NASCAR FIA reveals the development of Le Mans Garage 56 entry

UK £5.95 / US $14.50
September 2023 / Vol 33 No 9

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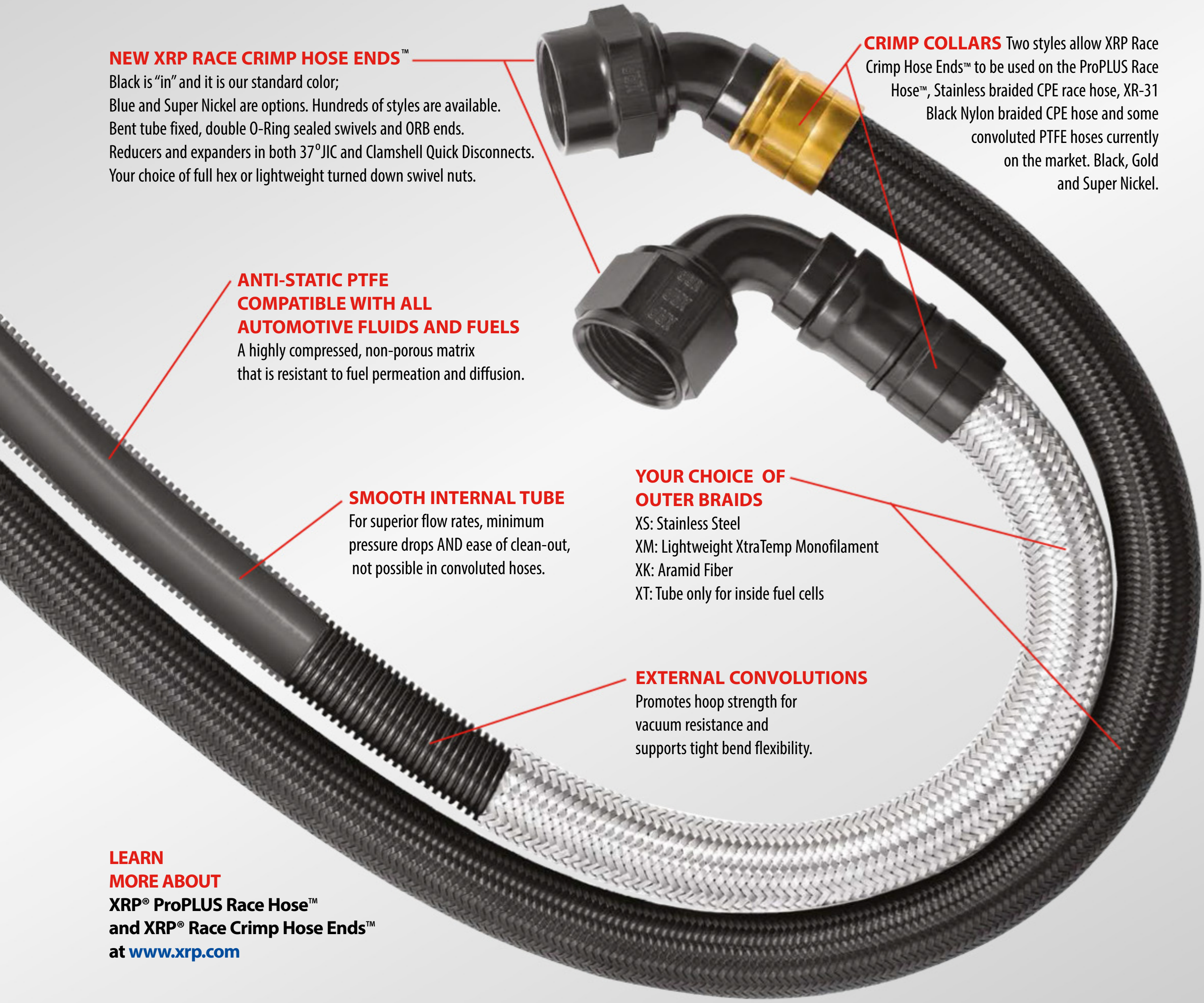

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Taming the beast

With 30 years of experience at Dallara, Jos Claes is perfectly placed to describe how true driving talent affects engineering a racecar

When people ask me to tell them about my job, they tend only to want to hear the best parts. So, since you don't want to hear about the miserable moments, I'll concentrate on the good bits here.

During my early years in motor racing, I spent most of it as a track engineer, working in Formula 3 and F3000. This job, if taken to heart, must cause some of the most extreme fluctuations in emotions and mood status on earth. Well, in racing, then.

We should not simply accept satisfaction as the antithesis of dissatisfaction. That sounds far too fatalistic. No, we must believe that at least some of the race result is thanks to, or due to, the job we are doing.

However, when a real natural talent comes by, things can quickly look radically different

Just as the best student in class will not necessarily be the brightest in real life, the hardest working and best prepared driver will not necessarily become the next champion. Talent, in abundance, is the real game changer.

Without divulging anything, I could chew a bit over Nuvolari, or Senna, or Verstappen (the current F1 driver, not the retired one) but I suggest you read that in one of the many books written on these motorsport heroes. Instead, I'll take this opportunity to tell you about a curious episode that happened late in 1995.

Golden opportunities

I was working for the crack F3 team of Bertram Schäfer. We came out of two years of relative struggle due to a poor VW 16-valve engine in 1994, and a poor driver line up that messed up some golden opportunities we had in 1995.

A few days before packing up for the Macau Grand Prix, we went to that fantastic test track in the middle of France, in Lurcy-Lévis. It's always a pleasure to go to that track as it has everything it takes to identify the very best of drivers. The subjects in this case all came from the lower racing classes and we intended to catch the star before any other team would.

In the morning, the 'professor F3 driver', Max Angelelli, set a time for us to have a reference. Then we installed this little kid behind the wheel and let him out on the track he had never seen before. His fourth lap, third timed lap, was merely 0.2s off the reference time set.

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The extremely talented Nick Heidfeld surprisingly never won a race in F1. Shown here in a Sauber BMW in 2009

He was called in and received not a contract to sign, but a bollocking from boss Bertram. I heard shouting about going too fast, taking too many risks, crashing the car and more.

The young driver stayed completely stoic and then calmly asked if he was now being asked to drive slowly, or drive as a racing driver. Remember here, this potential new recruit had never driven anything above a Formula Ford, which had no downforce, and never raced a car with more than 110bhp and yet managed an 'Angelelli' lap time after just 7.2km (three times the 2.4km lap length) behind the wheel of an F3 car around a very challenging track.

It is still a mystery to me why Nick Heidfeld never won any F1 grands prix. He was one of those natural talents you spot immediately as on the fast lane to Formula 1.

You may be wondering, aloud perhaps, that this is 'only' Nick Heidfeld. Yes, but on top of talented youngsters, there is more. Look at how Verstappen compares to his team-mates.

Better balance

The point is that with such talented drivers behind the wheel, the engineering of the racecar becomes a different job, full of pleasant moments. These drivers seem to have fewer problems with balance and handling than others. Mostly, they can drive around a problem better than others. They also talk more to the point, which means they accept the car will never be perfect, certainly not for the full distance of a race, and know how to focus on the problem that, when solved, has the biggest effect on lap time. They forget about the little imperfections in the car because they concentrate on riding the horse that they are given.

Yes, the racecar is a living creature during the course of a race. It loses weight, altering the weight distribution, it consumes its tyres and it picks up dirt, which causes changes to the aerodynamics.

You want it to be perfect for a complete race distance? Dream on. Get on with it. Wreck the hell out of it and stop focusing on every detail that is not as you would wish it to be.

The engineer understands that the last click of extra rebound control on the rear dampers was possibly not the winning move. That winning move was probably the driver who coped best with the imperfections of the car.

Engineering a racecar (which includes engineering the driver's mind) is so much easier with an exceptional talent in the cockpit. Just as it was in Nuvolari's time, investing in the best driver is the most efficient 'lap time' investment a team can make. Ignoring that is dumb and, worse, an expression of arrogance.

Engineering a racecar (which includes engineering the driver's mind) is so much easier with an exceptional talent in the cockpit

Bull ring

The Lamborghini SC63 is an all-new prototype that will start track testing this year and will compete in the FIA WEC and IMSA next season

By ANDREW COTTON

Lamborghini has leveraged its position as part of the Volkswagen Audi Group, not only borrowing the Xtrac gearbox from Audi's stalled LMDh programme to speed up the development process, but also its simulation software, and some of its engineers, too

Lamborghini's decision to join the sportscar prototype ranks was a long time coming. Achieving board sign off took longer than expected but, once it was given, the team wasted no time in commissioning French company, Ligier, to build a new chassis, and it worked with long-time engine partner, Autotecnica Motori, to build a completely new 3.8-litre, twin-turbo V8 engine for it.

The manufacturer says it will only run a factory team in the next four years, something of a blow to its customers who may have wanted to step up from the Lamborghini Trofeo or GT3 series. The factory cars will be run by the Iron Lynx team, managed by former racer, Andrea Piccini, on both sides of the Atlantic.

An intensive development programme will start in August and is planned for the remainder of 2023, with a view to being ready for the first race of the WEC, in Qatar in March 2024. It is not currently planned to contest the Daytona 24-hours; Qatar is only one third of that race distance and the team wants to start carefully in order to be ready for a full attack on Le Mans.

With such a long lead up to the decision being taken, much of the design work was already done by the time the button was pushed to go ahead with the programme. However, quite quickly there were some changes to the original plan, notably to the engine concept. The idea was to develop a new road car-based engine that would also power the Huracan's successor, but that plan was shelved relatively early on due to the complexities of adapting a production car engine for racing.

An intensive development programme will start in August… with a view to being ready for the first race of the WEC… [and] in order to be ready for a full attack on Le Mans

It was, apparently, also the link with Autotecnica Motori that encouraged the manufacturer towards the race engine that will power the SC63. The company had already designed a nice V6 engine with a plan to one day put it into an LMDh car. When the road car engine plan was being re-considered, it was decided to switch to that engine instead, and for Lamborghini to then develop it into a twin-turbo V8.

Lamborghini did have the option of building an LMH car from the ground up, which would have entailed the development of a new hybrid system as well, but opted to go with an LMDh design instead. In doing so, it selected Ligier as the only one of four chassis manufacturers that didn't already have a deal with an OEM. That decision enabled the maufacturer to have a heavy influence on the chassis design.

An aggressive cut out under the nose, coupled with a Formula 1-style tea tray leading edge to the floor, will set the car apart from the others in the LMDh class, though according to Lamborghini's head of motorsport, Giorgio Sanna, this design was simply the easiest way to generate the downforce needed to hit the performance windows specified by the FIA.

Spares box

The LMDh platform allows the car to race on both sides of the Atlantic more easily than an LMH variety of prototype. It also means it uses a spec hybrid system, including the battery from WAE, MGU from Bosch and gearbox from Xtrac. However, the gearbox lead times are so long that, once sister VAG company Audi confirmed it would not race its two LMDh Prototypes, Lamborghini plundered the spare chassis and took the gearboxes to start testing.

That wasn't the only part that was procured from Audi Sport; so was its simulator and some of the staff that worked on the LMP1 and LMDh programmes for the German manufacturer.

Despite taking the Audi 'boxes, it is not fair to say the gearboxes are a straight plug 'n' play. Re-purposing the Audi's 'boxes merely sped up the delivery process when it was needed, there are still plenty of areas in which the team can make a difference, including the choice of gear ratios and differential.

'The gearbox is a common part like the hybrid, but with the gearbox you can choose a lot of things,' confirms technical manager at Lamborghini Squadra Corse, Leonardo Galante. 'Your ratios, differential ramps, pre-loader… are all things to play with.

'Of course, there are a couple of points you cannot touch, too. The suspension is fixed on the gearbox, for example, but you're completely free on the bellhousing. And that bellhousing is customised and rigid.

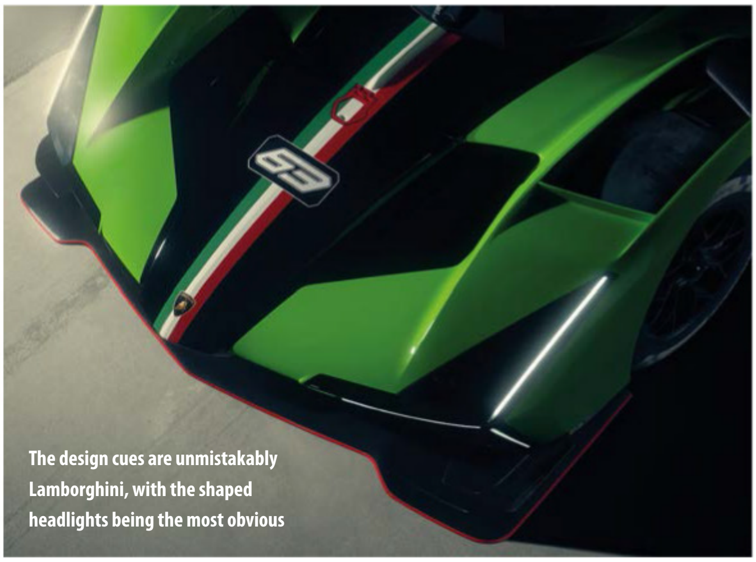
Only one bodykit is allowed in the regulations and the design team has to make the decision whether to focus on Le Mans or the high downforce circuits that make up the rest of the WEC and IMSA schedule

A nod to classic production models of the past, as well as other aggressive styling cues are notable features of the SC63

'The cooling layout basically drives all of the car layout'

Leonardo Galante, technical manager at Lamborghini Squadra Corse

To pass the FIA's high-speed take-off at yaw test, the team opted for a dorsal fin



The design cues are unmistakably Lamborghini, with the shaped headlights being the most obvious

'The bellhousing is also the seat for the front of the wishbones of the rear axle, so you have a lot of freedom to decide the kinematics of the rear end. Then we also fit part of the rear suspension to the bellhousing.

'We don't have the traditional dampers,' Galante continues. 'Regarding the springs, you have one heave element, and one roll element. It's exactly the same in the front axle, and that gives you the possibility to split, or control in a completely independent way, the heave and pitch and roll.

'This is a little bit exciting, because you can build some component that is doing its job only for this particular movement.'

Heat extraction

Extraction of heat has been a major factor in the car, as it is for all hybrid prototypes. The SC63 runs a total of eight different radiators, including for the gearbox, condenser for the air conditioning, intercoolers, energy recovery and storage system, while also having two regular water radiators.

'The cooling layout basically drives all the car layout, because it is not so easy [to fit it all in],' says Galante. 'You need to get the proper air into the big radiators to cool everything down and achieve the target temperatures. You have to guess the worst case scenario for the cooling because you are not able to blank off the radiator inlets [due to regulatory restrictions]. It is a matter of trade off and compromise.'

Likewise, the aerodynamics are a trade off. Under LMDh regulations, only one bodykit is allowed, and it is homologated. Very little can then be done to the car from track to track in terms of adjusting the aero, other than adjusting ride height settings, rake angle and the team's choice of single adjustable device. Teams are allowed to blank off the brake ducts, but otherwise the car is pretty much the same from circuit to circuit.

A question of balance

The Balance of Performance windows are small, and the car has to fit within these aero windows in every condition. They are measured in wind tunnels at Sauber in Switzerland and Windshear in the US for their respective markets. The team has to work out, firstly, which end of the car will be aero adjustable, and then secondly, whether it targets a low or high-downforce car.

'What is very difficult is that, performance-wise, you have only one aero device to control the adjustability of the car,' says Galante. 'And with this one part, you need to adjust the total amount of downforce, and that is all a balance. So, the question is whether or not I do a car that is low drag, with downforce properly balanced for Le Mans, [but which is suitable for when] I go to a high-downforce racetrack, and I can adjust to make work?

'Or, do I go the opposite way, and build a car for the high-downforce race, and then see what happens at Le Mans? This is always a tricky job, because we have just one little device and that's the compromise.'

Whichever way the team decides to go, the prototype also has to pass the FIA-mandated test for take-off speed at high yaw angle. To do so, the team has opted for what is now a traditional engine cover fin and large rear wing end plates, but that then also affects the car's high-speed cornering effect.

'When the car is cornering, basically the aerodynamics must generate a stable moment around the car in order to avoid snap, or a strange behaviour, and this is a core stability margin that is related to the position of the c of g,' says Galante.

Simulation partners

With the car still to take to the track to begin testing, at time of writing, the development team has worked hard on simulators, using both the procured Audi system and engineers, along with the sim' used at AVL, with whom Lamborghini has partnered.

Along with the Driver-in-the-Loop simulator, AVL has also provided some of the facilities for bench testing the engine and gearbox. The challenge now is to match the data in the virtual world with reality, and that is not a step that can be under estimated.

'We are using a simulator in Sant Agata Bolognese that we took from Audi Sport,' says Sanna. 'Audi was using it when they were developing the LMDh and the LMP1. It is a very good one, and we are also partners with AVL. We are using their simulator, including the DiL in Graz, and the car running on the dyno. We used our own simulator to define the concept of the car, then with the AVL one we also validated the entire car.

'We started in August [2022], and the car has already run a lot in the simulator. We will firstly track validate the car with the Audi and AVL simulators, but will focus on our internal one because it is easy to use and it is working very well.'

Active engineering

Two of the big areas in which the manufacturer is active is the engine and the styling. The twin turbochargers on the 3.8-litre V8 are mounted in a cold vee configuration, so outside the vee angle of the engine. This is partly due to cooling issues, but also partly due to better weight distribution and ease of servicing. It is a differentiator to the future road car Huracan engine, which will have the turbos mounted in a hot vee configuration.

The power unit is entirely new, developed in conjunction with the chassis, and has already run extensively on the dyno in preparation for track testing, which is due to start in August this year.

The chassis cuts in dramatically under the nose. The SC63 features an F1-style 'tea tray' leading edge to the car's floor

Lamborghini has elected to stay with its GT3 software partner, Bosch, for the LMDh project, the company providing the all-important ECU for the car.

'The job we did with Bosch on the dyno is very productive,' confirms Sanna. 'Bosch also bring the experience from the other manufacturers. Not data, because we don't need it, but experience from the thermic engine and the MGU, which is fundamental to have in-house.'

Like the V8s from Porsche and Cadillac, the new Lamborghini engine has a flat plane crank, and Sanna says this has not shown up any of the drawbacks normally associated with such a design, such as vibration. Porsche had to re-design its 919 engine due to vibration issues at the start of its programme in 2014, all manufacturers struggled with it in the DTM, and Porsche still has the same issues with its 963 on which it is still working. One of the main issues of the engine vibration is the sensors, and the subsequent reliability of the MGU. Other manufacturers have taken steps to isolate the sensors to protect them, and Lamborghini may have to go down that same path. 'I trust the technicians and, looking at the first results, we are satisfied,' says Sanna of the bench test results.

Right now, as the car is in its test phase, Lamborghini is not subject to the same restrictions as those cars that are currently racing. The amount of data that can be transmitted back to the pit from sensors is not as limited as in race conditions and so in the early stages of testing the team will run with redundant senors to reduce the risk of a car-stopping failure. Those race restrictions are one of the reasons why simulation is so important at this stage.

The [twin turbo V8] power unit is entirely new, developed in conjunction with the chassis, and has already run extensively on the dyno in preparation for track testing

Production values

With the aerodynamic performance limited, the LMDh regulations allow the road car stylists to become involved in the design of the car, and that means Lamborghini's

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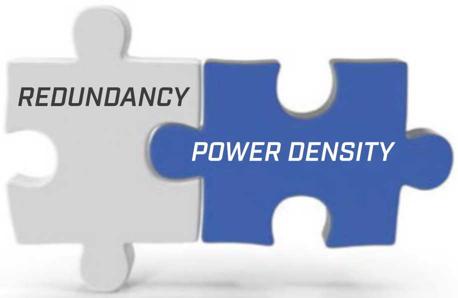

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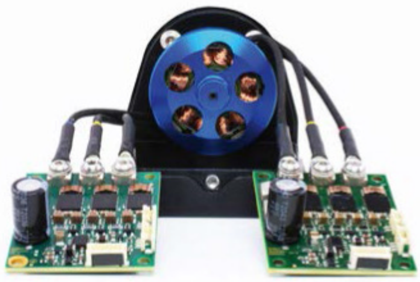

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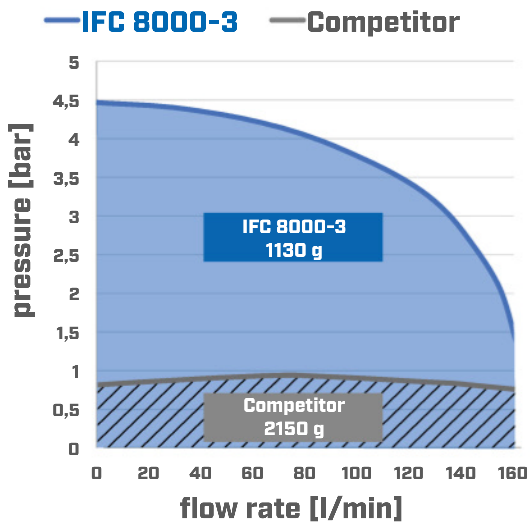

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Centro Stile team designed the car's overall look. Immediately obvious are the y-shape front and rear headlights that fit with the production car values, but there are other, more subtle design cues on the SC63.

'The main impression of the front is driven by the Y-shaped signature lights,' says head of Centro Stile, Mitja Borkert. 'Of course, the cabin and main character of the type of car is driven by the FIA, while the shape of the monocoque is from Lamborghini, within the parameters of the FIA.

'Then you can spot little design cues of Lamborghini. In front of the side panel on the body sides, you'll see NACA air intakes, inspired by the air intake of the Countach, and the rear wheelarch also has this typical shape. It's not just a round wheelarch, we gave this acceleration towards the front and this is related to the real artists we have in our design language. We also have these two hexagonal exhaust pipes, and two reflectors that relate to the Revuelto.

'From the beginning, my brief to my team was that this car be highly functional. There are the typical hexagonal shapes and, where they don't need to be soft, they are finished with the typical sharpness of a Lamborghini. I also said that when the car enters the pit lane at Le Mans, I want to see from far away that it is our Lamborghini coming in.'

Functionally, the first priority was to establish stability of the aero platform as mentioned before, but the second priority was to reduce drag and it was here, particularly around the rear wheels, that huge gains were made. The team was searching for downforce with minimum drag penalty, and tested several solutions for the rear of the car before hitting on a solution that made it to track testing phase. 'We started making some Gurney flaps just to try in the wind tunnel but we were hoping they would not work because it was really ugly,' says senior modeller, Andrea Sironi. 'One other issue was the design of the rear crash box. We managed, luckily, to have the [right] shape. The rear crash box has to collapse on itself so it must be linear, and the shape we had in the top was making a big difference on the crash testing. Everyone makes it square, but the shape of ours actually increases the rigidity of the rear crash box. Ligier was also astonished.'

Efficiency gains

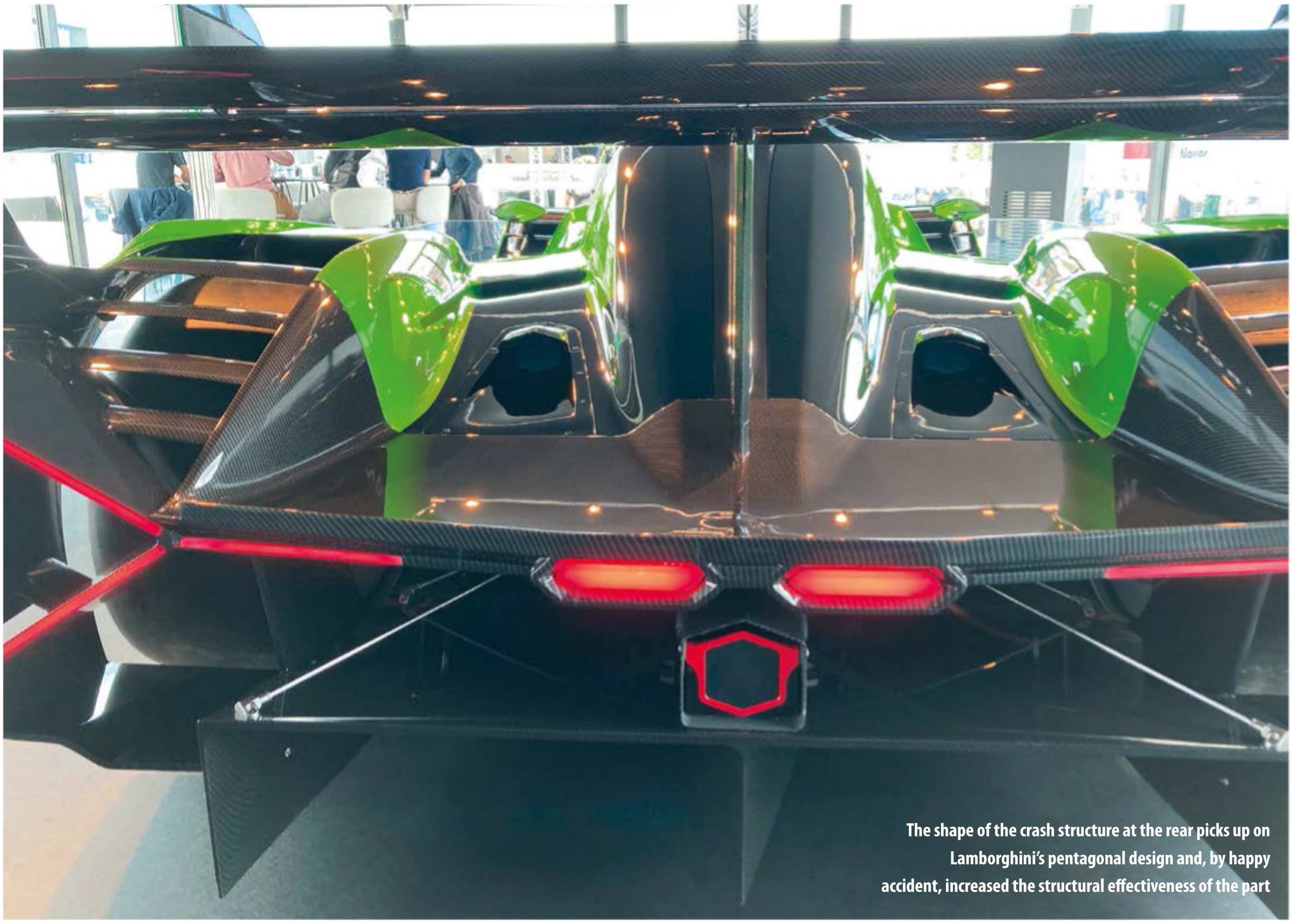
Clearly, the team spent a lot of time working on the small details of the bodywork, and the car has not yet been frozen into its homologation so there will be more gains to be made. Final validation and homologation will take place later this year, ready for final tests in January of next year.

'The main impression at the front is driven by the Y-shaped signature lights… then you can spot little design cues of Lamborghini'

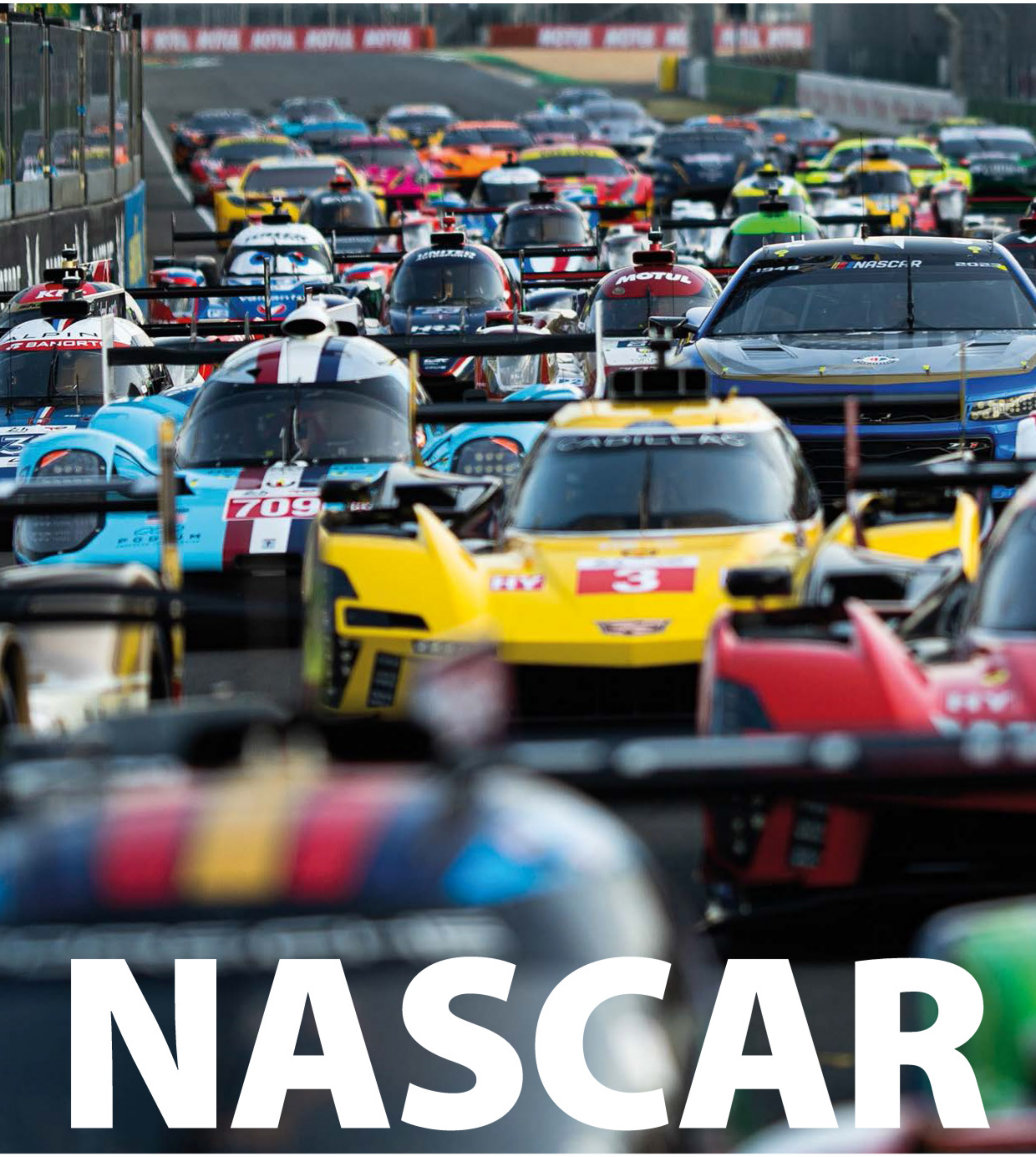
Mitja Borkert, head of Centro Stile

The driving squad is made up from the stars of Lamborghini's GT programme, such as Andrea Calderelli and Mirko Bortolotti, along with Daniil Kvyat and Romain Grosjean, who bring their expertise from grand prix racing. That, says Lamborghini, has helped it work out the hybrid management and cockpit layout faster, due to its drivers' experience in Formula 1.

The car will race in the long-distance races in IMSA, alongside a full World Endurance Championship programme, and the plan is to have two cars race at Le Mans. This, alongside the GT3 programme in SRO and WEC, will mean a huge presence for the brand in endurance racing.



The shape of the crash structure at the rear picks up on Lamborghini's pentagonal design and, by happy accident, increased the structural effectiveness of the part



NASCAR does Le Mans

XPB

The NASCAR towered over the rest of the Le Mans grid, and necessitated a new approach to its safety parameters

The new Gen 7 car ran successfully at Le Mans, but before it could the FIA had to ensure it was safe to run at the French track. Xavier Mestelan explains what the process entailed

By ANDREW COTTON

The decision to enter a Gen 7 Chevrolet Camaro NASCAR into the FIA World Endurance Championship race at Le Mans was something of a surprise when it was announced in March 2022. Much of the ensuing controversy surrounded the fact that the Garage 56 entry is meant to be for experimental technologies, and there was no way the Camaro met that criteria. There was an attempt to introduce hybrid technology to the car but, due to a shortage of available parts and time, as well as the added weight and complexity involved, that plan was shelved.

The car did ran on standard biofuel for the WEC, developed by TotalEnergies, yet there was more technical development on this car. The story went much further, with a complete re-work of the car by Hendrick Motorsports, Dallara and suppliers including Goodyear, to bring the Camaro up to FIA safety standards needed to run at Le Mans.

Walk the line

Development of the Camaro focused on the reduction of weight. A typical NASCAR weighs in at 3500lb, nearly 1600kg, and with the car boasting a power output of more than 500kW (around 700bhp) there was a high chance that if it crashed heavily, the barriers would not be able to easily contain it.

There was also the issue of class stratification. The NASCAR was an invitational entry, so could not interfere with other cars around it competing for a championship.

Clearly, there was a fine line to be walked. The car had to be fast enough to not be a mobile chicane for those going for the championship, slow enough in the right parts of the track to not get in anyone's way, while also being safe enough for the Le Mans circuit to accommodate it.

In stepped the FIA, which already works with NASCAR on other projects, including the future direction of motorsport, as well as hybrid and HANS safety, to set out the safety parameters that would allow the car to race. It took its base regulations for GT3 as a starting point and consequently, alongside the weight reduction the FIA had other areas of concern that also needed to be addressed.

DPPI

Xavier Mestelan, chief technical and safety officer at the FIA

Getty

Tyres were a critical element, but also an unknown one from the FIA's perspective, as the NASCAR's cornering speed was one of the biggest concerns for the regulatory body prior to the race

'To reduce the weight for safety concern was important, but also for performance,' says Xavier Mestelan, chief technical and safety officer at the FIA, whose team worked closely with both Hendrick Motorsports and Dallara on the technical development of the Camaro.

'When speaking of safety, it is important to imagine how the car manages in the middle of the track with other GT amateurs, LMP2 and Hypercars, and this was a target to reduce the weight of the car, with agreement from Hendricks.'

Superior speed

Of the other areas that needed consideration, the first was one of the car's top speed. NASCAR typically works on ovals, with high speed a priority for teams and drivers, but for Le Mans the worry was that the car would be too fast in a straight line, less so in the corners. The major concern was that it could pass an LMP2 car with its superior straight-line speed, but then have to brake much earlier than the prototype, increasing the risk of an accident.

'This animal was not that different to a GT,' says Mestelan. 'The car itself was different but, in terms of safety requirements, we can consider both cars very close. The target was therefore the same, to manage the car among other cars, to reduce the impact in case of a crash between two cars or a car to the barrier.

'But to come back to the weight, it was crucial, and at the end the minimum weight we achieved was 1340kg, so more or less 70kg more than a GTE. That was very close, but this is why we modified the rollcage with them, to achieve the loss of weight.

'We also worked on other topics, like the brakes with the carbon disc, which affected the efficiency of the brakes, but we also saved some kilos there as well.'

In order to reduce the top speed, Hendrick Motorsports elected to run the high-downforce package on the car, which had the added bonus of increasing performance through the high-speed Porsche Curves. Despite doing so, the final race results show the Camaro had an average over its five quickest speeds through the traps of 312km/h, around 6km/h faster than the quickest GTE car's fastest five speeds.

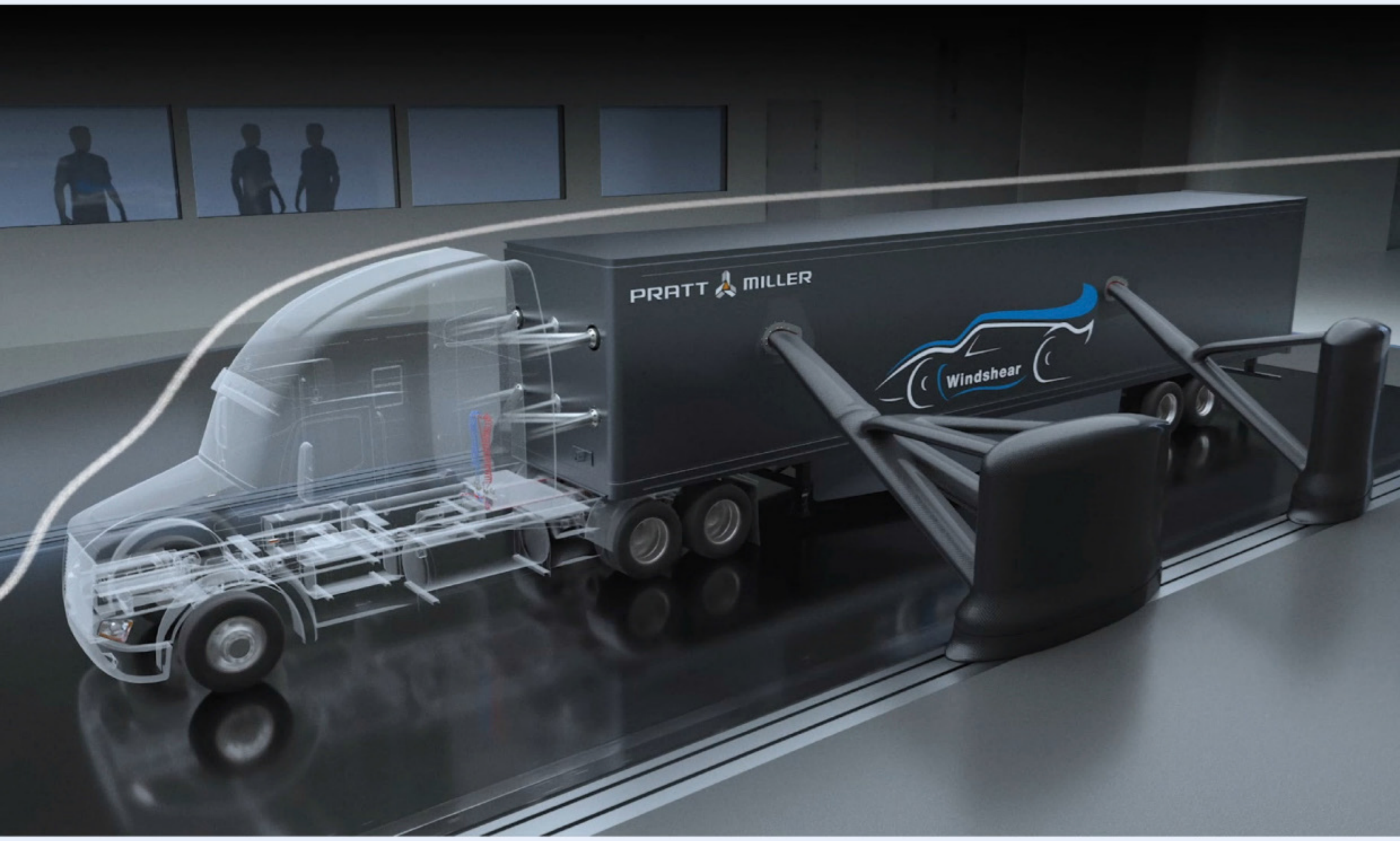
However, the FIA team also had to consider the Goodyear tyres that were developed specifically for the car. Goodyear is sole supplier to NASCAR and so was a natural partner for the Garage 56 project. In order to help the development process, the team in the US leaned heavily on its UK counterparts, who supply the LMP2 class in the WEC and have vast experience of GTs and prototypes. The Europeans were able to advise them on construction and compounds, with a view to double or triple stinting the rubber, as well as the loads that would be seen by the tyre in competition. This information was critical from a safety perspective, but it was also a performance tool the FIA was not able to simulate until it had seen the car in action.

'This animal was not that different to a GT. The car itself was different but, in terms of safety requirements, we can consider both cars very close'

Xavier Mestelan, chief technical and safety officer at the FIA

'The final lap time is driven mainly by the tyres, because they developed specific tyres for this race, and it was difficult to know if the car would be faster or slower than the GTE cars,' says Mestelan. 'We knew the car would be a rocket in a straight line, but there were more questions about the car in the corners. In the end, it was 0.5s faster than the GTE if you take the 20 per cent best lap time, so it was good for the grid, and the fans.'

Prior to the race, the FIA worked on the assumption that the Camaro would lap around the slowest times of the GTE category in qualifying, but that proved to be wrong. With its higher than expected top speed, and with the high-downforce package offering help in the Porsche Curves, the car qualified comfortably ahead of the fastest GTE car, and so the plan to have the NASCAR start from



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the back of the grid had to be shelved. While the Hendrick team felt the car would be able to lap around 3m52s, it actually qualified in 3m47, in among the LMP2 times.

This was less of a concern than might have been expected. Having reduced the weight to a satisfactory level, and improved the brakes, the car was still close enough to the GT cars to not raise undue concern about the speed.

Impact driver

The next issue, then, that had to be looked at was a potential impact with the barrier. Here, the simulation work specified by the FIA was critical as the organisation did not crash test the car before the competition. Instead, it was up to the competitor to provide the computer simulation that confirmed the car would meet the FIA's standards, and it did so.

By the FIA's own criteria, a car with 150kg extra mass over the homologated minimum (75kg for the driver, 75kg for fuel) must be subjected to an impact against a solid, vertical barrier placed at right angles to the longitudinal axis of the car at a minimum speed of 14m/s. For the rear impact structure, it is subjected to 11m/s impact speed.

At these speeds, the FIA's criteria for safety against the barrier is that the model must not exceed an average deceleration of 25*g*, and must absorb the impact throughout the structure of the car. To achieve that, the team needed to develop the front and rear crash structures in order to take these high loads.

The nature of accidents that NASCAR and Le Mans cars experience are generally quite different. A typical NASCAR accident is a glancing, high-speed blow against a concrete wall, while a Le Mans car is more likely to hit a metal guardrail or tyre stack. Speeds are generally lower for a Le Mans car, although it has to be recognised that NASCAR does race on street courses, too.

'For the crash structure, when you develop a standard you have to take into account the eco system,' says Mestelan. 'That includes the barrier, how it will be contacted, is it a normal circuit or a city track? What NASCAR did was something suitable for their tracks and their race conditions, and we did the same for our tracks. It is not that one standard is better than another.'

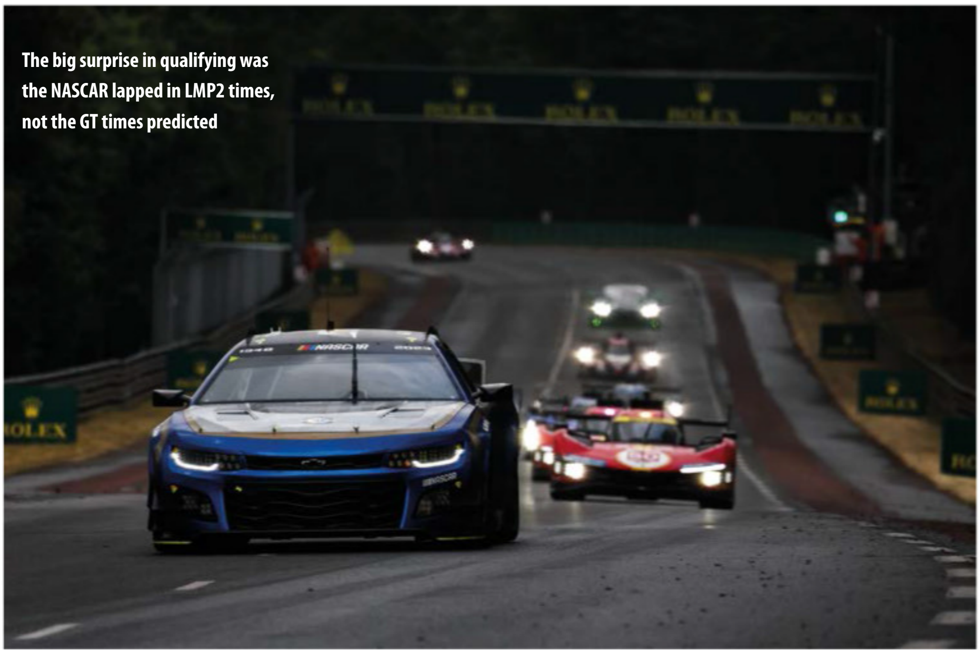
With those figures locked in, and NASCAR having submitted its computer-generated data on the car, the next things the FIA had to look at were the rollcage and the location of the car's fuel tank.

NASCAR changed the design of the rollcage for the reduced weight of the car, and that contributed to the overall weight loss.

The team also had to move the fuel tank from behind the rear axle to a more central location, ahead of the rear axle. That obviously meant the c of g moved forward, particularly with a full tank of fuel onboard,

2023 TECH SPECS: Garage 56 NASCAR vs Next Gen NASCAR

	Garage 56	Next Gen
Length	195.4in / 4961mm	193.4in
Width	78.6in / 1996.4mm	78.6in
Height	50.4in / 1280mm	50.4in
Wheelbase	110in / 2794mm	110in
Weight	2960lb / 1342kg	~ 3485lb
Spoiler	6in / 152.4mm	4in
Body	2023 Chevrolet Camaro ZL1 composite symmetric body featuring integral flap systems, camera mounts and dive planes	Composite symmetric body featuring integral flap systems, camera mounts and OEM-specific design elements
Underwing	Full carbon undertray with Le Mans-spec splitter, engine panel and rear diffuser	Full carbon undertray with centre stepped splitter and rear diffuser
Chassis	Steel tubing with bolt-on front and rear clips and front / rear bumpers	Steel tubing with bolt-on front and rear clips and front / rear bumpers
Transaxle	Five-speed paddle shift sequential with ramp and plate differential	Five-speed manual sequential with ramp and plate differential
Suspension	Double wishbone billet aluminium control arms with adjustable coilover shock absorbers	Double wishbone billet aluminium control arms with adjustable coilover shock absorbers
Steering	Rack and pinion	Rack and pinion
Wheels	BBS-G56 forged aluminium	18 x 12in forged aluminium
Dry fronts	18 x 12.5in/ 462 x 317.5mm	
Dry rears	18 x 13.5in / 462 x 342.9mm	
Wets	18 x 12in / 462 x 304.8mm	
Tyres	Goodyear Racing Eagles	Goodyear Racing Eagles
Dry fronts	365/35R18 (day / night)	365/35R18
Dry rears	380/35R18 (day / night)	
Wets	365/35R18 (inter / full)	
Brakes	Six-piston monobloc front calipers and four-piston monobloc rear calipers / heavy duty carbon disc package	Six-piston monobloc front calipers and four-piston monobloc rear calipers / heavy duty and light duty disc packages
Front brake discs	15 x 1.57in / 381 x 40mm carbon disc with titanium bell	15in
Rear brake discs	14 x 1.26in / 355.6 x 32mm carbon disc with titanium bell	14in
Engine	Chevrolet R07 cast iron small block V8	Chevrolet R07 cast iron small block V8
Displacement	358ci / 5.8-litre	358ci
Induction system	Naturally aspirated	Naturally aspirated
Fuel system	Fuel injection	Fuel injection
Oil system	Dry sump	Dry sump
Cooling	Air exits radiator through bonnet louvers	Air exits radiator through bonnet louvres
Exhaust	Split side-exit exhaust	Split side-exit exhaust
Fuel cell	32 gallons / 127L (Total Excellium Racing 100)	~20 gallons (Sunoco Green E15)



The big surprise in qualifying was the NASCAR lapped in LMP2 times, not the GT times predicted

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

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While some thought the NASCAR entry a joke to start with, it proved itself a very capable racecar, and offered up some lessons that may well find themselves into European racing in the future

but the location of the fuel tank was a red line the FIA refused to back down on.

The steering column was another area of concern, although that was easier to solve. The US regulations also stipulate the steering column must collapse in an impact, the *way* in which it deforms is different to that specified by the FIA. 'There was some adjustment, but not much,' says Mestelan.

The NASCAR's polycarbonate windscreen was allowed to stay, but the fact the car didn't have any doors initially raised eyebrows. This time it was NASCAR's turn to stand firm, wanting to retain some of its heritage, including the use of trolley jacks to raise the car in the pits. In the race, the car ran without side windows, and drivers climbed in and out through the hatch during changes as they normally would at the start or end of a typical NASCAR race. A happy by-product of this decision was that with only netting covering the side window apertures, drag was increased, slowing the car in a straight line.

'What was important [to the FIA] was that the driver could jump out of the car in seven seconds on the driver side, and nine seconds on the co-driver side. Honestly, that was something easily achievable,' says Mestelan.

While this was an FIA-homologated race and the car had to meet FIA standards, there were two areas in particular that stood out where the FIA could learn from its American counterparts. The first is access to the driver through the roof hatch. The European standard is that the marshals must be able to reach a driver's head, in order to be able to remove a helmet before the driver is extracted from the car. NASCAR's hatch is far bigger, allowing marshals greater access to a driver in the event of a crash.

The right balance

The second area was the way in which the seat was located within the car. NASCAR's solution is to create a monocoque within the car's safety cell, and mount the driver seat and belts to that. That is more akin to the FIA's criteria for a single-seat racecar. However, this way of mounting the seat is more expensive and may never achieve a price point that will work for customer racing, or even factory racing GT3 cars.

'The difference is important in this point,' notes Mestelan, 'so it is something that is interesting for the future. To develop new safety standards and regulations, and reduce the amount of fatalities, we have to do that, it is inescapable. But motorsport also has to be as affordable as possible, and it is important for us to keep in mind this point, too. We have to improve safety, but also ensure the drivers can compete in the next 10 years, so we have to find the right balance.'

NASCAR was certainly not constrained in this respect. Those involved on the development side of the Garage 56 project were stunned at how much money was invested, saying they had never been involved in anything like this in their professional lives. That was partly what made the project so exciting for the engineers.

'Garage 56 was strange as it is dedicated to new technology, but it was very exciting,' notes Mastelan. 'NASCAR racing is a dream for a lot of people, and a lot of people [in Europe] are following what is happening in the US. At the end, it is nice for us and very exciting because it is completely new. As in the US, the car is extreme in terms of weight, power and design, so very different to what we are looking for in F1 and rallying.'

'What was important was that the driver could jump out of the car in seven seconds on the driver side, and nine seconds on the co-driver side. Honestly, that was something easily achievable'

Xavier Mestelan

For the time being, this was a one-off project, and the car had its final run at the Goodwood Festival of Speed in July. But NASCAR has run at Le Mans before and, after the success of this programme and the strengthening ties between the FIA, ACO and IMSA, there is every chance we will see another Stock Car in the endurance classic in the future.

Despite the critics at the start, the car itself was a crowd pleaser; a loud, fast and spectacular entry to the centenary race, and overall the project was considered a highly expensive success story.

Trident tested

Maserati took the decision to step back into the world of GT racing with its new GT2 contender, the MC20, which it hopes will dominate the customer racing market

By ANDREW COTTON

Maserati will return to GT competition for the first time since the end of the MC12 programme in 2010. The marque launched its GT2 challenger, the MC20, at the Spa 24-hour race weekend at the end of June.

While the MC12 took part in the FIA GT1 World Championship, the MC20 has been targeted at the customer driver in the lower-level GT2 category, and it is scheduled to make its race debut later this year.

There are some vital components that have yet to be confirmed, such as the manufacturer and specification of the gearbox, but Maserati is confident it will be ready to contest at least one race this season ahead of delivery to customers for competition next year.

How many cars it sells is open to question, as the GT2 class has still to take off as hoped. Right now, GT3 is the top category, and it is booming. No fewer than 70 cars started at the Spa 24 hours in June, and there seems to be no let up in demand. Ferrari is building, and has sold, more than 300 of its 296 GT3 cars, while Porsche, Ford and Corvette are all set to sell out their quotas of 2023 cars.

National series are growing with GT3 machinery, and so it seems a strange decision to launch a car into a customer-focused category that is poorly subscribed with customers and already populated by the likes of Porsche, Mercedes and Audi. With international grids barely reaching double figures, GT2 has a long way to go.

High hopes

Maserati hopes that the class will quickly pick up and says it to sell between 40 and 50 cars over the next three to four years, dependent

On paper, the decision to enter GT2 racing flies in the face of Maserati's philosophy, having entered Formula E to amplify its electric racing ambition

upon the market and the desire to buy a Trident car over other options. The Italian manufacturer is hoping it can play on its history in GT racing, and its brand image, to give the MC20 the boost it needs.

The cost of GT3 cars is escalating quickly, and prices are now heading towards the magic mark of €800,000 (approx. $900,000) purchase price. Running costs might be lower than the old GT1 cars, but the cars generate their lap times through more aero, and even professional drivers are now finding it harder to follow and overtake in high-speed corners.

It is becoming a class that is too hard for the customer driver to enjoy. With the GTE era ending, the pro drivers have few other options than to drive GT3 cars that are also becoming too expensive for the customers.

GT2 is aimed more at the customer driver, generating more power with less aero, and so the lap time is generated on the straight instead. As GT3 has now been accepted to the FIA World Endurance Championship for next season, it will continue that trend towards professional drivers, leaving GT2 to dominate the customer driver category.

Stéphane Ratel's plan originally was to allow GT2 and GT3 cars to race against each other, but that was firmly rejected by the GT3 teams. Instead, GT2 cars run in a separate race, despite the fact that Bronze-grade drivers are able to produce similar lap times to the GT3 cars, for a great deal less money.

There is another difference between the two categories. GT3 regulations have always been the property of the FIA since they were first introduced in 2005. Although they form the basis for Ratel's business, they are not his property and he has no influence over them.

New regulations, devised by the FIA in collaboration with the manufacturers, were introduced for this year, and Ratel objected to them. He therefore stepped away from his role on the GT Commission in February 2022.

As the Frenchman highlighted in his interview in *Racecar Engineering* V33N7, his issue with GT3 is that the pillars that he considers to hold up the class have been shaken. With so much invested in his racing series, he needs a safety net, which is provided by GT2. The arrival of Maserati into this world means there are more manufacturers than ever before in this burgeoning class, and Ratel's job now is to increase the customer base to ensure the manufacturers are making enough money to justify their investment in the category.

On paper, Maserati's decision to enter GT2 racing flies in the face of its own philosophy, having entered Formula E to amplify its electric racing ambition. However, there is nowhere currently for the manufacturer to race its electric version of the MC20 that is currently under development, so it had no option but to create a racecar out of its 3.0-litre V6 engine and return to its customer racing GT roots, with Ratel in GT2.

Building the future

'We have a long history of world excellence in motorsport and we are extremely proud to race with the extraordinary MC20,' says Davide Grasso, Maserati CEO. 'Racing has always been Maserati's natural habitat and now, both in the Fanatec GT2 European Series Championship and in the Formula E Championship, this brand is making a new start from its roots to build the future.'

The car was revealed at Spa earlier this year, and Maserati hopes to have it ready for customer delivery in the summer

The basis of Maserati's new GT2 car is the MC20 road car, which features the company's 'Nettuno' engine mated to a carbon tub. Both have been heavily modified for racing but, as a production car base, these two factors are fairly good starting points.

The MC20 production car is a two-seater, rear-mid engine sports car. The road car tub itself weighs less than 100kg, which sounds ideal for racing. However, Maserati has taken that base and developed it, handing the production of the tubs to specialist, Ycom, which is named as the production partner of the brand to produce the cars for customer competition.

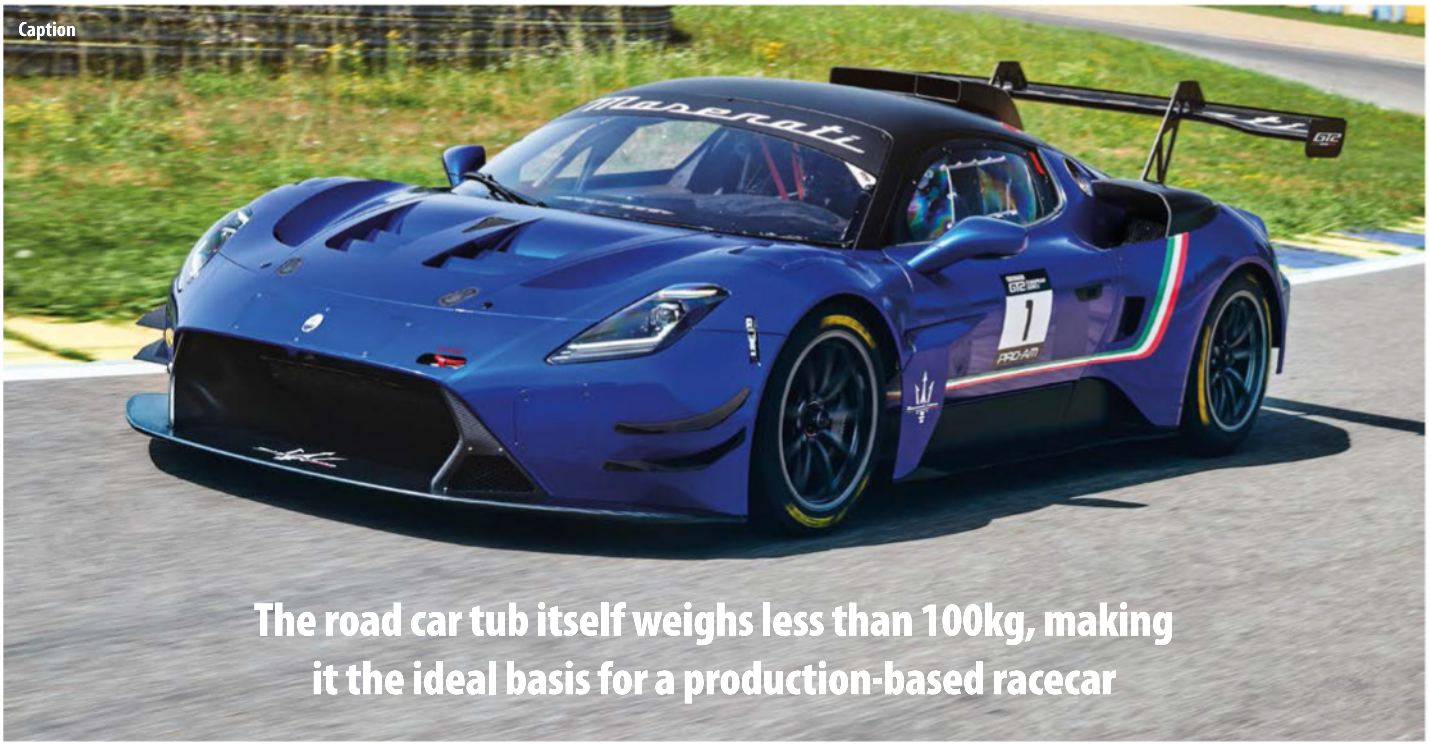
Price is a key driver for the sale of GT2 cars and clearly signing up with a racing specialist is more cost effective than taking tubs from the production line, as might be expected. The asking price for the MC20 GT2 car is €410,000 (approx. $461,500) plus taxes, so a similar amount to the original GT3 cars such as the Audi R8 and Mercedes AMG.

'It is the same monocoque. It is nearly the same front and rear frames, made from aluminium because we had to modify the attachment of the suspension,' explains Vincent Biard, chief engineer at Maserati at the launch of the car in Spa.

Formula 1 technology

The 3.0-litre, normally aspirated engine is a 90-degree V6 that features a dry sump and a twin-spark, pre-chamber ignition system inspired by Formula 1 technology. This is designed to reduce emissions and improve fuel economy in the road car, but clearly there is an advantage in the race application, too.

The road car engine weighs in at 220kg and the team has retained the powerplant



Caption

The road car tub itself weighs less than 100kg, making it the ideal basis for a production-based racecar

Switchgear in the cosy cockpit is targeted at the customer driver, with colour coding and a high-mounted set up

for racing with only minor modifications, notably to the turbo and the exhaust.

The engine already produced enough power to bring it into the Balance of Performance window, so there was little else that needed to be modified from the base.

As previously mentioned, power delivery to the wheels has yet to be finally determined. 'The gearbox is from racing, a six-speed sequential unit, but we are still developing it with suppliers. We haven't fixed the supplier yet,' confirms Biard.

Increased demand

Mounted to the carbon chassis are front and rear subframes that have also been modified to accommodate the racing optimised suspension, leaving rather less of the original road car than might be expected. The widened track has meant that new bodywork was needed while the circuit-version of the car also had increased cooling demands compared to the production car sister car.

The team had to move the radiators around the car, too. The result is new body panels that include louvres over the rear wheelarches, a new air intake to improve airflow to the radiators and a vent in the rear window to help to expel heat from the engine. 'We changed the location of the radiators,' admits Biard. 'There is a big radiator at the front, an air charger and cooler at the rear and intakes on the roof to help cool the gearbox.'

The roof also contains the now mandatory safety hatch to provide access to the driver's head in the event of a crash, and the seat is fixed in place, with adjustable pedals.

Brake cooling comes from scoops ahead of the rear wheels and airflow through the nose. The development team is considering an endurance pack in case a team does take up the chance to compete in a 24-hour race.

Other usual updates include the introduction of electronics from Cosworth,

The road car engine weighs in at 220kg and the team has retained the powerplant with only minor modifications

with a 6.5in screen mounted to the dashboard rather than the steering wheel, a pedal box from Alcon and switchgear designed to be simple to use for non-professional drivers, particularly at night.

'The ergonomics have been designed for the customer driver,' confirms Biard. 'It was an interesting convergence between the technical teams, the style and the customers. [Cockpit design] is really different and was an important part of the development.'

The development team didn't use a wind tunnel during the design phase, instead relying on CFD to bring the car into the right performance window with bodywork changes. The team also worked with the company's Centro Stile design outfit, as has now become normal practice in BoP racing.

The result is a car that retains the family resemblance to its road car base, yet which is perfectly suited to customer-focused racing..

'We used the dynamic simulator in the innovation lab in Modena, at Maserati,' says Biard. 'It is state-of-the-art, unique and it sped up development. We built a model of the car, so we knew the best suspension, design architecture, the tyres, then we created the model of this GT2 on the dynamic simulator. The virtual sign off, so the damper and suspension, is now very close to the final hardware release. It is really well correlated and a brilliant tool.

TECH SPEC: Maserati MC20

Vehicle
Single seater, non-road homologated racecar
Maserati Centro Stile design
Width / height (mm) 2020* x 1220*
Dry weight to be determined in BoP

Complies with FIA race safety requirements
FIA-homologated FT3 120l fuel tank
FIA-spec fire extinguisher

Engine
Maserati Nettuno
V6 90-degree twin turbo
3.0-litres
Power output to be determined in BoP (630bhp base engine under development)
Maserati Twin Combustion (MTC) twin spark with TJI double combustion control
Dry sump oiling

Drivetrain / transmission
2WD six-speed sequential racing gearbox with paddle shift
Racing clutch and self-locking, mechanical limited slip differential

Bodywork
MC20 GT2 racing kit bodywork
High performance aerodynamics
Multi-adjustable rear wing
High downforce
LED headlamps
FIA-approved rain light
Lexan front and side windows

Chassis
Carbon fibre central monocoque
FIA-homologated safety rollcage
3 / 4 onboard air jacks

Brakes
Racing calipers and ventilated disc brakes
Bespoke brake cooling

Wheels
Bespoke forged 18in aluminium rims
Centre lock fitting system
Slick tyres

Suspension
Double wishbone with semi-virtual steering axis
Adjustable racing dampers
Adjustable front and rear anti-roll bars

Interiors
Adjustable racing pedal box
Adjustable steering column
Six-point racing safety belt
Multi-function carbon fibre steering wheel
Rear-view camera display (optional)
In-car camera for video recording (optional)
Dash and data acquisition system
Driving performance optimisation display (optional)
Air conditioning
Tyre pressure monitoring system (optional)
Adjustable racing ABS and traction control

'The format of the Fanatec GT2 is for short races, but this car is eligible for a 24-hour endurance,' concludes Biard. 'The car is on sale in July, and we we aim to participate in the final races at the end of this year.'

Racing as a factory team is a model that was used by Maserati for the MC12, which went on to become a legendary racecar.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Mission possible

Despite flashes of brilliance, Haas F1 is still struggling to keep its car in the optimum performance window.* Racecar *investigates

By LAWRENCE BUTCHER

Haas's 2023 season has been a mixed bag to date, with the team only recording three finishes in the points as the summer break loomed. The issues seem to stem from a lack of consistency and unexpectedly high tyre wear, even though the team is now better resourced than ever, operating at the budget cap while still drawing many of its key components from Ferrari.

F1's rules have evolved in recent years to allow teams to purchase a far greater number of parts from other manufacturers. The list of Transferrable Components (TRCs), parts that can be bought in from another team, covers almost all powertrain and suspension-related components. Consequently, Haas buys in not only its powertrain from Ferrari, but also its front and rear suspension, gearbox, hydraulic system and a host of smaller elements.

'It is a central theme with the [team's] business model,' says team technical director, Simone Resta. 'We prefer to try to go in this direction, not invest in, or be forced to acquire, dynos or infrastructure. It's been a model that has worked well because we can contain our workforce.

'The team is, for sure, one of the smallest on the grid, in terms of resources, infrastructure and people. It is considerably smaller than our competitors.'

Development mission

Resta, and the rest of his team's mission is therefore to maximise development in the areas it can, while making best use of parts it takes from Ferrari.

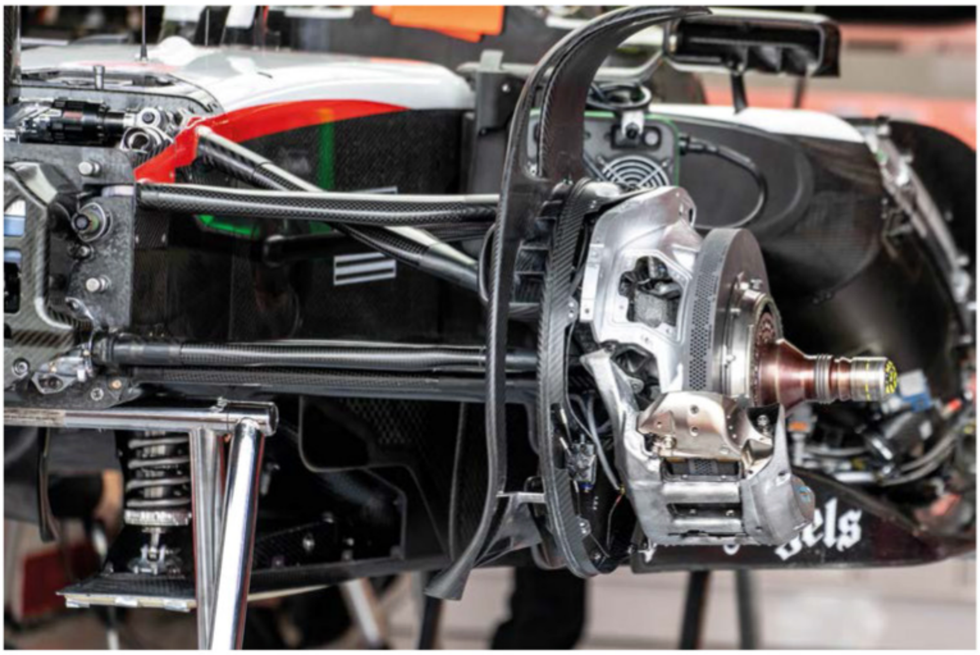
'It's about trying to work along the definition of the technical regulation – what is transferable, what is standard component, what is a listed component, and trying to focus the attention on all the components that are defined by the FIA as listed, which must be designed by the team.'

He sees this this as a pragmatic way of maximising development budget within the cost cap, though there are downsides: 'If you are an engineer, of course there are things you would like to change, but you cannot,' muses Resta.

For example, Ferrari might have pursued one development direction that is at odds to another path the Haas team sees promise in.

The team's mission is to maximise development in the areas it can, while making best use of parts it takes from Ferrari

Tyre degradation has proved an issue for Haas F1 in the season so far, but the team is working hard to find a solution

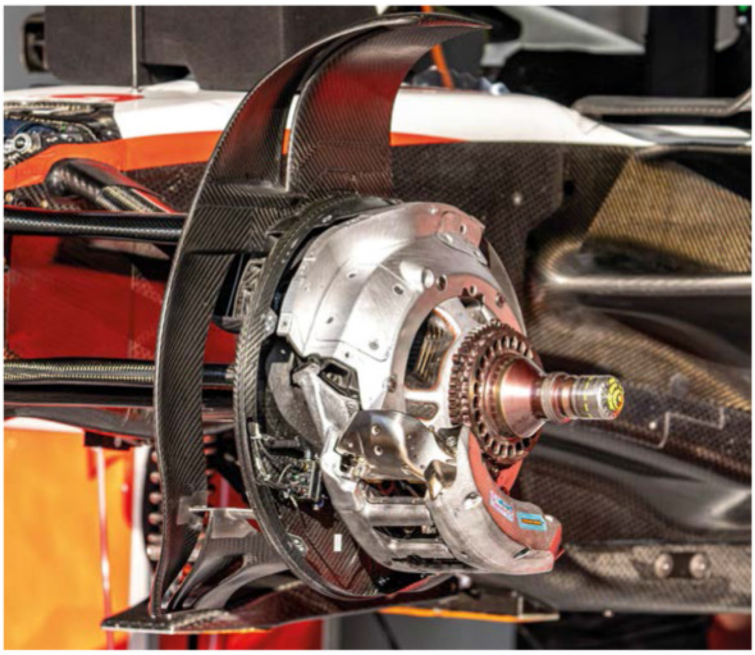


Under the new Transferrable Components rule that exists in Formula 1, Haas has chosen to buy in not just its powertrain, but also its front suspension, gearbox, hydraulic systems and other components from Ferrari, saving both money and development time

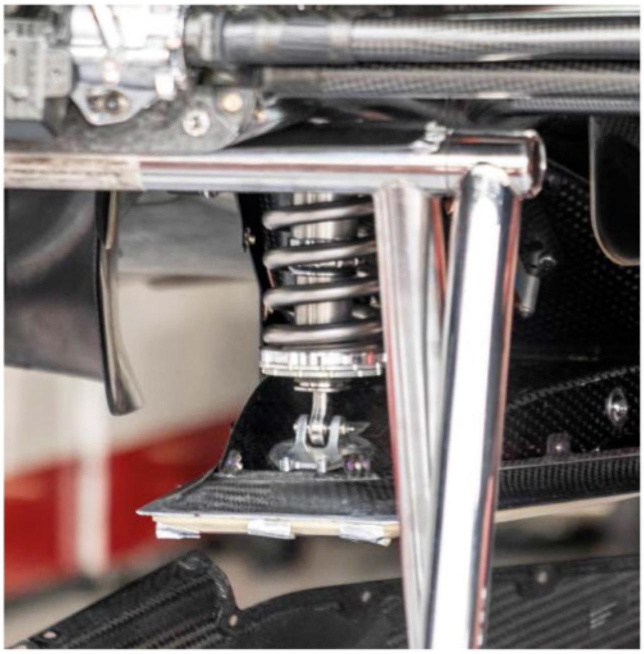
XPB

‘The team is, for sure, one of the smallest on the grid, in terms of resources, infrastructure and people’

Simone Resta, technical director at Haas F1



Developments are being brought to the grid at every round of the F1 championship, from brake ducts to body panels and aero components, and Resta is relishing the technical battle that is unfolding



Buying in components has its positives and negatives. From an engineer’s point of view there are things you might do differently, but that’s the compromise you accept

This does not mean he thinks Maranello is making the wrong choices, just different ones.

'They're doing a good job, but every engineer sees things differently. There could always be something done in a different way to better suit our ideas. But that's the trade off with trying to purchase as many components as we can. It is what it is, we just get on with it.'

A further potential source of frustration is that some parts, particularly those that have long lead times, maybe signed off later in the design process than Haas would ideally like. However, Resta suggests that for a small team without vast in-house resource, this is a constraint, whether one is working with a manufacturer like Ferrari, or traditional third party suppliers.

'You tend to outsource more, so the timings tend to be a little bit longer [than doing it ourselves]. We have to diversify, to adapt our work around the constraints.

'For sure, if it was left to our choice, sometimes we would define and freeze things a little bit earlier.'

This season has started to see a degree of design convergence across the Formula 1 grid, but Resta is of the opinion that the development curve remains steep. There is rampant innovation across the grid, some evolutions of 2022 concepts, others driven by rule changes for this year.

The VF-23's gearbox and rear suspension is also bought in from Ferrari, and has so far proved to be reliable and robust

'There are easy things to see,' he says. 'The glamourous bits – for example, the bodywork and the front wings – but there has been a lot of work on floors, and these were affected by the regulation changes from 2022-'23, with the sides being raised. It's a very important area of development but a difficult one to see.

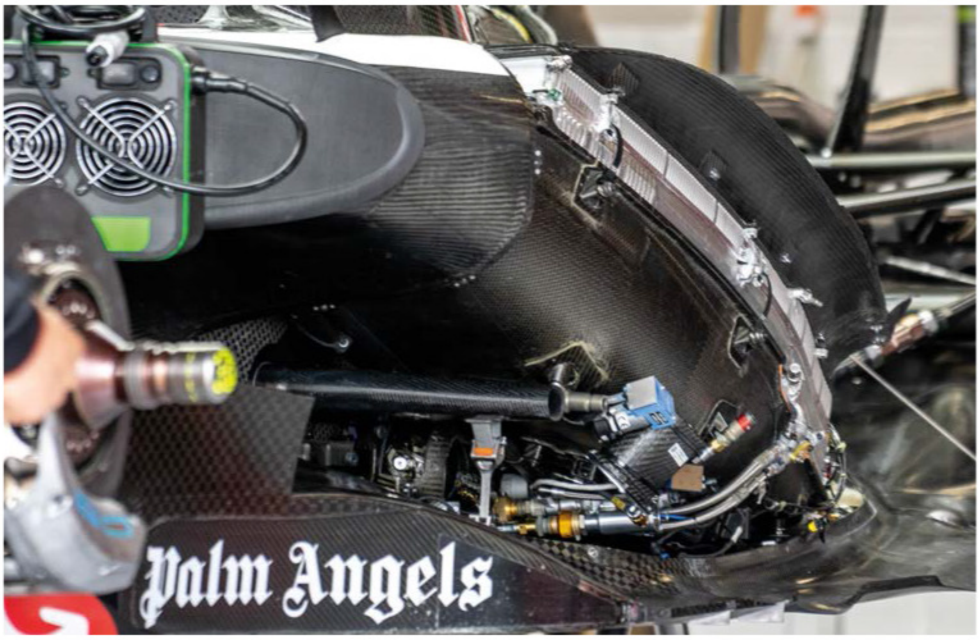
'I suppose there must be some convergence with bodywork. They have similar characteristics in a way, but they are all different versions.'

Dynamic approach

With the rate of updates across the grid so fierce, it would be easy for a smaller outfit like Haas to be left behind, but it has brought a variety of updates to the VF-23. In 2022, the team only introduced one major upgrade,

XPB

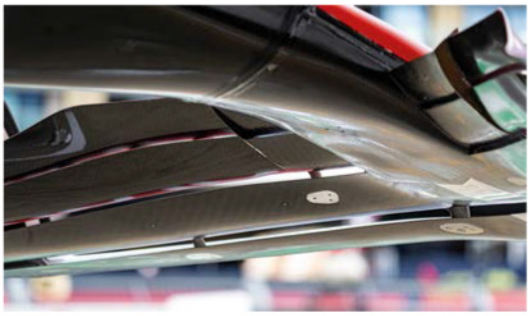
Despite the limitations of the new regulations, the F1 development race is as fierce now as it has ever been, and it's great to see smaller teams like Haas are not being left behind in the process



Resta is candid about Haas' progress, admitting the team still has much to learn but is working at a good pace, and moving forward

but for '23 it has taken a more dynamic approach. For example, the Miami GP in May saw the arrival of a new floor, followed by a new front wing for Monaco (originally scheduled for the cancelled Imola GP) and a revised beam wing at Silverstone.

Director of engineering, Ayao Komatsu, was surprised at the effectiveness of the Miami update, in particular. 'It's really positive


For 2023, Haas has brought some of its own developments to the table


These include, a new floor at Miami, and a new front wing for Monaco. The team hopes these will improve form over the rest of the year

for the team because the first major upgrade we brought to track in Miami, it just worked,' he says. 'It's not as simple as saying, coming from the wind tunnel, this is a big gain and should work, which happens quite often and you don't actually see it. This one was the opposite – it didn't make a huge difference in the wind tunnel in terms of headline numbers, but we believed it was worthwhile introducing it due to certain details we saw.

'At the track, we saw exactly the behaviour change we expected in the car, actually better than we anticipated.'

Resta reinforces the notion that the development battle is as intense as it has ever been in Formula 1. 'You can see the teams are changing everything. And it's quite an exciting battle between all the teams. You see them changing every two to three races. There's a lot of stuff going on with every part of the cars, from rear wings, brake ducts, the body or floor. It's an exciting technical fight and a very strong competition. It's nice.'

Complex interactions

One of the big talking points of 2022 was porpoising and, according to Resta, a combination of rule changes and developments have reduced the issue, though understanding of the complex aerodynamic interactions in the underfloor area are still very much evolving.

'You have to learn the aerodynamic behaviour of the cars in these conditions, and that has proven a challenge for everyone.'

He is firmly of the opinion that there was insufficient appreciation of the potential issues, and that many underestimated the severity of the potential consequences of getting it wrong.

'Different teams had their own problems, and reacted in different ways. I think we were

In 2022, the team only introduced one major upgrade, but for '23 it has taken a more dynamic approach

quite fast in nailing it at a good level. I wouldn't say we got everything under control, because I think that would be too arrogant. I will say that when you start to understand how to deal with it, you learn more and more, then you learn how to predict it and how to make sure that when you bring something new to the track it is working properly.'

Resta is hesitant to say the porpoising problem has gone away, pointing to the constraints of modelling the underfloor.

'Teams are quite limited in what they can do in the wind tunnel with quasi-static tests, and you cannot recreate the high dynamic frequencies you have on the track. But still, between wind tunnel and CFD, you can learn and predict things and improve.

'It's a combination of the learning of all the teams, together with the regulation change this year, that has led to the better characteristics in terms of porpoising on the cars. You see only small oscillations now and it looks to be better for everyone.'

Erratic form

Though the VF-23 has shown some flashes of brilliance this season, it has proved tricky for the team to keep the car in the window consistently. Points finishes have been few and far between, despite often showing good pace in qualifying. As the mid-point of the season approached, it appeared the team was still somewhat in the dark on the reasons for its erratic form.

'If we had a solution, we wouldn't be discussing this,' remarks Resta. 'It is something we are trying to understand and working as a group on – the race team, the drivers, people in the factory – discussing the problems and trying to bring modifications quickly.'

The issues centre around tyre degradation, particularly when the car is running in heavy traffic, but also when temperatures are lower.

'We've had good races, like Miami, but also difficult races, like Spain,' observes Resta. 'Let's see if we are if we are touching the right topics in development progress in the next few races. We're really trying to follow an aggressive development programme, and we hope to see a tangible step race after race with the improvements. It's head down, humble, trying to push, work together as a team and share the problems.' R

In safe hands

***Racecar** goes on the World Rally Championship stages with the FIA to discover first hand how advances have made the current crop of cars the safest ever*

By DIETER RENCKEN

Talk FIA World Rally Championship and motorsport fans immediately recall the helter-skelter days of unrestricted, fire-belching, 600bhp Group B monsters such as the Lancia Delta S4, Peugeot 206 T16 and Audi Quattro S2. Ultimately, these cars were banned by the FIA as being too fast to race after a string of fatalities involving crews and spectators, though they're still remembered fondly.

Less well known, however, is that the current 500+ horsepower hybrid WRC cars are substantially faster per stage kilometre than their predecessors by virtue of the instant torque provided by their 134bhp electric motors, more sophisticated powertrain electronics, improved driveline systems and advances in tyre technologies. Indeed, current WRC cars are the quickest overall in the 50-year history of the series.

Increased speeds improve the spectacle, but also heighten the chances of high-speed incidents, all of which brings the FIA – as motorsport's global regulator and the EU-sanctioned body responsible for safety – into play to ensure the sport continues to thrive under all conditions, on all continents.

That is key to the WRC's popularity, both as a spectator sport and an incubator for the motor industry, particularly given the visual and technical similarities between consumer and competition vehicles. They are front-engined, hybrid-powered hatchbacks ferrying driver /passenger often on roads accessible to the public, albeit closed during events. These factors alone set WRC apart from Formula 1.

Estonian driver, Ott Tänak, in his Ford before crashing on the Monte Carlo rally. He barrel rolled into trees, but was unhurt and the hybrid system in the car was safe to touch

Photos: XPB

That is not the only difference between the FIA's race and rally championships. The essence of rallying – a competition staged on surfaces ranging from rough tracks in the African bush through snow-packed forestry lanes in Sweden and Finnish gravel roads to sinuous mountain passes in Croatia – means F1 safety standards cannot be cut and pasted across the FIA's various world championships.

High contrast

For starters, at no stage is an Formula 1 driver further than five kilometres from a fully-fledged medical centre and helicopter evacuation, plus safety and medical cars lead and / or follow the entire bunched-up field at critical moments. Contrast that with WRC. Here, front runners could be a stage or two ahead of back markers, with 50km between them, plus forests, gorges and wintry conditions that make helicopter landings challenging, if not at times impossible.

The closed road world championship has evolved its own safety regulations and procedures, most of which have trickled down to regional and national series. *Racecar Engineering* travelled to Rally Croatia to examine first hand how the WRC applies and evolves its unique safety standards.

During the weekend we were granted full access to key FIA personnel and team principals and engineers representing the three manufacturer outfits contesting the championship – Ford, Hyundai and Toyota – and travelled to loops of stages with FIA safety and medical delegates to gain first-hand experience of all procedures. We also prowled the service park during breaks and sat in Rally Control during a number of stages.

During the week preceding our visit, Hyundai had suffered the tragic loss of WRC driver, Craig Breen, during private testing in what by all accounts was a freak accident. The full report into it has yet to be released, but word is the popular Irishman slid off the road and made contact with a fence post.

The Zagreb service park was therefore a sombre place. A memorial service was held on Thursday after Rally Shakedown, and the incident served to open minds and hearts about safety. Crucially, what lessons could be learned for the future.

The closed road world championship has created its own safety regulations and procedures, most of which will trickle down to regional and nationals series

M-Sport's Malcolm Wilson says the current generation WRC racers are the safest rally cars ever. They are also the quickest

Evolving doors

No one is better placed to comment on the evolution of rally safety than M-Sport Ford team boss, Malcom Wilson, whose gait displays the signs of ankle fractures suffered over 40 years ago on the Scottish Rally.

'If you think about it,' he recalls ruefully, 'it wasn't even compulsory to have a front [roll] cage back then. I did have one, but it was aluminium so a complete waste. We didn't even have door bars for side impact…If I had been in a current [WRC] car even 10 years ago I wouldn't have had the damage where I broke my ankle. The FIA have done a very good job of evolving safety significantly in the last few years.'

Safety cells

The Cumbrian, who scored WRC podiums, singles out the safety cells of the latest cars as the biggest recent advance. Effectively resembling Dakar buggies, to which mechanical parts, suspension and front / rear / roof crash structures are attached, the tubular steel structure provides a rigid two-seat cockpit. Body panels visually resembling a manufacturer's chosen product are then bolted to the exterior of the safety cell to provide a marketing link.

It's sometimes hard to land a safety helicopter by the stage, and many miles can separate the front runners from those at the back

While following helicopters provide dramatic on-stage footage for the WRC's global TV audience, choppers also play a vital safety role on event in an accident scenario

'This is the first time [WRC] hasn't used a production-based bodyshell,' notes Wilson. 'I got in the car the other week, and when you're in the car you get a 'wow' factor from the feeling of safety and the amount of room you've got for the side impact around you. I felt completely at home in the cockpit, I'm 100 per cent sure we've now got the safest cars we've ever had.'

Jari-Matti Latvala, 18-time WRC winner-turned-team boss of Toyota Gazoo Racing's WRC team concurs with Wilson on the basic rollcages in use when he started rallying 20-odd years ago, and laughs as he recalls rallying with rudimentary helmets and t-shirts worn under overalls.

Lateral protection

The Finn says the biggest safety advances of the 2000s were the carbon fibre seats with 'ears' providing head protection that were mandated after the 2005 death of co-driver, Michael Park, together with regulations which provide better lateral protection.

'Step by step we moved the driver and co-driver more inwards towards the centre of the car,' he notes.

'We also have to be realistic about motorsport. When you [compete], there will always be some sort of risk, you can't have zero risk. This you have to accept, and you have to have this mindset. Of course, we must try to come as close to zero as possible, but the truth is you will always have trees, and there is also this difference whether the tree is next to the road or on the outside of a corner.'

He moves the discussion to hybrid safety, which is, of course, topical given that such power units in the WRC are only in their second year, as opposed to F1, which first embraced the technology in 2009.

Hybrid safety

'We've spoken about inner car safety, which has progressed enormously, but we also need to talk about the hybrid system,' the Finn continues. 'Of course, [the FIA] had to be very careful, because it's not only what can happen in the accident, but also people touching [the car] afterwards. They believe it is as safe as it could be.'

His thoughts tally with those of FIA deputy president for sport, Robert Reid, 2001 World Champion with Richard Burns, who points out the hybrid 'boxes' fitted to Rally 1 cars to house batteries and electronic systems can sustain impacts of 70*g*.

'Over the years, motorsport has proven its technologies in very hostile environments, which definitely results in advances for the road car industry,' says the Scot.

Indeed, both safety cell and 'box' were inadvertently tested by Ott Tänak during the first event under the new regulations, the 2022 Monte Carlo Rally, after the Estonian flew off the road, barrel rolling through trees. Not only was the crew unharmed, but its 600V hybrid components were undamaged and the car safe to touch when it came to rest. You can see the crash on YouTube, keywords: Tänak walks away, Monte Carlo 2022.

Talking about hybrid power units introduces another safety element, namely training of local fire marshals who are posted at each stage, ready to extricate crews where required after crashes. All Rally 1 cars are fitted with green lights on both door pillars to indicate they are safe to touch. If not, fire crews go through the laid-down procedures to make the cars safe.

David Ryan, who has worked in Formula 1, WRC, WRX and e-Touring Cars, is responsible for safety training around hybrid systems. Using Tänak's accident as an example, we asked Ryan how marshals would have extricated the crew had the car not been safe.

'That was a pretty comprehensive one,' he recalls, 'and what happened on the Monte Carlo was a very good example of just how

The hybrid 'boxes' fitted to Rally 1 cars to house batteries and electronic systems can sustain impacts of 70*g*

Improved safety means that although accidents will still happen, drivers and co-drivers stand a better chance of survival than ever

good these cars are. That was the first time they ran, so we were all a bit nervous.

'To affect a safe entry into a car, marshals would need to approach it with the appropriate protective equipment. We teach them how to get into a car and try to understand the likely dangers. You've not only got just the [electrical] shock element, but also the fire element from the batteries.'

As for waterproofing – crucial where high voltages are concerned in cars that frequently cross rivers and other water hazards at speed – Thierry Neuville proved the integrity of the 'box' in this scenario by crashing his Hyundai into a river in Southern France during testing in wintry conditions ahead of last year's Monte Carlo Rally.

'The car lay there for three days [awaiting salvage in adverse terrain and conditions], and when they took the 'box' out and bench tested it, it was still working,' notes Ryan. 'They say they're waterproof to five metres,' adding that co-operation between the FIA's various hybrid / electric series has been invaluable in terms of gaining experience, whether the incidents were caused by driver error, fire or electronic malfunction.

Christian Loriaux, veteran rally engineer at the top level, and currently a consultant to Hyundai, adopts a philosophical attitude when asked about WRC safety: 'Is it a conflict between safety and performance? No, because in all fairness, when it comes to safety the regulations are important, because when we put the safety in a regulation, it's the same for everybody.

'If we say everybody must have three kilograms of foam, it's the same for everyone. Group B basically died because of its poor safety-to-weight ratio. The seats were three kilos because there were no regulations, now the seats weigh nine kilos.'

The Belgian also recalls testing at full chat without helmets or fireproof gear, cars driven by the likes of Colin McRae and Ari Vatanen in places like Corsica, which has massive rocky outcrops and drop-offs, and also remembers the howls of protest when HANS neck braces were mandated in rallying.

'At the time, the drivers said, "No way am I wearing that thing!" but then they were forced to, so they did. If you were to tell them now to drive without a HANS device they would refuse. The whole mentality [toward safety] has changed, and that's good.'

Operations template

So much for the cars and kit, but improvements in rally safety do not end there. The FIA has prepared a full operations rally template for WRC organisers, which outlines all procedures, including the publication of a safety dossier that contains risk management documentation, stage safety information and maps, spectator area plans, incident management plan and includes pointers for just about everything, right down to taping instructions to demarcate spectator areas on a stage.

Crowd control can be tricky at certain rallies, especially between stages, where it's normal to have racecars passing through villages

Travelling out early to each stage is the FIA WRC medical delegate, with professor Cem Boneva delegated the role in Croatia. We accompanied the Turk on the opening day's first loop, observing as he checked medical facilities, helicopter landing points and extraction / evacuation equipment per stage plus, where applicable, intermediate medical points. A local doctor, FIA trained on rally procedures, is assigned to each stage.

Boneva paid particular attention to the fire appliances at the start of each stage, each one containing not only extraction and cutting equipment, but also extinguishants suitable for both petrol and electrical fires.

The stages themselves are run along military lines, with a safety officer and deputy responsible for ensuring corner marshals control the crowds that inevitably congregate around the more dangerous segments.

Safety delegate

The FIA safety delegate, 1980's Group B rally legend, Michele Mouton, is driven through each stage shortly before Car 1, and it was a treat to observe her in action, forcefully pointing out a bunch of errant spectators, or imposing a no-go area after carefully considering the dangers of each corner. Anyone who doubts her credentials for the task should check out the *Queen of Speed* bio documentary on YouTube.

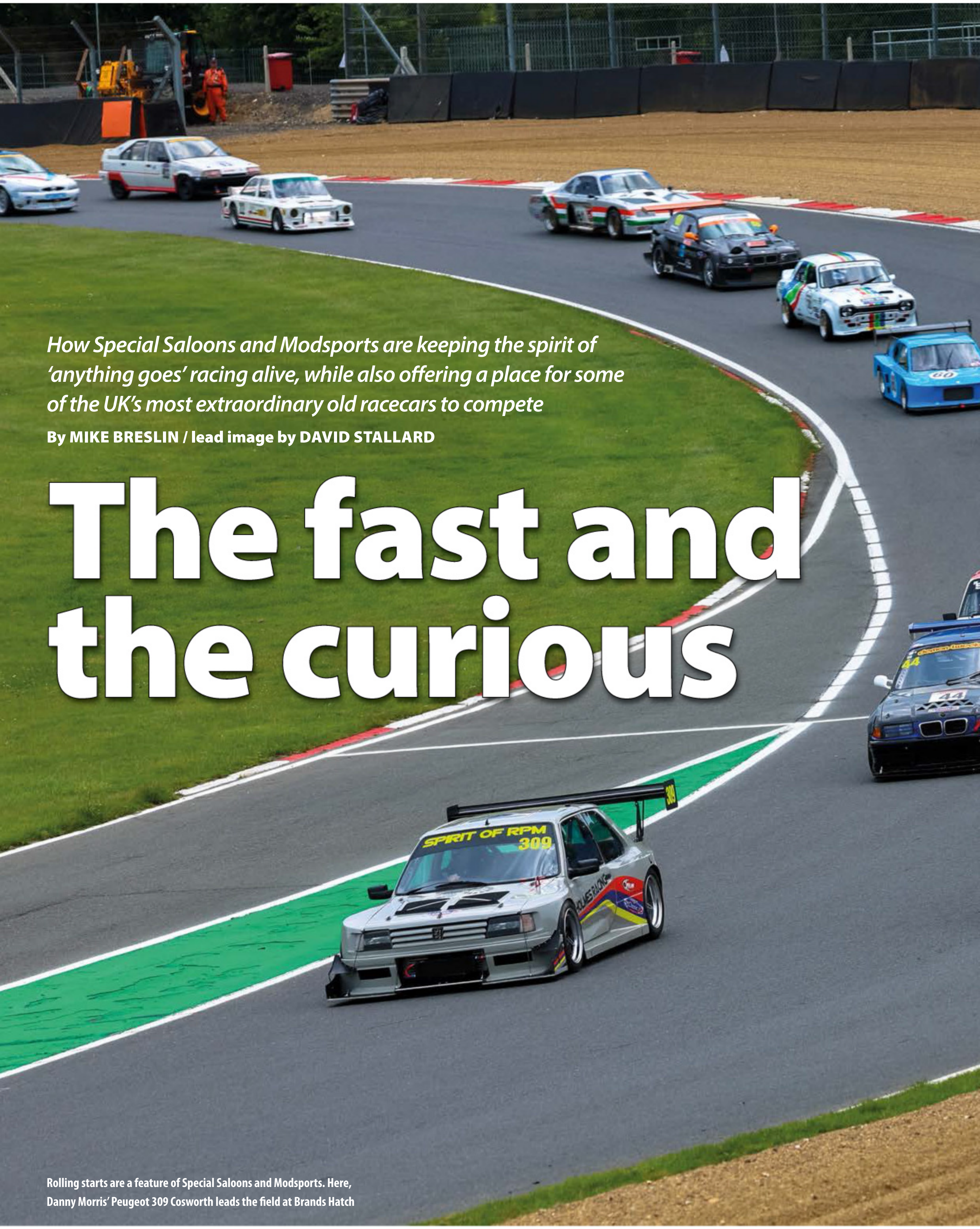
During our run through the second day's afternoon loop, Mouton was constantly in touch with her deputy, Nicolas Klinger, a former WRC co-driver who sits in Rally Control monitoring up to three split screens, each providing in-car footage taken in real time directly from the WRC system. Using this technology, even after Mouton had passed through a stage Rally Control is able to monitor crowd safety, the aforementioned errant spectators, and take action where it is deemed necessary.

Finally, the WRC's latest safety 'gizmo' is real time in-car tracking devices, which enable Rally Control and stage commanders to monitor the exact location of each car on a stage, with an immobile tracker flagging up an issue, either mechanical or incident.

The devices can be triggered on impact or manually and have 'Help' and 'Okay' buttons to inform Rally Control of their status. Fortunately, there were no emergency calls during our time in Croatia.

All this points to enormous progress in rally safety, most of which trickles down to lower categories where further lives and limbs can be saved. Lessons learned in hybrid packaging, extraction of crews and rapid response SOS systems also have applications in road cars, too.

The bottom line is that safety costs, but in the final analysis is simply not negotiable, and further progress in this field is inevitable.



How Special Saloons and Modsports are keeping the spirit of 'anything goes' racing alive, while also offering a place for some of the UK's most extraordinary old racecars to compete

By MIKE BRESLIN / lead image by DAVID STALLARD

The fast and the curious

Rolling starts are a feature of Special Saloons and Modsports. Here, Danny Morris' Peugeot 309 Cosworth leads the field at Brands Hatch

'We're really down to the pamphlet of a rule book that existed in the '70s. Provided the car keeps its basic silhouette above the halfway line, it's eligible'

Dave Smith, deputy driver representative for Modsports

There was a time when there was a huge appetite for watching cars which differed greatly in their technical philosophy compete against each other. These were races in which lightweight machines with outlandish, track-skimming, glass fibre bodies were pitted against rumbling muscle cars, and very often beat them. In the UK in the 1970s, this was so popular it was even televised, when most domestic motor racing was not. The category was known as Special Saloons.

Like many things from the '70s, such as flared trousers and *The Wombles*, Special Saloons died a death, though in the race series' case it was a long and lingering demise. The types of cars it catered for appeared over the following years in a number of one-circuit series, while various championships for similar cars came and went.

Since 2012, though, there has been a resurgence of interest in these machines in the shape of the Classic Sports Car Club's Special Saloon and Modsports series. This is a little bit different from a regular historic series, in that while it welcomes the old warhorses of yesteryear, new builds are also allowed to enter, just so long as the base vehicle is a pre-1993 production car. Key is that the cars should be built *in the spirit of* Special Saloons, and indeed Modsports – a similar 1970's category, but for sportscars.

'That is our dilemma,' says Dave Smith, deputy driver representative for the series and a leading light in the Special Saloon scene. 'If we were too strict on period, we wouldn't get the grids to put on a good show.'

Modern engine

Consequently, there is even room for cars with newer engines to compete.

'We brought in what we call modern engine classes,' Smith adds. 'So, if you had to replace your engine it was fine, rather than lose the car from the series because the original engine is too far gone.'

In the spirt of Special Saloons, the regulations are not too restrictive, either.

'We're really down to the pamphlet of a rule book that existed in the '70s,' says Smith. 'That is, provided the car keeps its basic silhouette above the halfway line, it's eligible.'

Which means items such as sequential gearboxes are allowed, because this is pre-1993 technology, and the same goes for enhancing aerodynamics, provided it's within the scope of the original Special Saloons regulations. All of which opens up possibilities for genuine technological development, albeit on old cars.

The irony is, though, that while there are plenty of eligible cars out there, many have been lost to more mainstream historic racing. This is because before they were turned into Special Saloons and the like, some were sports prototypes, or even single seaters, which were made redundant when the series they competed in faded away, and some have now been returned to their original guise.

Conversion rate

'Many of those that were converted have been re-converted,' confirms Smith. 'The best example has got to be the DFVW [a Formula 1 Cosworth-engined Volkswagen Type 3 Fastback]. That was based on the Gordon Murray-designed Duckhams car, which raced at Le Mans in '72, '73 and '74. They then took the sportscar body off, put a 'glass Volkswagen body on it and it raced in Super Saloons [the name of the championship that was the zenith of Special Saloons racing in the 1970s]. That car has now been converted back to the Duckhams version.'

Those Special Saloons that remain now have an arena in which to race, and the same goes for old Thundersaloons, and other variations on the lightly regulated saloon racer theme. There are plenty of cars, too, with the series having around 70 registrations a year, although the grids tend to be closer to 20, hitting 30 at the more popular meetings.

Incidentally, there is a similarly named series run by the Historic Sports Car Club (HSCC), which is more strictly 'historic' and caters for cars raced in period and based on pre-1980 production models.

But the Special Saloons and Modsports series is not just about providing great cars with a place to race. It also gives fans a portal into a much-missed era of UK motorsport. Further, it also presents *Racecar Engineering* with an excellent opportunity to trace the history of Special Saloon-type racing through some of the cars that are now competing.

Morris Minor V8

In the early days of Special Saloons in the 1960s, much of it was about fitting big engines into small cars, the sort of stuff you might talk about in a pub. 'What if we put a 6.3-litre V8 in a Morris Minor?' type of thing.

That is exactly what's been done with Craig Percy's 1967 example of the quaint and curvy British runabout. While the car itself is quite old school in its engineering philosophy, its development history is a little more recent than the 1960s.

Amusingly, Percy's 'Moggie' started life as a police car, and then morphed into a circuit racer around 15 years ago. So, while it was not active in Special Saloons in period, it is built very much in the spirit of the category, and therefore ideal for this series. It's ideal for Percy too, who bought the base car for very practical reasons.

'I'm 6ft 6, so I needed something with a bit of headroom,' he explains. 'I was also after a big, heavy engine that's reliable. I didn't want to rebuild it every few races.'

Craig Percy's 1967 Morris Minor started life as a police car, but now packs a 6.3-litre small block Chevy engine producing 430bhp

'Because it's so short, it does let go really quickly at the back… Either it's got the grip, or it's gone'

Craig Percy, car owner / driver

As far as aerodynamics go, the Morris has a front splitter and a big rear wing that's located as high in the airstream as possible. Percy says snap oversteer has been his main issue with the car

That engine is a 6.3-litre (383ci) small block Chevy V8, which gives 430bhp and about the same number in torque (lb.ft). It is used to propel a bodyshell that is similar to the original, except without the blue light on top, and with some very wide wheelarches covering the fat slick tyres, which are a prominent feature of the series.

From the bulkhead forward, however, it is a semi-spaceframe, supporting a power unit that sits very far back in the car, so it is pretty much a front-to-mid-mounted layout. With that iron block and mostly steel body, the car is not especially light for a Special Saloon, weighing in at around 1000kg.

The gearbox is a Tremec TR 3550 five-speed manual, and the drive is to a live Ford nine-inch axle with a Gripper LSD. Percy fitted the diff' himself, having found the original 'a bit snatchy.' This is one of the few modifications he has made to the car since buying it, others being to the cooling and power steering, the latter because, 'I was finding it so heavy on the front with the big engine and big tyres that it was quite hard to catch it when it went.'

And this car definitely does bite.

'Because it's so short, it does let go really quickly at the back. So I have to be sensitive to sliding,' Percy adds. 'I've not had a problem with understeer. It's always been a problem of not being able to feel the oversteer; the sensitivity through the car. Either it's got the grip, or it's gone. So I've played around with tyre pressures, which was the easiest way of controlling it, or at least being able to feel it.'

This rear-end unpredictability is partly due to the unusual rear suspension, Percy believes, which features two top links and a lower A frame. At the front, it's more conventional independent double wishbones.

As far as aero is concerned, the wing is certainly the standout component.

'It definitely helps, because it feels very light if you don't have it on the car. But there's a balance between it slowing the car down and being useful,' says Percy. 'The car's quite square at the front as well, so that wing needs to be as high as it can be.'

Special Saloons that remain now have an arena to race in, and the same goes for old Thundersaloons, and other variations on the lightly regulated saloon racer theme

Davrian Imp

Moving on to the 1970s, one car that is synonymous with the glory years of Special Saloon racing is the Hillman Imp, and its derivatives such as the Sunbeam Stiletto. Thanks to their rear engine design, these were often fitted with exotic race engines, taking advantage of the rule that engine position, and whether it was front or rear-wheel drive, was based on the configuration of the original car. Glass fibre facsimile bodyshells were then draped over spaceframe or monocoque racecar chassis.

Jeremy Burgoyne's car, however, is a little different, having been built from scratch by Welsh sports car maker, Davrian, in the 1970s.

'It's an aluminium honeycomb monocoque, a one off,' says Burgoyne. 'It originally weighed 405kg, back in the day before all the [safety] stuff had to go into it. But it's not a lot heavier now.'

The Imp is a pure silhouette racer, in that its original shape is unaltered above the upper portion of the body, but dramatically cut below. The suspension is double wishbone with coil springs at each corner. But while many of these cars often packed high-end race engines, Burgoyne's has a tuned, four-cylinder, 1040cc (64ci) Imp power unit running on twin 40 Weber carbs in the back, which gives around 120bhp – not bad for such an old unit, and ample for a light car like this in the '70s.

The gearbox is a Jack Knight four-speed unit, with an H-pattern shift, that is constantly stirred to keep the little engine on song.

'It's high-revving, around 10 and a bit,' confirm Burgoyne. 'What I find is you've got to keep the revs up. You can't let it drop below about 7000. You just keep it singing and away it goes.'

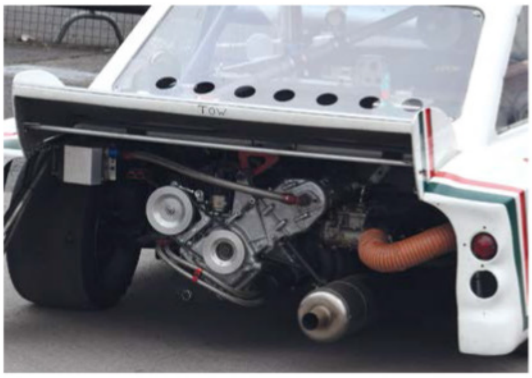
The aero remains the same as it was in period, a rear wing with Gurney flap.

'We don't want to change it, we want to keep it original,' says Burgoyne. 'But the problem with having a little car like this is that I can keep up with anything round the twiddly bits, but down the straights the bigger-engined cars are just gone.'

Hillman Imps were popular base cars in Special Saloons. Jeremy Burgoyne's example was built by Welsh Sportscar maker, Davrian, in the 1970s

'You can't let it drop below about 7000rpm. You just keep it singing and away it goes'

Jeremy Burgoyne, car owner / driver



With the engine position at the rear, Imps were a perfect base for silhouette racers based on Sports Prototypes. Burgoyne's car uses a highly tuned, 1040cc Hillman four-cylinder engine

Honda CRX

Moving away from the classic Special Saloon design, the Honda CRX of Thomas Carey has the powerplant moved to the rear. This would not have been allowed in the '70s and early '80s as the CRX was sold as a front-engined, front-wheel drive road car, but this was okay in later years in some series.

The car is usually fitted with a 2.0-litre (122ci), 292bhp Ford Cosworth BDG, but that went up in smoke last season and, at time of writing, Carey was campaigning the car with a 243bhp, 1760cc BDA version of the legendary four-cylinder race engine while the preferred unit was being repaired.

The car was built as a Hillman Imp to begin with and, beneath the snug-fitting CRX body there's a 1970's Royale Sports 2000 chassis.

It might look like a little bit like a Honda CRX, but there's not much Honda in Thomas Carey's racecar. The car's unusual semi-spaceframe monocoque chassis started life as a Royale Sports 2000

The CRX usually races with a 2.0-litre Cosworth BDG powerplant, but at this event was running with a 1760cc BDA. The diffuser is among a number of aerodynamic improvements made to the car

‘It’s the commitment… you can’t put it in the garage and go back two weeks later to roll it back out again. There’s always something to do’

Thomas Carey, car owner / driver

‘It’s a glass fibre honeycomb tubbed affair; a honeycomb tub with boarding, and it’s got aluminium angle to join it all together,’ explains Carey of the unusual semi-spaceframe style monocoque. ‘It’s all Royale rear suspension, and the engine frame is Royale too, as well as the uprights.’

Because sequential gearboxes were used in this type of car pre-1993, it’s within the spirit of the series to fit them – though not paddle shift, which came into general use later – and Carey has done so.

‘The biggest development in recent years is I’ve fitted a Hewland six-speed JFR [gearbox], which transformed the car,’ he says.

Another improvement has been the aero.

‘Many moons ago, the car used to be all open at the back and it had a single post rear wing that came off the original [Hewland] FT 200-type gearbox, but it wasn’t good,’ Carey admits. ‘So I put a diffuser on it and a new rear wing, which is the full width of the car.’

There’s also a splitter on the front.

Carey is clearly not shy when it comes to developing his car. He’s also trying to shave off some of its 570kg weight, but admits the work involved with running a machine like this is among the biggest challenges.

‘It’s the commitment, because you can’t put it in the garage and go back two weeks later to roll it back out again. There’s always something to do. It’s when you come home from work in the evenings you have to work on it, and then most of Saturday and all day Sunday, getting it ready for the next meeting.’

Vauxhall Carlton TS6000

While it might be hard work keeping these cars going, it’s also a labour of love, and this is most certainly the case when the car has a certain heritage. A number of very well-known machines compete in Special Saloons and Modsports on occasion – Baby Bertha, the Vauxhall Firenza made famous by Gerry Marshall among them – but the Vauxhall Carlton TS6000 of Neil Duke is certainly the best known Thundersaloon in the series.

This category was at its peak in the late 1980s to early ’90s, and was for cars with original bodyshells (though this particular example features some lightweight Kevlar body panels) so most of the magic was underneath, usually the engine. In this case it’s a 5.7-litre (350ci) Chevrolet V8, which gives around 600bhp and in excess of 400lb.ft of torque, according to Duke.

‘The engine is a small block Chevy, and it was built by Swindon race engines [now Swindon Powertrain],’ adds Duke, who has also campaigned a 2.0-litre BDG-engined Ford Anglia in the series.

‘This is a pretty good engine, but the other one [which is in need of a rebuild] will be the number one engine.’

The current motor is an iron block, while the one it will be replaced with is aluminium alloy, and 6.0 litres (366ci). It will have pretty much the same power, but a bit more torque available, at around 500lb.ft.

The Carlton, which weighs some 1150kg, was originally built by Dave Cook Racing Services, but has been put back on track by Steve Mole Motorsport. It uses a live rear axle, while Duke describes the Xtrac X700 ’box as ‘the size of a lorry gearbox’ and features a five-speed, dog leg H-pattern shift. There was also a locked diff’ in the car, but that has recently been replaced with a limited slip version.

A number of very well-known machines compete in Special Saloons and Modsports on occasion

Suspension is a 4-link, Watt’s linkage, coil and damper layout at the rear with a strut and roll bar system at the front.

The aero is also quite rudimentary, yet Duke says it does the job.

‘Pete Stevens [the car’s previous owner] took it out once without the splitter and apparently it handles like a pig when it’s not on the car,’ he notes. There’s also a quite substantial rear wing, which features a three-position adjustable plane.

As for any future changes, Duke says: ‘We’re not going to do any development work on it, just make it useable. But I first need to learn to drive it!’

Peugeot 309 Cosworth

Another Thundersaloon is Danny Morris’ Peugeot 309, and this perhaps reflects the philosophy of the series the best, as it has a rich history, while also having been developed to use all the allowed technology.

The car has been in the Morris family for over 30 years – Ray Addis was also involved in its build – and it was campaigned by Danny’s brother, Ricky Parker-Morris, for many seasons, until he sadly passed away in 2021. That said, it was off the track for two decades after a heavy crash in 1993.

The 309 was originally fitted with an engine from an Opel Manta 400 before that was swapped for a 2.0-litre, turbocharged YB from a Ford Sierra Cosworth 500. While this sort of transplant is par for the course for Special Saloons, the suspension and chassis treatment on this car is rather unusual.

‘We bought four uprights from a Tiga Group C2 Sportscar, a pull-rod suspension,’ explains Morris, who is also the driver representative for the series. ‘We then just sort of grafted them onto the ’shell.

This very well known Vauxhall Carlton TS6000 was a star in the British Thundersaloons series in the late 1980s, one of the many pre-1993, lightly regulated formulae Special Saloons and Modsports caters for

At the time these pictures were taken, the Carlton TS6000 had this cast iron block, 600bhp, 5.7-litre Chevy V8 fitted, but an aluminium alloy version of 6.0-litres is set to take its place

Danny Morris' Peugeot 309 benefits from improved aerodynamics since its Thundersaloons days, with new splitter, tunnel and rear wing fitted in recent times

'We bought four uprights from a Tiga Group C2 Sportscar, a pull-rod suspension, then just sort of grafted them onto the 'shell'

Danny Morris, car owner / driver

'We put a ladder frame down the centre of it to stiffen the car up, and everything is then mounted off that ladder frame. So, the engine, gearbox and diff' are all solid mounted, and then the ladder frame supports all the suspension that hangs off that.

'We adapted the pull-rod [suspension] a bit, because that was obviously a precursor to pushrod suspension, where you can magnify the movement for the damper and spring, whereas ours was reducing it,' Morris adds. 'So you had to have very heavy springs and very heavy damping. But we moved it out, so now we get more or less one-to-one with wheel movement on the dampers, but you still benefit from the fact that everything is mounted off a chassis, so your wheel weights are quite low.'

The car weighs around 950kg and the Cosworth YB develops about 600bhp at the flywheel which, unlike original 309s, goes straight to the rear wheels.

'In the Thundersaloons regulations, you weren't allowed to put the engine back behind the original bulkhead, but you *were* allowed to convert from front-wheel drive to rear-wheel drive,' notes Morris.

The car now also has a sequential gearbox, but where it really differs from the original is with the aerodynamics.

'For this series, you can actually go out back 200mm [with the rear wing], because that's what the original silhouette Special Saloons rules were. So we've done that,' says Morris, adding that a similar approach has been taken with the diffuser.

'When we originally built the car, we shaped the fuel tank so it provided some aero at the back; we created a wedge shape for that. Then [more recently] we just extended it out a bit because, again, we can go out to 200mm. It already had a flat bottom on it.

'Basically, the splitter, the tunnel and the rear wing are the additions since it was originally built.'

Morris admits the car is prone to understeer, but the ample power he has on tap helps to dial that out. The real problem with a highly developed machine like this in what is, let's not forget, a club-level motorsport series, is its complexity.

'It's not fragile, but it is complicated,' he says. 'And because of that it does need a lot of care and attention.'

Honourable mentions

That last quote points to the reason why Special Saloons and Modsports can be a bit of a lucky dip, in terms of what cars turn up at a meeting. These machines are sometimes fragile and temperamental, while parts to fix them can be hard to source, so they can easily be rendered *hors de combat* for a while.

At a recent meet at Thruxton, when *Racecar* trawled the paddock, there were a few regular competitors that weren't there but have been out since, two of which are certainly worthy of mention.

One of these is the staggering, newly built, 5.0-litre Ford V8-motivated Austin A30 of Andy Willis, which debuted recently and is very much akin to Percy's Morris Minor in its design philosophy.

Meanwhile, a rather more famous old racecar has returned to the track after 32 years, in the shape of David Enderby's VW Karmann Ghia, which is a proper silhouette racer based on a Tiga Sports 2000 monocoque and packing a 1700cc Ford BDA – just the sort of lightweight car that humbled the big V8-engined racers back in the heyday of Special Saloon racing.

What's great about Special Saloons and Modsports is that it allows both these

The 309 features a Cosworth YB engine that gives 600bhp, while drive is now via the rear wheels and its suspension is based around Tiga Group C2 uprights

approaches, and it does not stick rigidly to regulations or cut-off dates, which might disallow some cars that really should be out on track where they can be enjoyed by drivers and spectators alike. It is the best of both worlds if you like: a historic race series, yet also an arena where entrants can use their ingenuity and engineering nous to make a difference. Not only a glimpse of the past, then, but also keeping the racing ethos of the past very much alive.

David Enderby's Volkswagen Karmann Ghia appeared at testing last year. The car is the epitome of an old-school silhouette racer, being a Tiga Sports 2000 chassis with Ford BDA beneath a cut down replica 'shell

After the outstanding success of the Type 35, Bugatti's Type 59 should have followed suit, but the racing world never stays still for long…

By **WOUTER MELISSEN**

Form over function

Photos: Wouter Melissen

The Type 59 remains a fascinating epilogue to Bugatti's grand prix story and… a thing of absolute beauty

Ettore Bugatti was an artist. One of his sculptures also happens to be the most successful grand prix racecar of all time, the Bugatti Type 35. Introduced in 1924, the Type 35 amassed over 1000 race wins during the subsequent years. But Bugatti was also a conservative. He held on to the same basic design for nearly a decade, gradually evolving it into the Type 59 of 1933, the last of the great Bugatti grand prix cars.

Bugatti debuted the Type 35 at the 1924 Grand Prix d'Europe at Lyon in France. There was not one single element that made it stand out, though the Type 35 did have an exceptionally low weight compared to the other grand prix cars entered by the likes of Fiat, Alfa Romeo and Delage.

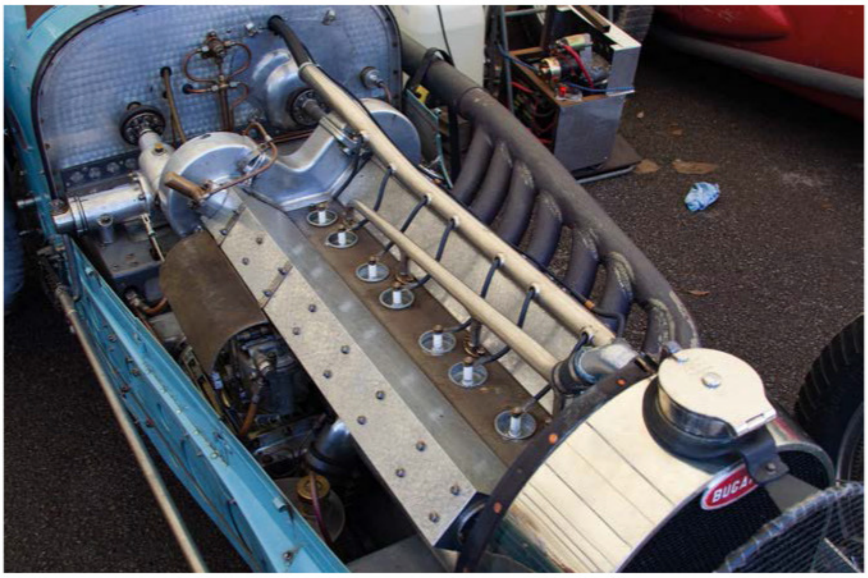
The Type 35 was built around a steel ladder frame and featured a two-piece hollow front axle with semi-elliptic leaf springs, alloy wheels with integrated brake drums and a horseshoe-shaped radiator.

Carried over from the earlier Type 30 was the car's straight-eight engine. This used five roller bearings for the crankshaft and a single overhead camshaft, driven by a shaft at the front of the engine. The camshaft actuated three valves per cylinder, two inlet and one exhaust, which were mounted vertically in the head, allowing the engine to have a very distinct, square appearance. The compact unit could rev up to 6000rpm and produced around 90 horsepower.

Outstanding design

The combination of all these subtle elements made for an outstanding design, though this did not appear to be so at the Type 35's debut. The six examples entered were held back by poorly vulcanised Dunlop tyres and did not initially impress.

The 1.5-litre Millers represented the state-of-the-art and were disassembled at the Bugatti factory to study every detail of its design

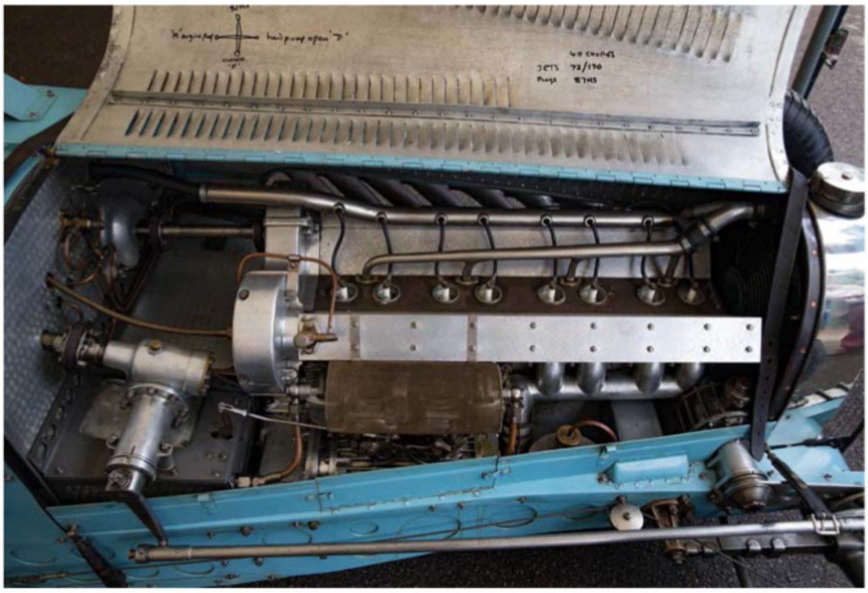


Ettore Bugatti persevered for several years with his SOHC straight-eight engine but, after buying and closely inspecting two American-made Miller racecars in 1929, he relented and changed to a double overhead cam design

These turned out to be teething problems, however, as the Bugatti Type 35's impressive list of victories would go on to show. Crucially, it would also become very popular with customers, who acquired the various Type 35 variants in the hundreds.

Bugatti was famously reluctant to complicate his clean and simple design with a supercharger and / or double overhead camshafts. At the time, the regulations were the same for naturally aspirated and forced induction powerplants, so supercharged designs had a clear advantage.

Bugatti did eventually cave and introduced the Type 35C in 1926. The C was short for *compresseur* and referred to the Roots-type supercharger fitted, which increased the engine's output by nearly 30bhp. A further evolution was the 2.3-litre, supercharged Type 35B, which was famously driven to victory in the inaugural Monaco Grand Prix in 1929.



The first Miller-inspired Bugatti engine appeared as a 2.3-litre unit in the Type 51 of 1930, then later on the 5.0-litre engine of the Type 50 / 54, which went on to be developed into the lighter, more nimble Type 59

Miller time

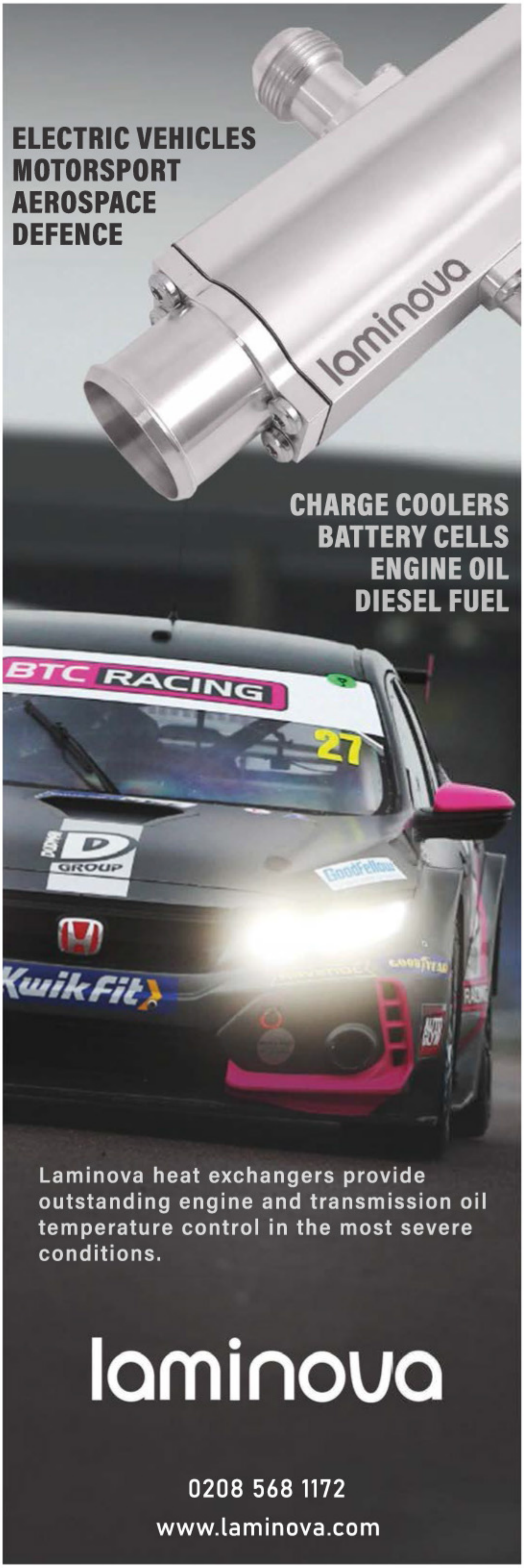
For a more comprehensive re-design, Bugatti needed encouragement from his more forward-thinking son, Jean. Barely 20-years old, he convinced his father to obtain the two Millers that had been raced in Europe by American, Léon Duray, during the 1929 season. These were traded for three Bugatti Type 43s, effectively Type 35Bs designed for road use. It was the top-of-the-range Bugatti model at the time, which underlines how highly the Millers were valued.

The 1.5-litre Millers represented the state-of-the-art and were disassembled at the Bugatti factory to study every detail of its design. Its straight-eight engine was equipped with a dual overhead camshaft head. This was of particular interest to the Bugattis, and would inspire future designs from the French company.

The Miller's front-wheel drive system reportedly also formed the basis for a four-wheel drive model, but that did not get beyond two experimental competition cars.

It was no surprise that little over a year after acquiring the Millers, Bugatti introduced the new Type 51 grand prix car.

One of the distinguishing features of a Type 59 is its wire wheels, with the brake drums an integral part of the design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Still instantly recognisable as a Type 35 derivative, it did feature a brand new engine. The bottom half of the earlier straight eight was carried over, but now fitted with a Miller-inspired head. Still using the angular design of the Bugatti engines, the new head featured twin overhead camshafts, actuating two valves per cylinder.

With the 2.3-litre engine now producing 160bhp, more success was had. A Type 51 won the 1931 French Grand Prix, and also scored a victory in the 1933 Monaco Grand Prix. It was popular with customers as well, as 40 examples were built. During this period, Bugatti also fielded the Type 54, which used a 5.0-litre engine fitted with the 'Miller head'. Originally designed for the roadgoing Type 50, the big engine proved too much for the delicate grand prix chassis it sat in, and the car was quickly, and quite rightly, nicknamed the 'widow maker'.

750 Formula

After a period of limited restrictions to the design, a new formula was introduced for the 1934 season by the Association Internationale des Automobile Club Reconnus, or AIACR. The precursor to today's FIA imposed a rule set that was quite straightforward, with the weight limit set at 750kg. The maximum weight limit that is, excluding driver, liquids and tyres. While intended to reign in performance, the new regulations certainly did not make the cars any safer.

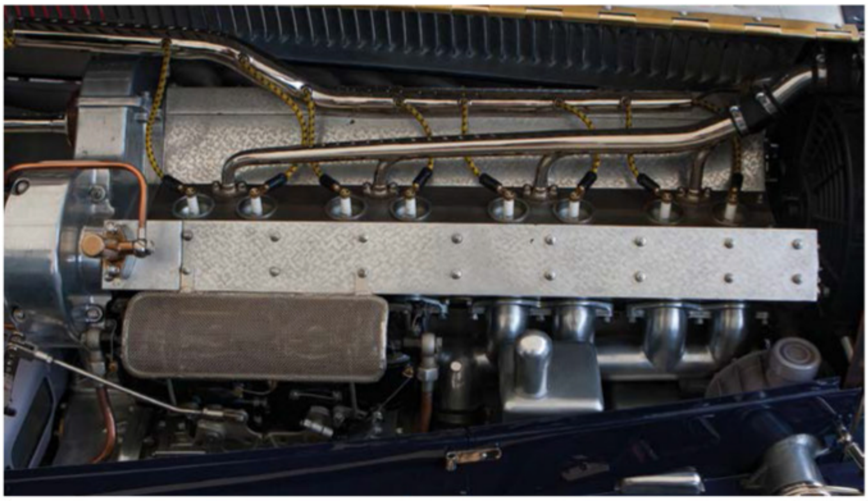
These regulation changes also coincided with an increase in nationalistic sympathies in some European countries. Each manufacturer represented their country of origin, and the cars were painted in the national colours; the Alfa Romeos and Maseratis raced in red, the Bugattis in blue.

Still looking at ways to peacefully demonstrate German superiority, the Nazi regime made funds available to support a grand prix effort. Mercedes-Benz and Auto Union took up the challenge. Story has it that the Mercedes-Benz grand prix car was ever so slightly overweight, prompting the mechanics to scrape the paint off the aluminium panels, changing the German racing colour from white to silver on the spot.

The French government saw less value in grand prix racing, so Bugatti was given no such state funding and restricted to its own resources to develop a car for the new 750kg Formula. The regulation changes were already announced in October of 1932, which meant Bugatti could start early. The result of that work was the Type 59, which debuted at the 1933 Spanish Grand Prix.

The Type 59 was again instantly recognisable as a Bugatti, thanks to its horseshoe-shaped radiator. The aluminium bodywork also followed the lines of the earlier Type 51 and Type 54. Ever the conservative, Bugatti even retained the offset driving position when rival grand prix cars were now *monopostos*. With the minimum cockpit width set at 850mm, there was also little room for a passenger.

Front end continued the Bugatti trend of a hollow, two-piece front axle with semi-elliptic leaf springs, though new for the Type 59 were complex and exotic Hydraulic de Ram shock absorbers, mounted inboard of the chassis rails



The displacement of the Type 59's straight-eight, DOHC engine was initially 2821cc, and it used plain bearings for the crank and dry sump oiling system, where its predecessors had utilised roller bearings, and a Roots-style supercharger

Recycled chassis

Underneath the familiar, blue-painted skin, the Type 59 was a direct development from the Type 54. Some even used recycled chassis as the big and heavy 'widow maker' was rendered obsolete by the 750kg Formula.

The chassis itself consisted of a steel ladder frame with a raised front and rear to clear the suspension. The middle sections of the frame were deeper to add rigidity.

The front end once again consisted of a hollow front axle with the two halves now threaded together. The semi-elliptic leaf springs were led through the axle. At the rear, a live axle was fitted with reversed quarter-elliptic leaf springs.

Whereas the earlier Type 35 and 51 chassis were tapered, the Type 59 chassis was full width at the rear and protruded through the bodywork. The rear leaf springs were bolted to the very end of the side members. New for the Type 59 were exotic Hydraulic de Ram shock absorbers. Mounted in-board, they were expensive to buy and complicated to maintain properly.

Very distinct piano wire wheels were used, replacing the iconic cast aluminium wheels used from the Type 35 through to the Type 54. The wires of the wheel served to handle lateral loads only. The wheels were driven and stopped by the brake drum that was attached

Very distinct piano wire wheels were used, replacing the iconic cast aluminium wheels used from the Type 35 through to the Type 54

to the rims through splines. Each wheel was attached to its axle by a single Rudge-Whitworth nut and, once removed, allowed immediate access to the brake shoes.

The brakes were actuated by a shaft connected to the pedal. Sticking out on either side of the chassis, it drove a small chain with the cables for the front and rear brakes connected on either end.

Scintilla magneto was mounted in the dash and shaft driven from one of the camshafts. It triggered a single plug ignition system with the plugs mounted vertically in the engine valley. The second camshaft drove the rev counter

Front and rear mechanical brakes were connected by this external chain drive, while the four copper pipes are a rudimentary oil cooler that relied on the passage of air over them to effect a change in temperature of the fluid within

Straight eight

Not surprisingly, the Type 59 was fitted with a straight-eight engine. As before, it a was monobloc, with the block and head cast as a single piece. In its original guise, the Type 59 engine had a 2821cc displacement with a bore and stroke of 67 and 100mm respectively. Bugatti had done away with the roller bearings previously used and instead installed six plain bearings for the crankshaft and a dry sump oil system.

Serving as a rather rudimentary oil cooler was a set of four copper pipes mounted in the airflow on the left-hand side of the chassis. The drive for the camshafts, water and oil pumps, and supercharger was through gears mounted at the back of the engine.

Again using the Miller-inspired design, the camshafts actuated the two valves per cylinder directly. One of the camshafts was connected through a shaft to the Scintilla magneto, which was mounted in the dashboard. The ignition was through a single plug mounted in the valley between the two camshafts. The other camshaft drove the large rev counter and also powered a pump that maintained pressure inside the fuel tank.

A single, Roots-type supercharger was bolted to the right-hand side of the engine, with a straightforward aluminium manifold

In an attempt to make the Type 59 more competitive, larger engines and a cowled radiator design were tried, but still the car failed to achieve the success of its forerunner, the Type 35 connecting it to the intake ports. Driven directly by gears at engine speed, it was fed the air and fuel mixture through a pair of Zenith carburettors placed on top of the supercharger. A rudimentary wire mesh was fitted to ensure no foreign objects could fall into the carburettors.

The eight exhausts were connected to a single pipe that increased slightly in diameter and ran on the outside of the car, waist high.

The straight-eight engine was placed low in the chassis to optimise the c of g. It was rigidly mounted in the frame on all four corners, adding further rigidity.

A new four-speed gearbox was installed separate from the engine. It took drive through Bugatti's proprietary wet, multi-disc clutch. Running underneath what would be the passenger seat was a short, tubular prop' shaft. There was no direct drive but instead two spur gears, one mounted above the other. These could easily be changed and served as reduction gears.

Although in most respects a very conventional design, the Type 59, like all Bugatti grand prix cars, was beautifully executed. In one of his books, *Great Marques Bugatti*, the somewhat biased historian, Hugh Conway, describes the design as follows: 'The Type 59 is the most beautiful two-seater racing car ever constructed, bristling with visual pleasures, and the few that remain must be among the most valuable automobiles in the world, certainly of those by normal unaided industry. But the car did not achieve what the Bugattis expected of it.'

Failure to impress

Bugatti had intended to race the Type 59 earlier in 1933 at the French Belgian Grands Prix in June. It did appear a month later in practice for the Belgian Grand Prix, but the new car was not deemed race ready until the Spanish Grand Prix in September that year. Three examples were entered, for René Dreyfus, Achille Varzi and 'Williams' (the latter did not actually start the race due to an accident in practice). During the race, Varzi and Dreyfus failed to impress, placing fourth and sixth of the six cars that finished.

Over the winter, Jean and Ettore Bugatti addressed the Type 59's weaknesses as best they could. To improve performance, the engine was bored to 77mm. This gave similar dimensions to that of the Type 57 road car. In competition trim, the engine was officially rated at 250bhp.

To meet the tight 750kg weight limit, the side members of the chassis were extensively drilled, the holes then covered from the back by lightweight duralumin panels.

Among the Type 59's rivals were the updated Alfa Romeo Tipo B, run by Scuderia Ferrari, and the all-new Mercedes-Benz W25 and V16-engined Auto Union Type A.

The German cars were not ready at the start of the season, but the Alfa Romeos immediately laid down the marker at the Monaco Grand Prix. French drivers, Guy Moll and Louis Chiron, scored a one-two victory, while the fastest Type 59 of René Dreyfus finished third, a lap down on the winners.

Once the German teams joined the fray, the bar was raised even further. Even when they were let down with teething problems, the crumbs were picked up by the Scuderia Ferrari team. A rare exception was the Belgian Grand Prix, where the Germans were absent. Only seven cars started the race and both Alfa Romeos retired. This allowed Dreyfus to score a rare win with the Type 59. At the end of the year, Jean-Pierre Wimille dominated the Algiers Grand Prix, beating Chiron and his Alfa Romeo on merit with the Type 59.

Customer racing

The results during the 1934 season were hardly an advertisement for the new Type 59, and consequently no new cars were sold to customers that year. Bugatti did, however, manage to sell off four of the six cars used in 1934 to British gentleman racers, and the cars were campaigned with considerable success on the British Isles at tracks such as Brooklands and Donington.

Never one to admit defeat, Bugatti carried on with the Type 59 on a smaller scale. Larger engines were tried, and also a cowled radiator. These updates were nowhere near sufficient to keep up with the rapid development in Germany. Especially the advances in metallurgy that helped Mercedes-Benz and Auto Union to improve performance, while staying within the 750kg weight limit. During the final year of the 750kg Formula, 1937,

The Type 59 came at a time when grand prix cars featured independent suspension and hydraulic brakes and were built using very exotic materials

Mercedes-Benz fielded the W125, which used a 5.6-litre, supercharged, eight-cylinder engine that was good for nearly 600bhp.

The grand prix cars built by Ettore and Jean Bugatti were works of art and, in their heyday, highly effective racers. Still very much a sculpture, the Type 59 came at a time when grand prix cars featured independent suspension and hydraulic brakes and were built using very exotic materials. Despite its lack of success, the Type 59 remains a fascinating epilogue to Bugatti's grand prix story and, as Hugh Conway rightly pointed out, a thing of absolute beauty.

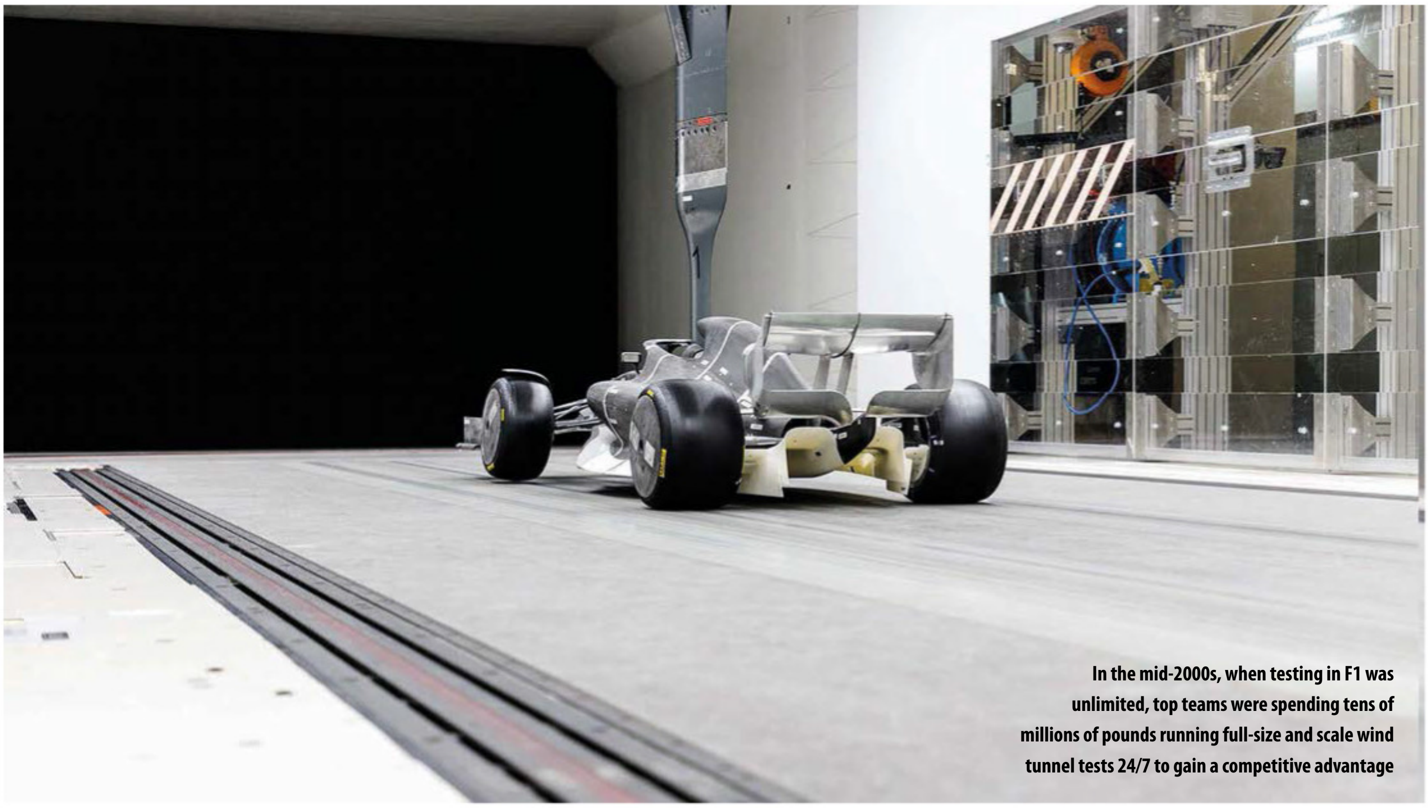
Fortunately, the four examples that were sold at the end of 1934 to British gentleman racers have survived. As Conway also predicted, they are indeed highly prized and now form part of prominent collections. The other cars that were retained were mostly recycled, and no longer exist in their original guise. One of these was re-bodied and eventually sold to King Leopold of Belgium. Still in lovely, original condition, it recently sold at auction for a staggering £9.5 million (approx. $12.45m).

Bugatti also persevered with an offset driving position, when rival manufacturers were turning to more symmetrical single seaters

Beyond the limits

In an effort to reduce costs, the FIA introduced a sliding scale of restrictions on all types of testing,* Racecar *reviews the system, and how teams are reacting to it

By GEMMA HATTON



In the mid-2000s, when testing in F1 was unlimited, top teams were spending tens of millions of pounds running full-size and scale wind tunnel tests 24/7 to gain a competitive advantage

The relentless hunt for performance in Formula 1 drives teams to exploit every possible opportunity for development. This leads to comprehensive testing programmes at the racetrack, rig centres, wind tunnels and in simulation. Yet despite the abundance of testing tools now available, there is never enough time for engineers to investigate every test condition. So, to try and test as many scenarios as possible, teams are constantly pushing the boundaries of how much time they can test, and how efficient they can be whilst testing.

Track testing

This became apparent in the early-to-mid 2000s when F1 teams had grown to engineering armies with budgets that allowed them to spend over 80 days testing at the track per season. These test days took place in between race events as well as pre- and post-season, and would often involve running three cars simultaneously at two different circuits. This was only made possible by having a separate trackside team dedicated to testing, leaving the race team to focus on the race weekends.

At that time, the only limit to a team's testing schedule was budget so teams spent as much money as they had available. This led to soaring costs, with some of the top teams spending around $400 million a year (compared to the current $135 million budget cap). So, in an attempt to control costs, the FIA started imposing restrictions.

Test mileage was first limited to 30,000km in 2008, which then reduced to 15,000km in 2009, when in-season testing was banned. Since then, pre-season testing has continually reduced and is now down to only three days, with several one day Pirelli tyre tests throughout the season.

Despite these restrictions, teams will still travel up to 150,000km and ship over 32,000 tonnes of freight, costing some $100 million, to compete in the 23 races on this year's calendar.

With the FIA limiting track testing in 2008, it was no longer possible to sign off components for durability on the track, so teams needed to find an alternative.

Around the same time, test rig hardware was evolving, and engine dynos were starting to match the high rpm requirements of F1. However, the likes of transmission dynos required very high speed and low inertia drive motors to mimic engine performance and Permanent Magnet Machines (PMM) were still in their infancy.

To further develop the capability of this hardware to reliably test F1 engines, more investment was necessary. Fortunately, with the FIA reducing track testing, teams had money available and so switched focus to the development of test rig technology.

Teams will still travel up to 150,000km and ship over 32,000 tonnes of freight… to compete in the 23 races on this year's calendar

Suddenly, teams needed battery emulators, cell and module testers, e-motor dynos, powertrain dynos and full vehicle test rigs

This was further accelerated in 2014 with the introduction of the hybrid regulations. Previously, conventional internal combustion engines (ICE) had been optimised using a single cylinder development engine and a few engine dynos. However, the complexity of the new hybrid systems demanded a completely new rig testing approach.

The 2014 power unit consists of six different elements: a 1.6-litre V6 engine; a MGU-K motor generator unit; a MGU-H motor generator unit; an energy store; a turbocharger and control electronics – all of which needed to be rigorously tested.

Suddenly, teams needed battery emulators, cell and module testers, e-motor dynos, powertrain dynos and full vehicle test rigs to test their power unit and transmission installations, along with all the necessary cooling systems and ancillaries.

Rise and fall

With some of these rigs costing millions of dollars each, spending once again started to rise as teams continued to improve the accuracy and reliability of their testing platforms. This injection of cash quickly made test rigs a major performance differentiator, which was proven by the dominance of Mercedes during this era, who invested heavily in its High-Performance Powertrains facility in Brixworth, UK.

To prevent costs from escalating further, the FIA introduced restrictions on power unit bench testing in 2021, on both engine dynos and Energy Recovery System (ERS) dynos. Both are limited to a maximum number of test benches, occupancy hours and operation hours. For 2023, the number of occupancy and operation hours were further reduced, and will continue to reduce until 2025.

An engine test bench is defined as any combination of engine dynos, powertrain dynos or full vehicle dynos – in other words, anything that requires a firing engine. Whereas ERS test benches are any combination of test benches for testing energy stores, MGUs or power electronics.

The regulations demand power unit suppliers to nominate nine engine test benches and four ERS test benches per 10-week period.

Year	2022	2023	2024	2025
Max test benches per year	9	9	9	9
Max Occupancy hours per year	6000	4000	2800	1600
Max Occupancy hours per period	1200	800	2800	1600
Max Overall Operation hours per year	750	500	350	200
Max Overall Operation hours per period	150	100	350	200
Max Operation hours per year on a Power Train Test Bench where car components can be classed as being provided for the sole purpose of PU performance and reliability	150	100	100	100

Power unit bench testing limits from the 2023 sporting regulations

Year	2022	2023	2024	2025
Max test benches	4	4	4	4
Max Occupancy hours per year	1600	1200	800	400
Max Occupancy hours per period	320	240	800	400
Max Operation hours per year	400	300	200	100
Max Operation hours per period	80	60	200	100

ERS bench testing limits from the 2023 sporting regulations

Operation hrs / year	2022	2023	2024	2025	2026	2027	2028	2029	2030
New PU Manufacturers after 2026	N-4	N-3	N-2	N-1	N				
2026 PU limit - ICE	300	5400 *			700	400	400	400	400
2026 PU limit - ERS	200	3400 *			500	400	400	400	400
* These limits are cumulative over the three years, 2023, 2024 and 2025									

ERS bench testing limits from 2026 onwards

As well as capping the number of test rigs, the regulations also apply limits to the number of operation and occupancy hours for which they are running. Power unit suppliers must manage the hours over five 10-week periods in a calendar year.

Operation hours is defined as the cumulative sum of the hours that a rig runs. For engines, this is any time when the engine is running above 7500rpm. For ERS testing, this is any time spent above 10A absolute current, or 1000rpm MGU speed, depending on what is being tested.

The total operational hours are calculated in the regulations with the following formula:

$$OPH = \sum_{n=1}^{n=N} NOPHn$$

Where,

N = number of test benches

NOPHn = number of hours during the period for bench number ***n***

Occupancy hours are measured slightly differently. Each day, the occupancy clock starts the first time an engine is run above 1000rpm, or an ERS element is above 10A absolute current or 1000rpm MGU speed. The clock stops the last time they fall below this at the end of the calendar day.

The total occupancy hours are calculated as:

$$OCH = \sum_{n=1}^{n=N} NOCHn$$

Where,

N = number of test benches

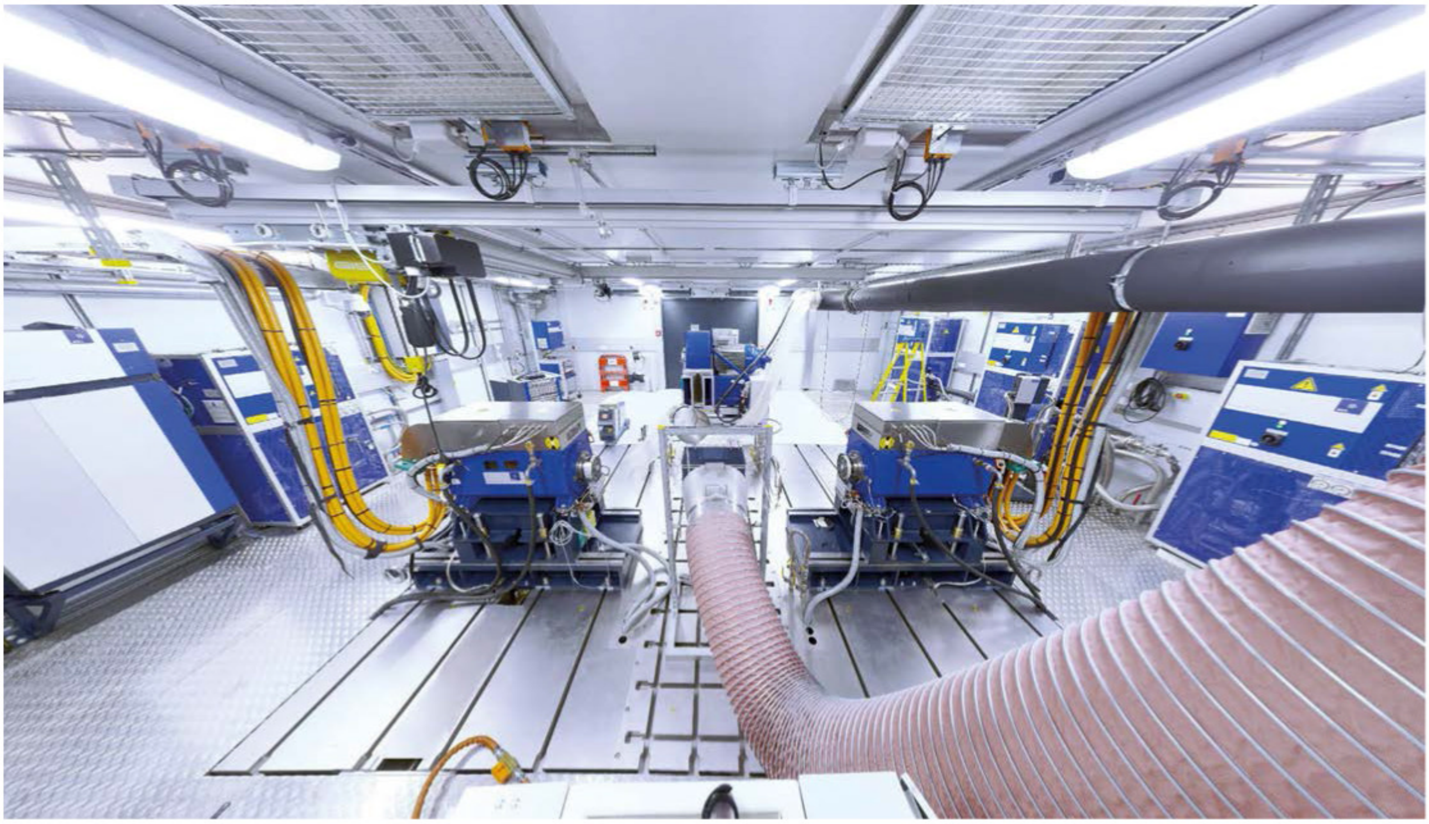
NOCHn = number of occupancy hours during the period for bench number ***n***

For 2026 onwards, the FIA has imposed separate testing limits. Teams also have to prove any current PU development is not adding to the 2026 PU time allocations.

Maximising testing times

With so many restrictions in place, and more on the horizon, teams have had to come up with new ways to maximise the output of every test. This has led to even more data channels, simulations and an increased focus on individual component testing.

'Before 2021, teams could run tests on the power unit 24/7 if they wanted to, but that is no longer the case,' highlights Martin Monschein, global business segment Manager at AVL.


AVL

Power unit testing restrictions has encouraged teams to focus more on individual component testing, ensuring parts like the e-motor are fully validated on rigs like this before using the precious hours available to test the power unit assembly as a whole

'However, the regulations do not restrict component testing, so this has become more of a focus and we have had to get creative with our testing platforms to try and achieve as much realism as possible within these tests.

'For example, by emulating different parts of the power unit, such as the e-motor or battery, we can trick the inverter into thinking it's operating within a power unit assembly, even though we are only testing the inverter itself. Techniques like this allow us to front load R&D development, which improves efficiency because each part is fully validated before testing the power unit as a whole, saving time when the timer is ticking.'

Another priority is preparation. Ensuring sensors are calibrated, the systems are ready and the test specimen has been prepared so it is already within its operating window before the test starts can be the difference between a successful and unsuccessful test.

'Another important strategy is streamlining testing programmes,' continues Monschein. 'Teams are having to condense tests and think of ways to apply the same load on the unit under test but in much less run time. So, the speed, load and power profiles of a powertrain can be classified into specific areas and teams can then calculate the time and conditions on the dyno that are equivalent to a full race of running, for example, if a team is testing a speed profile between 10,000 and 14,000rpm at full load and there are some braking zones. When condensing testing profiles, it is still important to hit the outer boundaries, in this case 10,000 or 14,000rpm as this is important to ensure the unit under test is also durable in these conditions.'

Aerodynamic testing

It is a similar story for aerodynamic testing. By 2008, the likes of BMW Sauber, Honda, Williams and Toyota were spending tens of millions of pounds on full-size wind tunnel testing. In some cases, teams were operating two wind tunnels simultaneously, seven days a week and 24 hours each day, completing up to 500 wind tunnel simulations per week, with each simulation incorporating approximately 20 different car attitudes. While teams such as BMW Sauber had the latest Albert 3 supercomputer, along with over 4000 Intel cores, and were leading the way in CFD hardware, other teams were not actually that far behind.

The first set of Aerodynamic Testing Restrictions (ATR) were introduced in January 2009 and limited teams to a certain amount of Wind On Time in the wind tunnel and Teraflops of CFD compute capacity. Wind tunnels were also restricted to a maximum wind speed of 50m/s (180kph) and only 60 per cent scale models were permitted.

Over the years, the regulations evolved and continued to reduce the amount of aerodynamic resources available to teams via a limit line. So, the more time a team chose to run CFD, the less time it would have available to utilise the wind tunnel, and *vice versa*.

For 2023, the aerodynamic testing regulations are the most stringent yet, and include a sliding scale of limits based on championship position

For 2023, the aerodynamic testing regulations are the most stringent yet, and include a sliding scale of limits based on championship position that was first introduced in 2021. The regulations consist of Restricted Wind Tunnel Testing (RWTT) and Restricted Computational Fluid Dynamics (RCFD) rules. In both cases, a Restricted Aerodynamic Test Geometry (RATG) is defined, which is a single fixed car bodywork and geometry configuration that applies to either physical wind tunnel models or meshed 3D bodies. For example, a wind tunnel test or CFD simulation of four dive vane positions on a wing end plate would require four RATGs.

Wind tunnel testing

Wind tunnel testing is controlled by a combination of runs, Wind On Time and occupancy. A run is logged each time the wind tunnel air speed exceeds 5m/s (18kph) and ends the first time it drops below 5m/s.

Wind on Time is a cumulative total of the time when the wind tunnel air speed is above 15m/s, while occupancy is the cumulative time elapsed between the first time the wind tunnel air speed is above 5m/s to the last time the wind tunnel air speed falls below 5m/s during a calendar day.

For example, if a team tests four front wing dive vanes during a single day, that will account for four runs. If each wind tunnel run requires the wind speed to be above 5m/s for 30 minutes, that will accrue two hours of Wind On Time. If the first of those runs starts at 08:00 and the last ends at 15:00, that would accrue seven hours of occupancy.

CFD simulations

The amount of CFD simulation a team can complete is limited by the number of RATG it can run, as well as the allocated computing resource. The latter used to be defined by Teraflops, which is the number of floating point operations completed within a CFD run. Now, however, this is defined by Mega Allocation Unit hours (MAUh), which essentially sums the theoretical number of computations that can be carried out in the time the simulation was running, without specifically counting each computation. MAUh is defined by the following formula:

AUh = (NCU*NSS*CCF) / 3600

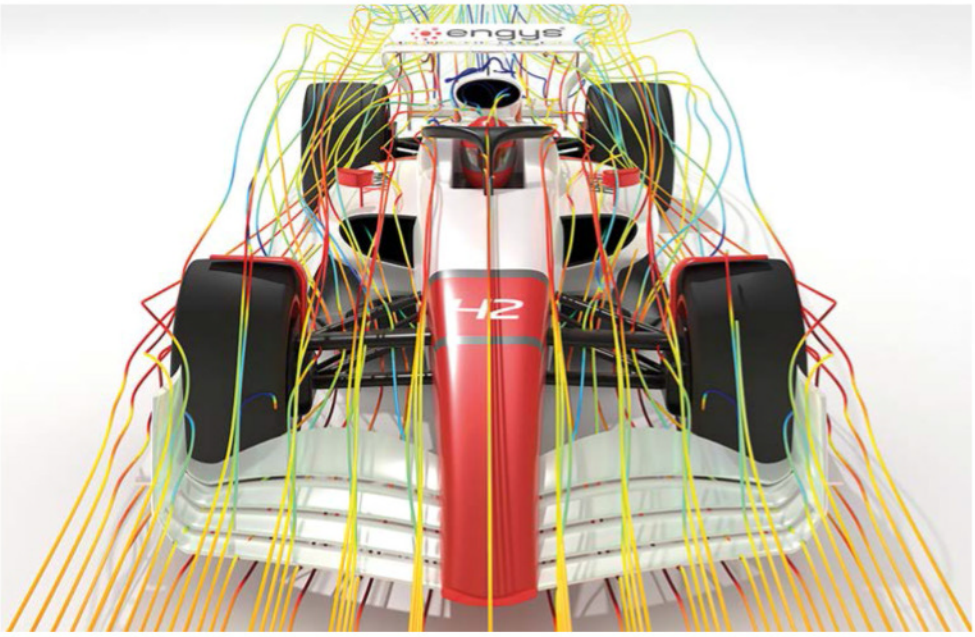
Where,

AUh = allocation unit hours (1MAUh = 1 x 106 AUh)
CCF = theoretical peak CPU clock frequency during the run
NCU = number of CPU cores used (no limits on multi-threading)
NSS = CPU clock time elapsed during the run

'Before these regulations were bought into effect, teams would characterise every feature of the car in CFD,' highlights Giampaolo Certraro, senior CFD developer at Engys, the company that supplies Helyx software to six Formula 1 teams. 'In some cases using both steady state and unsteady simulations.

'A steady state simulation calculates the averages of the flow characteristics, but mathematically it is essentially a snapshot. Whereas an unsteady simulation characterises the history of the flow as it passes over the car, so it is like sticking many steady state simulations together.

'Every time step of an unsteady simulation is probably equivalent to 70 or 80 per cent of a steady simulation. For example, if you had a timestep of 0.5s and you wanted to simulate 10s of unsteadiness, that would mean you have 20 time steps, which is equivalent to 20 steady state simulations. Although, unsteady simulations typically have much smaller time steps, such as one thousandth of a second.



Each time step of an unsteady simulation is equivalent to 70 or 80 per cent of a steady simulation

Wind tunnel limits for C=100%:

RWTT Runs	#	320
RWTT Wind On Time	hours	80
RWTT Occupancy	hours	400

CFD limits for C=100%:

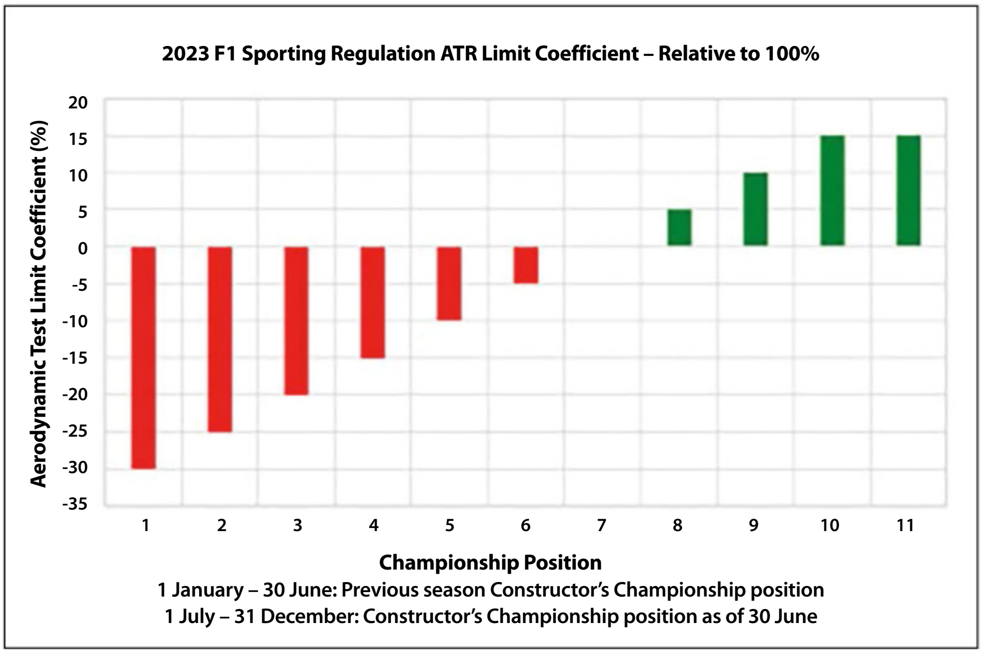
3D new RATGs used for solve or solve part of all RCFDs	#	2000
Compute used for solve part or parts of all RCFDs	MAUh	6

The wind tunnel and CFD limits for F1 teams

Coefficient C as a function of Championship position, P in 2022-2025:

Championship Classification	P	1	2	3	4	5	6	7	8	9	10+ or New Team
Value of C	%	70	75	80	85	90	95	100	105	110	115

The percentage of aerodynamic testing allowed for each championship position (with 100% defined in the table above)



The Aerodynamic Testing Restriction (ATR) limits of each championship position relative to 100 per cent

Teams are adopting new approaches to make the most of the restrictions, some choosing to trade accuracy for faster run times to save computing resource, particularly at the start of the season

'This requires a huge amount of cells, and therefore core hours, to simulate the entire geometry of a car, which is why unsteady simulations are rarely used in F1. If they are, they have much larger time steps and therefore reduced accuracy.'

Both the RWTT and RCFD restrictions apply throughout the full year, which is divided into Aerodynamic Testing Periods (ATPs). These last between seven and nine weeks and the specific dates are detailed in the Sporting Regulations, along with the allocated cumulative total of wind tunnel testing and CFD simulations for each ATP.

Position effect

Formula 1 has long steered clear of any form of success ballast or Balance of Performance intervention to slow cars down. However, this changed slightly in 2021 when the FIA introduced a sliding scale of the amount of aerodynamic testing a team is allowed based on championship position. The percentage of allowable RWTT and RCFD is now multiplied by a coefficient, 'C', which varies for each championship position, 'P'.

This championship position is based on the first half of the previous season's championship, up until 30 June, after which it switches to the team's current championship position.

To put some context to this, it means that for 2023, last year's Constructors' Champion, Red Bull, is only permitted to do 70 per cent of the aerodynamic testing allowed by the Sporting Regulations. Whereas the team who finished last in 2022, Williams, can do 115 per cent and therefore gain 15 per cent of additional CFD and wind tunnel time.

Aero testing tactics

Similar to the effect of the power unit testing restrictions, the ATR has forced teams to adopt a variety of new techniques and approaches to get the most out of shortened test times. To improve the efficiency of wind tunnel testing, teams have introduced continuous motion and sampling systems to eliminate what was previously dead time between runs, while new measurement and analysis techniques such as Particle Image Velocimetry (PIV) are being used to extract as much data as possible during a test.

For CFD simulations, teams are trading run time for accuracy to save a few more of those precious computing hours.

'For the first half of the season, teams will usually run lots of CFD simulations at low accuracy and focus on trends rather than absolute numbers,' explains Cetraro. 'Then, as the season goes on, they will refine this accuracy to optimise the performance of the aerodynamic package and any upgrades they want to make. However, if the season is not going so well, teams may decide to switch to developing the aerodynamics of next year's car much earlier.'

The regulations have also demanded a change in workflow. Just like front loading a power unit test on a rig, the same applies to CFD. With only the simulation run time restricted, teams have focused on minimising the overall turnaround time of a typical CFD simulation, in particular tuning the set up of the computational grid generation and post-processing of the simulation data.

With only the simulation run time restricted, teams have focused on minimising the overall turnaround time of a typical CFD simulation

'There has also been talk about the FIA allowing the use of GPUs from next season onwards,' says Cetraro. 'The FIA dictates the specific hardware teams use to run their CFD simulations, and currently GPUs are not permitted. However, with GPUs becoming more popular in other industries that use CFD, I think it's only a matter of time before the FIA have to allow the use of this technology.

'This will require a huge amount of work from CFD suppliers,' continues Cetraro. 'CFD code is written specifically for the hardware it is running on to maximise solver performance. So, to run efficiently on GPUs will require re-writing more than half our code and several years of development. It is a substantial amount of work, but something we are already working on to ensure that when these new rules are introduced, we are GPU ready for our customers.'

Top of the stops

We examine the current state-of-the-art in racecar braking systems and look at how the drive to electrification is changing the development path

By LAWRENCE BUTCHER

Brakes, alongside tyres, are probably the most important component of any racecar. Even Formula E, which tried to dispense with rear brakes for Gen 3, quickly realised that a mechanical means of retardation is still useful to have.

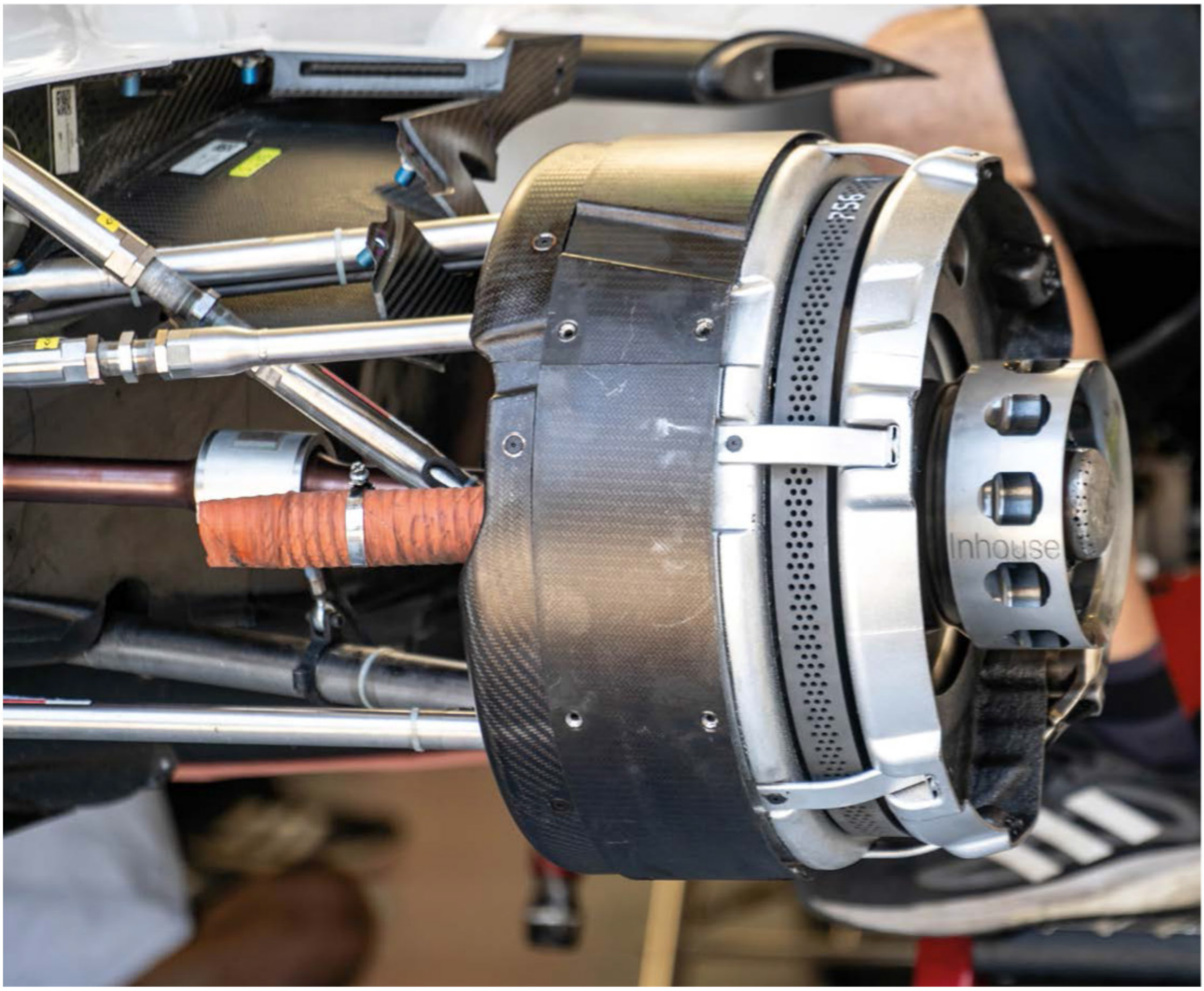
Since Dunlop first brought its disc brakes to Le Mans with Jaguar in 1953 (though the British company was not the first to see the benefits of caliper brakes), the basic principles of operation have not changed, but the level of optimisation has gone through the roof.

One only has to look at a Le Mans Hypercar, capable of completing a full 24-hour race on the same set of discs and pads, to appreciate just how impressive modern motorsport braking technology is.

Caliper consistency

Imagine a brake caliper as the letter C, with pistons mounted at both ends. When the brakes are engaged, the pistons apply force against the disc, causing the caliper to try to open up. This means that a portion of the force applied by the driver at the pedal is lost due to deflection in the caliper body. This deflection not only diminishes the efficiency of the driver's brake inputs but also introduces the possibility of a 'soft', or inconsistent, pedal sensation.

Furthermore, the caliper can also experience deflection due to the twisting force generated as the friction between the brake pads and disc intensifies. When this occurs, the pistons are pushed back into their bores, displacing the brake fluid.



Toyota's GR010 brake assembly is sized to accommodate hybrid energy braking in addition to the traditional pads and disc retardation, and can complete a full 24-hour race without replacement

Consequently, the driver must release the pedal pressure to compensate for this, or else the brakes may start to lock up. By maximising the stiffness of the caliper body, the impact of this flex on the braking system's feel and performance can be minimised. The outcome is a significantly more precise brake feel for the driver.

Building a stiff caliper has to be balanced against a host of competing demands, including reducing weight, space within the wheel, thermal management, material properties, manufacturability and cost

However, building a stiff caliper has to be balanced against a host of other competing demands, including but not limited to, reducing weight, space within the wheel, thermal management, material properties, manufacturability and cost. It is the compromises that each of these elements bring that have led to the current state-of-the-art in caliper construction.

Bridge optimisation

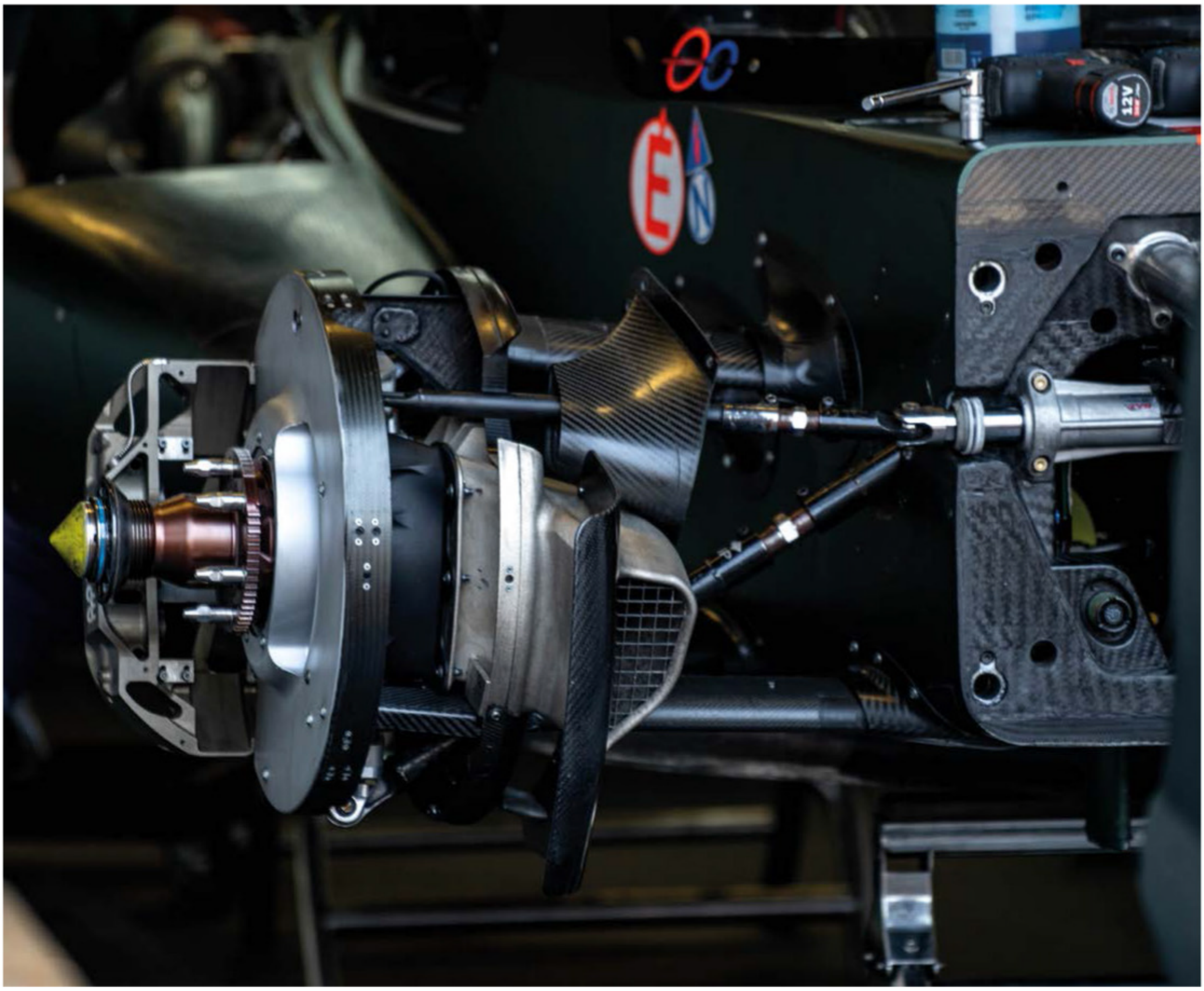
The most important area of the caliper in relation to stiffness is the bridge section between the two sides of the caliper. This is the part that needs to resist deflection as the pistons are in action. Ideally, this bridge would be as big as possible to maximise its stiffness, but such an approach is not practical when one has to consider the weight of the caliper and the space envelope within which it needs to fit. It is therefore the case that the form of the bridge and the material used for the caliper body needs to be optimised to provide the best compromise between stiffness and these other considerations.

Today, this optimisation is undertaken using advanced generative design methods and extensive FEA analysis of a caliper's structure, in order to ascertain exactly where material can be added and where it can be removed, in order to provide the best balance between stiffness, overall size and weight.

Design constraints, such as the location of fluid passageways, cylinder bores and structural requirements, are inputted. The software then runs iterations of the design to determine where material can be removed, resulting in an optimum shape that provides the lowest weight for the desired stiffness.

A further stage of processing is required to end up with a caliper that can actually be manufactured. Here, the arrival of five-axis machining centres changed the game, allowing ever more complex forms to be hewn from a single billet, including the piston bores, removing the need for a split design.

The result is the phenomenally intricate designs seen on current F1 cars, with complex cooling passageways integrated within the caliper and not one gram of excess material.



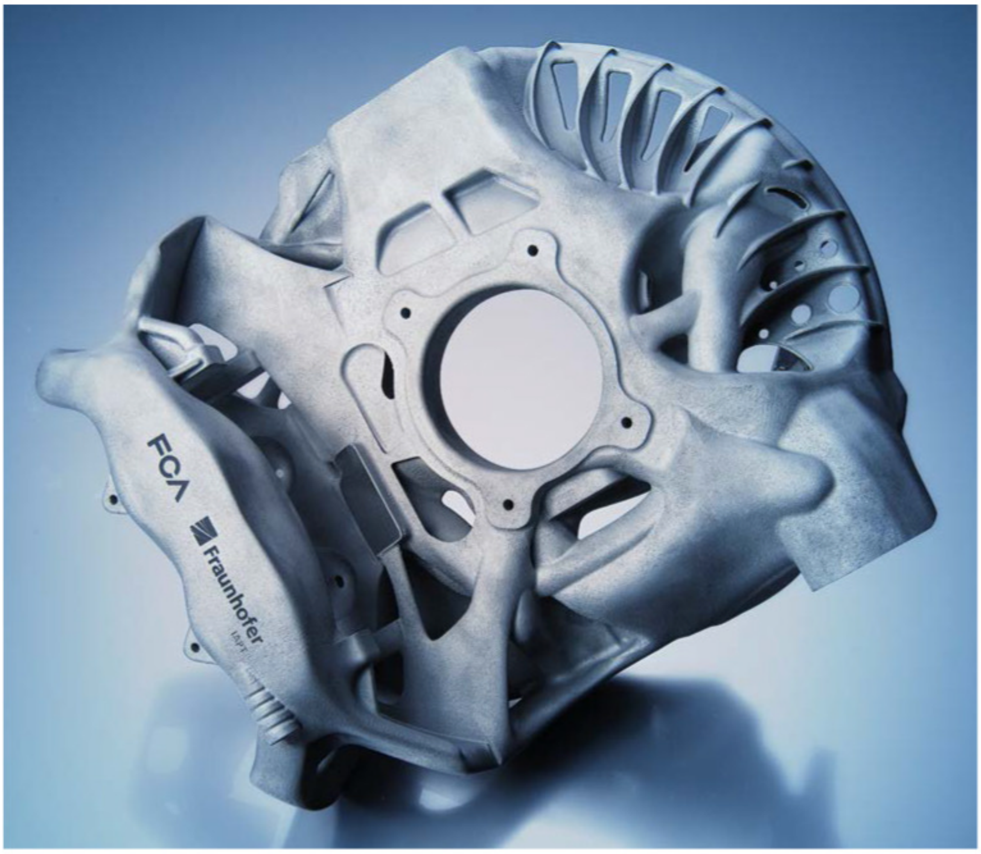
The Vanwall Vandervell 680 prototype Le Mans car brake set up, showing the cooling air ducts through the brake backing plate, something that's of critical importance on an endurance racer

This optimisation approach can be applied to calipers regardless of their end use, although the performance factors that are considered vary from application to application. For example, a brake caliper design destined for rallying will need to withstand the battering meted out by flying rocks and debris, which is far less of a concern for a circuit racer. As such, the construction will tend to err on the side of substantial.

Printed brakes

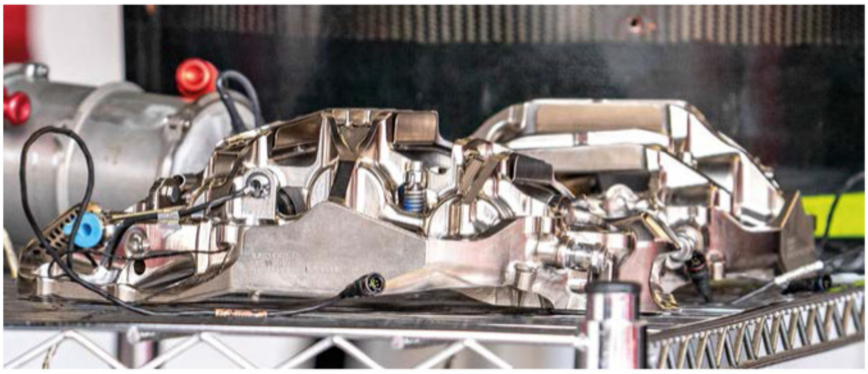
The next logical step on from machining calipers from billet is the use of additive manufacturing (AM), though as far as the author is aware, AM-produced calipers have not yet been raced competitively at a high level. However, there have been a number of conceptual studies, the most well publicised being a prototype titanium caliper Bugatti produced and tested with impressive results.

Another OEM effort, a cooperation between German research organisation, the Fraunhofer Institute, and what was then (2020) FCA, was the development of an integrated brake caliper and suspension upright for a 'future sportscar', additive manufactured from aluminium. Using topology optimisation, the team developed a prototype weighing 36 per cent less than the 12 individual parts of the conventionally manufactured assembly. The design was said to reduce assembly effort enormously, increase fatigue strength thanks to a more robust construction and perform better in terms of noise, vibration, and harshness (NVH).



What was at the time called FCA developed this additive manufactured integrated caliper and upright assembly for a 'future sportscar'

Another interesting concept study stems from the hotbed of innovation that is Formula Student, with a team from the 'Enzo Ferrari' Department of Engineering, University of Modena, devising a concept for an AM titanium caliper for use in FS competition (1).



2023 Alfa Romeo Sauber Formula 1 brake calipers, demonstrating their highly intricate and specialised topology

From 2022, the complex internal drillings made into Formula 1 carbon discs must be a minimum of 3mm in diameter

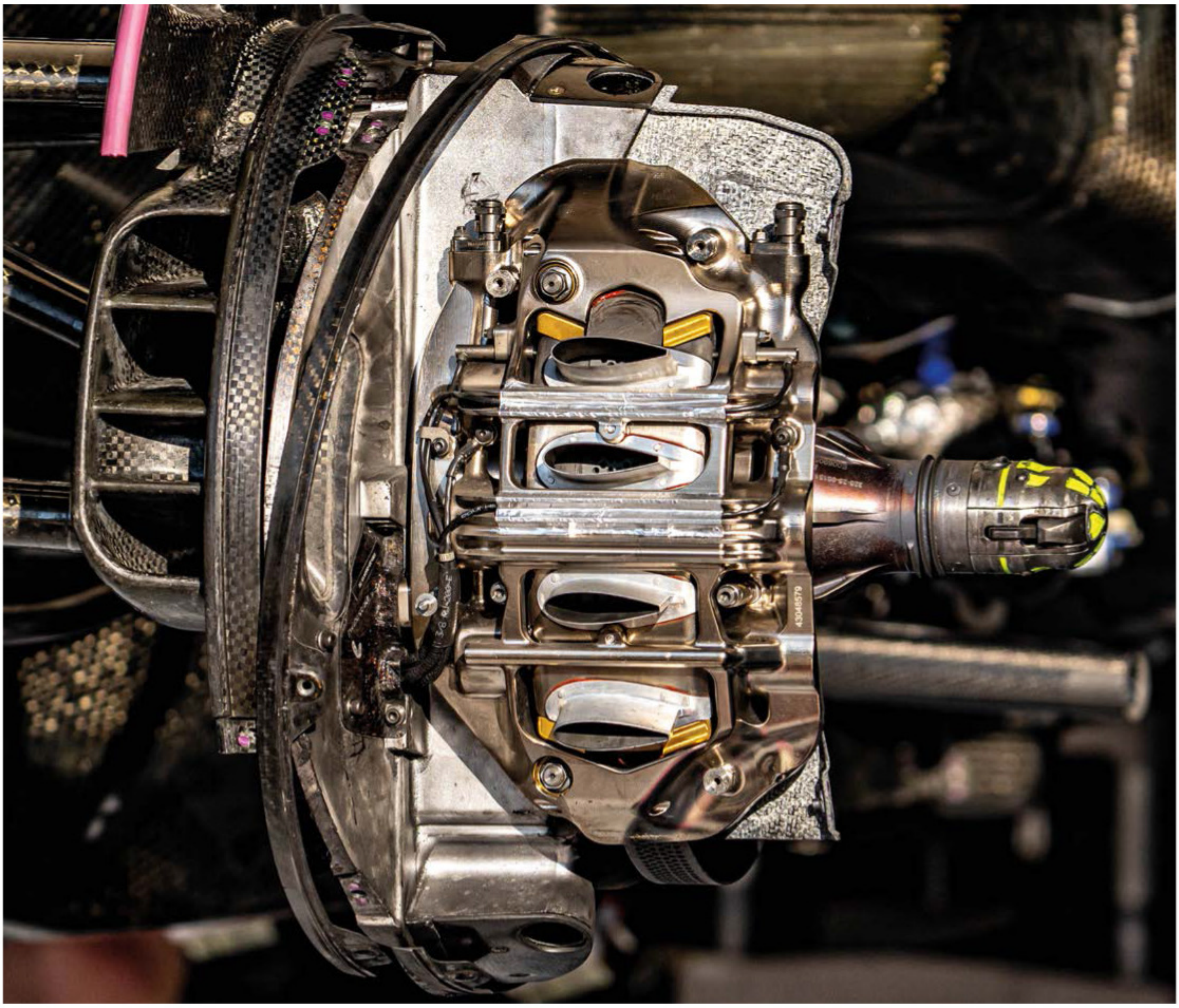
Using a reference caliper as a benchmark, the additive manufactured alternative came in approximately 25 per cent lighter without sacrificing any stiffness.

Despite these experimental efforts, there are still numerous hurdles to the adoption of AM for brake caliper manufacture. Not least, the fact that it is still early days for robust quality control of metallic parts, with every element of the build process having to be characterised, and even minute changes in build conditions potentially altering the material properties. When working with a billet of known material, the properties are well understood and assured from the outset, but AM is not yet at that point.

Ultimate optimisation

In the world of Formula 1, brake calipers are being optimised to an extraordinary degree. While the design and layout of the brake system in an F1 car may appear traditional, the caliper's importance as an integral part of the overall vehicle cannot be understated. Its interaction with the front upright, both structurally and from an airflow perspective, is of tremendous significance.

Regulations limit the areas where teams can gain a significant advantage in caliper design, but material development has played a vital role in achieving lighter and stiffer calipers over the years. Aluminium Metal Matrix Composite (MMC) materials, which combine aluminium alloy with ceramic reinforcements, have been used



The incredible complexity of Formula 1 brake calipers is further shown here by this 2023 Alpine brake caliper, which features integrated cooling chimneys within its design

F1 rule changes

2022 saw a significant overhaul of the brake system regulations in Formula 1, primarily intended to reduce costs, while also adapting to the introduction of 18in wheels. The most noticeable difference was that front disc size grew from a maximum of 278mm to between 325 and 330mm. At the same time, the rules placed a limitation on the size of the venting holes in the discs at a minimum of 3mm.

The aerodynamic regulations effectively banning venting of the brake cooling air outboard has meant the layout of '22-onward brake set ups are quite different to before. Previously, teams would often position the calipers in the most aerodynamically advantageous position, if not necessarily the best from a brake function or weight distribution perspective. Now, some teams have returned to a more traditional three o'clock mounting position. The change, coupled with the larger wheels, has also necessitated the design of the brake 'drums' be revised in order to still direct hot cooling air to the inside of the wheel (to help tyre warm up).

AP Racing's CP7480 Radi-CAL forged, monobloc, four-piston caliper is a popular choice on the rear in GT3 applications since the 1990s. These MMC calipers offered significantly lower weight and greater stiffness compared to traditional aluminium alloys, but are now banned by regulation.

This is unfortunate for brake designers as recent developments have further increased the strength of MMCs, with some commercially available materials having double the Young's modulus of aluminium. With the banning of MMCs, aluminium / lithium alloys have become the favoured material for caliper construction in Formula 1 due to the strength, reduced density and improved stiffness-to-weight ratio the material affords, though again the regulations place limits on the ratios of alloying elements allowed in their construction.

Feel the quality

Manufacturers also invest considerable effort in optimising the 'feel' of the brakes, in other words the quality of response the driver experiences when pressing the pedal. Brake feel is influenced by various factors, including the aforementioned caliper construction and stiffness, pedal design and the choice of pads and discs.

Consistency of pedal inputs for a given level of deceleration is crucial, and much effort thas been expended by manufacturers to ensure pistons retract consistently within the caliper. Piston seals can be tailored to influence the piston's movement, and mechanical pad retraction systems can be used to prevent dragging and enable cooling airflow, returning the pads to the exact same position after each application, providing a consistent level of pedal travel.

Temperature control is another important aspect of caliper design as brake fluid overheating can lead to compressibility and reduced braking efficiency. Heat transfer from the pad to the pistons needs to be minimised and manufacturers employ measures such as thermally insulating caps, or coatings, on the piston ends, as well as radial cooling holes to control piston temperatures. These details help prevent heat transfer into the brake fluid and maintain the serviceability of vital components like piston seals.

Thermal management of the discs, meanwhile, is taken care of by complex internal drillings (in the case of carbon-carbon brakes) or vent channels in iron discs.

Brake-by-wire

The technology known as brake-by-wire (BBW) arrived hand in hand with the era of hybrid and electric vehicles. Traditionally, braking relies on a hydraulic circuit providing a linear link between the driver's foot and the braking force. However, with the introduction of energy regeneration systems in hybrid and electric racing machines, the contribution of the driver and mechanical brakes needed to be modulated for consistent braking performance. Enter BBW.

BBW systems were first introduced in Formula 1 and the World Endurance Championship around 2014, while Formula E adopted the technology in 2018. Early BBW systems relied upon a valve controlled by the ECU to modulate brake pressure at the rear axle, balancing the braking force with energy regeneration. However, this approach had its challenges, as factors like battery charge, desired charge rate and energy already recovered needed to be accounted for, and a simple pressure control valve cannot provide the resolution needed to balance these.

De-coupled BBW systems, which remove the hydraulic connection between the pedal and calipers, are now allowed in Formula 1

The latest BBW systems, such as this IBSe from LSP, offer additional functionality, such as launch control and adjustable brake bias

Stable friction

Whilst electrification does influence brake sizing, friction brakes remain a requirement for several reasons. These include the need to achieve high braking torques above the energy recuperation capabilities of the motors, while also providing an additional safe solution in the case of electrical braking malfunctions.

As AP Racing's Richard Joyce, head of engineering, explains, brake-by-wire systems calculate the brake torque required from the friction brake systems after the regenerative braking torque has been subtracted.

'This requires a very stable brake µ in a range of brake operating conditions, including caliper pressure, rubbing speed and temperature. This has created the market for 'stable µ' friction couples, particularly with carbon-to-carbon brakes in the formulae using BBW.'

This has driven AP and other manufacturers to develop brake materials with very consistent friction µ performance, assessed via extensive dyno testing.

'The µ data for the friction couple creates a friction map, a form of look-up table, the BBW system accesses to determine the brake pressure required to be applied to the brake caliper to create the BBW target torque.'

Caliper construction and development is dependent on application. These AP Racing Rally Raid calipers, for example, need to be very robust to cope with the harsh terrain and flying debris found in the series

and Formula E, with a back-up hydraulic circuit maintained. In fully de-coupled systems, a pedal force simulator provides feedback to the driver's foot.

Different approaches to actuating de-coupled BBW exist, such as servo-based systems and linear actuators. The former comprise a high-pressure pump, accumulator and a servo valve that controls brake fluid flow offer higher flow rates and pressures, allowing for faster reaction times.

On-demand pressure

The main role of hydraulic components in BBW systems is to ensure precise and rapid brake pressure application. Pressurised accumulators, as provided to teams by several suppliers, provide high-pressure fluid on demand to help ensure this high frequency response. The BBW system's electronic control unit (ECU) manages the pressurised accumulator and communicates with the vehicle control unit (VCU) to balance mechanical braking and regenerative forces. In most cases, the BBW ECU handles the brake torque control, simplifying integration.

Achieving consistent braking performance with BBW systems is crucial, as even minor changes can affect a driver's confidence and lap times. Factors like brake pad and disc material, disc rotational speed and temperature all impact the torque applied for a given pressure. So teams work on friction maps to predict brake torque accurately and create a predictable and effective BBW system. In-house dynos are used for testing and development, allowing teams to fine tune their systems and account for factors like pad wear and fluid displacement.

Redundancy is a critical aspect of BBW systems. Most regulations require fully mechanical redundancy to ensure that if the BBW system fails, the driver still has braking capability. Failure detection and response are handled by the BBW control system. Failures can result in the loss of regenerative braking and potential wheel lock up, posing significant challenges for teams.

Interestingly, de-coupled brake-by-wire systems offer the possibility of using *less* rigid, and therefore lighter, calipers compared to conventional set ups. This is because the lack of a direct connection between the driver and the brake system reduces the impact of caliper flex on brake feel and performance, as the BBW system focuses on hitting a set braking torque target and does not care if more or less pressure is needed to achieve that.

Prominent role

Brake-by-wire technology will undoubtedly play an increasingly prominent role in the racing and production car worlds. As hybrids become more prevalent and the transition to EVs continues, BBW offers greater energy regeneration potential and enables the use of smaller, more power-dense battery packs.

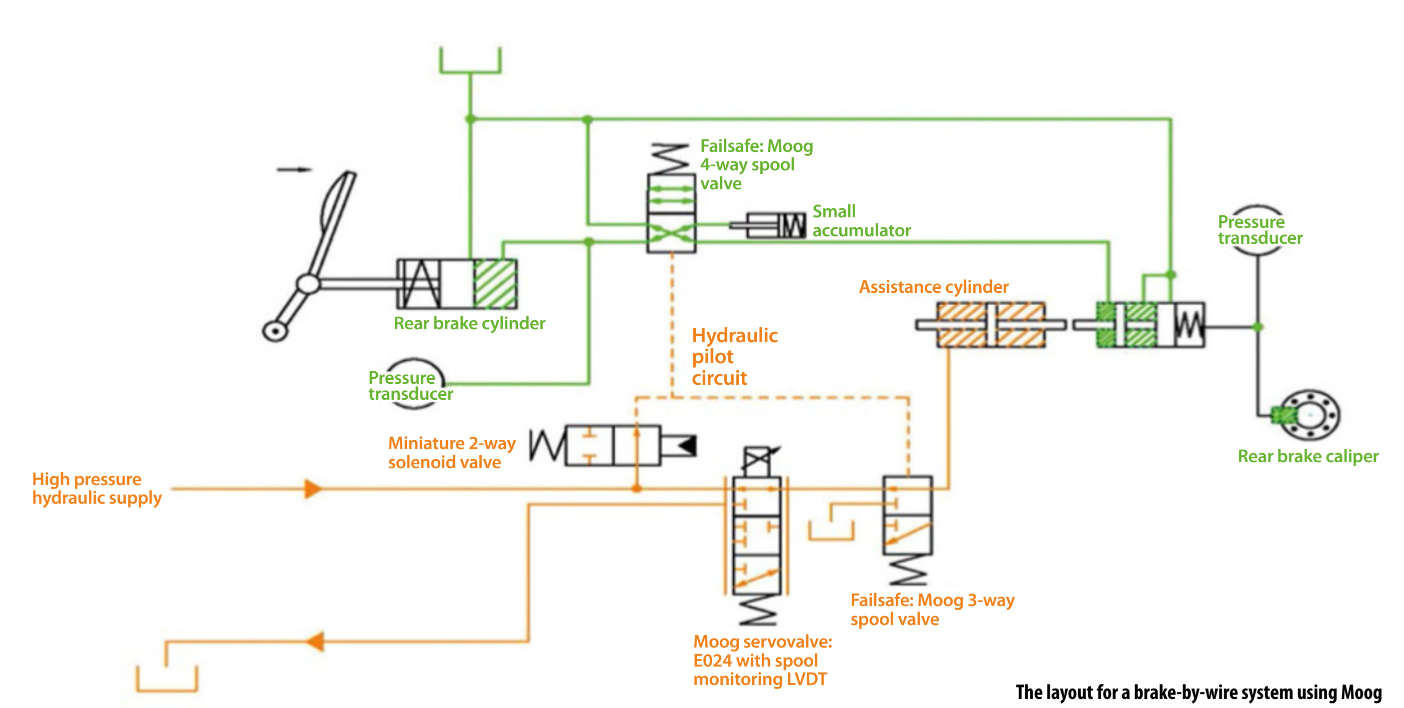
The implementation of new technologies and further optimisation of current systems will see the performance of BBW continue to improve. For example, LSP's latest system, IBSe, provides not only a very compact and fast-acting BBW, it also adds additional functionality such as launch control and electronically-adjustable brake bias, as well as the impressive ability to adjust regen' braking on each individual axle.

De-coupled brake-by-wire systems offer the possibility of using less rigid, and therefore lighter, calipers compared to conventional set ups

The individual hardware elements are also becoming ever more effective. Take Moog for example, long-time supplier of hydraulic systems to F1 and other series, which is heavily involved in the development of BBW systems. The company supplies everything from its stock-in-trade servo valves through to two-state valves that are vital to provide a failsafe mode if the brake-by-wire were to fail.

According to the company, some of the main developments it is seeing in the

Moog's E024 servo, used extensively in racing brake-by-wire systems

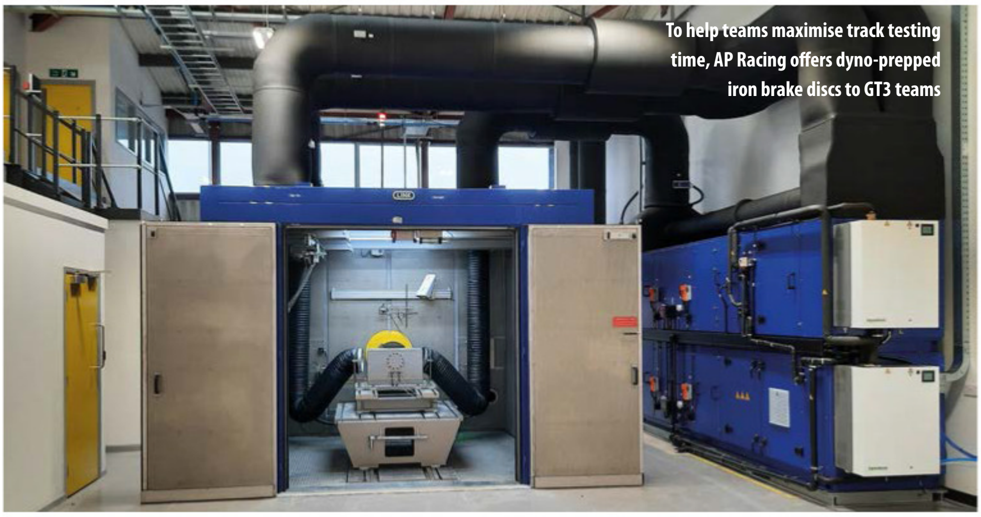


The layout for a brake-by-wire system using Moog components, showing how redundancy is built in

motorsport market relate to increasingly powerful regen' systems, and more advanced mapping solutions (such as perfectly meeting the change in brake torque demand on a hybrid as the driver downshifts).

These have forced it, among other developments, to improve the response rate of its tiny (sub 100g) E24 servo valves to provide the necessary speed of operation to enable such levels of control.

Additive manufacturing also has a role to play in brake-by-wire. LSP, for example, has been experimenting with AM hydraulic housings, providing greater freedom of design for the internal passageways, while also allowing for more flexible packaging and even greater weight reduction.



To help teams maximise track testing time, AP Racing offers dyno-prepped iron brake discs to GT3 teams

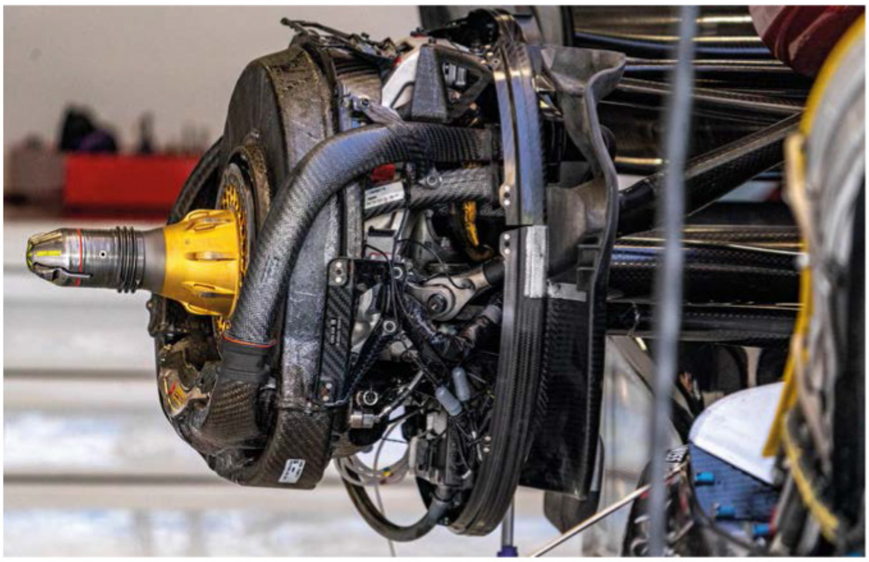
Perfect match

There are, of course, a host of smaller details not covered here that are vital to the efficient operation of a racecar's brake system. The perfect matching of pad compounds and disc material, for example, or the sizing of components such as master cylinders and calipers to provide the right feel and progression still apply. It is also the case that developments in the upper reaches of racing continue to trickle down to lower levels. Customer-spec Rally2 cars now come equipped with forged monobloc calipers, not so long ago the preserve of top-flight racers, while advanced, programmable ABS systems can be found in GT3 racers.

Brake development is constantly evolving and, while the drive toward electrification will alter some demands, it will not reduce the importance of this most vital of systems.

References

Dalpadulo, E., Pini, F., Leali, F. (2021). *Design for Additive Manufacturing of a Topology Optimized Brake Caliper Through CAD-Platform-Based Systematic Approach*. In: Roucoules, L., Paredes, M., Eynard, B., Morer Camo, P., Rizzi, C. (eds) *Advances on Mechanics, Design Engineering and Manufacturing III*. JCM 2020. Lecture Notes in Mechanical Engineering. Springer, Cham. https://doi.org/10.1007/978-3-030-70566-4_16



F1 brakes require an advanced BBW system that then can cope with a smaller assembly due to reduced pressures

Aston Martin has been using these small vanes on its rear brake drums to try and gain an aerodynamic advantage

GT Racing

As the GT3 category has evolved, so has the technology employed in the cars, including the braking systems.

In the early days of GT3, some cars still used standard rear brakes and front uprights. However, the category has since progressed to bespoke designs, with cars featuring scratch-built uprights and no original equipment manufacturer (OEM) running gear. Changes in FIA regulations, such as seat position and adjustment rules, have further driven the development of components, including adjustable reach pedal boxes to accommodate drivers of different sizes, allowing for quick position changes during pit stops.

One of the significant challenges for brake manufacturers in GT racing is the widespread use of anti-lock braking systems (ABS). While ABS is advantageous for amateur drivers, it places a heavy load on the brakes. Drivers are instructed to apply maximum braking force at every stop, which in turn leads to high pressures on the master cylinders. Various steps have been taken by brake manufacturers to accommodate these demands. For example, AP Racing has developed its ABS-specific Centre Valve master cylinders with dedicated seal designs to ensure reliability in extreme conditions.

Another GT-specific challenge stems from the fact that cars must use iron discs, which endure high temperatures and heavy braking loads. Proper break-in procedures and thermal conditioning are essential for the longevity of these discs and to avoid cracking. To this end, AP Racing has developed its own thermal shock tests to simulate the harshest on-track conditions, and the company offers dyno-prepped discs to help teams make the most of track testing time.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'Map reading

Part two, implementation of the essential engineering practice of aeromap generation

By **DANNY NOWLAN**

In part one of this mini-series last month, I talked about how to generate an aeromap, the tests you need to run and what you need to watch out for. In this follow-up article, I will focus on implementation. By that I mean what you need to look for in terms of data, how you set it up and, once you have the results, how you use them to create an aeromap. Finally, we will look at what you need to then validate it. As we are about to discover, this is not as intimidating as you might think.

The first step in this process is making sure your damper pots are correctly calibrated and functional. While this sounds obvious, it's something I see race teams screw up, or worse, overlook, on a regular basis. It has been said that eyes are the windows to the soul, and the racecar analogue of this is your damper pots. They tell you so much about the car and, if you don't get them right, you might as well pack up and go home before you've started.

Also, from time to time you will need to filter the data they produce, though if the damper pots and data logger are really well set up, you can omit this step. The immediate giveaway that a damper pot is degrading is if the signal becomes spikey. If you need to use a filter, I would recommend a time-based one at 20Hz. That will remove the noise that can deleteriously affect your calculations.

The next question that needs to be asked is once we have the damper data, where do you zero it? It's an important question because the split between zeroing in the air and zeroing on the ground is about 50 / 50. For aero work, I prefer to zero on the ground. For me, it makes the hand calculations easy and, even though ChassisSim can happily deal with dampers being zeroed on the air or the ground, I've found the most consistent results come from the dampers being zeroed on the ground.

So, if you are zeroing from the ground, where should you zero? Start on the flat patch, though I always double check with the car coming out of the pit lane, as shown in **figure 1**.

Note: you want to catch the car just as it is trundling out of the pit lane. In most cases, you won't have to do a thing, but it's always worth checking. Figure 1 covers you for when the logger starts to misbehave, or has firmware idiosyncrasies, or just when someone forgot to zero the dampers.

Datasets and match

Next question is what do we do with the data? Firstly, you need to break down what it corresponds to. To refresh your memory, **table 1** shows the test matrix used in part one last month, which will help you to know what datasets correspond with which channel.

SRO / Kevin Pecks

Zero your car's dampers on the flat patch first, but it's a great double check to do them again on exit from the pit lane

Table 1: Aero test procedure

Run no.	Set-up
1	frh_0 and rrh_0 + baseline rear wing
2	frh_0 and $rrh_0 + d\_rrh$ + baseline rear wing
3	frh_0 and $rrh_0 + 2{*}d\_rrh$ + baseline rear wing
4	frh_0 and $rrh_0 + 3{*}d\_rrh$ + baseline rear wing
5	$frh_0 - d\_rrh$ and rrh_0 + baseline rear wing
6	$frh_0 + d\_rrh$ and rrh_0 + baseline rear wing
7	frh_0 and rrh_0 + baseline rear wing
8	frh_0 and rrh_0 + baseline rear wing + 2 holes
9	frh_0 and rrh_0 + baseline rear wing + 3 holes

Where,

frh_0 = baseline front ride height as specified in the starting set-up
rrh_0 = baseline front ride height as specified in the starting set-up
d_rrh = delta rear ride height
d_frh = delta front ride height

What is essential to understand here is that every dataset you use needs to correspond to what is in **table 1**. Lose track of this and it will all turn to custard very quickly.

Once we have the data, calibrated it, zeroed it and appropriately assigned the data, the next step is to create the pitch sensitivity map. To do this, for each run we need to figure out the transient ride heights, downforce, drag and aero balance numbers. Once you have those, you can hand calculate, or use the ChassisSim aero modelling toolbox.

The method you use is up to you, but the trick here is to link together the pitch sensitivity runs into a single file. When you are done, it will look something like that shown in **figure 2**.

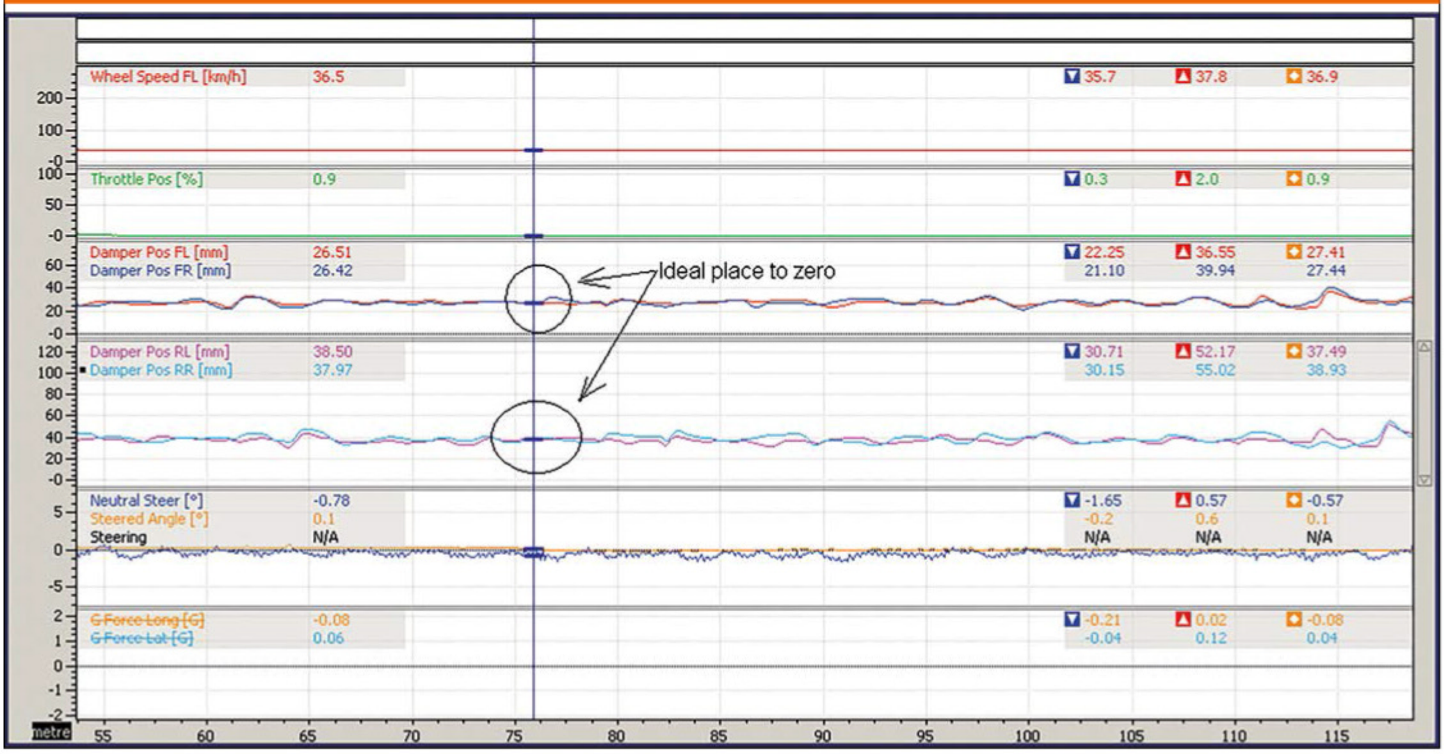
Figure 2 is an example of the output of the aero modelling toolbox. The first two columns are front and rear ride height (in m) and the last three columns are C_LA, C_DA and aero balance as percentage / 100 respectively.

Whichever units you use, the important thing is to wind up with something like **figure 2** that is spread over a surface, as opposed to a single line.

Curve fit

Once you have the pitch sensitivity runs collated into ride heights and aero coefficients you then need to curve fit the data. Before we talk about the options for that, it might be worth discussing the boundaries you set when you are curve fitting. This will save you an awful lot of grief in the long run.

Figure 1: Car being zeroed coming out of the pit lane



Choose your ride height boundaries for your aeromap, both front and rear, from the data you have collected. If you try and go outside of those boundaries, you are just guessing. Been there, done that.

In terms of curve fit options, your first port of call is the good old reliable second order surface curve fit. To do this, you are fitting the aero curve to that shown in **equation 1**.

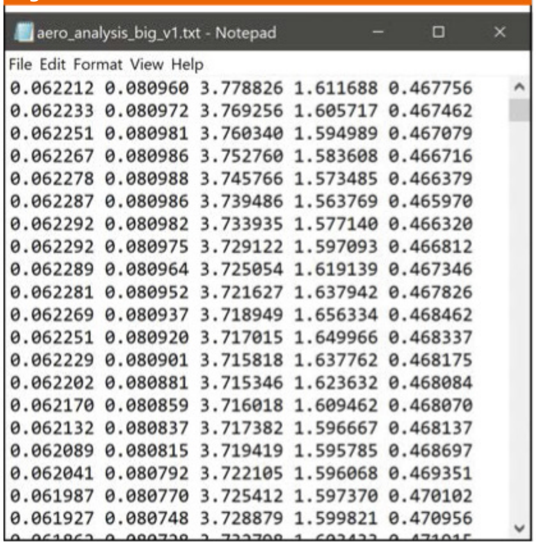
$$z = A \cdot x^2 + B \cdot y^2 + C \cdot x \cdot y + D \cdot x + E \cdot y + F \quad (1)$$

Here, z is the function of two variables we are fitting to, x and y equate to front and rear ride heights and $A - F$ are the constants of the equation.

The advantage of the second order surface fit is it's almost bulletproof, and straightforward to implement and calculate. As a first pass, it will put you in the right ballpark. However, it's worth noting here that it misses the nuances of an aeromap, but it certainly doesn't disgrace itself.

As a case in point, the aeromap I constructed for the first generation A1GP car was a second order surface fit with some local adjustments. Given the success I had with that, I consider this method not too shabby.

Figure 2: A concatenated aero file



aero_analysis_big_v1.txt - Notepad

File Edit Format View Help

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0.062212 0.080960 3.778826 1.611688 0.467756
0.062233 0.080972 3.769256 1.605717 0.467462
0.062251 0.080981 3.760340 1.594989 0.467079
0.062267 0.080986 3.752760 1.583608 0.466716
0.062278 0.080988 3.745766 1.573485 0.466379
0.062287 0.080986 3.739486 1.563769 0.465970
0.062292 0.080982 3.733935 1.577140 0.466320
0.062292 0.080975 3.729122 1.597093 0.466812
0.062289 0.080964 3.725054 1.619139 0.467346
0.062281 0.080952 3.721627 1.637942 0.467826
0.062269 0.080937 3.718949 1.656334 0.468462
0.062251 0.080920 3.717015 1.649966 0.468337
0.062229 0.080901 3.715818 1.637762 0.468175
0.062202 0.080881 3.715346 1.623632 0.468084
0.062170 0.080859 3.716018 1.609462 0.468070
0.062132 0.080837 3.717382 1.596667 0.468137
0.062089 0.080815 3.719419 1.595785 0.468697
0.062041 0.080792 3.722105 1.596068 0.469351
0.061987 0.080770 3.725412 1.597370 0.470102
0.061927 0.080748 3.728879 1.599821 0.470956
```

Curve fit two

Your second option is to use an aeromap surface fitting technique I discussed at length a number of years back, and have since documented on the ChassisSim YouTube channel. The basis of this technique is that you split the aeromap into front ride height segments and vary the parameters with rear ride height, and then use a simple second order curve fit. This is illustrated graphically in **figure 3**.

Just to jog everyone's memory, **equation 2** shows the mathematical basis for this.

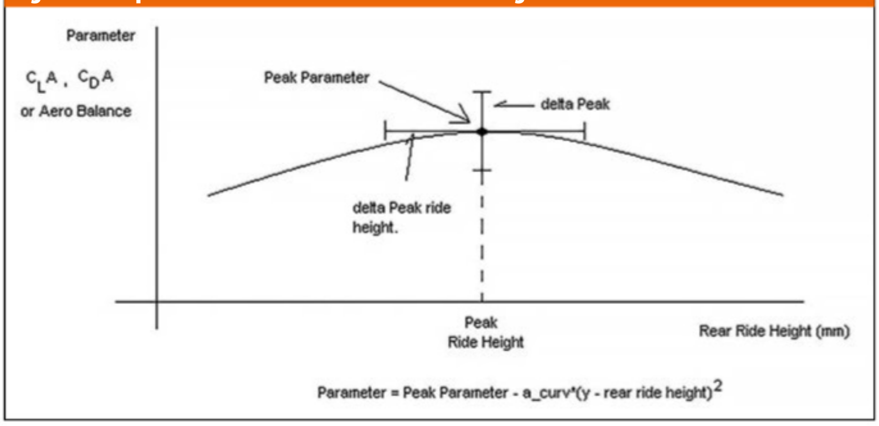
$$\begin{aligned} C_L A_{peak} &= c_1 - c_2 \cdot (x - c_3)^2 \\ a &= a_1 - a_2 \cdot (x - a_3)^2 \\ rh\_r\_peak &= r_1 - r_2 \cdot (x - r_3)^2 \\ C_L A &= C_L A_{peak} - a \cdot (y - rh\_r\_peak) \end{aligned} \quad (2)$$

Where,

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

Here, $C_L A_{peak}$ and $C_L A$ in **equation 2** can be interchanged for $C_D A$ and aero balance.

Figure 3: Graphical illustration of aero surface fitting



The beauty of a second order fit here is, provided you don't go out of bounds and the numbers stay reasonable, it's pretty close to bulletproof.

Where this method lives or dies, though, is on the curvature / inflection value. The biggest trap I have found is choosing curvature values way too high. A good start point is 50 +/- 10. Another good rule of thumb is that if the aeromap looks too flat, increase the curvature numbers. If it starts varying too much, decrease them.

In terms of the quality of the curve fit, this method is definitely a step above the second order surface fit.

User modification

Before we discuss varying downforce levels, remember the aero pitch sensitivity map creation process is not a fit and forget process. The onus is still on you, the end user, to review the results and make modifications if necessary. As a case in point, if the rear diffuser starts to stall at, say, a rear ride height of 10mm, you need to reflect that in the aeromap. This is the sort of stuff a curve fit won't see, so it's up to you to make sure you do something about it.

The next step is to classify your wing levels. Indulge me here for being ChassisSim specific, but it really illustrates what you need to do. When you are done with modelling the pitch sensitivity map, you'll have a peak C_LA and C_DA. What you need to do next is run the aero modelling toolbox for the various wing options, and then note the average results. Do that and you'll get something that looks like **table 2**.

Once you have this, you need to relate it to peak C_LA and C_DA. This is done via **equation 3**.

$$
\begin{aligned}
C_LA_{MAX}\_new &= C_LA_{MAX}\_bline + (C_LA\_new - C_LA\_bline)\\
C_DA_{MAX}\_new &= C_DA_{MAX}\_bline + (C_DA\_new - C_DA\_bline)\\
ab\_offset &= (ab\_new - ab\_bline)/100
\end{aligned}
\qquad (3)
$$

Here, $C_LA_{max\_new}$ and $C_DA_{max\_new}$ are what will be applied to the current aeromap. The variables $C_LA_{max\_bline}$ and $C_DA_{max\_bline}$ are the peak C_LA and C_DA of the base map we discussed earlier. The terms C_LA_{new} and C_DA_{new} are the average values you get from the ChassisSim aero modelling toolbox for a given wing setting. The values of C_LA_{bline} and C_DA_{bline} are the average results of the baseline.

Once we have all this, the peak aero levels can be calculated, and this is shown in **table 3**.

Validation

Now we have all this, the last step in this process is validation. Remember, simulation without validation is nothing more than speculation. You must validate what you do.

What I like to do is to organise my data into runs, and in each of those folders I'll have the data, the ChassisSim monster file, a car file that corresponds to what that ride height is and any other information I need. I will then run either a track replay or lap time simulation to make sure the aeromap is properly validated. An example of this is shown in **figure 4**.

This was some Sportscar work a customer of mine did in 2013 when the track replay simulation was in its infancy, so we used the lap time simulation to validate. We were only concerned with the straights, highlighted in the red section here, but you want to do this for all the runs you do. You won't nail it for every run but, if you get it in the ballpark, you're on the right track.

Conclusion

In closing, what we have just discussed here are the nuts and bolts of implementing aero modelling. The important thing to remember is that it's not rocket science, just common sense, though it does require great attention to detail. This, for me, is the key thing to take away from this. That, and not to be obsessed with obtaining the manufacturer aeromaps. What I have shown in this mini-series frees you from that constraint, and is your first step into a much larger world.

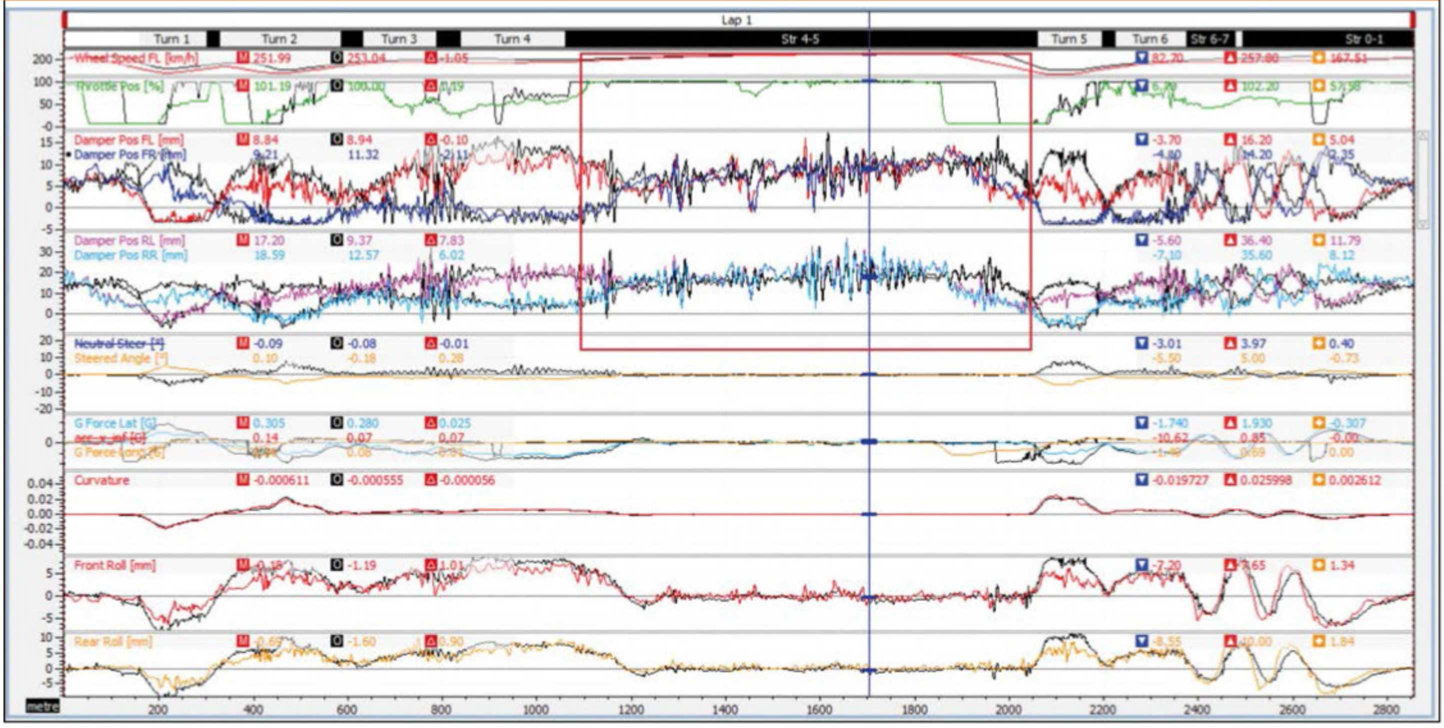
Table 2: Sample results from the ChassisSim aero modelling toolbox

Wing configuration	C_LA average	C_DA average	ab_average
Baseline	3.4	1.1	40
Rear wing + 2 holes	3.41	1.11	38
Rear wing + 3 holes	3.42	1.12	36

Table 3: Sample peak C_LA, C_DA and aero balance values

Wing configuration	C_LA_{max}	C_DA_{max}	ab_offset
Baseline	3.7	1.2	0
Rear wing + 2 holes	3.71	1.21	-0.02
Rear wing + 3 holes	3.72	1.22	-0.04

Figure 4: Example of aero validation



Interview – Ferdinando Cannizzo, head of GT racing car design and development, Ferrari

Saddle up

Ferrari took victory at Le Mans this year.* Racecar *sat down with Ferdinando Cannizzo to find out how the team went from zero to hero in 12 months

By MARCUS SCHURIG

Ferrari's Ferdinando Cannizzo

Ferrari's 499P turned its first laps at Fiorano in July 2022, and, within 12 months, the car was a Le Mans winner.

It had a helping hand in several areas. Tyre warmers were re-introduced to the championship for this race only, on the grounds of safety. This allowed Ferrari to be able to select harder compound tyres in cooler temperatures. There was also a Balance of Performance shift in favour of Ferrari (and against Toyota), which put the two cars on a more even footing.

However, it cannot be argued that the Italian team still needed to execute the race. The drivers, engineers, mechanics and strategists had to perform to the highest level, and even then Toyota came close to winning with its GR010. A crash on Sunday afternoon while chasing the Ferrari down ultimately cost the Japanese their coveted fifth successive win as the 499P struggled to re-start at its final pit stop.

The fact that Ferrari was able to complete the 24-hour race reliably was something that even the team itself didn't consider likely. A stone made its way through the smallest of gaps in the bodywork to damage the radiator cooling the hybrid system in the quicker of the two Ferraris, an extraordinary feat that Nicklas Nielsen considered 'almost impossible'.

Alessandro Pier Guidi spun into the gravel on Saturday night, but the new safety car regulations played into their hands.

Marcus Schurig: *You managed to win LM outright on your first attempt. How was this possible?*
Ferdinando Cannizzo: Several factors contributed to our success. First of all, the programme was well prepared from the beginning. The timeline was tight, so it was important to take the right

Our target was to make the perfect car for the regulations in place

An as-yet unidentified problem with the high voltage system on the no.51 car caused a couple of heart-stopping moments in the pits when the car struggled to re-start, and that is something the team is still investigating

Ferrari attributes much of its success at Le Mans to lessons learned through its hugely successful GTE class racing programme

Photos: XPB

decisions from a design perspective, and on the technical side.

Firstly, you need to analyse the regulations and define the technical targets, in order to be fully competitive. Our target was to make the perfect car for the regulations in place. We also had to understand the progression rate of this particular formula, so how cars are naturally improving over the years, which is an important side aspect.

For that, we did not only look at Hypercars, but also at past predecessors like LMP1 hybrid, because if you dial your car to the current performance level, you might lose out in a couple of years.

Secondly, you need a proper plan to cover the workloads in different departments, like chassis, powertrains, hybrid and so on. To make sure, you match the deadlines, so that you can start track testing and development at the projected timeline.

To be entirely transparent with you, we started testing with a delay of two weeks, but we nearly got it right! This was an impressive achievement from everyone involved at Ferrari, because it was absolutely crucial to start testing in July 2022.

MS: ***You started the test phase immediately with two cars, and I assume that was instrumental to get the mileage you wanted?***
FC: That's correct, it was a crucial part of our preparation. If you test with two cars, you collect double the amount of data and, if anything goes wrong, you have a second car to back up the testing plan.

You can also split programmes if you have two cars – for example, performance testing and endurance testing. If you have a problem with one car, you can carry on with the other car, which means you normally never stop during a test programme.

The early test start with two cars also allowed us to train the teams of mechanics and engineers. This was crucial for the preparation of the race team, because clearly you want to start at the highest possible level, operationally, at the first race.

MS: ***In Sebring [where the team set pole position time and finished on the podium behind the Toyotas] your team looked sorted. Not flawless, but well organised.***
FC: That was the target. We wanted to be on a competitive level at our first race. We also had a very humble approach, because we know there are no short cuts in some areas. We knew we would make mistakes, but we didn't want to look like beginners and embarrass ourselves, and I honestly believe we achieved that goal at the first outing in Sebring.

We were confident we would do well but, at the same time, we

If you test with two cars, you collect double the amount of data and, if anything goes wrong, you have a second car to back up the testing plan

were humble and knew that we had to learn, and for that you also must be allowed to make mistakes and learn from them.

[Pole position] was a very proud moment for us, but we knew the race would be much more difficult, and it was! We went testing after Sebring to improve our package, and we put on some good racing, although we also made a couple of mistakes, but that is part of the process. It was great to see we matched the performance levels we targeted in Portimao and Spa.

MS: ***There is always a lot of uncharted territory when you arrive in a new formula, like the tyre situation for example…***
FC: That's absolutely true. We started testing with last year's compounds, obviously, and we needed to adopt to the new tyre specification, which was not easy, so we had a steep learning curve.

In the end, we collected a couple of podium positions, which was nice, and that proved we were heading in the right direction. At the same time, we were closing the gap to Toyota race by race, and obviously our internal target was to be right with them coming to Le Mans.

MS: ***Ferrari looked like a solid team with a very solid car at Le Mans. Was that the case?***
FC: Yes, that was indeed the case. We have proven that we learned our lessons from the testing phase and the first few races. We had a perfect plan for qualifying and got pole position. During the first couple of races, we were never shy to show our performance, so we were pushing all the time to see where we are in relation to the competition. We were never holding anything back, like in Spa, where we fought very hard to catch the Porsche and secure the third place.

When you work for Ferrari, you need to give your best. At Le Mans, everything just came together.

MS: ***The pressure on you to perform must have been huge?***
FC: You will be surprised to hear that there was no pressure at all, it had to come naturally. We progressed on all fronts operationally, so did the drivers, and the cars. It is like a big puzzle, and the pieces have to come together at the right time.

MS: ***Were you surprised to secure pole position at Le Mans?***
FC: We were more surprised that Toyota wasn't pushing as much as we expected.

MS: ***In the second part of the race, when it was between you and Toyota, we thought that maybe Ferrari was holding back a little and not showing everything. Is that correct?***
FC: I don't think so. It was a fast race, the pace was strong from both competitors, particularly in the second part of the race. But obviously you are not trying to destroy the car in hour 17, so you need to balance speed against cautiousness. You always have to have a safety margin to make it to hour 24, which was our most important overall target.

In the end we were also lucky, because our competitor made a mistake under pressure, which gave us a most welcome margin.

MS: ***If Hirakawa had not made the mistake, and if you had the issue at the last stop that you had, would Toyota have won?***
FC: Most probably, yes, so it was a tight and fierce battle.

MS: ***What happened at the two pit stops where you had delays?***
FC: We still have not fully understood what happened. It appears we had a drop of tension in the high voltage system, which compromised the re-start of the car after the pit stop. But we need still to understand exactly what the reason was.

MS: ***At the first incident you lost 65 seconds, at the last stop you lost 1m46s. Why was there such a difference?***
FC: When it happened the first time, we were surprised and needed to come up with a plan. We tried a couple of things and then decided to do a full power cycle to cure the problem.

At the second incident we had a better understanding. It had to do with low tension from the battery, so we had a plan, but it somehow didn't work out at the first try. The stress then was huge for everybody involved because it was the very last stop. It was very intense for all of us, but we were only bystanders. The engineers and the driver had the full pressure on them to make it work.

I remember when I finally saw the headlights going on again – that was a huge moment of relief. I was really proud of everyone, as they had taken the right decisions at the right time.

MS: ***I have not seen any major issues or mistakes on the operational, or reliability, side of things, which is quite impressive considering this was your first Le Mans for the car, and the team.***
FC: We have not had any reliability issues at all. The no.50 car needed a repair for the hybrid cooling because a stone hit the radiator, which was very frustrating, but had nothing to do with reliability. That caused us to lose all the water from the cooling [system], so we had to change the hybrid radiator, which cost us six laps. Apart from that, the no.50 car had no issues at all.

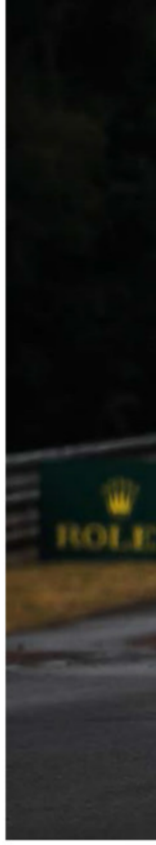
For the no.51 car, we had the delays at the two pit stops as discussed, but we managed to work around that problem.

To be honest, I think we have had a good track record with reliability since the start of the season, although they were races with a shorter distance in comparison to Le Mans. However, it gave us confidence that we would be able conquer the long distance at Le Mans as well.

Reliability is always a crucial thing for the first year, and we knew that. We had issues during testing, as was to be expected, but managed to eliminate one problem after the other. Our first 24-hour test in Aragon in November 2022 was actually quite good. The second one in Portimão less so, probably because we were pushing harder and went much quicker. The third test also went quite well, which gave us confidence for Le Mans.

In hindsight, the car was running quite reliably from the very beginning, which allowed us to run it continuously throughout the testing phase. That undoubtedly contributed to the level of reliability we demonstrated in Le Mans.

Toyota kissed goodbye to a sixth consecutive Le Mans win when Ryo Hirakawa hit the barrier at Arnage with less than two hours left



A freak accident when a stone penetrated the hybrid cooling radiator lost the no.50 car six laps, but otherwise it performed faultlessly for the full 24 hours

Reliability was key to our performance and success, because without reliability the whole development programme would have been compromised

I remember that the car even went exceptionally well at the very first shakedown test, which kind of set the tone for the rest of the development phase.

Generally speaking, reliability was key to our performance and success, because without reliability the whole development programme would have been compromised, and so would have been our performance and result in Le Mans at the race itself.

MS: ***Tyre degradation at Le Mans is clearly an important factor. Did we even see quadruple stints?***
FC: First of all, Le Mans is a low degradation circuit, we all know that. I am not sure we did a proper quadruple stint, but we did triple stints easily and on a regular basis. The car was good on tyre degradation at Le Mans, which was again our target.

I could not see any advantage for Toyota, whether we're talking consistency or speed.

MS: ***Looking at speed and 20 per cent of fastest laps, the no.50 Ferrari was in front, followed by its sister car and the no.5 Porsche. Was that a surprise to you?***
FC: No, we were expecting Porsche to be very strong on pace.

MS: ***What is your opinion of the yellows and the new safety car regulations [with wave-bys for the first time]?***
FC: I think it is a step in the right direction, because now you don't lose 90 seconds by picking up the wrong safety car, which in the past was down to luck, or bad luck. I think it's good that you don't lose the race because you are unlucky.

The only aspect is that we need to work on shortening the process. It took too long to go through the complicated process, but again, I believe it was a step in the right direction. I certainly see it as an improvement. The yellows have not decided the outcome of the race, and that's how it should be.

MS: ***Ferrari clearly had a good top speed, not only at Le Mans, but also at Spa. Some argue that might have to do with [blowing exhaust gas onto] the middle rear wing. What's your answer to that?***
FC: We all have to be in the same small window, drag vs downforce, and it's the same for everyone.

Secondly, as I mentioned at the official presentation, the middle wing originally popped up in the design process, mainly for styling reasons. Thirdly, a wing has only ever increased downforce, never decreased downforce, or increased top speed. Even with the middle wing, you have to hit the performance window for the aerodynamics so, roughly speaking, all Hypercars have the same drag and downforce level.

What I can say is that we worked very hard and aggressively at Spa and at Le Mans to achieve a good top speed. If you look carefully, you will find out we definitely did not have the fastest cars in the Porsche Curves, so maybe we could have been faster there, if we would have sacrificed top speed.

In any case, if you compare straight line performance, our competitors were clearly not too far away from us.

For sure, you only have a very small margin to play with in the performance windows. And if you look at the overtaking manoeuvres during the race, that was more down to different tyres than down to top speed.

MS: ***Are the cars too boxed in by the performance windows. For example, aerodynamics?***
FC: First of all, it is what it is. The rule makers decide the rules, and we have to race according to the rules. If the margin we have to work in is small, that is just how it is. What I can say is that the engineers have to focus on the problem at hand, not so much on the regulation. So if you lack top speed, you need to find a solution, but find it within the boundaries of the regulations.

In theory, the nominal performance is the same for everyone in Hypercars. Our approach is to find performance in the given windows. At Ferrari, we are quite good at that, thanks to the experience with the 488 in the GTE class.

In GTE, you face the same situation. The car is frozen by the homologation, and no changes are allowed. Yet still you need to find performance if you want to win races. We have managed to improve the performance of the 488 GTE over the years – worth a couple of seconds at Le Mans – with the same car.

Okay, the tyres played a part in that as well, but still. It is the same for Hypercars. We have improved our engineering approach in GTE and learned a lot. We've learned there are things that can be done to improve performance, even if you cannot change the car, or parts of the car, you focus on set-up, making cars more gentle on tyres, smooth on kerbs, more responsive in change of direction and faster in acceleration.

Marcus Schurig is editor of Sport Auto *and* Motorsport Aktuell *magazines in Germany*

IN BRIEF

Formula 1 has confirmed its 2024 schedule will include 24 races, starting in Bahrain on 2 March and ending in Abu Dhabi on December 8. Despite the increased schedule, the sport says it has organised its calendar to be more sustainable. The Japanese Grand Prix has moved to April and Azerbaijan to September, while the Gulf will have back-to-back races, Qatar a week earlier than the season finale.

Tyre company, **Goodyear**, ran its original branding from 1898 in the FIA WEC at Monza in July as the race coincided with its 125th anniversary. Tyres carried the original logos, as did the trackside advertising, while merchandising included branded caps and sustainable water bottles.

The company supplies the LMP2 grid this year, and next year will be the sole tyre supplier to the GT3 category.

The **24 Hours of Nürburgring** will next year be part of the Intercontinental GT Challenge. The race already features many of the manufacturers that contest the series, which looks to provide local teams with manufacturer support in their respective regions. Pirelli will not be the sole tyre supplier for the event, and the SRO will not do the Balance of Performance for the race.

LMP3, the feeder Prototype formula, will switch to an **ORECA** twin-turbo V6 for the 2025-2029 homologation. The category had used the Nismo-supplied VK56. The decision to go with ORECA is believed to be a portent for the manufacturer to also submit a tender for the LMP2 engine deal. LMP2, which will continue to race in the US, Asia and European Le Mans Series, is currently supplied by Gibson.

Formula 1 and the FIA are working together to drive STEM engagement in schools through a series of **STEM Challenge days** facilitated by education charity, The Smallpeice Trust. The STEM Challenge Days are part of the continued commitment by F1 to increase diversity in motorsport and make the sport more accessible.

AP Racing expanding

AP Racing, the world-renowned brake and clutch supplier, is experiencing a period of unprecedented growth, with 190 people now employed across the business. An increase in demand from OEMs and the motorsport industry has also resulted in the launch of an active recruitment programme by the company.

During the last 12 months, the Coventry, UK-based manufacturer has seen business increase at a significant rate as a result of its involvement in key motorsport events. As a result, the firm is now in a strong position to strategically recruit for key new roles in both the UK and the US to drive the business forward.

The team are currently recruiting across all departments and levels of seniority. Some of the roles currently available at AP Racing include manufacturing engineer, purchasing buyer, CAE engineer, buyer / planner, customer services representative and motorsport customer support engineer.

David Hamblin, managing director at AP Racing, commented:

Experiencing growth across both its motorsport and OEM platforms, AP Racing is a success story

'Thanks to the support of OEMs and the motorsport industry, our business has grown rapidly over the last 12 months and I'm really proud of the whole team.

'In the last couple of years, we've boosted our workforce heavily and we're excited to be recruiting for a range of new roles to further strengthen the business as we experience this exciting period of growth. At AP Racing, we're passionate about what we do, so ensuring we're recruiting talent with the same passion is vital to our success.

'Another key aspect of our recruitment campaign is our exciting range of undergraduate placements that help and support the next generation of engineers, managers and technicians.'

To view the full range of current positions available at AP Racing visit: https://apracing.com/about/vacancies

GTWC confirms bio-fuel switch

The SRO has extended its deal with multi-energy firm, TotalEnergies, and will introduce Excellium Racing 100 fuel into the GT World Challenge Europe and Asia for next season.

The move to the new fuel for the GT3 series brings it into line with the FIA World Endurance Championship that has already run Excellium 100 for two years, and which next year will introduce GT3 cars to its grid.

The fuel, which is produced using the residue from the wine industry and reduces CO_2 emissions by 65 per cent over its full life cycle, does require engine re-mapping to run it.

GT3 grid to join the FIA WEC in running on TotalEnergies' Excellium Racing 100 fuel next season

However, the French company says that aligning the GT World Challenge and FIA WEC series will reduce the amount of work required for manufacturers and the teams.

TotalEnergies' deal with the FIA WEC sees the fuel being used until 2026, after which the company will look to introduce improvements in its production process, although it says it will not change the finished product.

There have been some teething issues with the introduction of the fuel in the WEC, notably with it leaking into engine oil systems, though this seems to have been largely cured by teams pre-heating the engine oil, which allows the fuel to dissolve. The fuel also burns at a higher temperature compared to traditional options.

Costs to the competitors will rise as a result of the change, but the championship has indicated that it intends to help customer teams cope with the predicted price rises.

Audi calls halt to customer racing

Audi has confirmed it will cancel factory support for its customer racing programmes from the end of this year. The German car firm will continue to support teams running its cars in various championships around the world, but will not provide drivers to customer teams, and will not build any new GT3 racecars after March 2024.

The move brings to an end Audi's intense involvement in endurance racing. The programme started in 1999 with the arrival of the R8R and R8C prototypes, extending into the R8, R10, R15 and R18, while alongside that was a GT3 programme with the R8 road car-based model that started in 2009.

Audi has more than 600 cars racing around the world, and the existing cars will have their homologation extended to allow them to continue to compete.

Audi's factory prototype programme ended after the dieselgate scandal in 2016, and the decision to end customer racing activities did not come as a surprise. The manufacturer has no successor to the R8 GT3, although one was planned for release at the end of 2022, based on the new Lamborghini Huracan model.

Audi had confirmed it would return to Le Mans with an LMDh programme, sharing the Multimatic chassis and Porsche engine with its sister company, along with the spec hybrid system. Audi's responsibility was the bodywork and running the cars but, having announced the programme, it then dramatically cancelled it at the start of 2022.

Rumours that the Formula 1 programme would be cancelled in favour of a re-start of the Le Mans programme, and change in focus to the profitable customer racing division, proved to be wide of the mark, particularly as it transpired that sister company, Lamborghini, had plundered the Audi LMDh chassis for long lead time parts, such as the gearbox.

There was no mention in the announcement of Audi's Dakar programme, although many expect this also to be cancelled after the event in December this year, leaving all focus to shift towards the Formula 1 programme that is due to hit the track in 2026.

Management changes heralded the changes at Audi Sport, with Markus Duesmann fired from his role of CEO in June following poor sales, notably in China, to be replaced by Gernot Döllner, who starts on 1 September. Döllner was previously the Volkswagen Group strategy boss and is expected to push forward the 'Vorsprung 2030' strategy, with the extension of the brand's electrification portfolio.

Audi was involved in the FIA Formula E series for seven years, but withdrew in 2021. It also cancelled its factory involvement in the DTM in 2020, and is now expected to look at future electric racing projects, working with the FIA to produce a set of rules and series in which to compete.

SRO

It's all change at Audi, with the manufacturer first pulling out of prototypes and now support of customer GT racing, with Dakar expected to be next on the hit list. The F1 programme is still alive

Full charge for eTruck racing

Truck racing has taken its first big steps into the world of electrification with the arrival of the eTruck project, announced at the Nürburgring in July. Developed by six-time Truck Racing champion, Jochen Hahn, the new truck is a bespoke design, from chassis to bodywork and powertrain.

The decision to build the eTruck came after the FIA World Motorsport Council gave the green light to the project at the end of June 2022.

With partners, Bosch and IVECO, work started almost immediately ready for the launch.

The current FIA regulations allow all-electric and hybrid powertrains to race alongside combustion-engined trucks in the series.

The next task is to create enough power supply at the tracks the series visits to allow the eTrucks to charge up for the races.

'We have the unique opportunity to positively shape the reputation of the commercial vehicle industry and instil the idea of trucks as sustainable means of transport in people's minds,' says ETRA managing director, Georg Fuchs.

An all-new racing eTruck aims to improve the wider image of the commercial vehicle industry

Equality madness

It's one step forward and one step backwards in the BoP race

In the last edition of *Racecar Engineering* we wrote about the level of trust the manufacturers have in the sanctioning bodies over the issue of Balance of Performance, and how their decisions taken at Le Mans will affect their relationship going forwards.

It didn't take long for the scenario to play out as expected. The weekend that magazine hit the shelves, the WEC was on track again, with Ferrari celebrating its homecoming to Monza. There, a new Balance of Performance table was published. Ferrari felt so aggrieved post-race that it didn't have a chance to fight, and the organisation doubled down on its ban on publicly commenting on the system, so the manufacturer cancelled all press engagements.

To say this was a debacle is rather understating the situation. There is, apparently, a discussion taking place on whether or not to introduce performance balancing into Formula 1 to try to break up the long periods of domination by one driver or manufacturer. If this is the case, it has to be on the scale of the daftest idea I have ever heard.

Balance of Performance was conceived to work in non-manufacturer racing championships. It was designed to break the duopoly of Ferrari and Porsche in GT racing, and to allow in other makes and models with different drivetrain layouts.

The idea was to bring everyone into a lap time delta of around half a second. With non-professional drivers making a bigger difference to overall race performance, that was all that was needed. It worked.

Party politics

But as more manufacturers joined the party, so the arguments raged. The pro drivers can lap within a few tenths of each other and they are now the stars of the show, rather than the customer drivers. The cars therefore have to be balanced closer than the half second originally planned, on different tracks, in different temperatures and on different surfaces. In GT racing the tracks are categorised into A (high speed such as Monza and Macau), B is Spa and Paul Ricard without the chicane on the straight, C for the majority of tracks and D for street courses.

In the WEC prototypes, it's slightly different. The FIA tried an ambitious programme to balance the cars on all tracks using tiny performance windows of weight, power and measured aero efficiency. The organisers then had tools to adjust cars within performance windows, and on paper it looked as though it would all be simple.

Nothing is ever simple in racing, though, and the shock was by how much the FIA and ACO underestimated the task at hand. They changed the BoP for Le Mans, taking into account second-order effects, such as tyre management and overall team performance. Toyota was livid, Ferrari delighted. No one was allowed to talk about it, officially.

By Monza, the adjustment had gone back to the original plan, taking into account only the first-order parameters. Ferrari claimed that, like at Portimao in April, it could have been lapped, but for a fortunately-timed safety car.

We were robbed

Cue a toys-pram-floor interface. Ferrari's position was that there was nothing it could say about the race that didn't bring up the issue of performance balancing, so they said nothing. Either BoP is a key performance differentiator and so should be discussed openly, or it's benign, done correctly, and the focus is on team performance.

Either BoP is a key performance differentiator and so should be discussed… or it's correct

Toyota, meanwhile, had a great weekend, winning the race and confirming that, having lost Le Mans to Ferrari, its primary target was to upset the Italians at Monza. It worked brilliantly.

Whilst being unable to try to influence the BoP, teams are allowed in the sporting regulations to say what the changes do to their cars.

Even with that in mind, teams struggled to make sense of the changes for Monza. Cadillac, for example, was slow in a straight line at Le Mans but quick in the Porsche Curves, so had both its power and weight reduced. Cue much head scratching. Porsche was crippled by BoP changes for Monza and, with a clean race, claimed it would have finished seventh and eighth. That can't be right, either.

This is a mess. The ACO and FIA know what they have to do. They did it at Le Mans, but then reverted to the old plan, with predictable results. Toyota runs its team well, the others have a long way to go to catch up but, rather than give everyone a fair chance, the organisers are balancing the potential of one car, and leaving the rest up to the teams.

Does anyone really think racing will improve if BoP is introduced into F1? To my mind, a back-to-back title meant something until around 2000. Then we had the Ferrari / Schumacher era, then the Vettel / Red Bull era, the Hamilton / Mercedes era, and now we are gripped in the Verstappen / Red Bull era. Something changed. I'd suggest the FIA looks elsewhere within its rules for a solution. BoP is not it.

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Inside the world of modern motorsport technology
Racecar engineering

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

Racecar Engineering (ISSN No: 0961-1096, USPS No: 463) is published monthly by The Chelsea Magazine Company Limited, and distributed in the USA by Asendia USA, 701 Ashland Ave, Folcroft PA. POSTMASTER: send address changes to Racecar Engineering, 701 Ashland Ave, Folcroft, PA. 19032.

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

THE CHELSEA MAGAZINE COMPANY LTD
TELEGRAPH MEDIA GROUP

www.racecar-engineering.com


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