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Back to the future

Looking back through our coverage of Formula 1 in 2021, it was perhaps surprising how little we actually wrote about the current cars, focusing instead on the political and technological future of Formula 1, and motor racing in general.

Normally, the cars of the season are fascinating enough, with teams adapting to new powertrains, or new regulations throughout the year, while also homing in on the single biggest performance differentiator, be it aerodynamic or mechanical.

We usually carry features covering the majority of the cars on the grid, but this year has been a little different. The regulations were fixed from 2020, and so development potential has been reduced. It has still taken place – there would be no point remaining in F1 if a team, or engineer, wasn't looking for that unfair advantage and there were rule changes, albeit subtle ones.

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The reason we have concentrated on the political side is because, with two sets of new technical regulations coming in 2022 and 2026, there has been plenty to talk about. These discussions have centred around Formula 1 remaining relevant to the wider industry, which is itself unsure of its own direction, while also retaining its place as the pinnacle of motor racing technology, and reducing budgets to manageable levels. It's not an easy tightrope to walk.

As governments, particularly in Europe, relentlessly repeat the electric mantra, and actively promote the sale of electric cars through grants and tax cuts, Formula 1 must find a way not only to remain competitive using internal combustion engines, supported by hybrid power as it has since 2014, but also to remain valuable to the motor manufacturers coming under intense political pressure.

Finding a route to a sustainable future has not been easy. Enabling the cars to race closer together was a key part of the regulations for 2022 as a new audience has been attracted to the sport thanks to Liberty's programming, as was making the aesthetics of the car work, including going to more road-relevant, 18in wheel rims. Powertrain will be fixed, and budget caps put into place to help make the environment more agreeable to interested parties.

The longer-term rule set looks at those powertrains, but there are so many options to be considered. Even the fuel is up for discussion, as is the amount and cost of electric drive.

At the end of this season, we say goodbye to the 13in wheels that have been a feature of Formula 1 for almost 40 years. We also say goodbye to Honda, which has brought its third era of Formula 1 to a close after a turbulent start that gave way to a mightily impressive finish. Red Bull takes on the intellectual property rights for the power unit, and will now build its own engines.

We also say goodbye to many of the aero devices that are designed to increase efficiency at the expense of a following car, a move that it is hoped will eventually lead to an end to DRS in the following rule set, or earlier.

Testing with the mule cars has already taken place, before the all-new cars hit the track in February ready to start racing again in March. It's a short winter break, and teams will be working hard in their simulators to develop their all-new cars and give themselves the best chance they can next year.

Andrew Cotton, Editor

XPB

CONTENTS

2021 vision

The new season started with an overall rules freeze but there were some subtle, significant changes for the teams to take on board

By Stewart Mitchell

Red Bull Technology teams helped push through an engine freeze so they could competitively use Honda power until the start of the new power unit era, which comes into play in 2025 or 2026

An unexpected freeze in development (a consequence of the coronavirus pandemic pushing the new era of F1 to 2022) could have left viewers thinking the 2021 Formula 1 World Championship would be very similar to 2020, with teams simply carrying over much of their cars' design for another year, but that would be a mistake.

The final 2021 regulations, published by the FIA in late 2020, featured several detailed revisions.

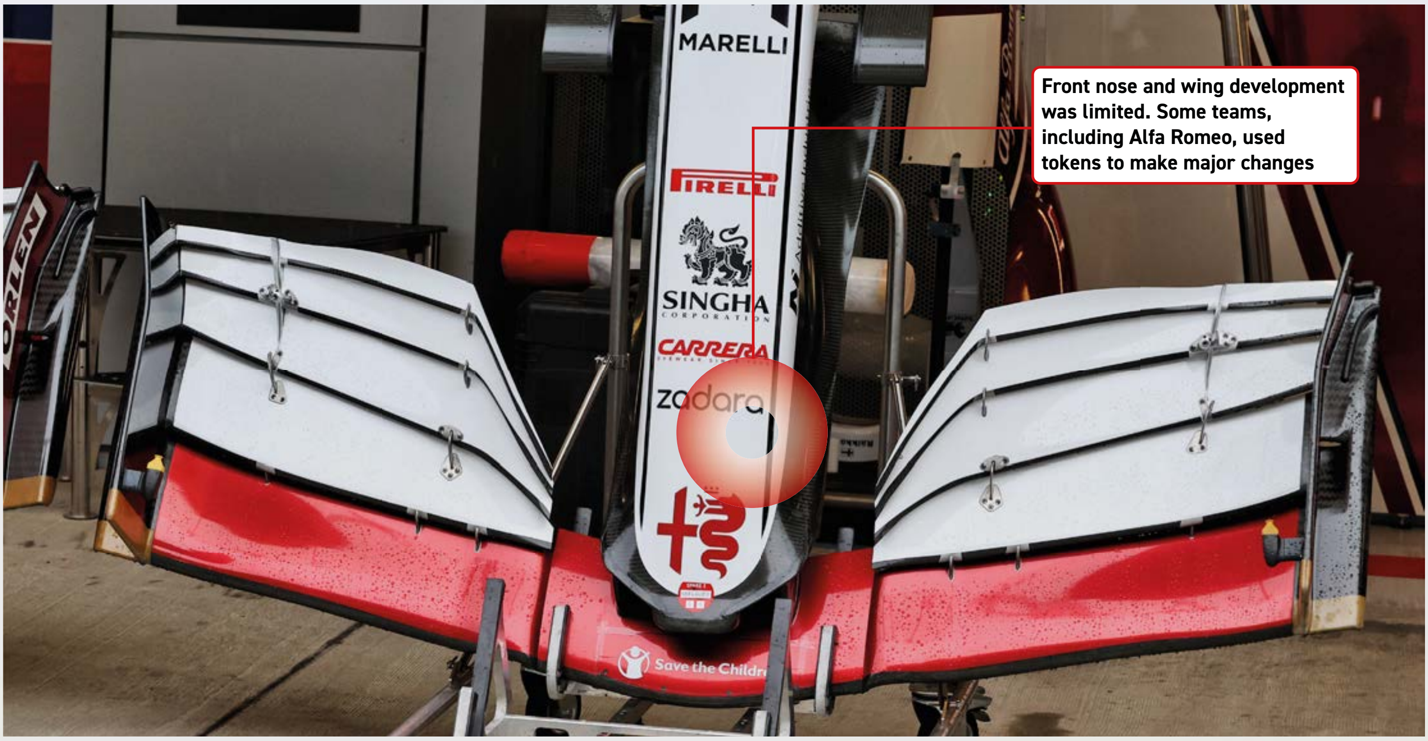
The changes were initially penned as calming measures in response to the ever-increasing downforce the cars deliver, which some feared would push the Pirelli tyres beyond safe limits.

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

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

Aerodynamic revisions

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



Additionally, the rules prevented designers including any fully enclosed holes in the floor, through which to manipulate airflow, be they slots, holes or aerodynamically-shaped furniture.

These revisions decreased the floor's working area used to generate downforce from under the car and reduced the ability to seal the floor to work the diffuser as effectively as possible.

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

The allowable flex, and therefore the floor's minimum stiffness, was also adjusted ahead of the 2021 season in a bid to reduce the use of it as a moveable surface to influence aerodynamics. The floor was only allowed to flex up to 8mm vertically when 500N of load was applied, a reduction from the

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

10mm of flex permitted in the 2020 regulations under the same load.

The diffuser was also amended to lessen its ability to create downforce, with the height of the boundary-controlling vertical elements required to be 50mm shorter than those used in 2020.

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

During the drafting period of the 2021 rules, Andy Green, technical director of the then Racing Point squad (now Aston Martin Racing) noted; 'After evaluating the new floor's impact, it's a huge change. The small alteration, relatively speaking, has had quite a significant impact on the car's performance. It is not just a re-development of the floor, unfortunately, it's a re-development almost of the front-to-back aerodynamics of the car to try and recover it.'

Investigation into how these aerodynamic changes were going to impact car performance started before the beginning of the season, with several teams trialling full-scale packages to gather real-world data as far back as the first half of the 2020 season.

McLaren Racing tested a floor with the prescribed 100mm diagonal cut out on each side at the Belgian Grand Prix in August 2020 with its Renault-powered MCL35, ahead of its switch to Mercedes for the 2021 season. Following this test, the team's technical director, James Key, commented; 'It's a shame it had to be done, but there are good reasons for it as we enter the third year of these cars [after the regulation update in 2019], and they are getting quicker and quicker… to the point where, in some cases, driver resolution is lost in high-speed corners and they go by instinct more than conscious decisions in those moments.

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

'Affecting the floor around the rear tyres and diffuser and brakes leads to unique development, and we have had to learn so much about these quite critical and sensitive areas.

'In that respect, it is showing we could not carry over design from 2020 and make the car work, which would have been a much more natural progression.

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

Ahead of the launch of Mercedes' 2021 car early in March, James Allison, the team's technical director, also commented on the new aerodynamic rules for this season.

'There was concern that if we left the cars' aerodynamic development unchecked, performance would keep increasing, as it's been doing for several seasons now.

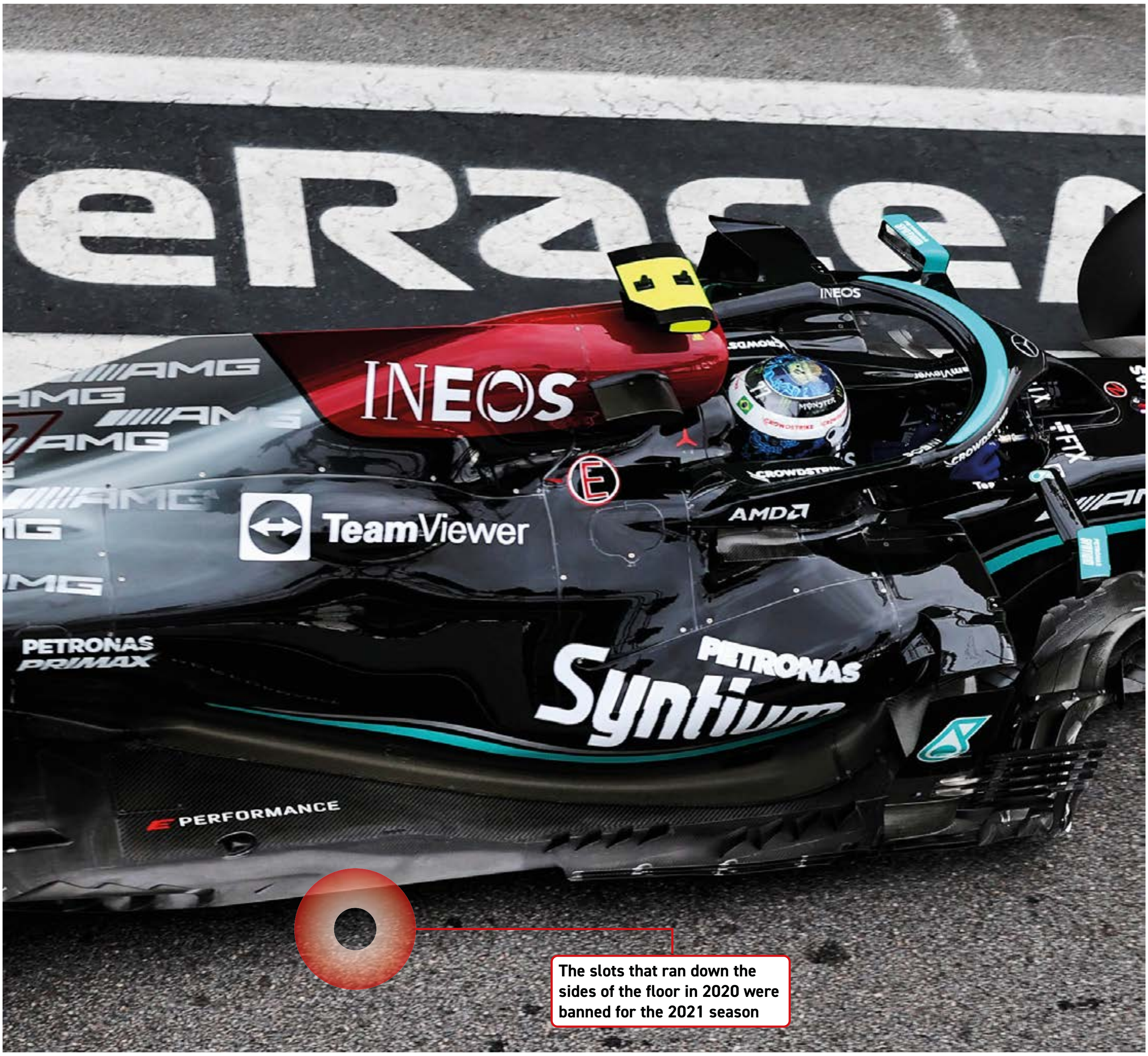
'The risk was the cars would outgrow the tyres, and perhaps even aspects of the circuits, so there was a need to bring performance down a bit.

'For us, the combination of the aerodynamic changes to the regulations in their rawest form brings the performance of the car back to somewhere near 2019 levels of downforce.

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

Andy Green, technical director at Aston Martin Racing

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



The slots that ran down the sides of the floor in 2020 were banned for the 2021 season

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

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

Powertrain

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

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

Power unit development was also limited further still for 2021. As always, the power unit manufacturers searched for more performance from their products, but the intense effort behind that in 2021 had to be made in the context of a rule environment where there was less opportunity for mistakes.

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

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

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

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

Hollow bodies

A clarification was also made regarding hollow cavities. For 2021, they had to be a uniform cylindrical shape of a constant diameter.

As such, the advantages of using exotic construction techniques for hollow components was curtailed.

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

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

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

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

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

Unanimous support

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

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

The freeze was widely welcomed to keep huge engine improvement costs down, and fixing it at three years was considered the best option. A high-level working group was established, including current and potential engine manufacturers and fuel suppliers, to consider the route F1 should take after that and the results of those discussions will be released in December 2021.

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

MD Media

New, more robust tyres from sole supplier, Pirelli, were around 3kg heavier than those of the 2020 season

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

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

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

'The new tyres are designed to help us race safely and fast through the 2021 season.'

Robust rubber

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

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

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

CFD reduction

Similarly, CFD work on the cars was also curtailed and position linked. The testing period for substantial CFD work typically runs for around 10 weeks, depending on the time of the year. The nominal number of results produced at this time was approximately 2000. With the new system in place, Mercedes could only generate 1800 CFD results during the 2021 testing period, while Williams was allowed to produce 2250.

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

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

James Allison, technical director at Mercedes F1

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

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

With F1 heading into a new era in 2022, these restrictions will become significant when teams transition from 2021 to 2022 development, and were expected to play a critical role halfway through the season as development permissions reset.

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

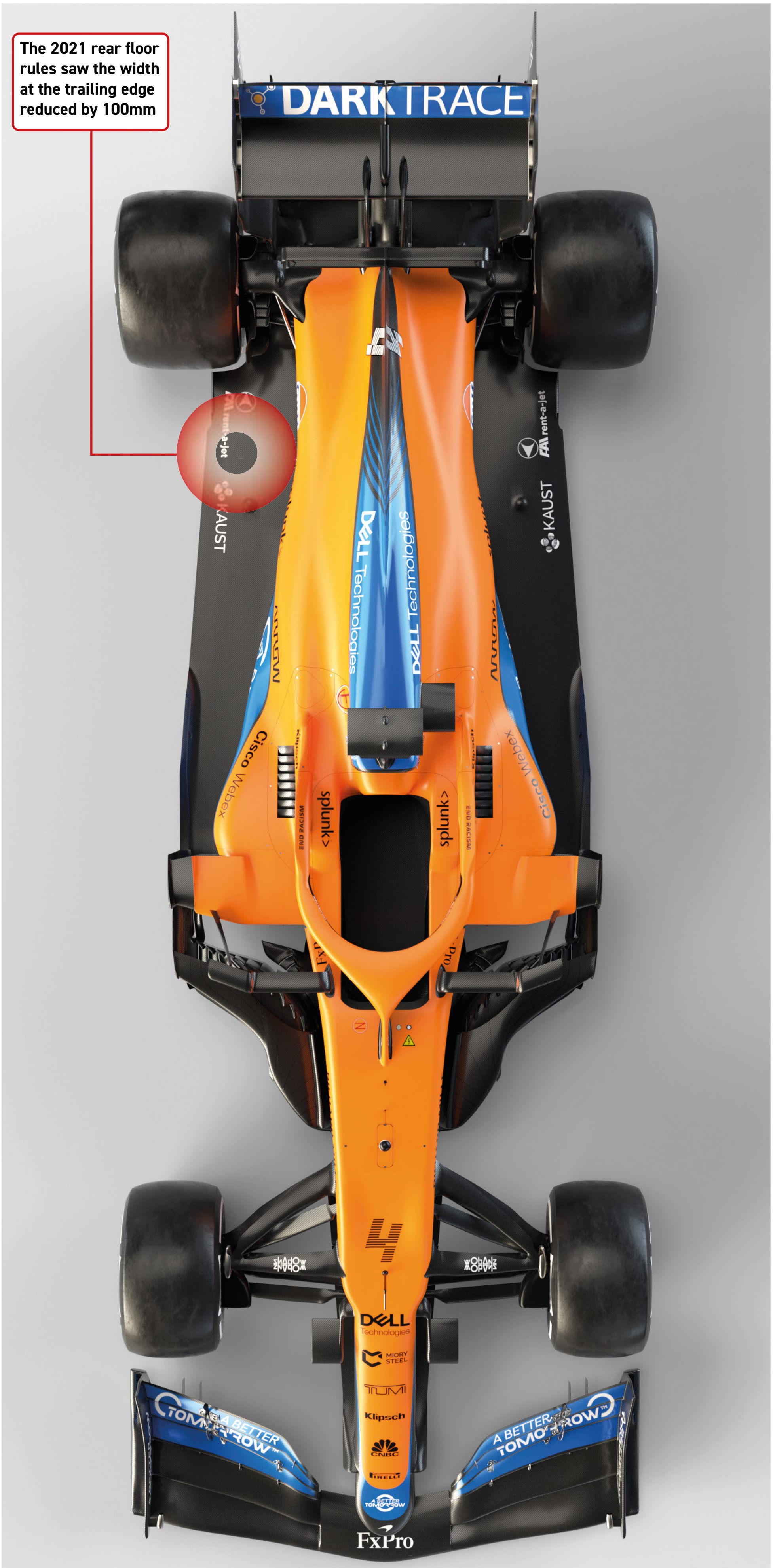
Opportunity knocks

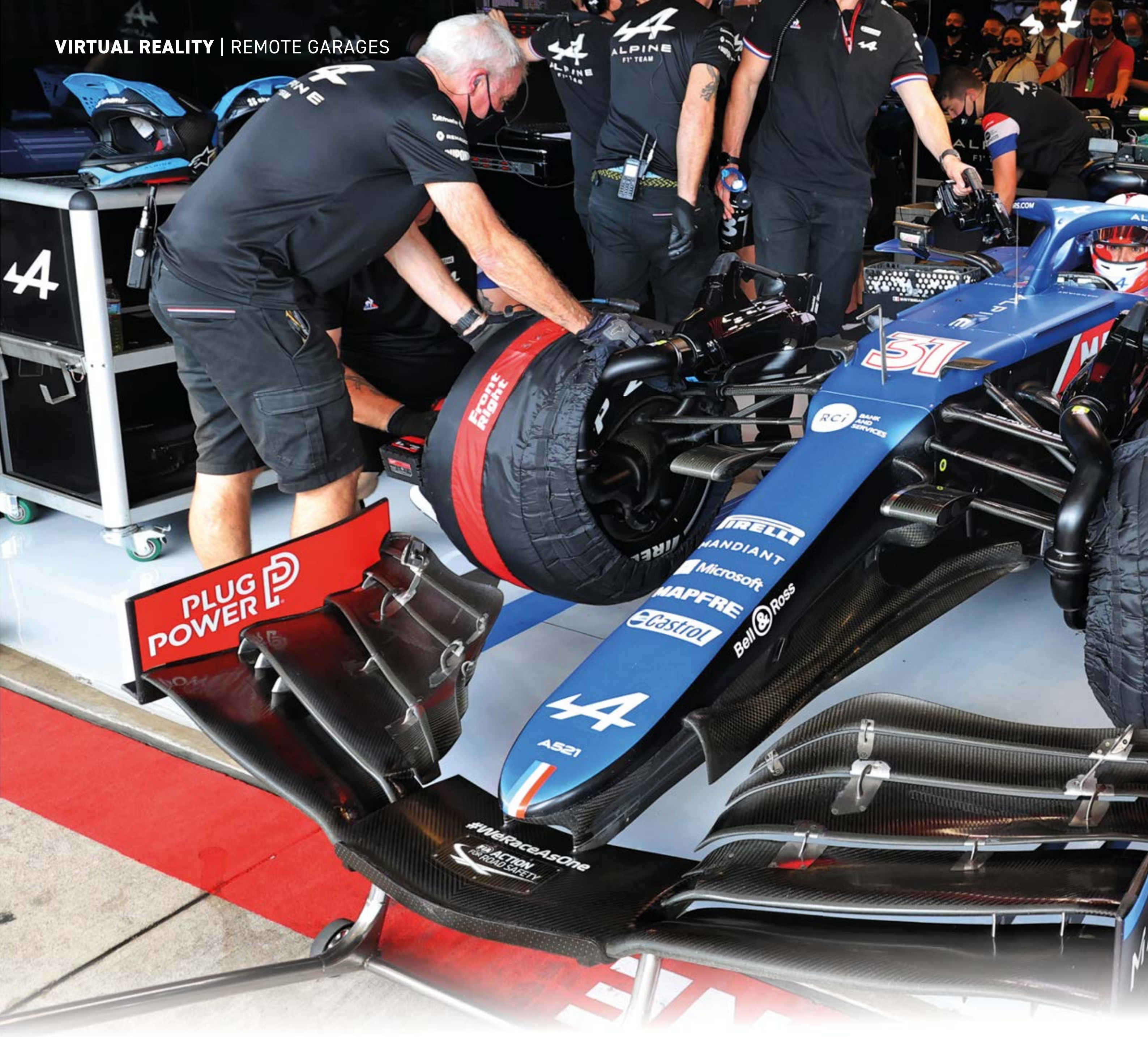
'For us, the challenge has been about adapting our world so we get more and more out of every single opportunity in the wind tunnel – making sure each run is as valuable to us as possible,' Allison continued.

'Regarding CFD compute, we have adapted our methodology and approach to make those calculations as valuable as possible. This adapted approach should mitigate, and maybe even completely offset, the effect of this reduction in the amount we're allowed to use these fundamental tools.'

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

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





Remote control

Called variously 'virtual garages', 'mission control' or 'race support rooms' is the future of race engineering sitting in the warm back at HQ?

By DIETER RENCKEN

Once Formula 1 took the decision to resume action in July 2020 after a Covid-induced three-month break, one of the crucial criteria was the number of travelling staff per team permitted paddock access via tightly controlled 'bubbles'. The decision largely hinged on restrictions imposed by authorities in the region the sport targeted for its return, namely Austria's Styrian province, home to the Red Bull Ring.

A limit of 80 staff per team was imposed, half the number a well-heeled team would usually take to grands prix, of which around 60 are required to directly operate two cars, with the balance providing engineering, logistics, media, marketing and hospitality services. Although the last three activities were downsized considerably, it soon became clear some of the performance-related functions would need to be executed remotely.

The remote garages … have their roots not in foresight but in circumstance

Alpine F1 operates a mix of proprietary and in-house software in its remote garage, but also regularly checks social media channels like Twitter and Instagram

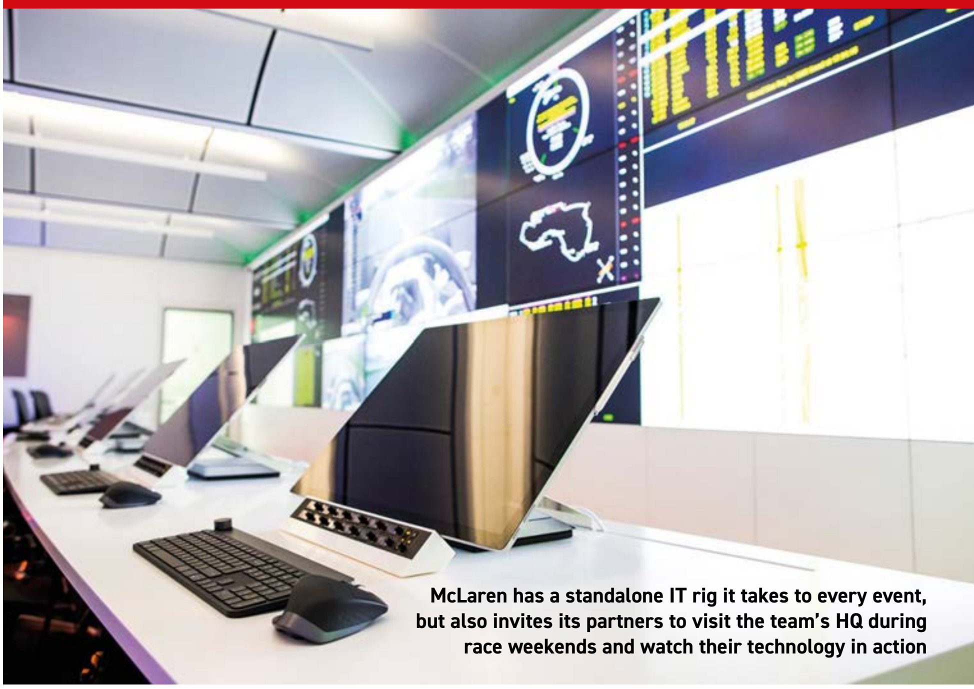
Fortunately, Formula 1 had form in this area, having developed hi-tech data transfer channels over the past two decades. This enabled it to be the first global sport to return to action once restrictions were lifted, initially by way of 'ghost' races that were staged behind locked gates. Without remote technologies, those first races would have been considerably more complex to stage.

As is so often the case in Formula 1, though, the remote garages, which directly connect trackside teams to their factories via data links, have their roots not in foresight but in circumstance, in this case the enforced absence of Ross Brawn from the 2002 Japanese Grand Prix – reportedly due to a slipped disc – during his Ferrari technical directorship.

Brawn, now managing director of F1, mandated Ferrari's IT department provide access to trackside data to enable him to direct the weekend's proceedings from a 'virtual pit wall perch' in his home in Surrey, UK. Significantly, the team noticed little difference.

'When he talks to us, it's so clear it sounds as if he's here at the circuit,' said Ferrari driver, Rubens Barrichello, of 'Virtual Ross' during that weekend's press call. '[Brawn] was also not at Monza on the Friday of [that year's] Italian Grand Prix, but it was as if he was there. He talked to us and we could hear him just as normal.'

McLaren's IT crowd



McLaren has a standalone IT rig it takes to every event, but also invites its partners to visit the team's HQ during race weekends and watch their technology in action

Teams have leveraged their commercial partners in the quest for the best in virtual garages, with HP, Pure Storage, AMD and Tata Communications partnering Mercedes, Cognizant title partner to Aston Martin and AWS inking a deal with Ferrari. Kapersky and Acronis represent two of the data security companies currently in F1.

McLaren, which recently added more partners than any other, boasts Dell Technologies, conference platform Webex and cyber surveillance company Darktrace, developed in conjunction with British intelligence agencies. These provide the bulk of the team's virtual garage kit.

'We have an IT rig that we take with us,' says Ed Green, McLaren's head of commercial technology. 'We have only one set, and it travels to every race. It's full of computers and storage and servers, which come from Dell. Should the worst happen and the

The need for growth is that there is an ever-increasing amount of data available, and there are ever more eyes available for it

Dominique Riefstahl, race support team leader, Mercedes F1

That slipped disc sowed the seed for the logical next step. And when F1 restricted the number of passes per team and imposed curfews, it just provided further impetus for remote garages, variously known as 'virtual garages', 'mission control' or 'race support rooms'. However, there was also another trigger.

'When we had constraints from regulations that limited how many engineers we could take to the race track, we started to think about what we could do to not lose [data] we had in terms of analysis on reliability and on performance,' explains Laurent Mekies, Ferrari's racing director. 'That's how the ideas of remote garages were born.'

Size matters

As is usually the case in F1, successful implementation of any new concept, combined with personnel migration between teams soon sees copycat editions up and down the pit lane. Within a year, all major teams had their own versions in place, albeit to varying effects and of differing sizes.

That said, the more funding teams had, the more sophisticated their technologies, and the greater their virtual head counts.

'We're now in our fifth iteration of the race support room [RSR],' explains Dominique Riefstahl, Mercedes F1 race support team leader. 'It started off with a tiny cupboard behind one of the meeting rooms, where literally you had two people sat in there, primarily trying to run simulations and doing analysis on both cars.

'Over the years it's grown in size, from two people to about 10 people, then 20. These days, there's 30 of us in there. Obviously, the need for growth is that there is an ever-increasing amount of data available, and there are ever more eyes available for it. At the same time, the numbers of people at the track reduced. As a result, you tend to find some roles are now happening in the RSR as opposed to the track.'

However, in an ironic twist, remote garages came close to extinction in 2018 after Brawn proposed they be banned on cost grounds and to level the playing field under F1's incoming 'new era' regulations, due for introduction in 2022 after being pushed out a year as a result of Covid. Team bosses pushed back robustly.

'What cost?' Otmar Szafnauer of Racing Point (now Aston Martin) questioned. 'We have the virtual garage already, and so does everyone else. That cost is sunk. Getting rid of it is only going to cost everyone.

'We also have sponsorship for it. We'd lose that, too. So you've got to ask yourself if there is no cost benefit in getting rid of the virtual garage, are they asking us to get rid of it because we compete with [F1] on sponsorship?'

Mercedes F1 CEO, Toto Wolff, was equally critical: 'I think it's a very bad idea because we've invested in virtual garages,' the Austrian argued. 'It's a great selling proposition for partners and sponsors. There's not only engineers in our virtual garage back at Brackley. We have sponsors there, we're trying to have cooperations with hi-tech companies and this is the part they are most interested in.

'As far as I know, many teams have managed to commercialise the race support structures back in the factories and, of course, it gives you an advantage if you've got more brains working on solutions and problems. For us it's become a point of sale.'

Informed decisions

Ultimately, sense prevailed, with F1's return to action under Covid later vindicating the decision. Team bosses had fought long and hard for the reprieve for good reason though. Apart from the obvious cost and performance benefits, there are real safety aspects in the data from incidents that can be immediately analysed back at base and informed decisions taken. From that perspective alone, it is critical links do not drop out.

According to Juan Rodriguez, head of the race operations room for Sauber (racing as Alfa Romeo F1), most teams prefer land or submarine optic cables, which are routed through switchable nodes rather than satellite connections.

Riefstahl reckons the last full outage Mercedes suffered occurred in 2013, but says 'the most dangerous bit' – in terms of reliability – is the last kilometre.

Mid-size team, Alfa Romeo, boasts an impressive inventory of trackside garage kit, namely 60 virtual machines running bespoke software and 55 PCs supported by 40 notebooks and eight tablets, all hooked up to team HQ in Hinwil, Switzerland via a MPLS (multi-protocol label switching) system that directs data along the shortest, most stable route in real time with minimal latency (delay).

Juan Rodriguez heads the race operations room at Alfa Romeo F1, which contains 60 machines running bespoke software

internet pipe all the way to our mission control in McLaren Technology Centre go down, we can run the race on its own with those Dell servers.'

For cyber security, McLaren relies heavily on Darktrace, rather than humans, as the artificial intelligence system is on guard 24/7, including race weekends. Green recalls an incident during last year's (ultimately cancelled) Australian Grand Prix when McLaren was protected from sophisticated attacks after the algorithms picked up unusual flurries of emails.

A senior F1 figure's computer had been hacked, sending emails containing 'links' to McLaren staff, some of whom would not regularly receive emails from the individual. Darktrace intercepted the emails and quarantined them. Had just one link been clicked, the team's systems, and potentially the race, could have been compromised.

The artificial intelligence system is on guard 24/7, including race weekends

Webex has become the standard platform for McLaren meetings, whether internal, external or track to HQ, while Splunk, another McLaren partner, provides software for pre- and post-race analysis.

In common with other teams, McLaren activates its partner links by inviting sponsors and guests to the McLaren Technology Centre during race weekends, providing real-time demonstrations of mission control in action. Guests become part of the team for the race by following the data flow via headsets and giant screens erected in the boulevard area, where historic McLarens are on display.

'We have a viewing gallery adjacent to our mission control behind privacy glass, which we can turn on and off, so people can watch mission control in action,' confirms Green.

During the Azerbaijan Grand Prix weekend, around 10,000 files comprising mainly telemetry, voice and video data totaling 500Gb were transferred. These numbers largely tally with those provided by the other teams interviewed for this feature, although McLaren professes to transfer three times that amount.

'From the radios, videos, cameras from the pit stops, cameras from the garage and all the software needed to run the car, as well as the telemetry and the delivery channels, we are able to have a normal communication with the track [garage from the operations room],' Rodriguez explains.

'There's about 400 channels of sensors on the car,' says Riefstahl. 'If you take a load cell in the suspension and a displacement sensing in the suspension, that's only two channels coming off the car but, by the time you resolve those in terms of forces, and you've done that everywhere around the car, we augment that to about 40,000 channels.'

Teams don't, of course, monitor all 40,000 channels, as he explains: 'With a lot of the channels, especially when they are compound channels, you don't need all of the steps that are in between, you look at the final numbers. If something goes wrong with the final number, then you start going back down through the chain, but we do have mechanisms that monitor certain channels and flags them immediately [if there is a massive offset].'

Live telemetry

Live timing telemetry for all teams is provided by the standard Atlas software, which is part and parcel of the compulsory McLaren-supplied electronic control units mandated by the FIA. Teams have developed their own add-ons to these for simplified processing, lap averaging and bespoke requirements, while the engineering software suites are usually team specific and developed in house.

For strategic simulations, the majority of teams rely on the RaceWatch package from SBG Sports Software, which provides the full suite endorsed by FIA F1 race director, Michael Masi.

Bernadette Collins, head of race strategy for Aston Martin F1 team, says a number of teams, including her own, 'developed their own versions off the back of that. But it gets to a point where the cost of developing software – the resource required vs off-the-shelf software – is key.

'For that sort of software, a lot of it is the parameters you put in, rather than the information you get out. The video analysis, for example, which F1 developed, what they call 'Pit Wall', provides all the onboard videos from other drivers. That's pretty robust and we pay them for licences on that.'

Bernadette Collins, head of race strategy at Aston Martin F1, emphasises the importance of open communication between track and mission control, with no information hidden from either department

Laptops, notebooks and tablets are all linked into teams' data strategy, with robust cyber security in place

According to Chris Dyer, head of vehicle performance at Alpine F1, the team operates a mix of proprietary and in-house software: 'We are using SBG for timing information, then, like all teams, we use Atlas for telemetry data. We have our bespoke systems and software that sit on top of those common building blocks.'

Staffing strategy

Mission control staff numbers during race weekends typically run to 35 heads, although individual faces may change depending upon track programmes.

Strategy staff may not be required during free practices, while there can be less aero group attendance during a race, for example. That is a major benefit of remote garages: staff can be swapped, or called in, as required, whereas once they're trackside there is no flexibility.

'We have a mix of people in the remote garage. We have people from vehicle performance, from the aero group, race strategy and a person who belongs to the race team and doesn't travel,' says Dyer.

> It gets to a point where the cost of developing software – the resource required vs off-the-shelf software – is key
>
> *Bernadette Collins, head of race strategy, Aston Martin F1*

'Then we have a couple of support people – one or two from the design office following reliability issues. The breakdown of the operation changes through the weekend, with less performance people in the group after parc ferme and more from strategy,' the Australian says, adding that under Covid rules some mission control staff members were even able to work from home.

Depending on a team's relationship with its power unit supplier, a PU support engineer could physically or virtually be in mission control. Then, as the sophistication

Virtual working


Since Covid, home working has become reality for many people, and the technology available to implement it successfully has accelerated dramatically

Dennis Dean

Working remotely is not the sole preserve of F1 teams, with the FIA and brake supplier, Brembo, embracing virtual reality solutions under Covid.

The governing body has long operated connected systems for back-up purposes, but as Chris Bentley, the FIA's head of information systems, explains, these came into their own once F1 returned to action as a number of stewards on the traditional F1 roster were not permitted by their governments to travel internationally.

'When you have an international panel of stewards and the direction of what we're trying to achieve, [then] you've got someone with the level of experience as, say, [chairman of the F1 stewards] Gary Connelly based in Australia, or Tim Mayer in America, we had to look at things in a different way.

'That's where we started to build on top of the remote services we had. We doubled our bandwidth for the track to cover not only the stewarding but also software engineers for extra service provision that would normally be at the track.'

The acid test

The system was put to the test for the 2020 Le Mans 24 Hours event when Mayer was stuck in Georgia, USA, and the FIA connected him to the French circuit via 'a box of goodies', which Bentley says allowed him to connect to race control and the stewards group.

'The quality of this was quite strange because it was as though he was next door, which is very eerie when you've got someone on the other side of the Atlantic,' says Bentley. 'There was minimal latency because when we plug these things in our technical partner, Riedel, manages the connections end to end for him, from the point in his house right into the track.'

The system again proved its worth when F2 / 3 steward, Dennis Dean, was unable to travel to Sochi from Washington DC in September due to a passport issue. Again, the system worked flawlessly.

Due to restrictions on media at grands prix, the FIA introduced video conferencing and, while the FIA accepts that personal interface between journalists and interview subjects is crucial in certain circumstances, the platform will be used increasingly for more casual media calls. 'We swapped the whole emphasis of our network connectivity to sending data to people coming in remotely, and sending [back-up] data overnight or later in the day,' concludes Bentley. 'That is something that will continue because we've been able to do quite a lot of things successfully this way.'

As for a supplier like Brembo, which supplies 90 per cent of the F1 teams with brake componentry, it traditionally sent two engineers to the track who would consult with individual teams on an as-needed basis. Unlike Pirelli, which provides a dedicated tyre engineer to each team, and could therefore incorporate them into their 'bubbles', the Brembo engineers could not do similar as they needed to move between teams.

Andrea Algeri, Brembo Racing's F1 customer manager, says the company adapted processes developed with Ferrari, who in 2017 requested a dedicated engineer during race weekends who worked remotely. So, between last year's (cancelled) Australian Grand Prix in March 2020 and the recent US Grand Prix in October 2021, attended by Algeri, Brembo had no physical trackside presence at all. It worked, under the circumstances, but he concedes personal contact is vital and so Brembo will in future rotate its engineers, with one travelling to events and the other operating remotely. The best of both worlds, if you will.

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of driver-in-loop simulators improves, so teams experiment with set-ups, and then feed results to the team, often before sessions end. Equally, requests can go the other way, with trackside engineers asking those back at base for specific simulator set-ups.

Data flow

Collins, who recently featured on the Forbes list of 30 Under 30s for contributions to manufacturing and industry, says that within Aston Martin there are totally open data flows between mission control and trackside garages: 'There's nothing hidden between the trackside environment and the people who are plugging laptops into mission control,' she says. 'Everything comes back via IT link. Additionally, everything on the intercom feed comes back to mission control, all the videos come back and any live stream images from garage cameras.

'A few years ago, when the FIA tried to tie down what teams were allowed to tell drivers on the radio, tried to ban coded messages, they got to the point of saying, "We're not going to police this any more, but everyone else is going to get your intercom." All of that gets fed back to mission control and processed [for strategic] reasons there rather than at the track.'

However, not all track intelligence comes via normal channels: 'We'll also go and look at certain websites for a competitor, or see what information we might gather from Twitter and Instagram and Reddit, because teams give away quite a bit of information over those channels,' smiles Dyer.

The key to the concept: gathering information and intelligence in a relatively calm and methodical environment... and then supplying crucial support to those in the midst of battle

Therein lies the key to the concept: gathering information and intelligence in a relatively calm and methodical environment, one well away from the direct stresses of the trackside garage, and then supplying crucial support to those in the midst of battle to try to gain an advantage.

Apart from undoubtedly easing F1's return to action, the acid test for virtual garages is how realistic they actually are, particularly as they increasingly rely on artificial intelligence and augmented reality scenarios. Riefstahl relates an anecdote which underscores their realism: 'We had a case where Lewis [Hamilton] was discussing his steering wheel with his control engineer and at some point he said, "I just want you to come down and do it." To which the engineer replied, "I can't, I'm in Brackley…"

'It shows how transparent communication can be, and how much people rely on us providing information, analysis and support, without realising at times that we're not actually physically there with them at the track.' That is the reality of virtual garages.

A word in your Shell-like

Racecar investigates the highly complex world of Formula 1 fuels and lubricants

By Stewart Mitchell

The evolution of fuels and lubricants in Formula 1 is one of the most critical and untold stories of the sport in the current era. The introduction of the hybrid regulations in 2014 changed the engineering formula for the internal combustion powertrain from an air-limited, mechanically-restricted formula to an energy-limited one.

This shift in concept altered the engineering approach, and set the road map to the world's most efficient race powertrains, now producing over 1000bhp from the combination of 1.6-litre, turbocharged V6 internal combustion engine (ICE) and energy recovery system (ERS) at a thermal efficiency of over 50 per cent.

For the current turbocharged V6 formula, the restricting element is no longer the oxidising component of the combustion, it is the hydrocarbon element. This forces engineers to think completely differently about the whole process of combustion.

The absolute power of the engine derives from its ability to transfer the joules of energy stored in chemical form into kinetic energy. The challenge is to adapt the air-to-fuel ratio and combustion parameters to extract the most energy out of each fuel droplet, rather than simply adding more.

The number of joules of energy entering a contemporary F1 engine can be considered a constant as the regulations fix a fuel mass flow rate of 100kg/h. The ratio of energy entering the engine in fuel form to that turned into useable kinetic energy is the primary target for the fuel engineers.

'The 50 per cent plus thermal efficiency of the current crop of Formula 1 engines is extremely impressive, and most of that is attributed to the mechanical design of the engines,' explains Benoit Poulet, Formula 1 fuel development manager and trackside team leader at Shell. 'However, the fuel contributes 25 per cent of the functional thermal efficiency of the engine.

'Of course, the engines were not at 50 per cent thermal efficiency on day one of these regulations in 2014, so this journey has been ongoing for the last seven years.'

Fuel evolution

The limiting factor of the naturally aspirated, fixed displacement, air-limited engines was how high they could rev, which is a function of combustion speed and mechanical stress.

‘Engineers set about developing the fuel chemistry to go through the combustion process as fast as possible’

Benoit Poulet, Formula 1 fuel development manager and trackside team leader at Shell

Ferrari’s SF21 FIA Formula 1 World Championship contender features no fewer than seven products from its principal partner, Shell, helping it to work as efficiently as possible

There were two major elements of the fuel formulations for that era: they were designed to balance peak power output potential (as a function of calorific value and combustion speed) and fuel consumption. The use of each was track dependent.

In the hybrid era, the mass of fuel for the race is limited and the fuel flow is limited in mass at any given time. So, the mass becomes a fixed parameter. This takes out the track dependency as it was in the past. Engineers can also trade off kilograms of fuel carried against fuel consumption and peak power, as a function of the vehicle dynamics gains to be had from carrying less fuel at certain tracks.

'With the current hybrid regulations, which fix the fuel in mass, the track dependency is out,' notes Poulet. 'It is the same in Monaco as it is in Monza, and even going to Mexico as well if we also include the air pressure parameter. It doesn't change.

'However, although the fuel type trade-off no longer exists, you see another exchange in the current regulations set. Because the fuel flow and fuel load are prescribed in kilograms, there is scope for development of the calorific value of the fuel.

'When the energy-limited formula came into place and research into the fuel started, Shell discovered that some fuel molecules produce significantly more energy than others. The development targets then shifted to finding how engineers can apply as much energy into one kilogram of fuel and generate the proper pressure and motion for the direct injected gasoline engine.'

The research octane number (RON), which gives a ranking of how close to the most efficient moment the spark plug can ignite the fuel, is a primary driver in the combustion development of the high-efficiency fuel.

'In theory, you want all combustion to happen instantaneously at top dead centre (TDC),' highlights Poulet. 'Physics dictates that this cannot occur as combustion is a process that happens in stages. Despite this ideal being physically impossible to achieve, the engineers set about developing the fuel chemistry to go through the combustion process as fast as possible.'

Knock control

Because the current engines are turbocharged, there is a lot more motion and chaos in the combustion chamber than with the old naturally aspirated engines. So spontaneous combustion (aka knock) is a substantial limitation and consideration for contemporary Formula 1 race fuel blends.

Combustion chamber, piston crown and piston ring pack design are all critical in the mitigation of knock, which is why companies like Shell work so closely with their Formula 1 engine design squad partners at Scuderia Ferrari.

'With the energy that you get into one kilogram of fuel, how much you will be able to condition the fuel to combust completely and as close as possible to TDC, and how quickly it will happen, has changed dramatically since the start of the energy-limited formula began,' highlights Poulet.

'Additionally, despite the [15,000rpm] rev limit and the operating rpm of the current Formula 1 engines being significantly lower than the previous naturally aspirated, air-limited formula [now operating at peak rpm around 12,500-13,000rpm], engineers want the pressure build up from combustion to happen even faster than before.

'When the piston starts to go down, the chamber volume increases, which means work is required to build the pressure inside the chamber until BDC.'

Achieving efficient combustion in a fuel-limited formula pushes engineers to run the engines ever leaner, and drives technology such as pre-chamber ignition and the use of homogenous charge combustion ignition

Efficient combustion

The combustion parameters are defined first before the mechanical geometry around it is configured. Achieving efficient combustion in a fuel-limited formula pushes engineers to run the engines ever leaner, and consequently drives technology such as pre-chamber ignition and the use of homogenous charge combustion ignition (HCCI).

XPB

Ferrari's SF21 is significantly better performing than its predecessor, the SF90, scoring a second place podium at the 2021 Monaco GP. Fuel for thought

XPB

Shell's bespoke racing fuels are designed to extract maximum efficiency from every molecule that goes into Ferrari's 1.6-litre, turbocharged, V6 race engines

'Every fuel molecule must meet the required amount of air to satisfy the peak efficiency in desired power regions of output,' says Poulet. 'Running the engine lean pushes the combustion into a more knock sensitive and unstable state as every non-stoichiometric event can disturb the ideal combustion.

'Hardware and fuel formulations produce the basis from where high performance, ultra-lean combustion science can prevail in an ultra-high load environment, such as that seen in contemporary Formula 1 powertrains. That is where our development of the fuel behaviour in a lean environment prevails. We now have stable, precise, lean and powerful combustion in all load cases.'

Calorific density optimisation is a huge part of development as the only control parameters regarding fuel specified is the type and its weight. Improving calorific density can yield performance gains, as packaging the specified 110kg of fuel in a smaller volume will aid vehicle dynamics.

'Every fuel molecule must meet the required amount of air to satisfy the peak efficiency in desired power regions of output'

Benoit Poulet

When engineers look to increase the potential of a kilogramme of fuel there are trade-offs between the weight of molecules and their overall performance.

'Formula 1 tightly regulates the fuel constituents, like in the road car environment,' explains Poulet. 'The critical parameters of density, combustion speed and calorific value are thereby the nature of the prescribed compounds. Ninety nine per cent of the compounds found in the Shell Formula 1 fuel are also in its high-power road car fuels.

'Shell simulates various fuel densities to see how it affects engine performance in the Formula 1 operating window at the given load case. The higher density fuels we have found recently have enabled the 110kg of starting fuel load to package in less volume, allowing the chassis and aerodynamic teams to design a physically more efficient car.'

Mechanical elements

The Ferrari SF 21 engine is the co-optimisation / co-design effort of Ferrari's mechanical engineering team and Shell's fuel and lubrication team. Neither develops without coinciding with the other.

When it comes to the piston crown, combustion chamber shape and the piston ring pack design, Shell wants to come with the capability to map the influence of the fuel, and *vice versa*, quickly.

For this, the company has developed significant digital combustion modelling and simulation capabilities within the Shell group, leveraging the power of the Ferrari Formula 1 team.

'Suppose some developments influence the mechanical elements of the engine, such as compression ratio, which is the primary driver in engine efficiency,' notes Poulet. 'In that case, that will lead to another journey in pressure and temperature inside the combustion chamber. Feeding these mechanical alterations into Shell's modelling software, the algorithms can generate, compare and contrast millions of possible fuel formulations that immediately identify the regions of constituents that could achieve, or exceed, the desired combustion performance targets.'

Since 2017, Shell has been heavily developing algorithms to help it identify the optimal fuel recipe for Formula 1. Shell's optimisation algorithms process over 250,000 formulations of fuel per year for the Scuderia Ferrari Formula 1 engine. It maps almost every fuel recipe that *could* be made, and then digitally tests it with the Ferrari Formula 1 engine model.

System optimisation

Along with extracting high performance from the lean burn principle, Formula 1 must consider post-combustion energy because Formula 1 engines are turbocharged. The turbocharger has a very different demand compared to the crankshaft torque requirement from the engine, as Poulet explains: 'This is a system engineering optimisation task as, if you isolate the internal combustion engine from the turbocharger, the powertrain would not be optimised for peak power performance.

'A lack of consideration for the enthalpy of the exhaust gas post-combustion in a current Formula 1 engine will not yield the most efficient solution'

Benoit Poulet

Shell engineers working in a mobile laboratory testing fuel and oil samples for evaluation and development

Shell

'An example of this would be optimising the compression ratio to generate an improvement in thermal efficiency. This is great for mechanical torque at the crankshaft, but removes enthalpy from the exhaust gas and the turbine. The enthalpy removed from the exhaust gas cannot be recovered from the hybrid part on the turbocharger, and so you reduce the scope for recovery and, therefore, deployment of the MGU units on the car.

'Overall, a lack of consideration for the enthalpy of the exhaust gas post-combustion in a current Formula 1 engine will not yield the most efficient solution.

'Formula 1 is not a design of experiment that has no limit. With the experience we have, we can refine the fuel, engine and mapping to improve the operation. This may see losses in enthalpy in the exhaust gas that will sacrifice some potential on the ERS side but, if that yields a higher potential in overall efficiency for race conditions, it is considered.'

As the turbocharger has acoustic and oscillating pressure effects on the exhaust flow, it is also used as an input to fuel formulations to identify recipes that may mitigate some of these adverse effects on efficiency.

'Even with today's technology, with the advancements in AI and compute for simulation, it would be impossible to simulate all of the pressure wave oscillations caused by the exhaust gas as it exits the combustion chamber, travels down the exhaust pipes and interacts with the turbine,' says Poulet.

'However, it is possible to generate a very accurate energy map and enthalpy of the exhaust gas as it enters and passes through the exhaust system. We take this type of information from a 1D simulation into a 3D space, which gives us quite a precise picture of the potential of the gas exchange through the engine, exhaust and turbocharger feedback system.'

Working alongside the Ferrari engineers to design and develop back pressure reducing exhaust designs that capitalise on the post-combustion enthalpy of the exhaust gas is another significant part of the development process and partnership between Shell and Ferrari.

'Any energy released as pressure or sound out of the engine can be harvested by the turbo and the electric machine attached to it,' notes Poulet. 'The flow through the exhaust before the turbine is critical for the overall performance as it contributes to the only unlimited energy recovery source in the car's ERS.'

Lubrication side

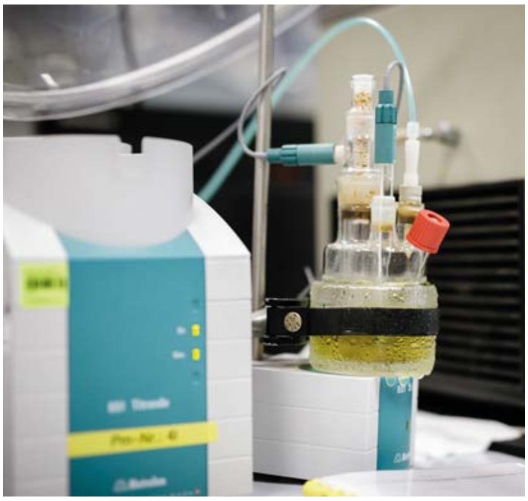
Efficient use of the energy to increase the power output in an engine would not be complete without considering lubricants.

'We must consider the oil when we speak about the total power output over 1000bhp for a powertrain system as power dense as the current Formula 1 engines,' says Poulet. 'There are hundreds of kilowatts of energy released as heat, which must be extracted from the source areas of the heat and expelled to the outside air.

'Of course, the lubrication side of the oil must prevent contact between sliding surfaces, but the heat extracting capability of the current oils is better than ever.'

So, not only must the oil in current Formula 1 engines lubricate and cool the engine components and turbo, and not generate wear, but it must also get all the calories of heat away from the engine in the most efficient way, all the while contending with temperatures as high as 1000degC without any oxidation or breakdown.

With an energy-limited system, mechanical efficiency is the biggest contributor to overall efficiency. Without friction, there would be no mechanical losses in the engine's operation, which, of course, is impossible. The lubricant therefore separates mechanical elements of the engine with a fluid film that allows them to pass over each other without contact.



Shell

Shell F1 race fuel test formulation undergoing experiments in the laboratory

The FIA and Formula 1 have increased the durability and reliability requirements of the powertrain. Ten years ago, each engine only had to complete two race weekends, whereas now, every Formula 1 engine completes more than seven race weekends, or over 5500kms, more akin to the mileage covered by the race-winning car at the 24 Hours of Le Mans.

Heat control

'A formulation of a Formula 1 lubricant that must contend with extracting a considerable amount of heat, preventing sliding contact under all race conditions, and maintaining engine wear throughout the race is very challenging to find,' says Poulet. 'It must be thin to achieve extreme sliding and boundary layer efficiency between the mechanical elements through the engine, but the other characteristics require very different chemistry. To tackle these challenges, Shell has developed a technology it calls GTL, a base oil technology taking natural gas and combining the natural gas atom into longer chains, making them more stable in all sorts of high-stress conditions.'

Racing fluid test equipment at Shell's Formula 1 laboratory

Shell

Shell additive packages to improve the performance of its lubricants

Shell

A fully sustainable fuel is the primary target for the upcoming generations of Formula 1 as it drives towards carbon neutral by the end of the decade

Unlike mPAO synthetic base oils, which can have as little as 10 per cent homogenised synthetic base oil constituents, the GTL technology developed by Shell takes the atoms of natural gas (methane) and combines them in a process that includes exerting huge pressure on the gas until it builds a liquid with the desired chain properties. In this case, the GTL process makes the resulting lubricant a 100 per cent synthetic solution, built atom by atom into chains. 'It is like being able to do the perfect recipe all the time,' says Poulet.

'The oil formulation not only needs to be the combination of low viscosity to impose a low coefficient of friction, while maintaining a buffer of oil to avoid metallic contact and have high thermal capacity and conductivity, but it must also have low volatility parameters because the FIA regulates oil consumption. Depending on the engine's characteristics, the distribution between these different parameters is not always even and often sees one characteristic more highly weighted than another.'

Traditionally, increasing power in a race engine increases the heat generated. That additional heat must be contained if engine efficiency is to improve. However, the higher the chamber temperature, the more volatile it is and the higher the risk of knock. Additionally, as Formula 1 is so aero dependent, the aerodynamicists want the powertrain package as tight as possible, including the cooling system.

'Tackling the heat is primarily the job of the engine oil,' says Poulet. 'The engine oil engineers work to develop the oil that has a higher heat capacity and a higher thermal conductivity to exchange the heat it is carrying away from the engine to the air using the smallest cooler volume possible.

'Because the quantity of energy provided to the engine is limited, more power is created through more efficient use of that limited power. This pushes the engineers to reduce the heat rejection by developing the fuel formulation to make more energy at a lower combustion temperature.'

Formula 1 has a mission to become carbon neutral by 2030. To do so, all suppliers and partners to the sport must take respective amounts of responsibility to achieve that target.

'Shell will continue to investigate all the elements inside the fuels to achieve this target and the extraction of their raw materials and processing stages of the fuel, not just post-combustion emissions,' highlights Poulet.

Bio-fuels

'Shell has been pushing for the inclusion of more bio sustainable components with no compromise. We were strong advocates of the passing of the Formula 1 fuel standards coming into regulation in 2022, including 10 per cent second-generation ethanol elements in the race fuel. We want to prove that this ethanol will be part of the journey of improving engine efficiency. This ethanol will be coming from non-food competing land sources, so the formulation of Formula 1 fuel will not take land away from agriculture land.'

The 10 per cent ethanol fuel percentage will facilitate several things when introduced into the Formula 1 fuels from the 2022 season onwards. The construction of the ethanol molecule means it carries a lower quantity of joules per kilogramme as a combustible vapour than the equivalent volume of Formula 1 race petrol.

However, as per all alcohol-based compounds, ethanol's evaporation characteristics mean it will extract temperature out of the combustion chamber during the initial stages of combustion. This allows the mapping engineers to lower the ignition advance, taking it closer to TDC and initiate better timed combustion. For these reasons, ethanol brings a favourable prospect to the efficiency potential of Formula 1 engines.

Design engineers can adjust several follow-on configuration parameters from these characteristics, thanks to introducing the higher ethanol content. The compression ratio is the primary beneficiary of the ethanol blend and could increase and drive the efficiency of combustion higher still.

Additionally, ethanol molecules contain oxygen. Instead of solely relying on the oxygen ingested into the engine through the intake, further oxygenation of the working fluids in the combustion chamber will occur with the higher percentage ethanol blend in the Formula 1 fuel. There is a lot of re-design and optimisation that engineers can implement into the air loop because it will no longer have the same target of kilograms per hour of oxygen from ingested air.

Shell currently has seven products inside the Ferrari Formula 1 car, including fuel, lubricants and e-fluids used to cool the power electronics, electric motors and controllers. These are designed, developed and supplied as part of the system engineering partnership the company has with the team. A fully sustainable fuel is the primary target for the upcoming generations of Formula 1 as it drives towards carbon neutral by the end of the decade.

Shape shifters

The shape of Formula 1 is changing for 2022 and beyond in a bid to improve the action on track by changing how car's interact in close proximity

By Stewart Mitchell

Formula 1 is making a revolutionary change for the 2022 season with one of the most extensive chassis regulation edits ever seen in the sport.

The new cars are flipping the rules on their head by introducing previously banned design characteristics and aerodynamic techniques, such as ground effect, and cutting back on once heavy development elements such as the sidepods.

The 2022 Formula 1 car will rely less on a surface-type aerodynamic regime, whereby much of the generated downforce is by elements seen above the car.

Moving forward, the car's downforce will predominantly come from tunnels under the floor that interact with the track surface.

This technique is known as the ground effect and is a far less sensitive aerodynamic regime than a surface-type one, producing less turbulence and a smaller wake.

The philosophy behind these regulations is to allow closer racing, with the potential for more overtakes by reducing the 'dirty air' rejected by a leading car.

Current Formula 1 cars lose 35 per cent of their downforce when running just 20m behind a car in front, measured from the lead car's nose to the following car's nose.

As the trailing car closes in, the loss raises to as much as 47 per cent at around 10m distance behind. The 2022 car, which puts a heavy onus on the ground effect, reduces those figures to four per cent at 20m, rising to 18 per cent at 10m.

The journey toward the 2022 aerodynamic regulations started in 2017 when Liberty Media took over Formula 1. The new owner's primary focus was to up the entertainment spectacle of Formula 1, and this rhetoric eventually filtered down to the technical regulations, which govern much of the on-track behaviour of the cars in competition.

Following the Liberty Media takeover, Formula 1's in-house technical team started to look at the then current state of the sport aerodynamically, notably in car-following scenarios, which it had not addressed before.

It was not a priority, nor was it in the scope for teams to investigate car-to-car interaction in this way as they were only ever searching for performance on their own cars.

Formula 1 has a small technical team, with just five personnel in the aerodynamics department, along with a few other engineers on other projects such as power units, vehicle simulation and the like.

Of those five in the aerodynamics group, there are three aerodynamicists and two designers, all with Formula 1 experience. All came from teams within the series. This is a tiny fraction of even the most minor Formula 1 team's aerodynamics department, so they certainly had their work cut out.

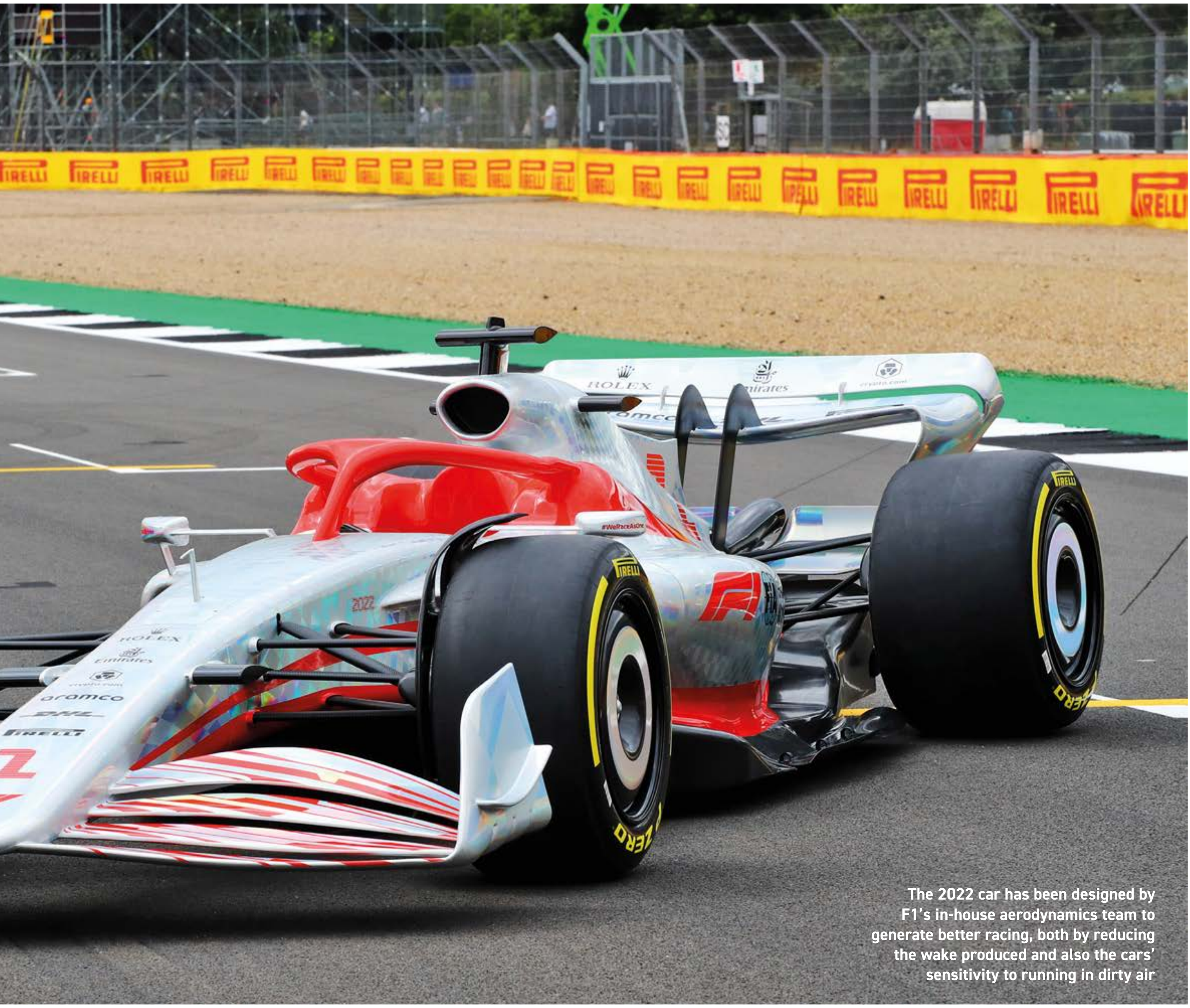
Technical resource

However, although the department is small, it has enormous computational resource, collaborating with Formula 1's technical partners, such as AWS, and far exceeding what teams can use.

Formula 1's technical department also has a wind tunnel at its disposal, although it should be noted that most of the work it undertook in this programme was computational. This is because the investigations were predominantly looking at two-car interactions, and there's no wind tunnel big enough to run two F1 cars at a sensible distance from each other.

In the F1 technical team's investigations, it became clear early on that there were

> **Following the Liberty Media takeover [in 2017], Formula 1's in-house technical team started to look at the then current state of the sport aerodynamically, notably in car-following scenarios**



The 2022 car has been designed by F1's in-house aerodynamics team to generate better racing, both by reducing the wake produced and also the cars' sensitivity to running in dirty air

XBP Images

considerable numbers at play in terms of performance delta from nominal to that associated with car-to-car interaction, and cars were losing as much as half of their downforce in a close following situation. That has also been a consistent theme in driver feedback since the 2021 generation of the Formula 1 technical regulations.

Drivers have often commented on the challenging feel of the car's handling and system management, particularly cooling, when running close behind another car.

Once F1 understood the problem, it set about deconstructing the cars to understand the elements driving the performance loss. The investigations showed two main areas of influence. Firstly, wake – the aerodynamic losses from the leading car and how they present to the next car. Secondly, the sensitivity of the following car to that wake. No matter what, following cars are always going to be driving through disturbed airflow.

So, the two strands of development became improving (reducing) the wake from the lead car and making the car less sensitive to driving through a disturbed fluid.

Since then, Formula 1's technical team has been evolving various geometries to address those problems. 'We've been very open minded about where to look, and developed and simulated many different options,' says Jason Somerville, head of aerodynamics at Formula 1. 'We even went back through history, looking at how car-to-car interaction was in different eras of the sport.

'We found that there's no magic era where cars were aerodynamically very downforce laden and also followed each other very well.

'We never really saw that, certainly not in our research, though we were able to capture some features that are proven to be particularly bad in those conditions.'

The differences between the 2021 and 2022 cars are readily apparent, as is the scope for development, due in part to the abolishment of existing Formula 1 features in elements such as the bargeboards.

When presented with undisturbed laminar flow, bargeboards are incredibly strong performance devices, but severely inferior when shown a heavily turbulent wake.

So, these were components that Formula 1's technical team highlighted as an area where they could reduce the sensitivities.

Ground effect

Central to the 2022 car's aero package is the shaped underbody with two large tunnels, which relies on the ground effect phenomenon to produce the highest proportion of the car's downforce.

Ground effect works though Bernoulli's principle, which states that an increase in the speed of a fluid occurs simultaneously with a decrease in static pressure, or a decrease in the fluid's potential energy.

So, by using a curved profile to the underside of the car's floor, a low-pressure zone will occur with the highest downforce-generating section at the throat (the section with the lowest volume / closest to the ground). The cross-sectional area available for air passing between the car's floor and the ground then shrinks from the entry to the throat and expands behind it.

This causes the air to accelerate and, as a result, the pressure under the floor drops, while the pressure on top of the car is unaffected. Combined together, this results in a net downward force.

'This is the first time Formula 1 has changed the primary physics of the floor since it brought in the stepped flat bottom regulations in the 1990s,' notes Somerville.

'With a shaped underbody for 2022, the floor will become much more powerful and will be a way of compensating for the lack of barge boards, which are particularly sensitive to driving through a wake. The result will be a car much more resilient to dirty air.

'Provided you're not feeding the underfloor with front-wheel wake, it will then remain a powerful downforce-generating device across a broader range of operating conditions.'

XBP Images

The 2021 cars are very sensitive to dirty air and drivers say difficult to manage in car-following scenarios

Performance philosophy

Naturally, a major focus for the teams now is to try and exploit the new conditions. In terms of the performance to be gained with the 2022 regulation philosophy, from our research combining the new floor and the new diffuser is a good few percentage points more powerful than the 2021 floors, with scope to be more powerful still.

'The regulations are our end game in terms of our research model,' continues Somerville. 'It hasn't had all the development and extracting performance from it at a competitive team's level yet.

'From what we understand, the cars will be running much lower rake in 2022 to get the sealing effect of the floor to generate the ground effect and work the tunnels in the floor in the most efficient way.'

The new, shaped underfloor also affects how the aerodynamic balance shifts when the car is subjected to wake. The largest aerodynamic load contribution will come from the centre of pressure of the floor, which is likely to be close to the middle of the car.

In contrast, the highest contributing aerodynamic devices of the 2021 cars comes from the wings located at each end of the car. The change here is reasonably positive for the drivers, as stability will be more consistent in the scenarios the cars see on track.

'We have done a great deal of work to try and ensure that the regulations haven't got anything intrinsically unbalanced about them,' says Somerville.

'It's inherent that you will see a lot of performance gains from the teams as they develop their cars, and that will have an effect on how the cars operate in dirty air.

The cars will be running much lower rake in 2022 to get the sealing effect of the floor to generate the ground effect and work the tunnels in the floor in the most efficient way

'For now, though, they are considerably less sensitive than the 2021 generation of cars. In theory, when one car follows another, the aerodynamic balance will remain quite stable. It's not like we're losing a lot on the front or at the rear. It's a relatively balanced loss to both axles, according to the research that we have done.'

XBP Images

The 2022 car's downforce will mainly come from a curved underfloor with tunnels that take advantage of Bernoulli's principle to interact with the track surface

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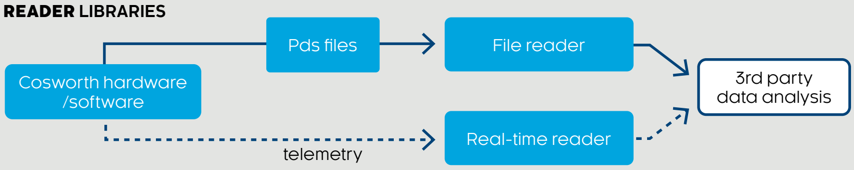

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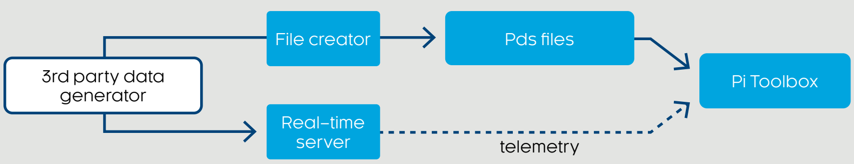

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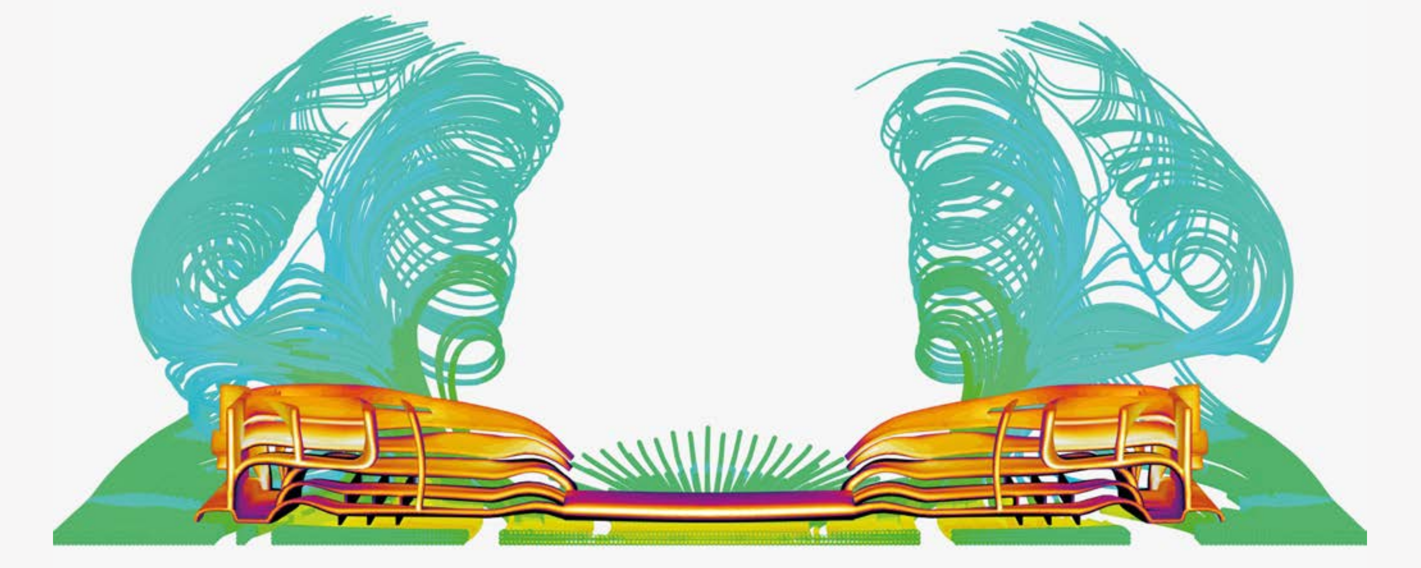


Simscale

Controlling the Y250 vortices shed from the front wing was very influential in the wing and underside's downforce-generating capability on the 2021 cars. These will be a thing of the past in 2022

Like the bargeboards, the front and rear wings on the current cars are also very wake sensitive so will become more simplified systems for 2022, and therefore less susceptible to dirty air. The 2022 regulations place less value on the front and rear wings in reaching target overall downforce figures, but the effect of the regulation changes here should produce lower drag cars compared to the 2021 models.

This, too, will provide more aerodynamic resilience in car-to-car interaction, as a lower drag car is not generating as much disturbed wake for the following car to drive through.

Front wing restrictions

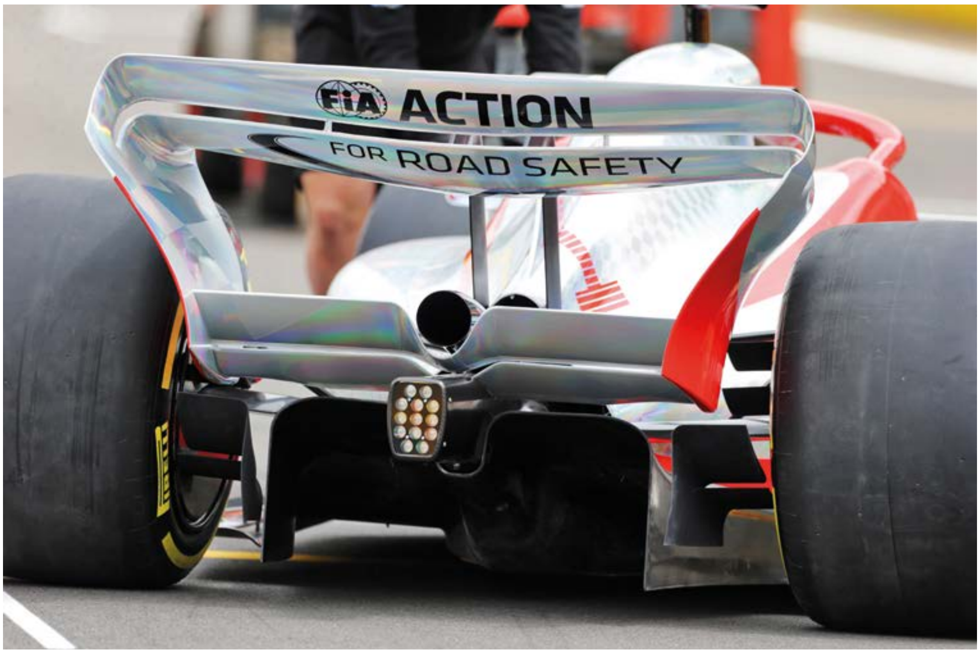
The 2022 regulations abolish the element-less 250mm section across the centre of the front wing in favour of wing elements that connect directly to the nose.

As such, the 2022 cars lack the Y250 vortex and its controlling devices, which have been present on Formula 1 cars since 2009. This will have a significant effect on the downforce-generating capability of the front wing and underbody flow feed.

'The element-less 250mm section across the centre of the front wing went quite early on in our research because it was something that didn't stand up to scrutiny,' explains Somerville of that decision. 'It was one of the first things that we found was very sensitive. For the 2022 prescribed nose area, the way it interacts with the front wing gives room for interpretation and there will likely be different philosophies in this area across the grid.'

In the 2021 generation of the Formula 1 rules, an enormous development avenue for teams was to outwash the front wheel wake with front wing end plates, front brake duct furniture and bargeboards.

These components contribute enormously to placing the front wheel wake



XBP Images

The 2022 rear wing enables flow to roll off the top of the wing tips and narrows the expansion of dirty air

XBP Images

Rear wing tip vortices, seen here being shed from the left tip of the Alfa Romeo, have a huge influence on the size and shape of the dirty air shed from the 2021 cars. These won't be a factor in 2022, and the hope is that the racing will be correspondingly closer

wide away from the chassis, not disturbing the aerodynamic features further down the car. With that front wheel wake being pushed outboard, away from the sidepods and underfloor, it is very difficult for a following car to maintain a stable aerodynamic platform when passing alongside it.

The lack of bargeboards means the ability to generate outwash from behind the front wheels has gone, so teams must now find more subtle ways to manage it.

The 2022 car removes some of these outwash-generating tools, and implements a considerably simplified front wing design with a radiused transition to the end plates, specifically designed to avoid too much vorticity around the front wheel.

Certain mandated components on the front drums also avoid generating too much outwash behind the front wheels, while the introduction of wake-deflecting fins over the front wheels and wheel fairings further manage front tyre wake and outwash. The aim of these devices is simple: to improve airflow around the high disturbance area of the wheels, reduce lateral wake and make it easier to pull alongside a car ahead.

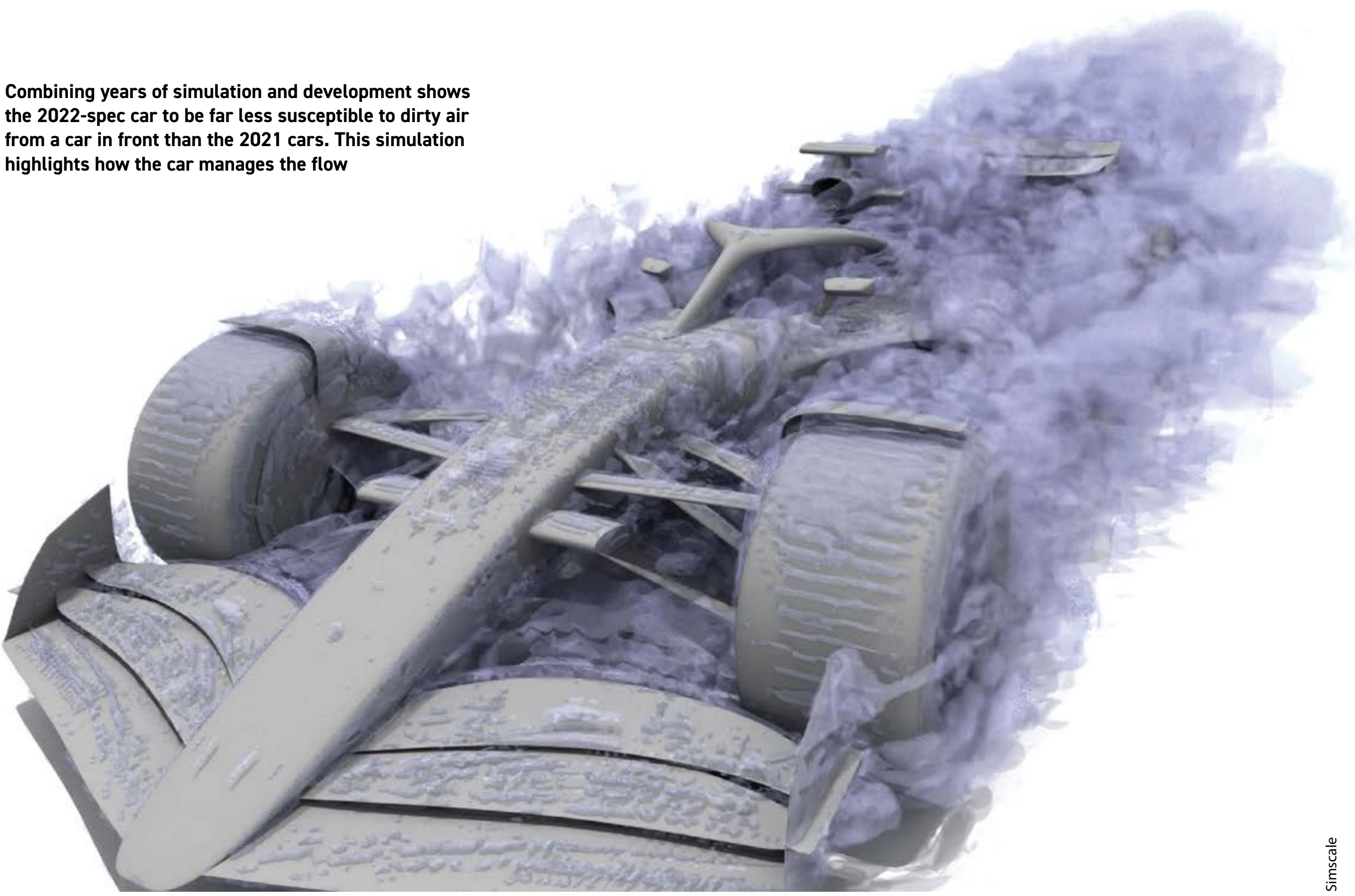
These elements all build up to create a car that still works aerodynamically in a wake situation and doesn't create the disturbing outwash the 2021 generation cars do.

XBP Images

The 2022 regulations abolish the element-less 250mm section across the centre of the front wing in favour of wing elements that connect directly to the nose

These elements build up to create a car that still works aerodynamically in a wake situation and doesn't create the disturbing outwash of the 2021 generation cars

Combining years of simulation and development shows the 2022-spec car to be far less susceptible to dirty air from a car in front than the 2021 cars. This simulation highlights how the car manages the flow



Simscale

A further tightly constrained area by regulation for the 2022 car is the rear wing. There is scope for teams to develop some elements to coincide with their philosophies, but it is far less free than the outgoing design.

The restrictions here predominantly focus on the tips, which coincide with the shape and size of the car's rearward wake. The new design enables the flow to roll off the top of the wing tips and narrows the expansion of dirty air coming off the back of the car.

However, according to Formula 1's technical design team, the regulations leave some unique upper profile design scope.

Additionally, the lower wing elements are quite open in terms of the regulations, which will provide a lot of development focus for teams to try and find the most efficient solution, particularly in integrating the wing with the flow coming out from the floor.

DRS to stay

DRS (the controversial drag reduction system) remains for the 2022 rear wings. The benefits Formula 1's aerodynamics department has found by reducing the effective downforce loss in following situations works against the following car's aerodynamics in drag reduction. As such, the 2022 regulations enhance the need for some form of DRS, as Somerville explains: 'Certainly, from our simulation work, we believe DRS is required.

'Because the cars will be able to follow each other closer through the corners, it follows that the cars should be closer to each other on corner exit. But because there's less of a hole being punched through the air by the lead car on the straights, cars will need DRS to get closer there.'

Larger cooling louvres are now permitted on the sidepods and engine cover, giving teams some opportunity to play around with cooling configurations, convergence of bodywork at the back of the car and the pressure delta at the diffuser.

'We wanted to ensure we weren't developing a set of regulations that were going to be hugely expensive, particularly with a budget cap in place,' says Somerville. 'We felt that although cooling louvres had come and gone over the last few years, the new regulations would favour reintroducing them as they are efficient. Plus there is no downside from a wake perspective.

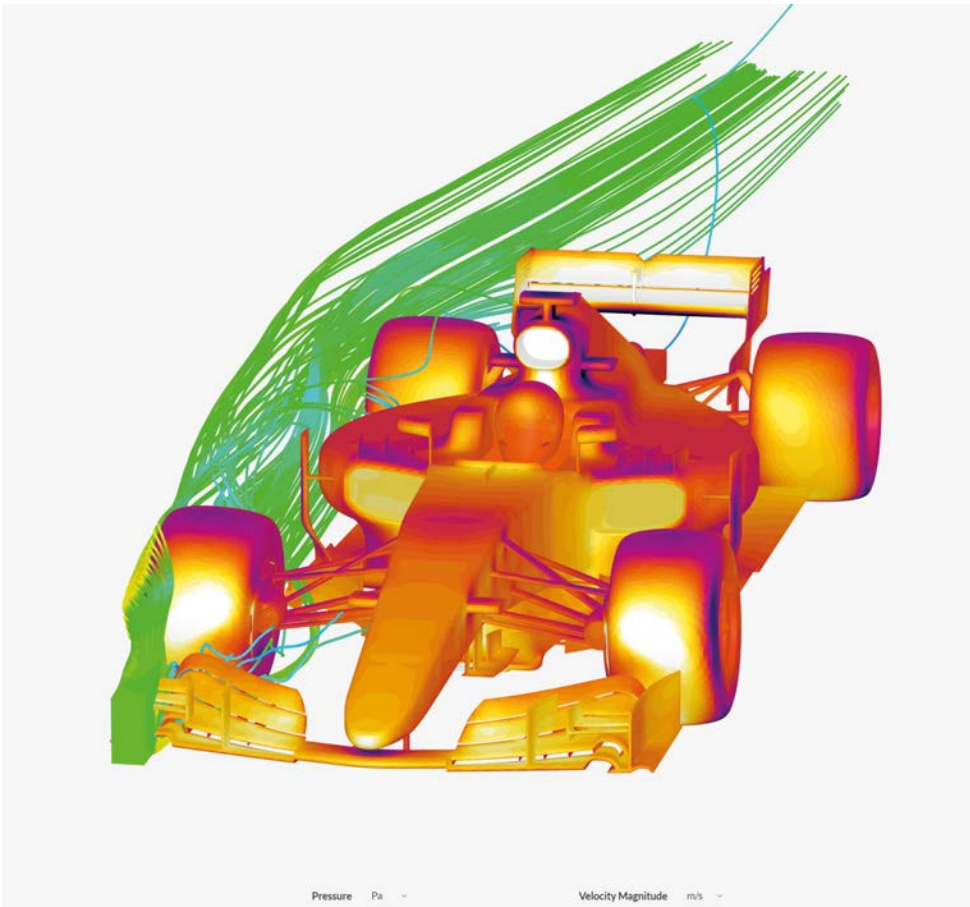
No sprouts

'Consequently, there's a region within the bodywork where teams can develop louvres and exits. It's reasonably tightly governed so there should be no aerodynamic devices sprouting from various apertures.'

As far as relative performance of the 2022 car is concerned, Somerville is confident about the potential. 'I think the cars will generally be more stable and work very well through the high-speed corners,' he says. 'Where we left this car [in terms of regulations], the performance figures were somewhere south of the current generation of cars, in the knowledge that teams will subsequently find performance.

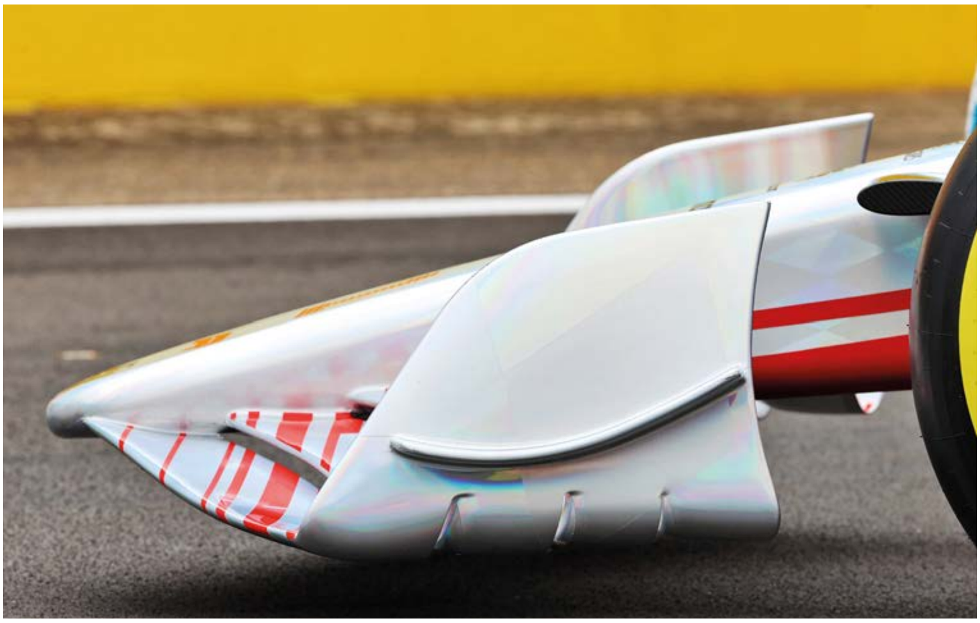
'Even before the start of the season there is a lot of chatter about teams making progress. If you put the 2022 Formula 1 base car on the 2021 grid, it would be a few seconds off the current car's pace, but I will be very surprised if teams haven't extracted most of that back from their ongoing development ahead the 2022 season.'

Come the start of testing in February and the first GP, we will start to find out.



Simscale

Under the 2021 rules, an enormous development avenue for teams was to outwash front wheel wake with front wing end plates, brake duct furniture and bargeboards. However, many of the outwash-generating elements have been removed for the 2022 car



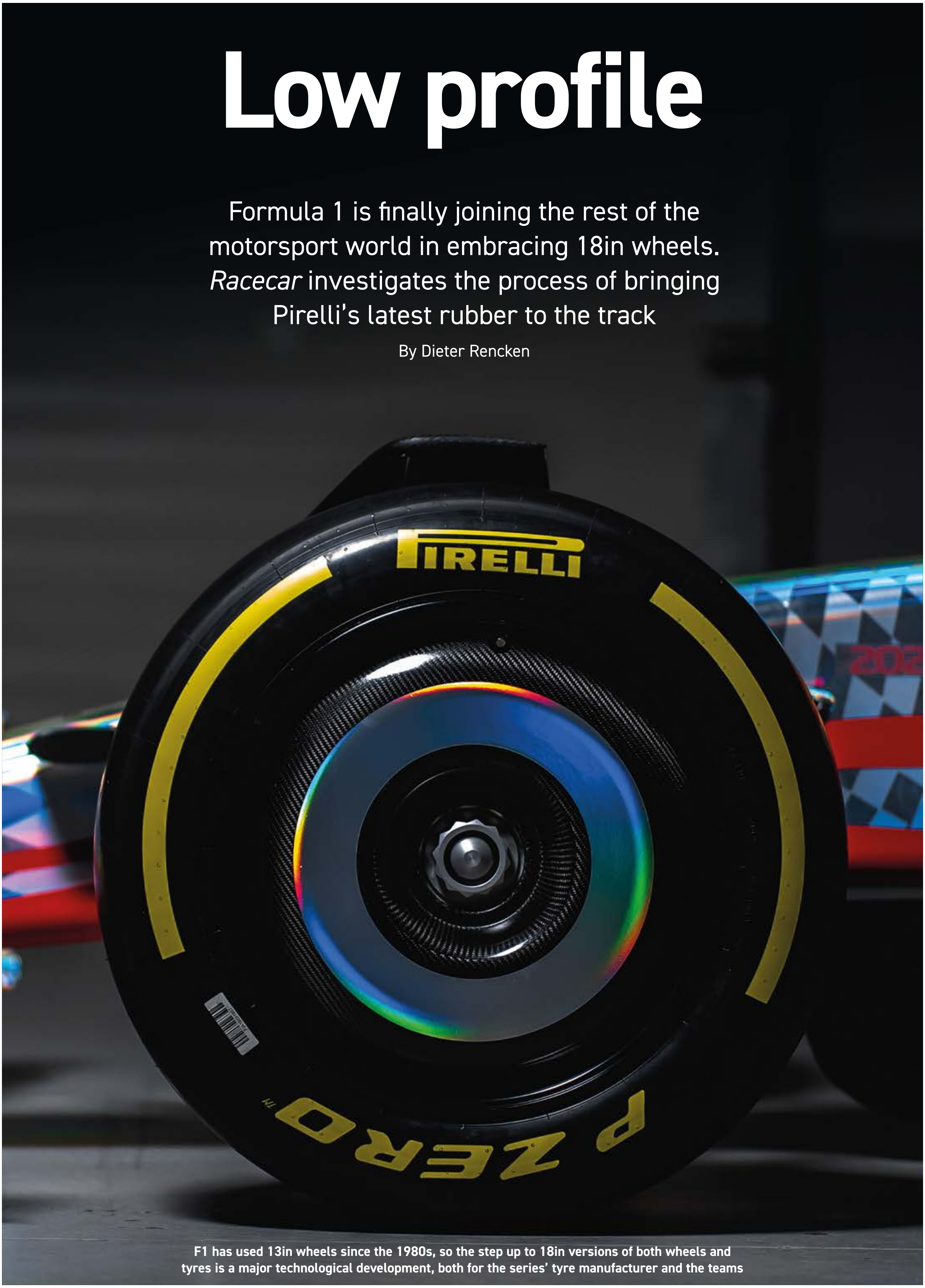
XBP Images

The swept back new front wing end plates take inspiration from the aircraft world in reducing the vortices generated at their tips

Low profile

Formula 1 is finally joining the rest of the motorsport world in embracing 18in wheels. *Racecar* investigates the process of bringing Pirelli's latest rubber to the track

By Dieter Rencken



Ryan Davis

F1 has used 13in wheels since the 1980s, so the step up to 18in versions of both wheels and tyres is a major technological development, both for the series' tyre manufacturer and the teams

For irrefutable proof that Formula 1 places road relevance at the very heart of its future technical regulations, look no further than the big black roundels that adorn each corner of a grand prix car. Where for 30 years the aspect ratios of F1's front and rear tyres had been unchanged at around 75 and 65 respectively, from next season the ratios will reduce dramatically to around half that, give or take a digit or two at each end.

The history of F1 tyre sizes and aspect ratios – the relationship between sidewall height and contact patch width expressed as a percentage – is as complex as it is convoluted. While road car tyres gradually grew in width and reduced in sidewall height, for political and economic reasons F1 doggedly stuck to the 13in wheel sizes originally introduced during the 1980s. Indeed, a case could be made that the F1 trucks that ferry cars and kit have more contemporary tyre ratios.

Rewind to 1985. With Goodyear enjoying an effective monopoly that ran through to 1996, sporadic competition rarely got a look in. The US tyre brand saw no reason to follow road car trends simply to beat itself. When Bridgestone entered F1 in 1997, the Japanese manufacturer suggested lower aspect ratios, only to be rebuffed after Goodyear, afraid of losing its competitive advantage, threatened to leave should the dimensions be changed.

When Goodyear did depart, two seasons later, Bridgestone, now by implication the sole supplier, applied the same arguments, reiterating them when Michelin announced its entry a year later.

After the French company left in 2007, Bridgestone was awarded the first of the FIA's sole supplier tenders, and simply carried over its rubber through to the end of 2010. Meanwhile, various other series across the globe embraced low profile tyres.

Pirelli replaced the Japanese company in 2011, but so hurried was the process that F1 had no choice but to stick with 13s until finally, with the 2021-'23 tender, both Pirelli and Hankook submitted documents – the former being successful – specifying 18in rims with reduced tyre aspect ratios. At last.

'New era' package

The new wheel sizes form an integral part of F1's 'new era' regulation package, which was planned for introduction in 2021, but delays caused by the Covid pandemic pushed the target season out a year. This, in turn, gave Pirelli additional development time, although track testing was temporarily placed on the back burner due to costs and the punishing 2020 schedule after racing resumed last July with 17 rounds in 160 days.

To compensate for Covid delays, Pirelli's contract was extended by a year. The irony of the latest delay, after so many lost seasons, is not lost on F1's decision makers. After decades of internal resistance to low-profile tyres, their introduction was disrupted by factors outside the control of the sport.

However, according to a source with knowledge of FIA processes, the decision to switch to low profiles is not as recent as we might think. '[It was taken] around five or six years ago in the interests of modernity and a bit more relevance,' our source says.

Due to the massive implications of the change on car design, it was delayed until a revised technical package was introduced, particularly as teams had (then) been promised regulatory stability on all major components until the end of the 2020 season.

Crucial to the decision was experience of low-profile tyres gained by the FIA from Formula E and World Endurance Championship tyre suppliers, in turn enabling the governing body to formulate a comprehensive specification list. Once the tender had been awarded, discussions with the Italian tyre company opened at FIA Technical Advisory Committee level.

Crucial to the decision was experience of low-profile tyres gained by the FIA from Formula E and World Endurance Championship tyre suppliers

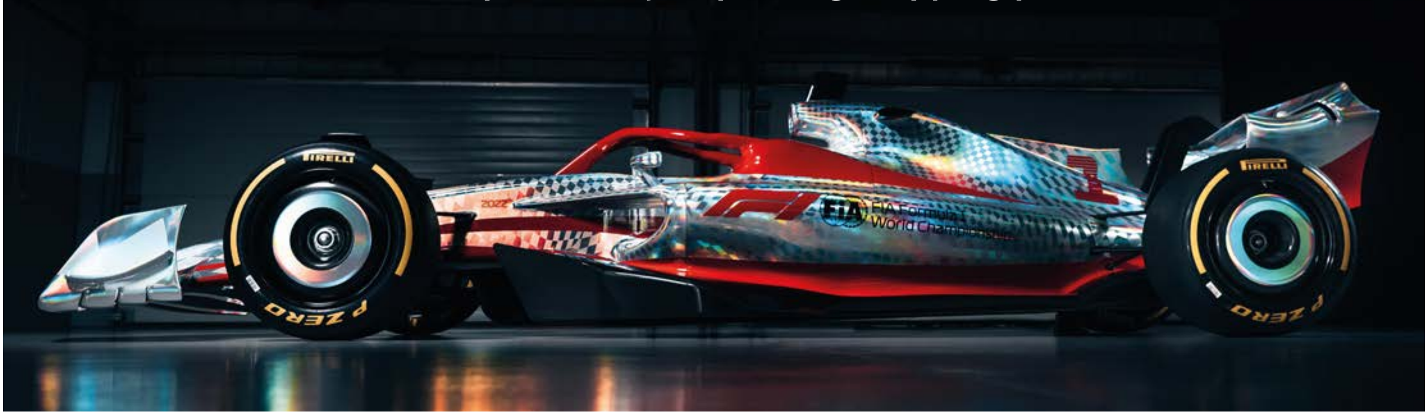
Advantage 18s

Apart from aesthetics, the advantages of larger rims and lower sidewall heights include more direct response to steering and braking input, greater control over spring rates as the 'jounce' of high sidewalls is reduced, and increased brake disc area, therefore potentially improving stopping power. This latter point could potentially see F1 adopt ceramic (or other) braking technologies as it strives 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,' a spokesperson for the brake company told *Racecar Engineering*.

'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

Advantages... include more direct response to steering and braking input, greater control over spring rates... and increased brake disc area, therefore potentially improving stopping power



Antoine Truchet

So great is the impact of the new tyres on Formula 1 car design that their introduction was delayed to coincide with the 2021 'new era' technical regulations, though of course Covid then reared its head and delayed those by a further year

XPB

The increase in tyre diameter from 660mm to 720mm has broad design implications, as does the greater distance between the brakes and the new wheel rims

that are sustainable for the environment. In Formula 1 this process has started.'

During initial Technical Advisory Committee (TAC) discussions, attended by all teams, FIA, F1 and Pirelli, it was agreed that tyre diameter would increase marginally (from 660mm to 720mm) with rims incorporating (fixed) wheel covers and finger recesses for ease of grip during carry and pitstop activities. Covers displaying graphic information were also considered, but these were pushed out, possibly to 2023.

'Obviously, [at that stage] there was an idea for F1 to completely change the cars for 2021, but that was postponed to 2022 [due to Covid],' notes Mario Isola, Pirelli's head of car racing. 'The discussion flow started with understanding some parameters in the technical regulations.'

Although these had not at that early stage been finalised, and would not be for another year, Isola says they requested information on expected levels of downforce [and resultant *g* forces], details on engine torque and power outputs and anticipated maximum speeds.

'Heat transfer is another important parameter because the spacing between the brakes and the rim is much higher,' Isola adds. 'Therefore, we predict there will a lot less heat transfer from the brakes.'

Only once these details had been verified – Isola smiles as he recalls some of the 'crazy figures' teams provided during a similar exercise in 2016 ahead of developing a range of wider tyres for 2017 – could Pirelli embark on preparing initial finite element models to design the first 'virtual' 18in tyres.

'We supplied to the teams two different models,' says Isola. 'One is a finite element model [FEM], the other is a thermal mechanical model of the tyre, which is what teams use in their simulators, including driver-in-the-loop simulators.'

He adds that Pirelli's FEM data is encrypted. 'We are the owner of the model and only we know what's inside, but we update it periodically depending on the feedback we get from the teams,' he stresses. 'Sometimes you get feedback from individual teams that is quite different.

'Then we ask for clarifications. Sometimes they realise that [with their simulations] not everything is perfect, so they adjust their simulations, or we can adjust our model.'

Parallel engineering

According to Pirelli's R&D chief, Pierangelo Misani, the various processes, from design through prototyping to testing and manufacture, were developed via its F1 engagement, and then adopted by the road car tyre and other divisions. Indeed, he says these techniques enabled the company to remotely develop three different road car tyre ranges during the height of the pandemic, all of which have since been launched.

'[F1] has enabled us to develop new techniques. If you need a tyre that is so light with less material than the standard one you have to reduce the tolerances. So, I can say the experience in Formula 1 is not purely related to materials, or geometry, or performance, but also to development tools and methods and manufacturing processes.

> **'Heat transfer is another important parameter because the spacing between the brakes and the rim is much higher'**
>
> *Mario Isola, head of car racing at Pirelli*

'There is not much difference between the development steps to develop Formula 1 tyres and street tyres simply because we use the experience and modelling tools from Formula 1 for both,' he says.

'The first step is virtual, then we go to physical [laboratory] testing, but there is a sequence of activities inside both steps.'

However, Misani stresses the profile of the tyre is fundamental. 'It determines how the tyre will generate forces, both because it's how you put the contact patch on the ground, but also how the forces generated are then transmitted to the rim, and then to the car, by what we call the 'ply line'.

'According to the geometry of this carcass, you have a quite different behaviour. When you move to 18in, you will typically realise a faster response [due primarily to less sidewall flex] than with 13in.'

The final profile is also crucial to the entire process as it dictates the moulds that are required for batch production of the prototype tyres used for both laboratory and

Pirelli

The new tyres started as finite element models and only became reality when approved by the FIA and teams

Pirelli

These were then tested in the lab for integrity and performance, and on track on the so-called 'mule' cars

track testing. Get the shape wrong and it's back to square one, whereas the materials used for actual carcass construction and compound ingredients can be fine tuned later on in the process.

Validation process

'We started to design a couple of different profiles, then the next step was to validate the profile,' explains Isola, adding that the selected profile is squarer than on current tyres due to the smaller, stiffer sidewall.

'We start from the models, then we prepare some physical prototypes, which are tested indoors [on high-speed rigs]. We have several different tests for integrity and for performance. The final validation is on track.

'To validate the profile we asked, and [FIA, F1 and the teams] agreed, to start testing [on the so-called 'mule' cars, adapted from 2018 cars to replicate ride height, downforce and car mass] in September 2019. That way we had the possibility to freeze the profile, and then start 2020 focussing our attention on construction and compounds.'

All was running to schedule at that point. Four teams had completed 'dry' tests, but then along came Covid, which brought the entire process to an immediate and inconvenient halt for around two months as all the teams went on a total, FIA-enforced shut down during April and May 2020.

In the interim, Pirelli continued with its indoor test programme at its Milan R&D base using tyres produced in batches of 10 by its F1 plant in Slatina, Romania and trucked overland to Italy. As an aside, Pirelli has replicated the F1 tyre production line at its Izmit, Turkey facility, just in case the Romanian plant is hit by a natural, or other, disaster.

Once the worst of the pandemic had blown over and F1 operations returned closer to normal in the early part of 2021, track testing resumed, with nine of 10 teams having committed to 2021 after expressions of interest were called for in August last year. Williams is still considering its options after being unable to confirm participation during its sale process to Dorilton Capital, which occurred just as the deadline loomed.

Even multiple World Champion, Lewis Hamilton, who usually shuns testing, offered his services during his Mercedes team's programme at Imola after the Emilia Romagna Grand Prix in April in 2021.

'It's probably one of the first [test days] I have ever volunteered for,' he said afterwards. 'So I immediately regretted it when I woke up in the morning on the day!

'It was a really great track to test at, though, and the weather was good, so I enjoyed it. I plan to be [in F1] next year [he said at the time] and want to be a part of it, so I want to help Pirelli towards having a better product. It's important for me to gauge what the starting point is, and what differences I can help with, so that from a driver point of view we have more mechanical grip from the tyres and less degradation. It was a good test, and though obviously it was only the first step with the new tyres, it definitely wasn't a bad place to start.'

Isola was equally upbeat after the Imola test. 'It provided us [Pirelli] with a result that was coherent across different cars and across different circuits,' he said. 'We had the possibility to validate different constructions, starting from Jerez to Bahrain, Imola and we are now in a situation where I would say the construction is almost finalised. [Next] we start a test campaign on compounds.'

As part of the programme, all tyre-specific data is shared with all teams, and then updated on an as-and-when basis.

Weight watchers

'We've had feedback lap times and basic information from each test, with technical bulletins coming through from Pirelli,' confirms Alpha Tauri technical director, Jody Egginton. 'We've done a lot of simulation work with the model [of] the tyre, so we understand what it's going to do, and we've got a good grip in vehicle dynamics terms.'

Pirelli

Although Covid delayed on-track testing, Pirelli continued its indoor test programme at its R&D facility in Milan, fine tuning the compounds that will be used

He also makes a point about a rather hefty elephant in the F1 paddock: 'We've got a big increase in tyre and wheel mass, plus we're not allowed to run inerters [from next year].'

The latest calculations suggest car mass will rise by 14kg, due to heavier wheel / rim assemblies, split approximately 3kg per front wheel and 4kg for each rear wheel. The reason is simple: for a given circumference, with low profile tyres, alloy largely displaces air and lightweight rubber.

Seven of the 10 scheduled 2021 tests, comprising a mix of dry, intermediate and wet running, had been completed at time of writing. Two further dry tests were subsequently planned for after the British and Hungarian Grands Prix respectively, with a final wet fling listed for Paul Ricard in France mid-September. After that, all 10 teams are expected to attend a composite test in Abu Dhabi after the final race of the season.

By that point the teams will be in the thick of manufacturing their new era car designs, having based concepts on a combination of data obtained from wind tunnel studies, simulations and CFD calculations. In each instance, input from Pirelli is crucial to the process, in particular tyre modelling data and 60 per cent scale wind tunnel tyres, which accurately simulate tyre behaviour at speed.

The latter, produced in a dedicated Pirelli studio in Rome, are a particular challenge as tyres make up approximately a third of frontal area, while spinning at enormous speeds. The resultant wake affects airflow across the car, while steered tyres deform in compression, yaw and pitch, causing changes in sidewall and contact patch shape. An aerodynamicist's nightmare, in other words, unless the wind tunnel tyres are spot on.

The 2022 challenge

For teams, however, the biggest challenge is yet to come – translating the tyre test data into sustainable on-track performance, as Ferrari racing director, Laurent Mekies, notes: '2022 will bring three massive pillars that are entirely new. Completely different aerodynamic regulations, different ways to operate the car [due to revised sporting regulations] and mechanical suspension, which nobody has had for 10 or 15 years. So, a lot of different limitations and, in the middle of those, how to 'switch on' the completely new tyres. I think that will be the big challenge.

'There will be a huge amount of discovery with the 18in [wheels and tyres]. It's a great challenge as a team to make sure we have the base to get the core understanding we need.

'It will be a steep learning curve, but in two years we will look back at the starting point and wonder what we were doing at the time.'

Although Mekies does not foresee the switch to 18in wheels alone resulting in major changes to the competitive order, he does see it as a contributory factor, when taken in conjunction with the 'pillars' listed above.

'I think it will be a combination of the concepts, the new regulations, how they interact with the tyres and how you make everything work,' he says. 'We have the potential to see a surprise from the midfield teams. It's risk and opportunity for everybody.'

> **'We are now in a situation where I would say the construction is almost finalised. [Next] we start a test campaign on compounds'**
>
> *Mario Isola, head of car racing at Pirelli*

All parties agree that the amount of research that has gone into the 2022 regulations by far exceeds what has gone before, whether at FIA, F1 or team level, while Pirelli has been afforded a longer timeframe than at any previous stage in its 10-year F1 history. Indeed, longer than any tyre supplier has *ever* been given, with the pandemic only widening that development window.

Come the 2022 season opener – probably in Bahrain, after even more warm weather tests on the desert island – the big black roundels that adorn each corner of a grand prix car will not only represent arguably the single biggest visual indicator of F1's 'new era', but the biggest advance in Formula 1 tyre technology since the sport adopted radial ply tyres in the 1970s. *That* is how radical the new 18in tyres are in F1 terms.

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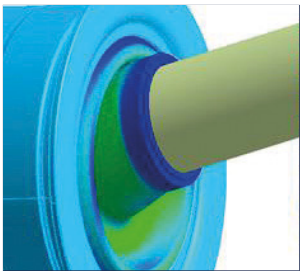

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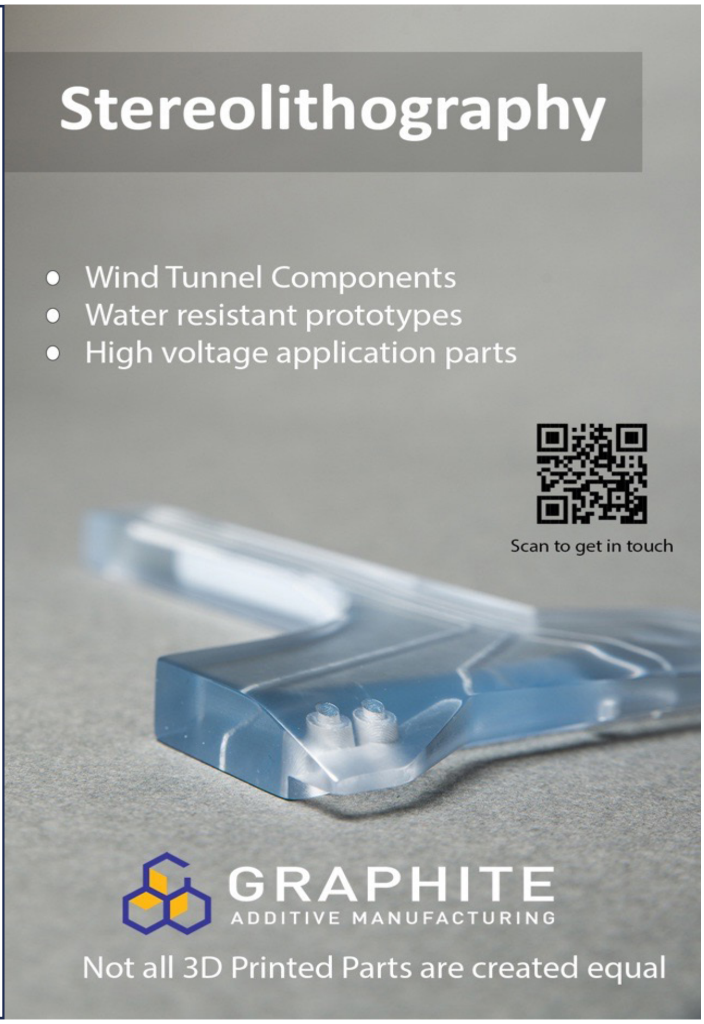


Fuel for thought

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

Honda's announcement in October 2020 that it will leave F1 at the end of the 2021 season, 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 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 its performances with Red Bull and their star driver, 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 sole PU 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 power unit 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 2020, the governing body delivered the first barrels of 100 per cent sustainable fuel, blended from bio-waste, ethanol produced from second-generation (inedible) plants and wood-based 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

Active aero, four-wheel drive and synthetic fuels are one set of plans on the table for 2025 as F1 seeks carbon neutrality

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.'

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 at the start of the year 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.'

F1 consumes around one million litres of fuel a year, a huge amount for natural resources and a synthetic fuel producer, but an insignificant amount to the major oil companies. That puts it in a difficult position

Power unit goals

Still, in February 2021, 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 provided two years to frame the regulations, a 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 former technical director for engines, told *Racecar Engineering*. 'So, we need to evolve.

'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 2021, 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.

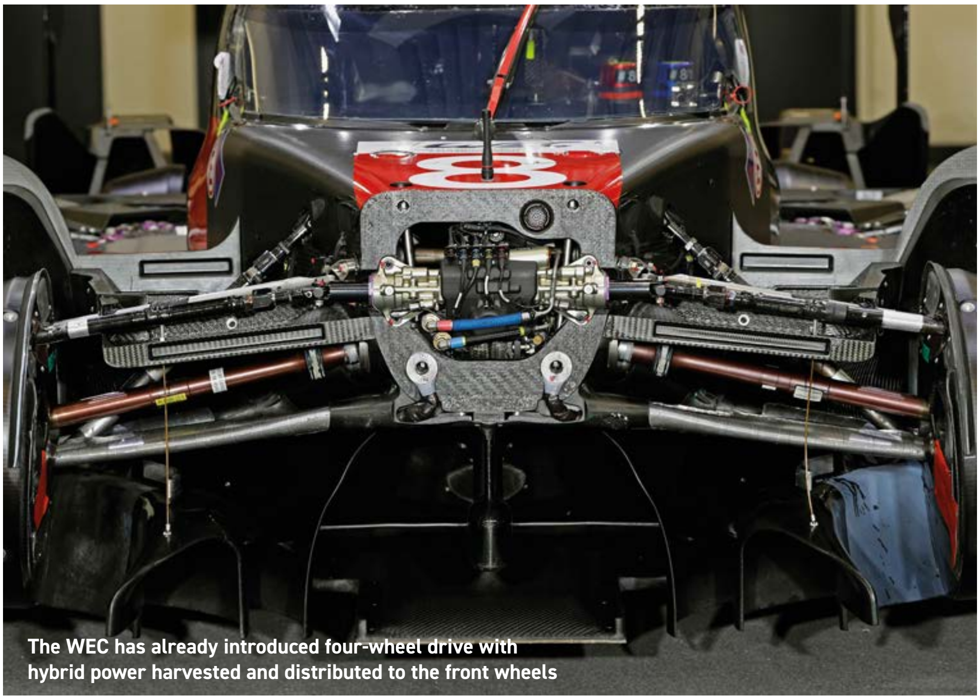
Simon, who announced his retirement shortly after this interview (to be replaced by Xavier Mestelan Pinon, former motorsport director for Stellantis), will remain a consultant to the governing body and believes the mix of objectives will retain existing PU suppliers, while also attracting incomers, all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

Covid postponed the introduction of the new F1 aero concept to 2022, the '21 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

‘We could probably maintain similar [15,000] rpm as we have today, so probably noise levels would be similar, 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 had a minimum mass of 145kg for ICE in 2020, and that rose 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_2 [or even] CO_2 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 do, 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, performance and cornering, but it's an added complexity.'

However, like Symonds, the former 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 early in the programme, and we are still looking far and wide. Together [with F1 and power unit suppliers] we will define the direction.'

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, and alternatives have not yet been properly investigated by politicians.

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

Bespoke fuel or 'drop-in' fuel?

Pat Symonds, F1's technical director, says 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_2 [reduction].

'The idea with these fuels is they will be low, or neutral CO_2. 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.'

'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

Power politics

Formula 1 is entering a new direction for its powertrains. *Dieter Rencken* takes us through the thought processes of the series and its competitors as the sport considers how to become more environmentally aware

Consider the plight of the FIA when formulating future power unit regulations for its various international series. Where once power units were restricted to internal combustion engines powered by fossil fuels and the only options, apart from ignition – spark (petrol) or compression (diesel) – were reciprocating or rotary pistons, configuration and two or four strokes, the choices have of late multiplied exponentially.

Indeed, the FIA's secretary general for sport, Peter Bayer, runs out of fingers as he lists the number of potential options: fossil or synthetic-fuelled spark; compression or rotary internal combustion engines (ICE); ditto with hybrid elements and / or powered by hydrogen or CNG (compressed natural gas); and purely electric motors, in turn energised by one of three variants, namely battery, hydrogen fuel cell or range-extended battery charged by any of the ICE types listed above.

That potentially makes for 10 basic power unit alternatives, each with at least one sub-option. It is, as Bayer freely admitted during the FIA's annual member club conference in Monte Carlo earlier in 2021, something of a power unit jungle out there, with none of the options on the table providing a universal solution, whether for sporting, transportation or commuter applications.

Road relevance

Consequently, the FIA, which holds global responsibility for both motorsport and mobility disciplines, elevated road relevance to the top of its agenda, and has plans to formulate motorsport regulations that ultimately benefit global four-wheeled mobility in all its forms. The electric vehicle (EV) boxes are, of course, ticked by Formula E and various battery-powered tin-top series, while the 2022 Dakar sees Audi enter a range-extender concept.

That said, it became abundantly clear during the FIA conference that electricity is not the only alternative for future mobility, and that the internal combustion engine will be around for decades to come, regardless of what ecologists and politicians preach. If for no other reason than the world simply cannot generate sufficient affordable electricity and deliver it in sufficient quantities to charging points across the globe.

In addition to this, Motorsport Industry Association (MIA) CEO, Chris Aylett, believes that, although consumers are being dictated

> **It became abundantly clear during the FIA conference that electricity is not the only alternative for future mobility, and that the internal combustion engine will be around for decades to come**

Formula 1 has to make a change to its power units in 2026, but agreement has been hard to find due to the different priorities of those involved: from drinks manufacturers to private teams, and mass production car companies to specialists such as Ferrari

to by governments to switch to electric, 'Too many nations *can't* adapt; can't afford it. Electric won't work everywhere. The internal combustion engine is a very efficient mode of mobility and has been so for 100 years

'There is still plenty of potential there if we were not in such a hurry to go electric. With regard to using sustainable fuels, I am quite sure we will go into the future with an urban electric solution and a non-urban solution.'

There is another factor: 95 per cent of the global vehicle park is ICE-powered, and these cars cannot be scrapped overnight. Something over-zealous politicians – typically elected for five-year spells, and therefore with no need to play long games – conveniently overlook in their determination to shade themselves green. Crucially, 90 per cent of the 85 million cars that will be added to roads this year will be fuel-powered to some degree.

Disciples of electric vehicles predict enormous strides in battery technology, often citing mass / power density advances that will reduce weight, cut costs and extend the range of EVs. However, they seldom acknowledge that such technologies apply equally to plug-in hybrid vehicles (PHEVs), and many deny that PHEVs could play a pivotal role in accelerating development of batteries, serving hybrid and EVs equally.

Yet both Renault and Alfa Romeo are currently committed to F1, despite corporate plans to go the all-electric route for their future product ranges. The latter's CEO, Jean-Phillipe Imparato, told *Racecar Engineering* that spin offs from F1's hybrid electrification provided the basis for the brand's recent extension of its contract with Sauber:

'The answer came naturally when I met [Sauber MD] Frederic Vasseur some months before, to bet on Formula 1 as a next step in terms of technological content to fit my product, because Formula 1 is electrified since 2010. For me, in terms of rationale, it feeds the [brand's] storytelling.'

However, the entire auto industry, including Formula 1, needs to dump fossil fuels and become carbon zero. Yet said public officials could not even agree on the emission standards needed, let alone provide road maps for the future. Compounding the matter is the fact that motorsport does not carry the highest political priority, yet it could, rather ironically, provide the technologies required for low or zero-carbon mobility solutions via synthetic fuels.

Poles apart

With F1 being both the most technological and visible of all FIA championships, it is the obvious series to pioneer sustainable fuels, and therefore this element lies at the heart of the sport's plans for its future power unit regulations, due to come into force at the end of 2024. However, these are to be delayed a year to provide a longer formulation window, but only if all parties agree.

Key in that statement is the word agree, for agreement in Formula 1 is an extremely scarce commodity, given all the players have contrasting agendas. On the one hand, Renault uses Formula 1 (largely) as a flagship for its range of mass-produced econo boxes. On the other, Red Bull enters two teams to sell energy drinks via Formula 1's popularity, yet aims to be totally self-sufficient – hence its decision to acquire the rights to Honda's designs as the basis for its own PUs.

Sitting between these two extremes are Mercedes and Ferrari, premium automotive brands, both with a determination to spend what it takes to prove their technical superiority to the world, particularly on the power unit front. Try slotting an incoming engine supplier (or two) into that lot, be that an independent or another car maker. Yet to secure its future, F1 desperately needs to attract at least one additional PU supplier.

An example of the conflict reigning between the factions was aired by Red Bull's Christian Horner and Mercedes motorsport boss, Toto Wolff, during the British Grand Prix weekend in July, 2021. Asked his preferences for future PUs, the former said: 'I think the combustion engine does have a future, so why not introduce high-revving engines that sound fantastic, and that do it in an environmentally-friendly manner?

The FIA's Peter Bayer admits there are many potential PU options to be considered

'I think the combustion engine does have a future, so why not introduce high-revving power units that sound fantastic, and do it in an environmentally-friendly manner?'

Christian Horner, team principal at Red Bull Racing

'I think biofuels and sustainable fuels enable you to do that. F1 could play a key ole with the fuels and with the fuel partners that we have on sustainability and zero emissions, with a high-performance, high-revving, emotive engine. I'm sure every grand prix will be packed.'

Wolff, though, immediately disagreed: 'Because it's what we [the older generation] think, but we are not the most relevant generation. When you ask an 18-year old or 22-year old what relevance noise has, most of them consume [F1] via different screens where noise has little or no relevance.

'I personally like it too, and I would like to have a 12-cylinder that screams down the road,' Wolff continued, 'but we are a sport and we are also a business. I think we would lose complete relevance with our partners, sponsors and major stakeholders if we weren't looking at the environment and the impact that we make.'

See the conflict? One represents an edgy energy drink, the other a premium auto brand, yet between them they have dominated the sport since 2010, and in 2021 staged one of Formula 1's epic battles.

Top-down strategy

To set the ball rolling ahead of 2025, the FIA and Formula 1 convened an engine summit during the 2021 Austrian Grand Prix weekend. In addition to F1 and FIA executives and senior officials, only CEOs of currently committed and potential engine suppliers were present at the meeting, held in the nearby five-star Hotel Steirerschlössl, a mini castle-like establishment owned by Red Bull proprietor, Dietrich Mateschitz.

The invitation list – Ferrari president, John Elkann; Mercedes / Renault CEOs,

Next year Audi will use a range extender on its RS Q e-Tron for the Dakar Rally, the manufacturer stating it will be able to complete daily stages without recharging. Could a similar technology be utilised in F1?

Toto Wolff of Mercedes F1 (left) and Christian Horner of Red Bull Racing have recently found themselves in disagreement over the direction Formula 1 should take with its PUs

Ola Kallenius and Luca de Meo; Horner representing Mateschitz, plus Porsche / Audi CEOs, Oliver Blume and Markus Duesmann – suggests the purpose was not to discuss engine configuration or hybrid elements (though these were broadly discussed) but to formulate a top-down strategy and determine what current suppliers are prepared to invest.

The FIA and F1 also hoped to gauge the terms under which Porsche or Audi would be prepared to join Formula 1.

This approach differs markedly from what went before, when ambitious engineers – mostly with little grasp of marketing or economics – trotted out wish lists that they submitted to the governing body. These were combined into a set of regulations that delivered the most complex, but efficient engines in automotive history, but at eye-watering costs said to average close to $2m per unit when measured across a season.

The summit agreed the new engines should deliver similar power levels to current units, so 1000bhp overall, but at lower cost (annual budgets of $100m, so around $30m per supplied team, as opposed to thrice that. They should run on zero-carbon fuels and provide substantially increased hybridisation (potentially a 50 / 50 split).

Various options were discussed in broad terms, including a switch from V6 to downsized, four-cylinder, inline units, as per road car trends, and scrapping the horrifically complex and expensive MGU-H units

Ferrari boss, John Elkann, was amongst the big names than attended the Austrian summit

On the surface, it is a simple enough list, yet fundamentally all the desired characteristics are mutually exclusive.

Various options were discussed in broad terms, including a switch from V6 to downsized, four-cylinder, inline units, as per road car trends, and scrapping the horrifically complex and expensive MGU-H units, which sap engine noise. Energy lost would be compensated for by front-wheel motor generators, creating the intriguing potential for all-wheel drive, although the engineering behind such a system would be complicated.

The main sticking points, however, appeared to be configuration and hybrid component: four cylinders or six, and the level of ICE / hybrid mix.

As potential newcomers, Audi and Porsche are pushing for a clean-sheet approach to provide a reset across the grid. Ferrari is said to be open to a turbocharged inline four powered by e-fuels, which it considers crucial to market acceptance of its future products.

Ironically, Mercedes and Renault, both of whom market ultra-high performance, four-cylinder road cars, are believed to favour sticking to the current architecture and power split on cost grounds, but no doubt hope to benefit from their hard-earned (expensive) experience under the current PU formula.

In addition, Renault believes AWD will be a costly, heavy and complicated add-on and questions why F1 risks alienating existing teams as it panders to two (still only potential) incomers, both from the VW Group. Unsaid is that de Meo is a former VW Group executive, having joined Renault from his SEAT CEO role.

'The discussion was, what are we doing in the future in terms of engine, because we want to save costs, so we don't want to re-invent the wheel,' Wolff, who did not attend the Austria summit as he is not a director of Mercedes High Performance Powertrains, told the FIA conference.

'We also want to have an engine that is relevant from 2025 to 2030, and we can't be old petrolheads with screaming engines when everybody expects us to be going electric. So these engines are still going to be fuelled [by zero-carbon fuels]. We are staying with the current V6 format, but the electric component is going to massively increase,' Wolff added, clearly pushing the Mercedes corporate line.

However, Horner does not believe retaining the current engines will reduce costs. 'Such engines will still cost $2m. We need to reduce that by half,' he says, having in May pushed for powertrain budget caps, with an annual $50m R&D limit.

Audi and Porsche

What, though, is the position of VW Group and either, or both, of its premium performance brands?

'Audi and the Volkswagen Group are quite a big organisation,' said Audi Formula E team boss, and the manuacturer's former factory Sportscar driver, Alan McNish, during the recent London Formula E round. 'We've got very good relationships through a lot of motorsport and we sit in on a lot of discussions. That doesn't mean to say they will all come to fruition, but you need to be in the discussions to understand.

Ola Kallenius, Mercedes CEO, represented the manufacturer at the 2021 power unit summit

'We are staying with the current V6 format, but the electric component is going to massively increase'

Toto Wolff, team principal and CEO at Mercedes

'Audi has sat in Formula 1 discussions in the past. [And so has the] Volkswagen Group, and that's part of evaluating where motorsport is,' McNish continued. 'It's not a matter of regulatory tourism, it's about guidance of where motorsport needs to go to stay relevant, because the car industry is clear where it's going.'

There is, however, a caveat to all these positions. Unless Porsche and / or Audi (or any other incoming brand) commits wholeheartedly to a new power unit formula, there is little rationale in dumping the current formula just for the sake of change. That makes little economic sense, unless Formula 1 as a whole benefits via increased participation from motor manufacturers.

In that case, it would not be inconceivable that Formula 1 sticks to its current V6, 1600cc format by converting its tried and tested engines to run on e-fuels or 'drop-in' fuels that require little modification. The MGU-H tech will, after all, have been amortised over 12 years, while reliability is no longer a major concern. Such a decision would be by far the cheapest, but ticks fewer boxes and would be highly unlikely to attract incoming brands.

The FIA was determined to prevent such a scenario, and made its position clear during two subsequent meetings held since the Austrian summit, during the British and Hungarian GPs. It is understood the FIA has now taken the decision at the invitation of the manufacturers, and will ratify the new regulations at the FIA World Motorsport Council meeting in December 2021.

The powers that be

There are already quite a few alternative energy solutions at play in the wider motorsport world, including of course Formula E. Scepticism abounded when, in 2011, the FIA conceived its first alternative energy championship, yet the series has gone from strength to strength. It now holds world championship status and boasts seven manufacturers – three more than Formula 1 – although Audi, BMW and Mercedes have all cancelled their Formula E programmes recently.

There's even now Extreme E, a rally series dedicated to electric vehicles.

Meanwhile, from this year, F1's support series, Porsche Supercup, and the European Truck Racing Championship have switched to petrol and diesel biofuels respectively, with Porsche reporting the former required only software updates to co-optimise engine and fuel performance, with output of the GT3 remaining unaffected.

The 2022 World Rally Championship goes a step further by integrating biofuels and hybridisation, while WRX's switch to full electric was delayed by the Covid pandemic.

2022 also sees Audi debut its RS Q e-Tron on the Dakar Rally, using a 600bhp, ex-DTM ICE to power an FE-derived MGU that charges 52kWh batteries to power two 335bhp FE electric motors. The car is said to be able to complete stages without regular charging, although the plan is for overnight charging via auxiliary generators.

Range extenders could also see use at Le Mans, with a rumoured Garage 56 entry using a Mazda rotary run at constant speed to charge batteries.

However, ACO president, Pierre Fillon, whose club promotes the 24-hour race, has stated, 'Hydrogen is one of the best energies for future mobility, and will play a key role in Le Mans in 10 years. We will have zero CO_2 emissions, with hydrogen as the top class and e-fuels in the lower classes, and we will stage an exemplary event in terms of social responsibility.'

In May, Toyota chairman, Akio Toyoda, completed the 24 Hours of Fuji in a turbocharged, three-cylinder Corolla fuelled by compressed hydrogen, an exercise the FIA's Peter Bayer described as 'Super interesting, something we are analysing and studying'.

'The goal is to become carbon-neutral,' Toyoda said of the project. 'If all cars become battery electric, one million jobs will be lost in Japan. I want to tell the world there is also this option to become carbon neutral.'

Motorsport now merely needs to introduce a series for hydrogen fuel cell technologies to cover the full spectrum of alternative energies…

Power switch

On top of all this, FIA president, Jean Todt, retires this year, and aims to hand over safe, sustainable sport to his successor, whoever that may be. Elections are scheduled for mid-December 2021, with current FIA deputy president for sport, Graham Stoker, and the UAE's Mohammed bin Sulayem both having announced their candidacies.

Contractually, the FIA has every right to act unilaterally. The Concorde Agreement expires at the end of 2025, and the FIA is under no legal obligation to agree 2026-onwards regulations with teams or engine suppliers. Indeed, it followed this policy for 2022's regulations. Having granted teams various opportunities for input, it took decisions in conjunction with Liberty Media, Formula 1's commercial rights holder. Precedent exists.

That Formula 1 needs to change its ways is clear. That the internal combustion engine is far from dead, equally so. The trick facing the FIA, Formula 1 and all engine suppliers, present and potential, is to manage the switch so the new direction finds lasting favour amongst fans, sponsors, promoters and broadcasters, all of whom will base their medium to long-term decisions on a sustainable, bio-fuelled, hybrid formula.

The ultimate irony is that after years of criticism of the current engine formula, this season is delivering the best racing for years in F1, yet its demise is being widely debated due to external factors, not all of which are within the sport's direct control.

At time of writing, it remains unclear what PU regulations F1 will race to from 2026, but the wait is nearly over and the framework is expected to be released mid-December 2021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