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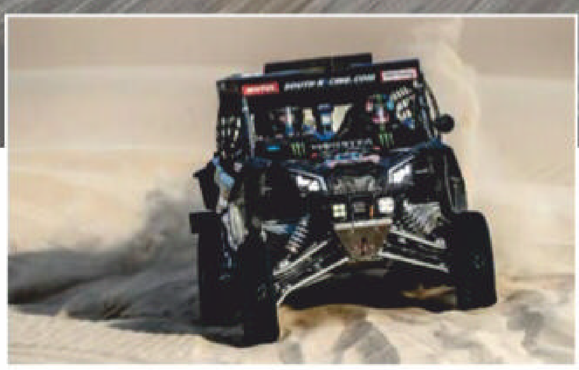
Corvette C8.R

All new mid-engine Le Mans racer breaks cover



Can-Am Maverick

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Aerodynamics 101

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Japanese Super GT

Technical analysis of the 2020 Class 1 GT500 cars

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Porsche returned to top-level factory motorsport in Formula E's pre-season test at Valencia in October. The series' sixth season kicks off in November

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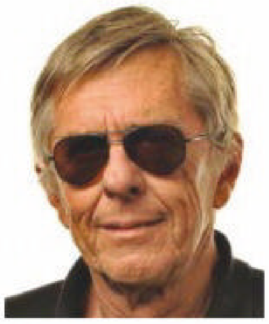


Tour of duty

In 1972 getting cars to an event could be as much of an adventure as the race itself

One of my previous columns (April, V29N4) was about the fact that come hell or high water the cars and kit always arrive at the track, and I hinted that there were many more stories to be told. So here we go again with a story from the start of the 1972 racing season that even after all these years stands out in the memory.

I had moved up to Formula 2 with a team for both Emerson and Wilson Fittipaldi and we had sourced our pristine white-painted Bedford Duple transporter from one B Ecclestone, who had a car dealership in London and was also then the new Brabham team owner. The Duple had been the Brabham F1 transporter and was a converted bus fitted with luxurious reclining aircraft seats in the front section and air con, the back being the workshop and where the cars went.

Blunder bus

It was all part of a package including one of the Lotus 69s Bernie had run in F2; which Emerson would drive alongside a new 69 we had for Wilson. I duly caught the train to London and turned up at Bernie's dealership to collect the transporter, having to wait around practically all day until the cheque cleared – Ecclestone not being the sort of character to release anything without seeing the money first.

In due course I drove up to our Norfolk workshop, had a shower and proceeded, with Wilson's half built 69 now also in the transporter, to Cosworth to collect the engines, using the time waiting for them to come off the dyno to trim the brand new bodywork.

Engines collected – still warm from the dyno – it was then a run down to Dover, where we started fitting the power units while waiting to board the ferry. It was then that we found out that one of our cars was not quite as advertised, having returned from Bogota, Columbia (where it had last raced) as deck cargo. So all the magnesium uprights had a corroded fur-coat, while the aluminium bits that where unpainted were pitted, with a coating of sea-salt over every nook and cranny. That was a bit more work than expected.

Once the other side of the Channel we then had a burst tyre; that led to another unpleasant discovery, the fact that the jack was missing. The solution was to find a garage in the one-horse French town we were close to, and convince the owner to let us borrow a jack. Backing the transporter into the garage was not easy, it cleared the entrance by only a couple of inches. Then the garage owner's jack blew its gasket as it was not designed to lift the weight. Luckily, this was after the spare had been slid over the wheel studs. We quickly tightened the nuts and left before the owner noticed and motored on to street race venue Pau, in the south of France.

Arriving at Pau we headed directly to the paddock to finish off the cars in the pouring rain, with tarpaulins pulled over the cars and us. There were no garages there and all the trucks were spread out under the trees at the park. The work continued throughout the night, with the added task of having to ream-out all the wheel holes on the three sets of rims and four new sets of dry rims as the wheel pegs were bigger than the holes and none fitted. Oh, and the reamers were the wrong size so the solution was to use a drill with some sand paper to get the pegs to fit. On 140 holes …

The Lotus 69 Formula 2 cars and the converted Bedford coach transporter pictured in a paddock later in the 1972 season

Considering the first couple of sessions were really shakedown runs for both our cars, retiring to the hotel was not an option, as the job list was reaching telephone book dimensions. Our food consisted of sandwiches and endless waffles with cream from the booths in the park.

The reclining seats in the transporter came in very handy for cat-naps, usually after cross-threading a nut or discovering a new leak when hoses had not been fitted properly on the third day without sleep – this added to a week of flat-out 15-hour days building the cars and travelling.

Qualifying did not go too badly, apart from having one damaged car that had been bitten by a kerb, a usual result of pounding around a street track. I don't remember where we were on the grid – but by then the only goal was to get the cars in the race and have a shower, eat and sleep.

Kerbed enthusiasm

Race day dawned with most of the wets re-drilled, but we didn't need them as it turned out to be dry. If memory serves me right Wilson's car ended up with a lack of directional precision, all the wheel bearings developing a huge amount of play as the pre-load had obviously been skipped at Lotus when throwing them out to the team – the standard operating procedure of the builders at that time was to deliver the cars as a unit just for ease of shipping, the teams themselves doing proper race prep. The dry track had put a higher load on the wheels, loosening them, and the car was retired after hitting kerbs and exhibiting an alarming weave everywhere.

Emerson's car retired while in second place when the fire extinguisher's electric connector short-circuited and cut all the electrics due to corrosion within it, a consequence of the deck cargo trip. We had re-done almost all the looms because of corrosion but in the mountain of work that one slipped the net.

It was not an auspicious start to the year, but finally getting back to the hotel after loading the transporter meant an hour-long shower then down to the restaurant to have a proper meal. The food was delicious, but the end of the meal's warm glow after dessert and coffee was spoiled by the news, not mentioned until then, that Emerson and Wilson thought we should immediately leave, that evening, to Nurburgring to test on the Tuesday to sort out the cars and make sure we were ready for the following race.

I come from an English family, but I had grown up in Brazil speaking English at home. I thought I had very good English, but that night I learned several new English words I had not encountered before when the one Brit we had working at the team threw a huge wobbly.

But all that was a pale prelude to the epic last trip of the year. But you'll have to wait a bit for that story – it will be in a forthcoming issue.

Once the other side of the Channel a tyre on the transporter burst, which led to another unpleasant discovery, the fact that the jack was missing

Rough justice

Should technical infringements in F1 be handled with a bit more common sense?

Since the last grand prix, a multitude of engineers have been working ceaselessly on analysing your chassis and PU performance, seeing how any possible improvements can be incorporated, taking into account the peculiarities of the circuit to be raced on this weekend. Constant simulation, including by reserve drivers back at base, has arrived at what seems to be the best combination of power modes, suspension and aero settings to start free practice. Throughout these sessions the set-up has been continuously honed to follow the changing weather and track conditions, to bring you the confidence in handling and balance that you need in order to commit fully to braking and corner entry speed. Practice times are middling; but after big efforts in qualifying you scrape into 10th with a good opportunity to get valuable points in the race.

Wasted effort

Then comes the gut-wrenching news that all your qualifying times have been disallowed, putting you to the back of the grid. This is because of a claimed potential advantage created by your PU's MGU-K over-revving – for just one microsecond – in Q1. Such an infinitesimal duration of extra power (and on your slowest lap) should only warrant a warning, surely? At worst, cancellation of your fastest lap in the session as an example of how zero-tolerance is applied, but not being kicked-out of qualifying totally.

It isn't hard to comprehend Daniel Ricciardo's furious reaction when this happened to him at the Russian GP. I understand also Kevin Magnussen's frustration at being penalised in the Sochi event for not completely following the race director's instructions regarding negotiating all the off-track bollards at Turn 2. It seems that it was virtually impossible for him, from where he went off, to comply with the instruction in full. He didn't rejoin without having slowed down significantly, unlike F2's Nikita Mazepin who was reckless in not doing so and was rightly given heavy punishment after causing carnage. Nine drivers receiving the same penalty at the same location during the weekend's races implies that this was a poorly considered solution to preventing drivers gaining an advantage by running off track.

XPB

Was it fair that Daniel Ricciardo was sent to the back of the grid at the Russian GP because of an MGU-K issue that gave him no advantage?

The Formula 1 world does continually make things more difficult for itself, don't you think? After the long-running criticisms of excessive and ill-judged penalties for what most of the participants regarded as just hard racing, it took the culmination of these expressed frustrations, when Sebastian Vettel was denied a probable victory in Canada, to make changes. One would think that the lesson had been learned and applied swiftly to other types of sanctions. However, with seemingly a lack of extended thinking, the issue of unnecessarily harsh penalties for technical matters has not been addressed, despite similarities in outcomes.

In view of the above and quite a few other contentious examples, not penalising Vettel for a jumped start at the Japanese Grand Prix at Suzuka was actually quite a welcome decision by the Formula 1 stewards. Whether the rules interpretation was correct or not (it appears that it *was*) clearly it gave him no advantage, rather it did the opposite, so 'no penalty' was justified.

Rules are rules?

There are many who will say 'the rules are the rules' and for consistency their application must be absolute. No grey areas. I understand but don't buy that. To some extent it's the easy way out. Stewards are akin to judges; the very term 'judge' implies exercising judgement, as in civilian courts. To my mind, the key words in implementing the majority of punishments should be 'intent' and 'gaining an advantage'. Intent, in terms of examining the real objective of the regulation concerned. Gaining of an advantage, or not, as a pragmatic rather than pedantic way of coming to a decision. Exceptions are dangerous manoeuvres, along with deliberate attempts to cheat the technical regulations.

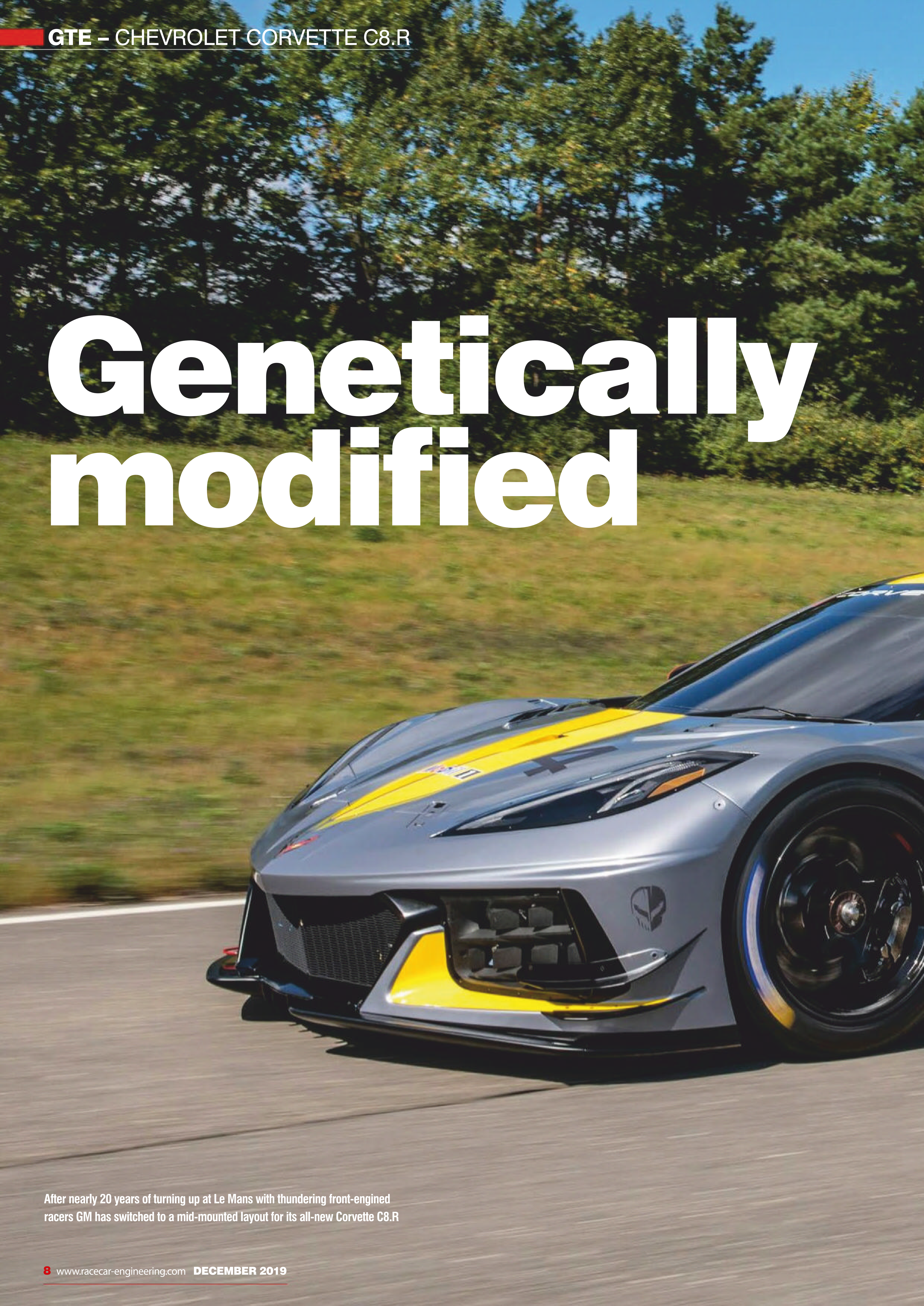
I fully appreciate that this policy makes the stewards' positions more difficult and open to increased challenges regarding lack of consistency, but for the sake of avoiding penalties out of all proportion to a marginal error it has to be worth it. Again, no different to the more down-to-earth approach to the sporting regulations now thankfully in force. Time to bring both in line.

Dark materials

Lessons are always there to be learned, but sometimes, as already alluded to, it takes a particular set of circumstances for this to happen. At the beginning of the Japanese GP, Charles Leclerc's Ferrari shedding shrapnel on following cars to the extent of taking out Lewis Hamilton's mirror was quite spectacular but otherwise rather dangerous. Surely, therefore, there is an argument for mandating particularly vulnerable parts such as front wing end-plates are made from a material that – unlike carbon fibre composite – does not shatter and disintegrate so easily when damaged, while still being sufficiently rigid to resist the aero loads? With the number of alternatives to carbon that are now available, it should be easily do-able without much weight penalty. It's not clear if the new regulations for 2021 permit bargeboards of any kind, but if they do the same logic applies. Perhaps this should also extend to the edges of what is now the floor (but likely to be termed a running-board when the long-overdue ground-effect underbodies are introduced), thereby reducing collateral damage when contact occurs. A positive by-product of these measures would be to improve the racing by cars not being handicapped, or even eliminated, so easily, particularly during lap one's cut and thrust.

Too late to introduce for 2020 of course – or is it? As safety measures the FIA could impose them, and I cannot see why, because it shouldn't affect aero performance, this would be such a big deal for the constructors to implement. Imagine, here would be a safety improvement that has no adverse effect on performance or driver skills.

To my mind the key words in implementing the majority of punishments in Formula 1 should be 'intent' and 'gaining an advantage'



Genetically modified

After nearly 20 years of turning up at Le Mans with thundering front-engined racers GM has switched to a mid-mounted layout for its all-new Corvette C8.R

'It's a design change and there are pretty much zero carry-over parts compared to the C7.R'

By opting for a mid-engine layout GM has broken with tradition with its all-new Corvette, but early indications are that the C8.R GTE racing version is likely to continue the fabled marque's very long run of Le Mans success

By ANDREW COTTON

One unbroken feature of the last 20 years at Le Mans has been GM's Corvette racecars, competing in the GTE Pro category. It's the longest uninterrupted run of appearances by a manufacturer team in the history of the event, and in October the company started the next phase of this long chapter in endurance racing with the unveiling of its new C8.R GTE/GTLM car.

Since the Chevrolet Corvettes first rolled down pit road at the circuit de la Sarthe in 2000 there has been a close relationship between the road and race departments. Lessons learnt from the C5R were translated into the C6 that was produced for the road, and the learnings from that were put into the C6.R that raced at Le Mans for the first time in 2005, winning the class on its debut. The C6.R fed into the C7, and the C7 into the C7.R that debuted in 2014.

However, bucking the trend, the C8.R is a totally new concept; a mid-engine design, a departure from anything that the company has raced at Le Mans before. At the launch, in Road Atlanta during the Petit Le Mans IMSA finale, both the road and race teams were tight-lipped about the new road car; the C8 Stingray. They were also a little reticent when it came to the racecar too, as it's not yet been homologated.

The car has gone through testing and is expected to make its race debut at the Daytona 24 hours in January, if the homologation process goes well. It is then likely to pull double duty at Sebring in March, running in the WEC 1000-mile race on Friday, before the Sebring 12 hours on Saturday. This is to give the FIA a chance to see the car in competition in one of its own events, so that it can balance it before Le Mans in June.

The car completed a demonstration lap ahead of the Petit Le Mans and first impressions were that this is another crowd-pleaser.

Road and track

The design team started the programme with a clean sheet of paper two years ago, and unlike previous programmes that fed into each other, this one started with input from both departments simultaneously.

'It was important for us to develop the new racecar alongside the production car, so that each product could properly take advantage of the new architecture,' says Ed Piatek, Corvette chief engineer on the road car side. 'The benefits of this mid-engine supercar will be obvious on the street and the race track.'

Anyone who says that a Corvette should be front-engined might be right, based on recent history, but at the launch the company was keen to explain that the so-called father of the Corvette, Zora Arkus-Duntov, designed the CERV 1, a mid-engine car, as far back as 1960. Various other mid-engine Corvettes have been produced, including the Astro II, but this is the first one that has actually been put into production. The layout of the C8.R brings the Corvette into line with Ferrari and Porsche, both of which carry the engine ahead of the rear wheels. But more importantly it opens up a lot of benefits from an aero standpoint.

'There was a rule shift back in 2016 in GTE that allowed bigger front diffusers, bigger rear diffusers, and on the C7 there was small evolution because to actually utilise them you need to make fairly large subframe changes and also suspension changes, and so, knowing the future and what was coming [with the new C8], it wasn't going to be worth tearing the car up,' says Corvette Racing's vehicle integration engineer Ben Johnson. 'Knowing that was to come, we were able to maximise the front and rear diffuser at the beginning.

'We started our aero tuning studies in the DIL [Driver in the Loop] rig, giving the aero team as much freedom as we could. We said: "here's the free volumes from the FIA, do whatever you

'It was important to develop the racecar alongside the production car, so that each product could take advantage of the new architecture'

want in here and we will build the structure around it". There are always compromises and limitations, but that's why it is such a departure from C7 in terms of those structures just to maximise the aero. There still may be Balance of Performance, so the lap times will be the same [as C7.R], but it helps you in terms of stint performance and tyre performance and different ambient and track conditions. The aero rules are narrow to control costs, but we took the opportunity and made big advancements.'

Paradigm shift

Moving the engine to the mid-section of the car freed up the design team to play with the front diffuser, while a small Xtrac gearbox at the rear – bespoke for the car – has allowed for a more efficient rear diffuser. The entire underfloor has been sculpted to clean up airflow to the rear of the car, while the over-body sees a few slight departures from the production C8.

'Everyone pushes the wing as far back and high up as they can and then you section the rear fascia at the maximum line to help rear downforce and extraction,' says Johnson of the design at the rear. 'There is a lot of work on the diffuser, but one of the advantages of a clean sheet design front and rear is the communication between the two, and they have a better relationship.

'You are trying to manage the airflow to the front and maximise the downforce there, and also feed the diffuser to achieve the balance,' Johnson adds. 'You could produce more downforce on the front, but you could never balance the car and it is those studies, controlling pitch sensitivities and all those aspects, that give you the performance. You can find those balances in the DIL rig and give the group those targets, rather than them trying to find it all through downforce and then having a penalty for balance or stability [later]. The iterative loop of that, trying to do it up front rather than scrambling to do it when you get to full size, is that [at full size] the parts changes are expensive and complex.'

There have been mid-engine Corvette concepts in the past – pictured is the 1968 Astro II – but the C8 is the first on the road

Rear view

Having the rear wing pretty much in the driver's eye-line at the rear means rear visibility relies on the rear facing camera that was introduced by the team with Bosch. The racecar also features an engine intake at the bottom of the rear window. This was an area that had minimal impact on airflow to the wing, but it was not an idea adopted for the production car as it would have disturbed rear visibility for the driver.

'On the production Stingray we draw the induction air through the openings on the side of the car, but when we did the modelling for the aerodynamics on this car, especially because all racecars come with a rear wing, if you pull air off the rear window you clean up the boundary layer and make the wing more efficient, while getting some good ram high

The design of the rear diffuser has been exploited to the maximum, while a small and bespoke Xtrac gearbox plus a sculptured underfloor will help clear up the airflow to it. The huge wing means the view out the back is via camera only

'The aero rules are pretty narrow to control costs, but we took the opportunity and made big advancements'

pressure flow for the intake,' says Piatek. 'It was a solution that works well on the racecar, but on the road car it would hurt visibility.'

By placing the intake where it is in the rear of the racecar, it freed up the air intakes on either side of the car for other cooling purposes. This was critical, because while the old car had the engine at the front and gearbox at the rear, meaning a long prop-shaft, now all the components are housed in the same area.

But this means there are other things to worry about. 'Thermal management is a big challenge,' Johnson admits. 'Before, we had the temperature of the gearbox and thermal load of the gearbox at the back of the racecar and the engine at the front of it, and you could manage them separately. Now they are in the same area, and then things that want to be cool, like the compressors and alternators, are in the same area, so where before you could rely on passive cooling, there's now heat shielding and active cooling going on.'

Cool pack

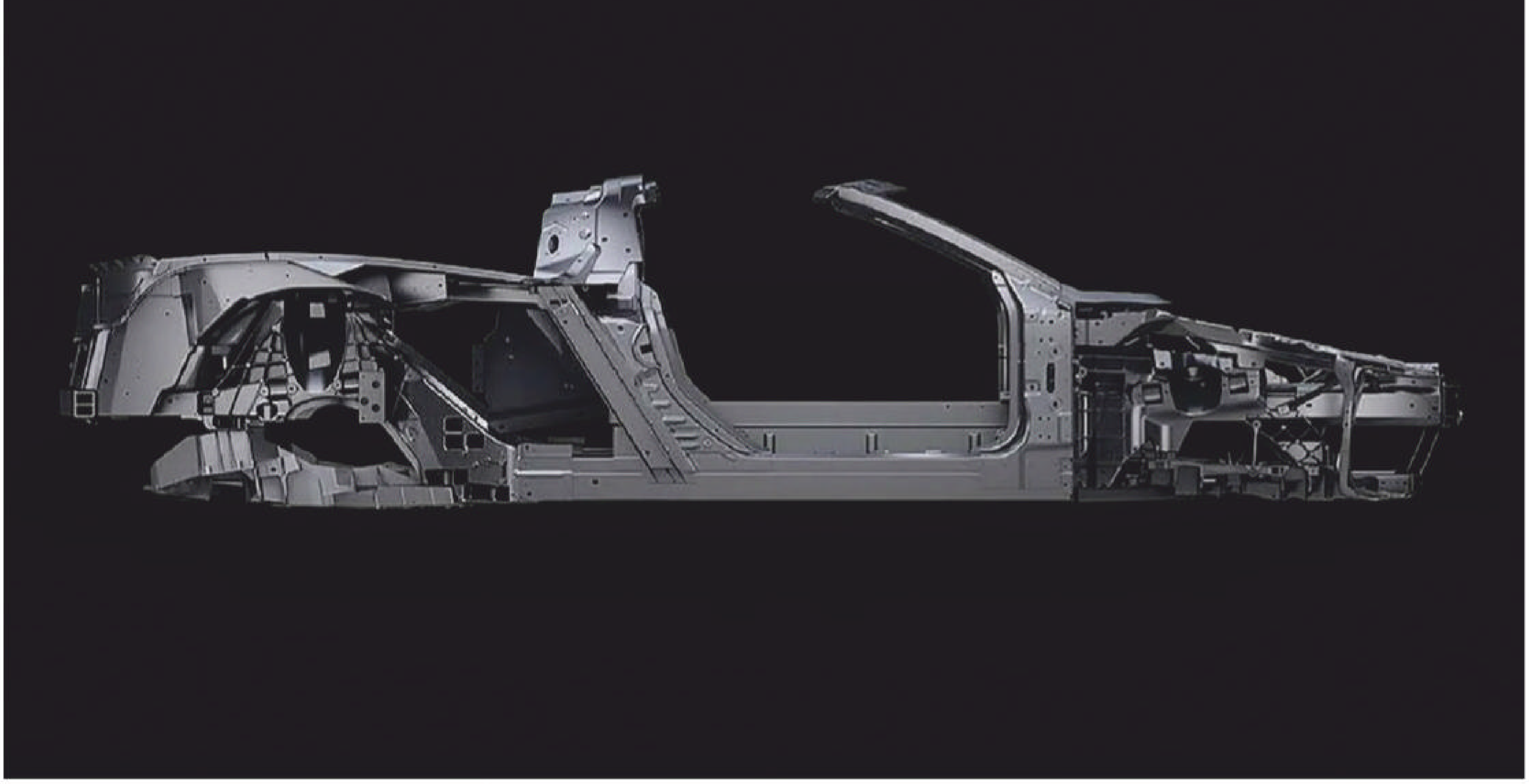
Where the production car has its luggage space at the front, the race team has used the area to house a single front radiator, following Porsche's design – before it changed this the German manufacturer had a radiator on either side at the front, which frequently led to leaks following on-track incidents. Air extraction on the C8.R is via the ducts behind the front wheels, an efficient design that was not previously available to the team before, with the front-engine layout.

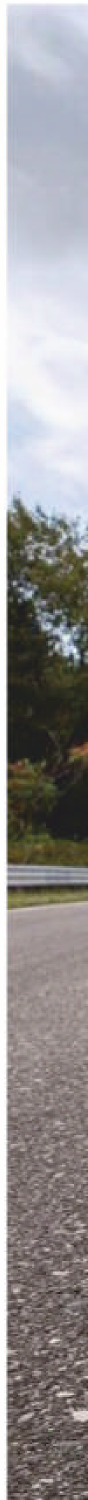
'The front wheel arch you can't vent by rule, but [the exit] is the radiator exit and that helps you with wing performance and giving the best air onto the wing,' says Johnson. 'These exits are used differently to the production car. Normally with a front-engine car you are doing it all at the front, so you somehow compromise the radiator. You either have more things in the water loop that you have to cool, or you are stacking radiators, which all add to cooling performance, so the exits on the side of the racecar help with the gearbox and air conditioning and things like that.'

The upper surfaces of the racecar are very close to that of the production car that was presented earlier in 2019, per regulation, but there are clearly a lot of design tweaks that were designed to improve the car's performance on track. Incidentally, developing both road and racecar at the same time was the model used by

Incoming brake supplier Alcon has produced new and larger front and rear discs and bigger pads for the Corvette C8.R

The chassis for the C8.R is based upon the convertible Stingray. It's been constructed using new processes designed to increase its stiffness while reducing its weight





'Where with the front-engine Corvette you could rely on passive cooling, there is now heat shielding and active cooling going on'

‘I would think that we are not at a performance level yet that we could get through Le Mans or Daytona without changing brakes’

Ford with its GT, with Canadian firm Multimatic developing both in conjunction with each other. The Ford GT went on to have a successful endurance career, which was brought to a close at the Petit Le Mans. Multimatic has now turned its attention to the Aston Martin Valkyrie hypercar, and is producing the track version alongside the production car once again.

Cabin pressures

Photographing the cockpit of the C8.R was not permitted at the launch, as this was a test car, one that was not yet perfected for racing. But the team did admit that, after careful consideration, it had decided to maintain a dashboard mounted display rather than put everything on to the steering wheel, as other manufacturers have opted to do. It has also talked to drivers about switchgear layout and cleaned up that area so that they are not searching around for the right switch in the middle of the night on the Mulsanne Straight. Working with Bosch, engineers believe they have made significant improvements to the layout. They have also carried over all of the safety aspects that were designed and implemented into the C7.R, including a fixed seat and side impact protection.

Under the skin there are some significant changes. Corvette has followed Aston Martin’s lead and switched to Alcon for its stopping power, and the firm produced new size front and rear brake discs and pads specifically for the Corvette, due to its unusual needs.

‘We did a big benchmarking study and all the suppliers are converging on to some really good parts, so there are small deltas to work on,’ says Johnson. ‘But Alcon has been really good to work with on a technical partnership and every car packaging is slightly different, and they were happy to work with something that was for our car rather than an off-the-shelf thing. This car has more rear weight bias [than the C7.R], and you run more rear brake than on the C7 so they have grown in size, and we have a much bigger rotor [disc] on the front. Ultimately with braking you are still limited by aero force and tyre grip, but having the larger components can help in endurance racing and can give you bigger windows for brake changes and things like that.

‘I would expect that we are not in a performance level yet that we can get through Le Mans or Daytona without changing brakes,’ Johnson adds. ‘You could probably choose a pad that would get you there, and we don’t have that information yet, but you would likely want a pad that you change once but then have more ultimate performance. The sporting rules [had] dictated that there was no penalty for changing brakes at Le Mans, but now there is one. Making up the 20 seconds of a brake change [isn’t so difficult, because] making up 15 seconds on the track is possible if the drivers are more comfortable on the brakes.’

Chassis secrets

The collaboration between road and racecar on the chassis side is evident with the suspension pick up points, which are the same for both products. Yet here, for the first time, the team started to evade *Racecar’s* questions a little. ‘We had a completely clean sheet as to how the chassis is constructed and the suspension mounted, so we could optimise all of that,’ says Johnson. ‘People will want to get their eyes on it. It is not something that you are going to say “I’ve never seen that before,” but we have put a lot of work into everything and we have come

While the side intakes give a clue to the engine position these aggressive looking ducts are for cooling purposes only and the main air intake for the power unit is on the rear of the C8.R

'Things were coming loose in testing that we never thought about on the C7.R – over a 24-hour race that's going to be interesting'

up with something that we like so far.' No doubt the homologation papers will reveal everything, but the C8.R racecar has yet to finalise that process – hence the reticence.

The chassis construction itself has actually made use of the convertible layout, with new processes designed to increase stiffness and reduce the weight of the base chassis. By increasing the strength and stiffness the team has reduced the demand on the roll cage fitted to the car. It also means that any weight added to the car can be introduced lower down, helping with overall performance.

Weighting game

The team was unwilling to give out any figures on weight distribution, other than to say that it drove everything from aero loads to tyre specification. 'The initial deal that you have to do is based on *this* weight distribution, we want *this* aero, and come up with a trade study knowing the limitations of the tyre development,' says Johnson. 'You try to come to a point that you make the decisions early on before you ever get to the track, that what you are utilising doesn't become a problem where you are rear grip limited because you have too much at the front of the car, or you are asking too much of the rear tyre because of the weight distribution. With the base weight distribution, the ability to shift it within the regulations, we have a pretty wide envelope. We can move the engine as close to the centre of gravity as you can, but there are limitations on the firewalls, chassis structures and fuel cells and so on. The rules save you from yourself.'

While moving the engine to the centre of the car may seem extreme, so might be the new engine itself. That said, very few details were available, not only due to homologation but also because it hasn't yet been announced what engine is coming for the production car. It is believed that there will be a 500bhp normally aspirated engine, then a 700bhp turbo, followed by a 900bhp hybrid. For now, this is a 5.5-litre flat plane crank normally aspirated design.

'If you have a four-valve engine, it breathes better and you have a lot better efficiency, and a flat plane crank doesn't have counter weighting on the crankshaft, that gives you better response, and those are the primary reasons why you would do a flat plane crank,' says Piatek. 'You don't put counter weighting on the crankshaft, but there is very significant second order lateral vibration that you have to manage, but you do get the responsiveness.'

These vibrations have been something of a headache for the Corvette race team. The impact of the vibrations was already known, and so the design accommodated it as much as it could, but there were still areas that shook themselves loose in testing.

'It is a challenge,' admits Johnson. 'It is something we knew was coming in from the production team, the modes of the vibration, and we built in as much as we could to put our operating range outside of those excitation modes. We have seen things in testing that we have had to address due to the vibration, but nothing fundamental, nothing that has stopped a test or required huge changes to the car, but things were coming loose that we never thought about on the C7. Over a 24-hour race that's going to be interesting.'

The mid-engine layout has meant a shorter propshaft, which itself acts as a damper and was able to mask some of the vibration from the gearbox. 'You stiffen it and it isolates a lot of the shifting vibration and the modes between the engine and the gearbox, but ultimately getting it out of the system is a known challenge,' says Johnson. 'It's a design change and there are pretty much zero carry-over parts compared to the C7. The whole time you are looking at every system on the C7 and saying that you cannot apply that directly. So, we had to look at how you take the principles on C7 and then do them on a new platform.'

Record runner

This completely new car will undergo further testing at the tail-end of 2019 and hit the track in competition in 2020. It remains to be seen how much of a step forward it has taken compared to the C7.R. The ultimate test will come at Le Mans in June, provided Corvette gets invited by the ACO. Having not yet been homologated before the start of the WEC season, it will take a dispensation to race the car there, but it seems highly unlikely that the ACO will spoil what will be a record of 21 consecutive years at the race for Corvette.

The GTLM version of the C8.R is set to make its debut at Daytona in January, the GTE spec car at Sebring in March

Superpower

At long last the Class 1 global GT category lives, with DTM and Super GT's GT500 all but merging technically and even racing against each other. But how have the three Japanese manufacturers managed to adapt to the new formula?

By *RACECAR* STAFF

‘We believe for certain that this is a big step towards the globalisation of GT competition by GTA and ITR’

Just like the coming together of tectonic plates, the merging of the German DTM and Japanese GT500 series has taken a very long time, but finally they featured on track together at the last round of the DTM at Hockenheim in October.

For the first time the six manufacturers ran together in competition, in qualifying and in the second race of the weekend. It was not necessarily a fair fight, the Japanese had brought their old cars to compete against the latest models from the DTM, and the lap times and race results showed a comprehensive win for the Europeans on home soil.

At the time of writing BMW, Audi and Aston Martin were set to go to Fuji, Japan, in November, for a full-scale race weekend that is the next stage of integration before the Japanese Class 1 cars race in 2020.

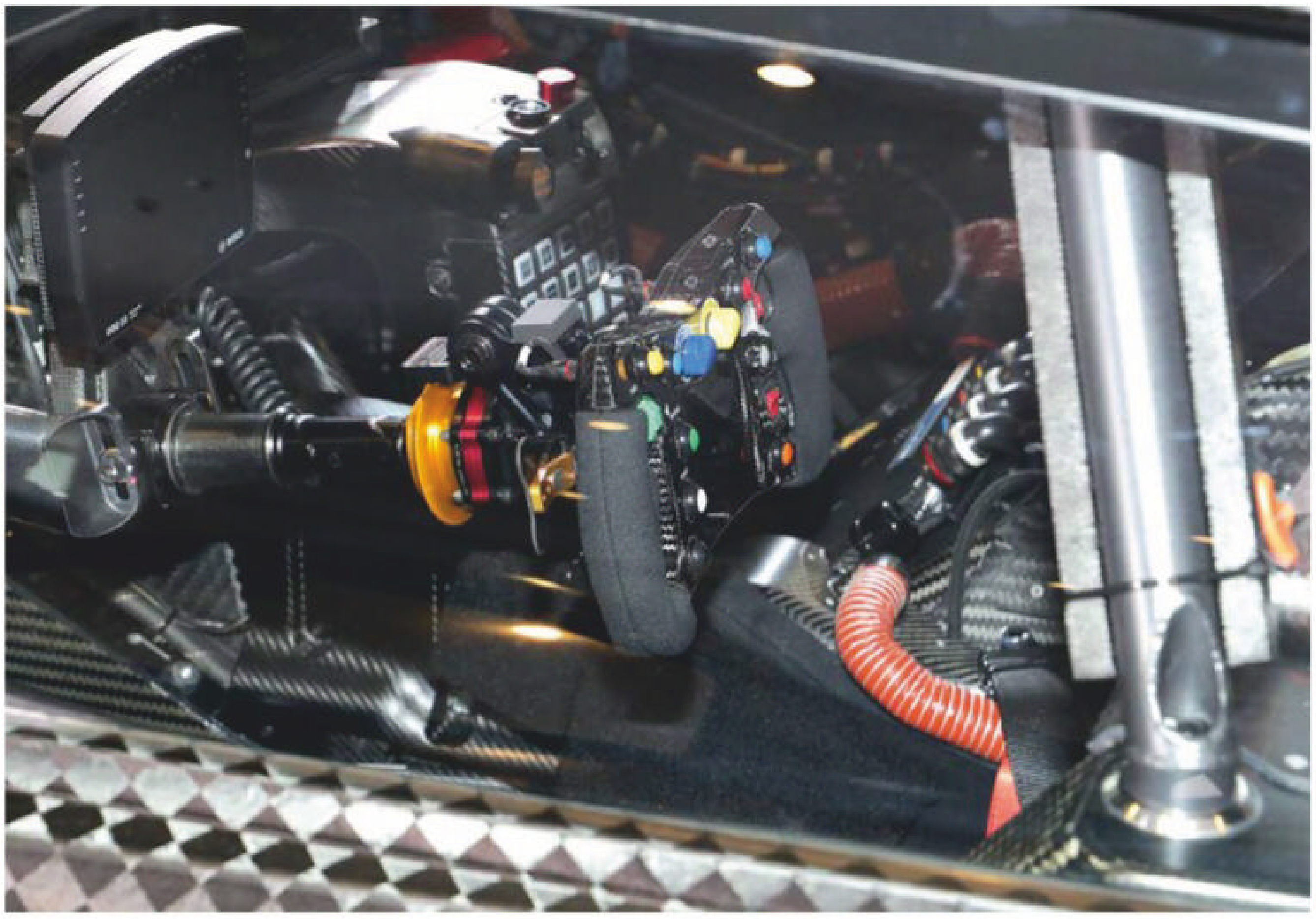
Honda's new GT500 has its engine in the front, rather than mid-mounted as it is in its 2019 Super GT racecar

Japan's 2020 vision

Prior to the German race the Japanese manufacturers – Honda, Nissan and Toyota – presented the new Class 1-compliant cars that will take part in next year's joint races. Importantly, Honda, a company that said if it needed to run a front-engine layout it would leave the series, has produced a front-engined version of the NSX for next season. In doing so it has now overcome a major stumbling block that has delayed the integration of the two regulations, while also threatening the very existence of the Japanese series.

'The new Class 1 regulation is one that we at GTA [Super GT and therefore GT500's promoter] have consolidated jointly with ITR, the organisers of Germany's DTM series, based on discussions with the Japanese and [European] car makers involved,' said GTA Chairman Masaaki Bandoh at the launch of the new cars. 'The adoption of this regulation now makes it possible for DTM competitors to participate in Super GT from 2020, and conversely Super GT competitors can also compete in DTM. This globalisation of GT competition is a project that GTA and ITR have been pursuing for some time, and this time we have the participation of Honda to develop an all-new car to comply with the Class 1 regulation so it can continue competing in Super GT next season. We believe for certain that this big first step toward the globalisation of GT competition by GTA and ITR is sure to have a big effect on the motorsport world, not only in Japan's Super GT and Germany's DTM series, but also on competitions in Asia, Europe and the world going forward.'

The Super GT Series took on the DTM chassis regulations in 2014. This was a technical concept that was developed between Mercedes (then still in the DTM), Audi and BMW, each of them coming up with a significant part of the overall package. However, BMW's involvement in the DTM was conditional on the series introducing a global platform. There had been moves to tie up with Grand-AM, and more latterly IMSA in the United States – in the latter case in the form of DTM America in 2017 – but after this came to nothing Japan looked like the only option.


The cockpit switching and much of the electronics package, including a Bosch ECU, is now common across all Class 1 cars

Super 'charged

The chassis switch was the first step of the integration, followed by new power units, and the Japanese were in fact the first to take on the 2-litre, 4-cylinder turbocharged engines that were agreed for Class 1.

However, as mentioned above, Honda had great difficulty in accepting the new chassis, as the manufacturer needed to run a hybrid NSX in a bid to retain the necessary links to its production car. With the new DTM-developed chassis designed for a front-engine layout, that simply didn't work, and the car finished up with major overheating problems.

Honda eventually ditched the hybrid system altogether, although it persisted with the mid-engine, as it stayed faithful to the layout of its road-going NSX. However, in the new for 2020 Super GT racecar it has now relocated the engine to the front for the first time.

Meanwhile, the European manufacturers have run into problems switching from their V8s to the smaller capacity turbo engines, particularly with the strain on the propshafts, which saw some of them explode due to

'The adoption of this regulation now makes it possible for DTM cars to participate in Super GT from 2020, while GT500s can compete in DTM'

frequency resonance (see May's issue, V29N5 and also June's, V29N6).

The Japanese have largely overcome this issue since they introduced the engines. All, that is, except for Honda, which has never had to run such a long propshaft to the rear wheels, and therefore has experienced the same dramas as its European counterparts. 'If there is a four-wheel dyno, it can be perfected, but there is no such facility,' says lead engineer Mr Saeki.

There are still differences between the two series, of course, with the European series featuring a single tyre supplier, while the Japanese retain their tradition of open tyre competition. Within the engine, the Japanese have also held on to the technology that enables them to run pre-chamber ignition. But both of these differences are not enough to prevent a joining-up of the two series.

The Supra showed good pace at Suzuka and TRD is pleased with the way the car closely resembles its road going cousin

Suzuka shakedown

Honda struggled to get its hands on the common parts in time for the first Suzuka test and its shakedown was therefore postponed. Therefore, what was presented at the launch was a show car, without the engine installed. The relocation of the engine means that the bonnet needed to be raised slightly, but the engineers have worked hard to ensure that the shape of the nose, and therefore the brand identity, has not been too compromised. The bonnet air outlet is open to the rear because it needs to be vented more than it was with previous models.

Honda's rivals, Toyota and Nissan, have much more experience running with the front engine layouts. Toyota's new Supra has carried over aerodynamic parts from its previous designs, while the characteristic nose of the production car has become inconspicuous when scaled to the size and regulations of GT machines. 'We are not going to change the development concept drastically, we are searching for an optimal solution based on Class 1 regulations,' says Yuji Tachikawa of TRD Yuasa.

Due to extra fuel the Supra was running heavy, yet at the test in Suzuka it recorded a time of 1m47.273s, one second faster than its predecessor, the Lexus LC500, at the 2016 shakedown – and that 2016 time was set on tyres that were of a one-shot qualifying type.

Supra GT

After the first test one of the Toyota engineers reported: 'Since the chassis is shared, the roll rigidity is insufficient [for us]. There is also a part where the aerodynamics is shared, so the downforce has also been reduced.'

'We are not going to change the development concept drastically, we are searching for an optimal solution based on Class 1 regulations'

The Nissan GT-R looks even meaner in its test spec black livery. Nismo reports that the new car has shown characteristics out on the track that are quite similar to this year's racer

Because of Super GT's high-grip tyres, the Class 1 suspension and driveshafts will need development to cope with the extra loads

Unlike the current machine, the centre console switches are arranged in a grid pattern. Also, the Bosch ECU is now mandatory, but Toyota has struggled to handle the new system.

Under Class 1 regulations the underside of the body and the rear fender are common to all models. The diffuser was originally common, but the shape was changed and the bottom of the vertical fin has now gone. The Supra's lateral duct is simple, but the team plans to try another version before the homologation deadline.

Suspension worries

The suspension parts (rockers, arms, stabilisers, uprights) are common, but are tailored to the DTM, which has low grip, and some teams are concerned about the lack of strength due to the insubstantial control arms. With the Japanese high-grip tyres, the suspension and driveshafts will need development to cope with the extra loads. TRD has recently introduced a simulator and is using it to prepare for this.

Nissan's new GT-R features a radically shaped lateral duct, and while the grip levels appear to have dropped thanks to the new aero regulations, the car showed some characteristics that were similar to the old example. The GT-R was quicker than at its shakedown in 2016, but was still off the pace of the Toyota, and like its rival it suffered from teething issues with the Bosch electronics system.

While the air intake ducts are extreme and give the Nissan its trademark aggressive look, the mirrors are also of distinctive design and follow the form of those on the DTM car. The horizontal stay on which the mirror is mounted has a wing shape when viewed closely.

The rear of the diffuser and the rear fender is common to all the Class 1 racecars, which leads to less downforce at the back. That trait must then be balanced at the front.

Nissan's aerodynamic mirrors follow a trend set by the DTM cars

Mission accomplished

Testing the new cars will continue through the winter, and the first race next year will probably throw up new problems that must be sorted before the cars meet their European counterparts in full competition – although a schedule has yet to be released. There is no doubt, however, that the two series have finally achieved what many thought was impossible due to the long gestation period of bringing the two series together. Six manufacturers, three from Europe and three from Japan, with high specification touring cars on track at the same time is the culmination of many years of work.

With thanks to Autosport Japan for original reporting, and Shimpei Suzuki for images.

Desert storm

The side-by-side class for utility task vehicles (UTVs) has proven to be hugely popular on the Dakar in recent years. *Racecar* took a close look at what's become the buggy of choice in the category, the Can-Am Maverick X3 x RS, to find out why

By LEIGH O'GORMAN

The Can-Am Maverick X3 x RS in action. In many respects UTVs are ATVs for two people, hence the 'side-by-side' name, but with the roof and roll cage they are certainly more car than bike

When a class for UTVs (utility task vehicles) was added to Dakar competition in 2017, few would have envisaged that a single vehicle would become dominant in just a couple of years – especially one that was not then even on the entry list.

But then Bombardier Recreational Products (BRP) entered the fray with the Can-Am Maverick X3 x RS in 2018, and this changed everything. While the field was only slightly up to 11 – from eight in 2017 when it comprised a mix of Yamaha and Polaris UTVs – the bar had been raised substantially, as success was immediate for the North American brand, with Reinaldo Varela taking victory in the Can-Am machine on its debut.

The 2019 result was even more emphatic, with the Maverick X3 x RS locking out the top 17 positions in the side-by-side class. Indeed, such has been the popularity of the vehicle that 24 out of the 30 side-by-side entries for the Peruvian-based event were Mavericks.

Side arm

Can-Am, while better known as the name of a sportscar series of the '60s and '70s to many in motorsport, is actually the off-road division of BRP, and it looked long and hard at what was needed before it finally opted on the philosophy for its Maverick racer, explains Olivier Camus, director of global marketing with BRP. 'We looked not only at the side-by-side category, but also at other segments including rally cars, pick-up trucks – all extreme vehicles – and we took the best technology of them all. We also tried to gather the maximum feedback from our customers to make sure that we were not only answering their needs, but also exceeding their needs.

'When we introduced the Maverick X3, we completely revolutionised the side-by-side sport category,' Camus adds. 'We built the chassis, the way we built the suspension and the way we [approached] the comfort for the driver were characteristics that were completely new for the industry.'

The concept of the X3 x RS was for it to remain as close to the stock unit as possible, while presenting it as an alternative to the increasingly expensive car class at the Dakar. But it also shook up the UTV class.

Dune tune

Both of Can-Am's victories in the side-by-side class on the Dakar came from machines prepared by Scott Abraham's South Racing squad – a German-based specialist service provider to the cross country and off-road market. 'To have good racing [success], it takes an excellent start vehicle,' Camus says. '[On top of] that, we also partnered with South Racing in terms of development for the Dakar, and they delivered a winning machine.'

For Abraham, the managing director of South Racing, it was the idea of developing a vehicle that was as close to the base product as possible that really appealed to him. 'I wanted to develop the X3 x RS, so that customers could race in cross-country events around the world,' he says. 'It encapsulates the points of what a side-by-side shoud be,

'When we introduced the Maverick X3 we completely revolutionised the side-by-side sport category'

South Racing has been responsible for much of Can-Am's success in the side-by-side class on the Dakar

because in cross-country competition, you can [purchase] some crazy expensive units, which might look like the original UTV, but don't really have the same concept [of the base vehicle].'

The team used the original chassis mounting points for the engine, gearbox and front and rear suspension, as that is stipulated in the regulations, but South Racing redesigned and constructed the roll cage in order to gain FIA accreditation – a process that Abraham admits was lengthy. 'You have to supply [every] detail of the design to the FIA for analysis; we had to supply a full crash test analysis and make sure the roll cage meets the standard.'


Light-weight and with a wheel at each corner, UTVs like the Maverick are well suited for driving in dunes

Sand blaster

Originally constructed from dual phase G80 steel, South Racing developed a chrome moly roll cage structure – a material specification structure required by the FIA – formed from 4130 alloy; a low-alloy steel unit, strengthened by chromium and molybdenum. These are elements that Abraham believes are essential for modern off-road racing, due to their high tensile strength and reduced elasticity.

The X3 x RS also features a full roof and a heavy duty high molecular weight skid plate. 'We are constrained by regulations, so for the Dakar we use 6mm aluminium skid plates. We ran a 7020 series aluminium skid plate that is purely for impact protection for the fuel cell, because the fuel cell sits under the driver.'

Whereas the original vehicle comes with a four-point safety harness, the FIA stipulates a six-point harness for driver safety. The height of the cockpit has also been raised by 150mm compared to the standard side-by-side machine. While this alteration does change the body-line of the vehicle, Abraham is keen to point out that safety is paramount. This also extends to the driver seating position and the seat's mounting points as well. 'We have fully adjustable brackets where you can adjust the height. It is a nuts and bolt system, because we have to conform to certain things, but it is a fully adjustable position for the driver, up and down, and it is the same for the top mount seatbelts.'

The X3 x RS also uses a fully adjustable steering column, which differs from the standard base unit, as for competition purposes this must be a mechanical system.

On the Dakar, given its nature, it's not unusual for drivers to plough through deserts and dunes enduring temperatures over 40degC ↳

On the Dakar it's not unusual for the crews to endure temperatures of over 40degC, and then it can be close to freezing at other times

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The Maverick is built around a roll cage anyway (above), but for use on the Dakar the spaceframe needed to be beefed up with motorsport-spec steels, while a roof was added

'The main area we looked at was the cabin sealing, especially the lower half to make sure it was protected against the elements'

on one stage, before crossing mountainous peaks where it is close to freezing at other times. Such changeable conditions meant a challenge for the team. 'The T1 vehicles [the full-size car class] have variable air-conditioning,' Abraham says. 'But these are in some ways exposed to the elements, but that's the nature of the UTV; it's a cross between a car and a bike.

'The main area we looked at was cabin sealing, especially the lower half to make sure it was sealed against the elements,' Abraham adds. 'The drivers race with a closed-face helmet; we have an air blowing system which is plugged into the helmet and blows fresh filtered air, creating a fresh environment for the driver, maintaining the ambient temperature.'

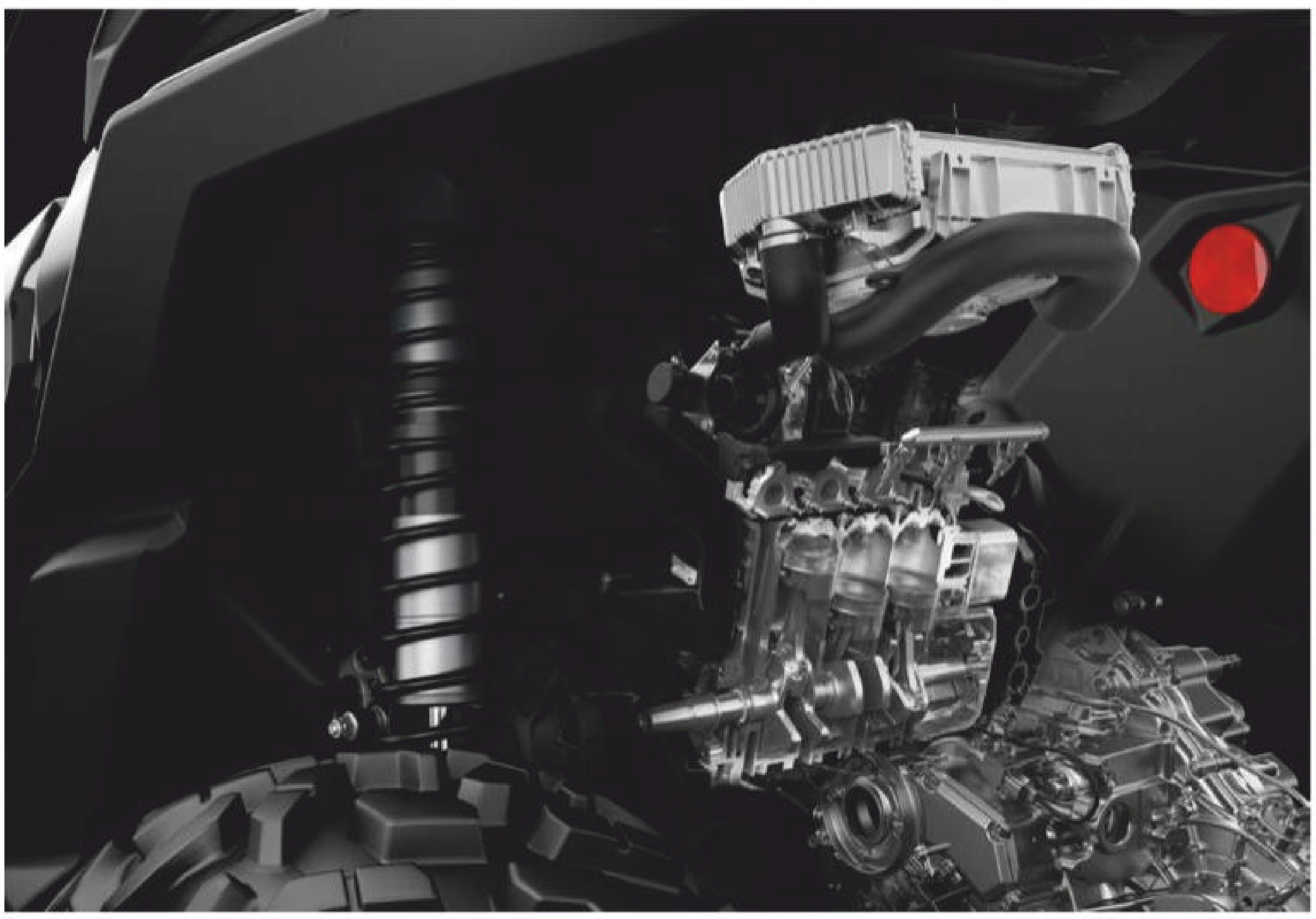
In cold conditions Abraham says there is little that can be done, which means much of this is down to the driver wearing the right kit.

Ahead in the sand

On the outside of the vehicle, the regulations limit aerodynamic development, with the X3 x RS using its original Can-Am bodywork. For South Racing, this meant what little could be done centred around the cooling, and the radiator has been relocated to the rear. 'In the case of an accident the radiator will be protected. Also, in terms of mud or debris, this stops the radiator from blocking,' Abraham says.

Whereas the weight distribution and centre of gravity of the original vehicle is slightly to the rear, Abraham says that the balance is closer to the centre in the race UTV. In the base vehicle, the dry sump, engine and crankshaft are all placed relatively low. However, with the bigger fuel tank, sited underneath the driver seat, the competition machine not only comes in at almost 100kg heavier, but the balance has also shifted slightly forward. 'You do want weight transfer under acceleration, and you want the traction over the rear wheels,' Abraham says. 'Even though it's four-wheel drive, when you brake you still need that stability on the front for turning into the corners.'

The weight transfer is not, though, a stable set of parameters, due to the weight shift from a UTV with a full fuel tank at the beginning of a stage, to its much-reduced mass at stage end. Abraham believes this is where driver judgement and skill can play a significant part ↳



The impressively reliable turbocharged triple-cylinder 900cc Rotax engine produces 172bhp and is pretty much a stock unit

'We have had just one CVT belt failure during racing conditions, and that was due to the clutch box being completely filled with water'

in the proceedings. 'That is also part of the skill of driving Dakar, you have to drive around the regulations,' he says. 'We found that a big challenge that we face on Dakar is that with a fuel cell that has, more-or-less, 120 litres, that amount of weight will change in the scope of two hours of racing, so you have to find a way to compromise for when the car is light and when the car is under full load.'

In competition, the X3 x RS runs with the original Can-Am wheelbase and track width, and many of the components from within the UTV are used on the race version.

The Maverick uses the original running gear, with the driveshaft, engine and gearbox all imported from the base UTV. However, there was that one key element, that we have already mentioned above, that could not be carried over from the original machine, for quite obvious reasons. 'We [installed] the 120-litre fuel cell [increased from 40 litres], which you need to do the minimum distance of 375km on any of the stages before refuelling,' says Abraham.

Little wonder

One area left virtually untouched is the engine, with the standard 900cc Rotax ACE (Advanced Combustion Efficiency) triple-cylinder turbo unit being run, generating 172bhp. 'It is a wonderful piece of equipment and Rotax have built a super reliable engine and we run all the stock items on the engine, we have no changes on that,' Abraham says. 'We didn't have any [problems] during the Dakar on anything on the engine. That's why we're staying along those lines of running the standard production unit.'

The Maverick X3 x RS also features three air intakes, each of them mounted well out of harm's way, which feed the engine, CVT and the primary and secondary clutches.

Speaking of the CVT (continuously variable transmission), the team has worked hard on this. 'It's something which has really been improved over recent years,' says Abraham. 'We ran the complete [2018] Dakar, that was 4500km and we had one belt failure during racing conditions, and we could explain that as it was due to the clutch box being completely filled with water.'

Camus says that cooling is vital when it comes to the transmission. 'The challenge with the CVT is to maintain the temperature as cool as possible,' he says. 'We optimised the cooling system inside the CVT chamber to keep the temperature as low as possible. To do that, we have on the Maverick X3 two inlets and two outlets, and within the CVT chambers we also have some fins on the driven pulley and the drive pulley, and those fins accelerate the airflow inside the chamber.'

Can-Am has developed a new differential system for the X3 x RS. 'They have brought in the Smart-Lok product, which is a variable locking differential with electronic controls,' says Abraham. 'It is an evolution of the common differential. It gives us the ability to have a fully locked diff for rock crawling and also different [settings] for trail riding or dune riding, so this is a much stronger unit than the original Visco-Lok [the previous generation differential].

'There will be a lot more to come from [Smart-Lok] in the future and I think the technology is limitless in terms of adapting it to where the customer wants to make use of their unit,' Abraham adds. 'The Smart-Lok gives the ability to tailor the front axle performance or tailor the differential to how you want to use it, which I think gives a versatility which is unmatched in side-by-side racing.'

The X3 x RS uses the base vehicle's electronic power steering module, called Dynamic Power Steering, which gives a competitor options to select between a minimum, medium and maximum level of assistance; the latter of the three, says Abraham, is best for the Dakar. The system can be disabled so that a driver can control the vehicle with a standard steering system, but Abraham says that if anyone did this they would need *very* strong arms to keep going for 500 to 600km every day.

Brake clause

In terms of stopping power, the X3 x RS comes with two possible brake options – developed in conjunction with J Juan Brake Systems – and which one of these is used largely depends on the type of event. 'On the Dakar the pace is quick, but it's not pushing 100 per cent all the way; the Dakar is a marathon,' says Abraham. 'When you change to other events, like the shorter events in Europe, then the loads put on to the brake systems are much higher and that primarily is coming from different tyre compounds, so we look to bigger brake discs to stop the car and have a more consistent brake.'

That said, Abraham adds that the additional strain on the brakes that comes with a vehicle running with over 120 litres of fuel on the Dakar means that the braking load would exceed the limitations of the original design specification.

There were some relatively minor modifications made to the suspension system, with the travel for the Dakar version restricted to 20 inches (by regulation) rather than set at 24 inches, as it is on the base UTV. The geometry has been imported from the standard unit, and Abraham says that Can-Am spent a fortune ↳

The Maverick uses a CVT transmission, which can be seen in this cutaway. Far right: the suspension is the same as used on the base UTV

'It has the capability to have a fully locked diff for rock crawling, and different settings for trail riding or dune riding'

Running a UTV could be as low as 20 per cent of the full car cost on the Dakar, and only 10 per cent of the cost on shorter events

developing this, with the base UTV using a trophy truck-like trailing arm that has three links dedicated to controlling camber, even during extensive wheel travel.

As far as dampers are concerned: 'When you get into the competition side of things, different drivers have different preferences from different companies, so there are different suppliers,' says Abraham. 'In the case of Dakar, we are using two different brands. One is a Dutch company called Reiger and the other is an American company called King, and those were the two different dampers that the drivers chose from.'

South Racing conducted extensive testing to evaluate damper settings taking into account the diminishing weight of the fuel. 'That involves working on the valving inside the shock absorbers, your rebounds, compressions and spring rates, which carry the vehicle and also [manages] how the vehicle reacts to larger shocks and bumps,' Abraham says.

The team has used KMC wheels, but tyre choice is entirely down to driver preference, depending on whether a stage is damp and muddy and thus requiring a tyre with more open chunkier treads, or is on a smooth, quick section with dunes, which may call for tyres with a closed tread pattern and wider surface area.

Profit of dune

But where this little race vehicle really comes up trumps is in the running costs, which are much smaller with the side-by-side vehicles than they are with the full-sized cars, particularly when measured against the top manufacturer entries from the likes of Toyota. Indeed, Abraham believes that running a UTV could be as low as 20 per cent of the full car cost on Dakar and only 10 per cent of the cost on shorter events.

However, it is not just in competition where savings are made. 'You can take the driveshaft of the unit and the standard dealer price is around €270 – depending on where you are in the world – and on a T1 car, you are looking at around €800 to €3000 for a driveshaft,' Abraham says. 'Even if you take a set of brake pads on the full-sized Dakar cars, you could be looking at almost €1600 for one set, but for two axles on a side-by-side, you could do that for €200.'

As for performance: 'For sure, your top factory teams and your top drivers, they are ahead, but an amateur driver in the car category is really not much faster than a good driver in side-by-side' Abraham says. 'The main thing here is, where the average speed is lower on an event, the side-by-sides come into their own because of the benefits of their acceleration and the lighter overall weight of the unit.'

The X factor

In terms of the total machine outlay, Camus says: 'What we tried to do was make sure that we were as close as possible to the production unit, so what Scott [Abraham] is doing is buying a base Can-Am, making his modifications and either selling it as a kit or selling the X3 fully modified. The target price for the X3 fully modified is around $60,000 (US).'

Clearly then, the side-by-side class represents significant cost reductions, but with a performance deficit that is far from outlandish. While factory teams may not yet be fully engaged with the class, it is easy to see why plucky amateurs can see the potential.

Maverick top gun

Given their early success, it is no wonder that Camus and BRP are delighted with the Maverick X3 x RS project. 'All the research we are doing show that we are exceeding expectations,' Camus says. 'This is really good news, not only because the product is a game changer, but also because it is super reliable, and people love that. Second thing is, in terms of racing, we have many, many victories already in hand. In competition, where the Maverick X3 is engaged it is winning, so for me it is a success.'

With the Dakar Rally moving to the Middle East in 2020, Can-Am are looking to add to its desert racing glory. As for the side-by-side category in off-road competition, it is increasing in popularity with each passing year, and provided the class remains sensible – in terms of controlling costs and development – it's likely that it will only expand its reach.

TECH SPEC: Can-Am Maverick X3 x RS

Chassis / roll cage
Chrome moly cage structure formed from 4130 alloy: roof fitted over cage; heavy duty skid plate.

Engine
Rotax ACE (Advanced Combustion Efficiency) 900cc Triple-cylinder turbocharged engine (172bhp), liquid cooled with integrated intercooler and Donaldson high-performance air filter; Intelligent Throttle Control (ITC); electronic fuel injection.

Transmission
Quick Response System X (QRS-X) CVT; Smart-Lok variable locking differential with electronic controls.

Suspension
Front: Trophy truck inspired double A-arm with sway bar. Rear: 4-link torsional trailing-arm X (TTX) with sway bar; 24in travel (regulated to 20-inch travel for Dakar). Reiger and King dampers used on Dakar.

Steering
Tri-Mode Dynamic Power Steering (DPS).

Brakes
Dual 262mm ventilated disc brakes with hydraulic twin-piston calipers on the front and dual 248mm ventilated disc brakes with hydraulic twin-piston calipers on the rear.

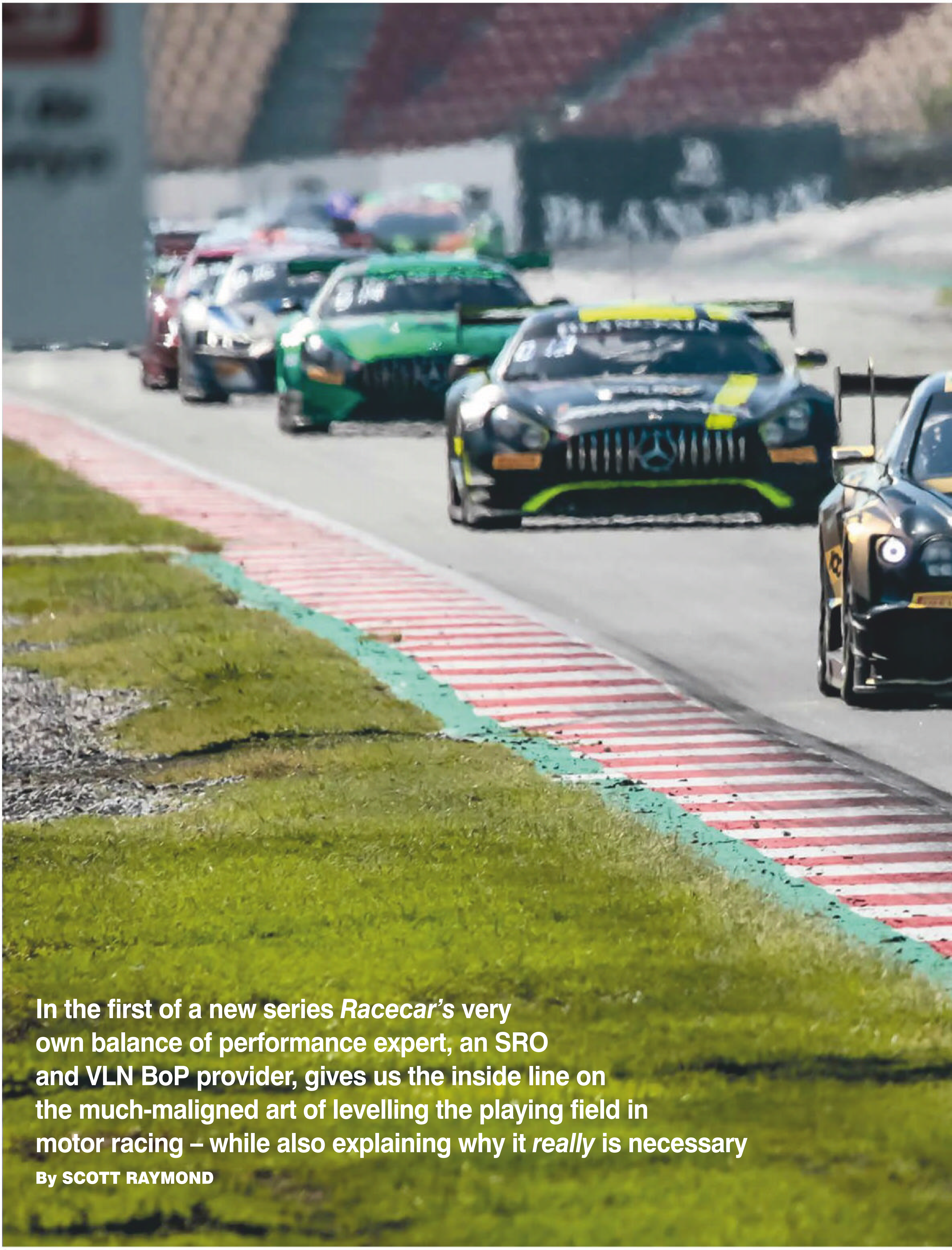
Wheels
KMC 14in (35.6cm) aluminium bead-lock.

Tyres
Brand is optional Front: 30 x 10 x 14in. (76.2 x 25.4 x 35.6cm); rear: 2.0 30 x 10 x 14in. (76.2 x 25.4 x 35.6cm).

Fuel Capacity
120 litres.

Dimensions
Length 132in (335.3cm); width 72in (182.9cm); height 67in (170.2cm); wheelbase: 102in (259.1 cm); ground clearance: 15in (38.1cm).

Estimated dry weight
1585lb (718.9kg).



In the first of a new series *Racecar's* very own balance of performance expert, an SRO and VLN BoP provider, gives us the inside line on the much-maligned art of levelling the playing field in motor racing – while also explaining why it *really* is necessary

By SCOTT RAYMOND

Getting the balance right

Balance of performance. For some, this seemingly innocent phrase evokes feelings of disgust, anger, anxiety, and/or betrayal. As someone who works on BoP every single day, I can't help but feel at least partly responsible for some of the negative emotions this simple phrase elicits. Do I have a guilty conscious about it? Not in the least, because I am actively working to change the way manufacturers, teams, drivers, and fans perceive performance balancing.

To understand what I am doing to change perceptions regarding BoP, we will have to first look at some important introductory topics related to it. But in writing this article it has become crystal clear that it will take more than one piece to cover all the ground I would like, so you can look forward to further instalments discussing BoP in future editions. In this issue, however, I will first explain what even qualifies me to write about balance of performance. From there I will risk ridicule and answer the question of whether BoP is even necessary (spoiler alert; if you vehemently hate BoP, you won't like my answer!). With the formalities behind us, I will next look at the purpose of BoP using a practical example, and finally discuss some of the factors motivating performance balancing decisions.

My first exposure to the world of BoP was during the early 2010s when working as a race engineer on a GT car in the Grand-Am series (now the IMSA WeatherTech Sportscar Championship). We felt the car needed more front downforce, so we designed a new venting system to prevent air from building up under the front bodywork. The proposed design was submitted to the powers that be at Grand-Am, and our proposal was ultimately rejected. Did I loathe those people for rejecting my idea? Of course! But that was a long time ago, and I have moved on to work alongside some of those very same people. Prior to engineering a car in Grand-Am my experience was primarily in open-wheel racing (Champ Car and IndyCar), and prototypes (ALMS LMP1 and P2). The closest I had come to BoP before engineering those cars was around 2004 with the Speed World Challenge Series and its rewards weight system.

In between my World Challenge and Grand-Am experiences, I worked with Newman-Haas Racing in Champ Car (Sebastien Bourdais), De Ferran Motorsports in ALMS and IndyCar (LMP2 and LMP1 with Gil de Ferran, Simon Pagenaud, and Scott Dixon, and IndyCar with Raphael Matos). The economy in 2010 was terrible, so I took a job as a professor of Motorsports Engineering at IUPUI (Indiana University-Purdue University Indianapolis), while continuing to race engineer cars at Dale Coyne Racing in IndyCar (Alex Lloyd and Bourdais again) and Andretti Autosport (Ryan Hunter-Reay, James Hinchcliffe and Marco Andretti).

In 2014 I joined IMSA where I was heavily involved in developing a new BoP process, determining which changes needed to be made to the racecars, and presenting the analysis results to participating manufacturers. I dived head-first into BoP, and while it was difficult and complicated, it was rewarding to see an approximate 30 per cent increase in the number of manufacturers participating under the IMSA umbrella from 2016 to 2017.

Parity animal

In 2017 I started my own company, ORCA Engineering, to develop software that can post-process massive amounts of logged vehicle data quickly, and efficiently. This software is called OPAA (ORCA Performance Analysis Application) and it was developed to support balance of performance; although the application applies to many domains outside the realm of performance balancing. ORCA Engineering is currently working with ADAC Nordrhein on the BoP for the Nurburgring 24h Race and the regular season VLN clients. In addition, ORCA works with SRO Motorsports in America and Europe. Both of these clients utilise OPAA to help determine which balance of performance changes are required preceding each event.

This is written by someone on the inside, and the perspectives provided here are based on practical experience rather than hypothetical bench racing scenarios

Above: Shining some light on the dark arts of balance of performance is a stated mission for *Racecar's* BoP man

Our writer's first experience of formulating a balance of performance process was with the IMSA series in the US

I am very fortunate to be able to draw from this wide range of experience in multiple types of racing, whether as a race engineer in ChampCar, IndyCar, LMP1, LMP2, or GT3; or doing BoP analysis and recommendations for DPi, LMP2, GTE, GT3, GT4, and touring cars. I can employ this knowledge in not only developing a state-of-the-art analysis tool, but also in applying the output of said tool to help clients achieve their goals. In fact, this is what makes this article unique – it is written by someone on the inside, and the perspectives provided are based on practical experience rather than hypothetical bench racing scenarios.

On balance

The question that's most often asked in racing is whether balance of performance is actually needed at all. I often hear or read statements that can be boiled down to something like: 'just let them race what they build,' 'may the best design win,' or 'it's racing, not charity', by pundits who believe BoP unnecessarily and artificially complicates racing. This inevitably leads to a common question in modern multi-manufacturer racing: 'Is BoP really necessary?'

I will put my neck on the line and say, "Yes. Absolutely!" This is not because my livelihood currently depends on racing series requiring BoP, but because I started a modestly successful company and *literally created* a new livelihood centred around the BoP process. Under no circumstances could anyone create a profitable company around an unnecessary process.

There are several more reasons why I believe BoP is absolutely necessary in modern multi-manufacturer racing, and many of these have been discussed elsewhere. For me, the most important reason to implement a balance of performance process is to maintain the sustainability of a racing class, and by association the sustainability of a racing series. Sustainability in this sense means a healthy field size, several engaged manufacturers, a budget that's justifiable to both team owners and manufacturers, and a dedicated fan base.

When a particular racing class has a healthy field size, it can work to attract more competitors to the series. Not only does this then make for much better racing, but it also acts as an insurance policy for the series and the team owners. When a series is not sustainable, the field size tends to shrink, and teams are forced to shut down or go elsewhere to race. But a healthy field means a series can afford to lose a few competitors due to factors beyond their control, without feeling too much pain.

Manufacturer involvement builds credibility for a series and is also a good source of revenue for it. Engaged manufacturers will hopefully spend money advertising their brand involvement and increase exposure of a racing series. Other manufacturers will likely be attracted to a series that has several other manufacturers involved and is viewed as a sustainable platform. Once again, increased manufacturer involvement acts like an insurance policy for a series, because one or two can leave and the series can still survive. In the end, you don't want a multi-manufacturer class to devolve into a single make class.

Balance of payments

The budget perspective is imperative to consider, for without BoP manufacturers would spend themselves into oblivion trying to gain any performance advantage possible over their competitors. Teams do the same if left to their own devices. There is nothing stopping a team or manufacturer from spending more than

Table 1: GT3 car dimensions

Vehicle	Engine Location	Length [m]	Width [m]	Height [m]	Frontal area [m²]	Frontal area [%]	Plan view area [m²]	Plan view area [%]
BMW M6 GT3	Front	5.017	1.900	1.394	2.649	12.7	9.531	0.0 [base]
Ferrari 488 GT3	Mid	4.605	1.975	1.206	2.382	1.3	9.095	-4.6
Porsche 911 GT3 R	Rear	4.562	1.852	1.270	2.352	0.0 [base]	8.447	-11.4

their competitors, but hopefully BoP helps prevent people from spending too much.

When a series grows it gains more fans, and without fans any high-level – that is, profitable – manufacturer involvement will soon disappear. Marketing a product to no one is a pretty poor strategy and one that is not generally employed by the more successful companies.

In summary, balance of performance is necessary because it leads to sustainable racing practices. Sustainability makes growth easier, and growth leads to more fans, and increased value for a series. Through understanding the necessity of BoP, we can easily understand the ultimate goal of it: to make sure all manufacturers and teams believe they can be competitive at any given race event.

Balance of performance is not about stifling creativity, or penalising someone for being too fast, it is simply about creating a sustainable racing environment that provides equal opportunities for all participants.

Case study

To understand the purpose of balance of performance, let's look at a real-world example. We will start off with three different GT3 cars designed by three different manufacturers: the BMW M6 GT3, Ferrari 488 GT3, and Porsche 911 GT3 R. We will look at some of the basic characteristics of the production versions of these cars and then infer how the racecars would perform relative to one another.

Each car has a different engine placement with respect to the chassis; the BMW M6 is designed with a front engine, while the Ferrari 488 was designed with a mid-engine, and the Porsche 911 was designed with a rear engine. The differences in engine location result in three different weight distributions, with the BMW having a forward, Ferrari having a balanced, and Porsche having a rearward distribution of mass.

A quick internet search reveals the overall dimensions of the base production models for each of these cars. These dimensions are not the exact dimensions of the racecar, but they are similar enough for us to demonstrate the impact of the overall dimensions (see **Table 1**). We will examine the effects of these dimensions on the aerodynamic characteristics, and also on the centre of gravity heights.

Aero properties

The first thing to point out aerodynamically is the variation in frontal area, with Porsche having the smallest frontal area, Ferrari only 1.3 per cent greater than the Porsche, and BMW 12.7 per

The BMW M6 GT3 should perform well in high-speed corners due to its high downforce potential and its weight distribution

The Ferrari was the best of our cars with an almost even weight distribution, low drag and a decent amount of downforce

The Porsche has low drag and a rearwards weight distribution, which gives it some advantages accelerating out of corners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I would recommend leaving the Ferrari alone; it will serve as a baseline, as our thought experiment shows it will likely be the best car overall

Homologation specials like the Maserati MC12, which competed in the FIA GT Championship from 2005 to 2009, are partly responsible for the introduction of BoP into GT competition

cent larger than the Porsche. The differences in frontal area have an impact on the drag induced by the vehicles at speed. Depending on the drag coefficients for the Ferrari and Porsche, they will experience similar resistive forces due to drag, while the BMW will experience considerably more resistance due to aerodynamic drag regardless of the drag coefficient.

Continuing with the aerodynamic properties of each vehicle, the plan view area (from the top looking down) will influence how much downforce the underside of the vehicle generates. From the top, you can think of the vehicle as a big wing where a larger area generally results in an increase of downforce. The plan view area of the BMW M6 is approximately 4.6 per cent greater than the Ferrari 488, and 11.4 per cent greater than the Porsche 911. From these numbers we can infer that the BMW will have the greatest downforce, followed by the Ferrari, and then the Porsche.

Centre of gravity

The last thing we will consider with respect to the overall dimensions is the height of the vehicle. This has an impact on the centre of gravity height, which in turn has an impact on the load transfer characteristics of the vehicle when braking, accelerating, and cornering. Generally, a vehicle with a taller height will have a higher centre of gravity because more material is located higher off the ground. In the case of the example cars, the Ferrari 488 has the lowest height, with the Porsche 911 64.0mm (5.3 per cent) taller than the Ferrari and the BMW M6 188.5 mm (15.6 per cent) taller than the Ferrari. The higher c.g height for the BMW could lead to a disadvantage under load transfer scenarios, because more load transfer equals reduced overall grip levels from the tyres.

At this point we have gathered together enough information to clearly show that regardless of the circuit, these three cars will make lap times in very different ways.

Car characteristics

Considering the BMW, we have a front-engined car with a forwards weight distribution, significantly higher drag, potentially lots of downforce, and a disadvantage from reduced overall grip in lateral or longitudinal load transfer. It should perform well in high-speed corners due to the higher downforce, and a weight distribution that favours high-speed stability. It should also perform well under high-acceleration and braking, also due to the stability. But it will suffer in low-speed corners where mechanical grip is paramount due to both the weight distribution and the effects of increased lateral load transfer. The BMW M6 will also be at a significant disadvantage on long straights due to the relatively high drag.

Moving to the Ferrari 488, we have a mid-engined vehicle with an almost even weight distribution, low aerodynamic drag, a decent amount of downforce, and a low c.g height providing an advantage under load transfer scenarios. The dimensional characteristics of this car are superior to the other cars in this example. The balanced weight distribution coupled with relatively high downforce, and minimal impact from load transfer, will enable this car to perform well under all braking and cornering scenarios. The low drag will make the car fast on straights, which when combined with increased cornering speeds will be a great advantage at circuits with long straight sections.

Finally, we have the Porsche 911, a rear-engined vehicle with a rearwards weight distribution, an equally low aerodynamic drag compared to the Ferrari 488, but less downforce and a small disadvantage under load transfer scenarios. The biggest advantage to the rearwards weight distribution will come on corner exit, as the load transfer on initial throttle application will only add to the high mass over the rear axle. If you have ever seen a Porsche accelerate out of a corner in the wet, you will know what I am talking about. The low drag of the car will help to make the car fast on straights, a situation that is made better by the ability to put power down. Depending on the quality of the aerodynamic devices, the Porsche will likely be slower than the Ferrari and BMW in high-speed corners because it could have less overall downforce. The Porsche should fall ↳

The sheer variety of marques involved in GT3 means that BoP is necessary to provide a level playing field, while without it there would not be such a diverse grid in the first place

The decisions associated with BoP are primarily motivated by three factors: politics, subjective observations and objective analysis

somewhere between the Ferrari and BMW in low-speed corners, but this is based strictly on the impacts of lateral load transfer.

So now that we have a fundamental understanding of how the racecars will perform, what can be done to achieve our goal of making sure all manufacturers and teams believe they can be competitive? We are going to approach the solution from a power and mass perspective to simplify the explanation.

Balancing act

I would recommend leaving the Ferrari 488 alone because it will serve as a baseline, and the conclusions of our thought experiment above show it will likely be the best overall car. Ferrari has done a good job designing a base vehicle for a racing platform, so let's not tamper with it for now. For the Porsche 911 I would recommend decreasing the base weight of the car slightly, as this will help it exploit its strengths on corner exit and will hopefully improve the low-speed cornering performance. For the BMW M6, I would recommend increasing the base power level to compensate for the higher drag level with a target of matching the acceleration rates of the Ferrari and Porsche. I would also add mass to the BMW to offset some of the effects of the added power and potentially fine-tune the acceleration rate. This could hurt it in low-speed corners, so the mass adjustment needs to be somewhat dependent on the layout of each circuit.

The engine layout and dimensions discussed above do not cover all of the parameters that need to be considered when looking at balancing different racing vehicles. In a future article we will review the vehicle parameters that influence balance of performance in more depth, and also look at how series officials can adjust various vehicle settings to achieve parity.

We now have some recommendations, but they only serve as a starting point. They are just ideas that need to be converted into decisions. In a situation where the only information you had was the weight and dimensions of a group of cars, you could apply these recommendations to create a starting point. Once you had an opportunity to collect some data on the cars, you could refine the recommendations to make better decisions. Now we need to look at some of the motivating factors behind making decisions in the realm of BoP.

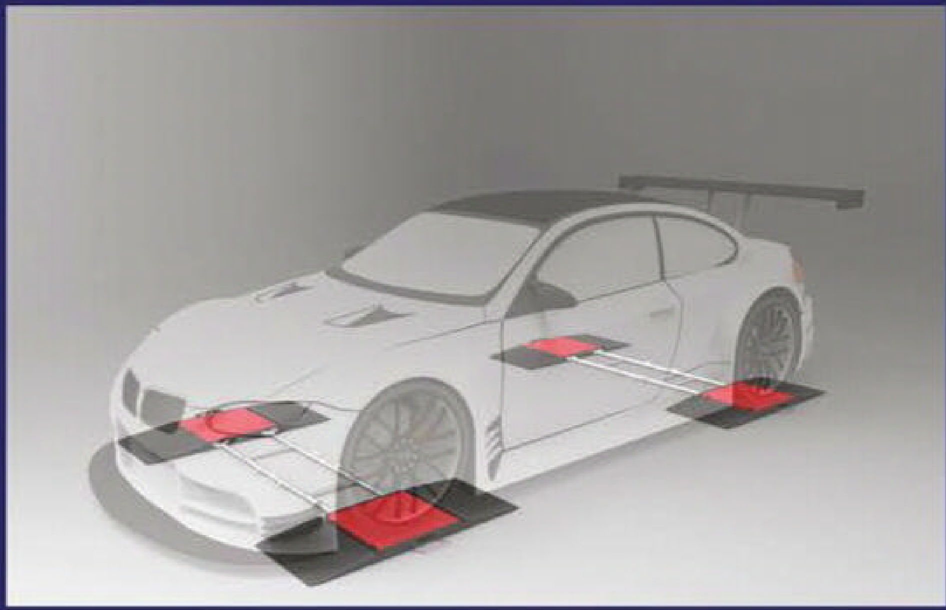
Decision making

The decisions associated with balance of performance are primarily motivated by three factors: politics, subjective observations, and objective analysis. Of these, I actually believe that any decisions rooted in subjective observations are the absolute worst.

Why have I not said that politics are the worst? Let's look at politically motived decision making before jumping to any conclusions. When politics motivate a BoP decision, that decision often appears absurd from the outside. There are enough smart people around, not directly involved with the decision-making process, who can figure out where decisions like this are coming from. The decision may be directionally correct, but too big of a change. For example, a GT3 car that is 2km/h too slow on a straight does not require a five per cent increase in power to achieve parity with the rest of the field. Directionally incorrect decisions are generally the more absurd ones, like removing 20kg from a prototype that has been setting quick theoretical lap times relative to the rest of the field. None of this justifies politics in balance of performance, in fact there is no place for politics in racing. I am simply pointing out that at least you can infer where the decision is coming from, which is better (only marginally, though) than having no idea at all.

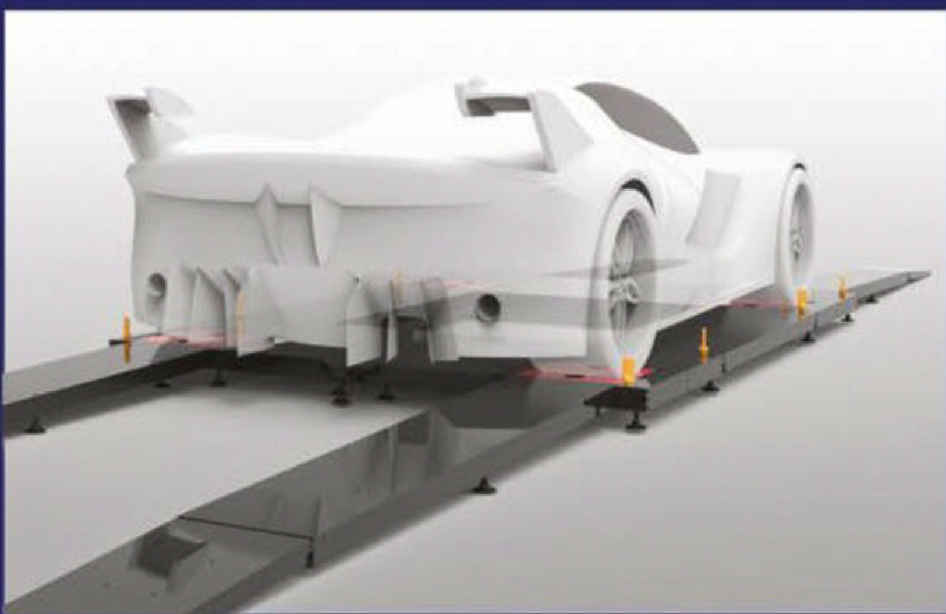
The wrong approach

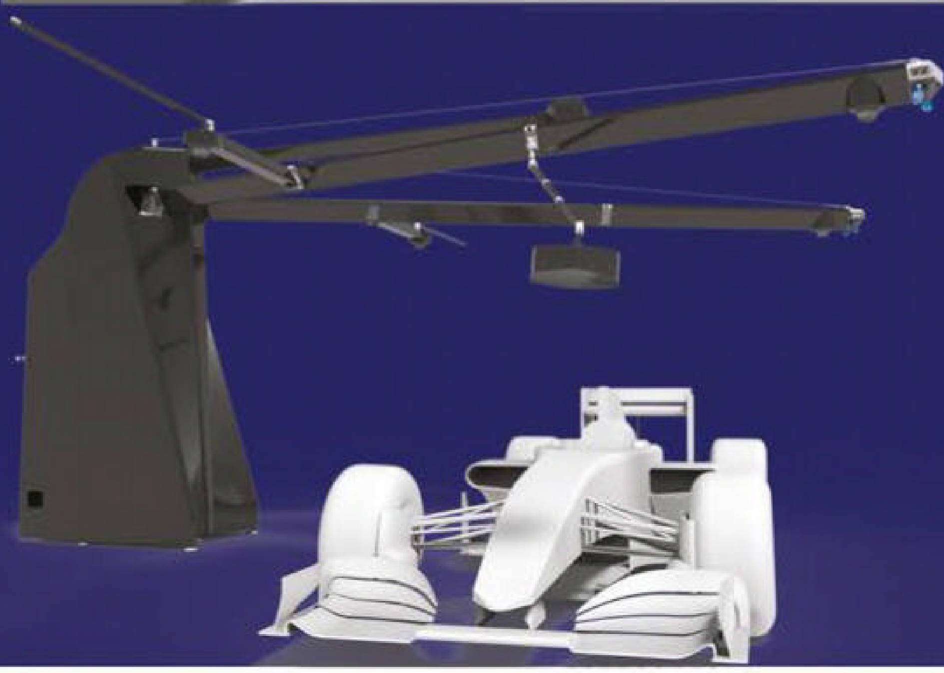
So, if having at a minimum some idea of the motivation behind a decision is better than having no idea at all, why is subjective decision making worse than politically motivated decisions? With subjective decision making you often know neither where a decision is coming from, what motivated it, nor if it is directionally correct. An example of the motivation behind a subjective decision would be a scenario where someone watching the race on TV noticed a car from one marque easily get by a car from a rival marque. Because of this observation, the marque passing its rival receives a 1.5 per



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Being faced with 50GB worth of data following a 24-hour race is exciting, in a masochistic kind of way, but also overwhelming

cent reduction in power going into the next event … because *clearly* that car has too much power if it can so readily pass other cars. But hold on, has the person making this decision taken everything into consideration? What if the car that completed the pass was nearing the end of its first stint on a set of tyres that can easily double stint and a low fuel load, while the rival car that was passed was on an out lap after changing to a new set of tyres and taking on a full load of fuel? Alternatively, imagine a situation where the driver of the rival car was bronze rated and the driver of the car completing the pass was a platinum, factory-back driver. In this case, the bronze driver simply took the preceding corner much slower than the platinum driver, so the platinum driver was easily able to overtake at the end of the straight.

Staying objective

Objective decision making is by far the best way to arrive at BoP conclusions, but it is also the hardest. This is perhaps why outsiders have a perception that BoP is only about politics. Objective decision-making is data-driven decision making, but being data-driven requires data. This data must be analysed to be meaningful, as all the data in the world is useless if you cannot, or do not, do anything with it.

But then you run into a problem *with* having all the data in the world: as it is extremely difficult to get through it all. Being faced with 50GB worth of data following a 24-hour race is exciting, in a masochistic kind of way, but is incredibly overwhelming. Unfortunately, of that 50GB worth of data, a good portion of it is crap. Whether the data is from a slow driver, under conditions where the car was bent slightly, or when a particularly important sensor or sensors failed, the person(s) analysing this data must be equipped to separate the good data from the mediocre and bad. Once you get to the point where you have separated the good data from the not so good, you are now faced with the task of highlighting areas of concern so that you can distribute your limited time and resources adequately on the correct priorities. By the way, did I mention that the next race is only a week away, and your conclusions were due yesterday?

The amount of data that comes out of races like the Spa 24 hours is staggering, which makes formulating a BoP a tough task

While this might seem crazy, this is actually what it is like trying to make objective decisions based on logged vehicle data. I can tell you from experience that it really sucks to spend half a day looking into a racecar's acceleration rate versus another car's acceleration rate only to find out that the accelerometer in one of the racecars was offset slightly.

Objective decision-making is data-driven then, and it is hard, but it is the only way to make correct balance of performance decisions.

Before leaving objective decision making, I would like to point out that the thought experiment with the GT3 cars was an objective exercise, and not subjective. The recommendations were derived from looking at factual information about the layout and dimensions for each car. We would be at a point now in that experiment to collect some vehicle data for each car so we can analyse the data and arrive at better objective decisions.

Top of the BoPs

The problem with objective decision making, though, is that it's very complex and time consuming. This is why I decided to develop the OPAA software I mentioned earlier to make the job easier. My first objective was to speed up the time it takes to get from raw vehicle data to the point where you are asking the right questions about the data you have obtained, and arriving at the correct answers. In that regard, the software can currently post-process that 50GB worth of data from a 24-hour race in approximately 8.5 hours. Compare this to this personal experience where one time, after three engineers had dedicated a total of 375 hours on the job, we finally arrived at a point where we knew what questions to ask, but not the answers to those questions.

One of the key features of the ORCA Performance Analysis Application is its ability to automatically exclude outliers and erroneous data. This feature is the most important time-saver of them all, as the crap data I referred to above is not even taken into consideration. This feature is also important because it is often very difficult to distinguish between valid and invalid data. By establishing a rule to identify outliers, the removal of the outliers then evolves from being subjective to objective.

Trend setting

Another key feature of the software is it can automatically generate a report with detailed plots displaying the trends in performance metrics for all cars participating at an event. By looking at trends versus a few, or at worse a single observation, you are doing an even better job at arriving at objective conclusions.

At this point there are still several topics to discuss with respect to balance of performance. In future articles I will expand on the process of objective decision making, examine some of the parameters that make BoP difficult, discuss sandbagging, and look at some of the vehicle parameters we can change, and how to decide which parameters need changing.

I hope, at a minimum, you now have some perspective on how I am working towards changing perceptions surrounding BoP. I'm not asking you to agree, but just make sure your decision on all this is less of an opinion, and more of an objective conclusion.

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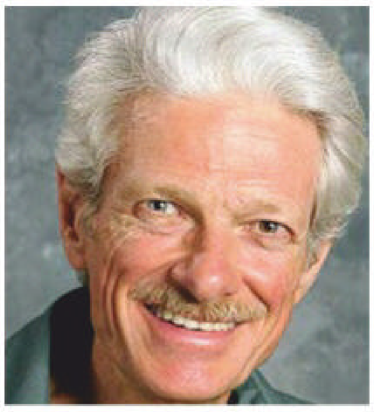

Middle management

GM's decision to reposition the engine for its new Corvette C8 prompts a question about the handling of mid-engine cars

By **MARK ORTIZ**

The Corvette C8 represents a break in tradition for the marque, which has previously only built cars with engines in the front

Q The advent of the new C8 Corvette with its mid mounted engine [see page 8] has inspired some comments on the handling characteristics of such cars. To quote: 'A mid-engine car has a low polar moment of inertia, allowing the car to change direction more easily', but 'it can be harder for a novice to recover should the tail break loose'. The second quote seems problematic or unclear. It would seem that the low moment of inertia, and relatively high ratio of wheel torques to inertia, that enable the mid-engine car to change direction easily should also allow control to be regained more easily in a skid.

Is this reasoning flawed? Or is the qualification of 'novice' here relevant? Would a pro not have the same problem? The central driver location would reduce the driver's lateral motion in a skid relative to a more rearward location, so that inertial information of a skid might be reduced, but the visual and inertial cues from rotation should be the same. Does the 'harder to recover' statement agree with reality?

THE CONSULTANT

A The polar moment of inertia referred to here is a measure of the car's rotational inertia about a vertical (*z*) axis. This is expressed mathematically as the radius of gyration, conventionally designated k, or k_z, times the car's mass. To understand what the radius of gyration is, imagine that all the car's mass was concentrated at one infinitely dense point, some distance from the centre of rotation we are considering. How far away would that notional single mass need to be, to have the same rotational inertia the car has? Stated another way, the car's mass, times the radius of gyration squared, times rotational acceleration, equals rotational inertia.

It is certainly correct that a car with centralised masses will change direction more readily

Note that the radius of gyration is squared here. If the radius of gyration is twice as big, that means the mass accelerates linearly twice as fast for a given rotational acceleration, and also the resulting inertial reaction acts at twice the radius, so the rotational inertia is four times as great. The implication for car design is that relatively small changes in the radius of gyration can have a big effect on car behaviour.

Accordingly, for a given rotational moment applied by the tyres (or anything else), rotational acceleration is inversely proportional to the square of the radius of gyration. When we reduce the radius of gyration, the car accelerates faster rotationally with a given excitation. So it is correct that a car with its masses centralised changes direction more readily. Or, more precisely, it changes yaw velocity (as distinct from yaw displacement) more readily. It starts rotating in yaw more readily, and it also stops or reverses yaw rotation more readily. This is particularly useful for chicanes, slaloms, and any opposite-direction turns in quick succession.

Polar exploration

The car actually has three polar moments of inertia, and three corresponding radii of gyration, for roll (k_x), pitch (k_y), and yaw (k_z).

When we locate masses closer to the relevant axis of rotation, along either of the other two axes, we reduce the rotational inertia about the axis of rotation. For yaw, we reduce the polar moment of inertia by locating masses closer to the middle of the car, either longitudinally or transversely. The question of the engine location mainly relates to longitudinal location of a major mass, but it's worth noting in passing that moving things in lateral has some effect as well.

For example, the Lancia D50 F1 car of 1954 had outrigger fuel tanks between the front and

It can be harder for a driver to hold on to a mid-engine car, like this Toyota MR2 racer, when the tail suddenly breaks loose

rear wheels, hung out on struts from the body. These were intended to act as a form of fairing between the wheels, and to also provide fuel storage in a location where fuel burn-off would have less effect on weight distribution than with a tank in the tail. There was also some fuel carried in the tail, along with the oil.

In 1955, the car was taken over by Ferrari and ran as the Lancia-Ferrari. It experimented with side tanks further in from the wheels, which reduced the yaw inertia. The first version with the tanks moved in retained fairings between the wheels but had the gap to the body filled in, and the tanks moved into that area. On the final version of the car, in 1958, the pontoons disappeared entirely, and there were smaller side tanks within a conventional-looking body. The reduction in tank capacity accompanied a switch from alcohol fuel to gasoline due to a rules change that year.

Such a change would also reduce roll inertia. This is less important, but it illustrates the point that moving a mass toward the centre along one axis always reduces rotational inertia about the other two axes, not just one.

Correspondingly, moving the engine toward the middle of the car along the *x* axis reduces rotational inertia about both the *y* and *z* axes; in pitch as well as yaw.

Ride quality

This has implications for ride quality. It affects what engineers call the k^2/ab ratio. (Note again the squaring of the k term.) This parameter comes from Maurice Olley's work for GM in the 1930s. In this expression, k is k_y, the radius of gyration in pitch, for just the sprung mass; *a* is the horizontal distance from the sprung mass c.g. to the front axle; *b* is the horizontal distance from the sprung mass c.g. to the rear axle. For best ride, especially in lightly damped passenger cars, we want a k^2/ab ratio close to one. Or at least that works best assuming we're holding the wheelbase constant.

Olley arrived at this conclusion through experiments that involved a 1930s passenger car with a k^2/ab ratio considerably less than one due to the wheels being toward the ends. Olley hung movable weights off the front and rear of the car to make the k^2/ab ratio adjustable. He found that if the car was really 'end heavy' it tended to oscillate in pitch. If the car was really 'centre heavy' instead, it felt stiffer, and thus harsher, in pitch. We should note that this relates to the car's response to a pitch excitation consisting of sequential excitations at the front and rear axle, as when negotiating a speed bump or raised railroad crossing. The k^2/ab ratio does not affect pitch displacement in response to braking or power application.

The required counter-steer input may be smaller in magnitude, but it generally needs to come quicker

Anyway, a mid-engine car tends to have a 'pitchier' ride over single-axle disturbances than one with the engine located closer to an axle. For sports cars, however, the central driver position makes pitch somewhat less noticeable to the driver, compared to a seating position close to the rear axle.

Degree of difficulty

Can it be harder for a novice to recover should the tail break loose? This pretty much does agree with reality, but the matter is a bit complicated. Partly, it depends on what we use to measure difficulty. In many cases, the required counter-steer input may be smaller in magnitude, but it generally needs to come quicker, and it also needs to be taken back out quicker as the tail grabs again and yaw acceleration reverses. The usual problem in catching a tail-slide is correcting too late, rather than too little, and often trying to compensate for lateness by over-correcting. If the required correction needs to be faster and also more delicate, that calls for greater quickness and finesse from the driver. Experience and training help with this.

Driver positioning is a factor, as well. Being seated close to the rear axle definitely does help you feel what's going on at the rear contact patches, and you can still feel the fronts through the steering. Being in the middle of the car has its advantages too, though. Usually, it's easier to see, at least to the front. As already mentioned, it's best for ride comfort, and it also makes the car feel more like an extension of your body. A rearward seating position produces more of a sensation of the car being a separate entity that's dragging you around by the ankles. That isn't really an impediment to driving the car, however.

For most road courses, really small yaw inertia isn't a huge advantage. For open road races, as held in continental Europe and Latin America up until the 1950s, it can even be desirable to have greater yaw inertia. This is particularly helpful when we may unexpectedly encounter small slippery pieces of road, such as sand washes across turns or oily patches. The car does a smaller wiggle in such situations if it has a lot of yaw inertia. That in turn means the driver can drive a bit closer to the limit of adhesion for a given level of risk.

With this in mind, the racecar designers back then weren't necessarily wrong to build cars with front engines and transaxles in the back, and they would have said that the resulting yaw inertia was a good thing.

In a mid-engined car, we can address this by making the wheelbase longer, and by setting the car up with a bit more understeer.

The Corvette trap

Although we can't really say that a car has a natural frequency in yaw, anecdotally it does seem that esse bends of particular frequencies tend to excite certain cars at yaw frequencies

Racing Porsche GT3s allow for adjustment of 'caster' at the rear as well as at the front, but this really has much more to do with the bump steer rather than anti-lift and anti-squat

that create something akin to a resonant response and can cause loss of control in cars with large k_z. There is a race track close to where I live that has what some people call the 'Corvette trap' for this reason. Chances are that the C8 will not have the same problem, at least at that place, on that track.

While much discussion of the rear mid-engine layout focuses on yaw inertia, its most compelling advantages probably lie elsewhere. Assuming we're using a large engine, and assuming we've chosen to drive only the rear wheels, putting the engine directly behind the driver gets us better propulsive traction and better braking than putting it in front, and hanging the engine behind the rear axle isn't a viable option if it's really big. Putting the engine behind the driver also lets us lower the driver's eye level and hence the roofline and the nose, improving aerodynamics.

Q What effect does 'caster' have in the rear of a Porsche GT3. Specifically, the race components for a Porsche GT3 allow for a similar adjustment for front caster in the rear; this same component allows anti-dive adjustment.

THE CONSULTANT

A The short answer here is that rear 'caster' adjustment affects rear bump steer, but has no significant effect on anti-lift or anti-squat, and also no effect on steering feel or caster jacking since we don't steer the rear wheels with the steering wheel.

The front adjustment looks similar, but it affects both bump steer and anti-dive along with caster. The difference in the effect on side view geometry is due to the front and rear suspensions being of different design above the lower control arm.

When we add caster at the front of the GT3 we move the ball joint forward and tilt the strut back

This car has strut front suspension and short and long arm (SLA) suspension in the rear, but the lower control arms in the rear look very similar to the front control arms. There is a lateral link and a compliance strut. At the front, the compliance strut is behind the lateral arm and in the rear the compliance strut runs forward from the lateral arm, but aside from that they look very similar. In the street version of the car, neither of these compliance struts adjust for length. That means the car doesn't even have caster adjustment at the front. There is no adjustment at the top of the MacPherson strut either, for camber or caster. That's pretty shocking, for a high-end, high performance sports car. Then again, there's no caster adjustment on a 356 Porsche either.

Adding caster

When we add caster at the front of this car, we move the ball joint forward and tilt the strut back. Regular readers may recall that a MacPherson strut has a virtual control arm plane perpendicular to the strut axis and containing the top pivot's centre of rotation. The virtual side view projected upper control arm is the line where that plane intersects the *XZ* wheel plane. When the strut tilts back more, the side view projected control arm inclines down toward the rear more, and intersects the nearly horizontal lower side view projected control arm further forward. That increases the jacking coefficient in braking for the wheel, and hence the amount of anti-dive.

At the rear, we have what is sometimes called a virtual A arm at the top of the upright: two separate links that converge to a point about where a ball joint would be if we had a one-piece A arm. With this layout, the side view projected upper control arm does not change its angle appreciably with caster adjustment, so the longitudinal jacking coefficients for propulsion and braking don't change appreciably either.

A friend of mine has a road-going Porsche 996. We've had it on the kinematics and compliance rig at Morse. It has a lot of bump steer on all four wheels. The fronts toe out in bump and the rears toe in. The owner reports that it steers itself very noticeably over just about any kind of bump. Apparently, the factory chooses to mask the car's limit oversteer with lots of roll understeer. To correct this by adjusting the compliance struts, we would add caster at the front and reduce it (tilt the upright forward) at the rear.

CONTACT

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

Our Reynard SF79 aero study comes to a close with some tweaks to improve balance plus some thoughts on an ultra-low drag set-up

By SIMON MCBEATH

The Reynard SF79 is highly competitive in Historic Formula Ford 2000, as it was back in the day when it took its designer, Adrian Reynard himself, to the FF2000 European Championship in 1979. Our test car is owned by Paul Allen, and though no stranger to the podium himself, he was keen to gain some end-of-straight speed with drag reduction. We learned how to do that, and much more besides, during a busy session in the MIRA full-scale wind tunnel. But would an ultra-low downforce, low drag package be even better?

Interim update

In our last issue (V29N11) we saw that flap angle and splitter length adjustments produced the expected effects on drag, downforce and balance. But we also found some surprising benefits from horizontal and vertical Gurneys on the rear edges of the nose, with drag reductions and downforce gains front *and* rear. And a change to an earlier design body top with a more streamlined-looking engine cover also offered the potential for similar downforce and balance with less drag.

At this stage in the session we had found set-ups that would generate similar balance to the baseline but with less drag, with less or similar downforce, but it wasn't yet 'mission accomplished' because we still had things to try. **Table 1** shows the data from Configuration 1, the baseline set-up as had been raced recently, with Configuration 16, which featured the aforementioned nose Gurneys as well as other changes outlined in the previous issue. Although not quite balanced in this guise, a small rear wing flap reduction would bring the balance into the target range of 34-38 per cent front, but would give less drag and more downforce than baseline. Efficiency, as given by –L/D, had increased markedly, but of more interest really was that the drag had been reduced, this possibly being a more critical parameter for these 135bhp racecars.

More surprises

Attention turned next to trying to obtain more front downforce to bring the balance into the target range. The first modification was to fit a flat panel under the nose, across the widest part, to fill in what was a hollow nose section in baseline configuration. The writer's confident expectation was that this would improve front downforce, as a similar modification that we showcased in September 2015 (V25N9) did to a Mallock Mk 18B Classic Clubmans car, where 70 counts of additional front downforce represented a 46 per cent gain. However, as a further reminder that what works on one car may not work on another, the results in **Table 2** tell a totally different tale. Perversely, whereas the Mallock gained 46 per cent front downforce, the effect on the Reynard was a *loss* of 46 per cent front downforce! We did not have the time to stop and investigate this apparently anomalous result and one can only speculate that perhaps the effective rake angle was not as level as we thought, or that a positive rake angle would be needed in this instance to obtain the desired result. We moved onto the

Illustrations: Simon McBeath

The Reynard SF79 was in its pomp 40 years ago but this example still does the business in Historic Formula Ford 2000

This was a further reminder that what can work well on one car might not work on another

A flat underside (white) in the splitter brought surprising results

Table 1: Baseline and interim data

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Baseline	0.509	0.407	0.140	0.268	34.3%	0.800
Configuration 16	0.490	0.441	0.131	0.310	29.7%	0.900

Table 2: The effects of fitting a flat panel under the nose – as delta values in counts where one count is a coefficient change of 0.001

	ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear	Δ%front	Δ-L/D
With flat panel	-3	-54	-61	+7	-11.6%	-106

Angled infill panel fitted below the splitter worked as expected, increasing downforce

This single element rear wing might provide an effective lower drag set-up for the Reynard

next configuration, but kept the unexpected effects of this change in mind for later.

Another modification *guaranteed* to bring positive benefits from a splitter is to put some form of upsweep on the underside. A short, angled infill panel that fitted under the forward-most part of the splitter was brought for test, and in view of the negative results from the previous modification the data were awaited with some unease. Nevertheless, this change did work as expected, and produced an interesting set of results, as shown in **Table 3**.

Although drag increased by a very small amount, front downforce increased markedly (by 34 per cent) and balance was at the upper end of the target range at 38 per cent front. This was the highest efficiency, highest downforce balanced configuration of the entire session, at a drag level 3.1 per cent lower than the baseline value, so this warranted a small celebration at least. But we were not quite done.

Final tweaks

For our last modification the team had brought along a single element wing (which had the same profile as the baseline wing's main element) cleverly mounted on test end plates that put the wing's trailing edge at the same overhang behind the rear axle as the baseline wing, and at the same height. A fairly arbitrary angle setting of 5.5 degrees was applied, and the data produced are shown in **Table 4**.

Clearly there was a significant loss of rear downforce and an associated increase in downforce felt at the front axle because of the reduction in the rear wing's leverage, with a concomitant large shift in balance (%front). However, the interesting figure is the drag value, lower by some way than the low flap angle figures with the dual-element wing.

Now let's play 'what if?' What if the front end, and to some extent the rear wing, were detuned to produce an even lower drag but balanced low downforce set-up?

Table 3: The effects of an angled infill panel under the splitter, compared with configuration 16 from Table 1

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Configuration 16	0.490	0.441	0.131	0.310	29.7%	0.900
Plus angled panel	0.493	0.462	0.176	0.287	38.0%	0.937

Table 4: Coefficients with a single element rear wing

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Single element	0.469	0.395	0.198	0.197	50.1%	0.842

Table 5: Hypothetical low drag configurations

	CD	-CL	-CLfront	-CLrear	%front	-L/D
HLD 1	0.466	0.374	0.153	0.220	41.8%	0.805
HLD 2	0.463	0.320	0.092	0.227	30.2%	0.699

Balance was at the upper end of the target range at 38 per cent front

The last nose modification, the angled under-splitter panel, added a little bit of drag and a large chunk of %front. So let's 'remove it' and simplistically subtract its delta values from the values in **Table 4** and call this 'Hypothetical low drag 1' (HLD 1) in **Table 5**.

Next, we don't want to remove modifications that decreased drag while increasing downforce, but the flat splitter under-panel decreased drag while reducing downforce, so let's add its delta values to HLD 1 and enter this as HLD 2 in **Table 5**. HLD 2 has a %front figure below the target range, but a reduction of the wing angle to a lower positive angle, even to zero or slightly negative, would bring the %front value into range while reducing drag further, possibly as much as 15 per cent or more below the baseline drag we began with. Would that be a faster set-up for some tracks at least? Historic Formula Ford 2000 at Monza, anyone?

Next month we start a new project.

Racecar's *thanks to Paul Allen, Jason Redding, Tom Smith and Ken Thorogood.*

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

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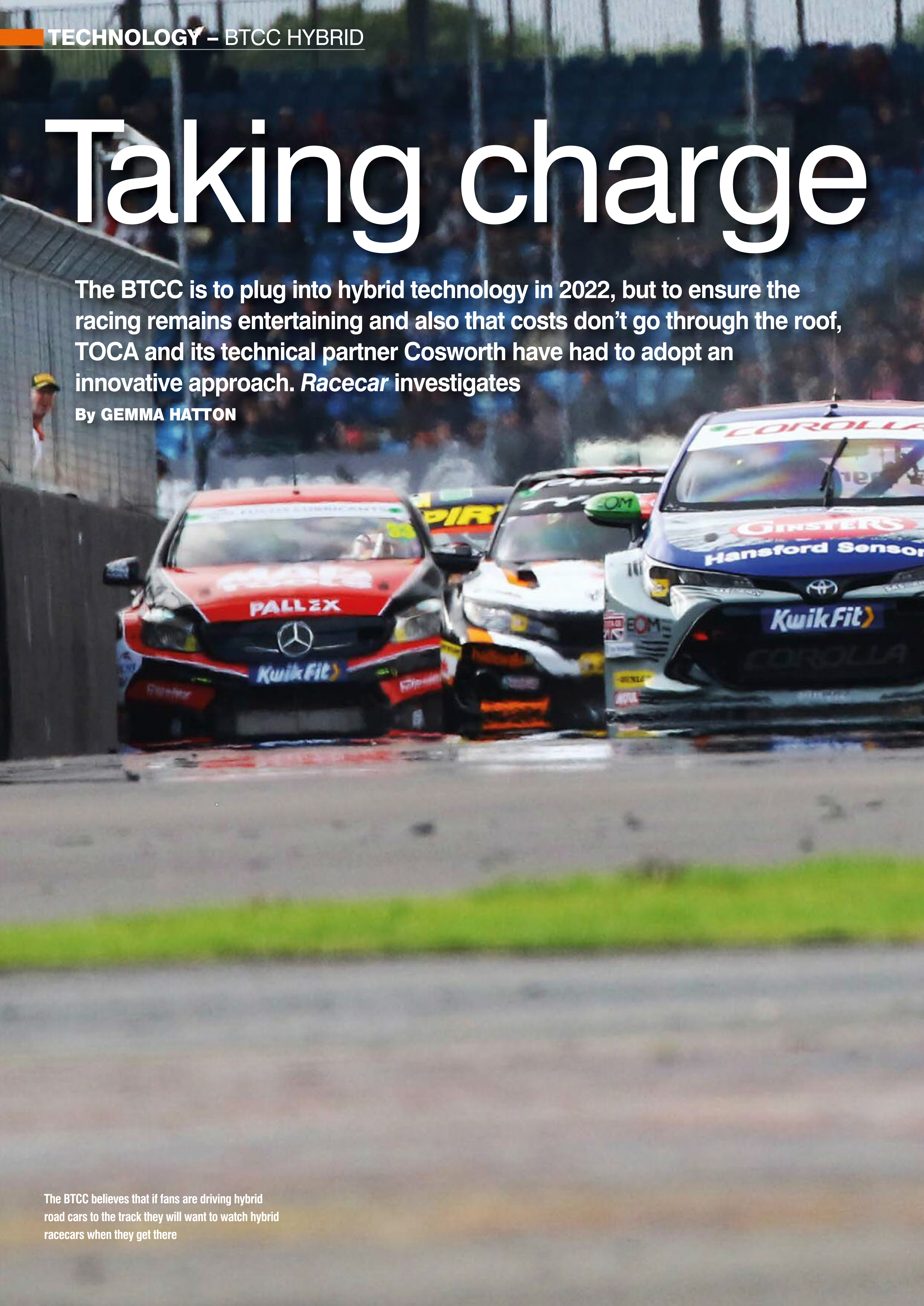
Taking charge

The BTCC is to plug into hybrid technology in 2022, but to ensure the racing remains entertaining and also that costs don't go through the roof, TOCA and its technical partner Cosworth have had to adopt an innovative approach. *Racecar* investigates

By GEMMA HATTON



The BTCC believes that if fans are driving hybrid road cars to the track they will want to watch hybrid racecars when they get there

‘This will put some more engineering into the BTCC and it will be interesting to see how the teams up and down the pit lane cope with the new challenge’

Electrification continues to sweep across the world of motorsport, with the BTCC being the latest championship to announce that it will be going hybrid, in 2022. Hybridising this series whilst retaining thrilling races, enthusiastic fans and full grids will not be easy, but on top of that there’s the added pressure of achieving this at minimal cost to the teams. The UK’s premier race series faces quite a challenge, then.

In very rough figures, the 2022 BTCC hybrid system will cost around one per cent of what Formula 1 teams spend on their hybrid system per year. Of course, the F1 system comprises more elements, is more complex and completes a lot more mileage, but it does give an idea of how small the money pot is for BTCC to go hybrid. Therefore, series promoter TOCA has had to adopt a completely new and innovative approach to hybridising its championship.

Road relevance

But why on earth is BTCC going hybrid anyway? One of the reasons why touring cars are popular is road relevance; the cars out on track are beefed up versions of those in the car parks. So, the argument goes, if you are arriving in a hybrid, then why not watch hybrids race?

‘It’s the way the automotive market is going and the BTCC has always been built on the philosophy that what you drive on the road is what we race on the track,’ explains Alan Gow, series director at BTCC. ‘All other major motorsports are going that way, it’s what you have to do to keep relevant to the automotive sector and the fans. But I wouldn’t have done it if it was going to hurt the racing. In fact, we’ve integrated the hybrid system in a way that will actually add an extra element to the racing.

‘We see hybrid not so much as an environmental aspect of our championship, but as additional performance,’ Gow adds.

'We are not a technological formula, this hybridisation is about improving the show, whilst also keeping us relevant in the world around us, but it is also a bit of free horsepower.'

Using the hybrid system to boost on-track performance is a clever strategy to aid overtaking and help win over the fans and is something that has already been exploited in Formula 1 and the WEC. The 'free' horsepower available in BTCC is estimated to be around 40bhp, which will be deployed by the driver via a button on the steering wheel. This hybrid boost button can be used for up to 15 seconds per lap, with no limit on the number of uses. The only restrictions are that the full 15 seconds cannot be used all at once and hybrid boost can only be deployed under full traction.

'They can deploy the hybrid energy to push to pass or defend,' Gow says 'It's not just a button that makes the driver in front a sitting duck, that's what I don't like about DRS in Formula 1. Whether or not a driver can respond quickly enough and defend against the guy coming up behind them will depend on how much energy the driver's saved on that lap.

'There will be some circuits where 15 seconds will be too much, for example at Knockhill, that's around a quarter of the lap,' Gow adds. 'So we will adjust the amount of energy that is going to be deployed by the driver depending on the circuit and conditions, but we will work that out nearer the time. It adds another element of strategy into the races. I'm looking forward to it, and most of the drivers are too, particularly the younger drivers as they are the PlayStation generation.'

Boosting the show

Another way in which the hybrid system will be utilised to manipulate the racing is through allocating different percentages of available boost to particular drivers per race, replacing the ballast system. Currently in the BTCC the regulations specify that the top 10 cars in the championship must carry additional weight or ballast during qualifying and for the first race. For race two and race three ballast is then allocated according to the finishing positions of race one and two respectively.

'Again, we will work that out nearer the time, but we all know the effect one kg has on the lap times, so we will relate that to hybrid through either reducing the number of hybrid bursts or percentage regen available,' says Gow. 'So the driver will just have less regen in the race that will be equal to running with the relevant amount of ballast. The main reason for doing it is so that we don't have to carry the additional weight of the ballast together with the battery. Otherwise we would have to start upgrading the tyres and suspension and getting into unnecessary costs.'

The battery will therefore replace the ballast box, and to avoid modifying the suspension and tyres TOCA has defined the weight of the hybrid system to be less than last year's maximum success ballast, which was 75kg – the ballast dropped to 54kg for 2019 as it was thought to be having too much of an effect on the racing.

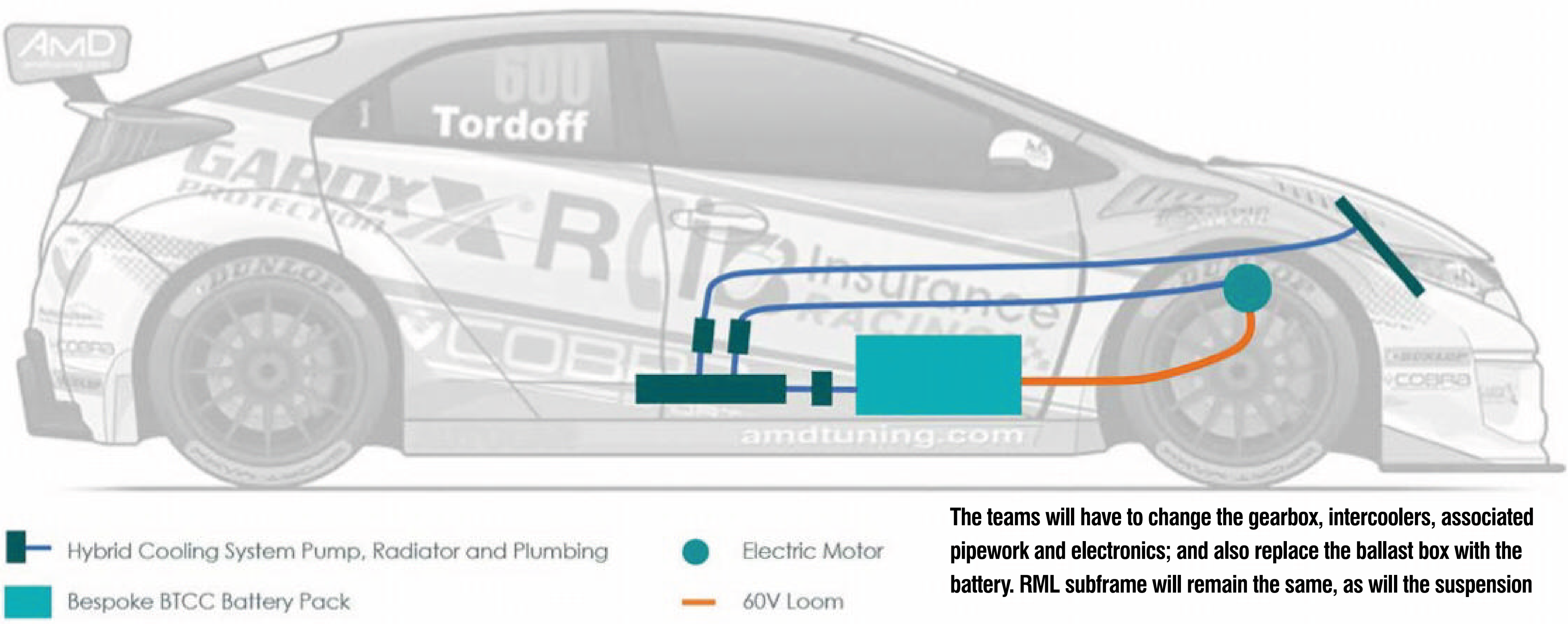
The original plan was to introduce the hybrid system in 2022, as this marks the end of the current contract cycle that TOCA has with many of the suppliers. However, Gow then challenged his team to see if the 2021 season was also feasible – and with a few early contract renewals this was possible. The choice between 2021 and 2022 was then presented to the major teams, along with the pros and cons of each, and the majority voted to bring it in 2022.

Approximately 40bhp will be available for overtaking, which will be activated via a boost button on the steering wheel

The weight of the system is to be less than the maximum ballast in 2018, which was 75kg

Complete package

Interestingly, TOCA did not opt for the conventional route of securing individual tenders with separate battery, motor and electronics suppliers. Instead, a tender went out for the entire hybrid package. 'Individual contracts are a recipe for disaster,' Gow says.



The teams will have to change the gearbox, intercoolers, associated pipework and electronics; and also replace the ballast box with the battery. RML subframe will remain the same, as will the suspension

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TOCA did not opt for the conventional route of securing individual tenders for separate battery, motor and electronics suppliers

'We put a tender out for the entire hybrid package which also included elements such as training and support engineers so there is no ongoing cost for the teams. We wanted to give a master contract to one company so it was their baby. That's the way I like to do business.'

Around 25 companies applied for the initial tender, but many withdrew once they saw how complex and detailed it was. This left two viable options and again the choice was put to the team owners, who voted for Cosworth.

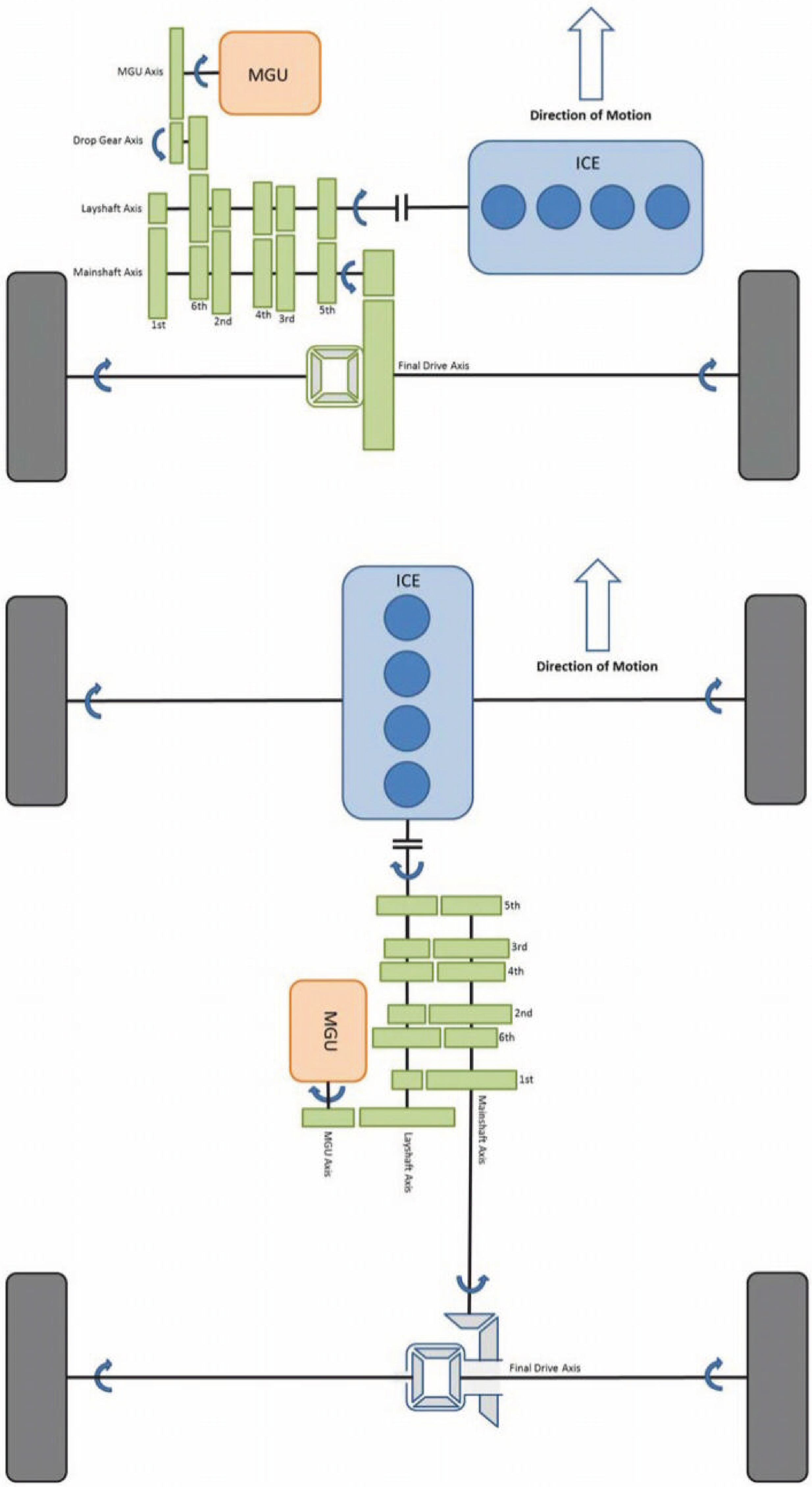
'We are effectively the umbrella organisation for the entire hybrid package,' explains Rob Kirk, head of Motorsport at Cosworth electronics. 'We are accountable for the delivery, performance and reliability of the hybrid system to TOCA and the teams. We hold regular meetings with our technical partners and we work together to try and achieve the performance targets for a commercially viable price. Also, from a packaging perspective it's important to us that there isn't a cost burden to the teams and we have been working closely with Xtrac to minimise the changes required for the teams.'

The technical partners include Delta Motorsport, which is supplying the batteries, Xtrac, which is in charge of integrating the motor into the transmission, and PWR, which will provide the cooling. These companies, along with Cosworth and TOCA, hold regular technical working groups with the sole aim of hybridising BTCC at a reasonable cost for the teams. With grids 30 cars strong comprising a mixture of factory-backed and independent teams, cost is crucial, and this has underpinned the entire design philosophy of the project.

'When I first thought about going hybrid I set a challenge to our technical department,' Gow says. 'I wanted it to cost £20,000 [per car per year] because that's the figure I think is doable for the teams, up and down the grid. I also wanted it to deliver around 100bhp and weigh the same as last year's maximum success ballast. Those were the three parameters I came up with and I said to our technical department, if you can complete that triangle of cost, horsepower and weight, then we will go hybrid.'

Integration challenge

The key to achieving the cost target was to integrate the entire hybrid system into the current spec of NGTC car, without altering the RML subframe. 'This was a huge engineering challenge. A clean sheet of paper would have been much easier and less time consuming,' says Peter Riches, BTCC technical director. 'We didn't want to alter the RML parts and frame, so Xtrac did an excellent job and managed to integrate the motor into both the front-wheel drive and rear-wheel drive gearboxes within the ↳



Integrating the motor into the transmission while meeting all the requirements of TOCA was a tough challenge for gearbox provider Xtrac. The optimum solution for both front-wheel drive (top) and rear-wheel drive (bottom) configurations was a P2 off-axis hybrid system, where the motor is positioned after the clutch and on the layshaft axis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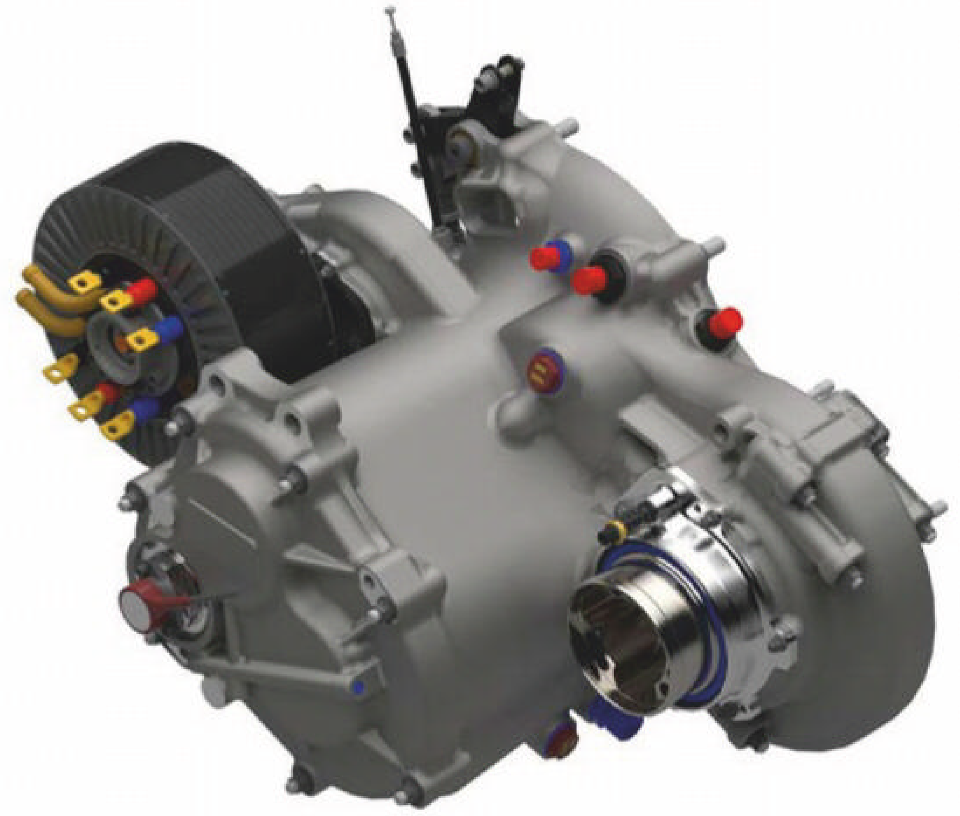
'The biggest challenge was integrating the same motor into both the FWD and RWD transmissions whilst equalising performance'



The Xtrac 2022 transmission concept with the integrated motor. Only seven new components are required, the rest will be carried over from the current BTCC transmission

current frame. We also wanted to leave as many standard items as possible, so we didn't want to have to redevelop the tyres or the suspension, that's why the weight of the system was defined as the same as last year's maximum ballast.'

Boxing clever

Cosworth selected its preferred motor and then provided the specification to Xtrac, which then had the very tricky task of integrating the motor into both the current front-wheel and rear-wheel drive gearbox concepts. 'The biggest challenge was integrating the same motor into both the front-wheel drive and rear-wheel drive transmissions whilst equalising performance,' explains Tom Cooper from Xtrac, the brains behind the hybrid transmission package. 'TOCA and Cosworth wanted to avoid having two different motor installations that would require additional performance balancing.

'Another constraint was the cost,' Cooper adds. 'My aim was to try and carry over as many components as possible, especially as the current gearboxes have been raced in BTCC for many years and so the teams have built up a really good inventory. Space was another constraint, particularly for the front-wheel drive vehicles. This was always going to be a big issue when designing a system into an already tight chassis. As many will know, RML designs and manufactures the front and rear subframes for the cars so I had to understand the limits of this current design. At an early stage RML informed me the current front-wheel drive subframe was already at its maximum width which made it more difficult to package any new components. So overall the front-wheel drive installation was more challenging and, therefore, mostly defined the concept, because the rear-wheel drive vehicles had more available space.'

With so many factors to consider, the positioning of the motor was a difficult task and one that required several iterations. With this in mind, Xtrac began working on the initial schemes before Cosworth had selected the motor and the first task was to decide on the drive axis and motor position.

Electric avenue

Another factor that dictated the motor position was the requirement for the cars to run on EV power only. 'When will the fans actually see the use of hybrid power in a race?,' Gow says. 'Okay, they may see some drivers pass each other out on track but other than that the only place you can demonstrate the fact that we have hybridisation in our cars is out of the pit lane. So at the start of every session the cars will drive out of the garage and down the end of the pit lane under full electric power and once they get to the circuit then they will engage their IC engines. It will be a great demonstration to everyone that we are in the hybrid era.'

The cars will only go down the pit lane under full EV power at the start of the session, any other time spent in the pit lane during qualifying or a race will be under IC power. This avoids teams having to switch their engines off during a tyre stop, for example, which could lead to the turbocharger overheating.

'One of the things that TOCA asked for at the beginning of the project was if the cars can run electric-only mode during pit lane activity,' Cooper says. 'The most efficient way to do this is to position the motor after the clutch so you can achieve a full disconnect between the engine and gearbox. When the clutch is depressed the engine can be switched off and the motor drive can still run through the transmission and out to the wheels. Whereas if you position the motor to drive on the front of the engine [P0, see below], the motor would need to transfer drive through the engine crankshaft and therefore turn over the engine. This would ultimately result in wasted energy which is why the best solution for electric-only mode is to position the motor post clutch or P2/P3 position. The RML subframe could also not accommodate a P0 and P1 motor drive unit in the front-wheel drive BTCC cars, which helped us make our decision.'

For reference, in the automotive world, motor position can be defined as P0 (on the front of the engine), P1 (after the engine but pre-clutch), P2 (after the clutch and along the transmission input axis) and P3 (after the clutch and along the transmission output axis).

Restricted axis

Cooper continues: 'If a motor is driving onto the layshaft axis it gives different performance characteristics than driving onto the mainshaft axis or the final drive axis, so we had to decide what axis the electric motor would drive on. If the motor is positioned to drive onto the final drive axis [gearbox output] the motor torque output would need to be much higher when compared to a motor driving onto the layshaft axis [gearbox input]. The motor diameter would be much larger if driven onto the final drive, which is fine on a rear-wheel drive car with the differential at the rear, but extremely difficult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The hybrid cars will leave the pits under electric power, so the motor has to be positioned after the clutch to allow a full disconnect between engine and transmission

to package onto the front-wheel drive. So, the options were between the mainshaft axis and the layshaft axis. Both have their benefits, but the main advantage from using the layshaft axis is the torque gain from using the gear cluster ratios to transmit drive onto the mainshaft axis. This also means that when you change gear you are constantly optimising the motor torque range through every ratio. That's the reasoning behind why we went for the layshaft axis.

'Once the drive axis was defined, we investigated multiple drop gear arrangements for both front-wheel drive and rear-wheel drive,' Cooper adds. 'To keep commonality between both car layouts, both designs needed to use the same ratio drop to remove any performance differences. Any gear on the layshaft axis can be used to transmit drive into the gearbox, and the early concepts utilised the layshaft sixth gear due to the position of this gear on the cluster. However, this had its downfalls; sixth gear had homologated multiple options for all circuits which meant if you changed sixth gear to a longer or shorter ratio you would also need to change the drop gears. Although this was a neat package for both front-wheel and rear-wheel drive, the installation was quite costly. The motor that Cosworth specified was relatively short in length, allowing us to change the arrangement and utilise the reverse layshaft gear. When the car is not in reverse this gear is used to transfer motor drive onto the layshaft and when the car is in reverse it operates as normal. Essentially, TOCA's brief, together with balancing the front-wheel drive and the rear-wheel drive, meant that the optimal position for the motor was post clutch and driving onto reverse gear on the layshaft axis.'

Seven up

Overall, Xtrac has carefully designed the transmission upgrade package to not only meet all the requirements from TOCA, but also minimise the cost for the BTCC teams. The result is an upgrade which will only require seven new components, the rest are carried over from the current transmission. Although some of these seven components are relatively large, such as the maincase which is expensive, with around three hundred components making up a transmission, carrying over just seven new bits is still pretty impressive.

In addition to a slightly different gearbox shape, the other required changes are to include replacing the current ballast box with the battery, some new intercoolers and all of the associated piping for these, while there will also be an upgrade to the electronics.

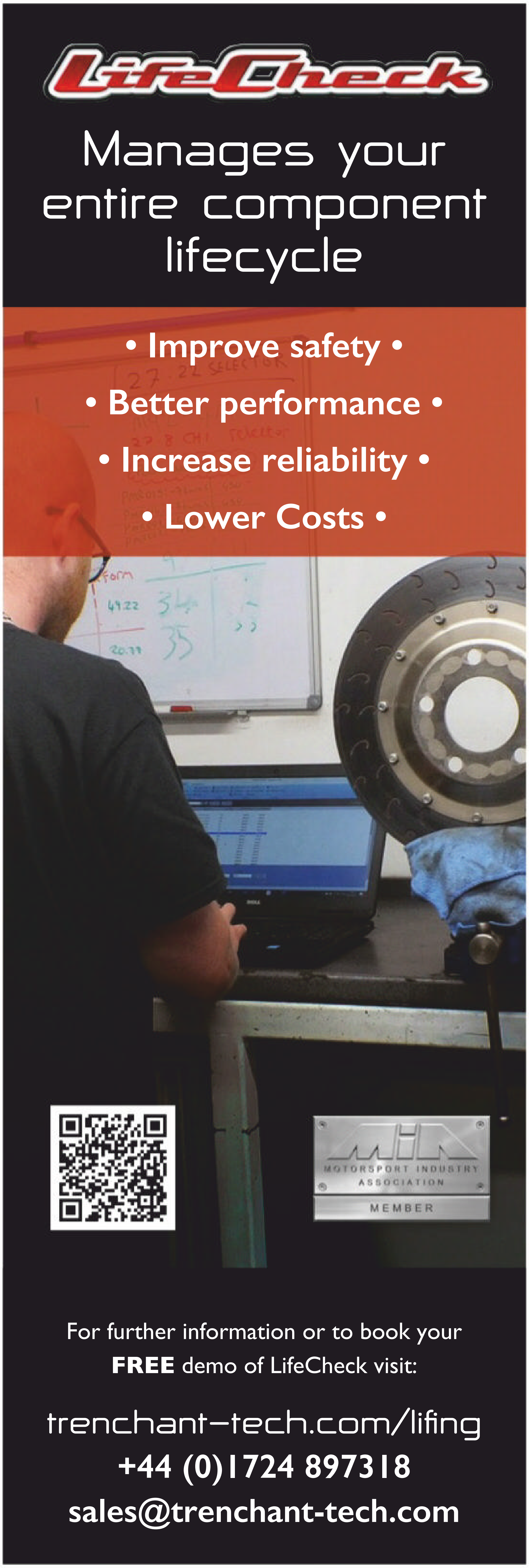
'The teams will lease the motor and the battery as part of the whole hybrid package which will come with the intercoolers and other components,' Riches says. 'But if they damage an intercooler, for example, then they'll have to purchase a new one. The Cosworth electronics package will also have to be upgraded to the third series, but it was always in the contract that series one of the electronics would be obsolete at the end of 2021, which means it would have been in these cars for 11 years.'

Looming large

This third generation of electronics has been designed to be upgradable, so that the BTCC teams who are already running the more advanced electronics will not have to purchase an entirely new system.

'Commercially, for the series it was very important that we help the BTCC teams to manage the costs of any changes, so there is the option to equip the racecar with a completely new set of electronics, or there is the ability for those with existing componentry to carry some of those components over,' Kirk says. 'The main change for the third generation of electronics is an upgrade to the engine controller. This will essentially become the vehicle controller which will require a new ↳

'Teams will lease the motor and the battery as part of the whole hybrid package, which comes with the intercoolers and other components'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‘It brings it back to the pit wall, because we are going to have to monitor how the drivers are making use of the hybrid boost during a race’

chassis harness. So we’re moving to a single box solution and our latest ECU.’

Despite the efforts of TOCA, Cosworth and the technical partners, there is still uncertainty within the BTCC teams. Those with smaller budgets are very concerned about the cost and the implications of converting to hybrid, especially those who run several cars. The other worry is the potential advantages and disadvantages a hybrid powertrain could bring to a front-wheel drive car *vs* a rear-wheel drive car, and how TOCA plan to balance this.

‘I think they’ve chosen the best option for going into the gearbox as it means we have the same drive wheels as each other [Front *vs* rear-wheel drive],’ says Steve Dudman, team principal at BTC Norlin, one of the younger yet successful independent BTCC teams. ‘The regen for a front-wheel drive car and a rear-wheel drive car is very different. We see some championships having problems with rear-wheel drive regen because the rears can lock during downshifts, especially if the cars are regenning mid-corner. So if the regen provides any form of braking effect then it could affect the amount of locking at the rear. Whereas front-drive cars will always gain an advantage, because all the weight is at the front so there is more load going through the wheels which minimises locking and then the power from the regen can be put directly into the fronts. It’s all theory at the moment, though.’

Equality drive

Equalising the front- and rear-drive performance is a topic of debate throughout the pit lane already, long before the addition of a hybrid system. However, TOCA is confident that it will be able to balance the performance. The different weight distribution of the FWD hybrid package *vs* the RWD package can be minimised with additional weight, while the ability to regen at either the front or rear wheels can be equalised via software. The amount of freedom teams will have to tune the regen, along with the finer details of how much and when the hybrid boost is available, will all be determined in the coming years. But one thing is for sure, it adds a whole new element to the BTCC.

‘It brings it back to the pit wall because we are going to have to monitor how the drivers are using the hybrid boost,’ Dudman says. ‘Especially in race situations, the racing is so close, it’s not like they will have a lap to think about the best deployment strategy. Also, if the driver wants to overtake three cars on one lap then somehow they are going to have to be aware of how many times they have used the boost button, so we will need a way of counting that on the pit wall to try and help the driver with their strategy. Balance of performance will be key, but then TOCA are usually very good with that.’

‘It’s going to be two years of challenges, but we need to get it up and running and start testing,’ Riches says. ‘It will put some more engineering back into the BTCC and it will be interesting to see how the teams up and down the pit lane cope with this new challenge.’

BTCC recharge

The first track tests will likely take place next summer, although the components will have already undergone rigorous simulation and dyno testing before then. Some of the upgraded parts, such as the transmission and the electronics, will be available next season, with the idea that if a team wants to build a new car they can then incorporate some of the components, which can then be easily upgraded to full hybrid spec in 2022.

‘It’s a good thing to tie in to what people are currently driving on the road today,’ Dudman says. ‘If people are driving into the car parks on electric power then maybe we should be driving on to the circuit on electric power. If you open up the bonnet, most people won’t understand what’s inside, but from the outside it looks like the car they drive to the shops in. It brings it back to people relating their road car to the racecars, which is what touring car racing has always been about.’

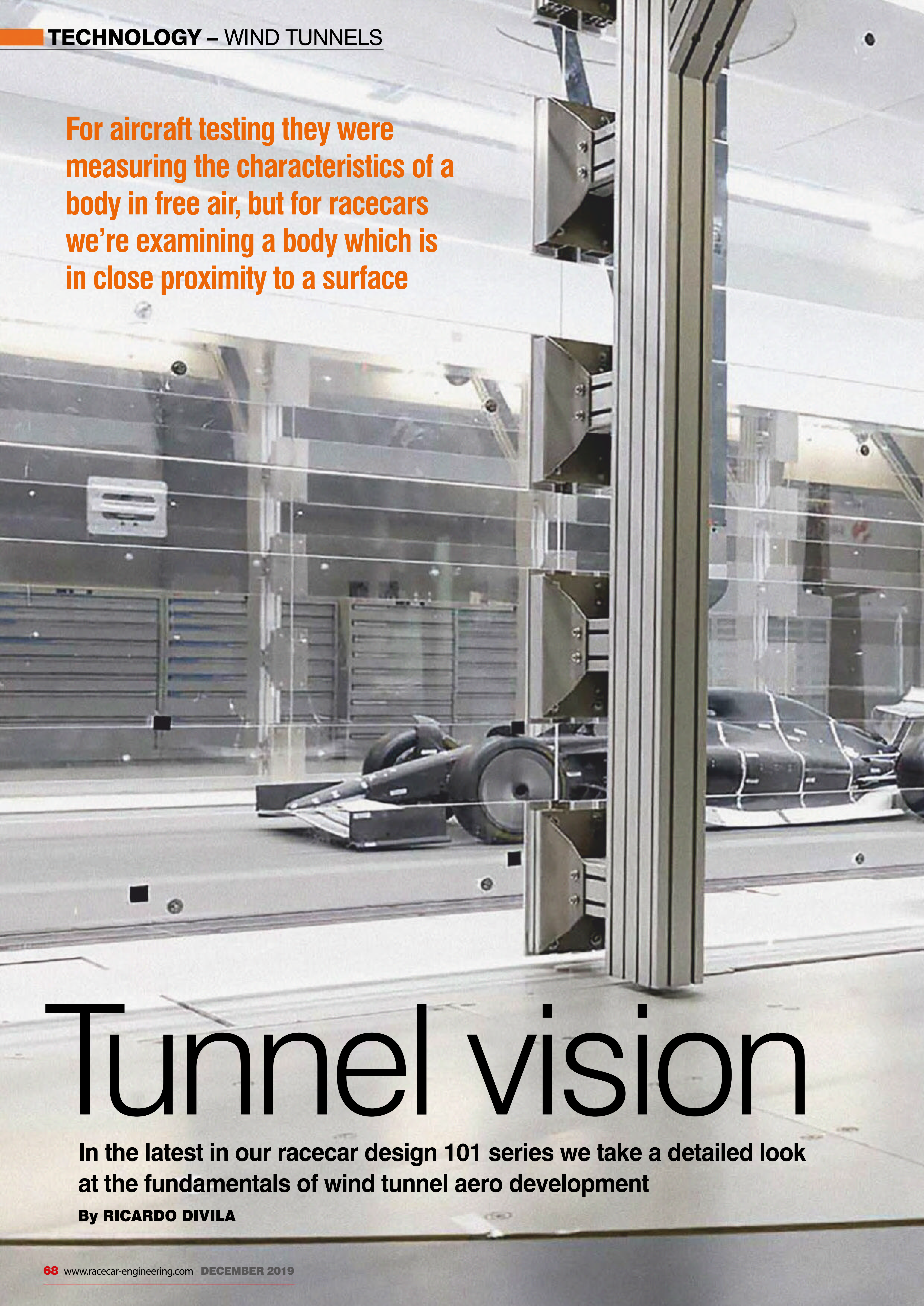
Technical overview: Cosworth BTCC 2022 hybrid system

P2 off-axis hybrid system:
- 60v high power – low volt system.
- Electric motor integrates within modified current BTCC Xtrac gearbox.
- Separate custom hybrid motor cooling unit.
- Utilising the best power-to-weight hybrid motor currently available.
- Compact size and weight: 7.5kg.
- Little disruption to current NGTC specification.
- Calibrated and driver-adjustable regeneration.

Bespoke Delta Motorsport 60v battery pack:
- Battery weight: 20 kg – housed within IP67 rated isolated composite safety cell.
- Incorporated battery coolant system.
- Quick release connectors.
- Easy removal and replacement – less than 10 minutes.
- Charging via 240v wall socket – one-hour full charge time.
- Replaces current ballast box.

Modifications required to current car:
- Updated gearbox case (not all internals) to incorporate electric motor.
- Additional electronic connections.
- Changes to some intercooler locations and pipes.
- Upgraded Cosworth ‘Antares’ electronics suite.
- Total fully installed system weight approximately 64kg – including electric motor, battery, controllers, looms, pumps, pipes, cables, fluids etc.

The BTCC races into its new era in 2022, but some of the upgraded components for the hybrid car will be available in 2020



For aircraft testing they were measuring the characteristics of a body in free air, but for racecars we're examining a body which is in close proximity to a surface

Tunnel vision

In the latest in our racecar design 101 series we take a detailed look at the fundamentals of wind tunnel aero development

By RICARDO DIVILA

A model of a Formula 1 car with the proposed 2021 aerodynamic package in the wind tunnel

It won't come as a surprise to most to hear that wind tunnels were initially developed for developing aircraft. But when road car speeds increased, this naturally brought the use of these same tunnels into the automotive world. Either full-scale or model aeronautic facilities were then used for decades, but the proximity to the ground caused some problems peculiar to cars. We will discuss this later, but first let us examine the wind tunnel itself.

Wind tunnels fall into two fundamental types, open and closed. The open or Eiffel type – made by Gustave Eiffel, of Parisian tower fame – certainly have their advantages. For a start, they are cheaper to build, while the pollutants – smoke, flow viz paints or fumes if an engine is running – are easily purged. On the other hand, there are also disadvantages: for instance, the size of the tunnel must be compatible to the size of the room it is housed in, as the room is the return path for the air. They tend to be noisy, and more expensive to run than closed tunnels.

The closed, or Gottingen, type of tunnel is where the air runs in a closed loop. The advantages are that they are cheaper to run and the quality of the flow can be easily controlled, while they are less noisy than the open type. On the other hand, they are more expensive to build, while the continuous losses of energy in the tunnel heats up the air, so the air may need cooling, especially in summer. Also, as the air recirculates, pollutants are not easy to purge.

Wind scale

These basic types can be of varying dimensions, depending on the type of work required, but we can use a scaled down model of whatever we are testing, again because of developments in the aeronautics world, though this will mean issues with scaling (see box out). Incidentally, talking of scale, some tunnels, like the Nasa Langley facility, can house a Boeing 737.

The speed of the tunnel can also vary, they can be transonic, supersonic or hypersonic. For racing cars, we will limit ourselves to low speed tunnels (relatively). They can also be low turbulence or high Reynolds number, or pressurised – for example, the Benetton experiment, which attempted to solve the scaling problems by running at high pressure. Another method to circumvent the scaling problem is to run in other fluids. I have had an interesting time with car models in a water tunnel, illuminating to say the least, and using dyes in the water is a very good way to see the flow around the car. Tricky work, though.

For aircraft testing we are measuring the aero characteristics of a body in free air, but for ground vehicles we are examining a body which is in close proximity to a surface; this brings in a series of additional problems in measurement, as the test section flow will have boundary layer problems as it builds up across the test section, with the interaction of tunnel floor and model. So, for automobile tunnels we now have the moving floor, a relatively recent development.

The dimensions of a wind tunnel will depend on several factors: the cost and space considerations, which speed range is required, what application area (for example aerospace, automotive, environmental flows and so forth), and required Reynolds number and Mach number. But whether open or closed, the tunnel will have several distinct sections (as can be seen on the image at the foot of this page).

Test section

The test or working section of the tunnel can have many cross-sectional geometries: rectangular, square, round, hexagonal, elliptical, or octagonal. This directly affects the tunnel building cost and the power required to run it, but shape itself does not affect the aerodynamic losses in the tunnel. The most usual cross-sectional shapes are rectangular or octagonal. An octagonal shape minimises the secondary flow problems you can have in the corners of a rectangular or square section.

The test section is not completely straight. This is because as the boundary layer grows in the test section, which will reduce its effective area increasing the velocity and decreasing the static pressure, most test sections will feature a small geometric increase of their cross-sectional area to overcome this. Usually the angle of the walls open in all directions by 0.5 degrees, maintaining speed and pressure.

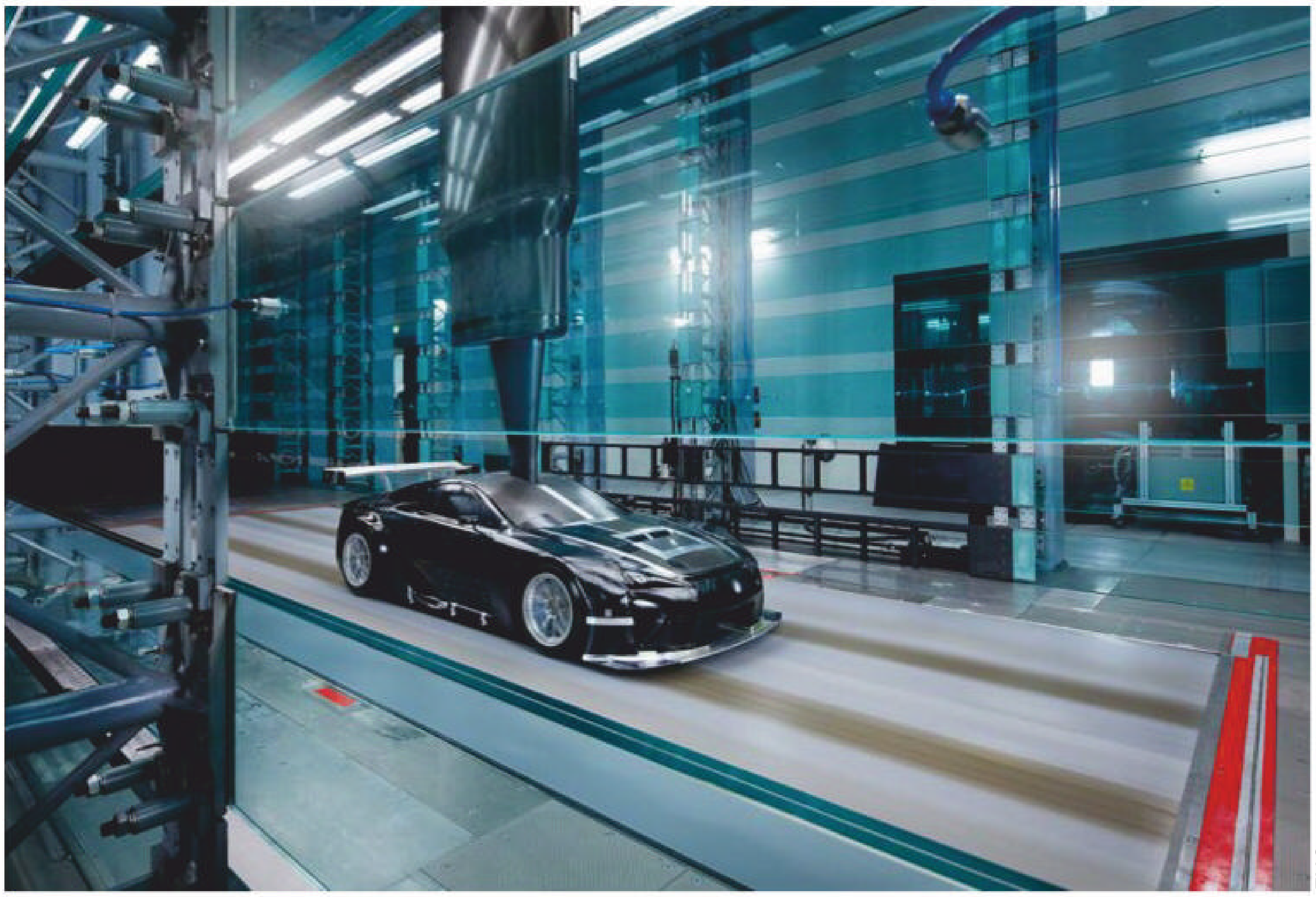
Test section length is usually one or two times the size of the major dimension of the cross section. For example, a 4m x 3m cross section would be 4m to 8m in length. It should be kept as short as possible, as there can be significant losses otherwise.

Although you depend mostly on the data from the scales it helps to have windows in the test section to watch the model and to be able to film smoke plumes from the control room. Also, you need good lighting, for the same reason. You will use many instruments apart from the scales, so passages into the test section for additional equipment should be available.

In the test section you can have either external scales or internal (in model), the moving belt and the pressure probes, particle image velocimetry and flow rakes. Beside the test section you will, of course, have the control room, with the various fan, belt, suction system controls and the logging instrumentation.

The top scales can be incorporated into the strut, while the strut itself will have a variety of different heave and pitch actuators, which will give you the capability to have a full attitude sweep continuously, without stopping the wind, which will save both time and energy.

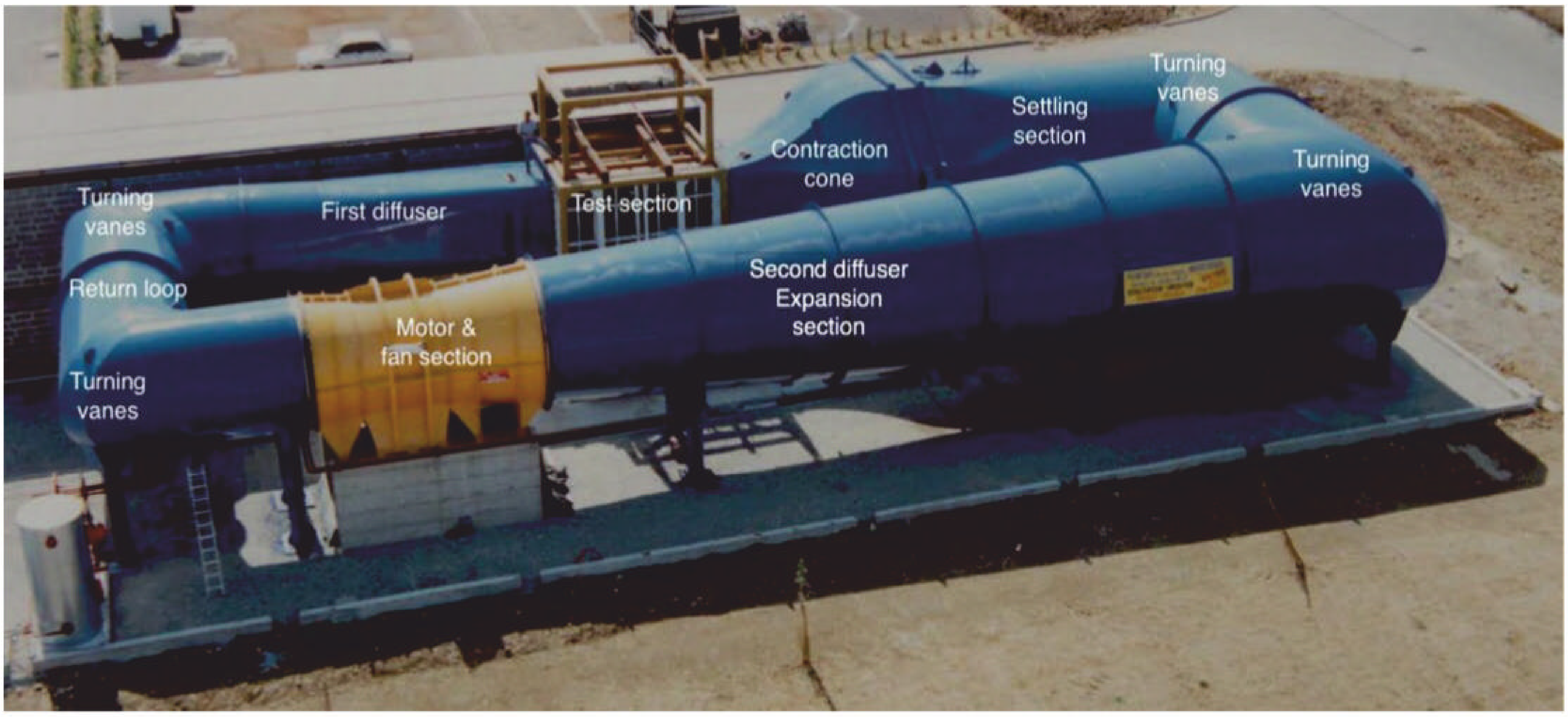
Downwind from the test section you have the diffuser. A wind tunnel could have the same ↳



TMG

TMG has two tunnels, one of which is full-scale. Both feature a continuous steel belt rolling road to provide a moving ground

An octagonal shape minimises the secondary flow problems you can have in the corners of a rectangular or square section



High-level tunnels will feature several distinct areas that join together to form a loop, so the air can be recirculated. Corners are needed and these will very often be 90-degree turns

cross-sectional area throughout, but power losses are a function of the cube of airspeed. Reducing the airspeed in the sections of the tunnel that are not used for measuring data lowers the cost of building and running it. Increasing the section reduces the speed.

But as the diffuser decreases airspeed, it increases static pressure, causing an adverse pressure gradient that can cause separation at the wall. Separated flow can cause vibrations, increased losses or oscillating airspeed in the test section (known as surging) and oscillating fan loading. Therefore the area increase of the two diffusers is usually a total maximum factor of five or six, to avoid separation.

Corner losses

Recirculating tunnels have corners to bring air around, mostly 90-degress bends connected by short constant area ducts – 180-degree bends have also been used. To avoid big losses the corners are equipped with turning vanes, either highly cambered plates or highly cambered aerofoils. The turning vanes can be adjustable to ensure good quality flow.

Corner loss coefficient can be ascertained. If there is no change in section area around the corner, the airspeed will be constant. Losses in the corner are due to the drag from skin friction and separation drag, which cause a drastic drop in static pressure, Δp. The corner loss coefficient is defined as:

$$\eta = \frac{\Delta p}{1/2\rho V^2} = \frac{\Delta p}{q}$$

A corner without vanes can have $\eta = 1$ but a corner which has well designed vanes may arrive at a value of $\eta = 0.1$.

The object of vanes is to apply a force on the flow perpendicular to the free stream, so the flow exerts a lift force on the vanes which in turn exert an equal and opposite force on the flow, perpendicular to it.

Fan boost

But to get a flow we first need a fan. The fan operates in a constant area duct; due to continuity. The airspeed is constant across the fan, so the fan does not accelerate the flow. It creates a difference in static pressure across its two sides. The static pressure difference is high in order to set the flow in motion, and can also be equal to the losses in static pressure in the tunnel in order to keep the flow speed constant.

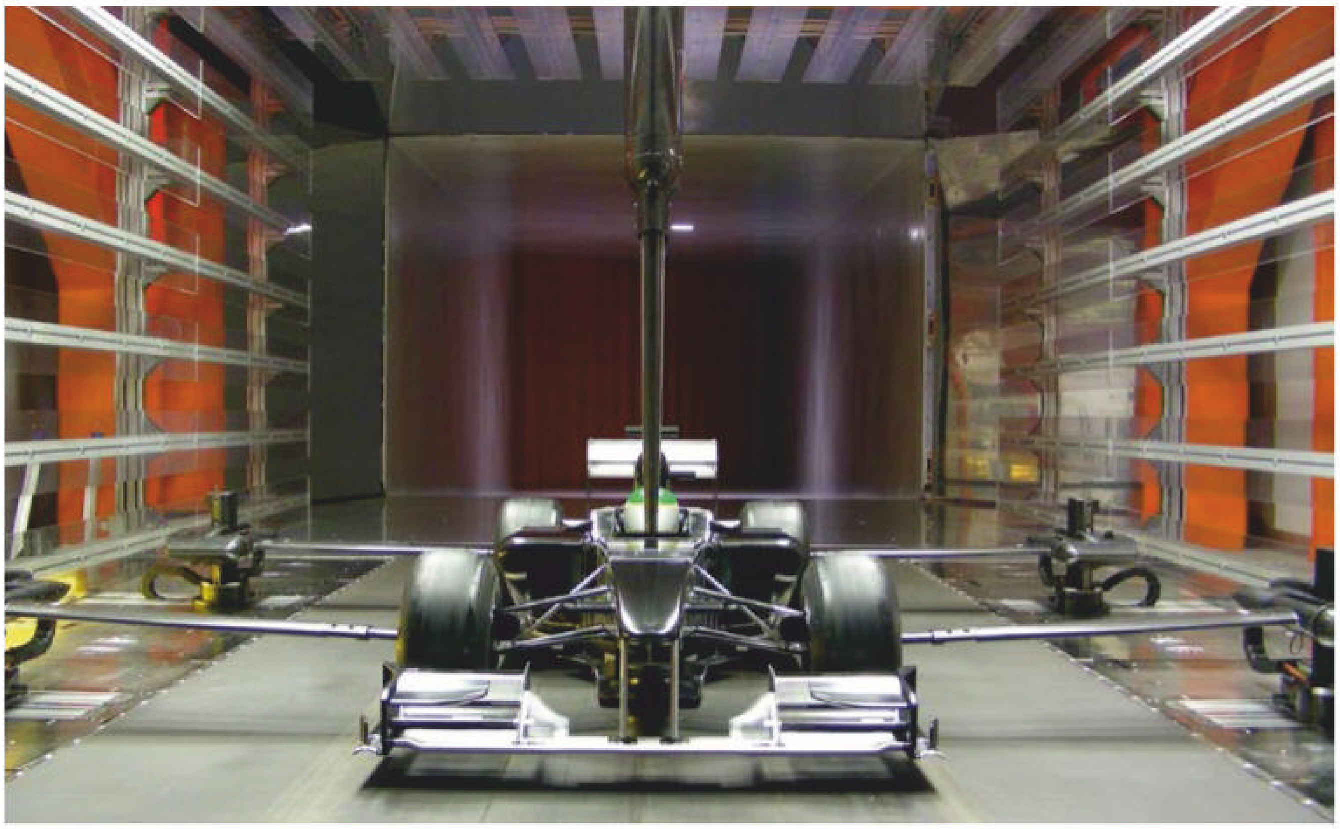
Fans will develop their highest efficiency when in a relatively high-speed flow, therefore they are not positioned in the section of the tunnel with the largest area. It is also good practice to not position them in the first diffuser because of the possibility of broken parts from models or loose tools damaging them, so they are usually placed after the second corner, before the second diffuser.

Fans or propellers produce a swirling flow. This disturbs the airflow, affecting the measures, which are best with a uniform constant flow. But three flow-straightening methods can be used. First, straightener vanes downstream of the fan. Second,upstream pre-rotating vanes rotating the flow in a direction opposite to that of the fan. Third, counter-rotating fans.

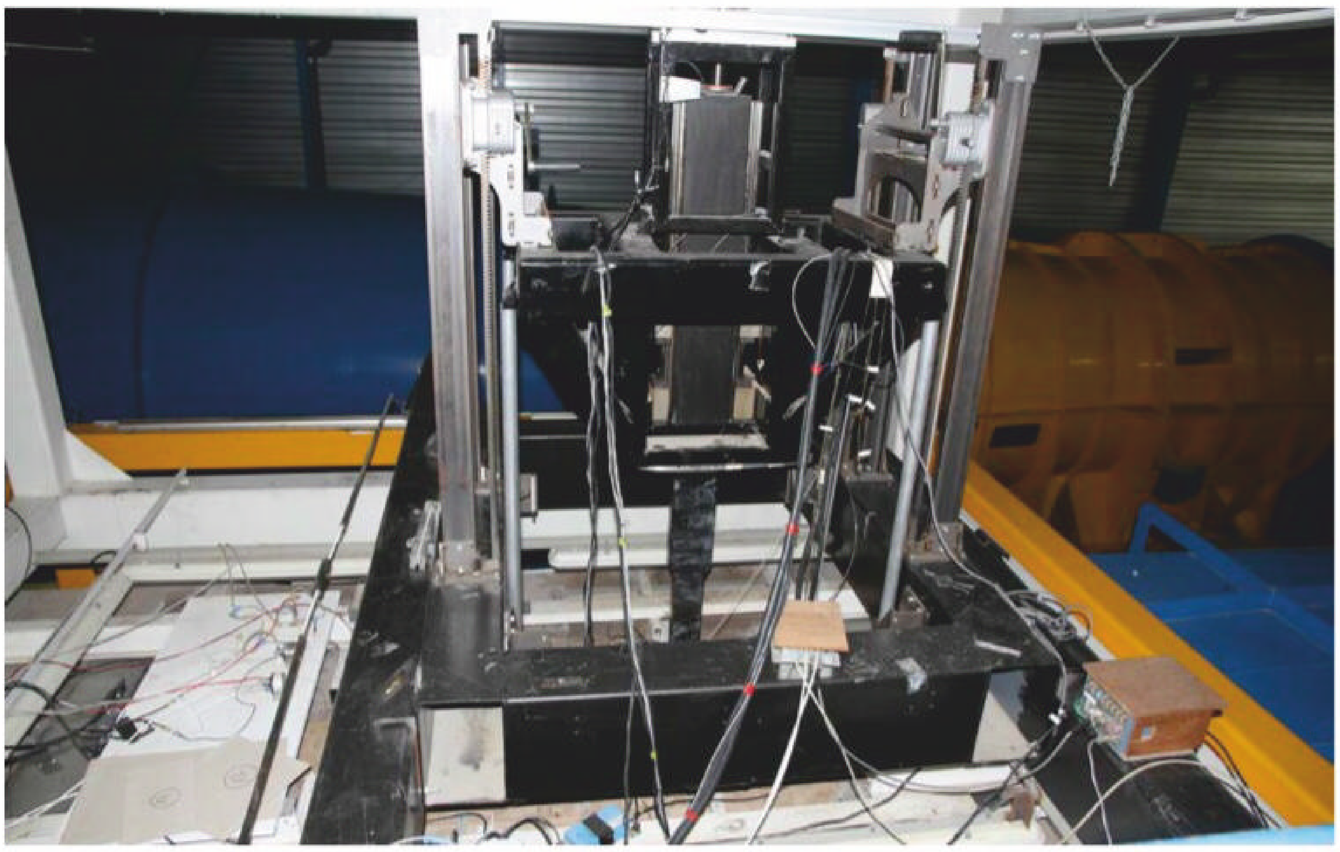
The fan motor is usually mounted inside a nacelle and it will usually require a cooling system, for the motor unit. This nacelle has a length to diameter ratio of about three. For 30 to 40 per cent of its length the nacelle maintains a constant diameter, then it has a closing cone angle of around five degrees.

Contraction cone

The contraction cone is after the diffuser, and sometimes the settling chamber, and its object is to accelerate the flow from the low power-loss speed to test section speed. This is a critical point in tunnel design, as there are adverse pressure gradients in the entrance and exit of the contraction cone which can cause boundary layer separation and secondary flow in the corners of rectangular cross-section cones, disturbing the test section flow, which needs to be as uniform and as constant as possible.



There are a variety of means for fixing a model in place. The control room should have a window, for viewing the test section



The top scales (above) will often be incorporated into the strut. Data from this is backed up with observations from the test

As the diffuser decreases airspeed it increases static pressure, causing an adverse pressure gradient that can cause separation at the wall

As the air characteristics are dependent on temperature and pressure, maintaining a constant environment is essential for accurate data

The secondary flow problem is solved by making the contraction cone octagonal and the adverse pressure gradient problem is solved by careful design of the geometry. Ironically, with the use of CFD the design can be optimised leading to contraction ratios of eight with very small losses and flow disturbance.

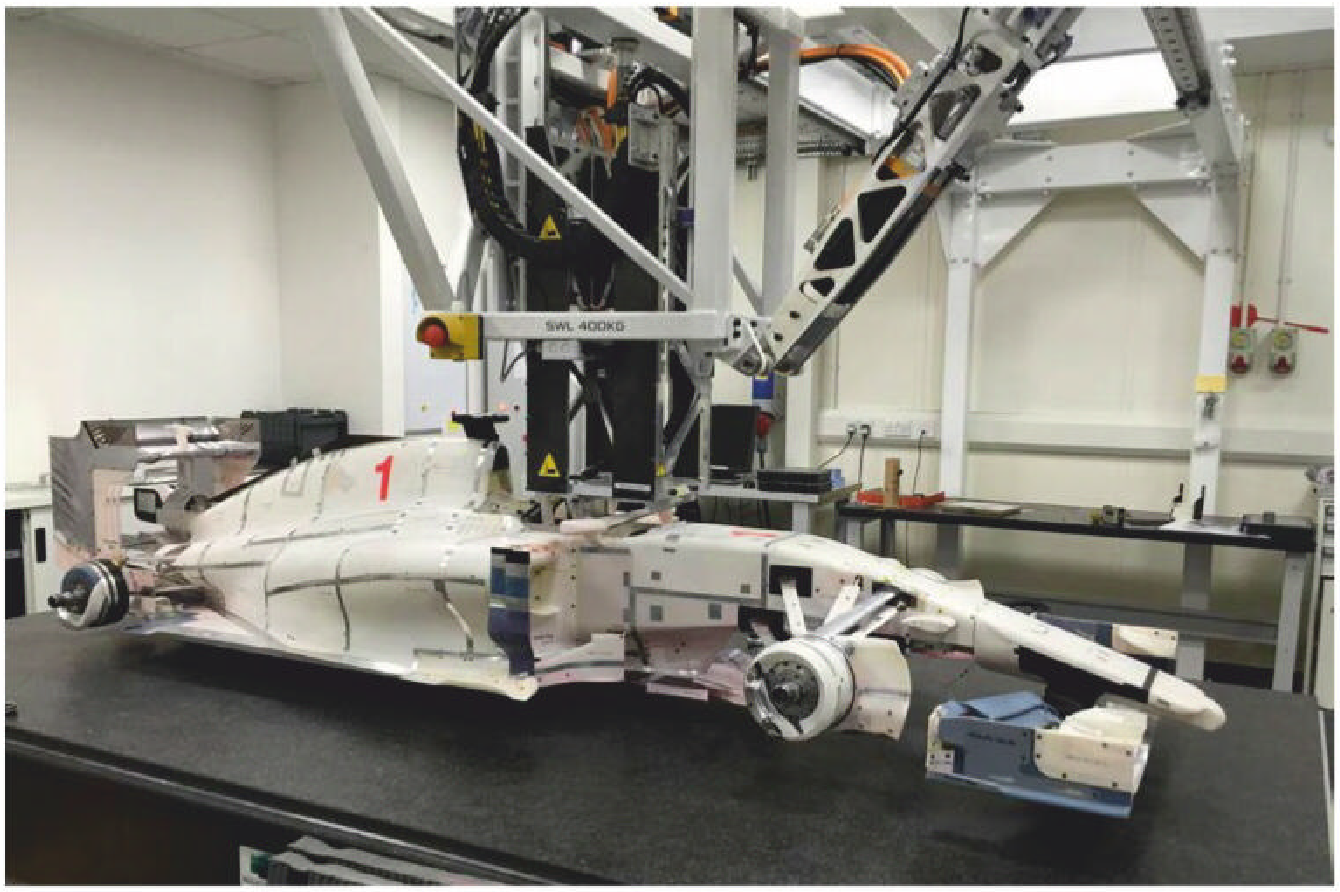
Handling heat

When the tunnel is in operation energy is lost from the flow in the form of heat and is constantly replaced by the fan, and as the test is being run the temperature of the flow increases until the heat gain is balanced by heat loss to the environment, but the equilibrium temperature can be too high for the required experiments. As the fluid (air) characteristics are dependent on temperature and pressure, maintaining a constant environment is essential for accurate and repeatable data acquisition. On some tunnels I have used sometimes you had to have short runs in hot ambient weather to avoid having a creeping change in measured values.

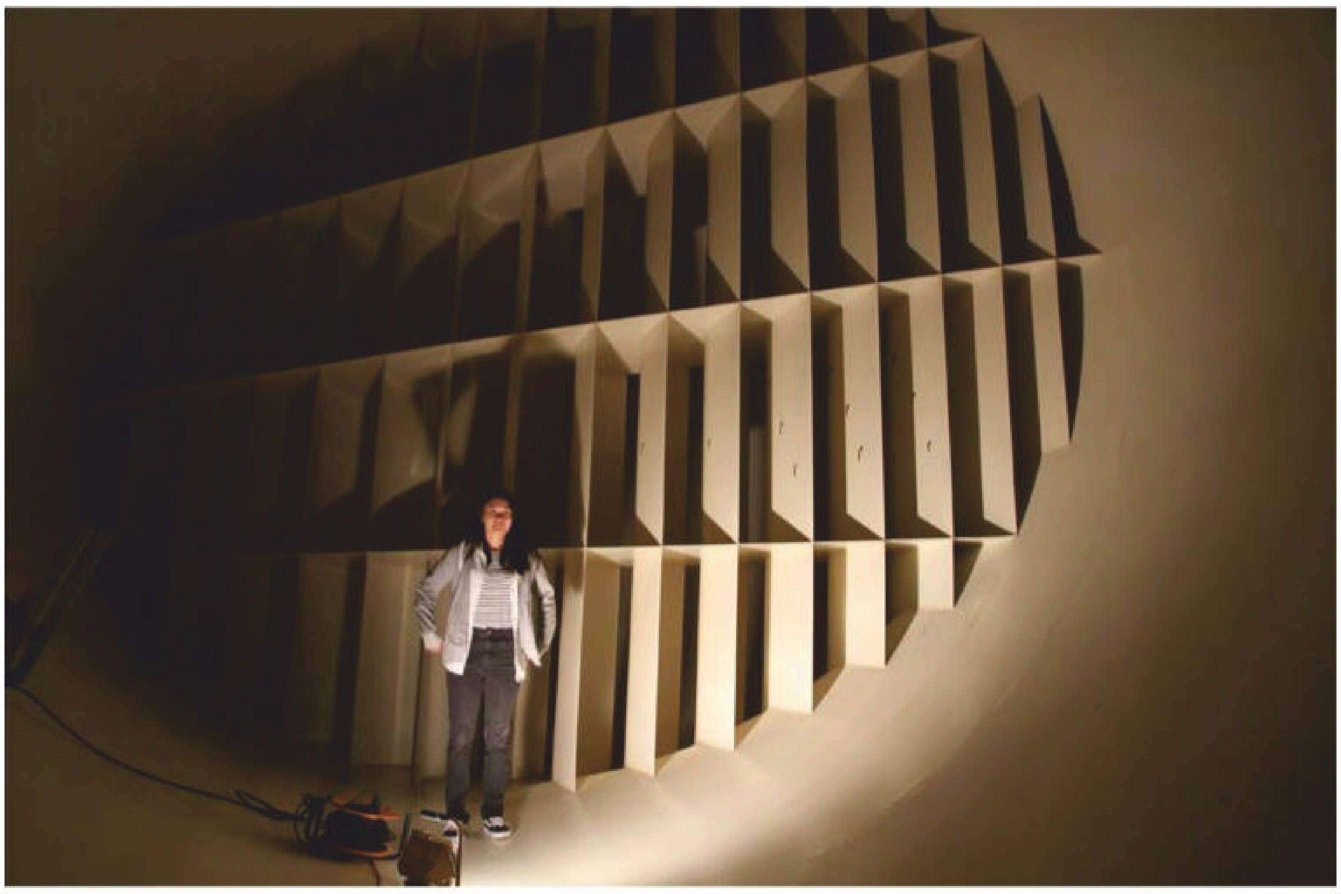
Logging the temperature can help in correcting the values recorded to a normalised value, but it's a time consuming method, adding to workload and being subject to errors, while pausing to allow cooling eats into the always scarce wind-on running time.

One tunnel I regularly used was well cooled with good air-conditioning in the control room, but the tunnel cooling system was overwhelmed in summer, leading to the surreal situation of having to open the test section door to cool down the mass of air by using the conditioned air from the control room.

Cooling methods used to maintain optimum conditions include using running water on the tunnel exterior, or water-cooled turning vanes, or a water-cooled radiator in the largest tunnel section. But having an air-exchanger continuously replacing the heated tunnel air with cool external air is one of the commonest systems used, and this requires no additional equipment. This tends to be most used in temperate climates, as environmental temperature stresses are smaller.



Strut with actuator and model. These days models are intricately detailed pieces, nothing like the clay items of yesteryear



To avoid big losses the tunnel corners are equipped with turning vanes, which are either highly cambered plates or aerofoils

Go with the flow

The flow quality is obviously an important aspect of a tunnel. This usually refers to the steadiness and uniformity of the flow – uniformity refers to spatial airspeed fluctuations which should not be more than 0.2-0.3 per cent of the average airspeed, and the spatial angular variations should be around 0.1deg at most.

As far as steadiness of flow is concerned, time-dependent velocity variations should be of small magnitude and of low frequency. These are the results of separated flow in the tunnel. A great deal of time is spent when commissioning the tunnel to make sure it has optimal flow.

One wind tunnel I worked on, and was also involved in the build of, had a major problem because it had too abrupt and wrongly shaped turning vanes, which caused a rhythmic shedding of turbulent air coming off them. The quick fix was to fit Gurney flaps on the end of the turning vanes while new ones with a better shape were manufactured, a major chore given the sheer size of the vanes.

One thing that can affect tunnels as much as it does racecars themselves is turbulence. This is unsteadiness at much higher frequency caused by wakes, noise, roughness etc. It is reduced by installing honeycombs and screens upstream of the contraction cone. Screens reduce axial turbulence more than lateral turbulence and honeycombs reduce lateral velocities.

Measure by measure

The above tells you how wind tunnels work, but what do they actually do? In short, a wind tunnel is an instrument to measure the forces developed by the body of the vehicle. These are, primarily, the drag, lift and distribution on the front axle and rear axle abbreviated in Cd, Cl, Clf and Clr. The coefficients are dimensionless

Wind tunnel scaling factors

The loads exerted by static air on a moving body are equal to those exerted by moving air on a static body, as long as the relative velocities between the air and the body are the same in both cases. For a truly representative wind tunnel experiment, then, the body must have its true size and the wind must have the speed that the object would have if it was moving, which is, of course, certainly the case with a full-scale tunnel.

But these conditions are not always possible. The use of the real vehicle will demand very big tunnels in some cases, so for convenience we use scaled down models for aerodynamic testing.

Several scaling laws can be used in order to render representative experiments where the size or airspeed have been scaled. Amongst these are the Reynolds number (and also Strouhal number and Mach number).

When we run a scale model of a racecar, we have to take in account the scaling factors for the values to be a valid correlation to the full-scale car. The more complex the aero geometry we have the more difficult it will be to correlate due to the critical influence of change from laminar flow to turbulent flow.

For such wind tunnels, the Reynolds number must be around 1,500,000 to 2,000,000 for the flow to be fully turbulent and thus simulate the real flow. In my early days on 25 per cent and then 30 per cent scale tunnels there were workarounds when you were running models close to the edge of your Reynolds number window, for instance by having a slightly off-scale slot, say between your wing mainplane and the flap or flaps on multi-element wings, to bring that part of the car close to the middle of range, then validating your empirical changes with measurements of downforce from the real car. But there was a lot of the suck-it-and-see 'lemon engineering' involved due to the pressure of development for better performance.

and when used with the frontal area give the forces we require to calculate our vehicle dynamics (in CdA and ClA).

Quick changes done on the configuration and parts of the model enable comparison testing and modifications to be examined, and the use of smoke wands, flow viz, pressure rakes, surface pressure plotting and tufts make it easier to visualise, analyse and understand the flow.

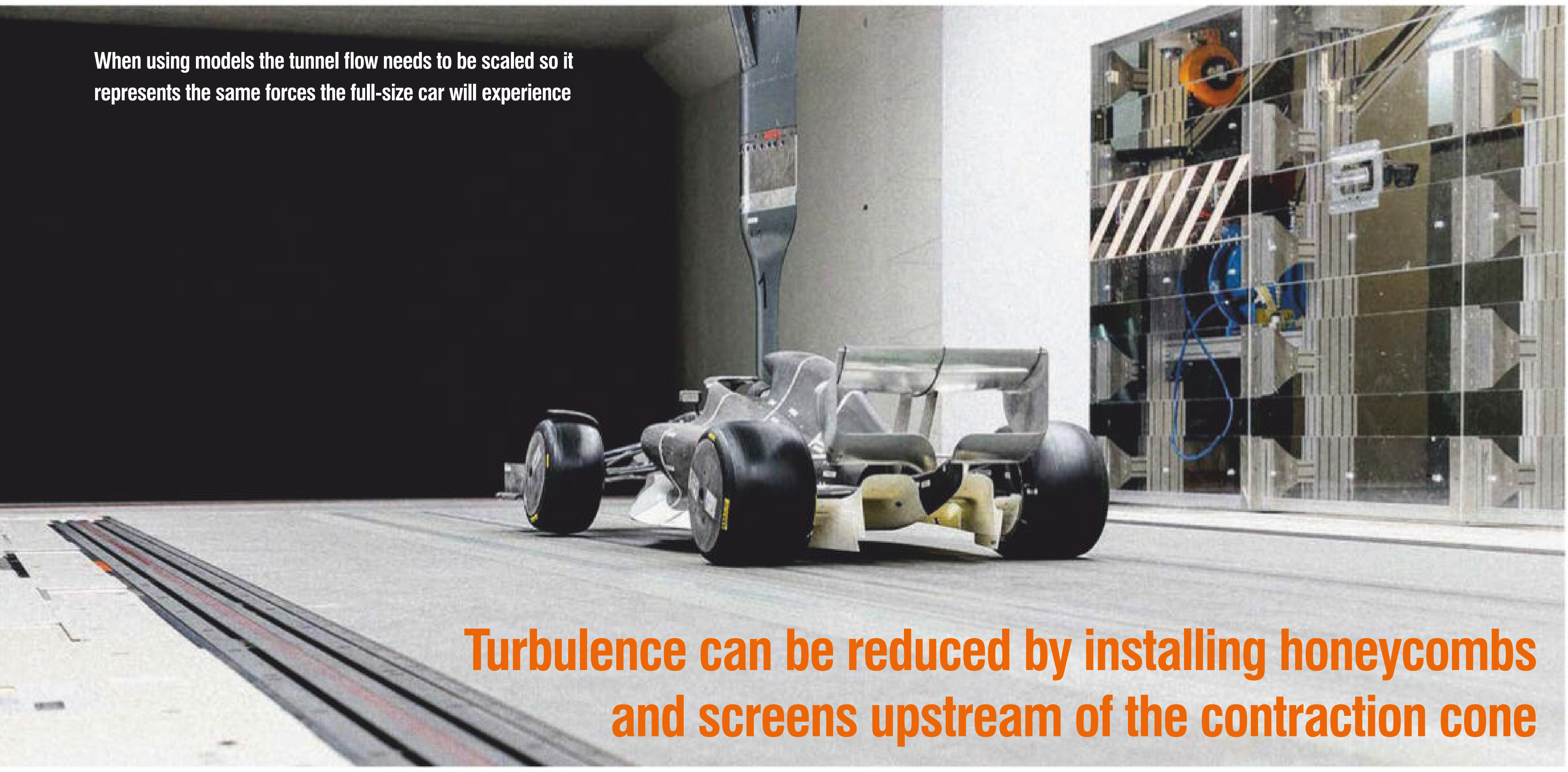
A Scanivalve (a pressure sensor with 46 or 64 channels measuring pressure outputting digital values through a cable) can also be installed in the model, likewise pressure sensors in the front and rear of radiators and ducting enable analysis of cooling systems. Also, using bespoke model tyres that deform like the real ones aid in being as close as possible to the real thing.

But to get it really close to the real thing, you need to simulate the way the car actually moves along the road; which means a moving ground wind tunnel. The first moving floor I am aware of was in the Langley 300-MPH 7x10ft tunnel, where three-eighth scale automobile models were tested with the ground-plane belt at free-stream velocity (with the boundary layer eliminated) as well as at a reduced velocity and zero velocity (with boundary layers) back in 1967. NASA had built it to examine STOL (short take off and landing) aircraft and ground effects in aircraft, for the take-off and landing phases.

Moving ground

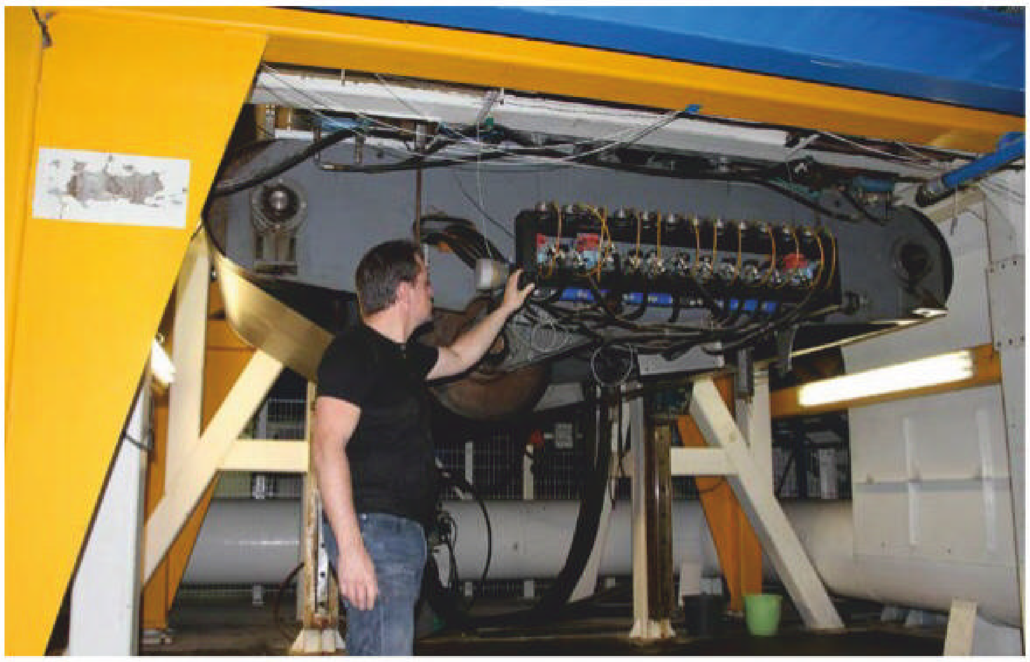
The main purpose of the NASA investigation was to determine to what extent the boundary layer on ground planes affects model automobile wind-tunnel data and whether a moving-belt ground plane was required or desirable. The three-eighth scale model was tested with the ground-plane belt moving and not moving. Most of the investigation was conducted at a free-stream velocity of 29m/sec; however, some runs were made at lower velocities to check the

The contraction cone is to accelerate the airflow from the low power-loss speed to the test section speed

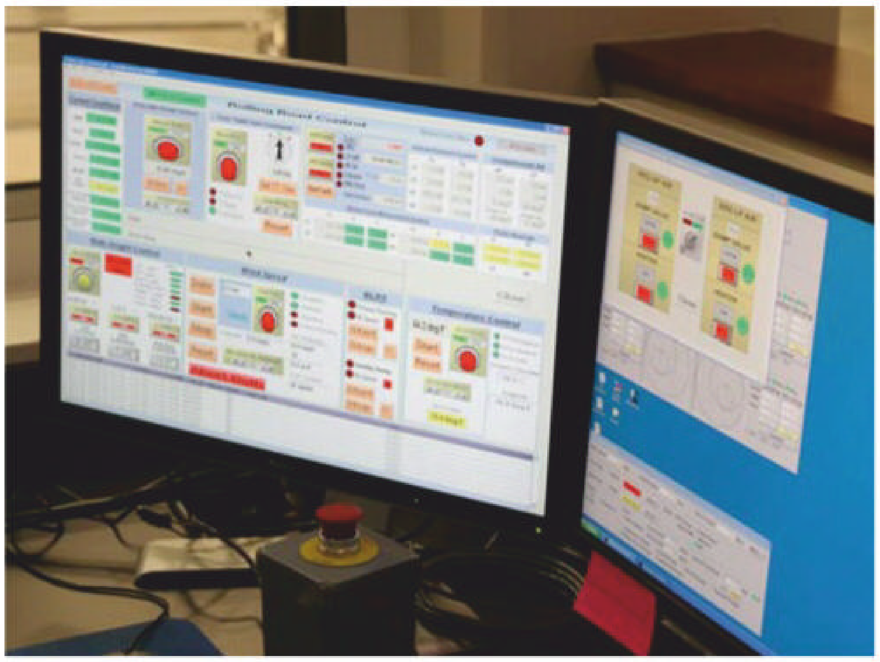


When using models the tunnel flow needs to be scaled so it represents the same forces the full-size car will experience

Turbulence can be reduced by installing honeycombs and screens upstream of the contraction cone



A moving ground belt pictured from below the test section. It took a long time to refine this tech



When things go wrong you need to hit that big red button – and hit it quickly!

effect of Reynolds number. The installation of a flush underbody was the only external variation investigated. The report is easily available on the web and I recommend it to anyone interested in understanding the effects and operation of moving grounds, as it covers the main points.

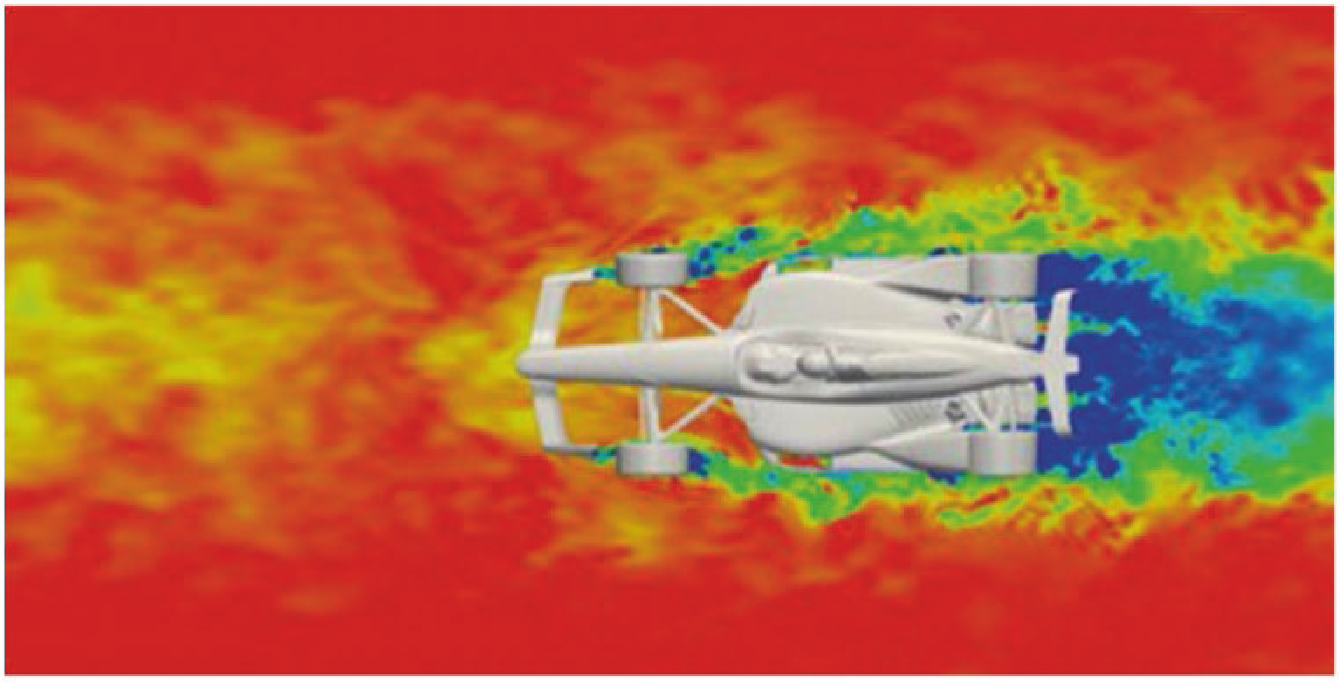
With the increasing understanding of these effects most automotive wind tunnels started incorporating moving belts and these are now commonplace. But it was a long uphill struggle to sort out the problems of suction to keep the belt from lifting, controlling and guiding the belt on the rollers, and having it move at the same speed as the air in the test section. These days an additional suction system reduces the boundary layer, with suction applied through a slot and a perforated plate just before and after the belt, which is synchronised to move at tunnel test section air speed.

As the downforce produced by the tunnels could be quite high, especially at the throat, and downforce being the pressure reduction due to Bernoulli, controlling the belt to keep it flat to the backing plate and not changing the clearance and shape under the car was critical.

One very promising racecar we had in the wind tunnel was difficult to operate on the track as the belt lifted due to the pressure, and the shape change under the car attenuated the CP (centre of pressure) migration by re-shaping itself due to the suction generated. Changing the rake and logging the CP and downforce, coupled to the model having a too thin wing shape, kept the change small, when in reality the stiffer under-shape and all too solid ground on the real car was almost uncontrollable.

Incidentally, model build and dimensioning merits is an article just for itself, not to mention aero-elasticity and strut stability, but here we are talking about tunnel fundamentals.

I was once involved in the build and development of a wind tunnel with moving ground and I can bear witness that when any factors of the belt speed, plus the software to control it, doesn't work quite right then the occasional loss of a belt wreaks havoc in the tunnel, not to mention to the model itself.



Auto Research Center LLC

While CFD capability is getting better all the time it has not quite reached the point where it can replace the wind tunnel

There are stories of the loss of an F1 car in a full-scale tunnel when one of the tethers failed

Losing a model in the tunnel when either the mounting system or attachment fails make the mesh downstream from the test section a very good investment. If you have ever lost a model, or parts of it, during testing you will not forget it, it can be quite dramatic. Not surprisingly, the big red button on the tunnel control console should be easily accessible for when you need to shut everything down quickly. This is not only restricted to cars, aircraft tunnels also have the mesh for their *oopsies*, but cars on belts introduce an added control and attachment problem. There are even stories doing the rounds of the loss of an F1 car in a full-scale tunnel when one of the tethers failed …

Virtual aero testing

Today we are at another stage of development in aerodynamic testing, and the silicon chip and programming using numerical analysis and data structures have combined to enable all the testing and development of new shapes and concepts to be done virtually using computational fluid dynamics (CFD).

Computers are used to perform the calculations required to simulate the free-stream flow of the fluid, and the interaction of the fluid (liquids and gases) with surfaces defined by boundary conditions. With high-speed supercomputers better solutions can be achieved, and these are often required to solve the largest and most complex problems.

Ongoing research has yielded software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Yet initial validation of such software is still typically performed using experimental apparatus such as wind tunnels. In addition, previously performed analytical or empirical analysis of a particular problem can be used for comparison. A final validation is often performed using full-scale testing.

The current state of the art in CFD is improving as programming and computers evolve, but the wind tunnel is still used as the essential tool to validate it and will probably still have at least a decade of useful life before being superseded by computing.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Vest world

Keeping your driver cool can mean the difference between winning and losing a race, but could hi-tech underwear really be the answer? *Racecar* puts Walero's NASA-standard kit to the test

By BRADLEY APPLETON

The scene was set for the first back-to-back Bathurst win in 10 years. In October 2018 on the Mount Panorama circuit the Supercheap Auto Bathurst 1000 was in its closing stages and the Erebus Penrite Racing car driven by David Reynolds and Luke Youlden, which had dominated the weekend and led the majority of the race, was engaged in a head-to-head battle with veteran Craig Lowndes.

Then, suddenly, Reynolds suffered crippling leg cramps. His ability to apply the pedals was severely restricted, and he lost the feeling of his foot being either on the brake or on throttle. His margin over Lowndes shrunk, and he relinquished the lead just a few laps from the final round of pit stops. The stop would be the final nail in Erebus' hopes of back-to-back wins, as Reynolds' leg cramped again, and he lost his ability to depress the clutch pedal whilst the racecar was up on jacks, causing the rear wheels to spin and earning a penalty.

Reynold's physical problems were caused by severe dehydration. Whilst it was later revealed that sleep deprivation and lack of fluid intake were contributing factors, sitting in a hot Holden Commodore for hours over a triple stint, where cockpit temperatures can often rise above 60degC, was found to be the main factor. And there are many other examples of drivers suffering from high cockpit temperatures.

Cool rulings

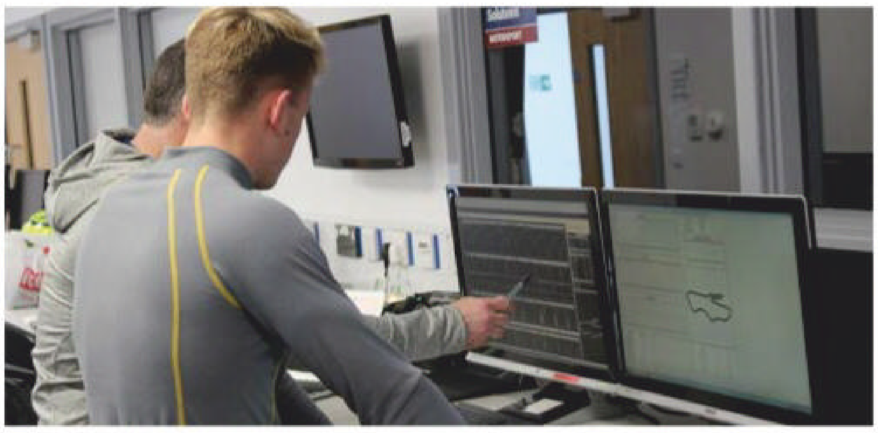
The conditions that drivers experienced at Le Mans in 2005 led to rule changes being introduced by the ACO. The endurance classic was the first race to make air-conditioning a requirement, as of 2007. In the current WEC regulations, closed cars are fitted with a thermometer, which must be placed level with the driver's helmet, in the middle of the car. If the temperature around the driver exceeds the value defined by the regulations (32degC maximum when the ambient temperature is less than or equal to 25degC, a temperature less than or equal to ambient temperature + 7degC if it is above 25degC); the racecar will be stopped until the temperature drops again.

This is all to do with thermoregulation, a process that allows your body to maintain its core internal temperature, and all thermoregulation mechanisms are designed to return your body to a state of equilibrium. An average human core body temperature is generally between 36.5 to 37degC. There is a small window of flexibility for this temperature to increase, but once you get to the extremes of body temperature just two degrees higher at 39degC, it can seriously affect the body's ability to function. Increased sweating can quickly cause dehydration, leading to a loss of cognitive ability, dizziness, blurred vision, and other symptoms including nausea, muscle cramps and a rapid heartbeat.

This area of sports science has been of particular interest to former senior performance coach at renowned Hintsa Performance, Dean Fouache. He worked closely with ex-WEC LMP2 and current Blancpain GT team Strakka Racing as its head of human performance until August 2018. In Fouache's first season, the team competed in the 2016 Six Hours

A 3.3kg weight drop due to fluid loss over a one-hour stint was recorded for one driver – equivalent to five per cent of his overall body weight

NASA uses this technology in gloves worn by astronauts, to help them cope with the extreme temperature variations experienced in space



Race driver Jack Mitchell, wearing a Walero vest, reviews the results of the test

The study took place at Cranfield Simulation and involved two stints driving around Donington

of Circuit of the Americas in Austin, Texas. Weekend temperatures were consistently above 30degC, with Sunday's race starting at 36degC and a relative humidity of 60 per cent. These challenging conditions prompted Fouache to measure the weight of the drivers before and after their stints. For a particular driver, double Le Mans class winner Jonny Kane, Fouache recorded a 3.3kg drop due to fluid loss over a single one-hour stint in the car – equivalent to five per cent of his overall body weight.

'It was clear that, for racing in such extreme conditions, I had underestimated the physiological and cognitive stress that is put on a driver's body,' Fouache says. 'From then on, I felt it was crucial for me to understand the complexities of thermoregulation and its effects on the body. It's an area of human performance that is vital, especially in endurance racing.'

Space race

Racing underwear supplier Walero is looking to address these issues with a range of underwear base layers using NASA-developed Outlast temperature-regulating technology.

Most established racing underwear manufacturers use Nomex, a heat and flame resistant fibre, combined with traditional wicking fabric. Found in performance clothing such as football shirts and mountaineering jackets, wicking fabrics are made of hi-tech polyester, which absorbs very little water. A specially designed cross-section and a large surface area allows the material to pick up moisture and carry it away from the body. By spreading it out to then evaporate easily on the outside of the fabric, this aims to keep you cooler and dryer than non-wicking clothing.

However, this becomes an issue when the material does not have a source of airflow available to enable evaporation to take place. Walero's Patrick Grant explains: 'Wicking fabrics may feel cool when worn separately, but when worn under a non-breathable fireproof race suit, this restricts the airflow around the body, hindering the mechanism which cools the body through sweat evaporation.'

While wicking fabric is designed to take moisture away from the skin, it does not prevent you sweating in the first place. 'Walero underwear is aimed at being a prevention rather than a cure, and is designed to reduce the amount a person sweats altogether, reducing the dangers of dehydration and the chance of suffering from heat stress or fatigue,' Grant says.

Walero's clothing utilises phase change materials (PCM). A PCM is a substance with a high heat of fusion which, by melting and solidifying at certain temperatures, is capable of storing and releasing large amounts of energy. The technology is comparable to ice in a drink; as it changes from a solid to a liquid, it absorbs heat and cools the drink, keeping the drink at the desired temperature for longer.

Walero's underwear works in the same way, but the clothing is micro-encapsulated to be permanently enclosed and protected in a polymer shell to increase durability. This is incorporated into the fabric of the base layer, which gives Walero's underwear the capacity to absorb, store and release the excess heat from the skin when needed.

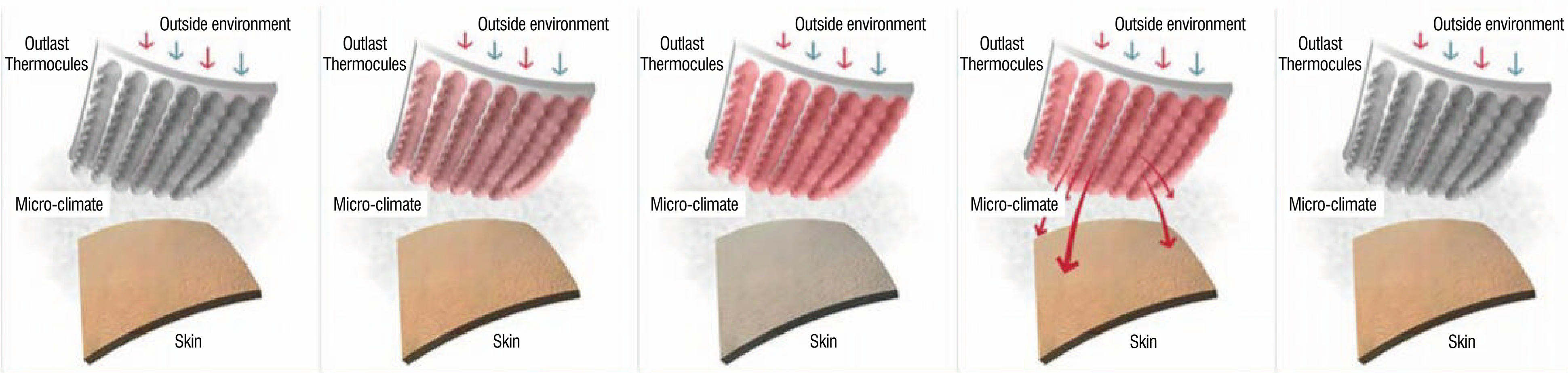
This type of material has been tried and tested across many different industries, including bed linen, socks and office chairs. NASA has even declared it a certified space technology for use in the gloves worn by astronauts, to help them cope with the extreme temperature variations experienced in space.

Test match

Through a chance encounter, Fouache was invited to conduct a controlled experiment to put the theory to the test, comparing driver performance when using a Walero base layer against a standard Nomex base layer. The test was conducted in the fully enclosed and temperature-controlled simulator room at Cranfield Simulation, home to one of the most technically advanced simulators outside F1.

Cranfield's innovative simulator has three different modules of motion technology, operating in 11 degrees of freedom across

How Outlast technology works



1. A driver's skin is exposed to temperature changes that affect the human body's micro-climate

2. When drivers overheat, their bodies naturally release excess heat and sweat to cool the skin

3. Outlast absorbs excess heat and stores it in microcapsules which are called Thermocules

4. When drivers start to cool, their stored heat is then released back into the body

5. The result is a constant comfort zone next to the race driver's skin, Walero claims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'We decided to measure three key metrics: the driver's body temperature increase, weight loss and average heart rate'

six axes. This includes a rectangular base platform with four linear actuators in each corner to simulate roll, pitch and heave movement, and a long-stroke actuator at the rear to simulate lateral yaw movement.

Additionally, the Proportional Rapid Onset (PRO) system allows the seat to move independently of the chassis, and is used to replicate very minor and high frequency movements in the fore/aft, vertical and lateral axes that cannot be produced by the main suspension platforms. Finally, the Sustained Motion Cueing System (SMCS) is composed of a number of unique pneumatic pressure modules situated around the cockpit seat and harness, which expand and contract to simulate the *g*-forces felt when cornering, braking and accelerating. These cues are progressive and thus proportional to the relevant *g* demand, and are continued until the demand is removed. Any three demands can be combined on to any axis at any one time, so both sustained and vibration cues can act at the same time on one axis or the sum of two different frequencies and amplitude. This is claimed to sustain the sensation of acceleration and deceleration indefinitely, misleading the brain in to believing the body is moving. It was for this reason this simulator was selected for the test, as the motion technology imparts similar sensations onto the body as found in reality, with the aim of exerting similar stresses onto the brain to produce similar levels of perspiration, as seen in a real racecar.

Figure 1: Lap time consistency

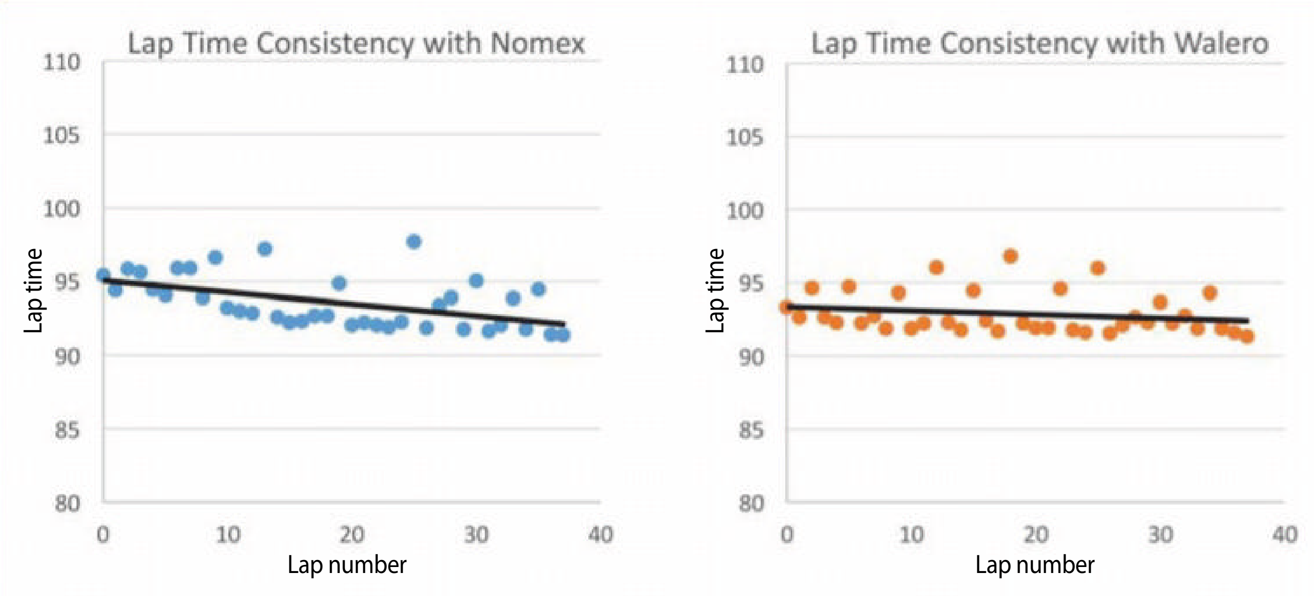
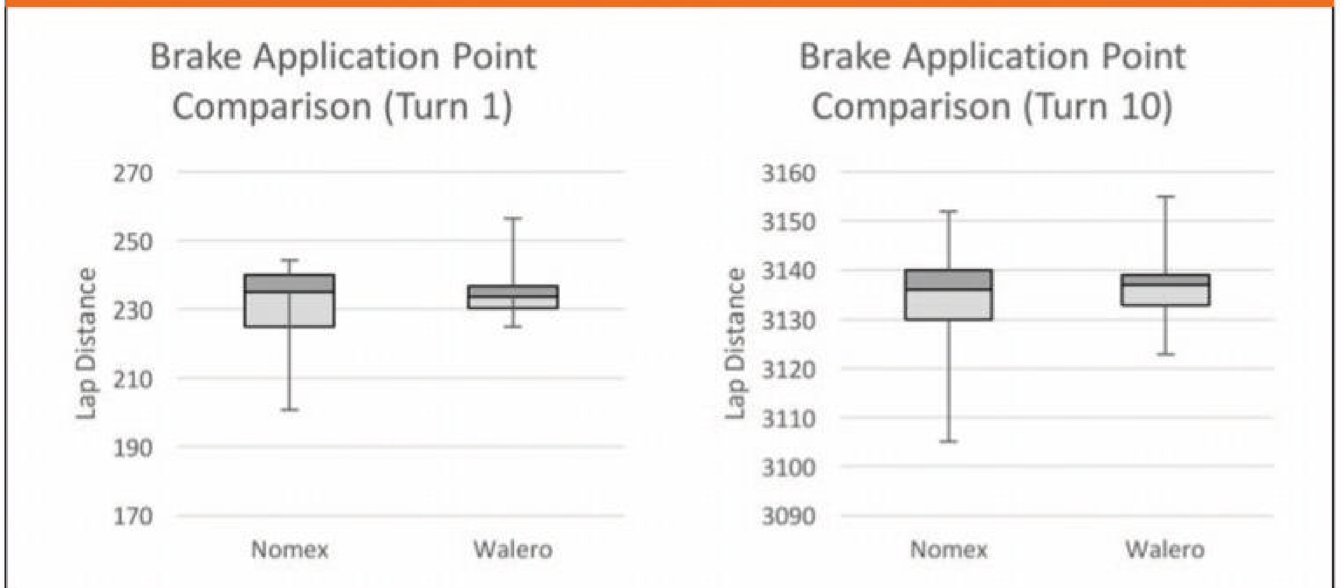


Figure 2: Brake application



The hot seat

Using 2018 British GT4 Champion Jack Mitchell as a test subject, the comparison study involved driving a Ginetta G55 GT4 vehicle model around Donington Park's Grand Prix configuration over a one-hour stint. On the first day Mitchell would wear standard Nomex race underwear, and then Walero underwear on the second. With the simulator room kept at a controlled 32degC, the upper limit for cockpit temperatures as defined by the FIA WEC technical regulations, Mitchell's starting body temperature on both of the test days was measured at 36.9degC.

On day one, wearing the standard Nomex underwear, Mitchell's temperature rose to 37.6degC in just 10 minutes, with a continuous progression to a peak of 38.4degC at the end of the stint. On day two, now wearing Walero, Mitchell experienced a noticeably slower increase in body temperature. He remained at his starting temperate of 36.9degC for the first 10 minutes of the stint, before gradually rising to a peak of 37.5degC at the end.

Additionally, Mitchell's average heart rate over the stint was reduced from 108bpm to 100bpm, and he lost 0.3kg in body weight when using Walero underwear compared to 0.5kg using the Nomex. Fouache found Mitchell sweated around 40 per cent less in the Walero underwear and his average heart rate was eight beats less over the course of the hour.

Best of the vest

Fouache says of the test: 'We decided to measure three key metrics: the driver's body temperature increase, weight loss and average heart rate. Walero's impact on these metrics was extremely impressive. A 0.9 degree difference between the two studies is a huge amount in terms of thermal regulation. Jack's body temperature elevated much more slowly when wearing the Walero base layer than he did in the Nomex, meaning his physiological and cognitive functions have the opportunity to perform optimally for a greater duration.

'If a driver is making better decisions while driving, the likelihood of him making mistakes, missing braking points or the apex of a corner which can cost valuable lap time decreases,' Fouache adds. 'As a by-product, his average lap time then becomes more stable.'

By comparing lap times throughout each stint it can be seen that, although small, there is an improvement in overall consistency, with better average and ultimate lap time using Walero *vs* standard Nomex (**Figure 1**).

This is further highlighted when looking at driver input consistency such as brake application point. This is a good indicator of driver concentration and ability to repeat a lap time consistently throughout the stint. This can be seen in the box plots in **Figure 2**, indicating a similar median value, but noticeably smaller range of brake application when using Walero in comparison to standard Nomex.

It has to be acknowledged that this was a small-scale test, with the use of just the one driver, and that some of the improvement could be down to Mitchell becoming more used to the simulator and car/track model. Nonetheless, this throws up interesting results that could serve as a wake-up call to those who currently ignore this side of race driver conditioning.

Index of performance

Racecar's simulation expert reveals his secret formula for calculating the stability index from yaw rate data

By DANNY NOWLAN

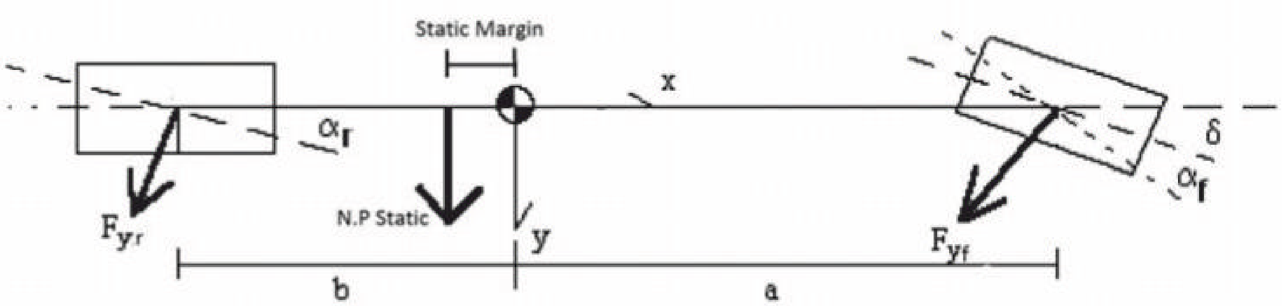
Give race drivers a stable platform and they should reward you with fast lap times

Since I deal with some top engineers in very senior formulae, I sometimes get asked some really interesting questions regarding simulation. For example, recently ChassisSim's US Dealer asked me whether I was able to figure out stability index from yaw rate? The answer to this question is not only yes, but also that there are some other very interesting things that spring up when we consider this.

But before I get into how it all works, it would be worthwhile taking a little time to provide a quick recap of what the stability index is. In a nutshell the stability index measures the moment arm non-dimensionalised by wheelbase between the centre of gravity and the centre of the lateral forces. This is illustrated in **Figure 1**.

This can be calculated through the vehicle model or it can be calculated from race data. Here we're going to discuss calculating, or at least approximating, the stability index from logged yaw rate data. To frame this discussion appropriately, this is not about calculating the

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

EQUATIONS

EQUATION 1

$$\frac{\partial C}{\partial \alpha} = \frac{\partial}{\partial \alpha}\left(-713.27\cdot\alpha^3 + 2.0267\cdot\alpha^2 + 13.713\cdot\alpha\right)$$
$$= -2139.81\cdot\alpha^2 + 4.0534\cdot\alpha + 13.713$$

Where:

a = is the steered angle

EQUATION 2

$$I_z \dot{r} = \left(a\cdot C_f + \frac{\partial N}{\partial b}\cdot\frac{C_f}{C_T}\right)\cdot d_s + \left(\frac{\partial N}{\partial r} + \frac{C_r'\cdot b - C_f\cdot a}{C_T\cdot V_x}\right)\cdot r + \frac{a\cdot C_f - b\cdot C_r'}{C_T}\cdot m_t\cdot a_y$$

Where:

I_z = polar moment of inertia about the z-axis (kgm2)
r = yaw rate (rad/s)
$\dot{r}$ = derivative of yaw rate (rad/s2)
a = distance of front axle to the centre of gravity
b = distance of the rear axle to the centre of gravity
V_x = forward speed (m/s)
a_y = lateral acceleration (m/s²)
C_f = slope of front tyre force vs slip angle (N/rad)
C'_r = slope of rear tyre force vs slip angle (N/rad)
$C_T = C_f + C'_r$
$\frac{\partial N}{\partial \beta}$ = slope of yaw moment vs side slip angle (Nm/rad)
$\frac{\partial N}{\partial r}$ = slope of yaw moment vs yaw rate (Nm/rad/s)

EQUATION 3

$$\left(a\cdot C_f + \frac{\partial N}{\partial \beta}\cdot\frac{C_f}{C_T}\right) \approx a\cdot(L_1 + L_2)\cdot\frac{\partial C}{\delta \alpha}$$

Where:

a = distance of the front axle to the c.g
L_1 = front left tyre load in N
L_2 = front right tyre load in N
$\frac{\partial C}{\partial \alpha}$ = normalised slope from Equation 1

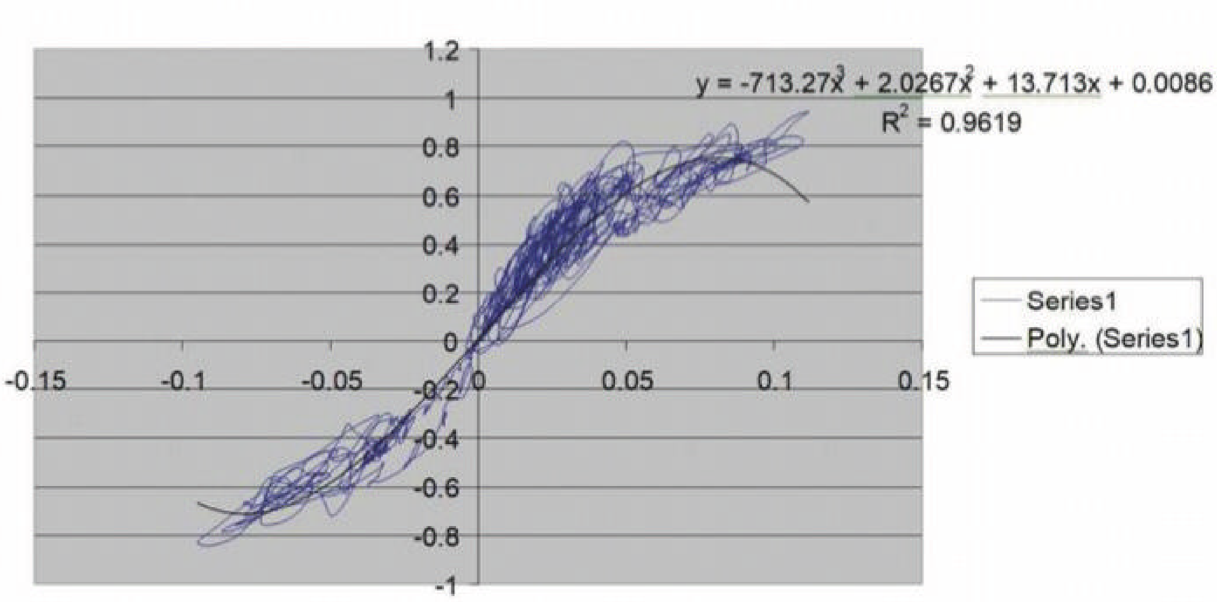
EQUATION 4

$$N_{NORM} \approx \frac{\left(I_z\cdot\dot{r} - a\cdot(L_1 + L_2)\cdot\frac{\partial C}{\delta\alpha}\cdot\partial_s\right)}{m_t\cdot g\cdot wb}$$

Where:

N_{NORM} = normalised moment (unit-less)
I_z = second moment of inertia on the z axis (kgm²)
$\dot{r}$ = derivative of yaw rate in rad/s²
a = distance of the front axle to the c.g
L_1 = front left tyre load in N
L_2 = front right tyre load in N
$\frac{\partial C}{\partial \alpha}$ = normalised slope we figured out in Equation 1
d_s = steered angle at the tyre in radians
wb = wheelbase in m
g = acceleration due to gravity (m/s²)

Figure 2: Plot of yaw rate *vs* steered angle in radians



The stability index can be calculated through the vehicle model or race data

stability index to within one per cent. Without the appropriate sensors and tyre models this would be unrealistic. However, what is about to be presented here is something that is more than sufficient for a comparative analysis while just using minimal channels. And this certainly makes this approach useful.

Force and function

The first part of this method is to resolve the tyre force derivative as a function of steered angle. A good approximation of this can be found with the yaw rate *vs* the steered angle plot. For this to work we must have the following conditions. First, yaw rate must be plotted in rad/s. Second, steered angle must be plotted at the tyre in radians.

Fortunately, to convert to radians you simply need to divide by 57.3 (I tried short cutting this as plotting deg/s and steered angle as deg but it failed miserably). You then want to curve fit the function shown in **Figure 2**.

The slope of this curve is what you will use for the $\delta C/\delta\alpha$ term later. In this case we have **Equation 1**. Here alpha is steered angle and the result of **Equation 1** is what you will use to figure out the control power of the front tyres.

The next step is to isolate the stability index component of the moment calculation. **Equation 2** illustrates what we are after with this. Here the two dominant terms are the *ds* term and the *ay* term. While the yaw rate term will have an impact (this is effectively the yaw damping term) **Equation 2** is dominated by steer and lateral acceleration.

We now need to resolve the steer term. A good approximation of this term can be found by making use of **Equation 3**.

Note here that it is critical that the strains L_1 and L_2 in **Equation 3** are entered zeroed in the air and not on the ground. Now that we have this we next need to calculate a normalised moment about the centre of gravity. This is given in **Equation 4**. Then, to get the stability index, all you need to do is plot **Equation 4** by lateral acceleration. The slope will be the stability index.

Take note

A couple of notes on what we have just done above. Firstly, you will see in **Equation 4** how we have divided by wheelbase and acceleration due to gravity. This is to ensure the results are non-dimensionalised, so you can't start making immediate comparisons.

Figure 3: Stability index plot for an F3 car

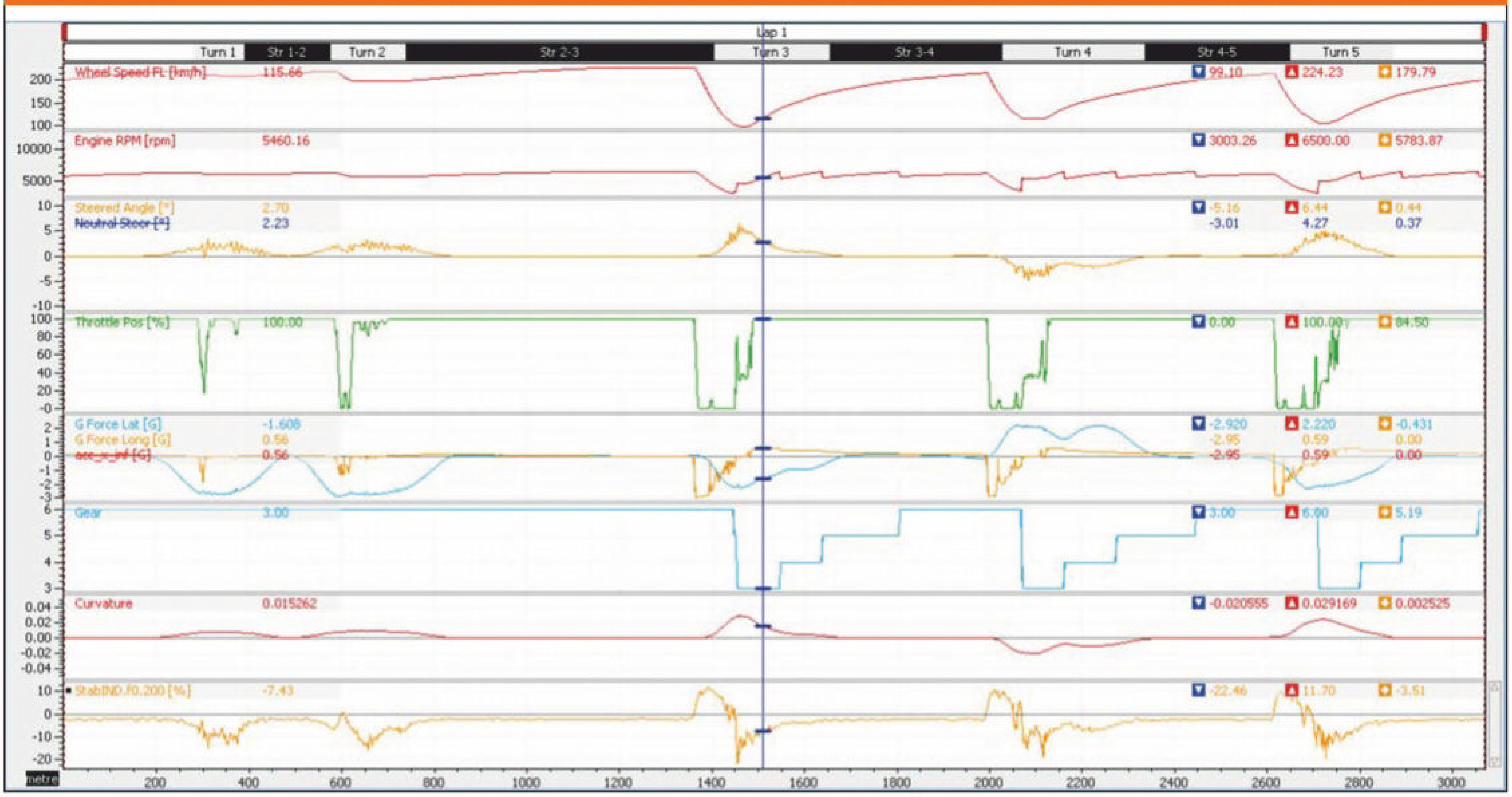
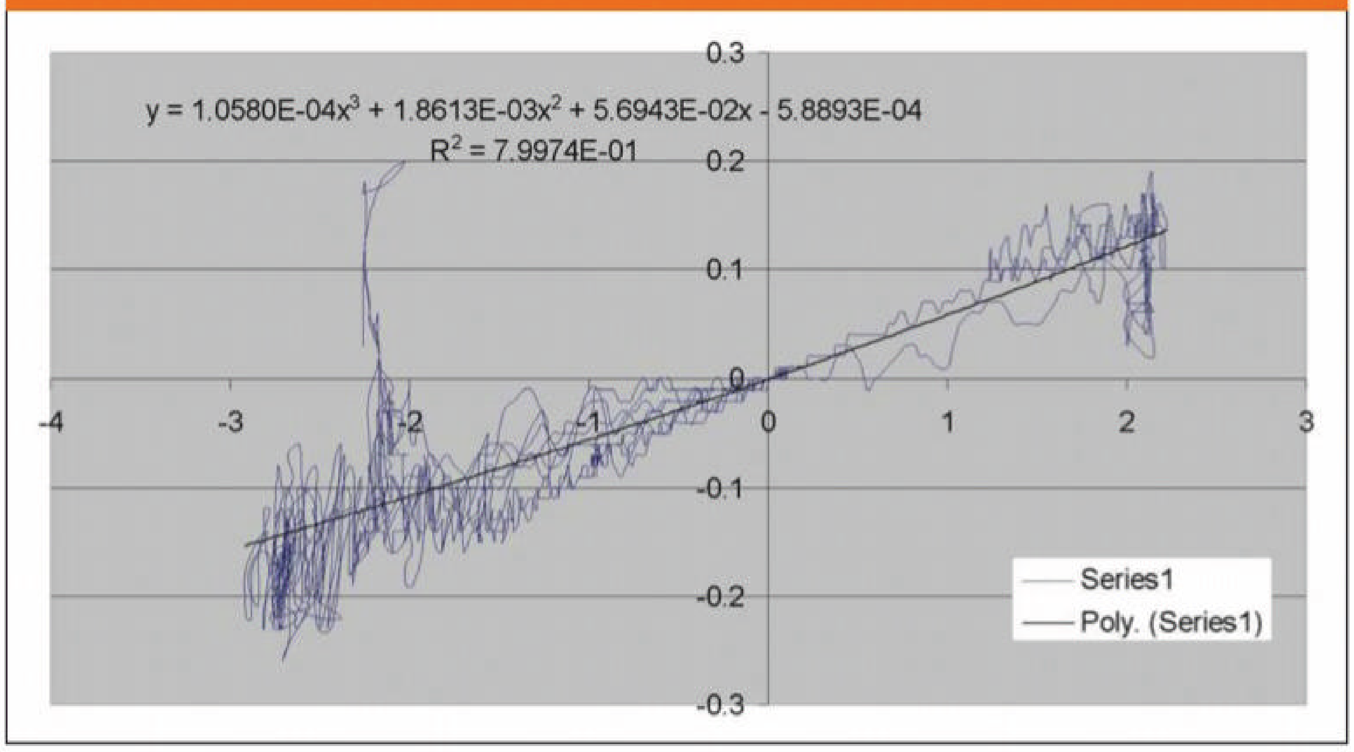


Figure 4: Inferred stability index



Also, the sign of both the yaw rate, the steered angle and the lateral acceleration will have a big impact on the results you are going to get. To minimise any confusion I would strongly recommend that when doing this analysis you stick to right-handed aircraft body coordinates. That is, positive yaw is for a right-hand turn and positive steer is for a right-hand turn. If you start mixing and matching this then things will break down very quickly.

Another point; some filtering of N_{NORM} will be required. If you're doing this as a sanity check from simulated results then I would recommend a time based-filter of 5Hz. This is because the simulator will apply changes much faster than an actual driver. If you're applying from actual results then I would start at 10Hz.

So let's review some Formula 3 results from a simulation run in ChassisSim and compare the inferred stability index to what you get back from it. The stability index from ChassisSim is shown in **Figure 3**.

The plot thickens

The plot of most interest is the final plot which is stability index. During braking and turn-in the results are a bit optimistic. This is because the current calculation uses a simple methodology which is perfectly legitimate for the mid-corner condition but struggles with extreme load transfer conditions. I do have a fix for this based on the mixed traction circle load conditions, I just haven't had time to implement it. However, the condition of most interest is the mid-corner condition anyway, and we can see that the stability index is hovering between -8 to -13 per cent and down the straights it is about -2.5 to -3 per cent. The inferred stability index isn't that far away.

If you're doing this from simulated data then I would recommend a time-based filter of 5Hz

The results of plotting the N_{NORM} *vs* lateral acceleration are shown in **Figure 4**. The first thing that should jump out here is that the slope is positive. This actually indicates stable behaviour because *ay* is positive for a left-hand turn. If I had plotted it the other way it would have turned out with the correct sign.

Looking at the curve fit, while we don't have an exact match the results are not awful. The baseline stability index at 0*g* is -5.69 per cent. Not a great match to our stability index from ChassisSim but not totally outrageous. However, when we start applying *g* the agreement becomes more reasonable.

For a lateral *g* figure of two the stability index is -6.56 per cent. This is a little bit closer to the stability index values at the mid-corner condition. While this is not ideal, it is certainly very far from the point where you should be getting downhearted with it in any way.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The primary reason for this error is the fact that we had to guess the $\frac{\partial C}{\partial \alpha}$ term and the errors in the curve fit. Given the constraints of this methodology, that we just had the yaw rate to make use of, we didn't have an exact measure of the lateral tyre force slip angle slope. We had to guess it from the yaw rate *vs* steer angle response. Not ideal, but as we can tell from the results, it's still useful.

However, the other driving factor of this error is the nature of the curve slope and how the maths channels are set up in your data logger. From **Figure 2** and **Equation 1** it can be seen we used a simple polynomial curve fit. While this is really easy to derive and get a slope from, this function is more trigonometric/exponential in nature. This is the point where the math functionality in Motec i2 Pro, Cosworth Toolbox and Magneti Marelli Wintax run out of steam. I'm not having a go at these packages, I actually think for what they are they are totally fit for purpose. But in a perfect world you would be doing this analysis in Matlab. However, as this would send most readers screaming to the hills in terror, we have to make do with what we have.

The punchline here, though, is that this methodology is more than sufficient for a comparative analysis and as a sanity check, so that the racecar will not swap ends on your driver. Yes, this is not perfect, but if you are looking for perfection then just maybe you should get out of motor racing.

Magic number?

One spin-off question, no pun intended, from all this is: can we use a single number to represent our stability index determinations? It is very tempting, because ever since the magic number was coined everyone always looks for this single metric. It's a bit like the holy grail of racecar engineering.

The answer to this question, as far as the stability index is concerned, comes from considering **Equation 5**, which is from an earlier article where I looked at the link between the magic number (lateral load transfer at the front) and the stability index.

The critical thing to think about here will be the ratio of the front and rear maximum lateral tyre forces. In my earlier article I plotted the variation in front lateral load transfer distribution to show the variation in stability index. This is one of the primary drivers as to why the front lateral load transfer distribution is such a critical metric. What we need to do now, though, is calculate the following ratio (**Equation 6**) as a function of speed where we hold the front lateral load transfer distribution and lateral acceleration constant. We are calculating this as scaling factor (SF).

This calculation is not as difficult as you might think. All you need is a simple tyre model, that is the initial coefficient of friction k_a and how this drops of with load k_b, and a rough idea of your average C_LA and the aero distribution in the corners. So, leaning on my previous article where we explored both the stability index and the front lateral load transfer distribution we have **Equation 7**.

Just to refresh everyone's memory, we have for the TC_{RAD} function **Equation 8**. So, all that we have to do now is to calculate the static loads. This will be given by **Equation 9**.

This will happily fill in the blanks for **Equation 7** and then you can plot the scaling factor as a function of velocity. If that number is constant then you know a single stability index number will apply. If it isn't, then you know you will require a more nuanced approach. Also, the awesome thing about all this is that you can do it in Excel or any spreadsheet of your choosing, provided it comes with basic maths functionality. To give you a head start I'll get you going with some basic car parameters, as shown in **Table 1**.

In closing, we have explored some very exciting possibilities here. We have established that we can indeed calculate stability index from the yaw rate sensor. While it will not give us an exact answer, it gives us something in the ballpark that is very usable. We have also looked at whether a single stability index number will apply everywhere. Now it's over to you to try this out for yourself.

EQUATIONS

EQUATION 5

$$\alpha_F = \frac{b\cdot(Fm(L_3)+Fm(L_4))}{a\cdot(Fm(L_1)+Fm(L_2))}\cdot\alpha_R$$

Where:

a = moment arm of front axle to centre of gravity (m)
b = moment arm of rear axle to centre of gravity
a_f = front slip angle
a_r = rear slip angle
$Fm(L_1)$ = max traction circle radius on the front left tyre (N)
$Fm(L_2)$ = max traction circle radius on the front left tyre (N)
$Fm(L_3)$ = max traction circle radius on the front left tyre (N)
$Fm(L_4)$ = max traction circle radius on the front left tyre (N)

EQUATION 6

$$SF = \frac{b\cdot(Fm(L_3)+Fm(L_4))}{a\cdot(Fm(L_1)+Fm(L_2))}$$

EQUATION 7

$$Fm(L_1)+Fm(L_2) = 2\cdot TC_{RAD}(L_{SF}) - 2\cdot k_{af}\cdot k_{bf}\cdot\left(\frac{pr\cdot m_t\cdot a_y\cdot h}{tm}\right)^2$$

$$Fm(L_3)+Fm(L_4) = 2\cdot TC_{RAD}(L_{SR}) - 2\cdot k_{ar}\cdot k_{br}\cdot\left(\frac{(1-pr)\cdot m_t\cdot a_y\cdot h}{tm}\right)^2$$

Where:

F_{yt} = total lateral force in N
L_{SF} = front corner weight in N (this includes aero load)
L_{SR} = rear corner weight in N (inclusive of aero load)
k_{af} = front tyre initial coefficient of friction
k_{bf} = front tyre drop off of coefficient with load
k_{ar} = rear tyre initial coefficient of friction
k_{br} = rear tyre drop off of coefficient with load
pr = lateral load transfer distribution at the front.
a_y = lateral acceleration in m/s2

EQUATION 8

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

EQUATION 9

$$L_{SF} = L_{f0} + awf\cdot C_LA\,{}^1\!/_2\cdot\rho\cdot V^2$$

$$L_{SR} = L_{r0} + (1-awf)\cdot C_LA\,{}^1\!/_2\cdot\rho\cdot V^2$$

Where:

L_{f0} = front static corner weight (N).
L_{r0} = rear static corner weight (N).
a_{wf} = front aero distribution factor (0 – 1)
C_LA = average C_LA value in the corners

Table 1: Basic Car parameters

Parameter	Value
Car mass	550kg
c.g height	0.3m
Front weight distribution	41%
Wheelbase	2.7m
Mean track	1.5m
A_y	2g
K_{af}	2.3
K_{bf}	8.5e-5
K_{ar}	2.4
K_{br}	7.3e-5
C_LA	2.3
Front aero balance	41%

Interview – Allan McNish

Tale of the unexpected

Audi's team boss tells us how his work in Formula E has helped to replace the buzz and challenge of competitive race driving

By MIKE BRESLIN

'The rules dictate the budgets, so they have got to be clear and well written and in a format that allows manufacturers to get involved at a reasonable cost'

When a racing driver hangs up his or her helmet after a long career there can be a real need to find something to fill the gap. Not all can do so, and many find themselves back in the cockpit soon after they retire. Others turn to different fields within the sport; some of them even become team bosses. But for Allan McNish, who stopped driving in 2013, two things were clear: he did not plan on racing again, and there was *no chance* that he would turn his hand to team management.

McNish, who won Le Mans three times and had a spell in F1 with Toyota, has been true to his word when it comes to race driving, but – and this would have surprised him more than anyone else six years ago – he is now going into his third season as team principal at the Audi Formula E operation. 'When I stopped driving I can honestly say that running a team was never, ever on my list of things I wanted to do, in fact it was probably on my list of things I didn't want to do,' McNish says. 'But Dr [Wolfgang] Ullrich [then Audi's motorsport boss] asked me to go to the first [Formula E] test of season three, because there was the start of the look towards eTron road car development, and motorsport always has to be at the leading edge of [road car development at Audi], as it was with the Le Mans programme. So I went along, just to scope it out, to look at it, to understand it, and then to see whether it was something that Audi should get involved in as a factory programme. At the end of the year we decided we wanted to do that, moving in in season four. And then we were actually sitting and talking about structure … And there was a big chart on the wall with "team principal" on it; and it had my name next to it.'

Managing expectations

Yet after the initial shock of this subsided, McNish actually warmed to the idea. 'The more I thought about it, the more I thought it would be a very interesting challenge; and it was something that really whetted my appetite like nothing I had done since I took the helmet off,' he says. 'I got that little adrenalin rush, and when I turned up at the first race of season four in Hong Kong, leading the charge if you like, there was an element of responsibility, but there was also an element that I was back where I belonged, which was at the front line.'

Yet the challenges of leading a team are very different to the challenges of race driving, especially a Formula E team. 'There's two challenges; one is over the race weekend, because the time-lines are so tight,' McNish says. 'That one-day format is fantastic in so many ways, because it's so exciting, it's so intense; but it's like a three-day format in terms of the energy you have to put into it. If you trip up at all in free practice one, then you can't get it back. If you don't quite get your warm-up procedure in qualifying sorted out, then you can easily be 18th or 19th on the grid. The intensity of it is very exciting and dynamic and I do like it. However, it is quite a lot of pressure.'

The second challenge McNish alludes to above is on a far broader scale, and that's to do with a manufacturer's responsibility to the series. 'We're all part of a process of building a championship; because it's still embryonic,' McNish says. 'I have likened it to a child at its first day at school, because it's still only five years old. You think of it as being much more mature than it is, but with a five-year old child you've got to let them try their own thing, you have got to make sure that they develop in the correct way. And that's where we all are with the championship.

'Audi jumped in earlier than most, because we believed in it; but at the same time I think all of the manufacturers, along with the FIA and FE, have got a responsibility to try and develop the championship,' McNish adds. 'We've got some meetings coming up about what we're proposing for season six and season seven, and we're actually talking about season nine and onwards, too.'

Factory records

However, while the manufacturers might be looking towards the future of FE, many will say that a reliance on car makers is never a good thing for a series, as they can leave when it suits them – or rather when their marketing needs change – while factory teams will often lead to budget inflation, too. 'I think generally there's a, reasonable, misunderstanding of some of these areas,' McNish says. 'At the end of the day the rules dictate the budgets. So, therefore the rules have got to be clear and well written and in a format that allows manufacturers to get involved at a reasonable cost, but also to get a return on that cost through the television, marketing, advertising

and everything else. So you have got technical return on the investment you make, in terms of how does it relate to road car technology, how relevant is it to what we are going to be doing in the future – not necessarily today but three, five years down the line – and also then what the television and marketing return is. But the rules dictate the technical costs, not the manufacturers, that's down to the FIA.

'I also don't necessarily see it as a big risk,' McNish adds. 'Because the way the championship regulations are now, I would say it is designed to be random. Which is a bit frustrating for a purist motorsport person like me, but actually is quite good from a sitting at home or in the grandstands point of view, because it isn't the same person winning all the time. So I don't think you are going to get into a position where one, two, or three manufacturers will dominate and no one else has a look in. So, if the costs are low enough – because of the regulations – and everyone has got a share of the pie – stands on the podium at some point – then what is the reason for them to leave?'

Resisting temptation

McNish is clearly relishing the role as team principal, despite his views six years ago, but what about that other thing he said he would not do when he hung up his helmet; return to the cockpit? Has he been tempted by the Audi Formula E racer? 'I drove the season two car around Berlin for two laps, and then I drove our season four car on to a stage and then back off!' he says. 'So, no I haven't driven it in anger. Part of the reason for this is personal, and part of it is practical. Personal is; when I took my helmet off, I took my helmet off. And that was it. It was very much a case of you do something right, or you don't do it at all. My last race was the end of November [2013], my licence then ran out on the 31st of December, and I never renewed my licence; that was it, done and dusted, on to the next chapter. At the same time, we get such a restricted number of test days in Formula E, why would I take one of those test days and give it to me for a bit of fun and entertainment?'

Then he adds: 'And also, I don't get paid to do that anymore.'

Smoke without fire: Audi goes into its third season as a factory operation in Riyadh, Saudi Arabia, at the end of November

RACE MOVES

XPB

Gunther Steiner, the team principal at Haas, has been fined €7500 for a radio message that was deemed to have caused 'moral injury' to a Formula 1 steward, while also being 'prejudicial to the interests of motorsport'. In the message, at the end of the Russian GP, Steiner criticised the stewards for giving Haas driver **Kevin Magnussen** a five second penalty that dropped him to ninth. Steiner said over the radio: 'If we didn't have a stupid idiotic steward we would be eighth.'

The Mercedes Formula 1 team has sacked four people after it carried out an investigation into discrimination. Few details are known, but it's been reported that the incidents were of a racist or religious nature. Mercedes said the matter concerned 'breaches of our diversity and equality policy'. Its statement added: 'We condemn this behaviour in the strongest terms and acted immediately. We value the diversity of our employees and it is a source of strength for our team.'

Tracey Lesetar-Smith is now senior vice president, general counsel at NASCAR. In her new role Lesetar-Smith will lead day-to-day operations of the sanctioning body's legal department at its Daytona Beach headquarters. **Karen Leetzow** is set to step down from the same role at the end of this year, having announced her intention to leave last year, but then opting to stay on to help with the merger between NASCAR and ISC (International Speedway Corporation).

Jon Flack is no longer president of the Arrow Schmidt Peterson Motorsports (SPM) IndyCar operation. Flack's departure came soon after the team's technical director, **Todd Malloy**, and also its public relations representative, **Veronica Knowlton**, left the team. SPM has recently tied up with McLaren Racing for next year's IndyCar Series and has now been renamed Arrow McLaren SP.

Rob Crawford, a multiple Bathurst 1000-winning Supercars team boss, is now managing Kostecki Brothers Racing's wildcard entry in the Pirtek Enduro Cup, the three endurance races that mark the end of the series' season. Crawford is best known for his time with Walkinshaw Racing from 2001 until 2011. More recently he worked at Kelly Racing from 2012 to 2014, before guiding 23Red Racing through its first season last year.

Jeremy Moore is to return to the Triple Eight Supercars squad, where he is to take on the role of technical director. Moore, who for the past five years has worked at Porsche – including a spell as engineer on the No.2 LMP1 car which won Le Mans and the WEC in 2016 – was previously at Triple Eight from 2003 until 2015, finishing up as its chief designer. He was due to start at the team in November.

Also at the Triple Eight Supercars team (see above), **Tony Price** has returned following spells at the Hyundai WRC operation and the Toyota WEC team. Price, who previously worked at Triple Eight from 2007 until 2014, is once again working in sub-assembly at the company

Indy 500 entrant **John Della Penna** has died at the age of 68 after a battle with cancer. Argentinian-born Della Penna started out running Formula Atlantic cars in the US in 1984 before moving up to the big time of both CART and IRL in 1996, doing both so as to assure a spot at Indianapolis, which was then an IRL event – his car finished third that year. Della Penna's team folded at the end of 2000.

Matt Borland, a crew chief at NASCAR Cup outfit Germain Racing, has been reinstated by the US stock car racing governing body after successfully completing its Road to Recovery programme. Borland had been suspended from NASCAR because of a failed drugs test, which he said was due to him unknowingly taking a banned substance, which was in a diet coffee.

Jochen Rudat has joined Automobili Pininfarina, the electric luxury and performance car brand, as its chief of sales officer. Rudat most recently occupied the role of director, Central Europe, with Tesla. He is a graduate of the BMW Academy and was dealer development manager for BMW Group Switzerland from 2006 to 2009, before moving to Tesla Motors.

Former football boss takes on FE chief executive role

Jamie Reigle, a former executive with Manchester United and the Los Angeles Rams, is the new CEO at Formula E.

Reigle is the electric race series' second CEO, the first being its founder, Alejandro Agag, who has now taken on the role of chairman – a move he had announced before the start of the 2018/19 season.


Reigle (left) will now work alongside FE founder Agag

Canadian Reigle comes to FE from his previous position as executive vice-president of business operations at NFL team the Los Angeles Rams. Before joining the Rams in 2017 he spent 10 years as a senior executive at Premier League football club Manchester United, where he was a member of the board of directors, oversaw global commercial activity, launched the club's Asia Pacific operations and led the company's initial public offering on the New York Stock Exchange.

Reigle will now work alongside Agag. The latter will concentrate on retaining relationships with key sponsors, teams and long-standing partners, while Reigle will oversee the overall management of the company and day-to-day operations.

'I'm delighted and honoured to be charged with leading Formula E through its next phase of development,' Reigle said. 'I've followed it from inception and admired the global sports platform Alejandro and his team have created. I'm eager to plug in and work with Alejandro to continue to develop it as the most exciting series in motorsport and a platform for the potential of the future of electric vehicles and sustainable mobility.'

Agag said: 'Jamie's wealth of experience working in sports properties across North America, Europe and Asia make him the best person for the job. With his addition to our existing executive team, we have an incredibly strong line-up to continue building and developing FE through our next growth cycle.'

Mazda's Doonan replaces Atherton as IMSA president

John Doonan, who has been leading Mazda's motorsport effort in the US for the past eight years, is to replace Scott Atherton as president of IMSA.

Doonan has plenty of IMSA experience, having steered Mazda's DPi campaign over recent seasons, and he steps into the president role following Atherton's recent announcement that he was to retire from the post.


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Scott Atherton is no longer president of the IMSA series

While IMSA has been Mazda's flagship programme – its RT24-P has chalked up three wins this year – Doonan has also overseen its Road to Indy and Road to 24 driver development schemes.

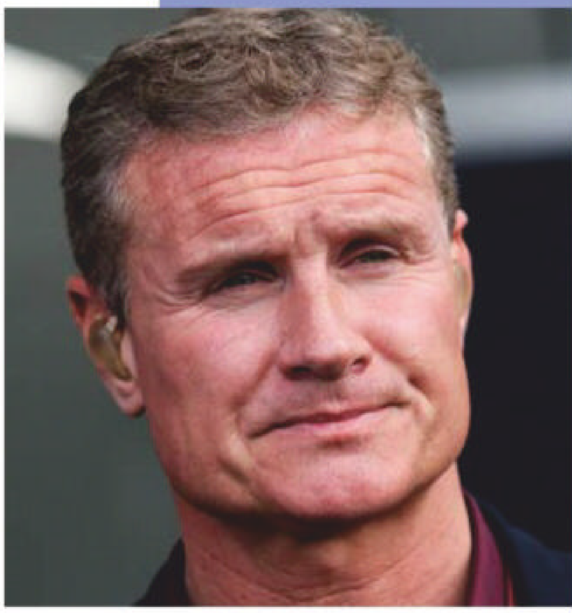
Outgoing president Atherton started his motorsport career as a sponsorship marketing executive in CART in 1985, before going on to fill a number of roles in the US, including president and CEO of Panoz Motor Sports Group. But he really made his name running the American Le Mans Series (ALMS). In this role he guided the ALMS through the successful merger with the Grand-Am series, the resulting entity now racing under the IMSA banner. He became president of IMSA when the merger was completed in November 2013.

Atherton intends to stay involved as a member of the board of directors at IMSA for next year and beyond.

Doonan said: 'I am very humbled and truly honoured to have the opportunity to join the IMSA team and I'm really looking forward to making a positive impact for our sport, our partners and our industry.'

IMSA's chief executive officer Ed Bennett said of Doonan's appointment: 'John is a fantastic choice to become our next president, to build upon the momentum of our just-completed 50th anniversary season and take our sport to the next level.'

RACE MOVES – continued


XPB

Former Formula 1 driver **David Coulthard** is the new president of the British Racing Drivers' Club (BRDC), the body which owns Silverstone circuit. Coulthard takes over from '60s rally legend **Paddy Hopkirk** – who committed himself to the role for just two years in 2017. The BRDC members have also elected three-time Indianapolis 500 winner **Dario Franchitti** to be the club's vice president.

The 2020 Sid Watkins Scholarship is to offer a fully funded FIA Safety Department role, and the winning candidate will be involved in safety research covering all areas 'from Formula 1 to karting'. Applicants are required to have 'recently completed an advanced tertiary qualification' (masters or PhD, for example). To apply for the scholarship email **safety@fia.com**

Adrian Newey is to be involved in the Veloce Racing entry in the new Extreme E championship – an off-road offshoot of Formula E which will run events in remote locations and begins in 2021. His role in the operation has been described as 'lead visionary'. FE champion **Jean-Eric Vergne** is one of the founders of the team, a sister operation to the Veloce FE squad.

Andrei Cheglakov, once the backer of the Marussia F1 team, has returned to motorsport as a member of the board of the new Veloce Racing Extreme E team (see above). Veloce is one of four teams to commit to the series so far.

Gregory and **Olivier Driot**, the sons of **Jean-Paul Driot**, are the new joint team principals of the Nissan e.dams Formula E team following their father's death in August. As reported in last month's issue, it had already been confirmed that they would take over the hugely successful DAMS single-seater operation, that Driot senior founded over 30 years ago.

Zak Brown, the CEO of McLaren Racing, has tweeted that he has stepped down from his role as a non-executive chairman of Motorsport Network, the media company that has recently been embroiled in controversy after selling off *F1 Racing* to Lifestyle Media and putting the cover price of *Autosport* up to £10.99, as it looks to consolidate its online business. Brown had held the position since 2016.

Dan Burge has been appointed commercial director at technical consultancy Lotus Engineering. Burge has previously worked at Williams Advanced Engineering and Prodrive Automotive Technologies. Prior to joining Lotus Engineering he ran his own technology consultancy.

Liam O'Neil has joined automotive communications specialist Red Marlin as its commercial director. O'Neil comes to the firm from the Advanced Propulsion Centre (APC), while he has also worked at Jaguar Land Rover and has been involved in PR activities for some of the biggest names in motorsport and automotive, including Williams Advanced Engineering, Ferrari, McLaren and Prodrive.

Chris Gabehart, the crew chief on the No.11 Joe Gibbs Racing Toyota in the NASCAR Cup, was fined $10,000 when one lug nut was discovered to be unsafely secured at the Dover International Speedway round of the series.

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

Plugging in to racing tech at the ASI show

With a focus on future technology January's Autosport show is unmissable for those working in the motorsport industry

Formula E will feature at ASI 2020

A core theme of the 30th Autosport International Show will be the future direction of the sport. Formula 1's 70th year will be celebrated with a contest for universities to submit their ideas on what the 2090 season, in another 70 years time, will look like. Could electric racing be dominant? Or will hydrogen or other energy sources take the lead? The results of Autosport's university challenge will be revealed at the show in January.

One of the FIA World Championships that is arguably blazing the trail in new tech is the FIA Formula E championship. In the middle of its 12 city world tour, Formula E will take pride of place at Birmingham's NEC with star cars and drivers promoting the 2020 London ePrix.

The addition of Formula E to the NEC line-up means that four different FIA World Championships will be represented at Autosport International. The WEC will bring virtual World Endurance Championship action to Birmingham with its Esports Series; the World Rally Championship will once again be featured, while 70 years of Formula 1 will be celebrated with cars from each decade on display. These will range from the Maserati 250F of the Stirling Moss and Juan-Manuel Fangio era to the modern-day hybrid technology of Lewis Hamilton's Mercedes.

This line-up will show the incredible technological advances driven by the world's top motorsport engineers, something that is well worth celebrating. Indeed, motorsport's most significant technological developments have included disc brakes, carbon fibre and most recently hybrid power. These technologies have gone on to have a substantial impact on the automotive industry and further afield. Fans will have a chance to have their say on this, nominating the most significant innovation of the 70 years with an online vote called RetroFuture

Fans at ASI will vote for the most influential motorsport technology

Celebrating tech

Autosport International Sales Manager, Andy Stewart, is keen to publicise the impact motorsport has had on the wider society: 'Beyond Formula 1, motorsport has a long tradition of pioneering technology that went on to play an integral role in everyday life and we are privileged to be able to share these stories,' he says. 'Whether it is things that have made us faster, cleaner or safer, many of the great brands and organisations we work with have been pivotal in the development of this technology. Autosport International's RetroFuture campaign will give us a chance to celebrate these contributions.'

After Autosport's committee has decided on the top 10 most influential motorsport technologies, the public vote, across Autosport International's Facebook and Twitter feeds, will give fans the opportunity to vote on what they think is actually the most influential tech.

The results of both the RetroFuture voting and the Autosport 2090 university project will be debated at the new Engineering Business Forum, which will feature keynote speakers, panel discussions and debates on the future of motorsport and how the industry affects day-to-day living. The trade-only Thursday and Friday will host five sessions, entry included with the purchase of a trade badge, starting from 10am on both days.

AUTOSPORT INTERNATIONAL ENGINEERING SHOW

Show information

Opening times

Autosport International opening times: 9am-6pm across both trade (Thursday and Friday) and public days (Saturday and Sunday).

Trade tickets

The trade tickets (Thursday and Friday) cost £27 (per day) with a two-day ticket costing £45. MSA members will be able to purchase a ticket for £22.50 while BRSCC members can attend the trade days for free.

Public tickets

- **Advance public tickets** (Saturday and Sunday) £19 for children (5-16) and £31 for adults.
- **Standard tickets** provide entry to Autosport International and the Performance and Tuning Car Show, plus a seat in the Live Action Arena.
- **Family** (two adult tickets and two child tickets) £84 valid for the Sunday and the Live Action Arena at 10am.
- **Paddock tickets** adults £41, children £29 including Live Action Arena, access to the backstage paddock area in the Live Action Arena and a Paddock guide.
- **VIP tickets** £113 (advance price) include all the perks of the paddock ticket as well as access to VIP Club Lounge, the VIP enclosure in the Live Action Arena, with complimentary refreshments, access to exclusive driver signing sessions in the VIP Lounge, plus a gift bag.

To purchase your tickets and take advantage of Autosport International's 10 per cent ticket offer visit the website: www.autosportinternational.com/tickets/

EXHIBITOR NEWS

Bcomp

Bcomp will be showcasing its natural fibre bodywork, as used by the Four Motors team in VLN, at ASI. 'Like Four Motors, Bcomp is a pioneer in the field of sustainable motorsport – and the goal is to be competitive with those technologies,' says Four Motors CEO Thomas von Lowis. Bcomp uses its award-winning sustainable light-weighting solutions, powerRibs and ampliTex, to replace carbon fibres, meaning the performance of carbon can be matched while reducing the CO_2 footprint by 75 per cent and costs up to 30 per cent. It is also currently the only natural fibre technology used commercially by several brands and racing series, we're told.

Verkline

As racing requires constant progress, always being one step ahead of the competition, Verkline has released the second version of its light tubular subframes for the Nissan GTR R35. The subframes can be used for track racing as well as quarter-mile drag events. Made of T45 steel (stronger than Co-Mo 4130 tubing), this is TIG welded and powder coated, characterised by increased rigidity compared to the factory solution and allowing easier servicing – thanks to better access to the underbody. The subframes are already being used by the fastest GTR R35s in the world, including one drag racing example with 2500bhp!

ASNU

The ASNU Classic GDI system has been designed for comparing injector against injector at a safe operating level and is suitable for use by anyone from apprentice-level mechanics to master level engineers. To enable a safe and easy examination of the injector's performance, the ASNU system runs the injectors at a lower and safer operating fuel pressure of up to a maximum of 10bar. This is because on a vehicle fitted with a GDI system the fuel pressure will operate at a potentially dangerous high level for the inexperienced, reaching anywhere between 75bar up to 200bar on some systems.

Warter Racing

Warter Racing 102 fuel is designed by the makers of Warter aviation fuels, a firm with over 40 years of successful experience in the manufacture of some of the best aircraft fuel in the world.

Warter's racing fuel is a high-octane petrol designed to fulfil a broad spectrum of racing applications and is used in many racing and rallying classes, including the WRC, rallycross and drifting. It is made to conform to the highest quality and performance standards (FIA Appendix J Compliant), yet is also easy on budgets, we're told.

Motordrive Seats

UK based Motordrive was delighted to have been declared the 2019 winner of the prestigious Autosport International Product Showcase Award – a win that followed the short-listing of its MD20 seat for the Professional Motorsport World Expo Technology of the Year award in 2018. With the launch of the MD20, the industry's lightest 6-point mounted FIA 8862-2009 seat, Motordrive claims it had achieved a world first in developing both 4- and 6-point mounted FIA advanced competition seats for race and rally.

The MD20 is now making headlines on the track, including in the British Touring Car Championship, World Rallycross and GT3, where FIA regulations require a 6-point seat going forward. The ultra-lightweight 7.5kg carbon shell of the MD20, along with its energy absorbing foam, personal branding and FIA8862-2009 safety, should make this Motordrive seat appealing to both race teams and drivers alike.

Winter is coming

With dark Brexit-shaped clouds hovering over UK motorsport businesses a visit to Autosport Engineering to meet prospective and current customers will be more vital than ever in January

By GEORGE BOLTON

The Autosport Engineering Show, held in association with *Racecar Engineering*, is gearing up to be one of the most successful in recent years, with advanced bookings up and stand space starting to sell out fast.

The show, part of the wider ASI extravaganza, is the perfect place for the industry to catch up following the Christmas break, and while the world wonders what effect Brexit will have on the UK supply companies that distribute globally, this does not seem to have hit this event's popularity.

At the time of writing, there is still no clear resolution to Brexit. But the UK government has taken out advertising in digital and print media, warning companies to prepare for the event itself, but in truth it will be months, or even years, before the effect is truly felt.

Top: The show is the ideal place to meet new customers and suppliers. Above: Xtrac is one of Motorsport Valley's top exporters

Uncertain times

No one really has a clue what will happen to British motorsport companies bidding for international tenders, but they are readying themselves in case they need to resort to carnets to transport their goods post-agreement; and the same might go for racecars, too. Companies are well able to meet this challenge; they did so before the trade agreements were in place, and so will be able to do so again if the need arises. And when it comes to motorsport companies, then they are far more resilient than most.

Take a UK motorsport company like Gibson, for example, which supplies the engines for LMP2 cars in Europe, Asia and the United States. It is optimistic that any agreement will not adversely affect its bid to win the contract for the next generation LMP2 car, due in 2022. What could affect it, though, would be a change in specification, if there is one, but right now even that has yet to be decided by the FIA and ACO.

Best of British

Gibson is not alone; Hewland and Xtrac both provide gearboxes to the current specification LMP2 cars while other companies use UK wind tunnel facilities and UK teams travel to continental Europe to test.

The Autosport Engineering Show is the third in a series of high-profile trade shows, following on from the PMW Show in Cologne in November, which largely caters for the European industry, and the always impressive PRI Show in December, held in Indianapolis, where more than 3000 stands are occupied over the course of the show – which is later than normal this year, taking place on December 12-14. You can be sure that each of these events will be well attended by British companies looking to continue trading with European and global partners.

The UK's Autosport Engineering show will be the ideal place, at the ideal time, to talk to British companies and see what opportunities remain. And it's clear that there will be opportunities; Brexit will not change that. But what this show offers is a forum in which to discuss how to make the most of any situations that arises. The UK will not lose its capabilities, and British companies that have been chosen to supply international race series will still be able to do so. Let's just hope it doesn't become even more complicated in the future.

The UK will not lose its capabilities and British motorsport companies that have been chosen to supply international race series will still be able to do so

Rocks and hard places

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PIT CREW

Editor
Andrew Cotton
@RacecarEd

Deputy editor
Gemma Hatton
@RacecarEngineer

Chief sub and news editor
Mike Breslin

Art editor
Barbara Stanley

Technical consultant
Peter Wright

Contributors
Bradley Appleton, Mike Blanchet, Ricardo Divila, Simon McBeath, Danny Nowlan, Leigh O'Gorman, Mark Ortiz, Scott Raymond

Photography
James Moy, Shimpei Suzuki, IMechE

Managing Director
Steve Ross **Tel** +44 (0) 20 7349 3730
Email steve.ross@chelseamagazines.com

Sales Director
Cameron Hay **Tel** +44 (0) 20 7349 3700
Email cameron.hay@chelseamagazines.com

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

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

Publisher Simon Temlett

Chief Operating Officer Kevin Petley

Managing director Paul Dobson

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

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

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News that Dyson had stopped work on its electric car hit the paddock in Road Atlanta mid-October, and immediately the alarm bells started to ring. There was a lot of racing know-how going into that car, yet the company decided that it was not going to make the money it needed to. The electric market will not sustain new companies such as Dyson as the competition hots up quicker than demand. Major car makers are pushing electric mobility now, and are shoving the smaller companies aside with ever-more appetising cars hitting the market.

Governments forced car manufacturers down a particular path, with zero emission at the exhaust cars, having dictated that the fleet average for a manufacturer should be 95g/km of carbon dioxide, or better. Manufacturers had no option but to pursue these policies to meet these stringent regulations. Car companies were forced to build what equated to (by regulation) zero emission cars to off-set their higher-polluting cars. The fact that only one part of the entire cycle was regulated, the running of the car, was immaterial to the target-driven politicians who have glossed over the energy required to build new cars and new batteries. Spying a possible business opportunity, companies such as Google, Apple and Dyson tried to pounce on an opportunity.

If the take up of electric cars is not there to sustain the investment from such companies, it must be considered that manufacturers may not sell the vast numbers of electric vehicles that they predicted in order to cover their development costs. It's pretty common to over-egg the pudding when it comes to predicted sales afterall. What happens to their profits when it comes to paying the fines for exceeding the prescribed CO_2 limit? Will car makers stop manufacturing the sports cars and SUVs in order to balance the environmental books, or press on and pay it?

There are signs that the trend for electric mobility is slowing, particularly in the major Chinese market

Should they pay fines, the knock-on effect into manufacturer motorsport will be felt, not least in endurance racing paddocks. As the WEC looks to launch new Hypercar regulations in 2020, it is looking for manufacturer involvement but finding it hard to get commitment. Committed are Toyota, and an essentially privately-funded Aston Martin Valkyrie, but there are no new contenders. McLaren confirmed that it is not coming, preferring instead to build up its customer and support bases for GT3 and GT4. With F1, IndyCar, customer racing and road cars, hypercar was considered a step too far. Porsche and Ferrari have both said no, and none of the VAG companies are likely to step into such a formula as it stands.

There are options to expand the scope of the regulations to include high-performance cars, such as the IMSA DPi, and DTM cars. They could run in separate classes - Le Mans has done that before - but this is will have to wait as the bodies wrestle with the details of the rules they have in their hands.

The IMSA paddock is looking to introduce new regulations, in 2022, and is considering a hybrid system to be introduced onto an LMP2 base car. I understood that all the usual suspects were involved in pitching for the spec system, and that IMSA and NASCAR are both looking at sharing the basic technology. According to one of the companies pitching for this, the crossover is critical as they would not be able to make a business case if only IMSA adopted it.

But IMSA is facing another problem, one that has often been seen in racing; next year it will lose five cars for a variety of reasons. The Ford GT programme has now finished, and the racecars have not yet been sold to customers. Action Express is dropping to one Cadillac; Core Autosport ended its DPi programme, and Ben Keating ended his IMSA career at the Petit Le Mans, switching to the WEC. IMSA now has three privateer cars in its DPi category on its grid for next year, and the team behind one of those was highly concerned at the ever rising costs involved in going racing. The series has options; it can better promote the LMP2 category for privateers, but it is a tough time to introduce new regulations and hybrid technology.

IMSA has to face the reality that if it chases manufacturers, it could in this economic climate be on a hiding to nothing. If it looks after the privateers, there is every chance that it will be running irrelevant technology by the end of the rule cycle at the end of 2026. It's a rock and a hard place, not only for them, but also for other racing series considering such technologies.

It could be that only the major manufacturers and early adopters such as Tesla can make full electric successful, but there are signs that the trend for electric and hybrid mobility is slowing, particularly in the major Chinese market.

Dyson stopping his programme does not change much in the industry, but the question has to be asked about the future of electric mobility. Coupled with the predicted global recession, is it now time to consider the possibility that the electric and hybrid bubble will burst, and start putting more effort into other sources of powering our automobiles, while reducing costs in racing by not introducing such technology?

ANDREW COTTON Editor