>> FIA invites companies to tender for Formula E – see P13

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Aeroscreen

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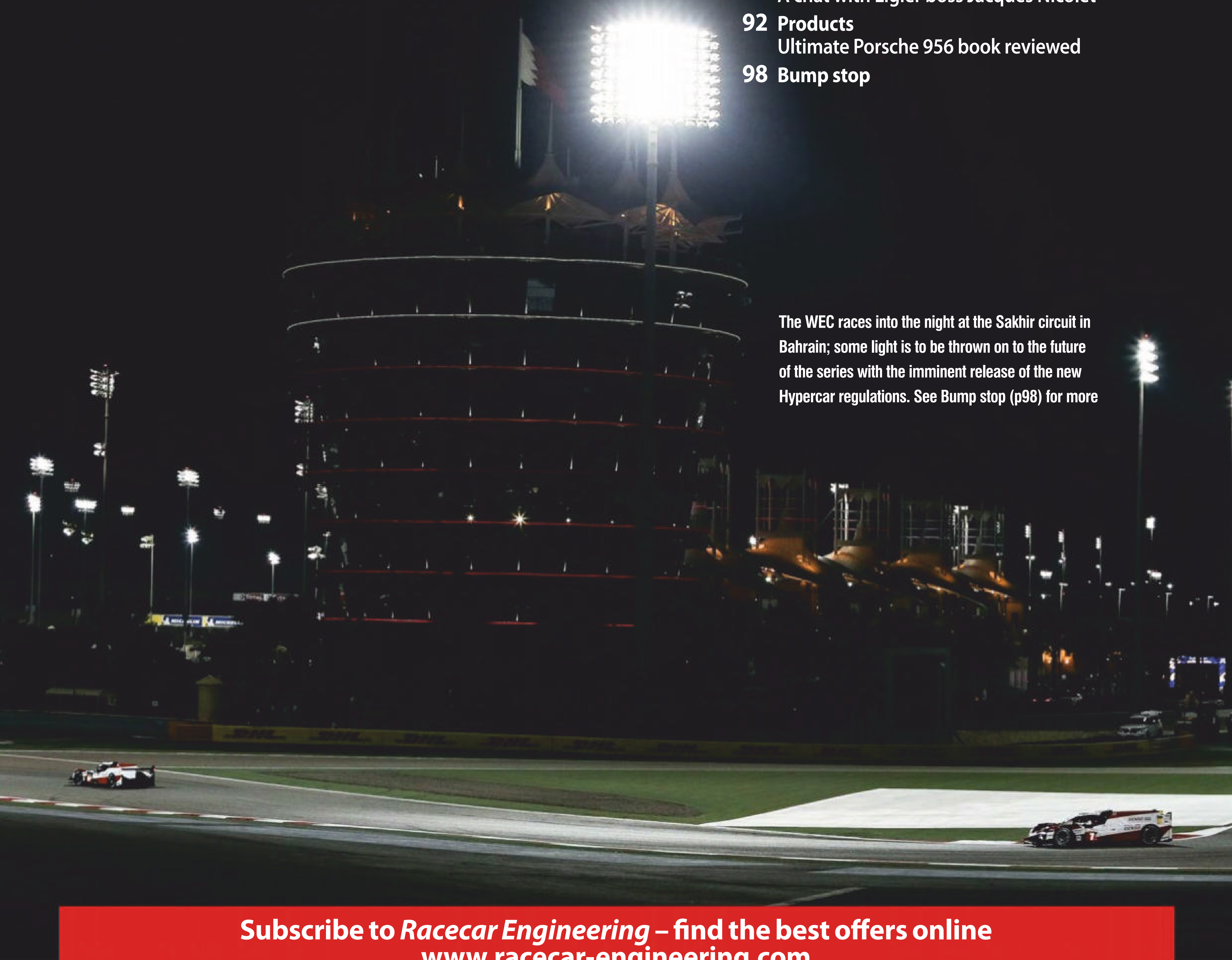
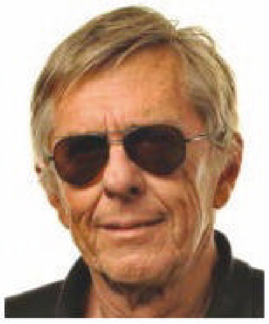


The WEC races into the night at the Sakhir circuit in Bahrain; some light is to be thrown on to the future of the series with the imminent release of the new Hypercar regulations. See Bump stop (p98) for more



Slot car racing

Is DRS a step too far in taking away driver skill, or is it a vital aspect of modern Formula 1?

The F1 drag reduction system (DRS) was introduced in 2011 as a means of enlivening racing, as the aero effects of following a car into a corner effectively made it impossible to be close enough to overtake down the next straight.

In a nutshell, the array of flaps, vortex conditioners, vortex generators, wings and diffusers on the leading racecar do sterling work to generate the maximum amount of downforce with the least amount of drag, but the wake that is thrown behind that racecar, very turbulent, can cut the downforce of the following car enormously.

There is laminar flow, where air runs along the surfaces and has a gradually increasing but thin boundary layer, and there is turbulent flow. The more complex the flow pattern of the air the car is running into, the less effective the wing and aerodynamic devices of the following car, hence the difficulty of cornering close to the lead car due to lessened downforce. The increasing complexity of the aero depends on flow running over the surfaces being 'clean'.

Rear wings consist of a main plane and a flap. The DRS allows the flap to open up to a maximum of 50mm gap from the fixed main plane, thus reducing drag and also downforce. This increases acceleration and top speed.

The effectiveness of the DRS gain will vary, depending on the track, so a low drag set-up for Monza will have a smaller effect. Other factors are the length of the DRS zone, and the character of the track immediately after the zone.

Fancy DRS

I have mixed feelings about DRS. As a concept, I would actually love to have it on the racecar to be used for the whole lap at the driver's discretion in the race (as it is in qualifying in Formula 1), or even automatically deployed depending on the track: on for the straights and off for the corners, a true active aerodynamics device.

We used it on the Nissan DeltaWing at Le Mans exactly like that, but this was an experimental Garage 56 racecar, which was running to different regulations. The original concept even had different angles of the flaps to provide more downforce on the inside flap for the corner, but eventually was used symmetrically as this was simpler and the downforce was greater – our simulation showing it to be faster.

DRS code

The current use of DRS is restricted by the rules; it can be used only when satisfying two conditions: when the following car is within one second of the racecar to be overtaken and the following racecar is in an overtaking zone as defined by the FIA before the race, the DRS zone.

The system may not be activated on the first two laps after the start of a grand prix, a restart, or a safety car deployment, and it may not be enabled if racing conditions are deemed to be too dangerous for its use by the race director, such as when it's raining. It cannot be used by the defending driver, unless within one second of another car in front. This, for the driver behind, is too much like shooting fish in a barrel.

The current use of it to facilitate overtaking is a bit unfair for the leading car, as the driver has no defence when the follower deploys it, and driver attitudes to it seem to follow my thoughts.

Sebastian Vettel once said he preferred throwing bananas 'Mario Kart style' over the use of DRS. Lewis Hamilton and Max Verstappen are also among the drivers who have criticised it, the former saying 'a band-aid for the poor quality of racing'. Juan Pablo Montoya described it as 'like giving Picasso Photoshop', because it made overtaking too easy with no defence for the defender. My objection precisely. But think about how it would be if we did not have DRS.

I say this because we can see it actually does work. Consider the 2019 Abu Dhabi Grand Prix, when a computer server crash forced the FIA to disable DRS use for the first 18 laps of the of the race, leaving Valtteri Bottas in the Mercedes stuck behind Nico Hulkenberg in the Renault due to the difficulty of overtaking without it, clearly showing track position to be a huge advantage. Hulkenberg's spirited defence was exactly what you would have all the time if no DRS was used.

So even if we don't like the idea on a fairness principle, the lack of it would make racing very boring, overtaking being the soul of competition. And don't get me started on another band-aid, the 'push to pass' button, although that's for the same reasons.

The new regulations for 2021 has a series of changes to ease overtaking by improving aerodynamics, allowing cars to follow more closely through corners. But even then, after 10 years of use, DRS will still be there, to ensure closer racing in case the aero doesn't do all that is being promised of it – nominally only having a 15 per cent loss of downforce when following another car compared to 50 per cent with the current aero.

XPB

The DRS mechanism and the flap is clear in this picture of the 2019 Alfa Romeo's rear wing. A slot that's 50mm deep opens up on activation to reduce drag and aid overtaking

Twenties flappers

But those values are from simulation and tunnel tests, and we will only know the true values when that aero is used in anger with real Formula 1 cars on the track. Presumably shorter or different DRS zones will be needed, too.

Perhaps in the future DRS may even be used as a true active aero for the whole lap to improve performance. Now that would be something.

Juan Pablo Montoya said DRS was 'like giving Picasso Photoshop' because it made overtaking too easy with no defence for the defender

Robo copped

Will autonomous motor racing bring its own set of environmental concerns?

Global warming and the contribution that petrol and diesel-powered vehicles make to this are hot topics. The huge part that agricultural, industrial, transport and marine diesels play in this seems to be conveniently overlooked in favour of the political game of targeting cars. I could devote the whole of this column to the fallacies that surround the headlong rush for all-electric, but this is not what *Racecar Engineering* is about. Instead, I want to highlight one of the contradictory automotive avenues in which motor racing appears set to play a part.

Roborace is being touted as a great proving ground, technically and for reasons of perception, for self-driving cars. I fail to see, aside from those who are addicted to computer gaming, the point in this driver-less racing car concept – it appears to be contrary to the whole ethos of motor racing, in which machine and man/woman *together* prove their capabilities and assume risks. How can developing the best algorithms replicate the adrenaline shot of taking a fast corner with throttle flat to the bulkhead, teetering on the edge of adhesion, when your natural senses are telling you to lift?

However, each to his, or her, own. It is certainly true that the world's major automotive manufacturers are spending many billions of pounds in developing autonomous vehicles, and Roborace could – perhaps – assist. However, car makers following this latest automotive avenue appear sheep-like, because for a start it's for a market that isn't yet proven to exist, certainly on the scale that will show a solid return on these vast investments.

Roborace aims to be the first global championship for autonomous cars, but might there be a flaw in its approach when it comes to green issues?

Emission impossible

Level 4, which means being completely driver-free, according to the head of Toyota's electronics supplier Denso: 'Will be a critical issue because battery capacity will be a prized and finite commodity'. So fully autonomous operation actually flies in the face of reducing global warming because the high-powered computing involved eats up so much electricity. In turn, extra cooling is essential to deal with the extra heat generated. Given that all this heat will float into the atmosphere, accompanied by the effects of the additional (often toxic) materials employed in making this stuff, I seriously question the logic for such concentration of resources. Apart from the herd instinct previously mentioned, of course. In fact, some manufacturers are becoming increasingly sceptical of going beyond driver-assistance-only (Level 2) stage.

As with so many political decisions, Albert Einstein's assertion that 'with every action there's an equal, opposite reaction' is ignored, often just for short-term expediency. Think how much more benefit would be created for all of us if the thousands of highly-intelligent engineers, scientists and technicians absorbed in autonomous technology were instead applying their skills to discovering innovative and achievable ways to really address global warming.

In contrast, I think F1's recent announcement regarding achieving carbon-neutrality by 2030 is fantastic. It is prescient, innovative and far-reaching, based on prioritising use of recoverable energy – including in the production facilities – reducing waste, moves to bio and synthetic fuels, enhancing the use of nature's carbon-capture capabilities, using the sport's engineering know-how to develop new technologies that can capture carbon from the atmosphere, and more.

I don't know whether 100 per cent carbon-recovery really can be achievable, but clearly this combination of measures should go a long way. The initiative is crucial, because although F1's carbon footprint is infinitesimally small in the overall scale of global warming, it is large compared to its value in sport, entertainment and technology-development. The acknowledgement of the overall picture, especially concerning the logistics involved in moving around the world and the emissions created by the race-goers as well as the participants, can only be applauded.

Moreover, little of it should detract from the spectacle and the challenge. These F1 initiatives will surely, as is usual, move downstream to all forms of the sport, at least in part, hopefully being replicated first by all major championships worldwide, starting with the WEC, IndyCar in the USA and the domestic series in Japan.

Green flag lapse

But this is of little benefit in combatting the often misinformed criticism that F1, and motorsport in general, will increasingly face from the green lobby, unless the wider world gets to know about it. To quote Chase Carey: 'Few people know that the current F1 hybrid power unit is the most efficient in the world, delivering more power using less fuel, and hence CO_2, than any other car.'

Well, why *do* few people know this? F1, Liberty, the FIA and the manufacturers currently involved should be shouting about it, along with the new carbon-neutral strategy. Investment in the full range of media must be employed in getting across the message, just as race coverage should frequently be used by the presenters to highlight the importance of the changes. Fans, too, must play their part, armed with facts to convincingly face down detractors whether in the pub or at work.

Much of the broad spectrum of measures being taken is transferable to other major sporting and entertainment events. Instead of being held up as a pariah, motor racing has the opportunity to become an ahead-of-time, shining technological example of leading the way in combatting CO_2 emissions and global warming while still providing a tremendous spectacle. But it all depends on *communication*. All this vision, hard work and innovation is of no worth if it becomes a best-kept secret as far as the public, authorities and governments are concerned. If you've got it, flaunt it. So it's down to all of us to do our bit.

Autonomous operation actually flies in the face of reducing global warming because the high-powered computing eats up so much electricity

IndyCar's Aeroscreen was widely considered to be more aesthetically pleasing than the Halo, but that wasn't the reason why it was adopted

Screen saver

With much higher cornering speeds and different risks to consider IndyCar concluded an F1-style Halo was not the right way to go, so this season the US series is debuting its own solution called Aeroscreen. Tino Belli – director, aerodynamic development – gave *Racecar* the fascinating inside story of its design and build

By ANDREW COTTON

Motor racing purists, it seems, have lost the argument over whether single seaters should carry head protection. Halos are now common on many high-level single seaters, including Formula 1, F2, F3 and Super Formula. More importantly, since its introduction in 2018, the then much-maligned device has been credited with saving the lives of race drivers in F1, F2 and F3.

Now, two years on from the debut of the Halo, IndyCar will introduce its head protection system into competition for the first time. The Aeroscreen has been developed by IndyCar in collaboration with Red Bull Advanced Technologies, and although the construction of the structure is totally different to that of Formula 1, it conforms to all FIA standards and has been tested to Formula 1 standards at Cranfield in the UK.

Yet while IndyCar may be late to the head protection party, that does not mean that the concept started late. In fact, Red Bull Advanced Technologies contacted IndyCar about the idea, and IndyCar's head of aero, Tino Belli, went to speak to Red Bull in 2016, just when the series was starting work on the Universal Aero Kit (UAK18) that replaced the manufacturer bodywork that had been developed by Honda and Chevrolet. That conversation didn't immediately lead to a relationship being forged, but communications started again early in 2019, and design work started in April.

Screen grab

Red Bull had already designed a single curvature screen that it tested in Formula 1 as part of the FIA's investigations into head protection, and IndyCar felt it was prudent to take its learning and turn it into a concept that was fit for the US series.

While the Halo was labelled as a flip flop (as in sandal), IndyCar's Aeroscreen was widely considered to be more aesthetically pleasing, but that wasn't the reason why the screen was adopted. The US series had slightly different requirements from its head protection system which meant that the laminate polycarbonate screen was necessary. While the majority of Formula 1 intrusions into the cockpit would likely come in cornering and therefore at a relatively low speed, IndyCar's accidents tend to be very different, particularly on the speedways where swiping a wall at more than 220mph leads to debris flying at high speed.

IndyCar had another issue with the Halo, too. If a piece of debris hit the underside of the top bar, for example, it could be deflected into the driver, thereby making the device more hazardous to the driver than running without it.

All of the above led to the Aeroscreen, which was developed by PPG. The screen, in turn, led to other issues, however, such as problems with the airflow to the driver and distortion and the glare from the lights, all of which had to be addressed in a short time-scale.

Safe and sound

Basically, the screen is a five-piece component weighing around 55lb, with a titanium top bar that is 3D printed by Austrian company Pankl. The pieces are welded together in a shape similar to the Halo and fixed to a piece of carbon and titanium that is bonded to the top of the cockpit rim. The bonded lower part of the system is constructed with a combination of titanium and carbon, with a Rohacell core.

The Rohacell foam is the most dense available for increased strength. The system was subjected to Cranfield's test process, where 125kN was applied to the top downwards, and to the side and compared to RBAT's FEA analysis. 'I have complete confidence that in all cases it will take 150kN and once we have produced enough parts we will load them up to destruction and see when it breaks,' says Belli.

The tested structure will actually be used on a racecar in pre-season testing, although IndyCar is unlikely to use it at Indianapolis for the 500, just to err on the side of caution.

The decision to 3D print the top frame meant that there were some long lead times – each of the systems takes about 10 weeks to make and IndyCar is in the process of producing 50 of them ready for the start of the season. So the production is stacked and they are being completed at a rate of three a week.

'The pre-production and production had to overlap,' Belli says. 'We hadn't signed off on everything before we were in production. We hadn't done our load test on the top frame and we were in production. We were relying on Red Bull getting their FEA right, and they did. Red Bull knew that we would have to do that. There are areas where the stresses are very high, and so took great care in their calculations.'

IndyCar's Aeroscreen in the simulator to establish the sight lines; a crucial consideration for any head protection device

The tube for cooling the helmet will start where the NTT sticker is. Openings will be on the opposite side to the refuelling rig

Fence defence

The rear of the system is bolted into the base of the roll hoop as that was the strongest part of the car that could be reached by the top bar, but there was another advantage to having the bar so high at the rear. 'Unlike F1 we have to worry about fence poles and [with] the standard Halo, when you got into a fence, it would act like a cam follower and the fence pole could hit the top of the driver's head,' says Belli. 'The other reason our racing is different from European racing, where most accidents happen in corners at lower speeds, our accidents on ovals happen at high speeds. You hit the wall, parts fly off, and we were concerned about these parts hitting the bottom of the Halo and being deflected into the driver's torso. Let's take a short oval, where minimum speeds are 150mph, and if anything that hits you at 150mph on the torso where you are completely unprotected, you are almost better to be hit on the helmet.'

At 9.6mm thick the Aeroscreen is probably the thickest in racing, yet there is no optical distortion that has been experienced. In fact,

'In European racing most crashes occur in corners at lower speeds, but IndyCar accidents on the ovals happen at very high speeds'

‘If anything hits you at 150mph on the torso where you are completely unprotected, then you are almost better off being hit on the helmet’

The Aeroscreen grew out of Red Bull’s single curvature screen approach to head protection. This was not taken up by Formula 1 and since 2018 the Halo device has been fitted to all F1 cars. Red Bull Advanced Technologies has worked with IndyCar on this project

Early incarnations of the IndyCar screen did not include the top structure, but it was never likely to race like this as the whole assembly needed to pass the stringent FIA safety tests the entire process, including cooling, has been surprisingly trouble-free.

'The Red Bull [F1] screen had problems with reflections and we don't seem to suffer with that,' says Belli. 'Maybe we have learned to black out the inside a bit better. We did try some anti-reflective film on the inside, but we have taken this out. We do have them if we need them, so Racing Optics do that for us, but we haven't really suffered from reflections.'

Detroit Race 1

But to say that the screen is now perfect would be incorrect. There is a slight worry for the design and aero team, and that is what will happen when running on a concrete street track in damp conditions. The phenomenon is known among the drivers as Detroit Race 1, after they experienced these conditions at that event and found that they had to wipe their visors to clear them of, what felt to the drivers like, muck thrown up on them.

'We have done a lot of talking to the teams that have done sportscars and we think it is a very small chance of being a problem,' says Belli. 'A flat windscreen such as that on a GT car has a high-pressure bubble at the base of the screen so the air hits it and slowly creeps around the edges. Our windscreen has no slow spots on it, it has very high speed airflow all over it and there is no stagnation point. We are pretty sure that we won't have a problem [such as Detroit Race 1], but it got us thinking and in CFD you can seed the flow with particles, and Dallara are investigating this now and we hope in the next couple of weeks they can tell us where the dirty bits will congregate.'

The Aeroscreen is a large, relatively heavy item and teams were expecting there to be a significant drag effect with its introduction but that has not been the case thanks to some intelligent thinking. The drivers who have tested the car in windy conditions have felt a slightly accentuated movement, but otherwise the screen's introduction has had a relatively minor effect on the overall performance. So little was the effect that teams actually felt that IndyCar's initial findings could not be trusted. 'Because it is such a visual part it looks as if it has a major aero impact, but in reality it's a small aero impact,' says Belli. 'The parts that are important aerodynamically cannot be seen by the fans, so that means the floor of the cars. You get minimal drag increase from the screen. If you can make the screen align with the natural streamlines [the air] doesn't really know that it's there.'

Andy Damerum of Red Bull Advanced Technologies examines one of the turning vanes above the top structure of the screen

'Because it is such a visible part it looks as if it has a major aero impact, but in reality it's a small aerodynamic effect'

Chassis integration

Integrating the screen into the cockpit was made more complicated by the fact that the chassis was introduced in 2012 and has been of the same design since. It has been able to cope with the manufacturer-developed downforce kits, with different tyre design and so on, but this is the biggest change to the chassis since it was introduced. The new car is only now in planning and may not be introduced until after the hybrid power unit in 2022 (see box out).

'The top frame is tied into the base of the roll hoop for strength, and then we get stability from the edges, and we like that because it keeps the halo above the drivers' head all the time,' says Belli. 'Our top frame ended up as less of a tubular structure and we have the benefit of following [European single seaters]. We saw what they did with the Halo and we had a clean sheet of paper. The FIA Safety Institute were brilliant – they had a lot of money and resource and we were very careful with anything they did to adapt it to our specific needs. Our halo is actually a different shape, 3D printed and moulded, but we have used the same FIA helmet free zone. We didn't just accept it, we looked at our big accidents, (for example, when Sebastien Bourdais hit the wall at Indianapolis)

Tino Belli (right) briefs (from left) Ganassi Racing team manager Barry Wanser, race engineer Chris Simmons, president of IndyCar Jay Frye, and driver Scott Dixon

'Integrating the screen into the cockpit was made more complicated by the fact that the Dallara DW12 chassis was introduced in 2012'

IndyCar has run the screen on speedways, road courses, in the rain and into darkness

where our drivers have moved to an extreme, and we checked that the helmet stayed within that helmet-free volume.'

While the driver was the principal concern for introducing the screen underneath the halo part of the structure, that then brought other challenges for the design team; namely cooling and air flow through the cockpit itself. For the cooling side of things, it was relatively straightforward, thanks to the relationship with Dallara that stretches back more than a decade. The Italian company provides cars for endurance racing with closed cockpit designs, and IndyCar was able to tap into that knowledge.

Cool heads

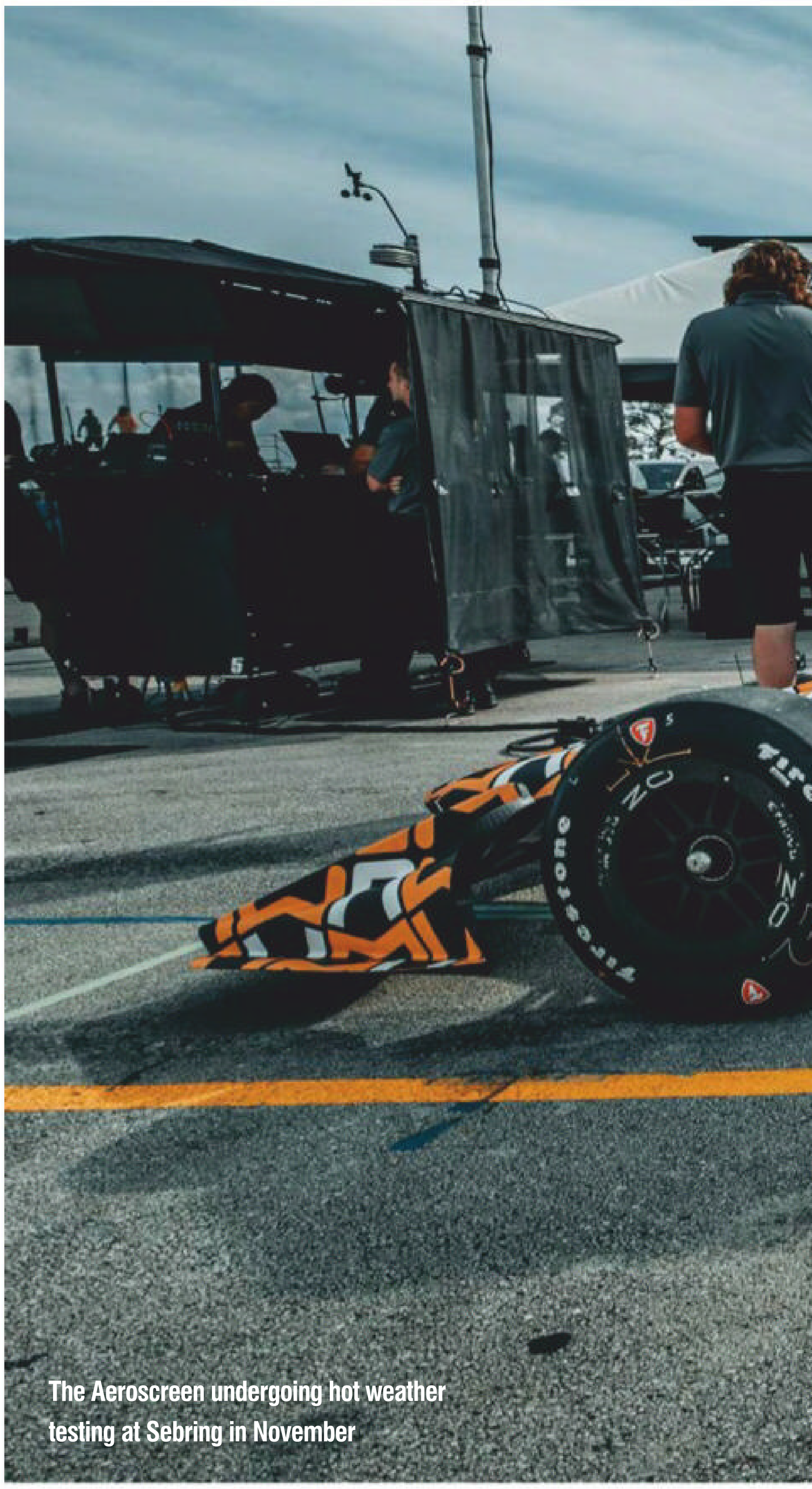
Early versions of the screen featured 'nostrils' ahead of it that simply fed air into the cockpit, but later versions saw the ducts from the nostrils extended across the dashboard to just behind the steering wheel. This was because IndyCar had initially focussed on keeping the driver's mouth cool, but after research elected to run the sort of helmet cooling that is now common in sportscars. A tube runs from the rear of the screen and plugs into the driver's helmet, keeping the entire head cool. 'That was definitely necessary for the road and street tracks, so that is mandatory,' says Belli. The tube can come from either side and it will, mandatorily, be the opposite side to the refuelling nozzle, the side of which is decided by the direction of the race track.

That left the ducts at the front to do a different job, and IndyCar decided to extend them across the dashboard to give the air less chance to disperse, and this gave teams the option of cooling either the drivers' torso or legs. A simple part inside the duct can be adjusted according to preference. For the more hotter days on a street track two tubes, labelled by Belli as 'torpedo tubes', in the nose feed air to the lower legs of the drivers.

'The base of the screen is highly stressed in an impact, and we have maximised an opening there [which still] satisfies the stresses, so you will see these kind of nostrils on there to duct the air in,' says Belli.

Screen tests

IndyCar has completed a number of track tests with the screen, running on speedways, road courses, in rain and into darkness, and so is confident that it has all the tools necessary to make it a success. Drivers have said that they could see the heating elements in the screen, but this only appears to be the case in the pit lane, so IndyCar is not concerned just yet. Everything else appears to be in hand, but perhaps the biggest test for the Aeroscreen is when a car carrying it is involved in the sort of accident it's been designed for.



The Aeroscreen undergoing hot weather testing at Sebring in November

Aeroscreen is probably the thickest screen used in racing anywhere in the world, at 9.6mm, and yet so far no optical distortion has been experienced by any of the IndyCar drivers

Indy future

The introduction of the new IndyCar chassis has now been delayed at least until 2022, partly due to the aero team focussing on the Aeroscreen. The initial plan was to change chassis in 2021, giving the teams a year adapting to it and then bring in the hybrid engine in 2022, but the new chassis may not be available until 2023 now, according to Tino Belli.

The new chassis is in the early planning stages and the design targets are only now being set. They will be based on the outgoing DW12, which was introduced in 2012 but which has been extensively developed since. 'The DW12 monocoque has been strengthened considerably pretty much on a yearly basis, and we have never gone back and measured the strength of the DW12,' Belli says. 'We will do it with the Halo [Aeroscreen] on in 2020, because those performance targets have to be the minimum for going forwards.

'With the UAK18 we introduced side impact structures which are considerably different to FIA side impact structures, which are tubular design. They are designed for a pure side impact. [But it is] designing a rule for someone who is designing their own sidepod and can do their own shape. We decided as we had a spec sidepod we should design our side impact structure for the type of impacts that occur in our series and to date we are very happy with the outcome.

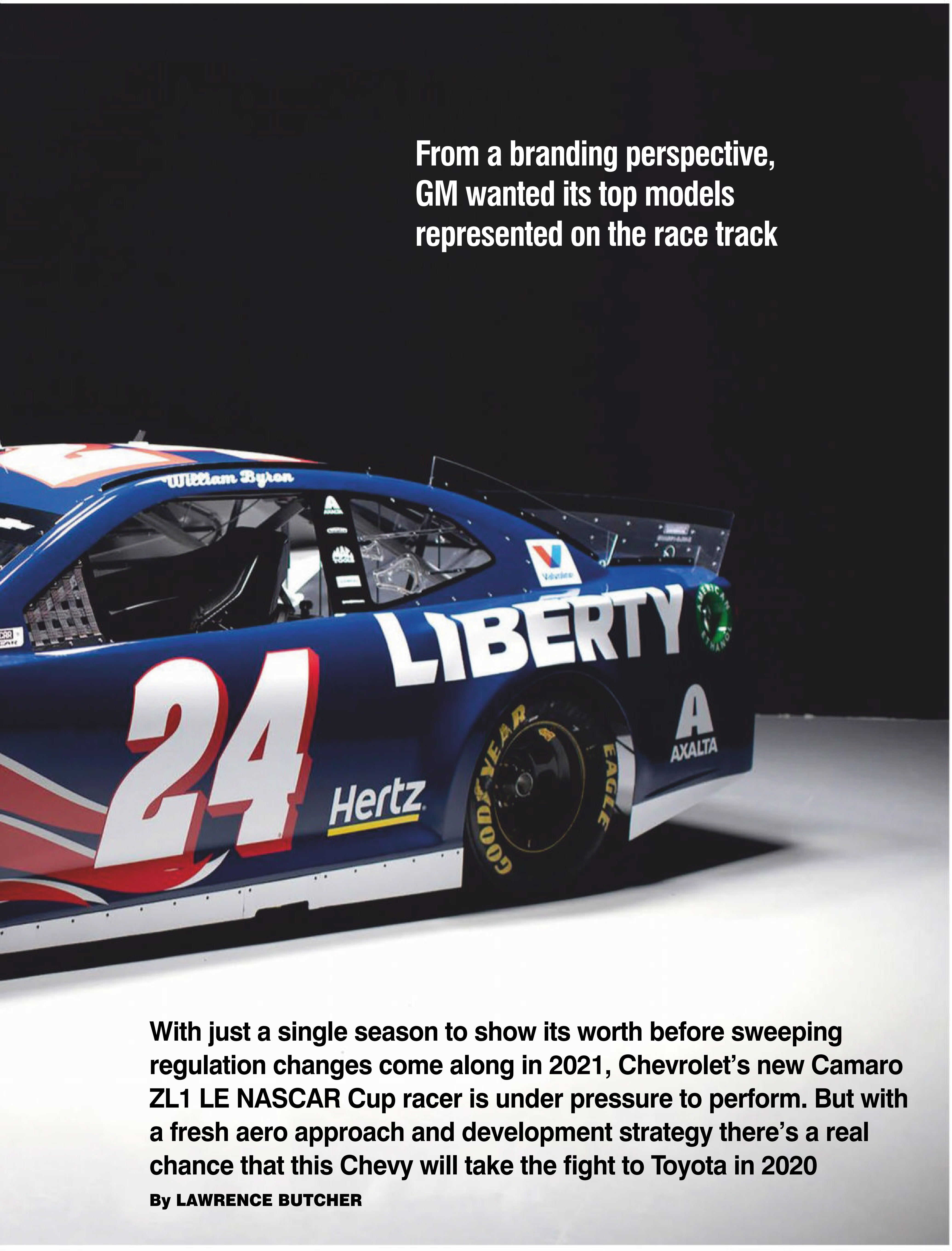
'We can feed the side impact structure loads better into the new tub, into the bulkheads and floor,' Belli adds.

The new chassis will need to cope with carrying and cooling a hybrid system and the entire cooling system will need a redesign. 'From an aero point of view the cooling system will have to be redone, we are going to need more cooling, and have to cool the energy storage,' says Belli. 'The probability is that the right-hand side of the car is going to have to have more air flow than the UAK18.'

The DW12 has been around since 2012 in different guises (this is 2013). A new chassis is being planned

One shot at glory

Photo: Joel Coleman/Liberty University



From a branding perspective, GM wanted its top models represented on the race track

With just a single season to show its worth before sweeping regulation changes come along in 2021, Chevrolet's new Camaro ZL1 LE NASCAR Cup racer is under pressure to perform. But with a fresh aero approach and development strategy there's a real chance that this Chevy will take the fight to Toyota in 2020

By LAWRENCE BUTCHER

Wind tunnel work on the new Chevrolet Camaro Cup car has taken place in the AeroDyn and Windshear tunnels in Mooresville, NC, using both full-scale racecars and models

In 2020, Chevrolet will be the only manufacturer introducing a revised body into NASCAR's Cup series, with the arrival of the Camaro ZL1 LE. Due to the series gaining an all new regulations package for 2021 (which is detailed on page 24), this car will only run for a single season.

In 2018, Chevrolet brought the Camaro body style to the top level of stock car racing, replacing the short-lived SS (the US market version of the Holden Commodore) which in turn had usurped the long serving Impala. Now there's a new version for 2020.

Single season car

That a manufacturer would dedicate development resources to such a single-year project may seem surprising, but as Patrick Suhy, manager of GM's NASCAR competition group explains, there was good reason for the commitment. 'When we did the 2018 car, it was done out of necessity, because the SS was going out of production, so to be compliant with NASCAR's rules on having a relevant production model, we had to pick something. The Camaro was the natural successor.'

In 2017, when the '18 Camaro was being developed, the ZL1 was the highest performance model in the Camaro range, making it the logical base for a Cup design. However, the range topping ZL1 LE would follow in early 2019 and, from a branding perspective, GM wanted its top models represented on the race track. 'It [the ZL1LE] is a true track car with much greater aerodynamic performance than the ZL1,' says Suhy. 'Our partners in marketing asked us what it would take to bring the car in.'

'The Next Gen car was then still in the planning stages and I don't think that even NASCAR thought it could happen for 2021'

However, branding was not the only motivation for the development of a new body. The time-frame for the '18 Camaro's development was tight, and as such Chevy knew there were further performance enhancing avenues it might have pursued. Suhy says: 'Our on-track performance certainly showed that we were lacking and that, combined with the desire to align the race track brand with the showroom, made it worthwhile.'

Furthermore, when the decision was made to update to the ZL1 LE, Chevrolet did not know it would only have such a short shelf life. 'At the time, the Next Gen NASCAR was still very much in the planning stages and I don't think that even NASCAR thought it could happen for 2021,' Suhy says. 'We thought we might have a two-year car at least.'

Compressed schedule

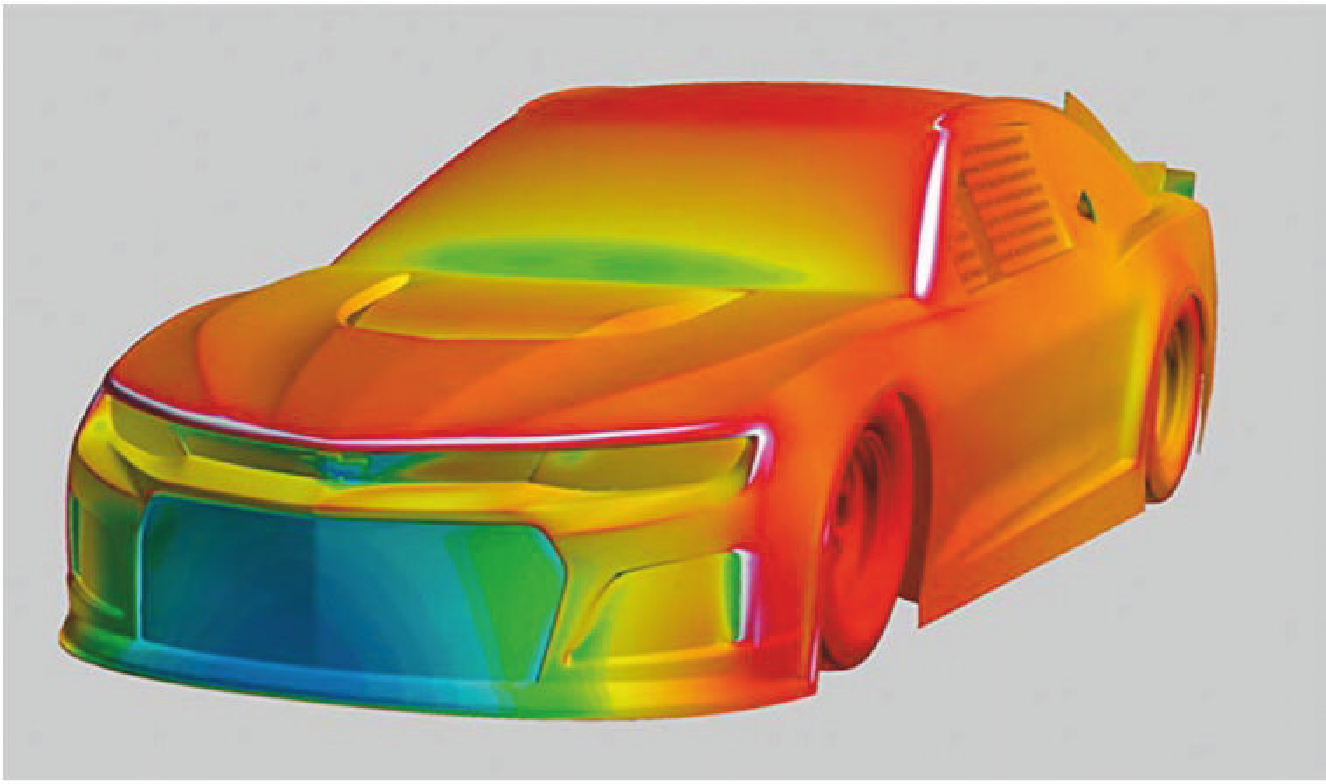
Development of the 2020 car worked on what Suhy calls a 'compressed' schedule. The way that NASCAR's inspection and approval process operates means that any new body must be ready for sign-off the summer before it is due to enter competition. The final submission date for the ZL1 LE would be July 2019. 'We started talking about the project in late summer 2018, so it was a short time-frame,' Suhy says. Fortunately, and unlike with the '18 ZL1 Camaro, which was the first update Chevrolet introduced

'We felt it was necessary to put together a dedicated group and we now have a lead aerodynamicist and a handful of CFD guys in it'

since the SS arrived back in 2013, time could be saved thanks to it already having a Camaro on the track to provide a baseline.

With its previous Gen 6 cars, Chevrolet had made use of its partner teams' resources for CFD and wind tunnel development, but for the new Camaro, it brought this work in-house. 'I don't know if we were late to the party on this [compared to other manufacturers], but we established a dedicated aero group [within GM],' says Suhy. 'We used to work collaboratively with our teams – and we still work very closely with them – sharing the load between our resources and the teams' resources.

'That was good at the time, because it increased the resources available and we could do a lot of work,' Suhy adds. 'But things have evolved; the race teams have less spare capacity to work on 'skunk works' type projects now. Because of that, we felt it necessary to put together a dedicated group. We now have a lead aerodynamicist and a handful of CFD guys working with them; the race teams are still involved, but we are providing all of the simulation and testing resources.'



Camaro flow visualisation. GM doing the aero development in-house has helped with the CFD and wind tunnel correlation

There were some useful features on the new road car that could be carried over into the Cup car

Teaming up

Retaining a close relationship with its partner teams is vital for Chevy, because, ultimately, they are the ones that are running, testing and simulating their racecars day in, day out. They have a better understanding than anyone of the aerodynamic minutia that brings on-track performance. If GM's race teams were not able to add their input to a new racecar, important aero gains could be overlooked.

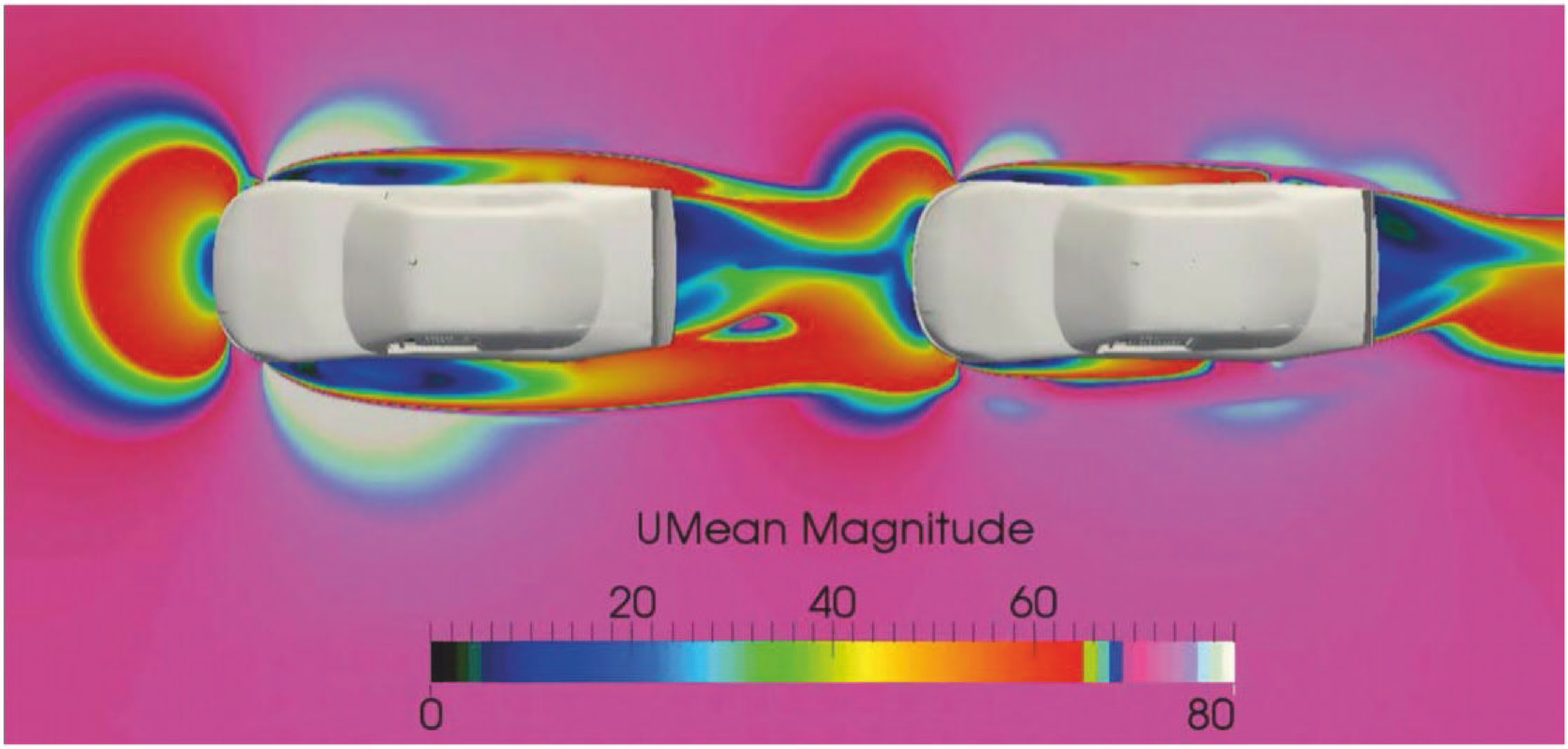
Suhy also points out the logistical complexity of coordinating efforts across four separate engineering groups (Hendrick Motorsport, Richard Childress Racing and Chip Ganassi Racing, plus GM). Different teams run different CAD packages, while also having variations in their CFD and wind tunnel programmes. But 'it has brought a lot of efficiency,' Suhy says.

Importantly, it also increased the effectiveness of the CFD and subsequent wind tunnel test programme for the Camaro (with both scale and full-size vehicles). 'We use one CAD and one CFD package and that enabled not just greater efficiency but also more certainty that the results were going to line up. There is art and science in CFD and if you have two or three different engineers running different CFD packages, having 100 per cent confidence that the results align would be challenging, even if you were testing the same parts.'

Having all of the simulation and test work under one roof allowed for very rapid correlation between CFD and wind tunnel, which, says Suhy, 'raised our confidence in the CFD results which in turn meant we could do more CFD work and focus the wind tunnel more precisely. I'd say with the last car, there was always a bit of a question mark over what we saw in CFD. I think it saved us a lot of time in not looking at things that were not going to be effective.'

Tunnel time

Alongside CFD, wind tunnel development was undertaken using a combination of the AeroDyn and Windshear tunnels in Mooresville,



CFD showing the drag bubble effect, which NASCAR concluded was spoiling the racing. Because of this all the Cup cars now have to run with the passive ducts shown on page 22

'Since the car was approved in mid-July we have been hitting the wind tunnel testing hard to ensure we are well prepared'

NC. These are two quite different facilities, with AeroDyn having a fixed floor and Windshear a moving ground plane. The important factor here is that AeroDyn is the facility NASCAR uses to approve a new body, so in order to be sure a design will actually hit NASCAR's target numbers, manufactures will all test here. 'When it comes to ultimate performance testing, we will go to Windshear and there we can see what the racecar will do on the race track; they [the tunnels and approach to testing in each] are two totally different things,' Suhy says.

Though the differentiation between the existing ZL1 Camaro and the LE variant may seem subtle, there were some useful features on the new road car that could be carried over into the Cup car. 'It has front dive planes and a rear wing,' Suhy says. 'NASCAR won't let us use the wing, but we could incorporate the dive planes in the front facia and take advantage of them.'

Photo: KJ Jugar/Liberty University

The rear wing from the road car was not allowed on the racecar and had to be replaced with NASCAR's spec boot spoiler

The sharp end

A rework of the Camaro front end was also beneficial in allowing Chevy to adapt to the specifics of the 2019-20 NASCAR rules package, which saw the addition of inlets on the front facia of the cars, venting into the wheel arches.

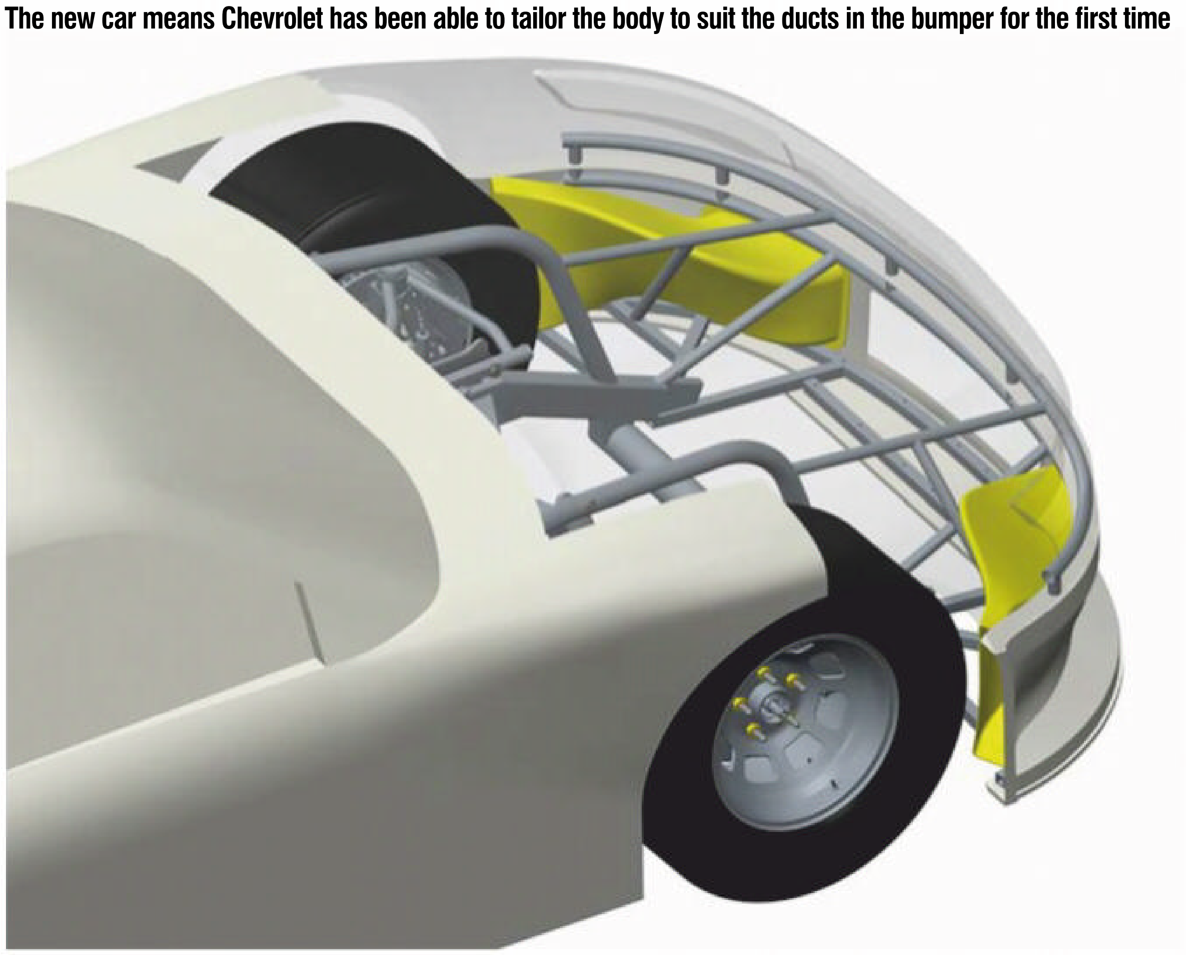
These vents were originally tested in 2018, then introduced full time for 2019, following an in-depth aero research programme by NASCAR. This found that the level of drag experienced by a following car varied as it closed on a leading vehicle, owing to the wake generated by the front car. Up to a certain point, a following car experienced a reduction in drag, but as it began to almost reach a leading car's bumper, drag would increase again, before dropping off as they ran bumper to bumper. Drivers would refer to this effect as the drag bubble.

NASCAR R&D identified the areas of a car's wake that caused this issue and sought to adapt the aero package to reduce its effect. Its answer was the use of passive ducts in the front bumper which fed air out though the wheel arches, effectively widening a car's wake (almost the exact opposite of what Formula 1 has tried to achieve with its 2021 rules package).

The above package was not confirmed or even fully developed when Chevy signed off the initial Camaro in mid-2017, with the '20 car representing its first chance to tailor the body to work with the ducts. 'Being able to manipulate the panels in that area, particularly with the dive planes, was useful,' Suhy says.

Concurrent to the arrival of the nose ducts in the Cup, NASCAR also cut engine power at all tracks with the exception of short and road courses, via the use of a tapered inlet spacer; limiting power to around 550bhp. According to Suhy, this meant that 'the old approach of just packing downforce on is gone. Teams have to make the choice between downforce and drag and having that extra tool [the dive planes] in the toolbox certainly gives more flexibility in trying to find the right L/D trade off'.

The new car means Chevrolet has been able to tailor the body to suit the ducts in the bumper for the first time



Aero limits

There are very few rule changes moving in to 2020 for teams to deal with. However off-track, one significant restriction will come into force; a limit of 150 hours wind tunnel testing per team, per year. Could it therefore be the case that, though the Chevy teams are getting a new, potentially more potent car for the season, this new limit prevents them fully exploiting it? 'I think the writing was on the wall that this was going to happen and we did plan accordingly,' Suhy says. 'We have been in the wind tunnel a lot this year, and since the car was approved in mid-July, we have been hitting the tunnel testing hard to ensure we are well prepared.'

The new Camaros will take to the track in anger for the first time at Daytona in February. Chevy will be hoping the one-year only update gives its teams the hammer they need to break Toyota's run of dominance in the Cup.

NASCAR's next generation stock car

The 2021 season will see a seismic shift in NASCAR, with all-new regulations moving the cars away from a template that has remained relatively unchanged since the 1970s. The current NASCAR Cup machinery retains many features that have been present for decades, not the least of which are chassis that feature 'truck arm' rear suspension, live rear axles and steering boxes rather than racks.

The 'Next Gen' Cup car will be a radical (by NASCAR standards) departure from the current Gen 6 machines. Tubeframe chassis will be retained, but the fabricated steel suspension set-ups, consisting of A-arms at the front and truck arms and live axle at the rear, will be replaced with machined uprights and double wishbones front and rear. The first prototype chassis were designed by Dallara in conjunction with NASCAR R&D.

For the first time, on-car adjustable dampers will be permitted, too, with four-way control of high and low-speed bump/rebound. The trademark 15in steel wheels, with five lug nuts, will also go the way of the dodo, to be replaced by 17in rims with centre-lock securing.

Transmission revamp

The current 358cui (5.8-litre), pushrod V8 engine package will be kept, at least until 2023, but instead of an H-pattern transmission a sequential transaxle, similar to that used in Australian Supercars, will be employed, with Xtrac awarded the contract for its supply.

There is also a tender process underway to secure a spec hybrid system for potential introduction in 2023, though details of its specification, or the engine it will be paired with, are sparse. There is also a desire for this system to be shared between both NASCAR and IMSA (which NASCAR owns).

One of the main reasons behind the move to a transaxle is safety; shifting the transmission to the rear of the car from adjacent to the drivers' legs allows them to be seated nearer the centre of the car, therefore allowing more space for energy absorbing safety structures. The new transaxle will also help teams reduce running costs. Currently, NASCAR uses ring and pinion ratios to tune performance from track to track, meaning teams have to carry a significant number of spares at considerable expense (around $10,000 a set). With the transaxle set-up, a drop gear system will allow for fast ratio changes at much lower cost (though to accommodate the wide range of track types, from Bristol to Daytona, there will still be a need for a smaller range of ring and pinion combinations). The sequential transmission will be manually shifted and, currently, there is no plan to introduce auto engine blipping on downshifts.

Wrapping the new chassis will be all new composite bodies, with markedly different proportions to the Gen 6 machines, making them appear far closer to production models. NASCAR's second tier Xfinity series already runs full composite shells and it was inevitable these would migrate to the top-level championship sooner rather than later.

The aerodynamic concept of the cars will also change significantly. Rather than the messy, exposed tubeframe undersides, which are ripe for exploitation by teams chasing incremental aerodynamic gains, a flat floor will be introduced with (to the undoubted horror of stock car aficionados) a rear diffuser. The hostile reception given to the CoT's rear wing in 2007 is still fresh in many memories, so the rear spoiler is retained.

Aerodynamic parity between different bodystyles will remain a priority for NASCAR and, as such, the current process of keeping so called 'gold' surfaces common across cars will remain, with manufacturers permitted styling freedom in certain areas. Through NASCAR's benchmarking and approval process, each manufacturer will have to submit its specific body designs and ensure they fall within the NASCAR window for downforce and drag, when assessed by the sanctioning body.

Though details of the new rule package are still being finalised, NASCAR, via its Research and Development department, has been track testing prototypes of a new car design, with manufacturers working on their own test chassis to develop bodywork variations since the middle of 2019. 'We have kinda got the band back together so to speak, with the manufacturers working with the NASCAR aero guys, in a similar way to the Gen 6,' says Suhy.

Control parts

While these changes will undoubtedly drag stock car design into at least the late 20th century (not the engineering know-how mind, as that is comparable to almost any series up to Formula 1), there is a downside. Almost every part on the cars will be spec, not simply tightly regulated, but sourced from single suppliers. NASCAR issued tenders for all of the components, from the main chassis frame, to wishbones, uprights, springs and dampers. The concept being that each of the teams will get a slice of the manufacturing pie, one making the suspension arms, one the chassis, etc. Theoretically, this means there will be no variation in componentry from one team to another, but remember, this is NASCAR. It can almost be guaranteed that the race teams are already investigating ways to add their own personal touches to the racecars, flying under the radar of NASCAR's tech inspections.

NASCAR has been testing 2021 spec racecars (above). The new rules will bring sweeping changes, including sequential gearboxes, modern suspension and composite bodies

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World class

With its elevation to FIA world championship status in the bag and 11 works squads on the grid, Formula E is in a very good place right now – but how have new sporting and technical rules affected the teams? *Racecar* went to season six's opening round in Saudi Arabia to find out

By GEMMA HATTON

For the first time in motorsport history Audi, Mercedes, BMW and Porsche are competing as factory entities in the same series

With 11 of the 12 teams manufacturer entries Formula E has the sort of works interest that other series can only dream of. Its sixth season kicked off in Saudi Arabia in November

Whether you like or even agree with the concept of electric cars or not, you simply cannot deny the monumental success of the Formula E championship, which has now been granted world championship status by the FIA, from season seven (2020/2021) onwards. With the category's sixth season already underway, the grid is now 26 cars strong with 11 of the 12 teams manufacturers, including Mercedes-Benz EQ and TAG-Heuer Porsche, who have both entered their rookie season in the championship. This means that for the first time in motorsport history Audi, Mercedes, BMW and Porsche are competing as factory entities in the same series. The closest this had come to pass previously was the 1999 Le Mans 24 hours, although on that occasion the Porsches entered were customer cars.

Alongside the new teams sits some new technical and sporting rules for season six. With each rule carefully designed and implemented to make driver skill and energy management strategies more crucial than ever before, season six could be the most competitive FE championship yet.

Porsche had a successful Formula E debut, picking up a second place at the Diriyah E-prix

Six pack

It was certainly competitive at the Diriyah E-prix in Saudi Arabia, which hosted the first two rounds of the 2019/2020 championship. Drivers using German manufacturer powertrains swept the board, with a win apiece for the BMW i Andretti Motorsport and Envision Virgin Racing, the latter running a customer Audi powertrain. Meanwhile, both the new entries from Porsche and Mercedes secured podiums despite issues in pre-season testing in Valencia – the former with a surprise second place for Andre Lotterer in race one, while Mercedes driver Stoffel Vandoorne claimed a double podium with two third places.

'We thought at the end of the season, maybe we'd have a podium, but now [to get one] in the first race, it was really good,' Porsche's vice president of motorsport and head of group motorsport at Volkswagen AG, Fritz Enzinger, told *Racecar*. 'I think it was important for the whole team, showing that, okay, we are going in the right direction here. You can see

New sponsors are also flocking to FE, Rokit signing up with Venturi at the start of the season

'It is the same team as on the Porsche 919 LMP1 programme, they have a lot of experience with the hybrid and it's really counted'

Subtle changes to the regulations on both the technical and the sporting side have already had a major influence on the racing

what it means for them, it's everything we wanted. It is the same team as the 919 programme [in LMP1] and so they have a great deal of experience with the hybrid, and it really counted. This is important, [as] you have young engineers who in the last six to eight years have had experience of some of the highest levels of racecars.'

New rules

But it's not just the arrival of the new works teams that is going to make season six so competitive. Although the regulations have largely stayed the same, subtle changes on both the technical and sporting side have already had a major influence on the racing.

Firstly, the red flag procedure is now faster to maximise on-track action. Secondly, there is now one championship point available for the top driver in the group qualifying stage, and three up for grabs for the driver that secures Super Pole. Therefore, the total number of championship points now available for each driver at each race is 30; one for qualifying, three for Super Pole, 25 for a race win and one for the fastest lap.

The qualifying format has also changed, which has led to a great deal of discussion throughout the paddock. Prior to season six, the qualifying groups were drawn randomly. Whereas now, aside from the first round of the season, the qualifying groups are to be based on the provisional general classification of the championship, in terms of the points each driver has. The groups of a maximum of six drivers are formed in descending order according to the points table. Therefore, the drivers at the head of the points table go out first and have to try and set a time on a very green and dusty track. This is even more of a disadvantage in FE because the street circuits can take a long time to clean up and rubber in. Therefore, this should naturally mix up the grid and ensure that the quickest car and driver combinations will tend to be mid-grid at best.

'The strongest point for this championship, of having so many different winners and such a tight championship, is not because of the equivalency

There are new rules regarding energy usage behind a safety car or under a full course yellow

Jean Todt (left) and FE's Alejandro Agag shake on the world championship deal

There have been few technical rule changes for season six while most of the FE development is now focussed on software and control strategy

The biggest technical change is a reduction of 1kWh of energy from the batteries for every minute of a race neutralisation

of the drivetrains, but because of the qualifying format,' says Audi Sport driver Lucas Di Grassi. 'I am not against it and it is what it is for everybody. It creates a lot of entertainment on the sporting side, yes. From the qualifying systems that we have had, this is the best one for the show. Better than anything random that we did in the past. But the qualifying system is [still] not the best, people are not really excited about it.'

Flagging energy levels

From a technical standpoint, the biggest change is a reduction of 1kWh of energy from the batteries for every minute of a race neutralisation or suspension, such as periods under safety car and full course yellows. The motivation for this rule came from the FIA and the race promoters, Formula E Operations, who were unhappy with the fact that teams would save energy during these periods which meant that they could then drive flat out for the rest of the race. Not only does this go against the energy-saving philosophy of Formula E, but it also resulted in an increased number of crashes and damage towards the end of the race.

'Last year there were quite a lot of red flag incidents and accident damage which is not ideal,' says Craig Wilson, who is the race director of Panasonic Jaguar Racing. 'This year by reducing the power by 1kWh for every minute of yellow flag or safety car, that is going to put a lot more focus on energy management. So we probably won't see as many cars attacking early on in the race as they will be saving energy for later on. Generally, energy management is going to play a much more significant role this year than it has in the past.'

Although crashes and damage may sound entertaining, the reality is that if everyone is driving flat out, overtaking, actual *racing*, is much more difficult. Whereas if drivers are managing energy, the difference in pace can actually increase the likelihood of an overtake.

The new safety car rules have been designed to spice up the on-track action later in the race

'Managing energy does actually encourage overtaking because when people are having to lift and coast they are carrying different levels of speed,' explains Gary Ekerold, sporting manager at the Jaguar team. 'When everyone is flat out they are all running at the same pace so it is almost impossible to overtake. I actually think by introducing this new regulation we will actually see more overtaking, especially towards the end of the race. It's exciting racing and currently there are not one or two

A new qualifying procedure, which has the drivers with the most points running on a green track early in the weekend, should help to mix up the grid and hence encourage overtaking

'We have got a fantastic championship here in Formula E; the racing is very exciting and the technology is future facing'

cars that are miles better than everyone else so we have got a fantastic championship here in Formula E; the racing is very exciting and the technology is future facing. We want to try and maintain that but continue to tweak the formula to make it even better.'

The Attack Mode that was introduced in season five is not only staying for season six but has now been boosted by 10kW to a total of 235kW. This defined zone at each circuit is set between a special set of transponders and drivers can activate a power boost by driving through the zone. The number and duration of 'attack zones' is decided at each event by the FIA due to the different characteristics of the street circuits that Formula E uses. When the car is in Attack Mode the Halo glows blue.

'There was a lot of scepticism around Attack Mode at the start of last season and I think it really was a huge success,' Wilson says. 'Attack Mode is something we live with now and I think it's a really interesting component. This year there will be an increase in power available (235kW) in Attack Mode so that will play an even more important role in racing.'

Another alteration to the Attack Mode rules is the fact that it now can't be activated for the first two laps of the race or when the cars are under a safety car or full course yellows. This forces the drivers to activate it under full race conditions, which means the time they lose going off-line is greater than if they were to activate it under a safety car or yellow flag. Therefore, the drivers and the teams will continue to face the dilemma of whether it is worth going off-line to activate it, and risk losing a position, to to gain that all important boost in power later on.

'The extra 10kW power in attack mode is easier for overtaking and given the nature of the tight circuits where track position is paramount, makes qualifying lower down [potentially due to group qualifying] slightly less painful,' says Virgin Racing's technical director Chris Gorne. 'Non-activation under SC/FCY [safety car, full course yellow] takes away an uncertainty that a competitor could gain an advantage later in the race if you had already used your activations, which was previously hard to defend against and occasionally ended in tears.'

The development race

In terms of the technical development that is ongoing in the Formula E championship, the area where the teams are now making the most gains is in software and control strategy. Indeed, many Formula E race engineers have stated that 'what aerodynamics is to Formula 1, the software is to Formula E.' This is why the new Jaguar i-Type 4, along with other FE cars, now features increased processing capacity.

'Any increase in capacity you can give yourself to be able to either develop more software, carry greater computing capacity on board, or achieve multiple functions with the software is critical,' says Ekerold. 'So it is very important to develop as much as you can on board while minimising weight. Being able to constantly have the latest processing power within the vehicle control module on the car helps this drive for software development and we have a whole team of people at Jaguar whose role is to develop new software for the racecar.'

The generation game

The next generation of Formula E racecar (the Gen3), to be introduced for season eight (2022/2023), is to include rapid charging with full front axle regeneration on what will be two-wheel drive designs. The plans for this have been largely agreed, and the idea is that the racecars will be difficult to drive fast, and that energy-boosting pit-stops with rapid charging will also be introduced.

The full front axle energy recuperation will also allow the Formula E team's designers to reduce the weight and the size of the battery due to gaining more energy from the regen.

Meanwhile, the FIA has set out a separate tender to companies that can supply rapid-charging infrastructure and hardware that is capable of charging a car within 30-seconds. The main concern is believed to be around how rapid charging could affect the chemistry of the Gen3 battery. The charging of batteries in a short time during a pit stop using, as an example, 800 volts, could have detrimental impacts on chemicals used in the battery and as a result cause thermal issues.

Professor Burkhard Goeschel, president of the FIA's Electric and New Energy Championship Commission says: 'That is still a challenge because you see the race duration which is less than one hour and we don't get more time, so if you go to fast charging it will be short. We cannot fill up the whole battery with energy so even then it has to take seconds, not minutes. That means that the charging power is becoming very high and so we have to manage it because if the charging power is becoming high then it's influencing the technology and the chemistry of the battery because batteries are normally [charged] slow. The processes on the electrodes are normally slow and if you are going far beyond you have to take care about the chemistry of the battery electrodes and how to manage that.'

Rapid charging in the pits during a race is set to become a feature of Formula E in season eight (2022/23)

Taking charge

Goeschel also says he and the FIA have had to delicately balance the rapid charging concept in order to avoid reliability issues with the new Gen3 package: 'I have to say that fast charging is forcing us to go a little bit to the extreme and so we have to look at how we save on this side, that we are not damaging the battery because it has a lifecycle of a full season. Now we are investigating and we are preparing a tender for that, but we have to investigate how to handle this issue.

'Our intention is to go in this direction because it is interesting from a sporting perspective,' Goeschel adds. 'But it is also interesting from the technology side because everybody wants to reduce the charging time and it might be that we can make a step forward to improve that.'

Sam Smith

Born free

With few technical regulations World Time Attack Challenge is racecar design heaven, but what sort of machine results when you're not hamstrung by the rules? To find out we asked one of the men behind the 2019-winning Porsche 968-derived RP968 to talk us through its development

By DEJAN NINIC

I f you have never heard of an Australian racecar known as RP968, then you're in for a treat. For while it might not have a flashy name, this is by no means an understated car. It's also a mighty quick machine, as back to back World Time Attack Challenge (WTAC) victories attest.

Regular readers of *Racecar* will be familiar with WTAC from a number of Danny Nowlan's features. In a nutshell this Australian series is close to anything-goes, over one lap against the clock; a recipe which throws up some *very* dramatic looking racecars. RP968 is no exception, but here we intend to go beyond the huge wings and reveal the real numbers, the actual data and the design philosophy behind this phenomenal racecar.

But first, that name. The '968' part of it is from the base car, a Porsche of that type, while the 'RP' stands for Rod Pobestek, the owner and the person behind the project, a man who said: 'I don't care about winning the event, I want to make the fastest car possible', after I expressed my extreme satisfaction that the lap-time of 1:19.2778 just posted by driver Bart Mawer was fast enough to set a new tin-top lap record at Sydney Motorsport Park (SMP) and, very likely, fast enough to win the WTAC event.

Pobestek, you see, had greater expectations and his goal was actually to set a new outright lap record, to beat the lap time that was achieved by the A1GP car driven by Nico Hulkenberg back in 2007, a 1:19.142. But then that's Pobestek, he's extremely competitive.

The Yokohama World Time Attack Challenge is the perfect playground for racecar designers to release their imagination and challenge their expertise. When Pobestek came to WTAC in 2014 and saw how differently each competitor interpreted its technical liberties, his life-long dream of making the fastest and most awesome Porsche 968 ever had a domain. Exactly one week later, Pobestek, Dr Sammy Diasinos (Dynamic Aero Solutions), Richard den Brinker (PR Technology) and yours truly (TT Suspension) gathered to discuss the opportunity and possibility, and to determine how his dream could eventually become a reality.

I've been engineering chassis, suspension and drivers in WTAC since 2010. I had experience with the tyres and the event. Diasinos had a

The World Time Attack Challenge is the perfect playground for racing car designers to release their imagination and challenge their expertise

decade of Formula 1 aerodynamic design and analysis experience. Den Brinker and his team can make anything – the harder the challenge the more interesting for him. So fast-forward five years and the dream hasn't just come to life, it's been reborn twice-over, thanks to CFD, FEA, lap-time simulation, welding, cutting, gluing, tuning and many sleepless nights. With each rebirth the car has attacked SMP (Sydney Motorsport Park) each year with another step gain in performance at a rate so quickly that it seems now that RP968 may only be competing against the clock, at least until the rise of a successor.

No holds barred

It's no secret that RP968 has the most-admired aerodynamic package of any WTAC car. Dynamic Aero Solutions has been involved in the design and evolution of the car's aerodynamics since the project was a dream. Over the last five years the full-car 3D CFD model has seen over 400 iterations, with Pobestek driving forward the evolution as he quickly learned to read the CFD data. **Figure 1** displays the gains in downforce and efficiency with each iteration.

The significance of Figure 1 is that the starting point (100 per cent) is the initial design of the body shape of the entire car that Pobestek imagined and Diasinos sketched. At the time, even Diasinos believed that this was a sensible and logical aerodynamic design: 'If it looks right, it must be right'. And it had all the right elements in the correct locations.

At this point in the design phase most WTAC car designers will stop designing and will make a start on manufacturing the racecar. For most the biggest concern is the time-frame. However, in the case of RP968, before any moulds were cut or fibres laid, the shape of all of the surfaces was optimised almost 200 times using CFD; and the predicted downforce increased by more than a factor of three while the efficiency more than doubled. We can see from Figure 1 that the gains with each iteration were almost linear with each step.

Fluid thinking

The above highlights the power of CFD over track testing or wind tunnel testing alone. CFD provides numerical and visual feedback of the effects of the changes and guides us in the specific areas of optimisation. It's not to say that the solution will be complete with only CFD, but for those looking not only to improve, but also understand the aerodynamics, CFD is a very powerful tool. CFD has made RP968 the car it now is, in both appearance and performance.

For those familiar with aerodynamic terminology, the best configuration of RP968 had a CL of 8.6 and an efficiency of 5.6. The theoretical aero balance was 48 per cent on the front axle with a static front mass distribution of 57 per cent. At 250km/h this equates to 37.5kN of downforce and 7.5kN of drag, requiring 521kW of power to overcome the drag at that speed. These forces are distributed as follows for the four major aerodynamic components: Front canard/wing/bar assembly: 29 per cent of the downforce and 19 per cent of the drag. Floor and diffuser assembly: 55 per cent of the downforce and 28 per cent of the drag. Rear wing assembly: 21 per cent of the downforce and 27 per cent of drag. Body: -5 per cent of downforce (i.e. lift) and 26 per cent of drag.

As the aerodynamic potential evolved in simulation and on track, Pobestek could see that the standard engine block and modified head that featured in the first version of RP968 would eventually lack the structural integrity to produce the power levels required. At the start of the project, 650kW (872bhp) engine power was deemed sufficient. Indeed, many believed that Pro Class WTAC cars needed to be four-wheel drive to convert such significant engine power into longitudinal acceleration.

But driver-in-the-loop simulations that Diasinos and I performed highlighted one important relationship: downforce creates tractive capacity. We could create more grip on the driven wheels with more downforce. So, as downforce increased, the necessity for 4WD reduced, and adjusting the aero balance rearward supported this gain.

I double-checked the tyre model load sensitivity and even adjusted it to be more conservative. The performance formula was now discovered and needed to be proved on the race

It's no secret that RP968 has the most-admired aerodynamic package of any of the WTAC cars

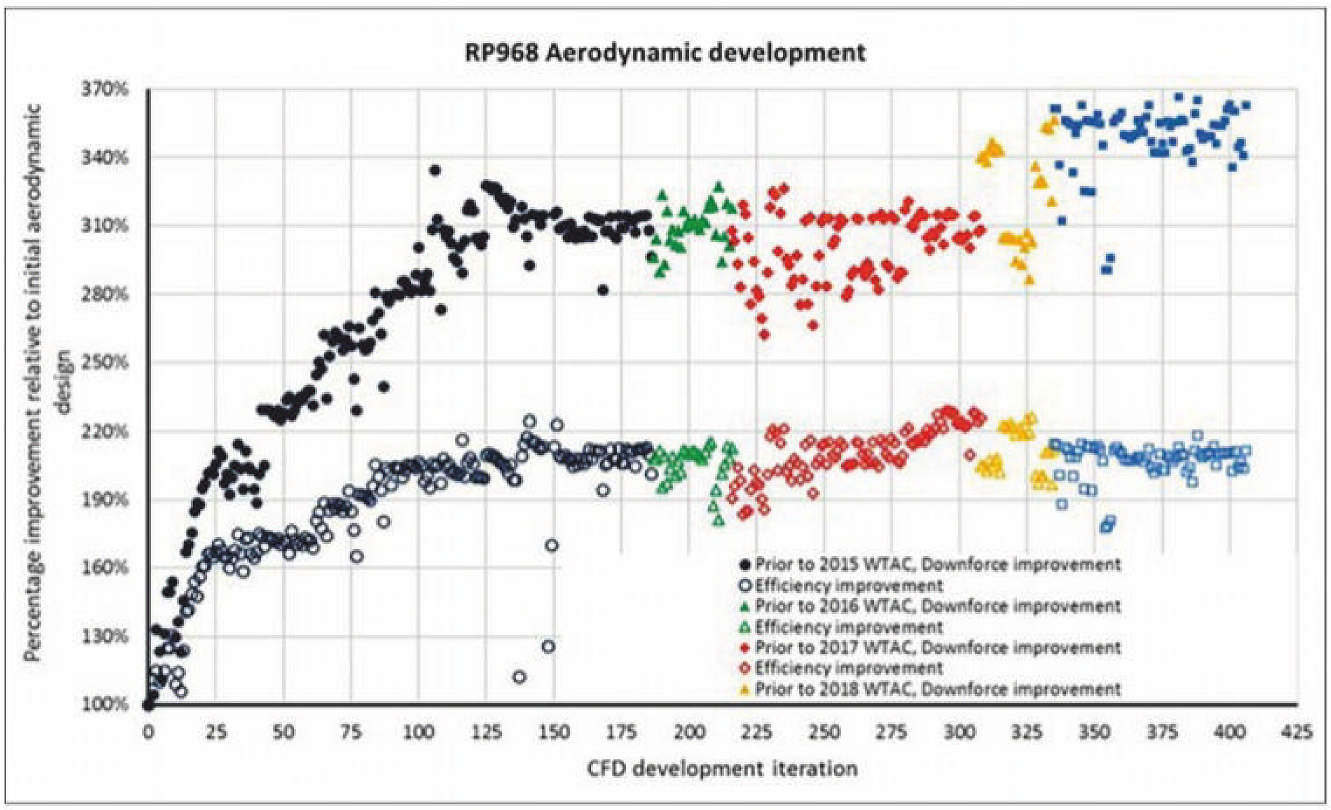
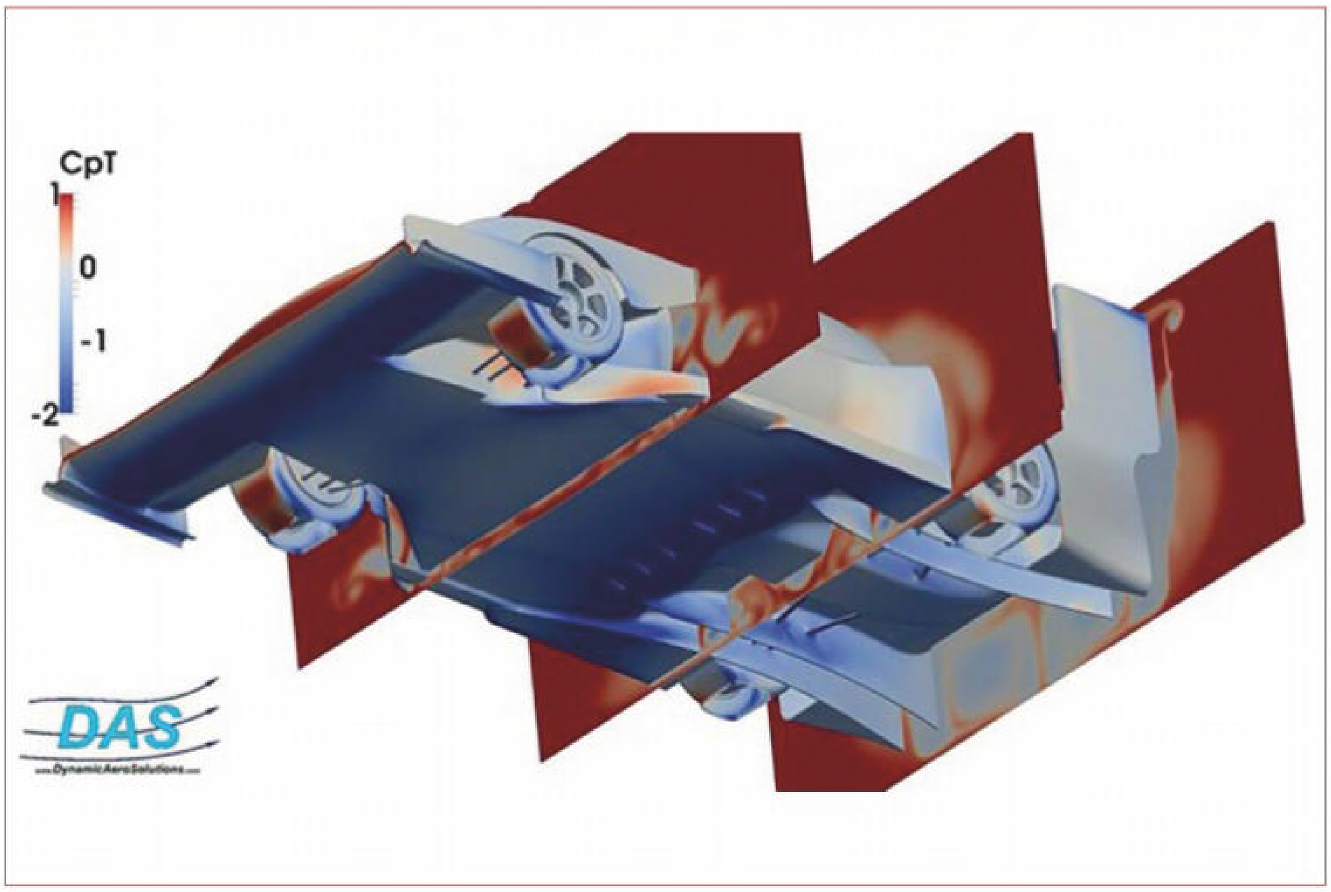


Figure 1: Aerodynamic performance improvement per CFD iteration. The starting point at 100 per cent is the initial design



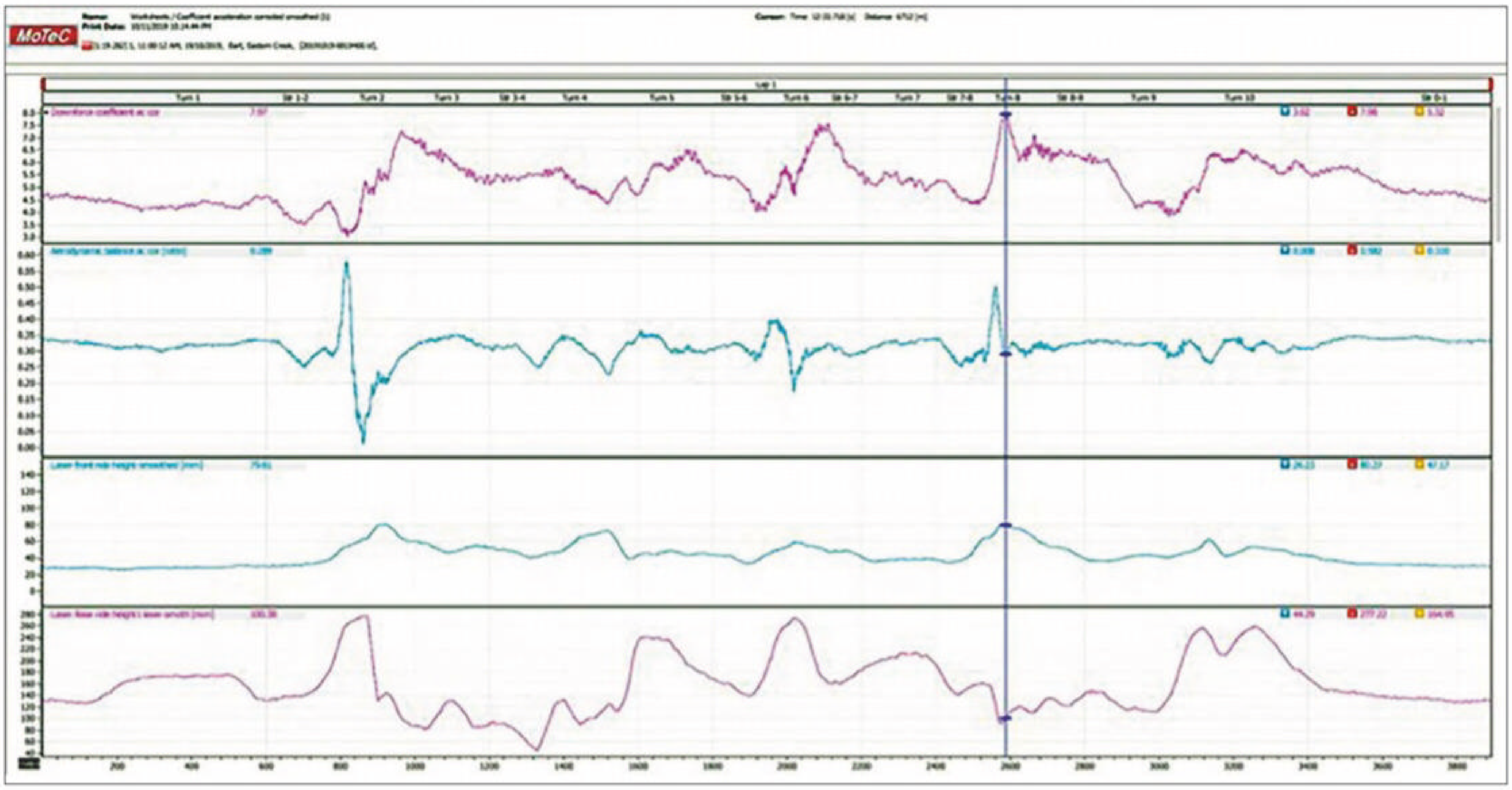
Flow visualisation under the car. The shape of all the surfaces was optimised almost 200 times during the CFD design stage track. With limited testing, a brave driver and an engine on its last legs at that point in time, we had proven one of the keys to the blistering performance of RP968: more downforce and more power, while maintaining efficiency and driveability, even at the cost of other seemingly critical performance characteristics such as the CoG position and the car mass.

With that information at hand Diasinos went on a mission designing a new front wing assembly, triple-element rear wing, improved bargeboards, wheel drums and a series of detailed vortex generators. Meanwhile, Pobestek and PR Technology delved into the power generation and I was left wondering how we would hold the chassis off the ground, retard it for the slow corners and coach Bart Mawer with driving it beyond what was known.

Pobestek's vision of a billet engine came to life in 2018 with the support of Elmer Racing in Finland, but it would require a further year to mature into the powerplant it is now. Additional new engine hardware, as specified by Pobestek in agreement with PR Technology, was selected with strength as a priority, with the new assembly said to be capable of withstanding 1200kW (1600bhp). With the newly promised structural integrity, Matt Gillmer from PR Technology was given the freedom to design the optimum powertrain with the agreed focus on driveability over outright power. However, where Gillmer earns his nickname, Magic, is in selecting components and engine operating parameters seemingly out of thin air, to produce a powerplant that works effectively almost immediately. The true magic is evidenced in the new engine package for 2019, coming together in just two weeks and running smoothly, including the gearshift operation, immediately as the team at PR Technology worked through day and night to get the car completed.

Talk the torque

In parallel with the RP968's design philosophy, Gillmer is persistent in the search for truth through numbers and testing, as proven with the latest addition of drive axle torque sensors – to measure the real power being



Aero data derived from damper strain-gauges, corrected for load transfer. The design philosophy was to pile on as much downforce as possible so as to be able use all the power

The aero treatment is extreme, to say the least. The floor and diffuser provide 55 per cent of the downforce, while that whopping rear wing brings a further 21 per cent

delivered under all conditions. Gillmer's style is not different to Diasinos' or mine. He spends the majority of the time during the design phase on the computer, running engine simulations considering volumetric efficiency, turbocharging system efficiency, and the fundamentals of tuning: injection and ignition.

The combination of the large swept volume and the new-to-market Garret G42 turbo not only gives RP968 a measured, reliable 860kW (1150bhp) at the rear wheels with a boost of 1.75bar, it also offers a very flexible power delivery, which has been the strength of the RP968 engine package since the first outing. Transmission of the torque to the transaxle is via a custom carbon fibre tail-shaft, housed in a carbon fibre torque tube complete with titanium rapid-prototype end housing – produced by Bastion Engineering – saving 12kg over the standard Porsche 968 torque tube.

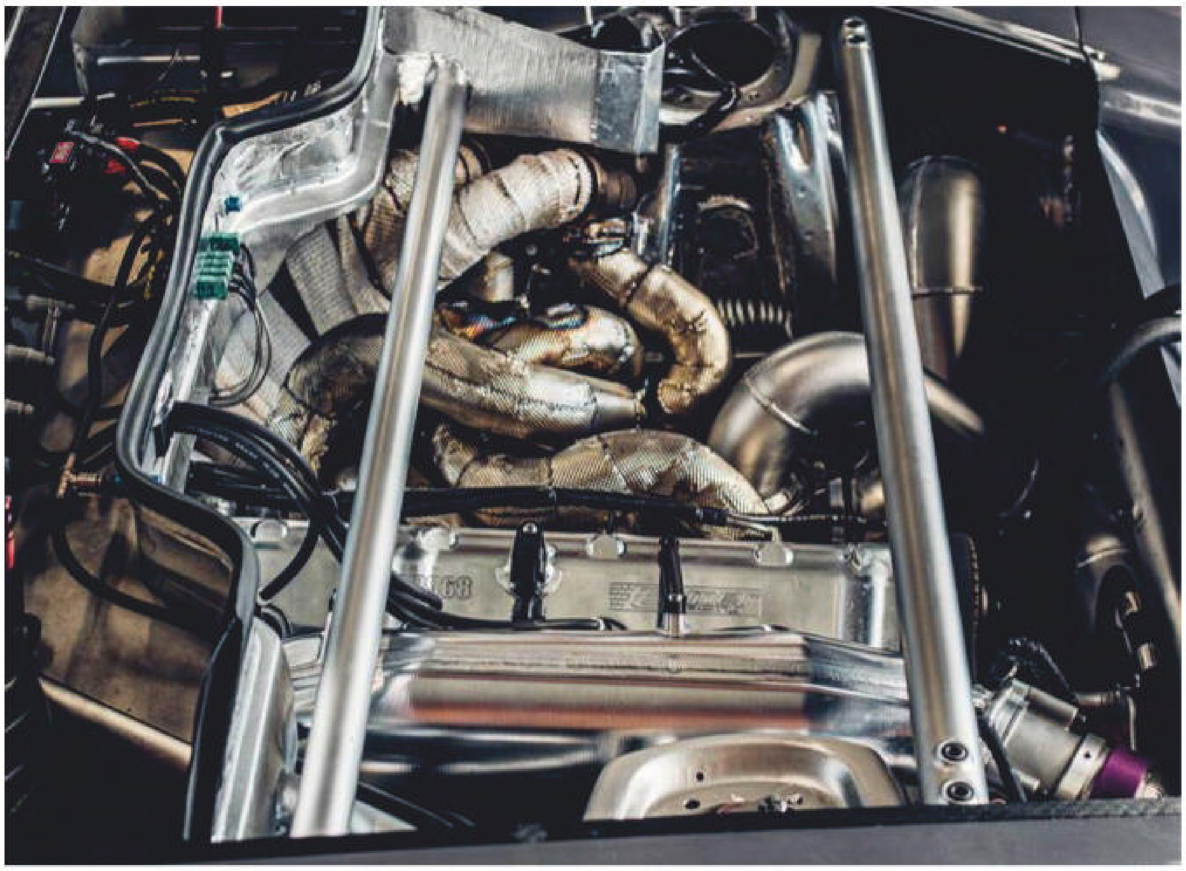
Electric shock

One of the key components that separates RP968 from all of the other Pro Class WTAC cars is the electronic suspension. The dampers in RP968, manufactured by Tractive Suspension in Holland, feature the company's patented DDA

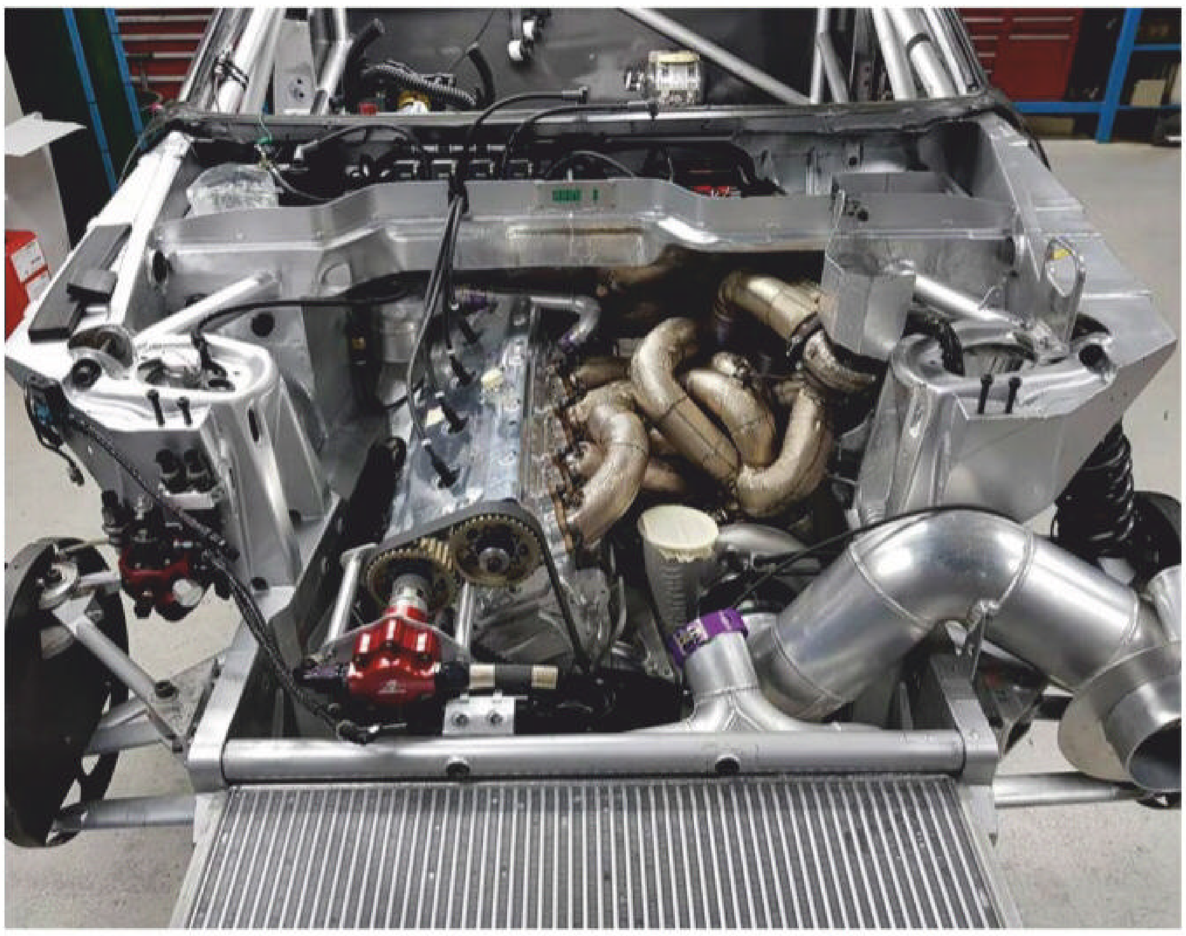
One of the key components that separates RP968 from the other Pro Class cars is the electronic suspension

solenoid valve. This valve can vary the damping ratio from approximately 0.1 to approximately 4.0, and anywhere in-between, at a rate up to 160Hz by controlling the piston bypass oil flow. The construction of the dampers is otherwise conventional with a piston, shim stack, remote reservoir and gas pressure of 30bar to create a stable environment against cavitation when the damper is asked to work its hardest. With such a wide range of damping stiffness available and fast response time, these dampers can be programmed to minimise tyre vibrations and control contact patch force variation. Inputs to the dampers include driver mode selection, lateral and longitudinal acceleration, damper position, damper speed and we have also been investigating lap-distance mode selection for fast/slow/smooth/bumpy sections of the track.

With the RP968, the dampers are predominantly used to control the platform of the chassis for optimum downforce and



Elmer-built engine produces 860kW (1153bhp). It's been designed with driver-friendly power delivery in mind



Boost for the 4-cylinder, 4-litre unit is via a Garret G42 turbocharger, while the cooling system is from PWR

While the dampers are electronic the geometry is classic double wishbone. Porsche brakes are linked to Bosch ABS system

Table 1. RP968 set-up and suspension specifications		
Parameter	**Front**	**Rear**
Total mass with driver and fuel	1216kg	
Mass distribution	53%	47%
Ground clearance at axle line (min. 50mm)	65mm	75mm
Wheelbase	2690mm	
Track (wheel centre-line)	1867mm	1867mm
Static camber	-3.2-degree per side	-2.4-degree per side
Static toe-in	0.0mm	2.0mm per side
Caster	9.4-degree	
Ackerman	Parallel steer	
Steering ratio	15.9:1	
KPI	18.8-degree	17.5-degree
Scrub radius	35.0mm	
Caster trail	30.7mm	
Static roll-centre height	36.9mm	84.9mm
Camber gain in heave	-0.017deg/mm	-0.174deg/mm
Motion Ratio	0.75	0.80
Main spring rate	400N/mm	350N/mm
Tender spring rate	70N/mm	60N/mm
Damper travel (metal-to-metal)	80mm	80mm
Bump rubber stack	3 x 20mm cone	3 x 20mm cone
Bump rubber engagement at ride	0.0mm	12.0mm
Roll sensitivity	0.271deg/G	
Front Lateral load transfer distribution	53.2%	

balance while still providing ideal wheel control for ride over bumps and kerbs. The DDA valve opens and closes as a function of the current running through the solenoid and the system draws, at most, 10 Amps. Coupled with remote reservoirs that are equipped with mechanical low-speed and high-speed compression damping adjustments, we can achieve excellent platform control and still have compliance over bumps and kerbs. With each damper able to be individually adjusted every 6ms, we can choose to control the platform with only one or two dampers through the transient phases and release the other dampers if we measure any significant tyre slip on a particular tyre.

Geometry set

The layout of the suspension geometry is as simple as it gets, with the classic double wishbone arrangement. The lower control arms are made from tear-drop cross-section CrMo tube, as they are in the airflow, while the upper arms are shielded within the bodywork to eliminate their negative impact to the air flow around the suspension members.

Table 1 summarises the suspension dynamics and kinematic parameters and **Figure 2** displays the rear damping rates and their range as a function of the current passing through them. The packaging of the suspension has the dampers off the upper arm and mounted directly to the chassis. The lack of push or pullrod off the lower arm has cleaned the airflow around the wheels, which is an area that is exploited in the aerodynamics. Rockers were omitted to mitigate compliance and reduce overall mass. The car was originally designed without anti-roll bars but they are now used, to reduce the body roll at low speeds. RP968 currently achieves lateral accelerations of 2.6*g* at 265km/h and 1.4*g* at 75km/h.

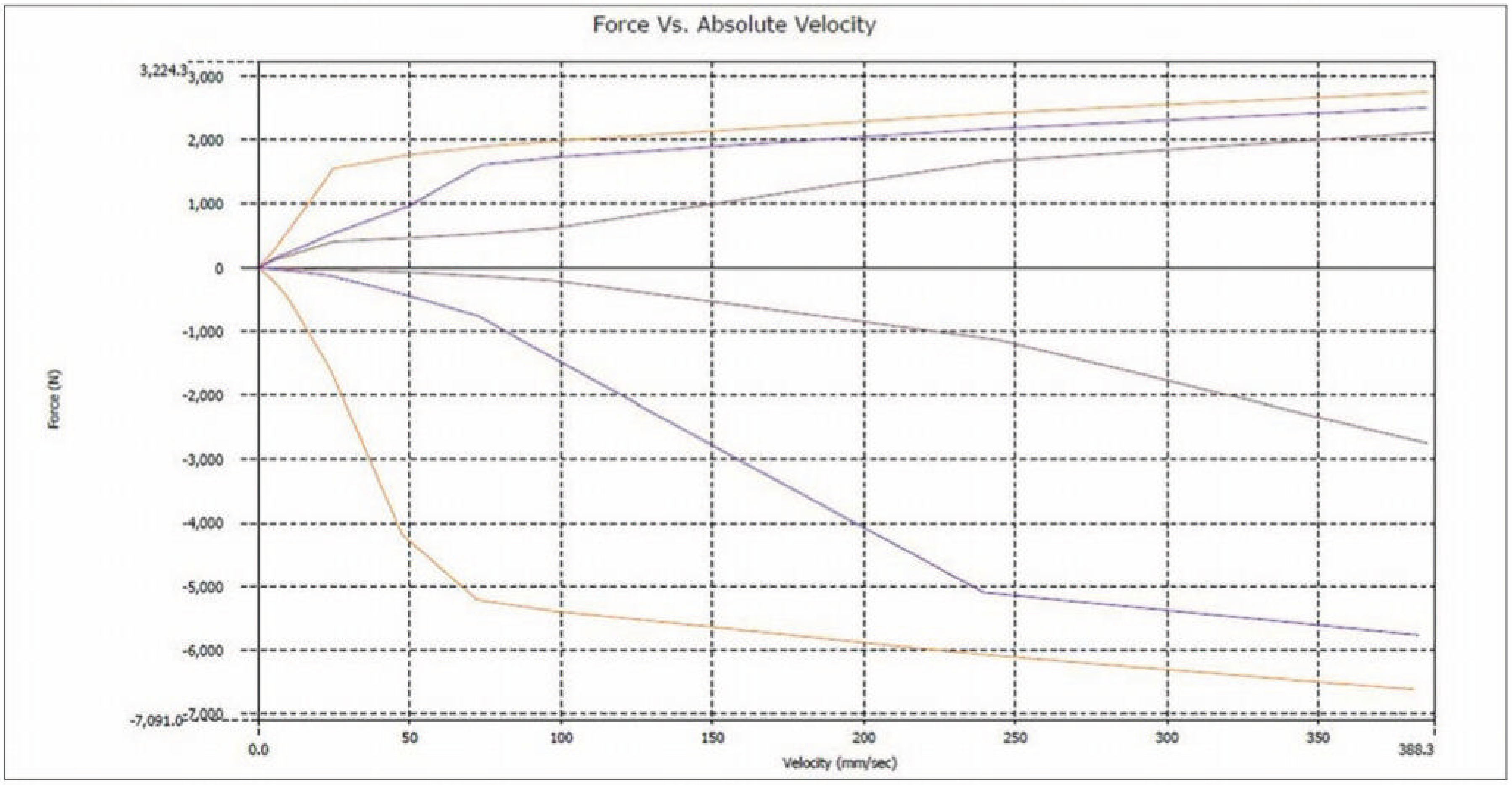


Figure 2: The rear damping rates at typical currents, and their range as a function of the current passing through them. Currents shown are 1.5A, 1.0A and 0.5A

If there is a secret to the success of RP968 it's that every step of design and development has seen simulation, investigation and scrutiny

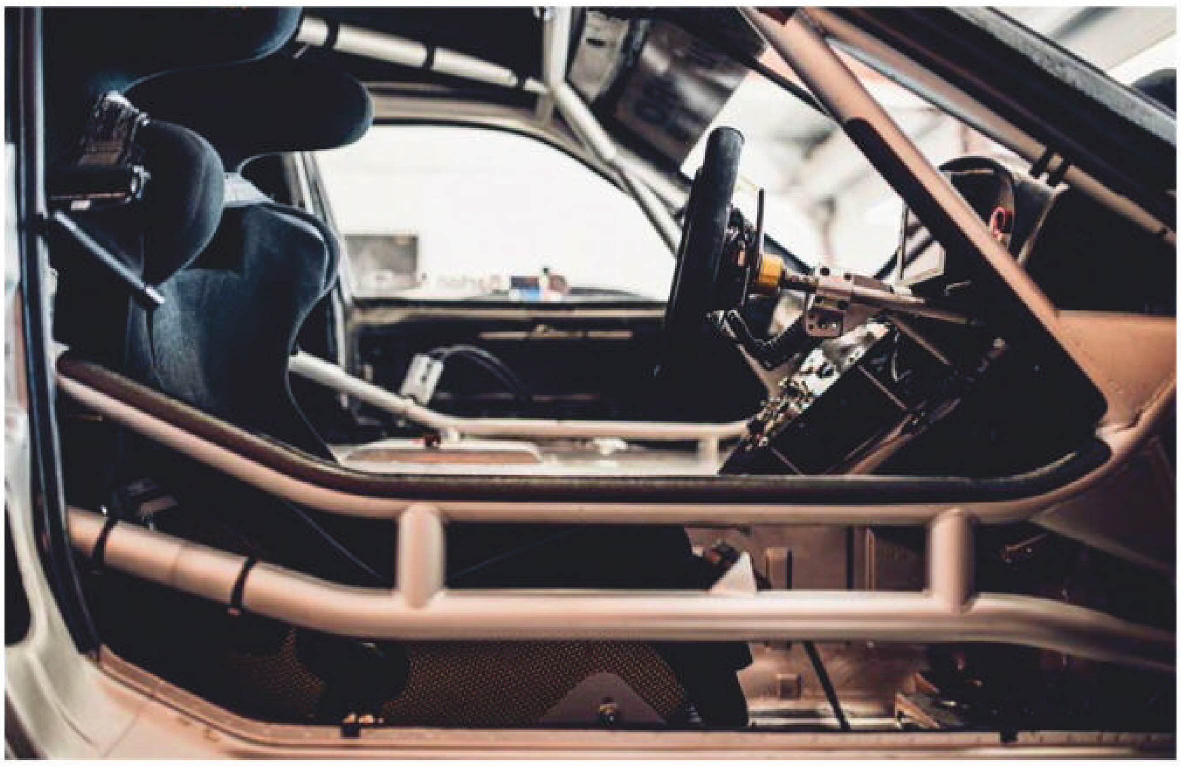


Photo: Lee / Gas Images

FIA spec cage fits within a CrMo sheet and steel tube chassis. Only 40 per cent of original 968 shell remains

RP968 uses the brakes only six times around SMP, with a maximum retardation of, typically, 2.3*g*. The brake discs are carbon ceramic material and sintered metal pads, providing the benefits of low mass and excellent friction. The maximum recorded pad temperatures have only reached 380degC, while the manufacturer indicates a peak coefficient closer to 500degC. The brake calipers are PFC, taken from the Porsche 991.1 GT3 Cup racecar. Wheel lock-ups are eliminated thanks to a Bosch motorsport ABS system, but it's being used more as a stop-safe tool, rather than giving the car the ability to brake super late, as is the case with current generation GT3 cars.

Chassis evolution

To tie all of the elements together, the chassis has seen significant design and evolution. As the principal designer of this and the suspension my vision for the car was to achieve lap times of 1:17.0 around SMP, which meant having a chassis capable of withstanding 3*g* cornering and 3*g* braking loads as well as vertical impacts from kerbs and bumps of up to 6*g*.

The regulations were exploited to their maximum at the time of design so only approximately 40 per cent of the original chassis was retained. The proposed chassis structure was modelled using FEA and the target chassis torsional stiffness, measured front suspension top mount to rear suspension top mount, of 10,000Nm/deg, was achieved, for a mass of 235kg (42.5Nm/deg/kg) which we considered heavy. In the following years the chassis has been optimised to over 13,500Nm/deg and had over 40kg of mass removed (69.2N/deg/kg).

The key to the chassis performance of RP968 is not the steel chassis, but the integration of the carbon body panels. The floor, diffuser, front wheel fenders, rear wheel fenders, roof, tail piece and front wing assembly are designed so that when they are assembled to the steel frame and to each other, they significantly increase the stiffness of the car. All body panels and aerodynamic appendages were also analysed with FEA. Careful observation of the competitor cars will show that almost all teams are still favouring low-mass construction to their body panels and not taking advantage of the load bearing capabilities of composite materials.

Wizards of Aus'

While CFD, FEA and simulations have played a significant role in the decision-making process of the design and development of RP968 the human element should not be forgotten, and particularly the input of driver Bart Mawer, who has played a bonding role to keep all the individuals working as a team. He has also helped solve many of the difficult design problems thanks to his daily efforts designing and fabricating racing car components.

If there is a secret to the success of RP968 it's that every step of design and development has seen simulation, investigation and scrutiny, and Pobestek has been at the centre of it. Attendees at the event this year would have observed, after each track session, a lengthy debrief involving the driver, engineering team and, of course, Pobestek, who wants to know every decision and the reason for it. The policy is simple and respectful. Everyone can contribute and make suggestions for improvements, and there are no bad ideas. This process is unlike any other I have experienced in my career. That's the one element of RP968 that can't simply be replicated and will be difficult to beat. As will the car.

TECH SPEC: RP968 Porsche 968 World Time Attack Challenge car

Chassis
Porsche 968 (1992) chassis modified with CrMo sheet and CrMo steel tube. Stiffness optimised using FEA. FIA homologated CrMo safety cage.

Body
Carbon fibre and Kevlar reinforced epoxy. Combination of resin-infusion and pre-peg methods. Designed to integrate with steel chassis to increase chassis stiffness.

Engine
Elmer Racing billet aluminium block, custom head and dry sump; 4-cylinder; 4-litre. Martini Racing E85 petrol. Garret G42 turbo with Custom twin scroll exhaust manifold; PR Tech Racing titanium exhaust system; Custom Plenum Creations billet aluminium inlet manifold; Turbosmart blow-off valve and dual 50mm wastegates.

Transmission
Albins ST6 transaxle; 6-speed, semi-automatic paddleshift; mechanical limited slip differential; 80mm diameter filament wound carbon fibre tail-shaft.

Cooling
PWR customer radiator and air-to-air intercooler; PWR heat exchanger with auxiliary rear-mounted air to oil cooler; Pierburn electric water pump. All cooling duct shape, dimension and placement optimised with CFD by Dynamic Aero Solutions.

Aerodynamics
Custom designed front bar, front canards, floor, diffuser and rear wing providing downforce and aerodynamic balance adjustment. All surfaces developed using CFD by Dynamic Aero Solutions resulting in CL of 8.6, efficiency of 5.6 and aero-balance 48 per cent front.

Suspension Kinematics
Double wishbone designed with low roll-centres, 0% anti-dive, 0% anti-squat and minimum lateral scrub under heave and roll (1.7mm total/degree body roll). CrMo aerofoil section control arms; camber and caster adjustment by shim on upper control arm inboard chassis bracket.

Suspension Dynamics
Coilover dampers actuating directly off upper control arm into chassis; Tractive Suspension electronic dampers with remote reservoirs, damper length adjustment for droop and pre-load control; Tractive Suspension bump rubbers; Eibach steel springs; TT Suspension custom blade-type adjustable anti-roll bars.

Steering
Titan UK steering rack with programmable electric power steering gain; ±16-degree steer available at the contact patch.

Brakes
PFC Carrera Cup brake calipers; Corvette carbon-ceramic brake discs; Pagid RS3 brake pads; Bosch Motorsport ABS; Dual master-cylinder with driver brake-balance adjustment.

Electronics
Emtron KV8 ECU for engine management, gear-shift management and traction control; MoTeC C187 dash and ACL for data logging; Tractive TCU programmable electronic damper controller.

Sensor Technology
Texense damper strain gauges; Izze Racing wireless tyre temperature and high-speed pressure monitoring system; Izze Racing driveshaft torque sensors; Izze Racing laser ride height sensors; linear damper potentiometers; steering column torque sensor; turbo speed; exhaust gas pressure and temperature; Inlet; boost; manifold pressure and temperature; all driver inputs; front and rear 6-DOF gyros.

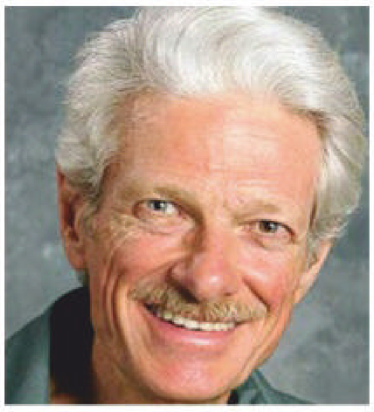
Seat
Racetech RT9129HRW; OMP Dyneema seatbelts.

Wheels
Rays TE37 11in.

Tyres
Yokohama A050 G/S (soft compound) 295/35/18.

Mass
Total mass with driver 1213kg; front mass distribution 53 per cent.

Dimensions
Wheelbase: 2690mm; track: 1867mm front and rear; length: 4740mm; width: 2085mm; height: 1330mm.



Roll play with a Rotax racer

The curious Novalink that is a feature of US F500 cars is the subject of a fascinating dialogue in this month's suspension master-class

By **MARK ORTIZ**

Rear end of an F500 racecar; note the pivoting frame with the two Panhard-type rods attached to it. The cars run with lightweight Rotax power units and are chain driven

Q Soon I will be designing an F500 car, and I have questions regarding their suspension. Above is a picture of a typical rear end; it seems to show two Panhard-like rods attached to a pivoting frame. The frame is hinged on both sides. At first I thought this set-up does not seem to allow any roll, other than that given by flexing of that frame. This may be part of the design intent, as the rules prohibit anti-roll bars. How do you determine the roll centre for this design? For F500 racecars, would there be an advantage to a low rear roll centre as found with the Mumford link?

Also, after studying the picture some more, I began to think that it looks like the axle can roll, if it is displaced sideways, per a four-bar linkage. But it would then roll in the wrong direction, causing the car to roll outwards in turn. I am confused.

THE CONSULTANT

A You're right, it can roll, and it has geometric pro-roll: roll centre below ground. The roll centre is essentially where the centerlines of the silver links meet, as it would be with a Mumford system. I've seen F500 cars occasionally but never had a client running one. It looks to me like they wouldn't be particularly tail-heavy since the engines are light. I would think that they'd have a tendency toward locked axle understeer, and that you'd want to have the inside rear relatively lightly loaded to combat that. Would that be correct?

Q That sounds reasonable, even according to my rookie knowledge. I take it that locked axle cars tend towards understeer, and that having a very low rear roll centre tends to load up the outside tyre, and is a way to remedy that understeer. It is interesting that many of these cars have long rear diffusers; wings are prohibited,

I think they would have a tendency toward locked axle understeer, and you would want to have the inside rear relatively lightly loaded to combat that

and the sportscar noses are limited to 1in front splitters, so the downforce is biased towards the rear. But would that not be a response to an oversteering car?

It bothers me that the axle location system that is shown allows some sideways movement of the axle, this on cars with chain or belt driven axles. A Mumford or Watt linkage would keep the axle centred. But apparently the movement is small enough not to be a problem.

A Actually, no, to the first question. A high rear roll centre results in more load transfer, other factors held constant. What sort of rear suspension do other F500 racecars have? The H-bar system has similar behaviour in roll to a Mumford linkage. The only real difference would be how the roll centre changes in ride or two-wheel heave. It stays the same height with respect to the ground, whereas with a Mumford it goes up and down some – exactly how depends on what variation of the system you are using.

If you started with a car that had a Panhard bar and was handling pretty well, and you substituted that system, without changing spring rates, you'd have a lot more roll and a lot more understeer. To have similar roll and similar understeer gradient, you'd need to spring the rear a lot stiffer. I'd stick with the Panhard bar, and make it adjustable for height.

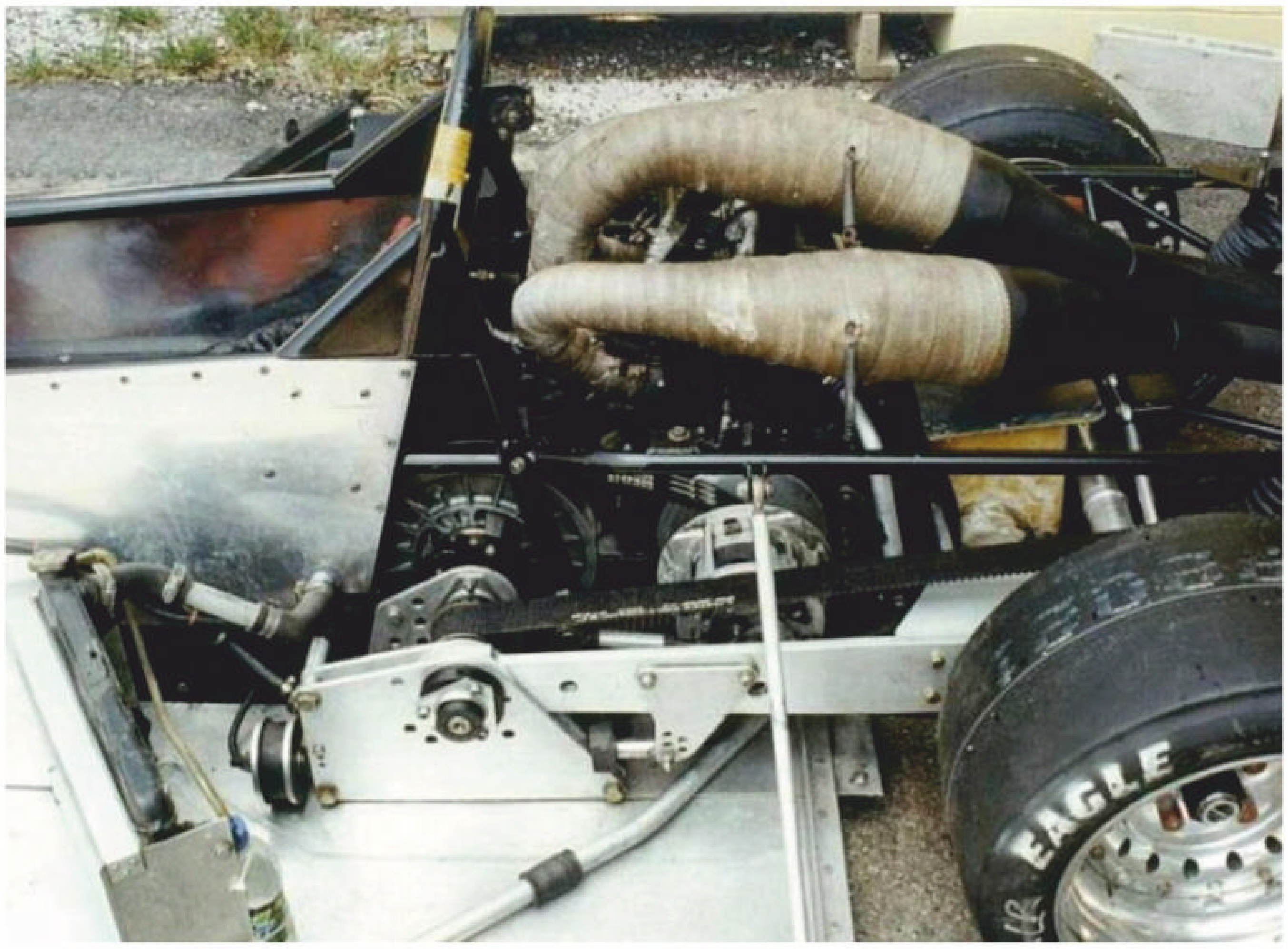
You could also be right that chain or belt retention would be more of a problem. There definitely would be more lateral movement at the top of the sprocket or pulley. Whether it would be enough to cause an issue would have to be determined by testing it.

Q After searching I found a little more information; a website which states: 'The car is converted to a modern 4-link suspension with a unique H-bar axle locator set-up, as opposed to a standard Panhard bar. This H-bar design is a collaboration between a few folks including the ex-head of Ford NASCAR suspension development.'

Another bit of information I found said that the F500 rear suspension was invented by Jay Novak, a suspension design engineer at Ford – and the man mentioned above.

I have also found mention of a DSR car which was derived from an F440 car, which has a description including the Novalink suspension (as it is called, after Novak). It appears to me that since it looks like an A-arm suspension from the side, that the birdcage/brake caliper could be integrated with the H-arm to produce anti-squat, something that Jay Novak has never incorporated, to my knowledge.

A The DSR car appears to have a very different version of the suspension than the first car, although I would say it qualifies as another example of the basic idea. In one picture I have seen I think I can see enough to determine that the H-link, as the swinging frame is apparently called (short for horizontal, I take it, since it isn't H shaped) is behind the axle and slightly above it, rather than ahead and way below, and the lateral links with rod ends slope upward at a shallow angle toward the H-link, rather than steeply downward, while the system has two trailing arms instead of four parallel trailing links.



The DSR racecar has the same swinging frame, or H-link, set-up as is seen on the F500; but there are some key differences

To have a similar roll and understeer gradient you would need to spring the rear a lot stiffer

When the lateral links are close to the horizontal, small changes to their length produce relatively large changes in the roll centre height. In theory, at least, they cannot be perfectly level; the system binds in roll if they are. This is one difference between this system and a Mumford linkage.

With four trailing links as on the first suspension you showed me, you can get anti-lift from the brake just by giving the trailing links some convergence toward the front, but with a single brake it's probably not a good idea because the downward jacking force would act off-centre and change the car's dynamic diagonal percentage. With trailing arms, as on the DSR car, the brake does produce considerable off-centre anti-lift if there's only one brake. Using a brake on each trailing arm would fix that. Using a brake on each birdcage would also allow symmetrical anti-lift with four trailing links.

However, it definitely would not work to try to react any brake torque through the H-link. It is simply not configured to resist longitudinal forces or brake torque.

The DSR does have considerable anti-squat under power, due to the slope of the top run of the drive belt. This also acts off-centre, which is not desirable but can be lived with. As shown, the car will roll rightward and gain diagonal percentage (LR + RF) under both power and braking. This can be compensated for to some extent by having a bit less than 50 per cent diagonal and a little leftward tilt statically.

With cylindrical bushings at the front of the trailing arms, the arms have to twist for the suspension to roll. That makes them act like anti-roll bars, and appears to me to violate the rule in F500 that nothing is supposed to be arranged to twist in roll and act as an ant-roll bar. However, there is no such rule in DSR. There is also no reason you couldn't use actual anti-roll bars, or hydraulic shocks.

CONTACT

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

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Wing tips

Our Ariel Atom wind tunnel study continues with a range of tweaks to the sprint championship-winning car's front wing

By SIMON MCBEATH

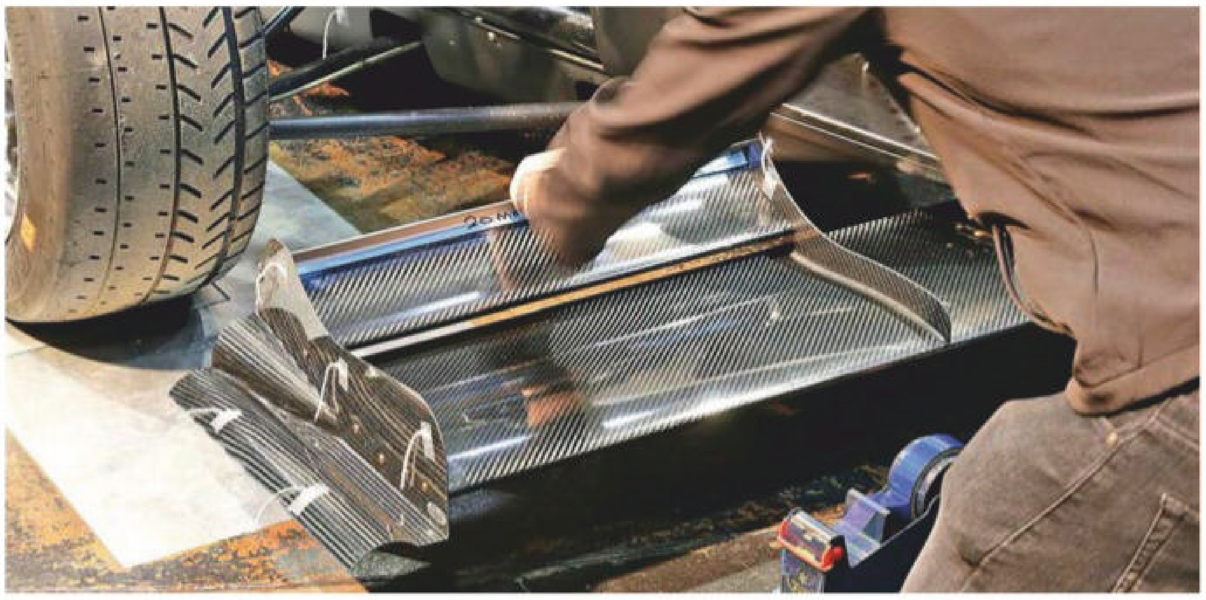
Our current project car is the 2019 UK Javelin Trackdays Sprint Series-winning Ariel Atom of owner/driver Stuart Drewell. Following engine power increases and fitting the wide span dual-element wings, car and driver set personal bests last season. In our previous issue we saw how the wings reversed the car's inherent, forward-biased positive aerodynamic lift to produce, after a series of modifications and adjustments, a significant amount of total downforce with a well-balanced front to rear ratio very close to the car's static front to rear weight distribution. As delivered to the wind tunnel though, the car actually had all its downforce at the rear and a small amount of front lift (see **Table 1**), so attention during our session in the MIRA full-scale wind tunnel initially focussed on increasing front downforce.

Illustrations: Simon McBeath

Initial focus during our wind tunnel session was on maximising front downforce by making some front wing adjustments

Front wing tweaks

The first adjustments made to the baseline set-up were front wing flap angle changes to establish where we were in the wing's operating range. It transpired that the flap was already at or very near its maximum angle because increasing or decreasing its angle both increased the baseline's front lift. So the flap was reset to baseline angle and flap Gurneys of 10mm and 20mm height were successively applied, with the results in **Table 2**. The data are given as delta values or changes in counts, where one count is a coefficient change of 0.001. The Gurneys produced very useful improvements, with significant forward balance shifts in each case. Note that the 20mm Gurney was only slightly more effective than the 10mm Gurney, but given the almost negligible drag increments from either Gurney and that the car needed all front downforce gains available, the 20mm Gurneys were retained. Regarding the small drag changes, regular Aerobytes readers will be familiar with this as a recurring theme in our single seater wind tunnel projects – that front wing changes, unlike changes to rear wings, rarely make much difference to drag. We will see more of this shortly.



Fitting the front wing flap trailing edge Gurneys proved useful, with significant forward balance shifts noted

Table 1: Baseline and balanced aerodynamic data

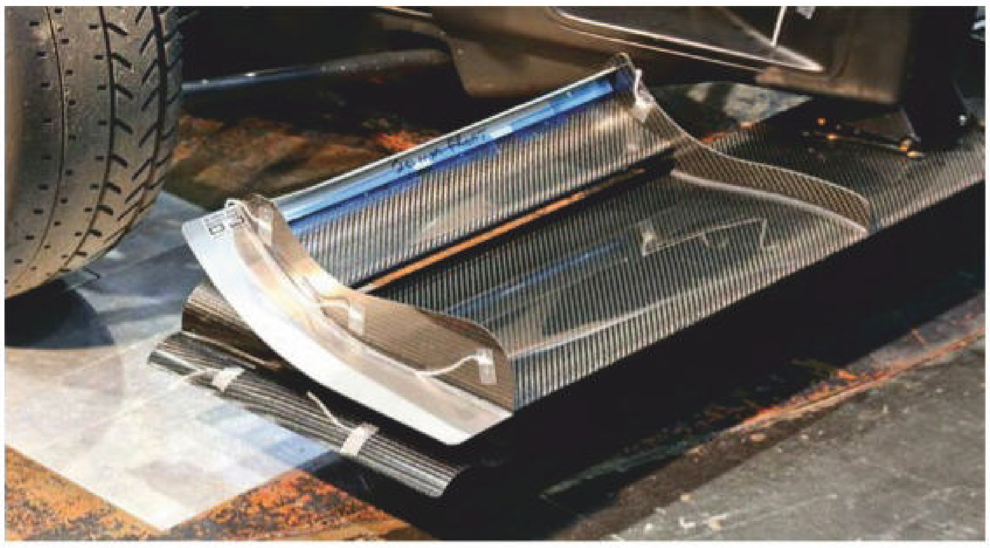
	CD	CL	CLfront	CLrear	%front	L/D
Baseline	0.658	-0.597	0.020	-0.616	-3.3%	-0.908
Balanced	0.587	-0.450	-0.160	-0.291	35.4%	-0.767

Table 2: The effects of front wing flap Gurneys as delta (∆) values

	∆CD	∆-CL	∆-CLfront	∆-CLrear	∆%front*	∆-L/D
+10mm Gurney	+2	+48	+65	-17	+11.5%	+74
+20mm Gurney	+3	+59	+79	-20	+13.7%	+89

* Changes in %front are absolute, not relative. Note: lift coefficents are now negative, hence downforce gains

Some parts to attach to the front wing end plates had been brought along for evaluation. The first of these was a pair of flip ups to attach to the outer face of the end plates. A second option was flip out wedges, which attached to the rear portion of the end plates and created an outward turning face, although the inner face remained flat and parallel to the car's centreline. Both these devices had been tried previously on the DJ Firestorm hillclimb single seater, the front wing of which was of a narrower span, so the comparisons with that application were interesting. **Table 3** gives the data for the two devices on the Atom, and **Table 4** for the Firestorm, in counts in both instances for easy comparison.



The front wing end plate flip ups brought modest front downforce and aero balance gains

Front wing end plate flip outs were very efficient, with a useful forward balance shift

Taking **Table 3** first, the effect of the flip ups on the Atom was a modest forwards balance shift through an increase in front downforce and a smaller decrease in rear downforce. Drag was little changed. The effect of the flip outs was more pronounced with an increase in front downforce for virtually no change in rear downforce combining to give a useful forwards balance shift along with a small drag reduction. The flip outs then were quite beneficial, and prompted thoughts of further modification to the rear portion of the front end plates to include also an outward turning inner face. That would have to wait for another time.

The different responses to similar devices on the DJ Firestorm in **Table 4** were interesting. The flip ups in that case were more aggressive and not only made a bigger change to front downforce but also reduced the drag, probably by easing more air over the larger front tyres. The flip outs, however, produced negative effects on the Firestorm (apart from slightly reduced drag) and it may be because inwash was more a natural feature of the narrower wing span, so the flip outs were perhaps fighting that, whereas outwash was predominant from the upper parts of the Atom's front end plates, hence the flip outs worked with and encouraged what was naturally happening.

No front wing

Reference was made earlier to the fact that changes to front wings do not generally make much difference to total drag. Indeed, the biggest change to drag on the Atom from any of the front wing changes we have seen here was the fitment of the flip outs, and that was probably because there was less air impinging on the front tyre rather than any inherent drag reduction on the wing or end plate. And this highlights the point because (as can be shown in CFD if not the wind tunnel) it is more often than not the case that an adjustment to the front wing that creates a drag change on the front wing itself produces an offsetting change downstream.

With this thought in mind, what happened when the front wing was completely removed from the Atom was particularly interesting, and the delta values for this change are given in **Table 5** (%front and –L/D have been deleted because front downforce changed to front lift). A large loss of front downforce was accompanied by an increase in drag. Put the other way around, the effect of fitting the front wing was to add a large amount of front downforce and reduce the drag by five counts (a little under one per cent). In contrast, the rear wing contributed comparable amounts of rear and total downforce to the front wing's front and total downforce contribution but added 70 counts of drag (around 13.4 per cent compared to the totally wingless car). So front wings not only don't change drag very much, they are, it seems, also capable of reducing it.

Table 3: The effects of flip ups and flip outs on the Ariel Atom

	ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear	Δ%front*	Δ-L/D
+flip ups	+2	+9	+17	-7	+2.8%	+13
+flip outs	-6	+35	+36	-1	+4.9%	+68

* Changes in %front are absolute, not relative.

Table 4: The effects of flip ups and flip outs on the DJ Firestorm

	ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear	Δ%front*	Δ-L/D
+flip ups	-11	+4	+55	-52	+2.9%	+40
+flip outs	-8	-37	-11	-26	n/c	-24

* Changes in %front are absolute, not relative.

Table 5: The effects of removing the front wing

	ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear
Remove f/wing	+5	-337	-456	+118

The front wing's upper tip vortex, from the top parts of the end plates, exhibited quite a large amount of outwash

CONTACT
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In these pages he uses data from MIRA to discuss common aerodynamic issues faced by racecar engineers

Tried and tested

To analyse the behaviour of the oil the gearbox is run on a rig with a Perspex casing, allowing engineers to view and record how it moves around the transmission

With Formula E demanding ultimate efficiency, transmission manufacturers are investing in new dyno technology to test gearboxes long before they get to the track. Yet as *Racecar* discovered, designing and using a rig that can cope with the peculiar challenges of FE requires some serious engineering

By GEMMA HATTON

Despite the abundance of modern racing technologies, component failure can still end a driver's race and even their chances in a championship. In the 2019 F1 season alone, there were a total of 58 retirements, 25 of which can be attributed to either component or pit stop issues or failure (not including crashes). Although with 20 cars running in 21 races, that's a failure rate of only 5.6 per cent, which is a huge improvement over seasons in the past.

Yet failure is still a part of motorsport, and this is because racing is such a brutal environment for any component or system to endure. However, as the regulations continue to restrict the number of components a team can use within a season, for both cost and equality reasons, parts are being pushed to their absolute limits. This is why motorsport has entered an era where reliability is more important than ever. Or, as the old saying goes, to finish first, you first have to finish.

Test case

The most effective way to ensure reliability of a part is to test, analyse and refine its design. Each iteration of this loop will further increase a component's reliability. Testing now comes in many forms including both virtual and physical experimentation. The task then becomes a lot more complicated when testing and optimising a sub-assembly of components, and even more complex when testing a major unit such as a transmission.

'We always break it down into sub-system tests,' says Adrian Moore, CEO of Xtrac. 'So if we want to test the oil pump, we wouldn't test the gearbox and the oil pump together. You can still get to the right answer, but it is harder because you can get distracted by other issues. Instead, we would test the oil pump itself and completely understand how it works. By analysing all the discrete units you gain a far better understanding of how they work individually. Then you can plug them all together and understand how the system works as a whole. So we like to build up to the sub-

'The aim of these rigs is to understand the performance and the characterisation of the transmission with a high level of accuracy and confidence'

The input motors of the rigs are large as they have been designed with durability and robustness in mind

assembly tests because that's a really effective way of understanding the product.'

Transmissions are not new to dyno testing, they have been put through their paces on rigs for years. However, with the growth of electric series such as Formula E, transmissions now need to reach astounding levels of efficiency to remain competitive. This is because Formula E is an energy-based formula, where teams only have a limited amount of energy to complete a race. For season six that is 52kWh of energy with braking regeneration added on top of that at a factor of 0.75 to account for losses (for every 1kW of braking regen, 0.75kW is actually released). Therefore, the transmission needs to lose as little energy as possible as it transfers the torque from the motor to the wheels.

'Broadly speaking, as the motor speed increases so does the efficiency of the motor, but the efficiency of the transmission decreases, so it's a complex relationship between the two,' Moore says. 'So a low speed motor would be inefficient itself but have a highly efficient transmission. Whereas a high-speed motor can be more efficient but the transmission is less efficient, so you have to balance those two requirements, which are in conflict.'

Efficiency drive

With Formula E utilising high speed and therefore high efficiency motors, the consequent lower transmission efficiency has been a key development area for both teams and transmission manufacturers. Rig testing has played a huge role in Formula E to try and boost not only the transmission efficiency, but the powertrain efficiency as a whole.

'The rigs that are most useful to us are our powertrain rigs which can run both the full car set-up and just the motor and inverter,' explains Gary Ekerold, sporting manager at Panasonic Jaguar Racing. 'That allows us to develop the control strategies of our software and also put mileage on these components for sign off. As we are limited to 15 days of pre-season testing in Formula E and the mileages are low, because we have to stop and charge, we're probably only averaging about 250km a day. Over 15 days you're looking at 3000km. When you are trying to validate something to run for a full season, which is 2000km, you have to put about 8000km

Articulated gimbal rigs like this simulate the *g* forces that the transmission would be subjected to in a real racecar out on the track

A transmission dyno at Ricardo. Note the large outboard motors which act as 'wheels', simulating the rolling resistance and braking torques to make the tests as realistic as possible

Today's Formula E powertrains are achieving efficiencies above 95 per cent, with the transmission itself close to 100 per cent

on it. So, before we even get to the track we have done thousands of kms on the rig, so we can focus on performance during testing rather than worrying about reliability.'

The result? Well today's Formula E powertrains are achieving efficiencies above 95 per cent, with the transmission itself close to 100 per cent. More details of the progression of Formula E transmission efficiency can be found in September 2019's edition (V29N9). Here, though, we will be looking at how you design a dyno to cope with a Formula E transmission.

First, we need to understand the principles behind a Formula E transmission. 'The engine in a conventional IC car spins at say 7000rpm, but the wheels don't spin at that speed, so you have to slow them down. That produces around 400Nm of torque, but you actually need 4000Nm of torque at the wheels, which is why you have gear ratios,' explains Tom Cooper, design and track support engineer at Xtrac. 'In electric cars, because the motors provide constant torque you typically don't need gear ratios so you can in many applications just run a single speed. If you had a motor that spins at 2000rpm, producing 1000Nm of torque, it will have a large diameter and be heavy. Whereas if you go for a motor that spins at 30,000rpm it can be a lot smaller in diameter because the smaller you go, the faster the motor spins, but the less torque it produces. So, you end up having this compound gear arrangement which allows you to utilise a smaller motor which spins fast but produces low torque. By putting that through a reduction ratio you can slow the shaft speeds down which increases the torque at the gearbox output.'

Shifting philosophies

Over the last five seasons Formula E teams have all converged to this single speed gearbox concept to minimise weight whilst improving efficiency. However, the reduction ratio required is so large that it is too much to do on a single gear pair, which is why teams have now opted for a two-stage single speed gearbox.

To optimise the efficiency of this gearbox, it needs to be tested, which means the forces, loads and torques the transmission is subjected to on a real car needs to be replicated on a dyno. 'The aim of these transmission rigs is to understand the performance and the characterisation of the transmission with a high level of accuracy and confidence,' explains Ian deSouza, test and development manager at Ricardo. 'Particularly when we're looking at motorsport applications, efficiency is critical and small gains in efficiency can make a big gain on track, so to measure those small efficiency gains, particularly when they are in the high 90s, you need high accuracy in the measurement. The key for a transmission dyno is to achieve high quality and repeatable data through careful control of the influence of external factors, whether that be the oil, temperature conditions or the powertrain. We can control all of those in a closed environment on a test rig.'

A transmission dyno consists of a large electric input motor which drives the


CADILLAC
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transmission; effectively simulating the torque provided from the powertrain, whether that be an internal combustion engine or an electric motor. The transmission then transfers this torque through to the 'wheels' via output and driveshafts. The 'wheels' on a dyno, however, are actually motors, so one at each corner. To fully simulate the loads going through the transmission, these outboard motors provide a resistance torque which emulates braking loads, rolling resistance and all the other torques that usually occur between the differential and the tyre contact patch.

This set-up can then be modified to suit a 2WD or 4WD transmission. The former will have the two rear motors simulating resistance torque, while the front two motors are driven so that the brakes can be tested. All four motors for the 4WD layout will supply resistance torque and will be driven by the input motor.

The challenge for testing high performance motorsport transmissions, such as Formula E, is the high motor speeds, which are currently around 30,000rpm. The input motors of the rig are large as they have been designed with durability and robustness in mind. Furthermore, to develop a flexible rig that can configure to a wide range of transmission types, the input motor needs to be able to provide a wide range of rpms too, and so be capable of delivering high amounts of power. High power motors produce low torque, so how do manufacturers use these high power motors, yet generate enough torque to test Formula E transmissions? They do what they do best – build a gearbox.

'To get to 30,000rpm brings challenges with areas like lubrication, gear design and burst speed because 30,000rpm is incredibly fast,' says deSouza. 'Power can be tuned to give you speed by using a gearbox, so effectively we have manufactured another gearbox, or dropbox, to get the input motor of the rig up to the speeds that a Formula E motor would provide. We can then change the ratios in this dropbox to give us an envelope of output speeds to suit a wide variety of transmission types. In the case of Formula E, where the electric motor is running exceptionally fast, we take our 520kW input rig motor which spins at 8000rpm and we step that up through a dropbox to get to the high motor speeds that the rig needs to simulate.'

Spin doctors

It may seem strange that companies are having to build a gearbox to test a gearbox, but this allows the manufacturers to not only develop a reliable, accurate and robust testing platform, but one that is also fully configurable to any transmission type. 'By using this dropbox to change the speed range, we can test a whole variety of powertrain motors and then their transmissions, whilst using the same rig,' explains deSouza. 'To maintain accuracy we want to be running the hardware in its most appropriate speed range. For instance, if I was running a standard internal combustion engine transmission with a max speed of 8000rpm I wouldn't run that against a gear set which will give me 30,000rpm range because I'd only be testing a small part of it. So, we change the gear set within the dropbox to give us the most appropriate testing conditions for the specific transmission we're testing.'

You may be asking, why don't they just run the FE motors themselves on the rig? Well, the manufacturers do that too, but for a system test rather than a transmission-specific test. As the potential performance of the transmission is much higher than that of the motor, to conduct a full sweep of transmission tests requires much more power than the FE motors can provide.

'If you run the Formula E transmission with its motors, it will only run for so long before it either reaches its de-rate condition, slowing testing progress, or experiences durability problems,' deSouza says. 'Furthermore, that motor is only applicable to that one

'To get to 30,000rpm brings challenges in areas like the lubrication, gear design and burst speed, because that is just incredibly fast'

The dedicated gearbox test rig room at Xtrac. The company tests discrete parts of the transmission to make sure they're working before then assessing the gearbox as a finished unit

transmission, so you have restricted the capabilities of the rig. You also need a lot of infrastructure because a battery simulator is required, and the inverter also needs to be incorporated and calibrated.'

However, arguably the most accurate way to replicate race conditions is to test the whole system and that does mean running the transmission in conjunction with its own motors. 'The best scenario is to run the car motor together with its gearbox on the rig because then you are testing the whole system,' says Moore. 'The more actual car components you can integrate into the rig and test, the more representative your system test becomes. But if we're not running the car motors and we want to focus on just a gearbox test, which is still an incredible amount of work, then we use the rig motors. This flexibility is new for us and why we've invested so heavily in our new 4E rig. Before, we've had to conduct that type of testing off-site. But now, having it in-house not only speeds up development time, but also means we're no longer dependent on third party suppliers. It provides a short-cut which is essential in Formula E because the timing and development cycles are so tight.'

Tilt testing

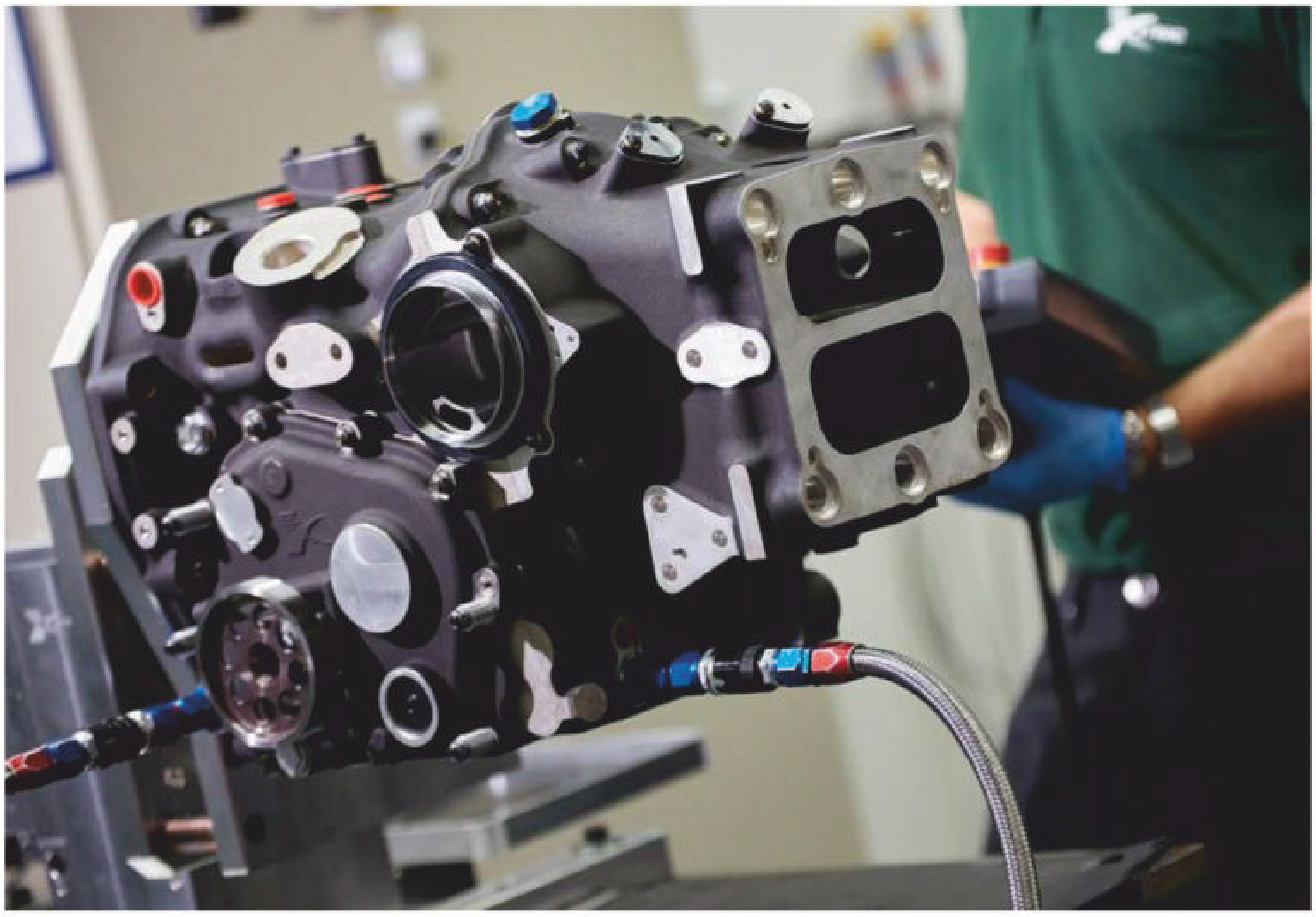
Once built, a transmission, both for IC and electric or hybrid cars, goes through a rigorous sweep of tests. The first of which analyses the behaviour of the oil system which can be done both statically and dynamically.

'We need to understand the functionality and the performance of the gearbox so we need to make sure that the lubrication regime is sufficient,' says deSouza. 'We need to ensure that the gearbox is lubricated throughout all driving conditions and no oil is leaking out of the breather systems, for example. To achieve this, one test we do is the tilt test, where the hardware is tilted at an angle which simulates going around a corner.'

Another way to test the oil system is on an articulated rig. 'The first test we do for a transmission project is we test the whole speed range at the static position. This validates the oil system,' says Moore. 'We then do the same again but on our articulated gimbal rig. This simulates the *g* forces the transmission would experience in a real car during braking, cornering and acceleration events. We run the transmission on this rig with a see-through perspex casing and analyse the high speed video footage so that we can compare and validate the behaviour of the oil during the test with our simulations.'

The next stage is to analyse the durability of the gearbox and there are a variety of ways to achieve this. Accelerated cycles can be run, for example, which subjects the transmission to the full load it could expect in its lifetime but within a shortened period of time. This type of cycle can be conducted when the gearbox is run directly on the test rig without its car motors and/or when the gearbox is driven by its car motors. However, to provide the required DC voltage to the car motors, a battery emulator is used. In this way, the whole powertrain package is driven and tested.

Xtrac EV 'box testing. Spinning up Formula E transmissions requires another gearbox or 'dropbox' which is fitted to the rig



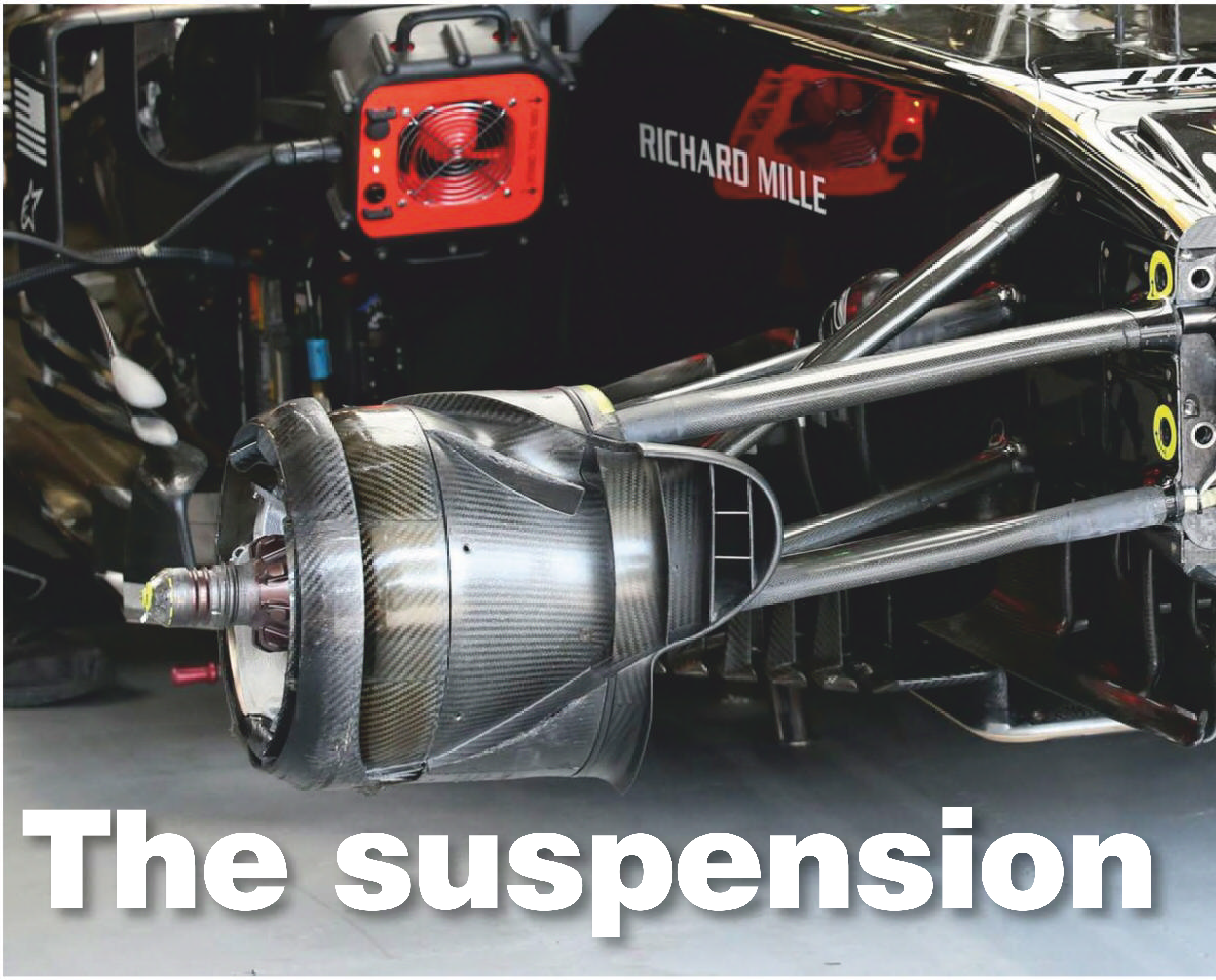
Xtrac LMP gearbox undergoing its spin rig testing. Efficiency and durability are vital in both Formula E and sportscar racing

'The best scenario is to run the racecar motor together with its gearbox on the rig'

'Boxing clever

Once the transmission's reliability has been proven, the next stage is to determine that all important efficiency. 'In an application such as Formula E where you are limited to the amount of power that you can deliver from a motor, you need to minimise the amount that you're going to lose in the system,' says deSouza. 'So we can take two separate pieces of hardware and run a baseline test. Then we run the same test on our designed hardware and compare the two. In this way, we can get a very accurate mapping of the efficiency performance not just as a single number, but as a 3D map that says actually in these conditions this is *x* per cent better than the other and in these conditions this is why.'

It may not be the first thing that springs to mind when talking about recent technical developments in Formula E, but the transmission is key to achieving maximum efficiency, which is so vital in an energy-based formula. This is why we have seen such rapid transmission development, along with such heightened secrecy, over the last few years. And dyno tech has had to be completely revolutionised to meet this demand.



The suspension

As the link between the wheels and the chassis the suspension is obviously a crucial aspect of any racecar, but how does it work and what does each component in a system actually do?

By JAHEE CAMPBELL-BRENNAN

A racecar's suspension is defined as a system of components mechanically connecting the road wheels to the chassis of a vehicle while allowing relative movement between them.

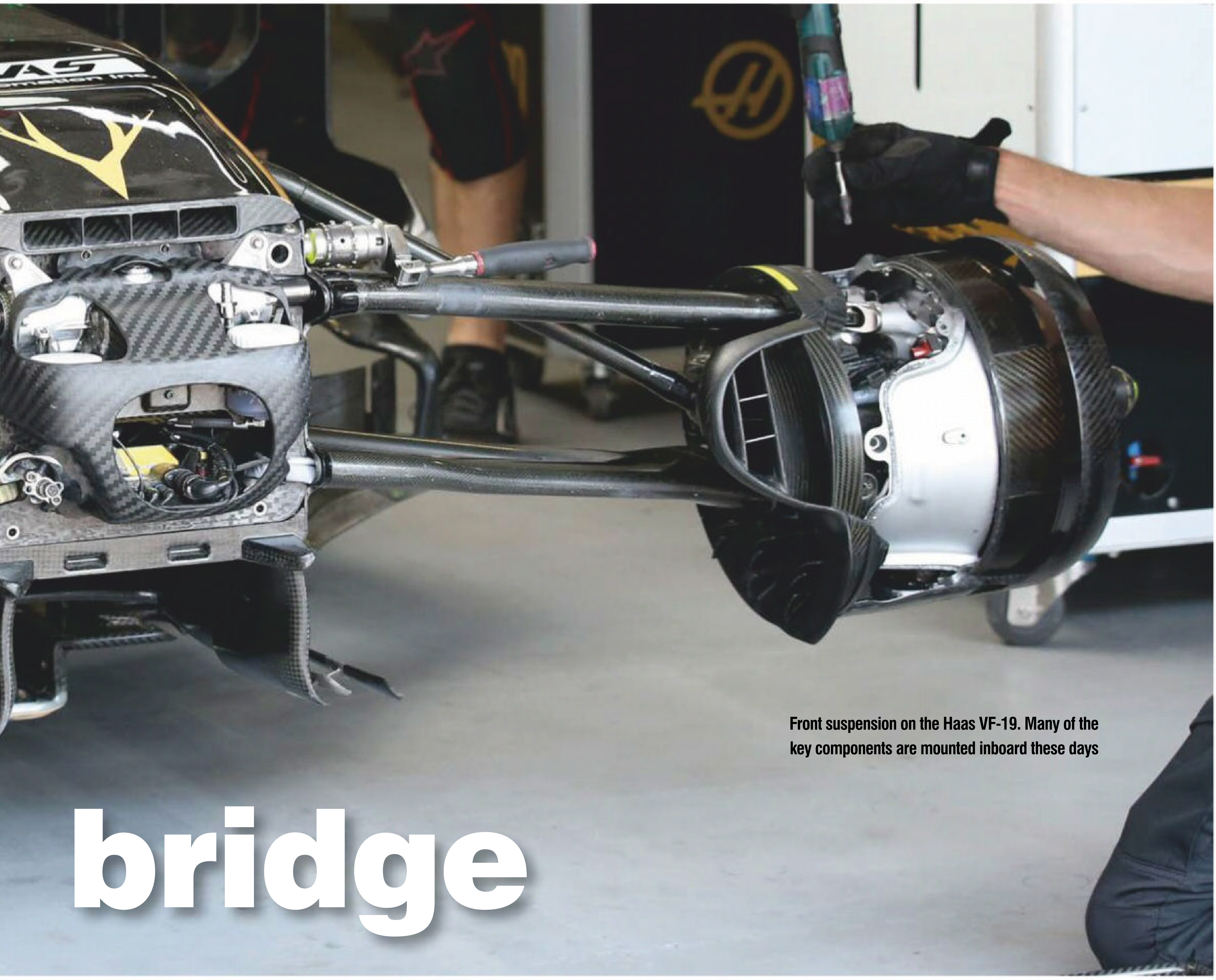
The suspension's job is to communicate and manage all the forces generated at the tyre-track interface (the contact patch) into the chassis of the vehicle. Undulations in the track surface, lateral accelerations experienced in cornering, longitudinal accelerations due to braking and throttle, as well as steering inputs, all pass through the racecar's suspension components. In reverse, the suspension system also defines how forces are transferred from the chassis into the contact patch through aerodynamic loading and weight transfer.

Load and balance

The manner in which the suspension system is designed and then set up is imperative in influencing not only the peak cornering loads of the racecar, but also cornering balance. It is therefore an area of substantial investment and R&D and sits alongside powertrain and aerodynamics as an extremely pivotal consideration for a racecar's performance.

A conventional suspension system consists of wheels and tyres, structural components such as control arms, spring-damper systems and, more recently, further specialised and unique solutions in hydraulic systems –and a neat piece of technology known as an inerter.

The racecar suspension system's prime task is to ensure that the tyre is operating in conditions that maximise forces generated at the contact patch. Being the sole point of contact between the car and the track surface, the tyres are the determining factor in the magnitude of all longitudinal and lateral forces generated during operation; the technology involved with racing tyres is therefore very important. While not directly part of the suspension system they are so inextricably linked that they really must be considered as an extension of it. The tyres also contribute to the frequency response of the unsprung and sprung mass – more on that in due course.



Front suspension on the Haas VF-19. Many of the key components are mounted inboard these days

bridge

Modern race tyres are a mix of natural and synthetic polymers with an array of further compounds, such as carbon black, silica and sulphur, added to improve their various mechanical properties. To cover the range of environmental conditions experienced on a race track, racing tyres are available in three configurations: slick, intermediate and wet.

Slick tyres, as you would imagine, are treadless and are used in dry conditions where maximum contact area is beneficial. They are developed to be at peak operating conditions throughout the temperatures experienced on dry surfaces. Due to the fact that there are no tread features, they are not able to disperse surface water and are therefore not suitable in anything other than patchy moisture.

Wet tyres, on the other hand, are used at the opposite end of the weather spectrum. They have deep tread features which allow standing water to be channelled away from the contact patch, minimising the potential of aquaplaning. The added cooling effect of water means that they never reach the high temperatures of slicks and they reach their peak grip potential at lower temperature. If wet tyres were used in dry conditions, they would rapidly overheat.

Intermediate tyres sit somewhere in-between wets and slicks, both in terms of the hardness of the compound and the depth and extent of their tread features. Intermediates are best used in conditions with little or no standing water but with a damp surface, or when the track is drying yet there is still too much moisture for slicks, but too little for wets.

Although maximising the tyre's contact patch through larger and wider wheels increases absolute grip, (minimised contact pressure = higher coefficient of friction), management of cornering balance through tyres is an important consideration in the vehicle dynamicist's toolbox.

Slip angle

To generate grip, tyres require a slip angle to be present. This is the angle formed between the direction of travel of the tyre and the pointing direction. Each tyre has a peak slip angle at which, for a given vertical load, it is producing its maximum cornering force and this is, in part, influenced by the suspension system.

Front to rear distribution of cornering stiffness (a measure of relative grip capability expressed as the force generated per degree of slip angle [N/degree]) must also be considered to maintain a desirable grip balance. This is one reason you see differing widths and even

While not directly part of the suspension the tyres are so inextricably linked that they really must be considered as an extension of it

As race engineers we really want to keep rotational energy and inertia to a minimum

diameters on particular racecars. However, the regulations usually limit the maximum width and diameter of the wheels.

But if the tyre is the key to grip, then the wheel is the structure that communicates these tyre forces into the chassis. As with all engineering structures, a wheel must be optimised to perform efficiently, especially as unlike all of the other suspension components it carries rotational energy as well as translational energy. As engineers we really want to keep rotational energy and inertia to a minimum, because it increases the energy input required to induce a change in wheel speed during braking and accelerating, which is detrimental.

In a translational sense, inertial effects manifest in a pronounced manner at the unsprung mass of the vehicle. A high unsprung mass possesses a higher energy for a given velocity, an effect which becomes apparent in both compression and rebound travel of the spring-damper, which must absorb this energy. Therefore, the frequency response of the wheel and thus the vehicle body is directly affected by the cumulative unsprung mass.

It's clear that low mass is crucial to reducing inertial penalties of the wheel, but in addition to mass, diameter is also important. Wheels of a smaller diameter are much better in this sense as rotational inertia is sensitive to the square of their radius and a trade-off with the contact patch must be weighed-up.

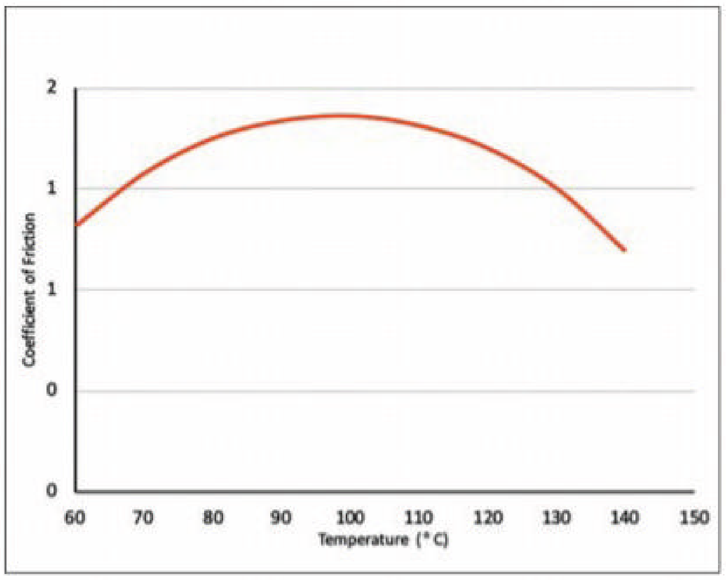
Pirelli's intermediate Formula 1 tyre. The tread features allow the water to be channelled away from the contact patch

With wheel diameters usually dictated either by the regulations or the vehicle itself (for example, brake disc size), to reduce the inertia engineers have to focus on light-weighting. This is why low density, high strength materials such as magnesium alloy are commonly used.

Structural parts

Next in the path of forces from tyre to chassis are the structural suspension components such as uprights/knuckles, control arms, pushrods, pullrods and associated hardware.

The primary function of all these components is, of course, to physically connect the wheels to the vehicle. Road cars adapted for the race track may feature configurations such as the MacPherson struts or trailing arms, but the most control and structural efficiency is offered by the double wishbone layout. Also sensitive to weight concerns, they are constructed from lightweight, stiff materials such as aluminium, titanium and carbon fibre.



Graph showing the relationship between CoF and tyre temperature

The advantages of the double wishbone layout are in part concerned with a particularly important sub-section of vehicle dynamics named kinematics – the understanding of the motion of objects without consideration of the forces causing the motion. With the wheel in mind, kinematics in this context is the dictator of

Formula 1 cars working their rubber hard at Silverstone last season. Each tyre has a peak slip angle at which, for a given vertical load, it is producing its maximum cornering force

how, dynamically, the contact patch of the tyre is oriented in relation to the race track's surface. As the wheel moves through its compression and rebound travel or is steered, characteristics such as camber gain, bump steer, scrub radius, Ackermann geometry and anti-dive/squat are all dictated by the arrangement of suspension linkages. The roll centre of an axle is also dictated by suspension control arms. Vertical placement of the roll centre defines the size of the moment arm acting at the CoG, tending to produce body roll and thus the magnitude of the roll moment.

Patch work

The encompassing objective of these measurable kinematic quantities is to maximise the tyres contact patch, at slip angles conducive to reaching peak cornering stiffness.

Besides ultimate performance, however, kinematic characteristics can also be used to manipulate feedback through the steering wheel, giving the driver a greater sensation of the car's behaviour. Increasing caster and SAI (steering axis inclination) angles increases the self-centring effort of the steered wheels and can give the feeling of greater stability or control, particularly at higher speeds.

The magnitude of the scrub radius, if large enough, can also give an indication of the grip levels between the left and right wheels, which can be useful in braking, as the steering wheel will tug away from the wheel losing adhesion. This needs to be implemented carefully, however, as the feedback can also become too high, resulting in high steering efforts and a physically demanding racecar.

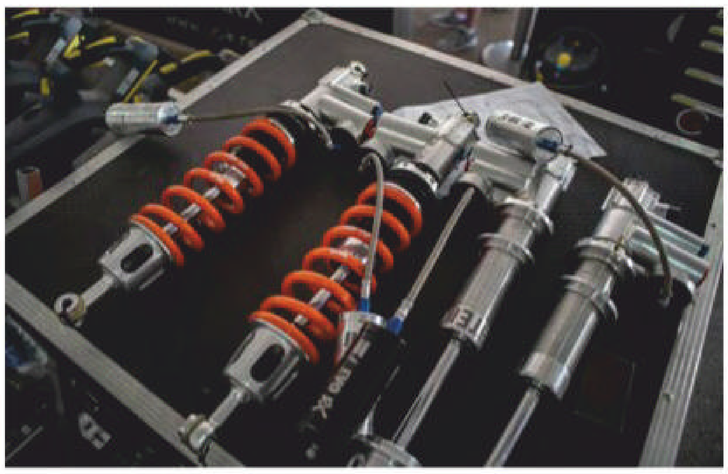
Designing precise suspension geometry into a car is pointless, though, if the structure is not sufficiently rigid that excess flex is prevented during vehicle running. For example, a lower control arm that flexes excessively under cornering can undo much of the camber gain designed into a system, or even give rise to induced toe, significantly affecting handling.

This opens the door to another branch of suspension design, which is aptly named compliance. The inherent compliance of a system receives a lot of focus and tuning during the design phase. Structural components must be sufficiently rigid that their compliant behaviour and ultimate strength meets the desired targets. However, because these components are unsprung, they introduce further sensitivities within the context of vehicle dynamics that must be considered; they are weight critical and so structural efficiency is paramount. Material choice is therefore a very important aspect of design. For this reason, low density, high strength metals such as aluminium and titanium are common, as well as composites such as carbon fibre.

Advancements in manufacturing technology have also seen new solutions that have been exploited in the search for structural efficiency. Sintered metal components such as uprights printed from titanium have allowed very complex and lightweight geometry to be manufactured that was previously not possible using milling technologies.

Double wishbone arrangements are used in most single seater and sports racecars. This is the 2019 Toro Rosso STR14

Designing precise suspension geometry into a car is pointless if the structure is not sufficiently rigid



The spring and damper set-up is a crucial aspect of the suspension

The Bilstein rallycross dampers have a large operating window

Springs and dampers

Turning to the suspension system components themselves, the spring-damper unit is arguably the most crucial component within the suspension system, with a significant influence on the vehicle dynamics. Unlike on road cars, the spring-dampers on racecars are not developed for ride quality or comfort, but solely for enabling the generation of grip.

Comprised of a coil spring and a hydraulic damper in a parallel arrangement, the spring exerts force proportional to its displacement from equilibrium and is effectively an energy store. As an elastic device, the input of kinetic energy is transformed into potential energy which it works to release, bringing the car back to static ride height. Conversely, the damper is a device which, due to the viscous properties of its working fluid, produces a force proportional to the velocity of its stroke. The higher the rate of compression or rebound, the larger its force. Kinetic energy is absorbed by the damper fluid, mostly as heat energy due to this viscous effect.

Put simply, the spring works to return the system to a point of equilibrium, while a damper works to control the rate in which the system is moved away from, or returned to, equilibrium. The magnitude of these effects are tuned to optimise the dynamics of a racecar.

The tyre effectively acts as a rising rate pneumatic spring with its own internal damping working in series with the main spring-damper unit. At a corner, the behaviour of the spring-damper-tyre system can be understood by equating it to a two DoF (degree of freedom) lumped mass. With the tyre spring rate essentially fixed, the spring rates of the spring and damping coefficients can be engineered accordingly to give the desired frequency response of the wheel assembly as a whole.

From car to car the desired frequency response varies widely depending on whether the emphasis is on mechanical or aerodynamic grip. As ever within engineering, these requirements demand constraints that are pretty much at opposite ends of the spectrum and vary across different championships. And one extreme example of that is rallycross.

Rough trade

'Our rallycross dampers have a large operating window,' says Daniel Pitsch, head of Road Racing Dampers at Bilstein. 'With 1600kg cars that can land from around 3m high, we have to accommodate piston speeds of up to 5.5m/s whilst generating damping forces as large as 70,000N, and this provides a very different challenge to road racing. A unique solution we implemented to help manage this is adjustable hydraulic bump stops, which wouldn't be necessary for our GT customers.

'With rallycross, the aim is to devise a damper that performs well with respect to contact patch pressure but is also able to follow and track the road surface over gravel and rocks etc.,' Pitsch adds. 'The goal is a compromise between both.'

With much smaller damper speeds and forces, road racing requires a different approach. Mechanical grip dictates a supple spring-damper to reduce variation in contact patch pressure, whilst aerodynamic grip, which isn't usually a large factor in off-road series, dictates a stiff set-up to mitigate the sensitivity of the aerodynamic platform to changes in ride height, pitch and roll, and also support the aerodynamic load exerted on the car's body.

Modern motorsport dampers offer a great deal of adjustability in damping, with higher end examples designed such that high and low speed compression and rebound damping rates can be changed easily in-situ – this is known as four-way adjustability where the 'speed' in this sense refers to the damper piston speed which is the rate at which the damper is compressed or extended. 'Typically, the transition from low speed to high speed valving is at around 0.1 to 0.2m/s piston speed,' says Olivier Lardon, who works in motorsport damper design at ZF Race Engineering.

Low and high speed

Low speed damping is associated with low frequency, high amplitude input such as body movement – roll and heave. It therefore has important effects in managing weight transfer as the vehicle accelerates longitudinally and laterally, especially so with transient conditions, such as upon initial turn-in.

Conversely, the high speed damping is concerned with higher frequency, low amplitude inputs such as peaks and imperfections in the road surface, or striking kerbs and running over loose gravel. high speed damping is very influential in dealing with variation in contact pressure and influencing grip behaviour on less smooth surfaces.

'Advancements in computer simulation methods have really advanced damper technology in recent years,' says Lardon. 'The biggest gains in our technology in recent years have been through the use of FEA in structural optimisation and CFD in improving our understanding of the hydraulic operation; internal fluid flows, cavitation and so on. Accurate simulations allow us to quickly evaluate ideas and concepts much more efficiently than we previously could.'

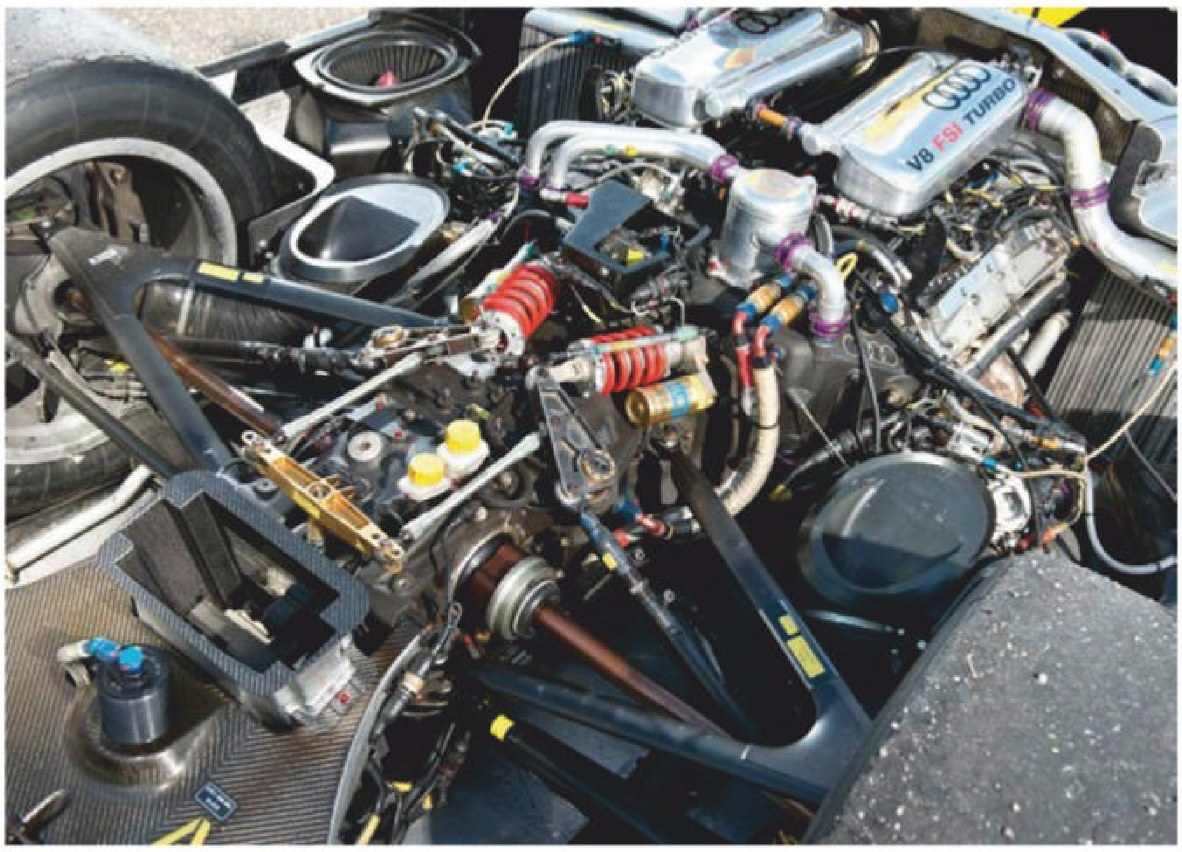
Being a hydraulic system, dampers suffer from an effect known as hysteresis. Hysteresis is inherent to hydraulic dampers and is caused by inefficiencies that absorb energy from the working fluid. 'The damper body and fluid lines flex as fluid pressure rises, sealing components are large contributors to this also,' says Pitsch. 'It's something we're constantly working to improve.'

Reducing hysteresis gives motorsport engineers more control of the force-velocity curve and a more consistent damper response, so this is a particularly important development area for the future of dampers.

Mode decoupling

One area of great interest in racecar suspension design is mode decoupling. This is about isolating and decoupling modes of chassis freedom (roll, pitch, heave and warp), incorporating independent spring and damping rates for each mode, which allows even further control of the chassis. As motorsport has matured there has been an increasingly

Rallycross jumps are a challenge for damper designers. Bilstein's products include adjustable hydraulic bump stops



Mode decoupling three-element rear suspension on the 2000 Audi R8 Le Mans car. Note the gold torsion bar

Reducing hysteresis gives the engineers more control of the force-velocity curve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complex set of solutions implemented; with anti-roll bars, three-element spring-damper systems, hydraulic cross-linking and other passive high technology systems emerging and helping teams to win races.

The most common and mechanically simple mode decoupling device is known as an anti-roll bar (ARB), sometimes called a roll spring. Excessive body roll, or rather inadequate roll stiffness (Newtons of force per degree of body roll) is detrimental to performance in various ways. The rotation of the body alters the wheel's orientation, causing a reduction in tyre contact area. Excessive roll also influences the transient period of dynamics, from the moment a steering input is applied until a steady-state condition is reached, resulting in a delayed yaw response. It can also compromise the effectiveness of the aerodynamic platform.

The action of the ARB is to laterally couple axle wheel pairs with a torsion spring. As the wheels move in opposite directions during roll, torsion is effected onto the bar which it resists. When the wheels travel up or down simultaneously there is no effect; decoupling the roll and heave modes.

However, it's important to note here that the ARB does not reduce total lateral weight transfer by reducing roll. This is influenced by the vehicle track and CoG height. It can, though, influence the lateral weight transfer distribution between the front and rear axles and it is therefore a device that can be used to fine-tune the cornering balance of the racecar.

When the track conditions are wet you need to dial in a softer suspension set-up, which is less likely to catch the driver out

The most common and mechanically simple mode decoupling device is an anti-roll bar

Well connected

One step further in the increasingly complex matrix of wheel control is hydraulic cross-linking, sometimes termed FRIC (Front-Rear InterConnected) systems. This form of interconnection can be achieved in different ways, but in essence links opposite wheel pairs (front-left to rear-right, front-right to rear-left) with hydraulic lines and incorporates valving systems to allow pitch and warp modes to be controlled separately to roll and heave. This has been seen in LMP1 and F1 cars in the past, and has been the subject of many regulatory discussions – and subsequent bans.

A relatively new addition to racecar tech is the inerter. Thus far we have covered the role of the spring, which exerts force proportional to the magnitude of displacement; and the damper, which exerts force proportional to the rate of change of displacement. An inerter, however, exerts a force proportional to the rate of change of velocity; acceleration.

Mounted in series with the spring-damper, the inerter has been seen to achieve this via two mediums, mechanical and fluid. The mechanical inerter converts input energy into rotational energy in the form a flywheel, while the fluid inerter uses the viscosity of a fluid to provide the inertance. The inertance generated acts to resist high frequency input accelerations such as vibration to the wheel assembly. The result of this is to reduce the variation in contact pressure between tyre and track. As we discussed in the spring-damper section, the reduction in such variation is paramount in a racing application, so there is a definite performance contribution with this tech.

Modern racecar suspensions are comprised of many different parts and all are inter-dependent and all must be configured to work in symbiosis. Much of the foundation of an effective suspension system must be laid during the development phase of a car; fixing most of the kinematics and component technologies. But a great deal can still be adjusted and tweaked in preparation for, and during, events.

Springs and dampers provide adjustment of the frequency response of the system, while adjustable suspension geometries influence kinematics and offer some trackside tweaking of the camber and toe responses to adjust cornering balance. Differing conditions such as weather, track surface type and aerodynamic set-ups will demand different set-up requirements for optimal performance – these are constantly moving goal posts.

There is therefore no single configuration of suspension components that provides optimal performance in all conditions experienced across a racing championship, and tuning these parameters is a skill in itself.

Vehicle dynamics, and therefore suspension systems, will continue to develop for as long as the search for quicker lap times exists. The disciplines of wheel design and other structural components are so well understood that advances here are perhaps at the point of diminishing returns, the small advancements to be made will be related to our understanding of materials science and the introduction of lighter, stiffer and stronger materials. Similarly, with kinematics, its utilisation is well understood and improvements to performance will relate more to individual understanding rather than development and evolution of the theory.

With a continued emphasis on simulation, though, development will be quicker and less costly, and multi-body analysis tools and lap-time simulators have increasingly proved their worth in racing in recent times.

Getting active

Some engineers might wish for a return to a past technology in motorsport in order to move forward, perhaps active suspension, for instance? 'It would be nice for us if we can return to electronically controlled dampers because they give us such control over the damping characteristic,' says Lardon. 'We are ultimately trying to recreate this with passive damping, which is challenging on the mechanical side.'

Of course, the regulations can be written to either progress development, or restrict development, but if F1's 2021 regulations are anything to go by, it seems that the latter is most likely. For now at least.

Waiver yellow flag

The new-for 2022 GT3 regulations will mean a radical change for one of motorsport's most successful categories, but might it also lead to cost hikes from the manufacturers? *Racecar* investigates

By ANDREW COTTON

New regulations have been agreed for GT3 for 2022 onwards, and passed by the FIA World Motorsport Council in December. The controversial new rules will mean a change to one of the most successful categories motorsport has seen. Yet while there is agreement from manufacturers not to go to extreme lengths in their pursuit of victory, and to respect the customer element of the category, these regulations do allow large scope for car development.

The situation has grown out of a problem BMW has had. It is developing its M4 for GT3 competition but has not been allowed into the category, as it stands, due to the M4 being a 'platform' car, sharing with other models in the group. While BMW argues that the car is almost the definition of a GT, or Grand Touring, car, compared to a supercar such as a Ferrari 488, the FIA says that the current regulations do not allow this car to compete in GT3.

BMW does not have another car that would fit the current GT3 regulations and it argues that many other manufacturers are in the same position, with cars that they might like to race – such as Audi with its A5, for instance.

The FIA also wanted to change the homologation regulations for GT3 in order to make the category more consistent and easier to manage. So, with the new regulations scheduled for 2022, it took the opportunity to make the changes it wanted.

Simplification

The regulations will bring together the technical and the homologation rules into a single document, which will make life easier for development teams as they will not need to ask the FIA what they can or cannot do. The cooling ducts on a Bentley, for example, are different to those on a Nissan, and different again on the BMW, which is a feature of the FIA endurance

Under the new regulations, a waiver that has been granted to a Bentley can also be applied to a Ferrari

The Bentley and Nissan are pure GT cars, yet in GT3 they race against supercars such as the Ferrari and sports cars like the Audi R8. The new rules will give this diverse field some common design elements

committee decisions, that are not necessarily consistent, and the body is now looking to avoid those anomalies. Permitted changes will be written down, but the basic concept is that all waivers that have been agreed will be available to all cars regardless of their origin.

Even Stephane Ratel, the father of GT3 racing, the category on which he has built a business empire, classes the cars as supercars, including the Ferrari and Lamborghini; sports cars such as the Porsche 911 and the Audi R8; and GT cars, such as the Bentley and Nissan.

Under the new regulations, a waiver that has been granted to a Bentley can also be applied to a Ferrari. While some cars need to make changes to their engines to bring them up to a performance level, making big developments in order to achieve it, others such as Audi and Ferrari race with less power than in the road cars so do not need to improve their powerplants.

A matter of trust

The crucial point now, though, is that they can, and Ratel has to trust the manufacturers that they will not push their new 2022 cars to the extreme. For the SRO and the FIA, the more freedom allowed to the manufacturers, the harder they will have to work in order to balance the cars and to make sure they know the intricate details of each model and their function in order to balance them properly.


Stephane Ratel has GT2 as a back-up in case GT3 costs escalate. As yet only Audi (pictured) and Porsche have built cars

Ratel has confirmed that he will not object to the regulations. The manufacturers have, he says, offered him their assurance that they will not build extreme cars and he says he will trust their judgement. The process started in January 2019 and for much of the year was dismissed by Ratel as the FIA sought to clearly identify the different design philosophies, with one proposal made to separate them out according to cockpit volume. This would have made the larger greenhouse of a Bentley a different category to a Ferrari, but they would then have needed to be balanced differently. Ratel's view was that if it ain't broke, don't fix it, but the manufacturers and the FIA have ploughed on regardless.

The changes that they have agreed, and which are now supported by Ratel, can include changing the alloys and piston design within the engine, thereby creating an expensive engine that will drive up the costs. Balance of Performance would bring that car back down in terms of overall performance, but the base cost of the car would be higher and a manufacturer such as Porsche, which can sell almost everything that it makes, could therefore produce an extreme version of its GT3. That

The new for 2022 GT3 regulations will bring the technical and the homologation rules together in one single document

NSX GT3. Honda is not keen on the 2022 GT3 rule changes but it supports the introduction of a separate hybrid and electric series (see boxout)

would put other manufacturers on alert, and they may not renew their commitment to the category if costs start to spiral out of control.

These new regulations have not been well-received in some quarters. 'Right now, the category is stable, so why change it?' asked JAS motorsport director Alessandro Mariani, a sentiment that is shared by Audi's head of Customer Racing, Christopher Reinke. 'It's working, so just leave it alone,' he said.

'What they try to do now is to get as many design items in a technical regulation,' said Audi's customer sport racing director Armin Plietsch. 'What the FIA is trying to do is reduce the amount of effort and fix as many design items and technical regulations that you as a manufacturer [need to design] so that you don't have to request every item … They want to keep free areas, and other things like the shape of the doors and the roof should be fixed so that people don't have to ask if they can do something. If the spirit is the same and we simplify the process it is a good thing, but it depends on the final outcome of it.'

Market forces

On the subject of trusting the manufacturers not to exercise the full potential of the regulations, and thus protecting the business case, Plietsch believes that the market will dictate what can and cannot be developed, and then sold. Customers will not be willing to invest any more money than they currently do, and with a financial downturn around the world expected, coupled with falling car sales, this is a category that must be protected.

'In a BoP class, what do you want to do? You have to sell the engines to the customers and they have to pay for the revisions to the engines,' says Plietsch. 'If you do engines like the WEC, no one will buy them. The engine power is so down on these cars, there is no necessity to have a race engine. They want to keep the engines as they are. There is so much potential in all the cars now. It is easy for everyone in this situation to increase the power by 30 to 40bhp without doing anything, just the restrictor size, so there is no need to do anything with the engine.'

Car makers might not renew their commitment to the category if costs start to spiral out of control

For Mercedes, the change to the regulations should not really alter anything and it welcomed the simplification of the rules. 'The GT3 philosophy is to combine cars that are not matched on the street with cars that are [matched] here on the race circuit, and the result is that you have a very close BoP and we can be proud of what we have here,' says Mercedes' head of Customer Racing Stefan Wendl. 'From my perspective, there is a certain amount of freedom needed for at least a non-supercar manufacturer, but on the other hand if you provide that same freedom to cars like the Ferrari, they have freedom that they don't need. They maybe also don't want to put it into the car because they become very expensive.

'On the one hand I can understand the FIA, they are not doing anything special. They are trying to make a regulation which is compliant for everybody because in the end [a] manufacturer [will] request something outside

Ratel has to place his trust in the manufacturers, who say they will not exploit the new rules to their full extent

Circuit racers

The FIA World Council is also going to promote the creation of an electrified GT category (E-GT), which will be either hybrid or all-electric, with final regulations to be announced in March – this will be to the GT3 regulations in all but powertrain. It will be solely for manufacturer racing, and races will be short and not part of the main GT3 event.

Volkswagen's announcement that all of its factory motorsport will be electric in future might have partly driven this initiative, as this could see the acceleration of this technology into mainstream racing, and the FIA is perhaps concerned that GT racing will be left behind.

The rough outline for E-GT is that the cars will be a second a lap slower than GT3 machines, with a speed deficit on the straight of up to 10km/h. There will be up to two MGUs producing more than 70kW in a car that weighs around 1300kg. Races will be limited to 20 minutes, meaning that this category will present no challenge at all to the current GT3 format.

Plans to introduce electric, or hybrid, GT cars are nothing new – McLaren, Porsche, Ferrari and Lotus have all tried to launch cars like this, but they failed as it was felt too early to adopt the technology in already heavy GT cars.

Manufacturers such as Honda have welcomed the idea of a hybrid GT car for manufacturer racing, but it has said that if it was pushed to start a large GT3 development programme there was a possibility that it would stop GT racing all-together. Currently the NSX is produced as a hybrid on the road, and that system needs to be removed for racing.

The rise of electric and hybrid supercars (Lotus Evija pictured) means GT racing has to move with the times. E-GT will race alongside GT3 in 2022

the guidelines, and the group of people have to decide if this is something that is necessary to compete with the other brands. This is a lot of work, responsibility and time. They have tried to make the process cleaner and leaner and make it more transparent.'

The over-riding concern is that the costs would increase in this customer-facing project, and that could threaten it in the longer term. 'We need to discuss this and find a way for the costs to stay in the window they are now,' Wendl says. 'The majority of the manufacturers are of the same opinion, that we don't want to change what is the GT3 now. We don't want to change GT3 itself. What we see now is GT3 and we should keep it, both in terms of costs, and also performance and the look of the car. And the FIA is not far off it. The FIA is not against GT3, but we have to find the right frame to make the life of the FIA a little bit easier.'

Contingency plan

Ratel is not in favour of cost caps, either upper or lower, and prefers that the market dictates the future sales of GT3 cars. There is no doubt that the new regulations will shake up this same market, but in the meantime Ratel is building his GT2 category as fast as possible in case the cost of GT3 racing escalates out of control. Porsche and Audi have created new cars for the class already, although McLaren failed to deliver its promised model in Barcelona in October.

There is now a real danger that the GT3 manufacturers, who were almost universally in favour of taking their cars to Le Mans to replace GTE, will now get their wish. With Aston Martin already confirmed as a Hypercar manufacturer, and Porsche and Ferrari clear targets to step up to the top class, the GTE manufacturers could decimate the category within the next three years. Ratel blocked the convergence talks when they looked as though they would drive up the cost of his GT3 baby, but maybe now he has to accept that the market is ready for such change?

Of course, the manufacturers might keep their promises of restraint, but having seen the escalation of aero development and increased speeds from the current GT3 racecars, it does seem unlikely that the cars will remain as affordable as they are now in the future.

GT3 is one of motorsport's great success stories and manufacturers will be hoping the new rules will not mean higher costs


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On the rebound

Our wizard of sim explains why lower rebound values that look great on a shaker rig do not necessarily work out so well on the track

By **DANNY NOWLAN**

Making sure the car is driveable is vital in classes where amateur drivers race, like LMP2. This means that you need to look beyond shaker rig results and think about the stability index

Recently I was having a robust discussion with a close colleague, after I had presented the shaker rig section of my ChassisSim boot-camp. He made the point that the shaker-rig analysis is all well and good, but when he has applied shaker rig results to a car out on the race track in the past he has always had to add rear low speed rebound.

This is most apparent in mid-engine racecars. In particular, he described one situation where the car was perfect on the rig and when it got to the track it was a disaster. I told him leave this with me to look at. Having now looked at this, I've concluded that the solution to this dilemma lies in how the aeromap of the car, and the inertias, affect the stability index of the car on turn-in.

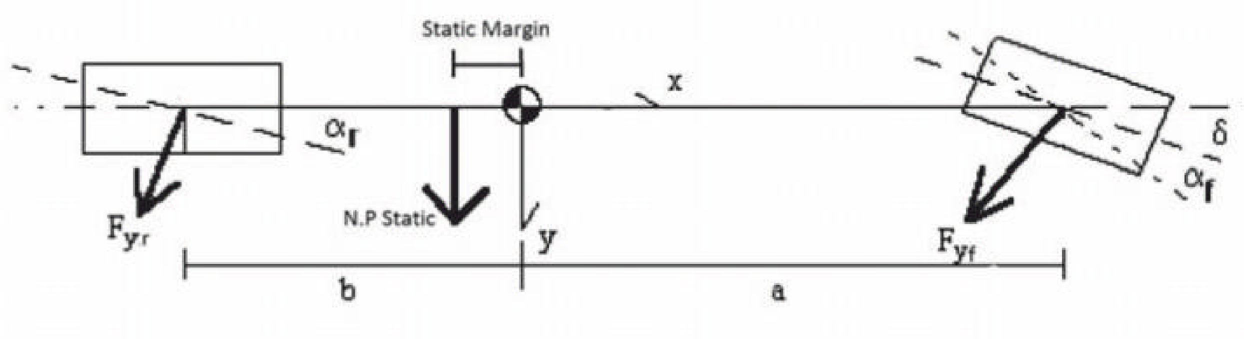
Driver confidence

A significant part of racecar performance is down to driver confidence, and nothing destroys a driver's confidence like having the car wanting to swap ends when it turns in. To quantify this, we used ChassisSim to change the rebound on a representative LMP2/Daytona Prototype spec racecar, and the only thing we changed was rebound damping at the rear. The results of this analysis were quite enlightening. Also, it's worth noting here that this is where ChassisSim really comes into its own, due to the transient nature of the lap time simulation algorithm.

To kick off this discussion it would be wise to remind you what the stability index is and what it means. It is illustrated in **Figure 1**.

The formula for this I have done to death in previous articles, but suffice to say the stability index is the static margin non-dimensionalised by wheelbase. Bottom line, the closer to or greater than 0 the stability index is the more nervous the racecar is going to be. Also, make no mistake here, the stability index is a living breathing thing, and it will change depending on where you are at in the corner.

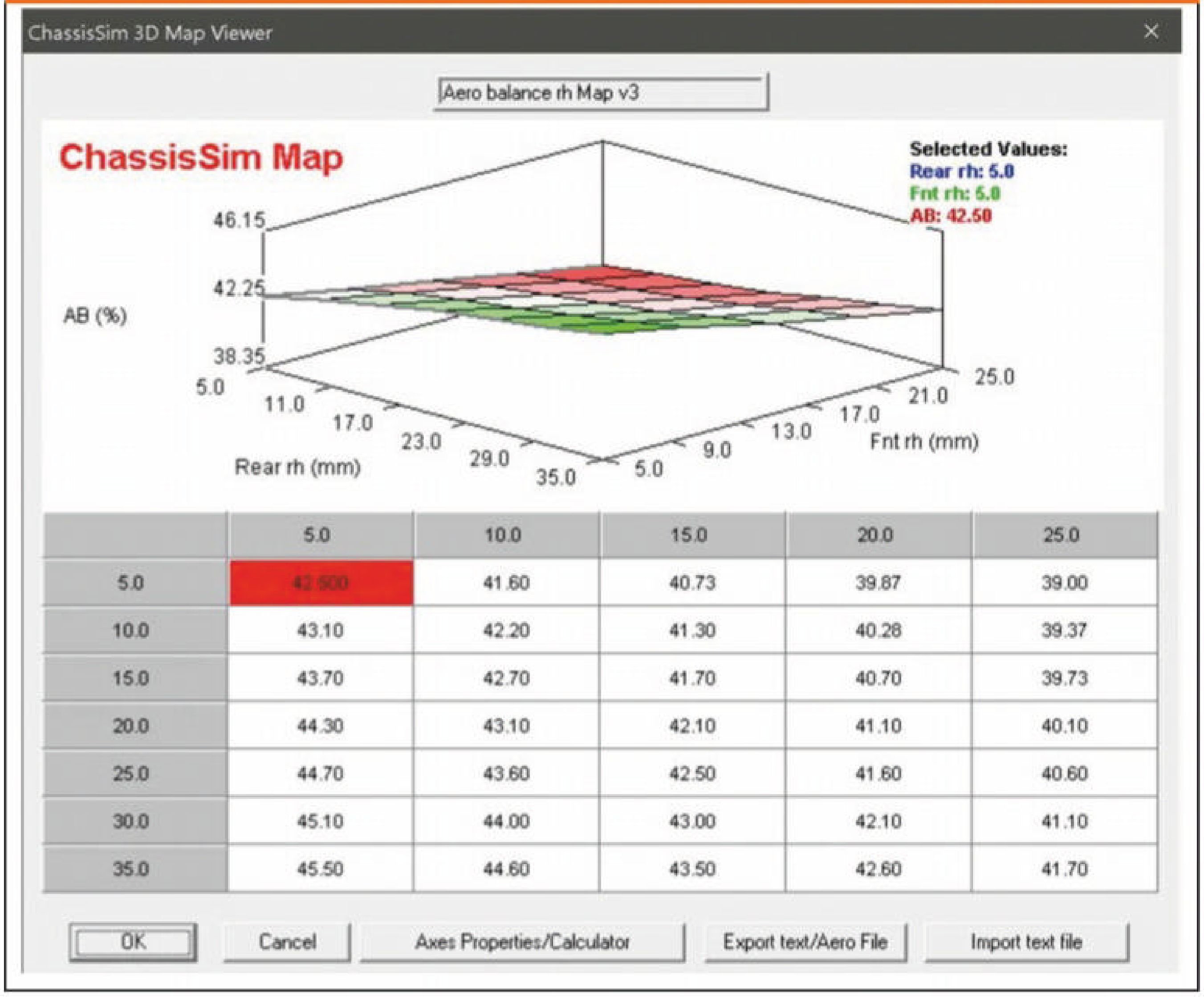
Figure 1: The stability index



Where:

F_{yf} = total front lateral forces
F_{yr} = total rear lateral forces
α_f = front slip angle
α_r = rear slip angle
δ = steered angle
a = distance of front axle to the centre of gravity
b = distance of the rear axle to the centre of gravity
$Static\ Margin$ = distance between the neutral point and centre of gravity
$NP\ Static$ = centre of the lateral forces

Figure 2: Representative aeromap for mid-engine racecar



	5.0	10.0	15.0	20.0	25.0
5.0	42.500	41.60	40.73	39.87	39.00
10.0	43.10	42.20	41.30	40.28	39.37
15.0	43.70	42.70	41.70	40.70	39.73
20.0	44.30	43.10	42.10	41.10	40.10
25.0	44.70	43.60	42.50	41.60	40.60
30.0	45.10	44.00	43.00	42.10	41.10
35.0	45.50	44.60	43.50	42.60	41.70

So, what about the rear rebound and why is it a go-to for stability for a mid-engine racecar, particularly when you have aero? The reason for this can be illustrated with a typical aeromap for a mid-engine racecar (**Figure 2**).

In this map front ride height is across and rear ride height is down. As can be seen, as the rear ride height goes up the aero balance goes up. Also, under braking this will be more pronounced because the front ride heights are at the minimum. This means the aero balance will be at its maximum. Also, the double whammy here is downforce follows this trend as well. On top of this, if you have a big heavy engine in the back the I_y and I_z (rotational inertias in the pitch and yaw axis) are going to be bigger which will further add to this effect.

So, to quantify this some representative simulations were run in ChassisSim. To keep this simple we took a current LMP2 set-up and simply chopped the rear rebound by 50 per cent. We also did some analysis with European LMP2 and Daytona Prototype inertia numbers. The circuit simulated was COTA and the results are summarised in **Table 1**.

Table 1: Summary of simulated results

Set-up	Lap time
LMP2 inertia standard damping	113.995s
LMP2 inertia rear rebound half	113.787s
DP inertia standard damping	115.195s
DP inertia rear rebound half	115.402s

Increased inertia

At this stage of the game I couldn't care less about lap time since this is not the point of this analysis. That said, the loss in lap time with the Daytona Prototype tells you the effect of the increased inertia, since you actually need the rear rebound to control this.

Reviewing the stability index under braking and turn-in for the LMP2 car with standard inertia was most revealing. This is illustrated in **Figure 3**. Since this is pseudo active data the

Figure 3: Plot of stability index for the LMP2 car with standard inertia

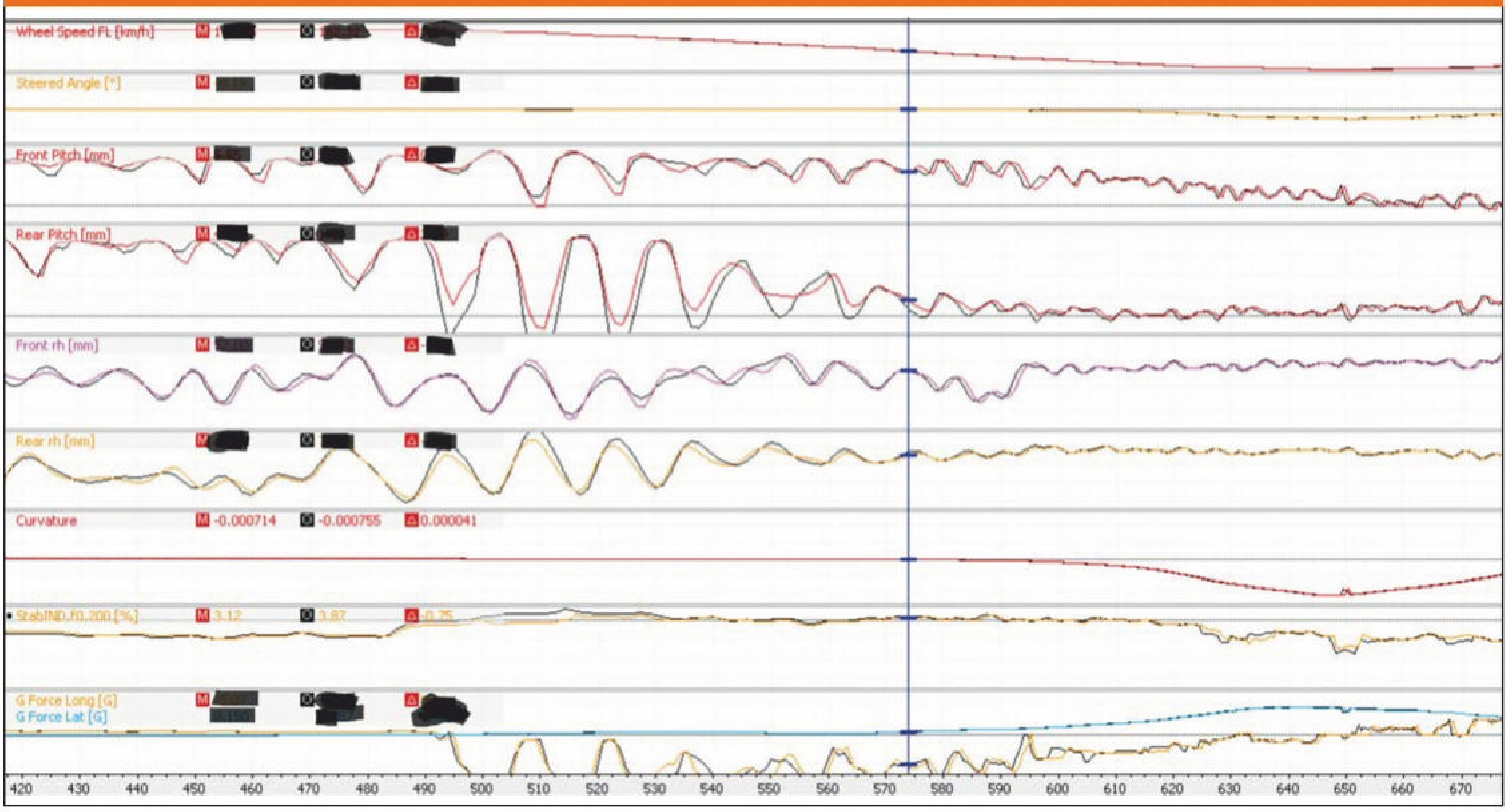
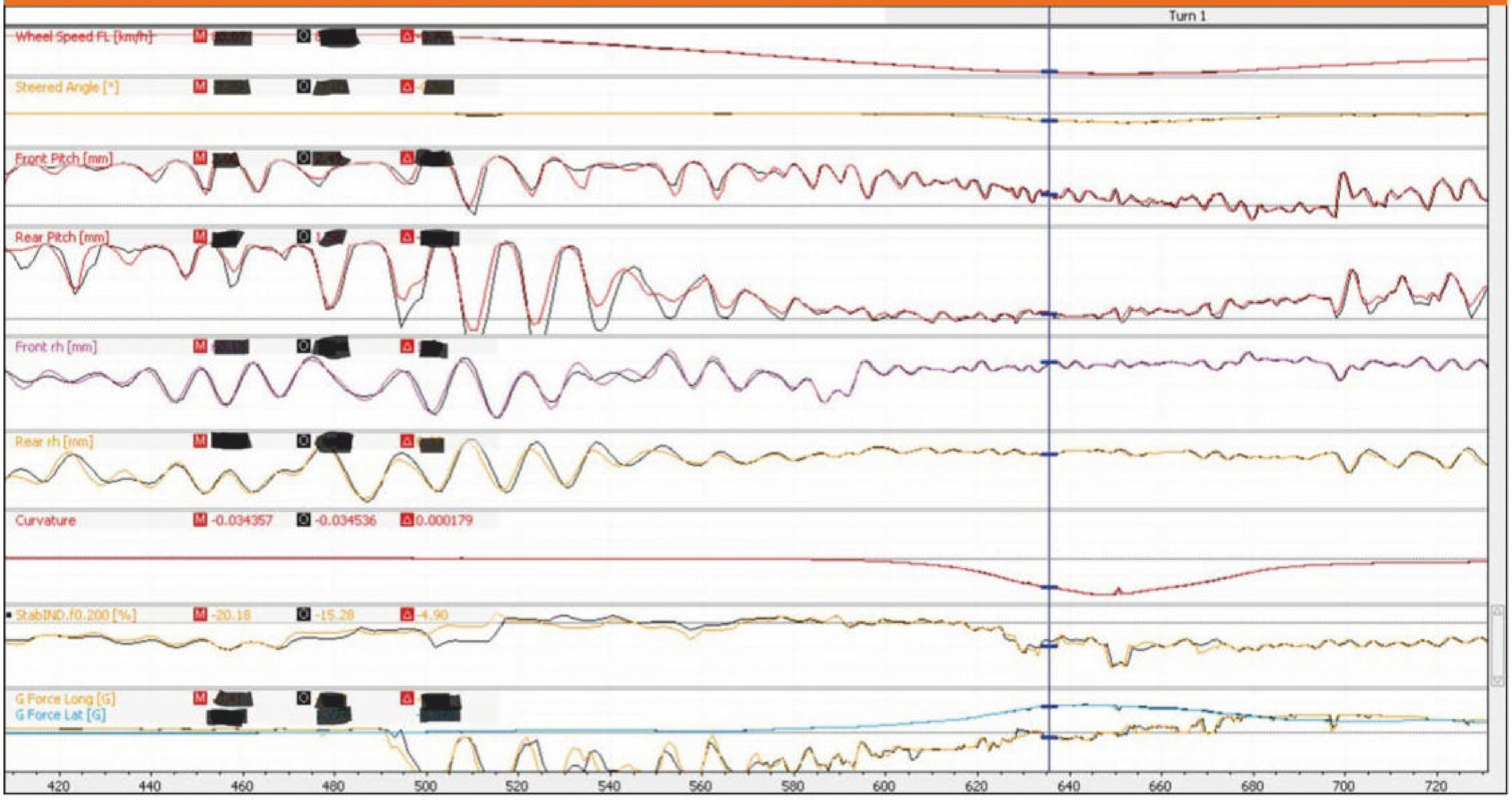


Figure 4: Stability index variation for LMP2 car with Daytona Prototype inertia



There is a key difference between analysing simulated *vs* actual data; simulation always knows where the grip is and it has no concept of fear

sensitive aspects have been redacted. To work everyone through the plots: first plot is car speed; second plot is steered angle; third and fourth plot is front and rear pitch; fifth and sixth is front and rear ride height; seventh is stability index in per cent, and the eighth plot is lateral and longitudinal acceleration.

The trace for the standard racecar is coloured, with the reduced rear rebound set-up shown in black. The effect of the damping on the stability index, particularly under heavy braking, stands out like a sore thumb. Under initial braking the stability index has shifted from plus two per cent to plus eight per cent. Also, as we progress through the turn, particularly as initial lateral acceleration is applied, the stability index has increased from plus two per cent to plus 2.86 per cent.

This is something that not only will a race driver feel, but it will also impact on their confidence. As can be seen from the sixth trace, what is driving this is the increased variation in rear ride height. This, in turn, increases the aero balance variation which is driving the increased stability index.

DP inertia

The Daytona Prototype results also showed a similar trend. This is illustrated in **Figure 4**. As per the LMP2 inertia case the results are very similar. If anything, the deltas under full brakes are even more pronounced. Under initial braking the delta in the stability index is plus nine per cent! This will definitely get a driver very cranky. Also, it is here where these increased inertias are really going to have an impact, since the variation in the rear ride height from the sixth trace is actually less than what it was for the LMP2 spec car. The other impact with the increased inertia is that the decreased stability index actually propagates to mid-corner.

Subtle changes

A couple of points about the analysis we have conducted here. Firstly, because I just did a blanket rear rebound reduction of 50 per cent this change will not propagate everywhere. The nature of the bumps on the track will dictate this situation. However, the trends in the reduction of car stability speak volumes.

One other thing to note is the changes here have been very subtle indeed. This is one of the key differences between analysing simulated *vs* actual data. Simulation always know where the grip is and it has no concept of fear, or it's own mortality. Consequently, you are looking for very subtle changes. That said, I was startled with the magnitude of the stability index deltas I was looking at here.

The other thing that this analysis illustrates is how simulation can go well beyond just using lap time. A colleague of mine once said to me the best and worst thing I ever did was put a lap time prediction into the lap time simulation results on ChassisSim. It was a good thing because at least you have some idea of how it went. It's a bad thing because this is the only thing you focus on. But when our focus is on stability index we couldn't give two hoots about lap time. This shows very clearly that racecar simulation extends well beyond just getting obsessed about the lap times.

The other thing to note is that this really illustrates why transient lap time simulation shines. Bottom line, this analysis would have been impossible to do with pseudo static simulation, and this really shows the areas of analysis that transient simulation open up.

Summing up

In closing, we have learnt quite a bit about the effects of rear rebound damping and just why it does what it does. The real difference from when you go from a shaker rig to an actual car is that this is where the aeromap and the inertias come into play.

The moral of the tale here is that while lower rebound values might look fantastic on a shaker rig, when you get it on to a racecar the body control becomes paramount and this is being driven by the stability index under braking. Also, the great thing is you can use simulation packages like ChassisSim to nail down exactly what is going on. This is a powerful tool to explore all this at length.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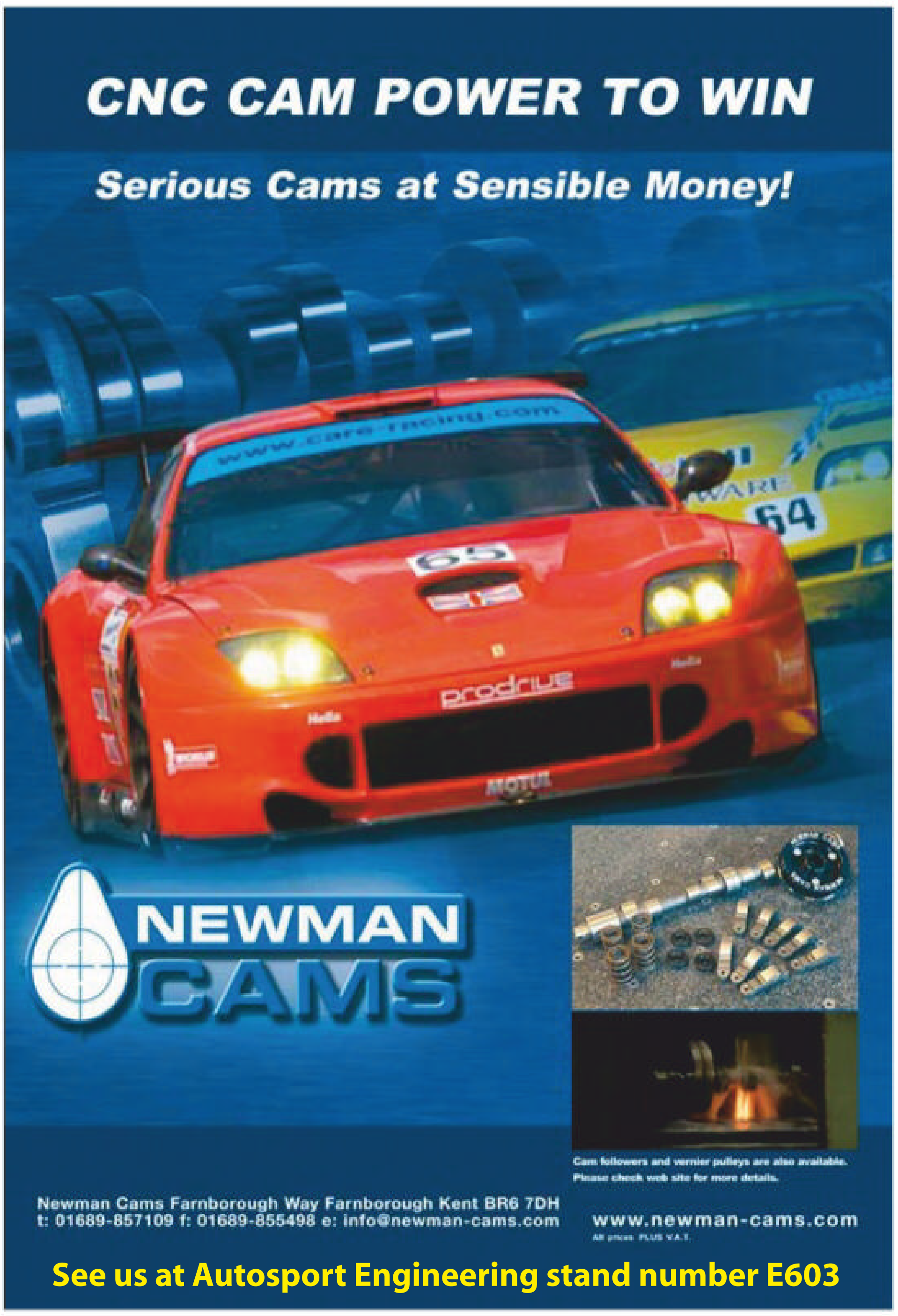
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Marcus Ericsson goes flying at Monza in 2018. Due to advances in safety race drivers are now able to survive shunts that might well have caused injury or worse in seasons gone by

Secure in the knowledge

When the FIA made a PRI Show presentation to explain its safety strategy, and the developments it's made to make motorsport less dangerous now and in the future, *Racecar* grabbed a front row seat

By ANDREW COTTON

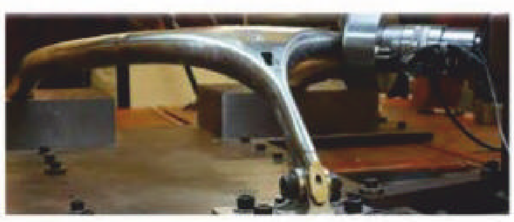
Making racing safer is a fundamental goal for all motor racing governing bodies, but none have quite the global reach of the FIA. The world governing body has constantly striven to deliver the latest technology and equipment to drivers and team members and at the PRI show mid-December its head of Competitor Safety, Nuno Costa, presented the latest thinking and timelines for introducing safety upgrades.

Safety in numbers

The safety team comprises four separate departments; Competitor Safety, Circuit and Rally Safety, Medical Rescue, and Research. Competitor Safety primarily focusses on safety within the cockpit across the range of motor racing activities, and the homologation and regulation of competitor safety equipment. Everything from helmets, head restraining systems, clothing and biometric devices fall into the remit of this department and the FIA is looking to upgrade the equipment it's responsible for over the next five years.








A very wide range of driver and racecar equipment comes under the remit of the FIA's Competitor Safety department

The 8862 seat is capable of withstanding high impact rates, to the tune of 70*g*, from the rear of the driver

The FIA's work on the 8862 seat has been ground-breaking

Also within its remit is the safety devices inside the cockpit survival cell, including seats, harnesses, fire extinguishers, roll cage padding, fuel cells, Halo and wheel tethers. Each of these areas is under constant review with a view to making the racing driver safer in competition.

The Circuit and Rally Safety department has the job of ensuring safe competition for all competitors, officials and spectators across all disciplines. Circuit regulation and homologation, safety equipment and licensing all fall into this area, along with circuit inspection and operational rally safety.

This department has produced the latest standard safety barriers, debris fencing, abrasive paint to replace gravel traps and light panels around the race circuits to aid communication with drivers out on the track.

Doctor know

The remit for Medical Rescue includes the on-circuit facilities, training, transport and personnel, but is also concerned with anti-doping and alcohol regulation and control, and the accreditation of trackside medical staff.

The Research department is involved in areas of development, with the introduction in recent years of ear plug accelerometers and high speed cameras to aid with accident investigations and GPS car data. This is also the department that conducts the investigations into accidents and produces the reports from which other departments can draw information.

The development cycle runs from accident data to crash analysis, leading to research projects such as the Halo, to the introduction of a new safety standard and finally new regulations.

Research's projects sees the FIA collaborate with other motorsport safety researchers from around the world to share and disseminate the latest findings. Currently, for example, the FIA is involved in the development of a new 360-degree cockpit safety initiative in which the driver is protected regardless of the angle of impact. This has included new seat standards, side-impact protection, leg protection and frontal impact protection.

Safe seat

Another research project undertaken by the FIA is the new race seats, with two options available. The 8862 seat is capable of withstanding high impact rates, to the tune of 70*g* from the rear of the driver, while the much cheaper 8855 can withstand up to 25*g* rear impact. Side loading is up to 70*g* and 15*g* respectively, but the FIA's Research department has worked on a way of bringing the performance more in line across the two seats, with nets.

Racing nets are nothing new; anyone who has seen the 1990 blockbuster *Days of Thunder* will notice that the film's hero, Cole Trickle, is protected by a window net. These new nets, though, are designed to support the race driver's shoulder and head during frontal angled collisions, and they have proven to be highly effective. Using the cheaper 8855 seat with a net, the rear impact absorption is unaffected, but the side-impact protection comes up to the same level as the more expensive 8862 seat, up to 70*g*.

The new helmet standard has been in force in Formula 1 since the start of the 2018 season

Head first

In *Racecar Engineering* we have covered the new standard 8860-2018 crash helmet that will be introduced across racing in the next few years (see September 2018, V28N9), and in our last edition (January, V30N1) we covered the new standard protective clothing. But when will drivers be expected to dip their hands in their pockets to buy the new material?

The crash helmet was accepted in 2018 and introduced into Formula 1, Formula 2, Formula E and the WRC in 2019. From this year the World Endurance Championship will use the helmet while Formula 3 and GT3 will be required to use them from 2021.

As for the new clothing, it was introduced into Formula E in late 2019, Formula 1, the WEC and WRC this season, while 2021 will see it introduced as compulsory attire in Formula 2, WRX and the FIA World Cup for cross country rallies. GT3 drivers will have to use it from 2022 and Formula 3 from 2023.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Interview – Jacques Nicolet

The Ligier guy

Ligier's CEO explains why its ongoing drive for a diverse product range means that its current issues in LMP2 are far from a crisis for the fabled marque

By MIKE BRESLIN

'At the moment I am feeling very content to have 100 Formula 4 cars running in the US'

Dallara aside, is there any other racecar constructor in the world with as diverse a selection of products as Ligier? The French concern estimates it has close to 300 cars out on track around the world right now, ranging from LMP2 and P3 sportscars, to F3 and F4 single seaters, not forgetting its new JS2 R GT car. What brings these all together, of course, is that famous name.

Last year was the 50th anniversary of the birth of Ligier as a racecar marque, and the 40th of its short period of dominance in Formula 1 at the beginning of 1979. The current incarnation of the company is owned by Jacques Nicolet – founder Guy Ligier died in 2015 – and has grown out of Nicolet's Onroak concern, as part of his wider Everspeed Group.

Racing pedigree

But the racecar production part of the firm is now operating firmly under the Ligier banner, and Nicolet is certain that this brings its own advantages. 'For us it's very important, because with the brand, with the name, we are the full history, and the brand is very recognisable because of its victories in Formula 1,' he says. 'It's very well known all around the world, and this has been very helpful for us, with the new products we are developing. For example, the Ligier JS2 R, our new GT, we have some US customers who would like to be the first to have a Ligier, because of the brand. For sure, it's also because of the product, which is very good, but the brand is very important.'

As is its history. 'Everything we are developing today has a link with the past,' Nicolet says. 'For instance, the Ligier JS2 R takes its inspiration from the Ligier JS2 created by Guy Ligier in the '70s, that finished second in the 1975 Le Mans 24 hours. Likewise, we have used our Formula 1 heritage and have designed a Formula 4 and a Formula 3, the Ligier JS F4 and the Ligier JS F3, which are running in the United States. So we are completely entrenched, we say, with the brand.'

Yet while the brand is tasting business success across the globe, its flagship product, the JS P217 LMP2, is not the P2 of choice with WEC operations, with no Ligiers present in the championship as teams opt for ORECA's 07. So why the fall from grace? 'There is not one reason, but for me we are clearly disappointed not to have had the possibility to have the joker [to develop the car further] that we had proposed,' Nicolet says. 'For sure, our car is good, we have won races with this LMP2, we have clinched pole position and finished second in the Asian Le Mans Series a few weeks ago in Shanghai. So, the car is good, but we need a little bit of improvement to reach the ORECA.'

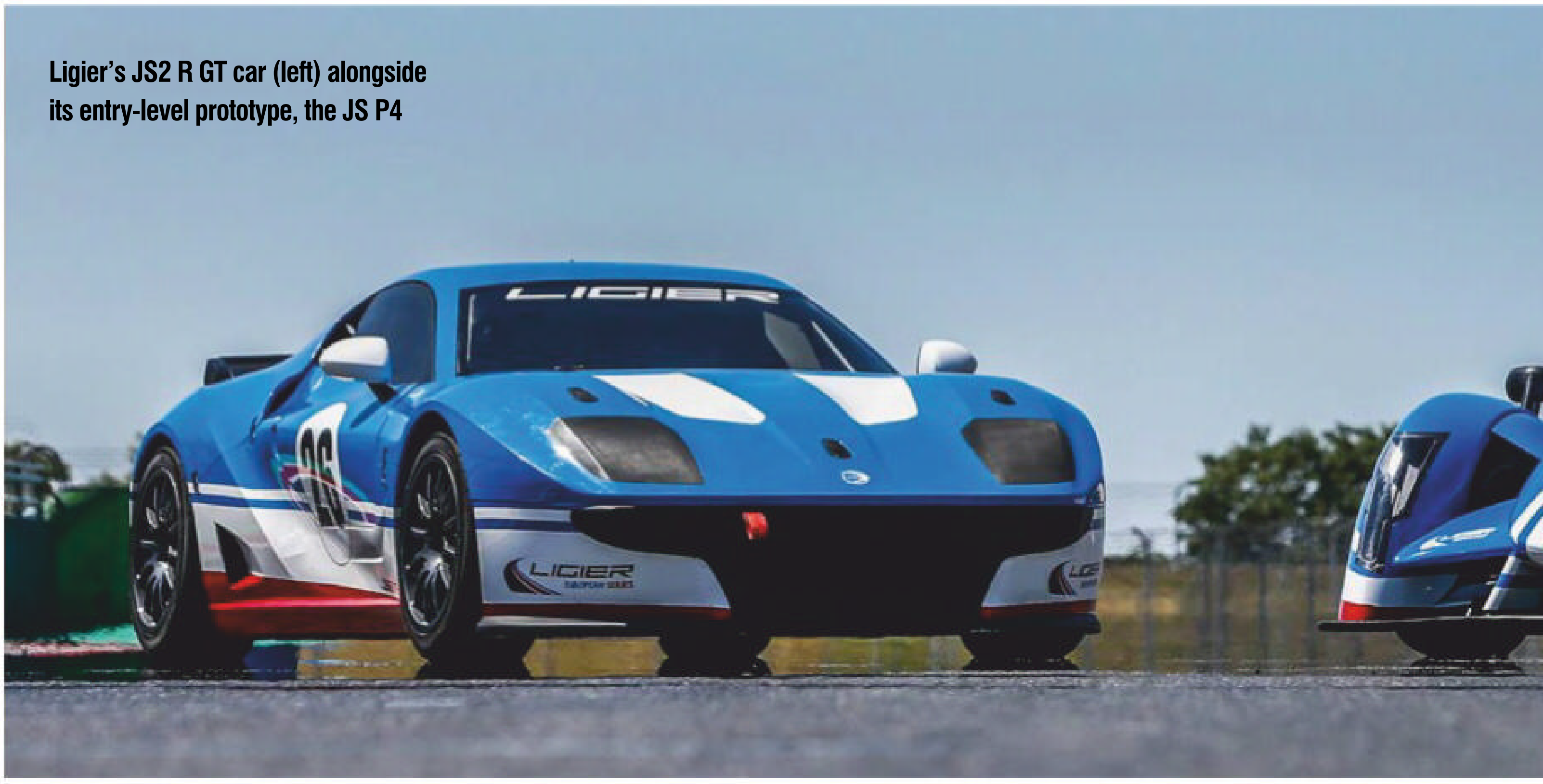
Ligier is certainly not done with P2, though. 'For sure, on our side we want to carry on with the LMP2 product,' Nicolet says. 'We have sold around 15 Ligier JS P217s so far. Now we are waiting for the regulators to find the parity between the P2 and the new Hypercar and LMP1. We know that the LMP2 homologation period will be extended for one more year, until 2022. We don't know exactly what will happen after.

'The LMP2 market is a very closed one;' Nicolet adds. 'There is only the European Le Mans Series, the WEC and the Le Mans 24 hours, IMSA and now the ASLMS [Asia] in which we are able to sell our cars, so there are only so many cars we can sell. For us, as a manufacturer, we would prefer to continue to be involved in the LMP2 market, but we have developed other products to diversify our business model.'

Three's a crowd

Chief amongst its other products is its LMP3, with 120 of all recent Ligiers sold examples of this neat little prototype. Now there's a new version, the Ligier JS P320. 'Our new P3 has a completely different bodywork, with new aero, we have adapted also the car to the new safety rules, and for the new engine; all around the cooling, for example,' Nicolet says. 'The monocoque is the same, but adapted with the new rules

Ligier's JS2 R GT car (left) alongside its entry-level prototype, the JS P4



with the side impact panels and so on. We have passed the homologation and the car has made a lot of tests and we are very happy with this new product.'

After three comes four, and with its JS P4 Ligier seems to have spotted a gap in the market, as far as closed prototypes are concerned. 'Our concept for the Ligier JS P4 is to have a first level for prototypes for the gentlemen driver and young drivers to start endurance races,' Nicolet says. 'Before, we had the CN car, but initially the CN was not designed for endurance racing, it was more adapted for the sprint race. There is also a question of safety for the gentleman driver. And our Ligier JS P4 has completely integrated the same rules of safety as LMP3.'

Hyper active

The LS P4 will this year compete in a new Ligier European Series, alongside the Ligier JS2 GT car, which, as Nicolet mentioned earlier, is a nod to a 1970s Le Mans racer. Nicolet is, in fact, a rapid high-level amateur driver who has tasted success at Le Mans himself – he was third in P2 in 2009 – and the 24 hours is a race that is close to his heart. So it's no surprise then that he has been keeping a close eye on the new Hypercar regulations.

'For me, at the moment I think the concept of Hypercar is a good idea, because for sure we need to have something new, and at the same time we need to be more adaptive and have a product that speaks more to the use of energy, with hybridisation, for example,' Nicolet says. 'But we need also to wait a little bit. We need to have more stability. If we start a new car for LMP to these new rules, [because] we are a small manufacturer, we need to be sure that the rules will remain the same for three, four, five years.

'We are very open to this possibility,' Nicolet adds. 'We just need to know how the Hypercar and P2 will all work together.'

Yet while Nicolet's heart is at Le Mans, for many Ligier is a name that's more synonymous with Formula 1. Other big names from the past have returned, Lotus for example, so might there ever be a chance we will see a Ligier back in F1? 'Now the level, and the financial part of Formula 1 is too difficult to reach, and from my side I prefer to have a complete and efficient company in racecar production,' Nicolet says. 'For me it's more important to have a complete diversification at a more reasonable level, than to have just two Ligiers racing in Formula 1. At the moment I am feeling very content to have 100 Formula 4s running in the US, and I think for the brand that is more important than being in Formula 1, because we need to have a product for the future, for the new generation and for the gentleman driver.'

All of which goes some way to explaining why Ligier works so hard to ensure it has such a diverse product line.

RACE MOVES

Andrew Jarvis has left the McLaren Formula 1 team, where he was **Lando Norris'** performance engineer. To mark his departure Norris raced with an image of Jarvis on his helmet at the season-closing Abu Dhabi Grand Prix. At the time of writing it was believed he was to be replaced by **Jose Manuel Lopez**, who has now left his post as performance engineer to **Kevin Magnussen** at the Haas team.

Frank Kelleher has been promoted to senior vice president and chief sales officer within NASCAR's Sales and Partnership Marketing department. Kelleher has spent the past 16 years working at International Speedway Corporation, the track operating company recently acquired by NASCAR. He takes over from **Jon Tuck**, who has left the company, and he will report to **Daryl Wolfe**, executive vice president and chief operations and sales officer. Kelleher will be based in the Daytona office.

Also at the NASCAR Sales and Partnership Marketing department (see above), **Michelle Byron** and **Jeff Wohlschlaeger** have both been promoted to vice president, partnership marketing. Byron has been with NASCAR for nearly 20 years and has most recently been responsible for looking after official partners such as Axalta, Chevrolet and Mobil 1. Wohlschlaeger has more than 25 years of sports industry experience. Both will report to **Jill Gregory**, executive vice president and chief marketing officer.

Formula 1 design legend **Gordon Murray** is considering a return to motorsport by way of the new Le Mans and WEC Hypercar regulations, using his upcoming T.50 £2m sportscar as a base for the project. While plans are in their very early stages Murray has said that his company, Gordon Murray Automotive, has met with the ACO and the FIA to discuss the possibility.

Former Indy Racing League (IRL) engine builder **Mickey Nickos** has died. His family run NEC Engines business, where he worked alongside his son **Dale**, initially made a name for itself building powerplants for short track and dirt track cars, especially in the US Midwest, and then became involved in top flight racing when the IRL opted to use stock-based V8s back in 1997.

John Martin, a man who fulfilled the role of driver, team owner, engine builder, chief mechanic and sponsor hunter for his team's shots at Indianapolis 500 glory back in the 1970s, has died at the age of 80. Martin, who last raced at Indy in 1976, started his motorsport career as a mechanic. For the past decade he had still been working as an engine builder.

It's been reported that **Michael Cannon** has left IndyCar outfit Dale Coyne Racing to join rival team Chip Ganassi Racing (CGR), where he will replace **Chris Simmons** as **Scott Dixon's** race engineer. Cannon, who engineered rookie **Santino Ferrucci** in 2019, has plenty of experience in IndyCar, having previously worked at the Minardi/HVM Champ Car operation, Ed Carpenter Racing, KV Racing, and Andretti Autosport. Simmons is believed to have moved to a new post within CGR.

Trevor Green-Smith has also left the Dale Coyne Racing IndyCar squad (see above), where he was assistant engineer on the **Sebastien Bourdais** car. He is moving to rival outfit Andretti Autosport. The Californian, who is a graduate of the Oxford Brookes University Motorsport Engineering course in the UK, came to Dale Coyne Racing in 2017.

Kate Gundlach, who was the assistant engineer to **Chris Simmons** at the Chip Ganassi Racing IndyCar squad, has departed her role on **Scott Dixon's** No. 9 car, moving to the Arrow McLaren SP operation, where she will work as a performance engineer.

The Stewart-Haas Racing NASCAR operation has moved crew chief **Mike Shiplett** from the Xfinity Series to the Cup for the oncoming season, where he will oversee the car of his 2019 driver, **Cole Custer**, the latter having stepped up to drive the team's No.41 Ford Mustang. While Custer is a Cup rookie Shiplett has chalked up 121 starts at NASCAR's highest level, between 2008 and 2011.

Nick Chester no longer part of the Renault F1 operation

Nick Chester, who has worked at the 'Enstone' Formula 1 squad since 2000, most recently in the role of chassis technical director, is to leave the Renault operation in a move that is part of an ongoing shake-up within the outfit's technical team.

Chester started at the then-Benetton team as a race engineer and then filled a variety of roles as its identity changed to Renault, then Lotus and then back to Renault again. Before joining Benetton he had worked at the Simtek and Arrows Formula 1 teams. He is now on gardening leave before he is able to officially depart the organisation

XPB

Chester had been at the Enstone team since 2000

In recent times Chester had worked under executive director Marcin Budkowski.

As reported in last month's *Racecar* (V30N1), Renault has also recently taken on Dirk de Beer as head of aerodynamics and has signed up Pat Fry; the latter in an unknown post, at time of writing.

Chester said: 'I have enjoyed 19 years in a team with great spirit and have worked with an incredibly loyal and talented group of people. I am looking forward to a new challenge and wish everybody in the team all the best for the future.'

Renault F1 managing director Cyril Abiteboul said: 'Nick has been a key part of Enstone for almost 20 years. His passion for the team has never wavered, despite experiencing some extremely challenging times. More recently, his commitment, technical insight and enthusiasm have inspired us to move from the back of the grid to the front of the midfield.'

The changes at Renault come after it finished a disappointing fifth in the constructors' championship, one place behind its customer team McLaren. It's also against the backdrop of an internal review being conducted into the wider company's operations, as announced in October last year by interim chief executive officer Clotilde Delbos, who has replaced former boss Carlos Ghosn.

Chester joins Peter Machin, who was formerly head of aero, in leaving the Renault F1 team as a result of the ongoing reorganisation.

OBITUARY – Domingos Piedade

Domingos Piedade, one of the main movers and shakers in Portuguese motorsport, a well-known driver manager and for a long-time a boss at German tuning giant AMG, has died at the age of 75.

Piedade worked with many race drivers during his career, and he came into the business as Emerson Fittipaldi's manager in 1972, sticking with the Brazilian through the Copersucar years. He was part of Aytron Senna's management team during the early part of his career, while he also managed fellow Portuguese Pedro Lamy.

As a team manager in sportscars Piedade worked at Joest during one of its most successful spells, involved in its Le Mans 24 hour wins with the Porsche 956 in both 1984 and 1985.

But it's for his work at AMG that he will be perhaps best remembered. He started at the German tuning firm when there were around 40 employees, and by the time he left that was up to around 1200 people and the company had become a part of Mercedes. Piedade was responsible for AMG's motorsport programmes during the 27 years he was with the company.

Piedade was also very well-known as a key player in the motor racing business in his native Portugal, where he was involved in bringing F1 to Estoril in 1984 – and he has been credited with introducing the medical car into Formula 1 at that very event. In 2007 he took on the job of running the same circuit, while he was also a popular F1 pundit on TV for many years.

With a career that touched almost every aspect of the sport, Piedade will be missed by many.

Domingos Piedade 1944-2019

RACE MOVES – continued

Cole Pearn has left NASCAR Cup outfit Joe Gibbs Racing, where he was crew chief for **Martin Truex Jr** on the No.19 Toyota, and he now intends to pursue opportunities outside of NASCAR. Truex is the only driver that Pearn has worked with as a crew chief in the NASCAR Cup Series. In 179 races, from 2015 to 2019, the pair have won 24 races, while they also won the championship itself in 2017.

Also at Stewart-Haas, crew chiefs **Mike Bugarewicz** and **Johnny Klausmeier** will swap cars for 2020. Bugarewicz had worked with **Clint Bowyer** on the No.14 car since 2017, but he will now tend the No.10 entry of **Aric Almirola**. Going the other way, Klausmeier will take over the crew chief duties on the Bowyer car.

Niki Lauda, the three-time Formula 1 world champion and former Mercedes grand prix team non-executive chairman who died in May of 2019, was honoured with a posthumous Personality of the Year Award at the end of season FIA Prize Gala in Paris in December. The Award was voted for by FIA accredited media.

It's been widely reported that **Lawrence Stroll**, who led a consortium that purchased Force India last year (renaming it Racing Point) has been linked with a move to obtain a large stake in car maker Aston Martin, which is a major sponsor of the Red Bull Formula 1 operation.

Ryan Thomas is the new president of Ultra 4 Racing, the US organisation that runs King of the Hammers – an off-road series that's a mix of desert racing and rock crawling. Thomas, a successful driver in the discipline, comes to the post from Jackson Motorsports Group, where he was director of product sales.

Five-time Bathurst 1000 winner **Steven Richards** has now taken on a management role at Supercars outfit Charlie Schwerkolt Racing (Team 18), having decided to hang up his helmet at the close of the 2019 season. He will now help the operation he drove for with its sponsorship deals in his role as relationships manager.

It's been reported that McLaren head of aerodynamics **Guillaume Cattelani** has now left the Formula 1 team and is currently on gardening leave. It's thought that he is set to join Haas once his contractual obligations have been fulfilled. Cattelani worked at Dallara, Peugeot Sport (LMP1) and then Lotus in Formula 1 before joining McLaren in the summer of 2014.

Brian Pattie has joined JTG Daugherty Racing for the 2020 NASCAR Cup season, where he will be crew chief for incoming driver **Ricky Stenhouse Jr** on the No.47 Chevrolet, thereby continuing a partnership the two have forged at Roush Fenway Racing over the past three years.

IMSA outfit BMW Team RLL has signed up **Chris Mower** as its new team manager. He joins the works BMW operation from Mazda Team Joest, where he was team coordinator. In recent times Mower has worked at Panther Racing as general manager, was team manager for the Nissan LMP1 programme and at KVSH Racing, while he has also had a spell working at Cosworth.

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Ultimate Works Porsche 956: the definitive history

It has been more than 30 years in the making, but *Racecar Engineering* contributor Serge Vanbockryck's definitive history of the works Porsche 956 racecars finally came out in 2019, published by Porter Press. Spread over two volumes and featuring 840 images in 800 pages, much of it from the Porsche archive and from professionals who attended the early races, this is indeed a comprehensive tome.

This is actually the first stage of the process of documenting the career of one of motor racing's most iconic, prolific and longest-serving racing cars. The second stage, yet to be published and due out in September 2020, will cover the later 962 era in detail.

The 956 started its career in 1982, and in the decade following its debut the car (and its equally legendary successor the 962) swept to five consecutive world championships and repeatedly won every classic sportscar race: the Le Mans 24 Hours seven times, the Daytona 24 hours six times, and the Sebring 12 hours four times, with victories in 39 world championship events and 55 IMSA races.

The book includes images of the wind tunnel models and the first tests of the car in March 1982

The car was built to the Group C regulations, introduced by FISA for the 1982 season. It was run by the Porsche factory in 1982, but true to Porsche's tradition was offered for sale to customers at the end of the year, and there was always a long waiting list of private teams eager to get their hands on a racecar that was clearly dominant in its first season.

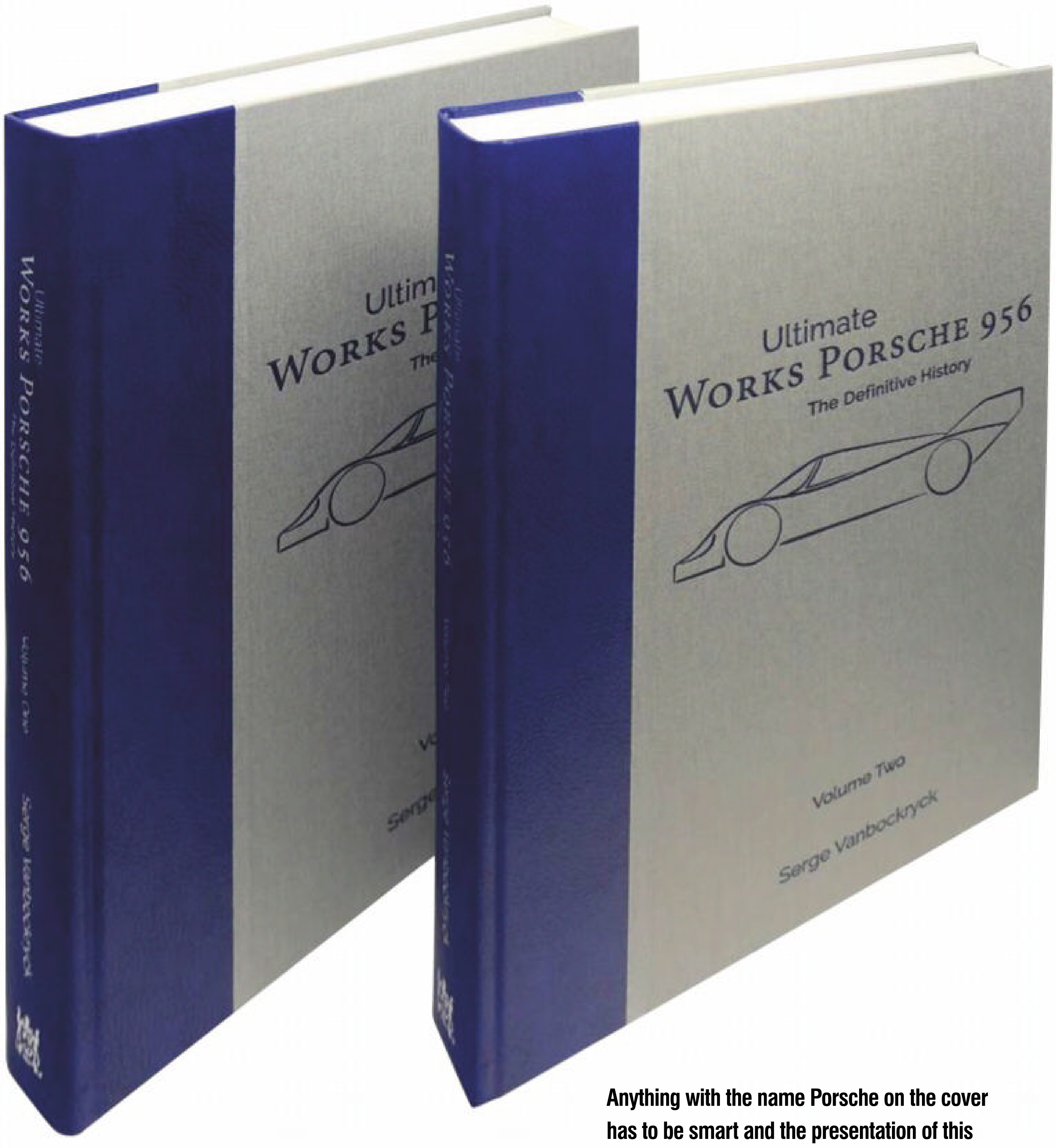
The works

These first two volumes cover the Rothmans-backed factory cars and feature the incredible development path that led to the stunning car's successful track debut in '82.

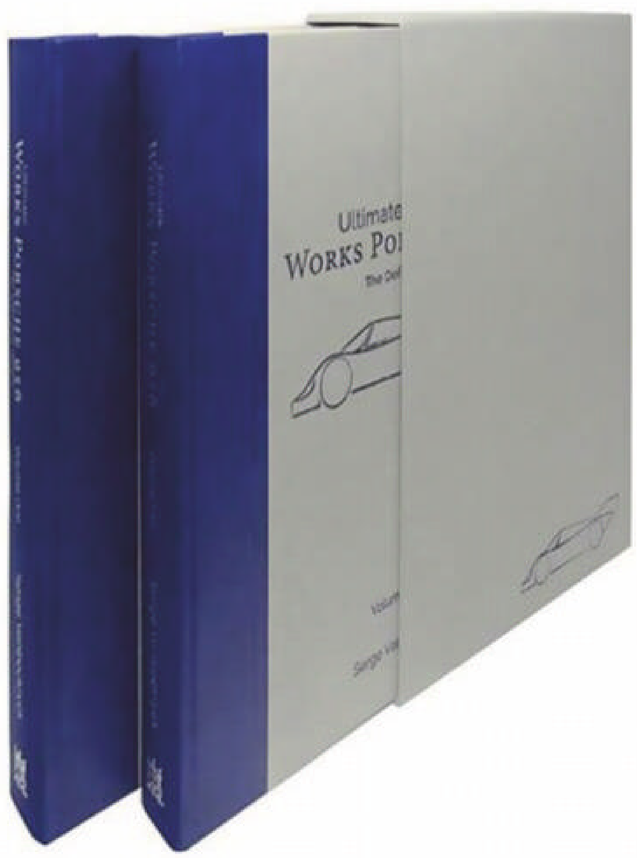
Volume 1 charts Porsche's racing history from the first Gmund coupes, through the development of the 917, into the turbocharged era with the development of the Porsche Carrera RSR, to the Indy-engined Le Mans-winning Porsche 936 of 1981, and through to the 936 and into the turbocharged era thanks to the development of the Porsche 924.

The book then moves smoothly into the 956 era, with images of the very first wind tunnel models through to the first tests of the racecar in March 1982, then it traces its history through to the end of the 1983 season.

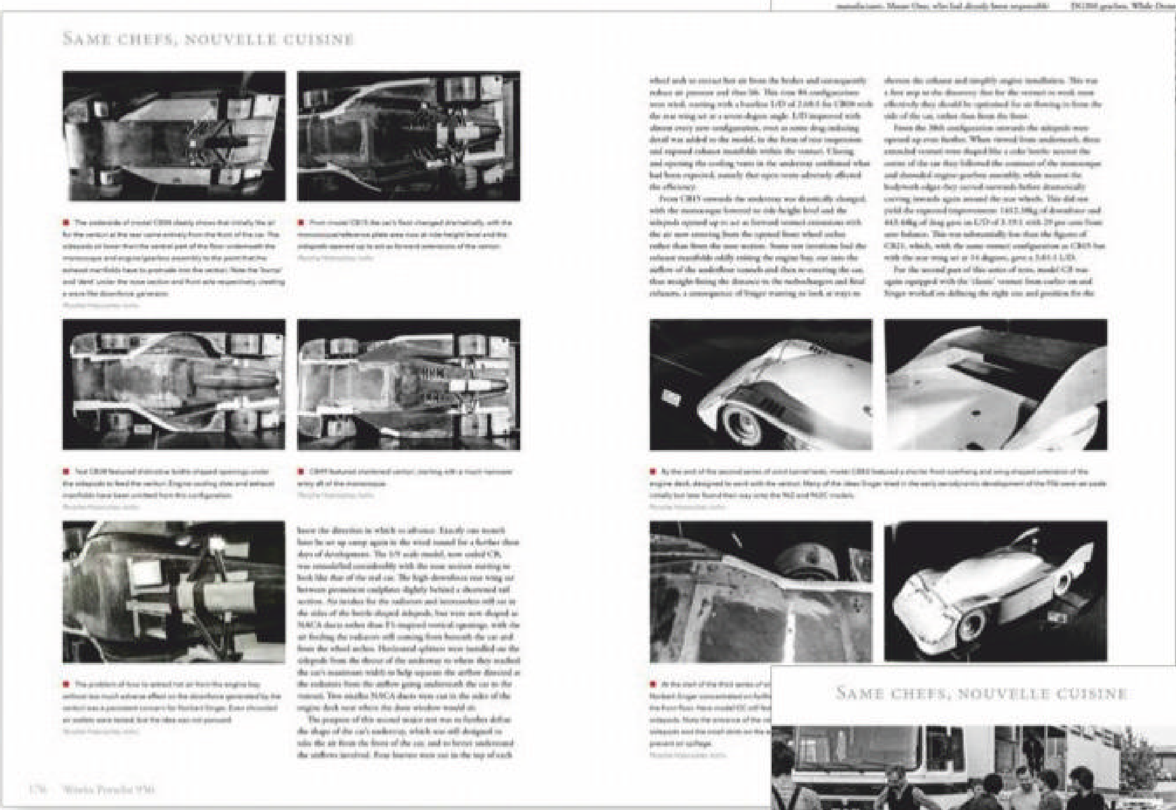
Volume 2 covers the 1984 and 1985 seasons, but it's the second half of the book in which the real value lies thanks to the painstaking research of the author. Vanbockryck profiles the drivers of the factory cars, including images of them racing other racecars, on his way to a detailed profiling of each of the 956 chassis. And when I say detailed, I mean detailed, with the inclusion of compression ratios for each race, gear ratios, gearbox and engine types, modifications from

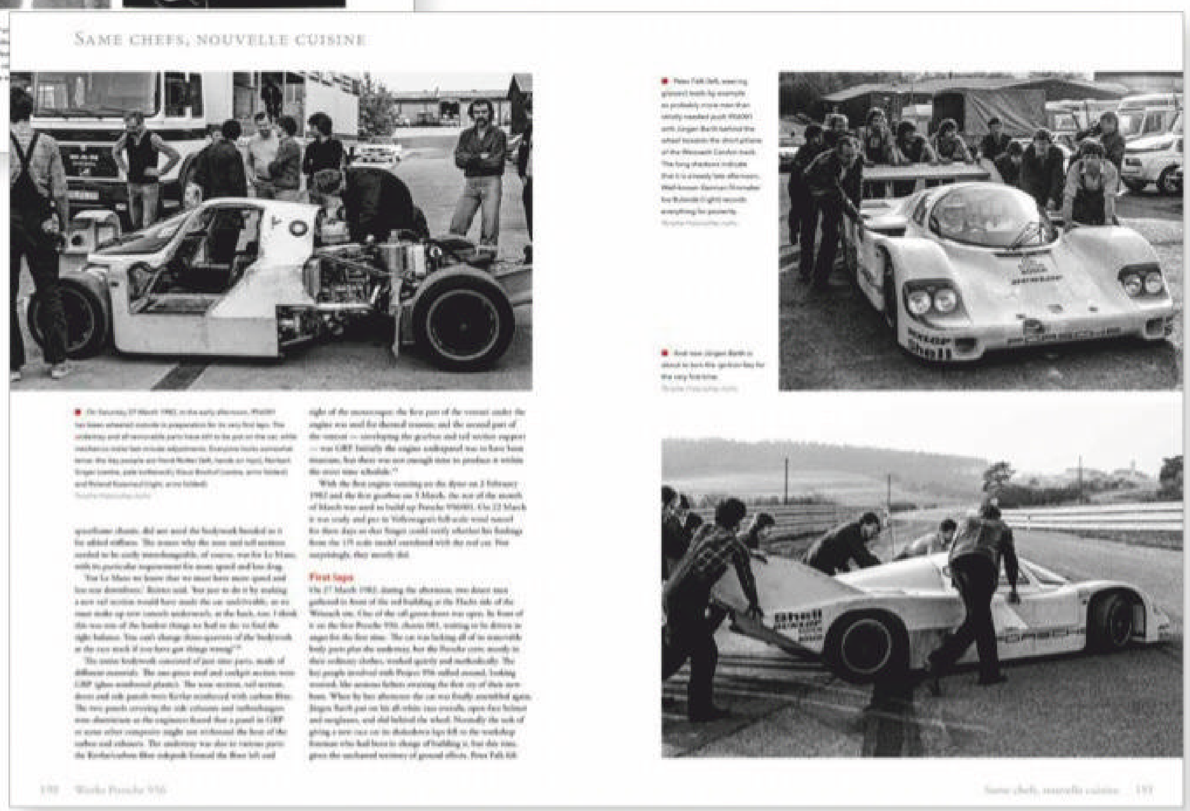


Anything with the name Porsche on the cover has to be smart and the presentation of this hefty offering does not disappoint



The chassis histories provide a fascinating day-by-day, race-by-race, insight into Porsche's racing department





With 850 pictures spread over 800 pages this two-volume tome is a treat for any true fan of sportscar racing's glorious Group C era

the original supplied chassis and images of each of the racecars in competition.

The chassis histories also provide a fascinating day-by-day, race-by-race, insight into Porsche's racing department, with each and every car for the period covered, even those that were written off or damaged and never raced again – which are now rolling museum pieces.

Most fascinating of all are the wind tunnel and development images from Porsche's own archive in Weissach, while also of great interest is the author's assertion that parts were developed by the factory, such as the front wing that was first fitted to Richard Lloyd's car in 1984, and later run by customer teams. No doubt the customer teams did their own research, but Vanbockryck's book has evidence that the factory was developing these devices before they were run by these teams.

There is also a description and a multitude of images of chassis 956 107, a car that was wasn't sold and was converted into a test mule that was used to run Porsche's 1.5-litre TAG turbo Formula 1 engine. Fitted with shrouds to direct exhaust gas under the rear wing, and with heat shielding around that rear wing, it was driven by Niki Lauda and John Watson, as well as Porsche's long-standing test driver Roland Kussmaul and also Le Mans winner Jurgen Barth, before the engine was released to McLaren.

Andrew Cotton

PUBLICATION DETAILS

Title:	*Ultimate Works Porsche 956: the definitive history*
Author:	Serge Vanbockryck
Published by:	Porter Press International
Specification:	800 pages, 850 images, 322,000 words
ISBN:	978-1-907085-98-7
Price:	£450 (limited to 956 copies)
Contact:	sales@porterpress.co.uk
Website:	porterpress.co.uk

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SCALES

Weight and see

EEC Performance has brought a wireless corner weight scale system, that has been developed with race engineers, to the market.

The seven-inch colour touch screen control, combined with a well-thought through layout has made the system easy to use, the company tells us. The Wi-POD can run multiple car set-ups, recording data history which is then available to view on screen and to download via USB for further analysis and record keeping.

Each corner has a maximum capacity of 800kg, and measures to an accuracy of 200g. The Automatic Track Compensation (ATC) system ensures that the Wi-POD weighs your vehicle accurately at any circuit without the need for local recalibration. The indicator is housed in a rugged waterproof case and is powered by a rechargeable Li-ion battery which gives around 10 hours life between charges.

www.eec-ltd.com

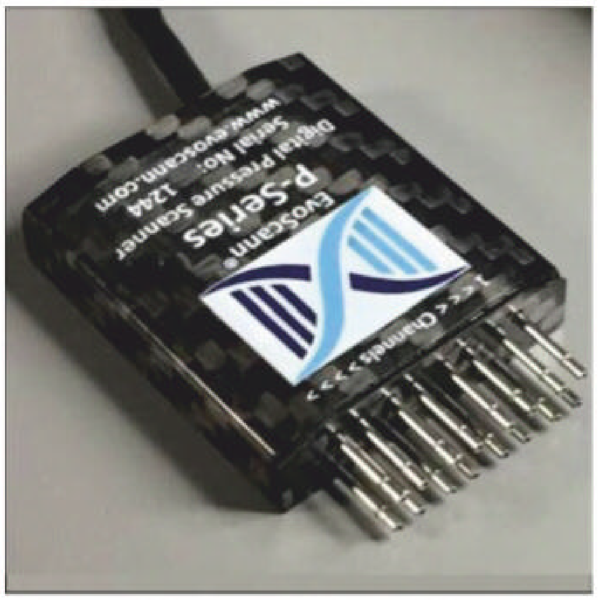
PRESSURE SCANNER

Handling the pressure

EvoScann has launched its new pressure scanner, the P16-A that, it tells us, is the smallest and lightest 16-channel miniature pressure scanner available.

Weighing less than 1g per channel, its compact dimensions allow it to fit in the tightest of spaces and it delivers fast and accurate digital data in absolute or calculated differential measurement. For details on this small but effective scanner, visit the company website.

www.evoscann.com



PUBLICATIONS

Cracking read

If your monthly *Racecar Engineering* fix is not quite enough for you, then check out our new publication, *Anatomy of a Racecar*.

This comprehensive 120-page bookazine covers every aspect of racecar design and build, with in-depth features on racecar aerodynamics, suspension, tyres, power units, composites, cooling, exhausts, high power race batteries and much, much more.

Written by *Racecar's* most popular writers, including Simon McBeath, Ricardo Divila Gemma Hatton and Andrew Cotton, the Anatomy of a Racecar also contains the quality images and detailed diagrams, graphs and tables *Racecar Engineering* has become known for. And best of all, all this engineering knowledge is available from the Chelsea Magazines shop for just £8.99.

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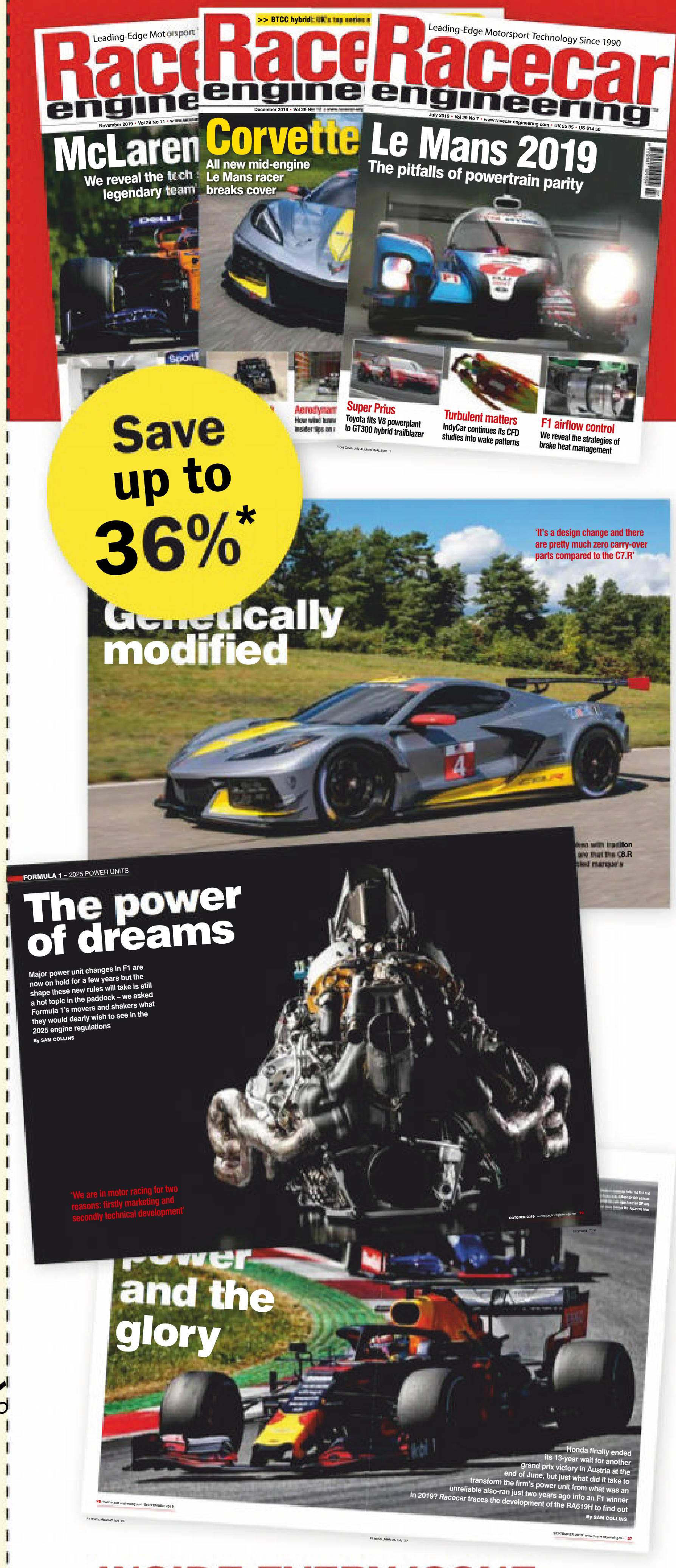

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The pieces of the motor racing jigsaw are starting to fall into place with regulations for Hypercar released early in January that will govern Le Mans for the foreseeable future; Formula 1 has rubber stamped its rules package; the GT3 regulations that will come in 2022 have been finalised, while the DTM and Super GT amalgamation under the Class 1 banner was all but completed in 2019 too. The uncertainty that has surrounded the racing world is now lifting and companies, suppliers, manufacturers and fans can start to make some proper plans.

There are still some issues that need to be solved, including the introduction of hybridisation and electrification into various forms of top-level motorsport, particularly in the US and rallying, and there is some doubt about how that technology will filter down into feeder formulae. Or, indeed, whether or not that tech will ever reach those series. There is still a lot of opposition to hybridisation, even from leading engineers in the governing bodies, with some pointing out even now that without changing the minimum weight to accommodate such systems they would not be viable in racing. And while the world looks for more efficient powertrains, the cars that we buy just get heavier.

Having secured Hypercar regulations, the ACO is still looking further ahead and pressing on with its plans for a hydrogen prototype that will run at Le Mans, perhaps in competition, in the middle of the decade, although the pressures associated with the technology, 700bar at some sealing points, is still frightening to more traditional engineers.

Key to the finalisation of the regulations is the commitment from motorsport to the short-term future of cost-controlled technology. There is still the sword of Damocles hanging over car makers about overall production sales and how that will marry with the expenditure required to race, although governing bodies continue their path of tendering for spec systems in an effort to control the costs. We have often written that spec parts do not turn out to be any cheaper, and that has been proven time and again, but the bodies are convinced that it's better to have one closed system with guaranteed sales for one manufacturer rather than multiple systems proving the best technology or capability.

The trend was always to fix a tyre partner before anything else, and many are now in place. Pirelli has F1 and GT globally until 2022, Michelin LMP1, DPi and GT until 2023, Firestone a long-standing relationship with IndyCar, Goodyear has LMP2 in the WEC until 2023, and Hankook the DTM series.

Le Mans can celebrate the return of an iconic French brand, a multiple winner

With the hybrid regulations fixed in endurance racing, Peugeot was able to announce that it was stepping back into the big race, Le Mans, although it came at the expense of its WRC programme. It needed a good news story and delivered it ahead of the announcement to abandon the series in which it is strongest. Citroen has always been associated with rallying and, even when it competed in the World Touring Car Championship, it was the rally team that ran the cars, with Sebastien Loeb driving. Its departure from the series is a big blow to the WRC, and in my opinion to the brand itself.

However, decisions are taken often for reasons that are not known to the public, and Le Mans can celebrate the return of an iconic French brand, a multiple winner, to join Toyota and Aston Martin in its top ranks. That was a big boost for the ACO, but now the work begins to establish the actual pace over a lap at Le Mans, nominally targeted at 3m30s for the first year. However, as Michelin noted, that was only a target and was likely to be beaten from the start. Once the true pace of the Hypercars are established, the ACO then has to work on the new LMP2 regulations and pace to keep them behind the top class, which then filters into LMP3, GTE and on into GT3.

I can't personally see how GTE can be sustained for the long-term future with the new GT3 regulations clearly allowing cars the ability to go faster, and with Aston Martin, Porsche and Ferrari potentially lured into the top class of either Hypercar in Europe or DPi in the US. My feeling is that the Corvette and Porsche that we featured in 2019 could be the last new cars for the finest racing category endurance racing has ever seen.

With all of this in place, engineers continue to look for other challenges and they can still be found. Pikes Peak retains its open technical regulations although safety is still its primary concern, while land speed records are as mind-boggling as ever. The forces that are required to break these barriers were previously considered beyond the capability of human kind. Time Attack may not be pushing physics quite as hard as the Bloodhound LSR vehicle, but it's also still an arena where ultimate lap time is the goal of the engineering (see page 36).

Over the next three years we are going to see all-new technologies in motorsport, with new cars and new concepts in all forms of motor racing, and *Racecar Engineering* will – as we have for 30 years now – be there to bring you all of the very latest innovation and technology.

ANDREW COTTON Editor