sportscar racing, started its most successful era ever. The new Group C class would ultimately unite more manufacturers (10) than ever before, or since, in any FIA world championship. It would be run to the same set of technical regulations for longer than any other discipline before or since (nine seasons in total between 1982 and 1990) and took the first tentative steps towards sustainable motorsport, long before it became fashionable, or indeed necessary.

In 1976, the Automobile Club de l'Ouest (ACO), organisers of the Le Mans 24 Hours, created its own class for closed cockpit Prototypes. It called it GTP, short for Grand Tourisme Prototype. Mainly aimed at smaller constructors, but quietly hoping for a manufacturer to think along the same lines, the GTP class called for Prototypes with closed bodywork, yet vaguely resembling a road car by the presence of a roof, doors, windscreen and headlights.

Over in America, John Bishop and his International Motor Sport Association (IMSA) faced the same problems as the Fédération Internationale du Sport Automobile (FISA): Porsche privateer teams were dominating the championship with their 935s, and American manufacturers had little interest in trying to beat them. So, at the end of 1980, IMSA decided to take a leaf out of the ACO's book and also create its own GTP class. At the same time, IMSA and FISA were having preliminary talks about the future of Sportscar racing on a global scale from 1982 onwards.

Run what you have

Under the leadership of its French president, Jean-Marie Balestre, the FISA had already begun to seriously consider the future of



Porsche attacked the challenge ahead without politics and with a clear vision, proper budget, major sponsor, solid pedigree and plenty of ambition

Sportscar racing. Mid-1980, it correctly recognised that many manufacturers would be interested in entering a championship, but only if a decent set of rules could make it attractive to them, without having to spend ridiculous sums of money to have only a slight chance of winning.

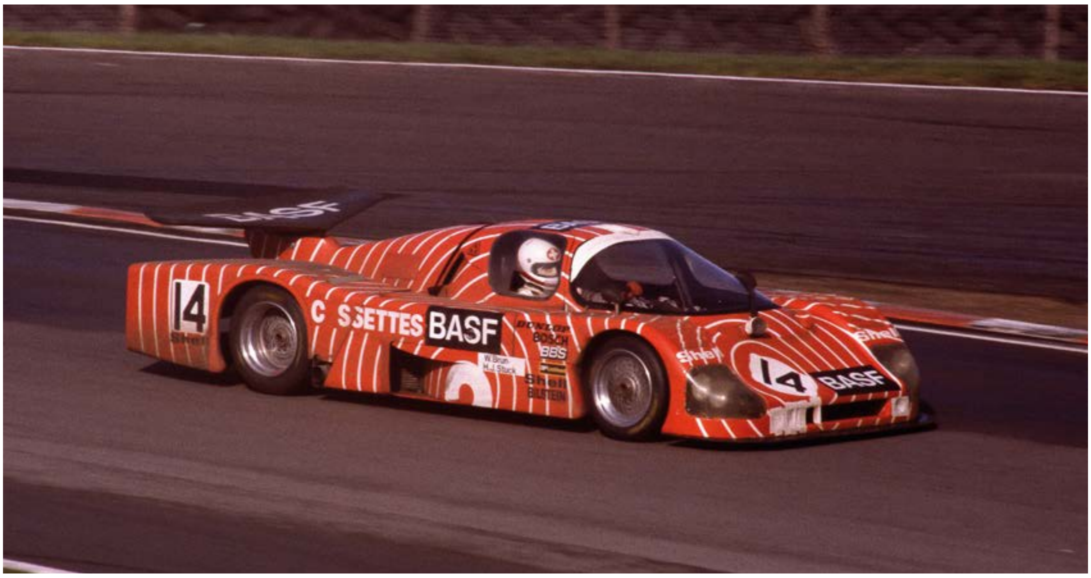
Balestre and his advisers identified the most expensive part of any racecar, in terms of development cost, was the engine. At the same time, the world's first oil crisis, less than 10 years earlier, had convinced them that motorsport should play a bigger role in bringing benefits to road cars. Their solution was to make the choice of engine totally free, as long as it came from a manufacturer that had already homologated a road car in either Group A (mass-produced Touring Cars) or Group B (limited-production GT cars), so no all-out racing engines from specialist companies.

There would be no limit on capacity, number of cylinders or engine architecture, and manufacturers were allowed to run normally aspirated, turbocharged, supercharged or rotary powerplants. The only – but very important – limitation placed upon them was fuel consumption, defined by the amount of fuel a car could use over a certain distance.

This very simple rule, used as the backbone for the Group C regulations, effectively meant manufacturers could develop *any* engine they had in their range and, critically, sell it to customer teams.

New car, new era

The first outline of the Group C regulations was drawn up by the FISA's Technical Commission in July 1980, and circulated to manufacturers and constructors showing interest. At the end of that year, a rough sketch of what a Group C car would be like was published, but it was not until October 1981 that the rules were set in stone.



©John Brooks

Walter Brun in his Sauber C6 BMW. This striking car was, in fact, entirely designed by engineers at Mercedes-Benz, then given to Sauber to develop

©John Brooks

The formidable Lancia LC1 (here with F1 driver, M

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The Kremer brothers' interpretation of the rules led to the sculpted, Porsche-engined CK5, though it was no match for the factory Porsches

In a nutshell, a Group C car's length could not exceed 480cm, with width limited to a maximum of 200cm. The car had to be at least 100cm high, but not higher than 110cm, with the top of the windscreen serving as the reference point. The windscreen had to have a convex outside edge and an internal width of minimum 90cm, measured 30cm from the top of the cockpit. Proper doors had to be fitted, one on each side, measuring at least 50cm at their lowest point, while the door windows had to be at least 40cm wide and 25cm high. Inside, the minimum cockpit width was set at 130cm (the cockpit dimensions were in fact based on those of a Porsche 917).

The front overhang could not be more than 20 per cent of the wheelbase, while the difference between the front and rear overhangs could not exceed 15 per cent of the wheelbase. This latter measure was clearly aimed at outlawing the typical Le Mans 'longtails', as seen on previous generations' cars.

To further prevent engineers being too creative in their aerodynamic approach, the regulations also stipulated that no mechanical part of the car – other than the exhausts, wheels and parts of the brake assemblies – should be seen when the car was viewed from the front, side or above.

Aerodynamics and ground effects, the latter making a big impact in Formula 1 at the time, were also strictly controlled. A flat reference plate, starting right behind the outer edge of the front wheels, had to measure at least 100 x 80cm. Venturi were allowed on Group C cars, although they could only start from the end of the reference plate, while at the same time no part of the car was allowed to protrude below the reference plate. Except, of course, for the wheels, which were limited to a 16in maximum width.

The capacity of the complete fuel system, including fuel lines, was limited to 100 litres. The fuel tank itself had to be within 65cm of the longitudinal axis of the car, and within the wheelbase, to improve safety in case of an accident.

The total dry weight of the car, without driver, was set at 800kg.

Initially, the fuel allocation was not limited *per se*, but by the number of pit stops, defined according to race distance. Except for Le Mans, all Group C races would be run to the traditional 1000km, or six-hour, distance. For races of 830-1000km, the FISA stipulated five refuelling stops, while 24-hour races were allocated 25.

However, by the time the championship got underway, the fuel allocation was set in stone at a maximum of 600 litres for 1000km / six-hour races, and 2600 litres for Le Mans. As a safety precaution, fuel had to be gravity fed, rather than pressure fed, the fuel flow set at 50 litres per minute, effectively setting a pit stop time of two minutes to refuel the car. This rule also allowed drivers to do up their seatbelts securely before speeding off again!

The Lancia loophole

Since the rules were only firmly confirmed as late as October 1981, just five months before the new era of Sportscar racing was to start, the FISA decided the 1982 World Endurance Championship would be a transitional year.

Lancia announced a full-on factory attack on the [1982] World Drivers' Championship with a pair of 1.4-litre, turbocharged LC1 Barchettas, driven by a gaggle of Formula 1 drivers

Alboreto) exploited the fact Group 6 cars could contest the Drivers' Championship

Reinhold Joest built his own Porsche-engined Group C car and, on paper at least, was Porsche's toughest opponent

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The Porsche 956 of Jacky Ickx ahead of Marc Surer in the Ford C100. Ford, however, pulled out after a disappointing 1982 season

Production-based Group 4 and 5 cars of the previous era were still allowed to compete, although they could not score points towards the Makes' Championship, only towards the Drivers' Championship. More importantly, the under-2000cc, open-top, Group 6 Prototypes, usually run by small privateer teams, would also still be allowed in, though again only able to score Drivers' Championship points.

But, instead of the usual bunch of Lolas, Osellas and Chevrons making up the numbers in the 'baby' Prototype class, Lancia announced a full-on factory attack on the World Drivers' Championship with a pair of 1.4-litre, turbocharged LC1 Barchettas, driven by a gaggle of Formula 1 drivers by the names of Michele Alboreto, Teo Fabi, Riccardo Patrese and Piercarlo Ghinzani.

Lancia had made this decision as early as July 1981, just a few weeks after Porsche decided to start work on its Group C contender. Although it was not officially said at the time, it was the lack of a proper engine that prompted Lancia to go the Group 6 route, using the double WEC-winning, 1425cc turbocharged engine from its Group 5 Beta Monte Carlo in a Dallara-designed chassis, rather than try a half-hearted attempt at a Group C car in the first year of the new era.

By the time Lancia showed its Group 6 car to the world, Ford Europe had already taken a head start on everybody else by building and entering its C100 pseudo Group C car in the final round of the 1981 World Championship of Makes at Brands Hatch. Or so it seemed. Politics interfered and, despite a new car for the 1982 season, Ford opted out of a long-term programme.

Unlike Ford, Porsche attacked the challenge ahead without politics and with a clear vision, proper budget, major sponsor, solid pedigree and plenty of ambition. The Type 956 project was given to Porsche's usual suspects. Norbert Singer, creator of the serial championship-winning 935 and *de facto* lead racing engineer, would oversee the programme and develop the aerodynamics. Horst Reitter would design the chassis. Eugen Kolb was in charge of manufacturing the bodywork. Meanwhile, engine engineers, Hans Mezger and Valentin Schäffer, were tasked with developing the 2.6-litre, flat six, Type 935/76 powerplant that had already proven successful in its first competitive appearance at the 1981 Le Mans 24 Hours in the back of the Ickx / Bell Jules Porsche 936/81.

Everything else was new to Porsche. It wasn't the choice of Singer and his men to abandon their usually successful spaceframe architecture, but using a monocoque was the only possible way to incorporate the venturi needed for the novel ground effect aerodynamics pioneered by the Lotus F1 team a few years earlier. Once the world of F1 had successfully embraced ground effect and 'wing cars', it was only a matter of time before this aerodynamic approach spilled over into the world of Sportscars. Porsche had never built a monocoque before but, as motorsport boss, Peter Falk, famously noted to Derek Bell when the Briton came to Stuttgart to sign his contract, 'we've never been wrong before.'

Gallic flair

Porsche's toughest opponent in the 1980 and 1981 Le Mans 24 Hours had been the local, eponymous outfit of gentleman driver, Jean Rondeau. In 1980, Rondeau beat Jacky Ickx and the Martini Porsche 936 of Reinhold Joest to become the first (and only ever) driver to win Le Mans with a car he had built himself, with a second Rondeau finishing in third overall, winning the GTP class.

One year later, it was a five-car Rondeau factory squad (the first time in Le Mans history a single team entered that many cars) that faced the factory 936s, but this time Ickx and Bell and their Jules Porsche 936/81 relegated the Rondeaus to second and third overall. From a small but ambitious *équipe*, with more freelance help and enthusiasm

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Lancia's attack was bolstered by a rollcall of Formula 1 drivers, including Riccardo Patrese shown here

Corporate archives Porsche AG

Porsche had Norbert Singer (left) develop the 956. Jacky Ickx (seated), Helmuth Bott (right)

than real professional and financial support, the Rondeau team had grown to become the leading independent Sportscar constructor in just five years, although neither driver nor team had done much outside Le Mans.

True, companies like Lola, March and others sold cars to the four corners of the world, whereas Rondeau did not sell any. But the success in Le Mans had put Rondeau firmly on the map, and more sponsors and technical help arrived, and along with it some seriously experienced drivers, to the point that Rondeau launched a full-on World Championship campaign in 1982. After all, the small company had proved it knew how to build a solid, if technically unspectacular, car around a customer-spec Cosworth engine, scoring class wins at Le Mans every year since Rondeau had persuaded French wallpaper company, Inaltéra, to back his project in 1976. Now, six years later, Rondeau was eager to prove his team and cars would be a force to be reckoned with outside of Le Mans as well.

©John Brooks

Guy Edwards and Rupert Keegan shared the factory Lola T610 Cosworth, a brutal study in aerodynamics and ground effect

Around the time Rondeau was planning his 1976 Le Mans campaign, the two directors of the small WM Sportscar team were having similar thoughts. After a decade of racing in lower national classes, the WM squad felt they were ready to attack the international scene, and the ACO had provided them with just the set of rules to match their ambitions.

The WM-Peugeot P76 made its debut the same year Rondeau's first car hit the scene, but Rondeau's team – and later Yves Courage's eponymous outfit as well – would always cast a shadow over Welter and Meunier's exploits. But in the late '70s, their consistent work and improvements on the cars had gained them the official support of Esso and Michelin. When a WM finished fourth overall in 1980, the team also gained official technical (and financial) support of engine supplier, Peugeot, for the 1981 campaign, the French car manufacturer figuring the WM team was its best chance to shine at Le Mans without entering a factory team. After all, Renault had been given a state ceremony after its win in 1978, and Jean Rondeau a much-publicised audience with French President, Valérie Giscard d'Estaing, in 1980, so Peugeot was keen for some nationwide publicity to help the company's dwindling sales figures.

In 1981, the little team from Thorigny, near Paris, had been the first to enter a Group C car in Le Mans, and now, courtesy of the technical backing from Peugeot, was considered a serious contender for the 1982 WEC title, even though it would be WM's first foray outside France.

Swiss precision

Swiss constructor, Peter Sauber, had been a household name in the smaller Prototype classes since 1970, usually equipping his clean-lined cars with Ford or BMW engines.

To create his new Group C car, Sauber forged an alliance with Swiss-German company Seger and Hoffmann (S&H), with whom he had already built the successful Group 5 BMW M1 a year earlier. While Sauber was put in charge of the aluminium honeycomb chassis, S&H looked after the overall concept and the bodywork, being specialists in the field of fibre-reinforced composites like carbon fibre and Kevlar for use in motorsports. As such, S&H could count the motorsports departments of Audi, BMW, Ford and Lancia among its many clients.

When they 'phoned aerodynamicist, Rüdiger Faul, at Mercedes-Benz for some freelance assistance, the surprise answer came that Mercedes-Benz already had a Group C car at the ready. What was more, S&H could have it. So, what would soon become the Sauber SHS-C6 had in fact been entirely designed by a group of Mercedes-Benz engineers, keen to see what could be done with these exciting new Group C rules. While some parts were carried over from Sauber's successful M1 project, the striking car with its big dorsal fin and unique, centrally-mounted, delta-shaped rear wing was, in reality, Mercedes' first Group C car.

Although the Mercedes engineers had developed a turbocharged, M117 V8 engine to go with its concept car, there would ultimately be no Mercedes engine

What would soon become the Sauber SHS-C6 had in fact been entirely designed by a group of Mercedes-Benz engineers

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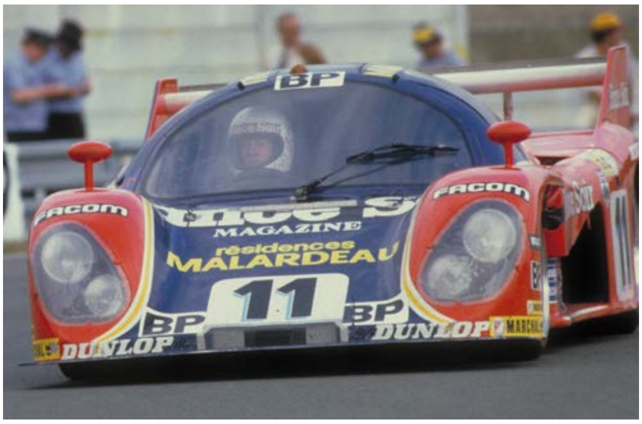
From the UK came Nimrod Racing in '81, running the Aston Martin C2, notably devoid of ground effect



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French gentleman driver / constructor, Jean Rondeau, built a very impressive Sportscar team, using Cosworth power in its M382 chassis, but in 1982 was outclassed by Porsche

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Henri Pescarolo's Rondeau M382 Cosworth (no.23) passes the WM P82, which from 1981 had Peugeot power and technical support

available to the Swiss team. Some suggest the engine wasn't ready but, more likely, the company wasn't yet ready to make a motorsport comeback after more than 25 years away. Instead, fellow Swiss, Heini Mader, looked after the 3.9-litre Ford Cosworth DFL engines, at the time the only customer engine available from a proper engine specialist. One car would be owned by Sauber himself, the second one was sold to Swiss millionaire, Walter Brun, while the German GS Tuning team entered and ran the cars. Well-known chemical conglomerate, BASF, sponsored the effort.

Passion before reason

The announcement of a new team entering the world of Sportscars was always a major affair in the past, especially one based in the UK, the technical epicentre of global motorsports. But when Nimrod Racing Automobiles announced its existence at the end of November 1981, doing so by revealing it would run Group C Aston Martins, the announcement made an even bigger impact. Set up by Aston Martin Lagonda executive chairman, Victor Gauntlett, Aston Martin dealer and Le Mans entrant, Robin Hamilton, and Pace Petroleum boss, Peter Livanos, Nimrod Racing's long-term ambition was clearly to one day win again at Le Mans, preferably within the five years allocated to the programme.

While Aston Martin was involved on the engine side, the project could hardly be called a factory effort. The car had been sketched by Robin Hamilton, but designed by Lola's Eric Broadley, even before Lola had started the design of the T600 for the IMSA championship. In other words, it wasn't exactly state-of-the-art, and didn't incorporate any ground effect. But, like the engine, it might do to learn the ropes. The V8 Aston Martin Tickford engine wasn't going to set the world alight either, with just two valves per cylinder, carburettors and a twin-plane crank to minimise engine vibration. Fuel injection was in the pipeline, though, the team was quick to point out at the launch.

Reinhold Joest, and also the Kremer brothers, decided to build their own chassis with a Porsche engine in the back. Joest took the conservative approach with his car and based the design on the 936 he had built up two years earlier. It featured a similar spaceframe chassis, but a longer wheelbase (276cm compared to the 243cm of the 936) and initially ran with an air-cooled, two-valve, 2142cc Type 911/78 engine, as originally seen in the 936/77. The engine delivered some 560bhp (later 660bhp) transmitted via a Type 920/50 gearbox.

To hold those horses, the car used the same braking system seen on the factory 935/78 'Moby Dick'. Belgian tobacco company, Belga, sponsored the car, which was entered in the WEC for the Belgian Martin brothers, Jean-Michel and Philippe.

British interest

Meanwhile, Britain's Lola had been the first constructor to respond to the new IMSA GTP rules, and in 1981 the Lola T600 made its debut on both sides of the Atlantic. In Europe, Guy Edwards and Emilio De Villota won two World Championship races in the Ford Cosworth DFL-powered, factory-supported T600, while Brian Redman scored five wins in the Cooke-Woods-run, Chevrolet-powered example *en route* to the 1981 IMSA title.

Fellow British constructor, March, also produced a GTP car at the request of BMW North America – the first manufacturer programme of the new era – but where the Lola was elegant and effective, the March-BMW was ugly and unsuccessful. It was scheduled to run the 1981 IMSA championship, as well as at Le Mans, but the lack of success saw the programme fold at the end of the season without racing in Europe.

For its new customers, March announced the 82G model, designed by Adrian Newey and conceived with two things in mind: user-friendliness for the teams and the possibility to use any engine you could find. It was a state-of-the-art Sportscar, featuring an aluminium honeycomb monocoque with the pedals behind the front wheel centreline, as per IMSA rules, a front suspension with wishbones with outboard damper / spring units and a rear suspension with rocker-operated inboard spring / damper units alongside the gearbox. Aerodynamics came from French forward thinker, Max Sardou, who had already signed for the March-BMW M1/C. Sardou had designed the March with massive venturi at the rear and a unique, adjustable wing in the nose section as well.

Lola also came up with a new car, the T610. It had a different aluminium honeycomb monocoque to the T600, and much more advanced aerodynamics. Whereas the March 82G was already aerodynamically superior to anything seen before then, the Lola T610 took the theory to the outer limits of practicality. Ground effect was exploited to the maximum permissible, with large venturi, covered rear wheels, a gigantic, adjustable front wing, similar to the one featured on the March, and a low rear wing with end plates connected to the rear bodywork. The car was designed specifically around the Ford Cosworth 3.9-litre DFL engine, but also provided for the turbocharged V8 Cosworth was known to be working on for 1983.

The first season

Thirty-four cars showed up for the opening round of the 1982 World Endurance Championship at Monza, ten of which were Group C cars, most brand new and barely tested. Consequently, it came as little surprise when Henri Pescarolo and Giorgio Francia in their Rondeau-Cosworth M382 won the race, since their car was basically an upgraded, bulletproof Group 6 car from the previous era, lacking any notion of ground effect. It was just as well the Rondeau held together as only one other Group C car finished the race, the equally artisanal WM-Peugeot finishing in sixth. Not even the works Lancias managed to stage a coup when the theoretically more potent Group Cs were at their weakest, both Barchettas succumbing to technical frailty.

By the next race in Silverstone, the world was back in order. The new Porsche 956 came, saw and conquered pole position by a country mile, but was cheated out of a dominant victory by the sporting regulations. These stipulated that the maximum amount of fuel for six-hour races be the same as for 1000km races, but the fast nature of the Silverstone track saw the cars cover well over 1100km in six hours. Ickx and Bell subsequently had to drive an economy run to second overall, beaten by the unrestricted Group 6 Lancia.

The Nürburgring 1000kms proved its reputation as a car breaker, with the only Group C car finishing being the Rondeau again, this time in second place behind the winning Martini Lancia.

A brand new Porsche 930 Turbo, driven by two local gentleman drivers, finished ninth overall and won Group B, a result that would normally only make the local Eifel news, but which a few months later would make headlines around the world.

The rest of the season is history. Porsche entered three 956s in Le Mans and finished the great race first, second and third. From then on, the German manufacturer won every race it entered, usually finishing 1-2.

Corporate archives Porsche AG

First appearance of the mighty Porsche 956 was at Silverstone in May '82. Jacky Ickx leads from Manfred Winkelhock in the Ford C100 and Bob Wollek in the Joest-Porsche 936C. It dominated the race, but didn't win as the fuel allocation was still being worked out

Corporate archives Porsche AG

The car that won the world title for Porsche: the 930 Turbo of gentleman drivers, Fritz Müller and Georg Memminger, scored 15 points in Group B at the Nürburgring, ultimately deciding the outcome of the Manufacturers' Championship

The world title at the end of the season was therefore Porsche's, but only because of a gaffe in the sporting regulations that allowed both Group C and Group B cars to score points for a manufacturer in the World Championship. Porsche therefore used the 15 points scored by two gentlemen drivers at the Nürburgring to beat Rondeau by 13 points. Missing out on the World Championship title that year marked the beginning of the end for Rondeau.

Lancia came to within 5.3 seconds of winning the Drivers' title with Riccardo Patrese, but lost out to Jacky Ickx. Undeterred, the Italians would commit to a brand new, Ferrari-engined Group C car for the following seasons.

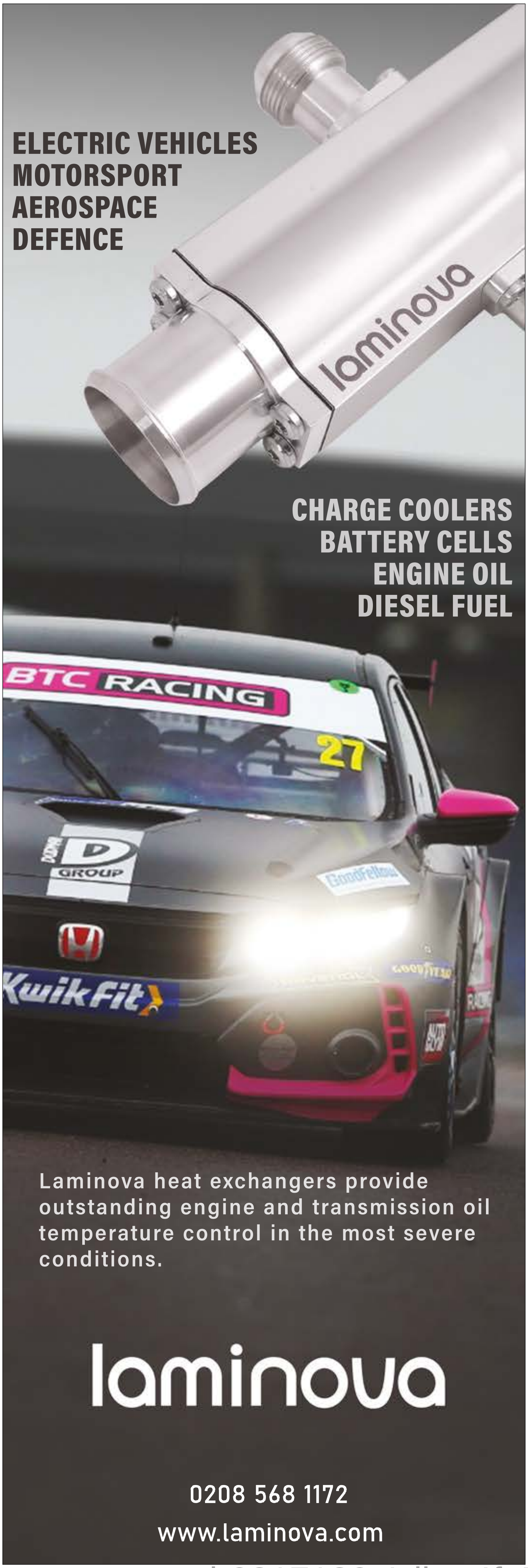
Ford didn't win anything in 1982, not even a podium finish, and its Sportscar programme was cancelled before the start of the next season. In fact, Ford would never be seen again in the top class of Sportscar racing.

For 1983 onwards, the points rules were fine tuned and Group B cars could no longer

Porsche entered three 956s in Le Mans and finished the great race first, second and third. From then on, the German manufacturer won every race it entered

score towards the Manufacturer championship. Likewise, all races were run to a 1000km distance, rather than six hours.

In terms of real racing, the WEC hadn't shown its real potential yet in 1982, though everybody had recognised it, and soon every great British, German and Japanese Sportscar manufacturers would join the fray, as would top privateer teams and major sponsors. Sportscar's golden age had just begun.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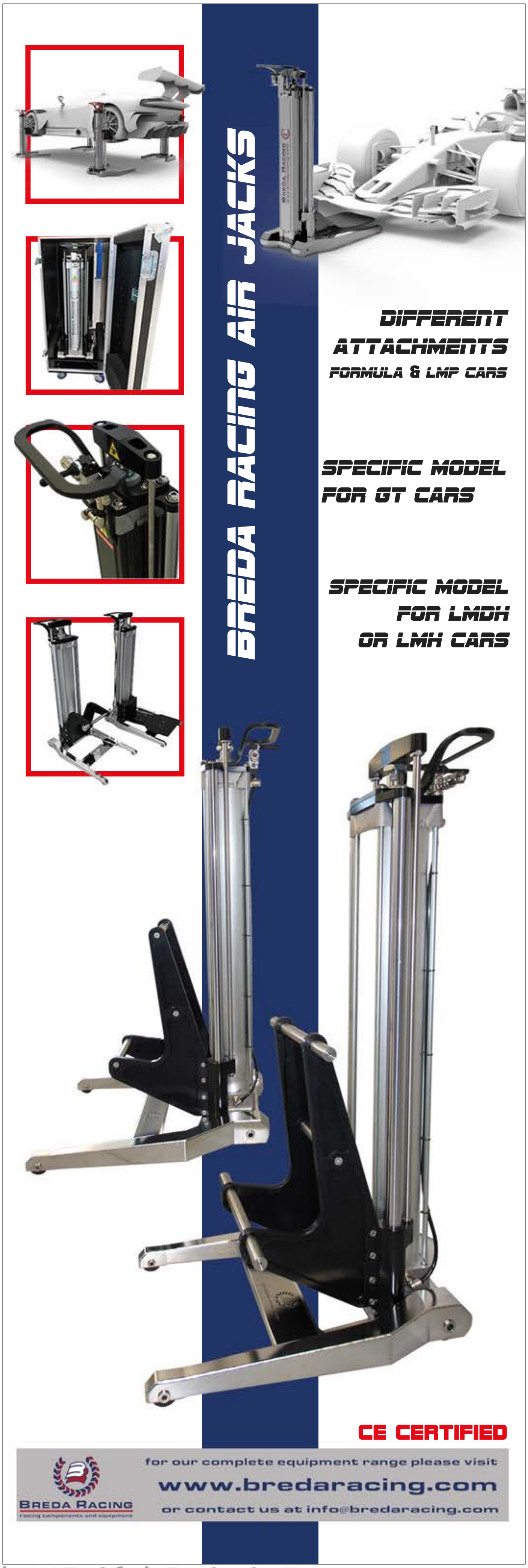
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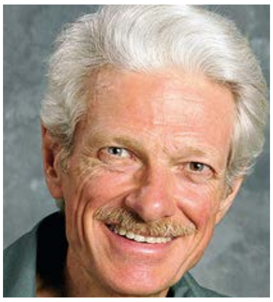


Of Panhard and Watt

Clearing up some confusion in Panhard rod position and Watt linkage use

By MARK ORTIZ

© Raytags | Dreamstime.com

A Panhard bar is common on live axle, rear-engined cars, though many old Trans-Am cars used a Watt linkage instead

Q As far as I understand, it is important to position a Panhard rod as horizontal as possible in the middle of the stroke of the suspension. This avoids excessive lateral movement between the axle and the body when going through the travel of the suspension.

Another important point is the height of the Panhard rod, as that will determine the roll centre of the rear axle. Together with the roll centre of the front axle, this will result in the roll axis of the vehicle. It is important then that the roll centre of the front axle is lower than the roll centre of the rear axle for a confident driving behaviour.

However, it is not always possible to place your Panhard rod on the rear axle in the position you ideally want. So, with that compromise, the placement of the roll centre of the rear axle, or the horizontal position of the Panhard rod is sacrificed when putting it underneath the vehicle. My first question then is which parameter is more important, the height of the Panhard rod (and thereby the height of the roll centre / roll axis) or its horizontal placement in the middle of the stroke?

My second question regards locating the Panhard rod. Is there a preferred side to fit to the axle and the chassis? And does the fixation point make any difference in driving behaviour?

THE CONSULTANT

A For road racing, or any application where the vehicle has to corner well in both directions, it is best to keep the Panhard bar as long as possible, and horizontal at mid-travel or static ride height. It doesn't make a lot of difference which end mounts to the frame, but there is a slight advantage in having the left end attached to the frame and the right end to the axle. That way, the rear roll centre is a little lower when the car is rolled to the left in a right turn, and a little higher in a left turn, which partially compensates for torque roll and torque wedge.

That does not apply in the case of a DeDion suspension or a non-driven axle, of course, only a live axle with a longitudinal driveshaft.

In oval track racing, however, it is more common to mount the right end to the frame, at least for pavement. That puts the bar in tension in a left turn, or when taking a right-side impact.

Some dirt cars you'll see use a short bar, mounted to the frame on the left and to the axle centre section on the right, with the left end considerably higher than the right. This is done to make the left rear of the car jack up when cornering. In combination with roll oversteer and slab-sided bodywork, this helps increase downforce and aerodynamic lateral force.

As to whether the height of the bar is the most important thing. Basically, yes, it is. More precisely, its height near the middle of the car is important. As a rough approximation, that can be treated as the roll centre height in most cases. However, we also need to consider interactions with the axle's longitudinal locating links. Depending on the design of these, lateral translation of the axle with respect to the frame can create rear steer effects.

It is also important that the mountings of the bar to both the axle and the frame be sufficiently rigid. I recall a passenger car engineer telling me of a car that kept exhibiting unstable behaviour in the lane change test at the test track. After trying all sorts of modifications to the front end and steering, they finally found the bracket where the Panhard bar was hung from the frame was flexing. Stiffening that up fixed the problem.

Q Why aren't Watt's links used in Stock Car racing? What are the pros and cons of using them, and how do you determine roll centres and anti-squat?

THE CONSULTANT

A First off, I like to use the term 'link' to mean a single tension / compression member with a pivot at each end. A mechanism using links, along with other elements, is a linkage. So I call the device in question a Watt linkage. That said, 'Watt's link' is in common usage and well understood.

Many readers will already know what a Watt linkage is. Named after the same person who gave his name to the SI unit of power, steam engine pioneer James Watt, it's a linkage with one rocker arm and two links. The links extend in opposite directions from the rocker, and the rocker has a pivot in between the points where the links attach. Watt first used the mechanism in his steam engines and is generally credited with inventing the principle.

It is best to keep the Panhard bar as long as possible, and horizontal at mid-travel or static ride height

If certain geometric requirements are met, the Watt linkage is a true straight-line motion device

If certain geometric requirements are met, the Watt linkage is a true straight-line motion device: within the entirety of its travel, the rocker pivot has a straight-line motion path. As shown in **Figure 1**, the requirements for this are:

- Straight rocker, arms at 180 degrees to each other.
- Arms equal length.
- Links equal length.
- At some point in the travel, the links must be parallel to each other and both perpendicular to the rocker.

For true straight-line motion at A, AB = AC and BD = EC.

To approximate straight-line motion at A with unequal link lengths, AB/AC = EC/BD, or AB*BD = AC*EC.

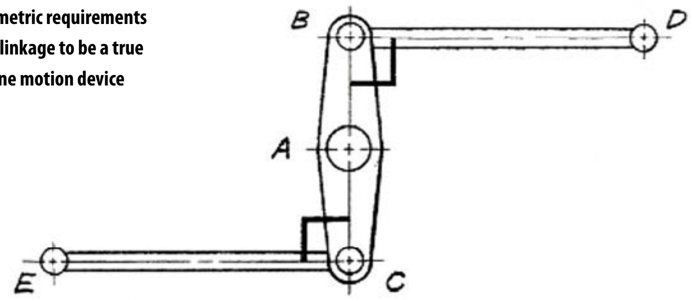
That is, the link lengths need to be inversely proportional to the arm lengths: the long link goes on the short arm.

Astute readers may notice that this is reminiscent of Maurice Olley's rule for approximating straight-line motion at the tyre contact patch with a short and long arm (SLA) suspension: the arm lengths should be inversely proportional to their heights above the contact patch. This is not really surprising as the Watt linkage and an SLA suspension are both types of four-bar linkages (where the sprung structure and unsprung member comprise two of the four bars).

When the links, or control arms, are not parallel to each other, the rocker, birdcage or upright moves about an instant centre where the centrelines of the locating links converge (**Figure 2**). When the links are parallel, the instant centre is undefined, and the motion path is instantaneously perpendicular to the links.

When the geometry provides straight-line motion, the instant centre's vertical movement exactly tracks that of the rocker pivot. However, the instant centre migrates a great deal horizontally. If a linkage, as shown, is used for longitudinal axle location, bump steer can be eliminated. With a birdcage rotating about the axle as the rocker, it is possible to mount a brake caliper on that birdcage, but this is inadvisable because the anti-lift will vary dramatically as the suspension moves.

Fig 1: Geometric requirements for a Watt linkage to be a true straight-line motion device



Just as an SLA suspension can be thought of as a virtual single arm instantaneously moving about the instant centre, so too can a Watt linkage be likened to a single link pivoting at the rocker pivot and the instant centre. Anti-squat and anti-lift will be the same as they would be with that single link. When the Watt linkage is used for lateral location, the rocker pivot will approximate the roll centre.

Grand National

Returning to the first part of the question, Watt linkages have been used in Stock Car racing. They are currently illegal in every class I know of but, for a time in the 1960s, were legal for what are now called Cup cars, and then later Grand National cars.

If I recall correctly, Smokey Yunick's infamous 'too long in the dryer' shrunken Chevelle had one for lateral axle location. When NASCAR went away from requiring genuinely stock suspension, for a time at least any rear suspension was legal as long as it used a 'passenger car-style' live axle (mainly so no quickchanges were used).

People came up with all sorts of stuff, and some of it was not very strong. This meant sometimes crashes would send 300lb wheel and axle assemblies flying through the air.

NASCAR then standardised the system and required the familiar truck arms, single Panhard bar and big coil springs. This created a stronger system, and also one that could reasonably be expected to tighten on-track competition through design standardisation. Really, this was just another step in the long march toward spec car racing, or spec chassis at least, which has culminated in the new G7 cars having true spec chassis, from a single manufacturer.

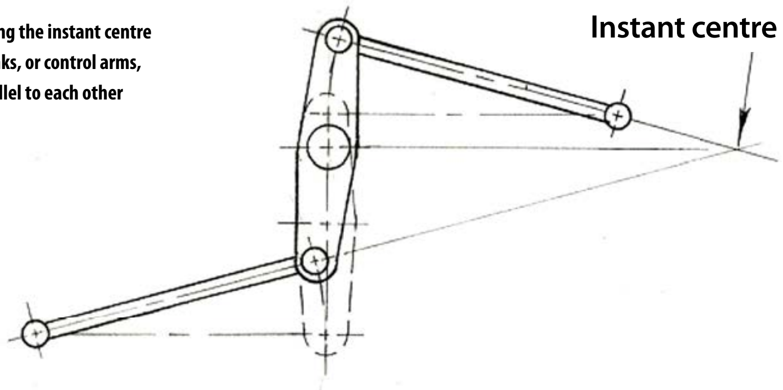
In Dirt Late Model racing, until fairly recently some Rayburn cars had Watt linkages for longitudinal axle location. The dirt racers called this a Z-link suspension. The linkage was designed to use the front and rear pick-up points a monoleaf would use, the rear link being the upper one and longer than the front one. The set-up worked well on a bumpy, tacky track.

However, since World of Outlaws has taken over what used to be the STARS series, these suspensions have been outlawed.

Almost all Sprint and Midget cars use Watt linkages for longitudinal axle location at the rear, with the front link as the upper one. Most commonly, the car has transverse torsion bars behind the axle, and the torsion bar arms serve as the lower links.

For a long time, Trans-Am road racing cars also had Watt linkages for lateral axle location, with the rocker lying horizontally under the axle centre section. This provided a very low roll centre, and true straight-line motion at the rocker midpoint.

Fig 2: Locating the instant centre when the links, or control arms, are not parallel to each other



CONTACT

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Peter Tomschi

Our subject, a 1995 TransAm Camaro GT1, leads some more modern machinery at the Salzburgring

Breathe easier

Applying CFD to the design of the engine inlet duct on a Camaro GT1

By SIMON McBEATH

Following a conventional external aerodynamics optimisation project that, along with chassis and engine improvements, saw our subject racecar move right to the sharp end of its competition arena, attention was switched to aspects of internal ducting.

In this feature, we're going to dip into work done on the engine inlet duct, involving inlet relocation to ensure an ambient temperature air feed to the engine and detail optimisation of the inlet aperture and downstream trunking to maximise airbox pressures.

In the November 2021 (V31N11) issue of *Racecar* we examined the optimisation of the front-mounted radiator duct on the 1995 TransAm Camaro GT1 of Swiss owner / racer, Daniel Buchi, which he races successfully alongside the similar car of his friend and colleague, Robert Brandli, in the Histo Cup in Austria, Hungary, Slovakia and Croatia.

Improved utilisation of the radiator matrix area was achieved, along with the bonus of another 10 per cent total downforce, simply by using CFD visualisations to highlight regions of flow separation, and applying relatively subtle design modifications to mitigate those separation regions. With that aspect of the car improved, we moved on to the engine inlet to see what, if any, gains could be achieved there.

Hot breath

The first aspect addressed was the inlet aperture's location. At the start of the programme, it was at the back of the bonnet (hood) in the centre, chosen in the expectation of raised air pressure in that region, and for its proximity to the engine air inlet filter housing. An obvious potential downside, though, was that the radiator outlet duct was not far upwind, so a method of examining the impact of this was devised.

In order to simplify and accelerate the CFD process on this phase of work, it was decided to use a quarter-car model. This saw just the front half of the more usual half-car model (split at the longitudinal symmetry plane) used for the simulations.

CAD was once again produced by James Kmieciak at Black Art Customs and, following interchanges with the owner on the measurements and geometry of the engine inlet tract, including the throttle bodies, doughnut-shape filter housing and air inlet aperture, a baseline model representing the current configuration was created.

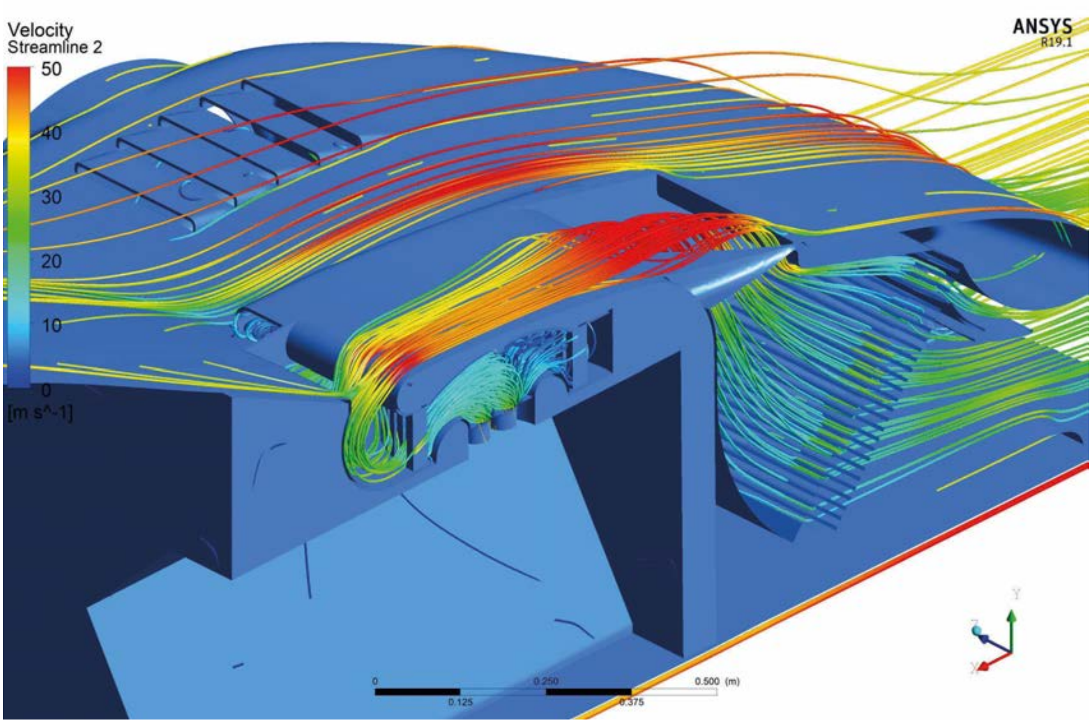

Fig 1: Streamlines projected upwind from the engine's throttle bodies indicated their primary origin was the radiator exit

The model was then used to examine where the air entering the throttle bodies was originating from by setting a boundary condition on the throttle body / engine interface that corresponded to the calculated engine inlet flow at 4000rpm. Airflow and ground speed were set as normal to simulate the car's forward motion.

From visualisations of streamlines projected upwind from the throttles, it was abundantly clear that the engine was, as predicted, inhaling hot air from the radiator's exit duct, as **Figure 1** shows. Not only that, the air entering the inlet tract was also losing significant energy through turning rapidly at the base of the windscreen and heading forwards again into the airbox, with the associated flow separations.

As a result, the static pressure in the airbox was lower than it could be, barely above ambient pressure when the car was moving at speed (160km/h air and ground speed were being used at this stage). **Figures 2** to **4** illustrate what was occurring at this stage.

To further explore the effect of drawing air in from the radiator exit duct, the model and boundary conditions were modified so a simplified thermal simulation could be performed. This enabled the airflow from the radiator exit to have a specified temperature applied to it, which allowed analysis of heated air downstream. Radiator exit temperature was set at 75degC, ambient at 25degC.

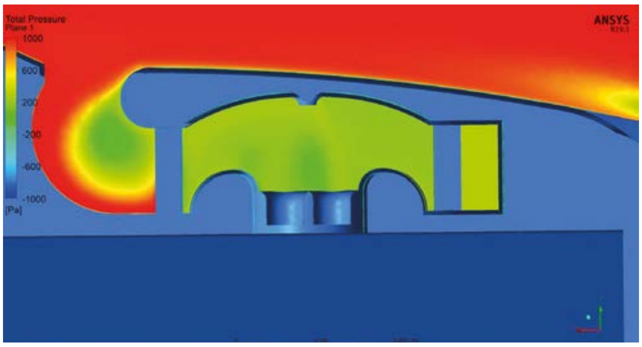

Fig 2: Total pressure plot on the symmetry plane shows the loss of energy (colour other than red) in the flow as it enters the original air inlet aperture at upper left

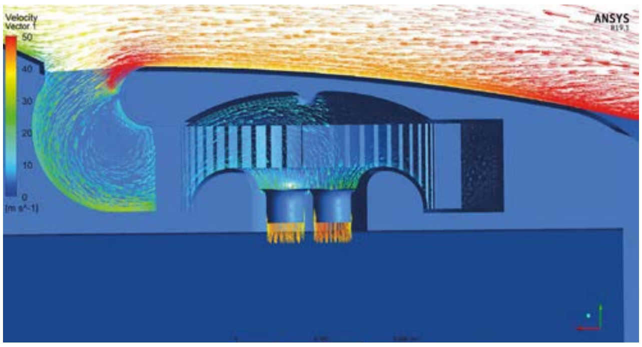

Fig 3: Vectors coloured by velocity on the symmetry plane show the airflow trying to turn 180 degrees and separating in the inlet, producing the energy losses seen in Fig 3

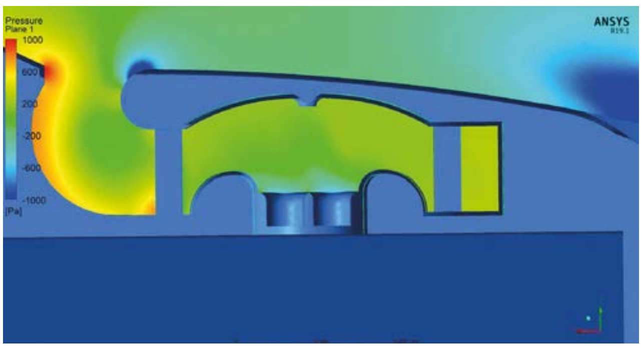

Fig 4: The same symmetry plane slice coloured by static pressure shows the pressures in the airbox barely above ambient pressure (zero on the scale at the left)

An obvious potential downside [of the original inlet aperture position at the base of the windscreen] was that the radiator outlet duct was not far upwind

Images: Simon McBeath except where stated

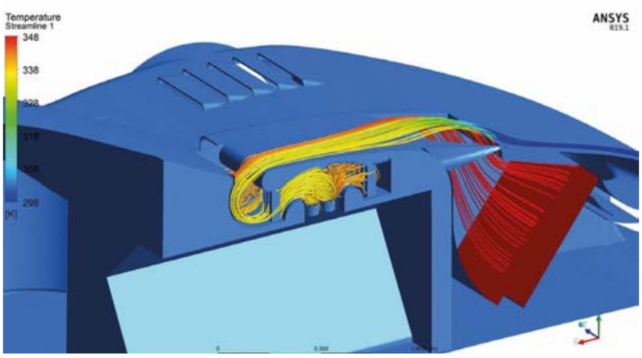

Fig 5: Hot air from the radiator exit was being inhaled into the engine with the original inlet aperture location

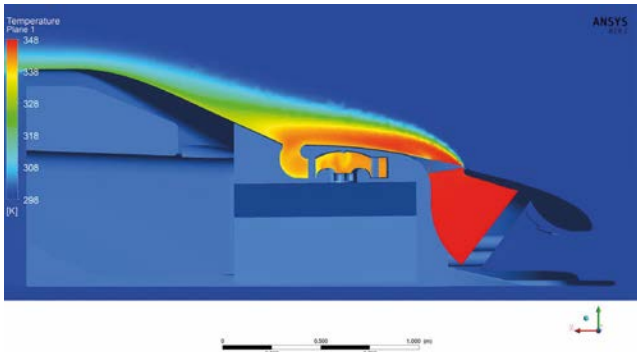

Fig 6: This symmetry plane slice shows how hot air from the radiator exit travelled downwind, much of it entering the airbox on this plane

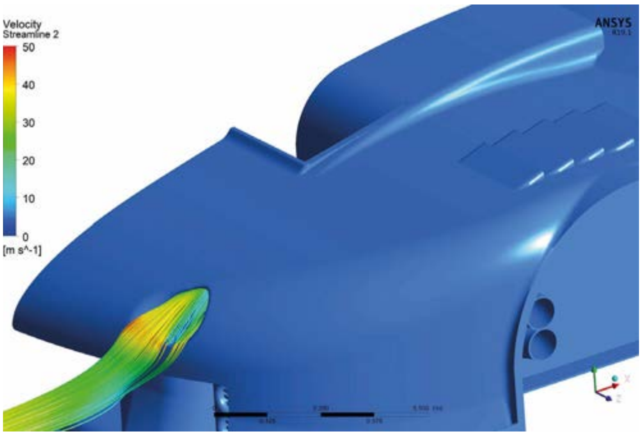

Fig 7: The inlet was initially relocated into the dummy headlight. At first glance, the flow looked to enter the aperture tidily…

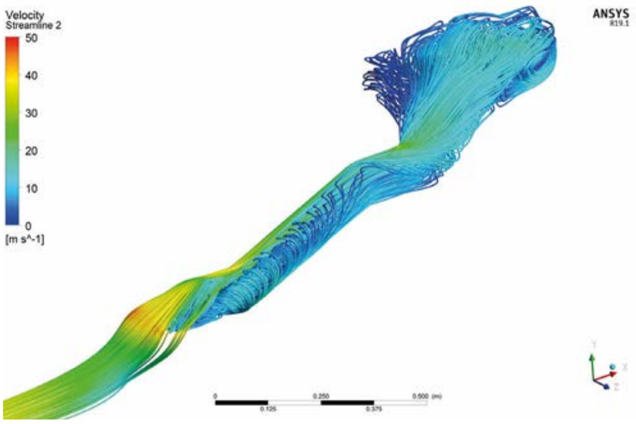

Fig 8: …but, hiding the car body showed the flow within the trunking inboard of the headlight aperture to be rather more complex and 'lossy'

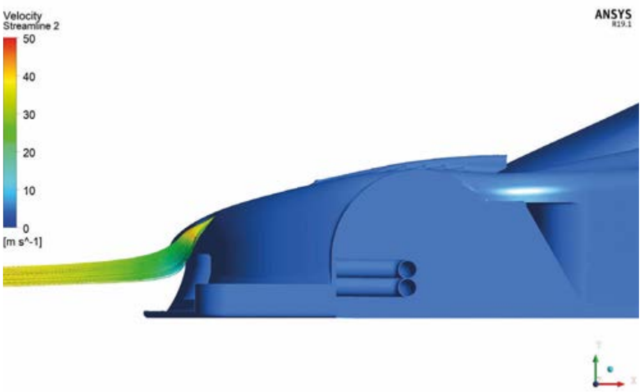

Fig 9: Side view of the same area shows how the airflow turns up towards the inlet

Fig 10: Hiding the car body again highlights the 'lossy' flow within the trunking

As can be seen in **Figure 5**, streamlines (coloured by temperature) emerged from the radiator face at 75degC and entered the filter housing and throttle bodies at between 57 and 67degC. **Figure 6** shows a longitudinal plane slice 50mm from the centreline of the car with temperature plotted on it, showing a different view of the hot air reaching the engine inlet system at a similar temperature range.

Subsequent real world testing and analysis of logged engine sensor data showed the actual temperature in the inlet reaching 58degC, which correlated pretty well with our simple thermal simulation. Additional logged data also showed the inlet pressure to drop at speed, which also corresponded, at least qualitatively, with the CFD prediction from the initial 4000rpm / 160km/h simulation. All good so far.

The next step then was to relocate the inlet to a position that inhaled ambient temperature air rather than hot air, and where dynamic pressure could be exploited in order to increase static pressure within the inlet system, both aspects theoretically enabling increased engine power.

Inlet moves

The owner's first preference for the new inlet duct location was in the left side dummy headlight position, which offered the least complicated route for the under-bonnet trunking from the inlet aperture to the air filter housing. **Figure 7** shows a close up isometric view of the first proposed inlet location, with streamlines coloured by velocity projected upwind from the engine throttle bodies, reflecting the 'middle-of-the-range' 4000rpm / 160km/h conditions again set for this simulation.

The airflow, coming from the left in the images, turned upwards and outwards as it approached and entered the duct, and the velocity can be seen to accelerate as the air turned over the lower lip of the duct aperture. **Figure 8** is the same view but with the racecar body hidden, allowing the internal streamlines to be clearly seen. It is immediately obvious that, while the external flow at the duct entry looked reasonably tidy, the flow within the circular-section trunking leading to the airbox was more complicated, as was the flow at the airbox entry itself.

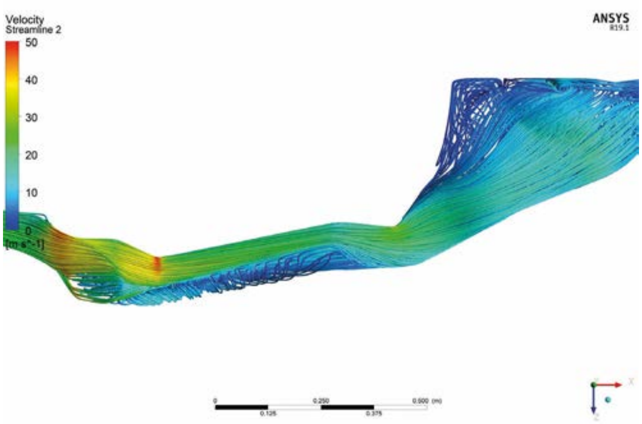

Fig 11: Viewed from above, with the body hidden, gives further information on the flow through the inlet and trunking. Note flow separation in the front of the airbox

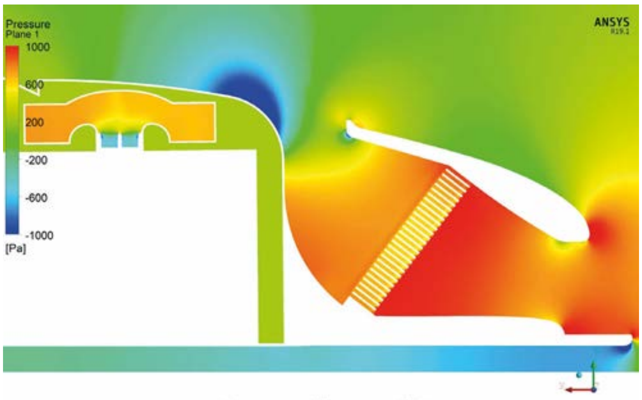

Fig 12: Symmetry plane slice shows static pressure in the airbox was now positive (orange), but not as high as highest static pressure regions on the front of the car (red)

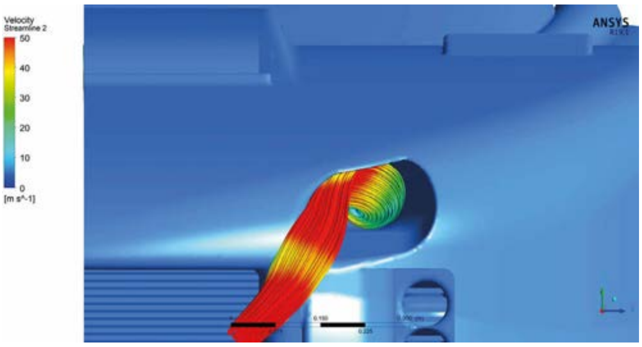

Fig 13: The inlet aperture was clearly oversized for higher speed / rpm

A decision [was made] to move the inlet downwards and further inboard, adjacent to the radiator duct, into what was fundamentally a higher static pressure zone

Figures 9 and **10** are comparable side views that clearly highlight the upwards angle of the flow as it encountered the duct inlet, and what appear to be flow separations from the outer part of the lower lip that get wrapped up in the reduced velocity, swirling flow in the outer part of the trunking. **Figure 11** is a closer, overhead view that further illustrates this, and also reveals flow separations in the forward part of the airbox at the right hand side of the image, which we will return to later.

Usefully though, as **Figure 12** shows, static pressure in the airbox was now positive. However, as can be seen from the colours, airbox pressure (shown in orange) was significantly less than the maximum static pressure in areas such as on the forward-most parts of the car (shown in red). To quantify this, pressure monitors were used in the CFD post-processor to glean some data on pressures in the airbox relative to the highest static pressures found on the front of the car.

Two monitor points were used, both on the symmetry plane, one just inside the front and one just inside the rear of the airbox, and a reference point was chosen on the forward-facing surround of the radiator inlet, where close to maximum static pressure was located. The front airbox monitor showed 61 per cent of maximum, the rear showed 67 per cent of maximum under the prevailing conditions of this run. Although this was a useful step forwards from the original configuration, it was felt that improvements could continue to be made.

Under pressure

Next followed a couple of detail modifications to try to increase airbox pressure. The changes included enlarging the inlet aperture and rotating it to better align with the onset flow direction, and these succeeded in eliminating most of the flow separations at the inlet lip. This, in turn, reduced the ensuing energy losses in the trunking and brought both the front and rear airbox monitor pressures up to 89 per cent of the reference maximum value, a further useful improvement.

However, it was clear from the streamlines projected upwind from the throttle bodies (**Figure 13**) that the inlet size was too large for this combination of speed and rpm so, before we went any further, checks at lower speed (100km/h and 6000rpm) and the much more important higher speed of 290km/h and 6000rpm were made. Airbox pressures at the lower speed / rpm combination were now 37 per cent (front) and 82 per cent (rear) of reference pressure.

Although the streamlines showed the duct inlet size to be better matched to these conditions (**Figure 14**), there was increased flow separation at the airbox entry (**Figure 15**) that left reduced energy (and therefore pressure) in the front of the airbox.

At the higher speed / rpm combination, despite the inlet size being too large, there was tidy flow at the airbox entry, with airbox pressures at 95 per cent (front) and 94 per cent (rear) of reference pressure.

A review at this point led to a decision to move the inlet downwards and further inboard, adjacent to the radiator duct, into what was fundamentally a higher static pressure zone. The inlet size was also reduced, hopefully to better match the requirements at the higher speed / higher rpm part of the range, and enable more efficient flow through the duct to the airbox (see p66).

After a couple of iterations of this relocation exercise, in which one of the brake duct inlets was also moved and the radius around the engine inlet aperture increased, the airbox pressures at high speed and rpm were up to 102 and 106 per cent of the reference location value, with the low speed figures at 54 and 93 per cent of the reference value, respectively. This was a useful step forwards and seemed to indicate that the inlet location was now pretty effective.

That said, there were still observable losses of energy (total pressure) in the trunking between the inlet aperture and the airbox, and at the entry to the airbox. In response, in a final detail change sequence, the trunking

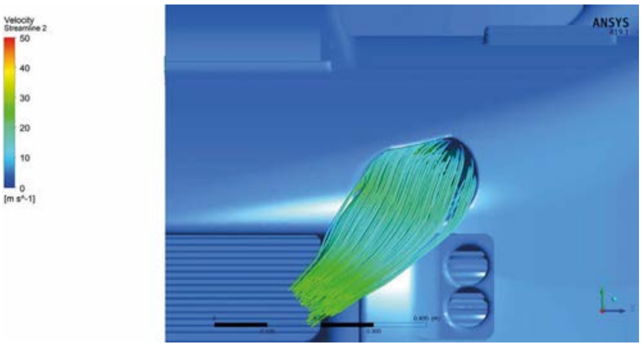

Fig 14: The inlet was better filled at the lower speed / rpm range in this guise…

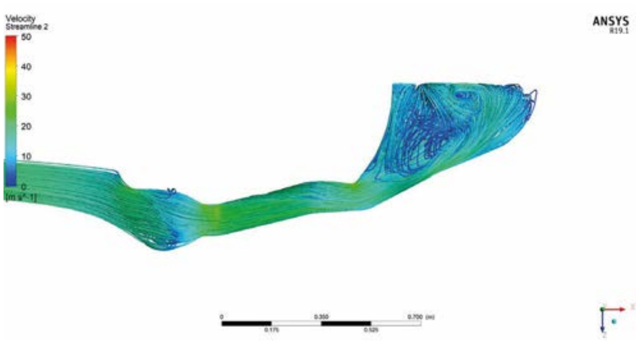

Fig 15: …but there was still significant flow separation evident in the airbox

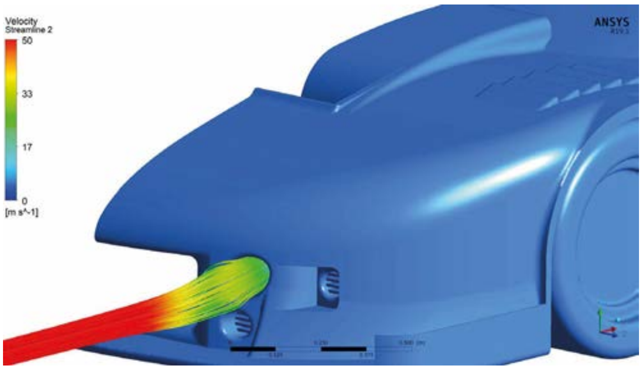

Fig 16: The final location of the inlet was lower and nearer the centre front of the car

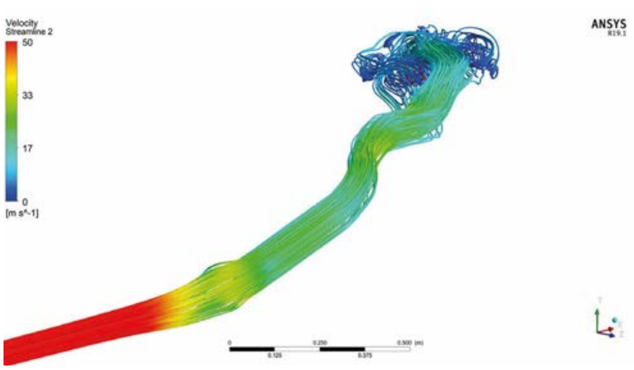

Fig 17: The flow through the trunking was now fairly organised. Separations in the airbox would be dealt with once the simulated air filter was in position

was better aligned with the approaching flow just inside the inlet aperture. The trunking itself was also straightened, and the convex radius in the forward part of the entry to the airbox increased. Although these last modifications didn't entirely eradicate the flow separations in the front of the airbox at the lower end of the car speed range, they did help to increase and even out the pressures in the airbox, culminating in high speed airbox pressures of 105 and 108 per cent of reference, while the lower speed values improved to 62 and 109 per cent (see **Figures 16** and **17** for a visual explanation).

The concluding part of this phase of the project was to tabulate airbox pressures at speed and rpm combinations requested by the owner, these essentially bracketing the most widely used speed and rpm range, from 100km/h and 5000rpm to the top speed the car is geared for at 7000rpm of 270km/h.

Filter tipped

For this stage, a CAD representation of the air filter (following the 'slotted block' concept used for cooler matrices in our projects) was placed in the airbox, and pressures were monitored at the front and rear of the airbox outside the filter, and also at front, rear and left side of the airbox inside the filter. The results are shown in **Table 1**.

We can see from the 'front outside' and 'rear outside' values of relative pressures outside the air filter that even at the lowest car speed tested the airbox pressures were up on previous iterations. This could just be because of resistance imposed by the filter, as well as any small gains accruing from the last design adjustments.

The pressure in the front of the airbox was still lower than at the rear but, as speed increased, the differential reduced and pressures were close to, or above, the reference static pressure on the front of the car. It's worth noting here that the reference pressure value at each speed was just over 90 per cent of the theoretical dynamic pressure, given by ½ρv² at each of those freestream speeds.

The best absolute values achieved in the outer airbox were just on 98 per cent of the

The best absolute values achieved in the outer airbox were just on 98 per cent of the dynamic pressure at the particular speed, so no 'ram air' effect was achieved

Airbox relative pressures versus speed and RPM, % of reference pressure							
Speed, kph	RPM	Fr, outside	R, outside	Reference Probe	Fr, inside	R, inside	Left, inside
100	5000	78%	108%	100%	59%	62%	60%
100	7000	45%	109%	100%	11%	16%	13%
160	5000	99%	108%	100%	91%	91%	91%
160	7000	87%	109%	100%	72%	74%	73%
220	5000	103%	108%	100%	99%	100%	100%
220	7000	99%	108%	100%	90%	91%	91%
270	7000	102%	108%	100%	97%	97%	97%

Table 1: Airbox pressures relative to a reference pressure on the front of the car, across the most used speed / rpm range

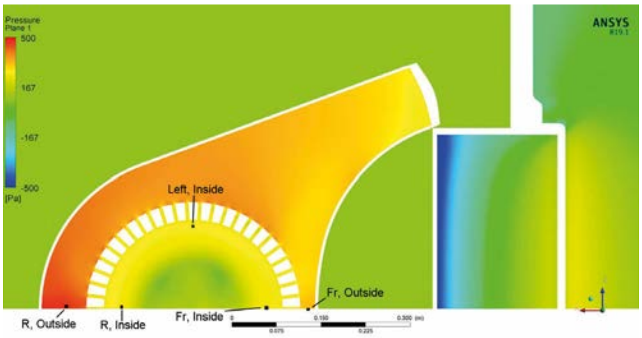

Fig 18: Horizontal slice shows raised static pressure in the airbox around the air filter but reduced pressure within the filter at low speed / rpm. Pressure probe locations in Table 1 are shown

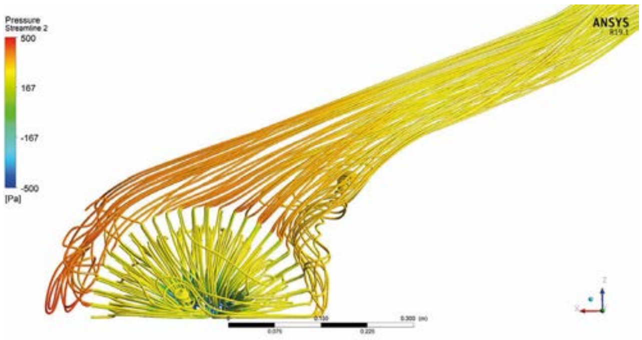

Fig 19: Streamlines coloured by static pressure show a reasonably tidy flow, but still some separation in the front of the airbox at low speed / rpm

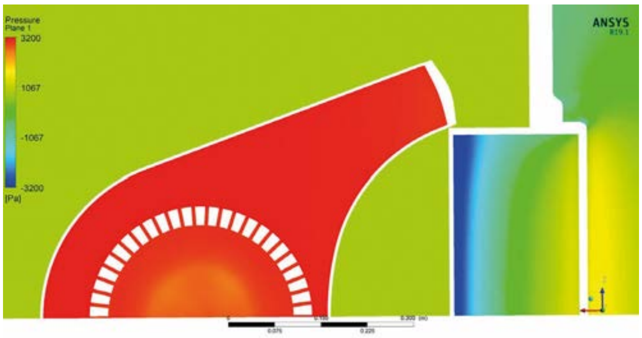

Fig 20: Static pressure in the airbox is high outside and in the filter at max speed / rpm

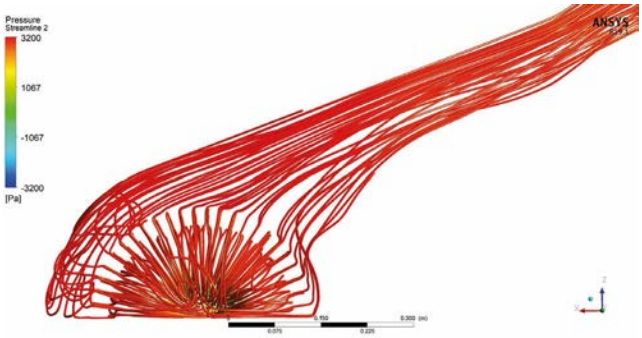

Fig 21: Streamlines show well organised flow in the airbox at maximum speed / rpm

dynamic pressure at the particular speed, so no 'ram effect' was achieved as such, just reasonably efficient capture of the available dynamic pressure, especially at higher speeds.

Inside the filter it was evident that, although the pressures were still just positive at the probe locations, even at the higher rpm, the depression caused by the flow being pulled through the throttle bodies dominated at lower car speeds (**figures 18** and **19**).

As car speed increased, however, the pressures inside the filter also increased and at maximum car speed and rpm were close to 88 per cent of the available dynamic pressure at this speed (**figures 20** and **21**). A marked improvement from the negative pressures (and hot air) found in the original airbox.

Once this speed / rpm mapping exercise was completed, the intake system geometry was transferred to the half-car model so the external aerodynamic parameters could be checked and balanced. Although there was a small loss of front-end downforce from integrating the internal flow to the engine, the car was easily re-balanced.

Now it was just down to the owner to implement these changes on the car.

Thanks to ANSYS/CADFEM for their support with the CFD software.

The new trunking and airbox created following CFD development

Peter Tomschi

The revised engine inlet ducts are clearly visible on the re-designed front panel of the Camaro GT in 2021

Sizing intake ducts

The following is an edited extract from *Competition Car Aerodynamics*, by this writer, and outlines a method for sizing an inlet duct. It is based on an example of a 2005 F1 engine originally provided by Dr Rob Lewis (then at Advantage CFD, now at TotalSim) but applicable in principle to other engines if capacity, rpm and volumetric efficiency (plus boost level, if pressure charged) figures are available.

Assuming technical regulations do not mandate an engine inlet restrictor, how big, and what shape should an airbox inlet be? Gut feeling suggests engine capacity and rpm are critical factors, but the amount of air an ICE shifts depends on its swept volume, rpm and volumetric efficiency (the ability to pump more air than its actual capacity). It's then relatively simple to calculate, for a given engine size and across a range of rpm, the volume (or mass) flow rate of air that enters the engine.

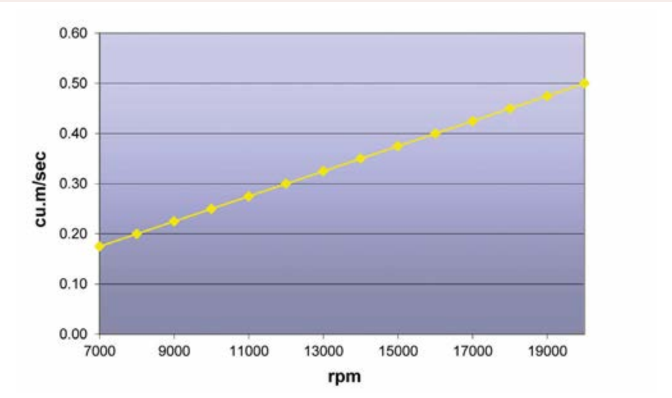

Fig 23: Volume flow rate of a 3.0-litre engine from 7000 to 20,000rpm, assuming a constant 115 per cent volumetric efficiency

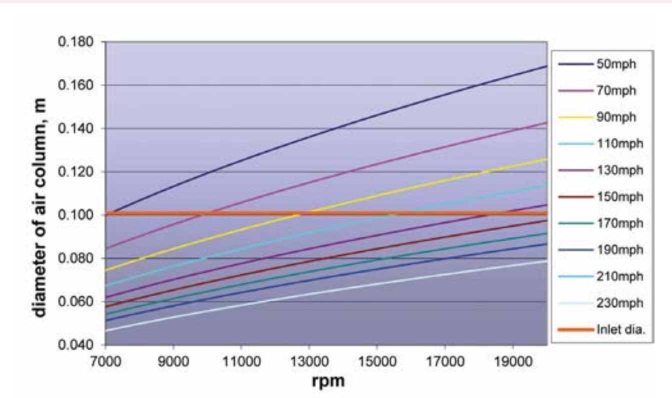

Fig 24: The diameter of the column of air entering an airbox across the same range of engine rpm and car speeds, assuming the column is cylindrical

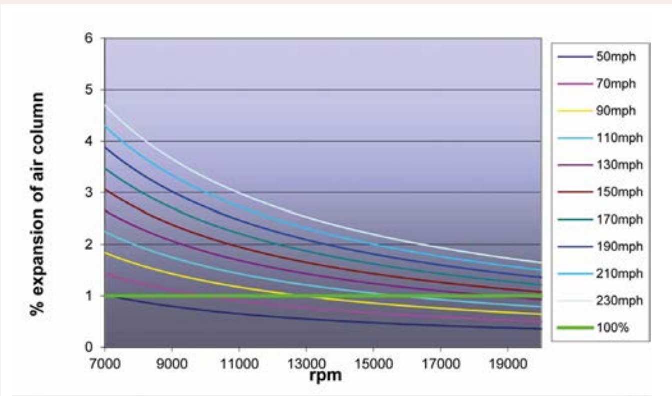

Fig 25: The expansion ratio of the air column entering the inlet aperture, shown as a percentage of the inlet area

Figure 23 illustrates this for an engine of 3.0-litre capacity, and over a rev range representative of a 2005 Formula 1 engine, with the simplifying assumption that volumetric efficiency is 115 per cent across the rev range.

A reasonably large airbox volume is generally deemed necessary so the engine has an adequate reservoir of slow moving, 'clean' air to inhale. For external aerodynamic efficiency, the entry to the airbox inlet should be small and, ideally, properly matched to the engine's needs so it scoops in just the right amount of air. But a glance at **Figure 23** shows this engine has a wide range of volumetric flows across its working rev range, which means it will have a range of breathing requirements.

To try and decide how big the inlet needs to be, the following concept relates the vehicle's forward speed to the volume flow rate of air inhaled by the engine at various rpm, and considers the air being sucked in as a column of air entering the airbox inlet. By dividing the volume flow rate by the car's speed, it is possible to calculate the theoretical cross sectional area of this column at the inlet, over the relevant range of speeds and rpm. For clarity, this can be calculated as if it were the diameter of a cylindrical column, and this data is graphed in **Figure 24**.

So, the size of the column of air approaching and entering the inlet varies with car speed and engine rpm, yet the inlet orifice size is (generally) fixed on a racecar. Take a 2005 F1 airbox inlet area, said to be $0.008m^2$, equivalent to approximately 0.1m in diameter if the orifice were circular, and depicted in **Figure 24** as the horizontal line marked 'inlet dia.'

When the column of air approaching the inlet is smaller than this, the column will expand as it enters the inlet. Conversely, when it is larger, it must contract at the inlet. In either situation, the inlet design must try and prevent unwanted flow separation through careful shaping.

Figure 25 shows this data calculated as the 'expansion ratio' of the air column by dividing this actual inlet area by the air column area at each combination of speed and rpm shown. An expansion ratio less than 100 per cent means the column has to contract as it enters the inlet, and a ratio greater than 100 per cent means the column will expand as it enters the inlet. The intersections of the line marked '100%' with the other graph lines shows the limited number of rpm / speed combinations at which the air column diameter actually matches the inlet size. (Clearly, if gearing was taken into account it would be apparent that many of these speed and rpm combinations will never actually be encountered).

Contraction, it seems, loses more energy than expansion of the column, and would probably lead to less efficient power production. However, contraction occurs mostly at low car speed and high rpm combinations, where the likelihood that power will exceed grip is greater anyway, so some losses would be tolerable. Nevertheless, the contracting airflow needs a smoothly radiused lip on the inlet to minimise the risk of flow separation here, which would increase those losses.

In circumstances where the air column expands (**Figure 26**) at the inlet (above the 100 per cent line), the emphasis is on designing an inlet that enables initial expansion here to be smooth and efficient, again requiring smooth shape transitions. The trick, though, is going to be to size the inlet orifice so the airflow into the airbox is at its most efficient, which we might reasonably assume is when there is neither contraction nor expansion, at the rpm and speed combinations that matter most.

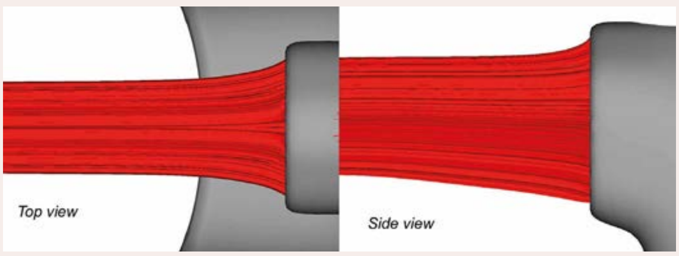

Fig 26: CFD plots of an expanding air column entering a 2005 Formula 1 airbox

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Forward thinking

AI and machine learning are already being exploited in racing, but the technology is moving apace.* Racecar *looks at how it could be used in the near future

By LAWRENCE BUTCHER

Look at any area of modern life and the term artificial intelligence (AI) is being thrown around with abandon. A toaster that claims to use AI to predict the level of charring, or a fridge that criticises your dietary habits? These are of spurious applications, of course, but AI and its subset, Machine Learning (ML), are key to many applications now taken for granted.

The most obvious of these are smart assistants, such as that Amazon Alexa, or the awful filters that can be applied to pictures and videos in some chat apps, both of which rely on AI. However, it is also starting to be leveraged in motor racing, automating a variety of tasks that traditionally suck up considerable amounts of engineering resources.

But what actually is AI?

The classical meaning of artificial intelligence is laid out in the Turing Test, defined by famed British code breaker, mathematician and father of modern computer science, Alan Turing. In the late 1940s, he suggested the possibility of a computer that could learn from experience and in an unpublished paper of 1948, *Intelligent Machines*,

NPL Archive

British mathematician and code breaker, Alan Turing, suggested the concept of AI in a paper written in 1948

Race teams already collect colossal amounts of data and, as AI requires training using historical data to make predictions about future events, are well placed to exploit this growing technology

laid down ideas for elements such as neural networks, which are now one of the foundation stones of modern AI.

Turing's test for whether true AI is achieved relies on a human interrogator, a human foil (who can assist the interrogator) and a computer. The interrogator can ask the computer as many questions as they like, with no limit on their scope (via a keyboard, rather than spoken word). If the computer is able to fool a sufficient number of interrogators, it is considered capable of intelligent thought. No AI system has yet come close to passing a pure Turing test, but this does not mean that AI is just marketing waffle, or that it is not useful.

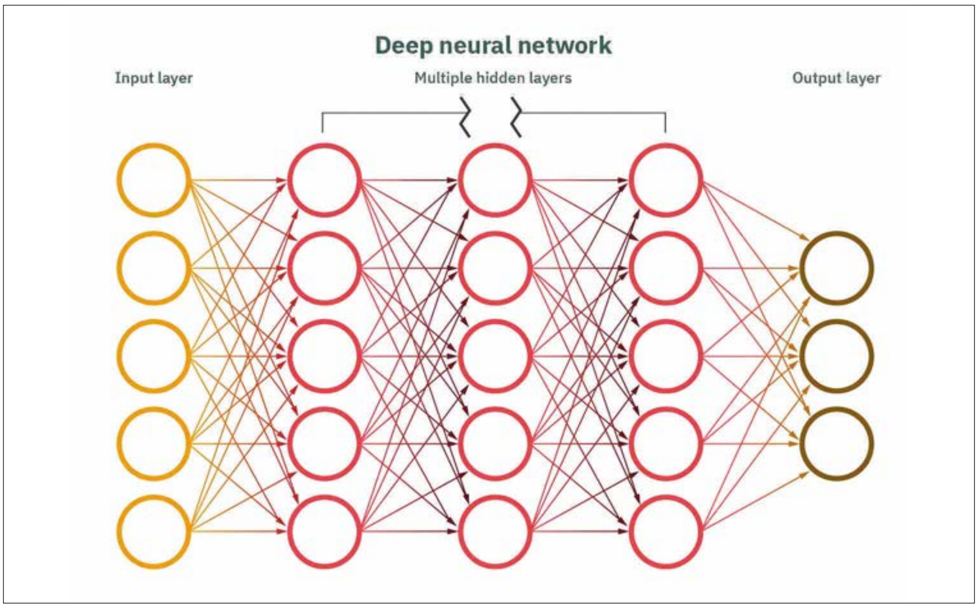
Fast forward to the 21st century, and machine learning, a form of AI that makes predictions based on data, has become a powerful tool. This can be considered a form of weak AI, as opposed to strong AI. Weak AI is trained to perform a narrow set of tasks, whereas strong AI is made up of a General AI and Super AI, the former being an AI classed as having the same intelligence as humans, the latter as having greater intelligence. For now, the idea of even a General AI remains nothing more than a theoretical concept so, for the purposes of this feature, the focus will be on weak AI and ML in particular.

Data rich

The basic concept of ML is training a computer to look at data and identify patterns and trends within it, which can then be used to complete tasks. In the case of racing, these can range from predicting ideal pit stop strategies through to advancing aerodynamic development. Neural networks are the most common AI tool used and are, in effect, series of algorithms that attempt to identify relationships between data in the same way a human brain would.

The network is made up of a series of nodes, known as neurons, which have a specific mathematical function. Networks can consist of multiple layers of neurons, which makes them capable of what is known as deep learning. Each neuron takes input data, extracts the information relevant to the task at hand (having been trained to identify said information) via a linear regression model, providing an output and moves that to the next layer. The result, or target outcome, is computed in the final layer. The effectiveness of the neural network relies on it being properly trained using a series of known (and validated) inputs and outputs which, as we shall see, means the traditional rule of garbage in = garbage out, still applies.

David Massegur, currently completing a PhD in the use of AI for engineering applications, and who spent 10 years as a Formula 1 aerodynamicist, says: 'What currently is being called machine learning in



IBM ??????

Neural networks are the most commonly used tools for AI and identify relationships using mathematical functions

motorsport is in its early stages, from a point of view that they're just trying to replace existing methods, which are not known as machine learning, but achieved similar to what we are now calling machine learning.

'It's not something new to engineering, but it is new techniques that are becoming increasingly famous because of [the attention on] artificial intelligence.'

By this he means that motorsport engineers are well used to harnessing the data they have and deploying it in conjunction with mathematical models in order to optimise performance. AI is simply another means of doing this. However, he highlights that there is potential for AI to create far more powerful tools than was traditionally possible.

'Where machine learning becomes interesting is when you have to undertake analysis with many, many inputs when it's impossible for a human brain to handle all those inputs in order to make a prediction.'

Racing applications

There are several areas where machine learning is currently particularly applicable in racing, some of which are better known than others. Take, for example, race strategy prediction, one of the first candidates picked up by racing teams as ripe for AI exploitation. Most teams have access to reams of data on previous races, so have the ideal source with which to train AI to predict potential outcomes of either their or other teams' decisions as a race progresses.

As covered in *Racecar Engineering* V30N12, GM's NASCAR teams deploy a system that uses historical data combined with machine learning to help inform crew chiefs' strategy calls, a complex task in Stock Car races, which tend to be more chaotic than Formula 1 (the 2020 decider exempted).

Machine learning, a form of AI that makes predictions based on data, has become a powerful tool

Key to this method's effectiveness is identifying which parameters make the greatest difference to the race result, drawn from a swathe of data sources, and training the algorithms using similar information. The impressive thing about the Pit Rho system used in NASCAR is that much of this training happens in real time, as historic data is augmented with fresh stats as a race unfolds.

'For this sort of application, harnessing ML is a no brainer because you can take data from any race in the last, say, 50 years,' notes Massegur. 'The patterns are similar. Okay, the cars keep on evolving and so on, but from one year to the next it's a similar pattern. And you have such a huge input data set that machine learning is very powerful.'

It therefore should come as no surprise that every F1 team now uses some form of machine learning to inform its race day decisions, and there are a variety of similar tools available for use at other levels of racing.

Design optimisation

A more recent area where AI has started to see use is design optimisation. The tried and tested methods of honing a design have been around in one form or another for decades: define an idea, either based on prior experience or a design of experiment, test it (often using simulation), verify the result and then repeat until what can be deemed an optimal design is achieved.

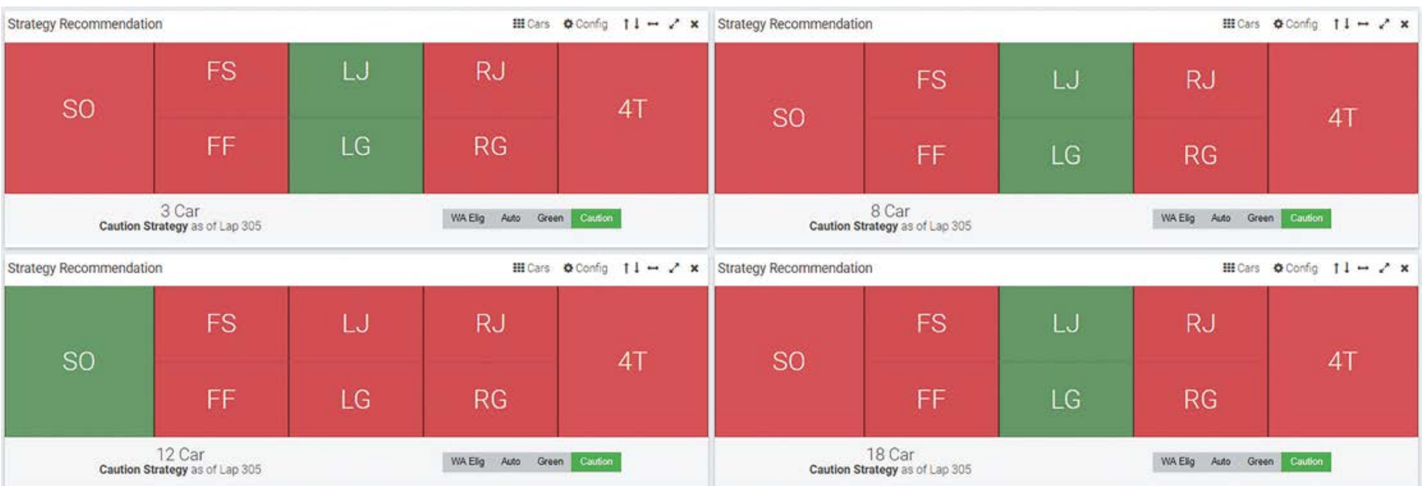
Machine learning can be used in many different ways in racecar engineering. This example data screen shows speed comparisons, suggested strategies and predicted competitor strategy

The basic concept of ML is training a computer to look at data and identify patterns and trends within it, which can then be used to complete tasks

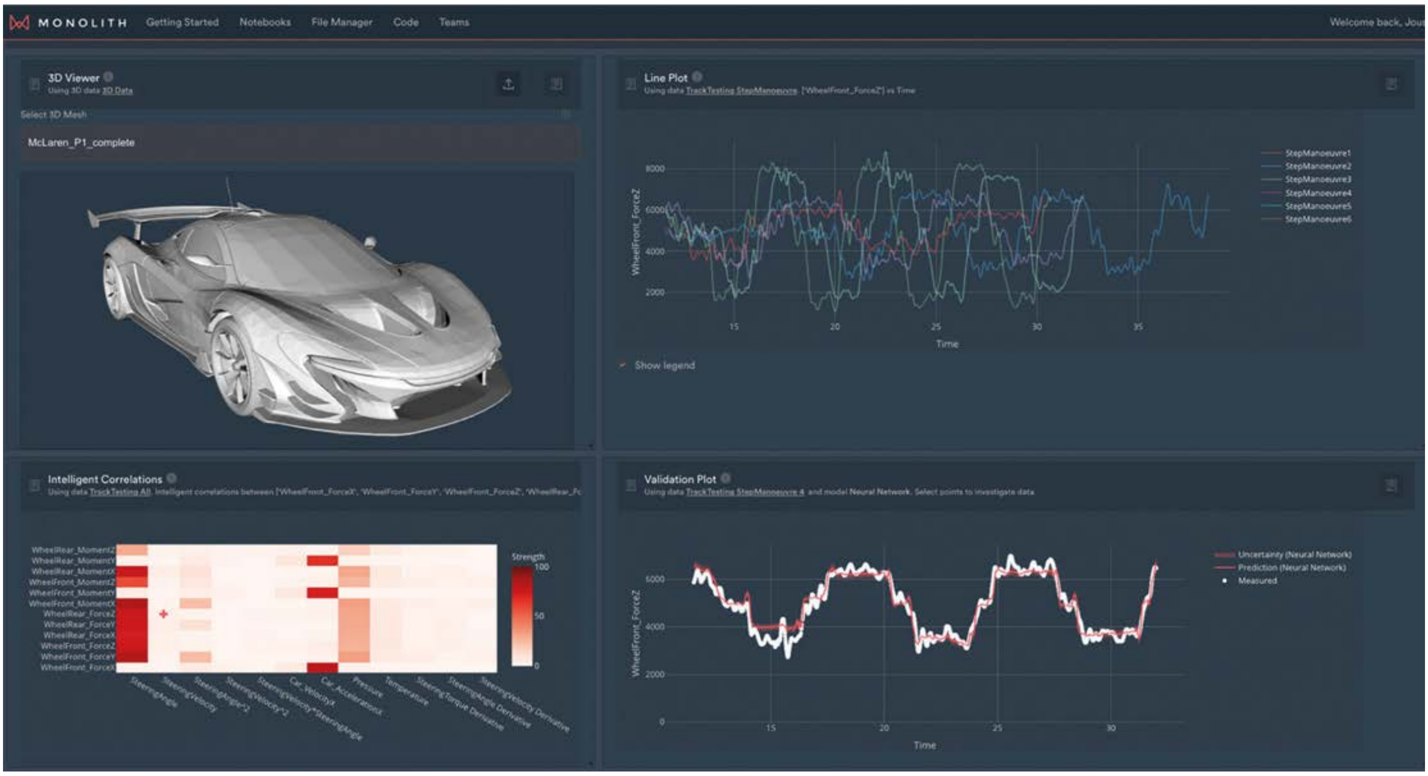
However, this is a very resource hungry approach. Take aerodynamic development as an example. In the past, teams would test hundreds of wind tunnel parts searching for the next gain in downforce or drag. CFD simulation now means it is not necessary to produce so many physical parts and something much closer to the ideal scenario can be reached before any actual components need to be made. However, even the best CFD – when working with the tight margins seen in Formula 1, for example, needs real world validation. Here, an ML-based approach can move things on a further step.

Rather than conduct a CFD run for every iteration of a part, if ML algorithms are properly deployed, a neural network can be trained using existing CFD data and, provided a realistic target is set, hundreds, or even thousands, of potential options can be run through quickly and the ones with the greatest potential singled out. This greatly reduces the computational workload and, importantly in the case of series such as F1 where wind tunnel and CFD runs are now limited, does not eat into valuable resource allocations.

If that all sounds a bit too straightforward, Massegur cautions



The caution strategy recommendations for the two RCR cars, and two non-Pit-Rho cars that led much of the Texas race but were ultimately beaten by the RCR cars because they pitted for four tyres



Monolith AI is a company offering a race engineer-friendly software interface that allows teams' data engineers to conduct machine learning experiments using their own collected data

that to make this an effective approach, it is paramount the algorithms be trained with reliable and relevant data. They are only making predictions, remember, and only work well when asked to solve similar problems to those with which they are trained.

It is also the case that ML only really starts to make sense with scale, when coupled with confidence in its results.

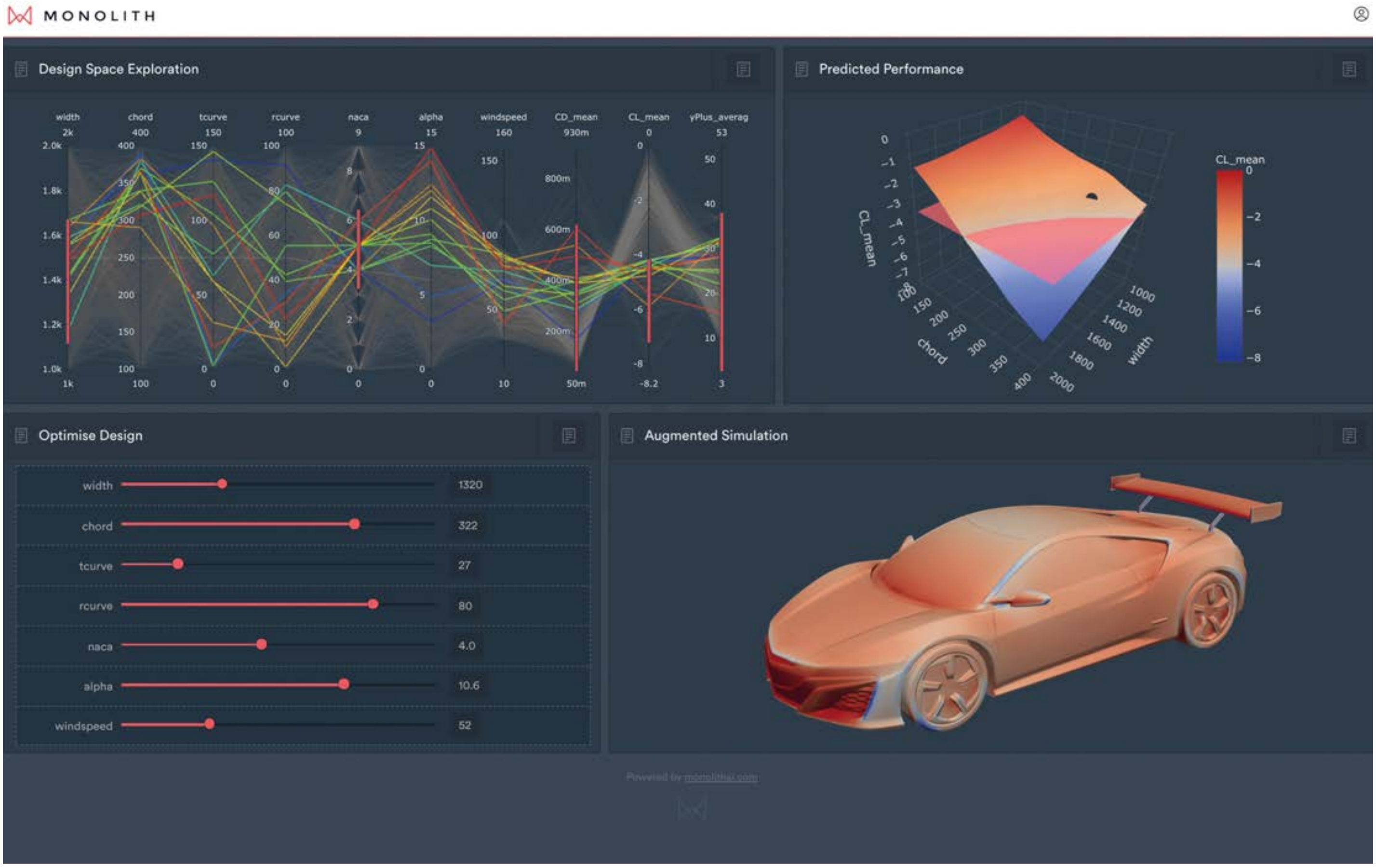
'You need to always keep an eye that the new predictions you are making are actually reliable. You only need to do a few [extra] simulations before you lose all the computational benefit. It is best if you undertake hundreds, or thousands, of simulations. And then, when you reach one prediction you're happy with, you verify it with the high fidelity tool.'

Oven ready

Until recently, if you wanted to harness the power of AI in motorsport, you either had to be a manufacturer team with the resources to run your own data science department, or have a technical partnership with an AI specialist, which is the route many F1 teams, and Toyota Gazoo Racing, have taken. Consequently, there are now a number of specialists offering (relatively) easy to access interfaces to allow engineers to leverage machine learning, without having to work out the back end details themselves.

Monolith AI is one such company, which works across a variety of industries and signed a partnership with LMP2 team, Jota Sport. What it offers is a software interface, accessible via a browser-based

LMP2 team, Jota Sport, started to use Monolith AI at Le Mans last year with a view to speeding up computational analysis



Monolith AI understand that machine learning is not the racecar engineers' area of expertise, so designed its Dashboard so engineers can easily use it to make predictions for design iterations

Data scientists don't necessarily understand that data in the same way the engineers do. And so a big part of the software is putting the capabilities in the hands of the engineer

Saravanan Sathyanandha CTO at Monolith AI

user interface (UI), where engineers can conduct ML experiments using their own data, without having to work out the intricacies of the computing element. This can range from running basic lap time simulations to honing car set-ups, right through to full design optimisation of mechanical and aerodynamic components.

Monolith's CTO, Saravanan Sathyanandha, explains: 'We are trying to empower engineers to be able to use AI for all kinds of production improvements. That can be a mix of trying to reduce the amount of testing and simulations they're running and helping them increase the performance of a design. With every case, you're kind of going through the same process – you have some product you're trying to design, you're doing either simulations or tests to generate data on them, and you're trying to iterate on that until you find your perfect design. Or as good as you can get.'

The underlying aim of the software is to allow engineering groups to do more with less. An LMP2 team, for example, is not going to be able to invest in the bespoke software and data engineering resources needed to develop an in-house AI programme. However, they still have plenty of historical data to work from, and it makes sense to put it to work with machine learning.

'We ask how can we help them use AI to analyse and give predictions for new designs, before they spend £100k running things through a wind tunnel and testing everything. We can then tell them in advance, actually, don't waste your time, these are going to be bad designs, you should try this instead,' adds Sathyanandha. 'AI is not their expertise, right? They understand motorsport, and they understand their cars really well. They want to be spending their time on engineering, that's what they're best at.'

Even outfits with considerable resource can gain benefit from systems such as Monolith AI's. Sathyanandha says it is often the case that an engineering department will send its data over to a separate data science team to crunch.

'But data scientists don't necessarily understand that data in the same way the engineers do. And so a big part of the software is putting the capabilities in the hands of the engineer. The software is designed so you don't need to be a data scientist to set up ML models and create AI workflows. They can look at something and say this doesn't make physical sense, and adjust and understand what the AI is doing in a way that data scientists can't.'

As highlighted, it is still relatively early days for AI and ML in motorsport and it remains, by and large, the preserve of well-resourced teams. However, as the technology continues to evolve, driven for the most part by advances in other areas of industry, there is the possibility that it will lead to an entirely new approach to engineering workflow. Rather than relying on traditional means of simulation and testing, ever more powerful AI could displace these tools and, in doing so, open up previously untapped development horizons, which are currently unfeasible due to limitations on computing power, or other resources.

For the foreseeable future, though, an engineer's intuition will still be needed to ensure things do not go astray, and a time when computers supplant the imaginations of an Adrian Newey or James Allison is still firmly in the realms of Sci-Fi.

Engineering chaos

The dangers of dumbing down motor racing

By DANNY NOWLAN

XPB

The fundamental aim of spec formulae is to 'improve the show', and make it all about the drivers, but what about the importance of the engineers that underpin the entire motorsport industry?

Over the Christmas break I was speaking to a number of colleagues. We spoke on many issues, but one theme that kept coming up was the dangers of spec formula. More scarily, how the parts in these formulae, and tools such as data acquisition, were becoming increasingly regulated.

If this continues, we could have a generation of engineers who are fundamentally disconnected from what they are doing so, when they get to the big time, they will be hopelessly out of their depth. This is an abyss we must avoid at all costs, and is what we'll be discussing in this article.

Techno hysteria

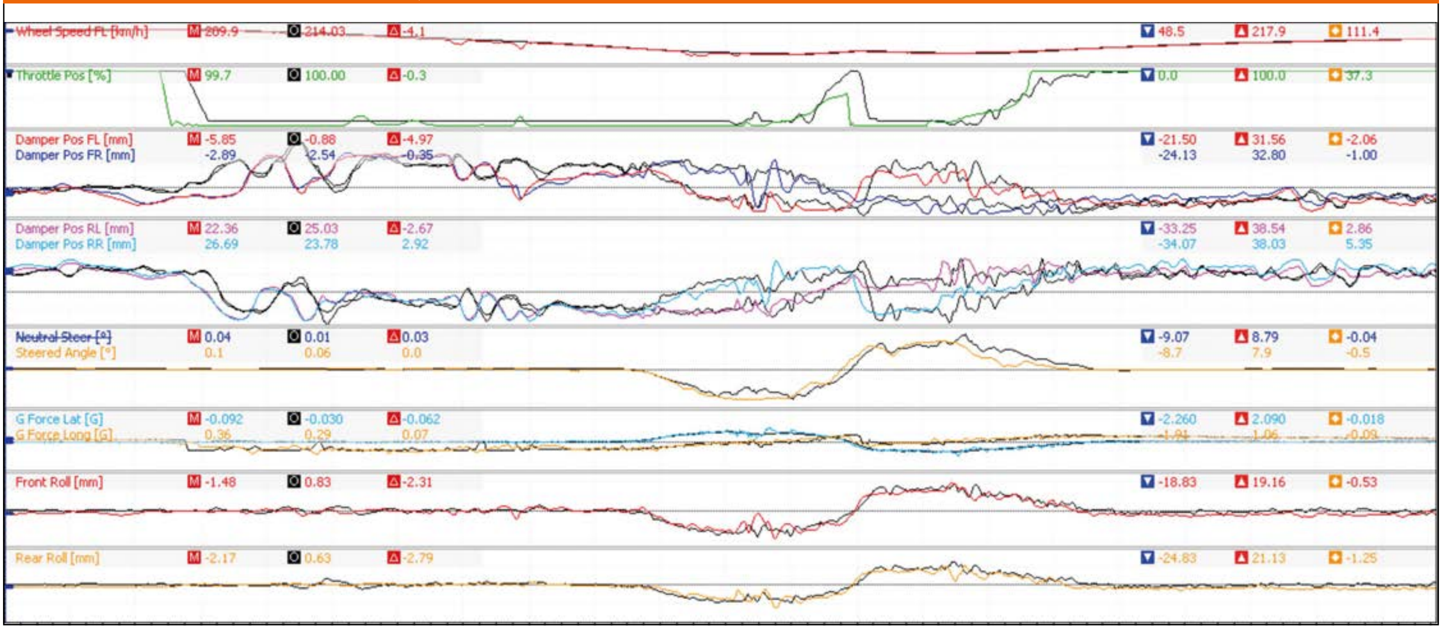
The reason we got into this mess is that as costs were climbing in the mid 1990s, and the Williams F1 team in particular were making everyone look silly with their active suspension system, the motorsport regulatory bodies panicked. A lot of this was fuelled by the resident techno hysteria that exists in motorsport. It's always been there, just burbling underneath the surface.

Don't believe me? Rock up at a motorsport event and mention traction control to a scrutineer and see what happens. And while you're about it, for grins, try turning up at a typical junior formula round with a laptop with a fancy 3D display with source code visible underneath and try explaining to the punters in technical detail why you think this is a good idea.

Indeed, I would go a lot further and say that, ultimately, the motorsport regulatory bodies figured we just need to make the cars all equal to make it all about the drivers.

If this continues, we could have a generation of engineers who are fundamentally disconnected from what they are doing

Figure 1: Actual vs simulated traces from tyre data generated from race data



This information is invaluable and allows a small team to compete on level terms with its bigger, and better funded, counterparts

Nice idea in theory but, in practice, all it does is lead to nose-to-tail racing. You see this abound in spec formulae these days and, if you don't get the magic start, you have a glorified conga train.

The crazy thing about the war being raged on technology in motor racing is that it has no basis in fact. This is particularly apparent in data acquisition. One of the things I speak about at length in the ChassisSim boot camps is the importance of the ChassisSim monster file. I say this not because I love the sound of my own voice, but because the contents of that monster file allow you to reverse engineer the circuit properties and, more importantly, the aero and tyre properties of the racecar. After all, the proof is in the pudding, as shown by the comparison of actual vs simulated data in **Fig 1**.

Here, actual is coloured and simulated is black, and the correlation of speed, lateral *g* and the damper traces speaks volumes for the veracity of this method.

So, just how onerous is the investment required to achieve this? Let's dig up the numbers from a previous article on data acquisition. What you need to log is shown in **Table 1**. All in, there are 17 channels to get you 90-95 per cent of the way there.

Table 1: Core channels you need to log

Channel	Role	Frequency
Engine rpm	Engine / Chassis	50Hz
Engine temperature	Engine	10Hz
Oil pressure	Engine	10Hz
Lateral acceleration	Chassis	200Hz
Vehicle speed	Chassis	50Hz
Inline acceleration	Chassis	200Hz
Vertical acceleration	Chassis	200Hz
Steering	Chassis	50Hz
Throttle	Engine / Chassis	50Hz
Front brake pressure	Chassis	50Hz
Rear brake pressure	Chassis	50Hz
Gear position sensor	Chassis	10Hz
Damper position FL	Chassis	200Hz
Damper position FR	Chassis	200Hz
Damper position RL	Chassis	200Hz
Damper position RR	Chassis	200Hz
GPS altitude	Chassis	10Hz

If I wanted the cherry on top, I would put in laser sensors and tyre temperature and pressure sensors, too. However, what you are seeing there forms the basis of the ChassisSim monster file and, if this didn't work, I'd be out of business overnight.

For a rough estimation of the outlay required to achieve this, see **Table 2**, though note that prices are shown in Australian dollars, so very roughly halve it for pounds and three quarters it for dollars.

Let me also state that what I have outlined here is the gold level standard. If you are on a tighter budget, you can find some AiM or MoTeC club-spec loggers that are perfectly capable of handling all you need for about $2500. Similarly, you can cut some corners on the sensor suite to further bring the price down. They may not last as long but they'll get you going. Do that and you could get started for a figure closer to $5000, plus install charges.

Table 2: Breakdown of prices for data logging – Motec option

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

To put that in perspective, that's roughly what you would spend in the upper formulae on a track hire and in lower formulae on three or four sets of tyres.

However, the real pay-off with this is what you can do with it. The most striking example is this high-speed oval comparison of simulated vs actual data, as presented in **Figure 2**.

Again, actual is coloured and simulated is black. The speeds, lateral acceleration and front pitch (the average of the front dampers) are all equivalent, but the actual rear pitch (average of the rear dampers) is about half that of the simulated dampers. Guess what? You have just identified a hole in the aero map and saved yourself an expensive trip to the wind tunnel. That, combined with the tyre modelling (the end results shown in **Figure 1**) and using some brains gives you the ability to quantify what the car is doing. This information is invaluable and allows a small team to compete on level terms with its bigger, and better funded counterparts. So I'm curious, and this is addressed to the motorsport regulators reading this, how exactly does this spoil the show?

Unlocking dampers

The other thing that is ringing alarm bells is thinking that damping is all too hard and we have to lock it all up in a sealed damper. I can tell you right now this train of thought is so intellectually bankrupt it would actually be funny, if it wasn't so serious. Let me break this down into its two constituent components.

The first thing you need to drive a damper properly is a damper dyno. There are a couple of ways you can do this. The first is to pick up a damper dyno from CTS Automation, which will set you back between US$8000 and $13,000. It will fit in a garage and you are good to go.

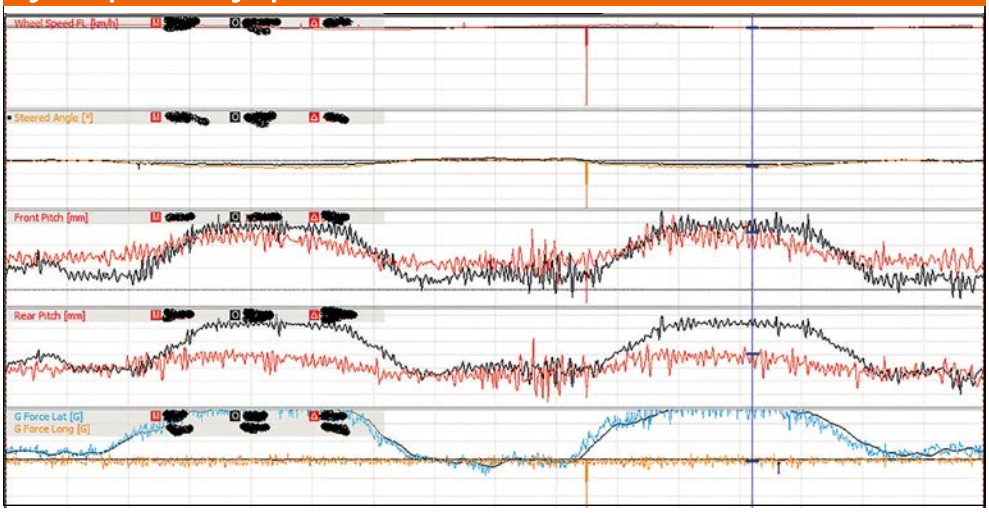
Again, this is the gold standard and pretty much bulletproof. There are lower cost options, or you could build your own. My US dealer, John Hayes, did exactly that for a fraction of the price and uses his for damper work and rating bump rubbers.

So, those saying a damper dyno is too expensive, or too hard, are constructing an argument with zero basis in fact.

The next thing you need to know is how to specify a damper curve. I have

The final, and most obvious, point in the process is to read the manual

Fig 2: Comparison of high-speed oval simulated vs actual data



covered this before in these articles in the past but, to really ram the point home, I'll give you a quick overview.

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

$$C_B = 2 \cdot \omega_0 \cdot m_B \cdot \zeta \qquad (1)$$

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

Where,

K_B = Wheel rate of the spring (N/m)
C_B = Wheel damping rate of the spring (N/m/s)
m_B = Mass of the quarter car
ω_0 = Natural frequency (rad/s)
ζ = Damping ratio

As you can see, all of this is high school-level maths and, if you can't work this out, OPB (other professions / pastimes beckon). Once you've got your head round that, combine it with the damper workbook guide shown in **Table 3**.

All this has pretty much formed the basis in which I specify dampers. What I do next is I use this start point with tools like the ChassisSim shaker rig toolbox to fill in the gaps for a damper specification. This is something I have done to death in the ChassisSim boot camps and on the ChassisSim YouTube channel. While it's far from perfect, it is brutally effective.

The final, and most obvious, point in the process is to read the manual of the damper, so you can start playing with the damper curve and get the shape you want. That might be offputting to some, but I can tell you right now it's not rocket science. If you can run a radio-controlled car, or 'plane, or helicopter, this is right up your alley.

Table 3: Damper ratio selection guide

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

You might now be asking what is involved in distilling the damper elements together? Well, this requires patience, homework, practice and dedication. Like anything worthwhile in life really. Is that going to break the bank? Hell no!

So I ask again – why do motorsport regulatory bodies insist on pandering to the lowest common intellectual denominator when a skilled damper engineer / performance engineer can soon have a small team punching well above its weight?

Everything we have discussed here about the importance of data logging, how to look at a damper curve that makes sense and how to use all this intelligently is a life saver when you start playing in the senior formulae. If we rob junior engineers of this opportunity, you put them in a situation where they start burning through time and money because they don't know which way is up. The bigger teams may be able to tolerate this, but smaller teams can't.

In closing, there is zero case for dumbing down engineers. As we have seen in both data acquisition and damper tuning, there is also no truth in this being an onerous financial imposition. Quite the contrary. With training and a bit of time and dedication, these relatively small investments soon pay for themselves, and are a great leveller in terms of performance.

What is more important than all that, though, is giving junior engineers the opportunity to play with all this and learn their craft in the vital training ground of the junior formulae, so they can hit the ground running in the senior formulae.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IN BRIEF

The **Australian Supercars** series has appointed **Shane Howard** to head the organisation, replacing **Sean Seamer.** Howard, the long-serving chief operating officer, has a remit to continue the domestic and international success of the series. He first worked for the organisation at the 1997 Bathurst 1000 and has since worked in the business development, operations, marketing and live entertainment departments.

'With the Gen3 hitting the track in 2023 and international borders beginning to re-open, [Shane] has a clear strategic vision for the future of Supercars, which the new ownership fully supports,' said Supercars' chairman, **Barclay Nettlefold.**

Pascal Zurlinden, formerly the head of factory motorsport at Porsche, has joined Multimatic as the company's director of performance engineering. He will report directly to MSVO executive vice president, Larry Holt. Multimatic is the development partner on Porsche's LMDh car that first appeared in January.

French manufacturer, **ORECA**, has committed to upgrade one of its engine test benches to evaluate hydrogen technology engines. The hydrogen test bench will allow ORECA Magny-Cours teams to give their projects a new dimension, and will also be made available to the company's main partners and customers in support of their achievements related to this new technology.

ORECA-Magny-Cours is also working on a future hydrogen engine that can be fitted to Dakar competition vehicles.

Driver-in-the-Loop vehicle simulation technology specialist, **Ansible Motion**, has received The Queen's Award for Enterprise, presented to company founder, **Kai Cammaerts**, at a ceremony at the company's Hethel headquarters in Norfolk, UK.

'It's always a proud moment to accept an award, particularly from a representative of Her Majesty the Queen,' said Cammaerts. 'We are honoured and humbled to receive The Queen's Award for Enterprise.'

Maserati is back

Maserati has returned to single-seat competition as a factory for the first time in 60 years, and a decade after its iconic MC12 competed in GT racing in customer hands. The Italian manufacturer confirmed in January that it will compete in the all-electric Formula E World Championship from season 9, scheduled to start in 2023.

The return will coincide with the introduction of the Generation 3 car and is intended to promote the marque's Folgore electric vehicle line, with knowledge flowing between track and road car production.

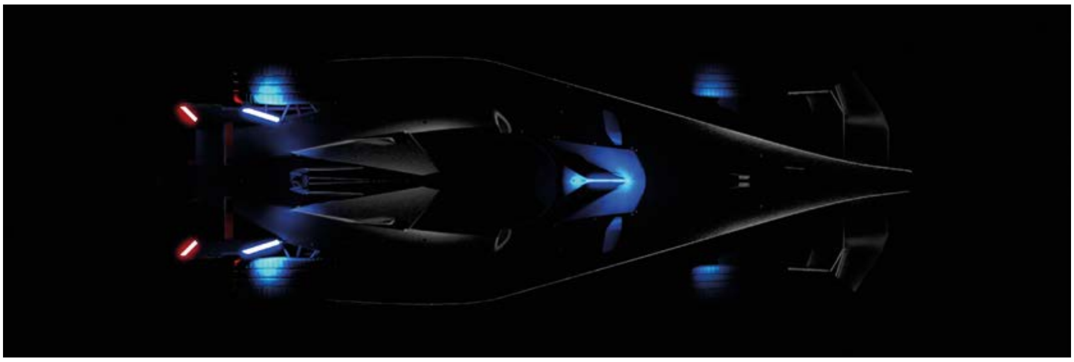
'We are very proud to be back where we belong as protagonists in the world of racing,' said Maserati CEO, Davide Grasso. 'We have a long history of world-class excellence in competition and we are ready to drive performance in the future.'

Maserati collected 14 GT trophies between 2004 and 2010 with the MC12, which followed the brand's success in Formula 1 in the 1950s and the Targa Florio in the 1920s.

'In the race for more performance, luxury and innovation, Folgore – our electrified line – is the purest expression of Maserati,' explained Grasso. 'That's why we decided to go back to racing in the FIA Formula E World Championship, meeting our customers in the city centres of the world, taking the Trident forward into the future.'

Maserati's return to world championship racing was long mooted, with many speculating that the Stellantis brand may be represented in the US endurance racing scene using the Peugeot 9X8 Hypercar concept. However, the manufacturer has selected the all-electric series instead.

'Maserati Formula E will be our technological laboratory to accelerate the development of high-efficiency electrified powertrains and intelligent software for our road sports cars,' said Jean-Marc Finot, senior vice president of Stellantis Motorsport. 'Formula E is the perfect championship for this purpose and we are very proud to be the first Italian brand to join the fold.'



Maserati says it is using Formula E as a technology laboratory to promote and accelerate development of its Folgore full-electric road car line

ERA to support ETCR in 2022

The new, all-electric, single-seat racing series, ERA, has been confirmed as a support race for the electric TCR series in the 2022 season. The ERA will join the FIA eTouring Car World Cup (ETCR) at the second round in Istanbul mid-May, before continuing in Hungary, Jarama, Zolder and finishing the season at Vallelunga.

A field of 10 junior drivers will race identical Mitsu-Bachi F110e single seaters in the 10 races.

The car features an ERA sub-chassis, designed and made in-house in Belgium, mated to a Dome F110 chassis which uses a 24kWh battery.

The ERA electric powertrain will produce a peak output of 130kW (175bhp), which is expected to power the 680kg car to a top speed of around 210km/h, while performance modes will be adaptable at the flick of a switch.

The proposed race schedule for the new all-electric series will include practice, two qualifying sessions and two races. Highlights of all the races will be broadcast on Eurosport in more than 70 countries across Europe and Asia.

Silent runnings: the new all-electric single-seater series will feature prominently on the bill at electric Touring Car World Cup rounds this year

TOYOTA GT3 CONCEPT UNVEILED

Toyota lifted the covers on its latest concept car, the GT3 Concept, at the Tokyo Motorshow in January with a promise to build a car this season. The vehicle will likely be based on the Supra that shares a platform with the BMW M4 and, as such, already has development work completed

IndyCar confirms Dallara again

The IndyCar series has confirmed a contract extension with chassis and aero manufacturer, Dallara, for an unspecified length of time. Dallara has been a chassis supplier to IndyCar for 26 years and has been the sole chassis supplier to the series since 2008. The Italian constructor strengthened its ties with IndyCar when it also signed an exclusive deal for chassis supply to the Indy Lights series in 2015.

'Dallara is honoured to have been part of this journey for 26 years and counting,' says Andrea Pontremoli, Dallara Group CEO. 'We understand the responsibility that comes in extending our partnership with IndyCar over the course of the years to come and are excited to be part of this long-term plan.

'Being such an integrated partner to IndyCar, we feel the inspirational leadership of Roger Penske, along with the management of Jay Frye, has allowed the series to have a continuous focus on safety, while always providing an exciting atmosphere for all of our competitors and fans.

'This partnership will continue to fall in line with Dallara's core values and what we want to see our technology and innovation developed for, adding emphasis to safety and sustainability for the future.'

IN BRIEF

United Autosports has been named as the official distributor for **Schuberth Helmets** in the UK, adding another brand to the Yorkshire-based motorsport company's portfolio, alongside racewear manufacturer HRX, and AERO Sustainable Paint Technology.

The **FIA World Touring Car Cup** organisation has two new appointments. **Jean-Baptiste Ley**, a qualified engineer who worked in the FIA European Rally Championship since 2014 joins as WTCR director, while **Marc Minari** has been named as the executive producer.

The **Formula E Championship** has extended its contract with logistics supplier **DHL**, which has been instrumental in organising the shipping for the cars, batteries and freight totalling 415 tonnes. The renewed partnership will see on and off track initiatives that highlight the joint commitment to environmental and social responsibility, and underscore DHL's role as a sustainability pioneer in the logistics industry.

Tyre manufacturer, **Goodyear**, has extended its relationship with the **Le Mans Virtual Series**, strengthening its ties with the Automobile Club de l'Ouest. In the real world, Goodyear has 14 overall wins at Le Mans, and is the sole supplier to this year's LMP2 category. 'The Le Mans Virtual Series is a fascinating complement to the real race that carries the same spirit of endurance racing as seen in the WEC and ELMS, so we are thrilled to be part of it,' said **Ben Crawley**, Goodyear's motorsport director.

All change on the magic roundabout

Former head of BMW M Motorsport, Mike Krack, has been named as the new team principal at Aston Martin Racing's Formula 1 programme, replacing Otmar Szafnauer, who is thought to be heading to the Alpine Formula 1 team in place of the departing Marcin Budkowski.

Krack's arrival at Aston Martin reunites him with driver, Sebastien Vettel, with whom he worked in both 2006 and 2007 as an engineer for the BMW Sauber team.

As head of BMW M Motorsport Krack oversaw the Formula E and GT race programmes, and the development of the forthcoming LMDh Le Mans programme that will make its debut in January 2023.

'It is a thrill and an honour to have been appointed to the position of team principal of Aston Martin Formula 1 team, and I am very grateful to Lawrence [Stroll] and Martin [Whitmarsh] for giving me such a fantastic opportunity,' said Krack in an Aston Martin team statement.

In BMW's statement, he said, 'I have spent a large portion of my professional life at BMW and have grown incredibly fond of the brand and my colleagues over all these great years. I would like to say thank you for everything we have achieved together in many different projects.

'However, it has always been a dream of mine to return to Formula 1 one day, and now I have been given the chance to do that.'

Former Audi factory boss, Andreas Roos, has been confirmed by BMW to take over Krack's role and will start work on February 1, 2022.

'I'm very much looking forward to my new role and thank BMW M GmbH for the trust they have shown in me,' said Roos. 'I have followed BMW M Motorsport for many years and it is something special for me to now be able to play a leading role in the next chapter of the brand's success story on the race track.'

Race against time

Peugeot is involved in a race against time to prepare its 9X8 Hypercar for the Le Mans 24-hour race in 2022, with the FIA and ACO insisting the car is seen in competition before it is allowed to enter the French endurance classic.

Under the FIA WEC regulations, the Hypercar is homologated for five years, and can only have one change to its specification during that time period. But with its unusual aerodynamic concept, that sees a lack of a downforce-generating rear wing, the team said it needed to validate its figures in track testing before it fully committed to the idea.

Pictures released in January confirmed the car had been testing in Aragon, Spain without the rear wing, but the French team has yet to set a firm race date.

Along with the images came a press release that said only that the two cars would *not* be racing at the opening round of the 2022 season at Sebring, Florida in March.

However, in order to balance the performance of the 9X8 against rivals from Toyota, Alpine and Glickenhaus, the ACO and FIA have stated that they want to see the car competing under race conditions ahead of Le Mans, meaning the car will have to make a race debut at the Spa 6 Hours in May, if the team wants to race at Le Mans.

'We need to see the car racing before admitting it to Le Mans,' said the ACO's technical director, Thierry Bouvet. 'Exemptions have been granted in the past, but now we are racing in a Balance of Performance category that will not be possible any more.'

In doing so, the FIA and ACO denied Peugeot the opportunity of giving the car its public debut at the Le Mans test day, held this year a week before the main race, in order to balance the performance on the French circuit.

Peugeot says it is on schedule, having tested the V6 engine in April, the hybrid system in November and the full package in December on the test bench ahead of the maiden track run later that same month.

In line with previous comment that the team would not compete at Le Mans unless it had opportunity to generate meaningful data ahead of the race, including a race finish, Peugeot's spokeswoman said the team's only priority at the moment was to continue testing ahead of final homologation.

Peugeot's wing-less 9X8 has been testing but, because of BoP, the ACO and FIA want to see it under race conditions before admitting it to Le Mans

NASCAR gets FIA call up

Gary Crotty, NASCAR executive vice president and chief legal counsel, has been elected by the FIA General Assembly as one of 36 judges to serve on the FIA Courts.

A member of NASCAR's board of directors, Crotty is the first NASCAR representative to serve in this capacity. His term, which began on 1 January 2022, runs through to 31 December 2025.

'It is an honour to be recognised and named to this prestigious post,' said Crotty. 'I thank the members of the FIA General Assembly for placing its faith in me and look forward to serving. It is one of the true highlights of my career.'

As an FIA judge, Crotty may sit on the FIA International Tribunal or International Court of Appeal. Both act independently from the other FIA bodies and FIA members.

'Gary has served NASCAR with passion and care for more than two decades, and has a well-deserved reputation as a strong voice for fairness and process,' said Jim France, NASCAR chairman and CEO. 'We thank the FIA General Assembly for recognising Gary and, by extension, NASCAR. They have chosen the right person for this honour.'

IN BRIEF

Williams has parted company with engineering director, **Adam Carter**, who had been with the team since 2016. In a statement, CEO, **Jost Capito**, said: 'As we look ahead at our engineering strategy and requirements for the next year and beyond, we have made changes in our engineering structure. Adam Carter has left the team and I would like to thank him for his hard work and contribution over the last six years.'

Four-time F1 champion, **Alain Prost**, made a spectacular exit from the **Renault Alpine F1** team. The Frenchman was a non-executive director, but the team opted not to renew his contract and went public with the news.

'It was agreed that we would announce together with the Alpine team,' said Prost on social media. 'No respect, sorry!'

He also stated he had refused an offer from the team due to a personal relationship issue.

Porsche's electric Taycan model will be the new safety car for the **FIA Formula E** series, which started at Diriyah, Saudi Arabia at the end of January. The Taycan Turbo S carried the colours of all 11 competing teams in the championship, as well as those of the FIA and Formula E.

Williams Advanced Engineering, which supplies battery and hybrid systems to World Championship racing, has been acquired by Australian iron ore producing company Fortescue Future Industries in a bid to drive down the latter's carbon emissions. The £164m investment means that FFI will be able to use WAE's knowledge to de-carbonise heavy industry. The heavy industrial sector accounts for more than 20 percent of global carbon emissions. 'Since the team sold a majority shareholding in WAE to EMK Capital a couple of years ago, EMK and the Management team have done a fantastic job of taking the business forward,' said Claire Williams. 'We are delighted that Fortescue are now taking over that mantle and see the value in the company and its people in tackling some of the biggst issues facing our world today.'

Bump 'n' run

Full grid, full season, it's full steam ahead for the WEC

The FIA World Endurance Championship unveiled a list of 39 cars entered for the full season this year, including six cars in the fastest Hypercar class, five in GTE Pro and a staggering 28 in the LMP2 and GTE-Am classes. That's proof positive, if ever you need it, that the discipline needs its privateers, who are willing to invest their own money into a global championship.

While the cap must be doffed at the ability to bring in such a number of cars for the WEC, one must also recognise that the selection committee had to turn away cars for reasons of pit allocation at the circuits and transport issues arising out of taking more cars.

While Peugeot confirmed its full-season entry with two cars, the team also acknowledged it will miss the first race in Sebring in March. The original build schedule for the car was constructed at a time that the WEC ran a so-called winter schedule. Le Mans 2022 was to be the last race of the 2021 / '22 season, and the '22 / '23 season was not supposed to start until August or September. Once the WEC switched back to a more traditional summer programme, Peugeot's engineers set about pulling forward the introduction of the team's wingless car (see news) and are likely to hit a target of racing at Spa in May. Bringing it forward to March for a race in the US was seemingly just too big an ask.

There were two notes of interest in Hypercar. One was the inclusion of a full-season entry by Jim Glickenhaus' team, which said it would only compete if assurance was given the car would be competitive against the Toyota GR010 under the series' Balance of Performance system. The other was the absence of the ByKolles Vanwall entry.

The latter said it had paid the entry fee and was expecting to compete, but a paperwork issue meant the FIA and ACO were unable to accept them for the full season. With a full grid, the organisers also confirmed the team is unable to enter on a race-by-race deal either, so the car will not be seen in competition this year, as things stand.

Questions, questions

My question to the FIA and the ACO was what had they offered Glickenhaus that encouraged him to enter for a full season that they could not offer last year and keep him for the final few races of the season, post Le Mans?

'In principle, BoP is a tool used to bring all the cars in a smaller performance window,' said the ACO's technical director, Thierry Bouvet. 'In the WEC BoP process, we include race eligibility [a certain number of laps in the dry to evaluate performance], tyre degredation with eclectic stints, occurrences and obviously performance before the BoP can come into play.

'It's the best way to avoid cost escalation in a championship, but it does not replace the need of a team to compete at its best. Together with our partners at the FIA, we constantly work on refining and improving the accuracy. However, this is an ongoing process, and this is clear to the manufacturers. We have never given any of the competitors any promises of changing the BoP in their favour.'

On the pace

With the LMP2 cars having their pace further diminished this year through aero and power reductions, the argument may run that the Toyota can be slowed to the pace of the Glickenhaus as there will be more room between the pace of Hypercar and LMP2. Toyota does not expect this to happen. Nor, I'm sure, does Peugeot.

With 15 entries this year, [LMP2] is clearly a popular choice

This is despite the fact the original target for Hypercar was a lap time at Le Mans of 3m30s in race conditions. Fastest qualifying lap was a 3m23.9, fastest race lap a 3m27.6, so in the first year the cars have obliterated the target lap time, and are expected to be even quicker in 2022 after a year of development.

I had another question for the series organisers, and that was how they would protect the LMP2 category of the WEC. With 15 entries this year, it's clearly a popular choice for the global series, despite also being the top class in the European and Asian Le Mans Series. In 2023, Hypercar will also include entries from Audi, Porsche, Ferrari and Cadillac. One or two LMP2 teams are expected to move up to the top class, but there is no guarantee of that yet, so LMP2 teams are likely to be turned away next year.

'That is a good opportunity to remind that the LMP2 category is important,' says championship manager, Frederic Lequien. 'It is tricky because with the success of the Hypercar we have to be very careful with the future of LMP2. It is more than a goal that this category will be a class for the 24 hours of Le Mans. We have a pyramid of endurance with the ELMS, and 'P2 has a strong place in it.'

It is not easy. The FIA and ACO have to tread a fine line between bringing in the manufacturers, balancing them properly, and also taking care of the privateers to ensure a stable, longer-term future for the class. We just have to wait and see how they solve it.

ANDREW COTTON Editor

Racecar engineering
Inside the world of modern motorsport technology

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Subscription rates
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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