FORMULA 1: Why are teams backing sprint race proposal for 2021?

Inside the world of modern motorsport technology

Racecar engineering™

UK £5.95 / US $14.50 • April 2021 / Vol 31 No 4 • www.racecar-engineering.com

F1 2021

What the new rule changes mean for teams this season

AMERICA'S CUP

Yachting meets F1 expertise in epic battle on the waves

GREEN CREDENTIALS

New carbon fibre recycling techniques in development

INDYCAR

How PPG's fighter canopy technology improves safety

CORVETTE

GM's racing boss discusses future programmes

04
9 770961 109104

Xtraordinary All-Fluid Filters

4 DIFFERENT SERIES. . . MODULAR. . .TONS OF OPTIONS

71 SERIES - *Our largest capacity filters. Large 2.47" diameter; Two lengths. Reusable SS elements: 10, 20, 45, 60, 75, 100 or 120 micron; High-pressure core. Choice of AN style or Quick Disconnect end caps. Options include: differential pressure by-pass valve; auxiliary ports for temp probe, pressure regulator, etc.; Outlet caps with differential pressure gauge ports to measure pressure drop.*

72 SERIES - *Same large-capacity, 2.47" diameter body as our 71 Series but with a 2-piece body that couples together with a Clamshell Quick Disconnect for quick service. 72 Series uses the same stainless steel elements, mounting hardware and end fittings as 71 Series.*

71 SERIES MULTI-STACK - FAILSAFE STAGED FILTRATION

Multi-Stack adapter sections allow the stacking of two or more 71 Series bodies, long or short, so you can combine a variety of filtration rates or backup elements. Use a coarse micron screen element to filter out large debris upstream, followed by a tighter micron second-stage element to get smaller contaminants. Options include: adapters with take-off ports to facilitate the use of a differential pressure gauge which monitors contamination levels in all stages of the filter assembly.

Stack and Stage For Maximum Protection On Race Day

SPACE SAVER SERIES - OUR MOST COMPACT FILTERS
3 Body Styles - 7 Choices of Screens

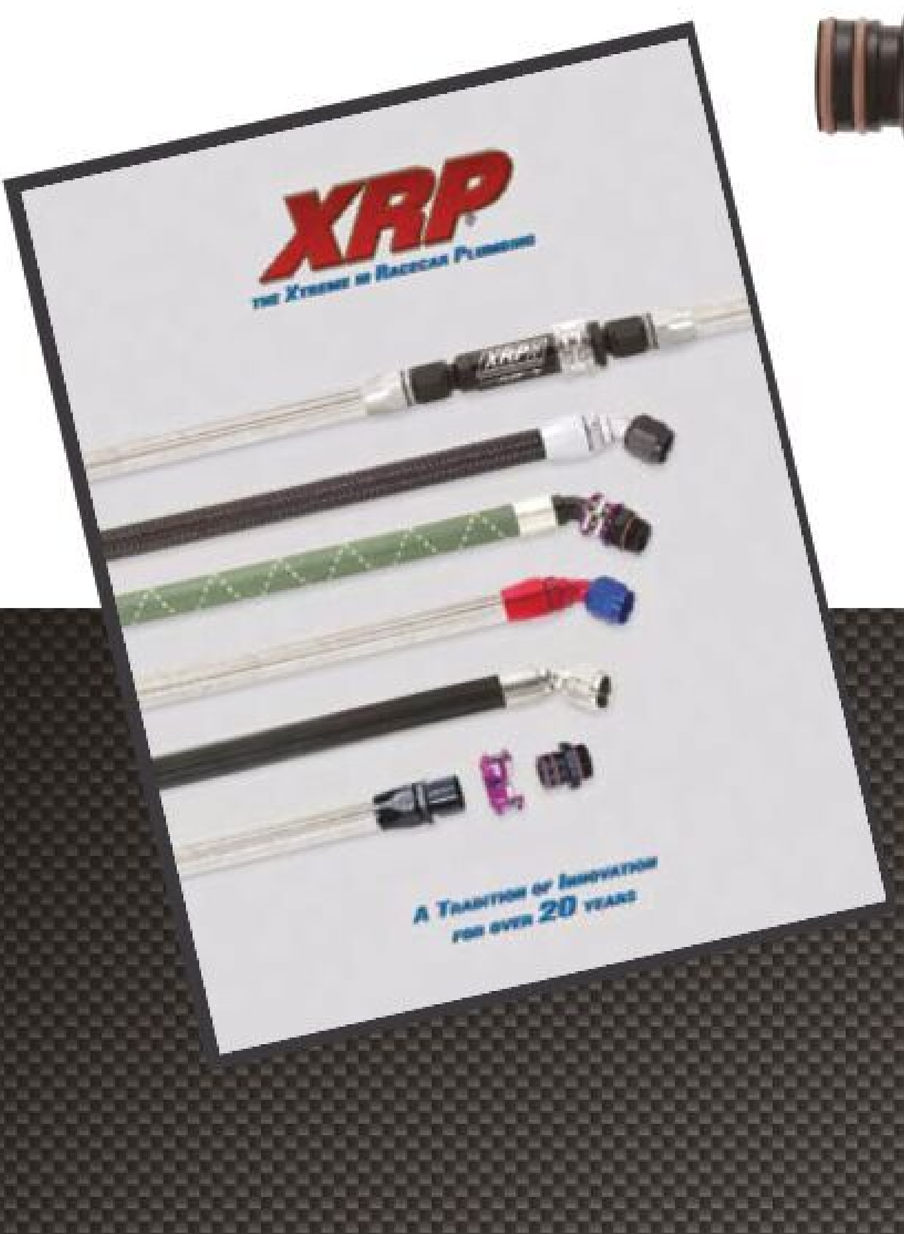
About 1 1/8" diameter, they fit everywhere and they do the job right for so many applications! 2 sets of O-Rings for a variety of racing fluids. Choose from 10, 20, 40, 60, 75, 100, or 120 micron screens suit all needs.

INTRODUCING THE NEW 70 SERIES

Compact 1.97" diameter body features a springless design to maximize filtering area in tight spaces. 70 Series filters are ideal for applications where space and weight are of primary concern. Bodies are available with AN-style end cap sizes -4 through -12, in heavy or lightweight wall versions. 70 Series filter elements come in two varieties: pleated cellulose (10 or 20 micron) or reusable pleated stainless steel wire (10, 20, 45, 60, 75, 100, or 120 micron). Undercut inlet end caps (sizes -4 through -10) offer maximum weight savings and modern look.

SPACE SAVER DRY SUMP - *Same space-saving size, these dry sump filters include a coarse-screen #16 mesh filter that protects your pump in high-volume race applications.*

70 SERIES Pleated Stainless Steel or Cellulose Elements



Follow us on Instagram #XRPracing

Like us on Facebook/XRPinc

Go to WWW.XRP.COM for catalog downloads & new products or contact us for 100-page color catalog.

XRP®

THE XTREME IN RACECAR PLUMBING

UNITED STATES XRP, Inc. sales@xrp.com tel 562 861 4765 fax 562 861 5503
EUROPE & UK Protec Fuel Systems Ltd. info@protecfuelpumps.com tel +44 (0) 121 572 6533

Michael McDowell (car no.34) ran third as the Daytona 500 came to a close, but took victory at NASCAR's showpiece event after a dramatic last-lap crash took out the leaders

COVER STORY

COLUMNS

FEATURES

TECHNICAL

BUSINESS


ARE DRY SUMP SYSTEMS
Everything DrySump!
Over 60 Varieties of Cast Aerospace Alloy CNC Machined Dry Sumps
Over 60 Different Dry Sumps Available!
LS1-6 "Fluidic" Dry Sump Pan
LS1-6, LS7 & LT 1-4
Over 11 Versions - Over 3100 SOLD!
LS1-6 "Ultra Shallow"
LS1-6 GTO/Monaro Dry Sump
LT1 1008-3 Corvette Stingray
SPINTRIC
"One of the most exciting developments uncovered in research... The new passive Air/Oil Separator.... Providing a doible benefit to overall oil system..."
DavidCooper- Race Engine Technology
CENTRIPETAL AIR/OIL SEPARATOR
FOR DRYSUMP SYSTEMS- TOTALLY PASSIVE
Watch on You Tube
Type "Sprintric"
AIR/OIL FROM SCAV PUMP
[redacted]
EXCESS AIR OUT
OIL RETURN TO TANK
SPINTRIC TECHNOLOGIES www.spintric.com
All NEW! "AXIAL FLOW SPINTRIC" Air / Oil Separator
6 PATENTS
SPINTRIC.COM SCAVENGE RET. OUT
SCAVENGE RETURN IN SPINTRIC TECHNOLOGIES
"One of the most impressive innovations at Autosport Engineering... disarmingly clever"
Ian Bamsey- Editor- Race Engine Technology
"PRODUCTS ENGINEERED WITH A PASSION"
916.652.5282
WWW.DRYSUMP.COM • WWW.SPINTRIC.COM

Background work

Daytona 24 hours – a lesson in perseverance and patience

I've just finished writing up a race summary for this year's Daytona 24-hour race and while I was disappointed we didn't win, that has somewhat subsided since analysing how Multimatic got the Mazda to the race finish. Finishing any 24-hour race on the lead lap is an achievement, and sometimes the background work to get there is never heard about. So, here is an insight into our 24-hour race and preparation.

In November 2020, we had just finished the Sebring 12 hours and it was a bittersweet result. The no.55 car won, but the race was the no.77's until a puncture with 14 laps to go. We also knew that some in the team would not be returning for 2021 as Mazda had announced the team was reducing to run a single car.

Back at the workshop, one race car was sent to the museum, while the other was stripped right back to dissect each and every part, nut, bolt and system. All faults were investigated and resolved, all bodywork parts overhauled, a new monocoque prepared and all parts mileaged and inspected. But, most significantly, a new team was created from the two crews. This all took three weeks.

Be prepared

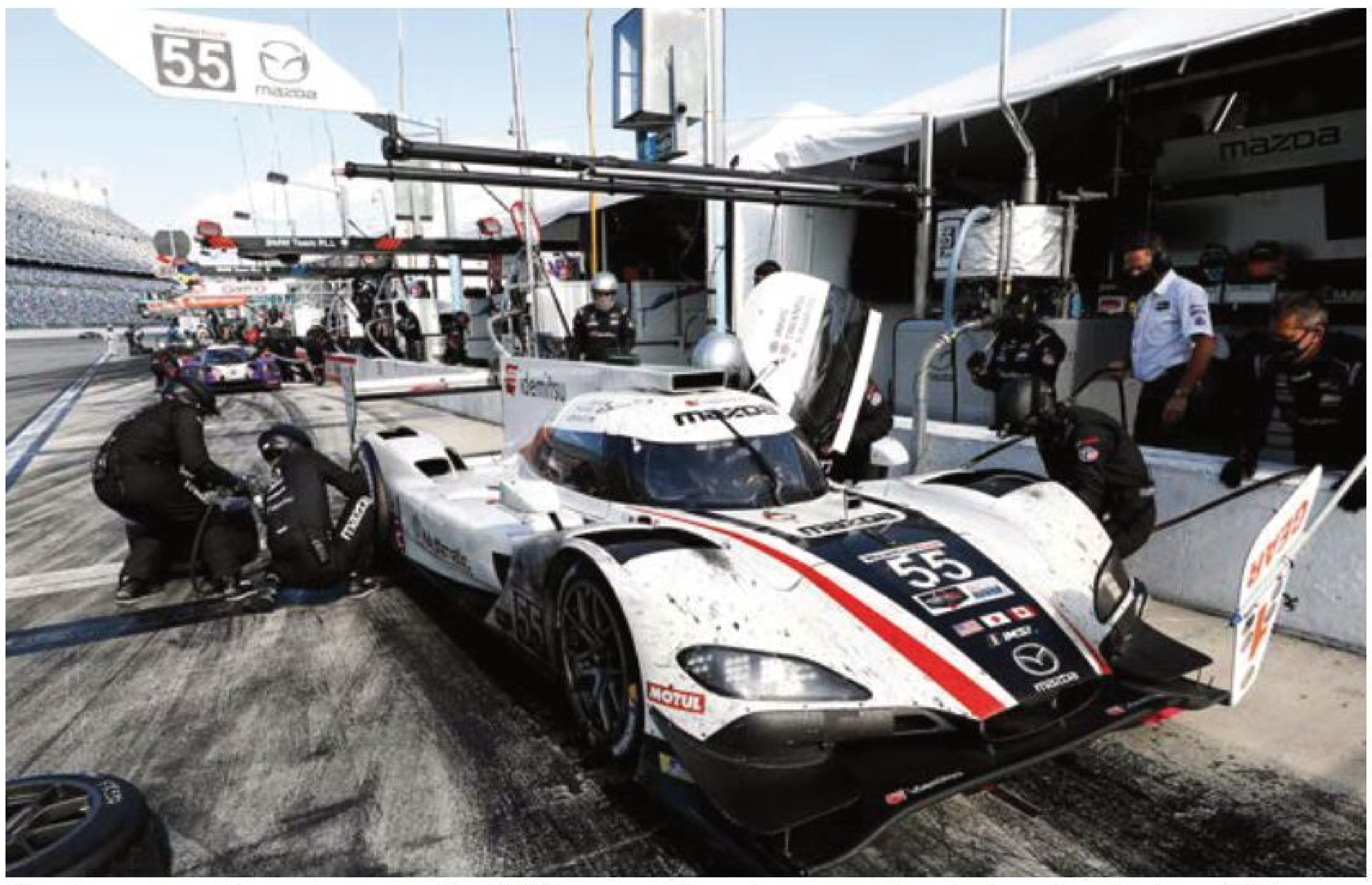
Two weeks before Christmas, the crew started to build up one test and one racecar. Good mechanics know how to hone their cars, and they did so. In addition, all spares needed to be prepared to the same standard, which was an immense amount of work.

The European team members arrived on 3 January for two days of testing at Sebring. We found some powerful set-up parameters, some problems and a lot of solutions. The next test was the 'ROAR before the 24' at Daytona, one weekend before the 24-hour race itself. I think we all preferred this option to the test earlier in January.

The test therefore became an extension of the race week, which meant it was fully utilised to prepare drivers, the team and the car for the race. I had set targets for each outing and we achieved most of them. As always, there were a couple of hiccups but, all in all, it was one of the smoothest preparations of any 24-hour race I have done.

The night before the race, the whole team sat down and went through the rules but even the best laid plans often go wrong.

Our race started with a problem shifting into first for the formation laps, and we dropped to the back of the grid. With the volume of cars, and similarity in speed between the LMP3 and GTLM cars, IMSA split the race start into two parts for safety, which put us even further back on track from the DPi field at the race start.



Michael Levitt

Mazda reduced to a single car for 2021 and, although preparation before the Daytona 24 hours was thorough, there were still issues faced mid-race. Final position was a creditable third

Oliver Jarvis drove the car like he stole it to get back to the front. A short full course yellow helped to bring us back to the prototype field, only to lose position again with a drive-through penalty for speeding into the pits.

The next challenge was having to enter a closed pit for emergency fuel as a yellow fell right before our next stop. Completing the cycle of stops again brought us within sight of the rest of the DPis, but we were last. We didn't know it at the time, but an issue at the rear of the car began to lose us downforce and performance.

A change of driver to Harry Tincknell brought with it unexpected radio issues, so we changed to Jonathan Bomarito earlier than planned.

The rear downforce issue caused more performance loss, and eventually we were lapped by the leader. At just over 200 laps in, an opportunity to fix this came along when a yellow forced all the leaders to pit. Here, I made an error because we didn't take the wave by. This mistake, however, did reinforce our team protocol, which we used spectacularly to turn our race around, and there were still 17 hours to go when the race returned to green.

Three and a half hours later, having got our lap back, we pitted under yellow, taking the wave by this time. The rear issue (caused by broken pins), now caused intermittent brake lights, forcing a tail change at this stop. Normally a 15s job, we lost over four minutes removing the broken pins before the new tail could go on. We were now 3.5 laps down with 13 hours to go.

Sprint finish

A combination of raw performance from the drivers, perfect stops from the guys and three more yellows where we cycled one lap forward each time brought us back onto the lead lap with five hours to go. Now it was time to sprint to the end for the final nine stints. We lost two seconds at the final stop, but cycled out just in front of the leaders. The last stint saw misfortune for one of our rivals, and ultimately we didn't have the pace to hold off another, finally having to settle for third.

Once stopped in the pits, the car didn't shift into first and the rear end once again showed issues that cost us downforce earlier in the race. It became clear we were right on the edge to make the podium. The hunger to win from all of us made the following possible: from over 212 seconds down, we finished 6.5s behind the winner. For sure, the IMSA rules allow this, but there was also the team performance. We never ever gave up.

Leena Gade is race engineer at Multimatic Engineering UK

The test therefore became an extension of the race week, which meant it was fully utilised to prepare drivers, the team and the car for the race

Don't forget the Hyper

Does Hypercar signify a return to the glory days of Sportscar racing?

As far as I am aware, the word 'hyper' was first used in the 1940s. The definition of the word relates mainly to human behaviour – mentally sensitive, over active, highly agitated etc. Quite how it became used to indicate speed probably dates from when aircraft and missiles began to explore the realms of Mach numbers way beyond supersonic, heading to Mach 5+. Thus hypersonic. Since then, hyper has come into popular terminology to describe something extreme. In the automotive world, it specifically infers ultra-high performance, hence Hypercar.

Now adopted by the ACO to replace the long-standing LMP1 as the premier class of the WEC, and therefore for the 24hrs of Le Mans, Hypercar is an emotive promotional tag to use in attracting fans and manufacturers, as already seems to be the case.

It's a pity then that LMH and LMDh are applied to differentiate the two car types. The latter, clumsy definition presumably to satisfy the ALMS, with regulations harmony in mind. Hardly rolls off the tongue though, does it?

Kit cars

I have to be honest – against the 'pure' LMH machines, the LMDh equivalents are more like exotic kit-cars to me, even if they are going to bear brand names such as Porsche. With the chassis, transmission, hybrid electric power unit, battery and control system all mandated from official suppliers, how else should I describe them? I understand Porsche's reasoning regarding return on investment, but I just can't view an LMDh as a *real* Porsche and a true flag waver for Ferdinand Porsche's heritage.

Porsche hasn't always manufactured its own monocoques by any means, but at least they have been made exclusively for the German manufacturer, which has always produced its own transmissions. However, trying to be pragmatic, the plus side is that Porsche (probably also Ferrari, Lamborghini etc if they enter) intends to sell its LMDh cars to customers. So, apparently, might one or two of the 'proper' LMH manufacturers, now the regulations have simplified these machines and reduced the cost of purchasing and running them. Good news.

It's something I have long supported if there is to be any chance of Sportscar racing returning to days long gone, when really good privateer or works-supported teams could obtain a Ferrari 512 or Porsche 917 and win outright.

To make this even more feasible, I hope cars can be leased, as is common with engines, to bring down the capital outlay required for outright purchase – something that is only feasible when there is a regulation / homologation freeze for multiple years, as now.

I confess that deep down I really dislike the application of BoP, especially at this level of motor racing. For me, it goes against one of the fundamental tenets of competition – to build a better machine than your competitors.

Chapeau! **to James Glickenhaus for investing in a Hypercar programme and preparing to take the fight to the manufacturer teams**

However, being realistic, I acknowledge that since technology overtook engineering, with the attendant massive cost escalation, equalising performance may be the only way to sustain many elements of the sport.

One-make racing is another, but that's worse!

What I struggle with a little concerning LMH is the extent of prescriptive technical regulations being applied when BoP is being enforced anyway, along with homologation. Chassis, engine and transmission c of g, component weights and weight distribution are all strictly dictated, I assume to address factors such as the effect on tyre performance / degradation from one car to another, and to cancel out the potential advantage / disadvantage offered by different circuits. The Editor makes the valid point that it's the only way to prevent technical directors constantly raising the 'unfair' card. Therefore, I have to confess admiration for the research and expertise that has gone into these regulations, expanding on knowledge gained from BoP in GTE, which I admit has worked well.

One must be fair to the ACO in its efforts to limit cost and encourage competition. The racing world has changed so much from when rule making covered just basic safety regs and dimensions, number of seats, normally aspirated or forced induction and cubic capacity!

Thank heavens

Very encouraging is the feedback from Sebastien Buemi on testing the new Toyota Hypercar. The rules apparently allow the car to be raced flat-out without having to lift and coast at strategic points on track to save fuel and recover energy, compared to the previous LMP1H machines, which were far more reliant on electric motor and battery power. Thank heavens for this.

Nevertheless, fuel consumption will inevitably come into the equation, along with tyre management. With heavier cars and reduced regen' braking, consistently powerful retardation may become an issue again. I don't doubt some clever lateral thinking will be employed to gain an advantage, despite the theoretical performance balancing of all cars. The smartest teams will use discretion if they are successful in this, to avoid being handicapped in some way, as happened to Toyota before. On this subject, one has to take one's hat off to Toyota for its loyal commitment to Le Mans and the WEC, despite having to accede to near-crippling penalties since Audi, Porsche etc. last departed, in order to make some kind of a race for the ACO to present over the past two years.

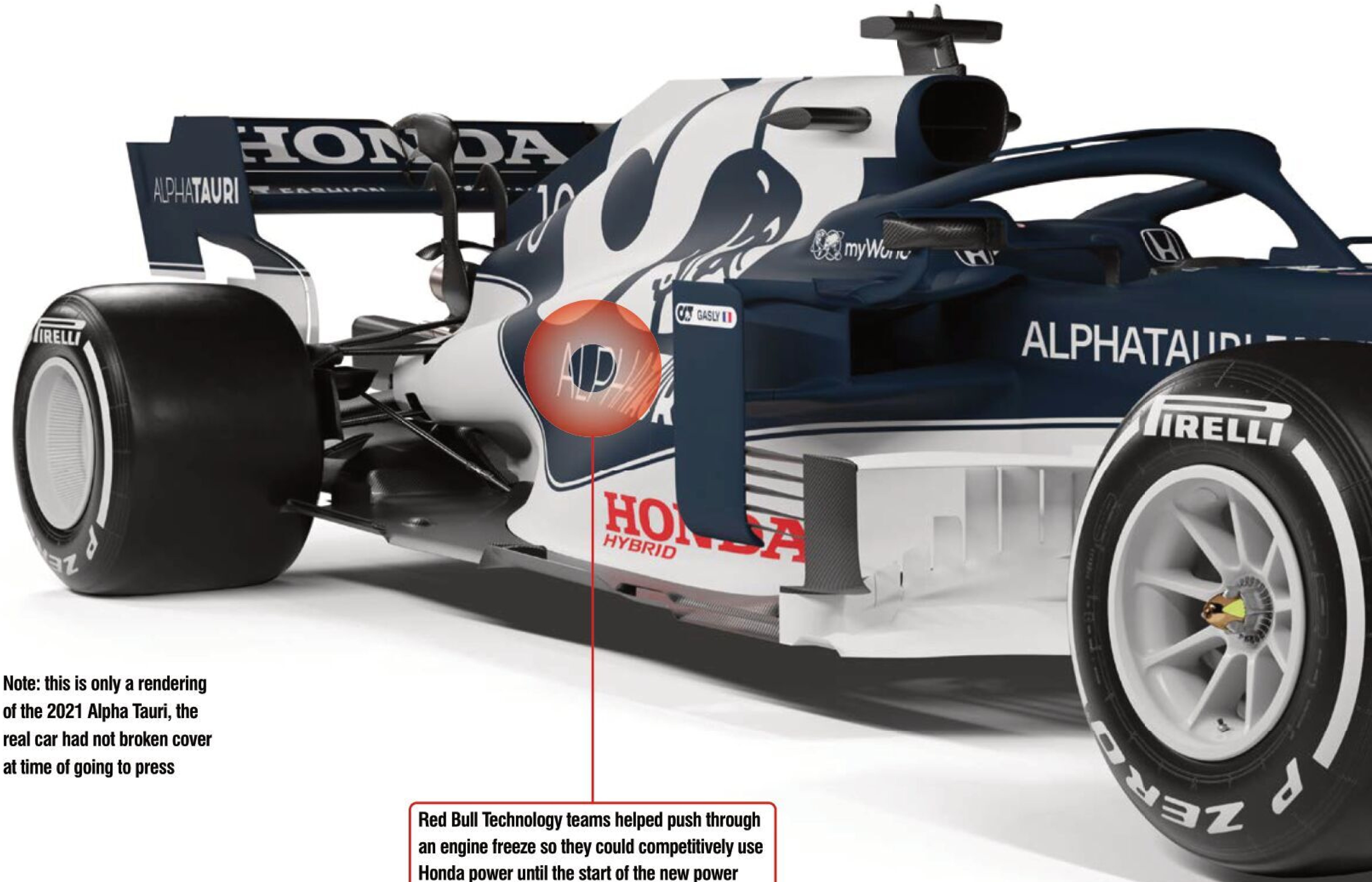
Chapeau! also to James Glickenhaus and his 007LMH project. It's commendable that any individual is prepared to invest in a ground-up Hypercar design and build programme, even including engine. Plus employing none other than Joest Racing to run it. I met Jim briefly once at Goodwood and his sheer enthusiasm shone through. Taking on the big manufacturers in such a professional way is an inspiration in these times when privateers rarely have a look in.

The LMDh equivalents are more like exotic kit cars to me, even if they are going to bear brand names such as Porsche

2021 vision

Racecar investigates the changes and challenges ahead for teams going into the forthcoming season

By STEWART MITCHELL



Note: this is only a rendering of the 2021 Alpha Tauri, the real car had not broken cover at time of going to press

Red Bull Technology teams helped push through an engine freeze so they could competitively use Honda power until the start of the new power unit era, likely to come into play in 2025

You could be mistaken in thinking the 2021 Formula 1 World Championship will be very similar to 2020, with teams carrying over much of their cars' design for another year – a consequence of the coronavirus pandemic pushing the new era of F1 to 2022.

However, the final 2021 regulations, published by the FIA in late 2020, feature several detailed revisions. These changes were initially penned as calming measures in response to the ever-increasing downforce the cars deliver, which some feared would push the Pirelli tyres beyond safe limits.

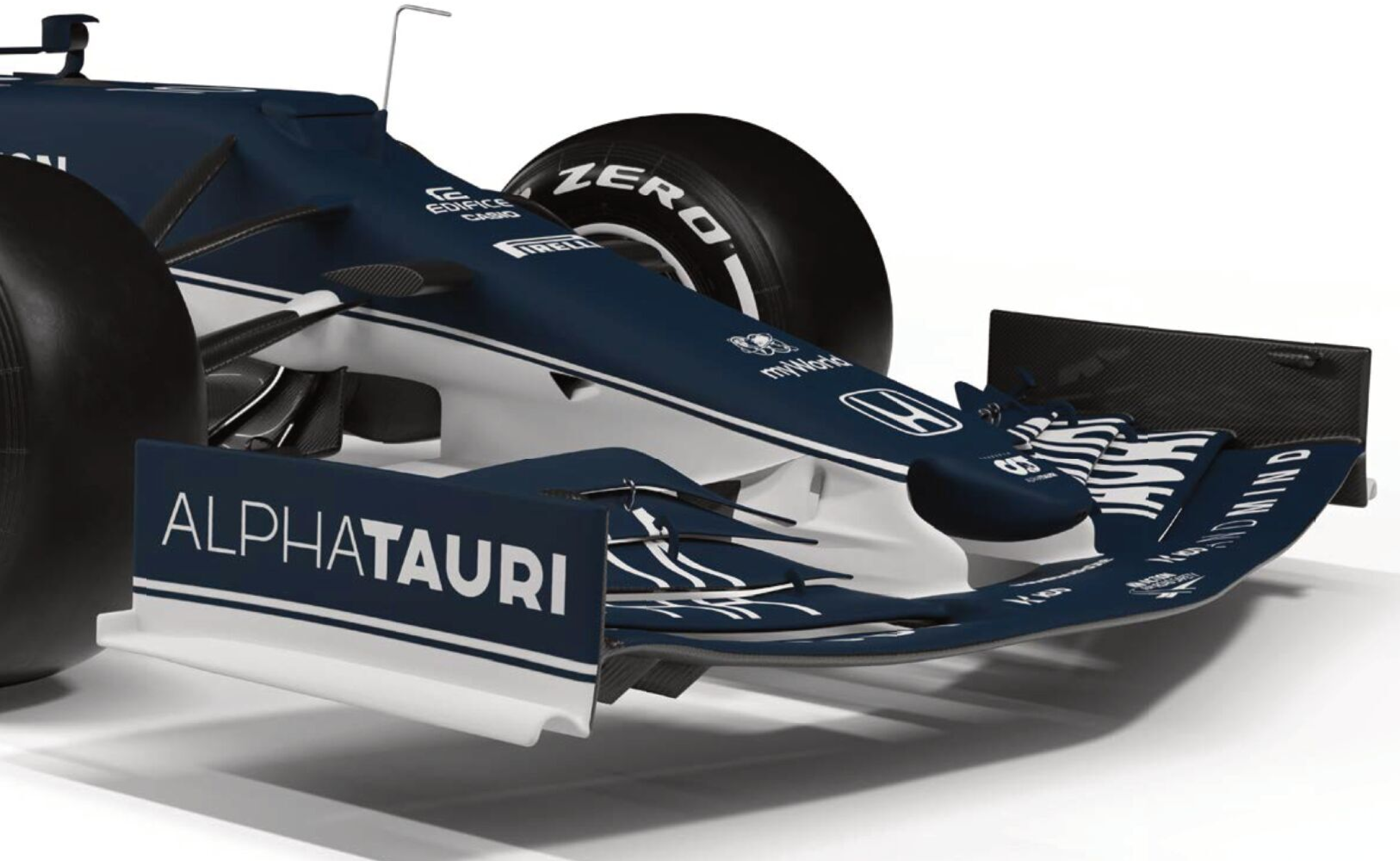
Additionally, the cars' overall pace is thought to have outgrown some tracks, certainly those that have remained unchanged as pace has steadily increased over the years.

The FIA and Formula 1 management hope the changes will force a 10 per cent reduction in overall downforce, enough they believe to cope with the above challenges, while the rule changes coinciding with that 10 per cent reduction have meant some significant challenges for all teams ahead of the 2021 season.

Aerodynamic changes

The largest contributor to the forecast drop in downforce is a new set of floor regulations. These will see a diagonal cut in the floors ahead of the rear tyres, reducing the width at the trailing edge by 100mm on each side.

Additionally, the rules prevent designers including any fully enclosed



The largest contributor to the forecast drop in downforce is a new set of floor regulations

holes in the floor, through which to manipulate airflow, be they slots, holes or aerodynamically-shaped furniture.

These changes decrease the floor's working area used to generate downforce from under the car and reduce the ability to seal the floor to work the diffuser as effectively as possible.

It will now be harder to control rear tyre wake influence on the diffuser stream and the aerodynamic consequences of varying sidewall bulge and contact patch squirt (the loss ejected by the tyre as it contacts the ground).

The allowable flex, and therefore the floor's minimum stiffness, has also been adjusted ahead of 2021 in a bid to reduce the use of it as a moveable surface to influence aerodynamics. The floor will now only be allowed to flex up to 8mm vertically when 500N of load is applied, a reduction from the 10mm of flex permitted in the 2020 regulations under the same load.

The diffuser has also been amended to lessen its ability to create downforce, with the height of the boundary controlling vertical elements required to be 50mm shorter this season when compared to last.

Winglets mounted in the lower half of the rear brake duct have also modified, and are now just two thirds of the 2020 width, restricted to a maximum of 80mm for 2021.

During the drafting period of the 2021 rules, Andy Green, technical director of the then Racing Point squad (now Aston Martin Racing), noted: 'After evaluating the new floor's impact, it's a huge change.

'The small alteration, relatively speaking, has had quite a significant impact on the car's performance. It is not just a re-development of the floor, unfortunately, it's a re-development almost of the front-to-back aerodynamics of the car to try and recover it.'

Investigation into how these aerodynamic changes will impact car performance has been ongoing for a while now, with several teams trialling full-scale packages to gather real-world data as far back as the first half of the 2020 season.

McLaren Racing tested a floor with the prescribed 100mm diagonal cut out on each side at the Belgian Grand Prix in August 2020 with its Renault-powered MCL35 ahead of its switch to Mercedes for this season. Following this test, the team's technical director, James Key, commented: 'It's a shame it had to be done, but there are good reasons for it as we enter the third year of these cars [after the regulation update in 2019], and they are getting quicker and quicker… to the point where, in some cases, driver resolution is lost in high-speed corners and they go by instincts more than conscious decisions in those moments.

'So, I think it is sensible to rein them in a little bit. As much as I agree it is reasonable to introduce the new regulations, it does mean we have had to do some bespoke aero development specifically for 2021 in areas you cannot easily change, nor easily find the right solution.

'Affecting the floor around the rear tyres and diffuser and brakes leads to unique development, and we have had to learn so much about these quite critical and sensitive areas. In that respect, it is showing we could not carry over design from 2020 and make the car work, which would have been a much more natural progression.

'But of course, it has affected everyone the same way and there's good reason behind it.'

Ahead of the launch of Mercedes' 2021 car early in March, James Allison, the team's technical director, also commented on the new aerodynamic rules for this season. 'There was a concern that if we left the aerodynamic development of these cars unchecked then performance would keep increasing, as it's been doing for several seasons now,' he said.

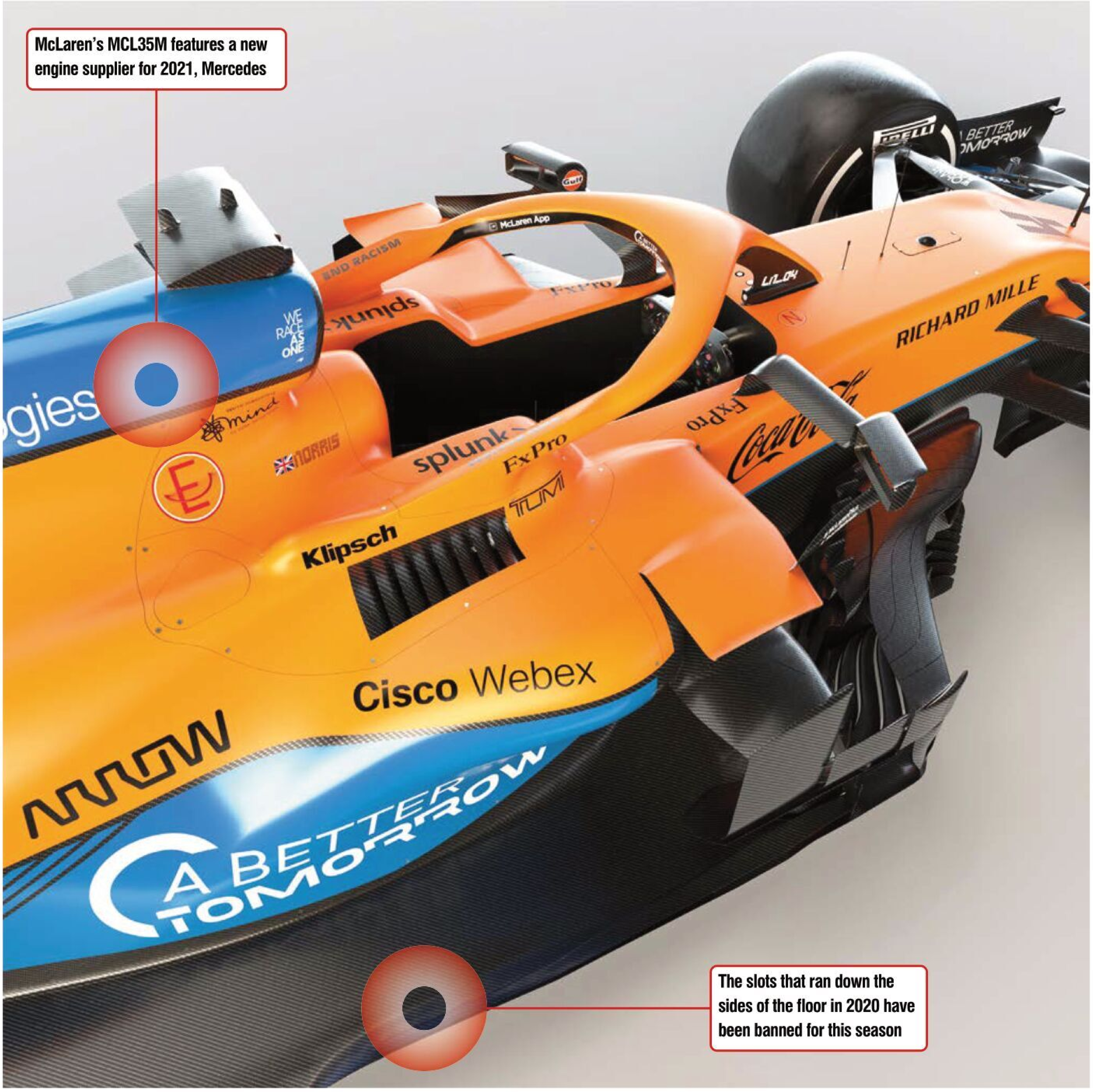
'The risk was the cars would outgrow the tyres, and perhaps even aspects of the circuits, so there was a need to bring performance down a bit. For us, the combination of the aerodynamic changes to the regulations in their rawest form brings the performance of the car back to somewhere near 2019 levels of downforce.

'It's been challenging to try and recover as much performance as possible, and it's been quite an entertaining ride in the wind tunnel and CFD.'

It is not just a re-development of the floor… it's a re-development almost of the front-to-back aerodynamics of the car to try and recover it

Andy Green, technical director at Aston Martin Racing

New diffuser regulations see the dividing strakes 50mm shorter than those of the previous season



Ferrari and Renault (Alpine for 2021) brought 2021 specification parts to track late in the 2020 season, combining the new rules and looking for data to feed into design.

Powertrain

Technical Directive 37, which came into force at the Monza round of the 2020 season, banned teams from using several power unit modes that permit different internal combustion engine and energy recovery system operations in qualifying and race sessions. This TD has carried over to 2021, but with an extra dimension added to it.

Not only will teams now be allowed only one mode for all sessions on a race weekend, in 2021 they are only permitted a set number of engine modes for the entire season.

Power unit development has also been limited further still for 2021. As always, the power unit manufacturers will search for more performance from their products, but the intense effort behind that now must be made in the context of a rule environment where there is less opportunity for mistakes.

In 2020, and previous years, there were three opportunities in the racing year where an upgrade to the power unit could arrive. With each new power unit, manufacturers could have a different design in all elements, permitting increased performance with every new unit brought to the track.

In 2021, however, teams are allowed just one opportunity to introduce a performance upgrade on the power unit. So they need to stack as many promotions into the new version as possible, and deliver it at the most effective point in the season.

According to Allison, this ramps up the pressure on the power unit organisations to ensure they obtain as much as possible from that single opportunity.

There have also been changes to the wording regarding the turbocharger wastegate and its tailpipe. Up until 2021, power units were required to have at least one wastegate tailpipe, though from now on they will not have to run the additional pipework if the manufacturer can design a system that does not require a wastegate. This change coincides with developments made in MGU-H technology.

Hollow bodies

A clarification has also been made regarding any hollow cavities that, for 2021, must conform to a uniform cylindrical shape of a constant diameter. As such, the advantages of using exotic construction techniques for hollow components has been curtailed.

To combat the use of oil and lubricants to boost combustion, and expensive new fuel development cycles to improve combustion efficiency, the FIA has added ruling relating to this issue, too.

As well as reducing the number of fuels and lubricants used throughout the season to just one set, two fuel flow meters with different anti-aliasing properties will now have to be used to prevent teams from overcoming the fuel flow limit.

Furthermore, a proposal to freeze power unit development from 2022 recently received unanimous approval from the FIA, Formula 1, the teams and the power unit manufacturers at an F1 Commission meeting.

Prior to this, engine development was set to cease for three seasons, starting in 2023. The new change means all manufacturers will have the opportunity to update their engines only once after the end of the 2021 season to make sure they are compatible with a new, increased percentage of synthetic fuels for 2022.

On the table was the suggestion that any manufacturer's power unit with a significant performance deficit could incorporate a system that artificially boosts performance. Ferrari and Red Bull were in favour of this, Mercedes and Renault were strongly opposed, calling it a Balance of Performance-style system that they believe is against Formula 1's DNA.

Unanimous support

And while Formula 1's new governance process doesn't require unanimity, *Racecar* understands that F1 and the FIA wanted full support of all changes from all manufacturers, and for them to agree to the freeze and the terms around it rather than having it forced upon them. In the end, there was unanimous support with no indication that a BoP method would be considered.

The engine freeze ensures Formula 1 keeps four manufacturers until its next generation engine chapter, likely to be brought forward from 2026 to 2025. Starting the new power unit chapter a year early was another proposal supported by all current manufacturers.

The freeze is widely welcomed to keep huge engine improvement costs down, and fixing it at three years was considered the best option. A high-level working group has been established, including current and potential engine manufacturers and fuel suppliers, to consider the route F1 should take after that, and it is expected to be some time before a specific direction is chosen.

Robust rubber

After concerns about the robustness of Pirelli's 2020 Formula 1 tyre, 2021 will see a new construction from the Italian manufacturer as it looks to tackle the punishment inflicted on its products by the current crop of Formula 1 cars.

MD Media

New, more robust tyres from sole supplier, Pirelli, for 2021 will be around 3kg heavier than those of the previous generation

'We got our first glimpse of these new 2021 tyres in Portimao, Portugal in 2020,' notes Allison. 'We've since had two other occasions where we could test them – Bahrain and then in Abu Dhabi, the last race of last year.

'That's not very much opportunity to take on board a new tyre and get ready for a new season with it because these tyres affect the way the car performs, they affect the way you have to design the aerodynamic platform and the way you have to set up the car.

'It's been a big challenge for us to try and dredge out of that track testing data we gathered last year and take as much as we can from tyre data supplied by Pirelli so we can optimise the car around the characteristics of these new tyres. The new tyres are designed to help us race safely and fast through the 2021 season.'

The more robust 2021 tyres from Pirelli carry a weight penalty of 0.75kg per tyre as a consequence of providing that durability. In addition to this, the cars' minimum weight has coincidentally been increased by 3kg, from 746kg to 749kg. This has not been a problem for some teams, as Allison noted: 'We were lucky enough to be one of the cars below the 2020 minimum weight limit. So, when the weight limit was raised by 3kg for 2021, we've had the freedom to figure out how best to invest that weight to get maximum performance.'

Aerodynamic testing allowance has already been reduced for 2021 following the coronavirus pandemic's effect in 2020. That is a global limit on testing on all teams to try and reduce costs. However, ahead of the 2021 season, the FIA implemented a new handicap-style system, which means the team that finished last in the championship will be allowed 112.5per cent of the 2020 limit, dropping in 2.5per cent increments for each position to give the top team 90per cent.

For us, the challenge has been about adapting our world so we get more and more out of every single opportunity in the wind tunnel

James Allison, Mercedes F1 technical director

With the baseline figure for wind tunnel runs per week in 2021 at 40, Mercedes as the reigning World Champion team will only be permitted 36 wind tunnel runs per week, while the last-place finisher in 2020, Williams, is allowed 45.

CFD reduction

Similarly, CFD work on the cars has also been curtailed and position linked. The testing period for substantial CFD work typically runs for around 10 weeks, depending on the time of the year. The nominal number of results produced at this time is approximately 2,000. With the new system in place, Mercedes can now only generate 1,800 CFD results during the 2021 testing period, while Williams is allowed to produce 2,250.

As second-place finishers in 2020, Red Bull is allocated one more wind tunnel run per week and can produce 50 more CFD results per testing period than Mercedes.

This handicap system is based solely on results and will be reset halfway through the season. Allowances for the latter half of 2021 will therefore depend on where teams are in the Constructors' Championship on 30 June after the French Grand Prix.

[CFD and wind tunnel] allowances for the latter half of 2021 will depend on where teams are in the Constructors' Championship on 30 June

With F1 heading into a new era in 2022, these restrictions will become significant when teams transfer their development efforts to the new regulations for next season. The transition from 2021 to 2022 development will play a critical role halfway through the season as development permissions are reset.

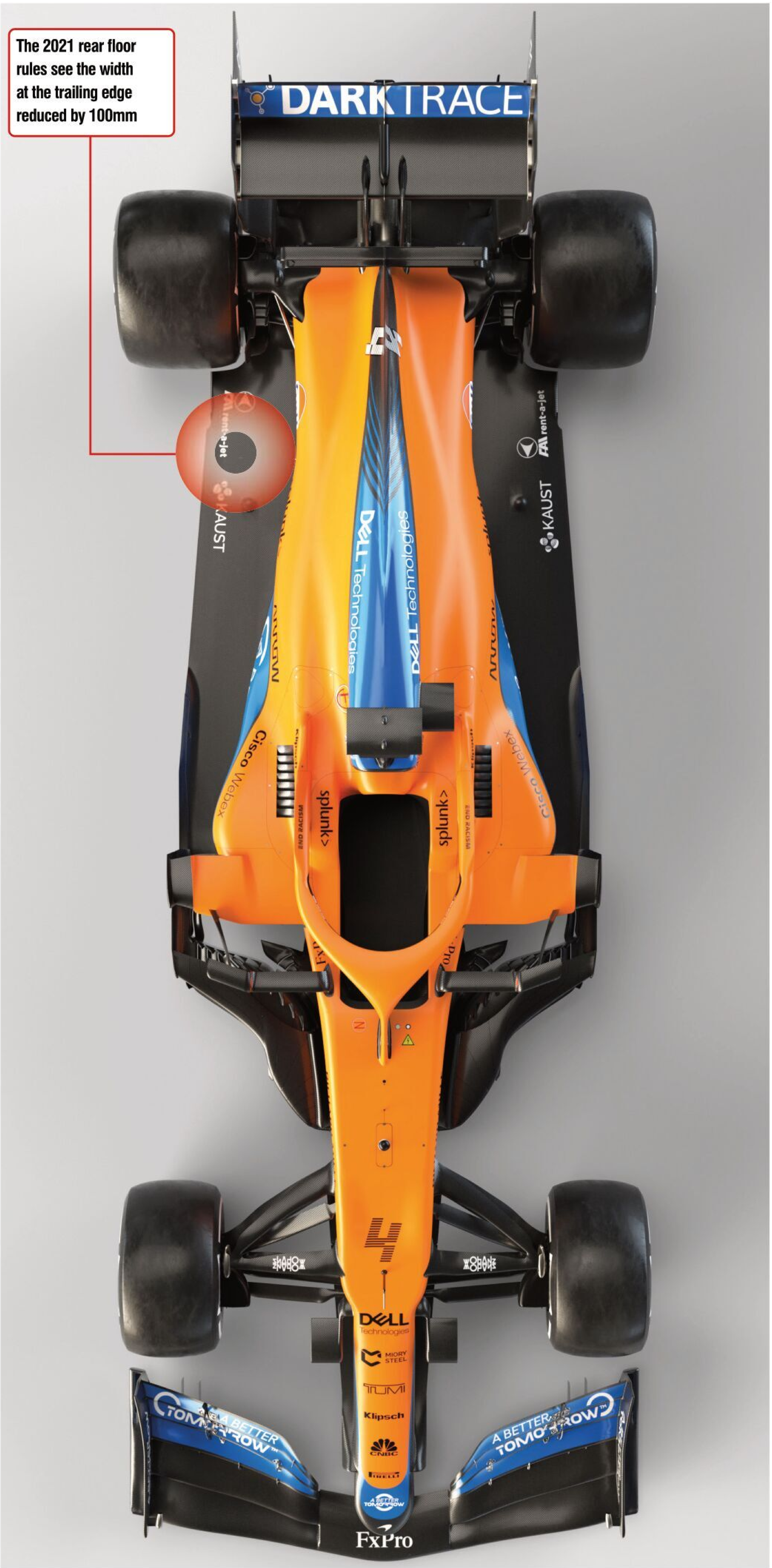
Clearly, champions Mercedes are the losers under the new testing regulations, but Allison remains sanguine. 'We were lucky enough to be good last year, and unfortunately we pay the price for that a little bit in 2021 and beyond because we get to use less of that fundamental asset – the wind tunnel and CFD compute – compared to our competitors.'

Opportunity knocks

'For us, the challenge has been about adapting our world so we get more and more out of every single opportunity in the wind tunnel – making sure each run is as valuable to us as possible. Regarding CFD compute, we have adapted our methodology and approach to make those calculations as valuable as possible. This adapted approach should mitigate, and maybe even completely offset, the effect of this reduction in the amount we're allowed to use these fundamental tools.'

Finally, the latest regulations will make the job of duplicating another team's design elements more difficult as it can now only be done through information obtained at events or tests. As such, any intelligence will be equally available to all competitors.

This effectively limits teams to using video or photography, as any other form of information transfer is now explicitly banned. Should a competitor be deemed to have a listed part that resembles one found on another car in the field, the FIA can request a team demonstrate its entire design process, including any work carried out ahead of the regulation coming into force.



The 2021 rear floor rules see the width at the trailing edge reduced by 100mm


HIGH-VALUE MANUFACTURING TECHNOLOGIES
THAT MAKE HISTORY IN MOTORSPORTS
WINDFORM ADVANCED 3D PRINTING
WITH CRP TECHNOLOGY
Functional prototypes and end-use parts using
Laser Sintering and Windform composite materials
HIGH PRECISION CNC MACHINING
WITH CRP MECCANICA
Processing machined parts with high-tech metals,
challenging geometries, tight tolerances
SUPPORTFREE™ METAL AM HAS ARRIVED TO EUROPE!
VELO 3D
CRP Meccanica is now the Italian Exclusive
Distributor and Account Distributor for Europe of
VELO3D metal 3D printers.
CRP TECHNOLOGY
PUSHING HIGH-TECH SINCE 1970
Quality, reliability, innovative and customized
solutions are our distinguished features.
CRP MECCANICA
info@crp-group.com | www.crp-group.com | phone: +39 059 821135

On a knife edge

How INEOS Team UK and Mercedes F1 Applied Science have collaborated on the America's Cup AC75

By DR CHARLES CLARKE NEW ZEALAND CORRESPONDENT

America's Cup is a team sport. It's a technical team sport. And so there's a lot of overlap

Toto Wolff, team principal at Mercedes F1

There is a general misconception that America's Cup yacht racing is Formula 1 on the water. Yes, the level of technology, speed of manufacture, speed of change and the totally committed 'teamwork' ethic are all very similar, but the America's Cup is continually pushing the envelope and evolving into the best version of itself. F1, on the other hand, is constrained to have similar vehicles with four wheels in contact with the ground the whole time, hopefully. Now, imagine those same cars with three asymmetric wheels being driven by rockets and you come a little closer to the foiling AC75 America's Cup concept.

Four years ago, right-minded people thought the Kiwis were completely mad to even think about foiling monohulls after the AC72 catamarans had proved so successful. Statically, it looked okay with a cant arm and a foil to leeward, a foiling rudder and continuous pressure on a wing sail, but these things have to tack and jibe, as well as travel in a straight line. What followed was some serious design and software development to make these ideas on paper actually work on water. All the systems on board have to be working to their optimum and be perfectly balanced for these devices to survive the rigours of racing. We have seen in spectacular fashion with American *Magic Patriot* what happens when the rudder just pops out of the water on an ambitious manoeuvre. If only they had gone the other way around the top mark. But hindsight is a wonderful thing in racing.

Wild horses

When you are effectively balancing the boat on one foil and a foiling rudder, a bit like a two-legged stool, in changeable wind conditions, even minor adjustments of all the other systems such as the wing sail downhaul and the jib can have major repercussions. The interaction of the skirt of the wing sail with the deck and how much jib to use has massive impacts too, as these boats are balanced on a knife edge when they are foiling. In strong wind conditions it must feel a bit like riding a wild horse, on the edge of catastrophe the whole time.

By a happy coincidence, INEOS Team UK and Mercedes F1 are in the same commercial stable led by Sir Jim Ratcliffe, chairman of petrochemical giant INEOS, who owns 33 per cent of Mercedes F1, so a technical partnership between the two companies made perfect sense. Particularly when you consider the intricacies of the foil wing hydraulic simulation, design, development and manufacture.

The next level

Sir Ben Ainslie, INEOS Team UK team principal and skipper, was always keen to have some kind of partnership with F1. 'It is game changing,' he insists at time of writing. 'Whether or not it will mean us winning the Cup this time around, I can't tell you right now. I hope it does. But either way, I hope we can continue working together, because it has the capability to take us to the next level.'

The partnership also provides significant expertise in CFD and systems simulation to help fine tune the foiling components the teams are allowed to change, and it gives INEOS Team UK direct access to the world leading, rapid manufacturing facilities at Mercedes F1 to make new parts for the foil wing system.

The cant arms and the electro-hydraulic actuators that drop the foil wings in

The AC75 design was created for this edition of the America's Cup. The boats can foil at three times the windspeed and have recorded more than 50 knots in racing conditions

It may not be F1 on water *per se*, but combining the engineering talents of the two disciplines has hastened and greatly improved the design and development process

Direct access to the world leading, rapid manufacturing facilities at Mercedes F1

Sir Ben Ainslie, INEOS Team UK principal and skipper

Photos: D Wilko – INEOS Team UK

The cant arms have a relatively neutral hydrodynamic section, a bit like wishbones in F1 suspension

and out of the water are a one-make component built by Persico. All boats must run the same cant arm package and the only allowed movements of the foil arms are cant about a fore and aft axis.

This system has a one-design battery to power it, so the energy for canting the foils is not derived from the manpower of the grinders. The teams all use the same battery to control the foil wing flaps, even though this is a part they can design and build themselves.

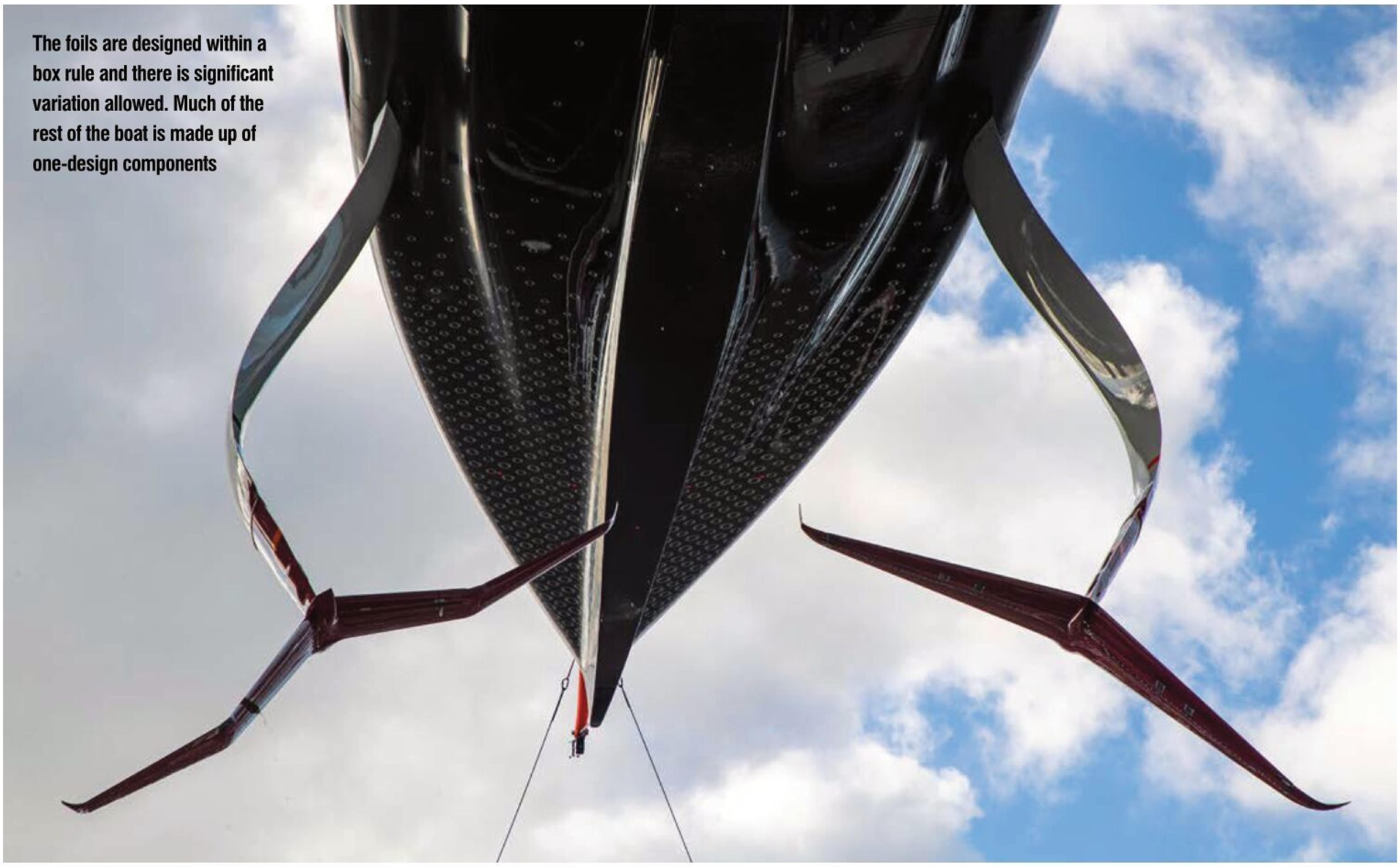
The cant arms have a relatively neutral hydrodynamic section, a bit like wishbones in F1 suspension. Teams cannot change the leading edge of the cant arms but they can modify the trailing edge to suit their foil wing configuration.

The boats are allowed three pairs of different foil wing configurations to cope with different sea and wind conditions. Once these components are 'declared', teams are allowed to develop these configurations during racing, as long as the referees deem the developments to be of existing parts, not new variants.

Teams are allowed to modify up to 20 per cent of the mass of the foil wings, as many times as they like. This actually provides quite a bit of freedom for significant changes to the foil wings. However, there are stringent weight and c of g rules for the foil package and, as the wings are modified, these requirements need to be complied with.

System simulation

The foil wings also have trailing edge flaps, a bit like ailerons on aircraft wings, so the lift can be carefully adjusted. All of this must be simulated prior to manufacture and the system simulation expertise of Mercedes F1 is a tremendous help in homing in on a promising development direction. Just as system simulation has revolutionised F1, the same technology can be used to simulate foil wing / water



The foils are designed within a box rule and there is significant variation allowed. Much of the rest of the boat is made up of one-design components

interactions, as well as interactions with the rest of the boat trimming systems.

'Superficially, the wings look simple from a hydrodynamic perspective,' says Thomas Batch, principal engineer at Mercedes F1 Applied Science on secondment at INEOS Team UK in New Zealand, 'but the internal mechanics, and their interface back through the hydraulic control systems, is much more complex.

'Packaging of the flap actuation systems, which allow us to control the flaps under impressively high loads and influence twist and roll components, is extremely tight to maximise performance. There is a huge amount of complexity and detail beneath the surface, which is key to extracting boat speed.'

Key metrics

The use of wind tunnels is prohibited in the AC75 programme. 'So your aerodynamic, hydrodynamic development tool is computational,' says Graham Miller, Mercedes F1 Applied Science director. 'Of course, they [INEOS Team UK] have their own system simulation capability, which is a key tool set. That's something Formula 1 has done for over 25 years and we're trying to help here.

'There is a direct correlation between the amount of time you spend on the simulator and your ultimate track performance. It may sound like basic stuff, but the ability to track and measure what you're doing on the simulation, and be able to correlate that back to sailing performance, are key metrics.'

So the more time you spend in the system simulator, the better the eventual outcome? 'From a correlation point of view, it is vital you take the CFD and put it through your VPP – your vehicle performance predictor – and system simulator and track it to the water, or the race track in our case. You're just constantly going around that loop, tuning and tuning and tuning. If you don't, you can go down a wrong development direction very easily.'

Data analysis is also key. Every scrap of data gathered from testing and racing on the water is fed back into the simulation, so the quality of the systems modelling and simulation constantly improves.

As well as the weight and c of g rules, there are also geometric limitations on the foils, explains Nick Holroyd, chief designer with INEOS Team UK. 'If you're looking from the transom forward, the rule defines a trapezium-shaped box. While longitudinally, the foils have to fit in the space between 10 and 12m forward of the transom. So essentially you have this 3D box the foil has to fit within. The trapezium is about four metres across its base and, to some degree, that defines the maximum span the foil wing can have.'

The rules also say the foil wings must be symmetrical about the centreline of the boat, but the individual wings don't need to be symmetrical, so teams are 'declaring' slightly asymmetric sets of foil wings to maximise the possible design changes. Doing this means that within one pair of wings a team can explore two different design and / or modification avenues in development.

Design validation

In F1, the limits placed on track testing and wind tunnel usage has meant teams have turned to system simulation to validate design changes, prior to detailed design and manufacture. Over the past 25 years, all F1 teams have developed significant system simulation expertise where they generate mathematical models, using specialised software like Matlab and Simulink, to model system components, from chassis through aero, suspension and tyres. These are all assembled and then tested in a physical driving simulator where the effects of design changes are validated by dedicated simulator drivers for consistency.

There is a huge amount of complexity and detail there beneath the surface, which is key to extracting boat speed

Thomas Batch, principal engineer at Mercedes F1 Applied Science

Live data is fed back to the technical team from the boat, as they train and race, in order for a full debrief to be ready as the sailors come ashore

Traditionally boat-to-boat testing has been central to a Cup campaign but the practice has been banned. Simulation is now key

In this way only effective developments make it through to detailed design.

The same techniques are used by Mercedes F1 to simulate the complex interactions of components and systems in the AC75, in order to validate potential design iterations. The foil wing changes are fed into the whole boat simulation so all the potential interactions can be assessed, and only beneficial developments are then fast tracked through the next stages of the design process.

This is essentially what happened between the Christmas Regatta, which was basically a shakedown exercise, and the first time the teams raced together competitively. Unfortunately, the INEOS Team UK performance the first time on the water was woeful, and not even the sailing prowess of Sir Ben Ainslie could make the team look halfway competitive. Six lost races later and the team sat dead last on points.

Simulation overdrive

After that, the CFD computers and system simulators in Auckland, New Zealand and the UK went into overdrive. In some respects, the 13-hour time difference was useful as it allowed work to continue 24 hours a day, and everyone in the UK and New Zealand were on top of every potential development.

In less than three weeks, the combined efforts of the engineers turned things around completely, with INEOS Team UK winning its first five races in the round robin stages of the Prada Cup, going straight into the final. The last race with *Luna Rossa*, the Italian challenger, was particularly spectacular, with nine lead changes and boat speeds in excess of 50 knots, more than twice the 22 knot peak wind speed. Not bad for a boat that had been written off by the pundits three weeks before.

Every scrap of data gathered from testing and racing on the water is fed back into the simulation

Ironically, because of this performance, INEOS Team UK were awarded the Christmas Race Trophy, which had not been awarded at Christmas as the racing had to be abandoned due to lack of wind on the last day.

And as if to demonstrate how complex these boats are, INEOS Team UK had to take a 15-minute delay before the start of the last race to fix a problem with its 'Cunningham', which is a downhaul adjustment to the mainsail, an essential device for trimming the boat and affecting the interface between the skirt of the sail and the deck.

It's interesting to note how Toto Wolff, team principal of Mercedes F1, recognises the technical similarities between both teams, though he is more focussed on team personnel dynamics, and what it might mean for Mercedes.

'The similarities are huge,' he says. 'Obviously, you have the aerodynamics, hydrodynamics, modelling, simulation and those sorts of things. But from my side, I am fascinated also by the learnings in terms of man management, performance under pressure and adaptability. America's Cup is a team sport. It's a technical team sport. And so there's a lot of overlap.'

With two Mercedes engineers based in Auckland with the team at the moment, Ainslie views the relationship as 'a genuine partnership'. Around 30 engineers from Mercedes Applied Science have worked on everything from a more efficient gearbox on the boat's grinding pedestals to improving computational efficiency and run-time of simulations. And from manufacturing manifolds to testing parts on a custom test rig.

Because the foil wings are so critical to the success of the boat, Mercedes brought that entire part of the build project in house at its Brackley, UK base to ensure accuracy, consistency and speed of delivery. Validation was then done on a bespoke test facility that put the foils through their paces structurally before they were delivered to Auckland.

Plug and play

'We did the modified foil wings at Brackley so we could do it in a clean environment, and they could do the simulation of the assembly, put it through its load cases and, ultimately, so Mercedes could deliver plug-and-play assemblies to the sailing team,' confirms Miller.

'Ultimately, it's very difficult to do this kind of manufacture in a boat shed, where you don't have hydraulic clean lay-up rooms and you don't have clean build assembly processes. If you did try to do that, you can't be doing it next to someone who's finishing off a piece of carbon, or spraying a bit of the boat somewhere.'

Sir Ben Ainslie is quick to acknowledge the assistance. 'With everything we were up against, we probably wouldn't have made it, frankly, if we hadn't had Mercedes' expertise and rapid manufacturing capacity. It's so complex.'

Nick Holroyd, chief designer at INEOS Team UK concludes: 'One of the biggest gifts from the Cup to the rest of yachting is

I think the greatest benefit of the [America's] Cup is really well experienced and educated engineers

Nick Holroyd, chief designer at INEOS Team UK

this design process. If you look at the Cup now, with Mercedes' involvement, we're 40+ people on the design side. If you multiply that out over three years, that's 100+ man years of design time. That's enough design time or resource to not only do the design, but actually push the design process forwards, build new tools and refine all of those things.

'Then you look at where that goes next. The simulators that came out of Emirates Team NZ are now being used to design the next generation of Volvo ocean boats, and ultimately that cascades down.

'You can talk about specifics – will the double-skin mainsail flow through? Maybe it will, maybe it won't, but ultimately, if you are anywhere near the performance end of yachting, I think the greatest benefit of the Cup is really well experienced and educated engineers. The people that wash through the Cup cycle and go on to do other things, and the tools and approaches and technologies they take with them.'

There is speculation in the sport that, while everyone has been focussed on the foil wings, the next 'big thing' in terms of development is the aforementioned double-skin wing mainsail and its control system, where the favourites, Emirates Team NZ, have stolen a march on the rest of fleet. Interestingly, recent shots of *Britannia*, INEOS Team UK's boat, appear to show a different rig altogether, so there appears to be considerable cross fertilisation out on the water as well.

Eat, sleep, test, repeat… Due to the time difference, data engineers from INEOS Team UK and Mercedes F1 Applied Science worked practically non-stop in the lead up to the Prada Cup

Photos: C Gregory – INEOS Team UK

Photos: Jason Critchell; Radical

Longer ran

Radical Sportscars has chosen the Ford EcoBoost for its latest customer-focused design and, in doing so, has produced its most powerful and interactive track day / racecar yet

By LAWRENCE BUTCHER

ge missile

A power-to-weight ratio of 586bhp per ton

Where we are seeing the market moving is a longer range car, with increased durability and ease of use

James Scott, technical development manager at Radical Sportscars

UK-based Radical Sportscars was one of the pioneers of the track day special market when it launched its 1100 Clubsport in 1997. Now, following some recent forays into road cars, and a management change in 2017, the company continues to go from strength to strength. Its best-selling car, the SR3, has shipped over 1300 units and the various one-make series running its cars are flourishing across the globe.

According to James Scott, technical development manager at the company, even through the ongoing pandemic Radical has been seeing a boom in demand for its products, and the order books are currently full, including requests for its latest model, the SR10.

Radical's cars have always been characterised by their high-revving, motorcycle-based engines. From the diminutive SR1, up to the raucous SR8, the company has largely developed its powertrains around motorcycle technology. However, for the SR10 it has diverged from this path and opted instead for a turbocharged in-line four, in the form of a 2.3-litre Ford EcoBoost engine. The lightweight four pot delivers 425bhp and 386ft.lbs of torque, which, thanks to the SR10's all-up weight of 725kg, equates to a power-to-weight ratio of 586bhp per ton. This makes it the most powerful machine in Radical's line up, pipping the SR8's 411bhp.

Endurance focused

'The DNA of the car is the same, and the fundamental chassis layout is the same as it's always been,' says Scott, who is keen to point out the SR10 is not replacing the SR8, which will still be available for those who need a naturally-aspirated V8 to get their fix.

The concept for the SR10 arrived from a desire to make a more endurance-focused, high-power Radical. 'We have sold 60-80 SR8s over the years, but

where we are seeing the market moving is a longer range car, with increased durability and ease of use,' Scott continues.

To a large degree, this demand stems from the US, which accounts for around half of the company's market, where many country clubs and driving schools use Radicals.

Looking at the popular SR3, which is powered by a modified Suzuki 1500cc bike engine, Radical recommends a rebuild interval of 40 hours on the engines. This figure is quickly eaten up in a car pounding constant laps with customer drivers. 'We wanted an engine that would last longer, and that is why we ended up with the 2.3 EcoBoost, which we can push to an 80-hour service interval, though we think we will probably end up extending that,' says Scott.

Going for Boost

The SR10 is not Radical's first experience with the EcoBoost engine range. Its RXC coupé, available in both track and road variants, used the 3.5-litre, twin- turbocharged V6 version.

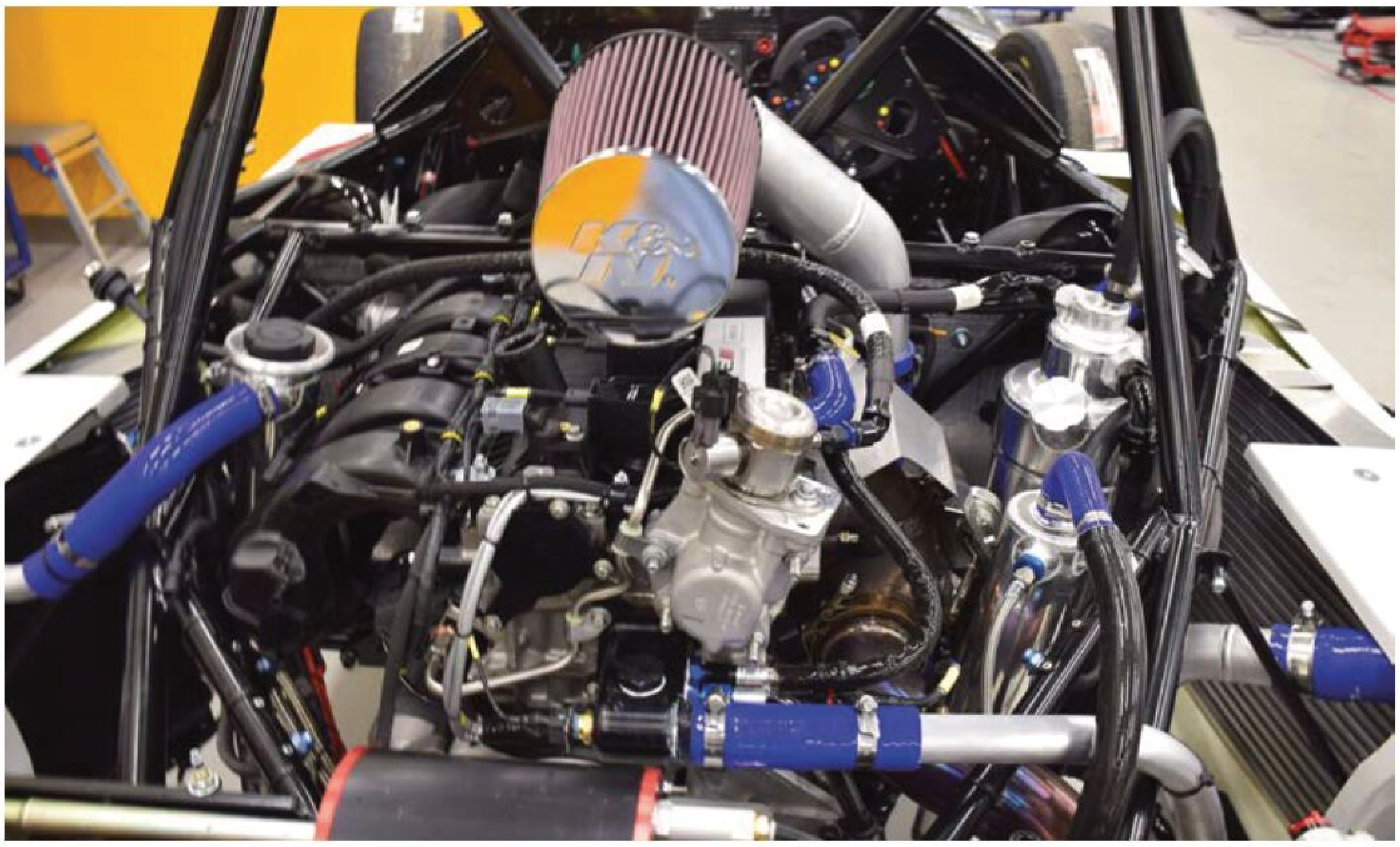
'That is where we learnt a lot about getting the most out of a turbo engine, working with Life Racing on the calibration side, getting a stable turbo motor with direct injection. From there, we moved on to the 2.3,' notes Scott.

Radical started out trying to retain as many standard components in the engine as possible but, muses Scott, 'We managed to break a lot along the way, so developed parts that worked.' For example, the turbo was not up to the rigours of competition use and, after trying a number of aftermarket options, Radical settled on a Garrett GTX 25. 'There are quite a lot of solutions out there for the 2.3 EcoBoost, but they are geared more towards fast road and drag race use, running for maybe 10 seconds. Because with our load cases we spend such a high percentage of time at full throttle – 60-70 per cent – you wear out parts pretty quickly. The Garrett has worked out to be a really nice package in the end.'

Creative solutions

Housing the turbo and its ancillaries within the confines of the SR10 chassis required a few creative solutions, including the use of additive manufacturing to produce a prototype inlet manifold in Inconel for testing purposes. 'It's nice to be able to use some of these new technologies, to speed up the development process. We were surprised how well it lasted through the development phase, and it was pretty cool,' remarks Scott.

A variety of other internal parts were uprated as development exposed their weaknesses, including the pistons. 'We were managing to pull the little ends out, and had some issues with cracking in the early days. We've ended up using one of Mahle's latest designs and that has been absolutely fine.'



2.3-litre Ford EcoBoost was originally to be kept largely stock, but through development ended up as a more race-orientated unit, with bespoke valvetrain parts, Mahle pistons and a Garrett GTX25 turbo. Service interval is high at 80 hours though

Because with our load cases we spend such a high percentage of time at full throttle – 60-70 per cent – you wear out parts pretty quickly

A much higher spec engine than initially envisaged, with considerable performance headroom

Other internal changes are as one would expect on an engine destined for hard track use. The crank is a balanced production unit, while the valves and associated ancillaries are bespoke. Naturally, the engine features a dry sump system, developed in conjunction with Ford specialists Mountune, who also supply a number of other engine components.

Scott notes that when the engine development programme was nearing its conclusion, even the Garrett turbo was starting to close in on its performance boundaries, approaching its speed limits at high boost pressures. 'We ended up running some faster cams in the engine, just to move a bit more air without having to run so much boost,' explains Scott of the measures taken there.

Despite an initial plan to retain as much of the production engine as possible, Scott points out that the development programme, and resulting component changes, means customers are receiving a much higher spec engine than initially envisaged, with considerable performance headroom.

'It all benefits the customer in the end, and we now have an engine with excellent endurance,' he concludes.

Performance window

Beyond the mechanical specification of the engine, Radical put considerable effort into its calibration, not just in terms of driveability, but also adjustability. 'This is the first car where we have a degree of calibration tuning accessible for the driver. Part of out new electronics package includes a custom steering wheel, and that has three manettino dials for controlling the maps and throttle response. Customers love to have a dial to play with, and it is something that will allow professional drivers to get the very most out of the car.

'We also wanted to be able to put in a really comfortable, safe mode, so someone can put their mate in the car, wind the throttle right down and limit torque to 40 per cent, just so they can get used to it.'

Another area to come in for an update was the transmission. While the bestselling SR3 and the V8-powered SR8 use a six-speed Quaife unit, the new car has seen a switch to a Hewland transmission, based on the company's Formula 2 unit.

Suspension design is typical of previous Radical products, but the SR10 sees a change to a Hewland TMT200 transmission

'We started development using the gearbox from the SR8, though we were obviously putting a lot more power through it. But when we started pushing to a more endurance-based project, we changed. As it was relatively late in the development process, we were looking at existing transmissions we could use. There were a couple of longitudinal 'boxes, but we ended up with the TMT200,' explains Scott.

A significant advantage of using a transmission that has already seen widespread use in many series is the range of ratios available, as Scott details: 'There are something like 60 gear pairs, and you can get pretty much whatever you want from that.' Radical offers the car with short, medium and long ratio set-ups, but the standard (medium) gearing is the best match for the power delivery characteristics of the engine. If necessary, bespoke ratios can be supplied.

The transmission works in conjunction with Radical's in house-developed paddle shift system and, according to Scott, has proved to be the most reliable gearbox the company has used to date.

Electrical refinement

'The things that make a Radical a Radical were kept,' says Scott in relation to the general chassis design of the SR10. The suspension layout and kinematics are effectively the same as the SR3 and SR8, though some areas have been updated to accommodate the new engine package. 'We wanted to keep the handling as it was, because customers love it, they also love more power – even better if it's reliable power – so what we wanted to do was update the things the driver interacts with.'

This included the electronics package, along with its associated dash display and driver controls, Scott pointing out that a driver spends most of their time in the car so updates to the cockpit are worthwhile. The wiring loom is now PDM (Power Distribution Module) based, so there are no relays or fuses in the car. Not only has this shift allowed for greater functionality from the electronics, it has also improved reliability, meaning a driver's day at the track is less likely to be spoilt by electrical gremlins.

The basis for the system is an AiM PDM 32, for which Radical is the first manufacturer customer. 'The system also allows us to do more intelligent things like monitoring the current draw on components. We can flag warnings when something is not working correctly and we can also monitor when things start to vary their current draw, indicating they are nearing the end of their service life,' notes Scott.

The steering wheel features an AiM display in a bespoke housing and uses CAN communication, which again cuts down on the physical amount of wiring. Where older Radicals are all toggle switches and 12V feeds, the SR10 features a CAN touch pad, the functionality of which can be customised if necessary. Overall, Scott says the focus on modernising the electrical system has brought multiple benefits.

This is the first car where we have a degree of calibration tuning accessible for the driver

We have a full range of sensors, more than some customers will need, and more than some LMP3 manufacturers provide as standard

Stylish, aerodynamic bodywork has seen a significant re-design, particularly in the sidepod area, mainly to improve the cooling package due to the use of a turbocharged engine

'It's a simplified, lightweight loom with greater functionality and reliability.'

Data package

The data logging capabilities of the car have also become more potent, though Scott suggests some owners will never look at any data, while others will study it meticulously. The data logger is integrated into the AiM system, with the added bonus of using AiM's standard analysis software, which is familiar to many racers from Karts upward.

Radical has offered features such as individual damper pots in its data packages for a long time, but has recently done a major update on the SR3, now offering the XX model which is equipped with a revamped data system, and that has been transferred to the SR10.

Providing a summary of the main additions, Scott says, 'We have a full range of sensors, more than some customers will need, and more than some LMP3 manufacturers provide as standard, but we know that the front runners in our championships will really make use of them.

'For example, we've added laser ride height front and rear, to allow the validation of the aerodynamics and also compare tyre squash against measured suspension movement.

'We've also added a TPMS kit, which can give pressures and internal temperatures. It's not an IR kit [measuring carcass temperature] yet, though we are looking at that, but it is enough to tell an amateur driver when their tyres are up to temperature.'

The company is also currently investigating adding further functionality such as cloud sharing of data.

The SR10's bodywork follows the established styling cues one would expect of a Radical, with the aero package honed to provide predictable handling on the limit, though there are some refinements to account for weight distribution of the four-cylinder engine. However, one area that needed considerable development over previous, naturally-aspirated cars was the cooling provision for the turbocharged motor. Given the global market for these cars, which can be running anywhere from Aberdeen to Arizona, having plenty of headroom in the cooling system is a key requirement.

Cooling challenge

Scott explains: 'The cooling is one of the bigger visual changes on the car, particularly in the sidepods. We did a lot of real-world testing and ended up completely redesigning the sidepods as a result. That has taken a lot of weight out of the car and provided the cooling we need to the intercoolers.

'Running more boost through the engine than it was originally designed to take means you have to work hard to keep it cool.'

Radical squeezed in the largest intercooler it could reasonably fit, fed via a large scoop on the sidepod, the intake of which tapers from the front wheelarch back. 'It was also important to make something that is pretty,' adds Scott. 'You can't understate how much an attractive car is worth to the customer, and it is a case of balancing form with function.'

After working through a variety of duct and louvre designs, Scott is very happy with the cooling performance achieved. 'We have inlet temperatures about 12-15 degrees above ambient, having started off at about 25 degrees with the original sidepod design.'

Despite the pressures due to Covid-19 lockdowns and general global disruption, when the first customer car left the factory, Scott was content it was the complete package. 'It was an interesting development period last year, and we struggled a lot with track testing, obviously, but we got quite fortunate in the end. Where we are based, there are quite a few airfields around so, in that period where everyone who provided testing facilities was shut down, we got on Google maps and found an airfield nearby we could go and test on. That was really important, getting the hours on the engine and validating it.'

Overall, the SR10 is probably the most polished car Radical has released to date and Scott is hopeful it will cement the company's reputation with its ever-growing global customer base.

'We've done more testing on this car than any other Radical, and that's been a big thing for us. Unfortunately, in the past, we maybe had to get cars out quicker than we might have liked, whereas now, we've got the time and resource to fully test everything before it goes out of the door.

'With the initial run of cars, there was very little we had to address. In the first month since the car was released, we sold 30 cars and have delivered 16 to date.'


WAVETRAC®
differentials
Because Smooth is Fast.
Wavetrac®:
A Better Differential.
Better on the road. Smoother on track.
That's why renowned manufacturer Radical Sportscars LTD specify
Wavetrac® in the amazing SR10.
RADICAL
SR10
There are over 100 Wavetrac® applications covering the world's most popular performance vehicles. Contact Wavetrac® today to transform your car.
www.wavetrac.eu
Europe
+44 02380 558636
www.wavetrac.net
USA
+1 949 362 8700

Pressure tests

The third part of the Nissan GT-R LM saga is dedicated to the mechanics who tirelessly built, unbuilt, fixed, coaxed and dragged the car through the 2014 / ’15 test programme

By SIMON MARSHALL

18 December 2014, COTA test. Note the exhaust covers are up and the rear wing end plates are not legal. Our interpretation of the rule as written allowed for bodywork narrower than the flat end plate rule to support the end plate but it was not the same as the FIA’s view. The lightweight doors would need a re-design to pass the crash test

Tim Whitteridge

Things were coming together quite late, many problems hadn't found their solution and many more complexities of working within the LMP-H class were only just starting to become apparent

Simon Marshall

17 November 2014. Car no.1 at All American Racers (AAR) ready for the first test. The programme was about the whole design, build and race team at this point, including AAR and Nismo personnel. It would grow to a cast list of more than 80 by the time of the Le Mans race. Ricardo Divila is standing at the rear next to Justin Gurney

Testing began with the car and crew at the All American Racers (AAR) factory in Santa Ana, California. Things were coming together quite late, many problems hadn't found their solution and many more complexities of working within the LMP-H class were only just starting to become apparent.

Early on in budget negotiations in 2013, Nissan had insisted on three cars at Le Mans. This was to later stress our operation to the max. The car's designer, Ben Bowlby, was in Europe and flew from the FIA in Paris to Cosworth in Northampton, UK in late September 2014. From there he drove to Flybrid in Silverstone and then flew back to AAR in California carrying a new transmission case, cast with rapid prototyped tooling in the USA. Then it was back to Xtrac, near Donington, UK for main-case machining. He waited there for the gearbox to be built, and then travelled back to Cosworth to consider the assembly of engine, gearbox and cooling system on its dyno.

Late October found him flying to Japan to visit Nismo with Motorsport Europe racing director, Darren Cox, and then returning to California, the long way round via Cosworth and Flybrid again. Ben isn't your usual company head. He's very hands on and hard to keep up with at all levels.

Meanwhile, back at the California workshop, the first chassis was being built early in November, initially with an aluminium gearbox case that was quite heavy, though the magnesium version would follow up.

The choice of business partners was obviously not based on geography. Torotrak, Xtrac, Cosworth, TotalSim and Racetech Harnessing were all 10,000 miles and an eight-hour time shift from California. But our group had been designing and making IndyCars, Champ Cars and Sportscars in America with these transatlantic relationships for years. For us, the UK still offered the most accessible supply of high-end racing products suitable for FIA-type racing. If you want to design a NASCAR, not so much.

First test

The first test was originally planned for 23 October 2014, but then pushed back to 6 November. But even before that, in September, concerns were raised by the AAR factory that the bodywork would not be ready in time. The whole body shape was first released at the start of June, but was still being revised after each CFD run until August. The process of making patterns and moulds ahead of the actual bodywork pieces is a gargantuan task and we were trying to make everything inside AAR, although some patterns for tooling were sent out to various machine shops in the LA area.

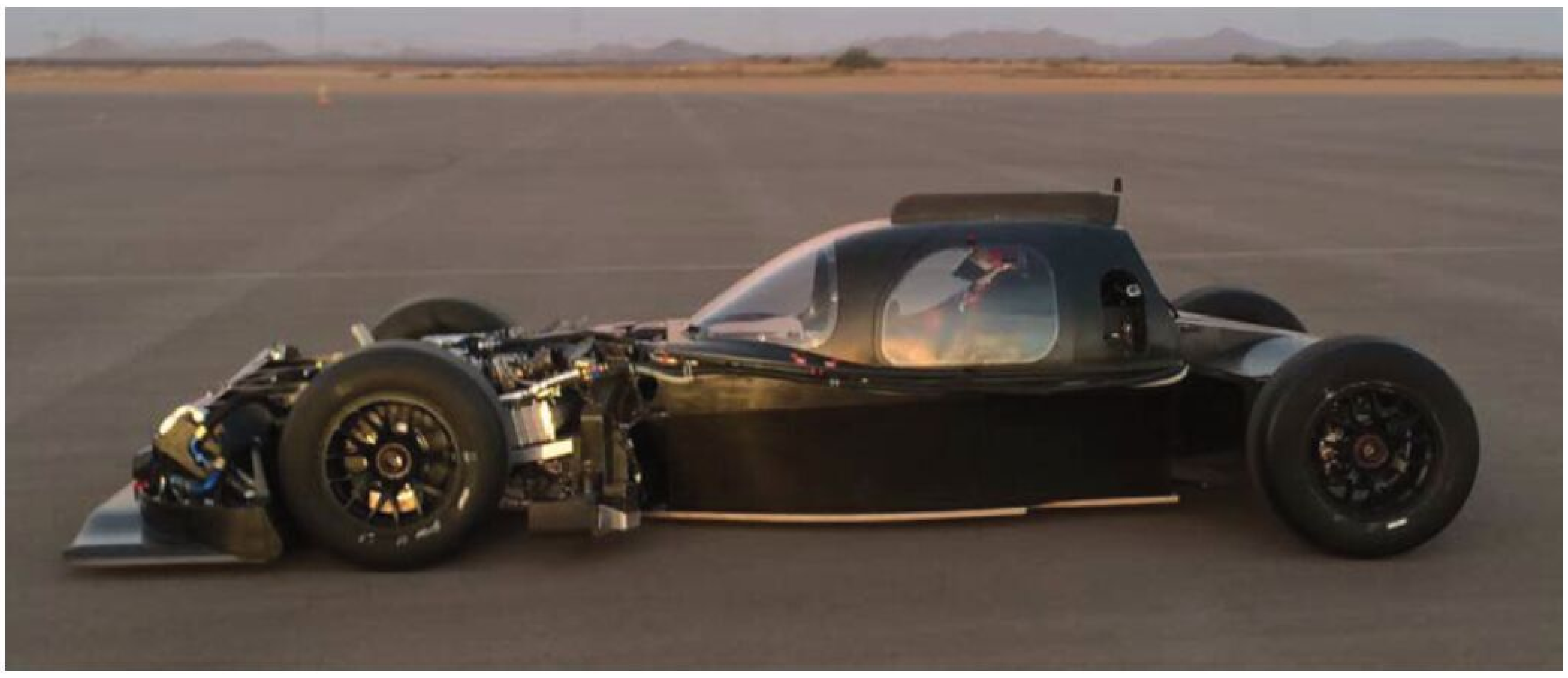
In the end, the first test eventually took place on 20-23 November at the Nissan test track in Stanfield, Arizona.

The test was looking bleak early on, when the gearbox failed with a broken mainshaft.

The whole body shape was first released at the start of June, but was still being revised after each CFD run until August

Racecar Engineering article VN

20 November 2014, first run at the Arizona Testing Centre. Without bodywork fitted, the architecture of the car was plain to see. Speeds were kept below 130mph initially for safety reasons, but a gearbox failure hampered the first test session



Simon Marshall

Note the simple plywood skid in place for those first tests in Arizona, with no underbody or FIA-regulation plank fitted

The shafts were short and thin walled, and so didn't have much capacity for wind up, which isn't at the top of the theoretical performance list, but is still key for toughness and longevity. We had spare internals, but the hole in this sole main case was more worrying. Jerry Brushard, our gearbox mechanic, proposed his tried and tested JB Weld epoxy which, after thorough cleaning, held all the pieces of the gearbox case together for the duration of the test.

Second test

The Energy Recovery System (ERS) arrived at AAR and was fitted in time for the second Arizona test over 7-11 December 2014, but was not functioning in any way. A shaft ran from the ERS forward through the 'v' of the engine into the gearbox, to harvest and deploy forwards. The rear differential, rear halfshafts and outboard step-down gears were fitted, but not the carbon propshaft from the ERS through the cockpit to the rear differential. Indeed, the carbon prop' was *never* fitted to the car. For the record, the rear differential weighed 32lb, the halfshafts and drop gears another 17lb per side.

Test drivers were Michael Krumm and Olivier Pla. Krumm had been in the Nissan camp for some time, and a good buddy of Ricardo Divila. He had recently tested and raced for DeltaWing and the Zeod RC at Le Mans and, along with Ben and Nissan, helped develop the Nissan Bladeglider from the modified Ariel Atom to the car displayed at the 2013 Tokyo Motor Show, and later demonstrated at the 2016 Olympics in Rio by Nissan CEO, Carlos Ghosn.

After these off-the-wall projects, Krumm was quite at home testing new concepts for the Nismo crazy concepts division. Indeed, Krumm's 2013 Nordschleife attack in the GT-R Nismo road car employed a lot more front power bias than you might expect.

Third test

The first magnesium gearbox arrived at Circuit of the Americas (COTA) in Texas prior to the third test on 17-24 December. Since this test was to culminate with a Superbowl commercial shoot, the car was wrapped in red with the Nissan Nismo livery for the first time.

The filming arrangement didn't hold up testing of the car, but did rather hold our feet

Track testing and subsequent full-scale tunnel tests showed a severe sensitivity to low front ride height with maximum rake

to the fire, and forced us to be on track, on time. The track experience was useful for our basic systems shakedowns, and the inevitable down time during filming gave us space to fix problems as they arose.

This was our first time running at night, using rapid prototyped headlight buckets with polycarbonate covers, designed in collaboration with Racetech Harnessing in the UK. In preparation we had cut holes in the bonnet (hood), to the scribe lines transferred from the tooling some weeks earlier.

The test ended with a gearbox failure, which was at the time inevitable, but we were thankful to get some miles in, and to please the hungry Nissan PR machine.

It was in November 2014 that AAR pulled back from the position of race team. The company had done a stellar job with production, and housing the team up to that point, but that meant Ben was compelled to set up a new company – Ben Bowlby Racing – and find new premises back in Indianapolis where the project was first conceived, together with Zack Eakin.

After the COTA test, the team members either returned home to California or the UK or moved to the new base in Indianapolis to see what the new year would bring.

Meanwhile, the cars and parts went from COTA to Indy. They stayed in trailers in the parking lot over the Christmas break and were taken inside in January, only to discover the change in climate during travel and storage had caused corrosion inside the engine water system. This isn't a new problem for teams trailering cars through different climates in the Americas, and the Cosworth doctors simply prescribed a dose of Cosworth coolant additive with corrosion inhibitor and the symptoms abated.

Wind tunnel tests

On 11 January 2015, we conducted our first wind tunnel test at Windshear in North Carolina. It's a well regarded and usually fully booked facility, so only the night shift was available to us now after our prior cancellations. The only car we had was the red wrapped test car from the COTA test. The second was the crash test chassis.

Downforce and drag numbers were very promising, but track testing and subsequent full-scale tunnel tests showed a severe sensitivity to low front ride height with maximum rake, as many have found with Sportscars, but we couldn't shake ours off with these early experiments.

When aggressively raked – which is where most cars' downforce thrives – the car was prone to bounce its front wheels off the belt, which is quite frightening given the cost of repairing the Windshear steel belt!

The CFD had shown that, for the requisite FIA safety reviews, the car was very stable in nose up and sideways attitudes. It was also very dart-like in returning to straight ahead. If the nose should pitch up significantly (*à la* the '90's Mercedes and Porsche at Le Mans) the two through ducts wouldn't allow pressure to build at the front of the underfloor.

We returned to Windshear in March for a second test with countermeasures in mind. We tried a number of additions (square leading edge, raised and lowered leading edges, Gurneys, fences etc.) and trims to the front splitter / diffuser region, but the problem remained.

Fourth test

We analysed slow motion video of the car porpoising at the next tests at COTA in January and February 2014, with low front ride height and high rake under braking.

Unlike other established LMP teams, we had undertaken no long-distance tests at this point. There was a 25-hour test planned for 25 January 2015 at Sebring, but at this point the car was still having trouble running for a one-hour fuel tank stint.

The front wheel engine braking was now more important to us as the ERS wasn't there to help the front brakes. The twist in this tale is that the front aero instability caused high frequency porpoising, in turn causing the front tyres to lock and unlock, effectively stopping and starting the engine four times per second. From the side of the track the car probably looked like it had bad brakes, the driver probably felt the vibration, but the biggest reaction came from the Cosworth data engineers!

It was at this time that the front splitter assembly (top skin, bottom skin and spars, like a wing construction) was failing. We were pulling a lot of negative pressure, and weakness in the bonding was exposed.

Fifth test

Spanish driver Marc Gene was impressed by the magnitude of braking from ERS when things seemed to be coming together at the Sebring test on 25 March, but the response of the flywheel system was quite erratic.

Tim Whitteridge

28 March 2015, in the new workshop of Ben Bowlby Racing in Indianapolis after AAR stepped back from the programme

Functioning hybrid cars and regular racecars should both be able to decelerate at the same rate as the process is ultimately a function of tyre grip, but the GT-R LM, as any race hybrid, had intentionally undersized brakes and the erratic ERS harvest turned the duty back to the brakes, which understandably over heated.

This was a watershed moment, where we knew the ERS would not be ready to test seriously any time soon, ruling out the possibility of ERS at Le Mans.

Through brake duct improvements, brake temperatures had been improved enough to run consecutive laps (!), but still more front brake cooling was needed.

Sixth test

On route from Sebring, we stopped at Palm Beach Raceway in Florida where we deployed the ERS for the first time. The fore / aft propshaft still wasn't fitted, but we were able to deploy to the front wheels. Harvesting was definitely improved, but the energy in the flywheels had decayed (through the wet clutch system) to near zero if unused by 10 seconds after harvest. This circuit, with its long double apex and end-of-straight hairpin, would make the car wait to deploy the ERS, and so we found that at corner exit there wasn't much left of the 30-40,000rpm flywheels by this time (see last article about power and flywheel rpm).

Marc Gene wasn't getting on with the quirks of the front-engine, front-drive nature of the car, and was plagued with the entry understeer vices that lead to bad exits, running off track a few times and damaging

The front aero instability caused high frequency porpoising, in turn causing the front tyres to lock and unlock, effectively stopping and starting the engine four times per second

the splitter. At that point, Gene and Nissan agreed to call it a day and he left.

It was by now apparent that we needed larger front brake discs in lieu of hybrid harvest stopping power, which in turn necessitated larger diameter front wheels. We needed six sets per car for three cars, which meant 36 new rims. This was not a decision made lightly.

The new BBS magnesium front wheels ware cast in Japan, machined in Germany and flown to Indy in a rush.

Front and rear wheels (without tyre) had to weigh a minimum of 7.5kg each. This is quite heavy for a race wheel, but the regs do attempt to add some reliability and safety (and affordability?) to the parts, which are of course then drawn and made in forged magnesium with the 'excess material' centred


Aerodynamic Pressure Scanning rEVOLUTIONised
Integral microprocessors
Direct digital output
Absolute & Differential measurement
High accuracy 8, 16, 64 channels
Smallest and lightest pressure scanners available
EvoScann®
P-Series
Digital Pressure Scanner
www.evoscann.com
36mm
33mm
Depth - 8mm
Weight <15g
EvoScann®
To request an EvoScann® demonstration or quotation call +44 (0)1264 316470 or email enquiries@evolutionmeasurement.com
www.EvoScann.com


MADE TO MEASURE
SUPERIOR QUALITY WHEELS FOR MOTORSPORT
MADE TO WIN
NEW FOR 2021
CR10 FLOW-FORMED (ALLU-LITE)
New, weight-saving wheel available in 15", 16", 17", 18", 19" & 20" and a variety of widths. Matt black or hyper silver. Available in centre lock.
TC5 FLOW-FORMED (ALLU-LITE)
18" x 8.0 / 8.5 / 9.0 / 10.0 / 11.5
Available in centre lock
MILLENNIUM RALLY IN WHITE
In diameters 15", 16", 17", 18" and a variety of widths
GR14 RALLY
In 15" and 16" diameters and a variety of widths. Available in 4, 5 and 6 stud
USE OF MODERN DESIGN AND MANUFACTURING TECHNIQUES RESULTS IN A ROBUST, LIGHTWEIGHT WHEEL
CUTTING EDGE WHEEL TECHNOLOGY
Incorporating the latest technology in FEA and FEM design and modern casting technologies, such as Flow-Forming, all race wheels are manufactured from LM25 (A356.2) primary aluminium alloy, heat treated, 100% pressure tested and undergo X-Ray inspection.
REVOLUTION
COMPETITION WHEELS
EMAIL INFO@RWIL.ORG.UK / TEL +44 (0)1623 860000
WWW.REVOLUTIONWHEELS.COM

on the heavy mounting flanges, with wafer thin rims to minimise rotational inertia.

Remember, the diameter of the rim dictates the maximum brake disc diameter possible. If you're not filling the wheel with brake disc, you shouldn't run such inertially retarded rims. To quote architect, Adolf Loos, 'Ornament is a crime'.

The initial tyre selection was Michelin radials, 16 x 14in wide front and 16 x 9in rear, made from specially constructed tooling. Michelin were good partners on the DeltaWing programme, also making specially sized tyres for us, with construction and compound tuning to optimise the car. Now, with this late tyre change, we were using the same front tyre size as the other LMP1 cars, albeit ours were driving the car as well.

Michelin had made a production plan well in advance of the season and, until now, we weren't accounted for with this tyre size. The tyres we got, all the way up to and including the race, were therefore a year or two old, and may not have been up to the standard of other teams' tyres. They were certainly not developed for this FF use.

Seventh and eighth tests

At the Bowling Green test from 30 March to 3 April, Mark Shulzhitskiy made his debut with the team, replacing Marc Gene.

The Silverstone race on 12 April and Spa on 2 May subsequently came and went. We had intended to be there for both of them, but that boat had long since sailed.

Prior to a return to Bowling Green for testing over 4-6 May, Ben Bowlby noted, 'Logistics is the big challenge now. We're in the final stages of freezing the design spec on what we're going to manufacture and go to Le Mans with. We've got two cars testing next Monday [4 May 2015], and we have to cycle nine drivers through those two cars.'

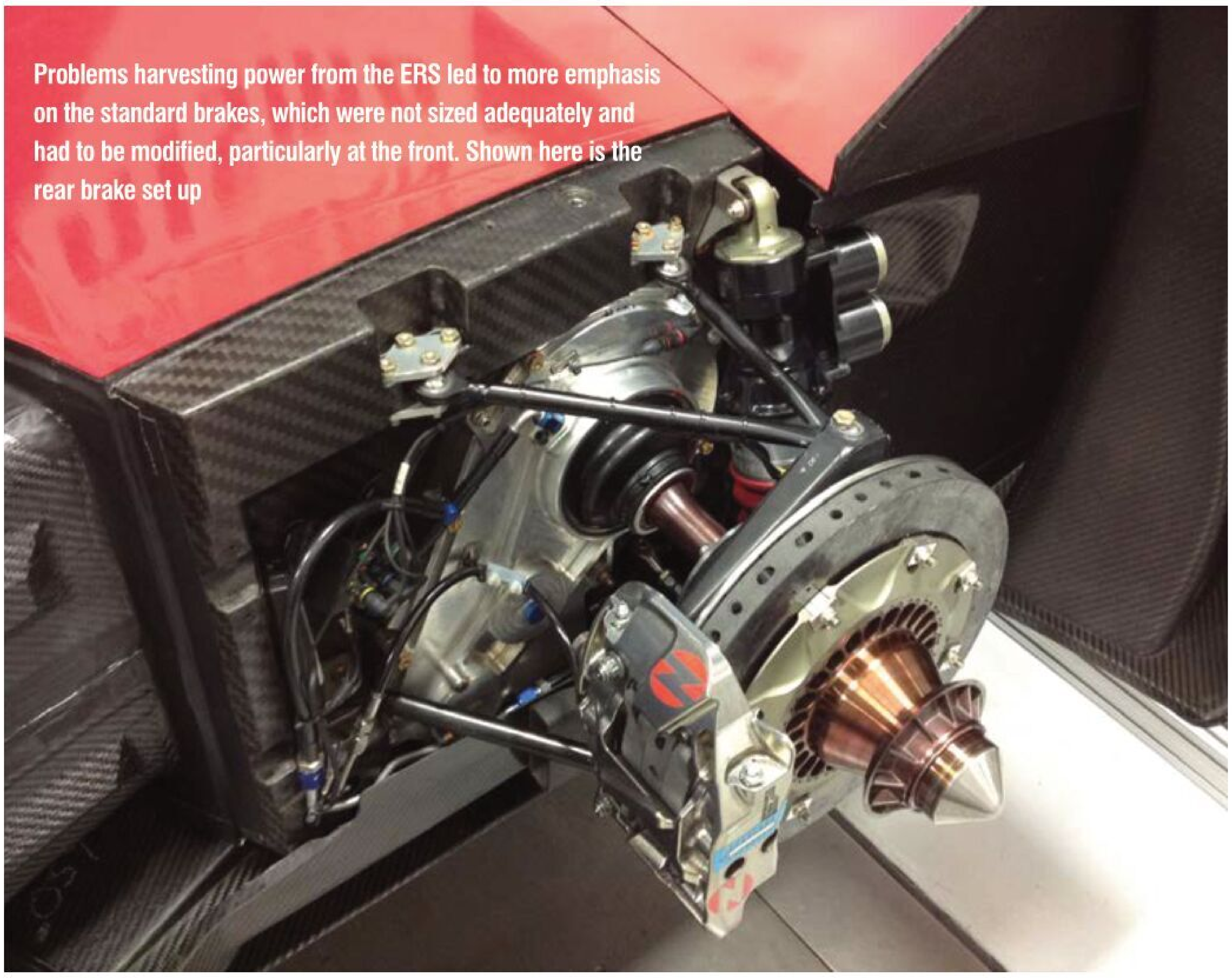
It was a great deal to ask. Could we therefore pull out of the 2015 season to re-group, fix our problems and come back stronger in 2016? These questions are never answered with a 'yes' from the money men. They had made a plan, and we were obliged to execute it, so pushed from the board room we had to march on.

Believe it or not, by this time we had started drawing the 2016 car, although all those doing the drawing had to put on race suits for testing and racing duties also.

As we couldn't persuade any P1 cars to join us at Bowling Green, Nissan paid for the Greaves team to bring its P2 car to set a benchmark time for us to compare against

Ricardo Divila had been the advisor to the Greaves team, and during 2013 Ben had been seconded to Greaves for a P2 aero development programme. This LMP2 benchmark, together with the Corvette GT car on track at the same time, would help us

If you're not filling the wheel with brake disc, you shouldn't run such inertially retarded rims



Problems harvesting power from the ERS led to more emphasis on the standard brakes, which were not sized adequately and had to be modified, particularly at the front. Shown here is the rear brake set up

Driving FF racecars

Michael Krumm explains some of the nuances of driving front-engine, front-wheel drive (FF) racecars in his book, *Driving on the Edge*, Second Edition 2015, Icon Publishing Ltd.

With permission from the author.

Driving an FF car fast is not such an easy thing. If, for example, you are using the traditional driving technique with an FF car, you would end up having heavy understeer most of the time and your lap times wouldn't be that great.

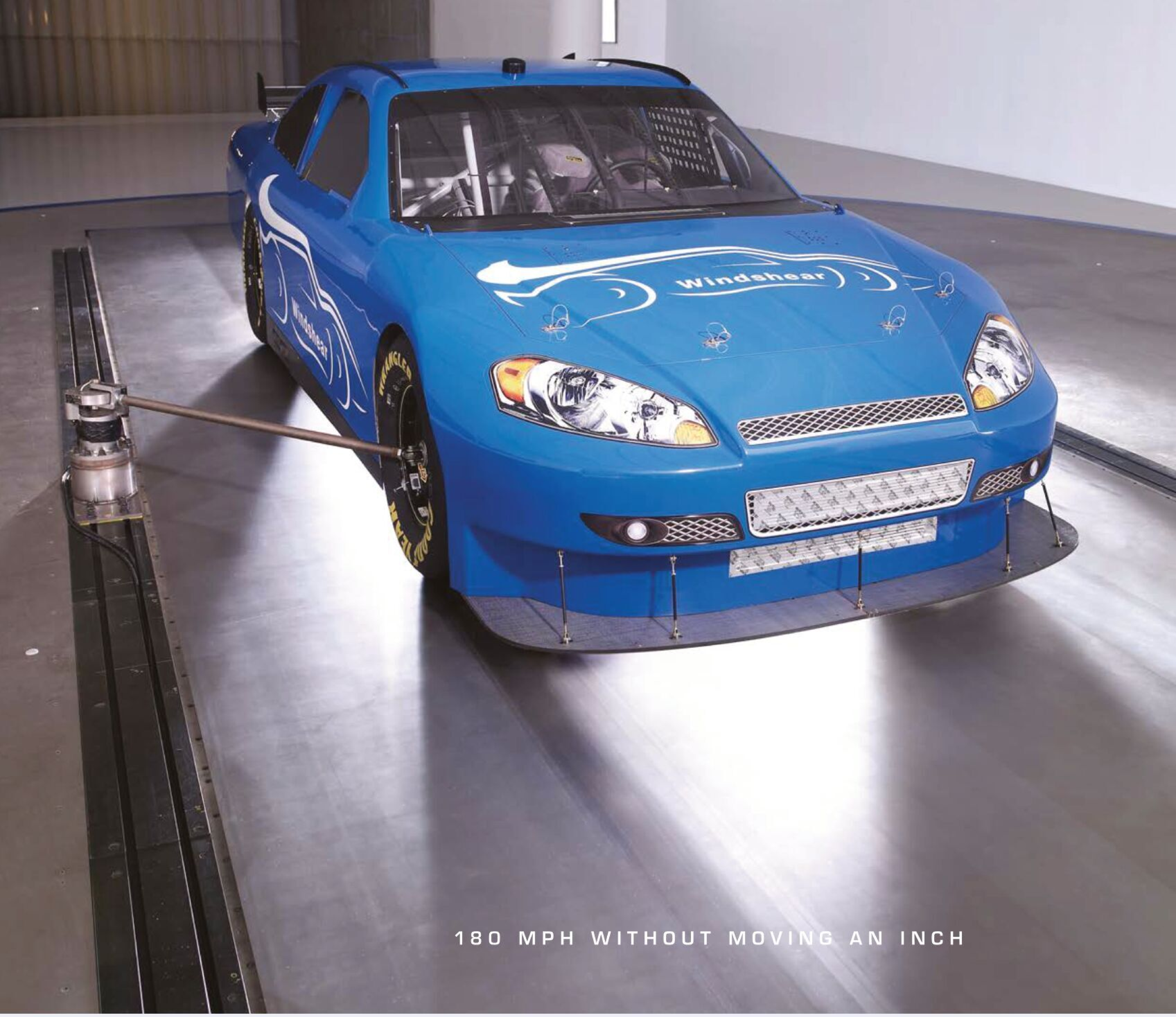
First of all, the lines that you take are almost the same in general. But there is a big difference in how you handle braking, throttle and your steering wheel. If you brake a little bit too late, or you trail brake into a corner with an FF car, then you get usually immediately big understeer, which prevents you from keeping a tight line around the corner. The FF car is heavy at the front and you tend to overload the front tyres easily. But also with the FF car the exit is so important. This is because traction is usually not very good in these cars.

To avoid this understeer and to get a perfect exit, there is a technique to use that only applies for FF cars. The moment when you turn into a corner, you already want to accelerate slightly and with lots of feeling. What happens here is that you avoid the front to be over-loaded. The differential also works differently at this moment and it is quite possible (depending on your car), that you will suddenly have more turn in ability than with no throttle pushed. Now you keep the record line with slowly applying more and more throttle. You must pay attention that under no circumstances you let the front wheels spin. Also important here is to turn the steering wheel as little and as slow as the corner allows you to. The more steering angle you put, the more you are prone to have wheel spin at the exit.

Regain control

Another point to keep in mind in a FF car is when you have sudden oversteer, usually you would have to reduce speed now while counter-steering in order to gain back control. Not in an FF car. Now you put down quickly full throttle. That will pull the car straight again instantly if you have enough power. An FF car with an oversteering balance is always the fastest, as it helps you change the angle of your car quicker.

Another thing to be careful with is braking and shifting down at the same time. It's easy to lock the front wheels and stop the engine if you don't use the heel and toe technique. Apply a lot of throttle while shifting down in order to keep the front wheels moving. Only the moving tyre can absorb enough braking force to slow the car.


180 MPH WITHOUT MOVING AN INCH

validate our in-house lap simulation (written by Chris Patton) and gauge where we would be relative to the P1 cars at LM.

For the Bowling Green tests we had high-grip and low-grip scenarios. The grip would be coming from the tyre modelling and the track surface modelling, but these are very difficult to get right if you've never tested the tyre, or the track.

The Greaves P2 car put in a lap at 52.4s. From the modelling of that car and the track, our sim' put it at 3m38s at Le Mans. In practice, it made third on the grid with 3m39s at Le Mans in 2015, so we were very close.

Chris' 2015 LM simulation of the Audi was 3m23s, which we estimated would be 3m26s with the extra weight required for 2015. The Nismo estimation projected the 2015 Audi at more like 3m20s with its simulations.

Our simulation for the Nissan was 51.0s at Bowling Green, which equated to 3m25s at Le Mans. Our actual Bowling Green figure was 52.6s, which gave 3m29s at Le Mans, without the ERS and with the 2MJ fuel allowance. This was still within reach of the field.

Opinions are like…

This was the first time I had been brought in as the third car race engineer for drivers, Lucas Ordonez, Mark Shulzhitskiy and Tsugio Matsuda. It's complicated to work with multiple drivers as I had three sets of feedback, three sets of complaints and mountains of data I had no time to look at. We were playing catch up. Our drivers were very different in height and bulk and the seat, steering wheel and pedals suited no one, apparently. The other six drivers also had their opinions about the car. It was good to see the team of drivers talking about the job in hand, but none of them were happy. We ran one of the only two cars available, and the 'car no.21 crew' spent much of the test just getting the drivers comfortable in the car and receiving set-up information from the other drivers.

With 65l (48.75kg) in the tank and 1.23l (0.92kg) per lap, we had a 52.8 lap stint here, with a 580bhp maximum. A 1.97-mile lap for 52.8 laps uses 17.17 US gallons, which equates to six mpg US – pretty good for a fast racecar, but not on the charts for a hybrid. We saw a 297km/h (184mph) top speed at Bowling Green with 5800rpm change up, and 6000rpm peak in fifth. With the new, larger front wheel and more brake cooling, this was the first time we were able to run through a tank of fuel without an interruption*, but by now it was May and time was running out. Our fourth instalment will cover the car's only competitive outing, at Le Mans.

** Michael Krumm's left front brake disc explosion was due to heat-related premature wear. With little time before Le Mans, this became our baseline for brake wear calculations*

Bowling Green, Kentucky is home to the Corvette team's test track. Built in 2013, it is modelled after some major features of the Le Mans circuit, including a 1000m straight, Mulsanne corner, Porsche Curves, Tertre Rouge and Playstation Chicane

Tim Whitteridge

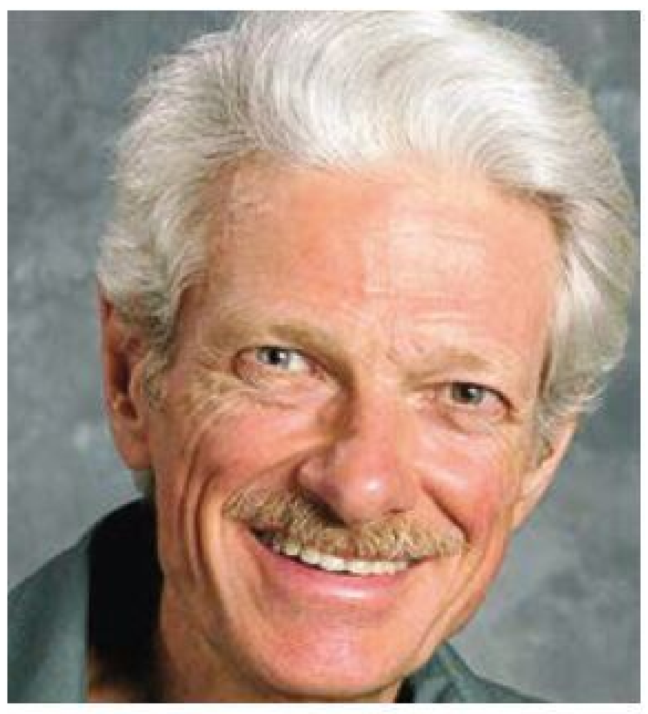
5 May 2015. Inside the circus tent at the Bowling Green, Kentucky tests where we set out to validate our simulation models

Tim Whitteridge

6 May 2015. When the front left brake disc exploded going into the replica Mulsanne Corner with Krumm at the wheel, it tore through the rim (a replacement is fitted in this pic) and the car hit the barrier broadside, folding up the left rear suspension


KRONTEC
HIGH PERFORMANCE COMPONENTS
WEINNOVATEMOTORSPORTINNOVATESUS
AIR JACK SYSTEM
Climate neutral
Product
REFUELING COUPLING
HYDRAULIC SYSTEM
STEERING WHEEL QUICK RELEASE
QUICK DISCONNECT COUPLING
FIRST CHOICE OF TOP-LEVEL MOTORSPORT TEAMS AND RACE SERIES
KRONTEC MASCHINENBAU GMBH
OBERTRAUBLING, DEUTSCHLAND
+49 (0)9401 - 52530
FOR MORE PRODUCT INFO
WWW.KRONTEC.DE
KRONTEC DESIGN LIMITED
SWINDON, ENGLAND
+44 (0) 1793 - 422000


VAC MOTORSPORTS
Mastercam
ARP
CP PISTONS
Drenth motorsport gearboxes
tilton
ARROW
SCHRICK
CAT CAMS
COMETIC
Dailey Engineering
QUAIFE
ATI PERFORMANCE PRODUCTS
850
LIQUI MOLY
BMW VRAKOVIŠTĚ CHOTĚTOV
VAC
Billet Engine Blocks
• High Strength 6061-T6 Aluminium Block
• Extreme Weight Savings over Factory Iron Block
• Can Stand 1500+ Horse Power
• S14 | S38 | M50 | M52 | S50 | S52 | S54 Applications
VAC
Stroker Kits
• Rally | Drag | Hill Climb | Road Racing | Drifting
• S14 | S38 | M50 | M52 | S50 | S52 | S50B30 | S50B32 | S54 | S65 | S85 Applications
VAC tilton
Clutch + Flywheel Kits
• Rally | Race | Carbon Clutches
• Lightweight Flywheel Included !
• Twin + Triple Disc Clutches in 5.5" + 7.25"
QUAIFE
Drenth motorsport gearboxes
Gearboxes + Differentials
• Rally | Drag | Hill Climb | Road Racing | Drifting
• BMW | Ford | Chevy | Honda and more !
• Sequential + H Pattern Applications
CP PISTONS
JE PISTONS
Forged Pistons
• Pistons avaliable from CP + JE
• Parts for VAC Stroker + Turbo Kits
• Perfect for High Performance Applications
VAC
Dailey Engineering
ROOTS STYLE DRY SUMP OIL PUMPS
Billet Dry Sump Kits
• Increased HP + Reliability
• 4-cyl | 6-cyl | V8 | V10 Applications
• Full Kits with Pumps also Available !
VAC
Billet Differential Covers
• Available for E36, E46 M3, E9x, Z4 / Supra
• Increased Oil Capacity and Cooling
• Improved Strength over Factory Cast Cover
www.VACmotorsports.com
@VACMOTORSPORTS
+1 (215) 462 - 4666 sales@vacmotorsports.com



Brace yourself

Improving stiffness of a vintage Stock Car front clip

By MARK ORTIZ

Q I've had this 'problem' on my mind for about a week now and have sent it to several engineering buddies of mine for consideration, but I'd like to know what you think.

This is a deflection mitigation problem. Consider only the 'planar' effects on the two chord members, nothing out of the plane that combines for torsion etc. I will use 'superposition' for other loads and 'out of plane' effects.

First of all, by far the biggest load of all (by a long shot) is acting upwards (plus x) at the end of the coilover shock. The other loads in x, y and z, at or near this, are small in comparison.

When the car is static on the ground, the plus x force is straight up, and is approximately one fourth the weight of the car ie the weight on that wheel. To use nice round numbers, let's say that load is 700lb.

Under maximum nominal load at this point, I can add 400lb to the 700lb, and when you reverse the direction of loading, the load diminishes and approaches zero. I get this from F=kx, and I know the historical travel numbers and spring rates. Hence, consider only the upward load of 1100lb at this point.

Next, note the lower chord member (2 x 2in square tube) is three times stiffer than the upper chord member (1.75in round tube) in 'cantilever bending'. If you consider the combination of square and round tubing as a composite beam, the weaker round member is in compression during maximum nominal loading.

You also have to be aware of local deflections at the point of application and the flexure of the mandrel bent tube bend. What do you think?

Combining a production car-style ladder frame with a tubular 'cage structure will *always* be a compromise

THE CONSULTANT

A First of all, the word 'chord' normally refers to a horizontal element of a truss, but what you have really isn't a truss, it's more a hodge podge of tubes, mostly loaded in bending. The design isn't something an engineer would come up with from a clean sheet of paper. Its origins are historic, and illustrate the perils of incremental design thinking. In other words, it was originally a production car ladder frame, and then some 'cage structure was added for crash protection.

If I remember correctly, the rules (at least in some sanctioning bodies) called for the main tubes to be continuous, like the main hoop of the cockpit 'cage, and that's why they have a bend. The design originally had a big spring acting on the lower rail, and a shock inside that, both having a motion ratio to the wheel of around 0.50. The lower rail was built to take the loads all by itself. After the 'cage structure was added, somebody realised you could improve the action of the shock by using a longer one, moving it outboard of the spring and mounting it to the 'cage structure instead. The shock then has a motion ratio around .70.

After that, somebody else realised you could eliminate the big spring entirely and just use a coilover. The result is the support force now goes into a part of the structure not originally designed for that purpose. However, cars run this way successfully because the whole thing is built fairly beefy.

If a scale under the wheel reads 700lb, the sprung weight is more like 600lb. The static axial force on the coilover is that divided by the 0.70 motion ratio, or about 840lb. There is a 240lb downward force at the inboard pivots of the lower control arm. So, you have the 600lb net support force, and you have 1,080lb trying to spread the lower and upper rails apart.

I'm wondering, what are you trying to do here? If you just want something that runs as well as similar cars, you can get that by just building it like similar cars. Most of those I've seen use 3 x 2in lower rails rather than 2 x 2in but, other than that, yours looks pretty conventional.

The front clip design of most Stock Cars is pretty miserable for structural efficiency, but cars can run that way. A better solution would be to engineer a proper spaceframe to go inside the Fairlane body, with good triangulation and loads applied at tube junctions. It wouldn't have the vintage look but it comes down to what your design objectives are.

You don't need to calculate deflections accurately. You know less deflection is better, and you have other design objectives and constraints you have to balance against that.

Its origins… illustrate the perils of incremental design thinking

They landed men on the moon before FEA, right?

The idea here is to build a 1968-style Stock Car using gut instinct, not modern analyis and simulation tools

Q ***contd.*** **True, what's there now is not a proper truss, but one can resolve the loads in any spaceframe, or spaceframe sub-element, using truss-style analysis from statics. By considering this a truss element, one can [analytically] try differing braces between the two 'chord' elements. Basically, what I'm after is the best way to 'lattice' between the upper and lower elements for maximum strength and minimum deflection.**

Rather than mindlessly copy an existing design, I am trying to 'parameterise' the design with respect to strength and stiffness. Yes, I'm trying to learn, but also to think. I want to make a thoughtful car.

I tried several bracing concepts in cardboard, looking for a treatment that mitigates the problems with the atrocious point load at the top of the coilover (the mandrel bend in the member is a deflection masterpiece).

As a wise man once said, 'The load goes where the stiffness is, the deflections go where the stiffness ain't.' I know, I know, an FEA would tell us the answer, and I've used that approach before in my professional career, but the secret to short fuse development is to get it as right as possible *before* the FEA. After all, they landed men on the moon before FEA, right?

In response to your question why, or at least what? I'm building this car like it was 1968, going with gut feeling and crude calculations. I guess I'm asking what does your gut say?

To put that into context, I ran asphalt short track for five years, and you sort of develop a sense of 'problem points' in a chassis by observing the bends, buckles and paint cracking. So come on Mark, let your hair down, pretend it's 1968, and you're on the development team!

THE CONSULTANT

A *contd.* Okay, I get you. Here goes… First off, not everything is in place in the pictures, so I can't tell what all the packaging constraints are going to be but, based on what I can see, I think I'd try running a tube roughly vertically from the inboard side of the coilover mount down behind the upper control arm mounting plate, tying into the crossmember. I'd add another tube from that point behind the upper control arm plate diagonally up and back to the bent top tube, meeting that where it meets the cross tube at the cowl, or as close as possible. I'd then combine this with a removable transverse K brace, horizontally connecting the coilover pick-up points and triangulating the top of the engine bay. In the process, I'd try to come up with a neat bracket combining the coilover mount, down tube attachment and the K member mounting.

It would also be nice to triangulate, or brace, the front face of the resulting 'tubular box' – the one in the yz plane per SAE and ISO axis conventions. This is where the front face of the engine block is, and the mountings and drives for the alternator, power steering pump and water pump. It is desirable to come up with a motor plate, or a weldment, that mounts all these components, ties the lower crossmember and the coilover mounts together, mounts the front of the engine to the frame and also doesn't block too much of the air exiting the radiator.

The load goes where the stiffness is, the deflections go where the stiffness ain't

CONTACT

Mark Ortiz Automotive is a chassis consultancy service primarily serving oval track and road racers. Here Mark answers your chassis set-up and handling queries. If you have a question for him, please don't hesitate to get in touch:

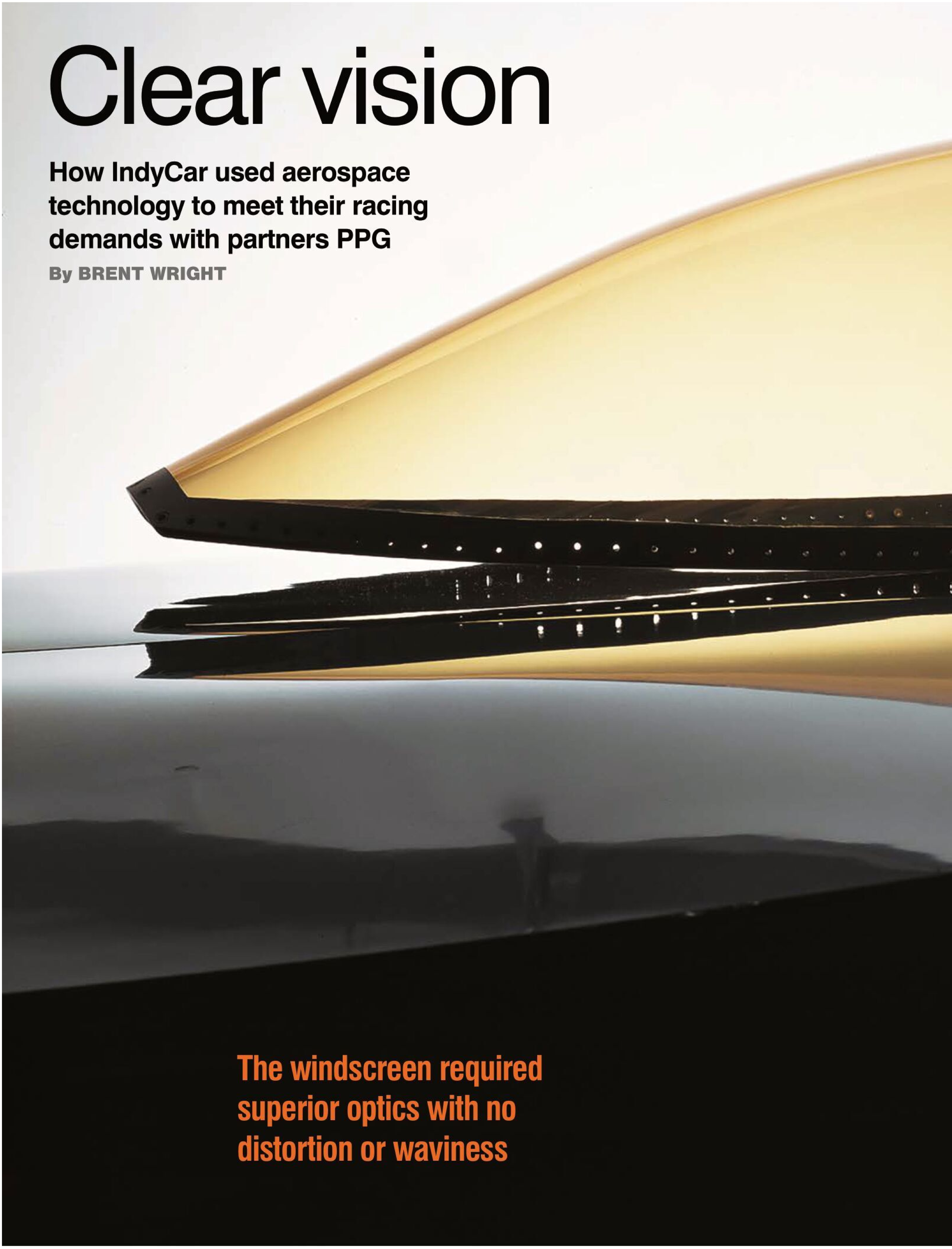
E: markortizauto@windstream.net
T: +1 704-933-8876
A: Mark Ortiz, 155 Wankel Drive, Kannapolis NC 28083-8200, USA


The cardboard represents the questioner's bracing concepts, none of which align with those of The Consultant, who recommends a tubular box structure and motor plate

Clear vision

How IndyCar used aerospace technology to meet their racing demands with partners PPG

By BRENT WRIGHT



The windscreen required superior optics with no distortion or waviness

PPG's polycarbonate technology is already well proven in the realm of jet fighter aircraft, where strength, visibility and impact resistance are all critical design briefs

With the debut of the NTT IndyCar series Aeroscreen in 2020, fighter jet pilots and racecar drivers have more in common than simply the need for speed. PPG impact-resistant transparencies now protect both from being struck by flying objects. Designed by Red Bull Advanced Technologies, the Aeroscreen consists of a PPG laminated polycarbonate windscreen attached to a titanium frame, all designed to reduce the risk of driver injury from flying debris.

The timeframe for producing the parts was tight. Overcoming the numerous design and production challenges inherent in such a uniquely shaped and advanced product, PPG delivered its first windscreen within eight months of engaging with IndyCar and Red Bull and supplied enough windscreens for the 2020 race series two months later.

The windscreen made its official debut at the Genesys 300 in June 2020 at Texas Motor Speedway and performed as designed throughout the season.

It had to withstand debris flying at velocities exceeding 220mph

PPG's involvement with IndyCar started when an executive was listening to a radio show on racecar driver protection. It was remarked that racecars needed something like a fighter jet canopy to protect drivers, and an idea was ignited. PPG is the world's leading producer of canopies and transparencies for military and commercial aircraft, and it was apparent the same design principles that protect air crews could protect racecar drivers.

Following that radio show in 2015, PPG reached out to IndyCar, and the two organisations began laying the foundation for an impact-resistant windscreen using the same advanced polycarbonate lamination technology as on fighter jets. In 2019, when IndyCar selected Red Bull Advanced Technologies to design the entire Aeroscreen assembly, PPG was ready. The windscreen's performance objectives were clear from the very beginning. Foremost, it had to withstand debris flying at velocities exceeding 220mph. Protecting against an airborne 22lb (approx. 10kg) tyre and wheel assembly would be difficult on a practical level, but handling lighter, more common track debris was not.

The windscreen required superior optics with no distortion or waviness, which was challenging on such a highly contoured shape. The design also had

Aerospace canopies must be capable of withstanding a 4lb (1.8kg) bird strike at speeds in excess of 380mph. The Aeroscreen windcreen passed similar tests up to 234mph, and only failed the 332mph test, which is around 100mph faster than the maximum speed of contemporary IndyCars

A direct technology transfer from the company's production of aerospace cockpit windows

to accommodate exterior tear-offs that could be removed during pit stops if dirty, as well as technology to prevent fog or condensation from forming on the windscreen's interior surface during a race.

Adding to the project's complexity was the need to rapidly design, manufacture and test the windscreen so it could be used throughout the entire 2020 IndyCar season, which was scheduled to begin on 15 March 2001. As things transpired, the season's start was later pushed back to June because of the pandemic.

Aerospace technology

From its earlier design and testing work with IndyCar, and its wealth of experience in the aerospace industry, PPG knew the windscreen would require a laminated construction. Its forming, laminating and machining could be a direct technology transfer from the company's production of aerospace cockpit windows and other transparencies.

Weighing a maximum of 18lb (8.16kg), the u-shaped windscreen is a single-piece design that measures 50in (127cm) long, 25in (63.5cm) wide, 12in (30.5cm) high and 3/8in (0.95cm) thick, without the tear-offs. Two layers of aircraft-grade, impact-resistant polycarbonate are

The single-piece windscreen is of triple layer construction, with two plies of polyurethane sandwiched between two layers of impact-resistant polycarbonate. Maximum weight is 18lb

joined with two interlayer plies made of a proprietary PPG polyurethane. The two polycarbonate layers are approximately 0.160in (0.4cm) thick, while the interlayer plies are a combined 0.050in (0.13cm) thick.

Aircon system

To prevent fog and condensation build up, PPG adapted its Aircon anti-ice system for aircraft to the windscreen's shape and the racecar's available voltage. This filament wire heating system is designed to accommodate low-voltage electrical power sources, including those on small to mid-sized commercial aircraft. On an IndyCar, the system heats 650in^2 (4194cm^2) of the 980in^2 (6323cm^2) windscreen.

PPG uses specially designed automated equipment to sew the anti-ice system into one of the interlayer plies. Busbars, which connect electrical power to the filament wires, are placed within the shadow of flanges at the bottom and an upper blackout area where teams apply graphics. This offers a clean overall optical aesthetic, with the PPG Aircon filament wires running through the windscreen nearly invisible to the human eye.

Because polycarbonate has an inherent vulnerability to scratching and chemical attacks, PPG coated the windscreen's interior and exterior surfaces with one of its abrasion-resistant coatings. The tear-offs are supplied by Racing Optics in pre-laminated stacks of four layers at 4mm thickness. The race teams apply a single base layer to the windscreen's outer surface and then two to three stacks of tear-offs, giving them a total of eight to 12 to use during a race.

Besides its radical contour shape, the windscreen veered from typical aerospace construction in its two different attachment methods – one to the racecar at the bottom and the other to Pankl's titanium, halo-shaped frame at the top.

This required PPG to create a custom construction process and fixturing to hold all the components in place during final assembly, and also ensure interchangeability across the IndyCar fleet. In addition, the project required new capabilities to drill holes through the sensitive polycarbonate transparency without causing stresses that could lead to cracks.

At the bottom, the windscreen is sandwiched in a flange joint made of Kevlar and glass fibres, adhered with a proprietary PPG polysulfide sealant. The flange sections are attached to the car's chassis structure using 25 fasteners and washers to distribute forces along the flange surface in the event of an impact. 20 bolts then fasten the top of the windscreen to the halo frame, with counterbore bushings in the windscreen ensuring the fastener heads are flush to the outer surface in the airstream. The bushings are installed using a PPG aerospace sealant.

The PPG Aircon filament wires running through the windscreen [are] nearly invisible to the human eye

Track validation

On a rainy day in February 2020, the PPG windscreen and Aeroscreen assembly was put to the test. an IndyCar outfitted with the new safety innovation hit the track at Circuit of the Americas in Austin, Texas. Despite weather-limited track time, the testing validated both the Aeroscreen and PPG transparency for track action, meaning the device was good to go for the 2020 season.

With the first race pushed back to June due to the pandemic, IndyCar took the opportunity for additional off-track testing. PPG had already conducted impact testing in its earlier work and proved the viability of the polycarbonate-laminate construction, but the company now focussed its testing specifically on the final windscreen design.

Spencer Pigot's car after crashing into the pit wall at the Indianapolis 500. The windscreen took a significant impact and damage was limited to minor cracking at an upper bolt hole

At the company's Huntsville, Alabama aerospace facility, a 4lb (1.8kg) gel pack was shot at the PPG windscreen at increasing speeds. The testing mirrored that for aerospace cockpit windows, which must withstand a strike by a 4lb 'bird' at speeds – often 380mph or more – in line with a given aircraft's operating envelope where birds can be encountered.

Impact testing

The PPG windscreen was tested at projectile speeds of 167, 203, and 234mph, significantly in excess of the 240mph top speeds contemporary IndyCars can reach at Indianapolis Motor Speedway (the fastest race in series history had an average car speed of 207mph). IndyCar also tested the screen at 332mph.

A testing failure was declared when the gel pack broke both the windscreen's polycarbonate plies. PPG test windscreens passed eight shots at speeds up to 234mph, but failed all three shots at 332mph. The upper impact limit for the windscreen therefore lies somewhere between these two speeds, comfortably faster than the 167mph target speed that was originally set by the IndyCar's technical team.

The impact testing further validated the suitability of the PPG windscreen design, with no modifications required.

The Aeroscreen debuted at the first race of the 2020 NTT IndyCar series at Texas Motor Speedway in June. Three of the 18 racecars, including that of winner, Scott Dixon, featured a PPG windscreen, either with or without the PPG Aircon system.

The Aeroscreen was used throughout the entire 2020 season and for 2021 all competitors will have the PPG screen fitted to their cars. Drivers reported no optical or impact issues with the windscreen, but did provide feedback on elevated cockpit temperatures and significant noise reduction with the addition of the Aeroscreen. No driver had to run the PPG Aircon system during the season to clear fog or condensation.

In July 2020 at the Iowa Speedway, the Aeroscreen experienced its first real-world test when Colton Herta's no.88 car went airborne over the no.21 car driven by rookie, Rinus VeeKay, striking VeeKay's windscreen and titanium halo frame. The Aeroscreen blocked parts of Herta's car from entering the no.21 car's cockpit and striking VeeKay. Driver, Marcus Ericsson, who was behind the two cars was also spared injury from the crash's flying debris because of the Aeroscreen. Other than a minor mark, VeeKay's windscreen was undamaged.

A second test came at the Indy 500 one month later, when Spencer Pigot's car crashed into the wall and pit road barrier. Pigot was uninjured, and a PPG evaluation of his windscreen showed only minor cracking at an upper bolt hole.

Protecting role

Speaking to *Autosport* magazine after the crash, Pigot said, 'I think that definitely I had a lot more protection than I would have had in that accident a year ago. I've not seen pictures of the car itself to see how marked up the Aeroscreen was, but I'm sure it played a role in helping protect me. If we'd had just a halo, I think stuff could have gotten in there.'

PPG is now working with IndyCar to address ways to keep the drivers cool

From concept to finished product in just eight months

Takuma Sato on his way to victory at the 2020 Indy 500, the first to be run with the Aeroscreen in place

Drivers reported no optical or impact issues with the windscreen, but did provide feedback on elevated cockpit temperatures and significant noise reduction

since the Aeroscreen blocks fresh air from blowing into the cockpit. No other modifications are being explored for the PPG windscreen, which will remain in use for the 2021 IndyCar season.

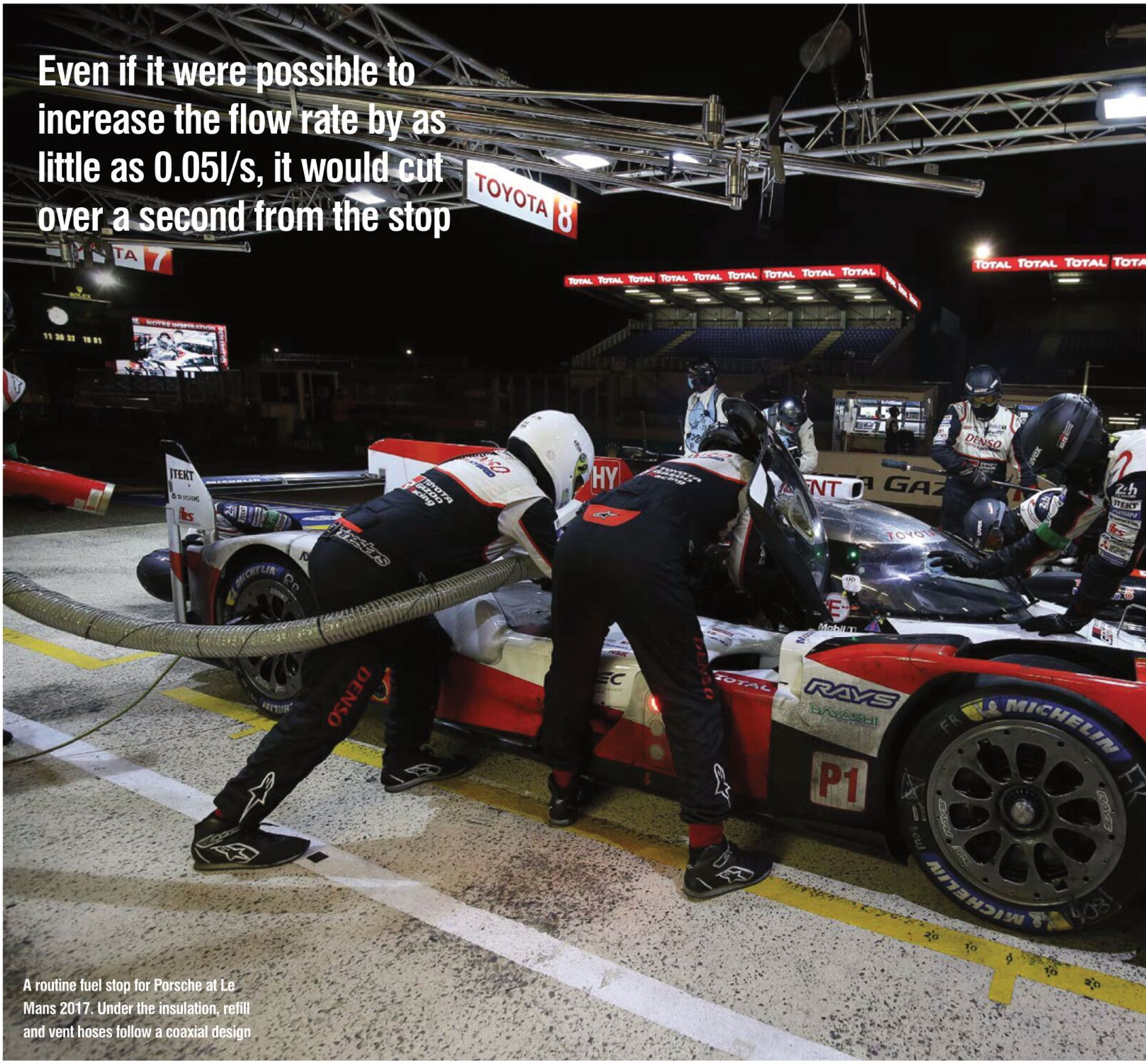
The winner's circle

In August 2020, a PPG team comprising Mike Briggs, Naomi Cassese, Casey McCarthy, Parker Smith, Colin Trinh, William Wittenberg and Brent Wright received the 54th annual Louis Schwitzer Award for contributions to the Aeroscreen's development. The PPG team was joined in the honour by Red Bull Advanced Technologies, IndyCar, Dallara, Pankl Racing Systems, Aerodine Composites and Isoclima.

The annual award is sponsored by BorgWarner and the Indiana section of the Society of Automotive Engineers (SAE) International and recognises engineers who innovate new concepts to improve competitive potential, with a focus on new technology for engine, powertrain, profile, chassis or safety. The technology also must adhere to the NTT IndyCar series specifications.

For PPG, the award was the culmination of a project that saw the company go from concept to finished product in just eight months. To put that into context, a similar aerospace transparency project would be considered accelerated if completed in 18 months.

In the process, the company broke new ground in creating a uniquely shaped windscreen, as well as the processes and tools required to manufacture and assemble it. These breakthroughs could influence the shape of tomorrow's military and commercial aircraft. The greatest achievement for PPG, however, was knowing its people and products help protect the lives of all the present and future drivers in IndyCar.



Even if it were possible to increase the flow rate by as little as 0.05l/s, it would cut over a second from the stop

A routine fuel stop for Porsche at Le Mans 2017. Under the insulation, refill and vent hoses follow a coaxial design

XPB

Go with the flow

Investigating the science and development process behind racecar refuelling

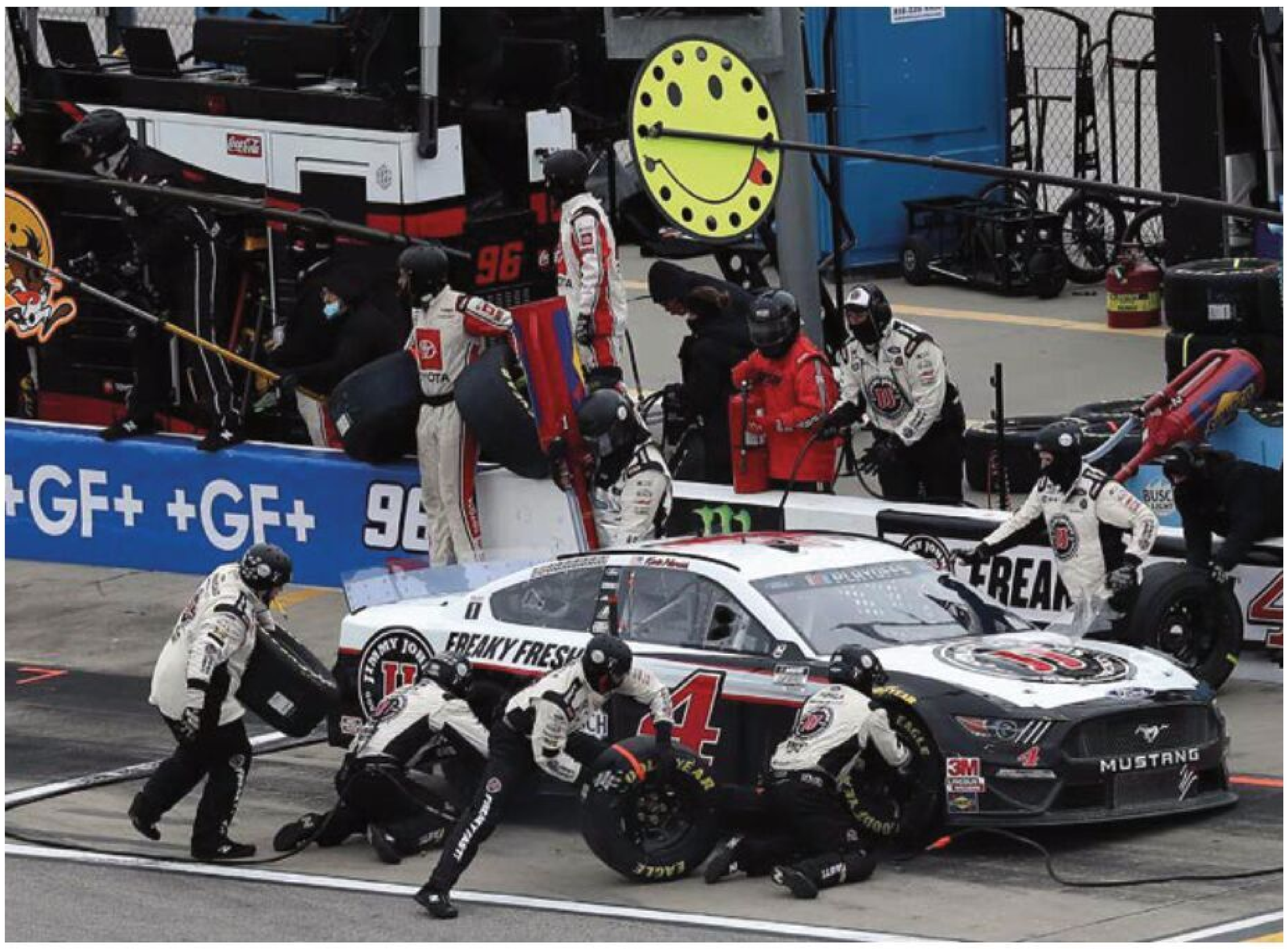
By JAHEE CAMPBELL-BRENNAN

Refuelling our cars is something most of us do as we go about our days and weeks without giving it much thought. Tank hits empty, we add fuel. Simple as that.

True to form though, by adding an element of time pressure, motorsport takes what are seen as inert tasks and adds some flair and science to them.

The fundamentals don't change – you add fuel while evacuating air from the tank. In principle, this is not dangerous, but trying to achieve that process as quickly as possible takes us into risky territory.

As time spent in the pits equals time lost on track, there's a clear motivation to deliver the required fuel as rapidly as possible, a motivation which has



Andrew Roberts

A modern day NASCAR pit stop. The refuelling operators have to physically manouevre 50kg dump cans

XPB

Refuelling can sometimes go very wrong, as happened at Monza in 2007 with the Luc Alphand Corvette team

resulted in some famous refuelling accidents involving technician or driver error and equipment malfunction.

In efforts to improve the safety of motorsport, regulations have been updated and adjusted over the years in various ways. Refuelling is no different.

Significant investment

Using Formula 1 as an example, in-race refuelling has featured in the championship on and off many times over the last decades, before most recently being abolished in 2010 for both financial and safety reasons. Up to that point, it was an area of significant investment, culminating in a six-person operation using equipment adapted from the aerospace industry.

Being aircraft technology adapted for motorsport, the refuelling equipment was designed to a different set of engineering requirements, and featured a long stroke to reach full engagement. 'This could cause issues as, during disconnection, it was susceptible to jamming, with the probe not fully disconnecting from the car side receptacle,' comments Matt Hawkins, motorsport specialist in the connectors division at Stäubli. 'There were some incidents where the lollypop man set the driver off whilst the equipment was still coupled.

'Some of the earlier refuelling systems also suffered from deterioration of the seals due to the bio-ethanol content of the fuel, which would dry out the rubber and potentially make disconnection a little more difficult.'

Back then, fuel was pumped to the cars under pressures of up to 12 litres per second in order to deliver the required quantities in a short period of time. If the coupling, or uncoupling, isn't made cleanly with such high flow rates, a lot of fuel can be spilled in a very short period of time. And when those fuel vapours encounter hot engine and exhaust components, as Jos Verstappen and his crew found in 1994 at Hockenheim, fire spreads quickly.

There were some equally scary events in IndyCar up until the mid 2000s when the series used 100 per cent methanol, which burns with no particulate emissions (soot) to glow yellow and at cooler temperature than petrol. Add in sunlight, or bright days, and the flames are largely invisible.

Fast forward to today, and we have a near global adoption of very tight refuelling regulations to prevent corners being cut and even out the playing field.

Coupling configurations, fuel supply techniques, storage / transport equipment and refuelling conditions are all highly controlled by the FIA / ACO, IndyCar, NASCAR and IMSA, with all equipment subject to tight scrutineering.

In WEC, for example, minimum refuelling times are mandated and strictly monitored. In many cases, the pit crew isn't even allowed to touch the car, which must have the engine switched off, until refuelling is completed.

Racing advantage?

So, if everyone is using spec equipment, and working to standardised conditions, there's no advantage to be gained in the refuelling process any more, right? Wrong.

The process can essentially be broken down into the following five phases: 1, hustle refuelling equipment to the car; 2, coupling of male refuelling probe to female tank socket; 3, fuel transfer into vehicle; 4, disconnection of coupling; 5, technician and equipment moving clear of the car.

Each of those phases offer opportunities to optimise a refuelling stop, but also the potential to introduce risk and expense.

Almost universally, fuel is supplied to the car from a pit-located supply tank via a hose. Unless you're competing in NASCAR, you don't have a fueller running around with 50kg+ of fuel on their back!

With modern regulations banning pressurised fuel delivery, fuel relies on gravity to drive the flow. The pit supply tank is located a strict 2m above the track surface and limited to ensure the effects of gravity cannot be used to increase the flow rate by introducing a pressure head. This is something that has been adopted by the vast majority of professional motorsport disciplines.

Couplings are universally dry break, which ensures fuel physically cannot flow unless the refuelling probe is fully inserted into the socket of the car's fuel tank.

Despite their apparent simplicity, the couplings are intricate pieces of engineering designed to ensure both safety and ease of operation by the technicians.

'The refuelling head is operated by two pivoted, lever handles that are also the carry points as the pit crew member approaches the vehicle,' explains Anthony Bird, motorsport accounts manager at Stäubli. 'The internal valving design ensures a smooth transition to the vehicle's tank plug during connection and disconnection. There are safety lock pins in the refuelling head, which only unlock the levers once the probe is coupled squarely with the socket. As the levers are pushed home, locking

Stäubli

Stäubli SAF 45 refuelling connectors are widely used in motorsport today

With modern regulations banning pressurised fuel delivery, fuel relies on gravity to drive the flow

claws engage to ensure the force required to maintain the connection is manageable and consistent throughout the fill.'

To ensure safety, the lever handles spring closed if they are released, ensuring any fuel flow is always intentional. They also earth the car to minimise the possibility of arcing and ignition of fuel vapour.

On the vehicle side, a spring-loaded plug is fitted to the entrance of the tank socket so the tank automatically seals as the refuelling probe is removed, and to ensure no fuel is spilled in the event of an accident.

Dead man's switch

Before any fuel can flow from the supply tank into the car, though, a manual 'dead man's switch' must be operated by a second member of the pit team. This is a spring-loaded ball valve located at the outlet of the pit supply tank. It's a 'fail closed' concept so, if a refuelling accident were to happen, or the driver leave the pit box with the hose attached, the technician releases the switch to stop flow out of the tank.

Once the pit crew have made the coupling and opened the dead man's switch, the fuel flows through flexible, insulated hoses. The maximum diameter is carefully regulated and ranges from 1.5in in FIA series to 3in in IndyCar. This controls flow rate and restricts the quantity of fuel in the hoses during the refuelling process.

Of course, a vent must also be provided for the gas being displaced by the incoming fuel. As this gas contains flammable vapours, it must be considered more carefully than simply a vent to atmosphere. Modern motorsport refuelling devices use a closed loop system in which the exhausted gas travels back into the pit supply tank through separate hoses of the same diameter, on the same axis, ensuring vapours have no exposure to sources of ignition.

'Coaxial design hoses feature two circular valving assemblies inside of each other, so the fill and vent hoses that are attached to the back of the refuelling head also run coaxially with the fuel delivery line inside the larger diameter vent line,' explains Bird.

If you're quick, you might then figure out that fuel delivery with this closed loop approach could potentially be 'assisted' by introducing negative pressure along the vent circuit in some way, pulling the fuel through to increase flow rate. Unfortunately, the regulators had that one covered early on.

The longest phase in the refuelling process by far is the transfer of fuel into the car, so it's also the phase that offers the largest scope for time saving.

Every second counts

'Today in WEC, a 100 litre fuel tank can take just over 45 seconds to fill up,' notes Giles Dawson, managing director at Aero Tec Laboratories (ATL). 'That's a flow rate of just over 2.2l/s. Compare this to a few years ago when regulations allowed pressurised fuel delivery, you could fill a 65l tank in around 3.5s, which equates to an 18.5l/s flow rate through what was then a 2in diameter hose.'

Forty five seconds is a long time to be sitting still during a race. Even if it were possible to increase the flow rate by as little as 0.05l/s, it would cut over a second from the stop. That might not sound like much, but over a 24-hour race where more than

25 refuelling stops might be made, that's a huge advantage. Enough to motivate some ingenious techniques to gain an advantage.

As regulations dictate, orifice plate-type restrictors are mandated at the exit of the pit supply tank to control the flow rate into the hoses. The idea is to limit the flow leaving the tank to make any downstream advantages impossible. The exact diameter of the restrictor is modified on a car-by-car basis to contribute towards BoP, but for the most part is around 30mm.

'Fuel rigs are scrutinised and passed or failed by running a calibrated ball through the restrictor opening. If the ball matched the orifice size in the restrictor, it passed, but this ultimately opened the door to exploration of what could be done to optimise flow through it without interfering with that opening,' explains Dawson.

In 2018, G-Drive Racing found itself disqualified for not complying with regulations after the ACO found it was using a bellmouth opening to the restrictor plate, causing the fuel flow through the orifice in a more laminar fashion, giving enough advantage to cut seconds from the team's refuelling stops. As it turned out, this contravention of the spirit of the regulations was especially unfortunate as the team won the LMP2 category with a greater margin than the modification of the restrictor opening afforded.

As the ACO added layers of regulation to refuelling practices, so it added technology to the supply tanks, monitoring how fuel was being transferred by teams with a fuel level sensor. The supply tank-mounted sensor produced data that allowed it to determine when refuelling began, ended and whether the process met minimum refuelling times.

In the same year, Dempsey-Proton Racing had all its championship points for that WEC season invalidated after it was discovered the team manipulated the code in its data logger to falsely record an additional two seconds refuelling time.

With such extreme penalties for looking outside of the rulebook, what space do teams have to innovate?

Cool runnings

Let's look a little further back to Group C Sportscar and F1 racing in the 1980s, when teams used to cool the fuel to -30degC in order to increase its density before refuelling. Compared to fuel at an ambient temperature of, say, 20degC, this allowed teams to fit around six per cent more fuel in due to it to occupying a smaller volume in the absence of heat. Or to deliver a specified mass of fuel at a given flow rate in a shorter time period.

With tank sizes of 195 litres, that meant a potential extra 11 litres in the tank, provided they could use it before it heated up again.

Breda

Today, computer-controlled bowsers can automatically transfer fuel from the storage barrels in the pits to the car's fuel tank

Cold fuel also has an added advantage in terms of engine performance, especially when combined with a higher boost pressure, as a colder, more dense intake charges allows an engine to produce more power.

Nowadays, fuel temperature is mandated at no less than 10degC lower than ambient. Breaking this rule will result in a penalty, but that doesn't stop teams from capitalising on the advantage offered by chilling fuel before delivering it to the insulated pit supply tank.

'We use traditional vapour compression systems, together with a petrol heat exchanger in our equipment to control fuel temperature,' comments Giorgio Breda, managing director and chief of electronics and software at Breda Racing. 'We have to have precise control to avoid any regulation infringements, so closed-loop software control is a requirement, too.'

Fuel quantities are always measured by weight rather than volume in motorsport, which is an important distinction. As weight is calculated via the acceleration experienced by the mass of fuel due to gravity, this means its weight registers differently at separate circuit locations. The important variable here is the geographical latitude of the circuit.

In the present day, developments in refuelling technology with objective to improve performance are walled off

As the earth is a slightly 'squashed' sphere, its radius is larger at the equator. Gravitational acceleration is lowest at the equator and highest at the poles (varying between approximately 9.76 to 9.83m/s^2). This means fuel scales need to be calibrated at each individual circuit to be accurate.

Development race

Regardless of how fast you can deliver fuel to the car's tank, the refill rate is locked to the venting rate but, outside of tightly controlled race conditions and regulated equipment, what room is there to develop the technology within the vehicle to aid refuelling times?

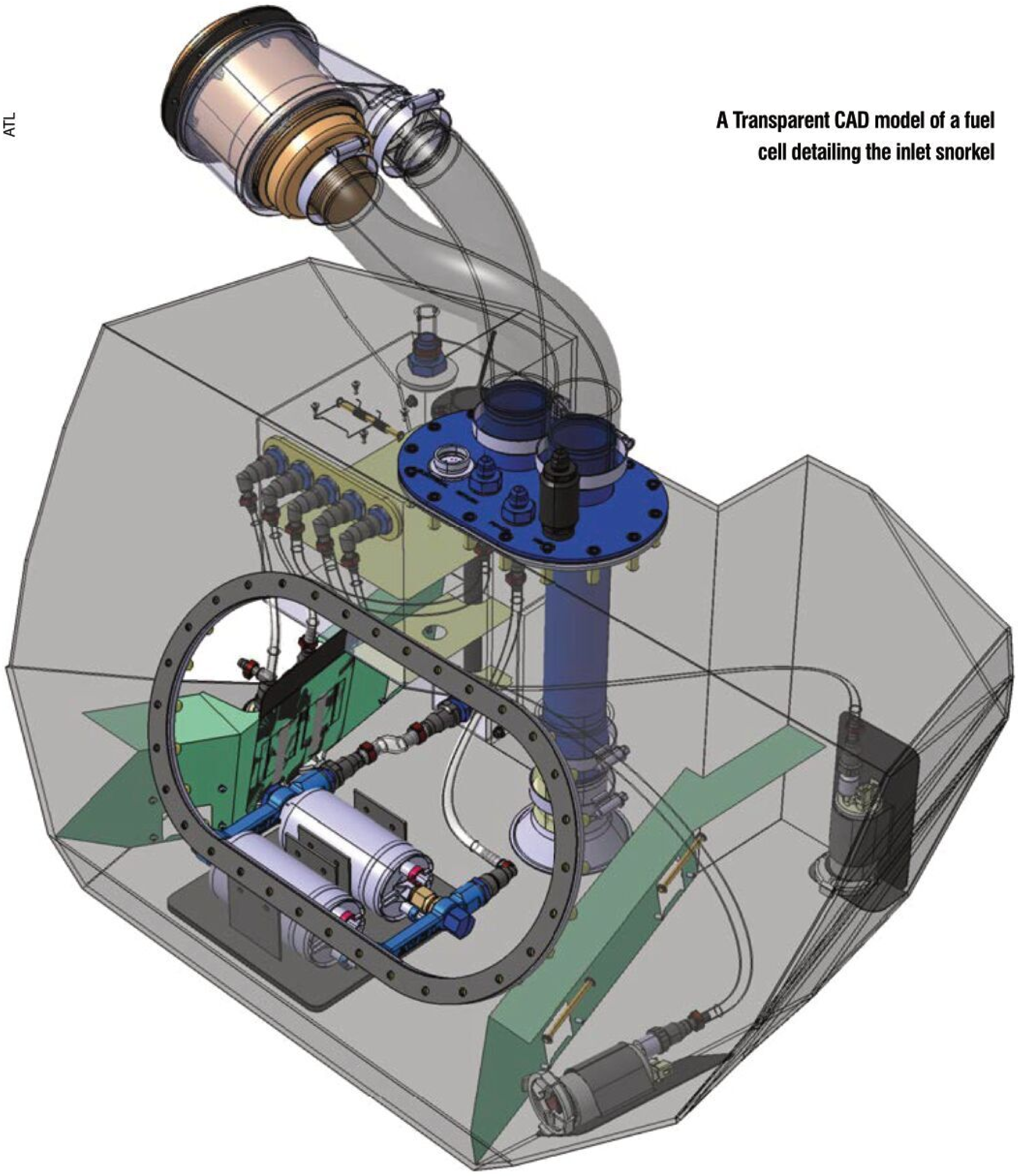
'When Porsche developed the RS Spyder in the early 2000s, there was a big focus on developing the refuelling speeds for that programme. Outside of F1, it was probably the only time it was focussed on properly,' notes Dawson. '[As a result,] the Porsche was so much quicker than anyone else, which started the development race on it.'

By focussing on baffling and filler inlet locations, the turbulence and concentration of vapours within the tank can be controlled, giving benefits in that it allows the gas to exit the tank with less resistance.

'At ATL, we discovered that keeping the vent gas laminar gave big advantages here, so most efforts to increase the fill speed on the vehicle side were associated with this,' continues Dawson. 'We worked with Porsche using transparent tanks to understand the filling characteristics and things like that. Delivering the fuel below the fluid line and optimising the venting geometry helped a lot.'

With Porsche's return to WEC in 2014, even more resource was invested into refuelling, which the ACO eventually caught wind of. Feeling it was contravening cost-cutting measures, the organisation closed off those development avenues by stipulating *minimum* refuelling times.

ATL



A Transparent CAD model of a fuel cell detailing the inlet snorkel

So in the present day, developments in refuelling technology with objective to improve performance are walled off, but there is still scope for development around the ergonomics and effectiveness of the equipment to make the process more efficient for the pit crew.

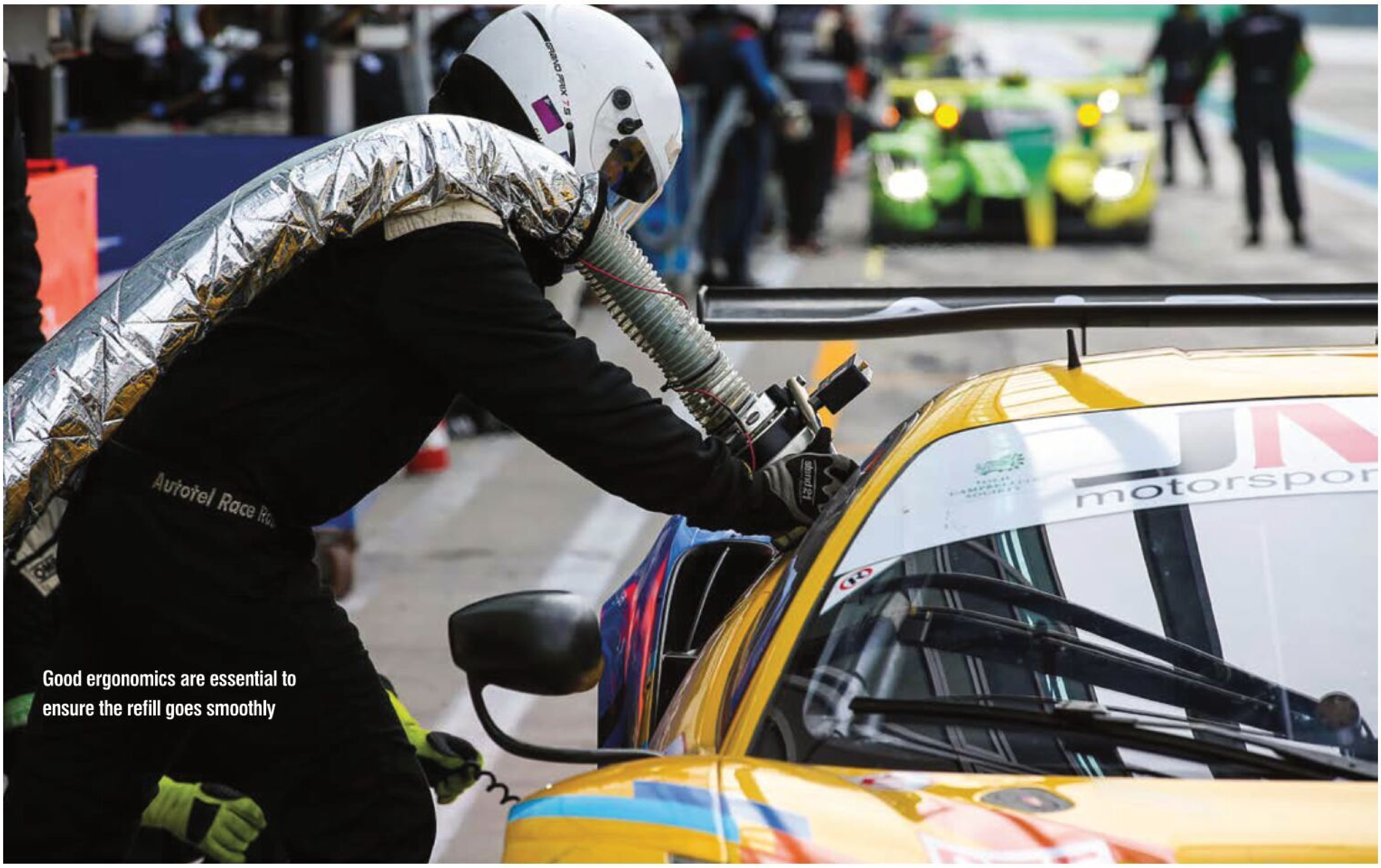
Making the equipment easier to handle, automating any operations where possible and developing components to help technicians be more accurate in their fuel delivery are new, but welcome innovations.

'We design our SAF system to provide a mechanical advantage as the coupling engages, which in turn reduces the effort needed by the refuelling pit crew member as the system opens the vent and begins the fill,' explains Bird. 'This kind of design avoids the operator having to apply excessive and increasing pressure to maintain the connection as the fuel tank is filled, which is not only tiring and dangerous, but can interfere with the speed of flow.'

Fuel bowsers

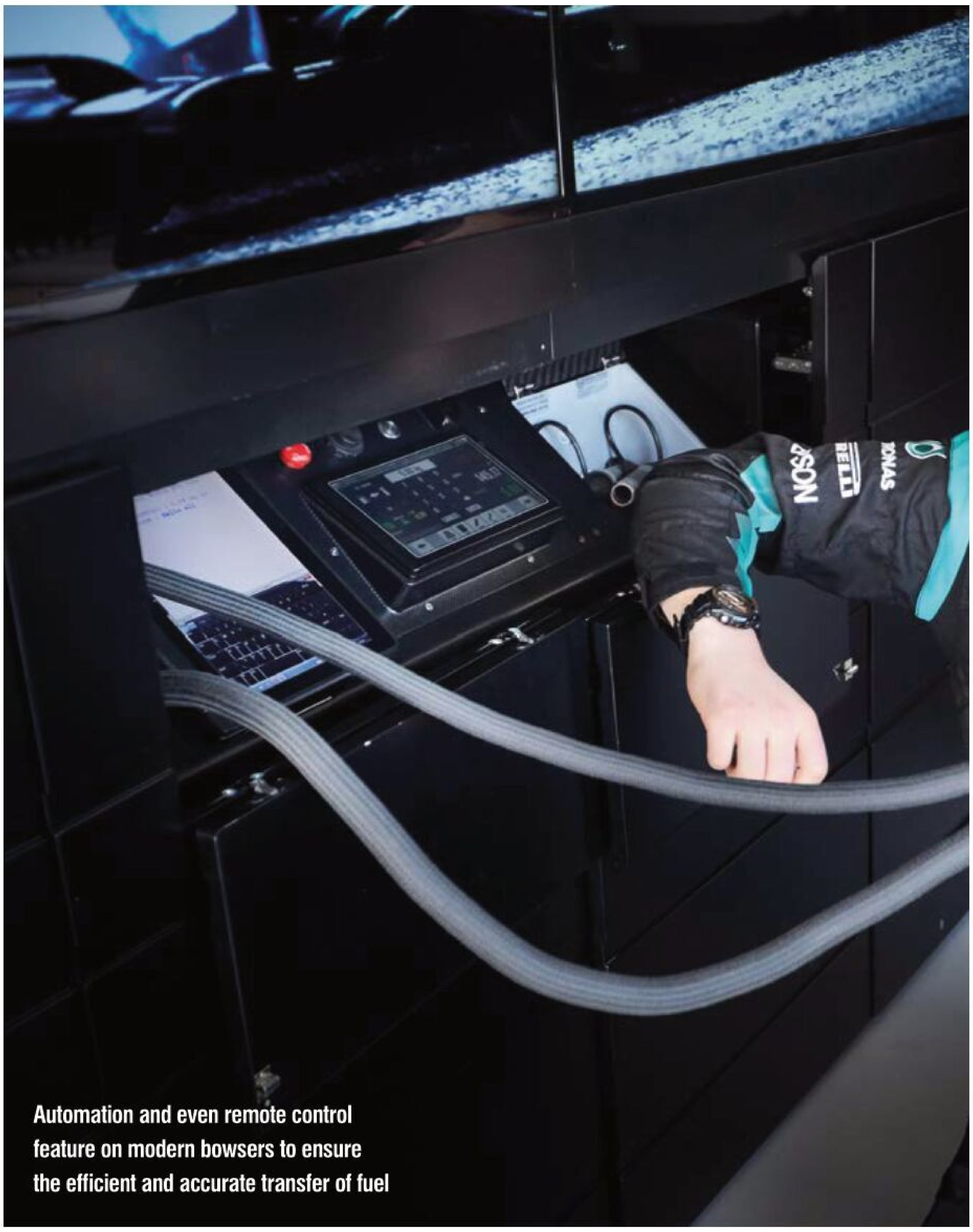
When not in race conditions ie practice and qualifying, and where in-race refuelling is prohibited, fuel is delivered from the main storage barrels to the cars via portable fuel bowsers, a piece of equipment which in the last ten years or so has also come a long way.

'We first got into this business nearly a decade ago now after we were asked to repair a bowser for a World Renault team,' says Derek Hodder, motorsport director at EEC.



Good ergonomics are essential to ensure the refill goes smoothly

EEC



Automation and even remote control feature on modern bowsers to ensure the efficient and accurate transfer of fuel

Breda

Timers help the operators deliver accurate quantities of fuel during a race refill

EEC

If you want to put, for example, 20.7kg of fuel into a car it's as easy as entering that amount into the bowser keyboard. The machine will do the rest

Derek Hodder, motorsport director at EEC

'It was using ancient technology. It had an open circuit board and relays that were underrated and would spark when fired. The fuel vent was open to atmosphere and it didn't even have a fuse from the battery. So, if there was ever a short circuit, the risk of fire was huge.'

Unsurprisingly, motorsport has now moved on from there to fully closed loop systems with automated fuel delivery, and proper circuitry.

Standard sensor equipment in refuelling bowsers today measures fuel temperature, weight (via load cells), fuel level and vent pressure, ensuring the system remains safe by shutting down automatically if a vent becomes blocked, for example. They also feature software control, which adds a level of autonomy to the process.

'Bowsers today provide a much safer method of transferring very precise fuel amounts to and from the car. Accuracy in their operation is very important to match a team's calculated fuel requirements,' continues Hodder. 'If you want to put, for example, 20.7kg of fuel into a car it's as easy as entering that amount into the bowser keyboard. The machine will do the rest, all automatically.'

Keeping up with developments in connectivity and the Internet of Things (IoT), bowsers can even be remotely programmed by the race engineer, which can help reduce workload in race weekends.

'In our higher spec bowsers, we wanted the possibility of remote equipment control to facilitate the pit crew. For safety reasons, some operations still need to be initiated at the bowser, with an operator at the dead man's button, but these developments have been well received,' adds Breda.

Time management

In race conditions, however, once the fuel is delivered from the bowser to the pit supply tanks, the refuelling technician must still manually ensure the required quantity of fuel is delivered. By precisely understanding the flow rate, it then becomes an exercise in monitoring the elapsed time and closing the flow once the specified delivery time is reached.

A neat development here is the fuel delivery timer. By providing an automatically activated second timer for the refueller to monitor, fuel quantities can be timed down to the tenth of a second by a skilled operator.

'The automatic timer activation was well received by the teams we work with,' notes Hodder. 'It can also store the last 10 fuel deliveries, which is great for record keeping. Together with the fuel bowsers, the refuelling information can be wirelessly transmitted to a computer in the pits so the race engineer can record how fuel is moving in and out of the car.'

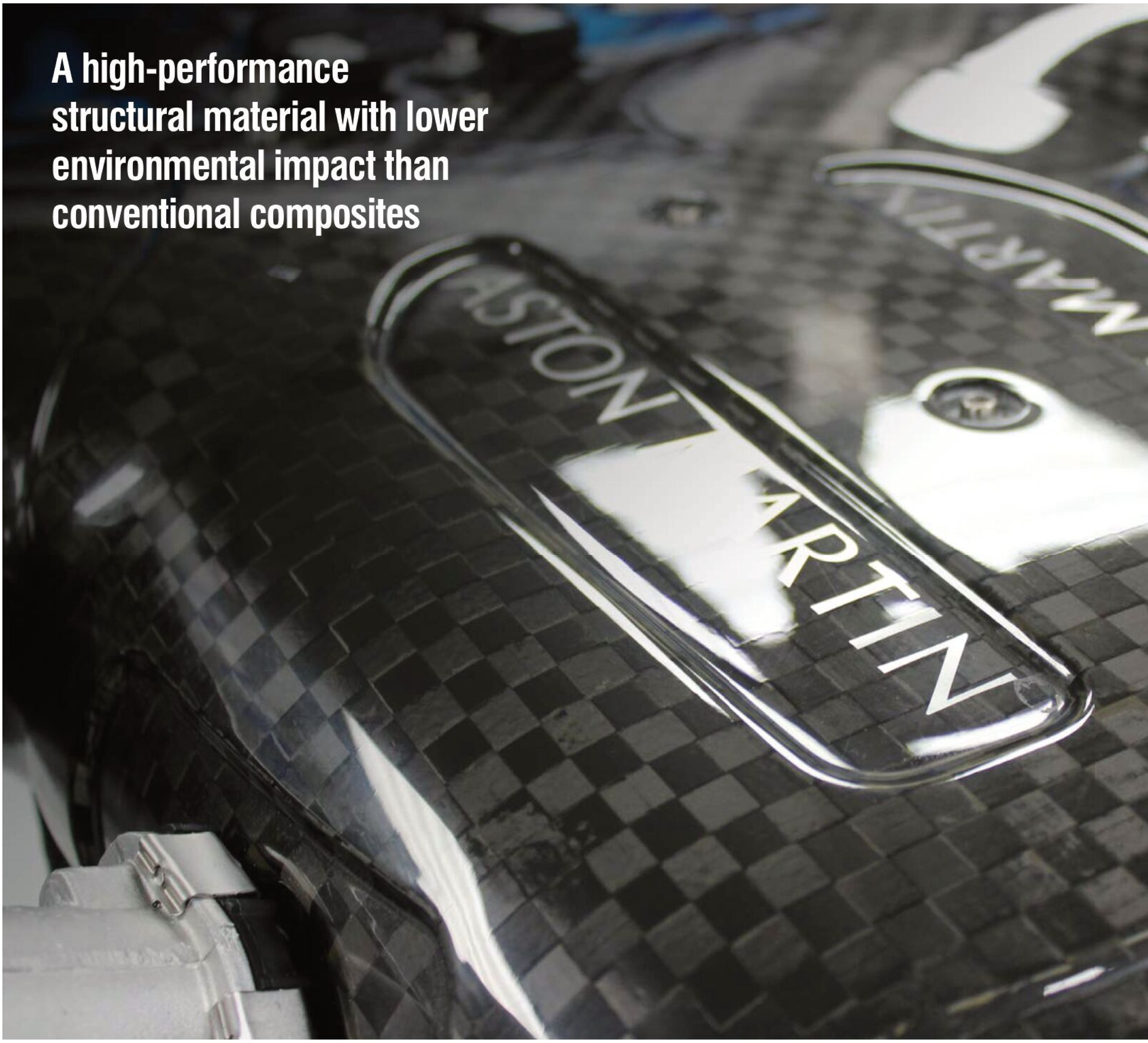
'In the future, we see current technology filtering down to smaller racing series. We're getting a lot of orders for our entry level 'eco' bowsers in regional F3 now. Five years ago, they wouldn't have imagined using bowsers in their racing, so it's good to see a more widespread use of safe refuelling equipment, which is definitely a positive for the safety of guests in the pit garages,' Hodder concludes.

Who'd have thought the simple act of refuelling would have caused so much turbulence (pun intended) in its history? Despite ever more restrictive regulations meaning the only avenues to explore for performance improvement in the process are firmly in the grey area of sportsmanship today, it's still a technology that continues to make developments in safety and ergonomics.


f-POD
Intelligent Race Fuel Bowsers
2020
SILVERSTONE
STROLL
0.00 kg
PUMP
QUEEN'S AWARD WINNING MACHINES - HANDLING FUEL SAFELY & ACCURATELY FOR PROFESSIONAL TEAMS WORLDWIDE
e-POD
Wireless Endurance Fuel Rig System
22.1
e-POD
Intelligent Fuel Timer
Wireless Fuel Stop Monitoring & Logging
Including: Endurance Fuel Rig Scales
Wireless Intelligent Fuel Timer
Wireless Fuel & Air Temperature Sensors
EEC
ESSENTIAL EQUIPMENT CONSORTIUM
EEC Performance Systems
00 44 (0)116 232 2335 enquiries@eec-ltd.com
www.eec-ltd.com


KINSLER
We did the Lucas metering for the Can-Am: 60's thru 70's; still do. Any injection: Road race, Sprint cars, Boats, Indy 500, NASCAR Cup, Drags, Motorcycles, Bonneville, Pullers, Street, etc. EFI, Constant Flow, Lucas Mechanical
Action Express Cadillac, '14, '15, '16, '17, IMSA Champs. 2018 Won driver & Mfr. Champs, overall '20 Daytona 24
Hyper Racing 600cc Sprint car
1971 McLaren M8F Can Am car. Ran Kinsler prepared MacKay intake Manifold with Lucas mechanical metering.
Monster Mesh™ Filter ©
EFI Injectors, all makes of Pressure Relief Valves, and Lucas Mechanical Metering Units, need 3 micron protection, but 3 micron filters plug up too quickly, so most racers use 10 micron, which is too coarse. We made this new element for NASCAR Cup cars: 10 micron premium paper top layer to take out 95% of the dirt, with a 3 micron precision Fiberglass lower layer.
Details: Kinsler.com home page.
10/3 Element
K-140 Pressure Relief Valve
Used on 95% of NASCAR Cup and INDY 500 cars
(248) 362-1145 Troy, Michigan USA sales@kinsler.com


ATL
AERO TEC LABORATORIES LTD
HIGH PERFORMANCE SAFETY FUEL CELLS
STANDARD OR CUSTOM SAVER CELLS
RANGING FROM 10 -170L
FIA APPROVED
CUSTOM DESIGN
FIA APPROVED
CUSTOM FUEL CELLS DESIGNED & MANUFACTURED BY ATL FITTED IN FORMULA ONE AND WRC CARS
CRASH RESISTANT, EXPLOSION SUPPRESSANT & EXTREMELY LIGHTWEIGHT
CUSTOM FUEL SYSTEMS
UTILISING DECADES OF MOTORSPORT KNOWLEDGE, ATL CAN SUPPLY AN FIA APPROVED LIGHTWEIGHT FUEL CELL WITH A FULL INTERNAL SYSTEM
HISTORIC REMAKE
RETAIN THE ORIGINAL LOOK OF YOUR TANK BY SENDING US A SKETCH, 3D CAD MODEL, EXISTING OR RE-MADE CONTAINER
FIA APPROVED
FIA APPROVED
VISIT OUR WEBSITE TO VIEW OUR FULL RANGE OF PRODUCTS
WWW.ATLLTD.COM
@ATLFUELCELLS
AERO TEC LABORATORIES LTD
SALES@ATLLTD.COM
+44 (0) 1908 351700



Photos: Stewart Mitchell

Carbon neutral

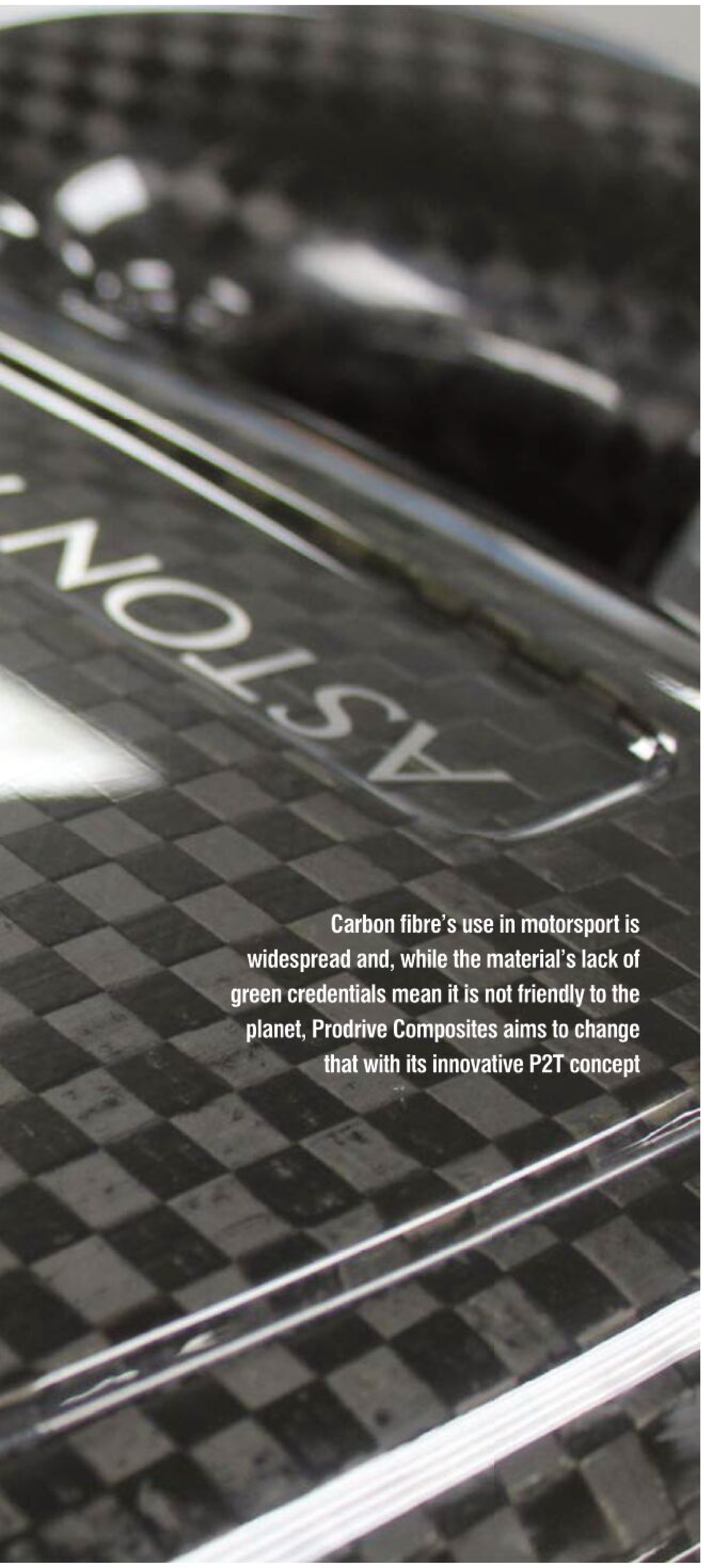
The world of carbon fibre is changing. With more emphasis on recycling, Prodrive Composites is leading the charge with its Primary to Tertiary process

By STEWART MITCHELL

Carbon fibre is not a recent invention, it has been around for more than 150 years, but the last half-century or so has seen significant improvements in its manufacturing process that allow for its excellent strength-to-weight and stiffness-to-weight ratios to be achieved and exploited.

Contemporary carbon fibres contain up to 95 per cent carbon, and have considerably improved tensile strength and modulus of elasticity over the earliest versions, up to 4,000MPa and 400GPa respectively.

Specific recent progress, linked with reductions in production and fabrication costs over the last few decades, has now made carbon fibre a favourite material for design engineers to use in the most demanding applications in the motorsport environment.



Carbon fibre's use in motorsport is widespread and, while the material's lack of green credentials mean it is not friendly to the planet, Prodrive Composites aims to change that with its innovative P2T concept

Carbon fibre is the go-to material for aerodynamic elements on racecars as its strength can be optimised in the direction it is loaded without significant weight or bulk where it is not needed. However, as such components are tailored to purpose, and made in small numbers, currently only virgin carbon fibre is used

The use of carbon fibre spreads beyond on-car elements. Pit equipment is now made from it and lightweight, 3D-printed parts can save precious time in pit stops. P2T recycled carbon fibre is ideal for this application

Historically, the composites industry has primarily used rolls of 'pre-preg' (woven fibre sheets pre-impregnated with resin), which are then laid up in moulds to produce 3D components, cured through heating to create the final shape. Thermosetting plastics have been the preferred resin for the carbon fibre composite as they are readily available materials to support this supply chain. However, better alternatives are still required if the motorsport industry is to be more sustainable in the future, and if tighter end-of-life regulations are introduced.

Milton Keynes, UK-based Prodrive Composites has developed a process for manufacturing recyclable composite components that can satisfy future end-of-life requirements without compromising the performance of the original parts.

P2T composites do not require heat or pressure during manufacture, which means there is no need for an autoclave

Concept overview

Called P2T (Primary to Tertiary), the process simplifies recycling and provides a composite material with the scope to fulfil a multitude of useful lifetimes. P2T composites do not require heat or pressure during manufacture, which means there is no need for an autoclave, reducing costs and enabling production to be scaled up without significant additional investment.

'The basis of the process is the use of a reactive thermoplastic resin instead of the more usual thermosetting type,' explains John McQuilliam, director of engineering at Prodrive Composites. 'A plastic monomer is reacted with a catalyst in the presence of the fibres to produce a cured laminate. We believe we are the first to develop this technique, which emerged through a development programme with an automotive OEM customer who required a high-performance structural material with lower environmental impact than conventional composites.'

By using the P2T process, Prodrive can now recycle composite parts multiple times.

However, the highest mechanical properties are obtained with the first use of the virgin fibres, enabling highly loaded structural items such as suspension wishbones to be manufactured.

Reclaiming process

There are quite a few different ways carbon fibre is currently being reclaimed, the most predominant of which is cut-offs during the manufacture of virgin carbon fibre components. Even with sophisticated manufacturing software that aids efficiency, a significant percentage of waste cut-offs are still generated across the many different industries in which the material is used. Much of the carbon fibre Prodrive is currently reclaiming comes from the aerospace industry where carbon fibre is used in the manufacturing of aircraft wings and fuselages.

To facilitate the gathering of processed waste material, Prodrive has partnered with ELG Carbon Fibre. 'We *want* somebody to take our waste, and we also needed to create a demand for a reclaimed waste product,' notes McQuilliam. 'Those concepts were the start of the P2T process.'

When a part reaches the end of its life, the fibres and much of the resin can be recycled by chemical or thermal depolymerisation, freeing up the raw material for a secondary role. To achieve this, the primary component has to be processed in a furnace at a temperature between 1000degC and 2000degC. Surprisingly, this does not affect the properties of the carbon fibres being extracted.

Waste management

'We take waste fibre from the whole carbon fibre supply chain, and we bring that on site to our facility,' explains Ben Andrews, field technical services engineer at ELG Carbon Fibre. 'We then remove anything that's not carbon fibre, whether that be a particular polymer or an epoxy resin or other contaminates through our furnace. The high-grade, high-value carbon fibre material remains.'

During the process, the carbon fibre cut-offs are fed into a continuous belt furnace, optimised for recycling carbon fibre so the material is heated in such a way as to prevent too much oxygen being present locally around the fibres. This prevents oxidisation on the surface of the fibres and the production of other contaminants that may stick to the wanted material.

This technique also reduces oxidisation of the resin as it is burnt off. The gasses produced during the process are chemically treated though a series of proprietary off-gassing processes, which remove harmful elements before it is released into the atmosphere as safe waste gas.

ELG Carbon Fibre

The carbon cut-offs are fed into a continuous belt furnace, specifically optimised for recycling carbon fibre. The material is heated in such a way as to prevent oxidisation and other contaminants forming on the surface of the fibres

ELG Carbon Fibre

The reclaimed material is processed into a quasi-isotropic mat, which can then be used for second order carbon fibre production

ELG Carbon Fibre

Close up of the quasi-isotropic mat Prodrive receives back following the reclamation process by ELG. These mats can only be produced from fibres over 10mm in length. Any shorter than that and the product of the recycling process has other uses

For items such as this plenum for a V12 racing engine light weight is the goal, and the stresses on the part are such that a quasi-isotropic P2T mat-based recycled carbon product could replace the virgin carbon fibre currently used in its construction

Natural fibre future

With a view to the future, Prodrive Composites has been developing natural fibre composites, bio-resins and considering all aspects of its business from a sustainability and recycling standpoint.

'We have parallel developments using two approaches to sustainability based on recycled fibres and natural fibres. Though our conventional composite manufacturing will continue, we expect the business' major growth to be from natural fibre composites,' says John McQuilliam, director of engineering at Prodrive Composites.

For one of the company's GT race programmes, the regulations state that all aerodynamic fixtures within the GT framework that are not standard on the road vehicle need to be made from natural fibre composites. The first thing Prodrive did was to develop the rear wing using natural flax fibre composite material.

'The GT reaches 210mph at the end of the longest straight on the calendar, and it needed to be able to take that load,' adds McQuilliam. 'Although flax-based fibres do not match carbon's mechanical strength, they inherently provide superior vibration damping. We carried out extensive engineering analysis to ensure we met all the strict aerodynamic, weight and deflection targets, as well as cost and manufacturing volume constraints.

'We developed a combination of weaves, laminates and manufacturing processes to minimise labour requirements and material costs. Compared to the carbon fibre design, it matches the strength, stiffness and deflection allowable within the regulations, and is slightly cheaper, too.

'With Formula 1 recently announcing its plan to become carbon neutral by 2030, we expect to see considerable growth in demand from across the motorsport sector for sustainable natural composites in the future.'

Although McQuilliam's praise is strong, he believes the success of such material needs to be considered in the context of its full life cycle.

'Natural fibres such as flax are not just carbon neutral, they can be carbon negative because they consume carbon as the plant grows,' he notes. 'Besides recyclable composites and natural fibres, we are also looking at the resins used. Bio-resins made from plant-based stock sacrifice some of the ultimate composite performance but offer a big advantage in sustainability.

We expect considerable growth in demand from across the motorsport sector for sustainable natural composites in the future

'As a commercial company, we generally need a customer enquiry to justify onward development. There is a sweet spot for manufacturing volume – not one-offs, or thousands-off, but quantities of a dozen to a few hundred. This is typical of niche automotive applications, and is always our immediate target when we are developing a new process.

'We are making our whole business more sustainable through measures such as improved process energy efficiency from shorter cycle times and lower temperatures, replacing wooden pallets with cardboard ones and exploring the switch to re-useable films and vacuum bags.

'We are also already paperless in our external supply chain controls, and will soon add our internal processes to the system.'

What is left are carbon fibres in their original format, whether that be unidirectional, bi-directional or woven. Following this, there needs to be some chopping element to provide an even distribution of fibres to generate the secondary form.

'This process is trickier with woven fabrics. If the fibre is in one direction, it's much easier to chop it to a regular length, and you get a uniform distribution of fibre, which makes subsequent process much easier,' notes Andrews.

'When you're trying to chop up woven fabrics, effectively the fibres are in at least two directions and therefore aligning those fibres through a chopping process is impractical. There are ways around it, to open up the fabric. You use a mechanical process to split the carbon fibre into the individual fibres and then there's an element of realigning. That's very challenging. These fibres can be as little as seven microns in diameter and, if you start playing with them too much, they turn into dust.'

Grading chart

The longer the fibres the better, from a mechanical performance point of view, and the longer they are, the simpler it is to turn them into a quasi-isotropic mat product that can either be used as it is or re-woven.

Moving down the fibre length chart to those around 10mm in length, these won't go into a quasi-isotropic mat, so are better suited as a reinforcement for polymers used in injection moulding.

Shorter again in fibre length is milled fibre, which is effectively carbon fibre dust. This is used in reinforcing resins, or to give antiseptic properties because carbon fibre is conductive. In some electronics components, for example, it is used to discharge current through the element.

ELG has developed a grading mechanism to determine intermediate modulus fibre, standard modulus fibre or basic fibre runs, enabling a guarantee of performance to customers.

'We get carbon fibre back from ELG in the form of a quasi-isotropic mat,' explains McQuilliam. 'That is an excellent material for making body panels when you do not have a predominant load direction.

'The other benefit of this format is it is quite a lofty material, and so will stretch and drape a little bit. As such, it is much more formable – similar in a sense to pressing sheet aluminium – and it is quite simple to produce various shapes with this type of quasi-isotropic mat using a single or double-sided mould to get the form you want.

'It is far more forgiving than woven lay-ups, without the pedantic tailoring you have to do with a fabric or even unidirectional material that doesn't stretch and must be cut into the exact shape it needs to be in its final form.

'The quasi-isotropic form is a one-size-fits-all concept that may not necessarily be the ultimate technological solution. Still, it is superior enough to tackle almost every non-structural application in racing.

'I wouldn't advocate it for primary structures such as chassis because it is much easier to get properties within a defined limit using virgin material with a known woven strategy in the load's direction.

'Another option is to combine the two where you have some virgin fibre material and include the remainder as a quasi-isotropic reclaimed element.'

Tertiary processing

When the secondary part reaches the end of its life, it can be chopped and re-moulded into block material with properties suitable for 3D solid components. This tertiary part can itself be recycled several times until, finally, just the re-melted resin is recovered and the milled fibres used to supply other, lower grade applications.

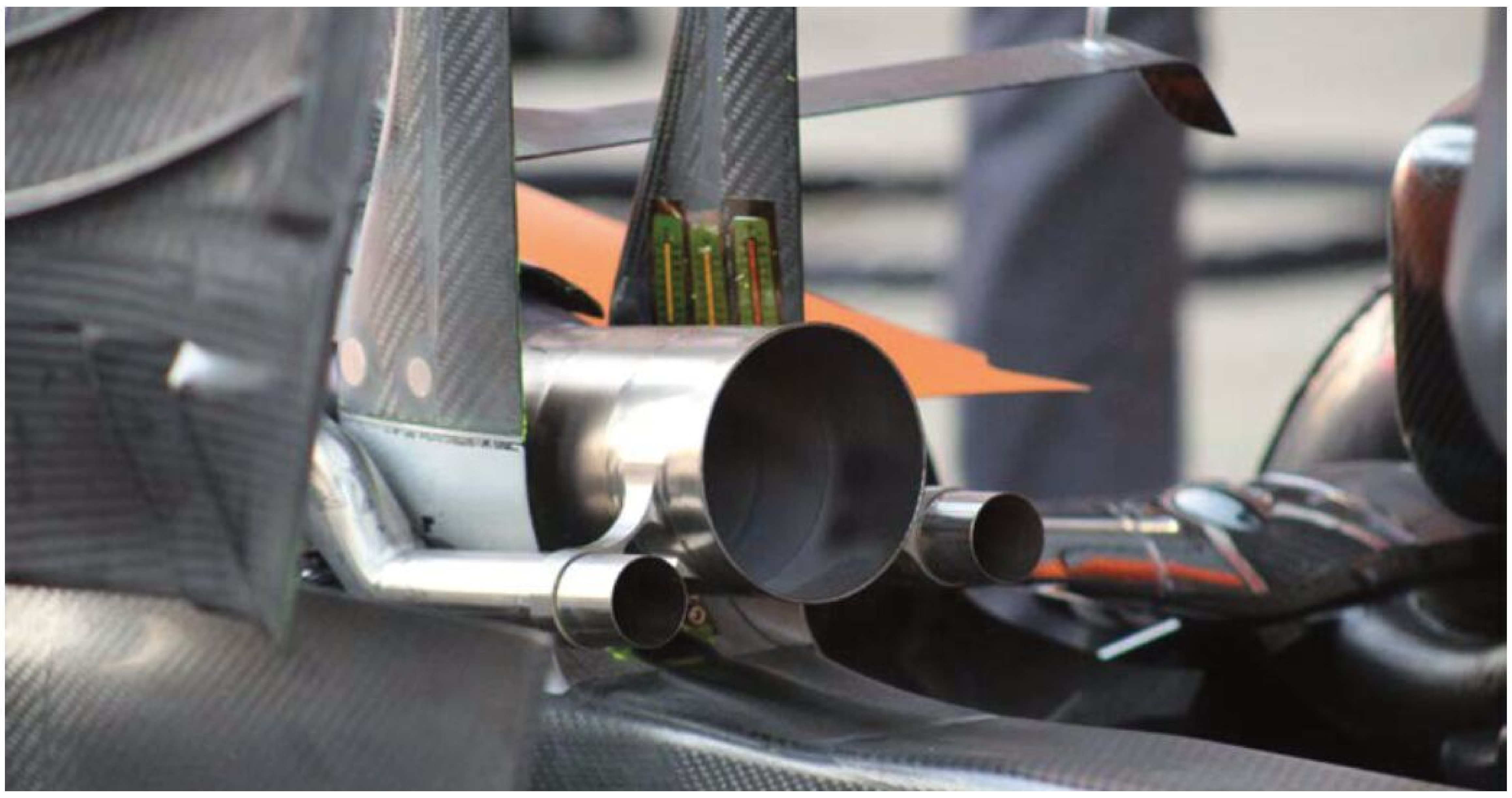
The P2T process is also compatible with advanced techniques, such as Tailored Fibre Placement (TFP), which many leading composite producers are adopting. TFP makes more efficient use of the fibres than a conventional weave and is highly complementary with the P2T approach to recycling.

'At the moment, the challenge is making it all commercially viable as there is so much labour and energy resource required, primarily through our furnace,' notes Andrews. 'High volume and economies of scale are the only ways to make it viable at the moment, which is why we have massive contracts with the likes of large aerospace manufacturers who give us uniform waste on a day-by-day basis. That's how we can continuously run [the furnace] and it makes financial sense.'

Future proofing

To future proof the P2T process, engineers must consider recycling in the design stage of components. 'We need to slightly modify how we make the primary parts and move them towards forms of reinforcement that are easier to reclaim,' explains McQuilliam. 'A critical element of this is the need for directional and bi-axial materials, rather than woven ones. With a tightly woven cloth, it is challenging to withdraw the fibres out of the matrix. They end up being chopped down to the length of the overlaps in the cloth, and so are challenging to reclaim for a secondary life format that is useful for the motorsport industry.

'As such, the first step of the process is to be aware of the secondary life these components can have, and use lay-up techniques and fibre design that enables easier reclamation of the fibres.'



Carbon fibre gearbox casing with a 3D printed titanium insert running either side of the exhaust transitions back to the carbon fibre rear wing stays. This ability to adhere to various other materials means carbon fibre elements can be integrated into many different structures. Using P2T thermoplastic resin carbon fibre here would be challenging, given the intense thermal load case in this area but, if the technology continues to develop, it could well be possible in the future

'We need to slightly modify how we make the primary parts and move them towards forms of reinforcement that are easier to reclaim'

John McQuilliam, director of engineering at Prodrive Composites

Another benefit of carbon fibre that race teams love is that one element can have multiple roles. Here, a carbon fibre motorcycle chassis doubles as a battery casing and also has cooling channels running through it. It's a complex case, but P2T carbon fibre structures could be suitable given the minimal thermal load here

In a P2T-compliant design process, engineers would also use a reactive thermoplastic resin. These can mix and infuse into the product in the same way as a standard thermoset resin, but can more easily be cut up, heated and pressed into shape. Should the original product's shape become distorted, it can be re-heated and bent back into shape. If the damage is worse than that, thermoplastics can be welded together and repaired.

Additionally, thermoplastics are less brittle, tending to deform under stress rather than crack like a thermoset. All these characteristics will ultimately help parts made from thermoplastics using the P2T technique become essentially infinitely recyclable.

Where this change of mindset will be more difficult is the motorsport industry, where carbon fibre used in racecars is highly tailored, teams using precisely the fibre type and form needed for different components. Ideal for optimum performance, but not well suited to recycling. Add to that the low volume manufacturing nature of the racecar industry and reclaiming at a sustainable cost becomes very difficult. Aerospace, on the other hand, uses a known fibre in a format that has been engineered and characterised for as much as 25 years, and produces thousands of tons of off-cuts per year. As such, the aerospace industry will be the primary supplier of virgin carbon fibre material for reclaiming through the P2T process for the time being.

Tyre modelling 101

What it means and what really counts in calculating it

By DANNY NOWLAN

When it comes to tyre models, most people are convinced it's either impossible, hocus pocus or you need 50 degrees in rocket science to complete the job. None of these preconceptions are true.

After nearly 25 years of doing this professionally, it still blows me away on a daily basis the sheer number of misconceptions out there about what a tyre model is, and what you do with it. While the subject is no trivial matter, there are some key points that race and data / performance engineers can use quite readily. I discuss these at length in the ChassisSim bootcamps and it's time these insights where shared on a larger scale. This will be the focus of this article.

The central thing to generating the tyre model is nailing the traction circle radius, or D term

Firstly, to set the scene, do not think of tyre models as dictated on high from a supernatural deity. Tyre models are tools to help you understand what is going on with the tyre. As I said in the tyre chapter of my book, *The Dynamics of the Racecar*, anyone who thinks they have the perfect tyre model needs to be locked up for their own safety. That said, there are some key take aways that can be employed in order to make sense of what the car is doing.

Empirical nature

The predominant tyre models out there are empirical in nature. The most quoted example of this is the Pacjeka tyre model. Tyre models like that in ChassisSim v3 are mostly empirical in nature, but derive their cues from first principle models like the Michelin TaMe tyre model. However, once you dig underneath the maths, most tyre models can be represented by **Figure 1**.

What this represents graphically is that any tyre model can be broken down into the form shown in **Equation 1**, below.

$$F'_{MAX} = fn(F_Z, T_T)$$
$$F_y = fn(\alpha, F_Z, T_T)\cdot C_{Fy\_MT}(\delta_{camb}, F_z)\cdot F'_{MAX}$$
$$F_x = fn(SR, F_Z, T_T)\cdot \mu'_{TC}(\delta_{camb}, F_z)\cdot F'_{MAX}$$

Where,

F'_{MAX} = Traction radius circle as a function of vertical load and temperature
F_y = Lateral force applied to the tyre (N)
F_x = Longitudinal force applied to the tyre (N)
C_{Fy_MT} = Lateral camber function
$\mu'_{TC}(\delta_{camb}, F_Z)$ = Longitudinal camber function
$fn(\alpha, F_Z, T_T)$ = Lateral slip angle function
$fn(SR, F_Z, T_T)$ = Longitudinal slip angle function

Effectively, the F'_{MAX} is the D term you see in the Pacjeka function and the camber and slip angle is all that horrible trigonometric function that sends most of the human population running into the hills in sheer, unabated terror. However, the key point here is your tyre forces are simply a product of the traction circle radius multiplied by the slip angle / ratio function, multiplied by the camber function.

Nailing the D term

Of all these terms, the central thing to generating the tyre model is nailing the traction circle radius, or D term. Once you understand this, everything else with tyre modelling will fall into place. Fortunately, there is a really simple way to understand this.

First, though, it's worth revisiting the second order fit of the traction circle radius

Figure 1: The outline of an empirical tyre model

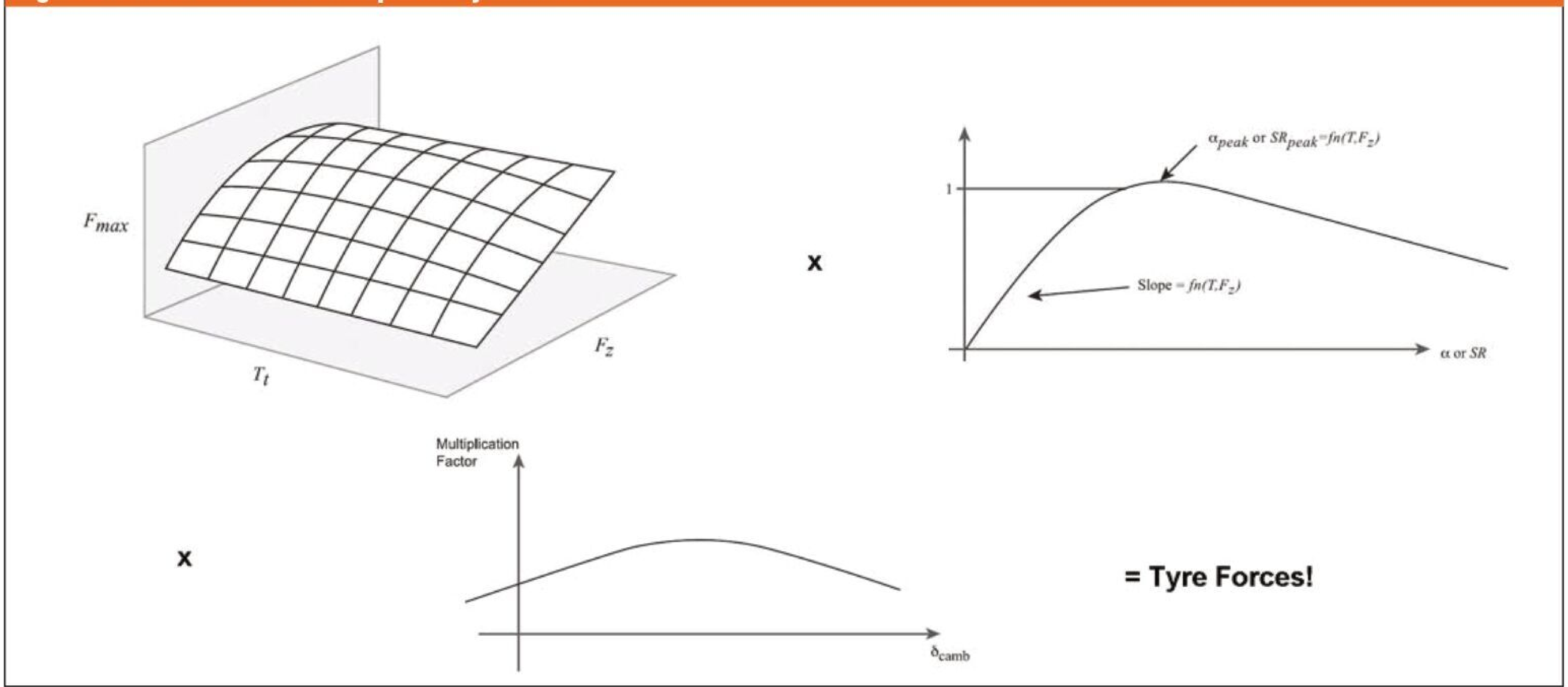


Figure 2: Second order plot of the traction circle vs load characteristic

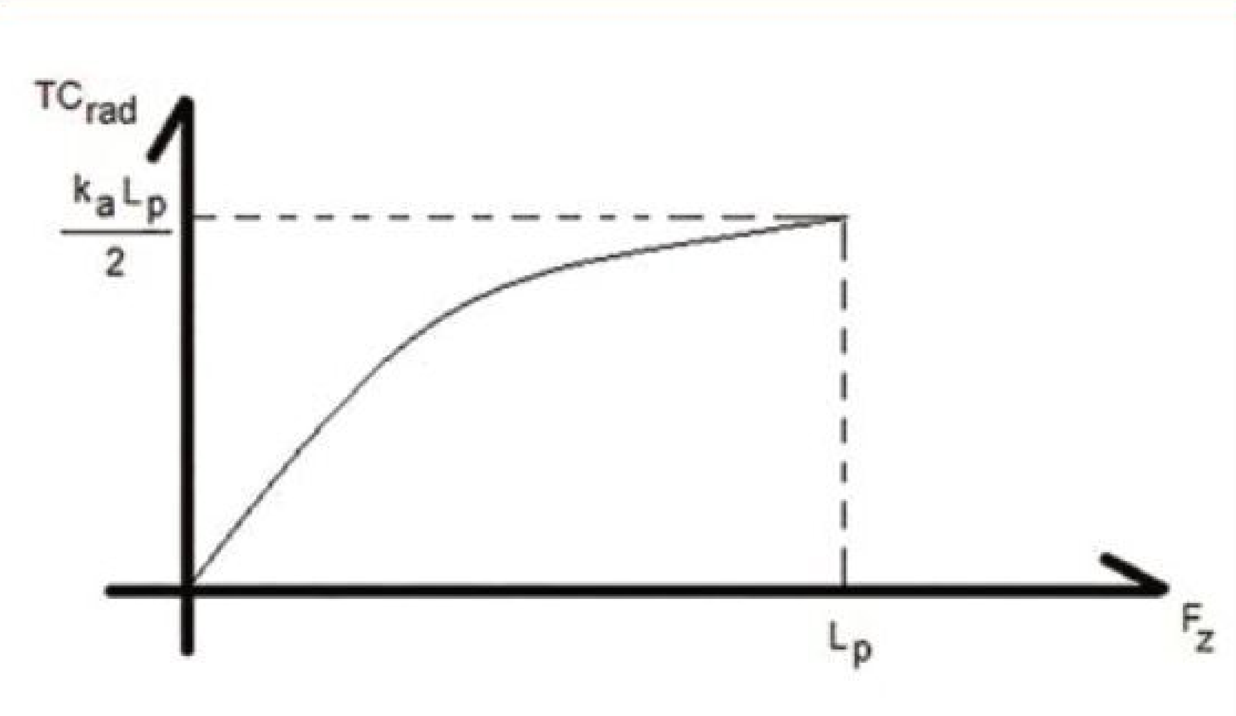
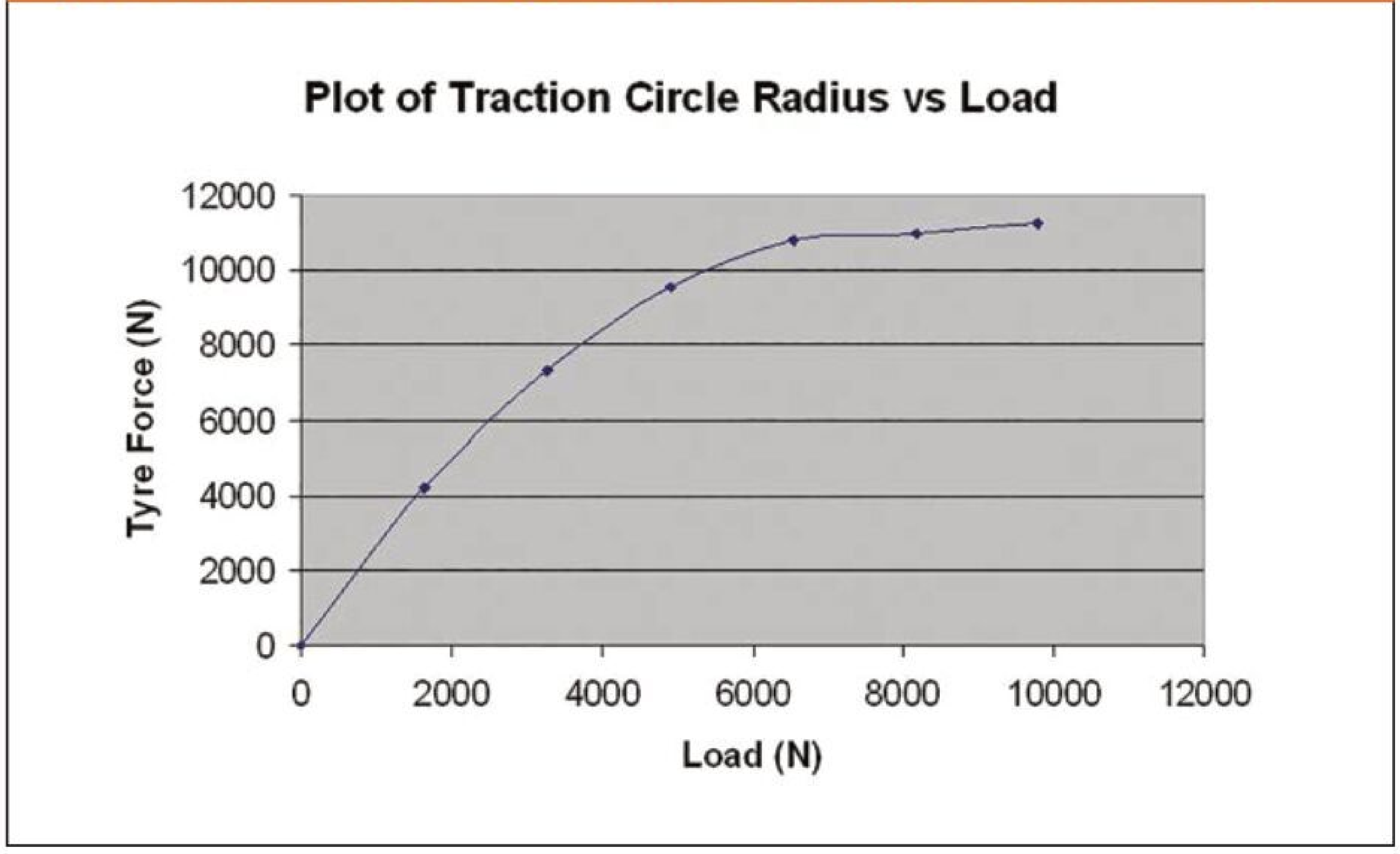


Figure 3: Illustration of the peak load and traction circle radius values



vs load characteristic. This can take many forms, but the most instructive way of looking at it is shown below in **Equation 2**.

$$TC_{RAD} = k_a(1 - k_b \cdot F_z) \cdot F_z$$

Where,

TC_{RAD} = Traction circle radius (N)
k_a = Initial coefficient of friction
k_b = Drop off of coefficient with load
F_z = Load on the tyre (N)

Table 1 shows some typical values for this.

Table 1: Typical open wheeler numbers for maximum tyre force with the coefficient of friction dropping off linearly with load

Parameter	Time
ka	2
kb	5.0 e-5 (1/N)

When you then plot this out, you'll have something that looks like **Figure 2**.

Where things become interesting is the relationship between the initial coefficient of friction and the peak tyre load that produces the most force. If we take the derivative of equation 1 with respect to load and set it to zero, we can show **Equation 3**.

$$L_p = \frac{1}{2 \cdot k_b}$$

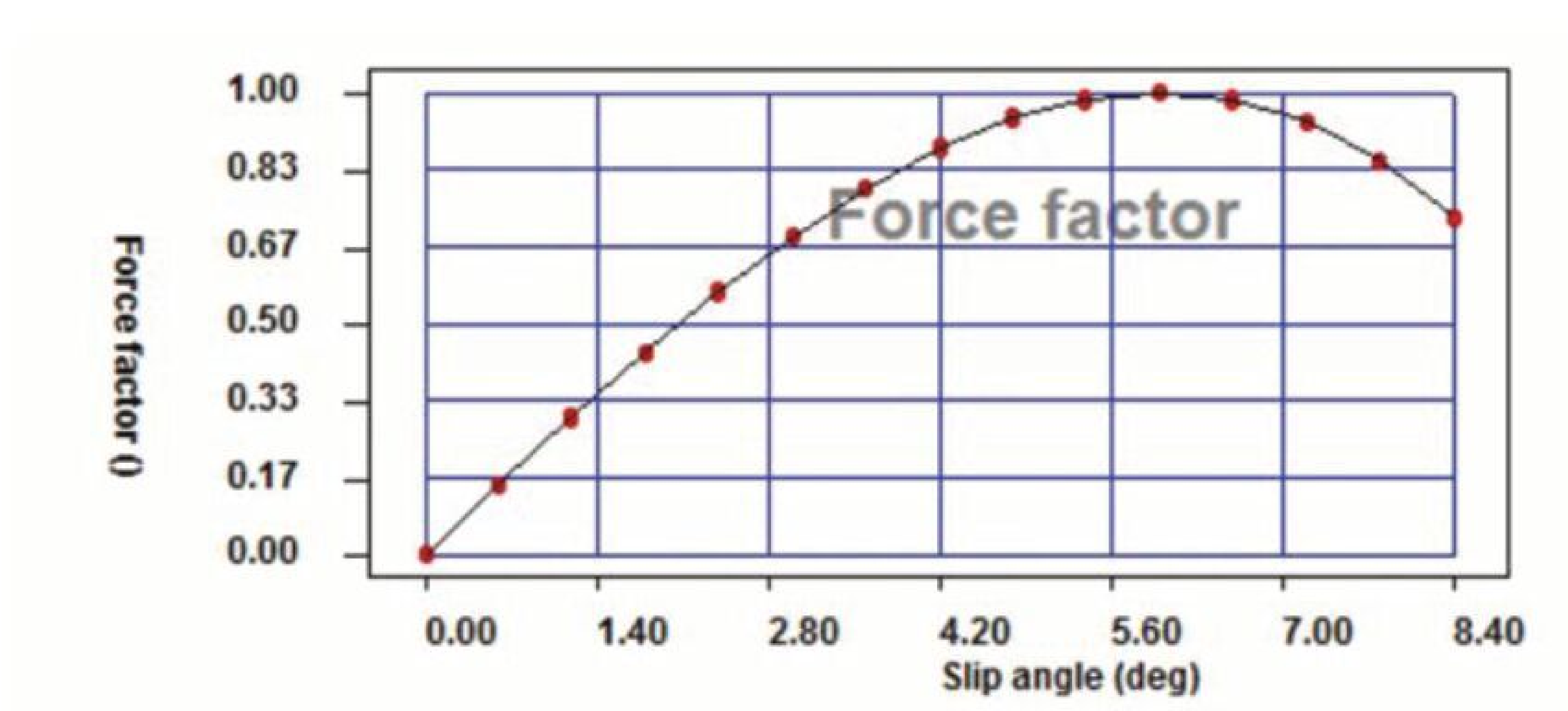
Where L_p is the load where the maximum value of the traction circle radius will occur. Doing a little bit more manipulation of **Equations 1** and **2**, the maximum possible value of the traction circle radius is shown in **Equation 4**.

$$TC_{RAD\_MAX} = \frac{k_a \cdot L_P}{2}$$

This is best illustrated graphically, and this is shown in **Figure 3**.

What this shows is that the maximum force of a tyre can be described by its peak load and initial coefficient of friction. A spin of this curve is that as the peak load decreases, the shape of **Figure 3** becomes more compressed, meaning you have more set-up sensitivity.

Figure 4: Non-dimensionalised tyre force curve vs slip angle



S angle	0.00	0.60	1.20	1.80	2.40	3.00	3.60	4.20	4.80	5.40	6.00	6.60	7.20	7.80	8.40
FFact	0.00	0.15	0.30	0.44	0.57	0.69	0.79	0.88	0.94	0.99	1.00	0.98	0.94	0.85	0.73

The downside is if you exceed this load, the tyre model will go over the curve and grip will drop off. The inverse of this is where the peak load is very large. In this situation, when you make a change it will do very little.

Heart and soul

Make no mistake, the relationship between the peak load at which the tyre generates peak grip and the peak vertical load you see on the racecar gives you the heart and soul of the set up. For example, if the delta you see between the peak load you see on track and the peak load of the tyre is 20-30 per cent, then this dictates a set-up with high roll and pitch centres and soft spring and damper rates.

To quote that *Pointer Sisters'* song from 1981, *Slow Hand*, this is a tyre that requires a lover with an easy touch. Conversely, if that delta is in the order of 50 per cent, you really need to muscle the tyre. This dictates low roll and pitch centres and high spring, bar and damper rates. This is a great rule of thumb that has served me very well. As always, it is imperative you validate this from race data. The key explanation for this is most tyre test rigs will overestimate peak tyre loads. The reason that is a tyre test rig will simply not generate the temperature and pressure conditions you see in real life on circuit. You can still get decent correlation from those models, but the set-up sensitivity will be awful.

The good news is you can use **Equations 2-4** and some simple force balance assumptions to get you started (I discussed this at length in my article in tyre modelling from nothing in 2016). If you don't want to do this, or can't be bothered, or are convinced in the supreme divine omnipotence of tyre test rigs, then OPB (other professions beckon).

Slip curves

The next thing to understand in the tyre model is the slip angle / slip ratio curve, because this is the primary driver of how sensitive the car is to steer and throttle input. To understand this, let's examine a typical non-dimensionalised tyre curve, as shown in **Figure 4**.

The number one driver in a tyre model is the traction circle radius vs load curve

Here, the horizontal axis is slip angle, and the vertical axis is normalised force. What you are seeing there is the default ChassisSim curve that has worked very well across a multitude of different types of racecars. In fairness, the post-slip curve needs a bit of work, but this will get you by for lap time simulation.

The reason this slip curve dictates the steering sensitivity lies in the derivation of control power. Referencing some of my earlier work, a linearised model for steering mathematically looks like **Equation 6**, below.

$$I_Z\dot{r} = \left(a\cdot C_f + \frac{\partial N}{\partial \beta}\cdot\frac{C_f}{C_T}\right)\cdot\delta_s + \left(\frac{\partial N}{\partial r} + \frac{C'_r\cdot b - C_f\cdot a}{C_T\cdot V_x}\right)\cdot r + \frac{a\cdot C_f - b\cdot C'_r}{C_T}\cdot m_t\cdot a_y$$

I'm not going to bore you with the terms of this because it will just bog us down here. However, by far and away the dominant term for steering is $a\cdot C_f$ term. The C_f term is given by **Equation 6**, below.

$$C_f = \frac{\partial C}{\partial \alpha}\cdot\left(Fm_1 + Fm_2\right)$$

Here we have,

C_f = Change in lateral force vs slip angle

$\frac{\partial C}{\partial \alpha}$ = Slope of the normalised slip curve

Fm_1 = Traction circle radius of the front left tyre

Fm_2 = Traction circle radius of the front right tyre

There is a camber multiplier term we have omitted, but what is shown here is the dominant term. Consequently, the less the peak slip angle, the more responsive the car is because the $\frac{\partial C}{\partial \alpha}$ term is bigger.

The longitudinal implication of this is the smaller your peak slip ratio, the more sensitive your car will be to differential adjustments. This is why peak slip angle and its slope dictate how sensitive the car is to steer and throttle inputs.

Camber effect

The last thing we need to discuss is the effect of camber, and here I am almost certainly going to rile some people. One of the failings of the Pacjeka model is the more camber you crank on, the better the tyre gets. That is perfectly fine for a motorbike tyre, but try telling Prema Powertrain or Ferrari to run 20 degrees of front camber for a high-downforce open wheeler and see how far you get.

It is for these reasons I went a very different way with the ChassisSim v3 tyre model with regards to camber. Mathematically, the formulation is shown below in **Equation 7**.

$$C_{Fy\_MT}(\delta_{camb}, F_z) = 1 - sf\_c\_y\cdot\frac{(\delta_{camb} - \delta_{OPT})^2}{100}$$

$$\mu'_{TC}(\delta_{camb}, F_z) = \mu_{MULT}\cdot\left(1 - sf\_c\_x\cdot\frac{\delta_{camb}^{\ 2}}{100}\right)$$

$$sf\_c\_y = sf\_c\_y\_0 + k\_c\_y\cdot F_z$$

$$sf\_c\_x = sf\_c\_x\_0 + k\_c\_x\cdot F_z$$

$$\mu_{MULT} = \mu_0 + k_u\cdot F_z$$

$$\delta_{OPT} = \delta_0 + k_\delta F_z$$

Where,

$C_{Fy\_MT}(\delta_{camb}, F_z)$ = Lateral camber tyre force multiplier function

$\mu'_{TC}(\delta_{camb}, F_z)$ = Longitudinal camber tyre force multiplier function

δ_{OPT} = Camber at which most lateral grip is generated

δ_{camb} = Negative camber of the tyre

sf_c_y = Lateral camber sensitivity per camber deg squared/100

sf_c_x = Longitudinal camber sensitivity per camber deg squared/100

The other terms you can chase up in my book, should you so desire, but honestly, the load terms are there for fine tuning and keeping the F1 and factory Sportscar guys happy. This is what happens when you have money to burn on vehicle modelling.

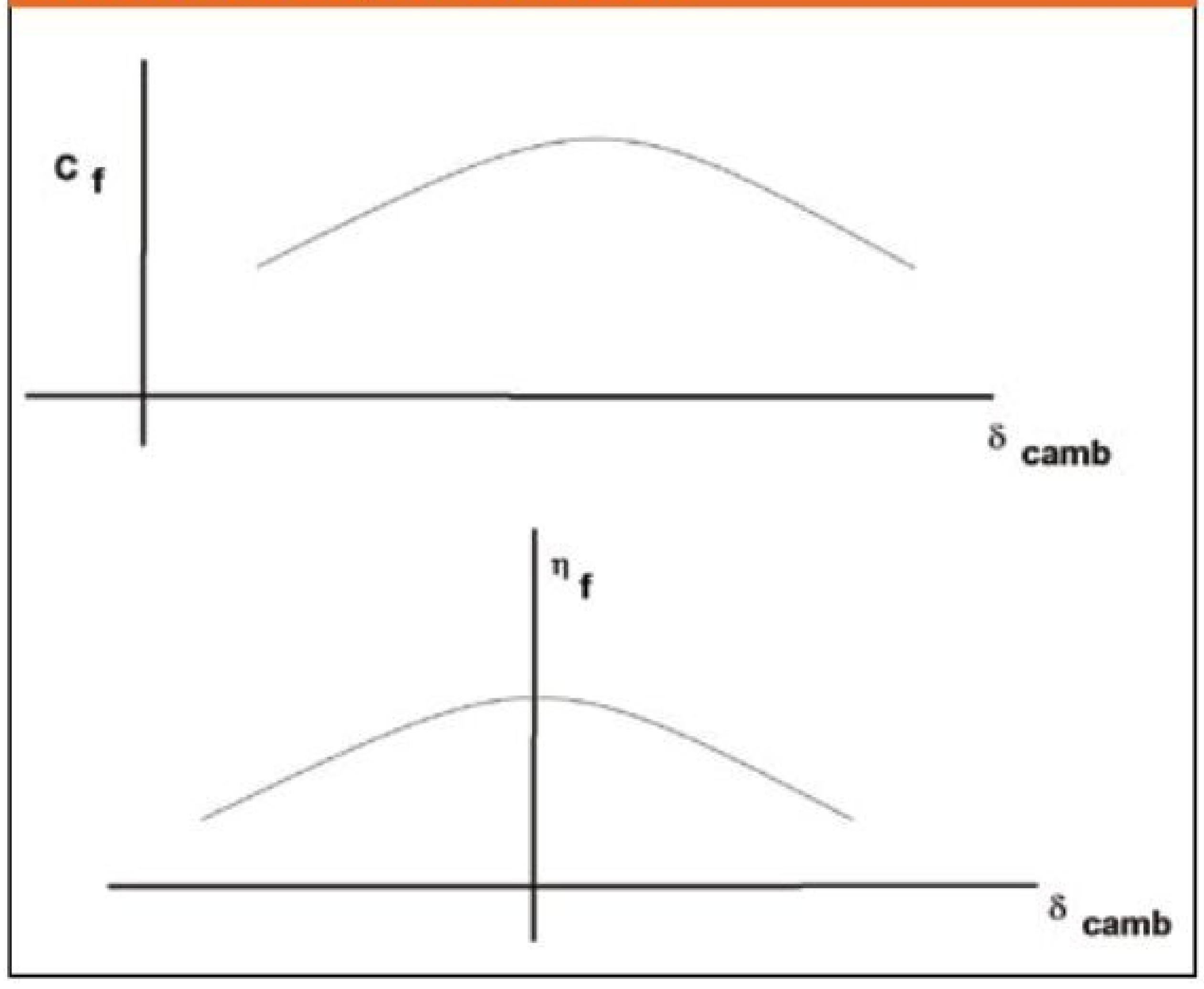
However, the important part to take from here is you can treat sf_c_y and sf_c_x in most cases as constant terms. There are some exceptions that prove the rule, but this is a pretty good start point.

For those averse to mathematics, **Equation 7** can be summarised graphically by **Figure 5**.

For the lateral case, the peak of this curve is dictated by the peak camber, while the curvature of these graphs are dictated by the sf_c_y and sf_c_x terms.

For the longitudinal case, the initial value is dictated by the term. This also is a key element in dictating the shape of the traction circle radius / ellipse. The bigger the term is, the narrower the traction circle radius and the more biased the tyre is to traction. The converse also applies, and this is one of the key drivers for whether you can or can't carry speed into a turn. **Table 2** gives you some reasonable start values.

Figure 5: Graphical representation of the camber multiplier function



These numbers haven't been pulled out of thin air. This is a collation of tyre model numbers from the ChassisSim community that have worked well, not just in correlation but for set-up sensitivity as well.

It bears repeating again here that every tyre model is an approximation. These are tools and frameworks to help you correlate what you see on track and apply it, and I cannot overstate the importance of using race data to validate and populate the tyre model.

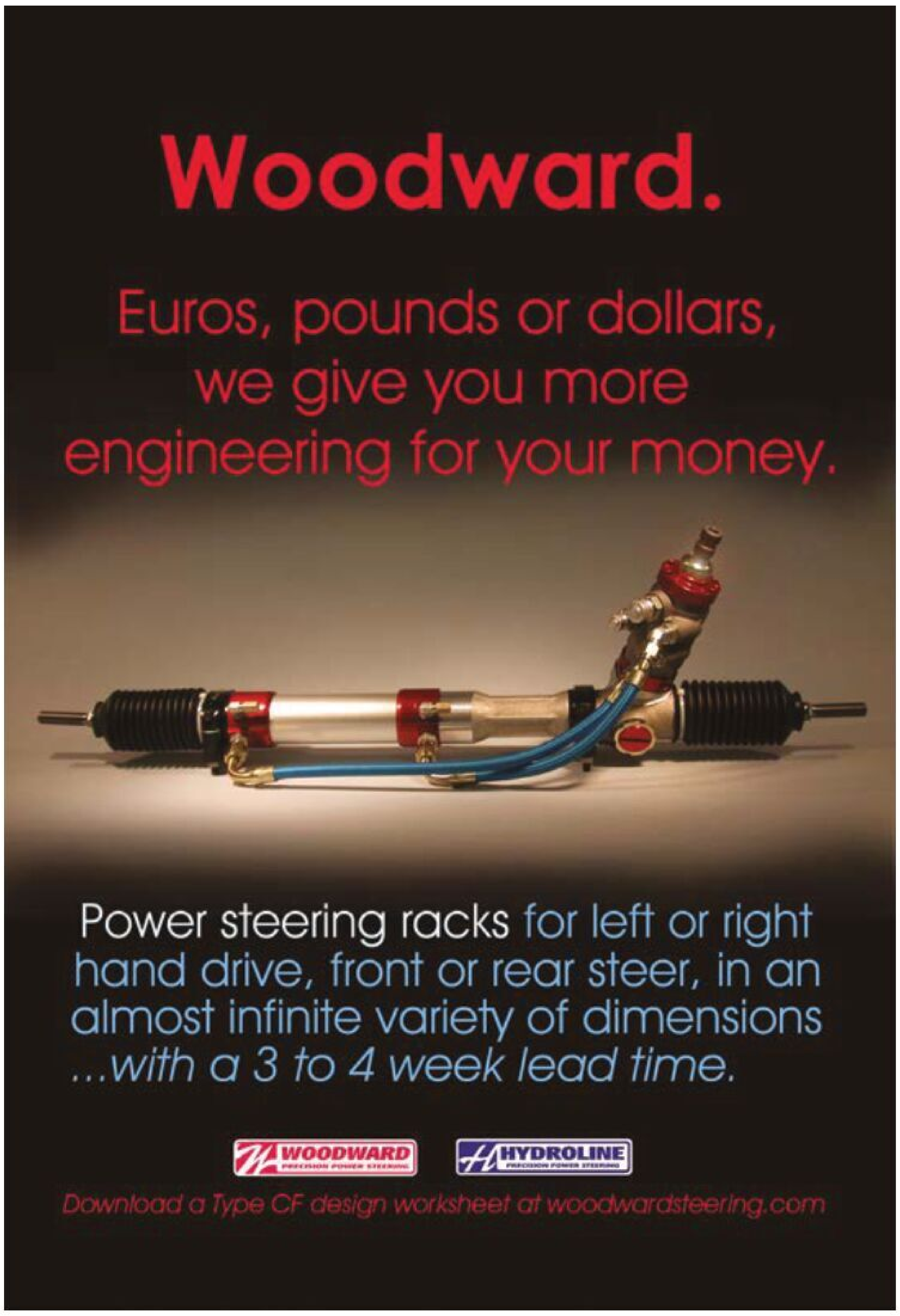
This toolbox has saved my neck on more occasions than I care to remember in formulae as diverse as Supercars, open wheelers and Sportscars, to name just a few. So, if someone declares they have tyre test rig results and don't need any of this nonsense of doing it from race data, you have my full permission to ask said person if they were born a moron, or was it a skill acquired as they went along!

In closing, we have established some simple frameworks here with which to help understand the racing tyre. This is not a trivial undertaking, but there are some steps we can take to help navigate the jungle. Firstly, the number one driver in a tyre model is the traction circle radius vs load curve. Get that right and everything flows from this. Then, once you understand the role of slip and camber, that will fill in the gaps.

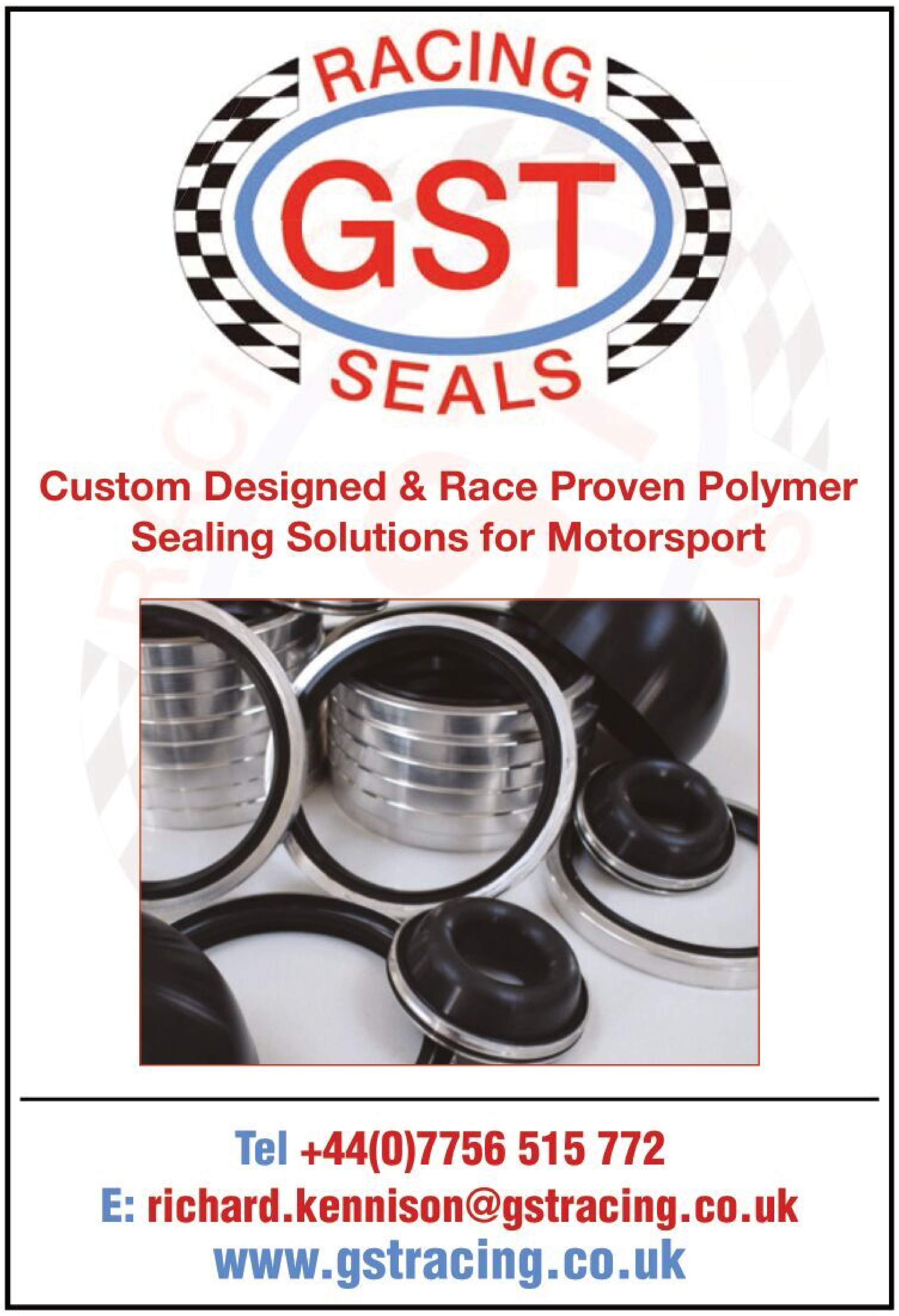
While this is not the complete story, a lot of set-up questions about where to go with the car will fall into place, particularly when you use race data to fill in the blanks.

Table 2: Ballpark numbers for lateral camber sensitivities

Parameter	Sportscar / Open wheeler	GT3 Value	Touring Car
$sf\_c\_y\_0$	2-3	1-2	0.5 - 1
$sf\_c\_x\_0$	2-3	1-2	0.5 - 1
k_c_y	0	0	0
k_c_x	0	0	0
μ_{MULT}	1	1	1


Woodward.
Euros, pounds or dollars, we give you more engineering for your money.
Power steering racks for left or right hand drive, front or rear steer, in an almost infinite variety of dimensions ...with a 3 to 4 week lead time.
WOODWARD
HYDROLINE
Download a Type CF design worksheet at woodwardsteering.com


D.A.T.A.S. LTD.
Data Analysis Tools And Simulation
RaceSim version 2.7.x
• Expert: Steady state, transient, 4 post, optimisation, strategy, etc
• Standard: Low cost lap simulation
• NasCar: Stock cars with live axle
• RaceSimE: For Formula E electric vehicles
• Sports & GT: BOP and hybrid sim.
Consultancy
• Vehicle Dynamics
• Racetrack support
• Software Development
Bespoke
• Dedicated RaceSim modules
• To customers specification
• Exclusive or semi-exclusive
D.A.T.A.S. LTD. THICKTHORN HALL NORFOLK NR9 3AT
TEL: +44 (0)1603 506526 +44 (0)7802 770345
http:// www. datas-ltd.com e-mail: info@datas-ltd.com


RACING GST SEALS
Custom Designed & Race Proven Polymer Sealing Solutions for Motorsport
Tel +44(0)7756 515 772
E: richard.kennison@gstracing.co.uk
www.gstracing.co.uk


Setrab ProLine
Oil coolers and Intercooler cores
Reliability Flexibility Know-how
Visit us at www.setrab.com/proline

Red Bull Powertrains to take on Honda hybrid

Formula 1 teams have unanimously agreed a freeze on engine development from 2022 after a commission meeting in February. The decision was reached in order to save costs before a new engine formula is introduced in 2025, the parameters of which were also confirmed at the meeting.

The key objectives for the 2025 power unit are that it should be more environmentally sustainable, and should include automotive relevance. It should also use fully sustainable fuel, significantly reduce costs and increase appeal to new manufacturers.

Red Bull later announced that it will take over the branding of Honda's power units after the Japanese manufacturer leaves the series at the end of this year. Honda will continue the development of the engines this season before departure, leaving the newly-formed Red Bull Powertrains with a competitive engine.

'We have been discussing this topic with Honda for some time, and following the FIA's decision to freeze power unit development from 2022, we could at last reach an agreement regarding the continued use of Honda's hybrid power units,' said Red Bull motorsport advisor, Helmut Marko.

'We are grateful for Honda's collaboration in this regard and for helping ensure both Red Bull Racing and Scuderia Alpha Tauri continue to have competitive power units.'

The new company will be housed and operated from Red Bull Racing's F1 team base on the Red Bull Technology campus in Milton Keynes, England.

Honda released the following statement: 'We are pleased that, following our decision to leave Formula 1 at the end of 2021, we have been able to reach an agreement for the two Red Bull-owned teams to use our F1 technology after 2021.'

XPB

Honda recently announced that the 2021 season will be its last in Formula 1 'for now' and, after seeing out this season of development, will hand its technology over to Red Bull Powertrains


XPB

Red Bull advisor, Helmut Marko, shakes hands with Masashi Yamamoto, Honda F1 managing director, on engine deal

Mazda confirms IMSA departure

Mazda has confirmed it will quit the IMSA United Sportscar series at the end of this season, having dropped to a single car entry for this year. The manufacturer has elected to make the move ahead of a change to LMDh regulations, which will include a compulsory spec hybrid system in 2023.

The Japanese manufacturer was one of the first to adopt the DPi regulations. The Riley Multimatic chassis was first entered by SpeedSource, then by Joest Racing, and finally by Multimatic itself. Under the Multimatic banner, the car took victory at Sebring in 2020.

'After five years of participating in IMSA's DPi series, Mazda is opting to end its programme at the close of the 2021 season with the Motul Petit Le Mans race in October. This was determined after an internal assessment of the current DPi seires and the future LMDh series, and concludes Mazda's participation in Prototype racing,' read a statement from the manufacturer.

'Starting in 2022, Mazda will focus its motorsport efforts on MX-5 Cup and grass roots racing. The MX-5 Cup, a signature one-make series, remains the cornerstone of Mazda's racing efforts.'

Jake Galstad

Mazda reduced its 2021 IMSA programme to a single car, and will leave at the end of this season, leaving only GM and Acura for 2022

The news came shortly after rival, Honda Performance Development, confirmed it will build a new LMDh car and will contest the IMSA series under the new rule set.

'Acura has been involved in Sportscar racing for some time in North America and it's very authentic,' confirmed its new boss, David Salters. 'It's a performance brand and they walk the walk. We support Sportscar racing and have done for decades. I think another couple of manufacturers are joining and, before you know it, you have four or five manufacturers on the grid and 15 cars racing, and that's quite impressive as a spectacle, isn't it? We want to be involved in that.'

Audi and Porsche have both confirmed they will build LMDh cars eligible to race in the US.

Goodyear to see in BTCC hybrid

A spate of tyre deals have been secured as Goodyear Tyres has been confirmed to continue its supply to the British Touring Car Championship (BTCC) after 24 years of support, as well as being confirmed as the official tyre partner of the Nürburgring.

Goodyear's BTCC deal is for five years, from 2022 through to 2026, and will bridge the phasing in of hybrid powertrains to the popular saloon car championship.

'With the introduction of hybrid power, new demands will be put onto the tyres and we are able to bring a lot of knowledge

and expertise to the programme, thanks to our experience working with leading OEMs where we are shod on some of their existing hybrid and electric vehicles,' says Ben Crawley, motorsport director for Goodyear Europe.

The deal in Germany sees Goodyear supply the Nürburgring Driving Academy, karting circuit and the off-road park. All company vehicles in the Nürburgring fleet will also be fitted with tyres from the rubber manufacturer's summer and winter portfolio.

BTCC/Ebrey

Goodyear Tyres will continue its support of the British Touring Car Championship for a further five years under a new agreement signed in 2021

IN BRIEF

AP Racing has been chosen by TOCA and the British Touring Car Championship to supply components for a further six years, including its Radi-CAL brake package, pedal box, air jacks and high-performance carbon clutch. The relationship between AP and the BTCC stretches back to 2002, when AP was chosen to be the BTCC's single source of brake and clutch components.

The **Catesby Tunnel** testing facility in Northamptonshire, UK will open later this year for aerodynamic testing and vehicle development. As featured in *RE*V24N11, the converted train tunnel has been adapted for full-scale testing, housing a 2.7km straight road test track that allows an extensive range of vehicle assessment studies. The sealed, underground working section ensures there is no wind and minimal temperature changes, and therefore provides a controlled environment for assured repeatable testing.

The test tunnel has been developed by Brackley-based **Aero Research Partners**.

Tyre manufacturer **Falken** has committed to the Nürburgring, and will sponsor the Nürburgring Endurance Series (NLS) for the 2021 season.

The FIA's Technical Director **Gilles Simon** has decided to retire but he will be kept on as a consultant. His place at the FIA will be taken by **Xavier Mestelan-Pinon** who will start in April 2021.

Motul has entered into a technical partnership with **Glickenhaus** to supply lubricants for its racing activities, including the new-for-2021 Hypercar, the 007C. The company will also supply lubricants to the team's GT3 programme and off-roading activities in rallying.

bf1systems, the market-leading provider of electronic and electrical solutions for the motorsport and automotive industries, and BGF portfolio company, has acquired KA Sensors as part of its acquisitive growth strategy.

Founded in 1994, bf1systems designs, manufactures and distributes high precision components, including steering wheels, tyre pressure and temperature monitoring systems, force measurement components and wiring harness assemblies to motorsport, including Formula 1, GT and Formula E, as well as to performance road cars, with a client list that includes Bugatti, Ferrari, Porsche, Aston Martin and McLaren.

SEEN: Audi's second generation TCR challenger, launched virtually in early February

www.kraelingbildagentur.de

Audi premiered its new RS3 LMS, the second generation TCR contender that is eligible under the FIA's Group A rule set. The car features the new Evo 4 version of the standard production 2.0-litre TFSI engine, which retains the block, cylinder head, crankshaft drive, valvetrain, injection system and turbocharger from the previous version of the engine.

Interview – Laura Klauser

The big three

General Motors has aligned the Corvette, Cadillac and Camaro racing programmes under one umbrella, all now managed by Laura Klauser

BY ANDREW COTTON

Klauser was already managing the hugely successful Cadillac DPi and Camaro GT4 racing programmes when she took on Corvette, so is well placed to lead the charge with all three, but is well aware the times they are a-changin'

When Corvette Racing's programme manager, Doug Fehan, decided to step away after more than 20 years in charge, he left some large shoes to be filled. General Motors' choice to replace him was Laura Klauser, who had already been managing the incredibly successful Cadillac DPi and Camaro GT4 programmes, thereby streamlining the manufacturer's approach to North American endurance racing.

Klauser took over Corvette's racing activities during a time of great change, with IMSA announcing at Daytona it will be cancelling the GTLM category, for GTE cars including the Corvette. Declining numbers of participants, as well as a pair of cost-effective replacements, has meant the class is no longer viable in the eyes of the organisation. It remains to be seen whether or not the ACO and FIA reach the same conclusion for the WEC but for Corvette, which has focussed on US racing and Le Mans, it signals the end of an era.

Corvette has raced in the class since 1998, and in 2019 brought out the C8.R, its first mid-engine racecar, that already has achieved race wins and the 2020 GTLM title. The one-two finish at Daytona in January was the perfect welcome present for Klauser, who must now decide on the future positioning of the cars. 'Before I took on Corvette, I had Cadillac and Camaro so those were already known entities. The big change is taking on Corvette as well,' she says.

Work smart

'The whole point [of doing that] is to try and figure out how we can be smarter on how we do the programmes as a whole. Before we were operating more in silos. You can't make good decisions for the company – to be efficient and to be budget conscious – when

If you're able to look at it holistically, you can be a lot smarter, and that's the point here

Klauser takes on Corvette just as the GT LM class is about to end after the 2021 season. Will we therefore now see a GT3-spec C8.R?

It's more about keeping an eye on budget, future direction and planning

you're operating as totally different entities. If you're able to look at it holistically, you can be a lot smarter, and that's the point here.

'The good news is all of these programmes are incredibly strong. We've got great teams and solid partners that support all of this, so it's more about keeping an eye on budget, future direction and planning, and just in general how GM is presented in the paddock.'

There are some decisions to be taken quickly. Does Corvette build a GT3 version of its C8.R, and with that have to sell 20 cars in the first two years in order to meet homologation criteria? Does the new-for-2023 LMDh category, with mild hybridisation, fit with the future trend of Cadillac, which GM has committed to electric mobility? How does GM retain a grip on costs with such major programme changes coming?

Platform shoes

'We knew changes were coming,' says Klauser of the position in which she finds herself. 'We know we can't run GTLM next year, and the DPi era is going to come to an end. If we want to stay in prototype racing, we accept we have to pony up to the LMDh platform.

'Since October, we've been going through everything. We've been checking all the platforms, trying to see what relates back to production for us, and we are looking at how we can do this with a balanced budget. What and who do we want to work with? Where do we want to put our brands? If we could do racing from scratch, what would we want to do?

'Unfortunately, nothing is confirmed right now because the way things work in the big company, you'd go through all the effort, get your package together and take it up in that first round of leadership. They get to massage it a little and add their sway and then it goes to the next round. And then eventually it goes all the way to the top. If they say this is great, we then have to figure out how to fund it.'

Company profile

For Cadillac, which has committed to a full electric production car line up by 2035, the spec hybrid LMDh platform does not meet the company's profile. There is certainly a danger, then, that the DPi programme will be brought to a close at the end of this era of prototype racing in the US when the regulations change in 2023.

'If you think from a practical standpoint, what we should be doing is pure electric racing,' says Klauser. 'On the flip side, the technology is not there to do the things we know and love, like the 24-hour races. That would be very interesting to do from pure electric power, but you would have to change battery packs.

'So, we're not ready to let go of the historical type of racing we've been doing now for generations with the Corvette and Cadillac. We don't want to give up on things like the Rolex 24, we want to still participate in them, we see value in that.

'IMSA and the ACO are looking at doing the hybrid as kind of a stepping stone. It's interesting that we're getting into the electric side, because pure electric racing fits better with our portfolio. But what do we want to do as a total package? You have to evaluate what your options are first, and there are a couple of electric series out there, but not necessarily a good fit for us.'

Electric radar

If GM is looking at electric racing, the FIA's electric GT series is certainly on Klauser's radar. It's not clear whether or not this could be for a Corvette GT3 platform car, or for the Camaro GT4, but GM is certainly interested in running electric product-based cars.

'I think it's good that IMSA and the ACO have this hybrid platform, LMDh, because I think we all know we have to change,' she says. 'The industry itself is changing. We can't just keep doing what we've been doing for the past century and think that it's going to be relevant. At some point, people are going to look at us as old dinosaur technology, and they don't want anything to do with us.

'So, we're taking our first steps here, and the GT electric platform that SRO is looking at is interesting. It's all going to be uncomfortable because it's something we haven't done before. But I think people taking leadership in these areas and pushing the OEMs to start thinking about this is good. GM is definitely trying to take a leadership in the industry side, going to electric and all that. So I think in racing you're going to see similar things happening, as long as the technology can match up with the show.'

While racing looks set to increase its reliance on customer programmes, that's not how Corvette has traditionally raced. There were some customer programmes with the C5.R in Europe, but the brand has never geared up in the way it would have to for GT3 competition. Conversely, the Cadillac DPi programme has been solely customer racing-based, yet with increased competition from Porsche, Audi and Acura already announced, Klauser is worried that the basis of the top category will change. One of the drivers behind that is the ability to race at Le Mans, which was never available to DPi teams, but which is certainly attractive to the VW Group organisations.

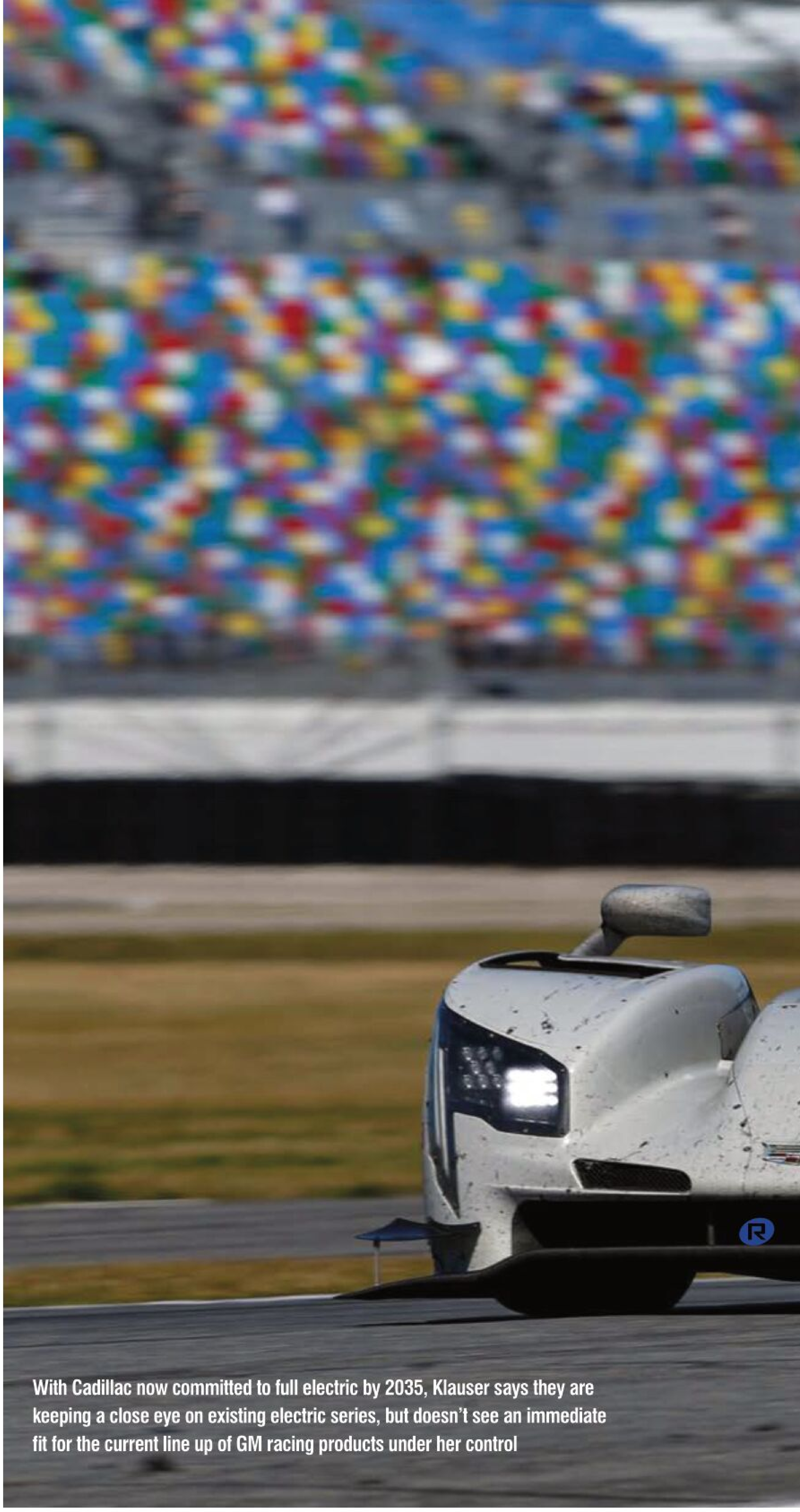
Customer programme

'It's very clear by the rules that you have to build quite a few cars in the first couple of years,' says Klauser of a future Corvette GT3 programme. 'Really, the only way to recoup costs there would be to have a customer programme. So that is definitely on the table, and we're not we're not shy or running away from that. If that's where we choose to play, I think it's highly likely that we would be doing the customer programme, because it's the only way that makes sense for the rules and the requirements.'

Running a factory-based programme for the top prototype category and against such competition could mean that GM has to consider a full factory-backed effort to win the big races.

'[Regarding LMDh], it's going to depend on how much money GM is going to let us spend. We have been very lucky that what we have with GTLM and DPi. We have done it in a way that is economical for racing.

'Looking to the future, would we do it exactly the same way with the new platforms? I don't know if it's the right fit for LMDh. There are some serious competitors that have announced they're coming in. If you look back historically, with what happened in LMP1, being able to be a little bit closer knit in a factory-style situation gives you a lot more control over the programme. I think staying pretty close in that arena is probably the right move.



With Cadillac now committed to full electric by 2035, Klauser says they are keeping a close eye on existing electric series, but doesn't see an immediate fit for the current line up of GM racing products under her control

'But on the flip side, some of these competitors have come out and said they're going to be doing customer racing with the prototype platform, and that's very interesting to me. These are the things we're working through.

'We've got great relationships with various teams, so there's definitely not a shortage of people that would love to be racing with us.'

Future mobility

On the topic of future mobility, the industry is still unsure where it will go, and racing series have been falling over themselves to provide opportunities to race. Electric is serviced by such as Formula E and Extreme E, hybrid by Formula 1 and endurance, and now Le Mans is looking at introducing hydrogen technology. Manufacturers are sitting in the technical working groups for each of these series, and more, trying to build a business case to take to their board of directors, but even there pitfalls await.

'We are all taking things in a slightly different direction,' confirms Klauser. 'The tricky thing is if we all pick different things,

We don't want to give up on things like the Rolex 24, we want to still participate in them, we see value in that

Ultimately, they want to have a packed grid with a good show, because that's how racing will stay relevant, and we need to make sure we're set up for that

and then you end up with one or two cars here, one or two cars there, and that doesn't work either. I think we saw that in GTLM.

'That's part of the reason I believe IMSA have made the decision they have [with LMDh]. They want to have a really strong class with a lot of cars participating as it's better for the show. We get it.

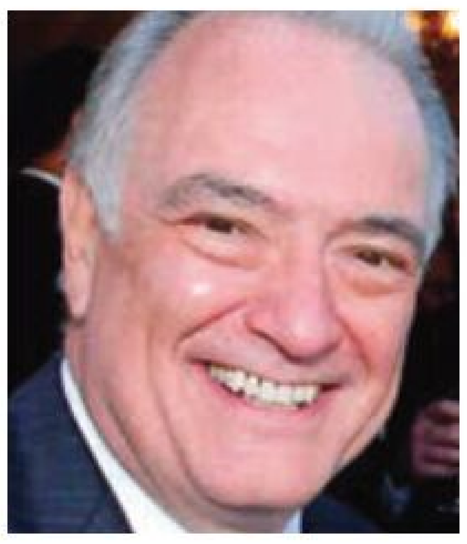
'So, I think, similar to what you're seeing in the industry. It's good to have these options so they can figure out where most of us are going to lean towards, and what makes more sense for us. And then I think they're going to have to probably phase some things out. You will see when the dust settles that this one over here has five interested, that one has seven, and then this has one or two. You can see naturally what's going to happen there.

'For most of the sanctioning bodies we sit on the councils and we talk to each other, which is great, because only when we sit down and understand where each of us are at can we help plan for the future, and talk about what we would buy into vs what doesn't make any sense to invest in.

'A lot of that has been happening before the LMDh platform was released. We had those discussions pretty regularly about adding a hybrid and I think those are important to figure out where everything should be going. Ultimately, they want to have a packed grid with a good show, because that's how racing will stay relevant, and we need to make sure we're set up for that.'

There is change afoot, be it from the racing series organisers changing their class structure, or from the industry that's still unclear about future fuels. Having an engineer to streamline and take General Motors forward could be an inspired move.

For Anything You Race



Listen, learn and adapt

Opportunities will follow confusion, but first you've got to be in the race

Lockdown slump. Biggest economic collapse for centuries. Brexit problems unresolved. Tesla share price up 420 per cent. Incomes rise two per cent in 2020. UK business has £100bn in cash reserves. Households have 'accidental' savings of £250bn…

Sound familiar, and at the same time confusing? I'm not surprised. These are the headlines in just one UK newspaper on day of writing. At the same time, the Bank of England says, 'UK has emerged from the worst recession in 300 years with households and businesses ship-shape. The UK economy is like a coiled spring, growth could hit 10 per cent or more this year.'

Unsurprisingly, many contacting the MIA are dealing with difficulties from this confusion, but most appear to feel positive about the future, despite no clear way forward following Brexit, Covid and economic recovery.

I am lucky that the MIA gives me daily contact with many in the motorsport and high performance automotive (HPA) industry. I listen and learn from their opinions and hear their cautious optimism.

Valuable race

The short 10-year timeline to ban fossil fuels is accelerating an exciting race to develop and deliver new powertrains. I doubt governments realise how many alternatives to their preferred battery solution will emerge to join this valuable race.

Legislation controlling consumer vehicle choice, a life essential for many around the world, is likely to meet yet unknown problems. Nations will react very differently as local interests and their abilities to embrace these changes vary greatly.

Hybrids, batteries, fuel cells, hydrogen, synthetic and variants of sustainable and biofuels will each accelerate their development, with outstanding success and disastrous failure.

There are certainly some exciting prospects as we enter a decade of extreme change in HPA and motorsport. The motorsport-based supply chain challenge now is to find which horses to back in the race.

Most car makers, large and small, will need motorsport-bred capabilities, technologies and experience. It is too early to say which will emerge as winners but, if you want to be in the race, you need to make the right choice now. And to do this, you must listen, learn and take advice from experienced leaders, and question key influencers who know the strategic ambitions of automotive and motorsport organisations. Help is at hand from the MIA, as you will read below.

Business activity in motorsport mirrors the wider economy and, having survived an extraordinary year, business after this first quarter seems relatively secure.


Jakob Ebrey

The BTCC expects that 30 per cent of its grid will be new cars in 2021

We cannot predict when fans can return to races. However, series with TV packages are positive and confident with full grids, good sponsorship and flexible calendars, if currently still affected by Covid. Surprisingly, there are many new racecar builds, too. BTCC expects 30 per cent of the grid will be new cars, which represents an extraordinary level of investment.

Historic and club racing, relying on private funding and few spectators, will be active with owner drivers spending their 2020 savings. In the USA, TV-supported series are doing well with increased viewers. Season openers at Daytona, the 500 and 24-hours, had exciting, close racing.

Rallying is having a tough time as its need for extensive tracks in public areas during Covid is making life difficult. Unfortunately, vital circuits not hosting TV-based events will struggle too, as will city-based racing, again due to Covid.

Motorsport Valley UK-based suppliers selling to domestic and international HPA and motorsport markets, on the other hand, are confident. They are enjoying good sales and reasonable profits by keeping reduced costs under control, even though Brexit is causing irritation and harm.

Short-term planning

How can you create a sensible, short-term business plan to meet such changes and challenges when 'navigating without a map?' My advice is to speak to senior successful business people with motorsport and HPA experience, and listen, learn and adapt their advice to your situation.

For 18 years, our popular Energy Efficient Motorsport (EEMS) conference has focussed on new, energy-efficient technologies, but this year's is different. Business planning help is the focus of the 2021 EEMS online conference on 24 March, so don't miss it. See https://the-mia.com/event/EEMS2021

Outstanding international motorsport and HPA business leaders will share their insights and knowledge to help you create short term business plans. You will hear from and question the likes of David Richards CBE, Pat Symonds, Jost Capito, Andy Cowell, Ulrich Baretzky and Iain Wight, amongst others.

Delegates will have the opportunity to understand the various entries in the 'race to 2030', and those that are most likely to succeed, as well as any with weaknesses. This knowledge will guide you to supply more entries in the race, with confidence and awareness of potential difficulties.

This is easily the most confusing and challenging business landscape for decades, but with energy, good ideas, excellent people, agility, speed of reaction and a sound marketplace, I am confident that the motorsport sector will succeed.

The biggest danger facing the business of motorsport right now is remaining static while all around us changes.

Please share your views and contact me on info@the-mia.com. I wish you every success, and we'll meet online at EEMS on 24 March.

The motorsport-based supply chain challenge now is to find which horses to back in the race

The International Journal of Motorsport Technology
Racecar engineering

PIT CREW

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

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

Chief sub editor
Mike Pye

Art editor
Barbara Stanley

Technical consultant
Peter Wright

Contributors
Chris Aylett, Mike Blanchet, Lawrence Butcher, Jahee Campbell-Brennan, Charles Clarke, Leena Gade, Simon Marshall, Danny Nowlan, Mark Ortiz, Brent Wright

Photography
James Moy

Managing director – sales Steve Ross
Tel +44 (0) 20 7349 3730
Email steve.ross@chelseamagazines.com

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

Circulation manager Daniel Webb
Tel +44 (0) 20 7349 3710
Email daniel.webb@chelseamagazines.com

Subscriptions and Marketing manager
Luke Chadwick **Tel** +44 (0) 20 7349 3700
Email luke.chadwick@chelseamagazines.com

Publisher Simon Temlett
Managing director James Dobson
Chairman Paul Dobson

Editorial and advertising
Racecar Engineering, Chelsea Magazine Company, Jubilee House, 2 Jubilee Place, London, SW3 3TQ
Tel +44 (0) 20 7349 3700
Fax +44 (0) 20 7349 3701

Subscriptions
Tel: +44 (0)1858 438443
Email: racecarengineering@subscription.co.uk
Online: www.subscription.co.uk/chelsea/help
Post: *Racecar Engineering*, Subscriptions Department, Sovereign Park, Lathkill St, Market Harborough, Leicestershire, United Kingdom, LE16 9EF

Did you know you can manage your subscription online?
Oversee your print and digital subscriptions online today simply by signing up at
https://www.subscription.co.uk/chelsea/Solo/
Stay up to date with the latest issues, update your personal details, and even renew your subscription with just a click of a button.

Subscription rates
UK (12 issues) £89
ROW (12 issues) £100
racecar@servicehelpline.co.uk

Back Issues
www.chelseamagazines.com/shop

News distribution
Seymour International Ltd, 2 East Poultry Avenue, London EC1A 9PT
Tel +44 (0) 20 7429 4000
Fax +44 (0) 20 7429 4001
Email info@seymour.co.uk

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

THE CHELSEA MAGAZINE COMPANY LTD

www.racecar-engineering.com

Lockdown musings

Strategy is the art of long-term planning and policy

I confess to being confused over the proposals for the future of Formula 1. Past attempts at 'improving' qualifying were an unmitigated disaster, and the sport should be looking to never repeat them. Yet here we are with a proposal for qualifying races and performance-balanced engines in the future. Worryingly, as this is written less than two months before the start of the season, there are few details on the table and more questions than answers. Matters such as mileage on component parts, spare cars in the event of an accident, coupled with the restrictions on the time mechanics may work on the car, are just the tip of the iceberg.

The first question to ask, then, is why are they looking to do this? Are they trying to make the weekend more attractive to fans so they can sell more tickets on Friday, when qualifying for the qualifying race will happen? Or are they unhappy with the qualifying format itself? Are they therefore looking to find a less predictable way of setting a grid for the main race on Sunday?

Then you have to move to *what* they are proposing. Is this the best way of engaging fans throughout the weekend? Will it increase the amount of time fans spend watching the cars on track? Does that increase the amount of television advertising they can attract on Friday? Is this the best way to reduce predictability?

Under pressure

What does it mean for the teams? They have to prepare for qualifying on the first day of track running, which then increases the pressure on them to prepare in advance. With more races introduced to the calendar sometime in the next five years, this advance preparation is even more pressurised. Aside from the impact on the teams back at base, it also increases the pressure at the track to prepare cars for qualifying with limited running on Friday and no time to test in like-for-like conditions Friday to Saturday. Actually, this is positive, as Leena Gade wrote in her column last month, but you don't need qualifying on a Friday for that.

For the Daytona 24 hours there was a qualifying race that replaced the pre-season test. I thought it was a great idea. The pre-race test normally takes place the first weekend of the year, which leaves teams and track preparation staff with limited time to enjoy New Year. Running early in January is unrepresentative of the race at the end of the month as the air and track temperatures are different, so the whole thing is a waste of time and effort.

The qualifying race made more sense, but trying to explain that pole position was for a qualifying race and not the main event was just one layer of complexity that was wasteful. It also meant no one took the qualifying race seriously as they stood to take performance balancing penalties ahead of the main race if they went too quick.

No matter what race you contest, there is only one lap that really matters, and that's the last one on Sunday. Anyone who watched the Daytona 500 would know that. Right now the focus for Formula 1 appears to be the first lap, and that might be a clue where to start looking.

Making that last lap something special in Formula 1 is, I think, more important than a qualifying lap on Friday. Artificially throwing a safety car would make a mockery of the rest of the weekend, and so is not an option. Such is the speed of pit stops and prescribed tyre allocation that introducing a compulsory stop in the last half of a race would also not make any difference at all.

The answer to livening up the last lap comes from offering teams different strategic options

My answer to livening up the last lap woud be to offer teams different strategic options. Making it less certain whether or not to change tyres once or twice during the course of a race could be managed by introducing different race lengths. Endurance racing reduced the number of tyre guns that a team can use. Slow the pit stops down and make it advantageous to change two tyres to gain track position at the final stop. It worked in the final race of the GT World Challenge in 2020, with Ferrari taking the title after a ballsy pit call, and it worked for Acura at the Daytona 24 hours. But it equally might *not* work – a team that stretches their tyres to the flag may run out of grip, or make a mistake under pressure.

The engine freeze is interesting in that it has allowed Red Bull Powertrains to enter the market with Honda's technology, and investment to maintain competitiveness will be limited. Christian Horner has hinted that there will be a method to ensure no one is left behind in terms of power and Stewart Mitchell discusses in his piece at the front of the magazine how it will be managed. However, what interest do the performing teams have in allowing an under-performing one to become more competitive, and thereby a greater threat to their prize fund?

I think Formula 1 is focused too much on the first lap, and might like to consider the last to be as important.

ANDREW COTTON Editor