FERRARI WEC: GT Competizioni boss on Hypercar programme p76

Inside the world of modern motorsport technology

Congression of m

UK £5.95 / US \$14.50 • May 2021 / Vol 31 No 5 • www.racecar-engineering.com

# F1 planning 44VD future

Moveable aero and synthetic fuels key to efficiency drive

#### Plus!

Technical directors under the spotlight ahead of 2021 season

#### **LE MANS**

Glickenhaus 007C Hypercar breaks records in testing

#### **RALLYING**

MSport's new Ford R3

contender in focus

#### **CARBON CAPTURE**

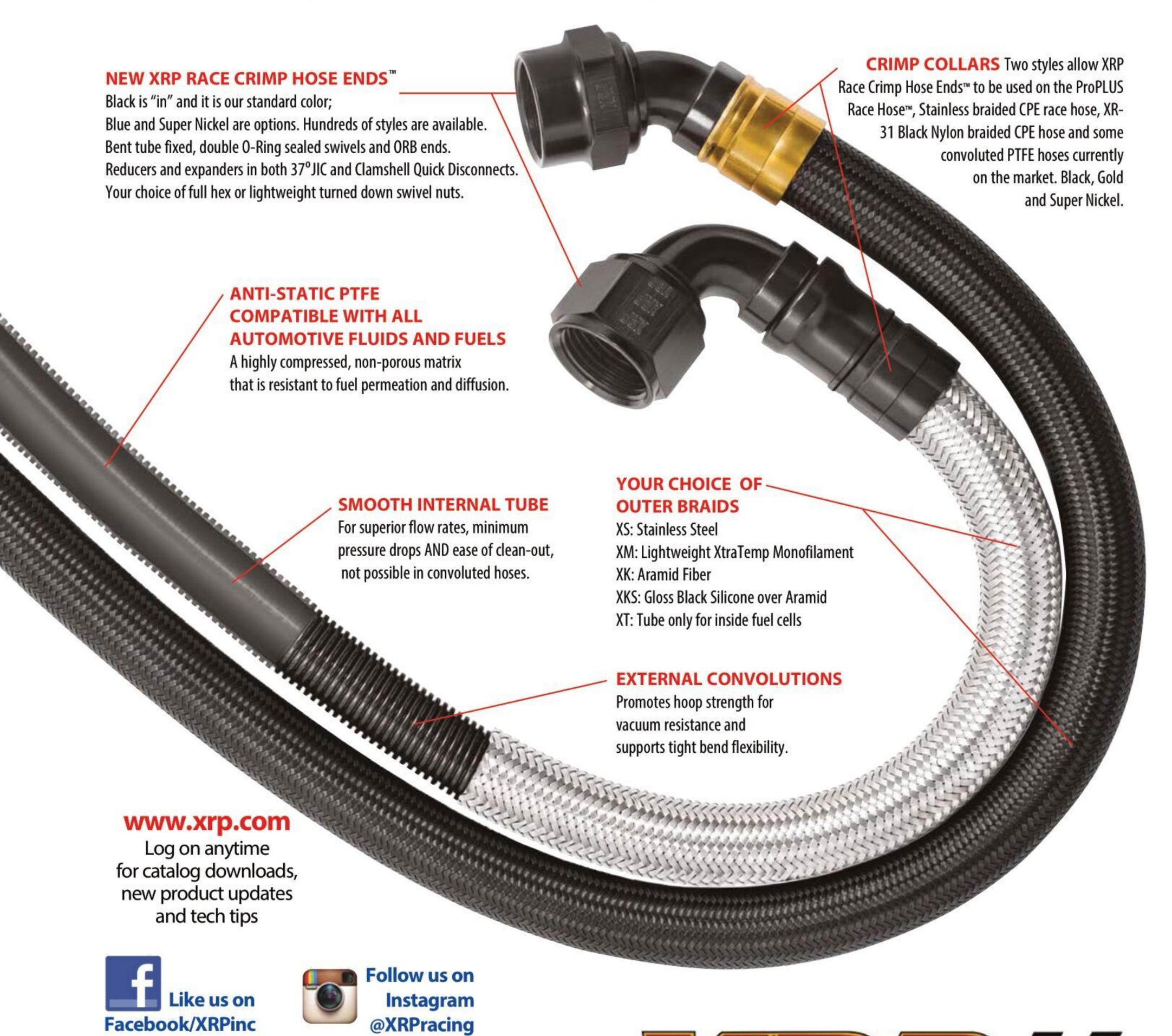
Revolution Racecars takes next step in safer construction



#### THE EVOLUTION IN FLUID HORSEPOWER

# XRP ProPLUS Race Hose and XRP Race Crimp Hose Ends

A full PTFE smooth-bore hose, manufactured using a patented process that creates convolutions only on the outside of the tube wall, where they belong for increased flexibility, not on the inside where they can impede flow. This smooth-bore race hose and crimp-on hose end system is sized to compete directly with convoluted hose on both inside diameter and weight while allowing for a tighter bend radius and greater flow per size. Ten sizes from -4 PLUS through -20. Additional "PLUS" sizes allow for even larger inside hose diameters as an option.



5630 Imperial Hwy., South Gate, CA 90280 XRP, Inc.

Tel: 562.861.4765 Email: sales@xrp.com

In Europe Protec Fuel Systems Ltd.

Tel: +44 (0) 121 572 6533 info@protecfuelpumps.com



THE XTREME IN RACECAR PLUMBING

#### **COVER STORY**

14 Formula 1 2025 Synthetic fuels and 4WD for F1 in the future

#### COLUMNS

- **Stewart Mitchell** The real meaning of sustainability
- **Mike Blanchet Customer care and** crew chief conflict

#### **FEATURES**

- Formula 1 preview How teams have coped with **Covid-era regulation changes**
- **20** Glickenhaus Hypercar The stage is set to take the fight to Toyota
- 28 IndyCar The ongoing battle for stability at unusual angles
- 38 MSport Rally3 The first of a new breed of Rally Car
- 46 Lancia D50 Badge engineering in the 1950s

#### **TECHNICAL**

- 55 The Consultant The long arm of the chassis law
- 58 Optimum G Calculating anti-roll bar stiffness
- **62** Revolution Racecars The A-One's radical new tub concept
- **70** Danny Nowlan Questioning the value of bump steer

#### **BUSINESS**

- 76 Interview Ferrari's Antonello Coletta in the spotlight
- 78 News All change, no change and cheap for a change
- 82 Bump stop

After a bruising Sebring 12 hours in Florida, the JDC Miller Cadillac emerged as an unlikely winner. Having endured a large crash mid-race, it finished with a broken rear wing

Subscribe to Racecar Engineering – find the best offers online www.chelseamagazines.com/CRCC215

Contact us with your comments and views on **I** Facebook.com/RacecarEngineering or **I** Twitter @RacecarEngineer

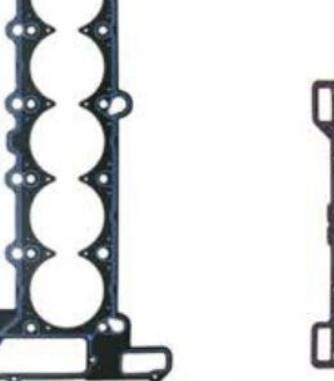


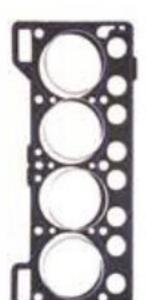
# MADE IN THE USA MADE FOR THE WORLD

Learn more about
Hastings Piston Rings at
www.hastingspistonrings.com.

### ATHENA

#### ATHENA RACE HEAD GASKETS





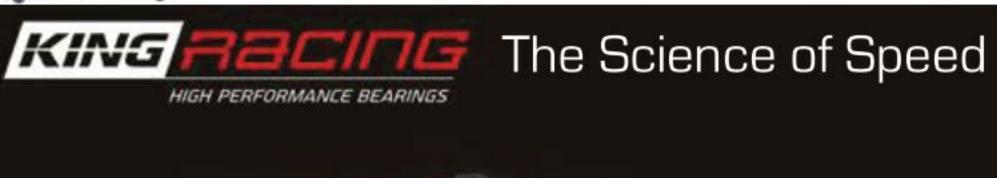














2nd place is for the other guy

XP BEARINGS - Tri-metal, Copper-lead HP BEARINGS - Bi-metal, Silicon Alloy



### ENGINE PARTS (UK) LTD

Purfleet: 01708 890494 sales@enginepartsuk.net







### Subjectively sustainable

#### To achieve true sustainability, we have to look beyond the obvious

ustainability is a word that's thrown around a lot these days. By definition, sustainable means 'able to be maintained at a certain rate or level' or 'conserving an ecological balance by avoiding depletion of natural resources.'

Across motorsport and the automotive industry in general, there is a lot of discussion about sustainability, which primarily revolves around synthetic fuels and alternative powertrain solutions. However, its definition seems to mean different things to different people, and the delta between the most sustainable and the least sustainable is vast.

If one just looks at renewable fuel production, hydrocarbon fuels and, in particular, alcohols for use in internal combustion engines, can be made from organic matter that can

be grown and harvested. But consider the rate of consumption per kilogram of fuel is significantly higher than the amount of time it takes to grow and process a kilogram of renewable organic fuel.

In fact, all the ingredients to produce alcohols, petrol and even jet fuel exist in the air, though the chemistry to turn air into a fuel is complex and energy intensive. As such, at the moment it is impossible to produce fuel using this method in a sustainable way. However, the process does take CO<sub>2</sub> out of the air, and carbon capture is something that should definitely be encouraged, even if it is soon to be returned to the air in another form.

#### **Carbon capture**

The methodology and chemical process undertaken during carbon capture can also be used to produce feedstocks for plastic production, or other long-chain liquid hydrocarbons that have a quasi-infinite lifecycle if they are properly recycled. Additionally, if we take CO<sub>2</sub> from the air and convert its use into construction or transport, we can essentially start to reverse the CO<sub>2</sub> problem. If the fuel burned in internal combustion engines becomes carbon neutral, it becomes a real prospect for sustainability.

Electrification in the automotive market, and in motorsport, has received a lot of positive press over the last decade, and even big OEMs are ceasing their internal combustion engine development left right and centre in a bid to win the hearts and souls of the green-minded legislators and governments around the world.

Electric car emissions are created away from the use phase, so are widely accepted, and lauded in terms of local air pollution and health issues in cities as they mitigate particulates, hydrocarbons and NOx. If we ignore range and charge time, one of the main challenges for electric vehicles at this stage is clean production of efficient powertrain.

This includes things like neodymium and samarium cobalt magnets for high-efficiency permanent magnet synchronous motors, as well

The Porsche 919 hybrid drive system – the crown jewel of one of the most efficient racing powertrains ever produced

as nickel-manganese-cobalt-based, lithium-ion cell technology. At the moment, the intense energy consumption in the manufacturing phase, including the extraction of raw materials for production of electric vehicles, means their footprint is significant, albeit not to the end user.

There is a huge amount of progress being made in the lithium-ion battery development space, with technologies such as cathode chemistry design being explored in the hope of delivering cathodes that hold more charge, are better suited to withstand prolonged cycling, and promote ion mobility - all of which could be used to increase the range and acceleration of electric vehicles.

Improved cathode design could also help reduce the dependency on cobalt for cells.

With ethical, sustainability and cost concerns surrounding cobalt, development like this will drive alternatives to the traditional cobalt containing cathodes and investigate a range of new cathode architectures and chemistries that could mitigate its use altogether.

Other current projects look to revolutionise how electrodes for lithium-ion batteries are manufactured, ushering in a new generation of smart, high performance electrodes.

Also on the horizon is sodium-ion battery technology, which could be used for static energy storage and low-cost vehicles.

With all the contemporary electric vehicle technology, and that which is on the near horizon, it would be foolish to think EV not part

> of the solution, even though the infrastructure needed to support a largely electrified transport network, and the generating capacity to keep everyone moving, is not yet here.

#### **Private challenge**

However, with all of the significant advances taking place in the motor vehicle powertrain engineering environment, it all seems futile when we consider private vehicle use. If one considers the amount of time private cars are used to travel from one location to another, most cars travel for less than six per cent of the time they are owned.

The biggest challenge private vehicles face is that they must have the energy storage, powertrain and occupant capacity all inside one autonomous (not in the self-driving sense) box. This is where the inefficiency lies.

If we consider private vehicle use strictly as transportation, shouldn't we be completely re-thinking the whole concept of transport? Surely the time, effort, money and brainpower going into private vehicle development could be used to create a completely different transport infrastructure, one where moving from one place to another is re-imagined in a whole new way – one that B is truly, and by definition, sustainable?

If the fuel burned in internal combustion engines becomes carbon neutral, it becomes a real prospect for sustainability



Design & manufacture of an adaptable range of set up, pit equipment & flight cases.







- Set up & pit equipment
- Flight cases
- Custom design work
- 3D printing & laser etching

Exclusive UK distributors for Fuel Safe Racing cells and exclusive distributors for Europe of ARE dry sump components









Complete dry sump systems for a wide range of vehicles.



Stock & custom made fuel cells with FIA certification.



Distributors for FEV fire suppression systems.

For more information visit our webiste or call us now.



Website: www.vmep-ltd.co.uk Email: info@vmep-ltd.co.uk Tel: 01789 453 967



@visionmotorsportengineering



### The age of conflict

The build quality of customer racers has improved since the good old days'

n the 1980's IndyCar, two British companies, first March and then Lola, introduced production racecars to the premier US open wheel motorsport world.

Previous to the successful Indy 500 forays by Lotus and Lola with F1-inspired machines, the traditional front-engined 'roadsters' dominated USAC. Constructors such as Kurtis Kraft produced limited numbers, but not on a series basis. Other engineering shops would design and manufacture components - chassis, suspension parts, gearboxes - which teams could purchase and around which they would build their own-named 'specials'.

The clear superiority of the mid-engined British makes led to copies being made in the US and individual designs based on the development of these concepts were commissioned. Lola's 1978 Indy 500-winning T500 persuaded makes such as Parnelli, Watson and Vollstedt to again follow, with Penske and McLaren producing several customer cars.

Jim Hall's F1-mimicking, groundeffect Chaparral brought sophistication, but at a significant cost.

But the much lower design and manufacturing costs prevalent in the UK at the time, together with the volume production experience and structure of a wide variety of single-seater and sportscars built up over many years, could not be reproduced in the States.

March was the first to exploit this market, closely followed by Lola (Reynard came along much later).

#### **Crew chief syndrome**

In the early phase of dealing with the American teams, one would frequently come across 'crew chief syndrome'. Long established as the core around which the team revolved, they wielded great influence on the team, and especially on the owners, many of whom at that time were not technically minded. To these rich businessmen, IndyCar was a passion and a hobby, so they relied heavily on the crew chiefs to run the show.

These sometimes rather colourful characters knew a lot about this type of racing, especially the unique demands of ovals and speedways, and often were damned good at their jobs.

Equally, many were not up to speed with the move from their intuitive, empirical engineering to the scientific, data-based approach required with the new, more aero-dependent racers.

Unsurprisingly, they were defensive of their rôles, and one can understand their resistance to young engineers coming over from Europe and telling them they'd got it all wrong!

These whippersnappers had a lot to learn in return, but it caused conflict until the betterfinanced teams began to build their own engineering resources. Working directly with the constructors' designers, and frequently having them embedded in the team for the race season, eventually helped to create a more productive, less caustic relationship.



The 1980s saw intense competition between Lola (pictured) and March both on track for results, and off-track for customer contracts

It must be said the general health and wealth of IndyCar at the time, and consequent sales / production demand led to serious issues with quality control. Bodywork, especially, was often extremely ill fitting, causing a lot of painfulto-receive disgruntlement. The biggest steps in accuracy of fit and finish were the moves to CAD / CAM design and manufacture, and to carbon composite instead of GRP bodywork, combined with improved assembly processes and communication.

Nevertheless, I'm amazed now at the minimal amount of information that was supplied with the cars, compared to that provided these days. One reason, of course, was the fierce rivalry between the two constructors, and the justifiable suspicion of tech transfer. Indeed, money did change hands sometimes! Not a factor now with

Dallara being the single chassis supplier, but the huge expansion of digital technology and the internet have also made a vast difference.

#### Change for change's sake

While accepting valid criticism of manufacturing issues, at Lola we were extremely frustrated when some teams would significantly change set-ups, and components, of new cars on delivery, without even a shakedown first to establish a baseline. It's natural for a properly operating team to inspect their new acquisition in detail, and check no assembly errors have crept in. If it's a fresh design, or a significantly upgraded version one, the engineers and mechanics will want to familiarise themselves with it. But the crew chief

> factor also sometimes extended to their own newly-appointed engineers, anxious to justify their employment by making unnecessary changes.

A lack of understanding of new kit could cause incorrect modification, and lead subsequently to rather unreasonable - occasionally arsecovering - complaints from customers when they didn't work out right. Not infrequently, reversion to the original specification proved to be the solution.

Likewise, when teams built their own cars in the Lola factory it proved immensely disruptive to the overall production progress, as did requests for deleting certain items, or replacing

them with non-standard ones.

Then there were those who failed to understand the difference between designing a fit-for-purpose production racecar (the design generally having not even been track tested due to tight pre-season delivery schedules) that can turn a profit compared to the focus a team can apply to a single car development with the luxury of being able to circuit test extensively to fully understand and fine tune their cars. Unsurprisingly, capable outfits with good engineering structures could significantly improve on the as-delivered racecars, as was always the intention. Despite all the hassle, the fierce competition between IndyCar constructors provided the keen motivational edge between success and failure which must now, surely, be missing?



Capable outfits with good engineering structures could significantly improve on the as-delivered racecars, as was always the intention

Racecar speaks with senior members of F1 at the Bahrain pre-season test to find out what the result of this most unusual lead up to a new season has been By DIETER RENCKEN

ormula 1's pre-season testing conundrum - how best to recover approximately 1.5 seconds lost due to aerodynamic restrictions and tyre sidewall construction changes has its roots in decisions taken by the sport's collective executive exactly a year apart, in June 2019 and June 2020.

The earlier decision, an agreement by simple majority to carry over that year's tyres into what would have been Formula 1's final season under the prevailing formula, in turn had a knock-on effect after the sport elected to roll over the technical regulations for another season due to the ravaging, and ongoing, effects of Covid-19. Simply put, F1 went into survival mode, but the decisions taken then have had a major knock-on effect on the 2021 season.

Retaining 2019's tyres for one more year was a commercial and technical no brainer. Sole tyre supplier, Pirelli, was well advanced with development of 18in tyres – back then slated for introduction in 2021 – and further developing 13 inchers meant splitting resources across two programmes, while projections were that teams would soon be concentrating fully on 2021's 'new era' cars. In short, 2019's tyres could cope for another year.

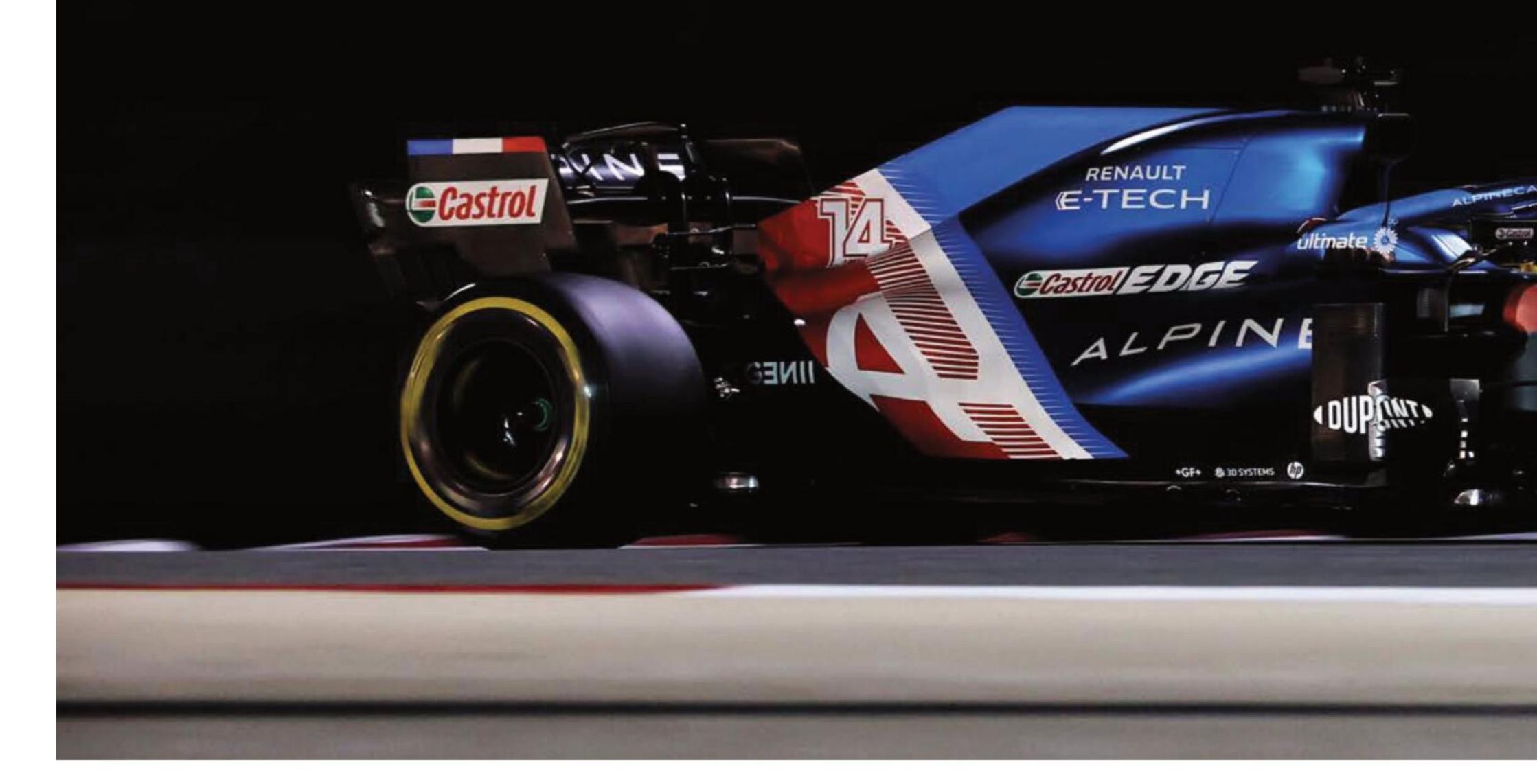
#### Revised regulations

Then came Covid, and with it various far-reaching decisions, including postponement of the 'new era'. Teams, though, had been continually developing their existing hardware, adding increasing amounts of downforce in the process. As a consequence, the FIA introduced

revised aerodynamic regulations aimed at reducing downforce to pre-2020 levels. These affected primarily floor dimensions and devices.

However, in order to prevent stagnation of the 'pecking order', the governing body allocated each team two tokens to enable them to develop their cars in strictly controlled areas. The odd team out was McLaren, which spent its tokens on switching from Renault to Mercedes power, demanding the construction of a totally new monocoque.

Pirelli was rightly concerned that a further year of aero development would place undue stresses on tyres originally developed in 2018 for the following season. Last year's British Grand Prix illustrated how close to the limit the tyres were, although to be fair the teams pushed their tyres beyond





Pirelli had to make changes to sidewall construction for its latest generation of tyres for Formula 1, and each tyre is now heavier than those used in 2020

The broad consensus... was that floor and associated aerodynamic changes amounted to a loss of a second per lap at the Bahrain circuit. Tyre loss was estimated at 0.3 seconds per lap, meaning teams faced a deficit of 1.3 seconds. Some put it at 1.5 seconds



Mario Isola, Pirelli car racing manager



#### FORMULA 1 - SEASON PREVIEW

the usual change points in that race after various incidents disrupted strategies. Still, the shredded rubber set alarms bell ringing.

A more robust range incorporating strengthened sidewalls and revised front profiles was developed post haste, ready for October testing. A number of drivers criticised the performance loss and increased weight – 750g per front tyre and 600g per rear. Pirelli countered that the cars had not been optimised for the tyres, so direct comparisons were meaningless.

#### The acid test

The various changes were detailed in last month's F1 launch special, but the acid test lies in lap times not wind tunnels, CFD numbers or pretty pictures. Teams seldom reveal their full arsenals during launches, while marketing schedules generally means renders and visuals are prepared before cars are test ready. Track testing is a different story entirely.

Racecar Engineering conducted a number of interviews with team technical directors and senior team members under the full glare of pre-season testing in Bahrain to gauge the consequences of regulation changes, tyre behaviour and other challenges they encountered.

The broad consensus of opinion over the three days was that floor and associated aerodynamic changes amounted to a loss of a second per lap at the Bahrain circuit. Tyre loss was estimated at 0.3 seconds per lap, meaning teams faced a deficit of 1.3 seconds. Some put it at 1.5 seconds.

'I believe that, compared to the original [regulations], we have downforce reduction in the range of 10 per cent,' explained Pirelli's car racing manager, Mario Isola, after the close of testing. 'That was the reason why the floor was modified. Obviously, the teams were working around the modifications, and the current situation is probably a downforce reduction in the range of five per cent.'

Saliently, he predicts 'zero lap delta' by the final race of the year. However, he did give the teams an unexpected bonus before the start of the second day: tyre pressure prescriptions were reduced by a further 1.5psi, making for a total 2psi reduction over last year's rubber, and so providing improved individual set-up windows.

'Pirelli must be satisfied that they've got the integrity they wanted, and presumably it means the simulation data they received from all the teams implies load has dropped and the aero [test] rigs have done what they'd hoped [for],' suggested Williams' head of vehicle performance, Dave Robson.

Direct comparisons are complicated by the fact last season's testing was conducted in February in Spain, rather than in Bahrain's 25degC heat. Last year's Bahrain race was also third from last of 17 rounds, while this year's event opens the final season. True to F1 form, each team found different solutions to the challenges of clawing back performance, both during the design stage and in season.

#### **Top floor solutions**

'I suppose the most different, and most increasingly detailed area, has been the top of the floor where we've lost the ability to use the edges of the floor to have certain [aero] devices,' said McLaren technical director, James Key. 'There's been various, quite

different solutions as to how you can treat the floor edge and the devices on top of the floor.'

It was McLaren that created the biggest stir of the weekend after rivals had sight of the MCL35M's diffuser, with its different but clearly logical and legal interpretations of the regulations governing the strakes on either side of the (floor centre) reference plane.

'You've got a certain regulation for a continuous surface in that area within the Y 250 [mm] position on either side of the centre line of the car,' explained technical director, James Key, with reference to Article 3.7.10(c) of the technical regulations.

This article states: All bodywork that is visible from beneath the car and less than 50mm above the reference plane, within 250mm of the car centre plane and situated behind a line 175mm ahead of the rear wheel centre line, must produce only a single, continuous curve when intersected with any horizontal plane.



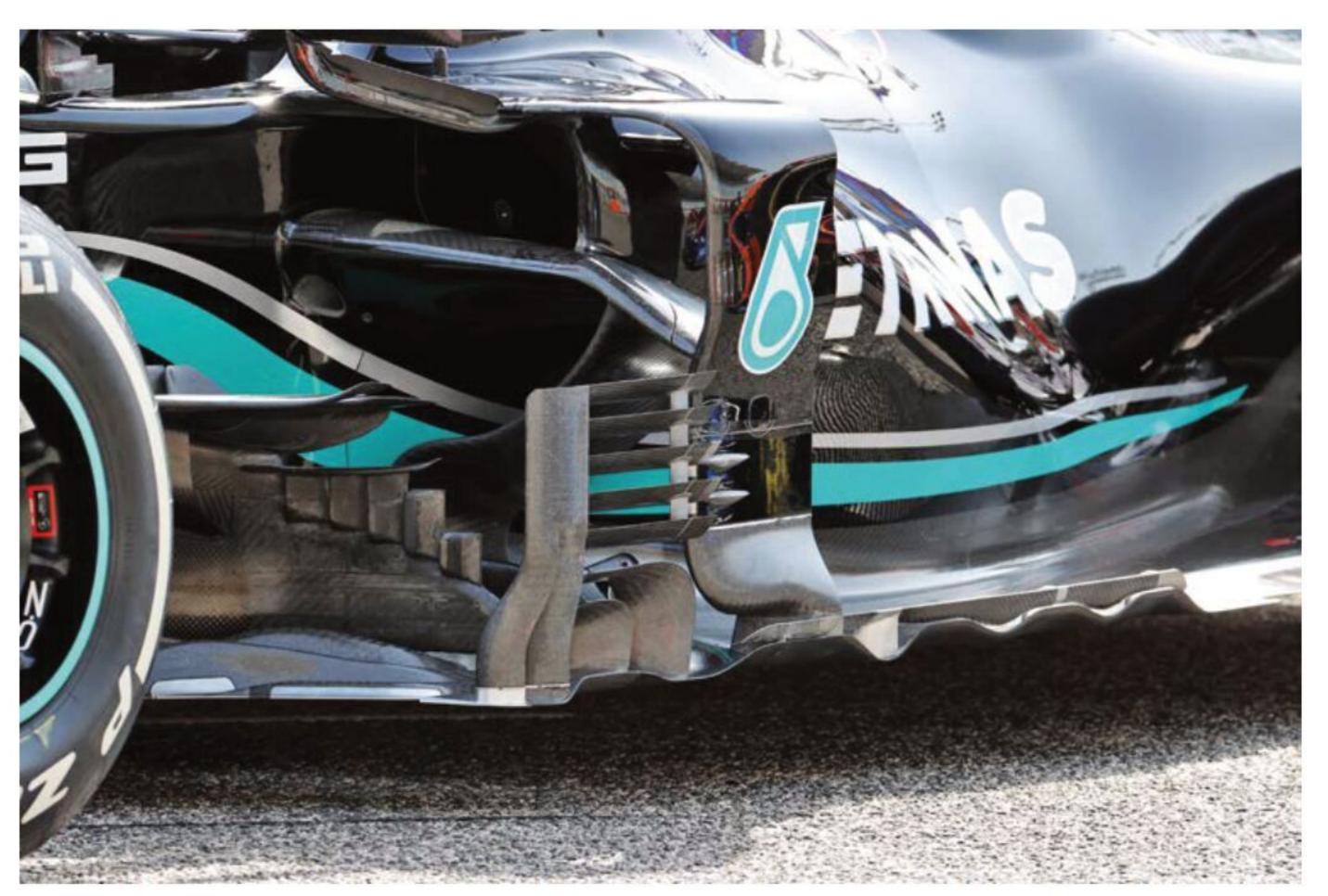
James Key, McLaren technical director



McLaren's interpretation of the side strakes on the diffuser in response to changes to floor regulations raised some eyebrows in pre-season testing



The move to Mercedes PU meant McLaren had to design a new car, but Key says the FIA understood their requirements



Mercedes turned up with a complex and innovative floor, but gearbox and apparent handling problems hampered the test

'The little vortex generators that you see on pretty much every car - the ones the rules allow – are parts that are governed by exactly the same rule, Key continued. 'It's one of those visible things that gets talked about a lot, but ultimately it's just part of a much wider picture of a complex bit of the back of a car. I'm sure it'll be forgotten by the time we get back here to race.'

In reality, the diffuser was the least of Key's design stage worries, given the team was contractually obliged to switch power unit suppliers, yet the engineers had little or no face-to-face contact with colleagues or their Mercedes counterparts due to the pandemic.

'We started with having to 'phone each other, or talk over a screen and communicate via email. We couldn't get together and discuss it ourselves, or get

together with our colleagues at Mercedes. It was a great technical challenge. Everything had to be done remotely from home, in a very digital way.

'Looking back, it was a fun, enjoyable challenge to produce some efficiencies we probably didn't know existed. The Mercedes is a great engine, it's very chassis-friendly in many respects, but it did have its challenges in that it is a different philosophy from Renault.'

Key says the biggest compromise the team faced was re-designing the chassis under homologation: 'All the bits we had to change had to be as similar as possible to last year. The FIA were really good with this. They recognised there were certain things homologated that we had to change, otherwise we couldn't build the car.'

'It's not just a case of developing the bits of the car the regulations forced you to develop. **Everything else** has to develop in reaction to changes you've made'

Jody Egginton, technical director at Scuderia AlphaTauri

The process certainly worked as, by midday on the first day's running, Daniel Ricciardo had topped the timesheets.

#### **CFD** correlation

Scuderia AlphaTauri's Jody Egginton confirmed the widely held estimate of a drop of about 30 points of downforce as a result of the regulations changes. Expressed in aerodynamic points, this figure chimes with Isola's percentage projections.

'We've done a good job of recovering it, so probably it's similar with the majority of teams, believes Egginton. 'We're flat out now trying to correlate our wind tunnel results to CFD, and also on track.

'It's not just a case of developing the bits of the car the regulations forced you to develop. Everything else has to develop in reaction to changes you've made. We've got new front suspension [and] we've got a new front wing. I'll commit to saying we've covered most of it, but now it's time for some number crunching to see exactly where we are.'

To add to the workload, over winter the team switched from its 50 per cent scale wind tunnel to sharing the 60 per cent facility owned by sister team, Red Bull.

'Our launch car was developed in Bicester, now we've moved to the Bedford wind tunnel, confirms Egginton, 'so there's some baselining needed. That is why we've probably got a bit more homework to do to understand exactly where we are now. But first thoughts are we've recovered most, if not all.'

Little did Egginton know that at the time of interview, in the hands of F1 rookie, Yuki Tsunoda, the AT02 would post second-fastest time overall behind Red Bull's Max Verstappen!

#### FORMULA 1 - SEASON PREVIEW

Marcin Budkowski, executive director of Alpine – the team formerly known as Renault – notes one side effect of the regulation changes is that correlation has been more challenging. 'When you touch an area like a rear corner, you get into correlation issues, usually between CFD, the wind tunnel and the track,' he says.

'I don't think it was intentional from the FIA to pose that extra challenge. It's usually the case when you have a new regulation, but it's proved trickier than we expected.'

#### Resource management

Budkowski went on to flag up other complicating factors: budget and wind tunnel restrictions. With 2022's cars being vastly different from the current crop, teams need to carefully plan convergence and crossover points as they no longer have the freedom to throw resources at both cars.

'Once you find that [lost] performance, you need to design parts and manufacture them. But the change is so massive for next year that you have to do it [early]. We expect teams to develop their car for a few races this year, then switch [to 2022 cars].'

He points out that new restrictions on aerodynamic testing – effectively a ballast on wind tunnel time and CFD runs – will increasingly favour lower placed teams. This implies the big three, Mercedes, Ferrari and Red Bull, will be hardest hit after previously having the freedom and wherewithal to develop two different cars concurrently.

That said, Haas faces no such choice: technical director, Simone Resta, admitted the US team has decided not to upgrade or develop its current package, preferring to spend the year, and budget, on its 2022 project.

'As a strategy, we are not planning to have developments during the year. So fundamentally, we are trying to introduce everything at the start of the season. Of course, [we will] do our best to take any opportunity that will be given, but we will move our focus onto main development for next year.'

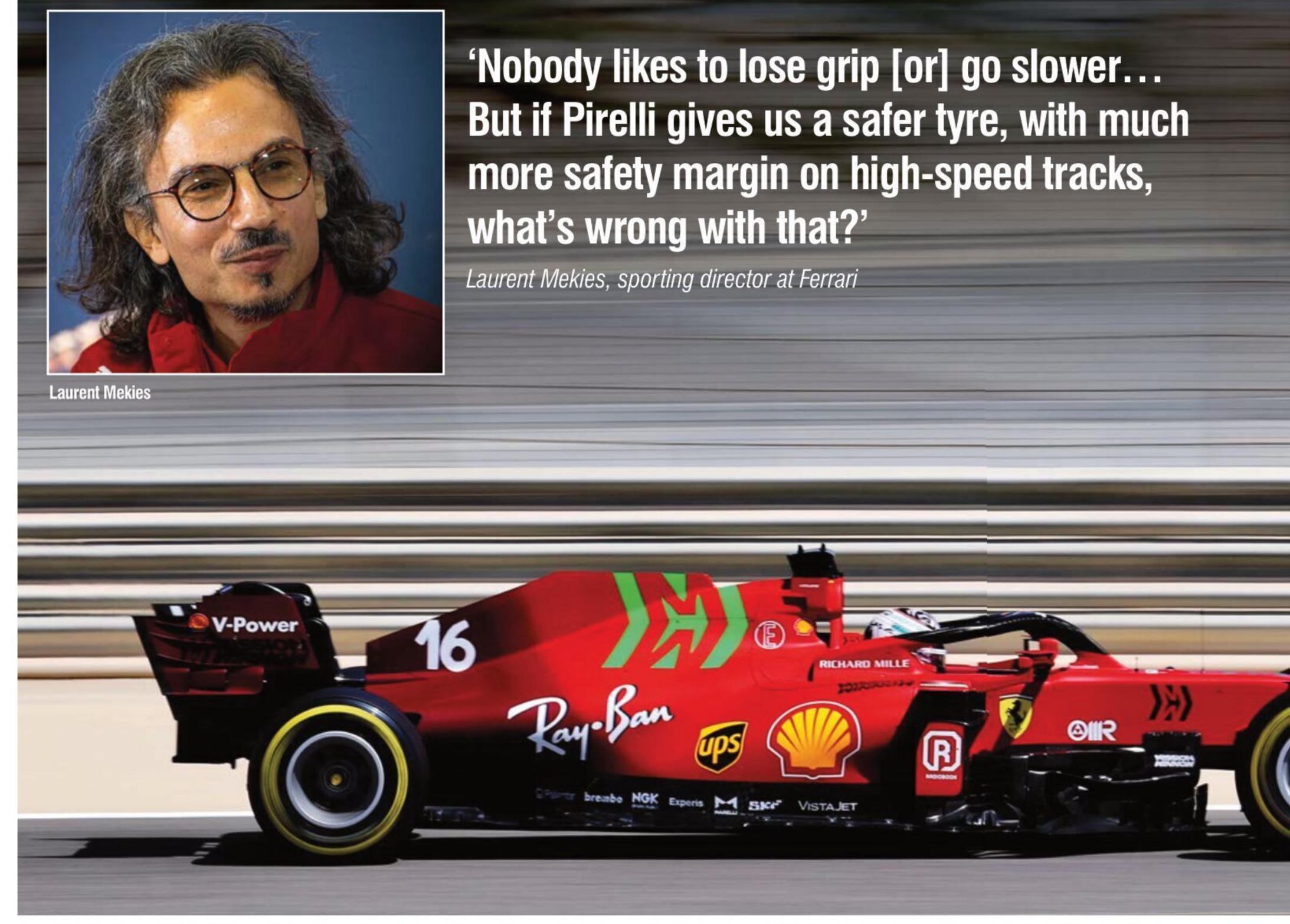
Laurent Mekies, Ferrari's sporting director, said the primary target in Bahrain was to maximise mileage, given that testing extended to only three days. During the final day's lunch break, he commented: 'So far,



Marcin Budkowski, Alpine F1 executive director

[with half a day to go] we have been running pretty much trouble free, and by the end [of the session] we are going to hit 2000kms, which is a great result for three days.

'Target number two is to model the car correlations, and we have worked in a structured way through the programme, trying not to get too distracted by what the other guys are doing. The other



Happy with the re-worked Pirelli tyres, Ferrari appeared cool, calm and collected, clocking up some 2000kms of test mileage with no apparent problems. Next stop correlation



High-rake cars, such as the Red Bull, seem to be less affected by the 2021 aero restrictions. Car was clear leader at the test

aspect is tyres. Once you have done these three things, you suddenly discover if you're competitive, or if you're not.'

Mekies says the Scuderia is fully in favour of Pirelli's decision to introduce a slightly slower, but inherently more robust, tyre construction for 2021. 'Nobody likes to lose grip [or] go slower - not the drivers, not the teams. But if Pirelli gives us a safer tyre,

with much more safety margin on highspeed tracks, what's wrong with that?

'So that's the approach we have in the team, and I think that will be embraced by everybody. Once you have forgotten about that small amount of grip you've lost, you have a safer tyre. Yes, it's a challenge because it's a new thing, but the real challenge is to ensure you will be amongst the teams that actually nail [the construction].'

#### Test gremlins

Not all teams were quite as upbeat though. Both Mercedes and Aston Martin endured fraught test sessions, the former losing most of the first day due to a gearbox glitch, the latter - a Mercedes partner team sourcing complete rear ends and other permissible parts from Mercedes - suffered similar gremlins.

To compound their problems, the aero restrictions are believed to adversely affect low-rake philosophy cars – those where the back end sits squatter - more so than high-rake cars such as the Red Bull.

'Missing practically all of the first half of the day was a setback, admitted Andrew

Shovlin, Mercedes' trackside engineering director, 'which meant we had to work pretty hard to recover it. Where we planned to do 10 or 12 timed laps on long runs, these came down to seven or eight, which is a little bit short really to assess some of the items you are looking at that might affect degradation or tyre wear.'

Reacting to allegations that the W12 looked twitchy, James Vowles, the team's director of strategy, responded: 'It was pretty evident the car was handling poorly and, conversely, the Red Bull looked what we would call 'planted', but it's also fair to say we have huge amounts of data available to us, and now a long journey lies ahead to understand what was causing that.'

Let's not forget, though, that Mercedes does have a reputation for sandbagging...

#### Conclusions

So, what did the teams (and Racecar Engineering) learn after the first pre-season test held outside of Europe since 2014? First off, Pirelli's tyres seem to tick all 2021's boxes. Secondly, all (and more) of the missing downforce will be recovered before teams switch to developing their 2022 cars. Thirdly, crossover points for making the switch will vary according to performance relative to the immediate opposition.

Finally, based on its showing at the Bahrain pre-season test, Red Bull goes into the first race weekend (which took place after Racecar went to press) as the clear favourite after what F1 consultant, Helmut Marko, termed 'the best start to a season for Red Bull yet.' Still, he also confirmed he has nagging suspicions that Mercedes either did not show its full hand, or will overcome its apparent handling niggles.

In other words, even after three days and 15,000 cumulative kilometres of highspeed testing, the final season under the current formula remains wide open.



#### Fastest times from pre-season testing



For reference: pole position time at the 2020 Bahrain Grand Prix, set by Lewis Hamilton, was 1m27.264s, though direct comparisons are meaningless as fuel loads and tyre conditions are not known

# Fuel for thought

With sweeping changes on the horizon for F1 in 2025, Racecar asks some of the key decision makers how 'the change' is progressing

By DIETER RENCKEN



F1's 2025 engine format could conceivably play a pivotal role in pioneering 'clean', non-electrical mobility

onda's exit announcement ostensibly to fund future electrification research and development mobility projects - sent shockwaves through Formula 1. It was the first such withdrawal since Liberty Media acquired the sport's commercial rights in 2017, and immediately set alarm bells ringing amongst investor communities.

'Who will be next?' Wall Street analysts asked, sending the FWONK share price tumbling.

The fact that Honda uttered the 'e' word made the announcement doubly ominous for the implication was that F1 was motorsport's dinosaur, reliant upon brash noise and dirty fossil fuels. That put it squarely at the mercy of 'green' brigades.

If Honda was prepared to walk, despite recent victories with Red Bull – a top three team employing Max Verstappen, one of the best drivers of his generation – why not Renault? Or Mercedes, which surely has nothing left to prove and would score considerable good will amongst young, upwardly mobile buyers who attach enormous street credibility to renewables, whether at home or in their automobiles.

'What happens if both manufacturers depart, leaving Ferrari the sole power unit supplier?' was the next question, posed to nervous suits in Liberty's head office.

In response, F1 took an immediate decision to go all out to not only retain its remaining PU suppliers, but attract at least one newcomer, preferably two, with VW Group and a Korean manufacturer being the most likely candidates, in that order. However, in order to achieve the objectives, F1 would need to ensure it is economically and environmentally sustainable by 2025, and that future engines are powered by non-fossil fuels.

#### **Fuel crisis**

Decisions taken, the FIA and F1 moved swiftly. In December, the governing body delivered the first barrels of 100 per cent sustainable fuel, blended from bio-waste, ethanol produced from secondgeneration (inedible) plants and woodbased toluene (to increase octane rating), to F1's engine suppliers for evaluation.

'By developing sustainable fuel made from bio-waste that can power Formula 1, we are taking a new step forward. With the support of the world's leading energy companies, we can combine the best technological and environmental performance,' said FIA president, Jean Todt.



Ross Brawn, F1 managing director



Pat Symonds, F1 chief technical officer



To that, F1 managing director, Ross
Brawn, added: 'Formula 1 has long
served as a platform for introducing
next generation advancements in the
automotive world. Our top sustainability
priority now is building a road map for
hybrid engines that reduce emissions and
offer real world benefits in road cars.'

It is still early days, though, and Pat Symonds, F1's chief technical officer, and the man charged by Liberty Media with ensuring F1 has the right technologies to deliver a sustainable, world-class spectacle, told *Racecar Engineering* during F1 testing in Bahrain that the blend did not tick all the boxes.

'That fuel didn't perform as well as we might have hoped,' he readily concedes. 'When I say that, we weren't expecting the same performance from it because the Formula 1 fuels we have at the moment have been tailored for energy density, above 43MJ per kg. They're incredibly energy dense fuels. So I think there's still some work to do.'

#### Power unit goals

Still, in February, the F1 Commission voted unanimously to expedite introduction of a revised PU formula to 2025, a year earlier than previously planned. Five goals were set for the next generation engines: incorporate sustainable technologies and be relevant to OEMs; be compatible with sustainable fuels; be 'powerful and emotive', albeit at lower costs to attract incoming suppliers; and be carbon neutral.

This revised date provides a sufficient runway for any incomers, while offering existing PU suppliers a four-year window to defray costs, with savings accruing through a development 'freeze' on current units. Crucially, this window also provides two years to frame the regulations and sufficient cushion to comply with the FIA's statutory two-year notice for changes that influence the BoP.

'From the technology side, we face a lot of challenges because we need to ensure better efficiency and reduce pollutants,' Gilles Simon, the FIA's technical director for engines, told *Racecar Engineering*. 'So, we need to evolve.



Formula 1 uses around one million litres of fuel a year in racing and testing, a huge amount for natural resources and a synthetic fuel producer, but an insignificant amount to the world's major oil companies. That puts it in a difficult position

'We also need to switch to sustainable fuels and promote new technologies, but we also have to consider costs. This is an important factor because we want to attract new manufacturers, and to do that we need to keep investment within reasonable limits.' Some challenge, then.

The timeline is for first power unit concepts to be presented to engine suppliers by June of this year, with the following six months devoted to evaluation and refining the various proposals ahead of drafting the regulations during 2022. FIA ratification will take place in December 2022. Once published, suppliers would have the necessary two years to develop their engines, resolve any issues and fine tune the regulations.

Simon, who announced his retirement shortly after this interview (to be replaced by Xavier Mestelan Pinon, former motorsport director for Stellantis), will remain a consultant to the governing body and believes the mix of objectives will retain existing PU suppliers, while also attracting incomers, all of whom need to simultaneously fund their road

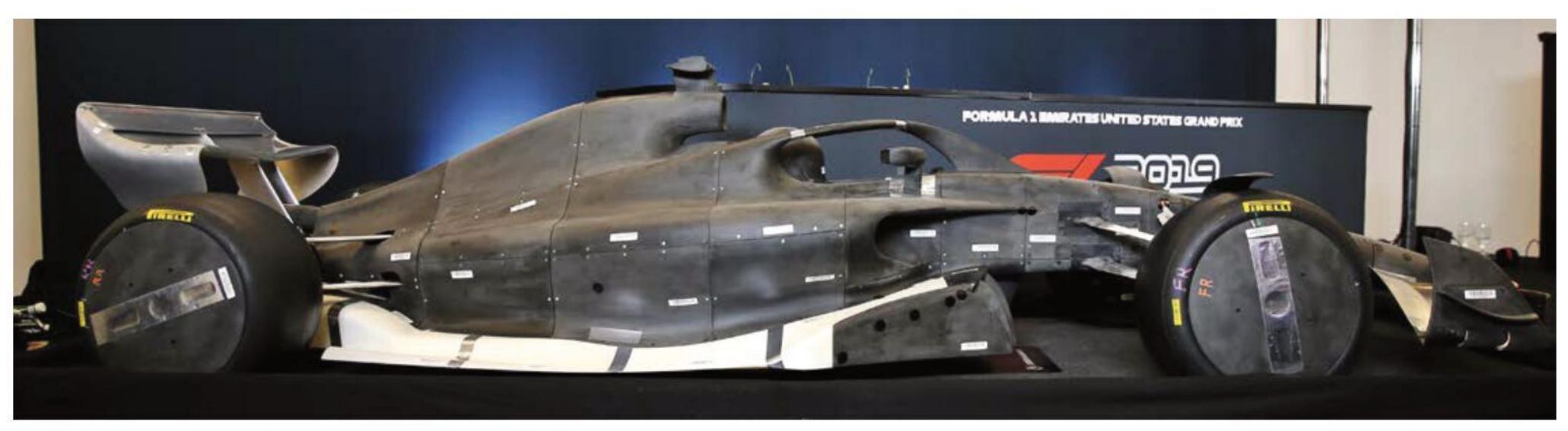
car electrification programmes. 'Such a balance we need to find,' he stresses.

#### **Emotive question**

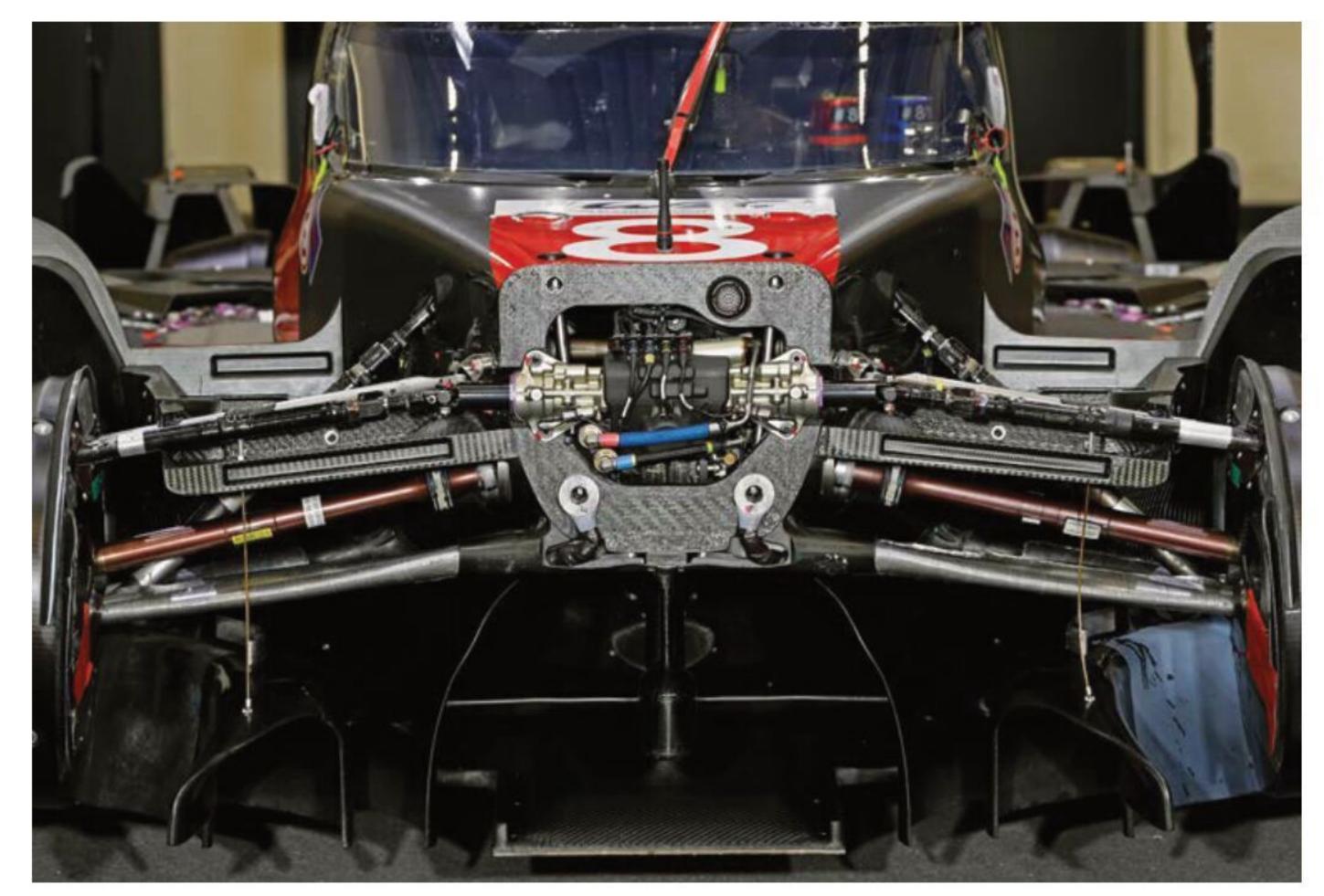
A potentially more difficult challenge is for F1 to remain 'powerful and emotive', implying noise levels and visceral thrill at least on par with current units. However, the most efficient route to power is via turbochargers and exhaust-driven motor-generators units (MGU). The latter sap noise, though, and are extremely complex, and consequently eye-wateringly costly. One possibility is to standardise MGU-H systems to reduce costs, but that would not alleviate the noise issue.

Simon stresses the engine formula is still very much a work in progress, but the Frenchman projects hybridised 800kW units, based on architectures largely similar to the current turbocharged, 1.6-litre, V6 units, also fitted with heat recovery units, split 50 / 50 between internal combustion engine (ICE) and electrical power, so 400kW per power source.

'We could probably maintain similar [15,000] rpm as we have today, so probably noise levels would be similar,



Covid has forced the introduction of the new F1 aero concept to be postponed until 2022, the 2021 cars retaining much of the previous year's chassis construction and aerodynamics



The WEC has already introduced four-wheel drive with hybrid power harvested and distributed to the front wheels

#### 'Our top sustainability priority now is building a road map for hybrid engines that reduce emissions and offer real world benefits in road cars'

Ross Brawn, F1 managing director

or slightly better, explains Simon, which would leave power output to satisfy the 'emotive' experience. This compares most favourably with the current power mix of 550kW ICE and 120kW provided by battery packs, so 670kW in total.

He believes advances in battery technologies are such that 'roughly the same magnitude of weight' as per current power units (which have a minimum mass of 145kg for ICE in 2020, going up to 150kg in 2021), energy store two generator units (heat and kinetic) and electronic control units can be maintained, despite a tripling in electrical energy. This illustrates the enormous strides made in battery densities since F1 introduced its current hybrid units in 2014.

So much for the hardware, what about the sustainable fuels F1 so desperately needed to hit carbon neutrality by 2025? Thereby providing a stay of execution for internal combustion in the face of an unrelenting onslaught from electrification? Crucially, F1 believes hybridised ICE units can, and should, exist comfortably alongside electrification.

'I think it's really important to understand that in Formula 1 we're not competing against electrification,' says Symonds. 'We're running alongside it. We believe that hybrids and e-fuels have their place. Synthetic fuels, particularly, have a great future and energy density is really important.'

#### Scaling up

The challenge, though, is one of scale. F1 uses around one million litres of fuel per annum, of which around a third is consumed in competition and the rest in testing, both track and bench. Although that figure will ultimately reduce as further restrictions are placed on testing, in industrial terms 1m litres is an insignificant volume, yet in laboratory terms it is enormous. F1 therefore currently sits in an uncomfortable middle zone in terms of fuel production.

'We initially set ourselves an objective to try and get to sustainable fuel by 2023, says Symonds, 'but the problem of the moment is not just a technical one, it's a supply problem. There are lots of good things going on all over the world as people look at sustainable fuels, but the reality is they're only in a sort of lab format.

'Therefore, we turned our attention to the next generation engine we had in mind for 2026. In view of the fact we couldn't put sustainable fuel into 2023's regulations, we said let's move the whole project forward to '25. It is a big ask, and there's a lot to do.'

Current regulations specify a 5.75 per cent biofuel component. 'A statement of intent that hasn't moved society on at all,' concedes Symonds, while from 2022 a 10 per cent (sustainable) ethanol element prevails. F1 has an ace up its sleeve, though, in its partnership with Saudi Arabian

oil company, Aramco, which extends beyond title and trackside sponsorship. The oil company is 'very supportive of our work and putting considerable resources into it for us, says Symonds.

Already, this class of sustainable energy has a name: e-fuel, on account both of (arguably) being cleaner overall than battery power (if the pollution created during the production of cells is factored into the equation), and due to the renewable electrical energy - mainly solar – used in the conversion of biomass and synthetics to combustible fuel.

Members of the Formula One Fuel Advisory Panel, comprising all major oil companies, not just existing team partners, are eagerly formulating brews that can be 'dropped into' existing engines with little or no modification. Such fuels are, of course, in the best interests of the oil companies, given that a billion fossil-fuelled cars are currently roaming the roads of the world, and these cannot simply be scrapped overnight.

'We will take advantage of the fact we're blending some pretty pure chemicals together. Drop-in fuel will be a nice clean fuel, continues Symonds. 'The idea of these synthetic fuels is they will be low CO<sub>2</sub> [or even] CO<sub>2</sub> neutral.

'But we also want to tackle the emissions problem. What we're looking at for 2025 is for the first time to bring in some emission regulations into Formula 1, and we'll be looking at particulates, especially the oxides in nitrogen.'

#### Same performance

Symonds is aiming for the same performance as current cars, but using one third less fuel. 'When I define 'same performance', I want the same speed, I want roughly the same lap time, roughly the same acceleration, and roughly the same braking capability. And I want roughly the same cornering capability, too.'

Will that entail a completely new chassis design to complement the proposed super frugal powertrains?

'You don't have to be an engineer to realise that one of the reasons we use quite a lot of fuel on these cars is because they're high drag. So, the first thing you've got to do, apart from moving into much more hybridisation, is get some drag out of it. That leads you to active aerodynamics on the car.'

With a targeted 400kW hybrid element and fuel consumption cut by a third off an already impressive ICE thermal efficiency index of 50 per cent, energy harvesting is obviously of the essence, so could the new formula embrace all-wheel drive to facilitate energy recovery at each corner, thereby doubling the rate?

'We will need to do front axle recovery,' believes Symonds. 'I say 'believe' because

it's not impossible to do it on the rear, but I don't think it's a very good solution. I would like us to be able to bring in carbon ceramic brakes [to reduce carbon brake particulates] and there's currently no carbon ceramic brake that would take our duty cycle.

#### Front drive and 4WD

'I believe we will have energy recovery on the front, and if you have energy recover on the front it sort of makes sense to drive [those wheels]. But we have to remember we're a sport, and what I don't want is cornering on absolute rails. So right at the beginning of the project, all our simulations start with using front drive, but only using it when lateral acceleration dropped to a certain level.

'It's quite interesting that the WEC and [Le Mans Prototypes] have a similar thing, and they have a speed limit on it.'

Indeed, a spokesperson for Brembo, F1's primary brake system supplier, confirmed the company is aiming to phase out carbon friction materials: 'Based on Brembo's strategy and new vision, we are already working on new materials and evolutionary processes in terms of consumption and emissions. This is our philosophy, not only because Formula 1 is asking all suppliers to adapt to this new sustainable approach, but because our corporate strategy is to produce materials that are sustainable for the environment. In F1, this process has started.'

Simon agrees that 4WD could be 'on the table. Obviously, a four-wheel-drive car is very efficient in terms of recovery, in terms of performance and in terms of cornering. But it's an added complexity.'

However, like Symonds, the FIA man is wary of unintended consequences and urges caution: 'We have to evaluate this properly. Is it the right direction for Formula 1 to go? We need to think about a completely new racecar [for the new engine]. It is still early in the programme, and we are still looking far and wide. Together [with F1 and power unit suppliers] we will define the direction.'

#### Bespoke fuel or 'drop-in' fuel?

Formula 1 considered bespoke fuels to maximise performance before deciding on 'drop-in' fuels, which replace existing fuels with minimal modifications required to the existing power units. Why, and what are the benefits, disadvantages and differences?

'Initially, our thinking for 2026 was that we would go through a co-optimisation process, because when you start to make synthetic fuel what you're effectively doing is combining carbon and hydrogen atoms. You're no longer reliant on what you're drilling out of the ground, instead you've got a big chemistry set in front of you.

'Within limits, you can do what you like with the chemistry set, and it's certainly possible to get around some of the disadvantages you can have with fuel drilled out of the ground and upscaled through refining.

'It can be a much purer fuel, without the sulphurs and other things you have to deal with. You can get your particulates down, and of course you can start to blend in some of the things that allow you to push your engine design a little bit further.

'It's simple thermodynamics that to get engine efficiency up, you need to get compression ratio up, and the reason you don't get compression ratio any higher is because you get pre-ignition. You can blend fuels that have better pre-ignition qualities, but those fuels tend to not have as much energy density as the fuels we use.

'Once you get into synthetic fuels, you can do this kind of optimisation process and design your engine and fuel together. When we were looking at 2026, we thought that's a good way to go.

#### A little bit better

'Bringing [the formula] forward to 2025 makes it a little bit more difficult. It also perhaps misses a trick, because if we did a fuel like that it would essentially have to run in an engine designed [specifically] for it, whereas if we produce what's called 'drop-in' fuel it can be used in any engine, so we're probably doing something a little bit better.

'Our thinking is turning more towards that [but] we will still take advantage of the fact we're blending pure chemicals together. Our 'drop-in' fuel will be nice and clean because our aim is going to be on CO<sub>2</sub> [reduction].

'The idea with these fuels is they will be low, or neutral CO<sub>2</sub>. Because we don't have an abundance of sustainable electricity, it's hard to say things are totally neutral, but we will certainly be using young carbon to produce these rather than carbon that's been around for millions of years.'

Whatever direction is finally agreed upon, there is no doubt the world is increasingly embracing electrification, yet battery power is not suitable for *all* applications. Developing countries require transportation, yet seldom have the infrastructures required by electric cars.

F1's 2025 engine format could conceivably play a pivotal role in pioneering 'clean', non-electrical mobility, thereby granting internal combustion engines a stay of execution. The FIA and F1 have under two years to make all the correct calls, then another two to formalise them. Miss those deadlines and ICE could be dead.

'I believe we will have energy recovery on the front, and if you have energy recover on the front it sort of makes sense to drive [those wheels]'

Pat Symonds, F1 chief technical officer



If four-wheel drive does indeed make it into Formula 1 for 2025, its deployment would most likely be subject to a lateral acceleration limit threshold



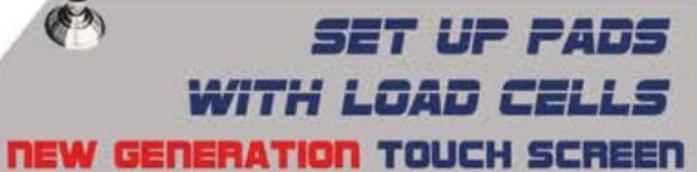




















SPECIAL AT WHEEL

AIR JACKS
CE CERTIFIED





REFUELLING

CE CERTIFIED



BR-IOO BASIC A SUPER MEDIUM LEVEL MODEL



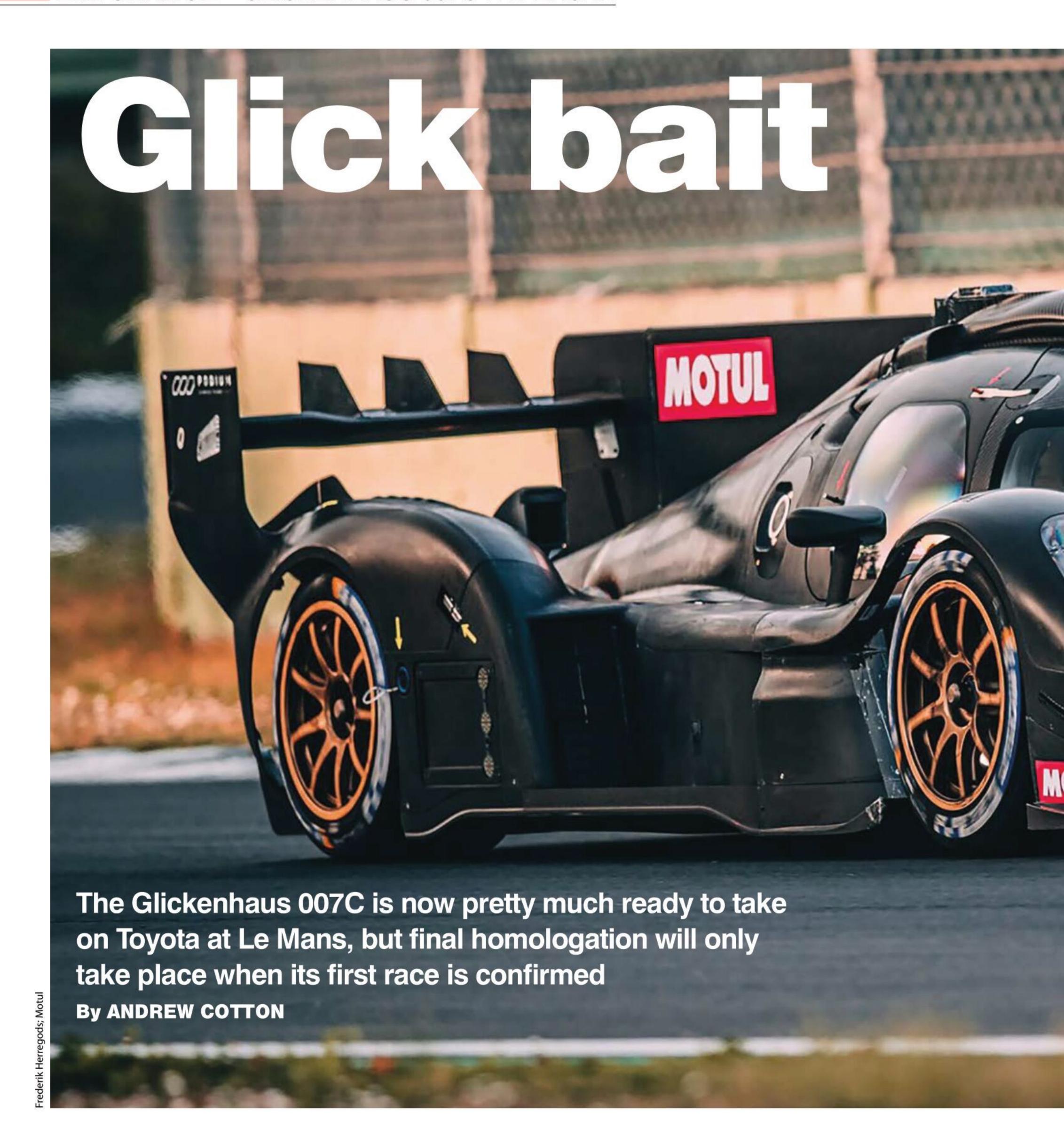


for our complete equipment range please visit

www.bredaracing.com

or contact us at info@bredaracing.com





im Glickenhaus has taken the next step in his commitment to endurance racing and signed up to take a Hypercar to this year's Le Mans 24 Hours, and compete in rounds of the FIA World Endurance Championship.

His 007C, a ground-up design that features a twin turbo V8 engine from Pipo Moteurs and a chassis from Podium Advanced Technologies, has completed its first track running and passed its crash tests in advance of the start of the FIA WEC.

However, the car is not yet finally homologated as, with the Covid pandemic continuing to cause havoc in Europe and to European racing schedules, and with a five-year fixed homologation by regulation in the WEC, the American is in no hurry to finalise the specification.

'There is not much point in doing so until we know when we will go racing, says Glickenhaus. 'The car is ready, but we are not going to rush to homologate it for a spectator-less race.'

The first round of the WEC, scheduled for Spa in May, is confirmed to take place behind closed doors, and with Portimao and Monza the second and third races in June and July, ahead of Le Mans in August, the team remains sceptical they will go ahead at all.

#### Reality check

'I think they should start the season in June,' says the American. 'For Spa, we will see where it goes, but I don't think there is a lot of reality here!



However, pending confirmation of the race, the team is aiming to be at Spa with one car for the pre-season test at the end of April, and a second to take part in the race itself. Drivers have been confirmed, the car has tested at Monza and Vallelunga, the team running it is Joest Racing, and the 007C has already shown promising form, beating the Vallelunga outright track record.

The story behind the development of the car has already been written about in REV30N8. The regulation changes to

accommodate the power output levels demanded by Aston Martin's wish to race the Valkyrie caused delays in the design and development process for Podium, and also meant Glickenhaus had to change engine manufacturer for the 007C.

However, the basic rule set from the FIA has led to a pretty straightforward design. With easily attainable aero figures to work to, the company has been able to focus its efforts on styling, driver comfort and accessibility for the mechanics to work on the car.

In the nose, the design team was free of the constraints faced by Toyota, which had to package an MGU and driveshafts due to its hybrid design.

#### A problem of balance

The aero is not challenging because the whole category is performance balanced. Howewver, while the old LMP1 cars were capable of lapping Le Mans in sub 3m15s, these new cars have a target lap time of more than 3m25s in qualifying and race 12 seconds



Though the 007C is not quite the ultimate road car cum racecar Glickenhaus imagined, its styling is consciously more closely related to a production car than a pure racing Prototype

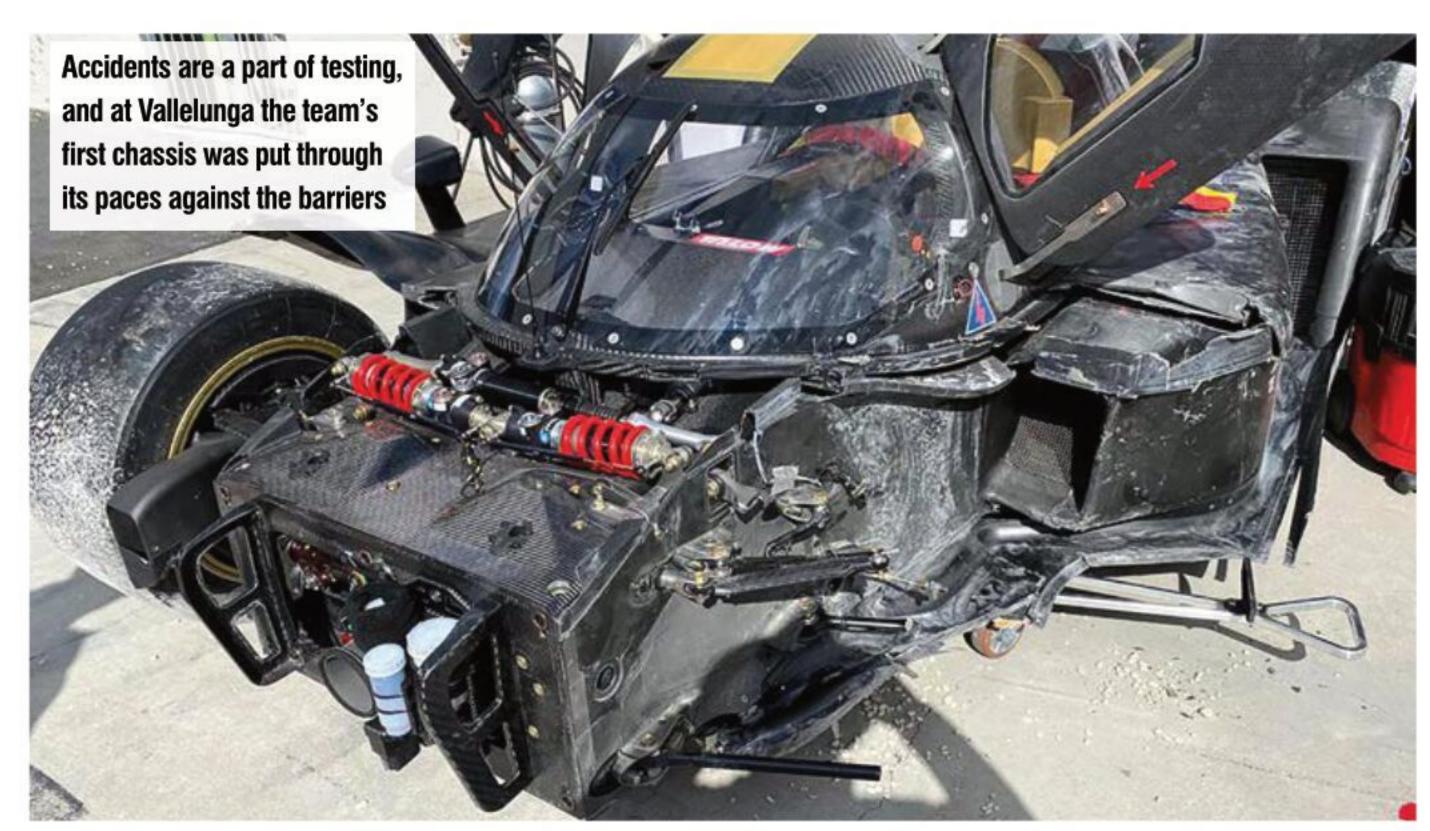
slower. That has put them directly into the old LMP2 car territory, so balancing the performance is not only about ensuring each of the Hypercars has a chance to win overall, but is also fast enough to beat the secondtier cars. The LMP2 cars have had power reduced and Goodyear was asked to produce slower tyres, but the teams and drivers were unhappy and so the performance windows of the Hypercars may yet change.

'The way the balance of performance works, it is quite easy, says Luca Ciancetti, head of automotive engineering and motorsport business lines at Podium Advanced Technologies. 'If you are slow you get power, and if you are fast you get weight. That is much simpler than reality because there are factors such as tyre degradation, fuel consumption and so on to take into account, but that's the basics of it.'

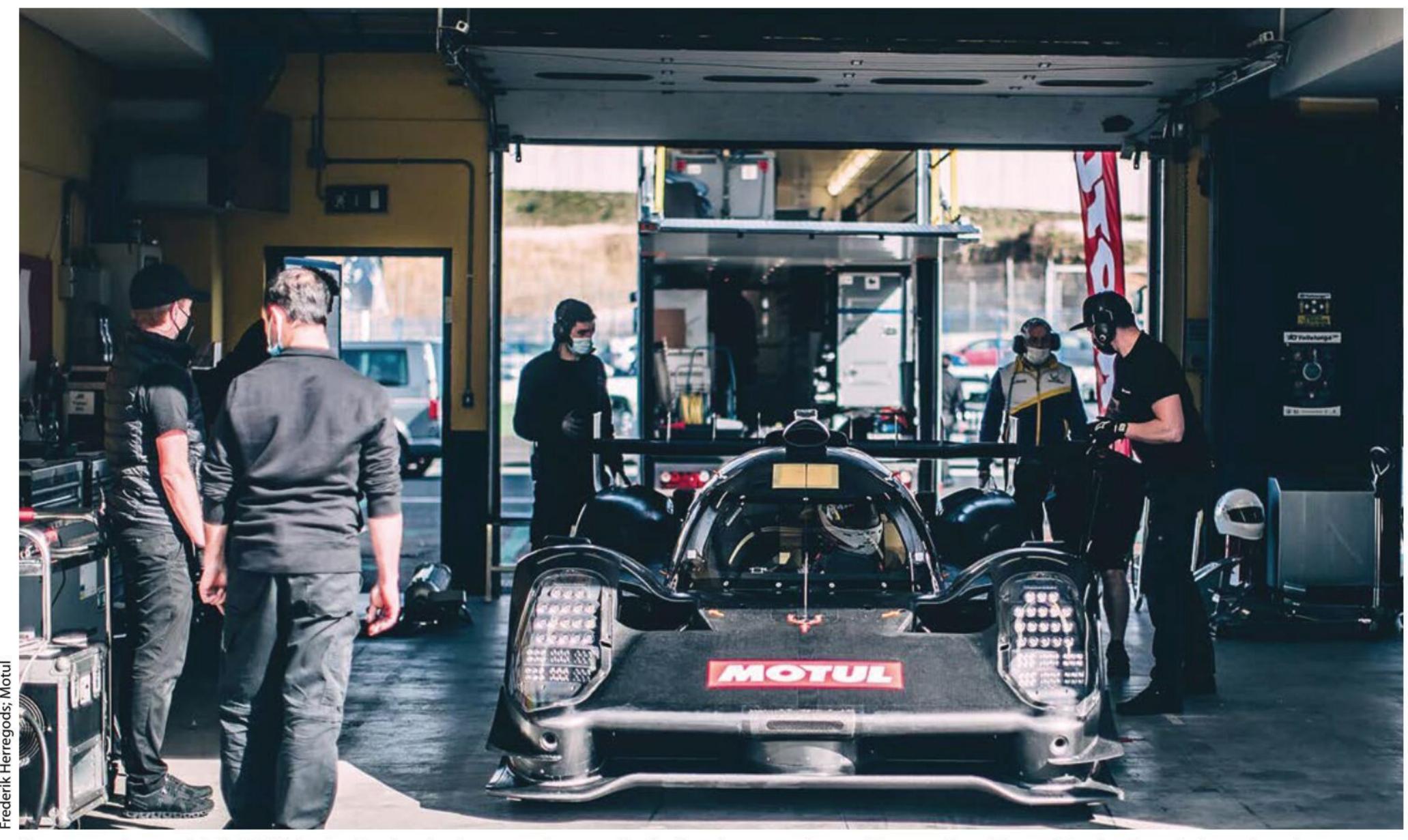
#### Performance difference

Already there have been changes to the basic Hypercar structure, with the Toyota given an extra 10kg, and Jim Glickenhaus believes that with its hybrid system, the GR010 will have better tyre wear on long runs.

Ciancetti does not believe that there will be a huge performance difference between the 007C and the Toyota GR010 over a single lap, though, as the power is limited between the two cars and monitored closely, while weight and weight distribution are also clearly defined by the regulations. What that means is the two will fight evenly for the



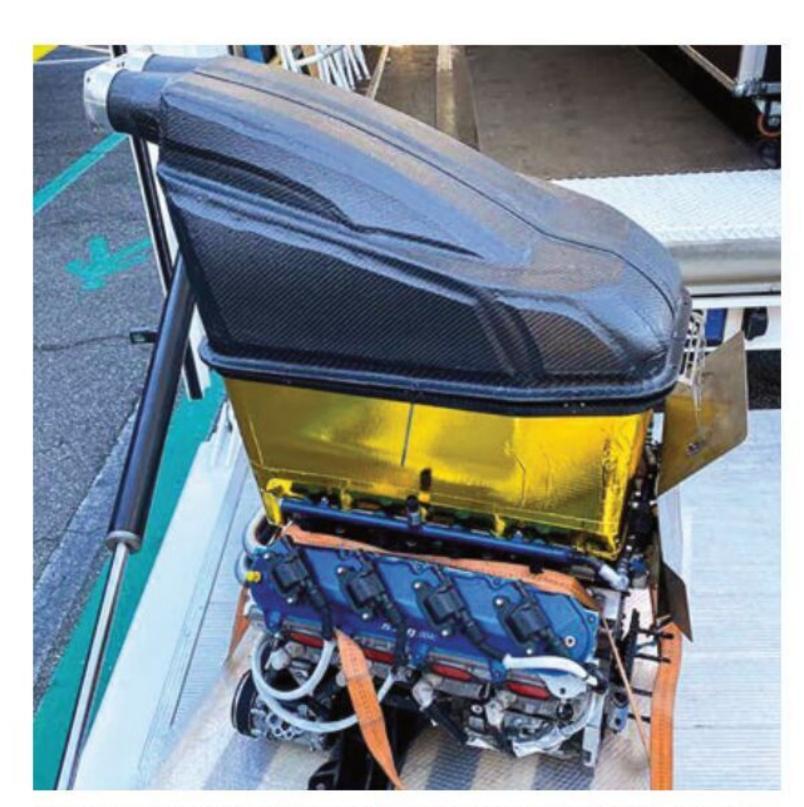




The aero on the car might look fairly benign, but there's a lot more going on under the floor than meets the eye. That, says Luca Ciancetti, is a key factor in the car's performance

#### The performance [targets] were not a huge challenge for us because once you are in the window, you are in the window

Luca Ciancetti, head of automotive engineering and motorsport business lines at Podium Advanced Technologies



Pipo Moteurs provided the car's V8 powerplant, which uses twin turbos to easily meet the performance targets for the class

honours in qualifying, but the Italian believes the outlier is the Alpine, the former LMP1 ORECA chassis raced by Rebellion. That car, powered by a Gibson engine, was designed to a different rule set capable of lapping Le Mans sub 3m20s in race conditions.

'I have no idea what they will do with Alpine because we have no knowledge of that car, admits Ciancetti. 'Toyota knows more than us because they had an LMP1 car so they can compare concepts, while we did not.'

That knowledge of a previous car could have been crucial in the design phase of the GR010, as Toyota had to scale back on its previous performance targets, while for Podium the Hypercar was a step up from the Glickenhaus 003C. The 003C is the car Glickenhaus races at the Nürburgring in the NLS championship (formerly the VLN), and which he hopes will be classed as a GT3 under new regulations due for 2023. That car was also developed by Podium.

#### Window shopping

'The performance [targets] were not a huge challenge for us because once you are in the window, you are in the window, says Ciancetti. 'We never found ourselves in a position where we were thinking we would not be able to get into the window. We had a feeling that it was not that difficult to get there.'

That allowed for some design freedom in the car and the Podium team was able to stick pretty closely to Jim Glickenhaus' original design concept. That is based on

the old idea of being able to drive beautiful cars to the track and race them, and then drive home again. While the 007C will not be able to run on the road, there are clear styling cues that are closer to production cars than a prototype racer and that also left Podium with freedom in technical design.

#### Importance in design

'From day one we really focused on giving more importance to the design of the suspension,' says Ciancetti. 'When you are designing the front of the car, one of the key choices is do I leave space for aero or can I optimise the suspension geometry and also have access to the suspension to make it easier to adjust? We understood it was better to have good suspension design with good access rather than leave a lot of room for aero that was really not needed.'

Driver comfort is important in a 24hour race and, again, the design of the cockpit was relatively straightforward. Without the need for a hybrid system, and all the components to control it, there was room to create a cleaner, less cluttered environment in which to work.

With a higher minimum weight for the car, teams have been able to design the chassis with safety as a high priority. The 007C passed its crash test set by the FIA in mid-March and, shortly afterwards, on cold tyres, the prototype crashed at Vallelunga, without major damage as all parts performed as designed.

#### **ENDURANCE** – GLICKENHAUS 007C HYPERCAR

'Again, I have to say the regulations do not give a lot of design freedom because so many of the parameters are set, including the minimum weight of the tub itself and also the position of the c of g, notes Ciancetti. 'At the end of the day, you have to deal with the chassis design, but our chassis today for the Hypercar is a completely different world compared to the older one.

'We don't have the super fancy materials in it because then you will end up with something to live with that you don't need. It is complex manufacturing and a complex construction, but it is not as difficult as it needed to be with an LMP1."

#### **Driver safety**

Seating position is critical, not only for driver comfort but also for safety, and the Glickenhaus has a more upright seating position than the LMP1 cars before. The driver's legs are positioned lower in the chassis, which not only helps with driver visibility, but also means the shoulder straps take more force than the seat in the event of an accident, reducing the possibility of backbreaking accidents as were seen in LMP1.

'If you were going for higher performance you probably would need to create some free volume for aero below the legs of the driver, but in our design the driver's legs are quite flat with the main plan of the lower part of the chassis, confirms Ciancetti. 'We could deal with that. With the additional design requirements you have to fulfil [with a hybrid] it is easier and more straightforward if you don't have that added complexity.'

In the discussion over the regulations, the change in engine outputs varied wildly,

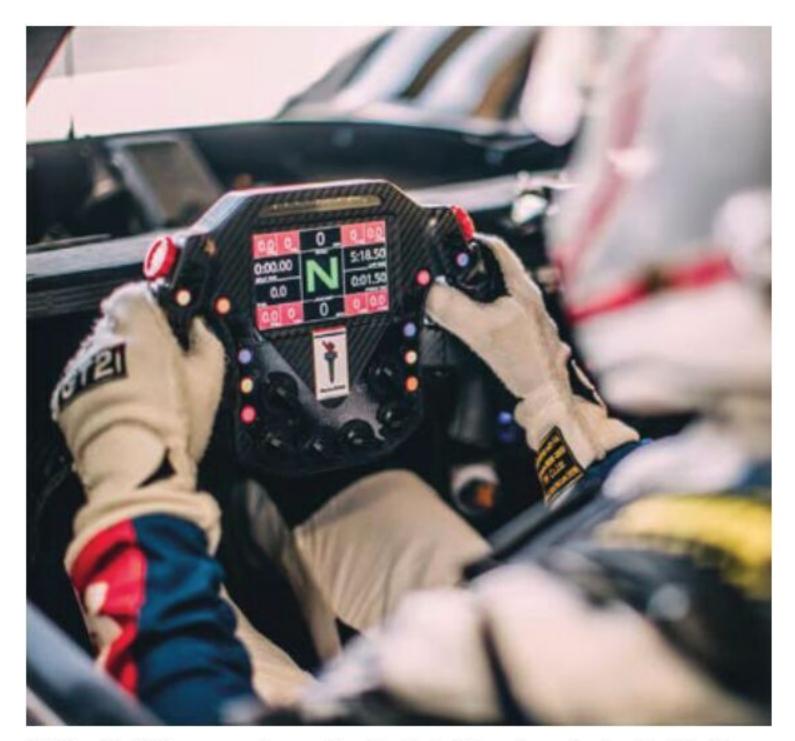


Driver safety and comfort has always been high on the agends, and the end result is a low, more upright seating position

from more than 1000bhp (745kW)to today's figure of 670bhp (500kW), comprised of either straight engine power as the Glickenhaus provides, or a combination of ICE and hybrid energy. Those negotiations affected the cooling requirements for the Glickenhaus design team, but not to a degree that caused massive concern.

#### **Keeping cool**

'One key point is that you are not allowed to make any cooling personalisation, so the car is not allowed to be taped up or have a more refined way of reducing the amount of air going through the radiator, explains Ciancetti. 'You therefore have to design a system that is able by itself to keep the working temperature of the engine in its proper range,



Without all the paraphernalia of a hybrid system to deal with, the driver compartment has been kept clean and uncluttered

#### A few words with Jim

RE: You seem to have hit a sweet spot with the fans in the pre-season with your digital media results and openness with the technology you are using. JG: 'It is tremendously pleasing. I don't understand the secrecy of everyone else. Would I steal an idea from Toyota just because they show me the underside of their car? It's

a joke. These cars are finished. They are spec'd and it's a BoP series. We have just been able to make our car a little prettier since the aero isn't that challenging.

'I don't understand why they [Toyota] have gone hybrid, either. What's the purpose? So that they can be seen to be green? The technology, and the money, and the extra complexity to do it is just stupid.

'They [the ACO] should have one set of rules for convergence and these should be the last of the ICE Prototypes.'

RE: You have said publicly that the LMH cars will not be competitive in IMSA, and the LMDh cars will not be quick in Europe. Why? JG: 'I said that until the day comes that fans believe an LMDh car could win the 24 Hours of Le Mans, and an LMH car can win the 24 hours of Daytona, you do not have

"The sanctioning bodies have to get honest. If they cannot find a way to have 100 per cent honesty and a transparent BoP, the whole thing is meaningless"

> convergence and you do not have a believable way forward. The sanctioning bodies have to get honest. If they cannot find a way to have 100 per cent honesty and a transparent BoP, the whole thing is meaningless.

RE: So can you win races this year? **JG:** The Toyota is going to be the fastest, unless they have reliability issues. If they don't, they will point blank be faster.

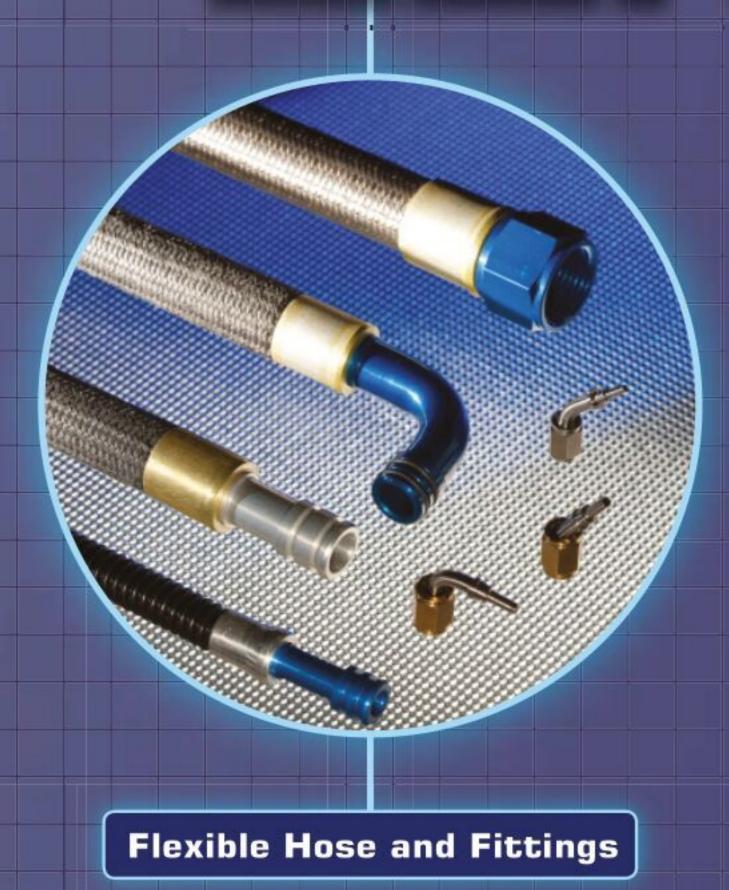
'We weigh the same, we are both pretty robust, but they could run away from us. But I think the ACO would be really unhappy if that happened because I don't think you can build a better two-wheel drive, non-hybrid LMH car.

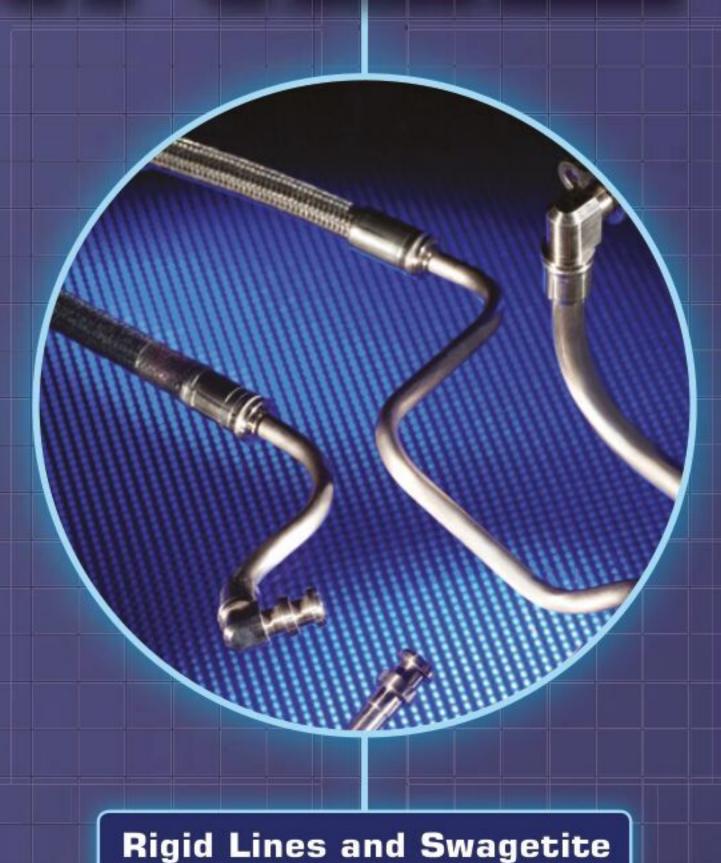
> 'I am not saying that Toyota cannot build a car that's slightly better, but it's not an order of magnitude. Either we will be really close, and they will have got it right, in which case it will

come down to who makes the fewest mistakes, and do they have any reliability issues, or one of us will be a lot faster than the other.

'There was a fascinating photograph of our cockpit and theirs, and there was 15 per cent more crap in theirs because it's all hybrid. The more electronics that you have in it, the more chance you have that something will go amiss.'

## INTELLIEFNIE THINIETTED







It's not by accident that, over the years, we have developed many successful partnerships with customers throughout motorsport - particularly in F1, endurance racing and WRC.

By applying intelligent analysis of their problems in the area of fluid transfer in high performance, high energy situations, we have established ourselves capable of providing innovative and cost-effective solutions.

#### SERVICES:

- 3D cad design service
- hose assembly
- hard-line manufacture
- cnc machining
- filtration design
- laser marking

#### PRODUCTS:

- Titeflex smoothbore and convoluted hose products and fittings
- Swagetite fittings and hard-line system solutions
- Pall Filtration systems
- CIRCOR Industria solenoid valves



G

INTELLIGENT CONNECTIONS

Maintain system integrity, save weight, cut costs. Make the connection now.

To find out how the quality of your own fluid transfer requirements can be improved, call our Technical Sales Team on

+44 (0) 1753 513080

FHS Motor Racing Ltd Albion Close Slough Berkshire SL2 5DT UK Tel: +44 (0)1753 513080 Email: info@fhsracing.co.uk Web: www.fhsracing.co.uk

#### **ENDURANCE – GLICKENHAUS 007C HYPERCAR**

and that means you have to work on the water cooling. That's quite easy stuff because you set the dimension of the cooling system by working to the worst track condition – so the lowest circuit with the highest temperature – and, if you do that, you can still be in the drag target of the homologation.

'It is tricky because we started the development of the car and the engine together, so we had to wait until we had the final figures for heat rejection from the engine. That affected the schedule of the programme, though, rather than the technical challenge.'

#### **Complex floor**

While the airflow looks to be relatively traditional, Podium developed a complex floor structure that is key to generating downforce for the car. The long nose hints at a potent splitter, but Ciancetti says it goes much further than that. 'We have a very complex floor and a very powerful flow,' says the Italian. 'We have a lot of air going under the car and it is a key performance factor. It was one of the most demanding elements to design.'

Right from the start, the team elected to go to the maximum length of car allowed by the regulations, but that meant rear stability might become an issue. Although the bespoke gearbox from Xtrac was finalised early, as was the rear suspension, the whole aero package was the last part to be signed off.

'We kept a lot of adjustability in the rear suspension in terms of damping and stiffness, but also geometry with the options we have,' says Ciancetti. 'With the rear wing it was a bit more tricky because the rear section of the



The car has now tested at Monza and Vallelunga, and shown the required pace. It's shaping up to be a close race at Le Mans

car was the last bit we released for the aero, but now we have a good solution. That rear section is key for the performance of the car.'

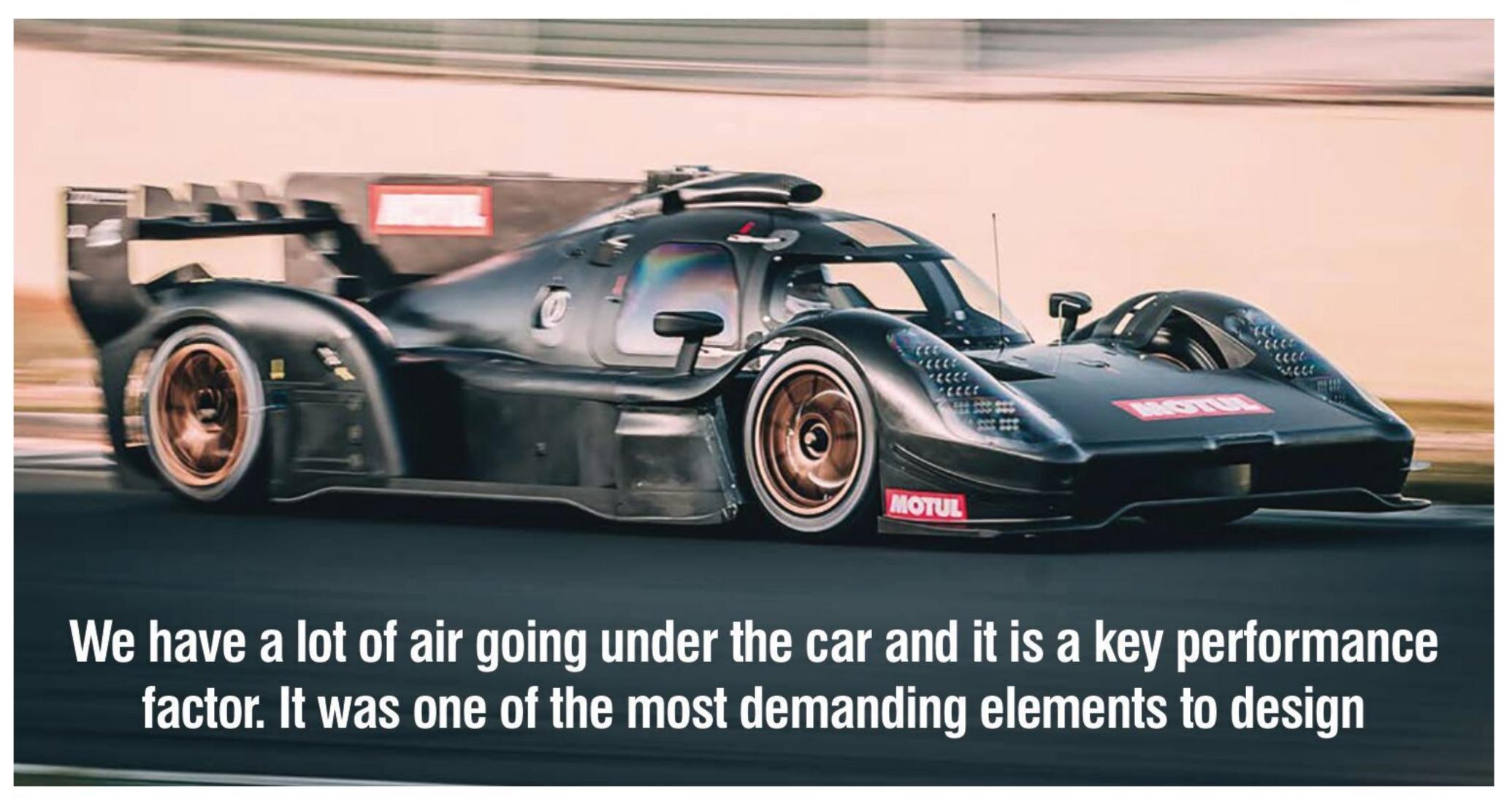
#### Yaw stability

Strakes on the rear wing are an unusual feature of the car, and the large rear wing end plates also suggest the team was looking for solutions to meet the stability at yaw angles stipulated by the FIA. While Toyota looked at designing its car without the fin over the engine cover, and Jim Glickenhaus hoped for the same, Podium decided that the fin was the most efficient solution.

'The reason for that solution [the rear wing] is the lateral stability of the car,' confirms Ciancetti. 'You have to demonstrate that your car is safe enough in lateral stability and, due to the shape of our car – due to some design choices we have a long car – it is much more difficult to achieve that. We had to add vertical fins.

'As already mentioned, as long as you are in the performance window you are fine. We have our hot spots in that window, and we are where we chose to be.'

Now it has to be seen how competitive the car is against the Toyota.



Like the Toyota GR010 it will race against, the 007C features a pronounced dorsal fin to meet the FIA's mandated yaw stability requirements, as well as vertical strakes on the rear wing



#### System Simulation | Design | Manufacture | Calorimeter Testing

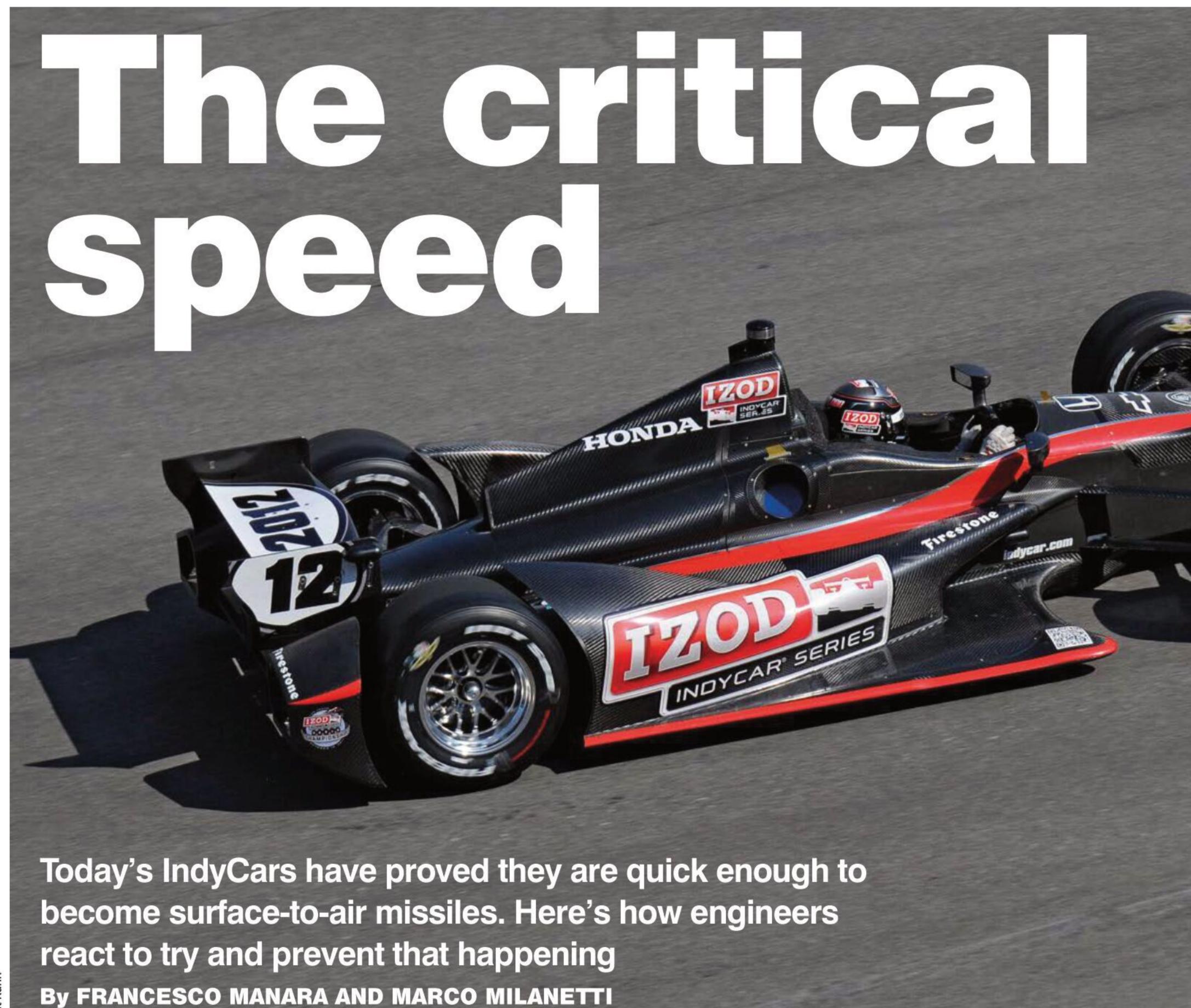
From initial concept, through to performance verification and production, PWR is your global solutions provider servicing all ICE, Hybrid and EV Cooling system requirements. By coupling advanced system simulation and test tools with latest technology manufacturing processes including additive manufacturing and unique vacuum brazing capabilities, PWR is your engineering partner for optimisation and production of all your cooling requirements.



PWR has partnered with VELO3D using their Sapphire machine technology and unique "SupportFree" processes enabling class leading thin wall capabilities and high quality surfaces without porosity. PWR manufacture higher quality internal channels, flow paths, and high aspect ratio walls for new designs that optimize heat transfer.

While conventional 3D printing systems often require supports for any geometry below 45°, PWR & VELO3D's Sapphire uniquely enables designs to be realized with overhangs down to 0° (horizontal), and large inner diameters without supports. PWR & VELO3D's Sapphire is the next generation metal additive manufacturing system designed to unlock Digital Manufacturing for mission critical applications.

PWR manufacture ruggedized liquid cooling plates and brazed chassis for Aerospace, Defence, Automotive and Motorsport markets. These components are used in a variety of end applications such as radar systems, autonomous vehicles, energy storage systems and power electronics cooling applications.



hat makes the Indy 500 unique in the racing environment is speed. The best-qualified car in 2020 reached an average lap speed of more than 230mph.

Clearly, the honour of being the fastest race in the world comes with the burden of many additional and bigger safety issues. The cars are always at the limit of every component's design range, while the drivers see everything happening at twice the average speed of a normal track. Moreover, doubling the speed increases kinetic energy by four times, so any impact with the barriers, or with flying debris, may potentially be a much more dangerous one.

From the aero side as well, such a condition brings further safety concerns.

When travelling at 230mph, the car is subject to almost 3000lb of aerodynamic load, almost

twice its own weight. This means the car could easily run upside down, pushed to the track by the air, despite the force of gravity.

It is easy to imagine, then, that when losing control of a car at that speed, taking it out of its design conditions, the forces generated on the vehicle can quickly lead to catastrophic results. In several conditions, especially when air is channelled under the floor, the car can become a lifting body, rather than a downforcing one, and the aero force can overcome the weight of the car, leading to a real take-off.

#### **Aerodynamic stability**

So when you are dealing with the aerodynamic stability of such a racecar, the very first thing to work on is to reduce the lift coefficient in any circumstances the car could face. Rather than just monitoring it, though, engineers introduced a more meaningful

parameter: the critical speed. As the lift force increases with the square of the velocity, if a car has a positive lift coefficient there will always be a sufficiently high velocity to raise the car, or to flip it around its axle. The speed at which the aerodynamic lift equals the weight of the car is defined as the critical speed. The target of the development, therefore, is to increase that parameter so that it is higher than the car's maximum speed. In any condition below this speed, the car is safe.

In parallel, the designers faced another challenge. It was maybe less obvious, but still a significant one in terms of driver safety. One way to reduce the risk of take-off is to reduce car speed at the point it reaches its lift-inducing dynamic conditions.

In this respect, the more the car slows down before hitting the wall, the less powerful the impact will be. In addition, at a lower speed the mechanical rebound will



In several conditions, especially when air is channelled under the floor, the car can become a lifting body, rather than a downforcing one, and the aero force can overcome the weight of the car leading to a real take-off

also be reduced, making it less likely the car achieves lifting conditions. Therefore, besides increasing the critical speed, the ability to reduce car speed after losing control is an important safety target as well. If the car has more downforce (less lift) while sliding towards the barriers, the friction generated by the tyres is greater, and the velocity of the impact reduces.

From this point of view, the choice to work with Dallara as single chassis supplier since 2012 allowed IndyCar to create a series where the focus on safety is prominent, something that can be harder to achieve in categories where there is competition among constructors.

As often happens in pioneering engineering applications, unfortunately, the engineers learned some harsh lessons from catastrophic crashes. In their neverending effort to improve safety, IndyCar and Dallara started to study the effect of aerodynamics on the cars in potentially lifting conditions in 2010. Year by year since then, the range of studied conditions has widened, so more different setups have been analysed and safety has improved in these conditions as a result.

Computational Fluid Dynamics (CFD) was identified early on as the ideal instrument to study such extreme conditions. Scale wind tunnel models were also examined in great detail to allow very precise, but small changes of ride height to be assessed.

#### Side wind

The first cause of concern was the condition with the car losing control and sliding sideways in yaw, where the angle between the direction of the wind and the car centreline is 90 degrees. Such a condition can also occur after a crash with another car.

From the aero point of view, the car is travelling sideways through the air at over 200mph, as shown in **Figure 1**. The diffuser and wings don't work at this angle, so they are not generating the usual downforce. On the contrary, the low central keel blocks the air passage under the car, causing a highpressure zone in this area (see Figure 2). At the same time, on the upper side the air experiences the acceleration determined by the convex surfaces of the sidepod, nose and engine cover, and subsequent lower pressure levels. The integral sum of the pressure field results in a lift force on the car

Lower pressure

Higher pressure

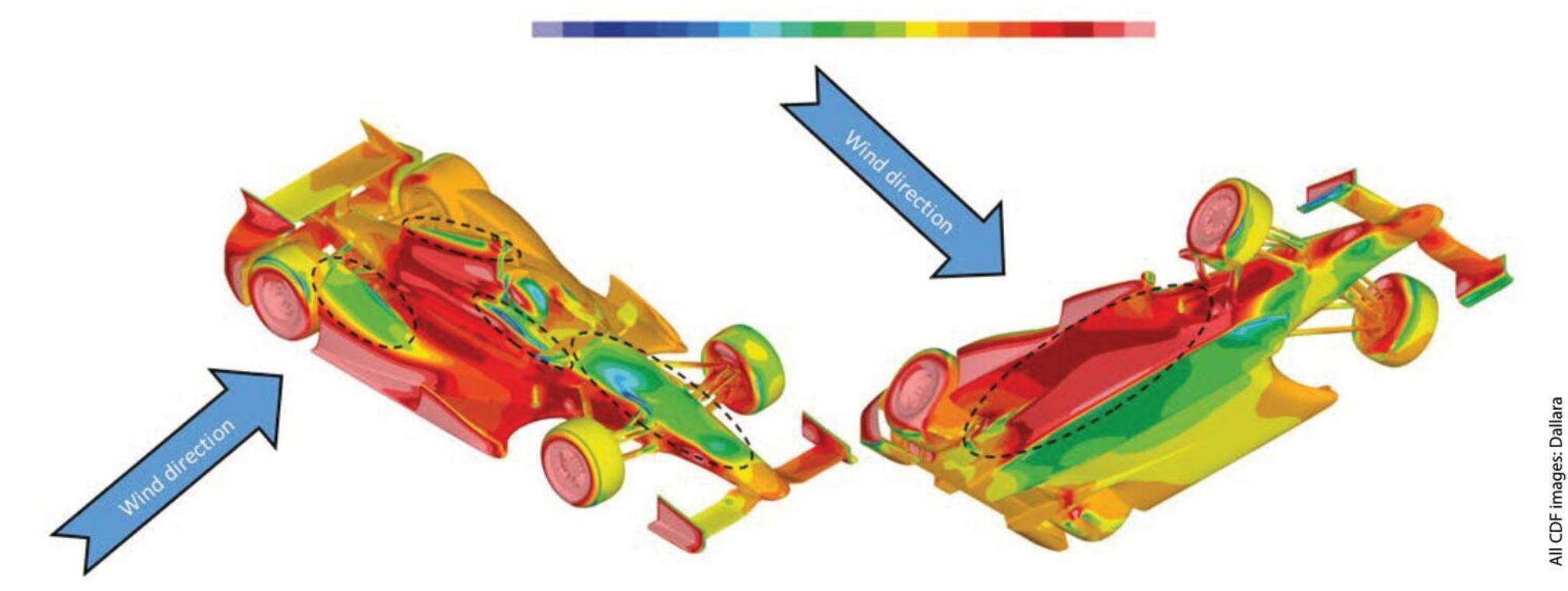


Figure 1: Suction areas on the upper body at 90-degrees yaw

Figure 2: Compression areas on the lower body at 90-degrees yaw

that, at a certain speed (the aforementioned critical speed), equals and overcomes the car weight and determines take-off.

The DW12 car, which made its debut in 2012, was the first occurrence of an aerodynamic design process which put sidewind stability ahead of pure performance. In fact, its shape was born after over a year of dedicated study to improve the downforce and the critical speed in these conditions.

#### **Domed skids**

After a few years without critical crashes, in 2015, when the constructors' Aerokits arrived, some heavy crashes occurred during Indy500 practice. Consequently, for 2016 IndyCar introduced the domed skids, the main purpose of which was to slow down the cars and reduce the strength of any impacts, after it was discovered take-off actually occurred at 180 degrees, after the car hit the wall.

But what do these domed skids look like, and how do they work? They were actually first seen in 2007, in the previous generation car, and consisted of a convex surface on the bottom of the car in the transversal flow direction, which at 90-degrees yaw induce a suction generating downforce (see **Figure 3**).

Unfortunately, as mechanics often use the flat surface of the underwing skid as a reference for measurements, a drawback of the domed skids was they removed an important reference for set-up, so made the race engineers' job more difficult at the track.

A deep analysis followed the 2016 crashes. In general, it is not easy to understand the tyres' conditions when a car is spinning at 230mph as everything happens in a few tenths of a second. The visible smoke generated by the high level of friction between tyre and ground used to be the most evident signal that tyres were slowing the car down. Following the introduction of the domed skid, engineers noted the spinning car tyres weren't generating smoke any more. This was a hint that, as a result of the huge loads generated in the 90-degree yaw condition, the tyres were exploding, therefore becoming ineffective in slowing the car while sliding. That suggested the downforce obtained with the domed skid in that particular condition was maybe even too high.

#### **Lateral bumps**

For this reason, the domed skids were removed in the 2018 Universal Aerokit, but their effect was partially restored with some lateral side bumps on the underwing, which generate a peak of local suction, as shown in **Figure 4**.

Moreover, the necessity to keep the critical speed at 90-degrees yaw under control brought additional vertical fins on the nose and on the engine cover as well.



Honda unveils its Aerokit in 2015 as manufacturers took a more active role in the design of their racecars

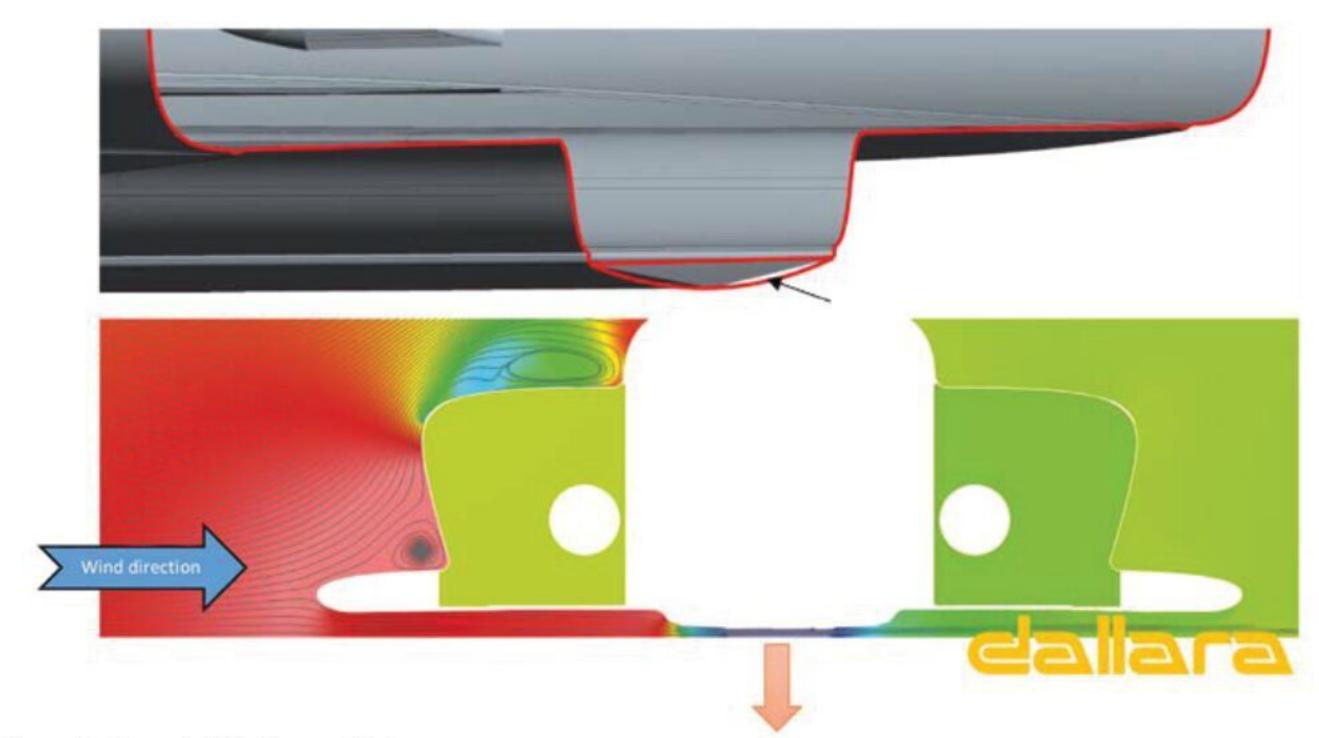


Figure 3: Domed skid effect at 90-degrees yaw

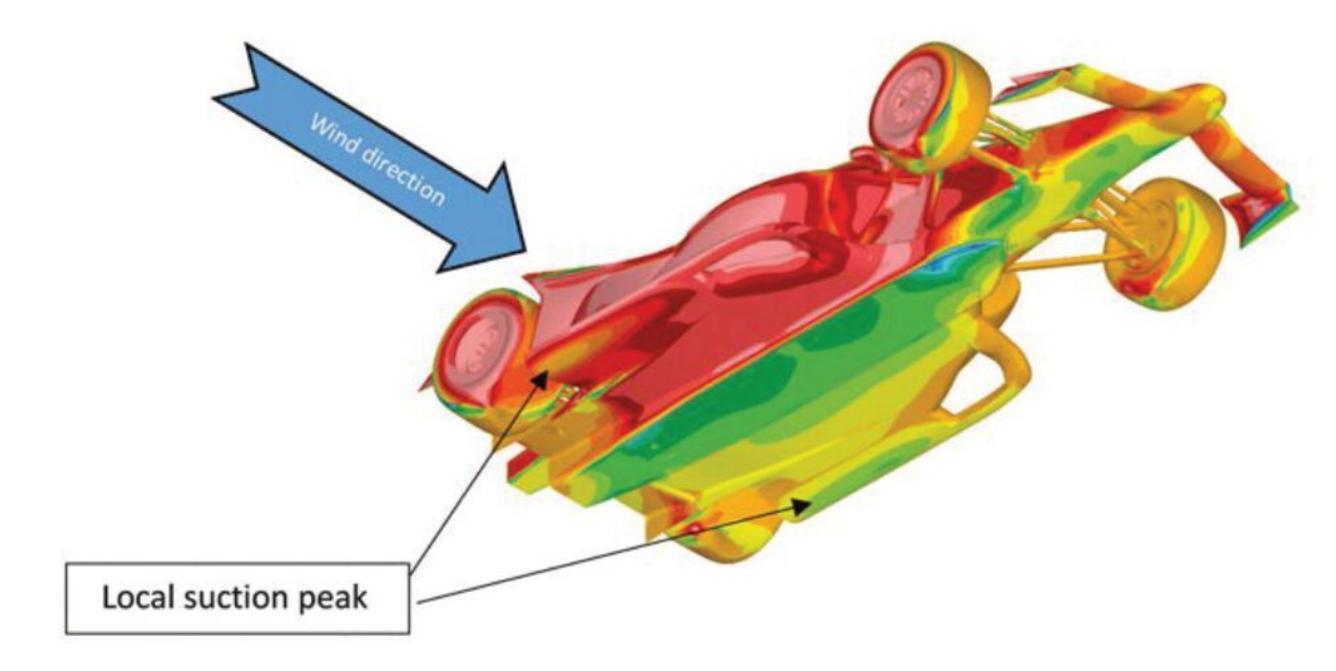


Figure 4: Effect of the side bumps that replaced the domed skids

As a result of the huge loads generated in the 90-degree yaw condition, the tyres were exploding, therefore becoming ineffective in slowing the car





KTM Sportcar GmbH congratulates Syntium Apple/KTM Cars Japan for it's class victory upon their premiere race with the brand new KTM X-BOW GTX.

Are you READY TO RACE? Contact us: x-bow@ktm.com



# Once any external phenomenon brings the car's nose up to five degrees, the underwing acts like a sail

Finally, a detail already discussed at length in a previous issue of *Racecar Engineering* (V30N10), was the introduction of a vertical wicker that extended from the nose to the convex, lifting surface of the polycarbonate windscreen when the Aeroscreen was implemented in 2020. The impact of the Aeroscreen on 90-degree take-off stability, which was originally detrimental, turned into in a beneficial contribution thanks to this small but important modification.

#### Nose down

In 2014, IndyCar and Dallara started to consider another take-off condition. Following analysis of the most recent and dramatic crashes, the designers realised that if any event had lifted the nose of the car, the flow could easily raise the car body, as shown in **Figure 5**. One of the most common situations that could bring the car nose up is the front wheels impacting the rear wheels of the car ahead. The counterrotating direction of the two tyres acts as a springboard, launching the nose of the following car into the air. This principle is generally true also for a front-wheel contact with any part of the bodywork of the car ahead, or between nose and rear wheels.

Therefore, when designing the new generation (2012-2014) car, much attention was put on mechanical measures to prevent interlocking wheels in side-by-side racing. This resulted in the design of a wider and longer flat underwing and the adoption of a rear bumper

From an aero point of view, the comparison between the 2011 IR11 car and the 2012 DW12 in a five-degree, nose-up pitch condition showed the take-off attitude was actually worsened by the new underwing surface. **Figure 6** shows a comparison between the two.

It is easy to understand how this can contribute to the take-off attitude of each car as, once any external phenomenon brings the car's nose up to five degrees, the underwing acts like a sail and lifts the car into the air. The larger the sail, the bigger the lifting force.



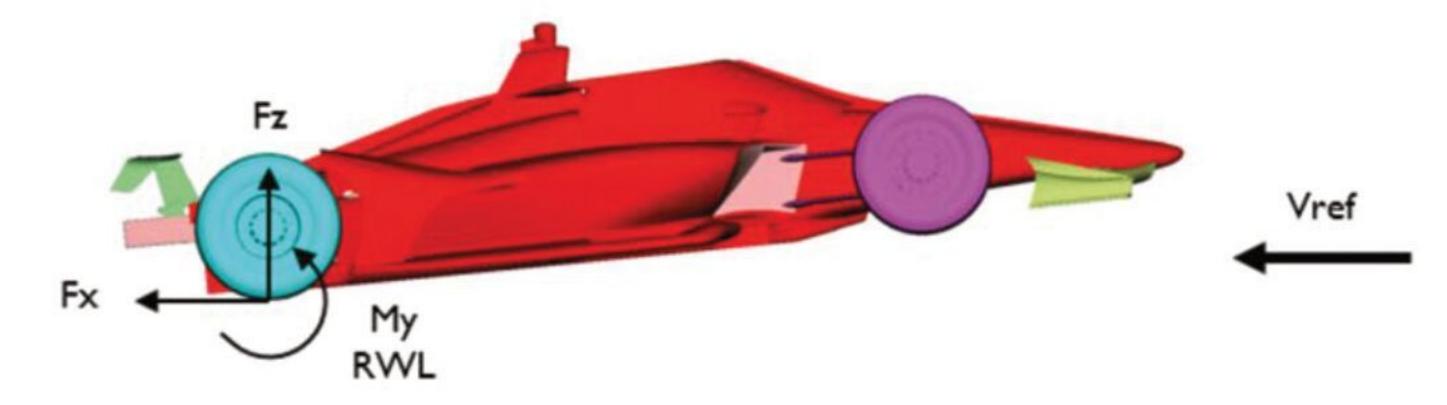


Figure 5: Aerodynamic forces at five-degree, nose-up pitch

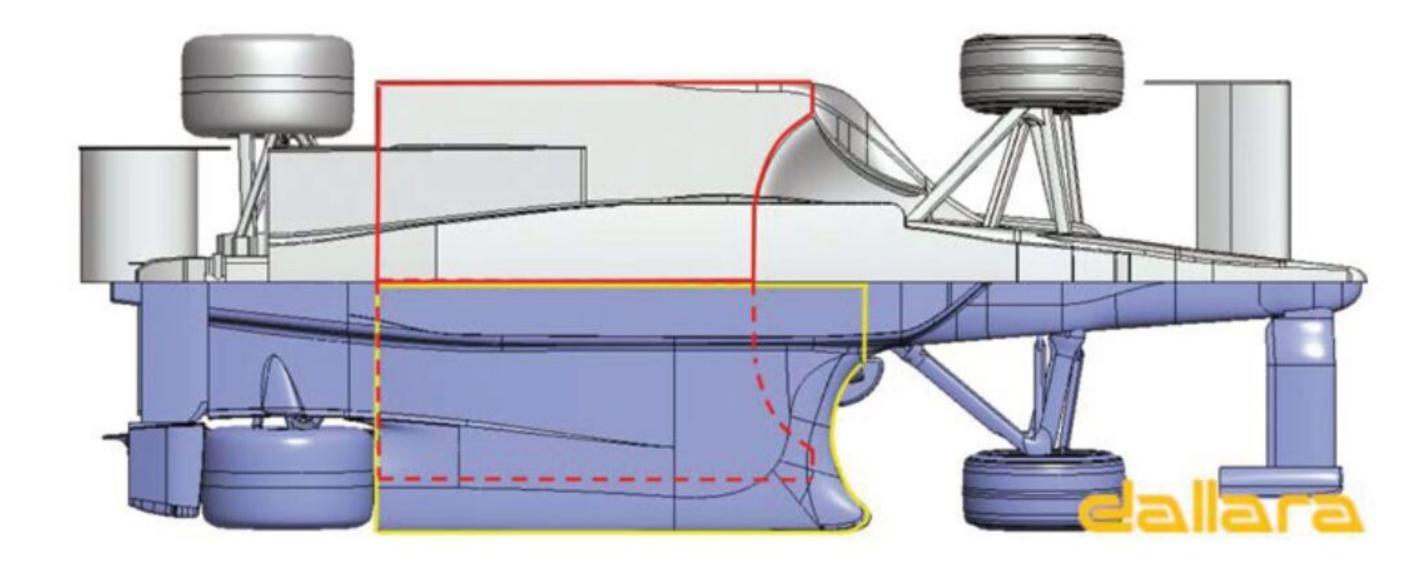


Figure 6: Comparison between the DW12 (yellow) and IR11 (red) underwing in plan view



Honda's version of the 'underwing' for the road street course in 2018 Cascadia Motion offers extensive experience in professional motorsports, supercar, hypercar, on- and off-road specialty vehicle, and heavy duty electrified propulsion systems and components

- 10 seasons supplying Formula 1 ERS/HERS components
- Multiple LeMans Prototype applications
- Sole supplier MotoE propulsion components
- Sole supplier eTCR series propulsion inverters
- Sole supplier FIA eRX2 Championship propulsion inverters
   Worlds fastest production Electric Car
- Worlds fastest production Electric Motorcycle
  - Pikes Peak, multiple hillclimb and special purpose cars and motorcycles



**CASCADIA** MOTION

www.cascadiamotion.com info@cascadiamotion.com

# MANUFACTURERS OF ADVANCED COMPOSITE PREG MATERIALS





Point Camera Here

To Visit Our Website

SHD Composite Materials Ltd offers an extensive range of high-performance prepreg materials to meet your specific racing requirements, consistently delivered within short lead times to the highest quality.

We work with our customers' to improve racing performance by reducing weight, increasing strength and enhancing driver safety, supplying prepreg for chassis, aero packages, body-work and heat shielding.

For further product information, please visit our website or contact sales@shdcomposites.com

Lower pressure

Higher pressure

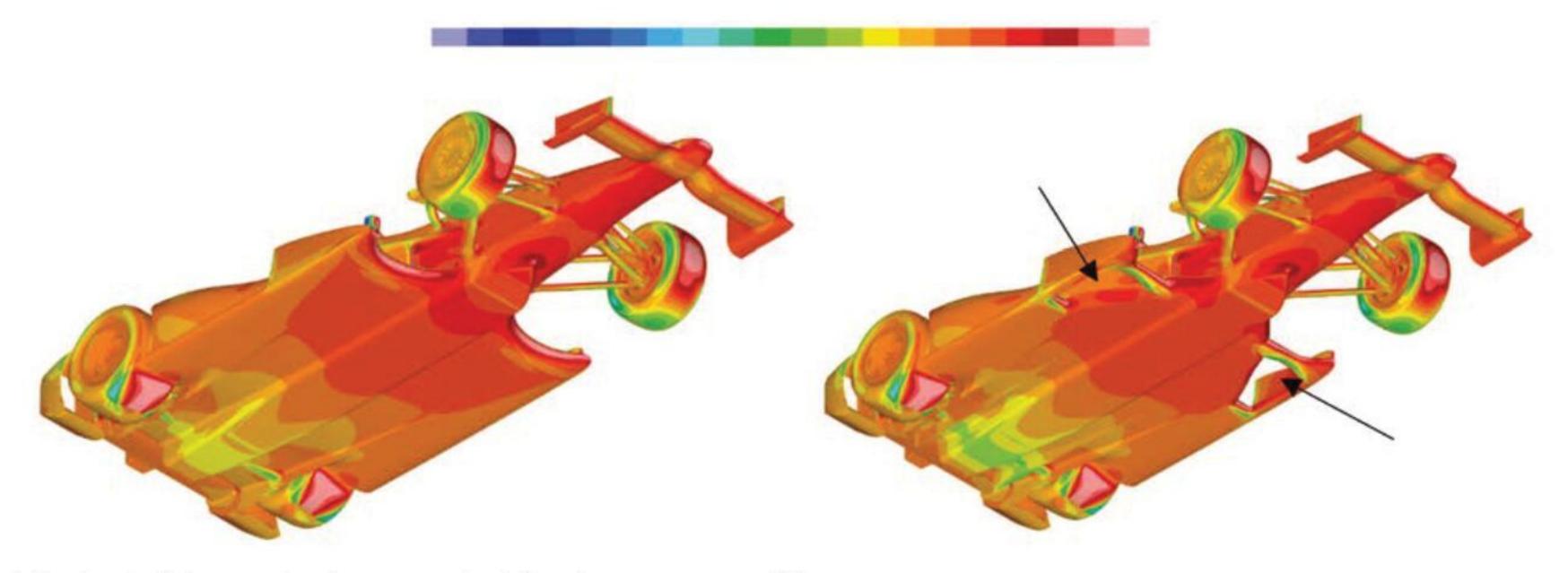


Figure 7: Effect of underwing holes on underwing compression in five-degree nose-up condition

In order to increase the critical speed in this nose-up condition, a large hole was introduced on each side of the front underwing, as shown in **Figure 7**, with the aim of reducing its surface area in plan view. The holes also had the effect of relieving compression in the surrounding area of the floor. The consequence of these combined effects was an increase in the critical speed of 30mph – a huge, and very worthwhile, improvement.

Table 1:	Effect of	underwing	holes on
nose-up			

Configuration	ΔVcrit
IR11	222mph
DW12	190mph
DW12 with underwing holes	222mph

Obviously, giving away such a wide piece of the underwing area also produced a big downforce loss in standard conditions. Fortunately, the Aerokit introduced that same year (2015) brought a big performance increase, together with some further complications and a significant rise in the cost. The net result was the adoption of this critical safety feature did not cause a reduction in performance.

So much so, IndyCar and Dallara retained similar holes with the IR18 Universal Aerokit, in order to keep the nose-up critical speed inside an acceptable safety range.

#### 180-degree yaw

The next area of study came about after the crashes that occurred in practice at the 2015 Indy 500. Within a few days of each other, three cars lost control, turned through 180 degrees yaw, hit the wall and then flipped over in the air. **Figure 8** shows a frame from Castroneves' crash.

After losing control in corner exit, the cars span and hit the wall. After impact, they proceeded parallel to the wall, but moving backwards. This condition is referred to as

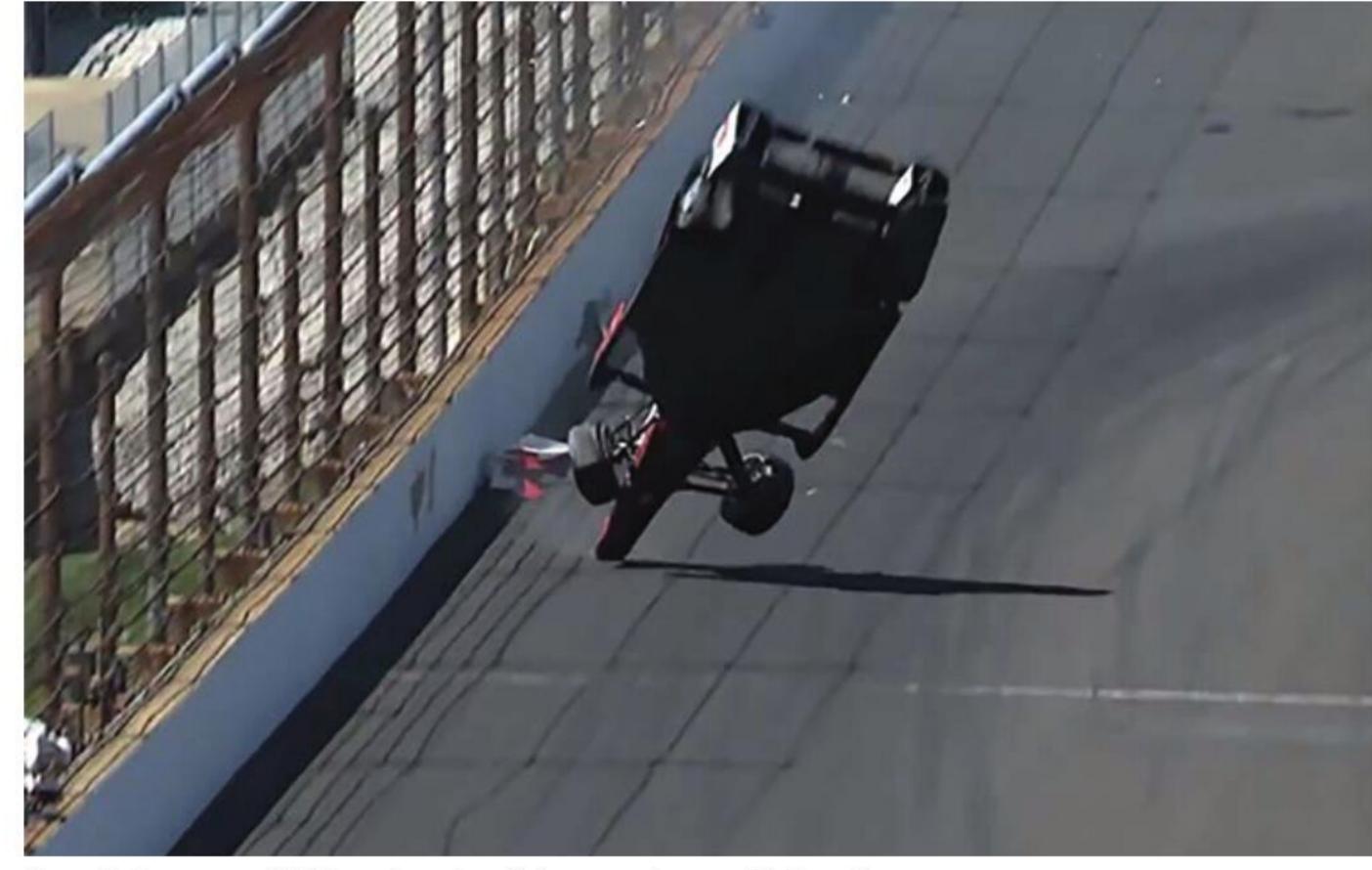


Figure 8: Castroneves' 2015 practice take-off after a rear impact with the wall

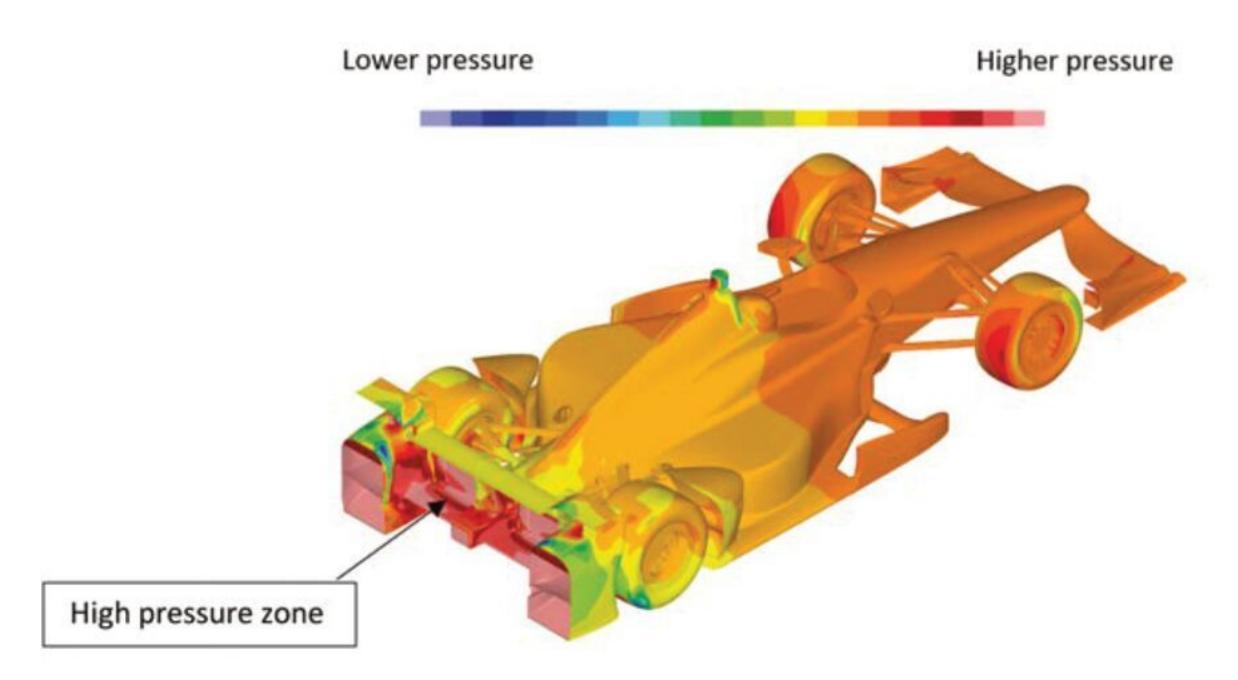


Figure 9: Pressure field with beam wing flip deployed and car travelling at 180-degrees yaw

180-degrees yaw, since the air direction is opposite to the car's normal angle of attack.

Consequently, for the following year, a flap was introduced on the beam wing, right between the bumpers and behind the rear diffuser. This aero device was designed to open automatically with aerodynamics force once the car started to spin.

When deployed, the flap induced a high-pressure zone on the beam wing, helping reduce the lift coefficient and the flipping moment. **Figure 9** shows the pressure field with the flap deployed, when the car is travelling backwards.

The inventors and designers of this device were subsequently awarded with

# Out in front!

Family owned and run since 1961,

# T&K Precision Ltd

are specialist manufacturers to the motor racing industry, including most major FI teams.

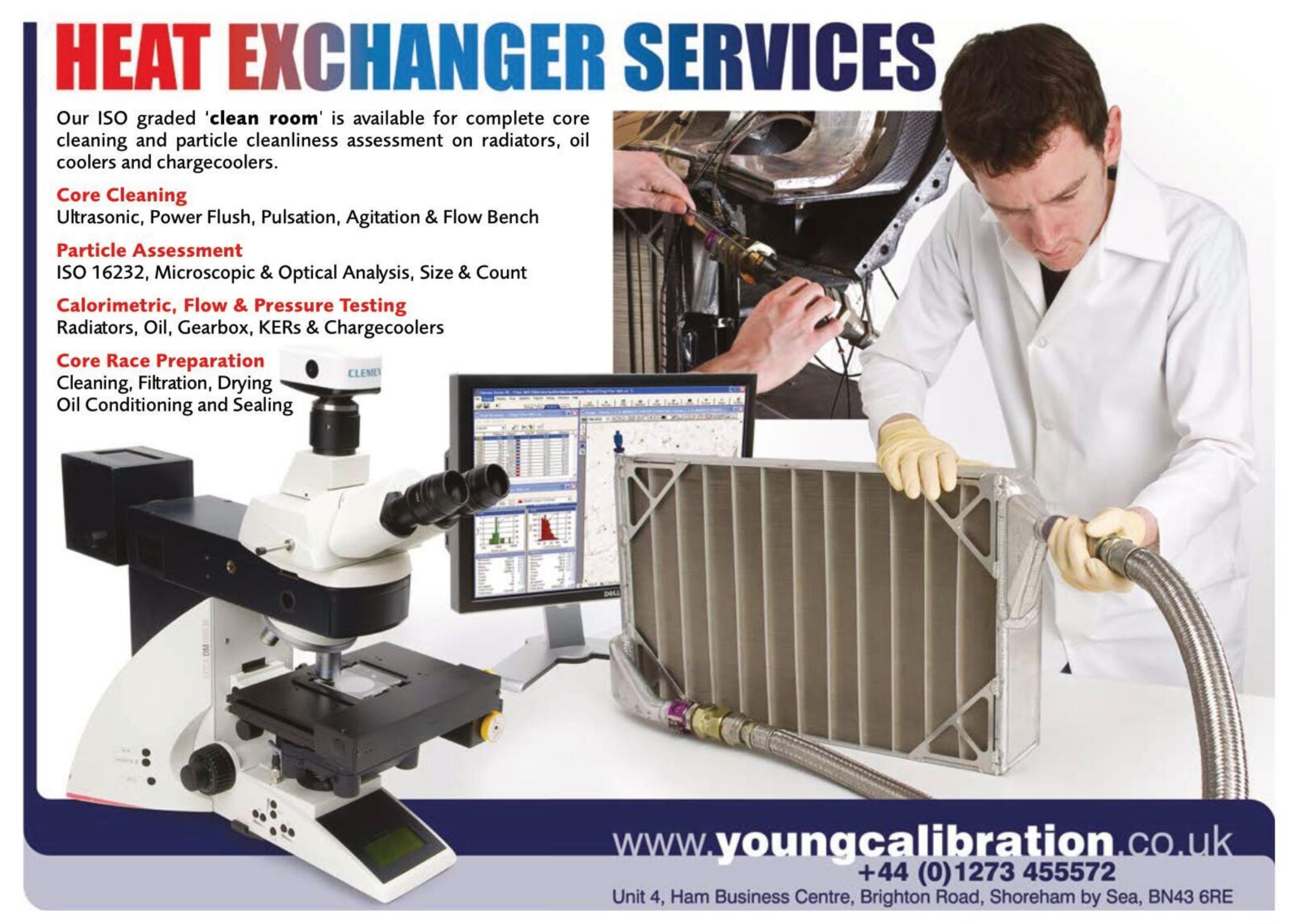


- Custom made, high tolerance
   Thread Rolled
   Studs & Fixings
- MP35N studs a speciality
- Fast turn-around
- Superior quality guaranteed

Check out our new website!

www.tkprecision.com

I0 Gatelodge Close,
Round Spinney, Northampton,
NN3 8RJ UK
Tel: (0) 1604 493 101
Fax: (0) 1604 493208
email: sales@tkprecision.com



the Louis Schwitzer Award in the same year: Tino Belli for IndyCar, Arron Melvin for Chevrolet and Alex Timmermans for Dallara.

Once more, the track was the only true judge. The following years showed the flip-flaps deployed correctly in practice, and no other 180-degree yaw flips were observed when cars were proceeding backwards.

In 2018, the Universal Aerokit for the back of the car was heavily re-designed, removing the rear bumpers and the beam wing. But remembering the precious lesson learned in 2016, the concept of the flip-flaps was carried over, though re-designed as a similar device located at the trailing edge of the floor, behind the rear suspension.

#### The leeward flip

In 2019, IndyCar and Dallara had to face another serious challenge to the stability of the car.

Suddenly, during Indy 500 practice, some cars lost control, hitting the barrier and starting to flip over their leeward axis. **Figure 10** shows a frame from O'Ward's crash.

The reason why these crashes happened in 2019 rather than in 2018 is not yet clear. Only minor aerodynamic changes were introduced on the front wing, and the other chassis components remained unchanged. More robust tyres at the front were the only major change. That could have modified the dynamics of the car during the spin section of the crash, leading the vehicle to hit the barriers in a position that favoured the aerodynamic-driven flip of the car.

In any case, the designers had to react quickly in order to reduce the possibility of seeing similar flips in the upcoming Indy 500 qualifications a week later. Detailed analysis of the videos showed the start of the flip was mechanical – the impact with the wall brought the car into a sideways slide with the windward side raised due to suspension failure on the opposite side. This channelled the flow under the floor and lifted the car. After this, the rest of the dynamics of the crash were driven by aerodynamics. The result was the car lifted into the air and flipped over its centreline axis.

A dedicated CFD study of the car in this new flipped condition was set up to understand the causes of the phenomenon and to investigate possible solutions.

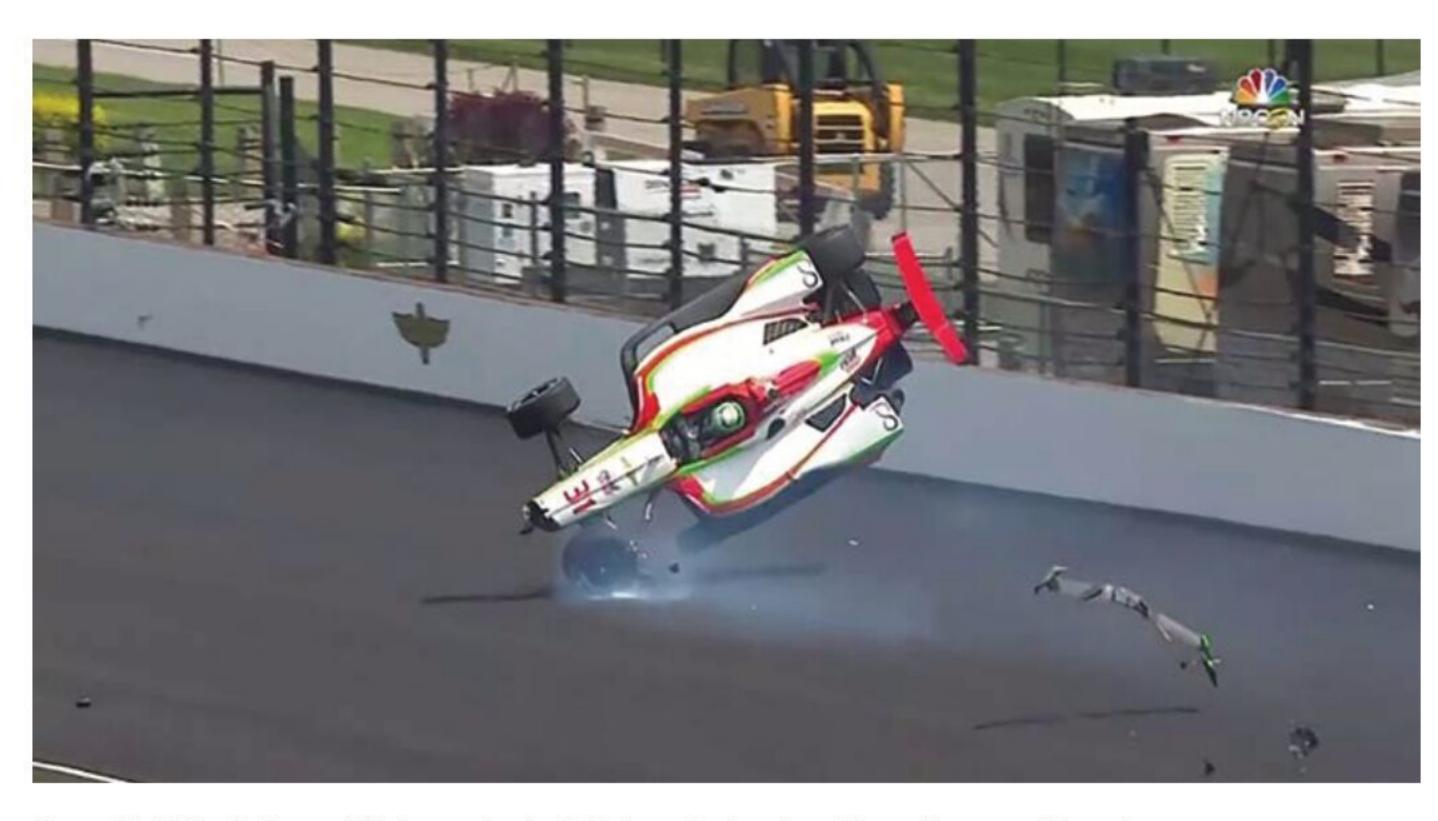


Figure 10: O'Ward's leeward flip in practice in 2019. Investigations into this accident are still ongoing

**Figure 11** shows how, in order to best represent the real condition, the track barrier was included in the model, and the front wing and left-hand side suspension failures were reproduced.

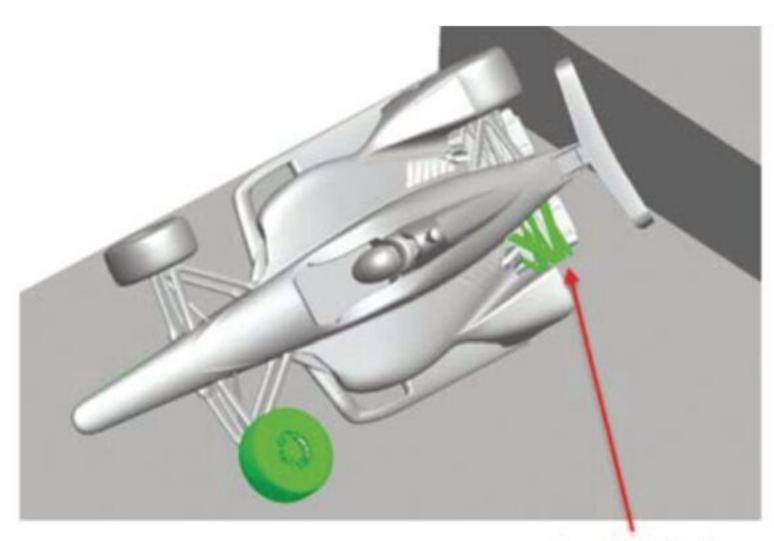
The first CFD simulation showed the suction on the top convex surfaces of the sidepod and the tyre ramp played a significant role in the overall lift coefficient. The suction effect on those surfaces was as critical as the compression generated under the floor.

During this study many different solutions were taken into account. Due to the very restrictive timeframe, only small and simple parts could be designed, produced and fitted to over 30 cars before the following event. An effective solution was to reduce the suction on the upper side through the introduction of vertical fins. **Figure 12** shows how these small parts could significantly alter the pressure field on the upper bodywork, when installed in the right places.

Moreover, the fins had practically zero effect on performance in the standard condition, making them an ideal solution.

#### **Never-ending story**

Safety is never a closed chapter in motorsport. As the recent and successful introduction of the Aeroscreen has displayed, race organisers and chassis constructors are always trying to make racecars safer, and to minimise the danger for all those involved in the events.



Rear left wheel removed. Suspensions are kept.

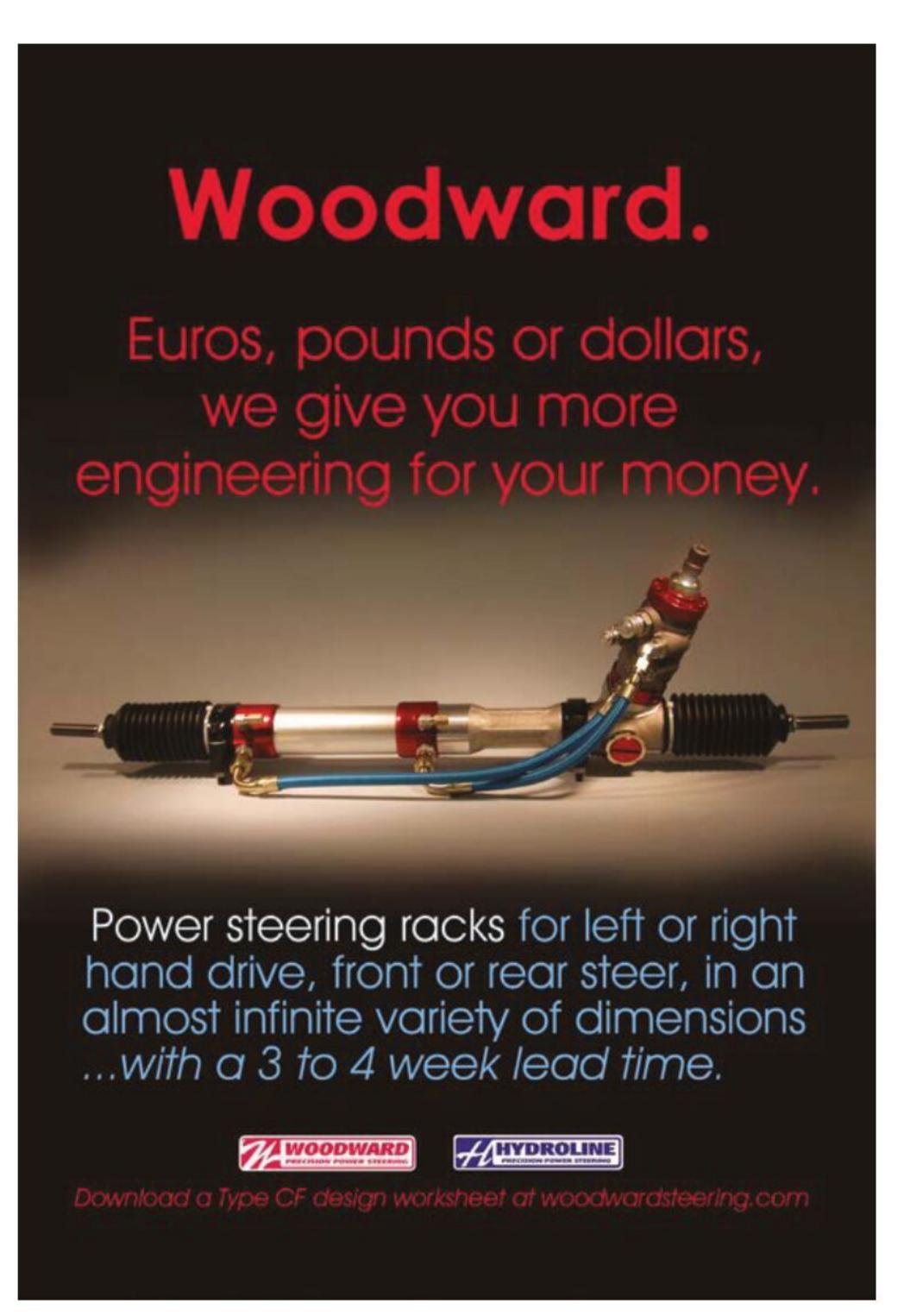
Figure 11: Simulation setting of the car in a leeward flip scenario

From an aero perspective, this means when a new car makes its debut, or a simple modification to a current car is implemented, the potential effect on crash dynamics must be considered. Any time a new component can alter the car's stability, the new critical velocities are computed from CFD simulation, and countermeasures taken if necessary.

At the same time, it is impossible to predict the sheer variety of situations that *could* potentially happen during a racing event, so the reality is continuously suggesting new testing conditions to be studied and improved. Dallara and IndyCar are always working to keep pace with these challenges and to make the fastest race in the world the safest one as well.



Figure 12: Effect of stability wickers on the leeward flip scenario. With no reduction in performance, these simple additions were deemed a resounding success





ACCELERATE EVERY STAGE OF DESIGN AND DEVELOPMENT WITH TOTALSIM US:

- Streamline pre-processing, post-processing, data management and more with automated CAE processes and workflows
- Perform highly-accurate CFD simulations with intuitive, web-based applications tailored to automotive designs
- Tap into our racing experience for on-track, wind tunnel and bench testing, performance mapping and aerodynamics analysis

EMPOWER YOUR TEAM WITH THE TOOLS TO OVERCOME CHALLENGES AND DELIVER HIGH-POWERED RESULTS.

CALL US ON +1.614.255.7426 (USA) OR +44 (0)1280 840316 (UK) OR EMAIL INFO@TOTALSIM.COM

TOTALSIM.com

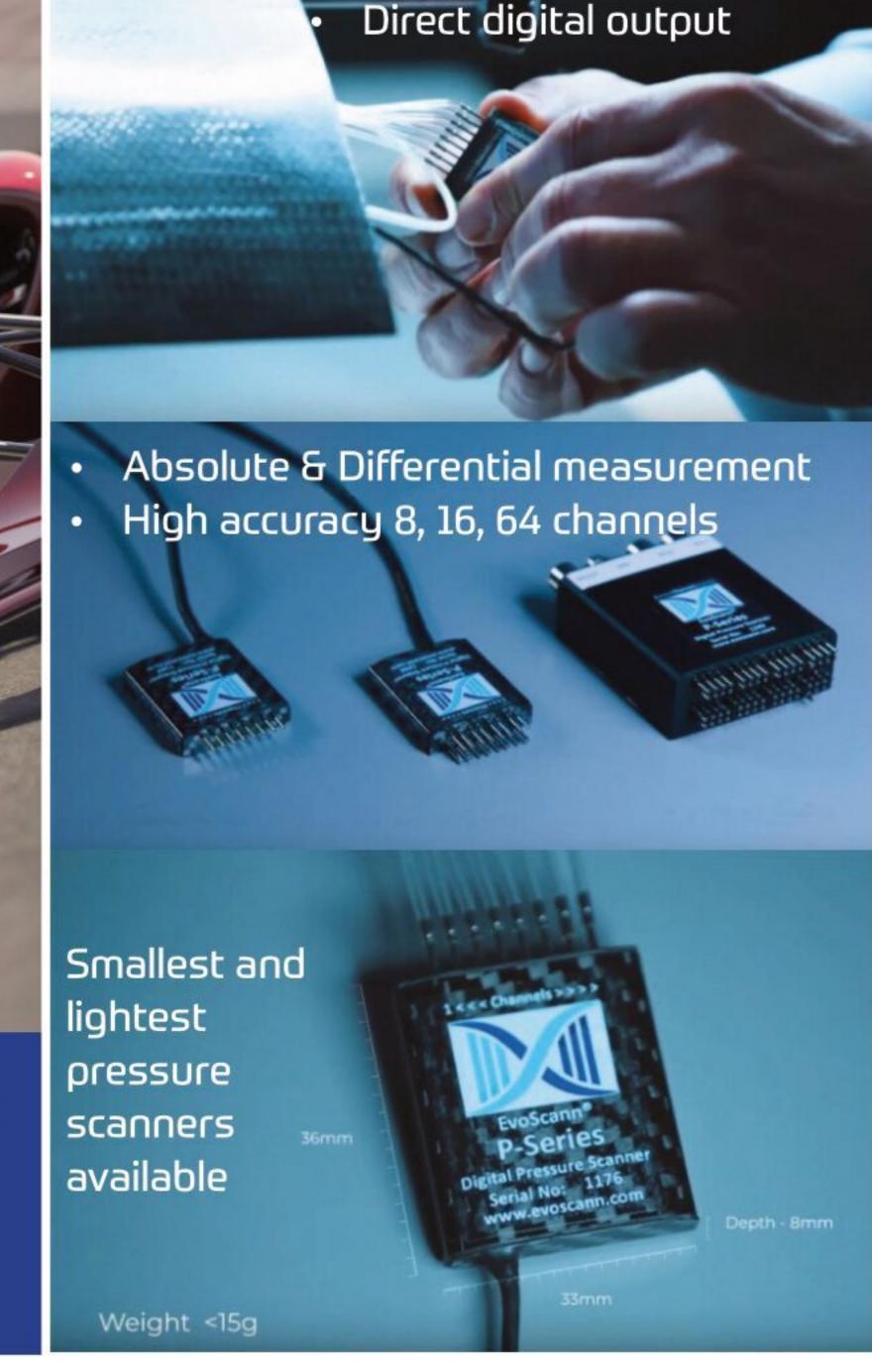
Integral microprocessors



To request an EvoScann® demonstration or quotation call +44 (0)1264 316470 or email enquiries@evolutionmeasurement.com

www.EvoScann.com

**EvoScann®** 



# Stepping Stone

Racecar examines
the first car out of the
blocks in the class
designed to bridge
the chasm between
Rally4 and Rally2
By LAWRENCE BUTCHER





he R5 class of rally car (now known as Rally2 under the FIA's new pyramid structure) has been one of the greatest regulatory successes of the past decade. With several thousand R5s now built by a host of manufacturers, the balance between performance and cost effectiveness hit the mark with competitors at both international and national level.

However, a Rally2 car is still far from cheap, coming in at close to €250,000 (approx. \$298,000) once spec'd in both gravel and tarmac trims, and with a few optional extras added to the mix. This is a huge jump from the €66,000 (approx. \$78,750) cost of a Rally4 (formerly R2) spec, FWD machine which, until this year, was the next step down on the WRC progression ladder.

For drivers wishing to step up to 4WD, there is also a considerable leap in performance, with cars outputting around 200bhp in Rally4 and close to 300bhp in Rally2.

Enter Rally3, which will now provide a stepping stone across this void.

# The early bird

As it was with R5, Malcom Wilson's Cumbria, UK-based MSport has been the first out of the blocks to homologate a car to the Rally3 rule set, developing an iteration of the evergreen Ford Fiesta. In fact, the team can take much of the credit for the creation of the class.

Maciej Woda, managing director at MSport's Poland base, where the majority of its customer cars are built, was at the heart of the plan. 'To be honest, Rally2 has become so competitive in all of the championships, those guys are really on the edge,' he says. 'Jumping from Rally4 to Rally2, the speed difference is massive and the cost difference even greater, so something [in between] was needed.'

In 2019, when MSport released its last generation R2 car, Woda asked the FIA if it would be interested in a bridging class. '[We asked] if there was something like a four-wheel-drive R2, and MSport built one, would they look into creating regulations? They said "Maybe," and we started to think about adding rear-wheel drive to our R2 car.'

Following a visit from the FIA's sporting department, interest began to grow as the company revealed its concept.

# Cost cap

The regulations specify that a Rally3 car should cost €100,000 (approx. \$119,350) ready to race. However, this excludes the cost of the new road car upon which it is built, which is needed to register the rally variant. 'A car in a sensible specification, either gravel or tarmac, will be roughly €120,000 [approx. \$143,250], so half the price of a Rally2 car, and about €50,000 [approx. \$59,700] more than a Rally4 car, which I think is a really good package,' says Woda.

# Jumping from Rally4 to 2, the speed difference is massive and the cost difference even greater, so something [in between] was needed

Maciej Woda, managing director at MSport, Poland

Of course, adding a rear differential to a FWD platform requires some fairly major modifications, not least to accommodate the driveline for the rear wheels. 'You need a wider tunnel, modifications to the front suspension and steering rack to accommodate the propshaft, things like that,' explains Woda. 'But the plan was to use as many R2 components as possible, including the 1000cc engine.'

In an FIA technical working group at the end of 2019, Toyota expressed an interest in developing a Rally3 car, but asked if the permitted maximum engine capacity could be upped to 1620cc (from 1330cc), as that was the closest engine it had in production.



Changing the two-wheel drive platform to four-wheel drive added complexity and required significant modifications to the 'shell, but resulted in a far superior racecar

There were no objections from the other manufacturers, and MSport continued to develop its concept with the turbocharged, three-cylinder, 1000cc Ford Fox engine. However, the team realised it needed to change. 'After a month or so, we thought we are going to lose out here when Peugeot and Citroën come with larger engines, but Fiesta also has a 1500cc engine in the ST version,' says Woda. 'We had to check [it was permitted to use the engine] with Ford, as the Fox engine is very important to them, and they said to go for it.' It was this change that, in turn, spurred others across the still developing car concept, taking it further away from its R2 roots.

# Starting over

'It meant we had to start pretty much from the beginning, because everything had to be altered. A bigger engine meant a new transmission, which had already been redesigned, and the supplier had started on tooling. The car then became a bit heavier, so we needed a different upright and different

dampers. Suddenly, we had a very different car, though we did still try to keep as many components from R2 as possible, notes Woda.

At the rear of the car, the regulations specify a legality box within which the rear suspension and differential can be fitted, with extensive chassis modification allowed in this area. Woda recalls MSport being quite vocal in its desire to keep these changes to a minimum, though, with a firm eye on cost control. 'We were something of a policeman when it came to the regulations, because we didn't want to give the same freedom as you have in a Rally2 car for the rear suspension. We pushed for elements such as the wishbones being the same front and rear and the dampers being the same. There was no point in trying to build a car to compete against one we already have in our range. It needed to be something different.'

On this same subject, he recalls one manufacturer suggesting composite rear bodywork should be allowed. 'We had to say we are not going that way. It needs to stay as a standard 'shell with the minimum modifications.' And stay it did. Even the rear wheelarches are standard parts, with just a few cut outs to accommodate components such as the roll bars and driveshafts. 'It was about keeping both the costs under control and the performance of the car where it should be. We were not looking for a car only 0.3-4 seconds behind a Rally2,' reinforces Woda.

When asked whether there was ever any consideration given to making the rear end running gear a spec part, Woda says the idea had not even come up in discussions. 'I think that would be very difficult to do with a rally car, and some manufacturers would definitely benefit more than others.'

# **Showing restraint**

Though engine regulations governing Rally3 allow for the same level of modification as Rally4, Woda reveals that the higher class car actually has a more restrained specification. The internals are uprated with revised con rods and pistons, while the crankshaft is the standard production. The oil sump, flywheel





and turbocharger are also replaced.

However, other highly stressed
components, including the valvetrain,
are standard production fare.

'There is no machining to the block or heads, it's all standard parts,' highlights Woda. It is testament to the quality of these parts that the service interval on the engine is 2500km, which for some competitors will be enough to see them through a season. 'The rebuild costs are only around €7000 (approx. \$8325), so it is not that expensive to run,' he adds.

The transmission is also more closely related to the Rally4 transmission, rather than the 4WD Rally2 version. 'That [FWD unit] was our starting point, and Sadev just re-designed it to accommodate a propshaft output,' explains Woda. 'When we moved to the bigger engine, they had to re-do the bellhousing and incorporate some internal changes to accommodate the greater torque, but it remains within the same family of transmissions as the Rally4.'

The rear differential is designed specifically for Rally3, and the rules only allow for a single set of ratios to be homologated across both gravel and tarmac specs. 'It is a bit smaller than Rally2 and the disconnect [to disengage the rear drive when the handbrake is applied] is also smaller, though to be honest it would probably be okay in Rally2,' says Woda.

Efforts were also made to keep the chassis changes required to go from gravel to tarmac trim as minimal as possible. For example, although the dampers differ between specifications, the damper bodies are the same. 'If you wanted, you could just buy the different specification inserts and swap between the two,' says Woda. It's likely that

most teams will opt for two full sets. Similarly, while the front brake discs differ, the rears are the same. Beyond this, only the front upright spigots onto which the uprights attach, and the steering arms need be changed, though of course there is a selection of underbody protection that must be added to the car for running on the rougher surface.

# **Testing trials**

The first MSport R3 car to be finished was in gravel spec. 'You can't just work on the gravel specification and then think about tarmac after,' notes Woda. 'The initial testing was on gravel and we have done more testing on gravel than tarmac.' One of the reasons for this bias, he says, was that much of the testing took place in Sardinia. 'We were trying to give the car a really hard time, to make sure nothing cracked, nothing broke, to make sure it was ready for customer hands.'

That such durability can be achieved from a car running so many production car parts is testament to advances in the automotive industry generally, a factor MSport has become acutely aware of over the past decade.

'If you look back 20-25 years on a World Rally Car, there was not a single component coming from road cars,' comments Woda. 'If you think of things like sensors, because the road car sensors were quite poor back then, and there weren't many of them, we were buying some really quite sophisticated, expensive versions, and they still didn't last very long. Nowadays, you can use a road car fly-by-wire throttle and it lasts forever. Then you have pressure sensors that cost just a couple of euro and are perfectly accurate and reliable.'

Engine: 1500cc, direct injected, turbocharged I3, DOHC

Transmission: Five-speed sequential with front and rear plate

differentials, manual RW disconnect

Suspension: MacPherson strut front and rear

Power output: 215bhp

Torque: 400Nm

Weight: 1210kg

When working within the tight cost constraints now present in customer classes, a large portion of savings come from sourcing best quality road car components, avoiding the need for bespoke, and expensive, motorsport versions. It is not just electronics where this approach applies. The Rally3 suspension wishbones are standard parts, as they are in Rally4, with the addition of welded inserts and reinforcements.

'We have a standard upright we modify and even standard steering rods and ends. That is key to keeping costs down, and the reliability of those components is amazing.'

# **Avoiding hassle**

In the case of Rally4, a customer can buy a selection of parts from MSport and then, if they wish, undertake modifications to the production parts themselves. However, this is not an approach the company will be taking with the Rally3, at least from the outset.

The [engine] rebuild costs are only around €7000 (approx. \$8325), so it is not that expensive to run







Though it is built to be competitive on all stages, where the new R3 car will really come into its own is on loose or icy terrain. On its debut in Finland, it acquitted itself admirably

'We will be building the bodyshells to FIA spec and, at the moment, will only be supplying complete cars, but we might supply kits in the future.

'If I am totally honest, it is more hassle to have customers put the cars together than build them. If someone is building 10 cars, it's not a problem. They may have a couple of issues with the first two, but then they crack on. But if it is a one man band, who wants to build just one car – and there is no disrespect meant here – they are unlikely to have the same amount of experience, and will have a lot of questions. So it can actually be more work for us than just building it.'

Highlighting the validity of this concern is the story of one R2 customer who had prolonged issues with their wiring loom, necessitating considerable correspondence with MSport's support team. After detailed investigation, it turned out that the customer had removed a section of cabling to reduce weight, and without it the functionality was compromised.

# On the pace

Compared to the more potent Rally2 machines, Woda expects the Rally3 to be around 1.5 seconds per km off their pace, and around 4-4.5 seconds faster than Rally4.

'My expectation is they will be closer to Rally2 than 4. When we come to very grippy, twisty tarmac, that difference will be less, but the biggest problem with Rally4 is lack of grip. If you take a Rally4 Fiesta to Finland, you will be spinning the wheels in fourth gear sometimes.'

Initially, he says, some drivers were slightly dismissive of the lower spec four-wheel-drive machines, given the potency of Rally2. 'The perception has been that it is just a four-wheel-drive Rally4 car, but it is quite a lot more. We did a driving day here in Poland and there were quite a few people who thought it wouldn't be all that special, but the response was very positive.'

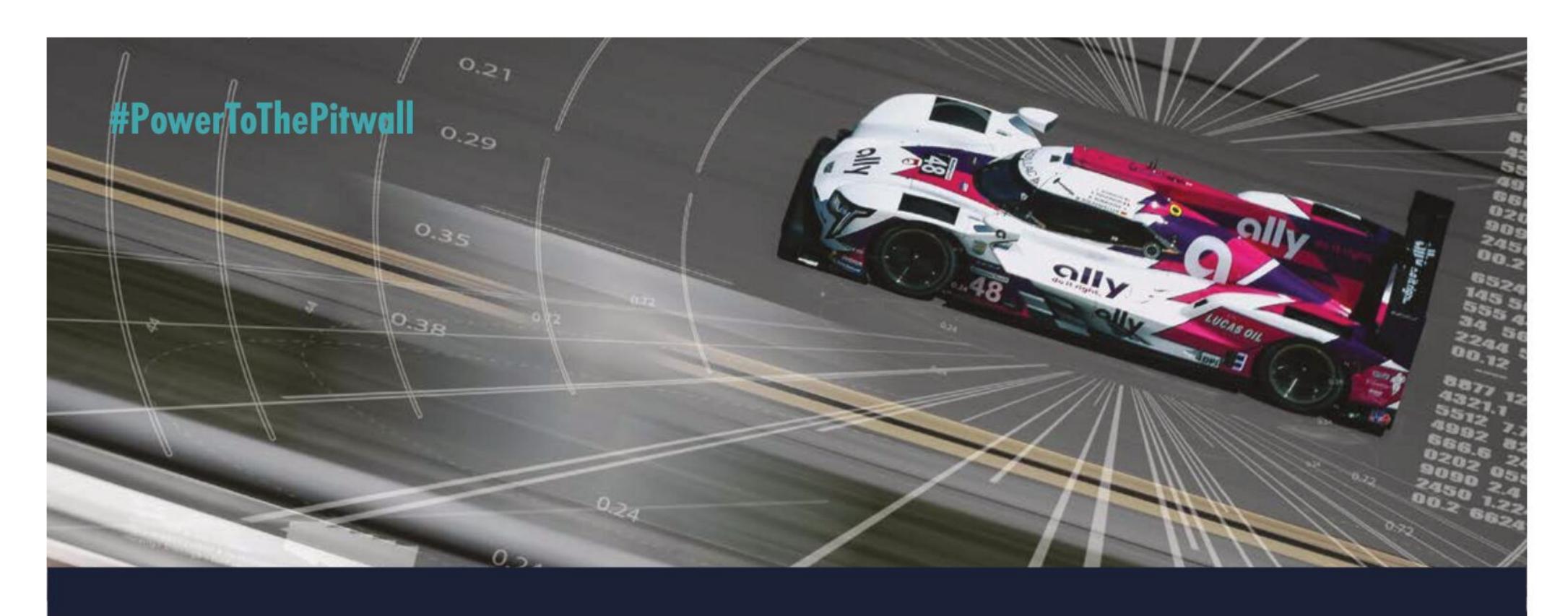
As to where the market share for Rally3 will come from, Woda believes many customers will be those that might be considering buying an old Rally2 car. 'I think it will also be a big opportunity for those that don't want a FWD car any more, but don't have the budget to jump into Rally2. That is who we are aiming for.

'I would be surprised if someone with the budget, and skills, for Rally2 would go down to Rally3. Though that said, if you had a championship with a few mid-range Rally2 cars, and you put a good driver in a Rally3, I think they would be up there.'

# The perception has been that it is just a four-wheel-drive Rally4 car, but it is quite a lot more

Overall, MSport is positive that the new class will prove as popular as R5 / Rally2, and the Fiesta did not disappoint in its debut outing on the Kouvola Finnish national rally round in early March. A Rally3, driven by Estonian Ken Torn, placed 11th overall, with only one, far more powerful, Group N machine in front of it, the rest of the field consisting of either R5 / Rally2 or S2000 cars.

From Woda's perspective, it is something of a miracle that the car was developed in such a short period, given the global challenges 2020 presented. I am absolutely amazed that we managed to design the car, get the suppliers on board and go testing [in that time]. Even when some of the suppliers were shut, they pushed to get us the bits they need. The team have done a great job with the strange and difficult year we've had,' he concluded.



# 24 Hour Race Proven. Again. And Again. And Again.

In 2020 Control Race Winning Telemetry helped its customers power to victories in the 24 hours of Daytona, Le Mans, Nurburgring and Spa-Francorchamps.



Contact us to learn more about our cellular telemetry solutions

cntrl.io win@cntrl.io

# RELENTLESS INNOVATION IN MOTORSPORTS TECHNOLOGY

# CONFUSED ABOUT EXHAUST?

# Come to the experts in exhaust design

For over 30 years,
Burns Stainless has
been helping racers
and champions design
exhaust systems. With
the use of X-Design
parametric exhaust
design software,
Burns can spec the
right exhaust for you.



Why build it twice, when we can help you get it right the first time.

WWW.BURNSSTAINLESS.COM | 949.631.5120





ianni Lancia must have followed the 1956 Formula 1 World Championship with a certain level of bemusement. His rivals of old, Scuderia Ferrari, won five of the seven grands prix in which the team competed, and Ferrari driver, Juan Manuel Fangio, was crowned World Champion at the end of the year. What made this particularly poignant for Lancia, though, was the fact the cars used by Scuderia Ferrari had started life late in 1954 and early in 1955 as Lancia D50s.

Designed under the technical leadership of the legendary Vittorio Jano, the cutting-edge Lancia grand prix car was the culmination of a vast competition programme that also included a full range of sports racers. In addition to indulging in motorsport for the first time in Lancia's long history, Gianni also commissioned the construction of the Lancia Tower, a brand new headquarters in Turin.

Ultimately proving his more prudent father and company founder, Vincenzo, right, the frivolous spending finally caught up with Gianni in 1955. Lancia was on the brink of bankruptcy and was only saved by wealthy Italian industrialist, Carlo Pesenti, in June 1956. He was keen to carry on producing the sophisticated machinery, but by that time the company's competition efforts had already ceased. As part of an earlier rescue attempt, the manufacturer's grand prix cars had been handed to Scuderia Ferrari, who had been desperately struggling with its four cylinder-engined machines against the mighty Mercedes-Benz team.

All this explains the background of how Scuderia Ferrari won the Formula 1 World Championship with a team comprised of Lancia racecars.

# Six of the best

Whether it was Gianni Lancia's plan to enter grand prix racing all along is not clear. What inspired the competition programme was a class win for a mildly modified Lancia Aurelia B20 GT production car in the 1951 Mille Miglia. This was hardly surprising as the Aurelia had been designed by a team lead by the aforementioned Jano. Hired by Lancia to head the company's technical department in 1945, Jano had previously been responsible for all the great Alfa Romeo road and racecars of the pre-war era. The Aurelia was introduced in 1950, and was the first series production car powered by a V6 engine.

This groundbreaking V6 would also form the basis for the range of sports cars that was duly developed by Jano and his team. But where the production engine used a single, centrally-mounted camshaft that operated the valves through pushrods, the V6 used in the racecars would feature bespoke cylinder heads equipped with a pair of overhead camshafts each. It was developed in a variety of sizes, starting with a 2.5-litre, and installed in a steel tubular spaceframe chassis.

Known as the D20, the first Lancia competition car was ready at the start of the 1953 season and one example won the Targa Florio in only its second appearance. The pace of development from there was relentless.

## **RACECAR INSIGHT - LANCIA D50**

Various different engine sizes were tried, the roof was cut off half-way through the first season to create the D23, and the rear suspension was comprehensively revised before the end of the year, resulting in the D24.

The work paid off, though, as the Lancia D24 won the 1953 edition of the gruelling Carrera Panamericana, and then in 1954 scored outright victories in the Targa Florio and the Mille Miglia.

However, in September of 1953, long before it was clear the sports car programme would be a success, Gianni Lancia decided that Scuderia Lancia would also join the Formula 1 World Championship.

# A new beginning

While the timeline of Lancia's motorsports exploits seems foolish, and probably was, it did make some sense to join Formula 1 at the start of 1954 as it was the first year of a new set of regulations. During the 1952 and '53 seasons, the grands prix were run for 2.0-litre Formula 2 cars due to the lack of full bore F1 racers. A renewed distinction was made in 1954, with the junior formula having its displacement limit reduced to 1.5-litres, while a new Formula 1 category was created with a 2.5-litre limit for naturally aspirated engines or 750cc when forced induction was used.

As the first V6 developed for the B20 sports car just months earlier displaced a little under the new Formula 1 limit, time could have been saved by starting with that engine design for the new grand prix engine. The Lancia engineering team, however, came to the conclusion that six cylinders would just not cut it. Instead, a brand new eight-cylinder unit was designed from scratch.

During his tenure at Alfa Romeo, Jano had already produced the fabulous '8C' engine, but that was an in-line eight. The new brief called for a much more compact V8 configuration. Like the earlier Lancia V6 competition engines, the new, all-aluminium, eight-cylinder engine featured a 90-degree cylinder angle. Each bank of four cylinders had two overhead camshafts driven from the crankshaft through gears mounted at the front of the engine. One each per cylinder, the intake and exhaust valves were mounted at 40 degrees.

At the rear of the engine, the two camshafts actuating the intake valves also drove the two coils. These powered the V8's twin-spark ignition. Mounted between the two cylinder banks were four twin-choke, 40mm Solex carburettors.

In its original configuration, the engine produced around 255bhp at 8200rpm, while running on an exotic fuel mixture that comprised 50 per cent 130 octane aviation petrol, 25 per cent benzole and 25 per cent alcohol.



Despite having a successful V6 race engine at its disposal, Lancia decided the F1 car should have an all-new V8 heart



It featured a 90-degree bank angle, gear-driven dual overhead cams, four 40mm Solex carburettors and twin-spark ignition



The timeline of Lancia's motorsports exploits seems foolish, and probably was



Though Enzo Ferrari ordered the GP cars be destroyed after the 1957 season, some of the original components were saved. However, prior to that, when the cars were transferred from Lancia to Ferrari ownership in 1955, Gianni Lancia reputedly kept one and a selection of parts. Consequently, there are two claimed original Lancia D50s in museums in Italy





The salvaged components were later used as the basis for a limited run of five D50 continuation models commissioned by Ferrari collector and chairman of JCB, Sir Anthony Bamford, and Lancia enthusiast, Anthony Maclean. All except Bamford's own car, pictured above, were built to Lancia spec, using the surviving original D50 museum car(s) for reference

# Lancia was the first to use the [V8] engine as an integral part of the car

As Colin Chapman would famously re-confirm some 15 years later with the Ford Cosworth DFV-engined Lotus Type 49, a compact V8 was capable of handling the requisite chassis loads. With the D50, however, Lancia was the first to use the engine as an integral part of the car. It was not fully stressed, but it did take the load of the top half of the spaceframe chassis. This not only saved weight as fewer steel tubes were needed, but also provided much better engine access.

Using the V8 as a partly stressed member was particularly impressive as the V8 was also angled 12 degrees to the left. This was done to allow the propshaft to run left of the driver. As a result, the seat could be mounted lower in the chassis, which in turn lowered the car's c of g.

# **Design brief**

A key part of the D50's design brief was to keep the weight as low as possible in the chassis, but also as close to the middle in order to improve handling. To this end, the five-speed gearbox was mounted at the rear of the car as an integral part of the final drive.

The quest for an ideal weight balance also led to a rather unusual placement of the fuel tanks. At the time, it was the norm to place the tanks in the tail of the car behind the rear axle. With this configuration, the fuel load had a considerable influence on the handling. There were no such issues on the D50 as the fuel tanks were mounted outboard in separate pontoons between the front and rear tyres. The Lancia's very short tail now only housed the oil tank.

The car was suspended by double wishbones at the front, while the rear end used a DeDion axle. On both ends, a transverse leaf spring was fitted. Hydraulic drum brakes with a 350mm diameter were mounted on all four corners.

By using the relatively small V8 engine, the D50 had a very short wheelbase, and the overall length was kept to a minimum by the location of the fuel tanks.

Designing, developing and building a bona fide grand prix car takes time, so it was no surprise that Scuderia Lancia was not ready to go at the start of the 1954 season. In fact, no new machine lined up for the season opening Argentinean Grand Prix. Instead, Ferrari effectively fielded a 2.5-litre version

of its Formula 2 car that had dominated the '52 and '53 seasons, while the new 250F was a more substantial evolution of the six cylinder-engined A6GCM Maserati had used in F2 during the previous two years.

The first all-new grand prix car built specifically for the 1954 2.5-litre regulations was the Mercedes-Benz W196 that debuted at the French Grand Prix in July of that year. Its biggest asset was its straight-eight engine that featured desmodromic valves and direct fuel injection. Like the Lancia, it too was equipped with a five-speed gearbox, but the rest of the chassis was less sophisticated. Another trick up Mercedes-Benz's sleeve was the fully enclosed, streamliner bodywork. Lead driver, Juan Manuel Fangio, hated this and had an open-wheel version made for the lower speed tracks. Regardless of the configuration used, the W196 was clearly the car to beat during the second half of the 1954 season.

Nevertheless, the German team kept close tabs on the development work being done in Turin as the D50, famously, was the only grand prix car really feared in Stuttgart.

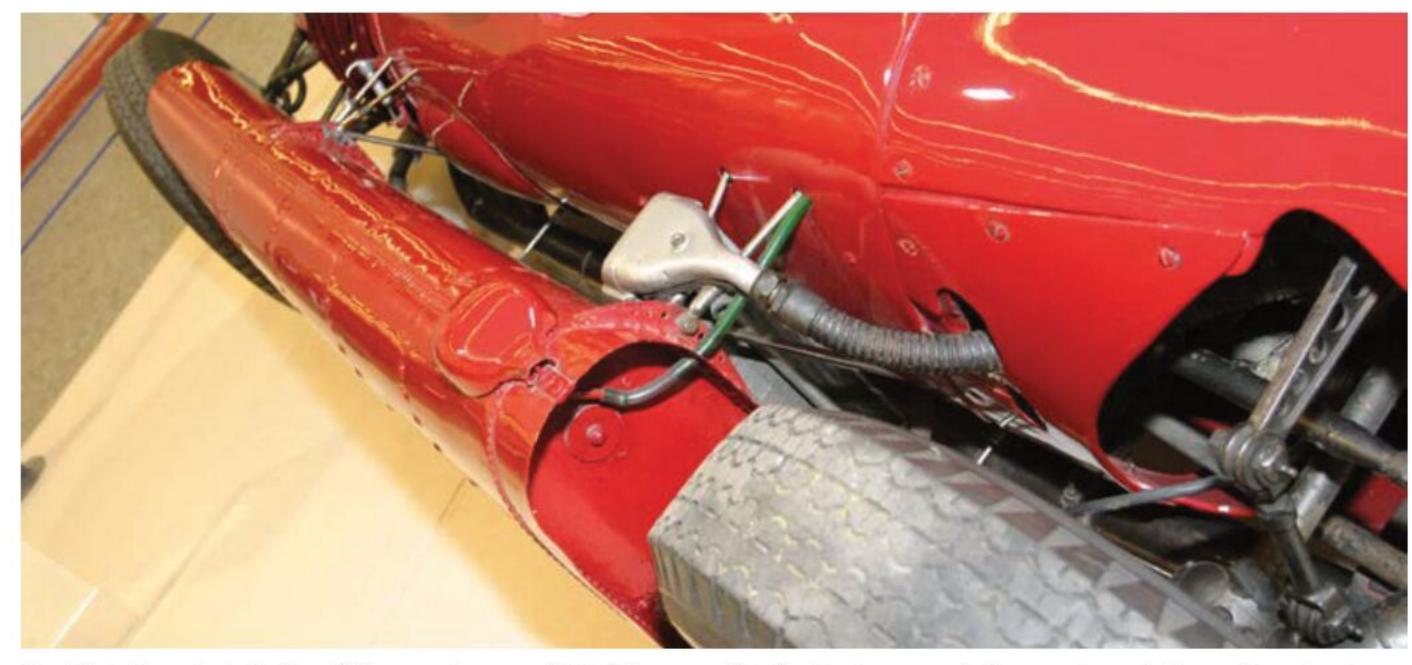
In addition to creating the hugely sophisticated racecar from scratch, Lancia had also managed to lure back-to-back World Champion, Alberto Ascari, away from Ferrari to become the team's lead driver. He made quite a sacrifice to join Lancia as he was forced to sit out most of the 1954 season, making it impossible to defend his title.

# Worth the wait

The highly anticipated debut of the D50 did not come until the final grand prix of 1954 in October at Pedralbas in Spain. As it turned out, it was not only well worth the wait, the fears in Stuttgart were justified. Ascari immediately qualified his D50 on pole position, a full second ahead of Fangio in the W196. The Italian's team mate, Luigi Villoresi, would start the race from fifth on the grid. After a slow start, Ascari grabbed the lead on lap three and set the fastest lap of the race before being forced to retire after just nine laps with a broken clutch. Villoresi's race was even shorter as his D50 succumbed to brake failure after two laps.

There was little time to re-group as the opening round of the 1955 World Championship was held in Buenos Aires on 16 January. It is believed that Scuderia Lancia brought five cars for its drivers to race, with Luigi Castellotti joining Villoresi and Ascari as the team's third driver. Once again, Ascari out qualified all four Mercedes drivers, but was beaten to pole by local ace, Froilán Gonzáles, in a year-old Ferrari.

The race itself, however, turned out to be an absolute disaster for the manufacturer, with Villoresi retiring due to a fuel leak and Ascari and Castellotti both crashing out.



Hard to believe in today's safety-conscious world, but these are the fuel tanks, mounted on pontoons between the wheels



Angling the engine 12 degrees meant the propshaft ran alongside the driver, who sat lower in the car to improve the c of g

# The D50, famously, was the only grand prix car really feared in Stuttgart

There was then a four-month gap in the calendar until round two of the championship, the Monaco GP, was due to be held. To build up some momentum, the D50s were fielded in minor races in the meantime. Ascari used the car to win the Gran Premio del Valentino in Turin and the Grand Premio di Napoli, while Castellotti placed second in the Pau Grand Prix.

Come Monaco, the bugs had been ironed out and Ascari shared the fastest time in qualifying with Juan Manual Fangio. For most of the race, Ascari fought valiantly against Fangio and his young British team mate, Stirling Moss. Fangio's was the first Mercedes-Benz to expire on lap 50 of 100. Moss was then forced to retire by the 80-lap mark, handing the lead to Ascari.



The Ferrari-modified cars featured this new, dual quad, open stub exhaust, which made the V8 engine sound absolutely brutal

Sadly, the experienced Italian never completed a lap in the lead as he famously crashed, flipping his D50 over the barrier into the harbour. Ascari survived and had to spend a night in hospital. Castellotti soldiered on and finished second behind a Ferrari.

# **Devastating blow**

In addition to feeling the financial strain of the ambitious programme, Scuderia Lancia was dealt a devastating blow four days later.











GO TO OUR WEBSITE TO VIEW OUR FULL RANGE OF MOTORSPORT ELECTRONICS

www.CARTEKMOTORSPORT.com

# POWER DISTRIBUTION PANELS

A switch panel and Power Distribution Module in one. Our Power Distribution Panels are a fully integrated solution designed to replace all the fuses, switches and relays of your race car.

- CONFIGURE CHANNELS IN 5A STEPS UP TO 30A.
- CHANNELS CAN BE PROGRAMMED TO CONTROL
   HEADLIGHTS/WIPERS/RAD FANS/STARTER MOTORS etc.
- EACH OUTPUT IS PROTECTED FROM SHORT CIRCUITS AND OVER-CURRENT.
- ADDITIONAL INPUTS ALLOW CHANNELS TO BE CONTROLLED BY ECU OR SWITCHES ON STEERING WHEEL...
- COMES WITH LABEL SHEETS FOR FULL CUSTOMISATION -RETRO EDITION NOW AVAILABLE.
- NO COMPLEX CONFIGURATION SOFTWARE AMP SETTINGS AND LOGIC FUNCTIONS ARE SELECTED THROUGH THE FRONT PANEL







### SOLID STATE BATTERY ISOLATORS

Cartek Battery Isolators are designed to overcome all of the problems and restrictions associated with mechanical and electro/mechanical battery disconnects.

- FULLY ELECTRONIC WITH NO MOVING PARTS COMPLETELY RESISTANT TO SHOCK AND VIBRATION.
- MUCH SMALLER AND LIGHTER THAN TRADITIONAL KILL SWITCH.
- MEETS NATIONAL AND FIA REGULATIONS.
- STATUS LED FOR FAULT DIAGNOSIS.
- SEALED INTERNAL AND EXTERNAL SWITCHES REPLACE TRADITIONAL PULL CABLES THAT ARE PRONE TO SEIZING.
- MOUNTS CLOSE TO THE BATTERY FOR REDUCED CABLING.
- QUICK AND EASY TO INSTALL.

Ascari was at Monza to see a friend test a Ferrari sports car and could not resist taking a turn behind the wheel. He crashed again, and this time the accident was fatal.

The programme was thereafter suspended, but Lancia did allow Jano to travel to Spa Francorchamps for the Belgian Grand Prix with a handful of mechanics, Eugenio Castellotti and two D50s. In what would be Lancia's final grand prix outing, Castellotti scored another pole position, and went on to average a staggering 197km/h on his first ever outing at this challenging track, beating Fangio by half a second. Sadly, victory again proved elusive as a gearbox failure ended the race for the sole D50 entered after 16 of the 36 laps.

After the Belgian Grand Prix, Gianni Lancia cancelled the competition programme and offered the cars for sale. This caught the attention of Prince Filippo Caracciolo, who was not only the president of the Italian Automobile Club (ACI) but also the father-in-law of Fiat supremo, Gianni Agnelli. Prince Caracciolo was keen to keep the sophisticated cars in Italian hands and devised a deal, together with Agnelli, that favoured Ferrari above all. The rival manufacturer would receive the cars and, in addition, an annual contribution of 50 million lira for five years from Fiat.

# Transfer to Ferrari

At a small ceremony in Turin on 26 July 1955, the transaction was concluded. Six D50s were lined up on the square for Ferrari to pick up. Also included was a set of unused streamliner bodywork. Another crucial part of the deal was that Jano would join the cars and work for Enzo Ferrari, who had already been his boss at Alfa Romeo two decades earlier.

Unmodified, three of the D50s were entered in the all-important Italian Grand Prix. In practice, they were beaten only by the three W196s. None of the D50s, however, started the race due to an issue with the tyres. The D50 was designed to run on Pirellis, but Ferrari had been under contract with Englebert. The Belgian tyre manufacturer kept their foot down and did not allow the Pirelli-shod cars to race under the Scuderia Ferrari banner.

Two weeks later, Scuderia Ferrari did race the D50 for the first time, in the International Gold Cup at Oulton Park, England. Mike Hawthorn used his D50 to finish second in the non-championship round, where Stirling Moss won, racing a Maserati 250F for the occasion.

During the off season, subtle modifications were made to the D50 design. A more conventional tail-mounted fuel tank was used. The pontoons were retained but, instead of being mounted on outriggers, they were now flush with the bodywork.

Perhaps the pontoons were retained as a means to reduce the drag without running a completely enclosed body?

The V8 engine was also modified to produce in excess of 265bhp, and there was a revised exhaust with four stubs exiting directly behind the front wheels on either side. This made for a thundering soundtrack unique to the Ferrari-modified Lancias.

Mercedes-Benz had ended its motorsports efforts after the disaster at Le Mans, so Ferrari was able to sign three-time World Champion, Fangio, to race for the team during the 1956 season. Castellotti was also part of the line up, back behind the wheel of a D50. Among the other drivers that raced the Ferrari-badged Lancias that year were Luigi Musso and Peter Collins.

Fangio won the first race of the season, after taking over the D50 of Musso after his own car had expired. Collins then won race three and four of the season before Fangio added two more to his tally. Fangio was crowned World Champion again, but left the team to race for Maserati in 1957. That year Ferrari continued to campaign derivatives of the Lancia design but with little effect.

# **Dino rising**

From the start of the '58 season, Formula 1 cars were allowed to run on commercially available petrol only, which the D50's V8 engine could not without major modifications. Anticipating this rule change, Jano was tasked with designing a new V6. This engine would be named Dino after Ferrari's late son, Alfredino, and would prove very successful as well. The subsequent Dino road cars used a derivative of this Jano-designed engine, underlining how profound an effect the deal between Lancia, the ACI and Fiat had been for Ferrari.

Having served their purpose, Enzo Ferrari ordered the V8-engined grand prix cars be disassembled. The chassis were scrapped, but most of the other components were saved.

# The fight between the nearly as advanced W196 and the D50 should have been absolutely epic

When Ferrari took over the cars, one was reportedly retained by Gianni Lancia, perhaps with enough spares to construct a second. Still in Lancia configuration, two original cars are now claimed to exist, with one on display in the National Automobile Museum in Turin, the other part of the Fiat Heritage collection.

Many of the components salvaged from the cars when they were dismantled were eventually acquired by noted Ferrari collector, Sir Anthony Bamford. By the mid-1990s Lancia enthusiast, Anthony Maclean, caught wind of this. He already owned a D24 recreation that had been built around an original engine and gearbox (the original D24s had suffered a similar fate as the D50s). Keen to resurrect the D50s as well, Maclean teamed up with Bamford and a number of craftsmen in Italy and the UK to rebuild the D50s using the original components. Brand new chassis and bodies had to be made, which was made possible by Lancia allowing access to its original car.

Five examples were built, and have since returned to the race track at events like the Goodwood Revival. All but one, Bamford's own example, are in Lancia configuration. Among the other current owners of the faithful replicas are noted collectors like Bernie Ecclestone and Miles Collier.

The Lancia D50 remains arguably the most sophisticated of all front-engined grand prix cars. Had the Lancia team been better funded and lasted for a full season, the fight between the nearly as advanced W196 and the D50 should have been absolutely epic.



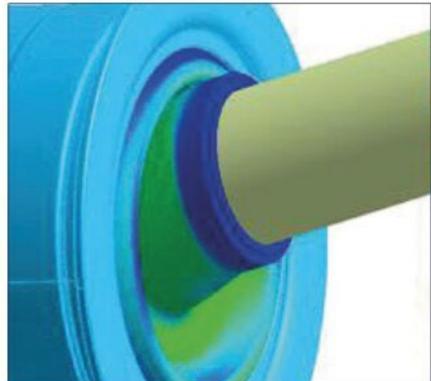
One of the continuation Lancia D50s under power at the end of the hillclimb at the Goodwood Revival in England



# **ACTIVE POLYMER TECHNOLOGIES**

# Design • Analysis • Manufacture





We specialise in the design and development of technologically advanced polymer products for use within motorsport, defence and industry.

Our design activities are dominated by expert use of the latest Finite Element Analysis software.

We manufacture high performance polymer products including:

- Low Profile CV boots
- High performance PTFE Lined shaft seals
- Bladder accumulators
- Custom polymer solutions
- AV mounts

For more information visit: www.active-polymer.com Tel: +44(0)7756 515772 • Email: support@active-polymer.com

# **Motorsports quality** ROD ENDS, Getecno SPHERICAL BEARINGS and BUSHINGS



Seals-it® **PERMAGLIDE®** 



Inch-metric

Deutsch, Fran

We speak

#### **ROD ENDS ACCESSORIES**

side seals, protection boots, jam nuts, right-hand and left-hand grooved bearings staking tools



Most extensive stock in Europe of US and EU made parts basic / regular / top performance product lines, flexible service, worldwide delivery support service to OEMs and regional distributors.

# AUTOMOTIVE



Think Automotive are specialists in oil cooling systems and all aspects of vehicle plumbing. We are the manufacturers and distributors of Mocal® and Laminova products.































We stock and distribute the finest automobile products, such as oil coolers, hosing, hose fittings, filler caps, water pumps, oil pumps, heater, gauges and more.

Tel:02085681172

Web: www.thinkauto.com

Email: info@thinkauto.com









# Intelligent Fully Featured Battery Power Control Systems



Fully programmable power control in a user friendly package.

Future Upgrade Path to HP8440.

#### Main Features:

- 180 Ampere continuous.
- 34 Output channels controlled as a function of conventional switches, CAN inputs or Virtual channels. With wiper Park on dedicated channels.
- Weight 496 gr.

# MEMBRANE PANEL



CAN Controlled Membrane Switch Panel. Tactile Operator Feedback. Multi Tap Capability. Warning LED's. Available With Your Custom Design.





#### Main Features:

- 200 Ampere continuous.
- Programmable Inrush Currents
- 34 Individually Programmable Output Channels
- 11 Conventional Switched Inputs
- 32 CAN Input Channels
- 20 Virtual Logic Channels
- CAN Export Facility
- Weight 680 gr.

Future Proof With Firmware upgrades

OVER 1000 UNITS SOLD WITH PROVEN RELIABILITY ENGINEERED & PRODUCED WITH OUR EXPERTISE IN HOUSE. LEARN MORE AT HPELEC.DK

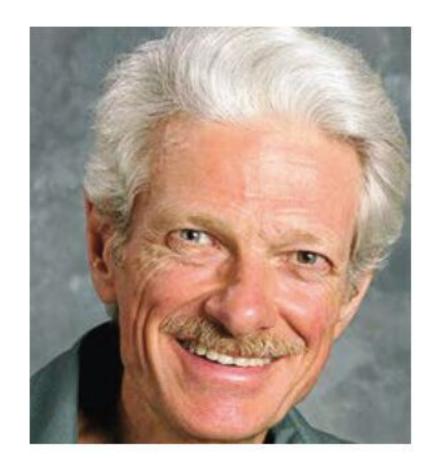


HP ELECTRONIK

Lundvej 17-19, Lund 7400 Herning · Denmark

Tel. +45 9626 4333

info@hpelec.dk Fax + 45 9626 4233 www.hpelec.dk



# Long in the tooth?

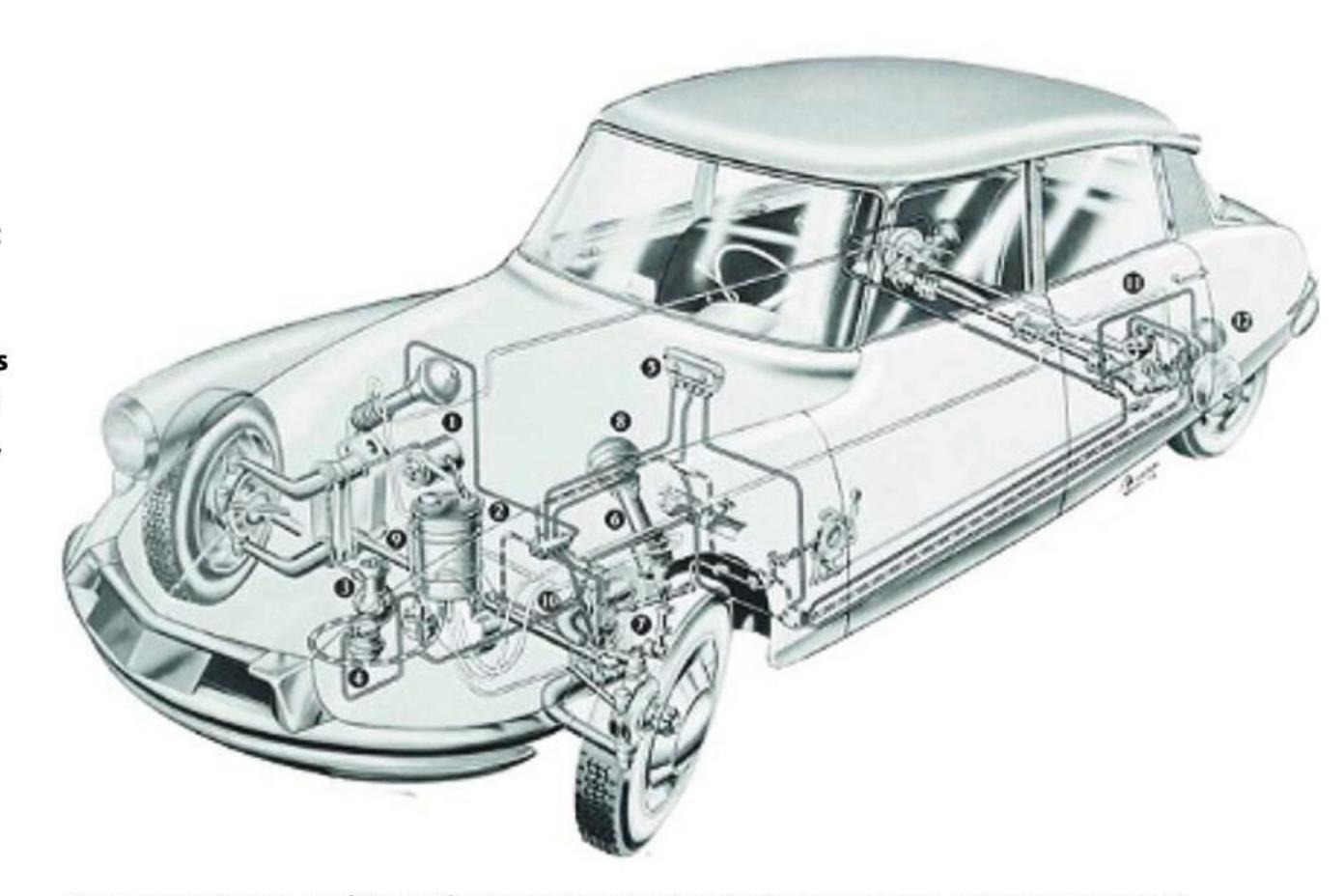
The pros and cons of leading, and trailing, arm suspension

#### By MARK ORTIZ

I wonder if you'd like to comment on leading and trailing arms on Citroëns, Volkswagens, old Fords and others? When a leading or trailing arm that slopes down toward the rear hits a bump, the rearward component of the force exerted on the arm tends to pull the chassis down, cancelling some or all of the upward force. So big Citroëns, with their long arms, have an awesome ride, and Beetles are great on rough roads.

A friend had a '48 Lincoln V12 coupe that had a great ride and cornered pretty flat without big anti-roll bars because of its high front and rear roll centres, and it just hit me, 70 years later, that that old, despised Ford suspension had long leading and trailing arms slanting down toward the rear.

Henry may have known something after all. What do you think?



Despite appearances, the Citroën DS does not have leading arm front suspension, rather an equal length parallel arm system with bellcranks to work the hydraulic suspension. Short trailing arms are used at the rear

## THE CONSULTANT

What really counts here is whether the wheel centre moves rearward as the suspension compresses.

In most suspensions, this means having a side view instant centre behind and below the wheel centre, or ahead and above. With parallel double trailing arms, as on a Beetle, the side view instant centre is undefined, but the hub moves rearward as the suspension compresses if the arms slope down toward the rear. One problem with this design is that if the arms need to be short for packaging and / or structural reasons, their side view inclination changes rapidly with suspension movement.

Additionally, if the arms are parallel and slope down toward the rear, we get pro-dive in braking.

The big Citroëns (DS / ID series) don't actually have leading arm front suspension, although the 2CV does. The latter has fairly long leading arms in front and trailing arms

in back, connected by a coil spring that resists roll and heave but not pitch or warp.

The DS / ID cars have fairly short trailing arms in back, along with an anti-roll bar. The front suspension has rather oddly designed control arms that sort of *look* like leading arms, but they're not. In fact, it's an equal-length parallel arm system with L-shaped arms that pivot about axes that are longitudinal, not transverse. The upper arm acts as a bellcrank to work the hydraulic suspension unit that provides springing and damping.

This is not a very structurally efficient shape for the arm, but it allows it to anchor to a structure entirely behind the drive axles (the structure forward of that point is designed to collapse and attenuate impact in a frontal collision). The unusual control arm shape also offers good wheel clearance when steering, with the steering axis deep inside the wheel.

Citroën used the same design, but back to front (ahead of the axle) in its SM model.

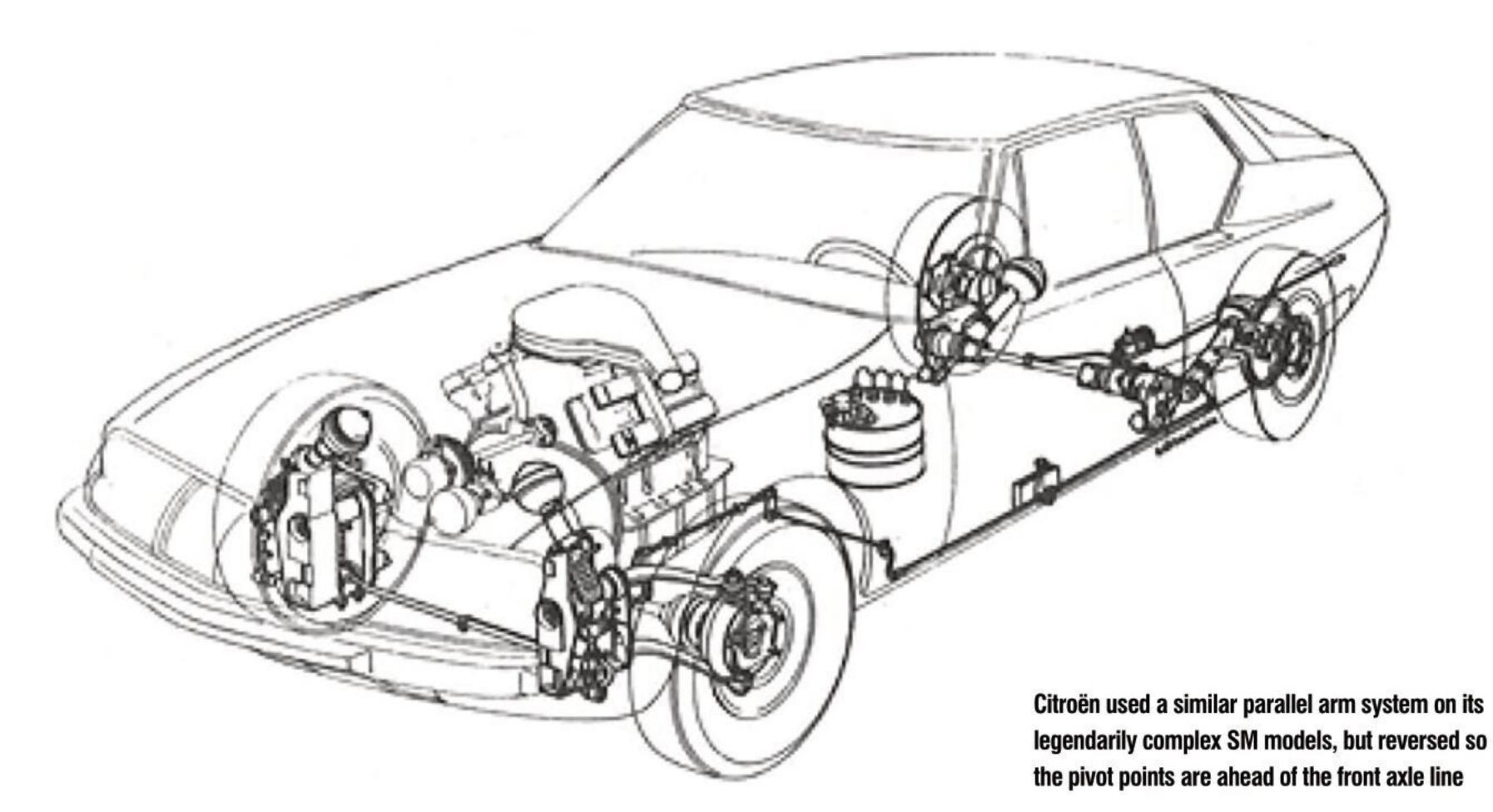
I would surmise this reversed position was necessary to accommodate the width of the Maserati V6 engine used in that car. The wheel does not move rearward in compression with this design, and there is no significant camber or caster change in heave. The upright moves straight up and down in side view.

## Comfortable ride

You are correct that the car does have a very comfortable ride, but this is mainly because it is so softly sprung and damped. The hydraulically-interconnected suspension can be described as active, to a limited degree, as it does displace the suspension using an engine-driven pump. However, this is mainly used to prevent large changes in pitch with variations in loading, and to permit adjustment of overall ride height. It isn't computer controlled, of course, but works by a sort of pendulum mechanism. It will try to resist pitch in braking, and this can make the car pitch rearward in braking and

# What really counts here is whether the wheel centre moves rearward as the suspension compresses

# What matters is the rate of lateral and longitudinal translation of the contact patch with respect to suspension displacement



look like it has a lot of anti-dive. It doesn't. The active suspension doesn't do this in response to lateral acceleration.

What is immediately noticeable to anyone watching one is how dramatically the DS / ID rolls in cornering, at least as much as a contemporary American sedan.

The 2CV, on the other hand, does have a lot of anti-dive. The single leading arms at the front are short enough to produce over 100 per cent anti-dive. However, in most loading conditions the pivot axes are not below hub height. The 2CV has a comfortable ride too, but again this is mainly just because the suspension is extremely soft.

### Beam axles

Citroenet.org.uk

Cars with beam axles at both ends can have a much higher roll axis (greater geometric antiroll) than cars with independent suspension, and they can indeed corner pretty flat with no anti-roll bars. Moreover, roll doesn't affect camber, so it doesn't matter a great deal if they do roll. The Ford design, with a single transverse leaf spring and radius arms angling back to a single central pivot aft of the engine, has a greater wheel rate in roll (more elastic roll resistance) than front suspensions with longitudinal leaf springs, because the latter must have the springs far enough inboard to let the wheels steer.

The Ford design also produces considerable anti-dive and is not subject to spring wrap up in braking, but also does not produce much rearward hub displacement in compression because the radius rod pivot is only a little bit below hub height.

Ford's design does have some problems with regard to lateral axle location. When the tyres generate lateral force, the axle and radius rod assembly tries to pivot about the radius rod pivot. This is resisted by the spring and its shackles, but this places large side loads on the shackles, and the system is consequently sensitive to the rigidity and wear condition of those shackles. It is better to add a Panhard bar, especially if using cross steering, as in the 1935 and later cars. The problem worsens when using split radius rods, or four parallel links, as is common in the modified suspensions of a great many hot rods.

One possible improvement, sometimes seen in oval track cars made shortly before Ford-derived leaf spring suspension was abandoned entirely, is to have just an eye and no shackle on one end of the spring. That simple modification turns half of the spring into a virtual Panhard bar, resisting lateral movement. It would also be possible to anchor the spring to the frame at two points rather than one, as in Corvettes, Fiats and Maseratis, to make it act stiffer in roll than in ride.

# Specific geometry

But back to the question of whether the axes of our suspension arms should run longitudinally or transversely. This doesn't matter as much as the specific geometry of the layout in question. Indeed, the axes can be angled in all sorts of ways. A Beetle-style trailing arm layout doesn't have to have the arms parallel in side view. It doesn't have to

have the pivot axes parallel in front view. Porsche actually used some trailing arm front suspensions late in the development of the RS61 in which the pivot axes of the upper arms sloped downward toward the centre of the car, providing some geometric roll resistance and camber recovery in roll.

# Angled axes

Many suspensions have either single or dual arms whose axes are angled in side view, top view and front view. When we can at least identify control arm planes, it is useful to find the front view and side view projected control arms and find front and side view instant centres from those.

In some cases, though, even that is not possible. But in all cases, what matters is the rate of lateral and longitudinal translation of the contact patch with respect to suspension displacement, when the wheel is rotationally locked in the appropriate manner eg with the brakes for braking, and through the driveshaft(s) for propulsion.

#### 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







# Bar talk

# Explaining the process used to determine anti-roll bar stiffness

#### By CLAUDE ROUELLE

n previous *OptimumG* articles, we have discussed how to define springs and dampers. We then took a little detour to talk about 'magic numbers', especially anti-roll stiffness distribution, a necessary step in determining front and rear anti-roll bars set-up. This month, we will demonstrate the meaning and usefulness of these magic numbers and, in doing so, take another step forward in understanding vehicle dynamics.

The process we use to choose anti-roll bar stiffness is not hugely different to the one we use to determine spring stiffness. It is a mix of calculations and experience.

Basically, the choice of front and rear anti-roll bar stiffnesses depends on the answer to two simple questions: what is the suspended mass roll stiffness that you want to achieve, and what is the anti-roll stiffness distribution you want?

The answer to the first question (roll stiffness) is often quantified in Nm/deg or roll gradient (deg/G), expressed in degree of roll angle of the suspended part per g (g being lateral acceleration). Experience and statistics give us a good idea of what the roll gradient generally is for different cars, as shown in **Figure 1**.

We need to be careful here though.

The roll gradient is described here as the suspended mass roll angle (in degrees) rotating around its roll axis for one g of lateral acceleration. Some engineers, however, will look at the *total* roll angle, which includes tyre deflection and compliance. In this article we will only consider the roll angle of the suspended mass about its own roll axis.

The roll moment is expressed as:

$$SMRM = SM * Ay * \Delta z(SMCG-RA)$$
 (1)

Here, in **Equation 1**, the roll moment is in Nm, SM is the suspended mass (in kg), Ay is lateral acceleration (m/sec<sup>2</sup>) and  $\Delta z$ (SMCG-RA) is the vertical distance between the suspended mass c of g and the roll axis (in m).

There are four components to the anti-roll moment including front springs and rear springs, as well as front and rear anti-roll bars.

To calculate the roll stiffness from the springs, let us follow the simple reasoning illustrated in **Figure 2**.

 If you know the track and you imagine a roll angle of one degree, you know how



There is a marked similarity in the experimental determination of both spring and anti-roll bar stiffness

Type of car	Minimum	Maximum
SUV	4.00	8.00
Most passenger cars	3.00	6.00
Sports cars	2.00	4.00
GT racecars	1.00	3.00
Low downforce racecars	0.50	1.50
High downforce racecars	0.25	0.75

much the wheel will move up. Let us call that wheel the outside wheel. Remember, we are not considering any tyre deflection or compliance here. The wheel assembly is supposed to be infinitely rigid, for now.

- If you know the wheel movement for one degree of roll, and you know the motion ratio, you can calculate the spring movement.
- If you know the spring movement and spring stiffness, you can calculate the spring force.
- 4. If you know the spring force and the motion ratio, you can calculate the force needed at the wheel to move that wheel up a distance that corresponds to a roll angle of one degree.
- That force will be the same on the other wheel (the inside one), but in the opposite direction.
- Multiply these two forces by their halftrack and you will get the anti-roll torque from the springs.

The anti-roll stiffness from the spring (ARS<sub>sp</sub>) can then be written as **Equation 2**:

$$ARS_{sp} = (Track^2 * Tan (roll angle) * K_{sp} / MR_{sp}^2) / 2$$
 (2)

Here, in **Equation 2**, ARS<sub>sp</sub> is in Nm/deg, the

track unit is metre, roll angle is expressed in degree (in this case, one degree), spring stiffness (K<sub>sp</sub>) is in N/m (note: N/m, not N/mm) and the motion ratio (MR<sub>sp</sub>) is the ratio between wheel movement and spring movement. In this case, it is unit-less.

**Equation 2** will be specifically applied for the anti-roll stiffness from the front and the rear springs.

$$ARS_{fsp} = (Track_f^2 * Tan (roll angle) * K_{fsp} / MR_{fsp}^2) / 2$$
 (3)

$$ARS_{rsp} = (Track_r^2 * Tan (roll angle) * K_{rsp} / MR_{rsp}^2) / 2$$
 (4)

Front and rear track could be different, but the front and rear roll angles are the same since we are not considering any possible chassis torsion or tyre deformation. Again, at least not for now.

To calculate the front and rear anti-roll stiffness from the anti-roll bars, we use a similar principle to the one we used for the springs. See the reasoning represented by the flowchart in **Figure 3**.

- If you know the roll angle and the track, you know how much the wheels are moving, up one side, down on the other.
- If you know the anti-roll bar motion ratio and the wheels' movement, you know much you twist the anti-roll bar.

Figure 2: Flow chart of the calculation of anti-roll stiffness from springs Axle half-track Vehicle roll angle Wheel movement Spring movement Spring motion ratio Spring force Spring stiffness Spring motion ratio Spring force at wheel Roll moment at wheel Axle half-track

Figure 3: Flow chart of the calculation of anti-roll stiffness from an antiroll bar Axle half-track Wheel movement Vehicle roll angle ARB torsion angle ARB motion ratio **ARB** stiffness ARB torque ARB motion ratio ARB effect at each wheel Axle half-track Roll moment at wheel

bar stiffness is quantified) ARB stiffness = ARB stiffness = Expressed in N/mm Expressed in Nm/deg Motion ratios used ARB stiffness expressed in Motion ratios for ARB stiffness expressed N/mm should be expressed in mm/mm (wheel in Nm/deg should be expressed in degree / movement / ARB arm movement) degree (roll angle / ARB torsion angle)

Figure 4: Different methods of quantifying ARB stiffness (make sure you

use the anti-roll bar motion ratio that corresponds to the way the anti-roll

- 3. If you know how much you twist the anti-roll bar and you know the anti-roll bar stiffness, you know the anti-roll bar torque.
- 4. If you know the anti-roll bar torque and the anti-roll bar motion ratio, you can calculate the force the anti-roll bar torque creates at each wheel for that roll angle. Again, tyre vertical stiffness and compliance are not yet considered.
- 5. If you know the vertical force created by the anti-roll bar at each wheel for a given roll angle and you know the track, you know the anti-roll torque created from the anti-roll bar.

The anti-roll stiffness from the anti-roll bar (ARS<sub>arb</sub>) can then be written as **Equation 5**.

$$ARS_{arb} = Track^2 * Tan (roll angle) * K_{arb} / MR_{arb}2$$

Here, ARS<sub>arb</sub> is in Nm/deg, the track unit is metre, the roll angle is expressed in degree (in this case, one degree) and the anti-roll bar's stiffness (Karb) in Nm/degree or in Nm/deg.

(5)

Why that choice? As expressed in Figure 4, the answer resides in the MRarb definition, but a little warning here; some engineers define the anti-roll bar motion ratio as a ratio of the wheel movement vs the edge of the anti-roll bar arm movement. The antiroll bar motion ratio will be expressed in mm/ mm and is therefore unit-less. In that case, the anti-roll bar stiffness must be quantified in N/mm or N/m: force vs displacement of the edge of the anti-roll bar arm, as shown on the left side of Figure 4.

Other engineers, meanwhile, will quantify anti-roll bar motion ratio as degree of roll vs degree of anti-roll bar torsion angle (deg/ deg). In that case, anti-roll bar stiffness must be quantified in Nm/deg, as shown on the right side of Figure 4.

# Bar testing

Anti-roll bar stiffness can also be measured on a specific anti-roll bar test bench, as shown in Figure 5, or directly on a Kinematic and Compliance (K&C) test rig, as shown in Figure 6, where the chassis is attached to the test bench, with the springs disconnected and plates on each wheel that move in opposite directions to simulate a given roll angle. The measurement of the induced load variations, together with knowledge of the track, will give the anti-roll stiffness measured at the wheels.

On the K&C bench, the test can be made with either the real tyres, or with dummy (solid) wheels. One of the advantages of this test is anti-roll stiffness will include all

The roll gradient is described here as the suspended mass roll angle (in degrees) rotating around its roll axis for one g of lateral acceleration





Figure 5: Anti-roll bar stiffness test bench with moveable arm (thanks to an adjustable rod length) on the left and measurement of the force on the right

the compliance effects, what we sometimes call the installation stiffness. In this case, in simulation the value of anti-roll bar motion ratio (K<sub>arb</sub>) will be one.

**Equation 5** will be specifically applied for the anti-roll stiffness from the front and the rear anti-roll bars.

$$ARS_{farb} = Track_f^2 * Tan (roll angle) * K_{farb} / MR_{farb}^2$$
 (6)

$$ARS_{rarb} = Track_r^2 * Tan (roll angle) * Kfarb / MR_{rarb}^2$$
 (7)

Front and rear tracks could be different, but the front and rear roll angles are the same, since in simplified simulation we do not consider any possible chassis torsion, tyre deflection or compliance. Again, for now.

There is a similarity in the experimental determination of springs and anti-roll bars: go as stiff as you can until the driver cannot control the car, performance passes a peak and /or your tyre temperatures are too high, and/or your tyres degrade too quickly.

# **Total stiffness**

The total anti-roll stiffness (TARS) is the sum of the front and rear springs anti-roll stiffness (ARS<sub>fsp</sub>) and (ARS<sub>rsp</sub>) and the front and rear anti-roll bars anti-roll stiffness (ARS<sub>farb</sub>) and (ARS<sub>rarb</sub>), as expressed in **Equation 8**.

$$TARS = ARS_{fsp} + ARS_{rsp} + ARS_{farb} + ARS_{rarb}$$
 (8)

The suspended mass roll angle, SM $\theta$  (in deg), will then be given by dividing the roll moment (in Nm) in **Equation 1** by the total roll stiffness (in Nm/deg) in **Equation 8**.

$$SM\theta = SMRM / TARS$$
 (9)

If you consider a specific lateral acceleration of 9.81m/sec<sup>2</sup> (one g), you will get the roll gradient in deg/g.

Let us now work the other way around. You know your suspended mass, the altitude of your suspended mass c of g and where the front and rear roll centres are, so you can calculate the vertical distance between the suspended mass c of g and the roll axis, and from there the roll moment for one g of lateral acceleration.

The experience will tell you what roll gradient you want. You can then calculate what your total roll stiffness TARS target should be for that roll gradient target.

# Sum of four parts

Remember, there are four components to your total roll stiffness: front and rear springs and front and rear anti-roll bars. You can work on any of them, but that would not be the smartest choice. As explained in a previous article, the front and rear springs have already been chosen for reasons of contact patch tyre load consistency and the effect springs have on ride heights and aerodynamic balance.

With the front and rear springs, you know the contribution of two out of the four contributors to the total anti-roll stiffness. Since you have decided the total anti-roll stiffness target, and you know the contribution of your front and rear springs stiffness, you can calculate the contribution of the sum of the front and rear anti-roll bars to the total anti-roll stiffness. But you cannot determine each individual front and rear anti-roll bars stiffness.

You have one equation with two unknowns, which means you need a second equation. And that is where the famous 'magic number' described in the previous article becomes useful.

The anti-roll stiffness distribution (ARSD) is the ratio of front anti-roll stiffness vs total anti-roll stiffness, as shown in Equation 10. It is often expressed as a percentage.

$$\begin{aligned} \mathsf{ARSD} &= 100 * (\mathsf{ARS}_\mathsf{fsp} + \mathsf{ARS}_\mathsf{farb}) / (\mathsf{ARS}_\mathsf{fsp} + \mathsf{ARS}_\mathsf{farb} + \mathsf{ARS}_\mathsf{rsp} \\ &+ \mathsf{ARS}_\mathsf{rarb}) \, (\mathsf{in} \, \%) \end{aligned} \tag{10}$$

As the springs have been previously determined, with total anti-roll stiffness and anti-roll stiffness distribution targets defined, the front and rear anti-roll bars' stiffness can be determined. We will give numerical example in future articles.

# **Practical examples**

Let us then conclude with two practical illustrations on anti-roll bars tuning.

1. When an engineer asks the driver what the car balance is, and the driver describes the car as understeering, the engineer has two solutions: softening the front anti-roll



Figure 6: Measuring anti-roll bar stiffness on a K&C test bench

bar or stiffening the rear one. Remember, playing with the front or rear springs is not a good idea as it could destroy your mechanical grip and / or aero balance. To make the right choice, the engineer needs to ask a second question: is the car too lazy or too nervous? If the answer is the former, the engineer will increase rear anti-roll bar stiffness as, usually, stiffer cars tend to be more responsive. If the answer is too nervous, the engineer will soften the front anti-roll bar.

2. If the driver finds the car well balanced but lazy because it is rolling too much, the engineer will increase the total roll stiffness and choose to increase both front and rear anti-roll bars' stiffness in such proportion that the anti-roll stiffness distribution is unchanged.

In the next few articles in Racecar Engineering, we will turn our attention to weight transfer and jacking forces, two further often R misunderstood topics.

Slip Angle is a summary of Claude Rouelle's OptimumG seminars, which are held worldwide throughout the year.

Public, onsite, and online OptimumG seminars are held worldwide throughout the year. The Advanced Vehicle Dynamics and the Data Driven Performance Engineering seminars present several theories and best practices that can be used by engineers when making decisions on how to improve vehicle performance. OptimumG engineers can also be found around the world working as consultants for top level teams.

#### CONTACT

**Claude Rouelle** 

Phone: + 1 303 752 1562

Enquiries: engineering@optimumg.com

Website: www.optimumg.com

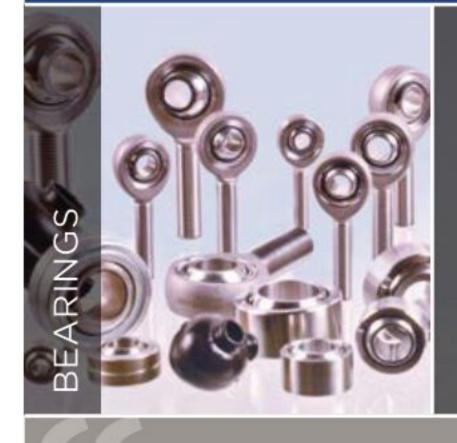


# Supplying the parts that others cannot reach

# Triderzt

# Racing Supplies











Our specialism is in the detail of race engineering - the hard to source simple things that can make or break a deadline. Check online, call us or call in.

CHECK **OUR WEBSITE** your search is nearly over.

The one-stop shop for parts and components

WWW.TRIDENTRACING.CO.UK

SILVERSTONE CIRCUIT 01327 857822



# Viva the Revolution

After 20 years at the head of Radical Sportscars, Phil Abbott has started again, with his focus firmly on cost, safety and sustainability

By STEWART MITCHELL

otorsport has a reputation for innovation across its ranks, from karting through to Formula 1, and everything in between.

The competitive nature of the sport forces high-speed development, quite unlike any other industry, and the engineering solutions that arise see some of the most advanced and technically sound solutions to vehicle performance and safety that might otherwise never be explored.

Revolution Racecars is the perfect example of just such an engineering-based revolution, as Phil Abbott and his partner companies aim to create a successor to one of the motorsport world's most popular Sportscars, the Radical SR3.

In the late 1970s, through to the mid-'80s, Abbott worked as a welder for Spyder Engineering, a company manufacturing replacement chassis for Lotus cars. In that time, the business made some 2500 spaceframe chassis, and so their construction became second nature to him.

He also took an active interest in motorsport. After racing Ginettas for a couple of years, he felt he had a good understanding of the nature of Sportscar design, but felt that nobody was making the type of racecar he himself wanted to drive.

'Speed in prototyping was something I picked up very early, and it became a vital tool for our business'

Abbott envisaged something like a modern Lotus 23b, a small, competitive, affordable sports racer that an amateur driver could put on a trailer and run themselves. He shared his vision with fellow racer, Mick Hyde, who would go on to become Abbott's partner in Radical Sportscars.

'The whole idea of Radical Sportscars was to provide a sports racer for racers like Mick Hyde and myself, says Abbott. 'I'd had experience of manufacturing spaceframe chassis in reasonable volume, and so we built our first car, the Radical Clubsport, and set off for the Autosport Show in 1997. The car was a small, open-cockpit, spaceframechassis Sportscar with drive provided by an 1100cc Kawasaki motorcycle engine!

# **Exceptional speed**

Abbott and Hyde's synergy of skills and drive made for an unusually successful duo when launching the company. A distinguishing feature that set them apart from other Sportscar manufacturers at the time was the exceptional speed they showed in adapting and prototyping new ideas and components.

'Mick could think of something on the way from Macclesfield to Peterborough, and we'd have it made before he got there,' remarks Abbott. 'Speed in prototyping was something I picked up very early on in my manufacturing and fabricating career, and it became a vital tool for our business.'

The same year, Radical debuted its second model, the Prosport. Another motorcycleengined, open-cockpit racer, but with more performance and tuning capability, including F3-size slick tyres and an adjustable rear wing.

In 2001 Radical Sportscars launched its first two-seater, the SR3, which would be eligible for international racing in FIA-sanctioned C3 class events. The SR3 was offered in 1300 and 1500cc versions, the most forceful of which put out a peak performance figure of 260bhp.





## **TECHNOLOGY – REVOLUTION A-ONE**

'A key element to Radical Sportscars' philosophy was adaptability and development,' continues Abbott.

'We didn't set out to employ loads of people. We learned on our feet and just kept on pushing the limits of our abilities as far as we could. When we didn't know enough, we contacted somebody who knew more, and used that methodology as often as we could.'

Radical Sportscars' rapid evolution would see within a decade the duo of Abbott and Hyde morph into a company employing 140 people, producing 160 racecars per year.

Abbott ran Radical Sportscars for 20 years, though in that time its evolution began to steer it away from the core values Abbott began with and retained throughout his time at the helm.

'There was a desire not to be a corporate entity, but to go back to being racing people producing cars for racers,' he says of what Radical Racecars became - a small volume manufacturer with nine models in the Sportscar market. Consequently, after a little over two decades, Abbott stepped away from the company, and on 1 November 2018, re-emerged with Revolution Racecars.

# The next thing

'Radical was sorted in its marketplace, and I wanted to do the next thing, explains Abbott. 'More specifically, I wanted to make the successor to the SR3.

'The SR3 was such a good all round racecar. All you needed was a can of fuel and a crash helmet to go racing. That was it.

'It invented the production racecar. But it's over 20 years old now and, when we first produced it, it was the right thing for the time. A Sportscar, or a sporting road car, with 200-300bhp was right back then, but today's sporting road car has 400-500bhp.

'Revolution Racecars was to be the successor of that, and to bring that same concept up to date, with higher performance and higher technology, but still have that driveability that an owner / driver could get out of the car.

'A few years back, I started looking into the composite racecar market to understand why all these cars cost so much money. It was undeniable. They were absolute works of art. The LMP3 production Ligier did was terrific because they productionised the LMP3 category, selling over a hundred in the first couple of years.

'However, all of the pre-preg work in those cars was very labour intensive, and therefore you have a considerable cost element to it. Curing pre-preg carbon fibre structures at 140degC or 160degC repeatedly means a pre-preg tub would see the autoclave five or six times during its production cycle, and each one took a great deal of energy to produce it.



Safety was paramount, and a conscious decision was made to sit occupants low down in a high-sided cockpit



A unique double halo concept was developed for additional safety and object intrusion protection

'I was looking for something that would provide the same strength and safety, but would fulfil the market the SR3 fulfilled all those years ago. I wanted to support those people that have to go to work on a Monday morning with both arms and legs working, so safety was paramount.

'Hurting your clients doesn't do to sell cars, so we wanted the ultimate safety by modern standards, way more than a tube-frame car.

'The LMP3 car is a fantastic product, but is priced out of the reach of the clients the SR3 supported. I wanted to halve that, so I looked around at available composite technologies. I met Dominik Dierkes from DD Compound, who had been working on resin infusion carbon fibre construction, which had seen a huge amount of development over recent years.

'DD Compound manufactures infusion systems and vacuum systems for infusion at a fairly advanced level for wind turbines, ocean-going boats, all kinds of things. I ascertained that I could use that technology 'The LMP3 car is a fantastic product, but is priced out of the reach of the clients the SR3 supported. I wanted to halve that'

to produce a composite racecar at the price point I desired, and together we developed a system to make a two-seater racecar tub.'

# Design process

With comfort in mind, the A-One tub is eggshaped in cross section to better fit a regular person's ergonomics, as they tend to be wider across the shoulders, and particularly around the elbows, when driving a car.



















Motorsport Systems Ltd, are a UK based dealer of Bosch Motorsport products. With an innate understanding of the motorsport industry, we specialise in delivering a personal service that gets your parts to you, on budget and on time. For further information on the products detailed above, please do not hesitate to call or email info@motorsport-systems.co.uk.





## **TECHNOLOGY - REVOLUTION A-ONE**

'We wanted the tub very deep, coming up over the shoulder of the driver, so they're completely cocooned in a composite tub – not sticking out the top, or anything like that,' says Abbott. 'The tub wraps around a driver's shape and supports two occupants together to produce an envelope that is an egg-shaped curved profile in its vertical plane.'

The tub is made in two halves, a top shell and a bottom shell, bonded together through the centreline. The bonded surface features a continuous curvature, removing any stress raising angles and providing high strength across the bonded centreline. This concept was critical for passing the prescribed FIA safety tests.

The design follows LMP style for aerodynamics, with a large, flat floor and mid-section, and a sizeable rear diffuser, which is reasonably unregulated in the market the car is built for. The front floor features an adjustable splitter design optimised for downforce.

'From early drawings, we went to TotalSim, who simulated the car in CFD, and we spent many weeks developing the aerodynamic performance of the floor, and then the whole car,' notes Abbott.

'We took guidance very early on in the design process to ensure once we engineered the whole thing, we'd got a basis where we could generate good downforce but also be tuneable. Our design criteria was for the bronze driver, not professionals, so the aerodynamics needed to very easily manageable and easy to set up. We wanted good balance and very benign, not ultra-sharp, handling.'

# High street style

Revolution Racecars took the unusual step of having a high street stylist design the car's bodywork. I think people buy fast cars, but also pretty cars, says Abbott. If you design a car too much around engineering and aerodynamics, you sometimes come up with an ugly looking car, or an aggressive looking car.

'Our target market wants something attractive and, particularly important for a new brand, we wanted it to still look fresh in five years.

'We talked to ex-head of Infiniti design, Simon Cox, about getting some sketches and then worked between engineering, aerodynamics and styling to gradually achieve the whole product.'

As far as scope for set-up and engineering the car, Revolution Racecars was particular in the freedoms it wanted left to the owner / driver for finessing performance to suit.

'We wanted it to be intuitive, and we did a lot of development with not only CFD but also on track with the same aero team from TotalSim,' notes Abbott.

'We went to the track with them and plotted the amount of downforce you get with different ride heights and different rake angles to be able to give the customer a practical aero map that is effective in many conditions.

'If the driver uses it for track days and there are some massive, aggressive curves, and the driver wants to lift the car and run a high ride height, we wanted to characterise how that affects the performance. We also wanted to understand and characterise how it operates in its most aggressive set-ups, with high rake angles and so on.

'Through all of those, we wanted the set-up to be whatever the customer wanted to run, within reason, and for the car to remain a benign, balanced package.

'The design does enjoy having a lot of rake, and the more rake you put in it, the more downforce and the more total load you get. Customers can move the load balance between 35 and 42 per cent adjustable to the front.

'Getting downforce on the front of Sportscars is usually a bit of an issue, but with the rear, you can put a big wing on it, and that's the other major tuning tool we have on this car.'

# '80 per cent less energy consumption in the manufacturing process compared to a contemporary LMP chassis'

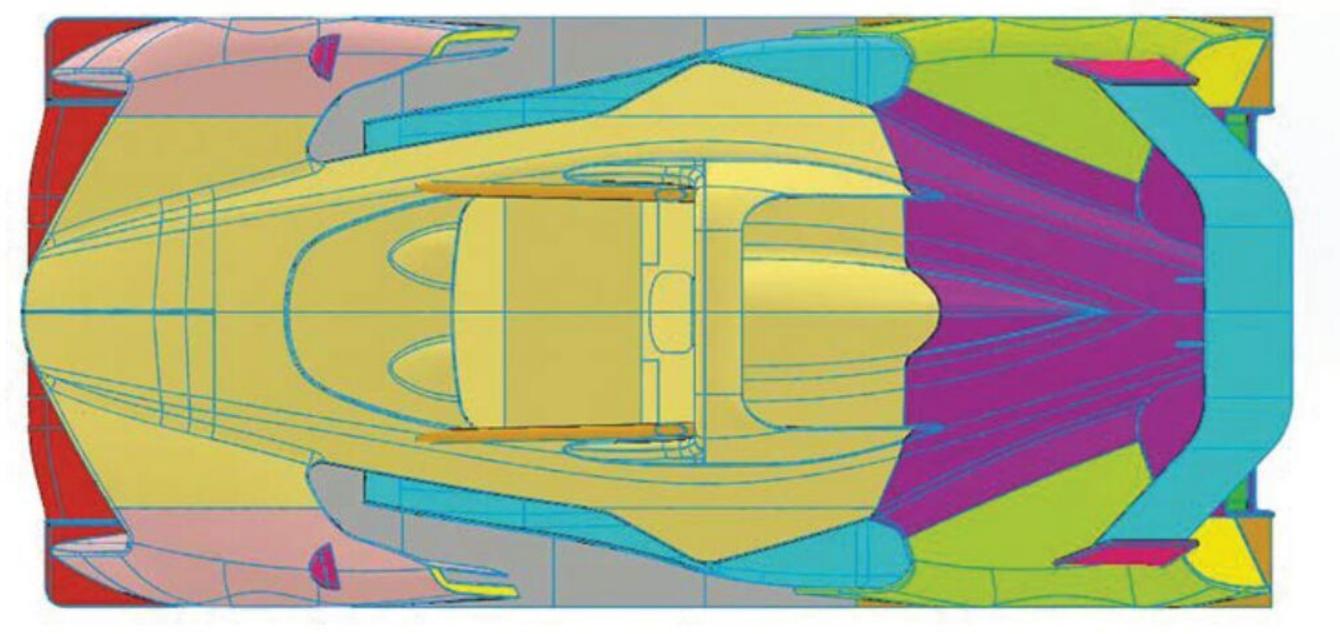
The story is the same with the chassis, which has adjustable anti-roll bars. 'Because we've got so much downforce, we designed in third element suspension, like you see on LMP3 cars, which gives it that additional control over the ride height. With these, you can stop it pitching and heaving under braking, as well as control how the car behaves with the varying force aerodynamics bring through the speed range of the car.'

# **Quadrax construction**

The chassis structure is made up of a series of carbon fibre layers called Quadrax.

Each Quadrax is four 250g carbon fibre





Revolution Racecar design concept borrowed from LMP2 / 3 practice, but with more of a sense of road car styling









## **TECHNOLOGY – RACECAR FOCUS: REVOLUTION A-ONE**

sheets sewn together – each with a different fibre orientation: zero degrees, 90 degrees, +45 degrees and -45 degrees – to become a single 1000g sheet.

The carbon fibre manufacturers do the sewing of the Quadrax, and Revolution Racecars uses four Quadrax layers in different orientations to create the chassis structure.

Abbott explains: 'We have two layers of 1000g Quadrax, which give us eight layers of conventional [carbon] fibre, plus a core, plus two more layers of Quadrax to make a 4000g carbon fibre structure.

'Those layers are then moulded, placed in a vacuum bag and infused with resin in one shot. That gives us the speed we need, but also reduces energy cost for the curing.'

It also removes the problems associated with pre-preg manufacturing. 'All pre-preg products have to be stored in a freezer because pre-preg will air dry,' explains Abbott. 'And, given enough time, it will start to degrade if it's just left out in ambient temperature. Factories producing carbon fibre structures using pre-preg technology must have rooms to contain the material pulled down to minus figures to prevent it going off.

'The resin infusion process uses dry fibres, which we can keep at ambient temperature, and the curing process is just one shot at 60degC, rather than as many as six shots at the 160degC often used for pre-preg chassis curing.

'We have calculated 80 per cent less energy consumption in the Revolution Racecars manufacturing process compared to a contemporary LMP chassis.'

# Safety testing

The FIA safety standard for testing the Revolution A-One sits under article 277, between a Formula 3 structure and a CN car, and complies to what is known as Free Formula. Revolution Racecars called in a company called CED to perform finite element analysis work as part of the design process, and the car's construction was characterised using a program called Ansys.

CED calculated the loads required by the FIA safety standards for Free Formula racecars and integrated them into the design. It was then up to DD Compound to produce the tub to the software's specification using the resin infusion technique.

For the crash structures, Revolution
Racecars made up small composite structures instrumented with accelerometers and put them on the drop tower at Cranfield University's advanced crash testing facility.
These provided a gauge in performance under load in compliance with the FIA's safety standard tests. The tests were carried out at a given speed, and the deceleration had to correlate with an average of 17g and nothing more than 20g.



'Ours is the first time the infusion technique has been used on a crash box,' notes Abbott. 'We had to do a lot of pretesting of components, and then crash the complete structure and measure it to get the required result. It wasn't a long process, it was swift, and we were very close the first time.

'When the chassis was done within the Free Formula safety regulation, it is similar to the strength of an LMP2 chassis,' notes Abbott. 'The load used for Free Formula are very similar to LMP2. The roll hoop structure must withstand 12 tons on an LMP2 car, and that's what we used on our car within the Free Formula framework.

'The chassis is placed into a jig with what resemble RSJ steel beams and, using a hydraulic ram, is squeezed between those two steel beams to the required load, which is about five tons. The chassis must withstand that load with no damage.

'It's relatively simple to achieve with this construction when it comes to strength and consistency because we're not using hundreds of small layers, we're using fewer, heavier layers. That makes it easier to achieve the same construction performance on every chassis. Our goals were to bring LMP2's level of safety performance to lower formulae at a more moderate cost and, wherever we could, to work on sustainability. With 80 per cent less energy required in the Revolution Racecar manufacturing phase compared to LMP2, and with the same safety, we are well on that journey.

'Now that we've created this chassis concept, and have repeatability in production, we can start to look at experimentation with different fibres, such as flax rather than carbon.

'There's still some work we can do, but that would take quite a bit more R&D. For now, we know the process – and we've seen the process working well here – and have the makings of something even more sustainable.'



Crash testing was done to FIA Free Formula regulations, which are similar to those required for LMP2 chassis structures

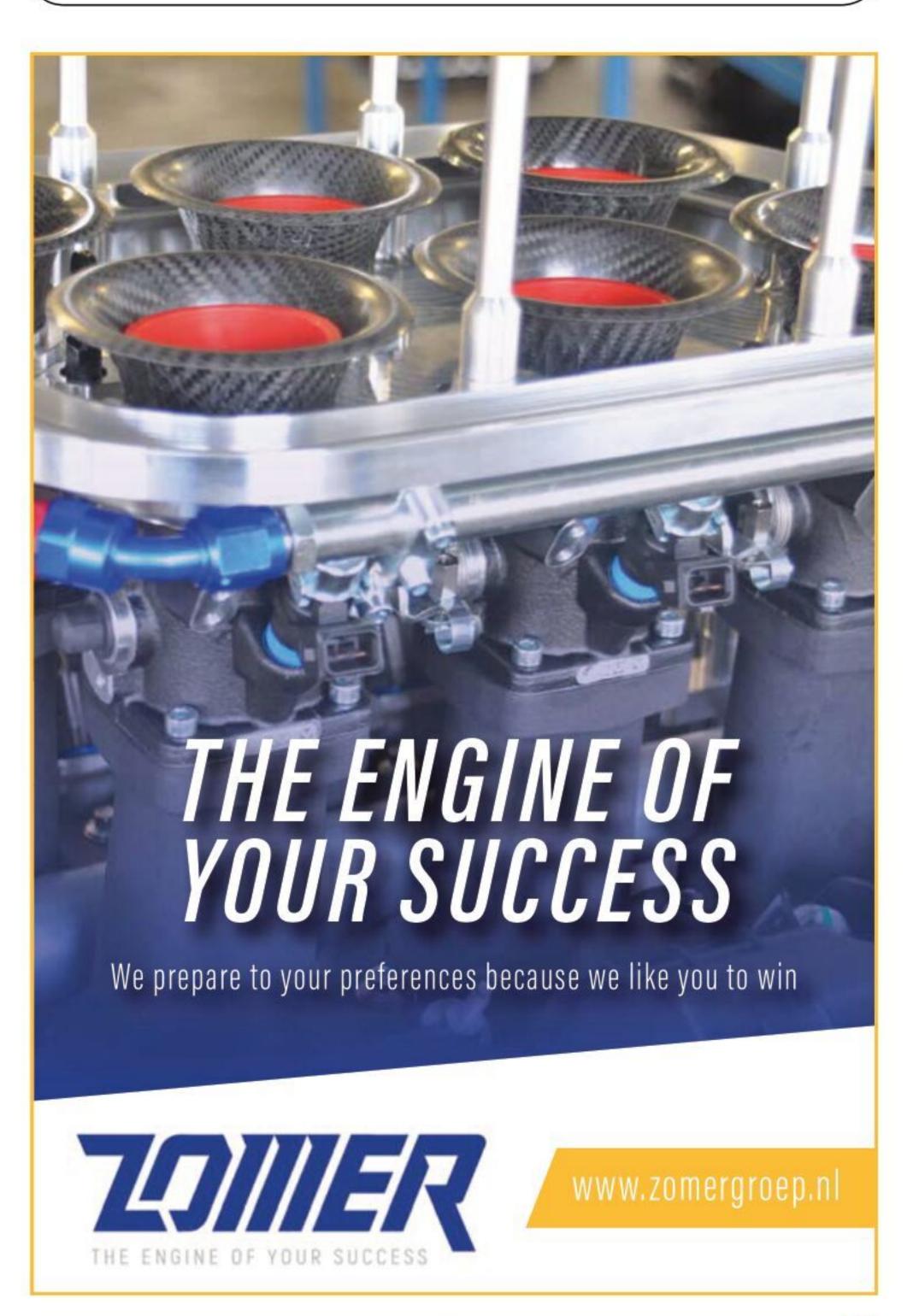
'Now that we've created this chassis concept, and have repeatability in production, we can start to look at experimentation with different fibres, such as flax rather than carbon'

The Revolution Trophy has its own class within the Sports Prototype Cup with rounds at GP-level circuits including Silverstone in England and Le Castellet in France. The 2021-specification Revolution A-One weighs in at 795kg and boasts an impressive 400bhp. The result is 500bhp per tonne, putting it only marginally down on LMP3 figures. However, with LMP2 levels of safety, it has the makings of a perfect customer racecar.











# Bump and grind

Is bump steer actually worth it?

### By DANNY NOWLAN

ne of the great myths that perpetuate racecar engineering is the role bump steer plays. Like its close cousin, roll centre, and anti-dive and anti-squat, if you want to see the sparks fly walk into a bar and full of race engineers and say bump steer is irrelevant. Then sit back and watch chaos unfold.

This recently came up on social media and, after a spirited discussion, a former student of mine suggested I do an article on this. So that is exactly what I am doing here and, after doing some sim' work, some very enlightening things were found.

Firstly, we need to define exactly what bump steer is so we can discuss it properly. Bump steer is the steered angle of the tyre as the wheel moves up and down. This is summarised in **Figure 1**, which shows a plot of toe angle vs wheel movement.

Here, bump steer is in degrees, wheel movement is in mm. Positive for the bump steer is toe out, and positive for the wheel movement is bump. Here we have clipped to +/-0.5 degrees.

Where the fun and games started was exploiting this to dial in the slip angle behaviour you want. The theory goes that as the car rolls, the outside wheel goes into bump and the inside wheel goes

into droop, and that you can manipulate that to obtain the behaviour you want. Conversely, you can also use this on the rear on a high-powered, rear-wheel-drive car for stability. Mathematically, what you are exploiting is shown in **Equation 1**.

$$\alpha_1 = \delta - \frac{a \cdot r + V_y}{V_x + tf \cdot r} \tag{1}$$

$$\alpha_2 = \delta - \frac{a \cdot r + V_y}{V_x - tf \cdot r}$$

$$\alpha_3 = \frac{b \cdot r - V_y}{V_x + tr \cdot r}$$

$$\alpha_4 = \frac{b \cdot r - V_y}{V_x - tr \cdot r}$$

where;

 $V_y$  sideways velocity

 $V_x$  forward velocity

r yaw rate

tf front track

tr rear track

 $\delta$  steered angle at the wheel

 $\alpha 1 - \alpha 4$  the slip angles of the tyre at the contact patches

A quick note to all the Pacjeka / FSAE fundamentalists out there: I realise this is the opposite of what you are used to but, when you run the numbers, you'll see the results are the same.

Now, what you are doing here is using the bump steer to make sure you can dial in the slip angles you want. A very sound theory but, as we shall see shortly, things tend to become a bit complicated, particularly on a bumpy circuit.

# Setting the scene

(2)

(3)

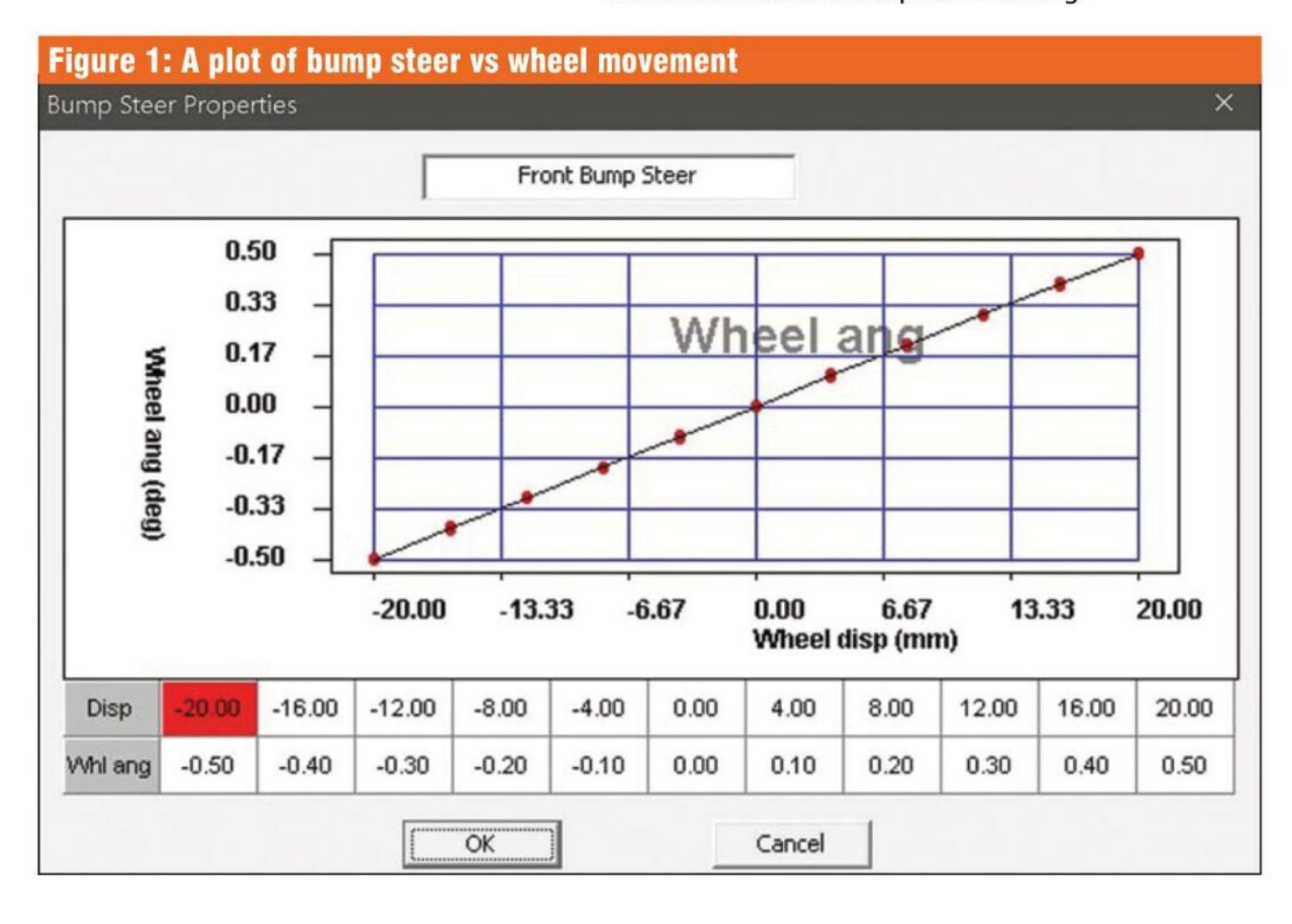
(4)

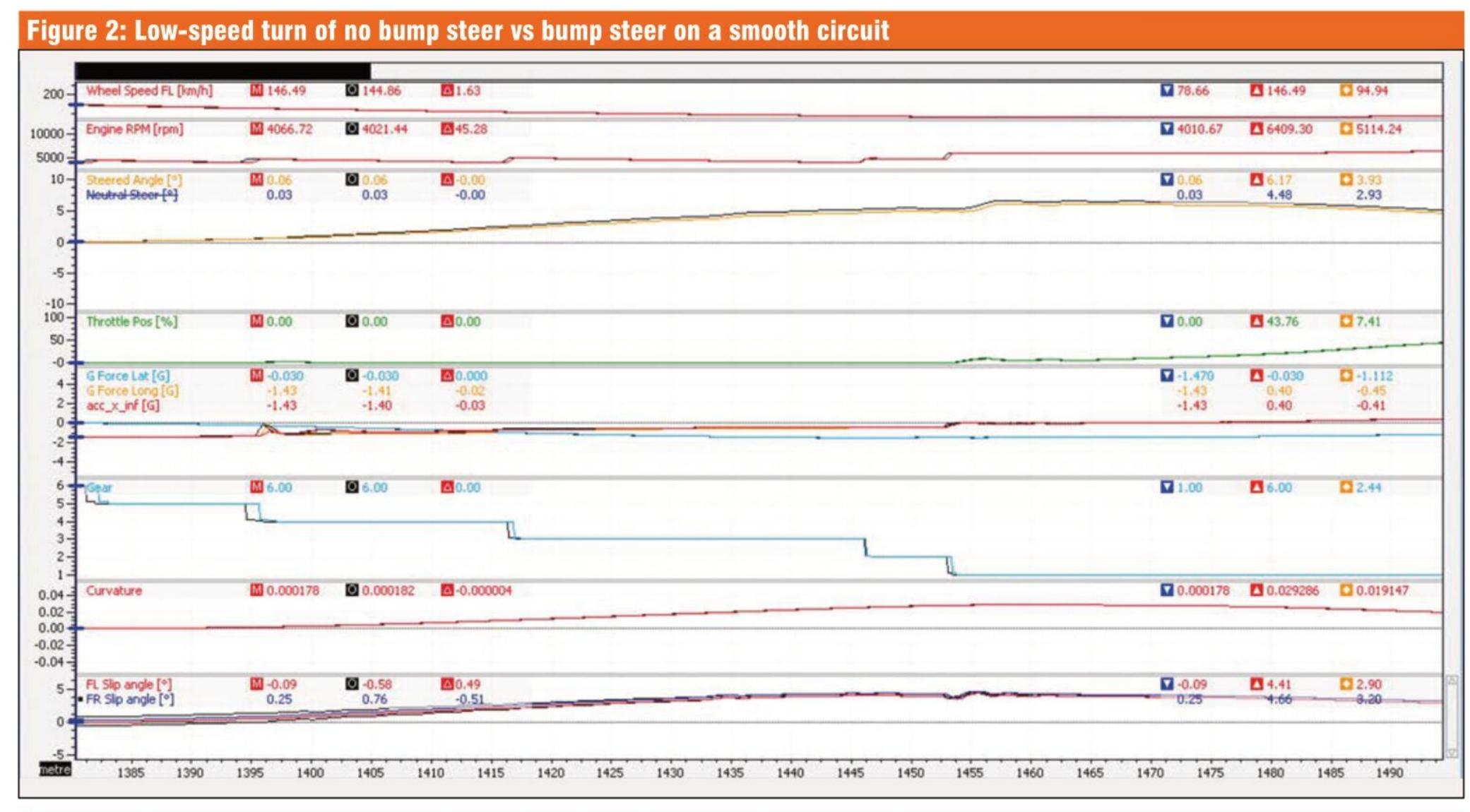
To set the scene, let's do a smooth circuit simulation for a live axle V8 Supercar at Willowbank / Queensland Raceway. The reason we have chosen this track is because of how bumpy it is, but this will become more apparent later on.

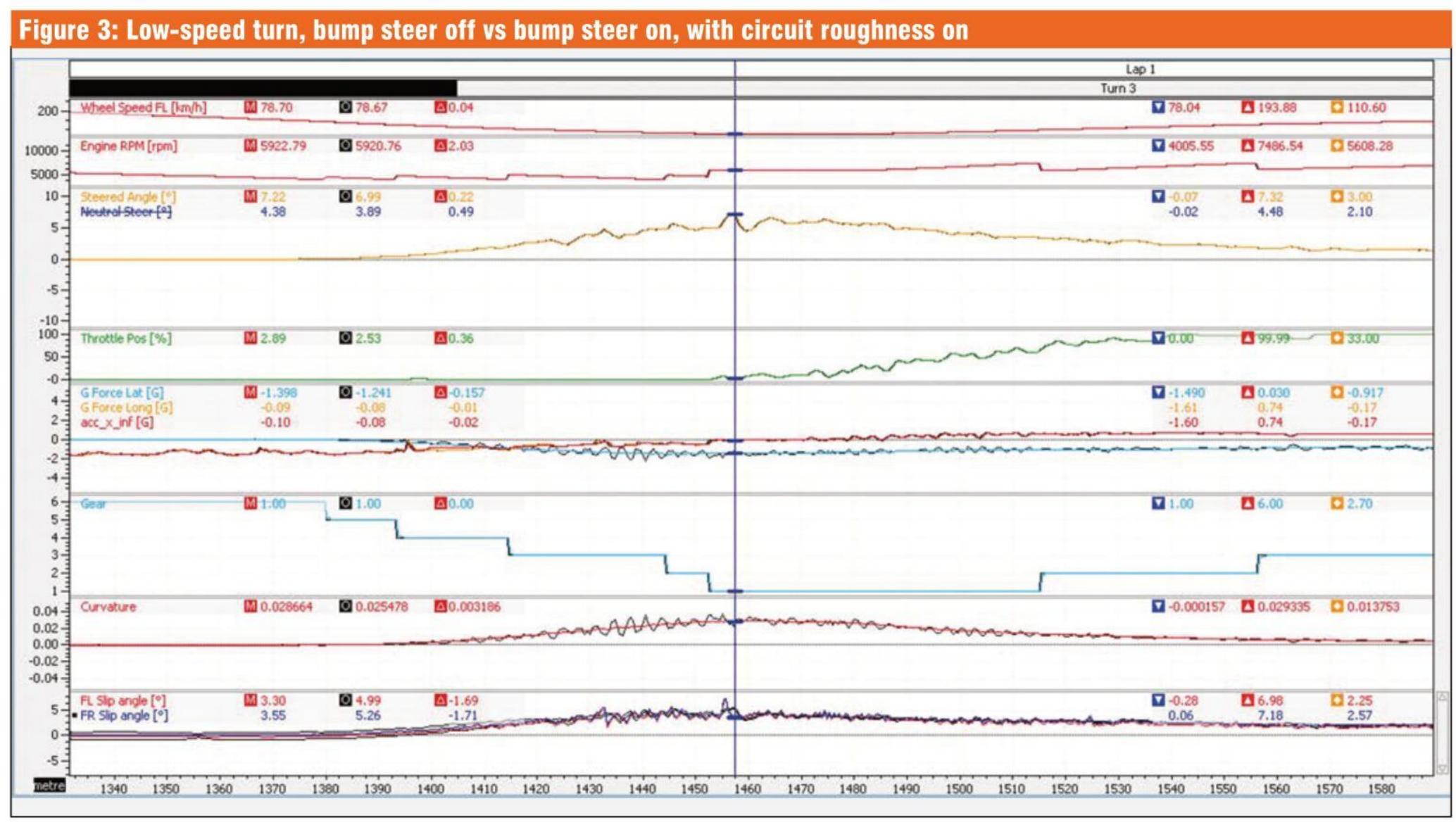
In terms of lap time, the results with the circuit bumps removed were virtually identical. The no bump steer case had a lap time of 66.9s and the bump steer on case (using the curve of **Figure 1**) was 66.94s. What is going on here is quite revealing, so let's have a look at one of the low-speed turns. See **Figure 2**.

The no bump steer case is coloured and the bump steer case is black. The numbers themselves are quite interesting.

# What you are doing here is using the bump steer to make sure you can dial in the slip angles you want







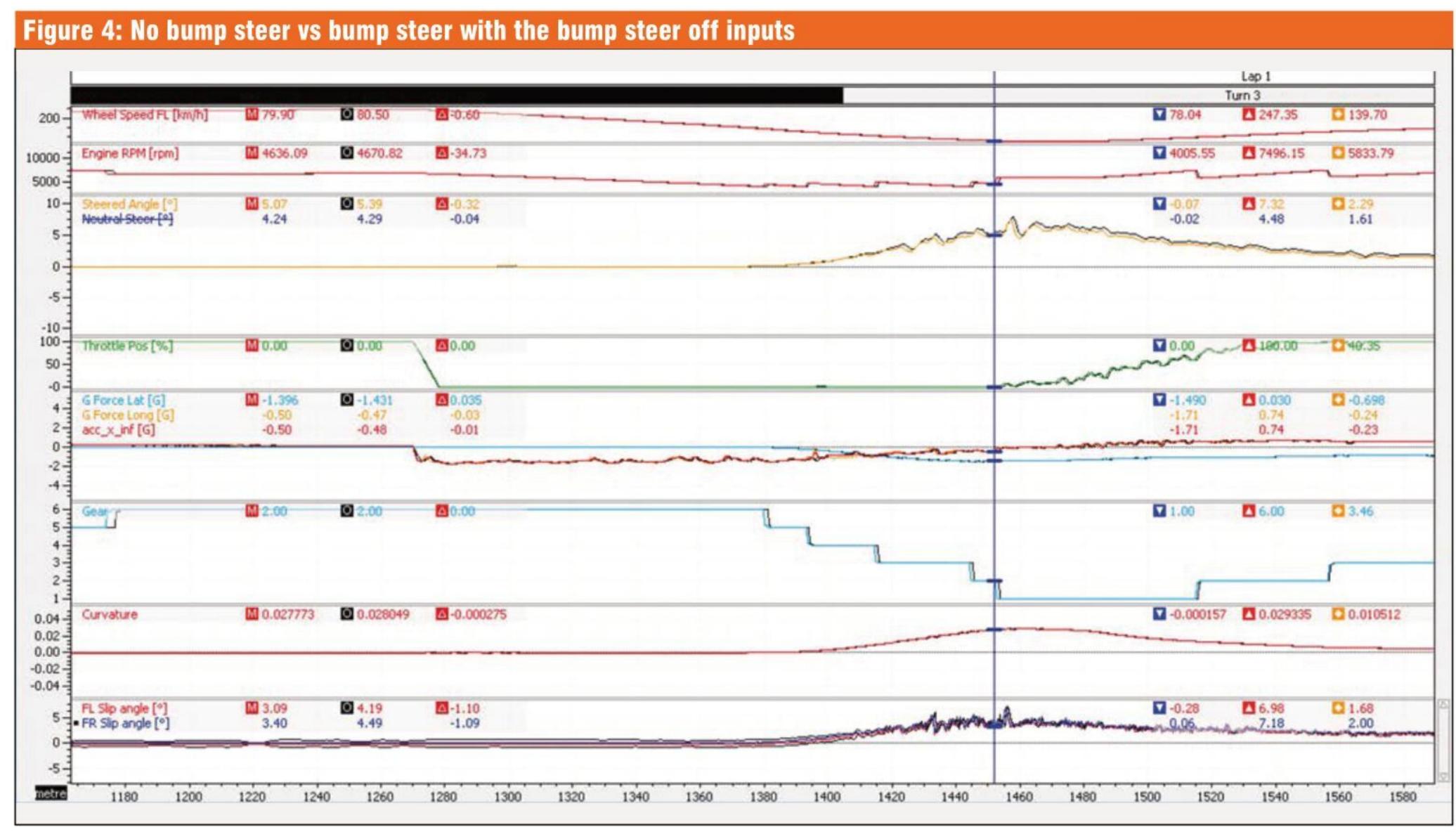
Going into the turn there is a considerable difference between the slip angles. The no bump steer case is +/-0.32 degrees, while the bump steer case is +0.81degrees and -0.5 degrees. Yet as we go further into the corner, the slip angles are virtually identical.

This observation doesn't surprise me, for a couple of key reasons. Firstly, you will see a difference going into the corner because of the car's attitude. This is something the driver will report back to you. However, by the time we get to the mid-corner condition, the slip angles are identical because the ChassisSim lap time simulation algorithm is designed to maximise performance. Consequently, it will change steer angle to suit so it can achieve the optimum slip angle. This is one of those things drivers will report in feedback but, in terms of absolute lap time, it won't make a huge difference.

This trend was seen with the circuit roughness turned on. The lap times

were identical at 69.5s. What is most revealing, though, is the results of the lap time simulation in the same corner, as shown in **Figure 3**.

Again, note here that I choose
Willowbank deliberately because the
circuit is notoriously bumpy and so
represents the worst case scenario.
As before, the bump steer off case is
coloured and the bump steer on case
is black to maximise the effect.



You can see that at mid-corner, the slip angles are the same, and that is the lap time simulation doing its job. However, what is most revealing is the lead up to the corner. If we look at the last trace, the front slip angles, note how at the 1180-1280m distance mark with the bump steer on case, the front slip angles are reversing. This is something the driver is going to notice.

# **Open loop simulation**

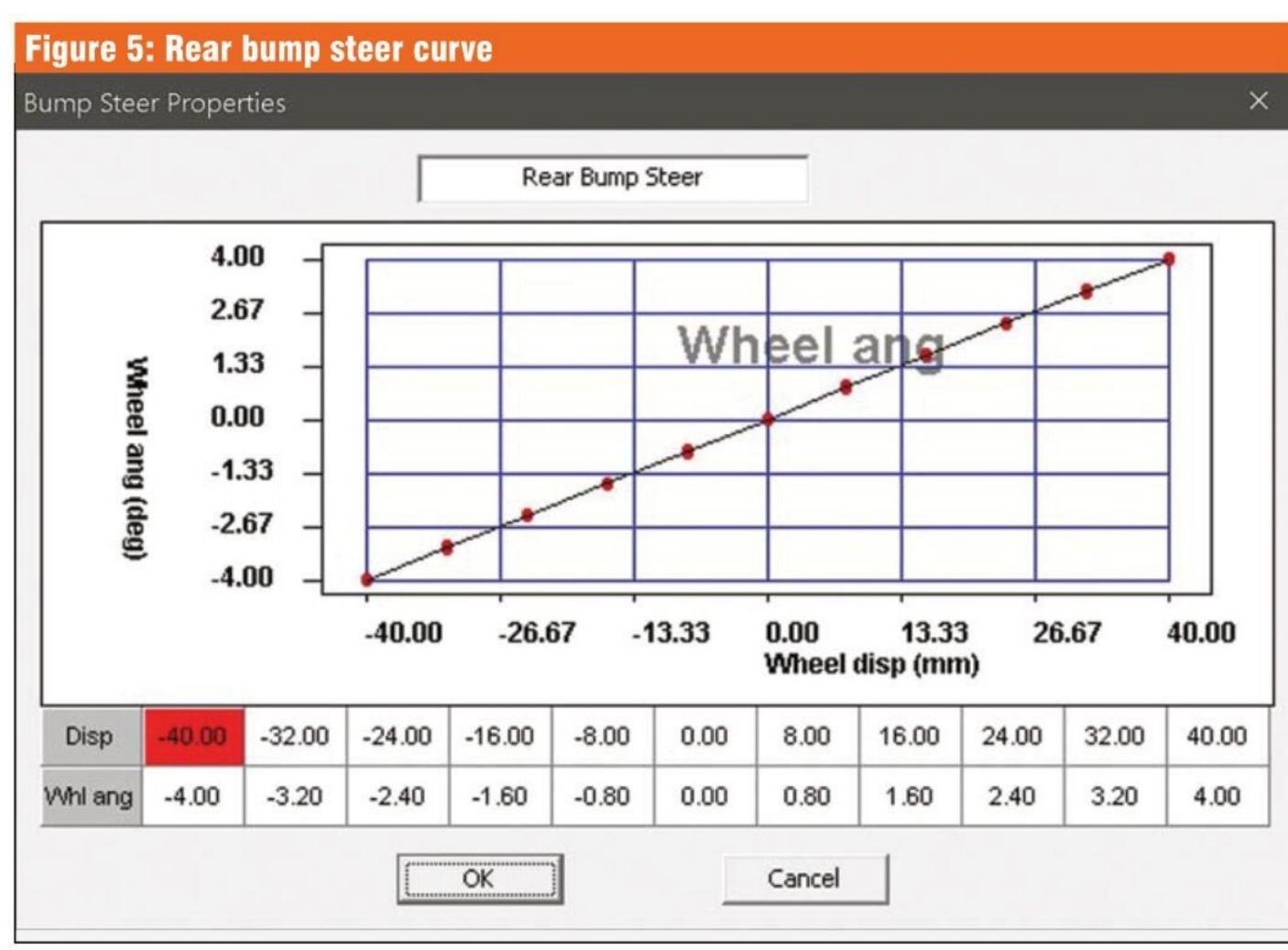
To complete this investigation, I took the inputs from the bump steer off case and used open loop simulation to run the bump steer case. The overlay is shown in **Figure 4**.

Here, the coloured trace is the no bump steer case and the black is where bump steer is included. As can be seen, there is a difference of over a degree at the midcorner condition this time. Again, the driver will report this back in their feedback.

The thing about this business is so much of what we do is about making drivers happy, so this is not to be ignored.

So, in the case where the bump steer is well conditioned, its primary focus is on driver feel, as opposed to raw speed.

However, one case we have to consider is what happens when the bump steer is poorly conditioned. And here's a good example for you: in the mid-2000s I worked on an entry level GT formula



(names and dates have been omitted so I don't get sued!) where a dominant factor in the roll bar set-up was keeping the rear tyre angles under control because the bump steer varied considerably. Can we replicate this under simulation?

To do so, we'll take our V8 Supercar but, instead of using front bump

steer, we'll use rear bump steer, and we'll increase it quite a bit. The curve we will use is shown in **Figure 5**.

As you can immediately see, this bump steer curve can be summarised in one word: awful.

Unsurprisingly, the simulation results on this were atrocious, and the simulated

# So much of what we do is about making drivers happy, so this is not to be ignored

# engineering

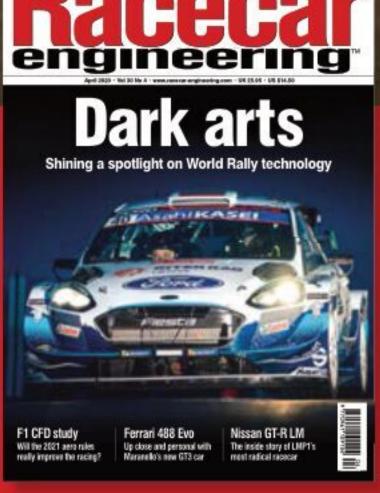
SAVE 30% OFF THE REGULAR PRICE



SUBSCRIBE TODAY ONE YEAR FOR £49.95/US\$84.95









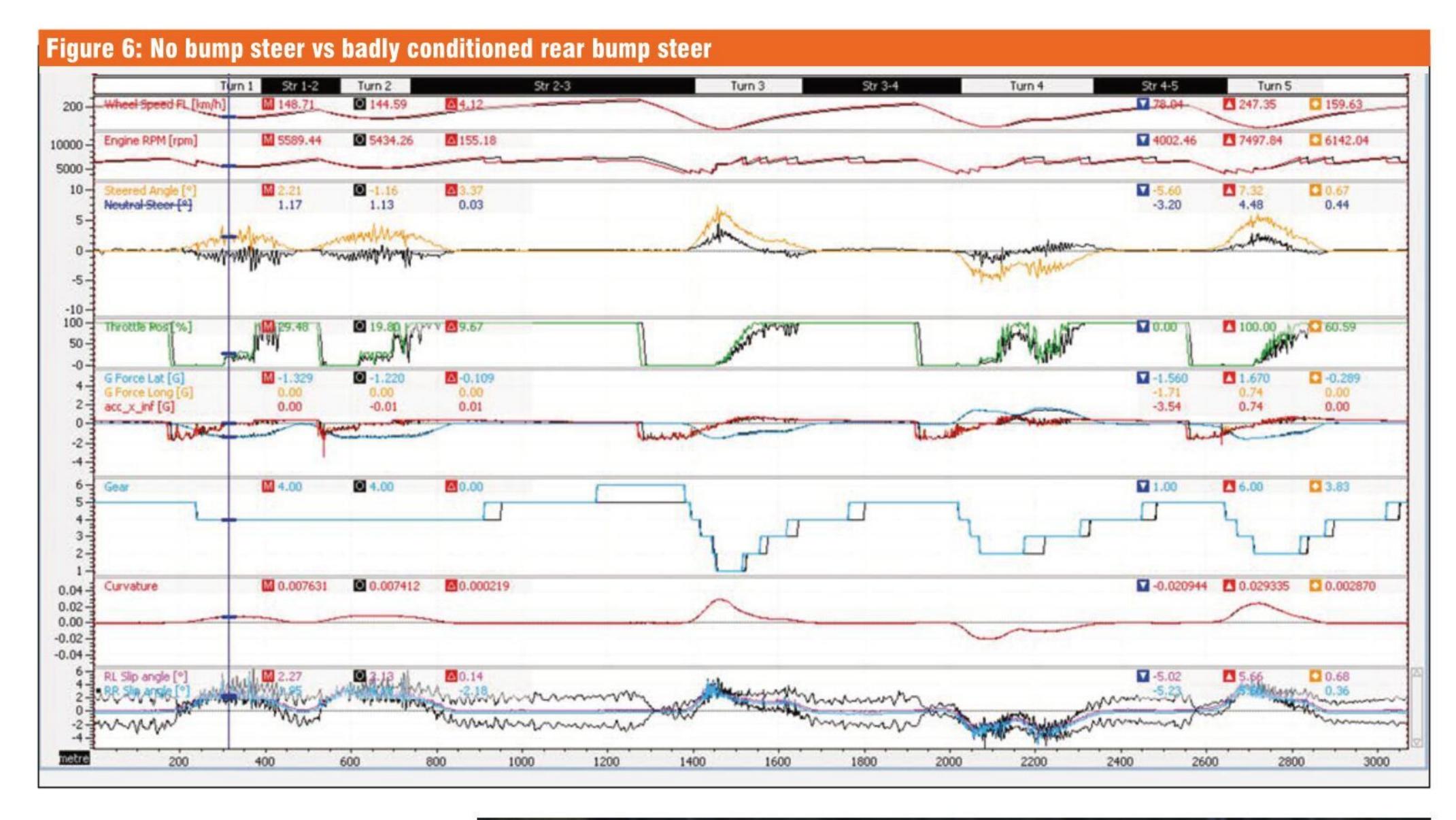
Racecar Engineering is the world's leading publication for motorsport technology and engineering. Every issue provides unrivalled technical analysis of everything from World Championship series including Formula 1, to grassroots racing

# 2 EASY WAYS TO ORDER

Subscribe online www.chelseamagazines.com/CRCEMA21 or call **+44 (0) 1858 438 442** (quoting code CRCEMA21)

NB: Prices and discounts based on our annual UK rate of £71.40/US rate of US\$91.95

If for any reason you're not happy with your subscription, you may cancel within 14 days of placing your order.



lap time with this rear bump steer setup was 71.59s. To appreciate the full extent of this horror show, let's look at the whole lap, as shown in **Figure 6**.

As before, the no bump steer case is coloured and the badly conditioned rear bump steer is black. We can see from the third trace that in steering, the car is chronically unstable everywhere. The thing that is driving this is the rear slip angles on the bump steer case. As can be seen from the last trace, they are all over the place and two degrees higher at mid-corner. In this case, the driver will be holding onto the racecar for dear life, and also wondering why it is so incredibly slow.

So, what is my take on all this?

## **Driver tuning**

Firstly, where the bump steer is well conditioned and the variation is, say, +/-0.5 degrees per 20mm or so, the primary function of bump steer is a driver tuning tool. While the simulation work showed in terms of absolute performance, its impact was negligible. As we could see from the slip angles leading into the turn (recall **Figures 2** and **3**) and the results of the open loop simulation (**Figure 4**), this is something the driver will notice and you, the engineer, will have to pay attention to.

However, what this analysis also shows is you don't want bump steer to get out of control either. As we saw in **Figure 6**, when the bump steer was in the order of +/-4 degrees / 40mm at the rear, the car was undriveable. This is where simulation is useful, particularly on a bumpy circuit,



Our simulation work here is done with a live axle V8 Supercar at the notoriously bumpy Willowbank / Queensland Raceway

because it will give you a very good calibration of what amount of bump steer you will be able to get away with. This in turn feeds back into your suspension geometry design so you know what you are aiming for.

## **Bump steer merits**

Finally, this discussion would not be complete without mention of some outliers to the bump steer question. Often you will see bump steer used to generate heat into the tyre. Due to the variation of slip angle, this approach can have some merit. However, given the reduction of the peak slip angle / ratio of the tyre over the years, it can also be fraught with difficulty, so proceed with extreme caution.

You can also use toe in with bump steer if you need to improve car stability for a high-power, RWD car. Axle steer on Sprint cars and Dirt Late Models is a great case in point. Again though, on a bumpy circuit proceed with caution.

In closing then, bump steer can present a mixed bag. For mild values of bump steer, the key factor is driver feel. But when bump steer gets out of control, it can have a deleterious effect on performance. Simulation can help here to define the values we need to look for.

That said, there are some situations where bump steer is advantageous, but the bottom line is there is not a one-size-fits-all solution with bump steer.

# Design of a Racecar

Modern racing technology – the inside story

Order your copy now - for delivery direct to your door



Brought to you by the team behind your favourite motorsport technology magazine,

Design of a Racecar is a comprehensive 120-page bookazine covering every aspect of racecar design and build, with in-depth features on design principles, optimisation, metrology, testing, wind tunnels, machining and much, much more.

Written by *Racecar Engineering's* most popular writers, including Simon McBeath, Stewart Mitchell, Lawrence Butcher and Andrew Cotton, **Design of a Racecar** also contains the quality images and detailed diagrams, graphs and tables *Racecar Engineering* is known for.

### **IN BRIEF**

The Le Mans 24 Hours announced its 62-car entry for the 89th edition of the race in August. The race will feature five Hypercars, 25 LMP2s, seven GTE Pro entries and no fewer than 24 GTE Am contenders.

Zircotec has launched a new heat shield solution that, it says, delivers a 40 per cent improvement in shielding and as much as 125degC reduction in exhaust surface temperature.

ZircoFlex Shield has been tested in a 350bhp, 2.0-litre British Touring Car Championship turbo engine.

AP Racing has been selected to supply front and rear braking to the FIA RX2e Championship, the first ever FIA electric Rallycross championship, which starts later in 2021.

The series will feature at six European events with a grid of identical, lightweight, four-wheel-drive cars, each built around a spaceframe chassis incorporating two independent powertrains alongside a 30kWh battery.

The cars have been designed by QEV Technologies and Olsbergs MSE and feature a motor capable of delivering 250kW (335bhp) and up to 510Nm of torque.

AP will provide calipers, discs, pedal box, balance bar adjuster and master cylinders to all cars.

McLaren Automotive scientist and engineer, Ella Podmore, has been crowned Young Woman Engineer of the Year by the Institution of Engineering and Technology (IET). Podmore has worked on the 765LT, Elva roadster and the recently revealed Artura, the first high performance, series-production hybrid from the company.

VP Racing will fuel the
British Rally Championship
for the 2021 season. The
company will be present at all
championship rounds with its
refuelling kits and equipment
to ensure safe handling and
distribution to competitors.

Aston Martin has joined
Mercedes as the safety and
medical car suppliers for the FIA
Formula 1 World Championship
from 2021. The company has
supplied specially equipped
versions of the Vantage,
while the Aston Martin DBX
will fulfil the car maker's
medical car commitment.

The FIA World Motorsport
Council has moved to clarify its
WRC and ERC sporting pyramid
following its meeting in March,
with Rally1 cars competing in
the WRC, Rally2 cars in the ERC
and WRC2 categories, Rally3
cars for ERC3 and Rally4 and 5
cars eligible for ERC4.

Brake manufacturer, Brembo,
has launched an upgrade
programme to its customer
catalogue. New lines include Pista
and FF calipers that are designed
for the track at an affordable
price. Also launched is the Sport
/ T3 brake disc, and an app' that
will allow customers to confirm
they are buying genuine parts.

Williams Advanced Engineering has teamed with GB Snowsports to provide assistance in preparation for the Paralympic Winter Games in Beijing in 2022.

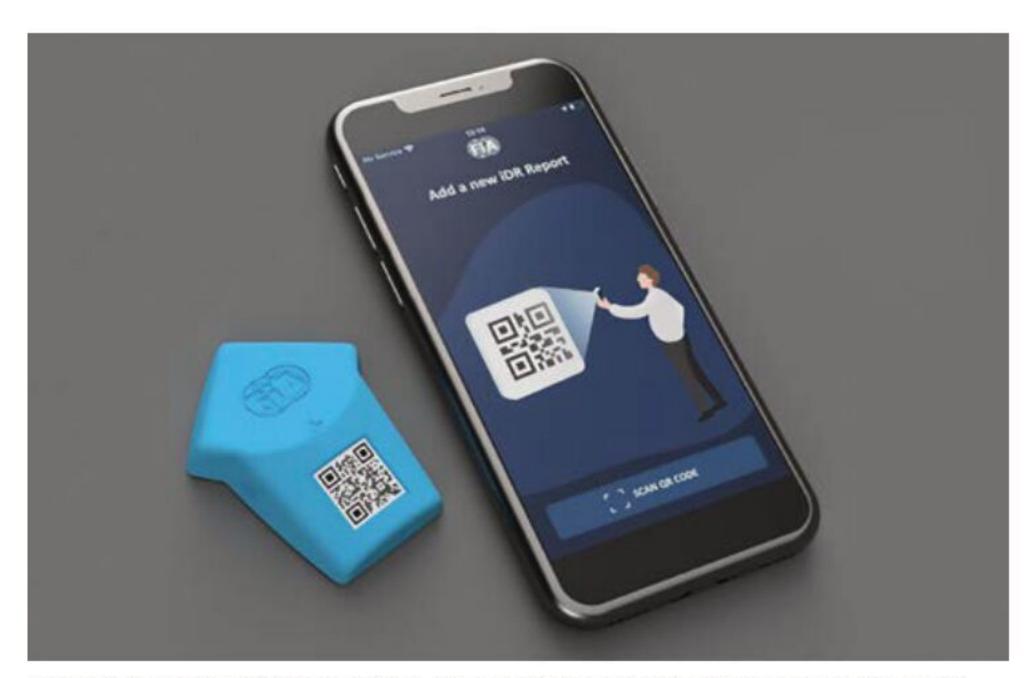
Drawing on expert knowledge from WAE's Sports and Human Performance Team, the partnership will see athletes and performance specialists from GB Snowsport's elite programme work with product designers, engineers and performance specialists to boost the nation's chance of success.

The partnership will be supported by industry-leading expertise from Coventry University, BAE Systems and Formaplex.

The FIA World Motorsport
Council has confirmed it has
selected a single battery
supplier for the new electric
GT Championship, and a
promoter for the series.

Sporting regulations have been approved for the GT3 competition, scheduled for this year's FIA Motorsport Games.

# Cost-effective crash recorder



At just 12g, and requiring no wiring, the new IDR can be fitted to any type of racecar

The FIA has developed a new, low-cost Impact Data Recorder (IDR), a major advancement in its effort to reduce fatal accidents around the world and improve safety in grass roots motorsport.

Developed by the FIA Safety
Department, in collaboration
with AiM Technologies in the UK,
the new IDR is a fraction of the
price of the current Accident Data
Recorder (ADR) used in top-flight
championships such as Formula 1
and the World Rally Championship.

Due to the cost of ADRs, they are currently only fitted to less than one per cent of racecars around the world, but the FIA is encouraging all National Sporting Authorities (ASNs) to incorporate these devices into their grass roots championships.

Graham Stoker, FIA deputy president for sport, said: 'This is a remarkable opportunity to improve safety in grass roots sport worldwide. We have created an affordable data recorder using modern technology that can be used in any championship, and we want everyone in the pyramid to fit this to their competition vehicles.

'Ultimately, using an IDR has to become part of the safety system in the vehicle, like putting on gloves or wearing a helmet.'

Ultimately, using an IDR has to become part of the safety system in the vehicle, like putting on gloves or wearing a helmet

Graham Stoker, FIA deputy president for sport

Adam Baker, FIA safety director, concurs: 'By utilising recent advancements in consumer electronics, we have been able to achieve a very low-cost device, making it possible for widescale adoption in grass roots competition. We encourage all ASNs to integrate this innovative new data recorder into their range of safety devices.'

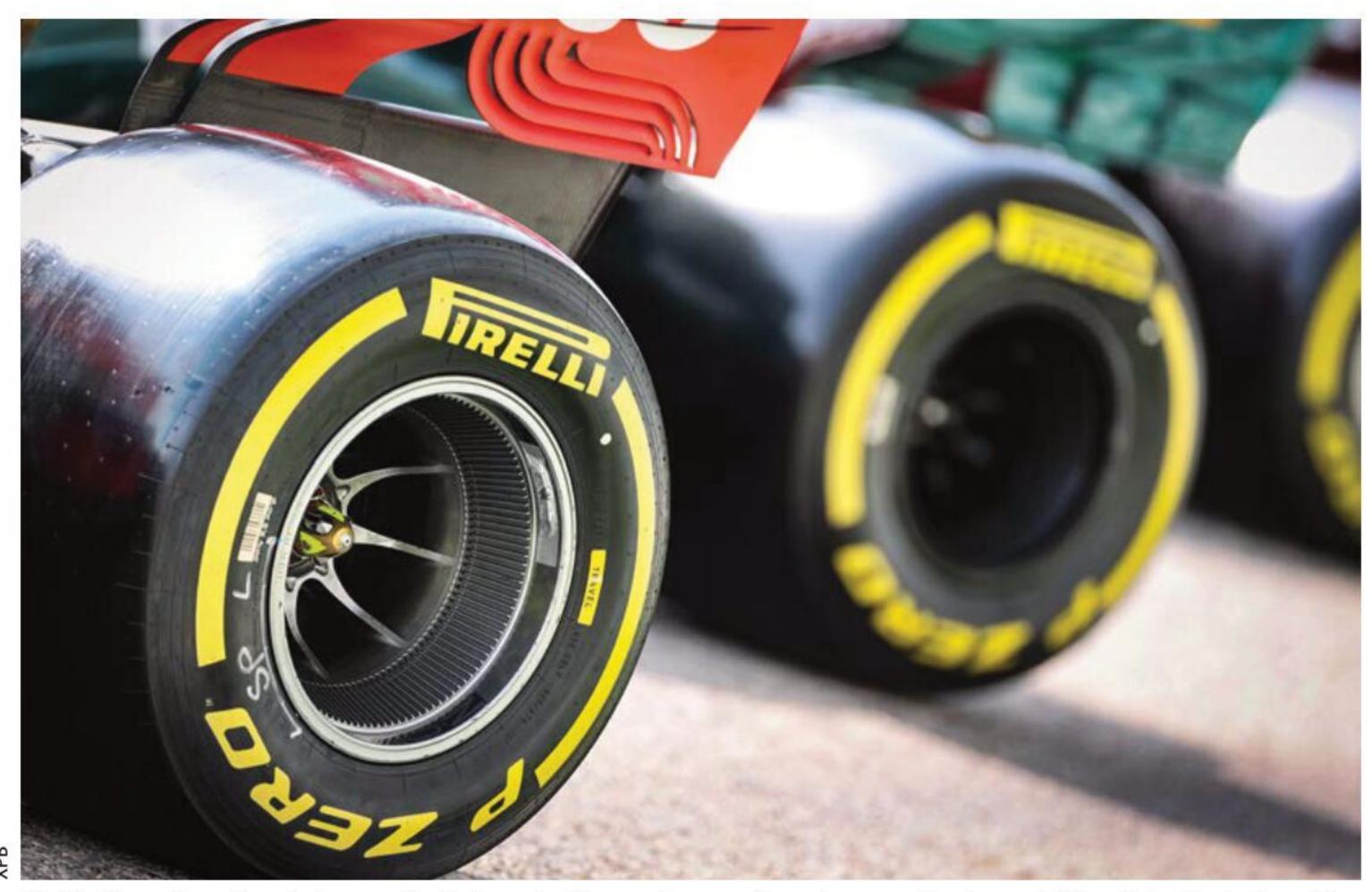
#### 99 per cent

Worldwide accident data collected by the FIA shows that 99 per cent of fatal accidents occur in amateur level motorsport and consequently contain no accident data recording. This makes it very difficult to attain a detailed understanding of the crash sequence and to learn from an accident to improve safety for the future.

The recorder measures just 6cm and weighs 12g. Housed in a smart polymer casing, the maintenance-free IDR requires no wiring or mounting, just a simple adhesion installation. Its internal battery is capable of recording over 80 incidents during its two-year lifespan, and the device is programmed to instantly records all high g and secondary impact data.

The IDR is part of a system that will include a secure access mobile application, allowing impact data to be downloaded from the IDR, stored securely on a cloud server and then distributed to the owning ASN. The app' also enables the user to submit supplementary information such as driver details, vehicle details and incident photographs, while its reporting functionality allows the ASN to gain a better perspective of every incident, with all information then held in one database.

# Pirelli sticks in Formula 1



Pirelli will remain as the sole tyre supplier to Formula 1 for an extra year after a freeze on development delayed the introduction of the 18in tyre this season. The most recent tyre tender from the FIA and Formula 1 in 2018 was for the supply of the 13in rubber during the 2020 season, followed by three consecutive seasons of 18in tyres from 2021 to 2023 inclusive.

# All change in the WEC

The schedule for the World **Endurance Championship (WEC)** has been thrown into disarray with the cancellation of the opening round in Sebring, Florida in March, replaced by Portimao that was confirmed early in March and then delayed to June, and moving the Le Mans 24 Hours to August.

The decision to confirm Portimao over alternatives at Paul Ricard in France and Barcelona in Spain was, according to sources, due to the

ability to host a pre-season test the preceding weekend to the race. However, travel between Portugal and the UK, where teams, drivers, engine suppliers, brake suppliers, tyre suppliers and gearbox suppliers are based, were suspended due to Covid numbers. The UK government also stipulated a quarantine period in a hotel upon return.

Portimao was therefore deferred to 13 June, but not before Le Mans was confirmed to move to

21-22 August in order to increase the possibility of attracting spectators to the event. That caused IMSA to have to re-schedule its GT race at Virginia International Raceway to allow its competitors to race at Le Mans, and the Intercontinental GT series, which had to re-schedule its race at Suzuka.

The changes mean the 2021 season will now start in Spa on 1 May, with the Prologue occurring a week beforehand, which adversely affects the Creventic series.

### **IN BRIEF**

Porsche has increased its stake in Croatian company, Rimac, from 15.5 to 24 per cent with an additional investment of €70m (approx. \$83.477m).

Rimac produces advanced electric powertrains, batteries, infotainment systems and other components related to electrification.

'Mate Rimac inspires us with his innovative ideas,' says Lutz Meschke, deputy chairman of the executive board at Porsche. 'By the same token, he benefits from our know-how in production and methodological expertise in development.

The FIA Formula 3 World Cup has been confirmed to take place at Macau on 21 November 2021, on the same billing as the FIA WTCR series.

**Graham Ingleby** from Reading, won the Formula E Tamiya model in our exclusive Racecar Engineering competition. Congratulations to him, and we hope he enjoys building and running his new car.

Michelin has been confirmed sole tyre supplier to the new GT3 formula DTM series, giving the French manufacturer a further foothold in the customer GT market currently dominated by Pirelli. Michelin's deal with DTM management is for one year.



British car-maker Ginetta has opened a new US base in South Boston, Virginia. The company has also acquired TMI AutoTech, the leading US low-volume sportscar manufacturer

Interview – Antonello Coletta

# Back in the saddle

Ferrari's return to factory Prototype racing after a 50-year absence has given the WEC another boost. Racecar talks to Ferrari's head of Attività Sportive GT incorporating Competizioni GT and Corse Clienti

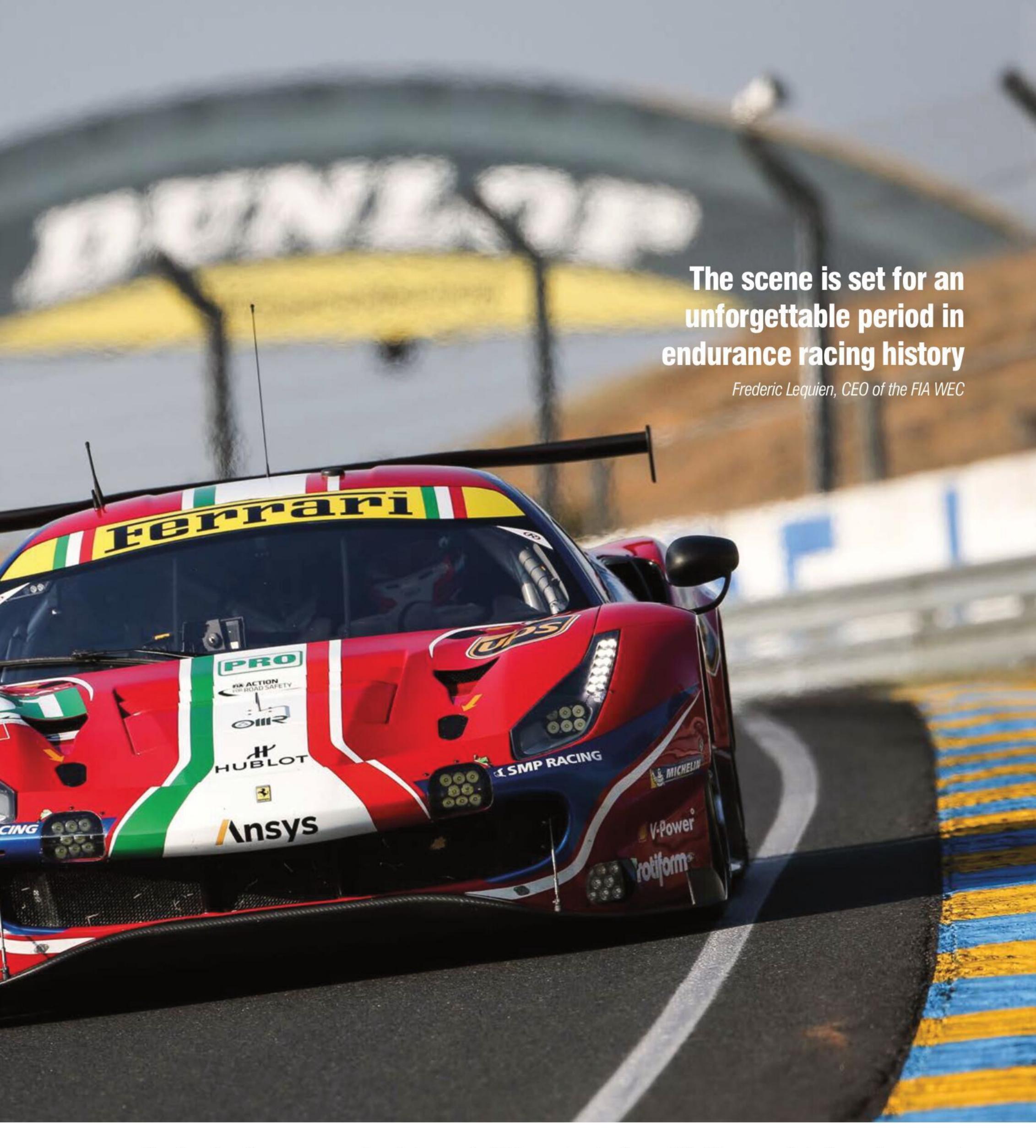
BY ANDREW COTTON





return to Le Mans for the first time since 1973 with a full factory team, aiming to add to its total of nine overall wins at the French endurance classic.

It was in 1965 that the marque last won at Le Mans, Masten Gregory and Jochen Rindt taking the chequered flag in their Ferrari 275LM, and it is half a century since the 312PB was entered by the factory.



Since then, Ferrari has remained in endurance racing competition, more recently with the Dallara-built Ferrari 333SP, which was also in contention for overall wins in the 1990s. There was also the Prodrive-built Ferrari 550 Maranello that did not have factory support and, under the Competizioni GT banner, the 430, 458 and 488s that have competed in customer hands, in GTE / GTLM and in GT3 / GTD categories.

Ferrari returns on the 100th anniversary of the Le Mans 24 Hours, and will line up on the grid alongside the Peugeot Hypercar, also scheduled for a 2023 debut, and the LMDh contenders from Porsche, Audi and Acura. Toyota and Glickenhaus will both debut their Hypercars this year, at the Spa 6-hours in May.

'The news that Ferrari is set to join the new Hypercar category is simply amazing, said Frederic

Lequien, the new CEO of the FIA WEC. 'What's even more incredible is that Ferrari will join at least five other manufacturers to compete in the WEC's top-tier category from 2023. The scene is set for an unforgettable period in endurance racing history.'

#### **Rumour mill**

Rumours of the return have been rife, and it was supposed to be announced in December 2020,

but a change of management delayed confirmation until the end of February 2021. Many thought Ferrari's involvement would be as a direct result of the Formula 1 cost cap forcing the manufacturer to reduce its workforce, and that it would be better used on another hybrid category. However, Antonello Coletta, head of Ferrari Attività Sportive GT, says this is not the case.

#### **BUSINESS** - PEOPLE

'In 2023, it will be exactly 50 years since Ferrari last raced in the top class but, since then, we have never stopped competing in endurance racing,' confirms the Italian. 'The reason is simple: it is part of Ferrari's DNA and history. However, the challenge of competing in the top class is different now and the new regulations – to which Ferrari has contributed and in which it has been involved since the first meetings – give us the chance to again fight for overall victory.

'We presented our ideas, sharing our project with top management, and received the green light to go ahead, independently of the introduction of the budget cap in Formula 1, even though many people thought this operation had come about with this new rule in mind.'

#### **Maintaining control**

There was some debate over whether Ferrari would opt for the LMDh rule set, which would involve a tie up with one of four chassis manufacturers (Dallara, Multimatic, Ligier or ORECA), and take a spec hybrid system, or go for LMH, where the Italian manufacturer would control the full design and build of the car. The latter is said to be considerably more expensive, despite both being subject to a five-year homologation period, with only one upgrade allowed within that time.

However, for Ferrari it was important to take that route, rather than potentially share chassis supplier and run a spec hybrid system.

'Right from the start, we have supported this as the best option for a manufacturer like Ferrari,' says Coletta. 'In the words of our chairman, John Elkann, in over 70 years of competition, our closed-wheel cars have triumphed on tracks worldwide, experimenting with cutting-edge technological solutions. These innovations naturally find their way into our production cars, hence the decision to invest in our own LMH project.

'Given our philosophy, it would have made little sense to choose otherwise. We want to design and build a car down to the last component.'

The design team within Ferrari will be led by Ferdinando

# 'The new regulations... give us the chance to again fight for overall victory'

Cannizzo, who was involved in the aerodynamic department of Ferrari during the late 1990s until 2005, specialising in thermal fluid dynamics and energy management, before becoming head of vehicle innovation and then moving into the hybrid and electric area of the company. Since 2016, he has been the Competizioni GT engineering director.

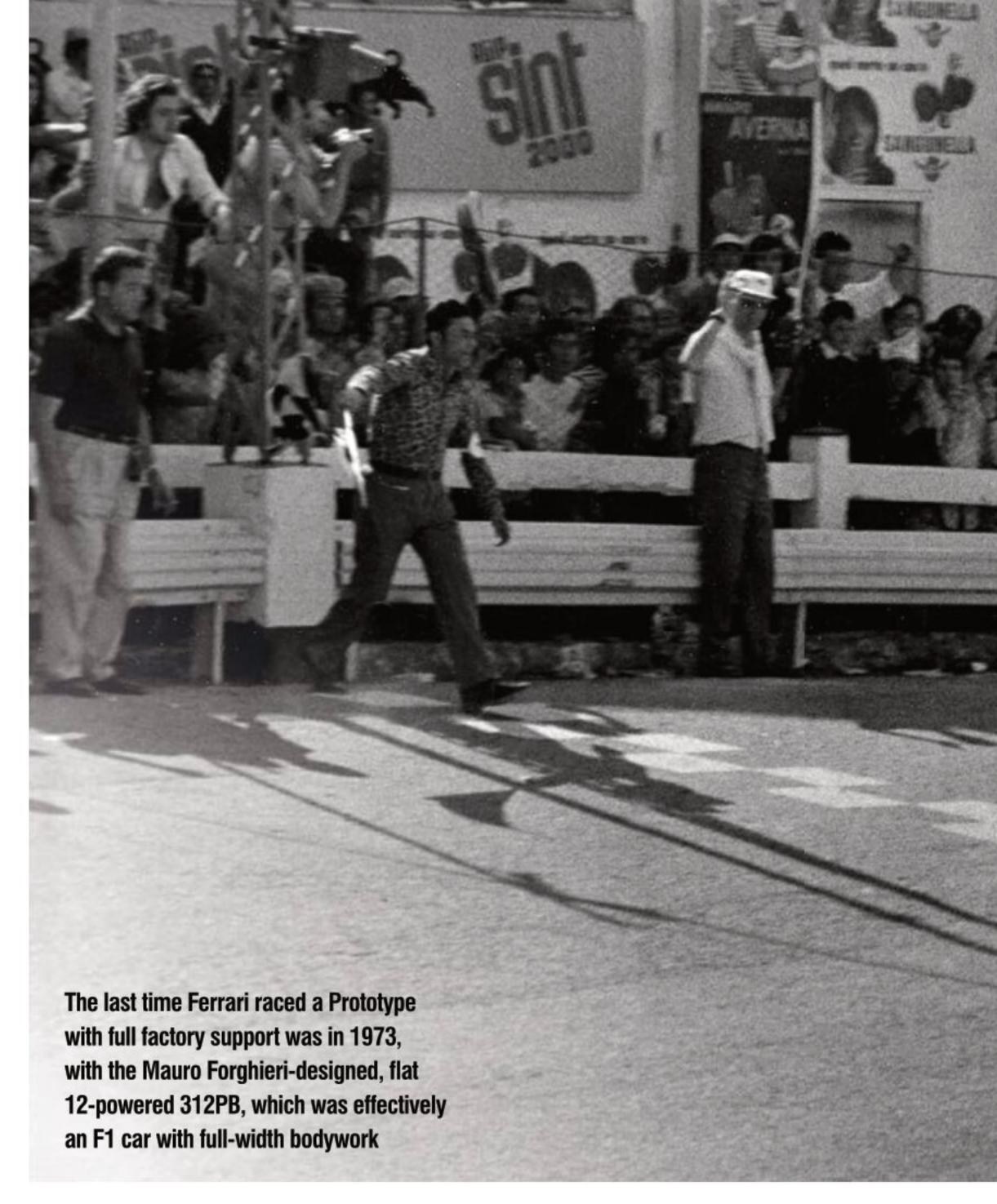
Other manufacturers involved in Hypercar have confirmed the aero targets are not particularly difficult to hit, while the minimum weight of the car allows for a focus on safety and comfort rather than outright performance. It is possible, then, to build a relatively straightforward car, and this is certainly what Ferrari is targeting with a compressed time schedule to compete.

#### **Dynamic testing**

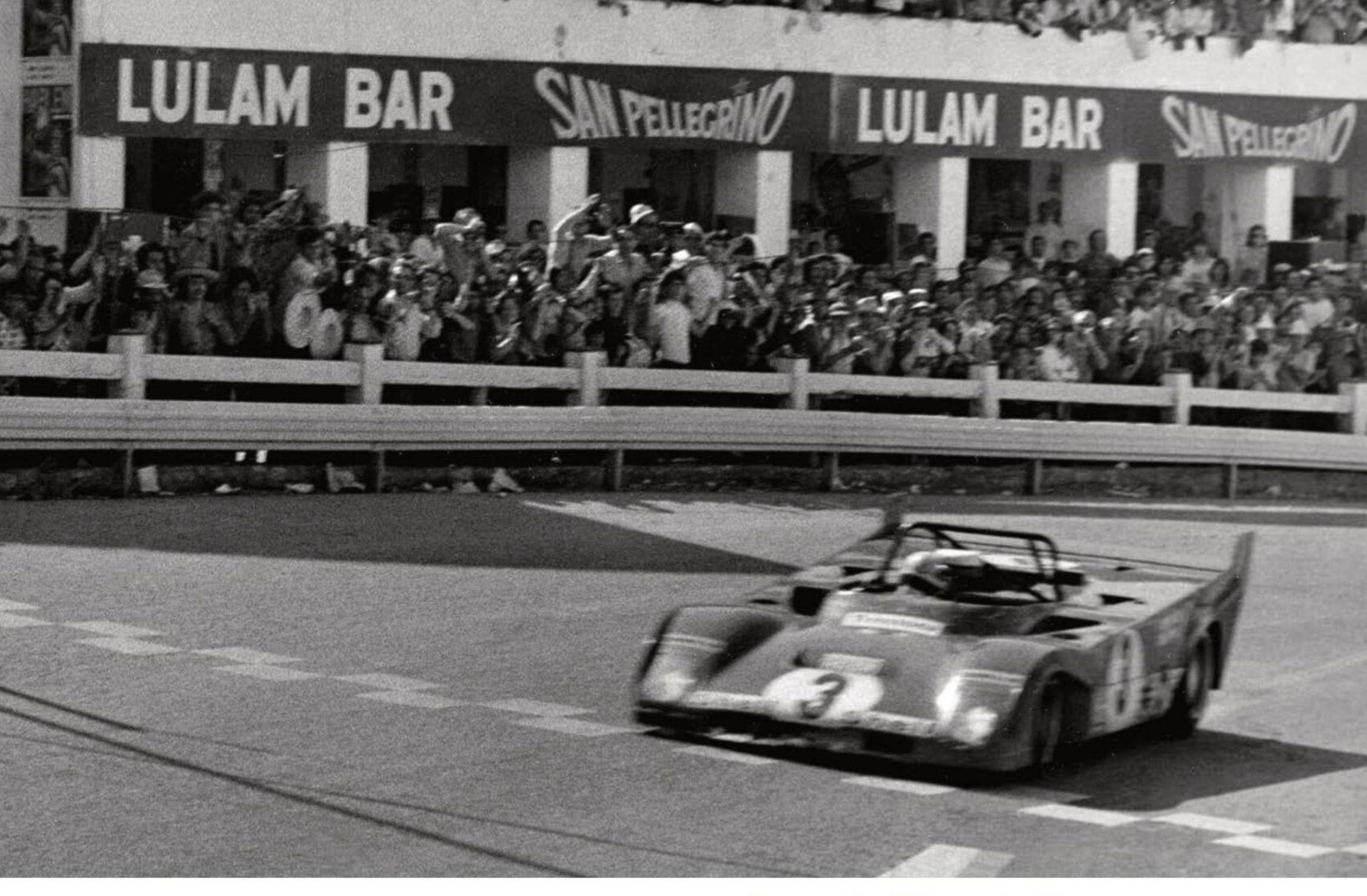
'It's still too early to provide an exact date regarding the track debut for development testing, but we have planned the various stages to start the dynamic testing on track in early 2022,' confirms Coletta. 'We have a lot of work to do, but everyone is very enthusiastic.'

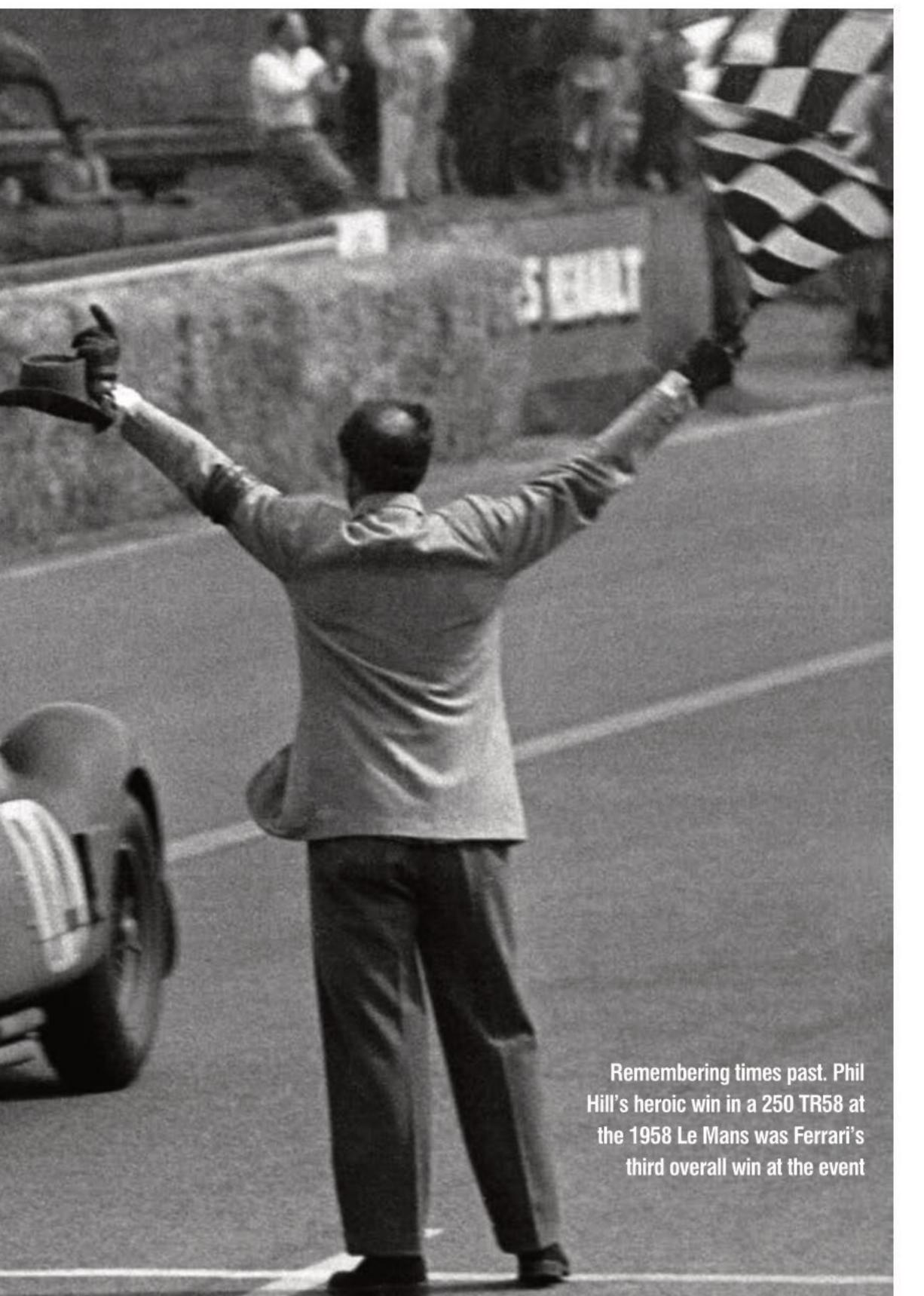
It is too early for Ferrari to confirm the identity of its technical partners, including gearbox suppliers and engine layout and configuration. This information will be released later in the design and development stage, but for now the design team will start work while the race teams vie for the factory contract to compete.

'It's Ferrari's project, so Ferrari will carry it out,' says Coletta of the 2022 test programme. 'AF Corse has been our official GT team in recent years, and we have won numerous victories and titles with this partner, including









# Ferrari will no doubt now be pushing IMSA to accept the Hypercar

world titles. Clearly, they are a partner we know well, but we have not decided anything yet.'

#### **Customer cars**

'As far as customer programmes are concerned, we have different priorities at the moment, namely completing the design of the car and getting it out on track. We'll definitely address this area, but it's still too early.'

Another team with its hat in the ring is the Risi Competizione team that competes in the IMSA United SportsCar series, and also races at Le Mans with considerable success. Both have run successful customer programmes with factory support in endurance racing.

Ferrari will no doubt now be pushing IMSA to accept the Hypercar so it can return to competition in Daytona, Sebring and Road Atlanta, as well as contest the FIA World Endurance Championship. 'Competizioni GT is, and will continue to be, structured so the LMH programme doesn't impact the GT programme for the cars that race in the WEC, and that support the teams competing with the Ferrari 488 GT3 Evo 2020 in the main GT championships,' confirms Coletta. 'These two activities run in parallel. There will be no problems whatsoever.'

The cards are starting to fall into alignment, with IMSA confirming it will not run a GTLM category in 2022, instead focussing its GT commitment on GT3. The WEC will likely hold out for another year before it too will switch to another platform. Ferrari is ideally placed in both existing GT categories, all under the guidance of Coletta

'My role won't change. I am still the manager of Attività Sportive GT. It's just I have to add another important challenge to the many programmes our department already deals with.'



# Four square

#### **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

Mike Blanchet, Lawrence Butcher, Francesco Manara, Marco Milanetti, Wouter Melissen, Danny Nowlan,

#### Photography

Mark Ortiz, Dieter Rencken,

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

CHELSEA MAGAZINE COMPANY

www.racecar-engineering.com

## 4WD in Formula 1 is not new, but the engineering challenge remains

These cars are

going to need a

stable aero platform

to work, at least

in the early years

he move to four-wheel drive in Formula 1
under new regulations that are being discussed
for 2025 is a revolution in terms of a rule set.
This would be the first time such a layout is
compulsory in the global single seat category.

It's not, however, the first time anyone has tried fourwheel drive in Formula 1. Lotus, BRM, Matra and McLaren have all done so, although none won a single race with it or saw enough benefit to continue with the technology.

Introducing a hybrid motor to the front axle is also nothing new – the Le Mans cars from Porsche, Toyota and Audi all had front motors, but the key difference is the minimum weight in these cars was higher, and the shape of the chassis more accommodating than a slimline F1 car.

Even Toyota has found packaging a challenge with its new Hypercar. Mounting the MGUs and cooling the motors is an engineering hurdle in a car built to a relatively easy to hit point on the lift / drag graph. Given the aero sensitivity of F1 cars, any disturbance at the front could cause mayhem downstream, and a lot of simulation work will be needed over the next few years to minimise that effect.

The tyre supplier will also have to create a new structure for the rubber to deal with both power and

steering for the first time in more than 50 years. It's not impossible by any means, but it is a step change in handling and driving style. And here comes the next problem.

When Audi went from twowheel drive to four in its R18 Prototype, set-up possibilities were a whole other world. It seems the FIA is already one step ahead of this and are talking about maximum lateral

acceleration limits before the front-wheel drive can kick in, but this adds another extra layer of complication.

## Stable platform

Toyota mastered front-wheel drive in its TS050, but that also featured interlinked suspension, which helped keep a stable aero platform, as did Porsche's 919. Porsche also experimented with warp control, but felt it a waste of energy on a flat track and added weight for little return.

At present, it is not clear whether Formula 1 will allow FRIC back in, although it seems daft to have it banned. These cars are going to need a stable aero platform to work, at least in the early years. It also has the opportunity to add in active suspension, which would do the same job but for much less money.

Bringing in moveable aero devices might work for F1. The idea was discussed and rejected for the 2014 rule set, and it would have increased fuel efficiency dramatically. In terms of reliability, there have been incidences of the DRS flap failing, but at an acceptable level, and no more than engine or gearbox failures in the same timeframe. Le Mans also looked at introducing such systems with its planned 2018 rule set but abandoned it as the manufacturers left the category. I objected to such devices on the grounds that at circuits such as Le Mans, and in endurance racing as a whole, debris is commonplace and far more likely to prevent a moveable structure from actually moving.

#### **Holding pattern**

All of this is being considered in order to extend the life of the ICE, making the whole car more efficient, and helping reduce fuel consumption figures. I can understand it. It's a holding pattern as the future propulsion systems for road cars is debated. Electric is not yet an option for F1 and, with synthetic fuels becoming more prevalent, it could be a plausible solution to our climate and mobility crisis.

However, it also takes Formula 1 one step further away from production car technology. Yes, supercars have

moveable aero, and hybrid systems, but the smaller, more cost-focused car market is far more traditional in its design and execution.

There is an argument that as the technology is developed in racing it can filter into production cars, and would reduce fuel consumption on a long run, for example. However, a more logical solution to this problem would

be to reduce the speed limit on the motorways and cut fuel consumption that way – cheaper for all concerned, if interminable to drive. Or introduce one extra gear, an overdrive. But haven't we been here before?

For all the benefits that motors in each of the four wheels introduce, would racing be any better for it? The cars would probably not be as sleek as they are now, and the unpredictability we all love in motorsport, most commonly brought about by adverse weather, would be reduced. So, the sport will go away from production car technology, introduce cars that are worse looking and potentially make the racing worse. All for the sake of keeping the ICE relevant. I am not sure this works.

**ANDREW COTTON Editor** 

To subscribe to *Racecar Engineering*, go to www.racecar-engineering.com/subscribe or email racecar@servicehelpline.co.uk telephone +44 (0) 1795 419837

<sup>•</sup> Racecar Engineering, incorporating Cars & Car Conversions and Rallysport, is published 12 times per annum and is available on subscription. Although due care has been taken to ensure that the content of this publication is accurate and up-to-date, the publisher can accept no liability for errors and omissions. Unless otherwise stated, this publication has not tested products or services that are described herein, and their inclusion does not imply any form of endorsement. By accepting advertisements in this publication, the publisher does not warrant their accuracy, nor accept responsibility for their contents. The publisher welcomes unsolicited manuscripts and illustrations but can accept no liability for their safe return. © 2021 Chelsea Magazine Company. All rights reserved.

<sup>•</sup> Reproduction (in whole or in part) of any text, photograph or illustration contained in this publication without the written permission of the publisher is strictly prohibited. Racecar Engineering (USPS 007-969) is published 12 times per year by Chelsea Magazine Company in England.

# FIND YOUR LINE TO FASTER TIMES





DRIVING PERFORMANCE OPTIMIZER THAT SHOWS THE TRUE OPTIMAL LAP™ YOU CAN ACTUALLY DRIVE.

Garmin.com/Catalyst

Warning: This device is intended only for recreational use in a circuit environment. Never use this device on public roadways. ©2020 Garmin Ltd. or its subsidiaries.



LAP TIMERS. DATA LOGGERS. CAMERAS. SENSORS.



# Reinventing The Wheel

THE NEW RANGE OF FORMULA & GT WHEELS

