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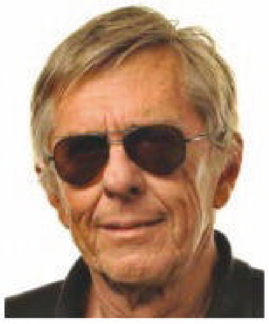

Unholy smoke

Exploring Formula 1's long and controversial addiction to tobacco sponsorship

Nicotine and caffeine have been my drugs of choice for a very long time now. Being a drug addict is not an easy life. I now have the effects of over five decades of smoking coming home to roost; my shortness of breath and yellow stained teeth attest to my stupidity in smoking. Another drawback is being forced to stand on the corners of buildings in the freezing cold or rain to satisfy the nicotine cravings.

Racing has the same addiction. Tobacco appeared as the first major sponsors in the late '60s, soon covering a big percentage of the grid, especially in F1. To my knowledge the first one to appear was in South Africa, in 1967. I will not mention any of the brands, they have damaged enough lives, so will get no free publicity.

Puffed up

As racing transitioned from a rich man's game into a serious business sponsorship, in the form of money and technical support from tyre or fuel companies, was replaced by tobacco companies, who wanted to associate its brands with the sport and driver glamour. Their entry into F1 was late in the game. For them, the promotional opportunities provided by the venues, the vehicles and the race suits, brought in new fields for publicity. They had used sports sponsorship earlier in other arenas so they could associate their products with health and wellbeing. In a perfect convergence of big tobacco companies who were already being squeezed by national governments, and the pressing need for more money for the teams, the stage was set for a big change.

They might be bad for you, but there's no denying that cigarette branding could look very good on an F1 car. This is a Lotus 72 at Goodwood's Festival of Speed

Lotus boss Colin Chapman was quick to grasp the implications of this and in the late '60s the team ran a red, gold and white liveried car advertising a tobacco brand. This first iconic livery, on its 49, was used all the way to the 72, after which there was a shift to a gold striped black livery, which still resonates today. The Lotus sponsorship removed once and for all the tradition of racing cars running in national colours, and purists were appalled as Chapman applied these commercial ideas that he had witnessed in the US.

Advertising is the primary means for the promotion of products and services by commercial businesses. It can be direct, as in overt paid-for space in broadcast, print and other media; or indirect, through media reporting of events or images containing direct advertising. The growth of TV transmission in Formula 1, and a wider reach for new spectators, provoked a stampede of big tobacco brands into grand prix racing.

Both approaches have been exploited by tobacco companies for many years, but as a result of increasing restrictions on direct advertising of tobacco on television and in other media in many countries since the late 1960s, tobacco companies have become increasingly reliant on indirect methods to promote their products.

McLaren ran a characteristic red and white livery of another tobacco firm, and kept its association for over 23 years. Ferrari's connection with that same firm is still extant even today, using more subliminal messages. Up to a relatively short time ago the brand was still incorporated in the team's name and logo; and it still appeared as a barcode up to 2010 in the latter.

Drag reduction

A UK government examination of advertising in the 1990s concluded that this had a significant impact on tobacco consumption, and the Government then introduced legislation to ban it. Formula 1 fought back longest and hardest. In January 1997 Bernie Ecclestone, then the F1 chief, donated £1m to the Labour Party. The donation became public knowledge in November that year, when Labour had taken power and after the new Government had announced that Formula 1 would be exempt from a ban on tobacco advertising. The subsequent scandal forced the UK Government to drop the exemption, and most forms of tobacco advertising and promotion in the UK were banned under the Tobacco Advertising and Promotion Act 2002, with a ban on advertising at sporting events coming into effect (under both EU and UK law) in 2005.

Public Elf warning

Similarly, the Evin law in France banning alcohol and tobacco in advertising had a great impact on the sport there. Elf had downsized its investment in bringing up drivers through the classes, so when tobacco was banned it was a body-blow to racing in the country. Just note the number of French F1 drivers today compared to pre-1991, when the law was passed, not to mention teams and racing businesses, in all classes.

As might be expected, the tobacco industry did its best to get around the law. Until mid-2008, Ferrari cars had brand logos in F1 races outside Europe, with footage of these races broadcast back into the EU, while white barcodes closely resembling those on cigarette packs appeared until 2010.

As mentioned above, the same company still sponsors Ferrari for about $100m a year, in return for gaining access to the team for promotions and hospitality aimed at the tobacco trade and garage forecourt shops. In some countries which still allowed advertising imaging on the cigarette packs, the cartons of this firm were printed with pictures of Ferrari Formula1 cars.

Indirect, or 'alibi' branding as it's known, proliferated in other F1 teams too, depending on the strong association of colour, layout and phrases connected with the brands.

Big tobacco's latest attempt at a corporate makeover shouldn't succeed in eradicating its association with death and disease. Its huge profits still come from products which are lethal.

Tobacco kills around seven million people a year across the globe, and around 80 per cent of the 1.1bn smokers worldwide live in low- and middle-income countries, where the burden of tobacco-related illness and death is heaviest. Far from the glamour of Formula 1.

This sponsorship removed once and for all the tradition of racing cars running in national colours, and the purists were appalled

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Gift from the gods

What is that separates the *great* Formula 1 drivers from the merely very good?

During the winter months, when motor racing action is scarce, some publications fill the empty news spaces with articles such as the 'Top 50 Drivers of 2019', claiming in-depth analysis from correspondents across the globe and ranking drivers from over 15 disciplines.

It can be mildly entertaining to briefly scan and argue over– although best indulged in the pub with a few mates over beers. However, once any analysis extends beyond the top 10, it really becomes a pointless exercise. Apart from how to evaluate drivers from extremely different types of competition given the specific sets of skills required, does being number 47 versus number 48 have any meaning? Okay, such page-fillers are not to be taken seriously, even if they are presented as such, but it does lead me on to a more interesting slant – how certain drivers are perceived as being world greats, while others who achieve more success are nonetheless not.

Triple crown

A prime example must be Graham Hill. Despite still being the only driver who has earned the much-coveted triple crown of winning the Le Mans 24 hours, the Indianapolis 500 and the F1 world championship (twice), he is not generally looked on as one of the greats. Rather, he appears to be respected as an extremely determined man who elevated his natural talent by application and will-power. Whereas flamboyant daredevil Gilles Villeneuve, for instance, who scored just six F1 victories, retains heroic status in the sport and is definitely included in this pantheon of legends. Jacques, his son, 1997 F1 world champion and an Indianapolis 500 winner, has never been granted the same accolade. Inevitably, this then brings me to the fundamental question, at least in motorsport, of what constitutes greatness?

If it was based purely on results, clearly anomalies such as the above – and there are many more – would not exist. Focusing now on F1 racing, then surely Graham Hill *should* be one of the greats, because when including his five Monaco GP wins on top of the triple crown, how else should he be considered? In addition, personality he had in spades, bravery in making a comeback after suffering severe injuries, multiple wins in a diverse range of disciplines (add saloon and GT cars to his CV), all against outstanding competition from the likes of Jim Clark, John Surtees, Dan Gurney and a host of other highly-talented drivers. He might not have been killed in a racing car, but death in a plane crash even ticked the box for those influenced by such an immortalising end to a career.

Pure genius

So what is the answer? Is it just sheer speed in driving a racecar; uncanny ability in wet conditions; determination and skill in overcoming sub-performing machinery; an obsessive will to win; the acceptance by most rivals, even if grudgingly, that when the chips are down and equipment is roughly equal, this driver is virtually unbeatable? Ha, here I think we have it – to attain the very top rung of greatness, it has to be all of them.

xpb

Ayrton Senna's ability behind the wheel was extraordinary while he was also charismatic – is it this rare mix of skill and character that makes a *great?*

While being self-effacing, multiple world champion Jim Clark, undeniably a great, possessed a highly competitive desire to be the best, despite being one of the most naturally-gifted racing drivers of all time. Jackie Stewart also qualifies.

However, greatness can be achieved sometimes through other attainments. Many would count Mario Andretti as a great, although he arguably lacked a couple of the above qualities, because of his successes in such a wide variety of racing, be it dirt-track, Indy, Formula 1, NASCAR stock cars, GT and sports prototypes, over more than three decades. Similarly, Niki Lauda and Alain Prost, who earned their spurs through the intelligent application of their great talent – in Lauda's case, of course, reputation mightily enhanced by his incredible come-back following the terrible burns he suffered at the Nurburgring in 1976.

Romanticism certainly serves to amplify reputations. The diminutive Tazio Nuvolari's feats in beating the mighty Silver Arrows cars pre-WW2 in his inferior Alfa Romeo turned him into a legend. A great, though, he certainly was, and utterly dedicated to driving. So, of course, was Alberto Ascari post-war, claiming win after win in his Ferrari with Fangio also on the grid, until his early death. While not questioning Argentinian Fangio's pre-eminence on the list of greats, with only two or three challengers, the gifted Italian is often overlooked, perhaps because his career was so short? There are many more examples, sometimes depending on whether or not a particular driver also captures the public imagination. Stirling Moss was never world champion, largely due to his machinery letting him down when it mattered, but his bravery and stunning race-winning record in F1 and sportscars led to him becoming Mr Motor Racing as far as the British public was concerned. He certainly earned the 'great' accolade. Then there was Ayrton Senna, charismatic but also a phenomenon behind the wheel.

Great expectations

Despite his four world championships, there is doubt regarding Sebastian Vettel's inclusion, because of his error-prone recent record. He may still have time to put that right. Time might also lead to Max Verstappen ascending to that hallowed title; he certainly has the makings.

Where Formula 1 is concerned, it is interesting that perhaps the most obvious choice for the top four in a list of race driving greats – Juan-Manuel Fangio, Ayrton Senna, Michael Schumacher and Lewis Hamilton – all attained the majority of their success in this one discipline.

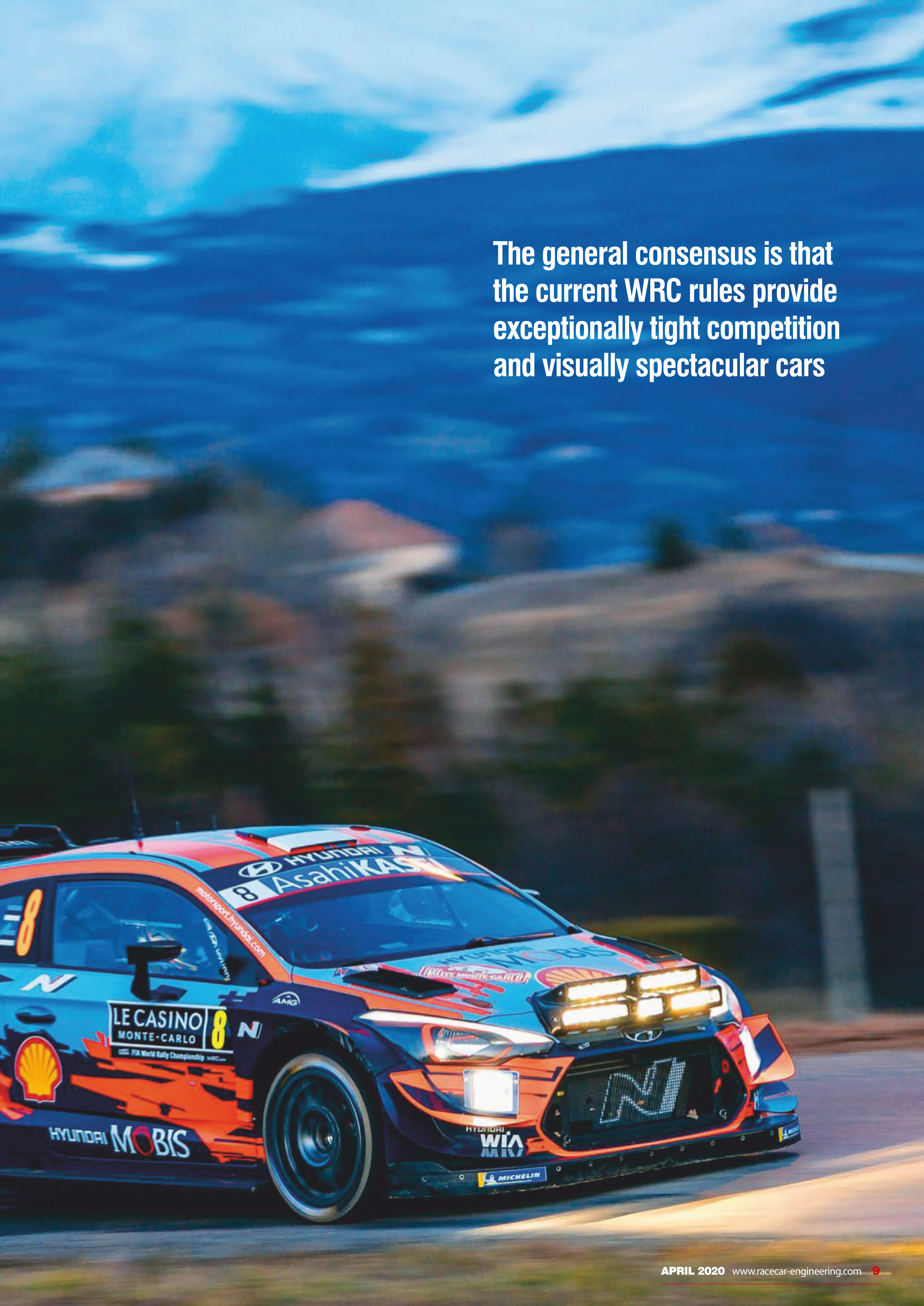
In Hamilton's case, he has never raced outside of single-seaters. Does this concentration on a specific goal and the particular skills and experience needed to attain it make the difference, on top of the essential natural ability?

Niki Lauda and Alain Prost earned their spurs through the intelligent application of their great talent

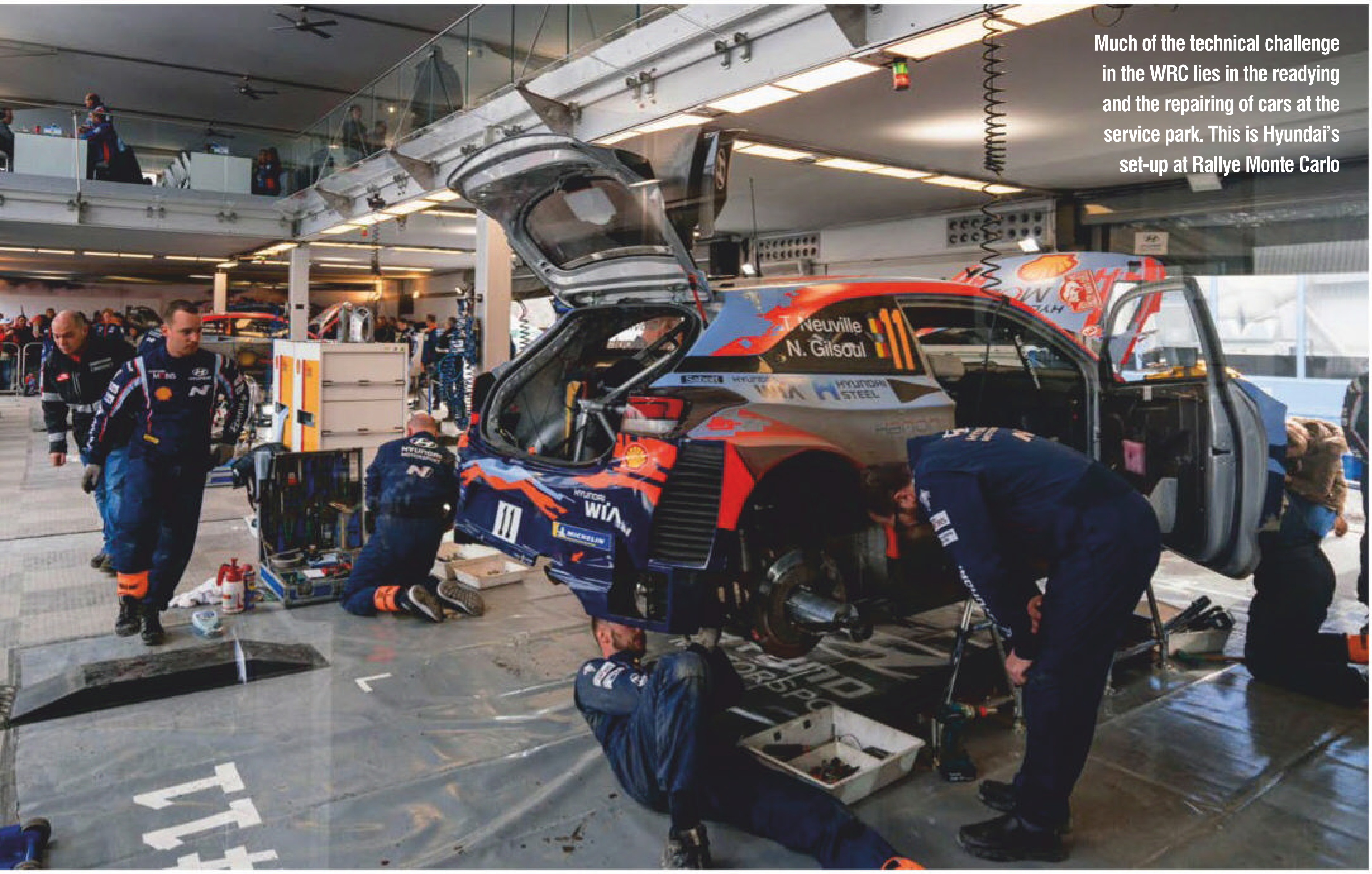
WR three

The WRC field might be down to just three manufacturer teams but the level of competition and innovation has certainly not diminished. *Racecar* went to the Monte Carlo season opener to catch up with the latest technical developments in rallying's premier class

By LAWRENCE BUTCHER



The general consensus is that the current WRC rules provide exceptionally tight competition and visually spectacular cars



Much of the technical challenge in the WRC lies in the readying and the repairing of cars at the service park. This is Hyundai's set-up at Rallye Monte Carlo

The 2020 season is actually slightly unusual, as this year the WRC teams have five jokers to play, rather than the usual three

The 2020 World Rally Championship got underway in Monte Carlo at the end of January. Though the current rule set, which arrived in 2017, is now entering the mature stage, the three remaining WRC teams – following Citroen's withdrawal at the end of 2019 – Toyota, Hyundai and M-Sport/Ford, are still bringing in updates to their cars.

Due to the joker system governing updates both between and through seasons, the introduction of any new part must be carefully assessed to ensure it provides the greatest possible performance gain. In this respect 2020 is actually a slightly unusual year as teams have five jokers to play, rather than the usual three. This is the result of an agreement between teams and the FIA to front-load some of 2021's jokers, as new regulations will apply in 2022.

Ford Fiesta WRC

Due to the system of limiting parts year on year, teams spread major updates across seasons. For example, M-Sport homologated several new components in late 2019, which would work together with further developments in 2020. 'We introduced a new rear suspension and some engine updates towards the end of last season,' says Chris Williams, technical director at the Ford Fiesta-running team. The engine parts were homologated, but were not put to use as they were reliant on other revisions that could not be introduced until the 2020 season.

The revamped rear suspension, which M-Sport had planned on using in the final round of 2019 in Australia (which was cancelled due to the bush fires) was, Williams explained, 'a design that gives us some more flexibility, to allow us to explore some different geometries.'

Though the rear suspension design in WRC is relatively open, Williams pointed out that there are constraints around the inboard locating points for the suspension arms. 'You have a 20mm box around your homologated suspension points you can work within,' he says.

Moving into 2020, the team had planned to bring a further raft of developments for the start of the season. 'We spent a load of time last year working on this year's jokers. For one reason or another, we are a little bit behind on introducing them, so they are going to come in throughout the year,' Williams says. He hopes they will all be introduced by the returning Kenya (Safari Rally) round which takes place in July.

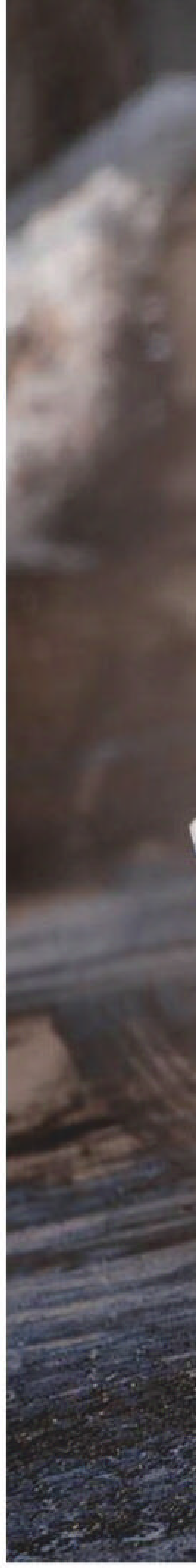
Williams was unwilling to divulge too much detail but said the changes will focus on the engine and were a result of the team's increased technical backing from Ford starting to bear fruit. 'They have simulation and computing resources we don't,' he says, adding that these resources were particularly relevant in areas such as combustion modelling, which is so important in the optimisation of the direct injection engines used in the WRC.

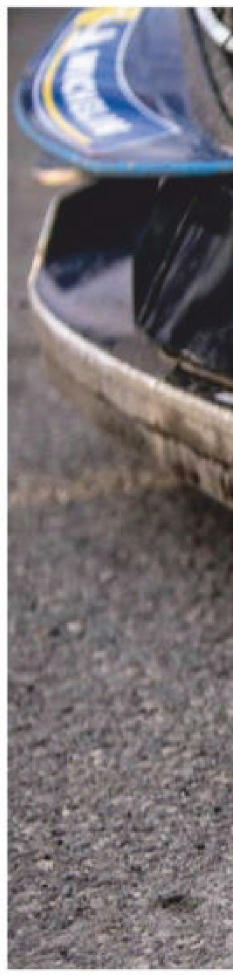
On Safari

Regarding the return of the Safari Rally, which is sure to present a unique set of challenges to the WRC teams, Williams says: 'You can't plan your whole development project around a single rally. We have to work around the whole championship and then do the best we can for Kenya. I'm not sure it will be anywhere near as extreme as previous Kenya rallies, but it is going to be interesting.'

M-Sport has a slight advantage on some of the competition in that it's R5 cars have been running in Africa over the last two years, competing in the local Kenya Safari Rally Championship. 'The feedback was okay,' says Williams. 'The biggest thing seemed to be dust bowls; cars literally beached in dust bowls. It gives us an idea of what is going on, but until they've set the stages and you rock up, you don't know. But it won't be the Kenya of old which was utterly horrific. [Then] you could lose an hour and still win the rally!'

The M-Sport team didn't have the greatest start to the season and on the very first day of Rallye Monte Carlo all three of its Fiesta WRCs suffered from overheating due to leaves





M-Sport has benefited from using Ford's huge simulation and computation resources to help develop the Fiesta

'We have to work around the whole championship, and then do the best we can for Kenya'

Mesh was placed over the Fiesta grilles to stop leaves clogging them up; this had caused overheating

M-Sport's recently revised rear suspension was run for the first time

A Toyota Yaris WRC kisses a snowy apex. The team worked on improving engine torque last year and is now looking at taking weight out of the car to give it more ballast options

clogging the front grilles. This problem was rectified with some rapid improvisation, the team fabricating and fitting mesh inserts in front of the main inlets.

Toyota Yaris WRC

Moving on to Toyota, 2019 was the year it finally came good for the Japanese manufacturer with Ott Tanak sealing the drivers' championship (Hyundai took the manufacturers' crown).

Last season, the Finland-based team introduced an engine update at its home rally, which was focussed on increasing torque, so as to rebalance its powerplant after previous updates concentrated on improving peak power at the expense of torque.

The team also deployed a number of bodywork jokers, which saw a new rear brake cooling solution introduced, with inlets higher up on the rear quarters compared to previous versions. The intent here was to reduce the amount of debris sucked into the inlets on dirtier rallies. A revised spec of side skirt was also developed, which remained geometrically the same as its predecessor but featured a different construction to improve durability.

Moving into 2020, Toyota had used three jokers by the start of the season. Speaking in Monte Carlo, technical director Tom Fowler explained: 'From a chassis point of view, we have done some light-weighting projects. During the last season, on some of the dirtier rallies we couldn't always get to the weight we wanted, so we have been looking to reduce the overall weight of the cars to allow more ballast.'

The focal point of this weight saving drive was the front hub/upright assembly. 'The reason we picked that area is because, when the car was originally developed – on a very tight time-scale – there was not time to entirely optimise the upright design,' Fowler says.

The Toyota, like most WRC cars, uses a complex upright which integrates the outer CV joint within the hub assembly. 'Machining those parts, from a very big piece of billet [aluminium] is very complicated,' Fowler says. 'It takes about four months to get a package of parts together for a few cars. That long lead time meant it was one of the first parts we designed for the car, and for a while we had a hub and an upright on the screens without much else around it.'

Thus, there was not time before Toyota's debut in 2017 to extensively optimise and then validate constant iterations of the parts.

Fowler says: 'We had to be very safe with the design, because if it failed during testing there wasn't time to redo it. It was an area where we knew there was scope to light-weight.'

The new uprights took over a year of development to get them right, in order to be introduced for 2020, with the implementation of this using up two jokers.

The third joker used by Toyota was to change its transmission ratios for tarmac. Teams are only permitted two sets of ratios, one for tarmac and one for gravel. The ratio

Toyota introduced a revised upright and hub assembly for 2020

Higher rear brake cooling inlets are now a feature of the Yaris WRC

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Photo: XPB

Hyundai's i20 made a winning start to the 2020 WRC with victory on the Monte Carlo. A new, lower-profile roof scoop was one of the few changes that could be seen on the car

swap was linked to the aforementioned engine updates. 'It was a combination of performance and reliability,' Fowler says. 'The significant torque increase we found for 2019 affects the transmission so we had to review the design, particularly for tarmac, as that is where you are putting the most torque down.'

This left the team with two updates still to use by the end of 2020. When asked whether these updates may be used to refine the Yaris's aerodynamics, Fowler says: 'Everyone else has been working on aero the past couple of years, but we haven't done so much ourselves because we are pretty confident with what we have got. But we are still doing some research and, actually, we don't know what we are going to use the jokers for yet. We have more than two things to use them on, and we are evaluating which are the best things to use them on.'

Hyundai's new rear diffuser. One with a centrally-mounted exhaust was tested pre-season, but this was not used on the rally

The GR Yaris

In January 2020, Toyota officially unveiled something akin to a homologation special version of the road going Yaris, dubbed the GR (Gazoo Racing) Yaris. This new car features four-wheel drive and a turbocharged 1600cc engine. Importantly, it also has a very different body to the regular Yaris. For starters, it is a three-door shell, which incorporates composite and aluminium and has a lower roof-line. At the start of February 2020, Toyota began testing a WRC version of the new car, which is destined to make its debut during the 2021 season.

However, according to Fowler, the GR is not simply a homologation special. 'It is actually a different way [of doing things] from what people might expect,' he says. 'We are involved in rally activity to research and collect data for high performance road cars. The GR Yaris has some relationship to what we do in WRC. It was not so much us trying to get a special car for rally, rather the road car engineers and our rally team engineers working together to bring back the idea of a four-wheel drive, hot turbocharged car for the performance enthusiast, and bring in some of the essence of the rally car. You couldn't drive a rally car on the road every day; it would annoy you rather a lot.'

He says that traits which are desirable to transfer from rally to road include an easy to drive car, with good balance. 'That's not always easy to achieve in a four-wheel drive car,' he says.

However, Fowler admits that there are undoubtedly some elements of the GR design that will be beneficial to the rally car. 'When we

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If a team was willing to spend the money, then aerodynamics in particular still has scope for considerable development

are involved in a car like this, there will of course be some benefits,' he says.

The Yaris GR based WRC will be a one-year wonder, as new rules will arrive in 2022 that make it obsolete. That the parent company is willing to dedicate no small amount of resource on a car with such a short lifespan is testament to the pride Toyota takes in its WRC exploits.

Hyundai i20 Coupe

Unfortunately, Hyundai team principal Andrea Adamo has instigated a blanket ban on discussing technical matters. That said, there are some developments which are impossible to hide, most notably the aero updates its brought for the 2020 season, specifically, a heavily reworked rear diffuser.

In an interesting twist, pre-season Hyundai was out testing its 2020 car with a revised rear diffuser, which took several design cues from Toyota and Ford, notably a more aggressive profile including a central mounted exhaust. Hyundai was the only team not to take advantage of exhaust blowing its diffuser when the current rules package was introduced in 2017, and as Toyota's Fowler noted at the end of 2019, 'I can't see why anyone wouldn't do it'.

However, come Monte Carlo, the diffuser Hyundai ran on the cars was of a different design to the one it tested. It was something of a hybrid between 2019 and '20 designs, reverting to an offset exhaust outlet, combined with the new diffuser profile. Unfortunately, the team was unwilling to comment on the reasons for the change – but it certainly raised some eyebrows in the rest of the paddock.

The new diffuser was the standout change for 2020, but the Hyundai team also introduced a new, lower profile roof scoop, this design having an impact on drag, while reducing the obstruction to the rear wing.

Overall, the current WRC regulations appear to provide a good balance between permitting engineering freedom, while keeping costs under control. Though one engineer did note that if a team was willing to spend the money, aerodynamics in particular still had scope for considerable development.

The general consensus is that since 2017 the WRC package has provided exceptionally tight racing and visually spectacular cars, a fact which no doubt pleases marketing departments. The FIA will have to be careful not to lose the momentum of the sport's growing popularity with its new rules, balancing a desire for cost control and environmental credentials, without sacrificing World Rallying's soul.

Surface tension

Even by rallying standards, Rallye Monte Carlo 2020 was characterised by hugely unpredictable conditions. Though a mix of snow, ice and dry tarmac is usual on the event, relatively warm daytime temperatures, that dropped come nightfall, made it a challenge for both drivers and ice crews. During the opening stages, which run over the first night, sections that were damp tarmac when the ice crews ran through 90 minutes before the start had turned to ice by the times cars were on the stage.

Monte Carlo Casino

Teams had to gamble as to the correct tyre choice, choosing between a mix of super soft, soft and studded tyres, searching for the best compromise. According to Chris Williams at M-Sport: 'Each of our cars took six tyres, two soft, two super soft and two studs.'

M-Sport's tactic here was to run a mix of tyre types through the night. For the first stage, at lower altitude, it opted for a mix of softs and super softs, running 'across the car' that is, with one of each type on front and rear axles.

For the second stage, at higher altitude, it ran a mix of super soft and studs, again across the car. 'We thought the last stage would be bad and to be fair it was,' Williams says. 'But the weather information at the time we chose tyres was that only five per cent of the stage was icy, but 20 per cent of it was wet. From what we had seen the day before, the wet bits turned to ice, but actually, they turned to slush. We gambled on that and felt we had to have two studs to give some confidence. It can ice up shockingly quick.'

But why run with a mix of tyres? 'We run them across the car, because that evens the car out a bit,' Williams says. 'If you run one axle or the other, you either have a very lively front or rear end. It is never a perfect balance, but it does average things out a bit. When we saw the first guys take six slicks, we thought, that's brave.'

As it turned out, 'brave' was the best route to take, as demonstrated by Hyundai's Thierry Neuville, who set a blistering pace well clear of the field on an all-slick set-up.

Star studded

However, as Williams pointed out, studs were still a good call for the rest of the drivers. 'If you looked at the second stage, in one section [Elfyn] Evans [Toyota] took something like 12 seconds out of Neuville, running on studs.' On sheet ice sections, the delta between slicks and studs is around 19 seconds/km.

'The tyre choice was very difficult, probably one of the most difficult Monte tyre choices I can remember,' Toyota's Tom Fowler says. 'As we got closer to the time on stage, it became more and more complicated, and we couldn't forecast with certainty whether it would or would not freeze. Our tyre calculation showed in the end that if you took two studs and two slicks, you would have exactly the same pace as four super softs. So we took two studs, because obviously the risk is higher when you only have slicks.'

Monte Carlo proved the WRC is the ultimate test for balancing a car between a compromised but safe set-up and outright pace.


With the roads freezing at nightfall tyre choice was a major headache on this year's Monte

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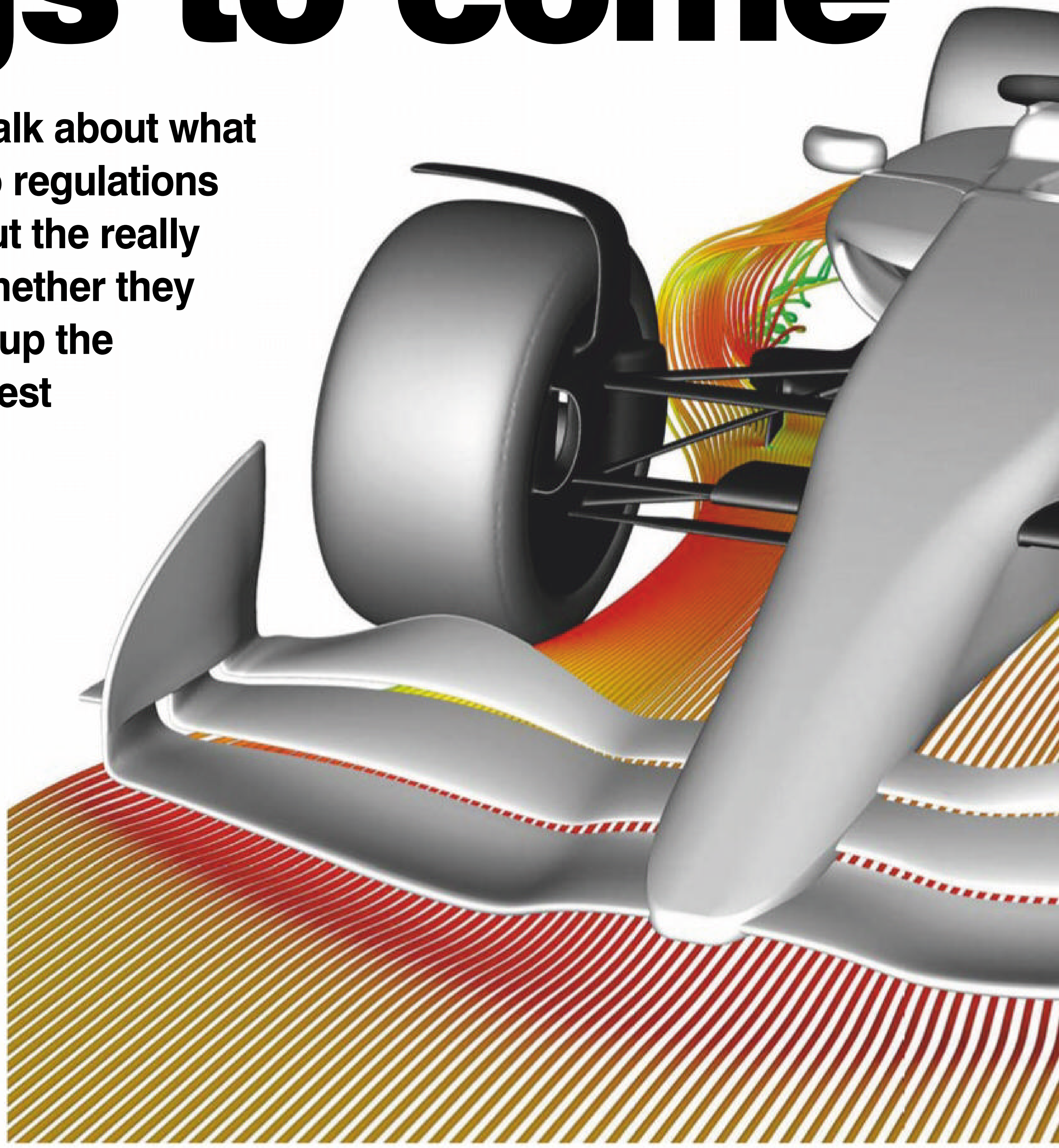
The shape of things to come

There's been plenty of talk about what the 2021 Formula 1 aero regulations are meant to achieve, but the really important question is whether they will work. *Racecar* fired up the CFD to put them to the test

By SIMON McBEATH



Our CAD model of a Formula 1 car with the 2021 aero rules package. F1 hopes this new approach will improve the racing

It is widely known that Formula 1 had assembled a group to conduct its own aerodynamics R&D during 2018-19, seeking a solution to the thorny problem of enabling the cars to race closely and to overtake more easily. In late 2019 that work was presented in outline, along with the FIA's regulations for 2021, which encompass major aerodynamic changes to create a package that is intended to allow reasonably high downforce with a more benign wake.

The nature and intent of the changes were detailed in January's issue (V30 N1), but in essence the new regulations outlaw the complex multiplicity of devices ahead of and behind the front wheels that, in the creation of downforce and the control of wheel wakes, were deemed simultaneously to be causing excessive disruption to the airflow encountered by following cars. This characteristic made it very difficult to follow another car closely, especially through high speed 'aero' corners, because of the substantial downforce losses incurred by the following car.

So next year we will have a return, after almost 40 years, to ground effect underbodies (though not quite as we saw back in the late 1970s and early '80s), simpler front wings and front wing end plates, wheel covers and a modified rear wing, all of which is designed to contribute to a narrower wake that, furthermore, is directed upwards behind the racecar to leave an improved environment in which a following car can operate. With numbers and visualisations from its own aerodynamics research to back up these claims, there seems to be good reasons for hope for F1.

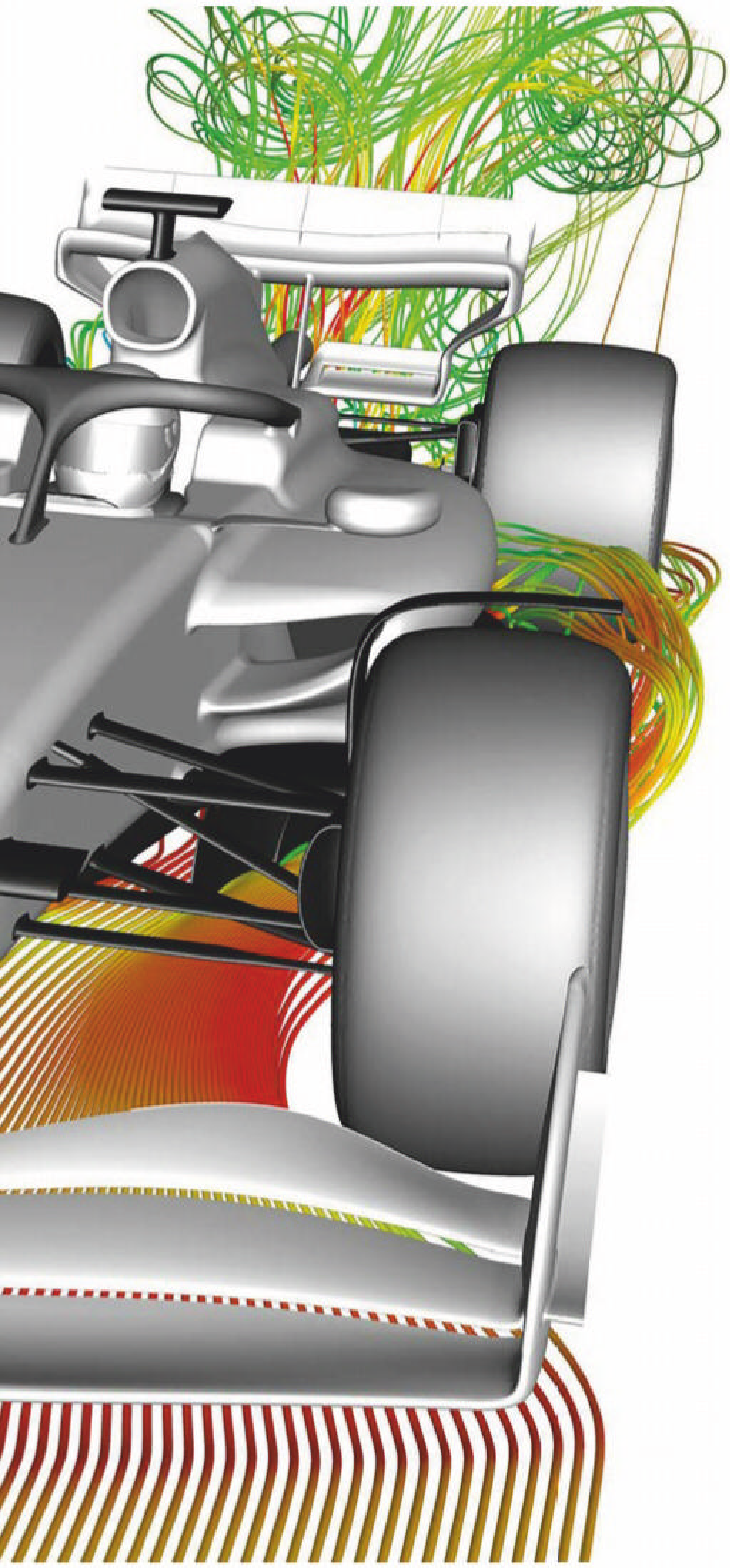
However, rather than wait until 2021, *Racecar* is able to bring you, via simulations performed once again by Miqdad Ali (MA) at Dynamic Flow Solutions, our own analysis of the effects of the new regulations, in terms of how the basic aero numbers compare to what we have now and, crucially, in line astern simulations to gauge the effects on a following car.

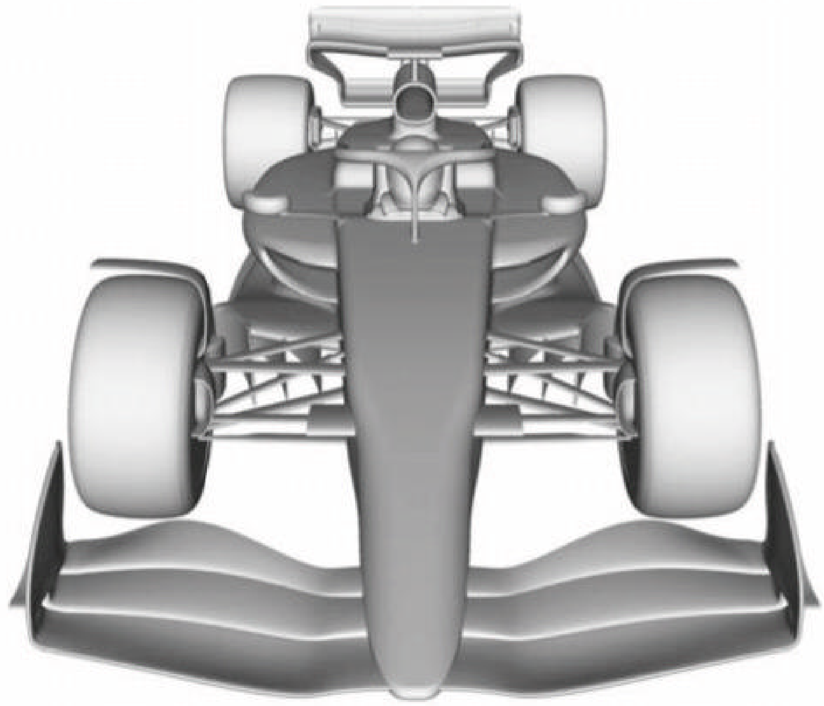
The real differences are in *how* the downforce is generated, and the consequences this has

The foreseeable future

Once the 2021 technical regulations became available MA was able to create another of his superb CAD models to comply with the new regulations. Clearly, what we see here is one engineer's interpretation (the new rules still leave some scope for design flexibility), but there is obviously a strong resemblance to the official images released by the governing body in its presentations of the new concept.

The much simpler 2021 front wing with flaps that butt up to the side of the nose eradicate the notorious y-250 vortices at a single stroke, and the removal of other part-span elements and turning vanes from the front wing and its end plate eliminates other seemingly undesirable aspects of the current front wing's flow field,

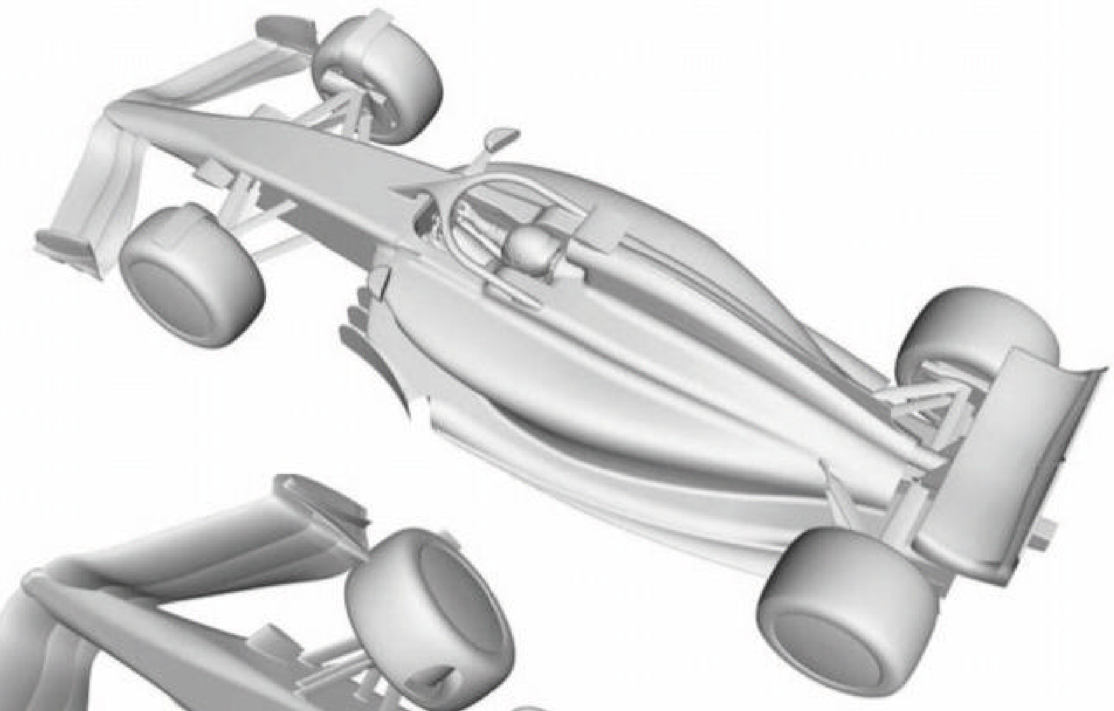


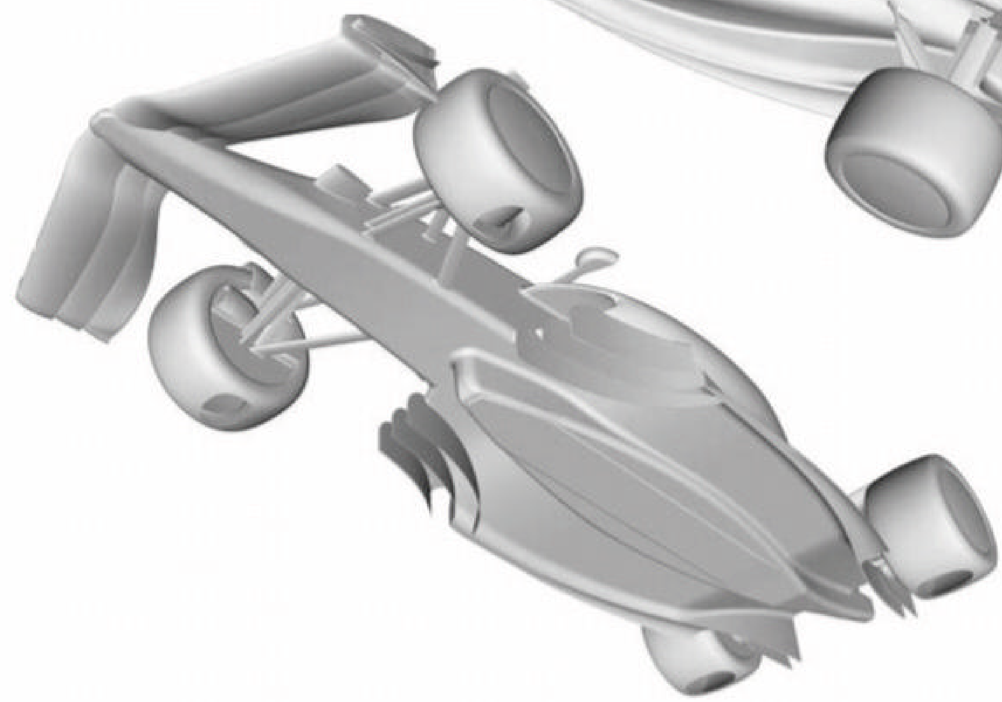


Right: Front wing is much simpler. Note the flow control devices above the tyres

Below: Overall the new rules will result in a less cluttered F1 car. The familiar 'Coke bottle' rear remains

Bottom: The current car's flat underside and short rear diffuser will be replaced with long venturi tunnels





Illustrations: Miqdad Ali

preventing excessive outwash. A simple flow control device is located above the front tyres, but gone is the plethora of devices ahead of the sidepods including bargeboards and related flow control paraphernalia.

The flat underside below the main portion of the current cars and the short rear diffuser is replaced with long venturi tunnels that extend from the more forwards leading edge of the sidepods to the rear of the car. Turning vanes (vortex generators) in the venturi inlets are one of very few other explicit flow control devices permitted, and are said to be important for the generation of downforce by the underbody.

The very familiar 'Coke bottle' convergent rear end upper surface packaging remains, and the twin tunnels converge tightly between the rear wheels to leave room just inboard of the rear wheels for brake duct-mounted devices, which will help manage the flows through this complex part of the Formula 1 car.

Clean and sleek

The rear wing is essentially a dual-element device above a lower single- or dual-element beam wing, but the rear end plates, wherein there is scope for some design variation, look very different to those currently in use. Overall then, the 2021 cars will look cleaner and sleeker.

Table 1: Aerodynamic numbers of our F1 2021 model

	CD.A	-CL.A	%front	-L/D
Baseline 2021	1.53	4.94	40.7	3.23

To ensure that his model was representative of this new generation, MA expended effort at the start of the project to optimise the model to be able to generate aerodynamic numbers (**Table 1**) that tallied with what Formula 1 had reported; that is, that downforce was around 10 per cent lower than current cars are achieving. This potential downforce decrease is consistent with predictions from some of the teams that, in the earliest stages of development at least, the cars might lap slower than the current generation. We've all heard that prediction

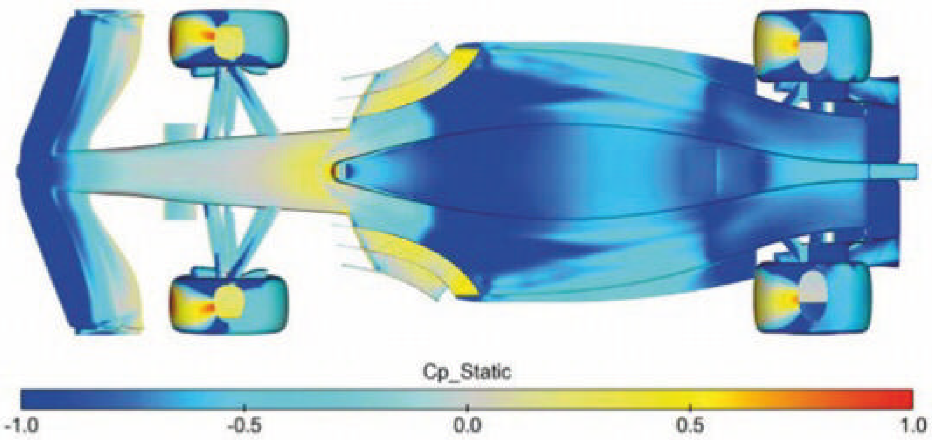


Figure 1: Pressures on the racecar's underside clearly reveal where most of the downforce is to be generated, shown in blue here. Ground effect returns in 2021

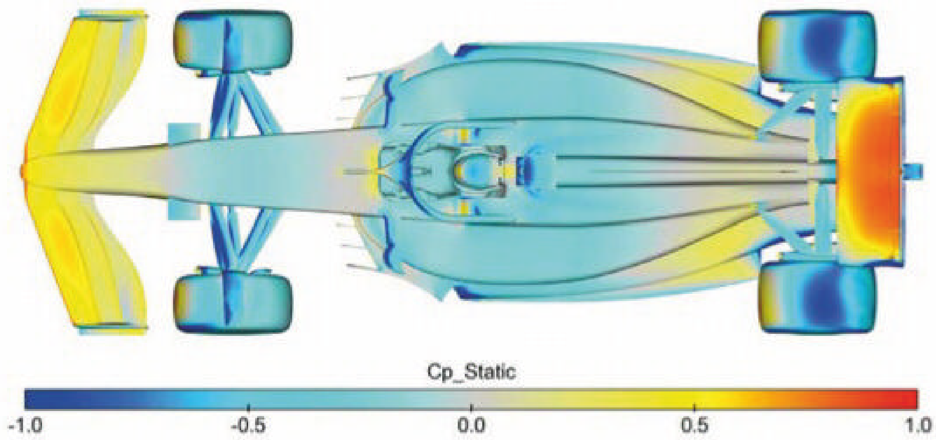


Figure 2: Top surface pressures show further downforce contributions from the wings, and lift from tyres and most of upper body. Here yellow and red show raised pressure

before when the governing body has issued new rules designed to peg back downforce levels. Maybe this time it will be different?

Figure 1 shows where pressure reductions under the car (blue areas) generate much of the total downforce. The turning vanes in the forward underbody (the venturi inlets) see raised pressure ahead of their upstream faces. Then, through a combination of the reduced ground clearance from the underbody inlet to the 'throat' section, and the vortices triggered by the turning vanes, the forward underbody beneath the cockpit sees substantial pressure reduction. Further aft, where the throat transitions to the rear diffuser, there is another 'suction peak', pressure then remains low right to the rear of the tunnels, above which the rear wing's low pressure underside can be seen, and the influence of this assists the extraction of air from the underbody.

Figure 2 shows where raised pressure (yellow and red) on the upper surfaces of the wings and the aft bodywork are adding to total downforce, although the tyres and much of the upper body create lift, as usual.

Head to head

Figures 3 to **5** demonstrate further differences between the current and 2021 rules cars by illustrating vorticity using the so-called lambda-2 criterion (which is a mathematical algorithm that detects and enables the visualisation of vortex cores in a fluid).

The vorticity generated by the front wing and bargeboard region of the current configuration can be seen in **Figure 3**, and the y-250 and bargeboard system vortices are especially apparent. Contrast this with the same areas of the 2021 Formula car in **Figure 4** and the differences are stark.

Figure 5 shows the undersides of the current Formula 1 car (on the left) and the 2021 car. Again there are key differences. The current car's vorticity is most prevalent ahead of and in the forward underbody, whereas that of the 2021 car is prevalent through the entire length

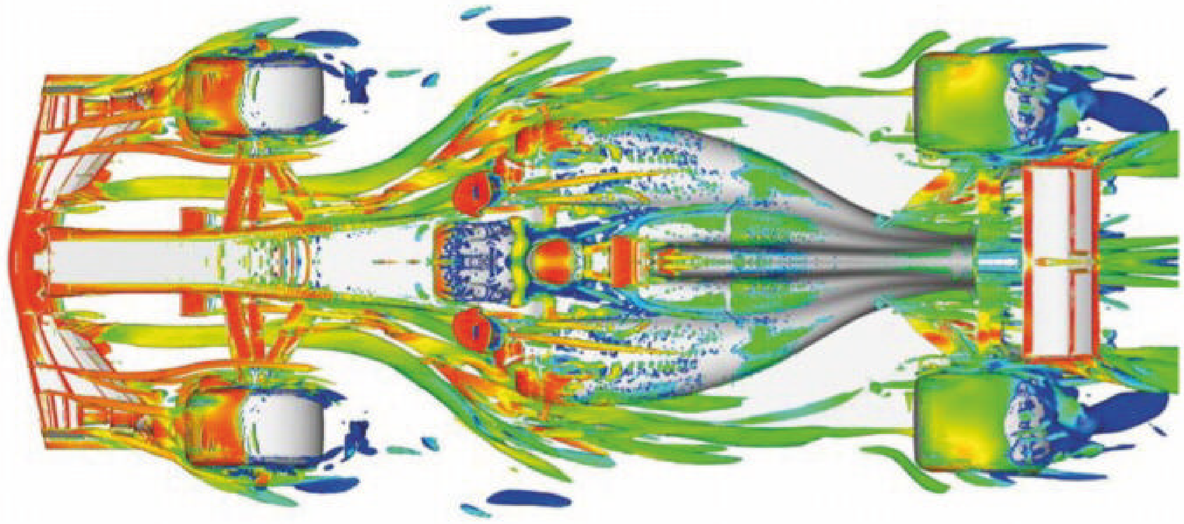


Figure 3: Top view of vortices on a Formula 1 car to the 2017 aerodynamic regulations, using lambda-2 criterion

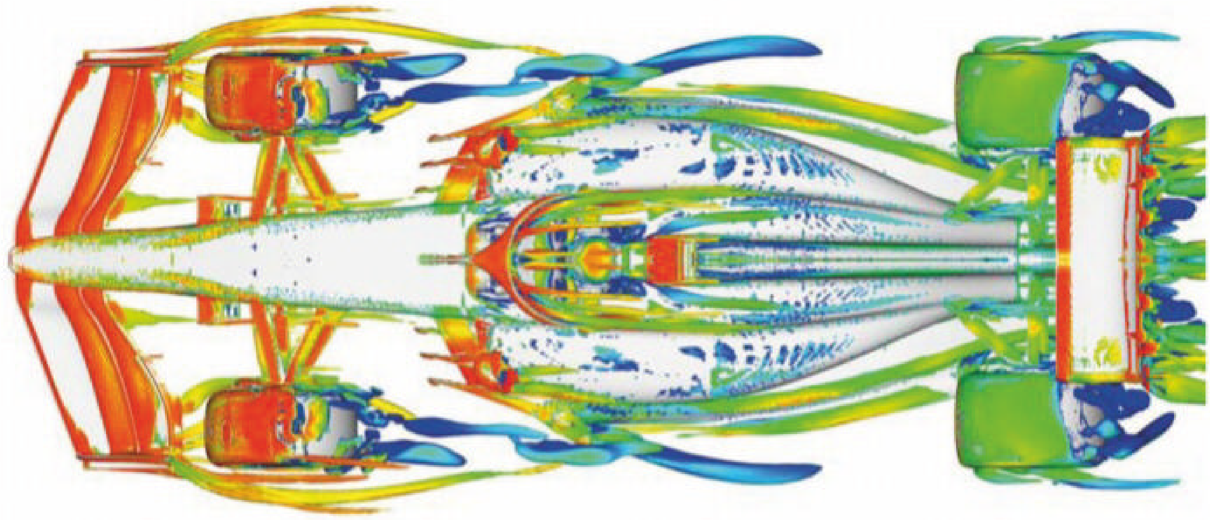


Figure 4: Top view of vortices on a car to the 2021 rules. When contrasted with the car above the differences are clear

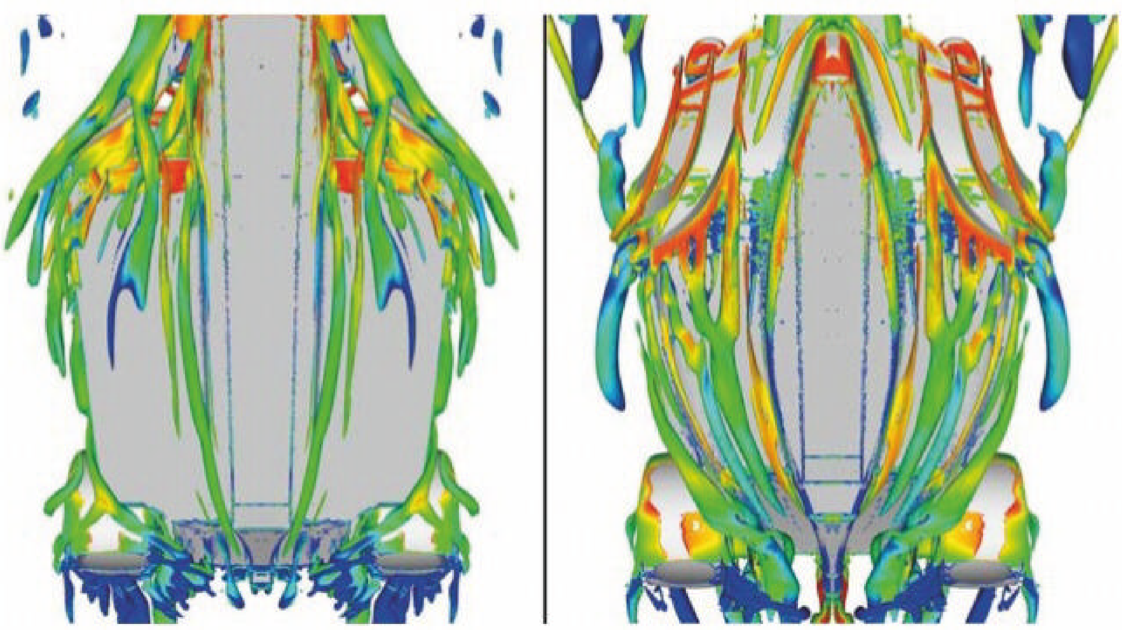


Figure 5: Vortices present in the underbodies of a car to the 2017 regulations (left) and also the 2021 model (right)

In essence the 2021 regulations outlaw the complex multiplicity of aero devices that are ahead of and behind the front wheels

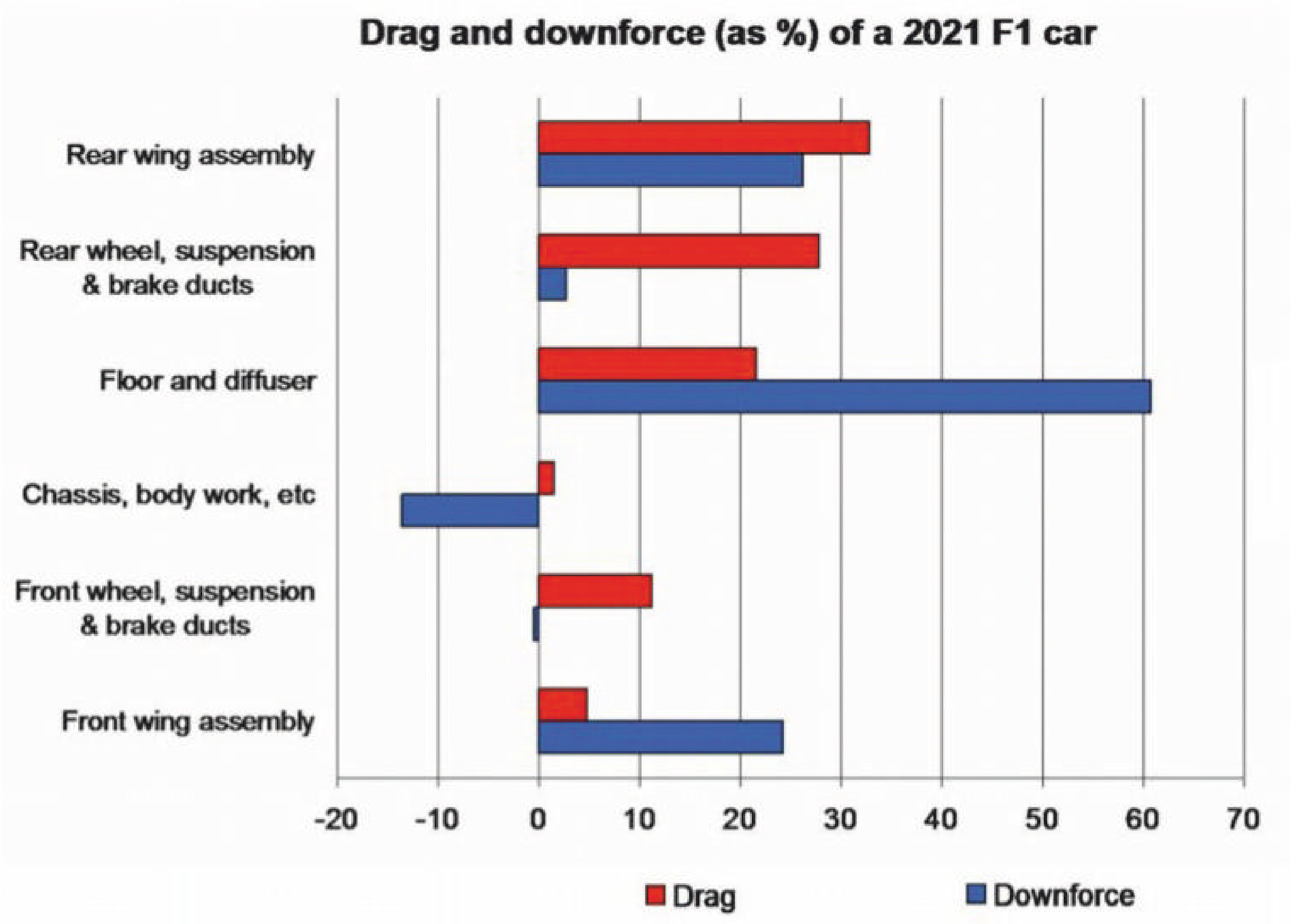


Figure 6: Force contributions of the 2021 car's major component groups. The underbody's downforce has not risen hugely

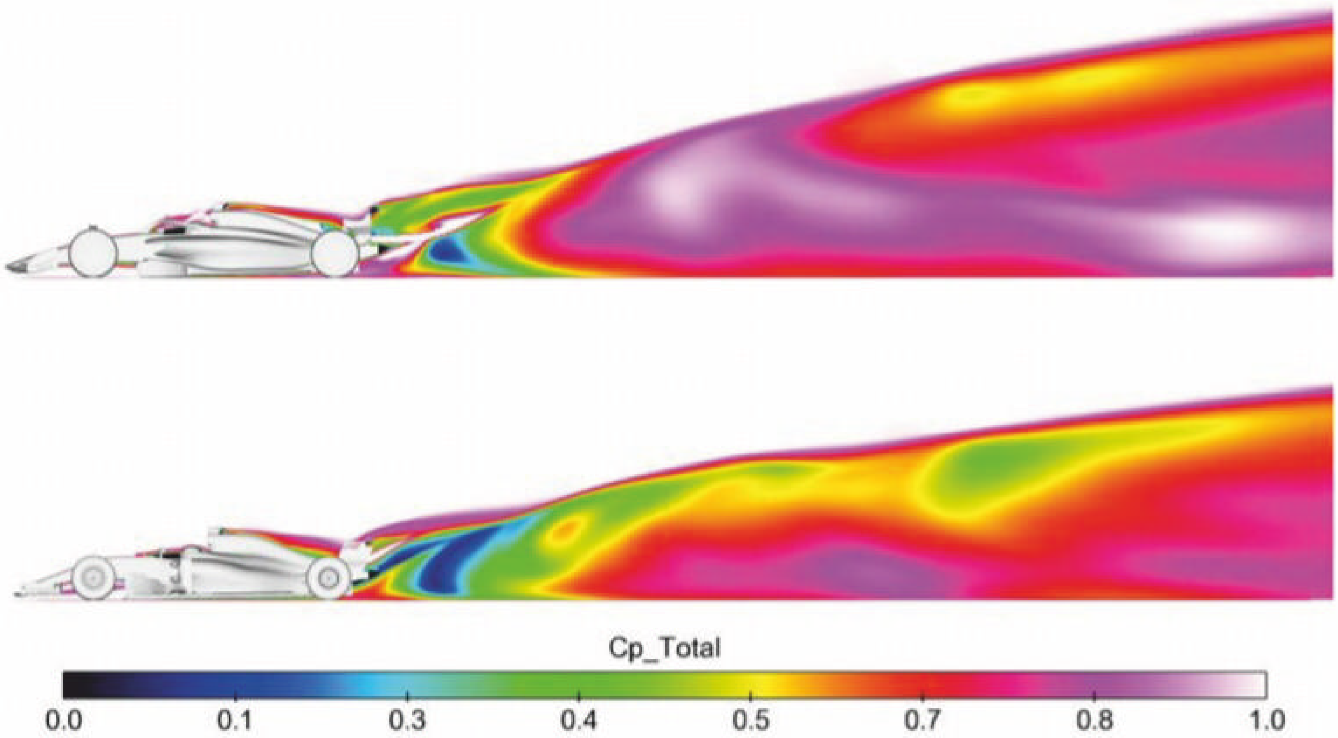


Figure 7: Total pressure slices showing wakes on symmetry plane of the 2017 rules car (bottom) and our 2021 model

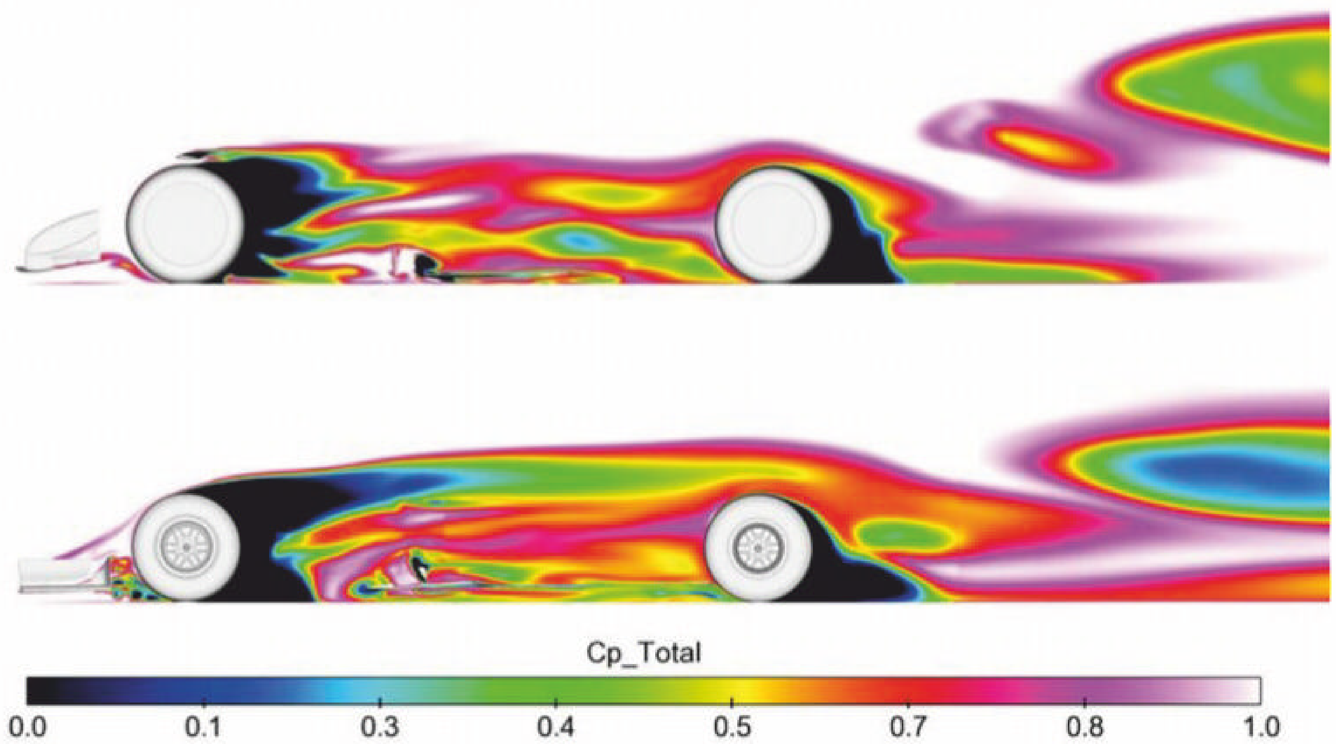


Figure 8: Total pressure slices showing wakes at the tyre centreline, with the 2017 rules Formula 1 car shown at the bottom

of the ground effect underbody. It is triggered by the turning vane/vortex generators at the front and then, as this forward-generated vorticity begins to dissipate, a large vortex is drawn into the diffuser on each side ahead of the rear tyres, helping to maintain low pressures in this part of the underbody.

Figure 6 shows the downforce and drag contributions of the major component groupings on our 2021 model. It is notable that the underbody's downforce contribution of 61 per cent has only modestly increased over the numbers we obtained for our 2013, 2016 and 2017 models analysed in previous issues, which averaged at 55 per cent of the total.

The rear wing's contribution is very similar at around 24 per cent. However, the front wing plays a reduced role at just 24 per cent of the total compared to an average of 34 per cent from the 2013/16/17 models. Small changes in the downforce and lift of the remaining components make up the difference.

So the biggest change to downforce contributions is that of the front wing, while the underbody is slightly more potent and with a more forwards centre of pressure to redress the front wing's deficit. The real

The biggest change to the downforce contributions is that of the front wing

differences, however, are in *how* the downforce is generated, and what consequences that has, as we shall now begin to see.

Take a look at **Figure 7**, which shows the total pressure coefficient or total energy in the wakes of a 2021 car (top) versus a current regulations car on the symmetry plane. Anything less than Cp.T = 1.0 indicates where the airflow has lost energy. It is immediately obvious that the energy losses behind the 2021 car from one car length behind and beyond are significantly less than with a current car. This means that a following car will be able to generate more downforce when one or more car lengths behind a 2021 car than it could behind a current car; there will still be downforce losses, but these will be smaller.

It is equally clear that at separations less than one car length the energy losses behind the 2021 car will be comparable to the current car, but this will likely always be true of an open-wheeled racecar of whatever aerodynamic configuration. **Figure 8** shows a similar Cp.T slice along a plane that cuts through the tyre centreline and the standout features here are the reduced height of the 2021 racecar's front

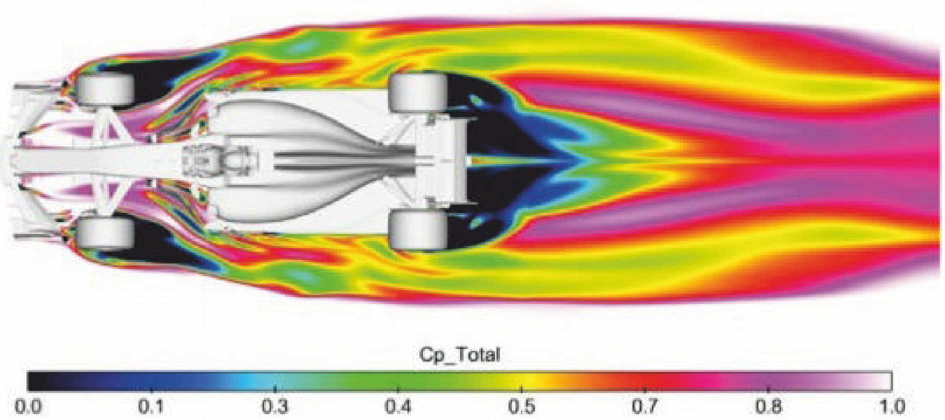


Figure 9: Total pressure slices at 100mm above ground on a 2017 regulations F1 car

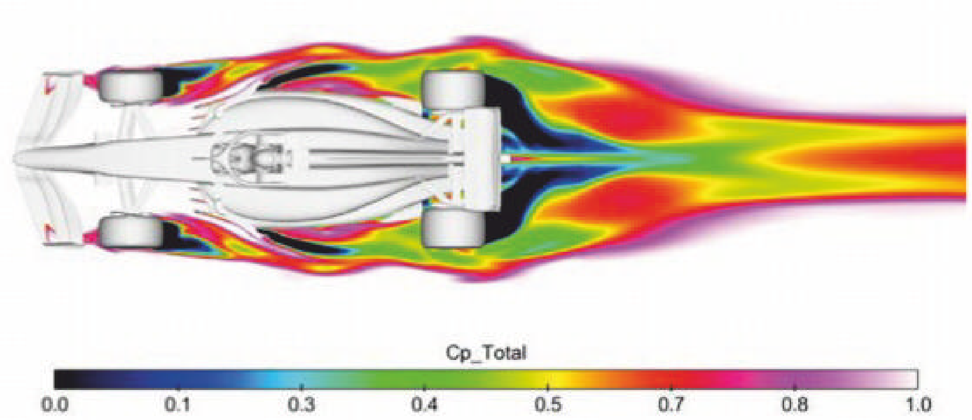


Figure 10: Total pressure slices at 100mm above ground on our 2021 rules model

wheel wake (top), thanks to the flow control device above it, and again the generally higher energy in the racecar's wake.

Figures 9 and **10** show overhead Cp.T slices at 100mm above the ground, and again clearly show the differences in the size of the cars' wakes. The wake of the 2021 car in **Figure 10** exhibits significantly less outwash from the front end all the way to the rear of the car and beyond, with the wake at this height tapering rapidly behind the car, allowing full energy air to flow inwards except in a narrow central zone. This will undoubtedly be one of the reasons that full width front wings have been reintroduced, in order to capitalise on the higher energy air that will now be available to the front wing either side of the car's centreline – at distances of one car's length and more at any rate.

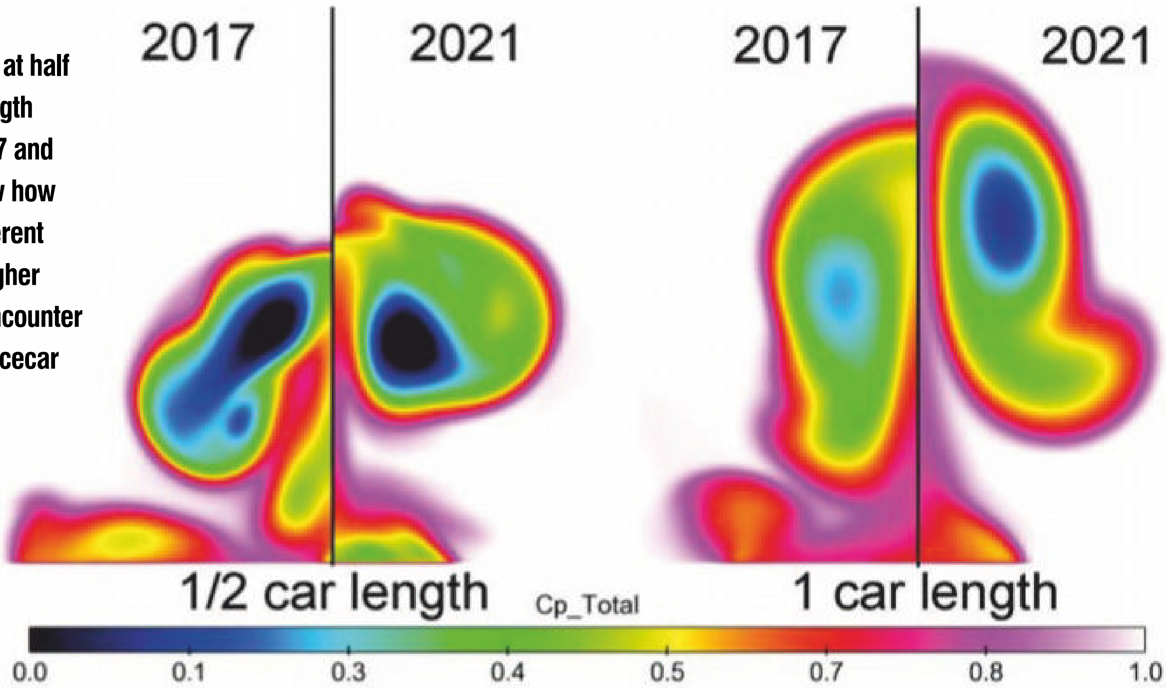
How has the 2021 car's wake been modified to create the above observations? Partly it is down to less outwash generation by the cleaner front end of the car, with neither the front wing nor the area just behind the front wheels being littered with innumerable outwash-inducing, front wheel wake control, devices. In addition to that, modifications to the rear wing and its height, combined with the rear wing's relationship with the new, much larger tunnel diffuser exits, has had the effect of creating increased upwash at the rear, lifting more of the wake above a following car. This upwash in turn induces inwash behind the car at lower heights, as we saw above and in Figures 9 and 10.

Figure 11 illustrates how the wake is lifted more with the 2021 rules car compared to the current rules car. Clearly both cars punch a big hole in the air – it couldn't be otherwise – but the 2021 car's wake is certainly smaller and draws in more freestream energy air at a height that will be of advantage to a following car, or perhaps more correctly 'of less disadvantage'.

Leading questions

Moving on to line-astern scenarios, MA repeated the process used in our previous studies of earlier Formula 1 rules configurations and their effects on the aerodynamics of following cars. Before we get into the quantitative comparisons with earlier rules sets though, **Figures 12** and **13** provide a qualitative visualisation of how the wake modifications brought by the 2021 regulations mean there will be less of

Figure 11: Total pressure slices at half and one car length behind the 2017 and 2021 cars show how the latter's different wake allows higher energy air to encounter the following racecar



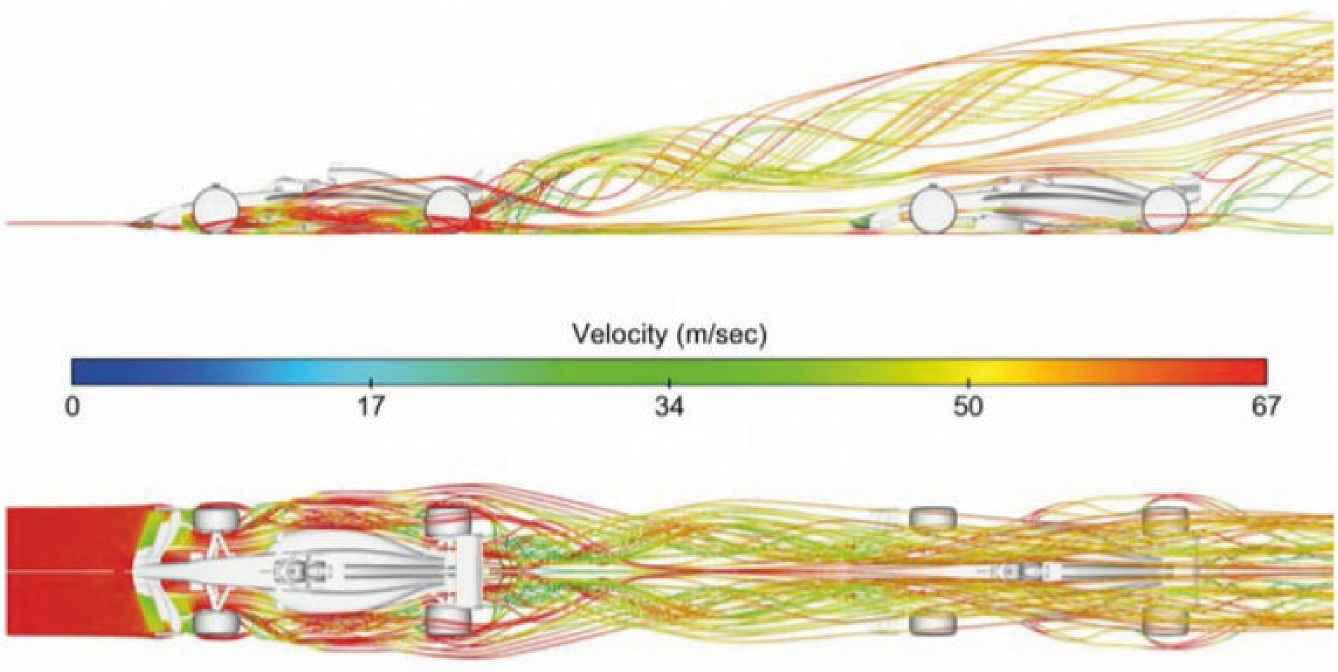


Figure 12: Streamlines projected from the 2021 leading racecar show the central wake passing above the following car

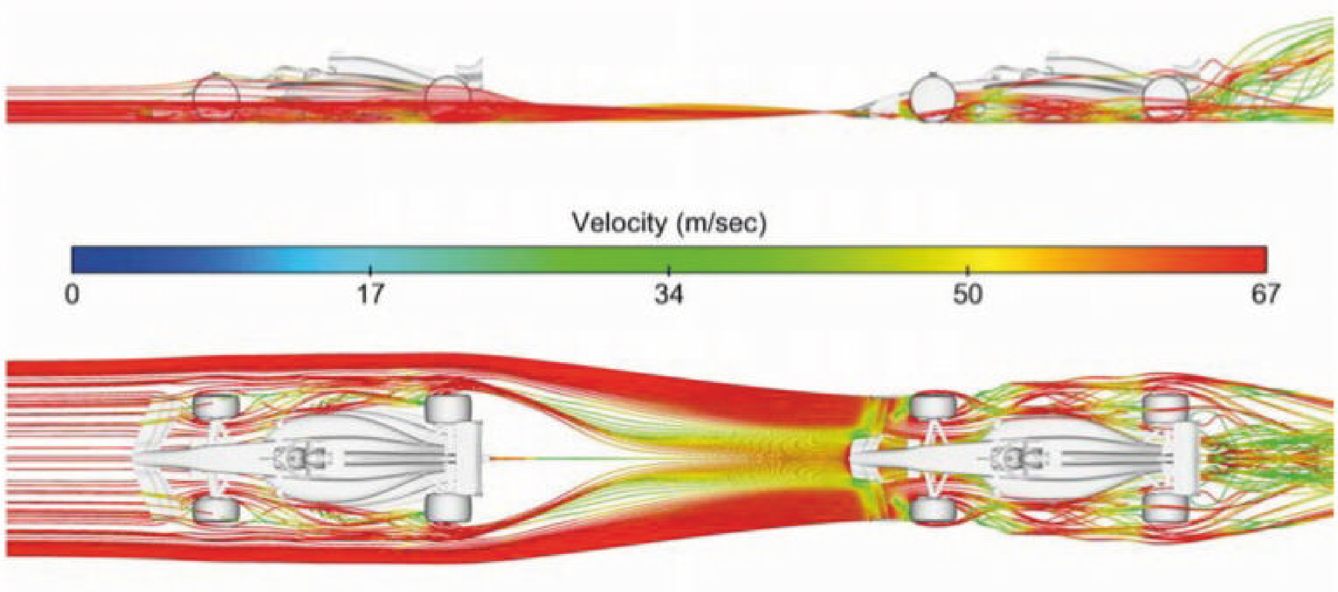


Figure 13: Streamlines projected from the 2021 following car show high energy air washes in behind the leading racecar

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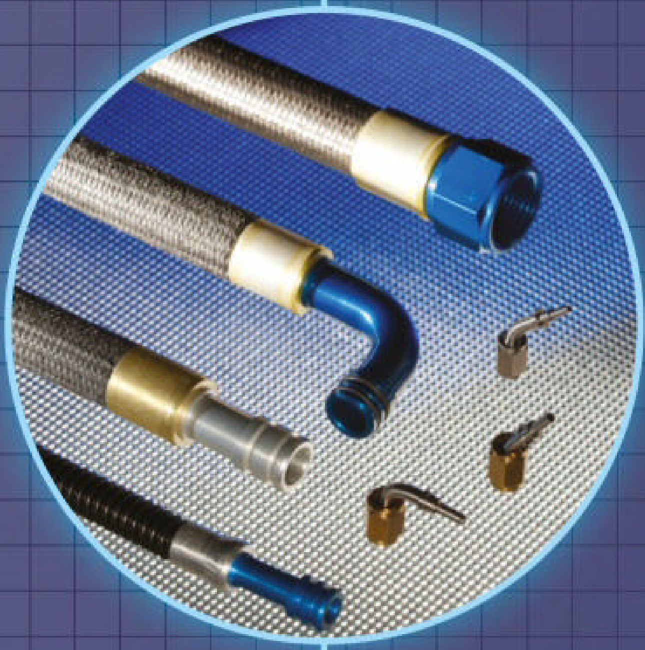

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a disadvantage to a following car relative to current and previous rules.

Figure 12 shows streamlines projected upstream and downstream from the lead car. It is evident that the streamlines emerging from between the rear wheels wash upwards and almost entirely over the following car, here one car's length behind the lead car. However, streamlines passing outside the lead car's wheels impinge upon the following car.

Figure 13 shows streamlines projected upstream and downstream from the following racecar, and reinforces the observation that the air encountering the following car comes substantially from outboard of the lead car, washing in below the lead racecar's wake. And as we saw earlier in this piece, this in-washing air is at or close to freestream energy.

Degrees of separation

Looking now at **Figure 14** we see the effects on MA's 2021 rules following car at a range of line-astern separations. Note that these numbers are all relative to a racecar in isolation. The changes shown in this graph are all relatively quite modest compared to the changes we reported on earlier rule sets cars; total downforce and front and rear downforce all decrease by significantly less on the 2021 car, and particularly noteworthy is that the accelerated decline at closer separations is considerably less marked on the 2021 racecar.

Another key issue is the effect on the aerodynamic balance of a following car as it closes on the car in front. **Figure 15** shows that the aero balance of our 2021 model was much less affected in this respect at larger separations than earlier cars, for example, the 2013 rules car, but the difference between the 2021 and 2013 cars became smaller at closer separations, so although the situation looks to have improved this could still be of significance for the 2021 cars. Noteworthy is that a ground effect concept car we analysed in September 2016 (V26N9) seemed to show a very good balance response to four-car separations, but it then became worse than the 2013 car at closer separations.

Figure 16 shows the effect on the pressures on the underside of our following 2021 car at one car length separation, red and yellow showing where pressures increased compared to the isolated case. It is evident that significant downforce was lost by the front wing. So once again, even though the balance aspect is an improvement on what afflicted cars to previous rule sets, a following car will still feel negative effects when closely following another car.

One criticism that has been levelled at the 2021 car data published by Formula 1, and which our data tends to support, is that the drag

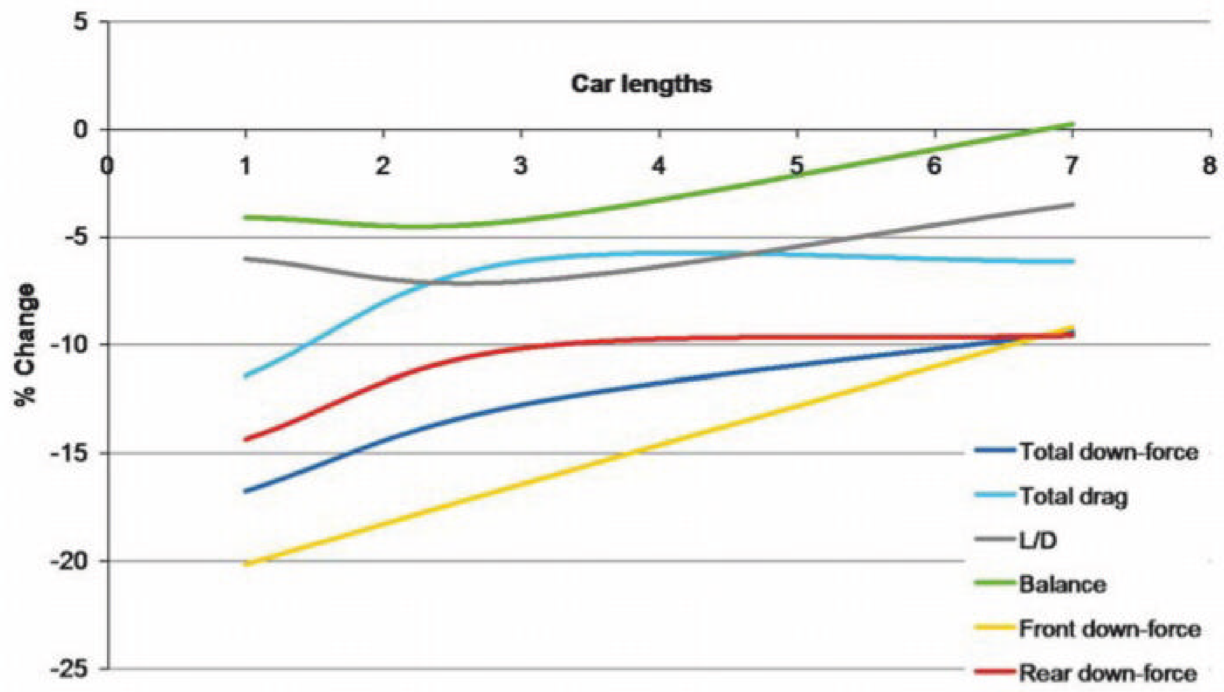

Figure 14: Aero effects on our following car model on major aerodynamic parameters, relative to a racecar in isolation

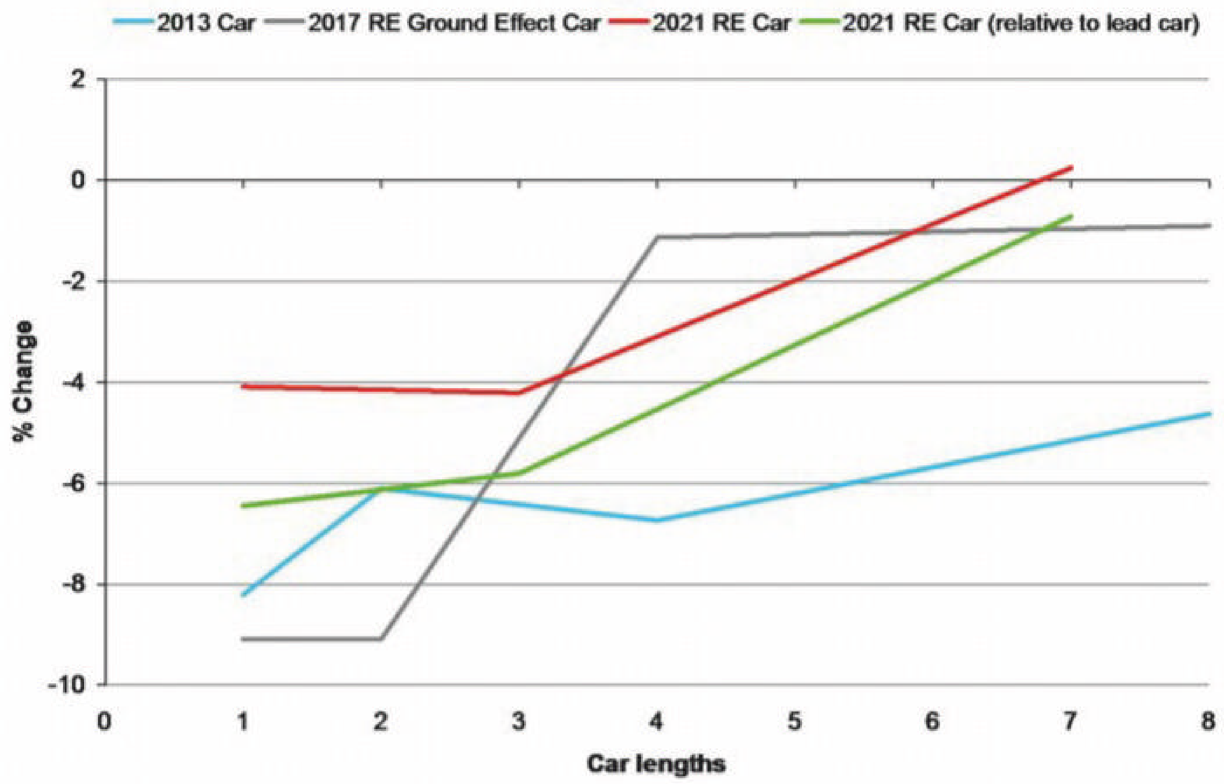

Figure 15: Comparison of effects on balance with a variety of following cars as they close up on the vehicle in front

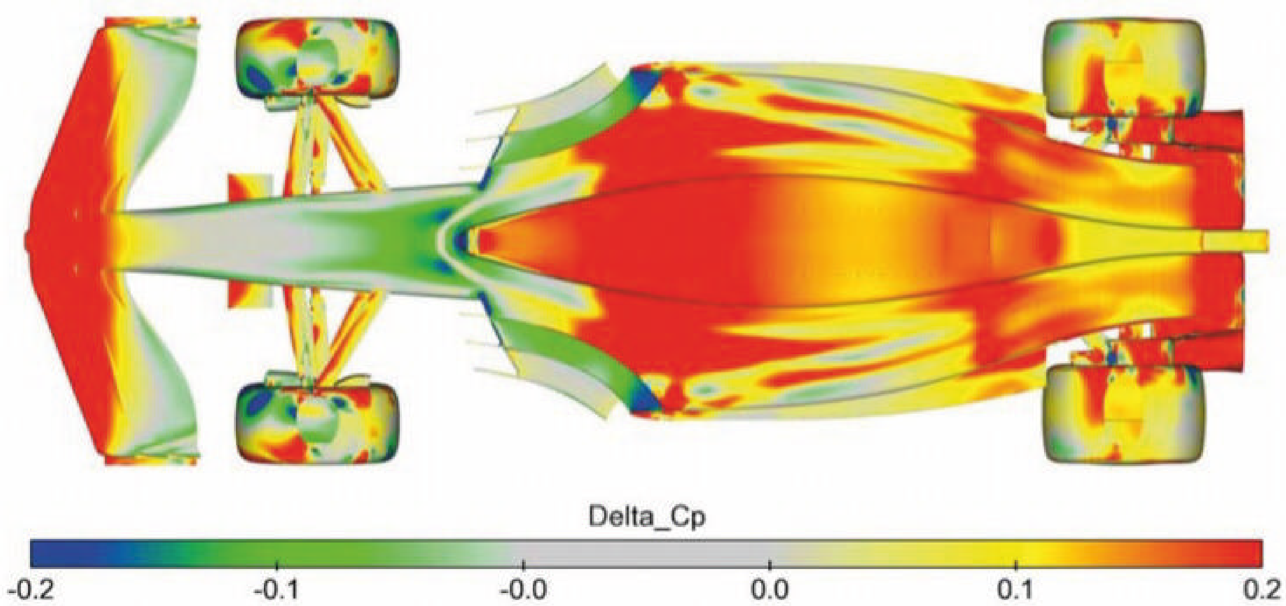

Figure 16: This shows the effect on the pressures on the underside of our following 2021 car at one car length separation

Even though the balance aspect is an improvement, a 2021 car will still feel negative effects when closely following another racecar

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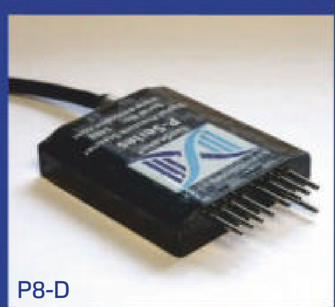

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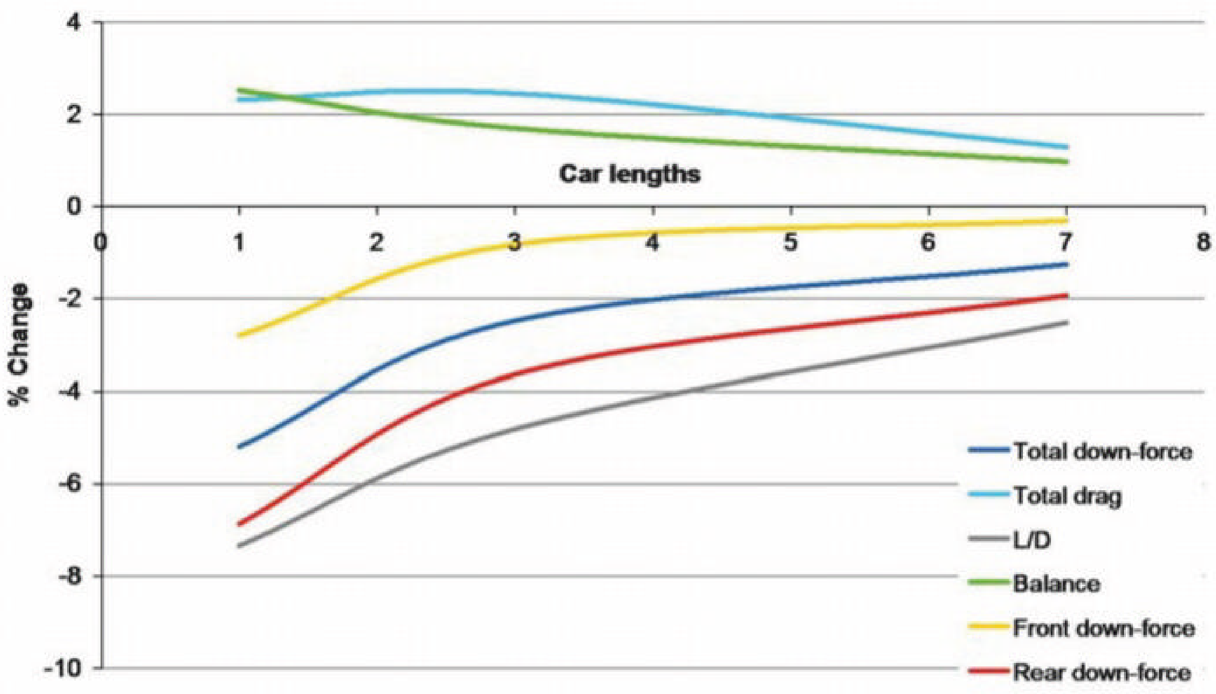

Figure 17: Effects on a leading 2021 rules Formula 1 car on major aerodynamic parameters, relative to a car in isolation

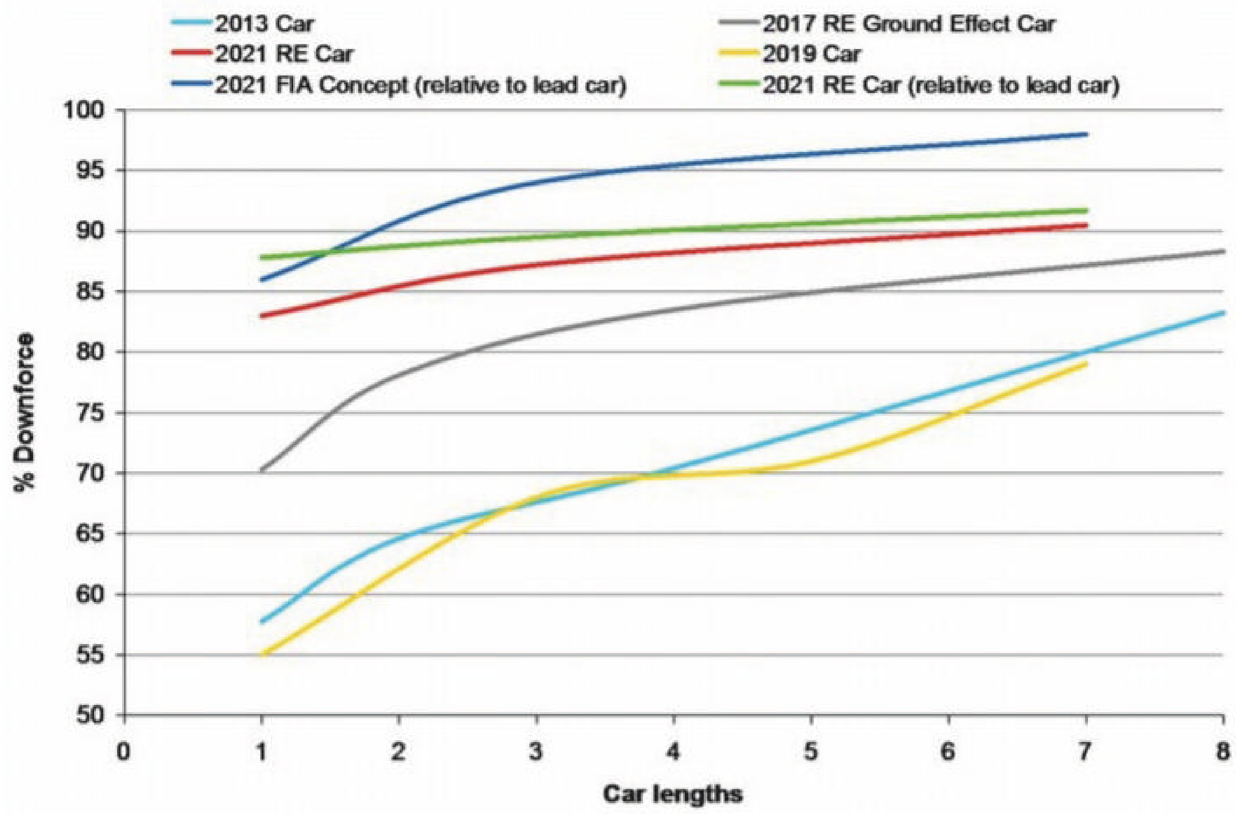

Figure 18: Comparison of 2021 rules model and earlier configurations showing total downforce losses on the following car

reduction on the following car is significantly less, especially at closer separations, and that this might adversely affect the ability to pick up a tow from the car in front. The retention of DRS may not be unrelated to this.

However, a mitigating factor, if perhaps not a game changer, is that the effects on the lead car may also come into play here, as **Figure 17** illustrates. Of particular note are the drag and balance curves; drag *increases* somewhat on the lead car as separation reduces, which would add to the effective tow obtained by a following car; and the aerodynamic balance of the lead car also shifts forwards as a following car gets closer, which would make the lead racecar's handling looser. Whether the magnitude of the balance change will be of much significance may only be known to drivers who possess a Formula 1 level of skill; doubtless we will hear many complaints on this score soon enough! But it's an interesting notion that the lead racecar may suffer slightly from increased drag and aerodynamic oversteer when a following car closes in on it.

We might see that some 2021 cars are going to be easier to follow, and to pass, than others

To put the 2021 following car numbers into a recent historical context, **Figure 18** illustrates the effects on total downforce at various line-astern car separations in our projects on cars to previous rule sets. The blue line at the top of the chart plots Formula 1's own figures on its 2021 rules concept. Note that it plotted the downforce losses *relative to the lead car* as opposed to our convention of comparing to a car in isolation, and this obviously makes a difference when, as described in the previous paragraph, the lead car's data become slightly worse as the cars get closer. So the green line represents the effect on the downforce of MA's following car also relative to the lead car, with the red line just below it being the comparison with a car in isolation to highlight the difference between the different approaches.

However, with this clarification taken into account, although there is a difference between the Formula 1 blue line and MA's green line, nevertheless it is very clear that downforce losses incurred by the following car in these simulations are considerably less using the 2021 rules aero package than they were on the 2013 and 2017/19 rules cars, and this must give cause for at least some optimism. That there is a difference between Formula 1's numbers and our 2021 numbers may, therefore, not be all that significant, given the improvement over the numbers in recent and current configurations.

The flipside of this is that the output of all the different design teams in Formula 1 will likely produce a range of wake signatures, and we could see that some cars are easier to follow, and to pass, than others.

Ground effect

As a quick aside, the grey line in the centre of Figure 18 shows the downforce losses with the ground effect car concept that we examined in V26N9, and although it was also an improvement on the 2013 and 2017 rules cars, nevertheless it did not achieve the improvement that Formula 1's R&D appears to have accomplished with the 2021 rules. At the same time it also demonstrates that espousing ground effect as the silver bullet to the issue of being able to follow and race closely was and is a gross over-generalisation. It's the detail that matters, which is why it has required a focussed, high-level research programme to come up with what looks like a decent solution.

Let's all hope that the 2021 solution does improve the racing, and also that the limitations within the rules really do ensure that the teams' inevitable efforts at clawing back an advantage do not spoil all that good work.

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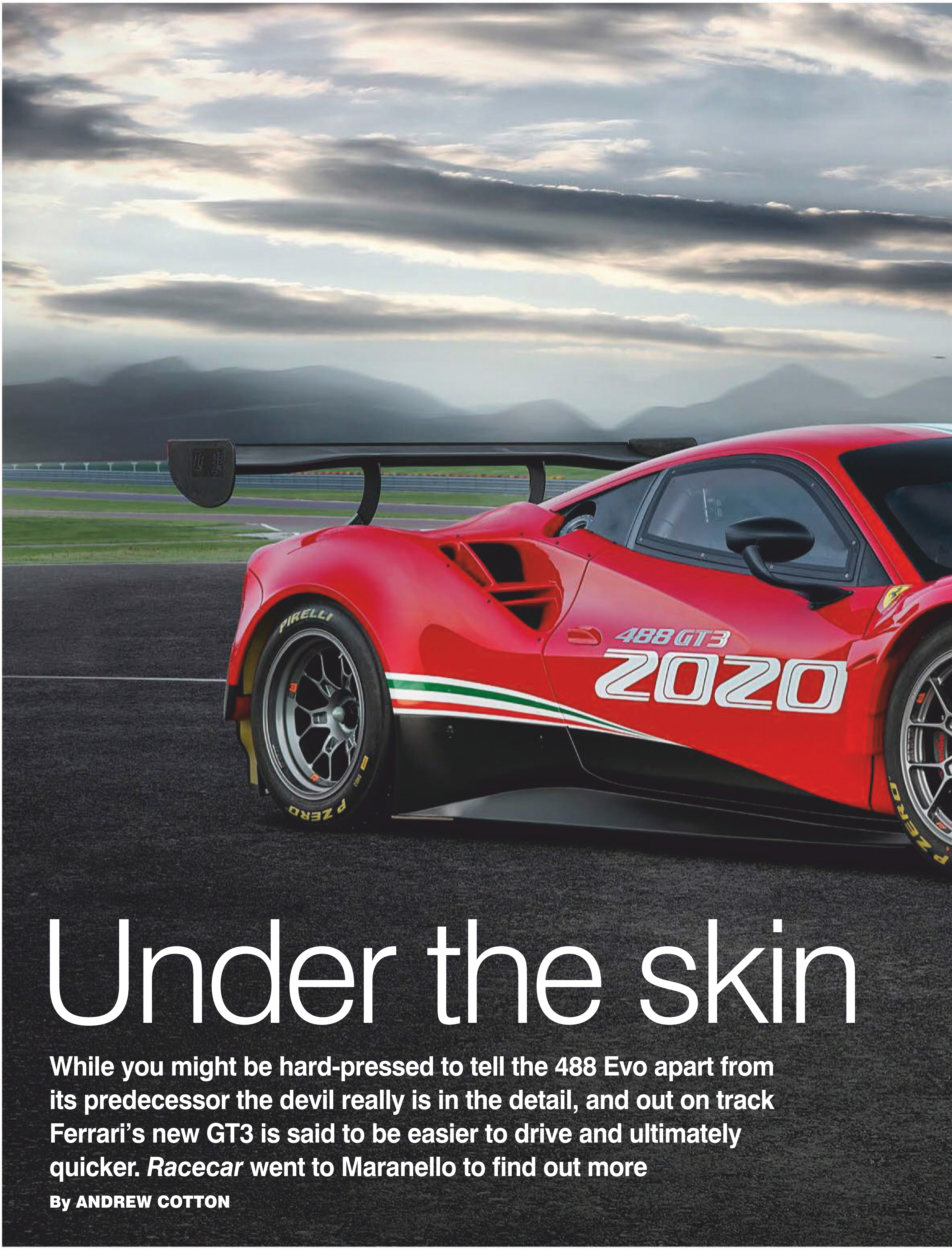

Under the skin

While you might be hard-pressed to tell the 488 Evo apart from its predecessor the devil really is in the detail, and out on track Ferrari's new GT3 is said to be easier to drive and ultimately quicker. *Racecar* went to Maranello to find out more

By ANDREW COTTON

18+

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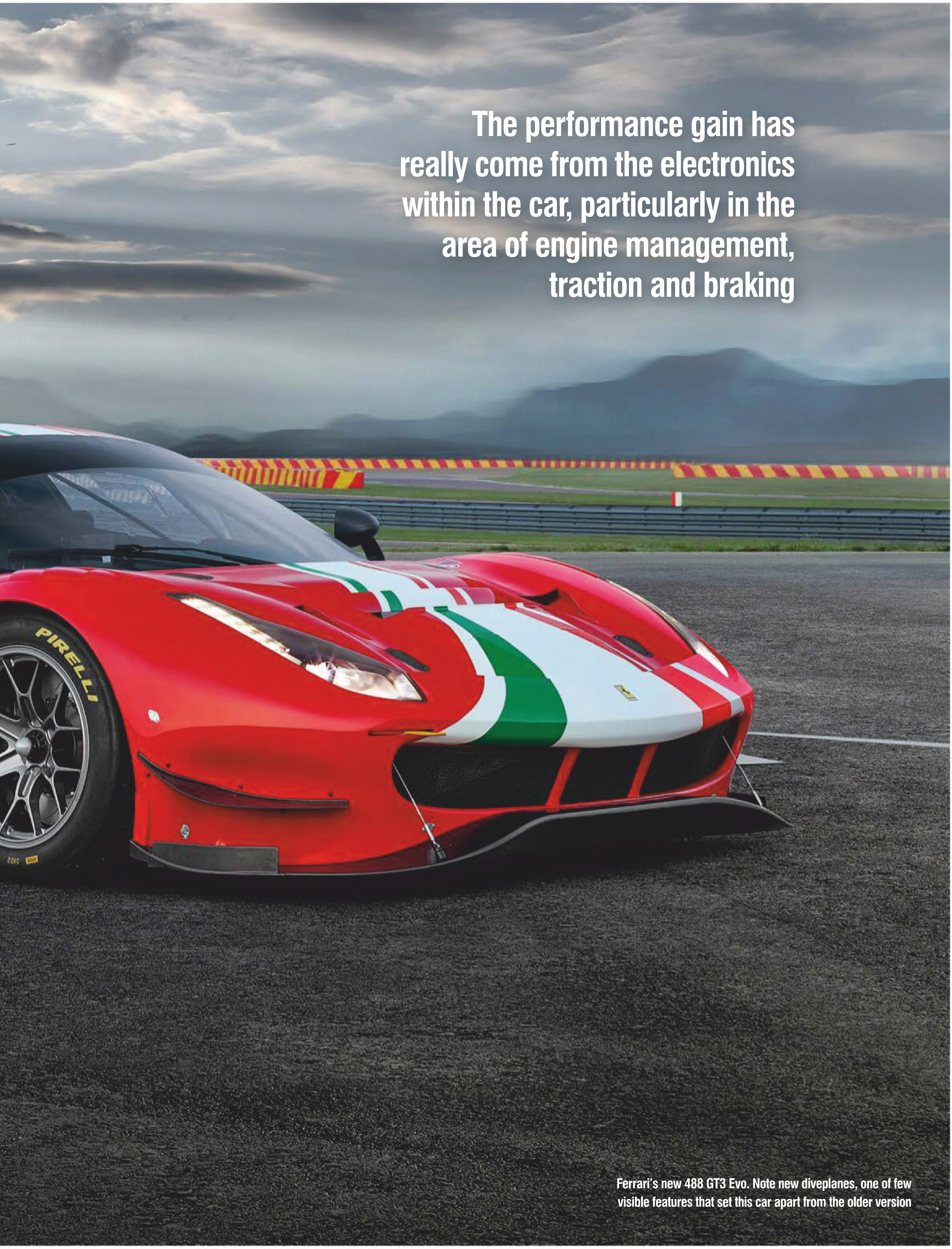
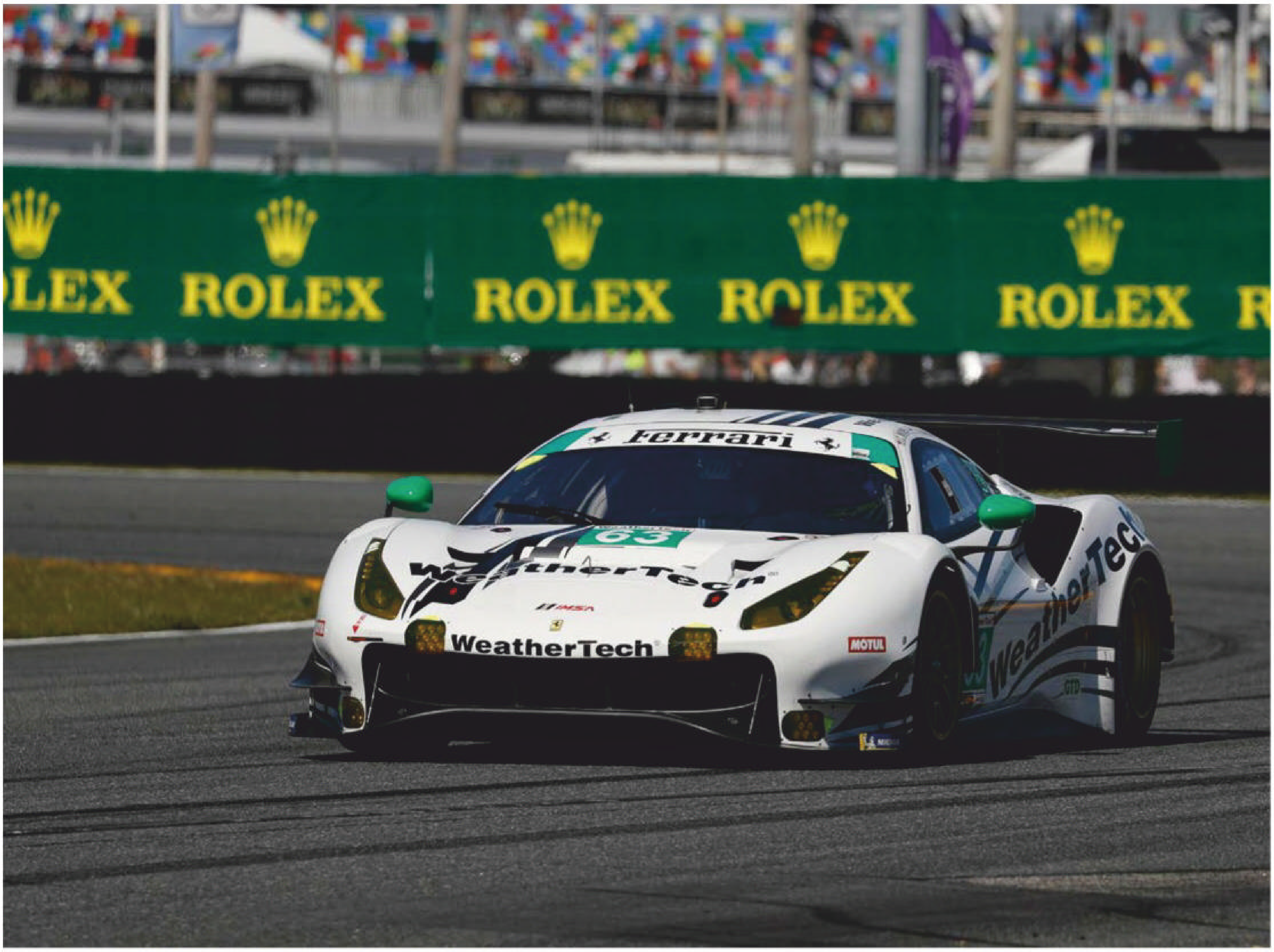


Ferrari's new 488 GT3 Evo. Note new diveplanes, one of few visible features that set this car apart from the older version



The 488 Evo has already made its race debut, at the Daytona 24 hours in January, where it finished on the podium. Ferrari believes that this new car is ideal for customer racing

Unlike the newer cars of many of its rivals, the difference between Ferrari's GT3 Evo version of the 488 and the 2019 version is not immediately obvious. In fact, a squint at the front bumper and front wheel arches will give the only external visual clues that this is a new car, a dive plane inserted into the recess in the bumper ahead of the front wheel while at the rear of the front wheel arch there is some wind tunnel-inspired trickery that was designed to increase frontal downforce. Other than that there is little to give the game away.

The reason for this curious lack of external change is that, according to its head of GT Track Car Development, Ferdinando Cannizzo, Ferrari itself was struggling to figure out what to do in order to update the original car. The previous model was already performing well, was close to the edge of the 'performance windows' specified by the FIA and had come close to winning titles. In terms of overall performance, there was little that the design team felt that it needed to do.

As is the case with all GT3 racecars these days, driver comfort was a key theme during the development of the 488 Evo

The reason for the lack of change externally is that Ferrari itself was struggling to figure out what to do in order to update the original car

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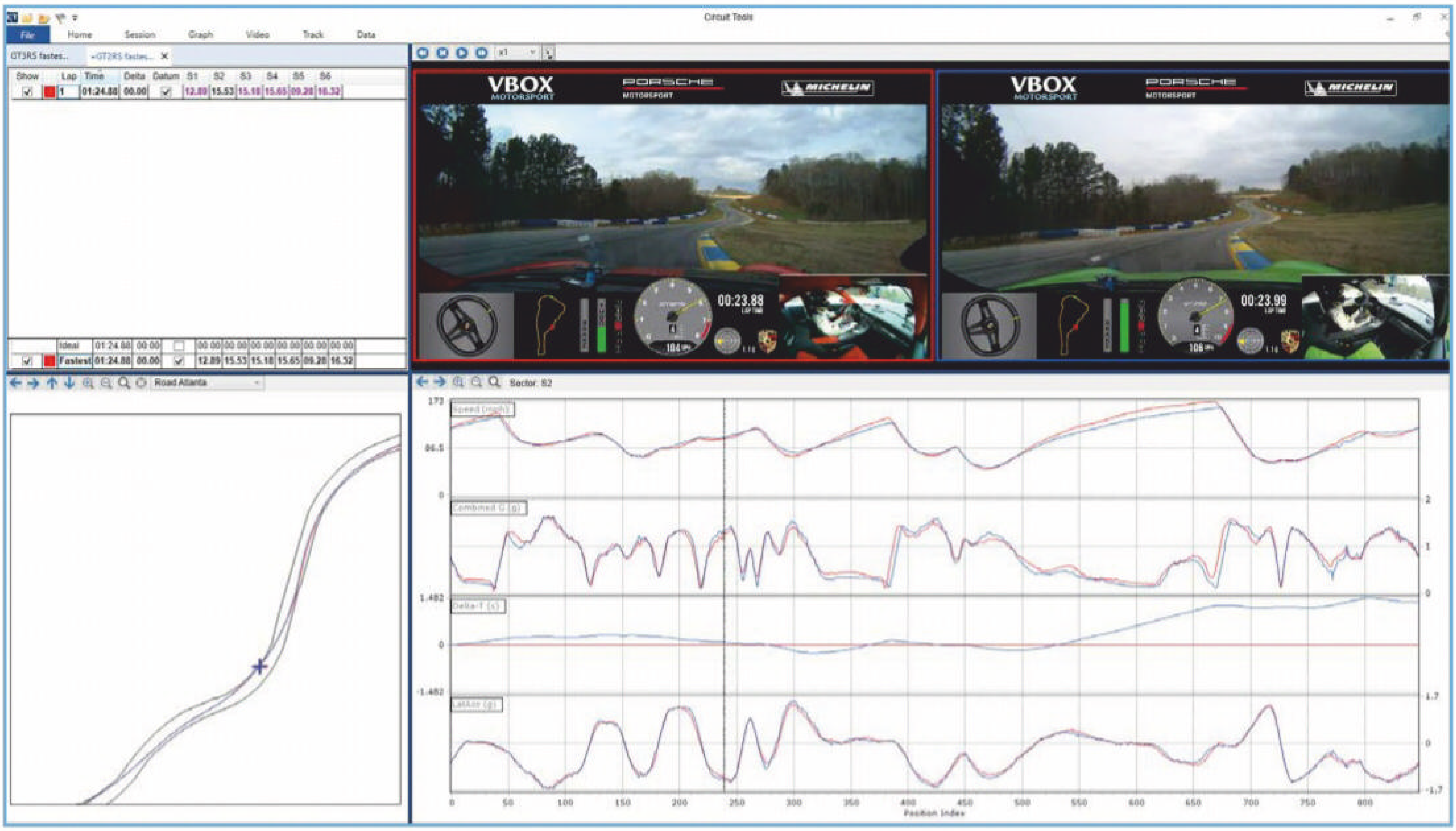

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‘We tried to find a new theoretical aero map that would give us the possibility to follow the other racecars more closely’

Yet, as always in racing, it turned out there were a few tweaks that would improve the car, after all and Ferrari, of course, decided to get stuck in. In doing so it has created a car that is easier to drive, better to race and above all, quicker. Ferrari hopes this will convince customers to part with cash to upgrade their existing car or, better still, buy a new one.

Changes to aero configuration improve the balance and make the car more raceable, particularly in traffic, while improvements to vehicle dynamics and cockpit ergonomics make it easier for the driver to compete over long distances, which can be up to 24 hours at Intercontinental GT races such as Spa.

But the performance gain has really come from the electronics within the car, particularly in the area of engine management, traction and braking, and Ferrari hopes that this will also help the car perform better in the wet.

Comfort zone

Because of the tight constraints of the GT3 regulations and the balancing of performance, all manufacturers involved have focused on improving driver comfort. This seems to be the antithesis of a racing car; a driver should put up with any discomfort that would get in the way of performance. However, in today's customer-focused world racecars are designed for the amateur driver rather than the professional, which has led to some rather dull updates that involve moving switches in the cockpit and so on. Ferrari has done something similar, proudly announcing that it has cut 2.4kg from its driver seat and not only that, but it has also developed an extra-large seat (XL) for the 'taller' driver.

Thankfully, however, Ferrari did also go for improved performance, but not in a conventional way, for while it piled on the downforce at the front, it also had to take it off

Some of the more obvious aerodynamic development on the 488 Evo can be seen in the area behind the front wheel arch

Ferrari's GT future

Ferrari plays an active role in the Technical Working Group that is deciding the future of endurance racing – including the amalgamation of the top prototype class (see page 88) – and it says that it will review its racing strategy in the future once the landscape becomes clear.

Currently the new GT3 regulations, set to come into force in 2022, will see the cars built to a technical rule book, and teams are looking at the possibility of the cars competing in the World Endurance Championship and at Le Mans. This would replace the GTE category, which currently features Corvette, Ferrari, BMW, Aston Martin and Porsche.

In GT3 there are more than 10 manufacturers and Antonello Coletta, head of the Competizione GT department, believes this could pose a problem. He does not want a customer racing platform to enter the professional world of motor racing under the FIA's control, and believes there is not enough room for both factory and customer teams, should such a decision be taken.

'The plateau has a closed number and if you have all the manufacturers of GT3 it is complicated,' Coletta says. 'We have 13 or 14 manufacturers in GT3 and it is a difficult situation to have them all. GT3 should be in a proper championship. Now it works very well, and we have many cars [competing]. Ferrari has a GT3 and it is a commercial category. It is important that the official cars are in GTE and customers in GT3.

'The politics of our competitors is different,' Coletta adds. 'We see manufacturers in GT3 and we have in front of us very many official cars from Mercedes, Lamborghini and Porsche, but this is a different philosophy. If the cars come to Le Mans this is another matter.'

Ferrari firmly believes that, should the Hypercar category adopt LMDh regulations, as will be announced at Sebring mid-March 2020, the GTE category will perish anyway as Porsche, Ferrari, Aston Martin and BMW would all consider stepping up. 'If we go ahead with a new platform, the GTE will die,' says Coletta. 'It could be that GTE Am will continue for two or three years … The press conference in Daytona [to announce the new regulations] was very important, but a first test to understand the [opinion] of all the manufacturers. Now, we get the important meeting to decide the best for all the world.'

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again in order to stay within the performance windows in which all GT cars are balanced.

'We tried to find a new theoretical aero map that would give us the possibility to follow other cars closely, and so facilitate overtaking, and reduce quite a lot the sensitivity to ride height change mainly at the front,' Cannizzo says of the new aero configuration. 'This was done by narrowing the front part of the door. If you look at this part of the car, behind the front wheel it is really narrow. This gave us the possibility to extract the flow from the splitter in a much more consistent way, so that any variation of the ride heights is dampened by this flow-field behaviour which is much more stable.

'We changed the design, narrowed the door, and the winglet behind the wheel, and completely changed the size and shape inside, and the direction of flow under the louvres,' Cannizzo adds. 'The top part and rear of the bodywork around the arch design was completely changed, which gave us a more consistent flow field around the car.'

Give and take

Following the increase of downforce, thanks to better air flow through the wheel arches, and the introduction of the diveplanes, Ferrari then had to take the unusual step of reducing downforce from other areas of the front of the car. It might sound counter-intuitive, but there is some sound reasoning behind this.

'We gained downforce at the front, but with the modification to the splitter under the car, removing some turning vanes we could tune the car in a proper way,' Cannizzo says. 'All of these modifications at the rear of the wheel arch was to increase the downforce, but the FIA said that there was the limit, and that was fair enough. So, if this is the limit, I now have an average of the aero map which is closer to the edge of the limit. The car is closer to the edge rather than travelling into an area where the aero is not performing so well.'

In the cold and often wet conditions during the night at Spa, Ferrari GT3 drivers may appreciate this effort

Reducing the number of turning vanes under the splitter meant the car had a more stable aero balance and is now less sensitive to ride height changes which should, in theory, help amateur drivers with set-up. A change to the front suspension has also aided the anti-dive characteristic of the old car, which has further helped with the overall handling. In the cold and often wet conditions during the night at Spa, Ferrari drivers may appreciate this effort.

The convergence talks some years ago, which aimed to bring the technical regulations of the professional GTE category to GT3 cars, famously failed, but that didn't stop Ferrari building a 'convergence car' anyway, sharing the chassis and much of the mechanicals between the cars it has competing in the two classes. And with the GT3 Evo this has continued. Stephane Ratel, the promoter of international GT3 racing, was afraid that bringing the GTE and GT3 regulations together would increase the cost of his GT3 cars and so nixed the idea of convergence. Now Ferrari has almost proved his point, with its GT3 car costing in the region of €600,000, more than many of its rivals' products.

TECH SPEC: Ferrari 488 GT3 Evo

Engine
Twin turbocharged 90-degree V8, 3.9-litre with VVT; maximum power, 600bhp at 7000rpm; maximum torque, around 700Nm at 6000rpm (power and torque BoP limited).

Brakes
Front, 390mm x 35mm; rear, 332mm x 32mm; new ABS system.

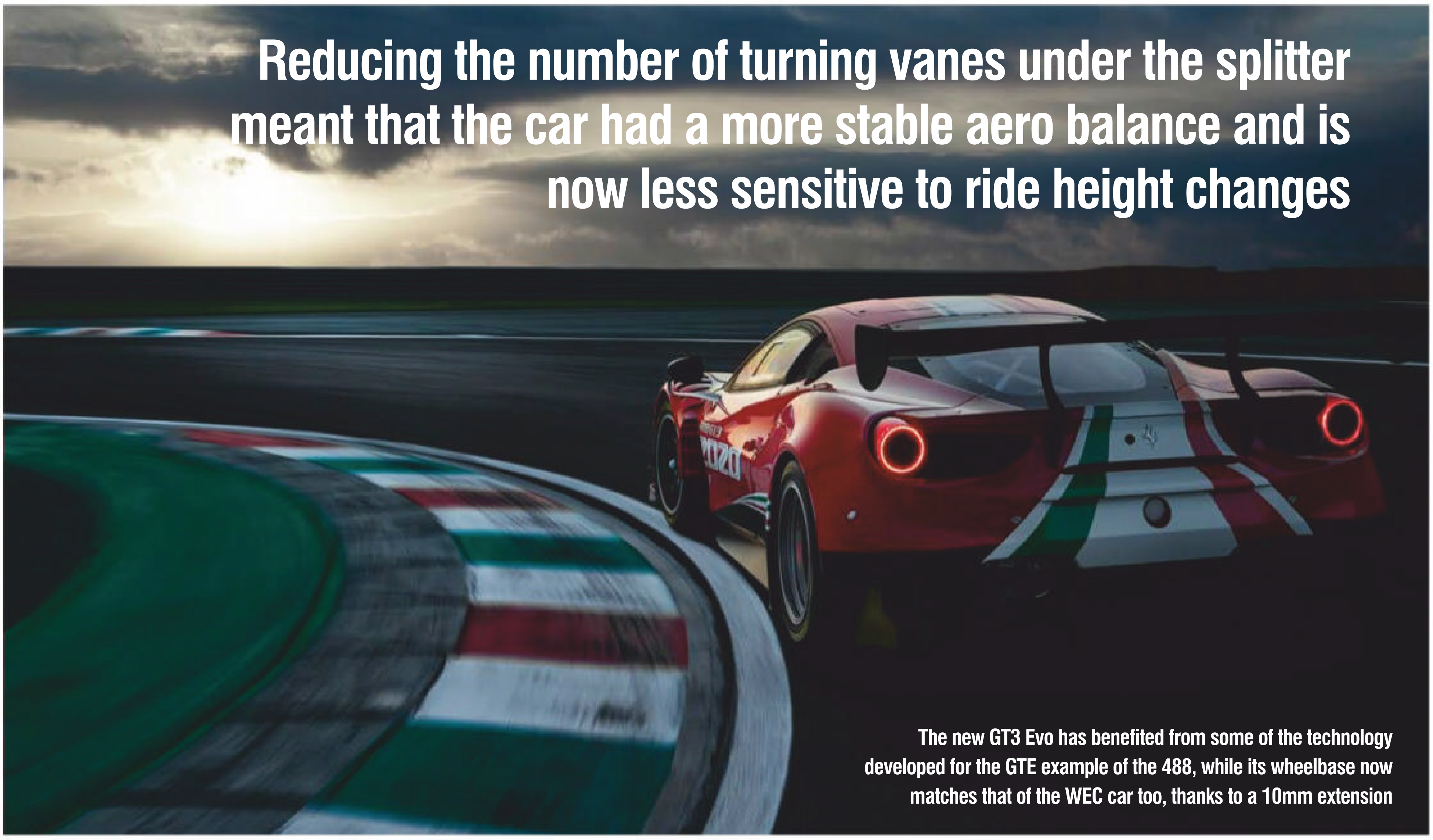
Tyres
Front, 30/68/18; rear, 31/71/18.

Dimensions
Length, 4633mm; height, 1090mm; width, 2050mm.

Weight
1260kg (BoP limited).

GTE influence

A change to the regulations several years ago allowed Ferrari the opportunity to further integrate its two designs in this Evo. The rear suspension has been modified, with the wheelbase lengthened by 10mm so that it matches that of the GTE car. Now, the only changes that are needed by a customer to switch between the two classes are the bodywork – which is far more constrained by the regulations in GTE guise – the powerplant – back to a road-car based engine rather than the air restrictor special of the Le Mans car –



Reducing the number of turning vanes under the splitter meant that the car had a more stable aero balance and is now less sensitive to ride height changes

The new GT3 Evo has benefited from some of the technology developed for the GTE example of the 488, while its wheelbase now matches that of the WEC car too, thanks to a 10mm extension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and the ABS system. Ferrari tells us that many race teams have already made this switch between classes with its previous GT racecars, but now that the rear suspension is identical they should find the process even easier.

The ABS system is all-new on the Evo version of the Ferrari and is part of a major electronics overhaul across the car. 'On this car we have a new ABS, new engine control and new traction control, all brand new,' says Cannizzo. 'The ABS relies on the new Bosch M5 motorsport hardware but most of the work was on the strategy. The hardware was able to take into account many different parameters, the old one only the longitudinal [forces on] the car, but the new one also combines corner entry [which includes lateral force too].'

The traction control system was also developed on the GTE car and has now been introduced to the customer version of the 488 for the first time, while Ferrari also worked hard on the engine management system to improve throttle response. 'On the engine control we completely changed the model on which it was based,' says Cannizzo. 'The result was more precise control of the engine, so the link between input and output is more direct. In the past, we had something good, but sometimes we were lacking [immediate

The ABS system is all-new on the Evo version of the Ferrari and is part of a major electronics overhaul for the car

response]. The dynamic of the input meant that in reaction to the pedal the engine did not respond as the driver expected. Now it is so impressive how direct this link is. This gave us quite a lot in terms of performance, because the drivers had more confidence in the car.'

Traction control has also been improved, helping the drivers on the exits of the corners, but these are fine details that could be expected of a balance of performance car.

Endurance kit

Ferrari also provides an extra endurance package, which includes a new front bumper, quick-fill couplings for engine oil and coolant, carbon-fibre clutch, brake calipers adopted from the GTE car and steel wheel nuts. It also offers sensors for the coolant levels and refuelling completion with warning lights, and Le Mans-type 4500 lumen LED main headlights housed within the new sculpted front bumper.

Ferrari will hope that this new racecar will sell well before the new GT3 regulations kick in for 2022 and that the changes it has made will give its customer teams the competitive edge they need to compete at the highest level. But it has a tough job ahead of it, with victory at the major races still eluding the GT3 version of the 488, against what must be acknowledged to be pseudo-factory teams from other manufacturers.

Yet Ferrari's philosophy is resolute; not to race against its own customers, and that has led to a results sheet that does not do justice to the car. 'In the GTD/GT3, our idea is that the category is not for the official team,' says Antonello Coletta, the head of the Competizione GT department at Ferrari, which is responsible for all racing activities outside Formula 1. 'If we organise an official team in GTD, we kill the chance of the [privateer].'

Ferrari has therefore focused its factory efforts on its GTE programme in the FIA World Endurance Championship.

Rising to the Challenge

Ferrari's 488 Evo Challenge car has benefited from a raft of aero updates

Ferrari has also launched the latest version of its Challenge car. This is the series that actually accounts for the bulk of its customer racing activities.

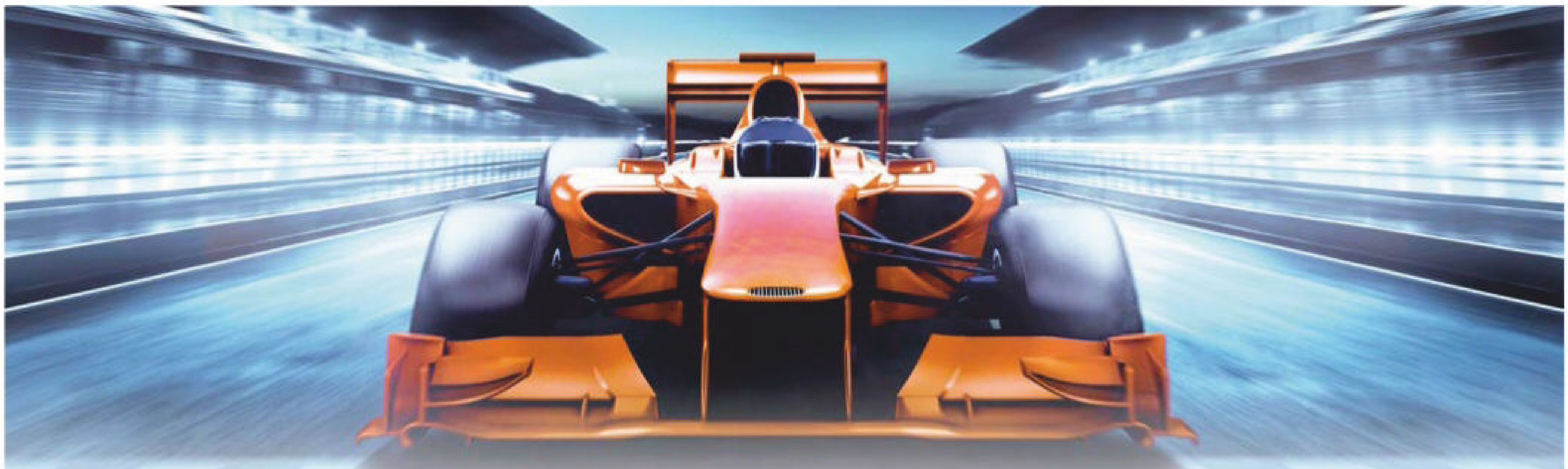
The Ferrari Challenge started in 1992 with the 348 and progressed through the 355, the 360, 430, 458 and now the 488.

The Evo had three major targets: to perform to a higher level than its predecessor; to be more consistent, and to be comfortable for the driver.

The performance target was a second a lap improvement at Mugello, and for this Ferrari has increased the downforce substantially, largely through fitting new front and rear bumpers, developing a new undertray and also a re-profiled rear wing. Meanwhile, balance was shifted 20 per cent further forwards to help to generate heat in the front tyres.

In order to improve the consistency, a new rear brake package has been introduced with thicker discs that also have a larger diameter. With the increased frontal downforce, drivers have the option of running more rear brake bias, hence the change in hardware.

Driver adaptability is improved thanks to a change to the ABS settings, with two dry settings and two for wet conditions. The price of a new Challenge car is €269,000, and the conversion kit to Evo spec is €35,000.



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Made to measure

The co-owner of Online Resources explains why its 3D scanning service has proven to be a vital tool for IndyCar in ensuring that its cars remain in an exactly correct configuration throughout the races and even an entire season

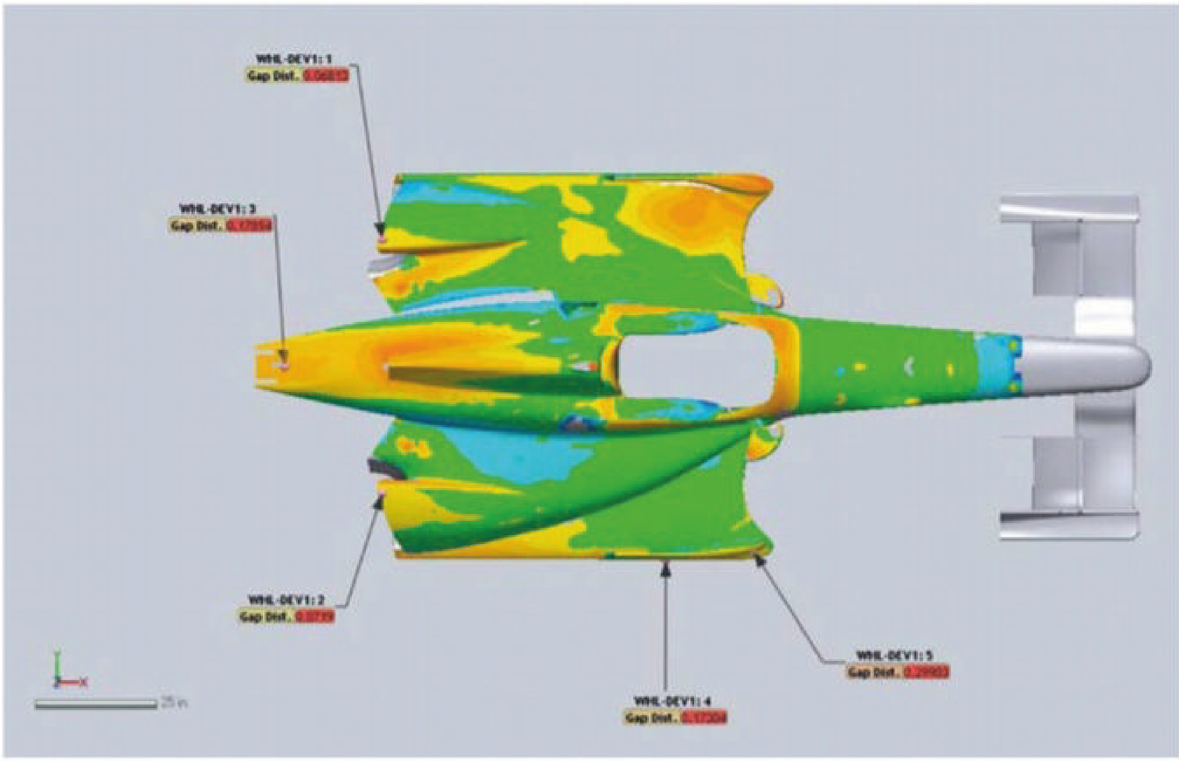
By JD SCHAUMBERG

We could confidently say we measured the entire car within the thickness of two human hairs

By 3D scanning its cars IndyCar is able to make sure they stay within the technical template throughout the season

Photo: IndyCar / Joe Skibinski

IndyCar tested the skills of Online Resources by placing a coin under the edge of this car's engine cover



This is a typical 3D scan of a racecar bodywork; the 2014 IndyCar that Online Resources first worked on

We were told an area of the racecar had been manipulated, and we needed to find this altered location

My dad, Jay, and I – owners of Online Resources Inc – were sitting in the lobby waiting for our invitation to see behind the double doors, and I couldn't help but drift back to my six-year-old self and my first memory of what is now known as IndyCar.

Over 25 years had passed since that practice day in May of 1990, when Arie Luyendyk claimed the fastest speed at 221mph. I still remember the red and blue No.30 car streaking around the track: the sights, the sounds, and the smells. I became a fan that day. It was a special time, just my dad and me, sharing what would become a passion for us both.

Our hosts arrived and my thoughts were interrupted as we were ushered into a large warehouse with a single 2014 IndyCar racecar in front of us. Our goal was to collect a digital 3D model of the car and measure it against the original design, or computer aided design (CAD). What we didn't realise was the hidden test before us, which had been set by IndyCar in order to prove our skills and equipment.

Put to the test

We were then told an area of the car had been manipulated, and we needed to locate this altered area. As we set up the 3D laser scanner we discussed the best process and got underway. My dad drove the computer and I had the $100,000 3D scanner we were using to collect the data. After 15 minutes of data collection, we compiled the scans and compared them to the original CAD design. As the IndyCar engineers looked over our shoulders the pressure was on. Trying to balance speed and quality, the report came to life. I was thrilled to see a bright red zone in a green sea of compliance; this told us we had found the spot.

But just as my nerves subsided, the director of Tech Inspection threw out a new request. 'Tell me how much of a difference that spot is,' he demanded, as he removed a coin from under the edge of the engine cover. We had achieved the speed, but did we get the accuracy needed? '0.06 inches,' Dad said with confidence.

As the director measured the coin with calipers, scepticism intact, he said: '0.062 inches, I'm sold.' He sounded slightly disappointed for not stumping us, but clearly more excited at having found a solution to IndyCar's problem. We achieved the speed it needed and kept an accuracy of 0.01 inches over the entire car. Little did we know what this moment meant for our small family-owned technology company.

Family firm

Online Resources is a small second-generation family business. Almost 30 years ago Jay and Tina Schaumberg started the company as a distributor of CAD/CAM software for CNC machines. It then grew beyond CAD/CAM and became a trusted source of many manufacturing technologies, including 3D scanning. Today it is known for its ability to collect 3D data for use in quality control, reverse engineering and automation. With a vast array of hardware and software solutions and problem-solving skills, it has become a highly respected supplier of 3D scanning technologies and technical solutions in the racing industry.

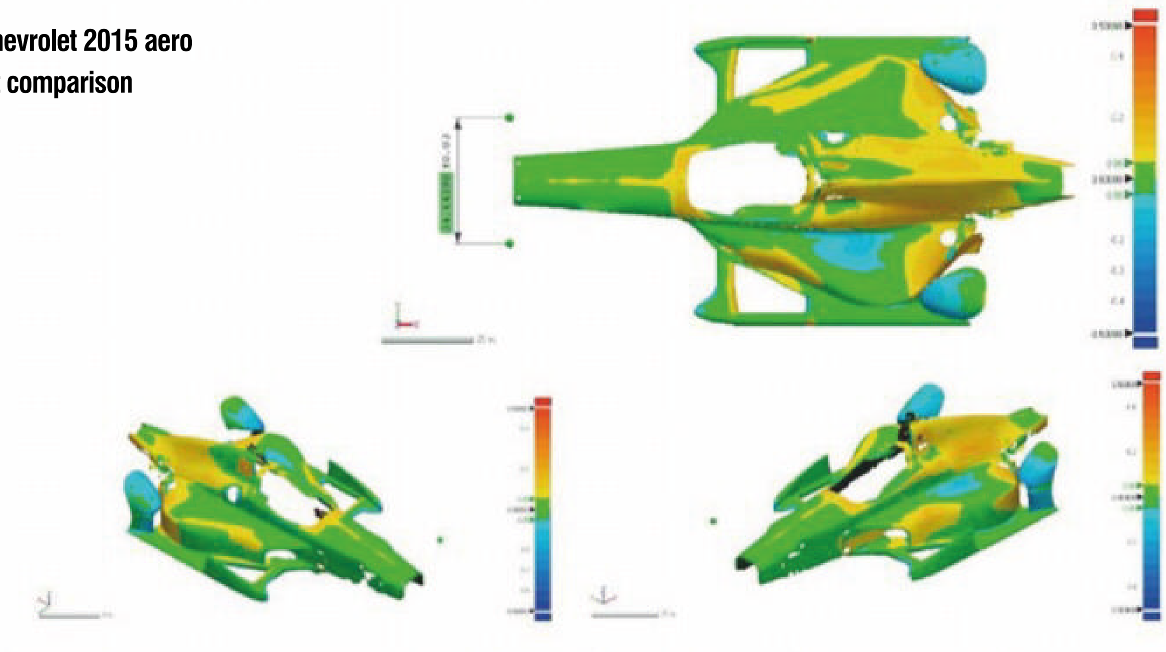
At the request of IndyCar, over the course of the 2014 season we travelled to the races testing the system in a tactical environment. The next season, 2015, would bring about a change in the aerodynamics of the cars, with Chevrolet and Honda each creating different aero kits. This would create another competitive level for the sport, but also another challenge for IndyCar technicians as to how they would oversee and monitor the new kits. The scanning system proved to be effective even in the race environment and was approved for use in 2015.

The new Honda and Chevy aero kits had up to 30 different homologated, or legal, configurations. This presented the huge challenge of making sure the corresponding configuration was correct, and that each one stayed in compliance on the track. But IndyCar now had an on-track system and software solution with the capability to collect and qualify the dimensional set-up of a racecar, and do it all quickly and accurately.

Suddenly, information previously unattainable was readily available. Questions such as the dimensional differences between hot versus cold cars, various underwing set-ups, repaired versus new parts, and many others were now able to be answered. The partnership between Online Resources and IndyCar flourished as we continued to refine this process of collecting on-site 3D data.

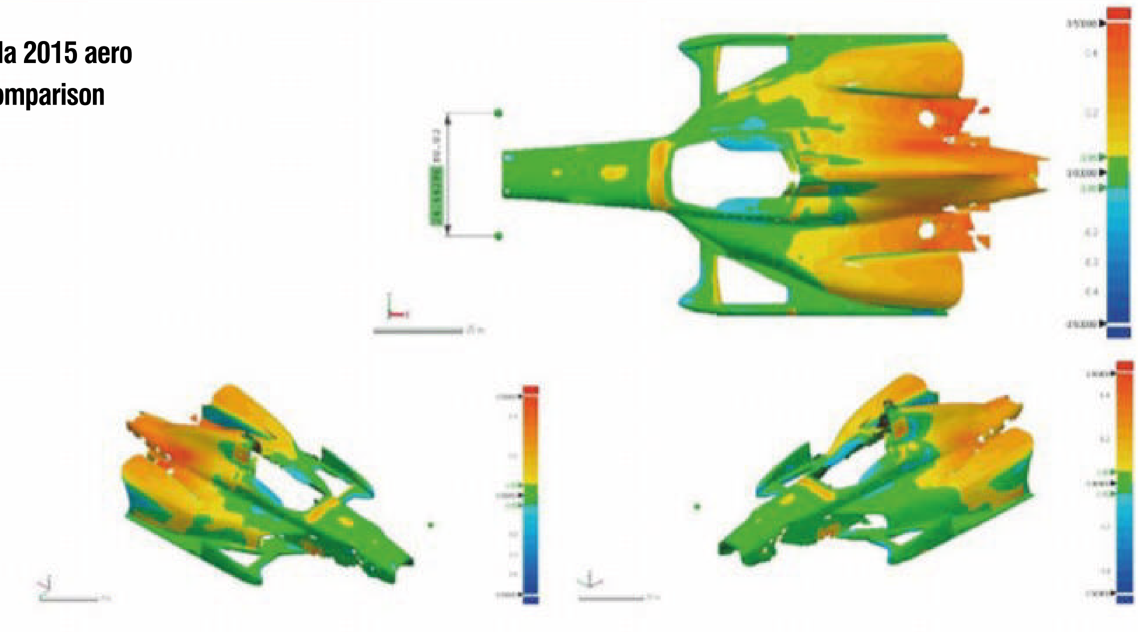
This data collection process needed to be able to identify flaws in the race configurations,

Chevrolet 2015 aero kit comparison



Name	Nominal Value	Actual Value	Deviation	Tolerance	# Of Points
Linear Dim.1	34.44398	34.44737	0.00339	±0.03	3556

Honda 2015 aero kit comparison



Name	Nominal Value	Actual Value	Deviation	Tolerance	# Of Points
Linear Dim.1	34.44398	34.4516	0.00762	±0.03	3085

but it also needed to be uniform and fair to the manufacturers and teams. Some of the questions to answer were: 1, Does collecting scan data from a team car and comparing it to manufacturers CAD represent a reasonable and accurate analysis? (data purity); 2, Do multiple scans of the same unchanged racecar yield the same results? (system and data repeatability); 3, What is the geometric difference of a racecar through one lap, one race, and one season? (car repeatability); and 4, How do we trace a racecar and all the sub-components through the life of the car? (data traceability).

Inspector gadgets

Using Geomagic Control X software, we were able to set-up test inspections. Geomagic Control X is an inspection software system which is able to overlay and compare scan data to CAD data (or even other scan data, as in comparing one car to another), providing measurable results of the comparisons by giving both specific measurements as well as colour images of the car showing areas of compliance or deviation. The combination of hard numbers with colour images allows engineers to quickly gain an understanding of the effect of sub-components to the global shape of the car. This was the first time an on-track process could collect every car pre-race with accurate metrics. As we moved forward in scanning the cars, we identified a comparison process primarily aimed at data purity and repeatability.

The single car inspection process (four alignments) consisted of: 1, Scan of car aligned to whole CAD; 2, Scan aligned to scan of the ideal car set-up (gold standard); 3, Scan of car aligned to monocoque of CAD; 4, scan aligned to monocoque of Gold Standard scan of car.

Data purity and repeatability gave us an accurate avenue to answer all of our other questions. The first research step taken was car

As we moved forward in scanning the racecars we identified a comparison process primarily aimed at data purity and repeatability

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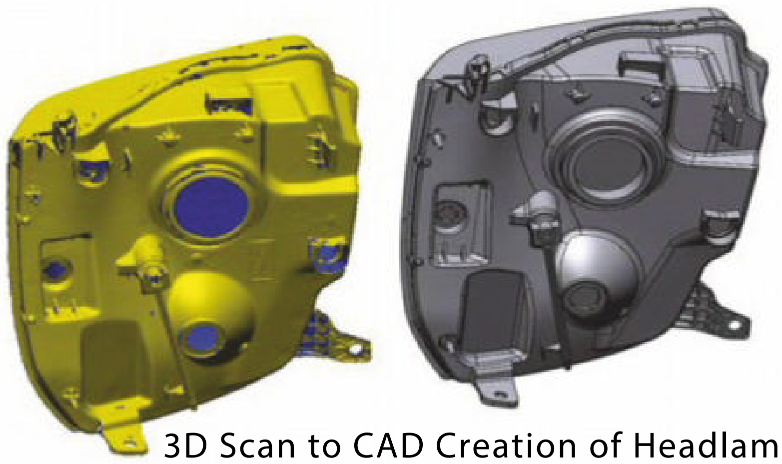
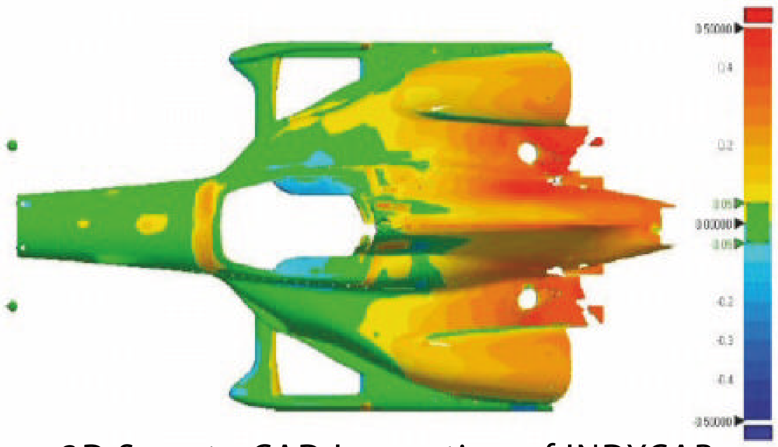


3D Scan to CAD Creation of Headlamp



3D Scan to CAD Inspection of INDYCAR

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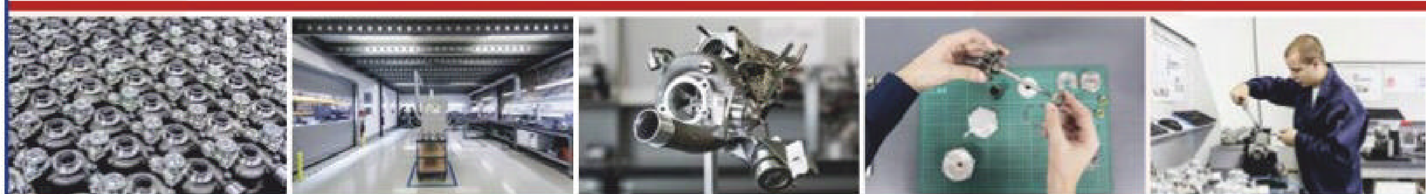

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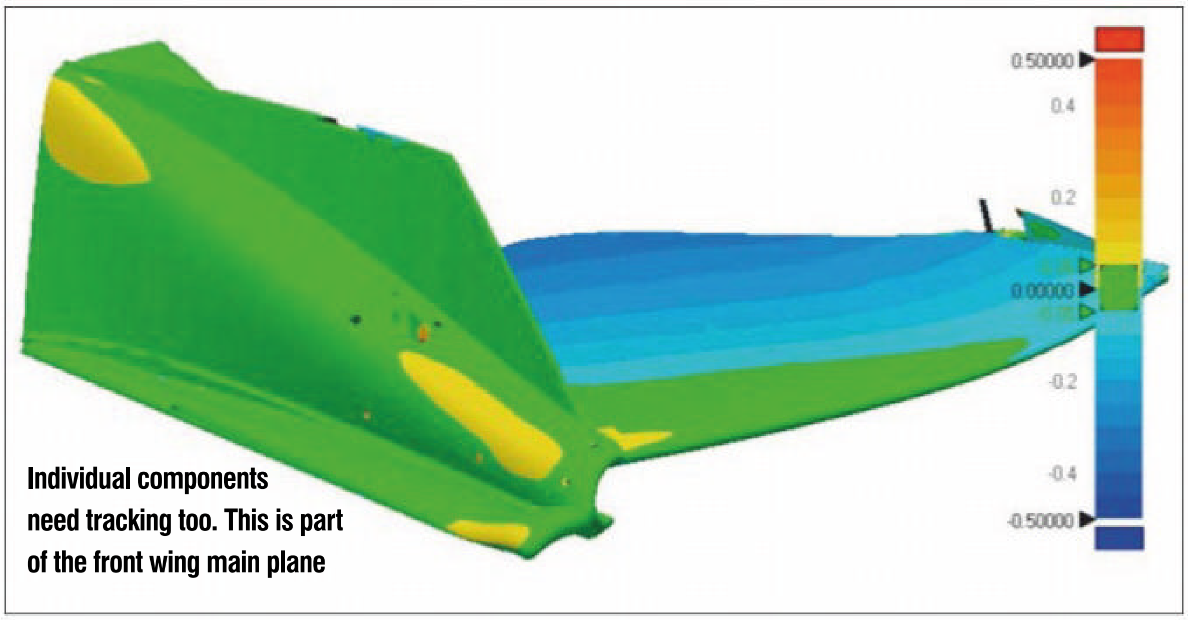
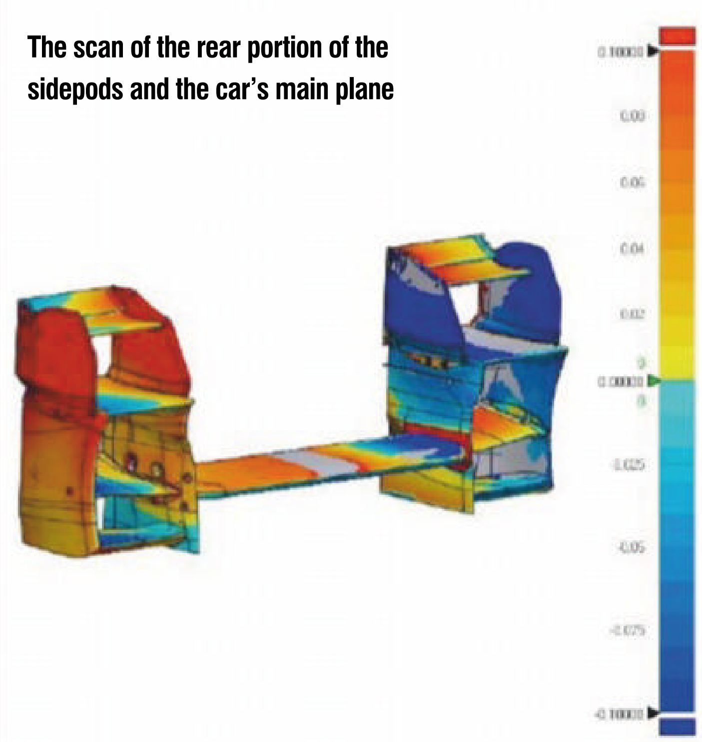
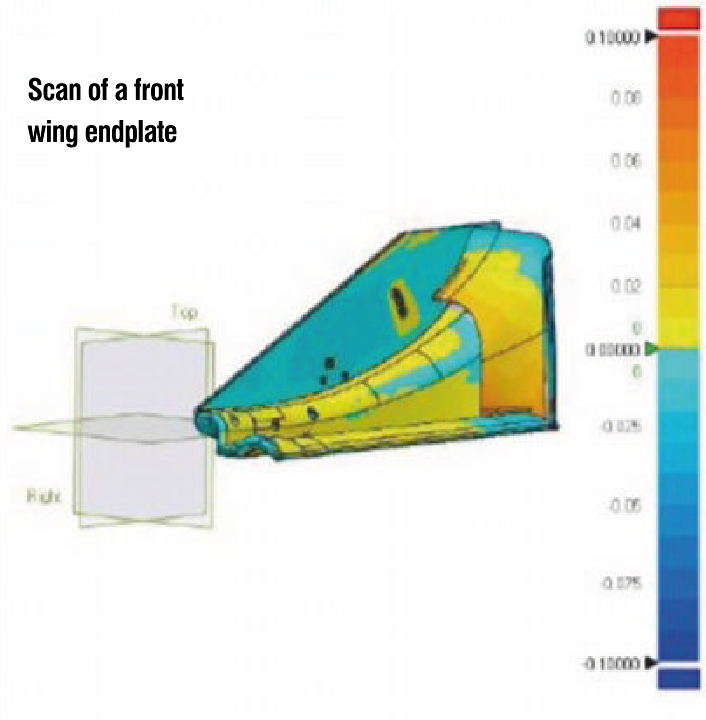


Individual components need tracking too. This is part of the front wing main plane



The scan of the rear portion of the sidepods and the car's main plane



Scan of a front wing endplate

repeatability. The main concern was if a 'hot car' would change shape, and the month of May at Indianapolis was a perfect time to test this. We ran the single car inspection process on cars after one lap, full test session (five to ten laps), and a whole race. The results showed very little movement, a testament to the integrity and stability of the racecars and set-ups.

Racer tracer

The first challenge of data traceability was one of data size. We were collecting over 30 gigabytes of data in just one pre-race inspection. Through a network of computers transferring files back and forth in real time we were able to quickly manage and archive over 200 data sets each race. All the images from each car, at each race, were organised chronologically. At the same time all the numerical results were collected and presented in a linear graph format. This gave IndyCar the ability to see changes in any specific measurement of a racecar throughout the season, as well as the global geometry change of a car throughout the season.

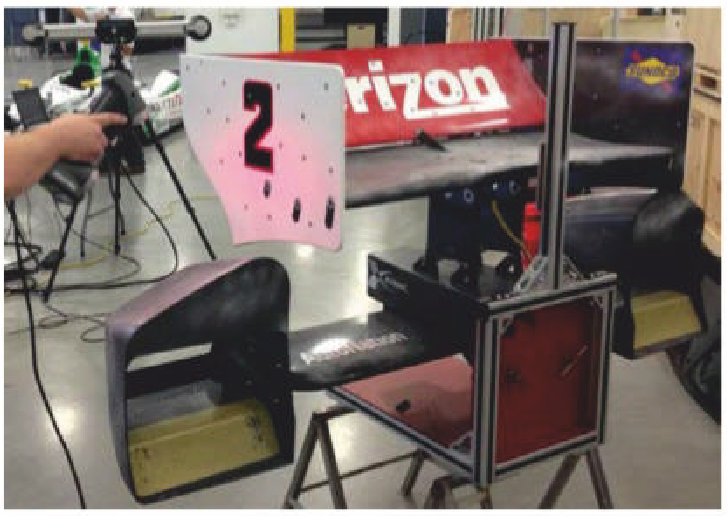
The second challenge of data traceability was how to track each sub-component of a racecar throughout the season. As the teams switched a front wing, rear wing or made fixes to wrecked components, we needed to track those sub-components in the same fashion as the global view of the car.

A car could have up to eight different body sub-components on a single chassis. To add to the complexity each of the eight sub-components were not tied to a specific chassis. Each time a chassis came through inspection the sub-components needed to be identified and tracked in a seasonal comparison to the chassis and the parts themselves. This led to a global and numerical traceability need for the racecars, and sub-components.

The second challenge of data traceability was how to track each sub-component of a racecar throughout the season

3D scanning with the first generation Creaform Metrascan 210

A Gold Standard car, shown being scanned here, is a base racecar with the ideal configuration and set-up



Scanning Gold Standard wheel pods with the Handyscan 700

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The Creaform Metrascan proved to be the perfect tool for the 3D scanning of IndyCars

The co-owners of car scanning firm Online Resources, Jay and JD Schaumberg (right), in the pits at the 2015 Indianapolis 500

Below: Scanning Alexander Rossi's 2016 Indy 500 winning car

There were several possible scanning tools with the capability to complete the job. But we found only one system which met the flexibility, accuracy, speed and ease of use criteria we needed; the Creaform Metrascan. The nature of 3D scanning relies on light, in this case a laser, to bounce off an object and back into the camera system. The overlapping areas of reflection from the two cameras allows the system to triangulate a 3D point. When millions of these points are combined, they create a digital representation of the car's surface.

The flexibility of the system was paramount. Since the cars range in colour and contrast, the scanning system needed to effectively capture shiny black surfaces, carbon fibre, as well as chrome-like wraps. Traditional 3D scanning systems rely on light reflections to collect data. When a dark object is scanned the laser is absorbed into the part allowing less reflection in the camera, this requires more laser power to collect data. When there is a shiny or reflective surface it causes the refraction of light similar to a well cut diamond, this is solved by increasing the amount of frames per second. These types of surfaces are typically challenging for 3D scanners. The Metrascan has the flexibility to adjust the power of the laser and shutter speed of the camera to overcome difficult surfaces.

It also performed in extreme weather conditions including rain and temps from 4.4degC to 43degC. In all of the different environments the scanner consistently performed at 0.005in error over the entire car. We could confidently say we measured the car within the thickness of two human hairs.

As IndyCar started to use this system as a required station of Tech Inspection we were dialling down the cycle time to complete a single car. After many discussions with IndyCar engineers, we decided that the ability to collect data while the car was rolling in the garage would be the largest time saver.

When the system was complete it could collect up to 50 million points of inspection in 10 minutes

The Metrascan allowed us to create a unique signature on each car giving the ability to calibrate the movement of the car and scanner to give data points with an accuracy of 0.0025in. When the system development was complete it could collect up to 50 million points of inspection within 10 minutes.

Measure of success

Jumping forward to May 29 2016, I was standing on the front straight at the Indianapolis Motor Speedway. Still in awe of the 'greatest spectacle in racing' I took in the spectacular start of the 100th anniversary race, and then quickly made my way back to the engineering trailer. As my dad and I sat down with the IndyCar engineers to review the data, Arie Luyendyk joined us at the workbench. It wasn't until this moment that I truly embraced where we were. My larger-than-life childhood hero was sitting across from me having a casual conversation, and my dad and I were some place that neither of us would have imagined over 25 years before.

I still have the same awe as my six-year-old self, but my fascination has grown. I now have an even greater appreciation of the technical and engineering marvel created by the people and teams of IndyCar. Little did my dad and I know that the journey we started one day in May of 1990 at the IMS would continue some 30 years later; a small family-owned company making a big difference in IndyCar.

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Drive to survive

Racecar's deputy editor, a former tyre engineer at Manor Racing, recounts the incredible tale of how the F1 minnow was able to race on in 2015 against almost insurmountable odds – including the crucial role this magazine played in the story

By GEMMA HATTON

The story of Manor Racing began in Monaco, 2014, when the team was still known as Marussia. At that race Jules Bianchi drove superbly to finish ninth; scoring the team's first ever F1 points. This put it ahead of both Sauber and Caterham in the championship, in ninth, a position it would retain until the end of the season. Which meant some all-important prize money.

'Up until that point the team had raced for five years without any major funding from prize-money,' says Graeme Lowdon, former CEO of Marussia. 'Smaller teams were spending around $120m per year to go racing, but we were having to find virtually all of that through sponsorship because the prize money we were getting was just a nominal amount. Larger teams were probably generating the same amount of sponsorship but, combined with their sizeable prize money allocation, they could spend significantly more to maintain their competitiveness. It was a difficult cycle to break because we were actually having to find the same amount of sponsorship as the bigger teams, but we weren't benefiting from the ability to spend that on developing the car. Due to the result in Monaco we were finally in a position where we would get paid a significant amount of prize money in 2015, so our business forecasts were literally transformed overnight.'

Jules Bianchi is hugged by Graeme Lowdon after scoring two points at Monaco in 2014. Without the prize money this entailed the team might not have been saved after it went into administration

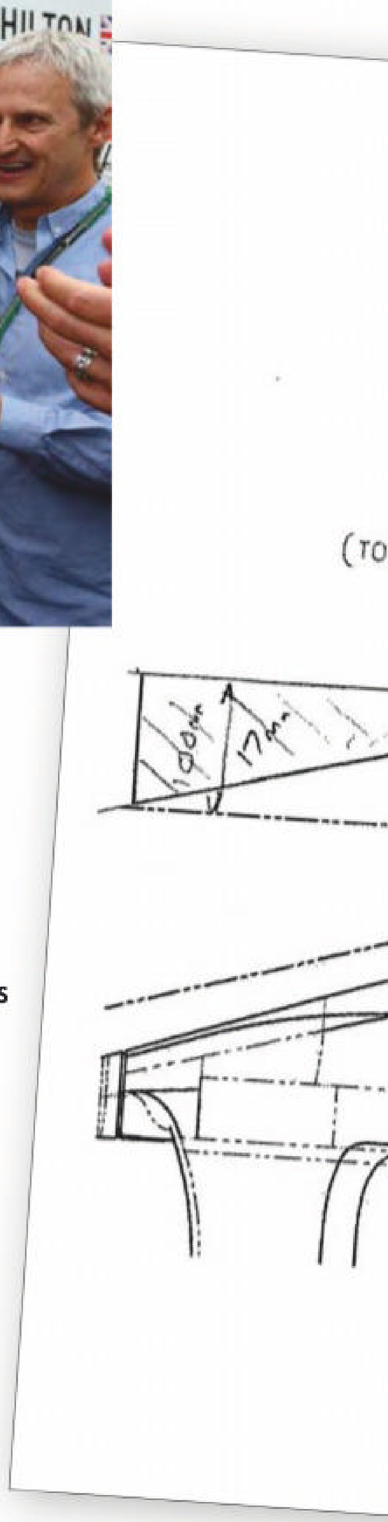
Tragedy in Japan

But after the highs of Monaco came the lows of the Japanese Grand Prix, where the team's hero Bianchi was involved in an ultimately fatal accident which devastated both Marussia and the entire racing community. To make matters worse, the first Russian Grand Prix was held a week later, and after this Marussia's main shareholder withdrew from the team, taking several sponsorship contracts with him. This left Marussia facing a phenomenal financial challenge if it wanted to keep racing.

'There was a very, very strong desire for the team to keep racing for financial, emotional and straightforward business reasons,' Lowdon says. 'Firstly, having those points on the board and that prize money made a huge difference in terms of the potential income for the team and the effect of that should never be underestimated; it is a game changer. Secondly, people forget that the teams that came into the sport in 2010 [as Manor did as Virgin Racing] had a very unique challenge where they had to develop and own all of their technical IP, nothing could be bought-in. We had to design and build everything and this takes an enormous amount of time to mature. Haas benefited from a major positive change in the regulations a few years later which meant that a new team could come in already armed with parts from other teams, reducing the time it takes to get a competitive car, but this was not available to us. So, despite our financial situation, we had already developed the IP and were starting to close the gap to the other teams.

'There was a very, very strong desire for the team to keep racing for financial, emotional and straightforward business reasons'

'Thirdly, there was an extremely strong emotional commitment because of the achievement of Jules in Monaco,' Lowdon adds. 'The close knit environment of the team meant that everyone felt that they had worked so hard for years to finally achieve that ninth place in the championship and Jules had played such an enormous part in achieving all that. We felt it would be a complete waste if that whole legacy was lost completely. So there was an extremely strong desire that the team should continue.'



Some of the freight from the aborted Abu Dhabi trip. The auctioneers decided to leave this out of the first auction, which meant the team retained all the necessary kit to go racing

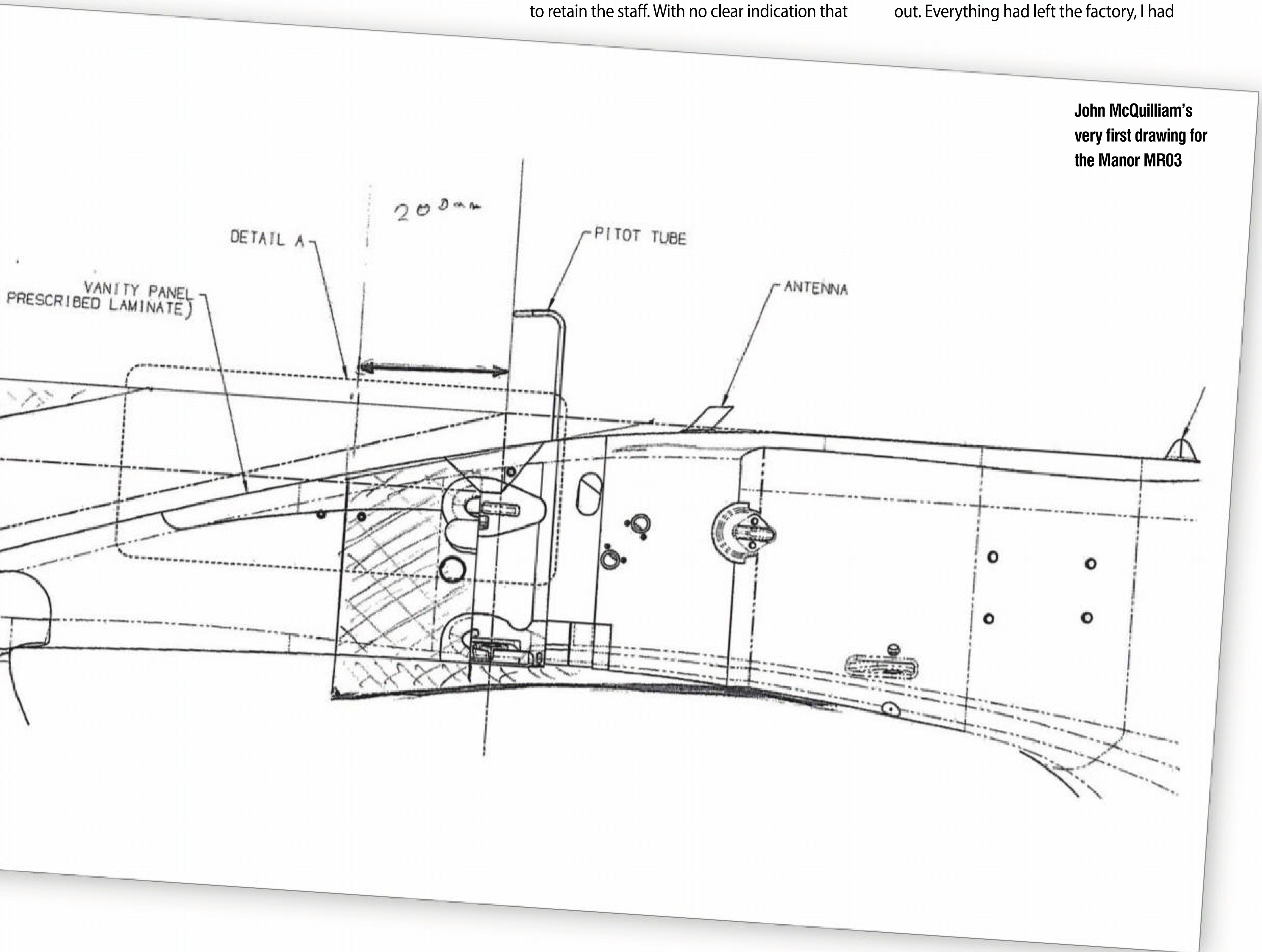
To help secure the team's future, Marussia appointed administrators on the 27th of October 2014, four days before the US Grand Prix. Geoff Rowley from FRP administrators, along with Lowdon, continued to hunt for a rescue plan. 'Appointing administrators provides the company with some breathing space where it can protect itself from creditors whilst restructuring its affairs to hopefully continue for the general benefit of all the creditors,' Lowdon says. 'It was our strong view that the best solution by far was to protect and rescue the original company. This is usually the best result for administrators in any situation, but particularly in this one. Geoff had the responsibility of getting the best result for the creditors and there was no guarantee that the company would survive, so it was a race against time to try and find a new investor.'

Drastic measures

Sadly, one of the first jobs of an administrator is to assess whether it is better for the creditors to retain the staff. With no clear indication that the company would survive, on 7 November the majority of employees were made redundant and an auction was planned.

Meanwhile, there was still an F1 season going on and by this point Marussia had missed the US and Brazilian GPs. While the commercial agreements in place at the time allowed a team to miss up to and including three race events without losing its entry (and therefore the prize money), there were still financial penalties for any race weekends missed, so Marussia's attention turned immediately to Abu Dhabi, which was on 23 November.

'We found somebody who agreed to inject some funds into the team, sufficient enough for us to be able to race in Abu Dhabi, and so the next few days were absolutely manic,' says Lowdon. 'We had to scramble around and get all the staff back, whilst ensuring all the equipment was packed and freighted to Abu Dhabi, as we had missed all of the shipping deadlines. We had huge support from Ferrari [its power unit supplier] who had already sent their engineers out. Everything had left the factory, I had



John McQuilliam's very first drawing for the Manor MR03

'It was four months of endless problem solving, whether that was financial, commercial, technical or regulatory'

packed my bag and was leaving for the airport when I received the message saying that the investor could pay some, but not all, of what they had committed to pay us. But that simply wasn't good enough for us, because under the terms of the administration we couldn't spend the money to go racing unless we had all of the costs fully covered. It was extremely disappointing and very frustrating.'

Fighting back

After this brief glimmer of hope, Marussia's future was looking extremely bleak, but this didn't stop Lowdon. 'I felt committed to the team and when everyone was made redundant I continued to work, unpaid, to try and find a solution, whilst representing the team in any necessary meetings. I had to ensure that everything possible had been done to try and find a solution to save the team.'

Consequently, Lowdon attended an F1 commission meeting in Geneva on 25 November, where the powers that be discussed the general state of F1 – it's worth remembering that Caterham was also in administration at this time. With the technical challenge of surviving and being ready for the 2015 season increasing every day, it was suggested during the meeting that these teams could run the previous year's car for the first three flyaway races, giving them enough time to prepare a 2015 car. The response was generally positive and FIA president Jean Todt concluded that once Marussia had secured the investment, the FIA would consider this proposal.

Lords of the Manor

What followed was another intense period of trying to find suitable investors and interestingly it was the dedication of the Marussia employees back in October that helped to seal the deal. 'The majority of designers kept their heads down and kept working because there was the belief that we would be saved,' says John McQuilliam, former chief designer at Marussia. 'We had virtually finished the design for the 2015 car and we had high hopes for it because it would have been the second year with the Ferrari engine so we had optimised the packaging and we had some really innovative cooling solutions. So we had designed this racecar, which was a step improvement compared to 2014, and some pictures of the wind tunnel model had made it into an article in *Racecar Engineering* magazine [V25N02]. Stephen Fitzpatrick, who is a big fan of motor racing, read the article and wanted to see if he could help us build and race that car.'

When the deal looked like it was going in the right direction, Lowdon then wrote to the FIA requesting the possibility to explore the opportunity of running a 2014 racecar in 2015, explaining that this would make life easier for the team, but this was not the only solution available to the team to help it survive.

Manor worked miracles to not only survive but also get a legal car to Melbourne for the start of the 2015 F1 season

In the meantime, Marussia had to keep its entry alive for the 2015 season and the deadline for paying the entry fee was looming. 'Clearly the administrator was not in a position to justify paying the entry fee of over half a million dollars from any funds they had because it was a complete gamble,' says Lowdon. 'But equally, if it wasn't paid then that would be the end of the story because irrelevant of what happens to the company, the team wouldn't have an entry. In the end my wife and I paid half, and we borrowed the rest from an interested party. To some extent that was a reflection of how strongly I felt that this was a highly attractive investment opportunity and I was absolutely convinced that we would find an investor.'

Despite this positivity the administrators still had an obligation to the creditors and there was a two day webcast auction in the middle of December. 'It was demoralising. You see everything that you have spent the last six years putting together being sold,' says Lowdon. 'But actually the fact that we had packed everything in our attempt to race at Abu Dhabi became pivotal to the survival of the team.'

With every item needed to go racing already packed in large containers, the auctioneers decided to defer selling those items to a later auction, and sell everything else in the meantime. 'So they sold a lot of old car parts and memorabilia and some of it had a lot of emotional attachment to us, but in reality we didn't need any of it to go racing,' Lowdon says. 'So we ended the year with our entry still intact, the company still alive and, actually, we still had all the equipment we needed to go racing.'

'The majority of the designers kept their heads down and kept working because there was the belief that we would be saved'

To the Manor born

By the second week of January 2015 an investor finally signed up to the team and Manor was reborn. But now the team had to get two legal cars ready for the season opener in Melbourne. The first hurdle was securing an engine, which was particularly challenging during the early years of the new hybrid era because year-on-year developments were huge. Ferrari did not have enough time to supply a 2015 engine, but it could provide a 2014 engine. The next question was, would that be legal?

'I spent a day with Charlie Whiting in Paris where we went through all the regulations,' says Lowdon. 'Charlie was fundamentally a racer as well, so although he had to enforce the rules he was very good at giving us his time and knowledge of the rules to see if we could come up with a legal solution. We found a way that the 2014 engine could be used in 2015 without having to change any of the regulations, so we then officially wrote to the FIA to check this and we got confirmation from them that it was indeed possible. That was the first major technical milestone.'

‘I can understand Force India’s point of view because the funding model in F1 only rewards the top 10 teams, so I don’t believe it was personal’

Now that this was deemed legal, the next challenge was to get a contract with Ferrari. In another F1 commission meeting in January, Lowdon approached Sergio Marchionne and Maurizio Arrivabene, who were representing Ferrari, to ask for a contract. ‘It was literally an elevator pitch,’ he says. ‘We went down in the elevator during the lunch break and I had five minutes to explain the details of the investor and the refinancing of the team. Sergio said he would give me an answer in the next 48 hours and sure enough we got our engine contract.’

By this stage Lowdon had confirmed with the FIA the legality of running a 2014 engine and he had also written to explore the possibility of running a 2014 racecar for either the first flyaways or the entirety of the season, as had been discussed at the earlier F1 Commission meeting. Crucially, Manor was not relying on this since it was aware that it would require regulation changes and McQuilliam was fully focussed on converting the 2014 cars to fully comply with the 2015 regulations.

‘At that time the FIA had decided that the high leg boxes and the high noses were no longer safe enough because there was too much potential for the cars to ride over one another which could injure the driver,’ says McQuilliam. ‘So for 2015 the new regulations included dropping the height of the front bulkhead and initially I just couldn’t see a way of doing it with our 2014 car.’

In the meantime a Strategy Group meeting had taken place, to which Manor was not invited. Statements were made to the press by Force India that the Strategy Group had decided that it was not going to allow Manor to take part in the 2015 season because they were not going to allow it to run an old 2014 car.

‘This was a shock to us because we didn’t even know that there was a meeting going on and also we had done everything that the FIA had asked of us in any case,’ says Lowdon. ‘We wanted them to consider the dispensation of using a 2014 car because it made logical sense to do so, but we certainly weren’t relying on that. John McQuilliam had already been hard at work and he was really motivated to find an engineering solution. There was some inspired thinking going on!’

McQuilliam says: ‘I can understand Force India’s point of view because the funding model only rewards the top 10 teams, so I don’t believe it was personal, but it felt personal at the time. But when I was told that we couldn’t use the old car, I was so determined to prove that we could.’

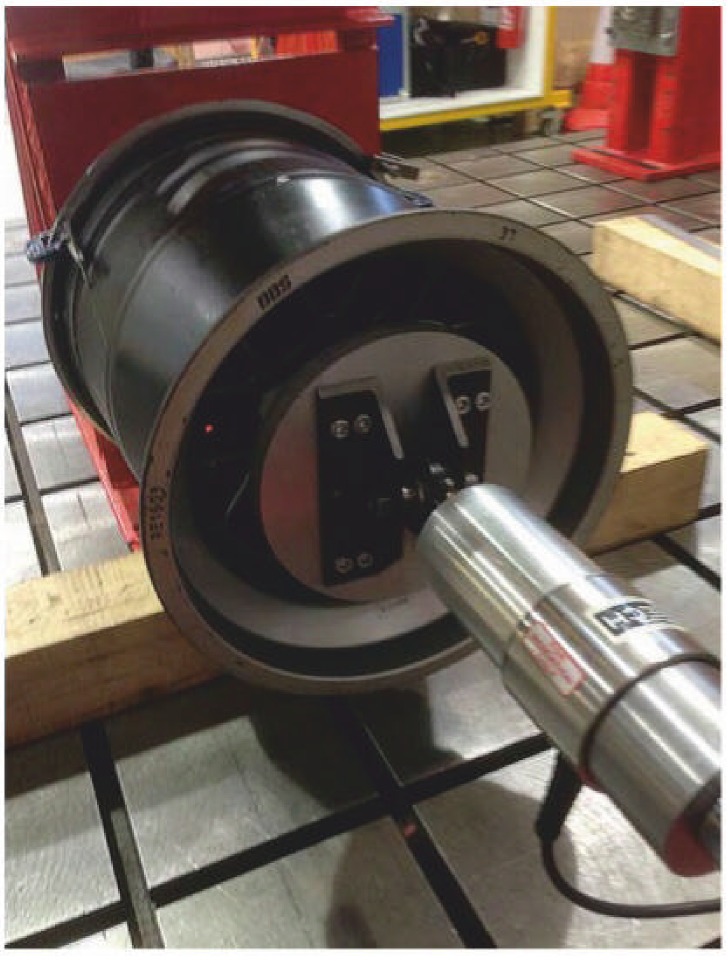
His ingenious solution was to extend the monocoque by 200mm, within which the front bulkhead slanted downwards to the new regulated height. To accommodate this, the nosebox had to be shorter, but the wheelbase along with the front wing remained in the same place. So the major tasks were only extending the chassis and designing a shorter nosebox.

Magnificent seven

At the time, McQuilliam had a full-time job and so along with some ex-Marussia designers in the evenings and weekends they worked on designing a new nosebox. Meanwhile, all the equipment was now back in the Manor offices in Dinnington, Sheffield, from which the original Formula 3 team had operated. Other than that, Manor had no facilities at all, but it did have the technical IP as well as computer servers and so could access the design of the old car. On February 13 a small team of seven people assembled in a rented office in Silverstone and committed to the project.

‘As well as extending the chassis and designing the new nosebox we had to design and build a bracing piece for the front suspension and also extend the Zylon panels on the side of the chassis,’ explains McQuilliam. ‘All that work was done with seven people. We started on the February 13 and we passed the crash tests, built multiple noses and modified the chassis ready for the first race in Melbourne. Looking back, without those five weeks Manor wouldn’t have existed for another two years. I

The 2016 car in the factory in January 2017. The team was set for its second year with Mercedes power and hopes were high, but sadly Manor folded before the F1 season started



New for 2015 was a wheel retention test; shown here at Cranfield

One of the two chassis that McQuilliam had converted to 2015 spec being prepared for the Australian GP

can't thank enough all the people that bent over backwards to make it happen, not just team members but all the suppliers too.'

A crucial addition to the team was ex-Cosworth technical director Nick Hayes, who had worked with McQuilliam at Marussia. 'At the start, the phrase John used was that he wanted to look after the car design and he wanted me to look after everything else,' says Hayes. 'My first job was to gather the information for the FIA submission, and we had one week to do it all. A lot of it was easy because we were just modifying last year's car. However, for 2015 the FIA had introduced a wheel retention test. We only had a small office and no kit, so to perform the test we designed a test using an old wheel rim, a broken hub and a nylon adapter and then we went to test it at Cranfield. It was the last day before deadline so I'd already written the FIA report assuming that it would pass, and when it did I put supporting photos in the report, drove to DHL and got it sent off. That was my first week.'

There was a similar rush to complete the crash tests for the re-designed noseboxes. 'The impact test passed first time, which is the most relieved I've ever been after a crash test,' says McQuilliam. 'We had a spare nosebox just in case, because we didn't have the benefit of much kit, so there was a little bit more variability in the manufacture than we would have liked. But when it passed, there was just myself, another designer, a new nosebox and the crashed one, all packed in my Mini driving back from Cranfield to Silverstone.'

Hayes says: 'After that it was a matter of recruiting and expanding to run a team properly and also get some kit. We managed to get some second-hand equipment from the Caterham auction to get us going and added a few essential new items as we went along. In some areas I think we probably had better kit than some of the bigger teams. In terms of the workforce I wanted to recruit people who were flexible in capability and approach. I knew that early on we would never have enough people for the jobs that needed doing if they could not jump between roles, so we made sure they could do several different jobs well. [It was] good for us and interesting for them. If there was a panic on any particular aspect, then anyone could jump on it. That was an ethos we carried on at Manor even 18 months later.'

By this time, the team had started to grow to around 25 members at the factory which the team had moved to in Banbury, while there were another 42 members of the race team, mostly ex-Marussia, who were flown out to the Australian GP. The two MR03s were put together in time for scrutineering, the cars passed, and unbelievably, Manor was ready to go racing.

Another hurdle

Unfortunately, fate intervened again. 'We got a call from Charlie to say that it looked like there might be a protest from one of the other teams,' says Lowdon. 'Although it wasn't an official protest Charlie wanted to run through everything that John McQuilliam had done to get the car 2015 legal. We literally had all the drawings spread out on the table and we methodically went through every stage of the design and John's thinking behind it. We had to call John in the UK at 3am so he could join the meeting. The conclusion was that John had come up with an incredibly elegant solution which was perfectly within the 2015 regulations.'

Whiting suggested to the team that was going to protest that it would be thrown out if it did so because it was clear Manor had done everything correctly. 'That was another one of those moments where you think you've got everything done and then you have to overcome yet another hurdle,' Lowdon says.

Looming issues

Things were further complicated by the fact that for 2015 the FIA had implemented new regulations for the ECU, the software and the wiring looms. With the car predominantly 2014 spec, this meant that all the team's own code was unsuitable to use. Meanwhile, Ferrari had upgraded its electronic architecture to satisfy the 2015 engine, and so didn't have the software to control the 2014 engine. Therefore, all the team's off-car calibration and set-up tools were also incompatible and required updating to 2015 spec. Finally, once this had been done, the Ferrari engineers could then start working through system checks and calibrations to ensure the powertrain was configured correctly. However, time was running out so despite the cars being mechanically complete and fully operational by the end of the weekend, the two MR03's did not run in Melbourne.

Chief designer John McQuilliam had come up with an incredibly elegant solution which was perfectly within the 2015 regulations

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'I'm very proud of what the Manor team delivered and it's amazing what can happen when somebody says you can't do something'

Consequently, Lowdon then had to justify to the FIA stewards that the team had 'used all reasonable endeavours' to get its cars running, and it wasn't just a case of turning up at Melbourne to tick the box to retain its 2015 entry. If the stewards disagreed, then not only would Manor have lost the money associated with that event, but it may have been thrown out the championship too. Fortunately, the stewards concluded that Manor had indeed taken part in the Australian Grand Prix and could continue its 2015 championship campaign.

'I remember coming away from Melbourne with an enormous sense of achievement even though we hadn't turned a wheel,' Lowdon says. 'It was four months of endless problem solving, whether that was a financial, commercial, technical or regulatory problem, and then we had situations like the Strategy Group meeting and protests which were just enormous distractions. But for each of these hurdles, we found a solution and I am immensely proud and will always be very grateful to everyone involved.'

Power switch

Manor completed the 2015 season and later that year confirmed an engine deal with Mercedes for 2016. This meant that it then had to re-engineer the car to suit a different powertrain, which was another technical challenge, but this time it had more than five weeks to do it.

Electronic issues stopped the Manor MR03s from running at the Australian GP but they did race for the rest of the season

During the 2016 season Pascal Wehrlein finished an impressive 10th in Austria, scoring a championship point that boosted Manor ahead of Sauber in the standings.

However, later that year at a wet and chaotic Brazilian Grand Prix, which featured five safety car appearances along with two red flags, Sauber finished ninth. This demoted Manor to 11th in the championship, reducing its prize money. Although this was just one of many reasons that the team ultimately folded in January 2017, it was a major factor in not securing future investment.

'I'm very proud of what that team delivered [in 2015/16] and it's amazing what will happen when somebody says you can't do something,' McQuilliam says. 'Manor was a great team and it was going places. The 2017 car would have been a good car too. It was the second year with the Mercedes engine so we really optimised the installation and we got as far as making the first chassis. By then we had switched from the McLaren wind tunnel to the Mercedes wind tunnel and the aero numbers were looking good as well.

'But at the end of the day when you run the numbers of owning an independent Formula 1 team it is very difficult to survive,' McQuilliam adds. 'You have to remember that we were effectively spending Stephen Fitzpatrick's children's inheritance money and I can't thank him enough for supporting the Manor team for those two years, if it wasn't for him, Manor F1 would never have existed.'

Hayes says: 'For me, the key was the people, you need to get good people and keep them motivated. You also need to be open to do things differently and not necessarily the way they've always been done. It's all about assessing the problem, figuring out how to solve it and then getting on with it. There were a lot of heroic efforts by both the team and suppliers throughout Manor's Formula 1 career and it involved some of the hardest work I've ever done in racing.'

A photo of the MR03 nose and chassis extension which was signed by the seven-strong engineering team


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Armed Escort

A modern take on an all-time classic this month, as we put a bewinged Ford Escort Mk 1 RSR in the MIRA wind tunnel

By SIMON MCBEATH

Illustrations: Simon McBeath

Above: The Escort RSR requires a strong front end if it is to achieve the target aero balance

Right: The Escort's final test figures closely matched those of Saxon Motorsport's BMW 1 Series, which we evaluated back in 2017

Our latest wind tunnel project car is the Escort RSR of Tim Foxlow, looked after by MEM Motorsport (a company well known in rally circles for producing, among other projects, the Proton IRIZ R5 WRC car).

The Escort RSR is actually one of SHP Preparations' creations, featuring a tubeframe chassis with GFRP Escort Mk 1 lookalike bodywork and, in this instance, a 2.5-litre Duratec engine with around 320bhp. This particular example is raced in a sports/saloon championship in northern England and Wales. Its owner/driver felt that it was possibly being held back by its aero package, and in some circumstances felt light at the front end.

With that in mind we headed for the MIRA full-scale wind tunnel with a couple of less potent wings and some front end parts to evaluate, because visually the car's aero package looked too rear-biased with its heavily cambered rear wing and modest front splitter.

The car's static weight distribution saw around 52 per cent on the front axle, so our aero balance target for steady state conditions was to achieve around 45 to 50 per cent of the total downforce on the front.

First run

The plan was first to map the 'as raced' wing and then try the alternative wings. However, as sometimes happens, the first run saw the plan rapidly change to a search for front downforce, because as delivered the car produced significant rear downforce but almost as much front lift. **Table 1** shows the starting figures compared to the 'best balanced', and we shall look at how this – and alternative balanced options – were divined in this and the next two issues. Note that the front lift coefficient was initially positive, and hence the balance figure (%front) appears as negative. Never good!

To put the balanced aerodynamic numbers into perspective it can help to compare them to similar types of cars we have evaluated in previous sessions. In **Table 2** are the data from the car with the nearest figures to the Escort, the Saxon Motorsport BMW 1 Series hatchback that we examined in V27N3-5, along with the Britcar BMW M3 E46 from V29N4-6 and the VW CC, the most recent BTCC car showcased in V18N7-9. The coefficients are shown multiplied by frontal area so as to be directly comparable.

Table 1: Initial and best balanced aerodynamic coefficients

	CD	CL	CLfront	CLrear	%front	-L/D
Initial	0.474	-0.202	+0.163	-0.365	-80.4%	0.427
Best	0.495	-0.447	-0.200	-0.246	44.8%	0.902

Table 2: Balanced data from comparable racecars

	CD.A	-CL.A	%front	-L/D
Escort RSR	0.990	0.894	44.8%	0.902
BMW 1 Series	1.048	1.074	45.2%	1.025
BMW M3 E46	0.946	1.327	48.9%	1.404
VW CC BTCC	0.763	0.398	87.3%	0.522

The Escort and the two BMWs all had quite similar static weight distributions in the 52-54 per cent range, so the target downforce balance was roughly the same for each. The drag of these three cars was similar too, but the BMW M3 was well ahead on total downforce and, hence, efficiency (-L/D). The BTCC VW CC was much more restricted in the generation of downforce by technical regulations, hence the lower CD.A and –CL.A figures. That the VW's downforce distribution was so heavily forward biased was also principally down to regulations that restrict rear downforce, but these cars, especially the front-wheel drive ones, nevertheless find benefit from front downforce.

Before moving to front end modifications, angle reductions were made to the originally fitted wing (which as delivered was set at a rather steep 10 degrees) with the expectation that the balance would be markedly improved.

The outcome was not as hoped, as **Table 3** reveals (here the cumulative change is expressed in 'counts', one count = coefficient change of 0.001). While the direction the numbers took with wing angle reductions was as anticipated, the magnitude of the changes was much less than expected. The most likely explanation concerns where the wing was located in relation to the onset flow, because when the smoke plume was applied to the car at the end of our session (with one of the alternative wings fitted) it was evident that there was flow separation almost from the top of the steeply angled rear screen, and the wing was mounted only just high enough to be in reasonably 'clean flow'. Furthermore the centre of the replacement wing was visibly stalled at the 10 degrees installation angle.

So, the original, more cambered wing at the same angle would also have been stalled across the centre, and as such only the outer ends would have been functioning efficiently. Given the steepness of the rear screen it may be possible that the centre of the original rear wing was stalled at all angles tested, meaning that in effect only the outer ends were responding to the angle adjustments. This, at least, would be an explanation for the poor response to the angle changes made.

Front end mods

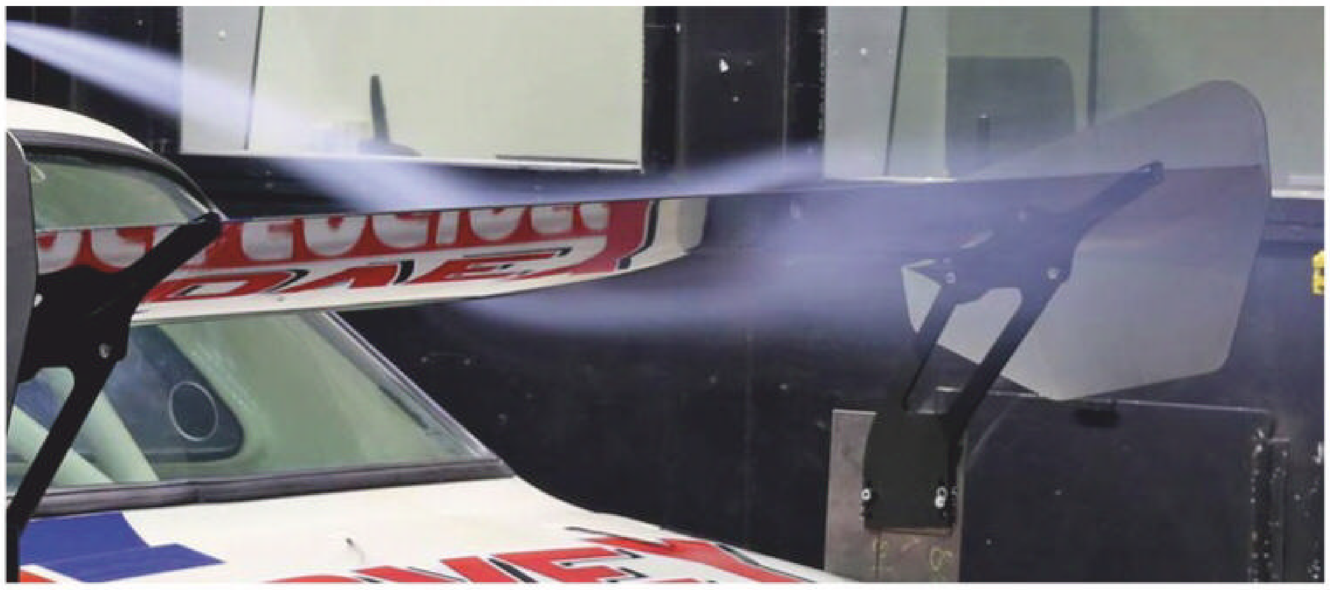
The first set of front end modifications involved the fitment of some upgraded splitter options, starting with a 25mm longer one, followed by exposing integral, basic front diffusers in this splitter, followed by fitting a 50mm longer splitter also with integral front diffusers. The results are collated into **Table 4**.

As can be seen, for just four counts of extra drag, a negligible amount, 64 counts of front lift reduction were obtained. And while this still did not achieve actual front downforce, it was a significant step towards that objective. The most significant single step came from exposing the front diffusers, an oft overlooked device for obtaining efficient front downforce even when in vary basic form.

It was MEM Motorsport boss Chris Mellors who noticed that the test splitter was inclined slightly nose up, a measured three degrees in the centre in fact. So the team took a few minutes to level it with some PU foam packers and the ubiquitous race tape. **Table 5** shows the pleasing result, the second biggest individual front downforce increment of the session, and a clear demonstration that frequently the devil is in the detail.

Next time we'll go through further front end mods that saw the car generate genuine front downforce with improved cooling capacity.

Racecar's thanks to Tim Foxlow, MEM Motorsport and DJ Engineering.



Stall at the wing's centre was apparent when it was set at steeper angles. The rear screen may well have caused this

Table 3: The effects of adjusting the original wing

	CD	CL	CLfront	CLrear	%front	-L/D
10deg	0.474	-0.202	+0.163	-0.365	-80.4%	0.427
5.4deg	0.457	-0.188	+0.154	-0.342	-82.1%	0.411
3.6deg	0.450	-0.182	+0.152	-0.334	-83.5%	0.405

Table 4: The effects of various splitter upgrades

	CD	CL	CLfront	CLrear	%front	-L/D
Original	0.457	-0.188	+0.154	-0.342	-82.1%	0.411
+25mm	0.458	-0.193	+0.145	-0.338	-75.1%	0.422
+ diffusers	0.460	-0.223	+0.110	-0.332	-49.2%	0.484
+50mm + diffusers	0.461	-0.238	+0.090	-0.329	-37.8%	0.517
Cumulative change	+4	+50	+64	-13	+44.3%*	+106

* Changes in %front are absolute, not relative.

Table 5: The effects of altering the splitter angle

	CD	CL	CLfront	CLrear	%front	-L/D
Initial	0.461	-0.238	+0.090	-0.329	-37.8%	0.517
Level	0.455	-0.277	+0.039	-0.315	-13.9%	0.608
Change	-6	+39	+51	-14	+23.9%*	+91

* Changes in %front are absolute, not relative

Resetting the splitter angle was a very useful tweak

Installing a test splitter fitted with front diffusers; just one of the options employed to find some front downfoce

CONTACT

Simon McBeath offers aerodynamic advisory services under his own brand of SM Aerotechniques – www.sm-aerotechniques.co.uk.
In these pages he uses data from MIRA to discuss common aerodynamic issues faced by racecar engineers

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Loaded questions

OptimumG's series on tuning springs and dampers continues with an explanation of the importance of tyre load variation

By CLAUDE ROUELLE

A TCR racer loads up its front right tyre in a corner. The relationship between vertical load and mechanical grip is a key factor when it comes to damper spec and spring rates

In the previous edition of *Racecar* (V30 N3), we tried to answer the question: how do we determine suspension spring rates and damping for a vehicle?

To answer this, it was necessary for us to first define the purpose of the suspension. We looked at how the suspension plays an important role in improving the driver and passenger comfort, handling, aerodynamics, mechanical grip, vibration and transient response.

With the purpose of a suspension defined, the next step was to select our spring and dampers. It was explained that to choose these it is necessary to first define the goals for the suspension system: driver comfort, tyre comfort, body control.

We then closed the loop by discussing how you should define your goal based on the track scenario: bumpy or smooth circuit, off-road, passenger vehicle or high/low downforce vehicle. This month we will be looking at one of these goals: tyre comfort.

As previously mentioned, tyre comfort is important for mechanical grip. Mechanical grip refers to the efficiency (friction factor) of the tyre. **Figure 1** shows a typical lateral force (*Fy*) versus slip angle (*SA*) curve, for five different vertical loads at zero degrees of camber, and a constant pressure. When testing a tyre, a typical chart used to understand the tyre's lateral performance is an *Fy-SA*, like this. In this article we won't delve into analysing the tyre's lateral performance based on this chart. Instead, we will use this to help illustrate mechanical grip.

Loading up

In Figure 1 we have plotted the same tyre at five different conditions (five different loads), and for each increase in vertical load we measure the lateral force. What we can observe is that as we increase the

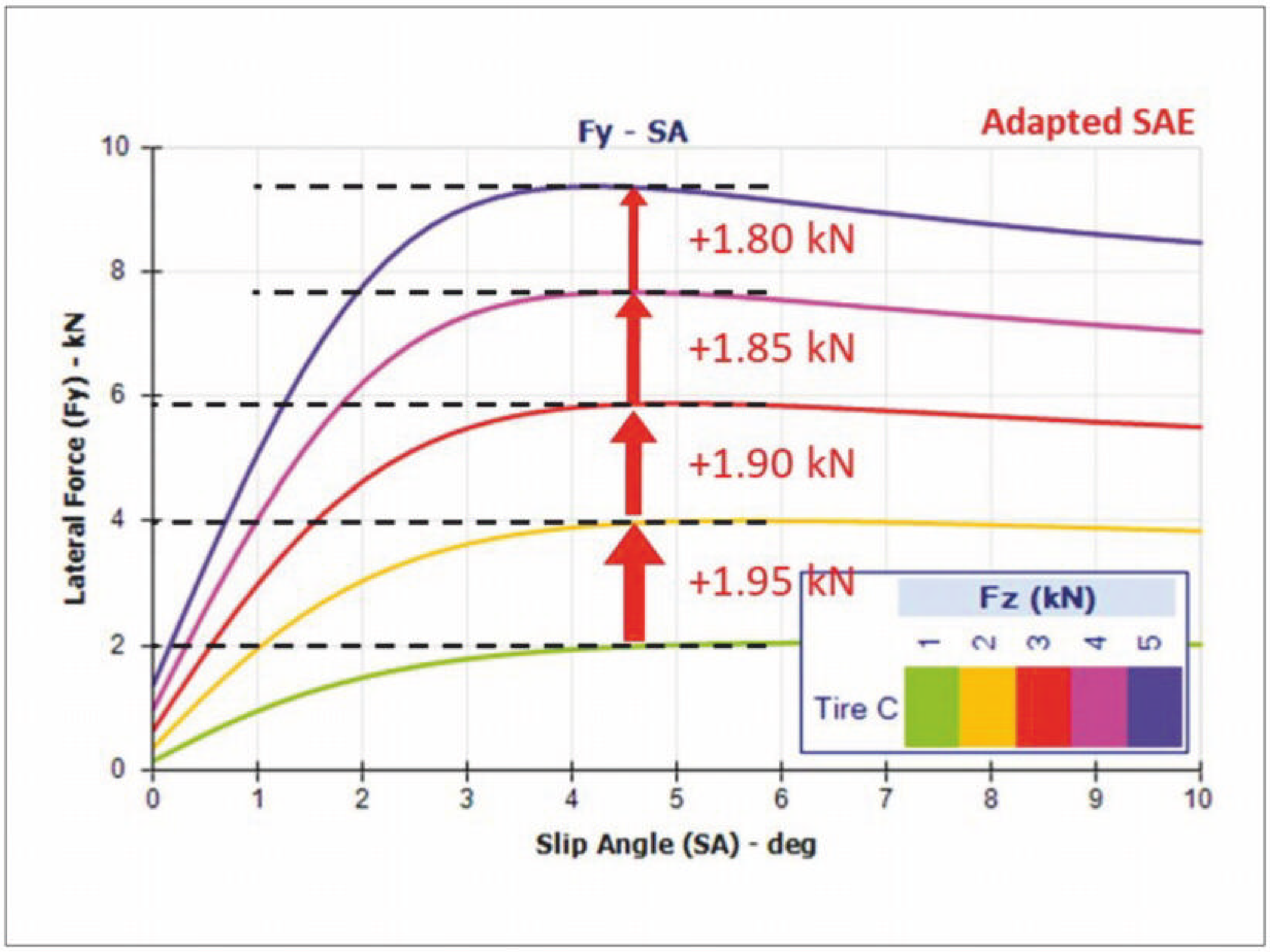

Figure 1: This shows lateral force (*Fy*) *vs* slip angle (*SA*) for five different vertical loads (*Fz*). It is the classic *Fy-SA* tyre chart

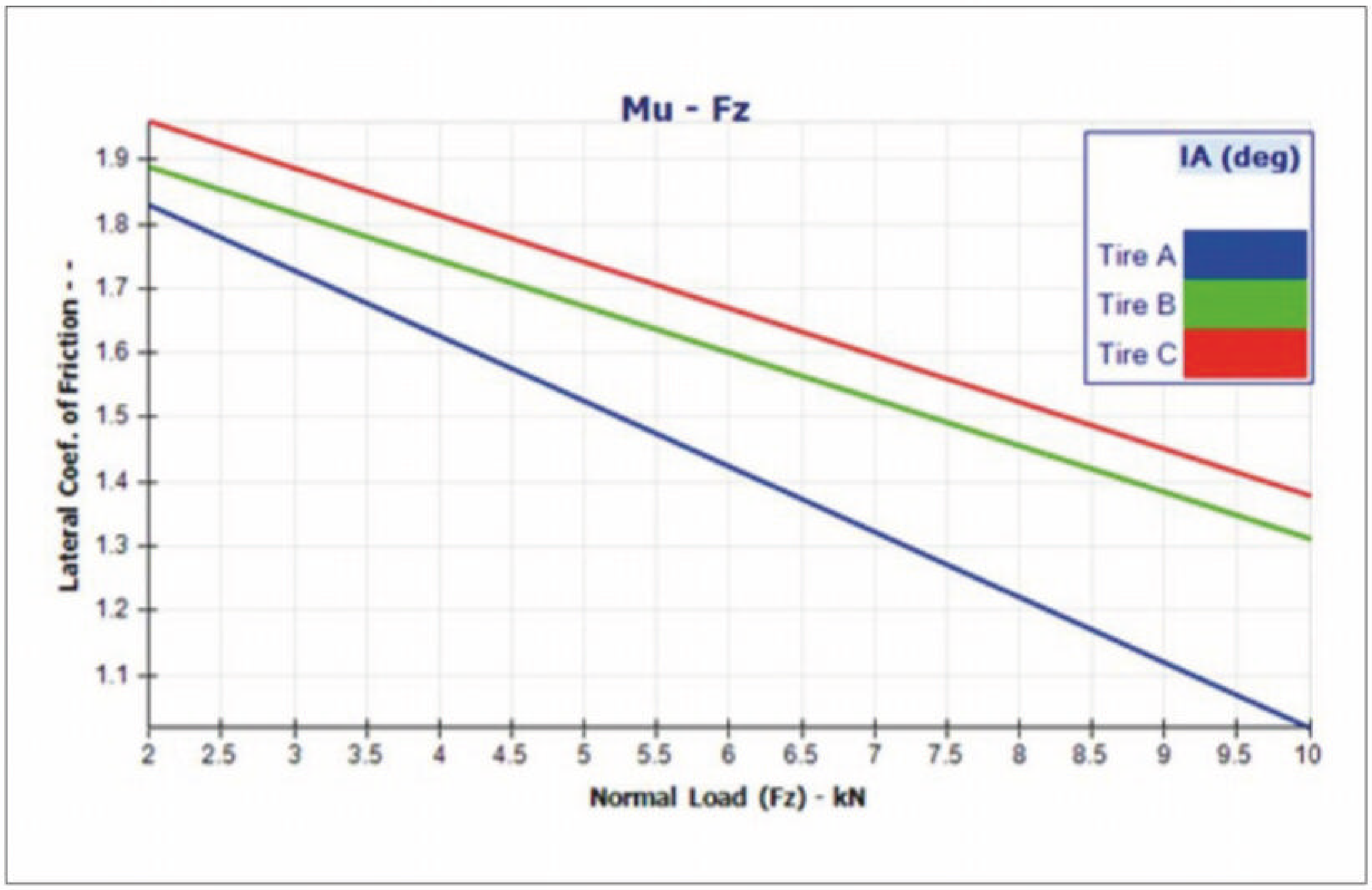

Figure 2: Lateral coefficient of friction *vs* vertical load for three different tyres plotted at zero degrees camber and a constant pressure

vertical load, from 1kN to 2kN; 2kN to 3kN and so on, we effectively have more lateral force. But looking closely you can see that the lateral force net gain is decreasing as we increase the vertical load. From a load of 1kN to 2kN the tyre lateral force increased by 1.95kN, from a vertical load of 2kN to 3kN the tyre net lateral force gain was 1.90kN. Effectively the tyre's lateral force increased, but the total amount decreased. That's why a tyre loses efficiency as you increase load.

Table 1: Table representation of Figure 1

Vertical load (kN)	Lateral force (kN)	Lateral force gain (kN)	Friction coefficient
1	2.00	-	2.00
2	3.95	1.95	1.97
3	5.85	1.90	1.95
4	7.70	1.85	1.92
5	9.50	1.80	1.90

Table 1 shows the same as in Figure 1. If we display it in a table, we can see more clearly that the friction coefficient is decreasing as we increase the load. The friction coefficient is calculated by dividing the lateral force per the corresponding vertical load (column two divided by column one).

A common chart used to investigate the tyre efficiency is the tyre efficiency versus the vertical load, which you can see in **Figure 2**. As an example, we have plotted the tyre coefficient of friction for three different tyres. You can see that, depending on the tyre, their load sensitivity will be different, in this case tyres B and C have almost the same tyre load sensitivity, although tyre C has more grip. Tyre A is the most load sensitive.

Knowing your tyre load sensitivity is important, because it will give you an idea of the set-up change sensitivity, as you change your weight transfer ratio. An example of doing this is by changing your spring stiffness.

Unsteady state

Up until now we have been discussing load sensitivity and mechanical grip. At this point we have understood that as we load the tyre more, we effectively have more lateral force, but this lateral force gain is smaller as we increase the load. This conclusion was made under the assumption the tyre was in a steady-state condition. The vertical load is applied, we wait until the load reaches a constant value and we measure the lateral force. Unfortunately, with the unevenness or bumpiness of the track, the vertical load is not constant.

As we have shown in a previous article (see November 2018, V28 N11) if the normal load on the tyre varies then the tyre coefficient of friction will decrease overall. The decrease in friction is due to the tyre load sensitivity and the delayed

Knowing your tyre load sensitivity is important, because this will give you an idea of the set-up change sensitivity

A lot of time is spent on seven-post rigs minimising tyre load variation, which in turn minimises the contact patch variation

response of the tyre to load changes (relaxation length/response lag). The decrease in friction factor corresponds to less lateral and longitudinal grip, the overall effect being slower lap times.

If a tyre is held at a steady operating condition and the normal load is increased, the friction factor of the tyre will decrease. When it is decreased the friction factor of the tyre will increase. But you always end up gaining less from the additional load at a lower friction factor than you lose from the decreased load at a higher factor. We can see the size of this effect if we have a good idea of the lateral friction factor of the tyre at different loads (as in Figure 1). In **Figure 3** we see a possible time-based load variation on a race tyre. In the plot we have a static reference load (average load) of 3000N and we are varying the load by 75 per cent (750N to 5250N) either way.

At each point on this curve we measure the lateral force. We then plot the lateral force (**Figure 4**). Additionally, in Figure 4 we have calculated the average lateral force and the average lateral force without the sinusoidal vertical load input. If we then calculate the average lateral force based on the sinusoidal vertical load input, the difference between the two is how much we lost due to the tyre load variation.

To understand how minimising the tyre load variation plays an important role on the mechanical grip, **Figure 5** is a summary of the lateral force loss for different amounts of tyre load variation for this particular racecar and tyre. As the load variation increases the lateral force loss becomes greater and greater. The effect is significant at high levels of tyre load variation.

Higher frequency

If a tyre is held at a constant operating condition but the normal load is varied, then the tyre will take time to gradually build up to the maximum steady-state force that is possible. Unfortunately, at higher frequency the load is constantly varying and the peak steady-state value is never achieved. The quicker the load is varying the worse the effect is. At high frequency and high amplitude of tyre load variation, the grip capacity is greatly diminished.

For that reason a lot of time is spent on four- and seven-post rigs minimising tyre load variation, which in turn minimises the tyre contact patch variation. What we've seen is that minimising it reduces the tyre load sensitivity, which in turn increases the performance of the racecar. Minimising the tyre load variation can be achieved by tuning your damper response and/or changing your spring stiffness.

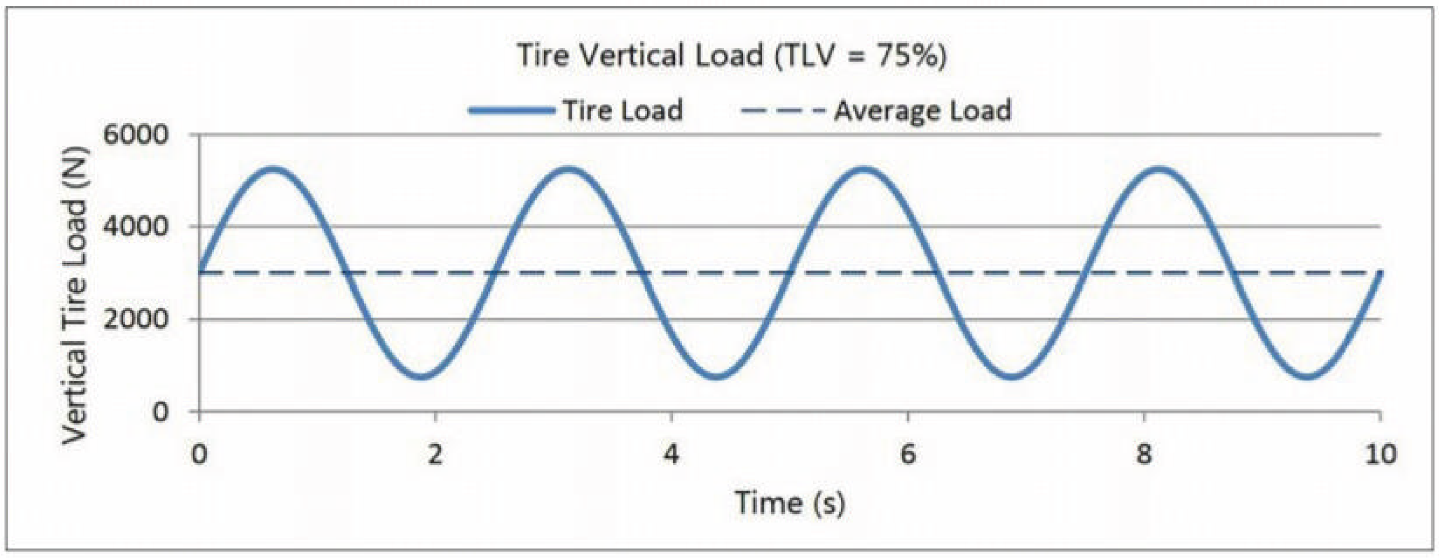

Figure 3: Load on a racing tyre for a sinusoidal profile. Variation is shown as the blue wavy line, with the average running through it

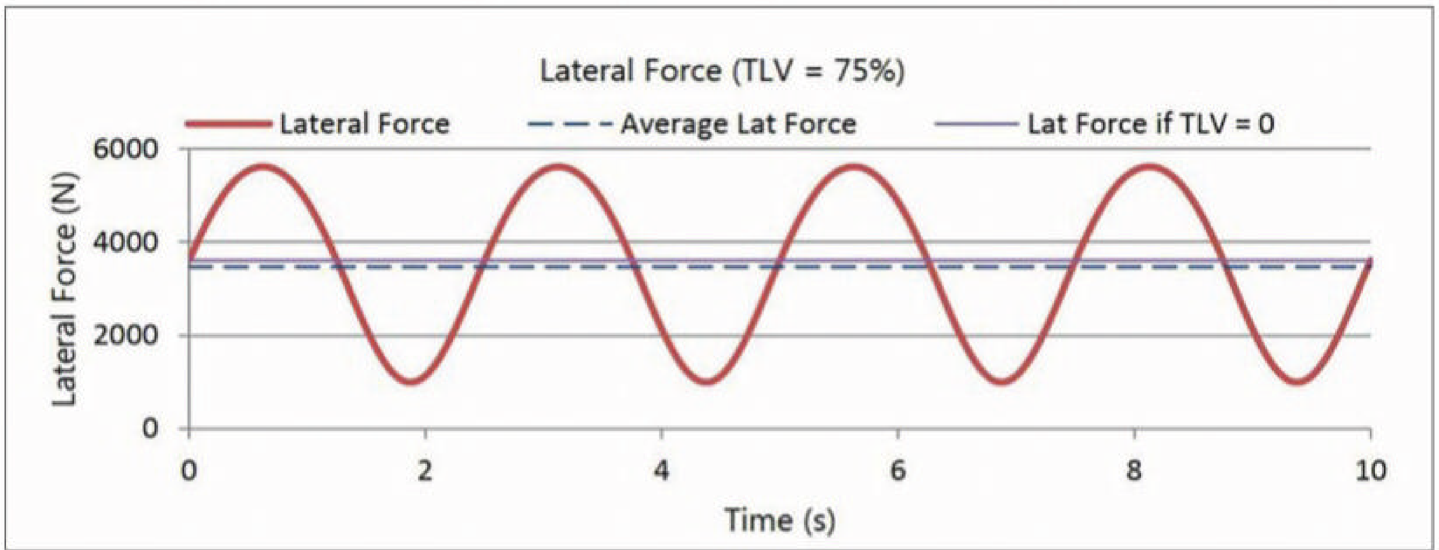

Figure 4: Here we have calculated the average lateral force and the average lateral force without the sinusoidal vertical load input

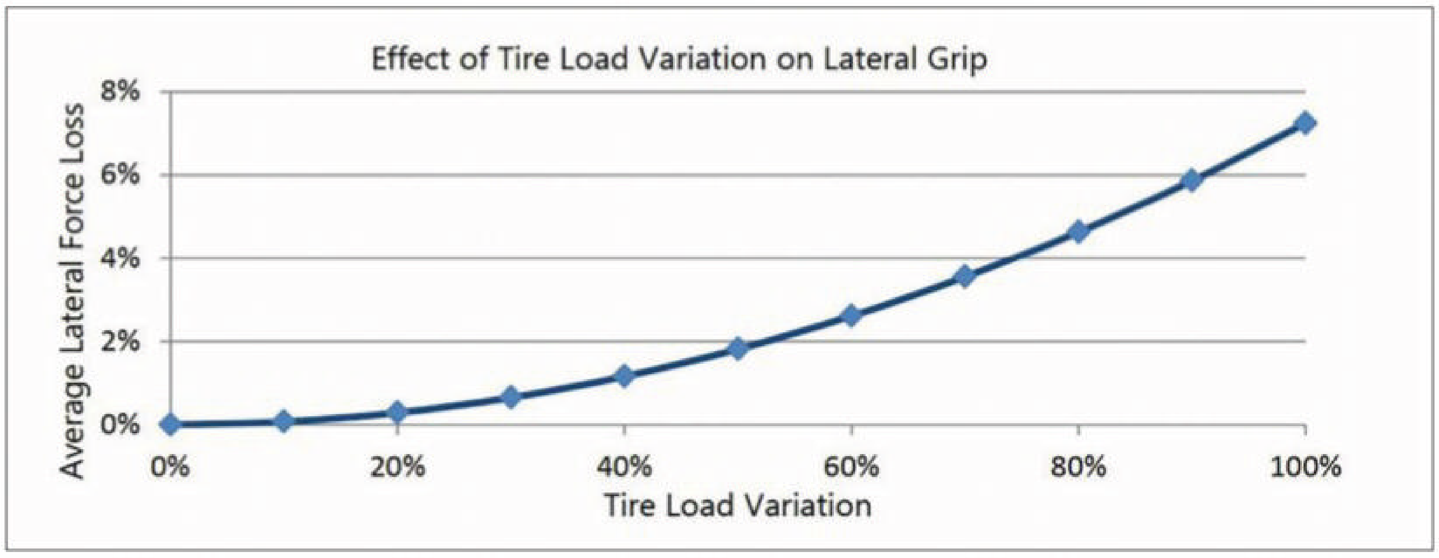

Figure 5: This is a summary of the lateral force loss for different amounts of tyre load variation for this particular racecar and tyre

Slip Angle is a summary of Claude Rouelle's OptimumG seminars.

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Forward thinking

With front-wheel drive for the ICE and an engine mounted at the sharp end, the Nissan GT-R LM of 2015 could perhaps lay claim to being the most radical Le Mans Prototype ever. In the first of a new series on this project the car's technical adviser, a *Racecar* regular, talks us through the philosophy behind this extraordinary machine

By RICARDO DIVILA

The 2015 Le Mans grid had a paradigm buster LMP1 in Nissan's GT-R LM, a car that delivered power from its internal combustion unit through the front wheels, and had that ICE in a front mid-engine position. But this did not happen by chance.

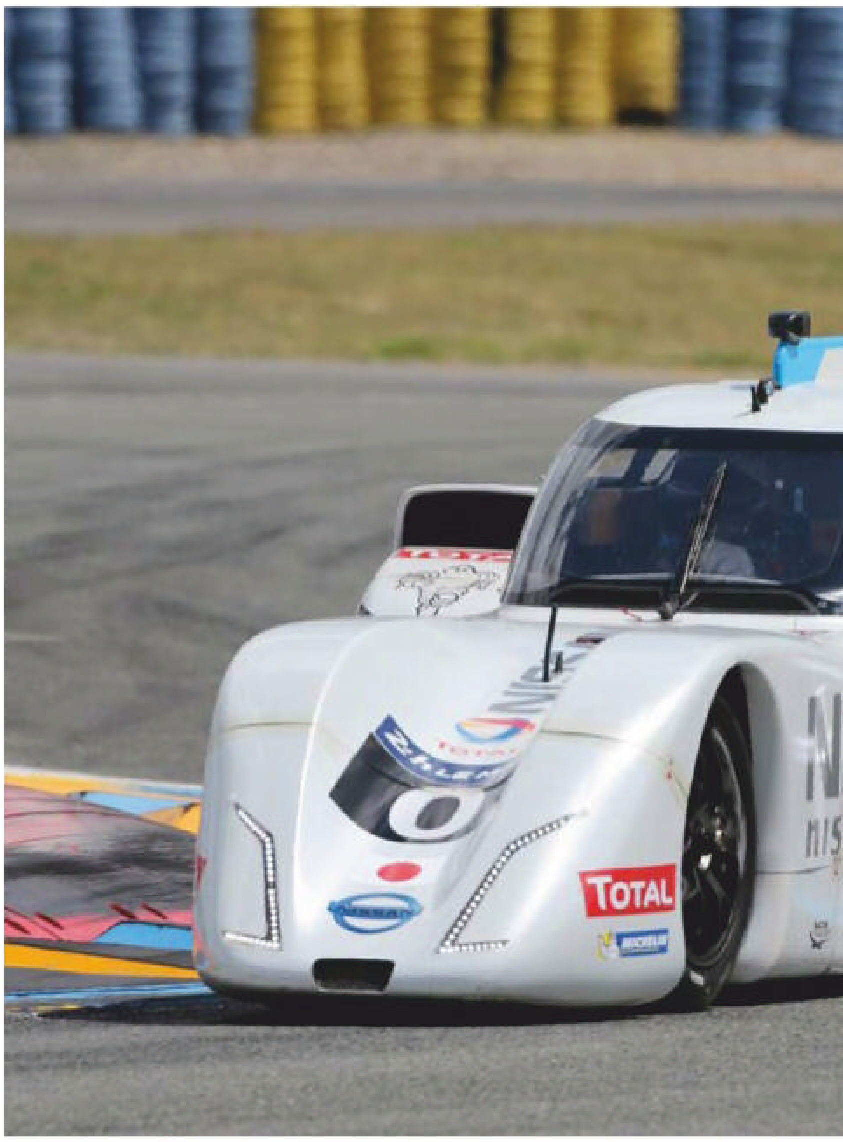
Regulations drive design choices and once the optimum lay-out proves itself there is a long period of refining the basic layout, until rules open up new possibilities. LMP1s had been quietly incorporating knowledge over a couple of decades with changes only being made as the ACO and the FIA jigged the regulations, bringing diesels and then hybrids into the fray.

The diesel/petrol equivalency rules were biased towards diesels by the ACO in response to the interests of two of the manufacturers that had been strongly supporting the series, Peugeot and Audi. The associated hybrid regulations also gave the amount of energy to be deployed by the KERS system, fixed to a maximum of 8MJ. After the first win by Audi with a hybrid, using energy harvested in the front axle and deployed to the front of the car, the gains perceived by other manufacturers led them to pressure the FIA/ACO to limit when it could be used, it being fixed at above 120km/h.

Nissan had already taken an innovative interpretation of the new Garage 56 rules in 2012, by building the Nissan Deltawing as an exercise in out-of-the-box thinking on how to produce a fast, efficient car with pure physics, and not limited by the regulations.

The Zeod was a continuation of that concept, but with added energy recovery with a hybrid electric drivetrain using lithium ion battery packs and an ultra-efficient engine, in which a battery was charged by the ICE and kinetic energy was harvested under braking, doing the first 12 laps of a stint with the ICE unit and deploying the stored energy for the final lap. This led to the first all-electric lap at Le Mans, reaching a speed above 300km/h.

The technical and commercial results due to the publicity returns for these limited projects, plus a couple of new rules, featured in the decision by Nissan to enter the WEC to compete against the cars already there: Audi, Toyota and the new contender, Porsche.



Le Mans return

The same design group that had worked on the Deltawing, led by Ben Bowlby, came up with a 'choice matrix' taking account of the regulations and what would be the requirement for Le Mans. The car would basically be designed around that. Le Mans being the biggest return in marketing terms, Nissan accepted that the car would be less competitive at other WEC venues – these being considered as tests for the development of the sub-systems and team for Le Mans. The last time Nissan had been at the French classic in the main race was in 1999.

Audi had been running at the WEC, and more specifically Le Mans, since 1999, investing a considerable amount of money yearly. Toyota

The small budget could only really work with a compact design team which was open to exploring new ideas

The GT-R LM at Le Mans in 2015, its only race. The fastest Nissan was some 20 seconds off pole and all three GT-Rs had very poor races. But the design principles behind this racecar were sound

The publicity it received from its Zeod Garage 56 entry helped persuade Nissan that an LMP1 campaign could be a good marketing move

was using the large resources of TMG and building on its systems. Porsche was a new contender in the field, but no stranger to the WEC – reputedly it had put aside a budget every year for over a decade to be ready for its return.

Budget-wise the resources for a three-year programme, knowingly smaller than the opposition, could only be deployed in a 'guerrilla'-like small, compact design and racing team, exploring new ideas, much in the spirit of the Deltawing and Zeod programmes, theoretically being more reactive and flexible.

The possible downside would be the time and resources to build up a completely new team, plus the logistical problems of being based in the US as against all the other teams being based in Europe. Having been exposed to the time lag inherent in this by earlier experience of building F1 cars in South America this always loomed large in my mind.

Design parameters

The main design areas that would have to be examined were: A; *Layout*. The ACO/FIA controls the aero by limiting rear wing sizes, that in turn limits how much total downforce you have because it needs to be balanced. To increase total capability the teams started pushing the driver and engine forwards, shifting weight percentage forward, while balancing weight percentage and aero percentage. As weight went up, front tyre sizes grew, with a corollary of reducing driver visibility as the fenders grew.

With the driver being pushed forward the engine also moves forward to achieve a favourable per cent CoG, and we reach a natural limit as feet position has to be behind the front wheel centreline. The second limitation is the intrusion of the rule-fixed foot-boxes into the area between the box and the wheel-wells, restricting exit flow from the front diffuser.

New regulations also gave a template for visibility, and part of this was the required height of the eye-level going up. This allowed the examining of a concept where the driver would sit behind the engine, as it opened up the percentage frontal area and the resulting diffuser expansion area, closely following the engine profile, improving efficiency.

B; *Aerodynamics*. This involved searching for the possible operating envelope and where it could be optimised. Experience has shown that ground effects can produce a better L/D ratio than an aerofoil, no matter how efficient the

Lemans 24H Race Result in 2013

			Race Best	QF Beat
1st	AUDI #2	348L	3'23"269	3'22"346
2nd	TOYOTA #8	347L	3'25"151	3'26"654
3rd	AUDI #3	347L	3'24"293	3'24"341
40th	Rebellion #12	275L	3'29"328	3'28"935

AUDI	ICE Diesel V6 3.7L Turbo ϕ45.1 360kW+
	Fuel Tank: 58L
	Weight: 915kg
TOYOTA	ICE Petrol V8 3.4L NA ϕ43.3 389kW
	Fuel Tank: 76L
	Weight: 915kg

⇒

Energy system	New
Tire	-7%
Weight	-45kg

1. Energy Management is important
2. Lap time may be slower
3. Weight Reduction will be a challenge

⇒

Lemans 24H Race Result in 2014

			Race Best	QF Best
1st	AUDI #2	379Laps	3'22"567	3'24"729
2nd	AUDI #1	376Laps	3'24"393	3'25"814
3rd	TOYOTA #8	374Laps	3'23"117	3'22"523
4th	Rebellion #12	360Laps	3'28"466	3'29"763

Fuel Charge		13Laps Each
Tyre&DR Change		4 Stints Each
Pit Stop		
	Full Service	80"-85"
	Refuel only	58"-62"
	Tire Change	22"-27"
Repair Time		
	AUDI #2	23'18"
	AUDI #1	17'36"
	TOYOTA #8	49'26"

Figure 1: Race data from previous years gave a baseline of the opposition's performance

latter is. Because any increase of downforce from an aerofoil will increase drag.

C; *Hybrid*. As a manufacturer Nissan had to incorporate an energy recovery system. The initial concept of the car would depend on the system chosen, given the options available. Whichever system was chosen would have to depend on technical partners who would supply the unit. There was some data available from the performance of competitors in previous years, analysing their pit stops and stint lengths, and their on-track deceleration and acceleration on several tracks with radar guns. These parameters were fed into simulation to examine different choices and the possible returns, and the choice of what ERS system to go for (**Figures 1** and **2**).

The design target was to lap under 3m20s to cater for year-on-year improvement. And the simulation with the chosen configuration indicated 3m19s was attainable.

D; *Engine configuration*. This meant taking into account the new rules on fuel allowance and consumption; the design based on Article 20.0 of the technical rules from 2014, which set max petrol flow, tank size and fuel energy per lap with different configurations (**Figure 3**).

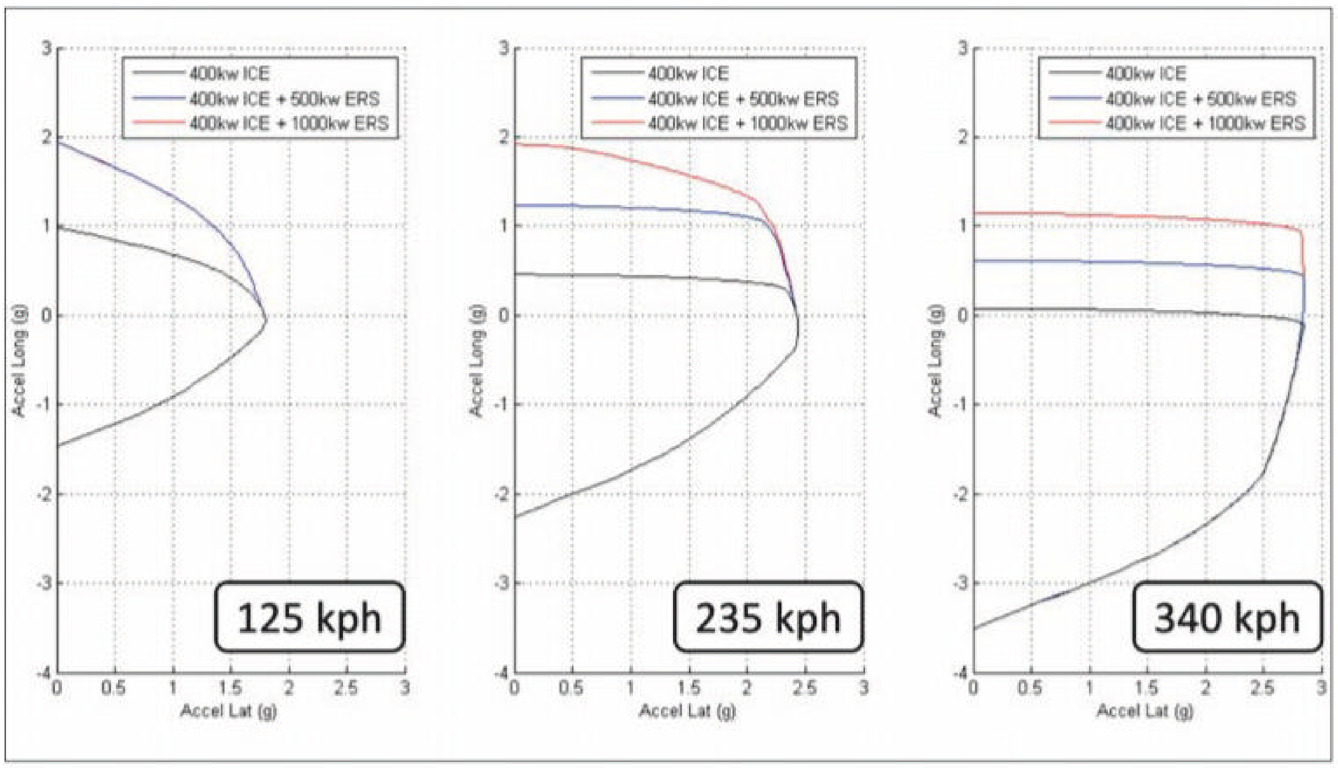


Figure 2: Nissan undertook a study of the capabilities of different non-ERS and ERS configurations at selected speeds

ERS OPTIONS LE MANS			
<2	<4	<6	<8

LE MANS TEST *length=* *13.629 km*

		No ERS	ERS OPTIONS			
Released Energy	MJ/Lap	0	<2	<4	<6	<8
Released Power	kW	0	Not limited	Not limited	Not limited	Not limited
Car Mass	kg	850	870	870	870	870
Petrol Energy	MJ/Lap	204.4	147.0	143.3	139.5	138.0
Max Petrol Flow	kg/h	106.5	94.8	92.4	90.0	89.0
Petrol capacity carried on-board	l	75.0	68.5	68.5	68.5	68.5
Fuel technology Factor Average	-	1.077*	1.077	1.077	1.077	1.077
Fuel technology Factor Pmax	-	1.076*	1.076	1.076	1.076	1.076
K Technology Factor	-	1	0.987	0.987	0.987	1
Diesel Energy	MJ/Lap		138.3	134.8	131.3	128.1
Max Diesel Flow	kg/h		81.0	79.0	77.0	75.1
Diesel capacity carried on-board	l		54.2	54.2	54.2	54.2

Figure 3: LMP1 regulations on fuel allowance, consumption and energy use as they were for the Le Mans test day in 2014

Decision matrix

We shall now run over the decision matrix (**Figure 4**) results by item, starting with the aero, and looking at the types of drag impacting a car. Parasitic drag is caused by moving a solid object through a fluid medium. In aerodynamics, the fluid medium concerned is the atmosphere. The principal components of parasitic drag are form drag, friction drag and interference drag.

Form drag is caused by the separation of the boundary layer from a surface and the wake created by this. It is primarily dependent upon the shape of the object. Skin friction drag is a component of profile drag, which is resistant force exerted on an object moving in a fluid. It's caused by the viscosity of fluids and is developed from laminar drag to turbulent drag; not much of an issue with racecars.

Then there is downforce induced drag. The known limiting factors are the total amount of downforce produced by the front being balanced by the total produced by the rear in a range of rake and roll and at the same time at the best efficiency, or L/D, the lift/drag ratio.

The ACO rules (Art 3.22.2) defined the size of the LMP1 car's rear wing: 'The primary device inducing downforce (negative lift) shall be a single aerodynamic device, adjustable, mounted at the rear of the car, with two aerodynamic profiles as a maximum (mainplane and flap). It must: be framed by a volume measuring 250mm horizontally x 150mm vertically x 1800mm transversally; and the primary [element] and the flap must each be obtained by extrusions from *Y* of a constant section, throughout the length of the rear wing.'

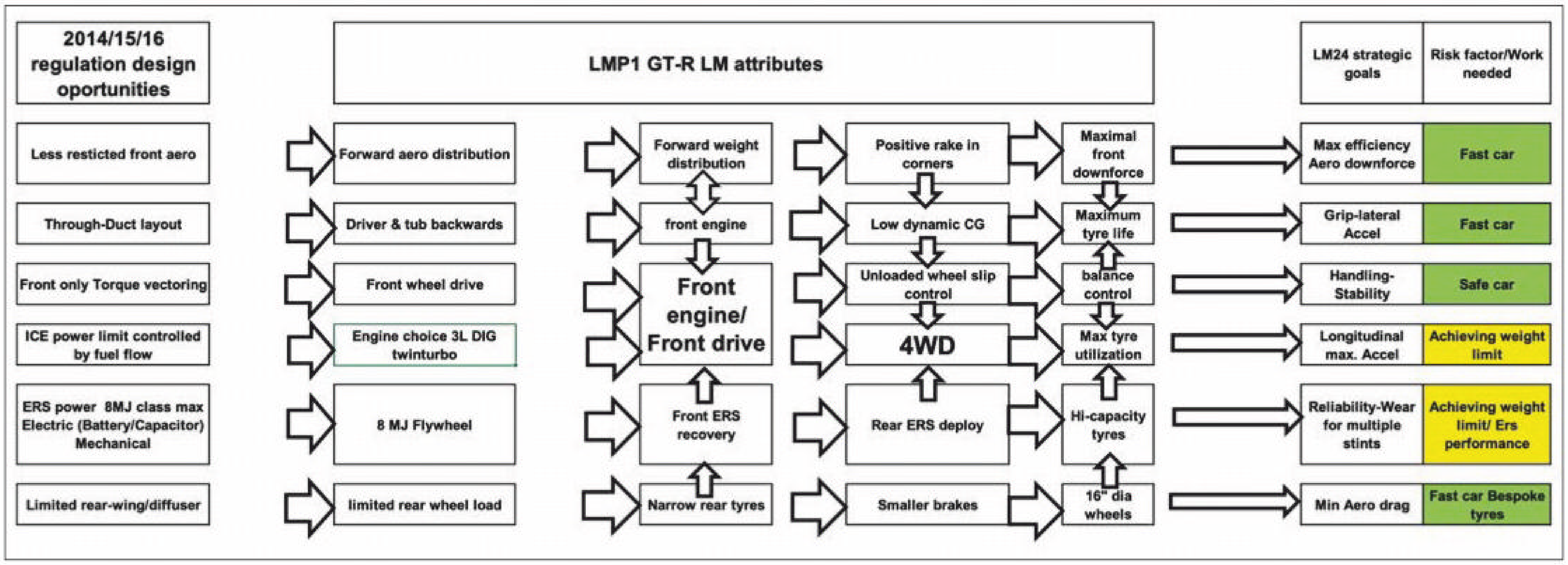


Figure 4: The decision matrix. This took into account the regulations and what would be required for Le Mans, ultimately helping to drive the radical design choices that were made

WEIGHT DISTRIBUTION AERO AND MECH: GT-R LM

CD	0.63		FT WGTH	635	TOTWGTH	960	A ftarea(m2)	%FTmechV	
CL	4.21	L/D 6.66	RRWGTH	325	%FT Aero	65.0	1.75	66.1	
Speed		Weigth Kg aero			Total WGTH AERO+MECH				
KPH	M/S	ft	rr	D ft rr	ft	rr	Dtot	%ftm+aer	D%ft
0.0	0.0	0.0	0.0	0.0	635.0	325.0	-310.0	66.15	0.0
100.0	27.8	242.7	130.7	-112.0	877.7	455.7	-422.0	65.82	-0.3
200.0	55.6	970.9	522.8	-448.1	1605.9	847.8	-758.1	65.45	-0.7
250.0	69.4	1517.0	816.8	-700.2	2152.0	1141.8	-1010.2	65.33	-0.8
300.0	83.3	2184.5	1176.3	-1008.2	2819.5	1501.3	-1318.2	65.25	-0.9
310.0	86.1	2332.5	1256.0	-1076.6	2967.5	1581.0	-1386.6	65.24	-0.9
320.0	88.9	2485.5	1338.3	-1147.1	3120.5	1663.3	-1457.1	65.23	-0.9
330.0	91.7	2643.2	1423.3	-1220.0	3278.2	1748.3	-1530.0	65.22	-0.9

WEIGHT DISTRIBUTION AERO AND MECH: PROTOTYPE

CD	0.75		FT WGTH	400	TOT WGTH	940	ftar(m2)V	%FTmechV	
CL	3.90	L/D 5.2	RRWGTH	540	%FT Aero	48.0	1.75	42.6	
Speed		Weigth Kg aero			Total WGTH AERO+MECH				
KPH	M/S	ft	rr	D ft rr	ft	rr	Dtot	%ftm+aer	D%ft
0.0	0.0	0.0	0.0	0.0	400.0	540.0	140.0	42.55	0.0
100.0	27.8	166.2	180.0	13.8	566.2	720.0	153.8	44.02	1.5
200.0	55.6	664.8	720.2	55.4	1064.8	1260.2	195.4	45.80	3.2
250.0	69.4	1038.7	1125.3	86.6	1438.7	1665.3	226.6	46.35	3.8
300.0	83.3	1495.8	1620.4	124.6	1895.8	2160.4	264.6	46.74	4.2
310.0	86.1	1597.2	1730.3	133.1	1997.2	2270.3	273.1	46.80	4.2
320.0	88.9	1701.9	1843.7	141.8	2101.9	2383.7	281.8	46.86	4.3
330.0	91.7	1809.9	1960.7	150.8	2209.9	2500.7	290.8	46.91	4.4

Figure 5: This shows aerodynamic balance shift at speed; the GT-R LM is the top table, while a regular prototype is bottom

Part	% total downforce	% total drag	L/D
Front splitter	43	19	10
Flat bottom	39	9	25
RR difuser	17	13	7.5
Rear wing	23	17	9
Bodywork	-19	11	
Front wheels	-1	3	
Rear wheels	0	8	
Internal flow	-1	20	
(Flat bottom & rr difuser)	56	22	9

Figure 6: Aerodynamic contribution of different component groups

In cars with downforce the ability to function at the optimum has to be a compromise

It thus tries to reduce the total downforce, and for it to be usable we have to balance front and rear downforce through the speed range of the lap and also match the weight distribution of the car. **Figure 5** exemplifies the aero unbalance or *Cp* shift with speed.

In racecars, more so when downforce is involved, the ability to function at the optimum has to be a compromise. Straightline speed is a factor, but on a track it also has to be tempered with the other phases, taking into account braking, turn-in under braking, neutral phase in corner, when neither brake or acceleration is involved (the case in a long sweeper), and gradual power-on for corner exit.

Then there are the weight transfer forces resulting from acceleration, deceleration and cornering to think about. On aero cars, the changes in ride height due to transfer compressing and extending the springing brings in a shift of centre of pressure, further altering the balance. The control of the aero forces becomes the ruling factor for handling.

When we have mixed aerodynamic systems, the case on most racecars, for example a front splitter/diffuser and a rear diffuser coupled with a rear wing, the chassis movement due to transfer changes the front aero percentage in different ratios. A front diffuser, overhung from the front axle line, will move downwards under braking, reducing ground clearance and increasing the aero force by a much greater value than the rear when raked. Separating the individual contributions, we can see in **Figure 6** the relative effectiveness of each.

Note that if we add the flat bottom and rear diffuser element, they supply 56 per cent of total downforce and 22 per cent of total drag. These are the parts that are most restricted by the regulations, so difficult to improve. The effect of the flat bottom is mostly dependent on the flow generated by the rear diffuser. The other take-away is that the ground effect average L/D beats any wing.

The other downforce producing item on the rear is the rear diffuser, but that is also restricted and not that efficient, being a flat plane starting at the leading edge of the rear tyre line and ending at a maximum height of 200mm at the rear end, having no more than two strakes. As this plane has to fit between the rear tyres it is effectively limited by the space available. One way to increase diffuser efficiency is therefore to use a smaller width rear tyre, a possibility opened up by the option of having more weight on the front with a rear driver position, and using bespoke tyres for the car.

Assuming we have the driver placed at the maximum forward position the splitter/diffuser exit area available (in red on **Figure 7**) is limited by the foot-box and the wheel-well (with lock allowance taken into account).

Moving the driver and tub backwards opens up the exit area (**Figure 8**). On the GT-R LM the ERS gear cluster was placed under the footwell area, with just the rotors ahead, enabling a gain on the area for exit as the engine moved back.

A V4 layout would enable an even bigger exit section, but initial CFD values with a V6 were so good it was not pursued further.

Jumping forward somewhat, the results of the decision matrix led to **Figure 9**.

Aero numbers

The layout and detail design worked to a simple set of formulas. The drag produced by the car is defined by the *Cd*, the coefficient of drag and the frontal area *A*, thus the comparison between configurations is based on *CdA*. The full formula is: *Drag = Cd * A * .5 * rho * V^2* (using appropriate units). If we use metric units, we would have, say, 278N of drag force at 97.5km/h at a frontal area of 2m^2 and *rho* (atmospheric density) of 1.225 kg/m^3 at a standard atmosphere (15degC and 1013.25mB), then you will have a *Cd* of 0.313.

The force is in Newtons multiplied by the speed in metres per second, giving the power in Watts. As an example; the average speed on a test run is 97.5km/h, which is 27 metres per second. So power is 278N multiplied by 27 m/s = 7500 Watts, or 7.5kW, which is 10bhp.

We can see the reason to reduce frontal area, then, as it directly reduces the force required to power the car at a given speed. But by now it is difficult to do this as it is designed to the maximum allowed width, in the case of LMP1, 1.9m, and the cockpit greenhouse is defined by the rules, to give driver safety, though it is pretty small as it is. Nevertheless, a 100mm reduction in maximum width and a change of tyre dimension can give a five per cent change in frontal area (**Figure 10**).

As an aside, the car's through tunnel aero concept actually gives the equivalent of a reduced frontal area, as the air from under the front does not get pushed sideways at the side exit. All the air from the front diffuser exits in a low pressure area behind the car.

From the equation above we can also see that drag increases by the square of the speed, and power required goes up with the cube of the speed. With Le Mans being characterised by the three long straights, high speed is attainable by keeping the *Cd* low. But there are also the Porsche Curves and the Dunlop complex plus Tertre Rouge, which all need reasonable aero downforce. So, back to best L/D, but with drag matched to top speed required, knowing what the opposition had and could possibly achieve for 2015.

It is easier to find high L/Ds on very high downforce racecars, but on low downforce cars it's difficult, as form and parasitic drag, plus mechanical rolling resistance, are a higher percentage of the total. A racecar with no downforce will still have drag.

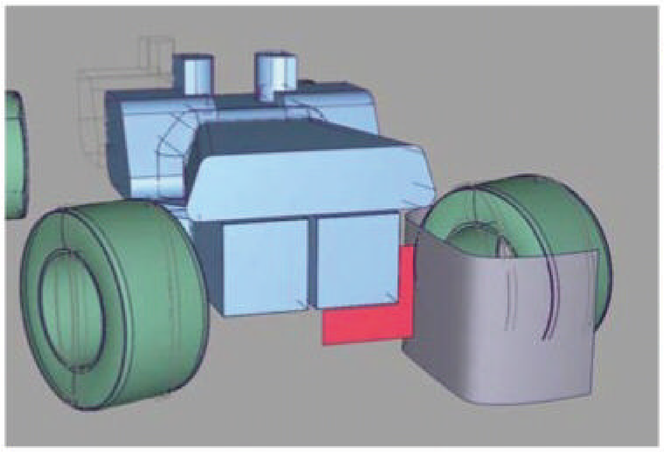


Figure 7: ACO cockpit template; red bit is diffuser exit area

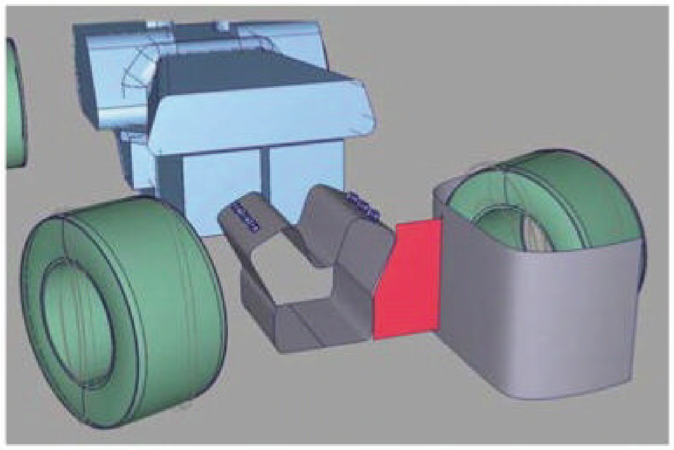


Figure 8: The ACO cockpit template for a front-engine layout

Figure 9: The overall aerodynamic approach, showing the pressure values on the front diffuser and the through tunnels

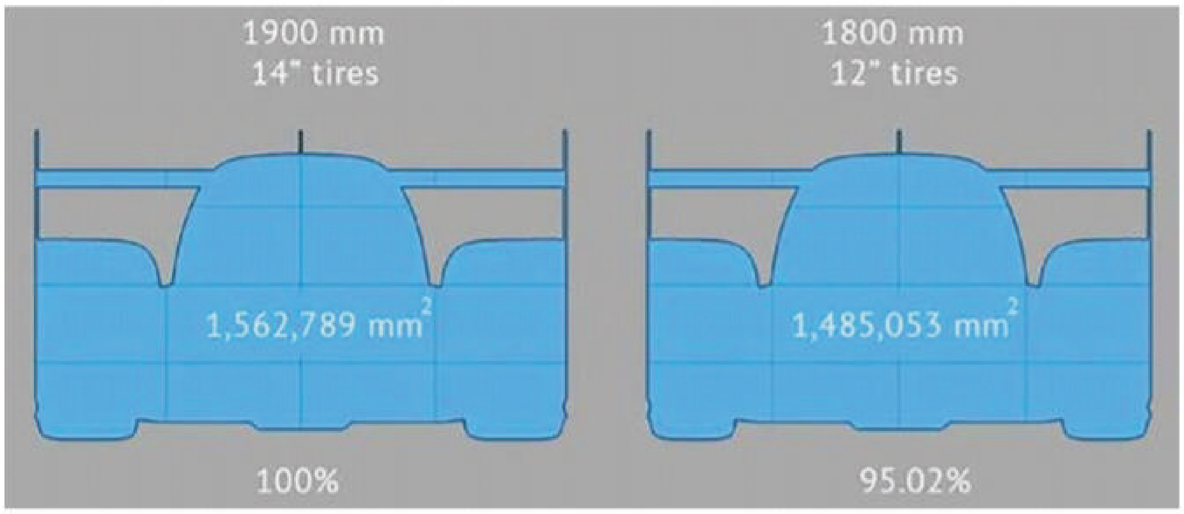
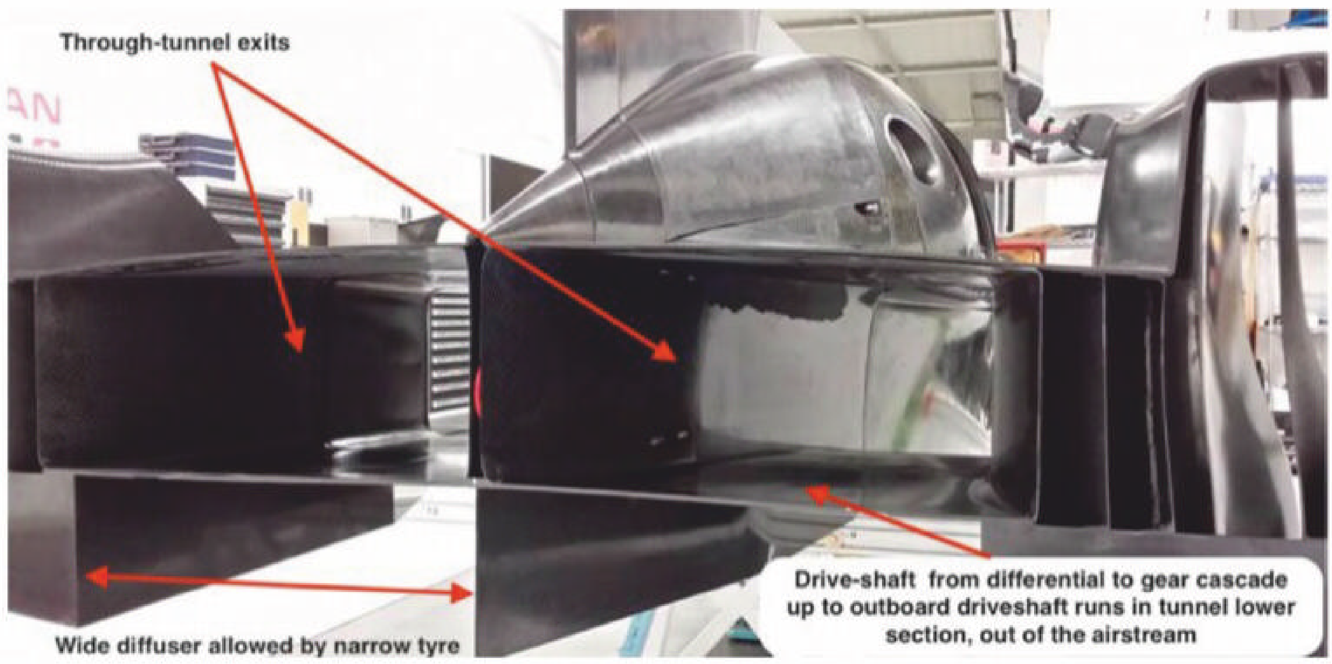


Figure 10: Cutting drag was a priority and this was helped by reducing the frontal area, compared to other LMP1 cars



The GT-R's through tunnel concept was actually equivalent to a reduced frontal area, again helping to cut the racecar's drag

A 100mm reduction in a racecar's maximum width and a smaller tyre dimension can result in a five per cent change in frontal area

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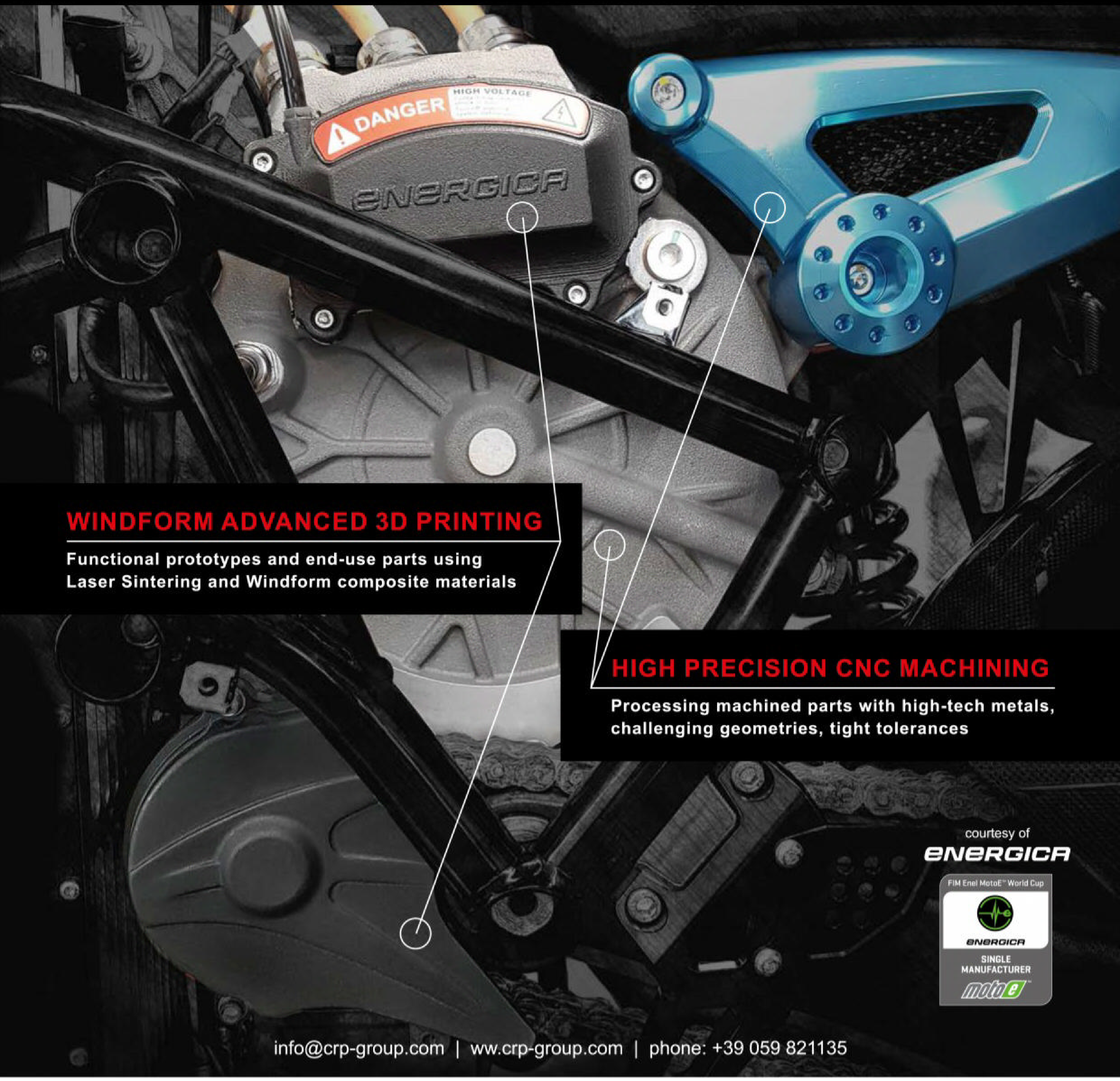

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Cosworth and Nissan started work on the different internal combustion engine layouts to choose a configuration, and they settled on a V6

As for the engine, with the fuel used being limited by a fixed volume on the tank, and the flow of fuel to the engine similarly being limited, the brief was quite easy; the most efficient use of the energy possible. Cosworth and Nissan started work on the different layouts to choose a configuration, and settled for a V6, part of the reason being the ease of balancing the engine in all vibrating modes; a plus for endurance racing, where vibration can affect car part reliability, although the load on the crank was significantly more, which added mass to it.

Bespoke 'box

The gearbox was a bespoke design. But the supplier struggled to meet the agreed design time-line, with the relationship subsequently becoming extremely tense, so there was unhappiness all round. To compound the problem, the number of foundries in the UK that could cast hi-quality casings was limited, and fully booked on other work, while the distance between the main design team in California and the gearbox manufacturer in the UK made communication slow, because the time difference of eight hours restricted direct consultation to small windows every day.

As production schedules slipped a plan B and plan C were prepared. A CNC machined from solid casing was envisaged, but eventually a foundry able to rapid-cast an aluminium casing was identified in Detroit.

For the initial car build we had to use a 3D printed mock-up so as not to slow progress. This 3D printing approach actually helped with mocking-up in many areas of the car, enabling work to be done while awaiting long-lead sub-assemblies from suppliers.

From the decision matrix, once the decision on layout was made, design also had to take into account that the car was to be used in endurance racing, so it had to have rapidly repairable and accessible components for quick pit stops, in case of failure or accidents. So the whole layout was done in a modular concept, to enable rapid response and also ease of maintenance between sessions.

The tyres also needed some careful consideration. With the car having a different weight %front, and needing extra capacity on the front for harvesting the energy aggressively, plus rears having to carry less weight when cornering and on the straights, yet with high horsepower being deployed in a straightline, this required a bespoke tyre. This was designed by Michelin. Final design sizes were 31/71-16 front and 20/71-16 rear, with compounds developed to suit. As we shall see later in this series, this was not without its problems.

KERS and effect

On initial design, brake dimensioning would be a function of work expected. The KERS would be absorbing the majority of kinetic energy, the conventional discs and calipers mostly used on the non-harvesting parts of the circuit and for pulling into the pits. The 8MJ capacity, then,

Parts were mocked up using 3D printing so work could continue even though long lead time items were still being made

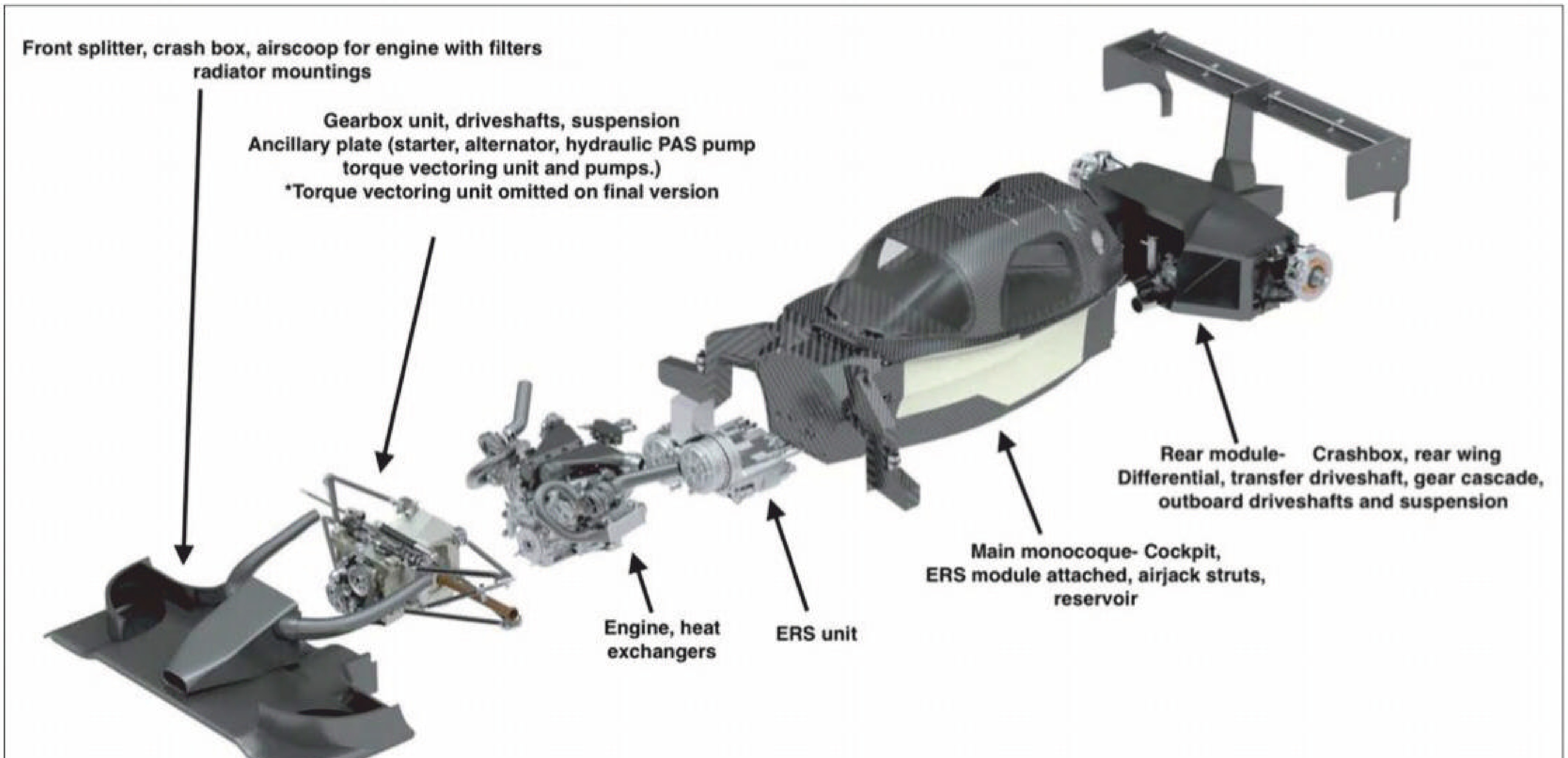

Figure 11: The modular concept was conceived to enable rapid repairs in a race and also help with ease of maintenance

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As a car slows down and the flywheel speeds up there is a transition stage at which the effort from the brakes will have to increase

allowed the brakes to be downsized. As for the choice of KERS, a comparison showed the assumed Toyota capacitor-based storage is less lossy, but the energy density is lower than the mechanical system, making the ERS, capacitors and control system heavier.

As a car slows down and the flywheel speeds up there is a transition stage at which the effort from the brakes has to increase as ERS capability reduces, the brake by wire system has to handle it smoothly. Also, in the regulations: 'In order to establish clearly-defined hybrid zones, those allowing energy to be transmitted between two braking phases, the Automobile Club de l'Ouest and the FIA have defined the zones where braking is sufficiently heavy to be taken into account, for every circuit during the racing season'. There were five on the Spa-Francorchamps circuit in the second round of the FIA World Endurance Championship on 5 May 2012, when this system was used for the first time. On the 13,629km Le Mans circuit in there were seven zones.

After the change in ERS deployment rules when the ACO/FIA limited it to only over 120km/h for four-wheel drive cars the optimal result would be from harvesting at the front and deploying at the rear, leading to the final configuration shown in **Figure 12**. The other advantage from front harvesting is that as weight shifts under braking and goes to the front it is less restricted by rear capability.

Weighty issues

Achieving the minimal weight in the regs, of 880kg, was dependent on the sub-unit suppliers keeping to assigned weight. Knowing that there was a drift and that an 8MJ ERS was going to be around 30kg overweight, this was checked in simulation to see the impact.

The ERS systems already in use were either fully electric, harvesting energy in the braking phase by an alternator/motor into a battery or a capacitor; or a mixed mechanical/electrical system where the energy would be harvested by an alternator, which would then spin a flywheel, recovering it with the reverse process to send back to the wheels. Existing systems were in the 2MJ range, a long way away from the regulatory maximum of 8MJ.

A bespoke dynamometer using the complete powertrain (engine, gearbox, ERS system driveshafts and front suspension) was used for development at Cosworth, and had good results, eventually completing three full Le Mans simulations, cycling through the acceleration, braking and energy recovery following the track use, shifting gears and stopping the engine for 50 seconds every 45 minutes, simulating pit stops and the heat soak during these. At the same time the fuel use and heat rejection to radiators and exchangers was monitored, validating the sizing and air flow required for track use, compared to predictions.

From the start of the discussions with the FIA/ACO there was a constant effort to clarify the regulations for LMP1, as these were not completely clear, having been devised with a mid rear-engine view, the paradigm at that time.

In the meantime there was a lot of simulation work to do. For instance, **Figure 13** shows an example of where ERS comes in. The red trace is speed trace with no ERS, black with 8MJ. Initial acceleration while traction-limited

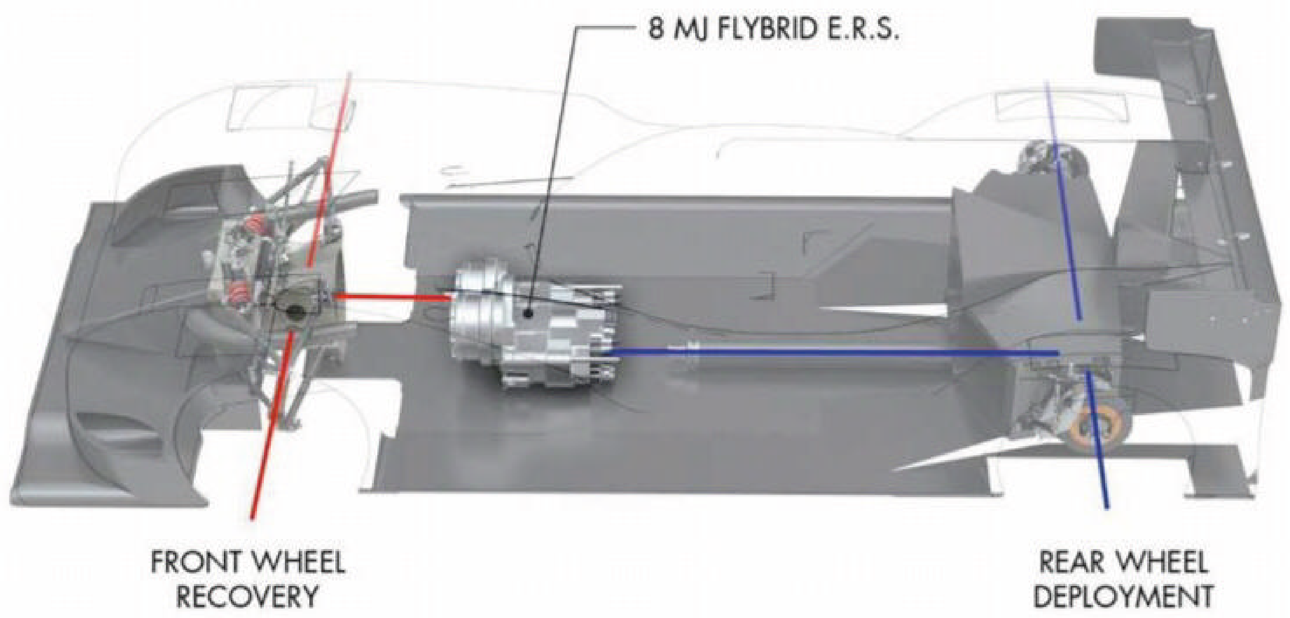
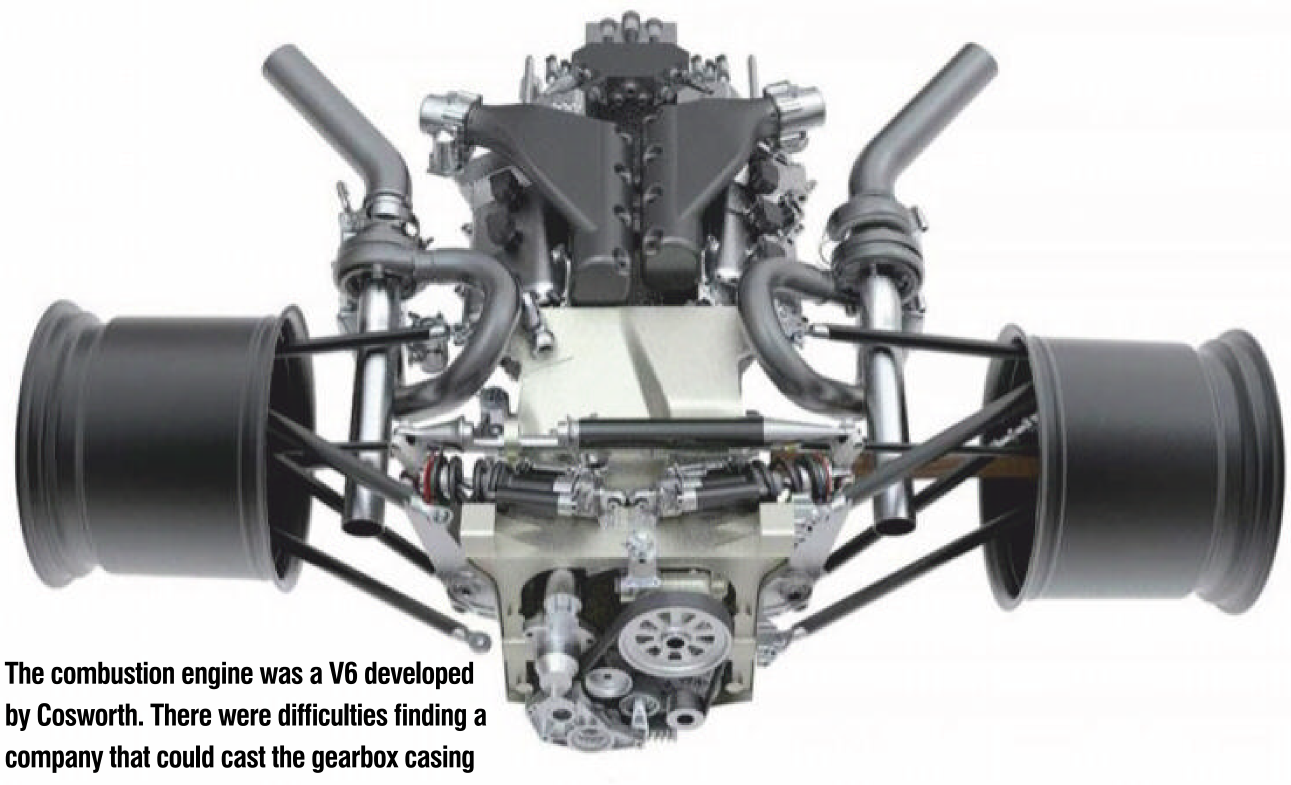


Figure 12: Rule changes meant that the optimal hybrid approach would be harvesting at the front and deploying at the rear

Naked Nissan GT-R from above. From this angle it's clear to see the car's modular design and its mid front-engine layout



The combustion engine was a V6 developed by Cosworth. There were difficulties finding a company that could cast the gearbox casing

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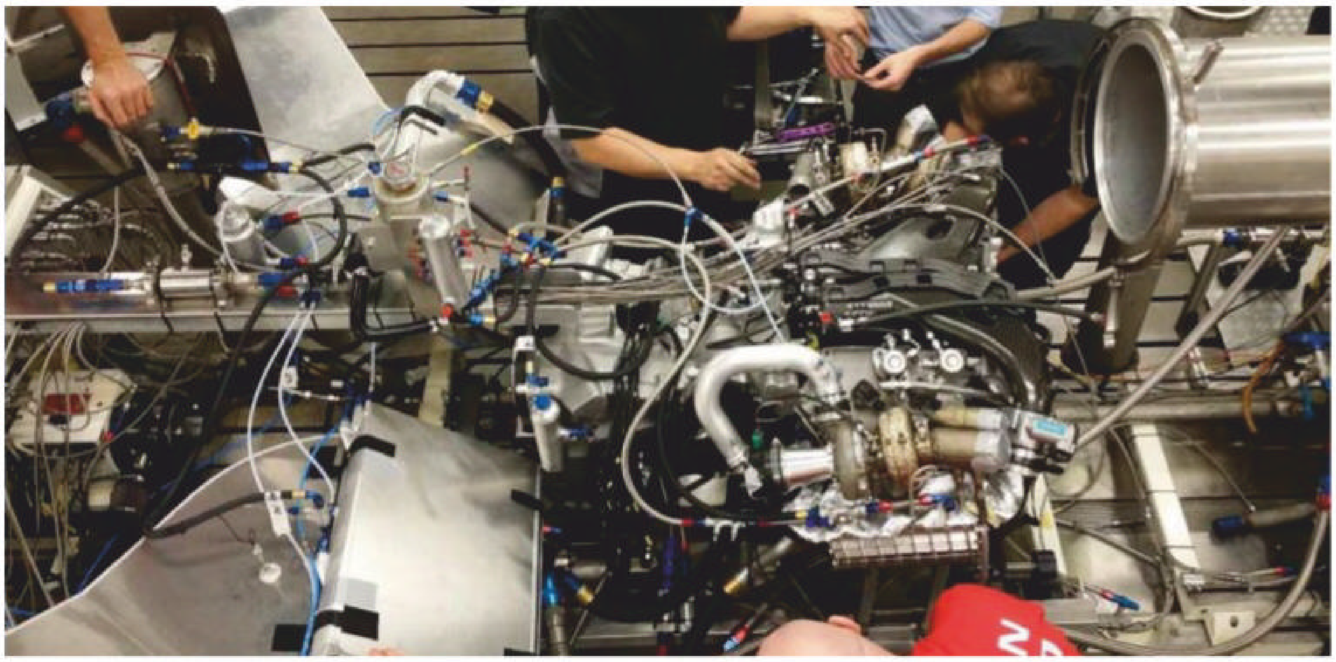

The full powertrain dyno simulated engine, ERS, gearbox and cooling; cycling it through every Le Mans lap and pit stop

> **The best use ERS deployable energy is found with a sweep through deployment lengths for each straight section**

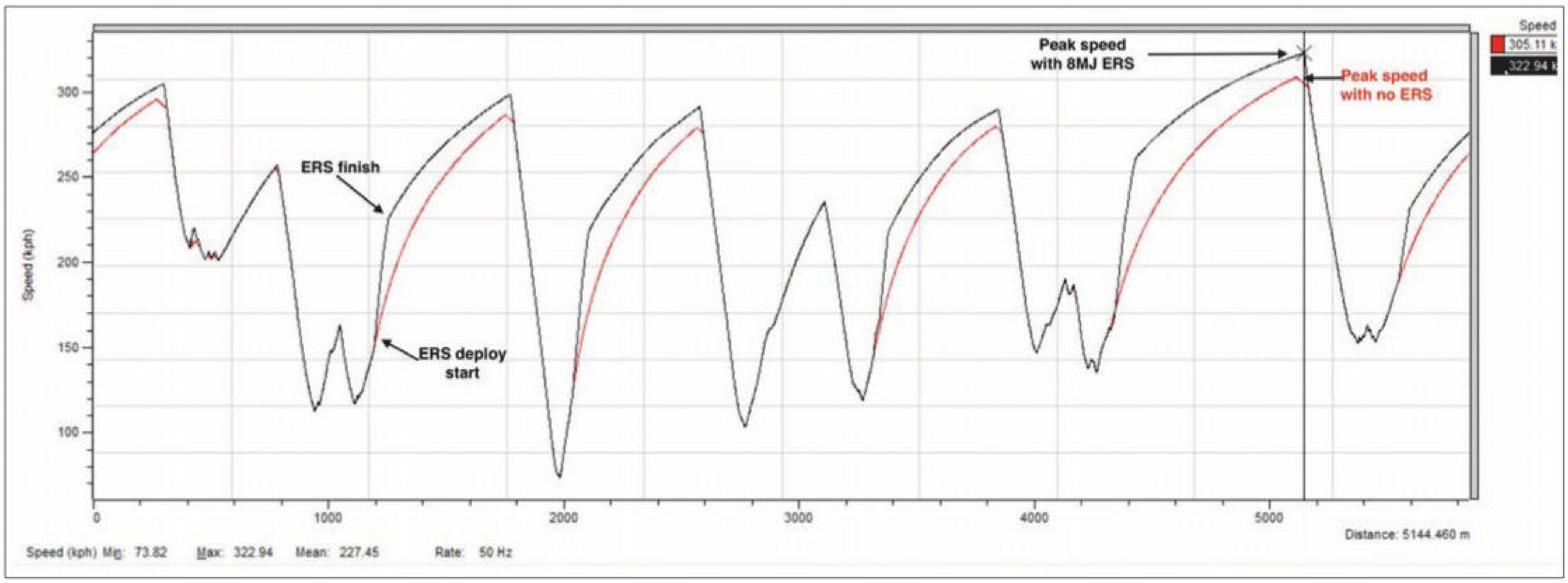

Figure 13: This shows where the ERS comes in on a typical lap (using Sebring as an example track). The red trace is the speed with no ERS, while the black is with 8MJ

is the same, but at around 140km/h the aero allows maximum acceleration (the black line accelerates as fast as braking deceleration). After around 230km/h it's pretty much the same as energy stored runs out. It is worth 3.8 seconds a lap around Sebring (which is the graph) and top speed goes from 308 to 323km/h with ERS. This simulation assumes all the energy is being recovered under braking. Note, not all straights have the additional acceleration.

But the ERS was not deployed on all the straights, it was used where there was a time gain only. A short straight will not justify the engagement, giving a couple of tenths against biggest gains. The time gained per lap is the derivative of the area between the black and red trace. At Le Mans, even with the longest straights of all the tracks in the WEC, it would still not reach terminal speed – these straights simply not being long enough.

Nevertheless, in the event, the trap speeds at the section to Indianapolis was around 15km/h faster than the opposition without ERS, and coming out of Mulsanne it was slower because of avoiding kerbs and being traction limited by all the power coming from the front axle (this was noted in the free practice). This was a good validation of the aero and drag values.

Calculating your ratios and checking top speed with power available is also corrected by ambient temperature and pressure, as air density will affect your power, fuel consumption and also downforce and drag. Note that the variation between the afternoon and night at Le Mans can be considerable.

Lift and coast

For Le Mans with ERS there is an automatic lift and coast at the end of a straight, as the onboard computer is comparing fuel use allowed for a lap (specified by the FIA/ACO) and predicting fuel used at the end of the lap, running the best strategy from the 'Energy Specific Lap Time' (ESL). ESL calculates lap time change for unit of additional energy deployed, so identifies the best use of energy.

Lap time is minimised when ESL is equal for all ERS deployment zones (or throttle clips). If ESL is not the same for two deployment zones, energy is moved from the lower ESL zone to the higher ESL zone until the ESL is equalised or no more energy can be moved. ESL will be different for ERS deployment and fuel clipping.

Best use ERS deployable energy is found with a sweep through deployment lengths for each straight section, creating an energy *vs* ESL curve for each straight, then combining the curves for each straight into a global energy *vs* ESL curve. From the sweeps selected the global ESL that corresponds to the desired deployment (e.g. two, four, six or eight megajoules) is chosen. Then you use the global ESL to find the deployment energy for each straight.

The ERS simulation runs through different combinations of flywheel energy management strategies, flywheel gearing evaluation and ERS energy harvesting opportunities (recovering before braking). It was also used to model the effects of torque vectoring in lap times and comparing open, spool, classic and torque vectoring differentials; modelling and previewing handling adjustment range and creating drive files for dyno testing.

Talking of differentials, the gains versus weight penalty of a torque vectoring unit on lap time led to a classic diff being used in the final version of the GT-R LM, and this had the added bonuses of increased reliability through it being a simplified system, while there was also a 23kg weight reduction.

Next time we will get into the details of the systems, the build and testing, and all the problems encountered –with the countermeasures employed explained.


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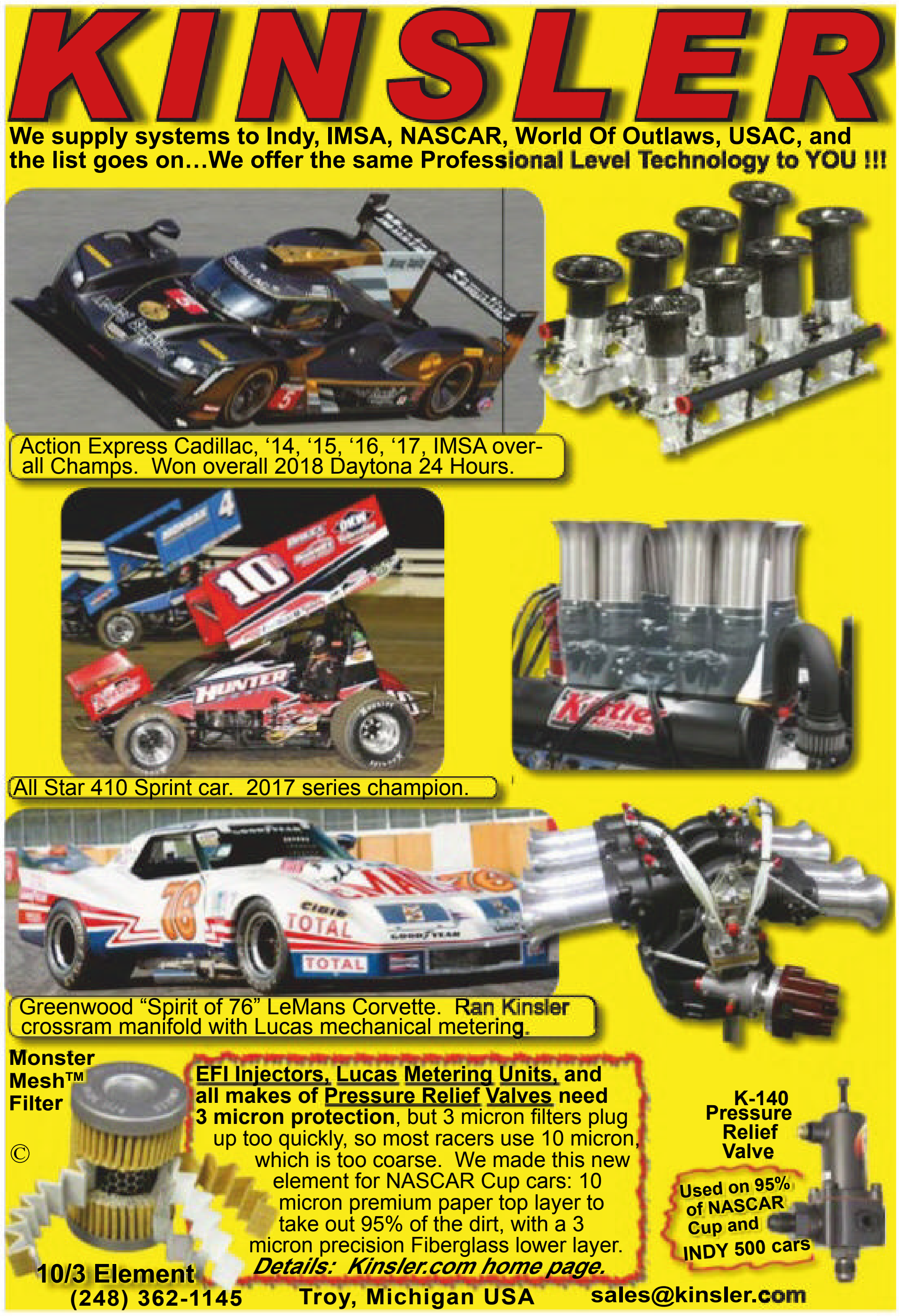
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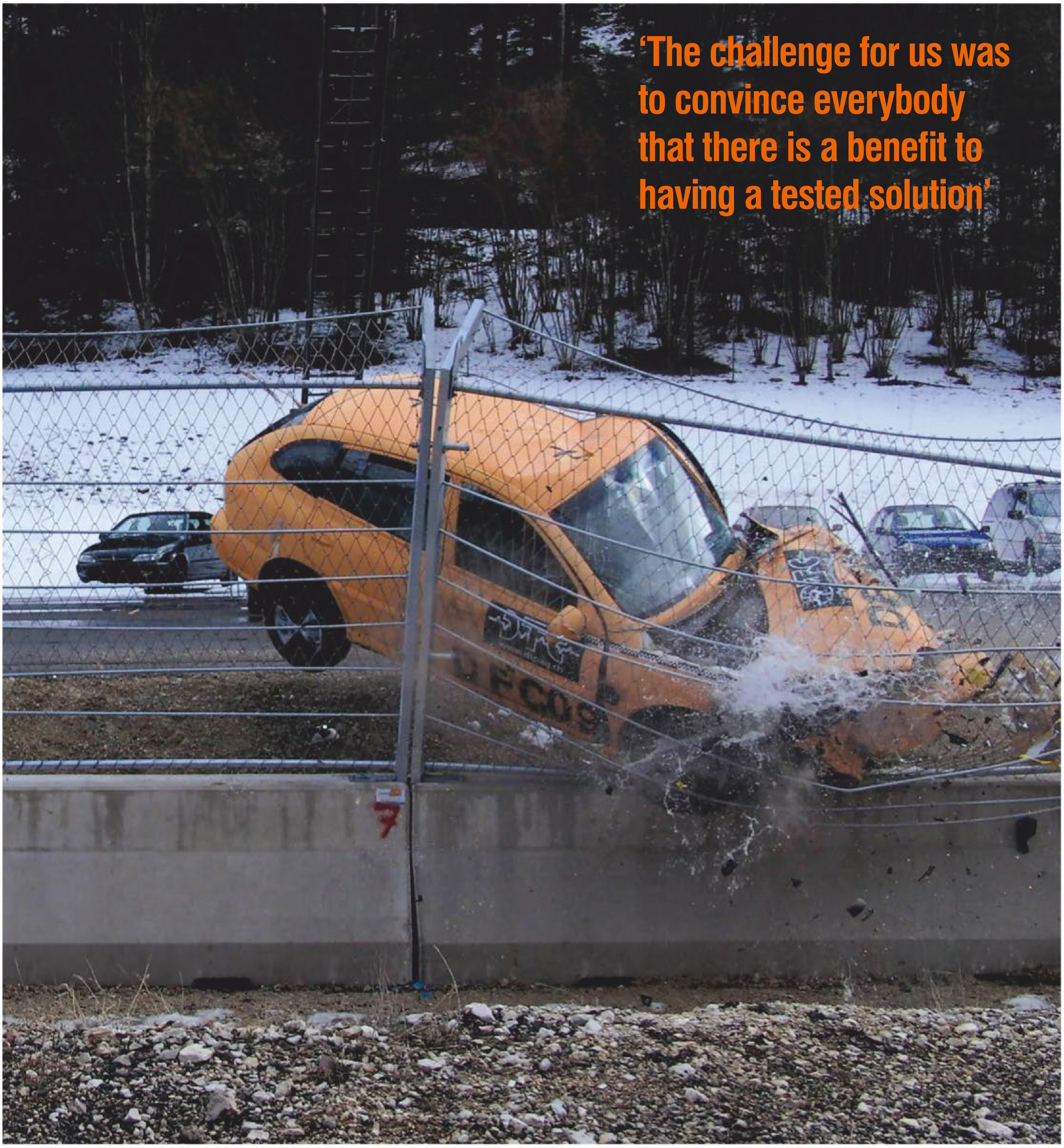
The fencing master

How a Swiss firm with a background in avalanche protection has helped set the standard for Formula 1 debris fences, and why installing them is most definitely a job for the experts

By ALTO ONO



'The challenge for us was to convince everybody that there is a benefit to having a tested solution'

The most up to date test for debris fencing involves a 1000kg car which is accelerated to 122km/h and crashed into the chain-link structure at a 20-degree angle and a height of 2m

With the introduction of significant improvements in safety standards the number of race drivers seriously injured and killed competing in the sport has hugely diminished. Over the past few decades, many new driver safety innovations have been introduced, from front and side impact structures to head restraints and the Halo. All these usually enable drivers to stay safe and walk away from even the worst of incidents.

However, the innovations and standardisation of circuit safety in order to protect the spectators and track workers has been comparatively lacking. Crashes such as at Bathurst in 2015, injuring a marshal standing behind a fence, or Sophia Floersch's accident at Macau in 2018 when she struck a photographer's building, come to mind.

While circuit safety to protect the driver has been an important factor of approvals of circuits into major racing series, up until now there was no homologation or standardised testing method for the safety guidelines of fences and walls put up to protect spectators, marshals, and track staff. This was in stark contrast to the advancement of the FIA's policies on driver safety kit, which must undergo rigorous tests, approvals, and frequent updates to standards.

Part of the lack of advancement of standards for debris fences was because the FIA seriously struggled to run repeatable tests, making it nearly impossible to compare the level of safety these barriers provided between each track. At the time, if the FIA wanted to test the performance of these fences, its method was to fire a wrecking ball at them using an air-powered cannon. But during these tests they were unable to ensure that the ball was providing the exact same impact each time.

To help resolve this the FIA has turned to the industry leader in testing high impact scenarios for fences, Geobrugg. The Swiss company is an expert in avalanche protection, slope stabilisation, and rock-fall barriers, and it has years of experience working with high tensile wire fences and testing them to the highest Swiss and International standards.

Setting the standard

To test the effectiveness of the solutions already incorporated at the tracks, Geobrugg helped the FIA realise a test where a 780kg steel ball was shot into a fence at 65km/h, at a height of 2.2m, which replicates the scenario of a Formula 1 car going airborne and then hitting a debris fence. Upon testing existing debris fence solutions, it quickly became clear that not only was there a large variance in approaches, but also a big discrepancy in performance.

'We realised after visiting all the different circuits around the globe that there are big differences between the execution of the construction,' says Geobrugg's motorsport director Jochen Braunwarth. 'So we informed the FIA about that and we told them we didn't feel very confident that the other systems were also performing as they should perform; complying with that original set of guidelines the FIA wanted to have.

'Because most of the solutions in the past were supplied by a local steel workshop just for one facility, they had their own solution for that one facility,' Braunwarth adds. 'If you move 500km in another direction, a different steel workshop would have their own solution, so nobody was coordinating. So, every time you go to a facility, it looks entirely different.'

Braunwarth and his team then took the initiative to see if modifying existing systems would help improve the quality overall. However, it quickly proved to be too challenging due to the sheer number of geometric variations and differences in individual performance.

Utilising its 50-plus years of experience in absorbing high energy impacts, Geobrugg sought this opportunity to make better debris fences that were more in line with the FIA's vision in its safety guidelines. By incorporating Geobrugg's unique high tensile mesh, that can withstand up to four times more force than conventional mesh, Braunwarth and his team were able to build a completely new design that not only met but exceeded the safety guidelines of the FIA at the time.

However, when Geobrugg decided to go to market with its new product, which was FIA tested and approved, it faced a new issue. 'The biggest challenge for us was the acceptance of something so different,' Braunwarth says. 'For the last 20 years, everything was homemade, or DIY. And nobody was checking these fences. If it looks okay and the schematics seemed like it was up to the FIA safety guidelines, that was enough. We were challenging the status quo. The challenge for us was to convince everybody that there is a benefit to have a tested solution.'

That said, some new circuits being built did see the benefit of a performance tested solution. Back in 2012 the Circuit of the Americas in Austin, Texas was one of the first major tracks to adopt Geobrugg's FIA approved debris fences. While they were called very late into the project, Braunwarth and his team were able to complete the design, production, and installation of a FIA approved debris fence within a period of six months. This was quite an impressive feat and another major track soon followed suit; Sochi.

However, more challenges lay ahead. While circuits like COTA and Sochi were happy to see a standardised and tested solution, many others were unsure of the method that was used. Braunwarth describes the initial test outlined above, of the 780kg steel sphere being shot into a fence at 65km/h, as 'a very severe, very theoretical test.' But he adds: 'Nobody was able to really transfer it to real-life scenarios on the circuit. This meant that all the hard work we put in was only to receive a very nice letter from the FIA saying that we are able to use our product on the race circuit, but it bore no merit.'

'We realised after visiting all the different circuits around the globe that there were big differences between the execution of the construction'

Geobrugg's high tensile mesh, shown in a fence at Singapore, can cope with up to four times more force than regular mesh

Geobrugg quickly relayed the feedback it had received from tracks about their tested solutions to the FIA. Around this time, the FIA had also started to collect information on motorsport incidents around the world as part of its World Accident Database initiative. This allowed it to gain an insight into what accidents have happened, which accidents are most common, and what can be done in order to prevent these incidents from becoming severe.

Crash test

The FIA then introduced a new, harder test for debris fences. This involves a 1000kg car accelerated to 122km/h into a debris fence at a 20-degree angle, at a height of 2m. Furthermore, in order to pass the test, the FIA Standard 3502-2018 states that: 'The resulting maximum dynamic deflection of any part of the fence system, measured as the distance between the fence section's foremost point before and rearmost point under impact, must not exceed 3m' with no significantly-sized piece of debris making it through the fence. This new standard was more in line with the FIA's vision of data-driven safety and there was a big push for circuits to adopt a tested fence.

With these new standards, Geobrugg had to retest all of its barriers, but only slight modifications were required to pass the new test criteria. Additionally, this new test method was an opportunity for Geobrugg and the FIA to really showcase what can go wrong if the installed fencing did not meet these standards.

Now as homologated pieces of circuit safety, spectator, marshal, and on-track staff safety standards have become identical to driver safety standards. For the first time this homologation standard guarantees that whether a person stands behind a permanent debris fence installation such as those being introduced at Zandvoort, or a temporary installation like the ones being introduced to the new Hanoi street circuit, there will be the same level of safety.

But as with all pieces of kit that are homologated, this meant that these barriers must be produced in the same way every time to ensure that the quality is exactly the same as those that have been tested. While this is not a huge problem for driver safety kit such as helmets and Nomex racesuits that can be easily shipped, it is quite a challenge for something as large as debris fences. In order to achieve this, a centralised supply chain had to be created and the barriers had to be made in such a way that they could be easily transported, not only between countries in Europe but across continents and sometimes by sea.

'The thing with our systems is that the whole debris fence is all bolted together,' Braunwarth says. 'So it's easy to ship and it's easy to locally assemble systems and make sure they are up to homologation standards. If you think of old, non-homologated systems that are often entirely welded together, how would you

The sphere test involved a 780kg steel ball hitting a fence at 65km/h at a height of 2.2m. This was to simulate a Formula 1 car getting airborne and then crashing into the structure

Fences must be produced in the same way every time, to ensure the quality of the structures

US Grand Prix venue COTA was quick to see the sense in installing debris fencing that was of a proven safety standard

guarantee that the welds you are testing are exactly the same as those being installed? You need to have a process in place to check it.'

By making it an all-bolted together solution, Geobrugg was able to create a centralised supply chain in Europe from where it can ship out its steel section of the debris fences globally, while maintaining full control of their quality in order to meet FIA homologation standards.

Concrete commitment

But one production challenge still remained; the bottom concrete barrier section. Because shipping such large quantities of concrete barriers to far off tracks such as Vietnam is simply not cost effective, Geobrugg ships the moulds and necessary materials to create the bottom section closer to the venue itself. But they do not simply just drop them off and expect the local manufacturers to build them. Since the homologation standards requires them to be built exactly the same way each time, this means that not only the same materials have to be used but also the same manufacturing methods must be followed.

Geobrugg expected that this might have been a challenge in a country like Vietnam, where the infrastructure is not at the same level as the other countries in which it produces its barriers. However, it was pleasantly surprised.

'We approached one of the largest and best pre-cast companies in Vietnam, and they did a fantastic job, beautiful quality control,' Braunwarth says. 'We were surprised by the level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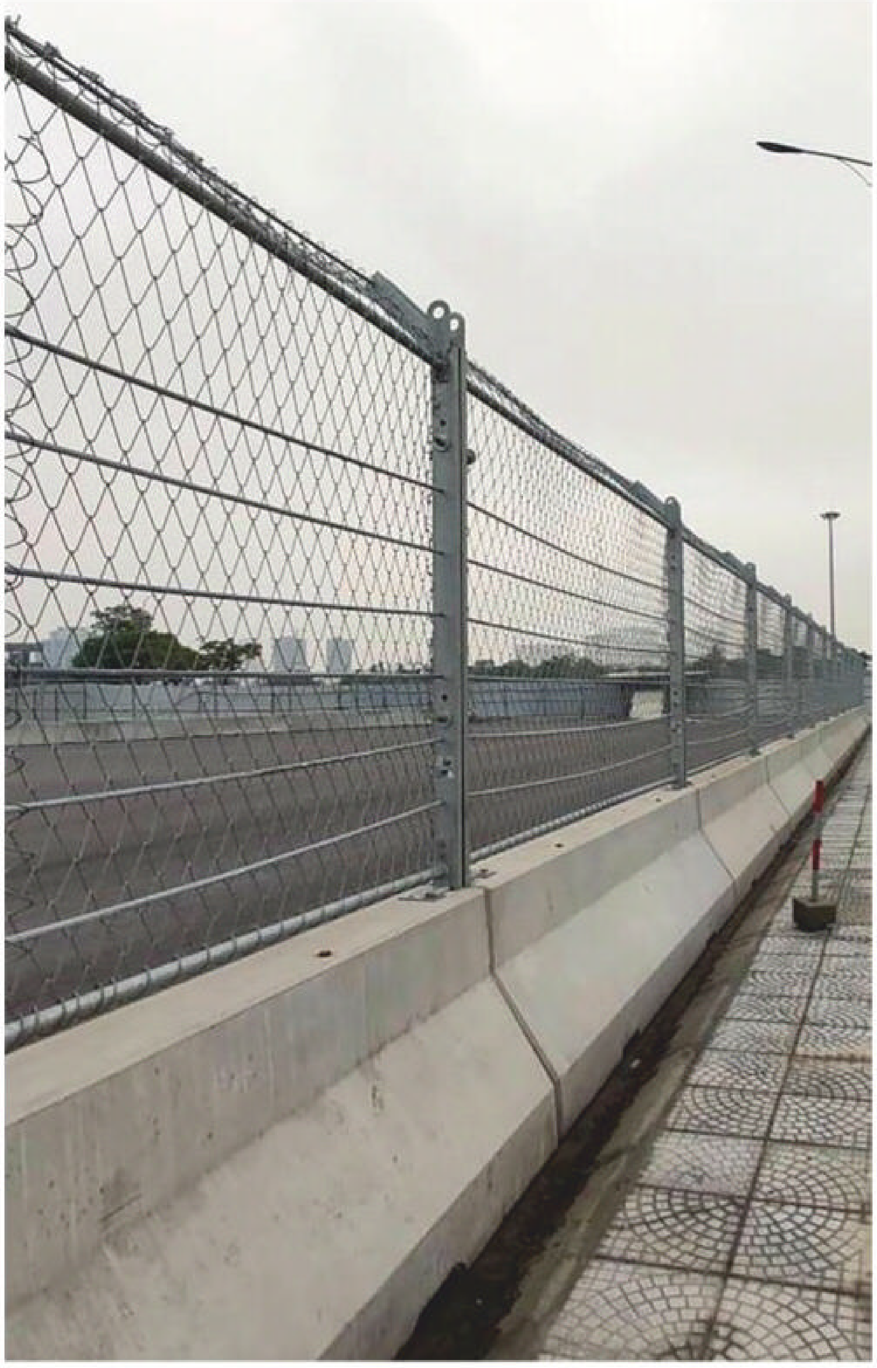

Concrete bases are difficult to ship and are often made locally to strict standards

Seal of approval. The FIA safety standard ensures each F1 track has effective debris fencing

of quality control, because it was to the same standards that we have in Germany where we normally manufacture all of the barriers.'

But for a temporary street circuit like the one in Hanoi, the challenges do not stop there. The homologation standards set by the FIA require that the debris fences are installed in the exact same way that they were installed for the test. 'Although we're not held responsible [by the FIA] for the installation itself, we have to make sure that it is done in a proper way. At the end of the day, we are ultimately responsible for the performance of the system,' Braunwarth says.

Linked up

Geobrugg is not just providing a fence, but also a service. 'The great advantage of working with a company like Geobrugg is that we have experience in delivering everything a client needs,' Braunwarth says. 'You can be sure everything will be thought of because of the experience we bring to the table. You have to remember that as a circuit owner, you only build once in a lifetime. So the project managers, except for maybe a design company, build one circuit. They don't know anything about the solutions and problems. So for us, it always starts off with an education.'

It is therefore important for Geobrugg to clearly communicate the importance of the debris fences, the proper installation procedures, and ensure that no detail is missed. But as circuits are built, trackside safety is often left until the last minute and, at times, Geobrugg is called in very late in the project. This means that it is required to not only speed up the manufacturing and the layout design but sometimes it must conduct both tasks in parallel. With all this, coordination with circuit designers, suppliers, and different departments is key to getting the project done on time.

To do this, Braunwarth emphasises the importance of communication and having boots on the ground at the site. 'We have one guy permanently on site and we have our own installation crew for certain tracks,' he says. 'This is critical to make sure that all the communication is properly done, and that there is no misunderstanding. For all the big projects we've done so far we've always had someone on site speaking the local language.'

Zandvoort provides a unique challenge of having to install barriers on a banked section of track

The importance of communication is further exemplified on a street circuit like Hanoi. The installation of debris fences needs to be done in a very short time period. And at the same time, the circuit is not only installing the concrete blocks and debris fences, but is also installing the grandstands, Tecpro barriers, CCTV cameras, marshalling systems, audio systems, networking infrastructure, and so on.

'With everything interlinked together, you need to understand the local language,' Braunwarth says. 'This is why, for Vietnam, we have a local project manager who speaks German, English, and Vietnamese, to make sure that we are able to comply with all the requirements the circuit, the organisers, and the governing bodies, put on the table last minute.'

Banking on it

But the importance of communication is also vital at permanent instalments such as those for Zandvoort. The Dutch track, which returns to Formula 1 this year, provides the unique challenge of having to install barriers on a banked section of track. 'That is very, very tricky to coordinate everything,' Braunwarth says, 'especially because there will be safety barriers installed in front of our barriers. We have to


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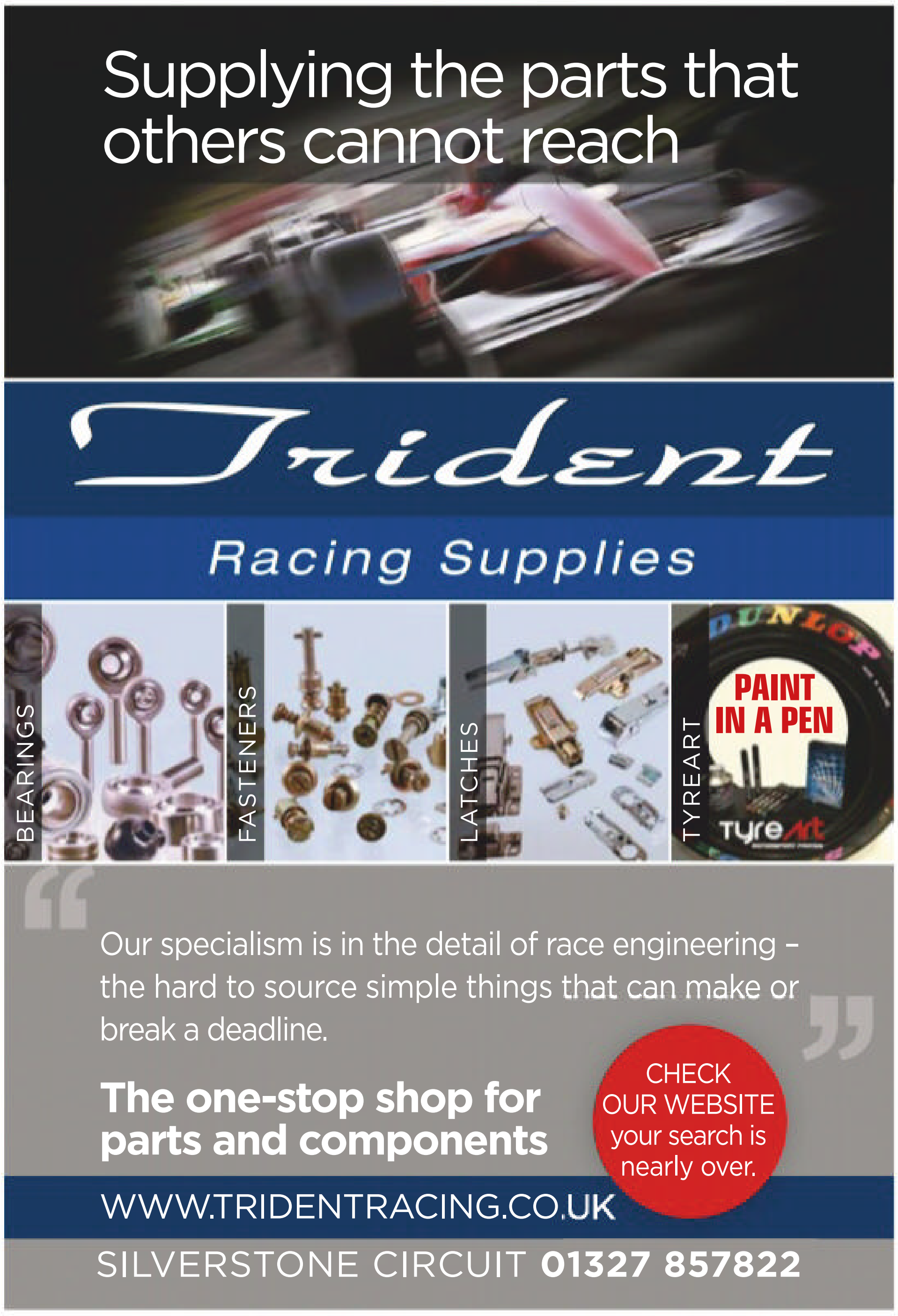
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'Two days before the event the media walk the circuit and mark the areas where they would like to have an opening for cameras'

make sure we coordinate everything with the circuit, the construction company, the safety barrier company, and the asphalt company.'

This is because the debris fences must be installed at the top the banked section. That means they cannot be installed if the safety fence is already installed, as this would require lifting the debris fences in the air. The fences cannot be lifted into the air as this would require a crane, and you cannot drive a heavy crane on the new asphalt. So, the top metal fence panels of the debris fences must be installed at a later stage than the bottom concrete section in order to ensure that the other companies involved with the circuit build are able to do everything.

New debris fencing has been installed at Zandvoort in readiness for its return to the F1 calender for the first time since 1985 in May of this year

Camera angles

Then there's the details to attend to, such as openings for TV cameras and photographers. Traditionally, media outlets and TV operators would dictate which spots around the circuit were a good place to catch the best shot. However, the best spot would change from event to event depending on the nature of the track and the opinions or expertise of the crews involved. This meant that circuits continued to make new windows in debris fences, often without closing them after the event. Without any standard for checking debris fences, circuits had no way of knowing what was the proper after-care of these windows, nor of understanding when these openings compromised the debris fences themselves.

'The idea here is to come up with a photographer opening, which you are able to install at a very late point to make [the client] happy,' Braunwarth says. 'These openings have to be a certain dimension to accommodate extended cameras or box cameras and the ultimate goal was to make it possible to easily close the opening after the event. The idea of these openings was really triggered by Charlie Whiting [former FIA safety delegate].'

The modularity of the solution was particularly important as many events greatly differ when it comes to camera needs. For example, top level racing such as the WEC or Formula 1 requires many openings as they are internationally televised and media outlets from all over the world fly to these races. On the other hand, national club racing does not require as many TV cameras. Geobrugg now produces 'flexible openings', introduced last year at the FIA World Rallycross in Spa.

'Two days before the event the media walk the circuit and mark the areas where they would like to have an opening, and we install the opening with a flexible frame, where we can customise the width of the opening,' Braunwarth says. 'This is all, of course, always in accordance with the homologation guidelines. We are simply able to just open the mesh, and then after the event we're able to close it again.'

The company is also able to do this in a safe manner without compromising the overall structure of the debris fence. This is done by cutting the mesh area of the desired section, fixing the mesh to the nearest round bar or cable, and inserting a border frame. After the event is finished, the cut mesh is then simply unfixed, lifted to cover the opening, and connected with round wire that has the same strength as the mesh itself.

Fenced in

While the model for mandating 3501-2017 and 3502-2018 homologated fences for the FIA will be like that of the Halo, with a phased introduction starting at the top levels of motorsport and then being adopted further and further down, there have already been some other unexpected benefits for Geobrugg. Its solutions have now been implemented for the proving grounds of companies such as Fiat-Chrysler, VW and Daimler. This is important, for while the greatest precautions are taken to ensure the safety of those in the vehicles that are tested, often engineers and drivers are left exposed in open areas where they might come in to change drivers or check on the car.

Not only does the new fencing put the minds of those working at these test facilities at ease, but it also makes it easier to prove to the insurance companies that a state-of-the-art solution has been implemented. This benefit has attracted some racing clubs, too. 'In one case in Miami, the insurance company for the track reduced their insurance premium,' Braunwarth says. 'A big part of this was that the insurance company no longer had to cover the performance of debris fences as another company is taking the responsibility of the quality and effectiveness of the solution.'

The positioning of the structure involves precise engineering

While debris fences are an important first step for circuit safety, Braunwarth believes that the further homologation specifications in the pipeline for other circuit safety devices, such as light panels, will help elevate the minimum bar for safety for tracks around the world.

'If you think of an individual checking a circuit for safety, it would be impossible to make sure everything is right unless you are an expert at everything,' Braunwarth says. 'And I believe that for most of the race circuit installations, you simply can't be an expert of everything. Homologation of equipment is a good way for the FIA to ensure quality standards for the circuit hardware. More and more standards introduced in the future will guarantee consistency and to make it a little bit easier for a circuit inspector to determine if things are a good solution or a bad solution.'

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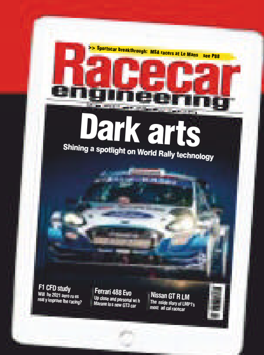


Lock, stock unravel

An enquiry from a stock car engineer has prompted *Racecar's* simulation expert to consider the merits of the locked differential

By DANNY NOWLAN

For a stock car on a road course a locked differential could be a better option than a limited slip diff – and it will certainly make it easier to drive while up on two wheels!

From time to time you get a job that you think is going to go in one direction but it actually winds up going in a totally different direction. For example, recently a friend of mine asked me to conduct some simulation work to see whether it was worthwhile putting a limited slip differential (LSD) into a road course stock car punching out around 600bhp.

We both reckoned that this should be a no brainer. But now I can see that we were massively wrong, for when I ran the numbers and put the simulations through ChassisSim it turned out that a locked diff was actually the way to go. We'll be exploring why here.

Key to the lock

But before we get into the simulation results it would be worth going over what a locked diff actually is. As I stated in my book *The Dynamics of the Racecar*, the locked diff makes sure that the inside and outside wheels are at the same rotational velocity. The schematic of the locked diff is shown in **Figure 1** (where *V* is forward speed, *t* is track and *r* is yaw rate).

Figure 1: Schematic of a locked differential

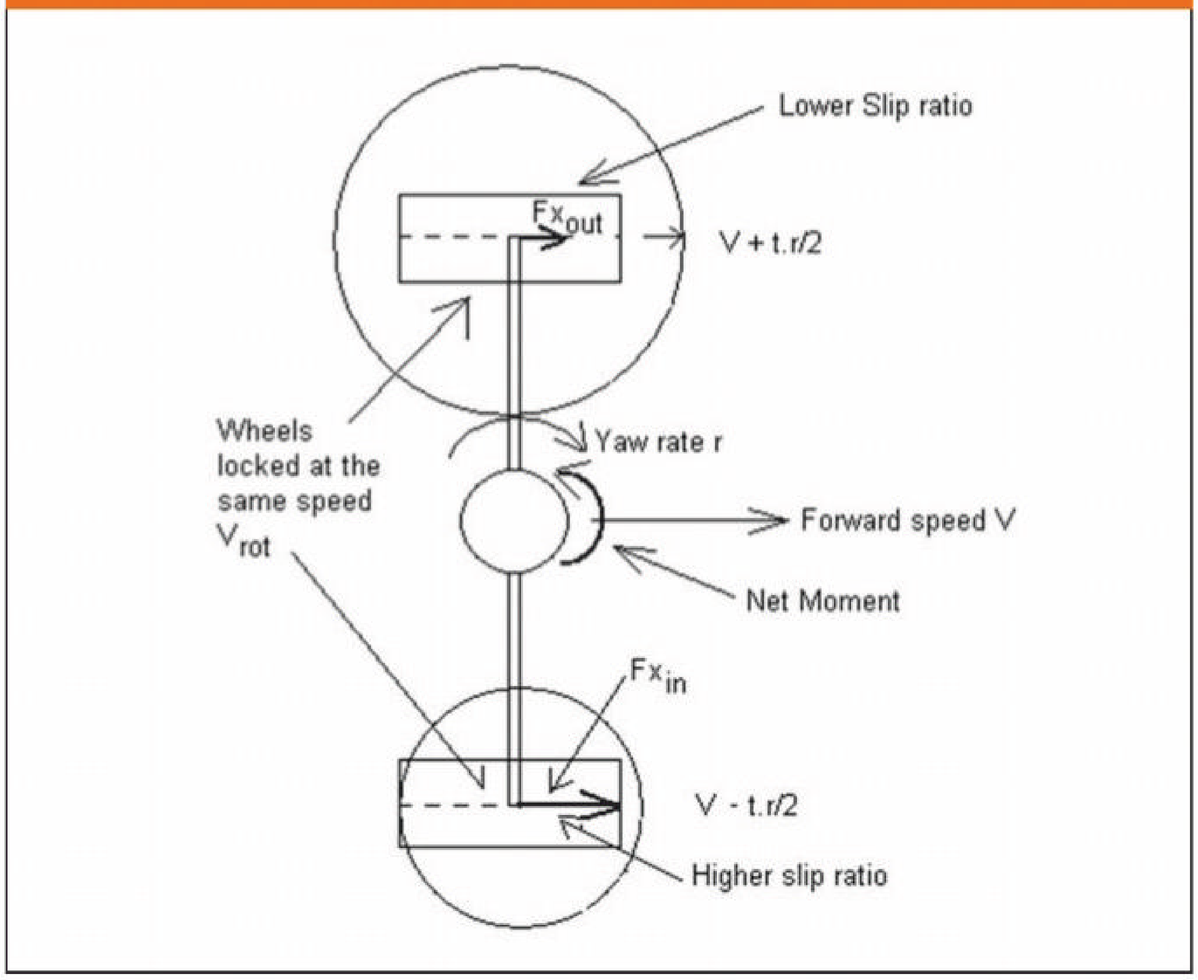
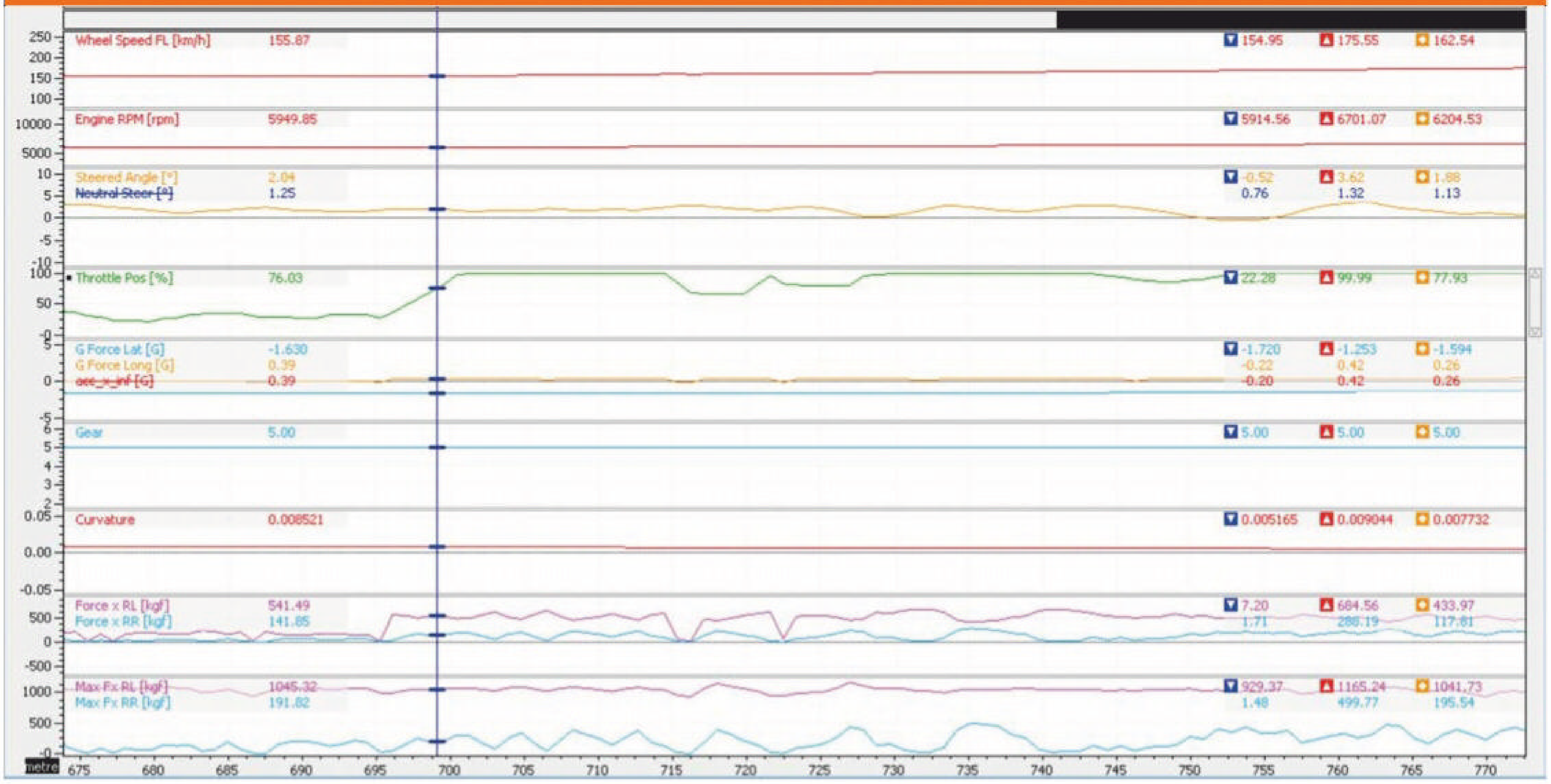


Figure 2: Baseline of the locked differential



If you stay within the traction limits of the rear tyres the main problem you will have to deal with when using a locked differential is understeer

If you stay within the traction limits of the tyre the problem you will have to deal with is understeer. This is a result of the fact that because both wheels are rotating at the same velocity, whether this is in braking or accelerating (the acceleration case is shown in Figure 1), the locked differential will always try and push you out of the turn.

The mathematics of this I will leave for another time, but the bottom line is that the locked diff is about as subtle as sending a special forces unit to break up a minor scuffle between a bunch of four-year-olds at a day care centre. This is particularly the case with low powered racecars and road cars.

Lock and load

That said, the locked differential does present a number of advantages, particularly as the power increases. For instance, you always know what the wheel velocities are and that they will be equal, and this makes it very easy to tune for stagger, particularly if you are running on the dirt. Also, as the load transfer equals out the locked diff comes to you.

But let's now get into the specifics of the racecar, which are summarised in **Table 1**.

Table 1: Racecar parameters

Parameter	Value
Mass	1150kg
Front weight distribution	50%
Front track	1.5m
Rear track	1.5m
Peak engine horsepower	440kW
Rear suspension type	Live axle

To make things simple, here I have used the V8 Supercar template. This particular example was based on a car optimised for turn-in with a live axle, which will have ramifications for the analysis which we will explore later on. Also, just for the record, all simulations were undertaken using ChassisSim, and performed at the Queensland Raceway circuit, which has a mixture of high-speed and low-speed corners on a track that's very bumpy. Consequently it is a great test for a racecar.

Base simulation

To begin with, a base simulation was run using the locked diff. Even though the locked diff may not provide the most elegant of simulations, **Figure 2** does show its effectiveness. The first two traces are speed and RPM respectively. The third and fourth traces are throttle and steered angle at the tyre. The fifth and sixth traces are lateral and longitudinal *g* and gear. The seventh trace is curvature.

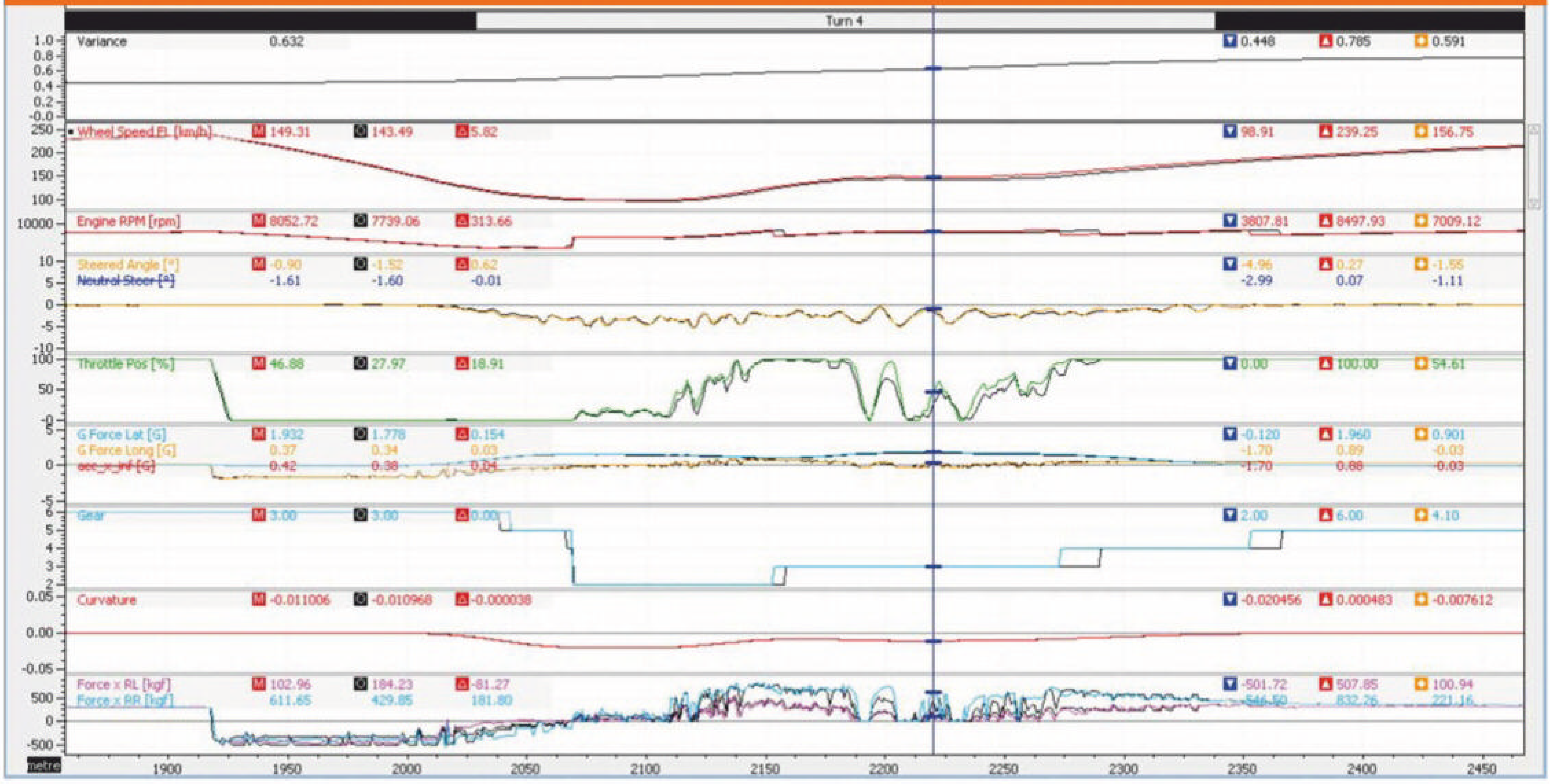
However, the important traces here are the final two. The eighth trace shows the maximum possible longitudinal force available from the tyre and the last trace shows the applied longitudinal force at the tyre. Figure 2 tells us some very revealing things about what is going on with the locked diff and to summarise this **Table 2** illustrates the distribution of the forces.

Just for clarification, the distribution of the forces is taken from the outside tyre side. The important thing here is the comparison of the distribution of the forces between the actual

Table 2: Distribution of the longitudinal forces for the locked diff

Dist	Throttle (%)	ay	Ideal Fx (kgf)	Actual Fx (kgf)	Ideal *vs* actual distribution
682.7	33.6	1.69*g*	1038/98	206/39.1	91%/84%
700	76.03	1.63*g*	1045/191.82	572/142	84%/80%

Figure 3: Locked diff *vs* LSD for traction under power



While the locked diff has all the sophistication of cracking an egg with a sledgehammer, in this case it has been brutally effective

case and what ChassisSim put down. In both cases the delta between the high-powered cases and the low-powered cases was seven per cent and four per cent respectively.

If you have a high-powered car you would be mad to walk away from this, then. While the locked diff has all the sophistication of cracking an egg with a sledgehammer, in this case it has also been brutally effective.

Table 3: Lap times at Queensland Raceway for a stock car with different diff parameters

Configuration	Lap time
Locked diff	1m04.97s
LSD 10% power, 5% coast	1m06.70s
LSD 30% power, 5% coast	1m06.45s
LSD 40% power, 10% coast	1m06.00s
LSD 40% power, locked coast	1m05.69s
LSD 60% power, locked coast	1m05.25s

Differing diffs

To complete this investigation a number of different diff parameters where tried and the results of all this is shown in **Table 3**.

What is apparent here is that for this particular stock car and this set-up a locked diff is obviously the preferred solution. When we got down to the last setting with an LSD with a locking ratio of 60 per cent under throttle, and locked diff on the way in, to all intents and purposes this is a locked differential.

While the simulated data showed the biggest gains were in turn-in and exit, looking at the comparison of the LSD with the 40 per cent power setting, the bulk of the time was lost under acceleration. This time loss for the acceleration component was 0.7s. The reason is that the LSD couldn't put the power down as effectively. This is shown in **Figure 3**. Here the locked differential is coloured and the LSD is black. The reason the LSD can't put power down as effectively as the locked diff can be deduced by the final trace. As can be seen, when we look at the applied longitudinal forces to the contact patch, the locked diff does a much more effective job of delivering more forces than the LSD. It is that simple.

Take note

But a couple of things to note with the results we have presented here. Firstly, the set-up used for this investigation was optimised for a locked live axle racecar to promote turn-in. Consequently, when we loosened the differential up in coast it would be more unstable. Once the differential was tightened up under coast (braking) we stopped losing time under turn-in. I was anticipating this, but I thought it would be offset by the advantages under traction. I was wrong.

Secondly, one investigation I didn't undertake was running this analysis with an independent situation. As I discussed in an article in 2011, when I was comparing what would happen when V8 Supercars was going to go from a live axle rear end to an independent rear end, these two suspension systems are fundamentally different animals, especially in the way they transfer load and then the impact of jacking forces. So, what might work very nicely for a live axle car might not translate to an independent rear suspension.

Also, you must always be aware that there is a downside to using a locked diff, particularly

You must always be aware that there is a downside to using a locked differential

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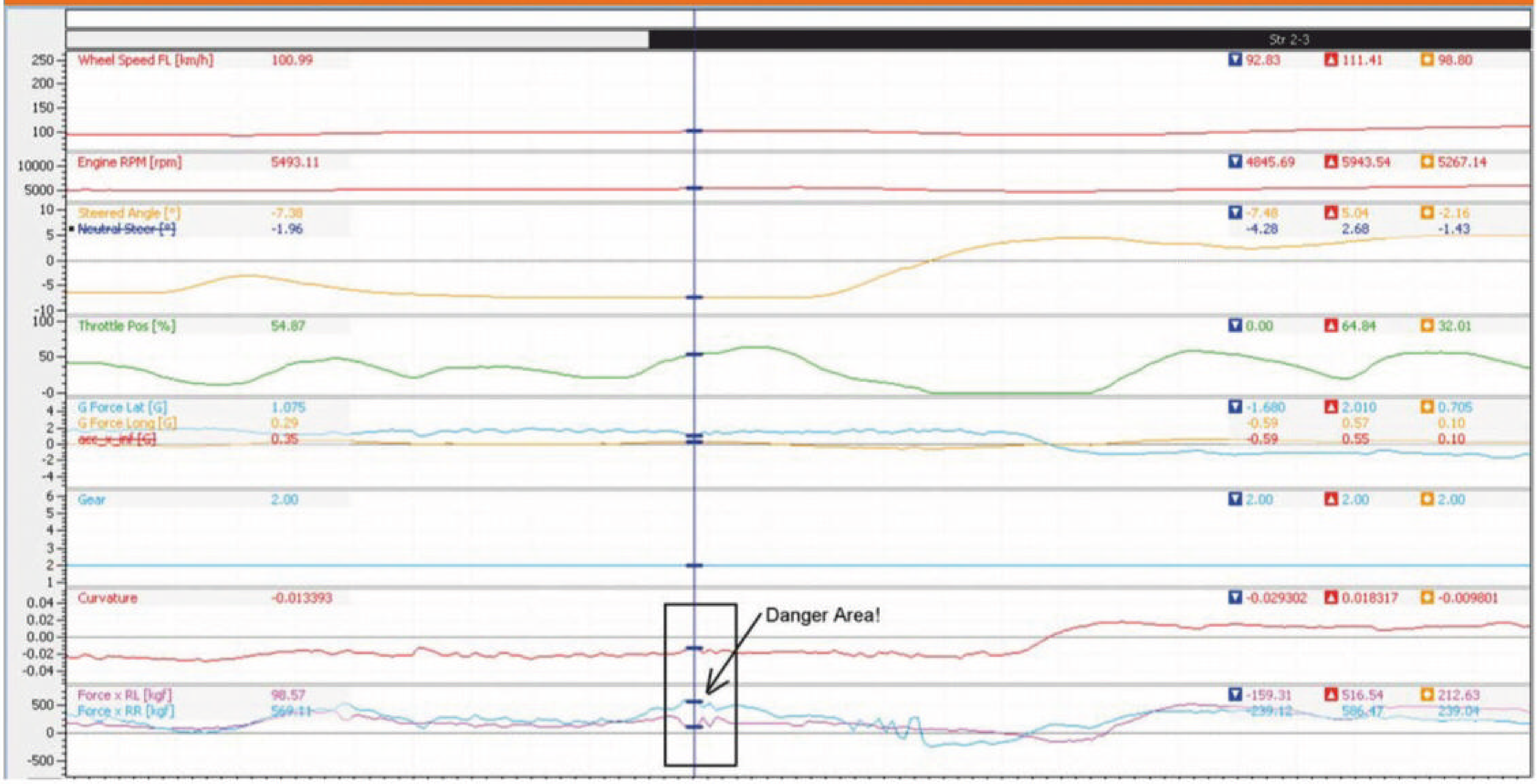
Figure 4: Plot of tyre forces in the post-stalled region for a locked differential



Something that has become apparent is that if you are dealing with a high-powered car then a locked diff does warrant some consideration

in the post-stalled region of manoeuvring. When we were developing ChassisSim driver in the loop one of the case studies we struggled with initially was when the locked differential broke traction. We did get on top of it (since my competitors read these articles I won't tell you how!) but the trace marked up in **Figure 4** illustrates the problem.

When we are at post-stall what happens is that since the locked differential has the same wheel velocities left to right their distribution of forces can be approximated by the maximum possible forces. Obviously, it won't get to those forces but it's not a bad approximation. However, the problem is the outside longitudinal tyre force is much greater than the inside tyre. This creates a significant oversteering moment and if you're not careful it will catch you out. This is particularly apparent when you are in the mid-corner condition.

Locked solid

All that said, one thing that has become apparent from this investigation is that if you are dealing with a high-powered racecar then the use of a locked diff does warrant some consideration. In particular, if we take a look at Table 2 again, the distribution of ideal tyre forces *vs* actual was very favourable. Also, the traction advantages that we have assessed in Figure 3 are quite compelling.

The other thing that this investigation highlighted is just what a critical tuning tool the differential is. The time loss under turn-in between the LSD under braking *vs* the locked diff was a classic case in point. The bottom line is, you ignore the diff at your peril.

Conclusion

In closing, while the locked differential isn't as fashionable as a modern limited slip differential in racing, there is much to be said for it. As we have found, with high-powered live axle stock cars the limited slip differential wasn't quite as good as we had anticipated compared to the locked diff. This was primarily due to the latter's excellent properties under traction.

While I am certainly not advocating that you get a TIG welder and weld up your differential here, there is much to be learnt from all we have looked at, and on a personal note this investigation has provided me with some excellent food for thought.

One category that makes use of locked diffs is drifting, where once the rear has broken away understeer is rarely an issue

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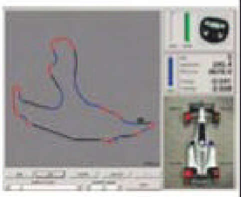

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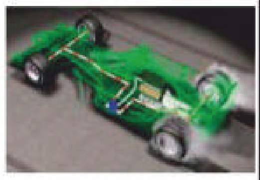

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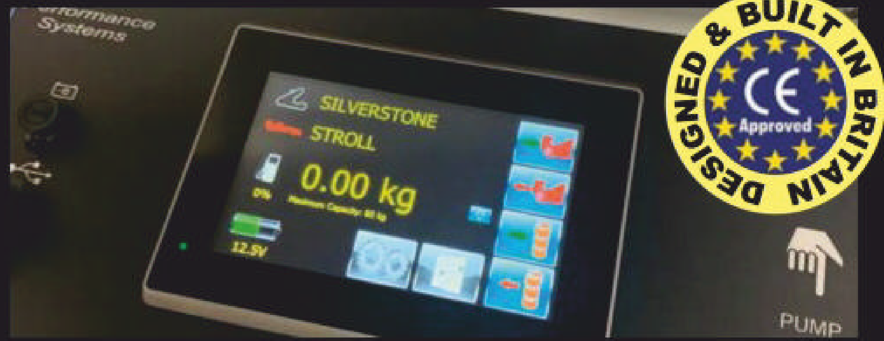

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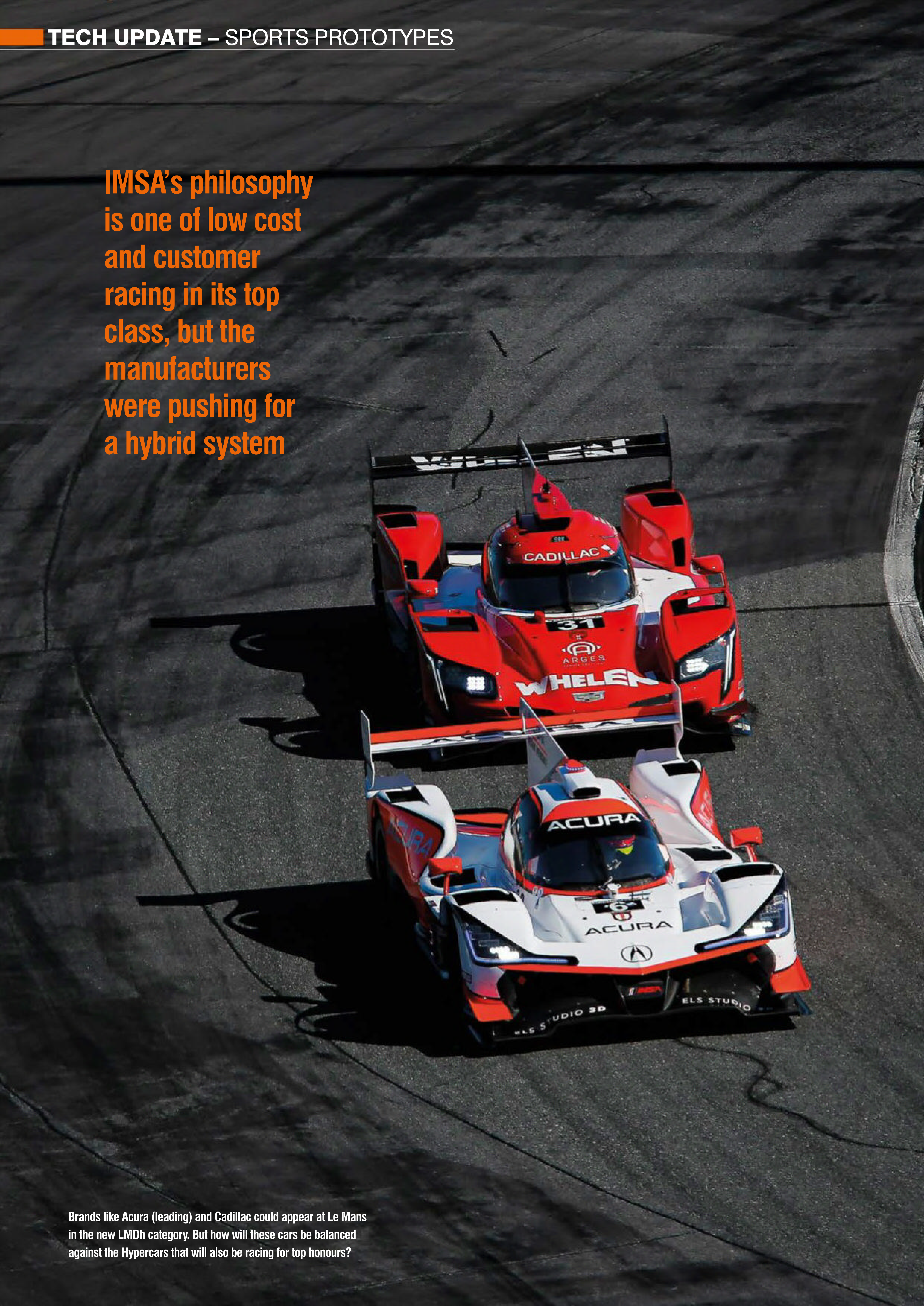


IMSA's philosophy is one of low cost and customer racing in its top class, but the manufacturers were pushing for a hybrid system

Brands like Acura (leading) and Cadillac could appear at Le Mans in the new LMDh category. But how will these cars be balanced against the Hypercars that will also be racing for top honours?

Hyper reality

A decision to bring the DPi and Hypercar regulations under the same umbrella was announced at Daytona and the initial reaction was rapturous – but now comes the hard work of drawing together two totally different concepts

By ANDREW COTTON

It's been a long time coming, but finally IMSA and the ACO sat down at Daytona in January to announce that their separate prototype classes would be brought together. This news was welcomed by all parties, including manufacturers, but then immediately the hard work started to meld these vastly different regulations together.

This story goes back a long way. The ACO and IMSA were working together on a set of regulations that would have united their series before the ACO veered off course and introduced the Hypercar concept in 2018. At the time, Porsche and Toyota were indicating that Hypercar is what they wanted; extreme hybrid technology for lower cost than the current LMP1 cars. The ACO delivered before Porsche abruptly cancelled its programme.

At that point the ACO could have changed direction, but it didn't, and instead at the following Le Mans in 2019 it reaffirmed its commitment to Hypercar, believing that other manufacturers would join. Those interested included Ferrari, McLaren, Aston Martin and Ford, but they all wanted a different base concept and at the time of the ACO's reaffirmation they still had different agendas.

Hyper market

In a bid to keep the whole thing together the ACO, and its partner the FIA, had already agreed to accommodate four different concepts; hybrid prototype, non-hybrid prototype, hybrid road car platform and non-hybrid road car platform. This would all be cost-controlled between €20m-€30m, and performance balanced.

Following the ACO restating its commitment to Hypercar, Aston Martin and Toyota confirmed their commitment to the new regulations. Then, in November, Peugeot announced that it, too, would commit to the top class and it seemed to be game on. The Peugeot announcement came a week before sister brand Citroen announced that it would withdraw from the WRC and was considered to be a softening of that blow, but they were in. However, Peugeot has never built a Hypercar, and is never likely to as a brand so its announcement was something of a mystery.

The ACO was confident that it was on the right path, however although the hoped-for manufacturer support was not forthcoming. Porsche had such little faith in the regulations that it didn't even present a programme to the board of directors in July 2019. They considered the formula to be expensive, and didn't have the money to compete with Toyota which openly admits that its budget will be €50m.

The Hypercar manufacturers have targeted around 850bhp as their power output, but the DPi manufacturers are aiming for 600bhp

On IMSA's side, the new DPi 2.0 regulations, due for introduction in January 2022, were in progress and by Christmas were almost complete. IMSA's philosophy is one of low cost, within range of customers racing in its top class, but some manufacturers were pushing for a high-power hybrid system. As one put it: 'Selling a prototype programme to the board without hybrid? Good luck'. IMSA has therefore sought the lowest-cost system that it could manage and by January's Daytona 24 hours had still to make a decision on supplier, and specification. By then, however, politics had intervened.

IMSA's prototype class is based on the ACO's LMP2 chassis, with cars supplied by Dallara, ORECA, Multimatic and Ligier. The main mechanical parts, including the brakes, suspension and gearbox, are all shared with the LMP2 cars, but the key difference is the engine; regulations are open but power and torque curves are performance balanced.

In terms of aero, road car product designers have been invited to contribute to the overall racecar design cues, safe in the knowledge that their designs are also performance balanced.

What has emerged are cars that are good looking, have a resemblance to product, and are cheap. The most expensive estimate for a season is $6m per car running costs and this has made IMSA's series rather attractive. The issues are: what will be chosen as the hybrid system, a matter that IMSA was addressing under its new regulations that are due in 2022; and that it would be signing off on a North American programme rather than a global one, rather limiting the return on investment.

January's announcement that DPi and Hypercar would be brought together has suddenly changed all of that; the DPi cars, called LMDh, will now have hybrid and will be able to compete at Le Mans. And coming from a tightly controlled cost base, this is a far cheaper way for car makers to go to Le Mans. Instantly, Peugeot's decision looked more likely, and other manufacturers, particularly those in GTE, were suddenly looking at a cheaper programme than currently, and with better return on investment.

Then in February came the bombshell; Aston Martin cancelled its Valkyrie Le Mans programme, and stated it would evaluate switching to the far cheaper LMDh platform.

State of the union

Suddenly the emphasis for the talks changed. The political situation was agreed only a week before the announcement in January, before leaving it to the engineers to bring together a cost-controlled formula that is focused on customer racing, DPi, and a technology-focused formula (LMP1) into a single top class. Engineers

Aston Martin committed early to Hypercar with its Valkyrie (right), but in February announced that it was not going to race the car after all. This will have a major effect on negotiations surrounding the new LMDh regulations

had two months to create this set of regulations, that are set to be announced at Sebring in March 2020 and there are a wealth of questions that had to be answered in short order.

According to lap time simulation from various sources, Toyota's Hypercar in year one will be able to lap the circuit in 3m23s, seven seconds faster than the ACO expected and right in the danger zone for tyre supplier Michelin. With heavier cars than the current LMP1 machines and travelling at speeds not much slower, the ACO must be worried about the high energy these would have in the event of an impact with its barriers.

Range anxiety

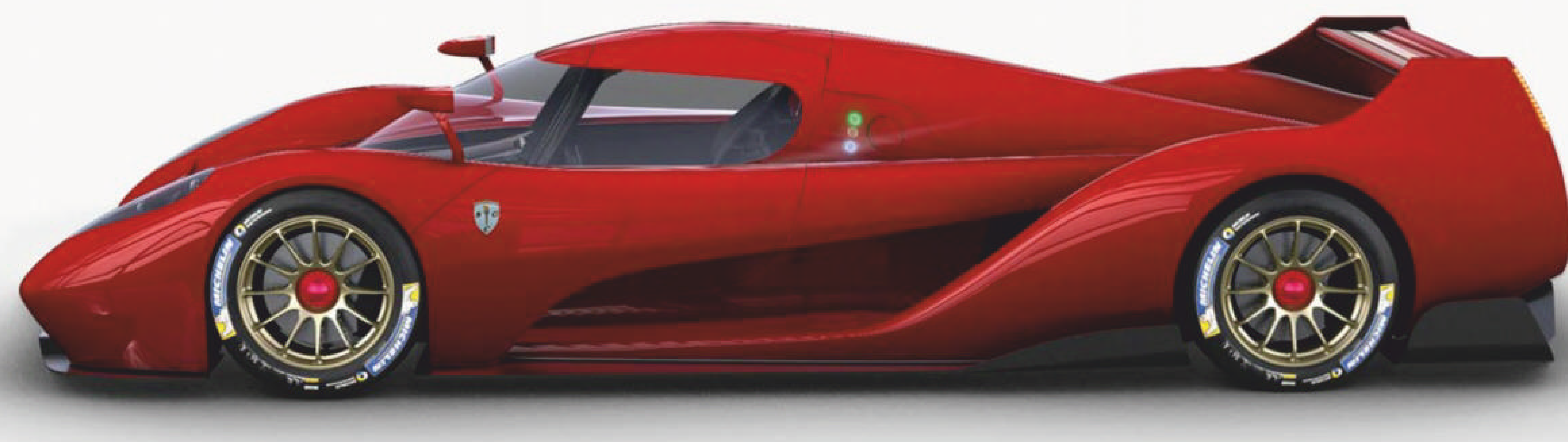
The second item to balance is that the Hypercar should be able to do between 12 to 14 laps at Le Mans on a single tank of fuel but based on current LMP2s, stint lengths are closer to 10 laps. New chassis design will be needed, then, for the new LMP2 class chassis suppliers, and these new chassis will be homologated for 10 years. The DPi cars should be lighter than the Hypercars which will help the balancing act.

The ACO was confident that it was on the right path but the manufacturer support was not forthcoming

However, the format for the base car has yet to be finalised. Could the FIA's non-hybrid prototype work, with a longer wheelbase than an LMP2 in order to accommodate the larger fuel tank and hybrid system? Or would it be an LMP2 with a small electric system? The hybrid parameters have (at time of writing) still to be set. Will IMSA go for a larger, 800V system that has been a feature on Porsche and Toyota's LMP1 cars of late, or will it go for a lower voltage system that may require a larger battery and motors to achieve the same goal?

IMSA put out its tender for the hybrid system but the proposals it received back were wide ranging. Some included a servicing package, others a lease, others a purchase payment plan. Some were low voltage, some went high, and costs to the teams were directly related to this. 'We will figure it out shortly,' said an IMSA spokesman at Daytona.

Glickenhaus is planning on entering its SCG 007 in Hypercar. The firm says its racecar (below) will weigh 1100kg and will be powered by a 840bhp twin-turbo V6 engine



The ACO has to be worried about the high energy these Hypercars would have in the event of an impact with its barriers at Le Mans

One of the keys to the DPi regulations is a new, long homologation cycle of the base LMP2 chassis. This is designed to give manufacturers stability, but there are lessons to be learned from the last round of lengthy homologation cycles in LMP2; balance of performance will encourage manufacturers to not lean towards a single supplier to the detriment of the others. Currently ORECA is the dominant manufacturer in LMP2 in the WEC, but the French firm says that this will be different under the next rules cycle. 'There will be performance windows in which we will fit,' says its technical director, David Floury.

The opportunity to race at both Daytona (pictured) and Le Mans will surely appeal to manufacturers and teams

These performance windows will be key to the negotiations. If, as mentioned above, the Hypercars are already scheduled to qualify seven seconds faster than the ACO's intended average race lap time, and Michelin is concerned about its tyre construction to cope with the larger loads, will the Hypercars have to have their performance restricted? Aston Martin's announcement would make this more likely, but what then happens to the pace of LMP2? The Hypercar manufacturers targeted around 850bhp as their total power output based on the Valkyrie but the DPi manufacturers are aiming for 600bhp plus hybrid power, which will limit development costs and make the engines more accessible to privateers. For Michelin, slowing the Hypercars would be an advantage and with the new balance in the negotiations, this seems to be a more likely outcome.

'We have finalised the outside geometry of the tyre so now we can make the mould, which means that we can build tyres, but we still have to work out what is needed,' says Michelin's Group Motorsport Activities director Matthieu Bonardel of their work on the Hypercar tyres. 'The cars are heavier than the current cars and not that much slower, so the load on the tyres has to be addressed. With the higher pressure we have to optimise the contact patch so that it works with the wear rate of the tyres.'

The tyre regulations for the WEC have already been changed following pressure from Michelin and addressing their concern. Previously the first tyre produced would have also had to be able to cope with Le Mans in 2024, but Michelin wanted a change. The tyre spec will change after year one when safety will be Michelin's sole priority, and the next iteration will last for years two and three, focusing on performance. For the final two years, which will be open to competition from Goodyear, Michelin will focus on longevity, giving the tyre manufacturer a progressive story to tell.

Any questions?

What is not known is the finer details of the new common platform cars, or what effect Aston Martin's announcement will have on the WEC itself. What engine development will be required, if any from existing DPi manufacturers Acura, Cadillac and Mazda? Will the manufacturers be forced to design and build new engines? How expensive will the new car be to buy and run, and can a privateer afford those costs? What space is required for the hybrid system and battery?

Ferrari also raised the issue of chassis construction. Would it be able to build its own chassis and put running parts from DPi on to it? 'If we take a chassis of the Hypercar and we put on [this] all the parts of the DPi, do you have the chance to go to the US or not?' asked Ferrari's Antonello Colletta, GT and Corse Clienti racing director. 'If you take all the parts of the DPi the cost will be low because it is the same brakes, same hybrid, same suspension, but it could be a chance to make a chassis. But we don't know if this is possible. Now it is possible that the US car goes to Le Mans, but not the European car to the US. This is a matter on the table.'

All of these questions are under discussion in a short time-frame and the target is moving. It's likely that the final set of regulations will be decided at Le Mans in June.

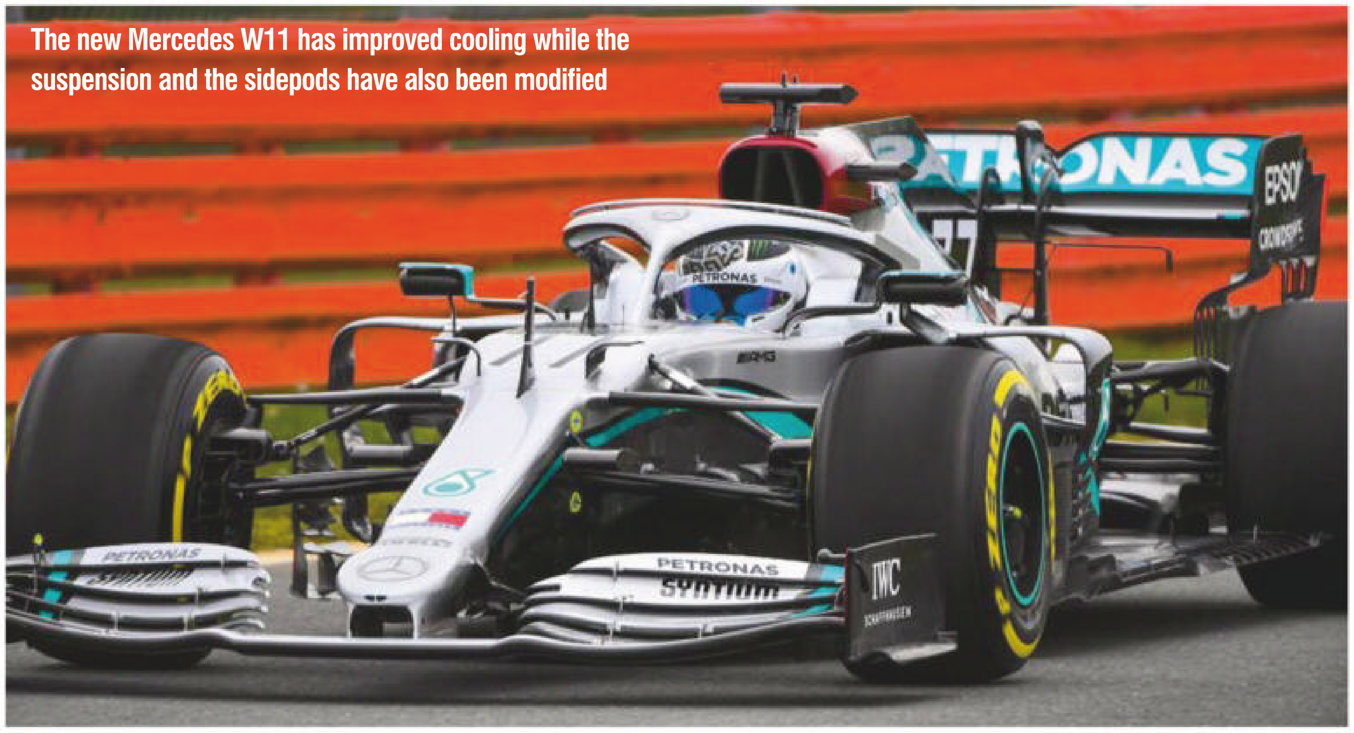
First sight: F1 2020

As a taster for next month's in-depth feature on this season's Formula 1 cars *Racecar* reveals some of the best new tech spotted at the launches

By GEMMA HATTON

With stable regulations for 2020, this year's F1 grid is very much an evolution of the last. This has allowed teams to focus on refining their aerodynamic concepts, packaging and cooling strategies. Yet although the cars may look similar, under the skin there have been endless technical tweaks; all trying to make a faster, lighter and more efficient racecar.

With 2021 on the horizon, the teams are also facing the challenge of when resources should be switched to developing their 2021 contender to kick start the next era of F1. Furthermore, teams will also be using this year's car as a testing platform for developing the systems which will remain unchanged for 2021, such as the power unit and its associated systems. So, while on the surface it all might all look very similar, as always in F1 there are plenty of technical developments.



The new Mercedes W11 has improved cooling while the suspension and the sidepods have also been modified

Although it might all look very similar, as always in F1 there has been plenty of development

Mercedes W11

Mercedes has taken a more aggressive approach with its 2020 car, with cooling the primary focus. Not only has the face area of the radiators increased, but Mercedes HPP, its engine arm, has also worked to increase the operating temperature of all the power unit coolants. This reduces the temperature difference between the cooling fluids and ambient, demanding less from the cooling package. Meanwhile, the upper side impact tube has been moved to the lower position and the sidepod inlets are now wider and shorter compared to last year.

Efficiency has been another target, with HPP reducing friction and bearing losses within the power unit through the use of coatings, which has helped to improve the efficiency of the electric motor and the power module. The suspension has also seen some development, with changes to the front uprights and wheel rims as well as a more 'adventurous' layout at the rear.

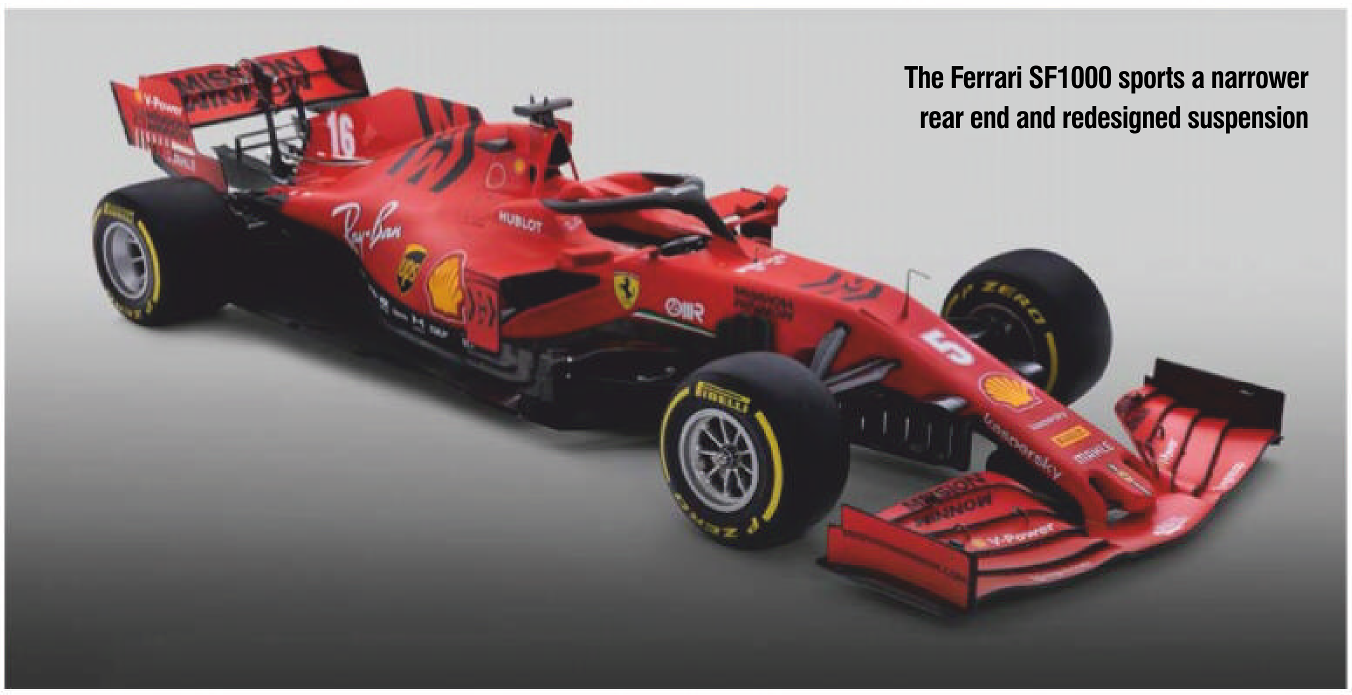
Ferrari SF1000

The SF1000 marks a major milestone for the Italian team as this will be the car that races in Ferrari's 1000th F1 grand prix later this year. Although it is again an evolution of last year's SF90, Ferrari has worked to go more extreme in all areas. This can be seen from the much narrower rear end which is a result of a much tighter packaging of the entire chassis, monocoque, gearbox and power unit. The suspension has also been redesigned to allow more flexibility in set-up.

One of the few rule changes for this year is a reduction in the oil consumption, which has been reduced by half. To accommodate for this change, Ferrari has modified the combustion chamber while refining the overall engine architecture.

Red Bull RB16

Visually, the RB16 is the most different to last year's car, when compared to the offerings from other teams, with the Milton Keynes operation once


The Ferrari SF1000 sports a narrower rear end and redesigned suspension

again showing its flair for aerodynamics. Similar to last year, the RB16 features an inlet at the leading edge of the nose, but now with an increased frontal area. There are also two wide slits at the top of the nose. With both the inlet and outlets for the S-duct also seeing some modifications we can assume that part of the purpose of this radical new nose concept is to help feed the S-duct, and therefore improve overall aerodynamic efficiency.

As well as some more aerodynamic tweaks in the bargeboard area of the RB16, the position of the forward lower wishbone on the rear suspension has also been modified.

McLaren MCL35

McLaren has now followed the pit lane trend with regards to the narrow sidepods and tighter rear end on its MCL35. Consequently, it has had to change its packaging philosophies around the power unit, cooling and transmission. A very different approach was taken with the rear suspension, while we're also told there are some 'new technologies' at the front of the car.

Look out for a full tech appraisal of the new F1 cars from winter testing next month.

Red Bull's RB16 has a new nose concept

McLaren has opted for narrow sidepods on the MCL35

RACE MOVES

Pat Fry has now officially started in his new position as technical director (chassis) at Renault's F1 team, replacing **Nick Chester**, who left the Enstone team after 19 years at the end of last season. Fry was previously at McLaren but that was in the temporary role of engineering director while the team awaited the arrival of **James Key**. Fry left McLaren in 2019 but had contractual obligations to fulfil before he could take up his role at Renault. He has also worked at Manor, Ferrari and Benetton in Formula 1.

Jeff Braun, the former CORE Autosport race engineer, joined the Era Motorsport LMP2 team for the opening round of the IMSA championship, the Daytona 24 hours, where he worked as its race strategist. His former team departed the series after a long and successful run at the end of the 2019 season. At the time of writing Braun was only committed to the Era squad for the Daytona event.

Well-known US sprint car driver and one-time Indianapolis 500 racer **Norman 'Bubby' Jones** has died at the age of 78. Known for his engineering ability, after hanging up his helmet Jones built racecars, while he also managed Perris Speedway in California. In 2004 he returned to Indianapolis to work for **Tony Stewart's** team.

The US Championship Off-Road series has taken on **Frank DeAngelo** as its new series director. DeAngelo, an accomplished off-road racer himself, has worked in motorsport for over 40 years, including spells with BF Goodrich, and also managing his own motorsports marketing company for a decade. For the past 21 years he has been the executive director of motorsport and client services for Jackson Motorsports Group. The series has also recently hired **Bill Savage** as its tech director.

Gary Bockman, an amateur and pro racer who was a well-known advocate for Portland International Raceway – and someone who often volunteered to work at the track – has died. When the facility's future was in some doubt in 2005 Bockman founded Friends of PIR, a non-profit support organisation. He was also a well-known driver coach.

NASCAR Xfinity operation Kaulig Racing has signed up **Bruce Schlickter** as crew chief on its No. 10 Chevrolet. Schlickter comes to the team from Stewart-Haas Racing, where he was a race engineer. Meanwhile, **Alex Yontz** stays on as crew chief on Kaulig's No.11 entry – he had been the damper specialist on the car but was promoted to fill the vacancy that was left when **Nick Harrison** died last year.

It's been reported that all but three of the Chip Ganassi Racing employees who were assigned to the now defunct Ford GT IMSA and WEC programme have stayed on with the CGR organisation to work in its IndyCar team. Among these, **Brad Goldberg** is now engineering new driver **Marcus Ericsson**, while Ford CGR team manager **Mike O'Gara** is race strategist on the same car.

Fernando Alonso is no longer an ambassador for the McLaren Formula 1 team. The Spaniard, a two-time world champion with Renault, had maintained his ties with the Woking squad after he finished driving for it at the end of 2018. His duties included advising the team's drivers and engineers.

Australian Supercars squad Team 18 has signed up former Gary Rogers Motorsport man **Manuel Sanchez**, who will be race engineer for **Mark Winterbottom** this season. Sanchez, who has spent the last six seasons with GRM, will have **Mark Sylvester** working alongside him as the car's data engineer. Sanchez is one of nine new signings Team 18 has made for the 2020 season.

Also at Team 18 (see above), **Matthew Saunders** has moved over from the Winterbottom entry to engineer the team's new second car, which is to be driven by **Scott Pye**. Saunders joined the team in September, having moved from Scott Taylor Motorsport, where he had been team manager. **Rory Jackermis**, who joins Team 18 from Australian Formula 3 squad R-Tek Motorsport, will be the data engineer on the car.

Formula 1 commercial operations boss quits

Sean Bratches has stepped down from his post as Formula 1's managing director of commercial operations, citing a move back the US to be closer to his family as the reason for his departure.

Bratches was one of a triumvirate of executives appointed when US firm Liberty Media bought F1 in January 2017, Chase Carey (chairman and CEO) and Ross Brawn (motorsports managing director) being the other two.

F1 has said that Bratches will not be replaced. However, he will 'continue to support the business in an advisory role from the US.'

XPB

Sean Bratches has stepped down from his post at F1

Former ESPN executive Bratches' role at Formula 1 was to focus on boosting its main revenue streams, specifically race hosting fees, sponsorship and broadcasting deals.

Carey said of Bratches' departure: 'I want to thank Sean on behalf of everyone at Formula 1 for the leadership, passion and expertise he has given to the business over the past three years. Sean has transformed the commercial side of Formula 1 and a testament to his work is shown in our momentum and growth as a business.

'I am pleased Sean will continue to be an advisor for us from his home in the US, he will always be part of the Formula 1 family and I look forward to his ongoing advice and counsel.'

Bratches said: 'The past three years at Formula 1 have been an incredible journey, one which I have enjoyed thoroughly. I want to personally thank the team at F1 for their extraordinary efforts and dedication, they are the best of the best and I am confident they will continue to serve fans and deliver on the strategy we have set in the years ahead. I am proud that I leave Formula 1 in a better position than when I joined in 2017 and I know that the foundation we have put in place as a team will continue to serve our fans around the world and reach new audiences.'

Ellie Norman, head of marketing, and Frank Arthofer, global head of digital media and licensing, will now report directly to Carey.

Williams bolsters F1 technical team with two new designers

Williams has made two key technical appointments in the run-up to the 2020 F1 season with David Worner from Red Bull and Jonathan Carter, formerly of Renault, set to join the team.

The signings come on the back of several departures last season, when high-profile names such as Dirk De Beer and Ed Wood, and more significantly then tech boss Paddy Lowe, left the team.

Both Worner and Carter will take up their new posts in 'the near future', deputy team principal Claire Williams has said, with the former joining as chief designer, taking on the post vacated by Wood. Worner previously worked in the same role at Red Bull, a post he had held since 2014 – Williams also states he was 'responsible for the Red Bull Racing/Scuderia Toro Rosso Synergies initiative' while there.

Carter, who joins Williams as deputy chief designer and head of design, was most recently at Renault. In the past both Worner and Carter worked at Arrows.

As part of a restructure that's resulted from the above appointments Adam Carter will now take on the post of chief engineer. At the time of writing there was still no word on who would replace Lowe as tech chief at the Grove-based team.

Claire Williams said: 'Dave and Jonathan bring enormous experience, knowledge and skills to the Williams team, and we are delighted that they are joining us in the near future. They will strengthen our design capabilities and work closely with Adam Carter, our chief engineer, and the other senior members of the engineering team on the design and development of the next generation of Williams F1 cars.'

RACE MOVES – continued

Former Ferrari strategist and driver academy boss **Luca Baldisserri** has joined Formula Renault Eurocup squad GRS (Global Race Services) as its chief engineer. He had been expected to work as technical director at US F4 team Jensen Global Advisors this year, but after visiting the GRS team at a test session he opted for the Spanish squad instead. Baldisserri's last spell in Formula 1 was as engineer to **Lance Stroll** at Williams in 2017 and 2018.

Sportscar maker Maserati has appointed **Bernard Loire** as chief commercial officer and **Paolo Tubito** as chief marketing officer. Loire began his career in 1988, first at Ford and then at Fiat. Since 2002 he has held various roles at Nissan and Mitsubishi Europe. Tubito started his career in PR in 1992 and since 1998 he has worked at Nike.

Heat shielding specialist Zircotec has taken on **Daniel Graham** as its principal design engineer (Specialist Systems). Graham has five years of experience working on heat management in Formula 1 and other motorsport categories, as well as six years of similar experience in the oil and gas industry earlier in his career.

The Laguna Seca track in California, now known as WeatherTech Raceway, has a new management team, headed by incoming president and general manager **John Narigi**. Meanwhile, returning to Laguna Seca as director of marketing and communications is **Barry Toepke**.

A documentary about the life of former FIA president **Max Mosley** has been made and is set to premier at the Manchester Film Festival on March 8. The 'warts and all' story, according to Mosley, has been produced and directed by **Michael Shevloff**, whose previous work includes the 2013 film *1:Life at the Limit*, which focused on Formula 1 safety. The new documentary is entitled *Mosley*.

Veteran NASCAR crew chief **Jeff 'Hollywood' Hammond** will tend the No.68 Clay Greenfield Motorsports car in the NASCAR Truck Series this season. Hammond started his career in 1974, working as a tyre changer, and progressed to a crew chief post in 1982, picking up two championships and 43 wins while looking after **Darrel Waltrip's** car, and becoming one of NASCAR's most successful crew chiefs in the process.

Luca de Meo has been appointed chief executive officer of Renault. De Meo has worked in the automotive industry for more than 20 years, starting at Renault before joining Toyota Europe, then the Fiat Group where he managed the Lancia, Fiat and Alfa Romeo brands. Since 2009 he has worked within the Volkswagen-Audi Group. Meanwhile, Clotilde Delbos, who has been interim CEO since **Carlos Ghosn's** high-profile departure, will continue in that role until she takes up the post of deputy CEO when de Meo starts as CEO at the beginning of July.

Jacques Villeneuve is to enter a team in the 2020 NASCAR Euro Series as he looks to expand the FEED young driver academy he started with **Patrick Lemarie** last year. FEED Racing will enter two cars, for Villeneuve and Lemarie, with the possibility that this will be expanded to four entries. Lemarie will share his entry – a feature of the Euro series – with 17-year-old Belgian **Simon Pilate**.

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

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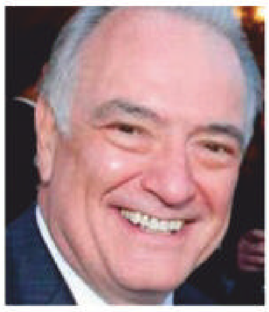

Politically correct

The MIA's CEO explains why representation is vital if Motorsport Valley is to thrive

The 2020s are set to be a memorable decade of change when new challenges also open new opportunities for business growth.

In the meantime we are, at last, seeing questions being raised of politicians' confidence in their electric battery solutions for automotive. These may face difficulties when their full life cycle, from the availability and extraction of raw materials to the final disposal of batteries, is better understood. They must soon explain their source for funding for the resources needed to deliver the extensive recharging infrastructure, for those they are now pressing to buy electric cars. Inevitable and considerable tax levies could be an unwelcome surprise for many.

Motorsport accelerates innovative solutions so we can expect new business demands on the high-performance engineering community. These include calls for help on alternative fuels, hybrid power, light-weighting and many other areas in which our sport can then demonstrate and popularise this tech with the public. Those supplying technology and engineering for motorsport have a good decade ahead.

But the dramatically changing business and political landscape will, soon, affect the motorsport industry in the UK and Europe.

The UK, home to Motorsport Valley, is now no longer part of the European Union, so now it has the independence to strike business deals with the EU and all countries of the world. Easier said than done, perhaps.

Euro vision

For nearly 50 years UK businesses have been part of the huge commercial family of Europe, one of the largest trading blocks in the world. All enjoyed easy, open access to all business being transacted and the skills and purchase power created.

Politicians and government officials will have to learn new lessons as industries fight for the attention of both the UK and EU government. Motorsport Valley has become a much appreciated and highly-valued asset to global motorsport; customers will want this unique business cluster to remain secure and grow strongly. After all, similar world-class business hubs, such as Silicon Valley and Hollywood, bring strength and wealth to their worldwide communities throughout changing times.

The commercial success of the business of motorsport is relatively new when compared to 150 years of automotive or 100 years of aerospace. By the time FOCA was formed, there had already been landings on the Moon and Concorde had flown.

Firm foundations

The foundations for the commercial success of motorsport were laid at the same time as the UK joined the European Community in 1973. Bernie Ecclestone created FOCA the following year, and Max Mosley and friends launched March Engineering to produce an unprecedented range of customer cars – Formula 1, F2, F3, Formula Ford and Cam-Am. When linked to demands from Lola, Lotus, Cosworth and others, the vital, unique supply chain that still underpins Motorsport Valley was created.

Former F1 boss Bernie Ecclestone's creation of FOCA in 1974 in many ways kick started the motorsport industry as we know it today

My own personal focus is on Formula 1, as it was this series which initially caught the imagination of TV channels in the early 1980s. Demand for motorsport on TV grew fast, bringing success to companies across Motorsport Valley – as always, Bernie's timing was outstanding.

Our global motorsport business community has only ever operated and prospered as part of the EU. So these are unprecedented times when we must make representations to government to secure their invaluable support. Clearly, UK motorsport businesses face a new horizon to which they must adapt, and fast – this is no time for complacency.

We urgently need to provide up-to-date market intelligence to the government so I encourage you to complete the National Motorsport Business Survey (go to www.the-mia.com for more).

Although 'representation' might sound boring, it is, right now, the most vital resource needed to engage with the government as new policies are created which underpin the UK's new independent status. Sectors which gain a foothold in new policy decisions will enjoy early benefits.

Already the MIA has engaged in many government consultations on every aspect of our motorsport business – shipping, exporting, future funding for research, development of skills etc. We explain our industry's knowledge, international strength, reputation, innovative skills, and the character which has made us a world leader.

The government must be made aware of the value and investment Motorsport Valley attracts from global partners on whom we heavily rely. They need to know of the valuable jobs we create and how we need to attract the best employees, without restrictions, from across Europe.

Any individual company can make representations to government but, understandably, they will, initially, focus on the largest employers and trade bodies which represent the most valuable sectors. To maximise our impact more motorsport companies need to recognise the importance to their future of representation at this time.

The MIA needs to increase the number of its motorsport and high-performance engineering corporate members fast, adding to the 300 or so we currently represent. We need, at least, 500 to show government the breadth and strength of our industry. We are determined to help motorsport to seize this chance and keep our industry in front of government. If you understand the vital importance of this, then please join us now.

Body image

The UK will need to find and support winners, and we must strongly promote the Motorsport Valley community as being one of these. But we have a battle as our young industry competes for attention against more substantial, longer established, historically recognised trade bodies. But rest assured, the MIA do everything possible to help you succeed in these exciting times.

The MIA needs at least 500 corporate members to show the UK government the breadth and strength of our industry

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Waving the green flag in F1

In November Formula 1 announced that it was planning to go carbon neutral by 2030 and the initiative was welcomed by Jean Todt. This was an interesting position to take; could a sport that is by its very nature a luxury, as is all professional sport, stop being a drain on resources? The proposal announced focused on various issues, such as logistics and travel, not only of the teams but also on the fans travelling to and from the races. At the time, the hybrid powertrains used in the cars, which are producing incredible levels of thermal efficiency, were identified as a key technology that would help F1 reach this hallowed goal.

In January 2020, the FIA and F1 became signatories of the United Nations Sport for Climate Action Framework, which aims to promote greater environmental responsibility; reduce overall climate impact; educate for climate action; promote sustainable and responsible consumption and advocate for climate action through communication. This all seems to be very sensible, and here at *Racecar Engineering* we fully support this drive towards a more sustainable future.

However, we also have to recognise that the sport will have to take serious action in order to do this and I do wonder if Formula 1 will be willing to given the level of sacrifice that I think it should be looking to make.

Since these two announcements, there have been a few spanners thrown into the works. The British government has decided to bring forward the ban on sales of diesel and petrol engines from 2040 to 2035 in order to increase the likelihood of them not being on the roads by its 2050 target. This also includes a ban on the sale of hybrids at the same time. I wonder how many other countries will adopt this stance, particularly on hybrid technology which is forming the basis of Formula 1 and sportscar rules, not to mention the WRC, IndyCar and NASCAR? How does this relate to racing's plans? Clearly, the work can continue to increase the efficiency brought about by hybridisation, but by 2030 it is highly likely that the manufacturers will have moved on to another fuel, or another technology. Is Formula 1, along with other major series, ready to accept that challenge?

> **Would Formula 1 be willing to go back to its roots and invest in pencils and rulers?**

Life cycle

Last year *Racecar* ran a piece by Professor Steve Sapsford in which he pointed out that out of the entire life cycle of a car, from mining the raw materials to build, delivery and disposal, only one part of the process was actually regulated; the fuel consumption while running the car. At a press junket to Ferrari in mid-February, we passed a monolithic structure which was the wind tunnel on site, built in 1997. Given the gains the power units have made since then, I wondered what gains have been made in wind tunnel efficiency? I am not talking about accuracy; more the reduced energy running them.

In the impressively stocked Clienti Corse department are F1 cars stretching back through the ages and the effect of a wind tunnel on design is clear. Lap times have dropped, but the cars are ugly. What would be the effect of banning all wind tunnel testing? It's clear that there would be an increased risk that one manufacturer could steal a march on the others, as Lotus did in 1978 with the Lotus 79 and ground effect, but Mercedes achieved that with its intelligent PU design in 2014, too. It gained an advantage that saw it win every world championship title since. At the Fiorano test circuit there is a square dedicated to Michael Schumacher, who won every drivers' title from 2000 to 2004, taking Ferrari to constructor titles each year too. So domination is nothing new. The fact that most teams use TMG's wind tunnel anyway makes me further wonder; what are teams doing with these structures?

End of storey

But there are other areas in which F1 could make an impact. Banning multi-storey structures in the paddock would be one way. Charly Lamm, the former boss of Schnitzer, told me at a DTM race how disappointed he was to come to a track and have Michelin Star quality food in such a structure; the cash could have been spent on the car! Ross Brawn has now said F1 is thinking of banning the huge travelling motorhomes.

Another issue is the environmental impact of the cloud. This has servers housed in secret locations consuming vast amounts of energy. Companies are focusing on increasing the amount of renewable sources of energy, and yes the digital age is having a positive effect on paper consumption. But what is the actual impact and can that be reduced?

Would F1 be willing to go back to its roots, and invest in pencils and rulers? We could have better looking cars, drawn to the eye of a designer rather than by a computer, cheaper to produce, and less wasteful. But there are two questions that must be answered. The first is whether or not that would in the long-term future save energy, or would the cars be less efficient? The second question is; what was the environmental impact of me going on a press junket to Italy?

ANDREW COTTON Editor

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