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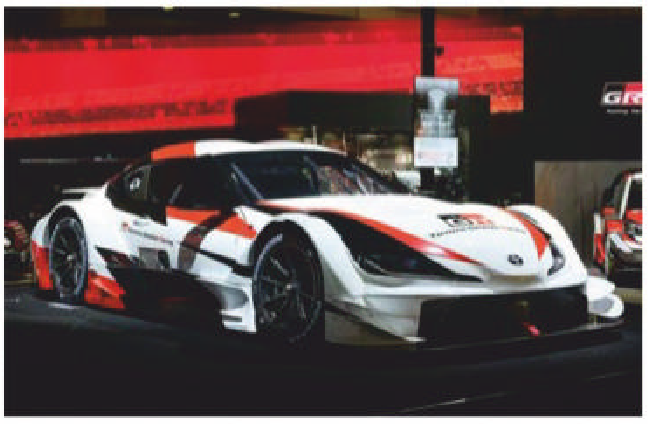

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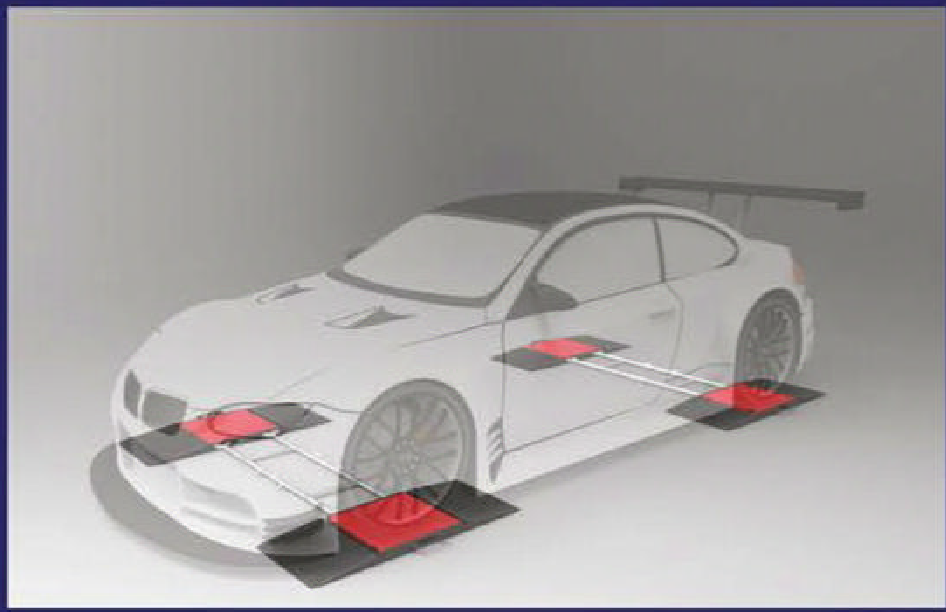



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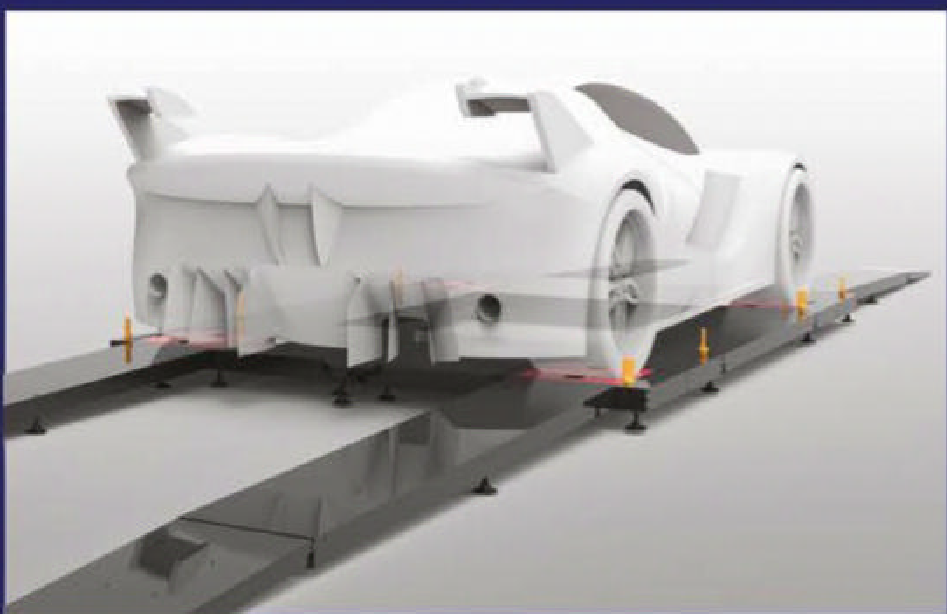





RL

Lost in translation

Why a good grasp of foreign languages is a very useful tool for the race engineer

English has become the lingua franca of the world, something probably related to the spread of the British Empire, then with the American move to hegemony in a polarised post-war world. In racing there is no escaping English, as the sport's official language, too.

Even the FIA, a French-heavy ruling body, bowed to this in writing the technical and sporting regulations for racing in English – those used for final arbitration – due to the number of British F1 teams, who brought all their lobbying efforts to bear to ensure this was the case.

Up until then I had successfully used my knowledge of the French version to open up loopholes to be exploited, and some years ago it was most entertaining to see Peter Warr and John Surtees at a Brazilian GP scrutineering, purple faced and frothing at the mouth after protesting one of my interpretations and being told: 'The French version is final'.

Talk the torque

During my early days in Japan, when I was still trying to learn the language, the team thought I actually did understand it well, for I could follow any technical discussion quite easily, as all the jargon terms were in English. After all, when the subject of car handling is being discussed the phrase '*Chotto* understeer, *tabun* front camber *matawa katai* rear bar *yoku narimasu*,' is practically self-explanatory, if you grasp the basics of vehicle dynamics.

English does have several advantages, too; like German it is concise and to the point, for no known historical reason, it just is. As proof, look at the FIA Regulations themselves, the English version being several pages shorter than the French, and more concrete in its definitions.

When trying to describe a permitted action English is quite precise, whereas in the Romance languages you have to put fences around the definition stating 'X is not permitted, neither is Y or Z. And no, neither is W', to corral the thrust of the regulation. The phrase 'anything not explicitly authorised is forbidden' is a stop to that problem, and sounds awkward in English, but makes complete sense in the looser languages.

Having often been in meetings with French, Italian, Brazilian and Spanish native speakers who also spoke English in a discussion with a Brit, I often had to interject the caveat 'What he really means is (explanation)' when I could see the looming misunderstanding. It could become rather contentious later if it involved money.

There were even more awkward moments when doing direct translation when the interlocutor didn't speak English at all. He rambled on for a couple of minutes, me doing a question in a short burst, getting the compact answer, then speaking for several minutes to convey the same information. This, of course, left the Anglophones thinking that I was either making things up or not translating everything, and the others confused at the shortness of the answer they heard in English compared to their translation.

The whole issue is the reason for the European epithet 'Perfidious Albion', resulting from all the treaties and business deals done in the past, both sides having proclaimed their bona fides, but tripping over the perceived meaning.

Motor racing is very good at communicating clearly when it needs to, but in a global sport the language barrier can cause problems

Likewise the Brits view all other nationalities darkly, muttering that they 'don't do whatever they have agreed to', when really it is just different ways of understanding words or phrases. It could conceivably have led to the dreaded 'B' word that is convulsing the UK now, but we will not go there.

Bad language

The Sapir-Whorf hypothesis of linguistic relativity holds that the structure of a language affects its speakers' *world view* or *cognition*. It hasn't been formally adopted, but we can see its thrust in examples like Orwell's Newspeak in the seminal novel, 1984. It is where not having the words, and thus the concepts, would make it impossible for people to think critically about the government, or even to contemplate that they might be impoverished or oppressed, by reducing the number of words to reduce the thoughts of the person. In other words 'we shape our tools then they shape us'. Language is a tool.

Speaking in tongues

Technical meetings at the FIA were even more entertaining on the endurance side, as most of the participants used the common English to adjudicate and decide where to go to in future rules, but were then using a second language otherwise. Hearing the muttered discussions in French, Italian or German of the relevant representatives on the sidelines when debating a point could be surreal.

We will not even go into the attempts to translate the proceedings into Japanese for my erstwhile employer. The use of the word 'Hai' (Yes) in Japanese does not mean agreement, not even 'I understand', but merely 'I have heard'.

Having acquired 11 languages of different roots; English from my mother, Portuguese from the environment (Brazil) and Czech, this gave a good base for other Anglo-Saxon, Slav and Romance languages, plus nine years of Latin at school led to an ease in learning them.

I had thought that comprehension was a given, until a completely non-western language thought process derailed my cortex. It's more complicated than we think.

Ludwig Wittgenstein's dictum 'if a lion could talk, we should not be able to understand him', means that the language games of lions are too different from our own to permit understanding. There is something in this theory.

This will lead to different interpretations; after all, we see the same thing even in the thought patterns of common language speakers of different political leanings. Throw in words with different linguistic roots and it will be chaos.

Taking all this into consideration – plus the fact that we don't even have a common electrical plug all over the world, each nation having its own preferred version – I cannot help but postulate that Shakespeare's 'confusion hath made it's masterpiece' will continue to flourish, and not only in the world of motor racing.

The phrase 'anything not explicitly authorised is forbidden' sounds awkward in English, but makes complete sense in some other languages

Once upon a time in the ouest

Should the ACO be looking to its glorious past for an answer to its hypercar conundrum?

The ACO has, with the FIA, and both with the best of intentions, got itself in a terrible tangle over the impending new regulations for its top Le Mans class. First it planned a pure 'hypercar' concept – purpose-built hybrid racing cars that just made styling and brand reference to road-going high-performance vehicles – but reality has dictated a compromise.

Now the plan is to allow the reverse of this (road-going hypercars modified for racing) to participate on so-called equalised terms with the dedicated race-designed machines. Neither now, apparently, have to be hybrids.

This immediately introduces the prospect, much-hated by many – myself included – of balance of performance, to which Vincent Beaumesnil of the ACO has already alluded. Moveable aero devices have gone, too, and on top of this is an increase in weight and also an increase in the target lap time at Le Mans, which brings these hypercars perilously close to LMP2 (the class meant for privateers) in lap times. Slowing LMP2 cars down significantly then brings knock-on problems with GT cars being faster on the straights and difficult to overtake, the reason why LMP2 performance was itself boosted not long ago.

Agenda bender

These shifting sands are largely the result of feedback from manufacturers, some already competing, others maybe just along for the ride, which indicates that the proposed likely budgets of €15m to €20m are still too rich for their palates. In trying to please everyone, the rule-makers are already in to the territory of pleasing nobody. It's right to listen to the competitors, serious or just flirting, but easy to fall into the trap of letting the inmates run the asylum, as has been the case for too long in Formula 1. Interested parties will almost always have their own particular, advantageous agenda in mind, rather than the greater good. Sorting through this kind of stuff and picking out the wheat from the chaff is what rule-makers need to do.

I feel for the ACO in several of the difficulties that it faces. The importance of the participation of manufacturers to the club – which it must be remembered is exactly that – should not be underestimated. Apart from the obvious benefit of an increase in paying spectators from having prestigious and exciting marques on the grid, income from expenditure by these corporate giants on paddock hospitality, merchandising concessions, VIP grandstand facilities and the myriad other ways in which the ACO can persuade them to part with their marketing dollars is very important to it in terms of surviving and being able to invest in continual improvements.

Against that is the ACO's awareness that it needs, as always, to retain a healthy privateer grid. To do so, there is the conundrum of providing sufficient opportunity for the independents to have a chance, at least, of getting on the podium overall, while giving the manufacturers the confidence that they won't be humiliated by an outfit spending a fraction of its budget. Solving such a tricky problem is not easy.

XPB

Could the approach taken with cars like the Porsche 917, where some were sold to privateers, work now? The ACO actually owns this example

There is also the FIA and ACO's obsession with relevance to production-car technology, most obviously the incorporation of very complex, extremely powerful electric hybrid powertrains allied to 4wd motivation. DTM, Super GT, Super Formula, IndyCar, IMSA DPi and NASCAR all run successfully and with the support of major automotive corporations with conventional ICE and 2wd. This also puts the lie to the oft-quoted pronouncements that manufacturers are only interested now in expending money on racing programmes if there is a link, however notional, to EVs. Giving exposure, credibility and prestige to the brand is still what matters, more than a connection with an electric power source. There is Formula E for this, after all, and other EV series no doubt still to come. But the ever-improving internal combustion engine still has a lot of innovative life in it. In its latest iteration of the regulations, the ACO seems at last to be acknowledging this.

Back to the future deux

But here's a thought. Retract and simplify. Take two issues – cost and giving privateers a chance. Way back when Porsche (917) and Ferrari (512) battled in Group 4, the requirement for a minimum number of homologated cars to be built (then 25) led to the great advantage that privateer teams could acquire and run them, often with great success, even against the works cars.

Complexity and cost are at a different level now, but as part of bringing these back into the real world, what if it was a condition of entry for the WEC/Le Mans that a minimum, say, of six hypercars, identical and in addition to those entered by any works team, have to be built and made available at a fixed price to independents? This would apply whether or not they were road-derived, rather than 20 minimum of the latter only (as recently proposed).

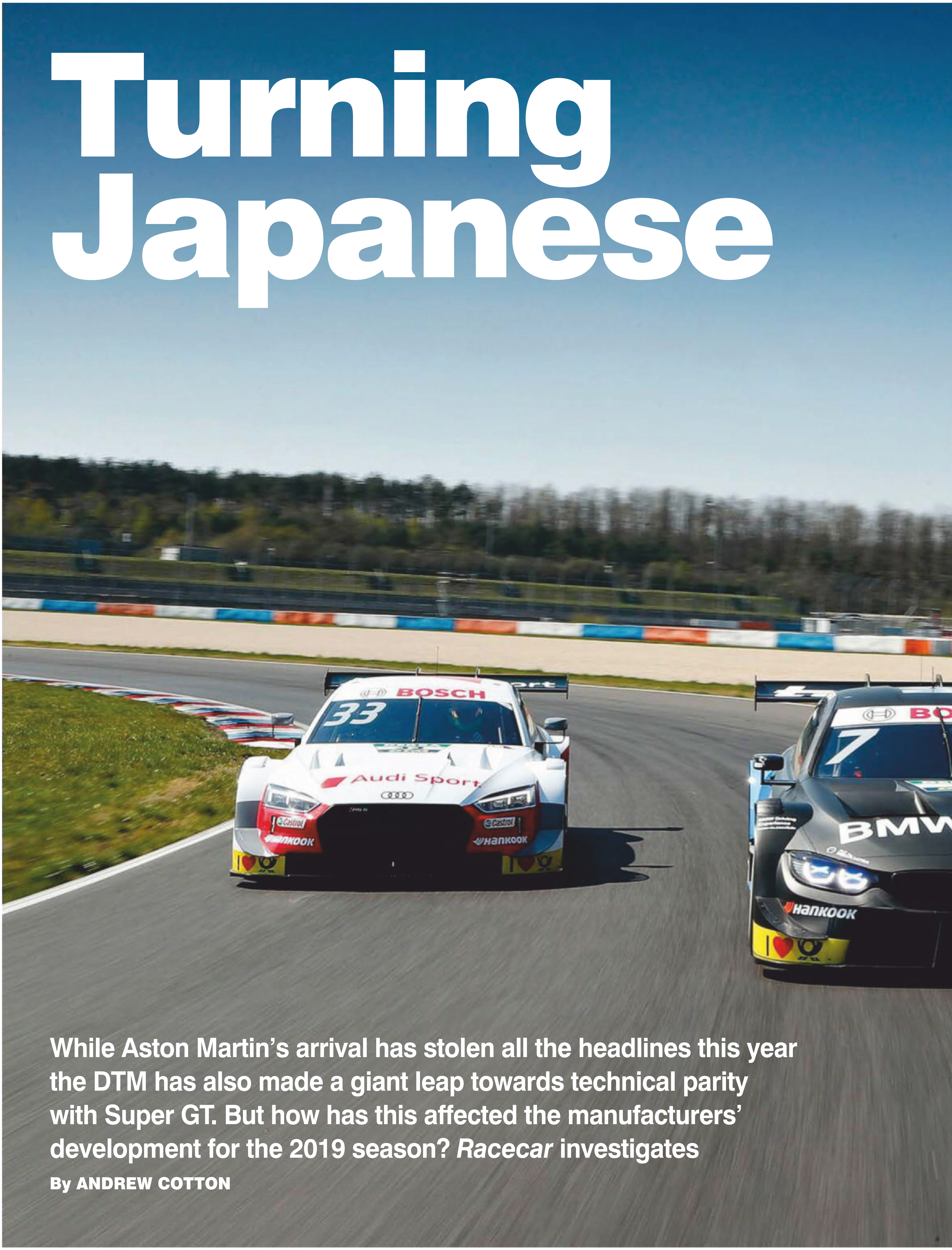
Part of the deal would be that the car and engine must be capable of being run by using no more personnel than a typical LMP2 team requires and to an overall budget limit. Restrict the number of data-recording channels permitted and rule that the power unit must be able to be fired up by the driver, in the cockpit, with just one additional team member assisting. This should also result in more robust, simpler and less expensive chassis/PU being designed and built, allowing privateer teams to compete with works teams.

The latter should always have an advantage in resources away from the track and in hiring the best drivers and team members and so on, but not an overwhelming one. In any case, it gives the car manufacturer added opportunities of winning; if an independent team is victorious with one of its racecars, it still enhances the brand.

This doesn't address the matter of trying to equalise different types of hybrid and other attempts at squaring the circle, but it might just be a start in unravelling the puzzle.

Part of the deal would be that the car and engine must be capable of being run using no more personnel than a typical LMP2 team requires

Turning Japanese



While Aston Martin's arrival has stolen all the headlines this year the DTM has also made a giant leap towards technical parity with Super GT. But how has this affected the manufacturers' development for the 2019 season? *Racecar* investigates

By ANDREW COTTON

The DTM has finally brought its engine, chassis and aero regulations within touching distance of the Japanese Super GT GT500 rule set, which before too long should see the likes of Audi, BMW and newcomer Aston Martin lining up to take on Super GT stalwarts Toyota, Nissan and Honda, if only in standalone events to begin with later this year. It's a mouth-watering prospect.

But the DTM has had to make some major changes to bring this about. This includes the new 2-litre, 4-cylinder turbo engine, which has meant the weight has gone down by around 35kg due to the new architecture, with a reduction of 50kg overall in the minimum weight of the car – now 986kg without the driver. A fuel restrictor, rather than a flow meter for the engine, has also been introduced.

The cars have more power, more torque, and more overtaking devices than in 2018, yet there is only limited scope for development around other affected areas, such as the front brakes, which could take a beating at some tracks.

Meanwhile, a wealth of aero changes have been introduced based on the Japanese regulations, including a new front splitter, floor, rear diffuser and a single plane rear wing; although typically there are still differences between the two that have yet to be resolved. For instance, at the last minute the DTM regulators decided to keep the DRS system that is unique to the German series, and also introduced a push to pass function.

All that said, there is no doubt that the regulations are close enough that the cars can run on track in competition, and that will happen at two events at the tail end of the year at Hockenheim (where three Super GT cars will be guest entries) and then at Fuji.

‘There is nothing we will not be able to deal with by just reducing the life-time of the parts and changing them earlier than in the past’

Implementing these changes was not without its issues for the manufacturers involved in the DTM, though. Audi, BMW and Aston Martin had major obstacles to overcome with the installation of the engine, and also with protecting other parts of the car from the vibrations generated by the new 4-cylinder unit. The cooling requirements for the turbocharged engine also had to change from last year’s V8 while, interestingly, the three manufacturers have opted for different layouts; two longitudinal, the other transverse, which has led to subtle differences in aero requirements.

Four-sight

To begin with the engines, the introduction of the new 4-cylinder units was a major headache for Audi, as was detailed in last month’s *Racecar Engineering* (V29N5). Vibration issues damaged its dynos in the early stages of development and it had to work hard to reduce the impact of that before it ran the engine in a car.

‘In our old WEC times [with its LMP1] we could do 32-hour endurance runs, but this is not foreseen in the DTM regulations,’ says Alex Loffler, head of Design, Chassis, Bodywork, and Aerodynamics at Audi Sport. ‘We couldn’t really test the car as we would have wanted with the new engine on track, so there may still be some fatigue and lifetime issues.

‘We haven’t sorted out everything completely but step by step we are getting there,’ Loffler adds. ‘When you fix the propshaft, the next item in the chain is the clutch, and then the gearbox. There is nothing we will not be able to deal with by just reducing the life-time of the components and changing them earlier than in the past, but this engine is very demanding. We had one occasion where, because we didn’t have a new component, we had to put in a V8 propshaft and it blew up into pieces. There was not one piece left of it that was larger than 100mm in length and 10mm in width. It took just a second for it to break.’

Bad vibrations

BMW had a slightly easier time of it, having run the 4-cylinder engine in the E30 M3 that raced in the old-style DTM. ‘We knew what we were facing, and there are two components,’ says Rudi Dittrich, general manager vehicle development for BMW’s DTM team. ‘One is the torsional vibration, the other is vertical vibration because your cylinders are all aligned vertically. For the torsional one you are allowed to have a torsional damper and we have experience in how to build one of those and it was quite successful. For the vertical ones, it is an integration topic, where you need to do your homework. You cannot calculate everything, that’s why you go testing, and we identified a few smaller areas where we needed to change it, but that is a normal development process and nothing dramatic.’

The weight of the engine was not so much of an issue for BMW, but Audi pushed the weight distribution forward by changing the material and thickness of the front bulkhead, which also increased the torsional stiffness of the chassis. ‘The steel subframe is the same as on the V8, the bulkhead is new,’ says Loffler. ‘This links the steel subframes left and right and the engine together, and that is now like the DTM cars from 2003-2011. If you look at the old cars, the new bulkhead looks very much the same. In the old days you could do it in carbon and make it nice and light, but now it is metallic.’

For Aston Martin, the HWA-developed engine was not a problem on the dynos, but integrating the unit into the chassis has been less straightforward. ‘Regarding the vibration on the rigs, we had nearly no problems but when we first ran the cars we had some issues,’ says HWA’s technical director Hubert Huger. ‘We used a mass damper [to help], but it is not finished. On the test rigs we were quite okay. In the car, it is not the engine, it is the engine environment.’

With the chassis fundamentally remaining the same, the engineers had to work on integrating the completely different size of engine in the space where a normally aspirated V8 used to sit. The chassis mounting points remained the same for the subframes and engine, which meant that adaptations had to be done to hang the engine properly.

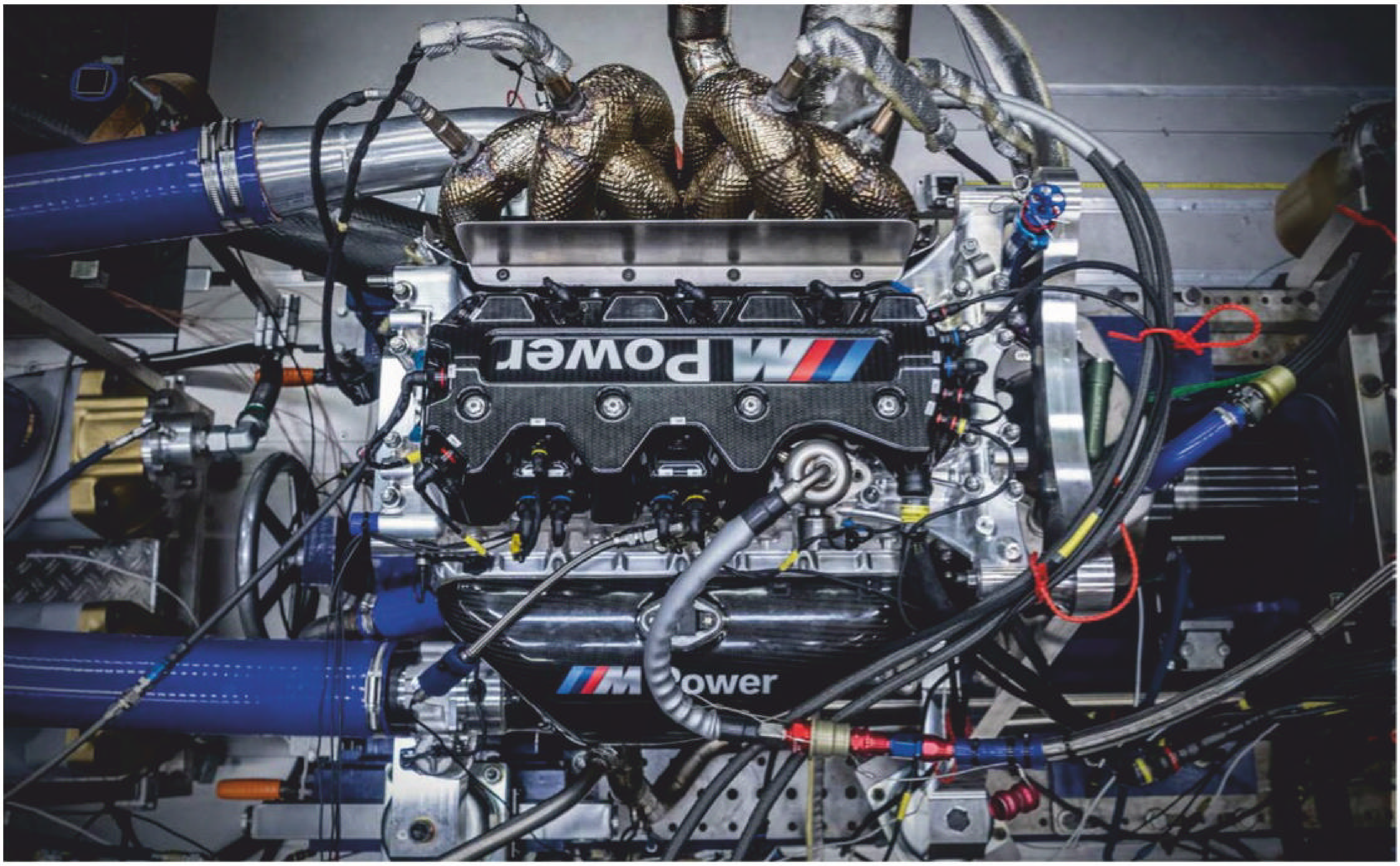
‘If you take out the V8 and stick in a rectangular brick like a 4-cylinder [you lose] a lot of torsional stiffness, so we tried to gain that back by having a special bulkhead in front of the engine,’ says Loffler. ‘The weight distribution, you have ballast weight and you place it where is best for you. The tendency was to put it more to the front, and that is true for this car as well, especially because with the higher engine power the rear tyres are stressed more than they were before. It is clear that you try to reduce the load on them and one possibility that you have is to move the weight to the front. The crash area, the lower part that feeds the crash load into the engine and into the monocoque, and the upper part where the steering and upper wishbone is attached, is completely new.’

Audi will continue to campaign its RS5 but under the skin there are many changes thanks to the DTM’s push for parity with GT500; chief amongst these is a new 4-cylinder engine

The big news for 2019 is the arrival of Aston Martin. Its Vantage will fill the vacuum created by the departure of long-time DTM entrant Mercedes at the end of last year

BMW sticks with its M4 for 2019. The new DTM car is 50kg lighter than the 2018 V8-engined version

‘If you take out the V8 engine and then stick in a rectangular brick like a 4-cylinder then you lose a lot of torsional stiffness’



BMW's new 4-cylinder DTM unit on the dyno. While Audi had some dramatic problems with vibrations in engine testing BMW was able to make use of previous four-pot experience

BMW says that it made the most of the opportunity to do something different with the mounting of the engine. 'We have used our latest tools in terms of generative design to come up with a good solution to not see it as a problem to have a 4-cylinder for a V8 compartment, but try to take advantage of the space that we have and make the best out of it,' says Dittrich. 'The front support structure and framing is good. The top part that is mounted to the monocoque is unchanged, and you had to take the mounting points with the remaining structure and build your front end from there.'

Tyre issues

Even though the engines are now alike there are still differences between the Japanese and the German versions of the cars, and the most obvious of those is the fact that the Japanese still have an on-going tyre war to keep their rubber engineers occupied, while the DTM retains the standard Hankook tyre which continues its relationship with the DTM for a ninth year. The Hankook tyres are actually unchanged compared to last year, despite the completely new aero package and weight distribution, so the way that the tyres are used has also had to be re-analysed in conjunction with the Japanese-related aero package.

'We have changed the front splitter, the floor, the rear wing to obviously converge to Class 1, so that means the aero has changed, and you cannot really compare the 2018 and 2019 car anymore, and you don't necessarily want to run them in the same way,' explains Dittrich. 'We took a blank sheet of paper, and said what does this car need, and how do we want to operate it? That then gives you a set of parameters where you want to end up with the car.

'We haven't added 35kg of ballast to the engine to copy what we had last year as the minimum weight of the cars is reduced as well, so you don't have 35kg of extra ballast in the car,' Dittrich adds. 'The front tyres have not changed but you have to look at it. Physically they are the same, but the way you use them is not the same. You have 100bhp more on the rear axle, so you also approach your corner with 20km/h more, so your braking power is different and so on. It is not a copy and paste job. You have to start from scratch and analyse what it is; how is the car being operated, what is your speed profile, what is your acceleration, how the energy is distributed, and you take it from there. To balance the car you have more parameters, so you have aero, weight distribution and mechanical balance and you need to get it all to work and make a concept out of that.'

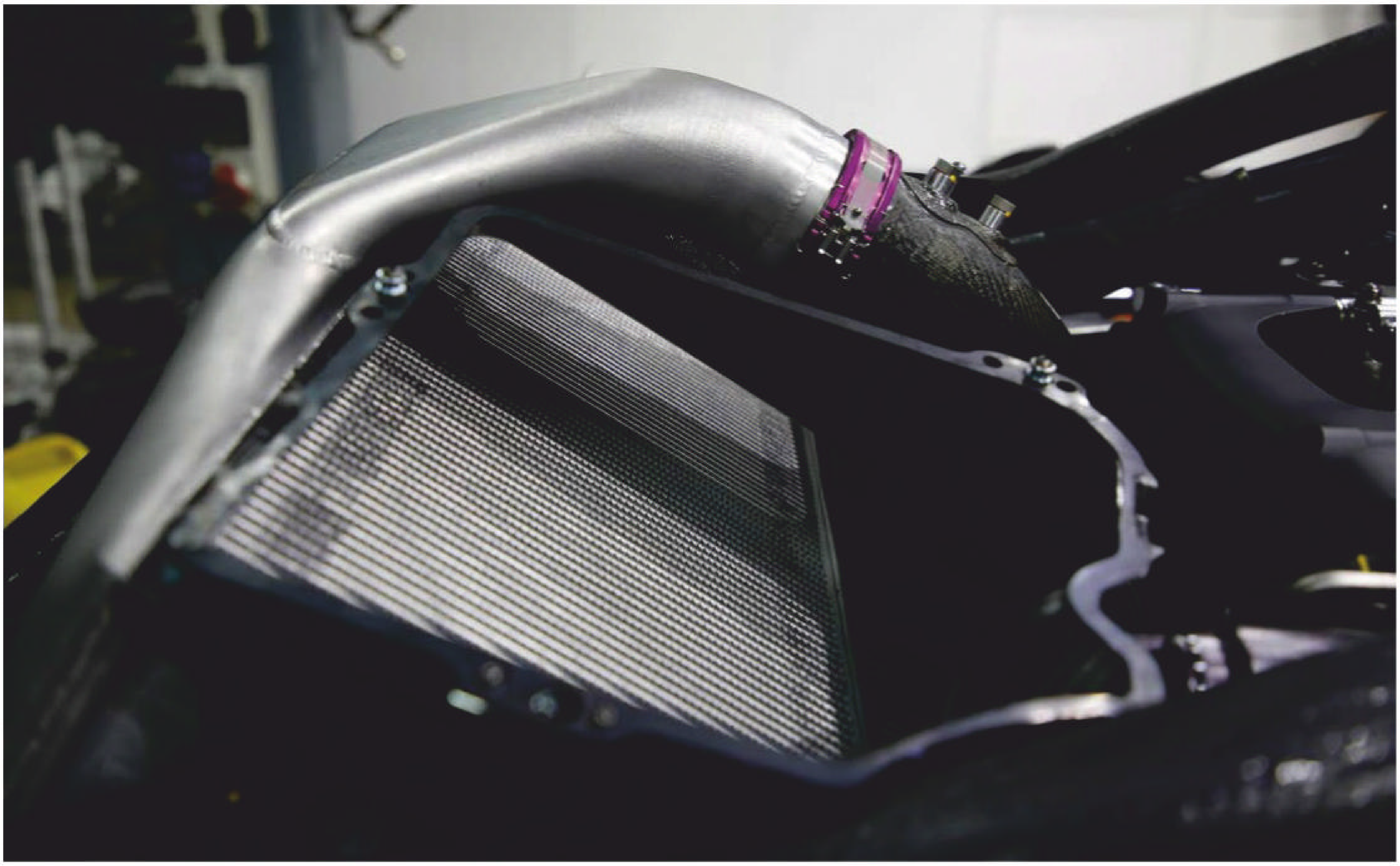
The mounting point for the front suspension is new, but the wishbones, uprights and damper location are all the same, so any room for manoeuvre is limited around how the manufacturers' front suspension kinematics can be modified. This was perhaps deliberate on the part of the DTM regulators as they did not want there to be big changes to components that could be carried over, thereby saving cost.

Brake test

The front brakes are going to take a battering on certain circuits, leading the DTM brake constructor AP Racing to produce a new front disc to help with the cooling. 'We are quite fine with the brakes,' says Huger. 'We ran the car in Estoril in 25degC, although it is not the most dependent track for brakes. DTM is looking for one special front brake disc for a few races from AP Racing, just for the front and we will run this at Norisring and Zolder. We tested it, and the cooling down time is a lot better. Maybe we run this disc in Hockenheim; each manufacturer has one set of discs per car.'

The front wheel arch is a common part, and even the area of transition from this to the manufacturer's bodywork is tightly regulated, to ensure that no one manufacturer finds a loophole to exploit. Even the wheels are a

'We took a blank sheet of paper and said what does this racecar really need and how do we want to operate it?'



BMW worked hard on the cooling package to deal with the heat generated by the turbo. Because of the intercooler the engine bay remains crowded, despite the smaller engine

The front splitter is shorter than in 2018 which is likely to change the pitch sensitivity of the cars

Provision for extra cooling is most evident on the bonnet. This is Audi's approach

common part. 'Now it is more important that you have an aero map that covers all positions of the car that you will find out on track and to know the behaviour of the car in all conditions and get the most out of it, that is the most important [thing] with all the regulated common aero geometries,' says Loffler.

Clipped wings

The new aero parts were not intended to add downforce to the cars, and so with a reduction in minimum weight of 50kg, more powerful engines and the less potent aerodynamics, the way that the DTM cars create their speed will change subtly for this season.

The front splitter, for example, is shorter than in 2018, which will change the pitch sensitivity of the cars, as will the shallower rear diffuser. However, the biggest change comes from the cooling requirements of the engine, and here BMW believes that it has made a huge gain compared to 2018. 'Regarding the cooling there are two aspects,' Dittrich says. 'One is you add 100bhp so that in itself would require more cooling, but the engine efficiency increased quite a bit so that the water cooling associated [with that increase in horsepower] was not proportionally increased. You do have additional need for an intercooler, so the front end, despite the engine being quite a bit smaller, is quite busy and crowded, and from the outside you mainly see the inlets and outlets of the ducts. Almost the entire bonnet is an outlet now, so that should tell you what is going on and therefore packaging that is not a straightforward job.

'How we split the outlet ducts, the Audi has gone for longitudinal split, us lateral,' Dietrich adds. 'We have analysed what the engine needs, where the sensitive areas are, where we want to operate it, and with the packaging we wanted, and you get the layout driven by the aero. You still have options, but with constraints you have made before, the aero tells you how to integrate it for the most efficient package.'

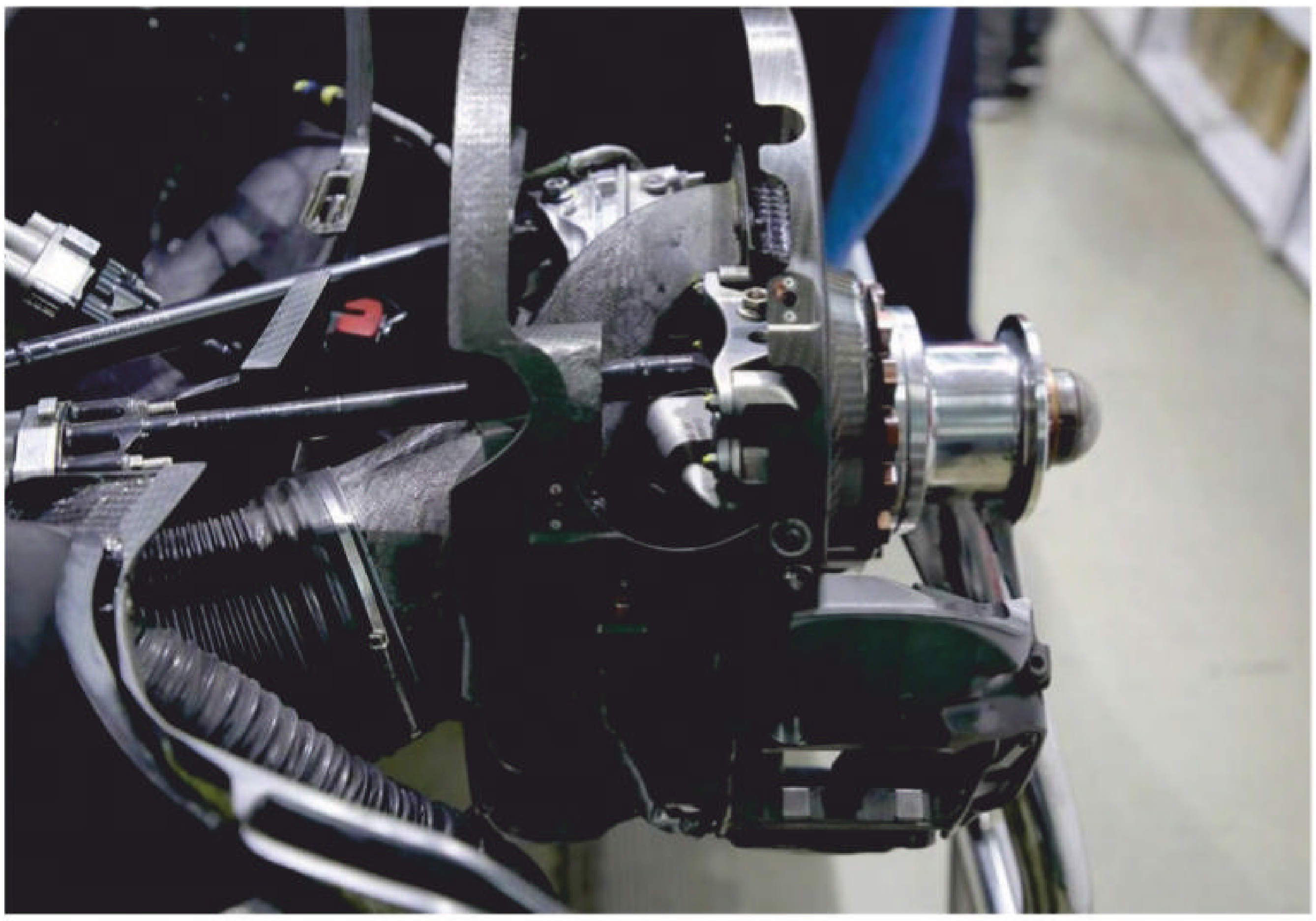
For this season the DTM cars are running with a shallower rear diffuser but the big aero talking point at the back of the car is the decision to run with DRS. There is also a new floor

'The cars are not as aggressive aerodynamically as they were a few years ago'

Huger agrees: 'I was surprised at the efficiency of the engine,' he says. 'It is quite good, so with the horsepower increase there is no linear increase in terms of water jacket, although the turbo is quite challenging to bring to the front of the car with the hotter temperatures.'

Hot stuff

It is not just the engine that requires a larger cooling package. Other hardware is also likely to suffer and the design teams were slightly restricted by the fact that some of them are common parts. 'With the higher performance of the car we need quite a bit of brake cooling, but we were not allowed to touch the common parts on the brake duct that is attached to the upright,' says Loffler. 'We could only change the parts in front, and on top. Because the exhaust system is getting quite hot you have to ventilate that too, and because the damper on the side where the turbo sits gets hot as well, that needs more attention to keep it at a half decent temperature. Getting the most out of it, you have to play a couple of iterations [and see] if it is better to send more air through, or have bigger intercoolers and send less air through, and then play with the pressure loss through the cores. That gives you an optimum.'



BMW front suspension. Upper and lower wishbones, uprights and damper locations are all carried over from last year

DRS to impress

One of the late changes to the regulations was the decision to keep DRS. Although this has been standard in the DTM for some time, there was a plan to drop it and run the rear wings as per Super GT regulations. However, organisers had a change of heart, and this has now opened up even more overtaking opportunities. 'It was introduced relatively late, so by the time the majority of the conceptual work was done, and maybe that was also the purpose, to prevent people from doing clever designs that are tailored for a DRS system,' says Dittrich. 'It is fairly straightforward. We know how it affects the car, but the cars are not as aggressive aerodynamically as they were a few years ago. Technically, it is not a problem to add it to the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'We proved that we could have a T-bone crash with this car, and in the racecar that was hit the survival cell was still intact'

car, and you determine your deltas and the effects and then you just continue.'

To further enhance the overtaking opportunities in the series there is also a push to pass. 'Regarding push to pass, it works very differently,' Dittrich says. 'The push to pass is an increase in the engine power, which is a major impact early on the straight or on a short straight, so when you are slow. That is when the delta in power is most effective.

'With DRS it is the complete opposite,' Dietrich adds. 'The DRS becomes more powerful as you go quicker, so it is more powerful on the longer straights, so you could say that the two working together, the push to pass early on the straight and the DRS later, or in different segments of the track for different purposes, can make it more interesting. Also, because the rear wing is not as aggressive anymore, you want to have a certain delta distance that you can create with DRS, otherwise it is for nothing.'

Pass notes

Clearly the plan is to keep DRS for a further year, and Audi can see that this will be one of the major areas of development. 'It was said that no one wants to have the DRS, but then they were a bit concerned that overtaking will be difficult, so it was re-introduced at a very late stage,' says Loffler. But it does put the DTM aero in a slightly different position to Super GT, which does not run DRS. 'It could be better,' admits Loffler. 'The regulations were supposed to make it as close as possible [with Super GT], so that if they go with us they don't have to change anything, but it is still not completely harmonised.'

For Huger, the majority of overtaking was done with DRS, and so it was logical to keep it. 'The first goal was to have the same rules as Class 1, but we changed our opinion because we were afraid of a non-overtaking situation, so we pushed for the DRS,' he says. 'The push to pass, the Japanese tested it once, and from my point of view it adds something.'

Crash tested

On the safety side, the crash structure of the DTM cars has been extensively tested with big accidents from which drivers have walked away. Mike Rockenfeller sustained nothing more than a broken metatarsal in his foot having been hit heavily by Gary Paffett's out of control Mercedes at the Norisring in 2017. It was a huge impact but the car stood up to it well. There was therefore no reason to change the design of the monocoque, but there have been changes to how it has been manufactured in order to cope with the increased heat of the turbo engine.

'The new monocoques will have a different resin system, since the old resin was a bit low [tolerance] for the heat that could be produced by this engine,' says Loffler. 'We have, for example, the manifold that is completely encapsulated, and you have some air flow through this area to have as minimum heat flow from the hot engine or exhaust into the monocoque or the driver. We changed the resin system, which will make it much easier for us to repair the monocoque and to cope with the higher temperatures. The moulds are the same, the layup is the same. The crash we had with Paffett against Rockenfeller in Norisring, it showed that the monocoque safety features are up to date. We proved that we could do a T-bone crash with this car, and in the T-boned car the survival cell was still intact.'

So, while the 2019 DTM racecars may look similar externally to their 2018 forebears, under the skin there have been a great number of changes, and some of those, such as retaining DRS, have come at the last minute. There is still a gap between the Japanese and the German regulations, but the DTM has taken a large step towards integration, and brought within reach the prospect of a World Cup with six manufacturers competing. Only when the two sets of cars meet at the end of the year, in Germany and then in Japan, will we know just how close the cars from the two top touring car series really are in terms of pace.

Late developer

One of the more obvious changes in the DTM this year is the arrival of Aston Martin, which has stepped in to fill the void left by Mercedes' departure at the end of the 2018 season. The car is based on the Vantage, but a late decision on rubber-stamping the programme left the team with very little time to prepare, and the outfit that's running the DTM car, R-Motorsport (which is developing the Aston Martin in conjunction with ex-Mercedes team HWA) now says that it is behind schedule in terms of the ideal development time-frame ahead of the first race of the year.

'The development team received the confirmation of the project late, and only started development work on October 22,' says HWA's technical director Hubert Huger. 'They had 85 days to prepare the car for the track, and although the engine development work had started in summer, they still had to build a full-scale car along with a wind tunnel model at the same time, while also completing a lot of CFD work.'

This aero development of the Aston Martin was not easy, as the shape of the basic Vantage did not fit with the profile of the DTM cars. 'The Vantage is quite short and quite wide compared to what we had,' says Huger. 'Therefore we scaled the car in [the] longitudinal [plane] quite a lot and had to scale it down in the y-direction [vertically], so the first impression of the car was that it looks different, but there was no other way, [as] we have no special rule to integrate the Aston Martin into the DTM regulations.'

The team says that it started initial design work just as others were doing their shakedowns. However, while this is a new project, from a clean sheet of paper, the performance differences between the manufacturers may not all be technically-related. 'The rear tyres are stressed more, and what we could see is that you can destroy the tyres in 10 to 12 laps, but in the same set-up you can run the car for 25 laps, so it is up to the driver and driving style,' says Huger. 'It is not a secret to push the weight distribution more to the front, you can work with the differential of course, but everyone has to deal with this. A lot of it is driver related. When Rene Rast joined the category, it was unbelievable how he could treat his tyres. Even his colleagues from Audi were unable to copy his driving style. They had all the data and even then they are not able to drive the same.'

The Aston Martin has had to be stretched and also squashed down a bit to fit the DTM's dimensional template

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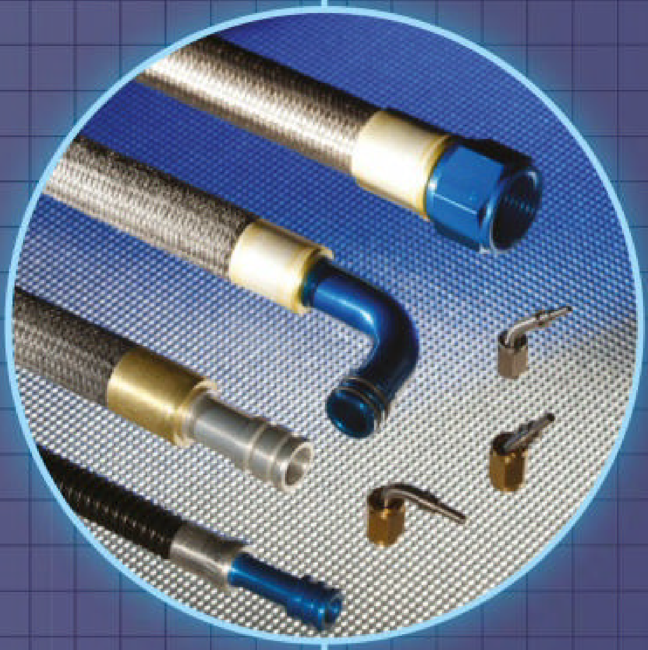

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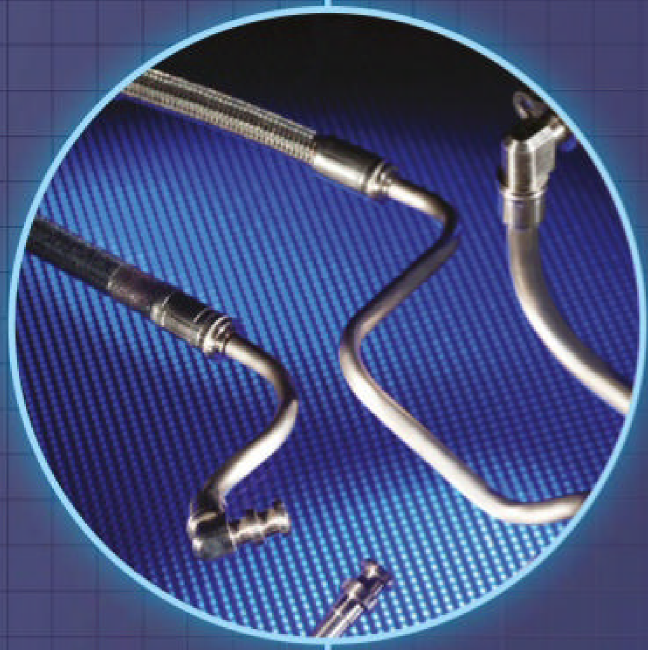

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Supra GT

With Class 1 regulations set to be fully introduced in Super GT in 2020 Toyota has taken the opportunity to wave goodbye to Lexus and say hello to Supra, but how will the new rules affect the development of this new GT500 car? *Racecar* spoke to TRD Japan's development boss to find out

By SAM COLLINS

Toyota will be using the fifth generation of its Supra as the base car for its GT500 programme from next year onwards. The definitive look of the car, which will be built to the Class 1 rules, has yet to be arrived at and it is very much a work in progress

It has taken almost a decade of negotiation but in October and November the GT500 class of Super GT and the German DTM will come together for a pair of challenge events. The first event will be held in Germany and will see a single racecar each from Lexus, Honda and Nissan take on the entire DTM field, then a few weeks later at Fuji Speedway the entire DTM field and the entire GT500 grid will come together for a two-race, six-manufacturer shootout.

This will be the final step towards the creation of the long promised Class 1 regulations which Super GT will, mostly, adopt for 2020, and which DTM has already implemented. To coincide with the introduction of the new regulations Toyota has decided that its Lexus brand will withdraw from GT500 and that it will now be represented by the new Toyota Supra model. The decision was long rumoured in Super GT circles, but was officially confirmed at the Tokyo Auto Salon in early 2019, where a GT500 specification Toyota Supra was revealed, alongside one of the previous Supras raced in Super GT in the mid 2000s.

Shape shifter

'When it was decided that we would use the Supra we took a look at the production car and noticed of course that the Supra is quite a small car and the GT500 cars are quite big,' Yoji Nagai, general manager, TRD Motor Sports Development Department, Technical Division, says. 'This is not a big problem as the regulations allow us to stretch and manipulate the shape, so we can rescale the production car to fit the GT500 template. For this reason the frontal area of the GT500 Supra will be identical to that of the Lexus LC GT500, even though the base models are totally different sizes. The wheelbase will carry over too, so in basic terms of changing the model the difference is not all that much on the final car. Aesthetically, it is a big change, but actually when you look at the numbers it is all very similar.'

Unlike the Lexus RC F and LC500 GT500 racecars built between 2014 and 2019, the Supra is to be built to the full Class 1 regulations (well, almost). Class 1 has gradually been introduced to GT500 over the last few years, with the introduction of a common chassis in 2014. This tub is dimensionally identical to that which has been used in DTM since 2012 but is manufactured in Japan by Toray Composites, leading to minor differences in specification to the German chassis. But for 2020 all GT500 teams will be forced to utilise new monocoques due to a change in the specification.

'The Supra will have a new chassis,' Nagai says. 'The chassis is changing slightly for 2020,

'When we applied the Supra's shape to the 2020 regulations we found that there was a really big drop off in performance'

'The frontal area of the GT500 Toyota Supra will be identical to that of the Lexus LC GT500, even though the base models are totally different sizes'

This Supra GT500 concept is merely indicative of what the final car will look like when it rolls out this summer

with a few minor differences to improve safety. In terms of design the DTM and GT500 chassis are identical, but we actually don't know how they compare in terms of stiffness, it would be very interesting to compare them.'

Super aero

Some elements will remain unchanged, however, such as the transmission and the overall car dimensions. But the biggest change will come with the aerodynamic packages of the cars, where both series will adopt the full Class 1 regulations – which are a lot more restrictive than the current GT500 package. The side channel of the cars are all of a single design under the Class 1 rules with the side plate used by most GT500 cars outlawed; currently this is a major development area in Super GT. Also, the many small aerodynamic flicks around the leading edge of the front wheel arch are to be replaced with a single large dive plane.

'Once the Supra was selected and we applied the shape to the 2020 regulations we found that there was a really big drop off in the performance, so the first priority was to recover as much of that lost performance as possible,' Nagai says. 'It was such a big drop as a result of the rule changes. I can say that it is proving very difficult to bring back the performance, it might have been an easier job if we had kept the same base model, but we had to change it. It is especially notable at the front of the car, the front downforce reduction is proportionally bigger than the rear, and to get the balance to be how we want it to be is inducing a lot of headaches for our engineers right now. There is not much we can do with the shape, and so it's a real struggle.'

A minor detail of the Class 1 regulations has also created an unexpected difficulty with

TECH SPEC: Toyota Supra GT500 to Class 1 (2020) regulations

Engine
TRD RI4AG 2-litre, in-line 4-cylinder with single turbocharger. Features direct injection and pre-chamber ignition

Chassis
Composite monocoque with steel upper cage; built to DTM regulations by Toray composites

Transmission
Hewland 6-speed sequential gearbox with ZF clutch; rear-wheel drive

Suspension
Double wishbone all-round

Brakes
AP 6-piston calipers (front), 4-piston (rear) with carbon/carbon friction material

The new Toyota Supra is a small car so its dimensions have had to be stretched for it to fit the GT500 technical template

introducing the Supra, unusually it relates to a commercial 'number plate board' which has featured on DTM cars in previous seasons but has been dropped in 2019, yet apparently is actually in the Class 1 regulations for 2020.

'The cooling of the Supra is very different to the LC500, just as a result of the different shape. The regulations give us some freedom in this area, not just for the identity of the car but also to optimise the cooling,' Nagai says. 'Actually the biggest issue with the new regulations is that the front of the car has to have a space reserved for sponsor branding, it is something DTM wanted but, of course, it is exactly where we would have liked to have put some ducting. At the moment we are studying the exact cooling layout and trying to get the most from it.'

The 2019 GT500 monocoque. Revisions will come in 2020 but it will remain dimensionally identical to the DTM version

Supra-natural

It is clear that the TRD engineers see the Supra as the car that is going to make something of a step change in the company's motorsport operations, but it is also in many ways a natural progression over what has come before. 'In 2014 when the new rules came in, we focussed on the engine, getting the turbocharging system right and reducing turbo lag,' Nagai says. 'We found that with the DTM based regulations that there is not a lot of space under the bonnet, and that created quite a big thermal management project, we had to keep the temperatures under control, especially on the exhaust side. With those areas the first generation RC F GT500 was really about reliability, but when we upgraded it then we started to bring a bit more performance. Moving to the LC500 we really pushed the performance even more. In 2017 we changed our car development strategy, and for 2020 with Supra we are changing things again. It is not just a case of changing the physical car, we are changing the tools we use to do that, both hardware and software. We have started using Modelbase a lot, we are doing a lot of theoretical car set-up and modelling before we get to the circuit with that, in new ways.'

But it is not only a change in the software the company is using, the Supra will also be the first car that TRD will develop in a brand new motorsport research and development facility in Japan, which features what may well be the most advanced automotive wind tunnel in the world. 'So far we have done the Supra development at both the Dome wind tunnel and at TMG, but we are actually constructing a completely new motorsport R&D centre

'In terms of design the DTM and GT500 chassis are identical, but we actually don't know how they compare when it comes to stiffness'

The 2020 Class 1 regulations are far more restrictive than current rules and some of the aero elements on the side of the cars that are a feature of GT500 will no longer be allowed


Performance
focused engine
components

The Supra will be the first car that TRD will develop in a brand new motorsport research and development facility in Japan

in Japan, the Shonan Technical Centre; the wind tunnel there is a 60 per cent rolling road design,' Nagai says. 'With the new tunnel we looked at the wind tunnels at TMG as a basis and improved on that, so it has the latest technology, it's really cutting edge.

'Beyond that the rest of the technical centre has a great range of other rigs and test capabilities,' Nagai adds. 'It's not just for TRD but the whole of Toyota. Some of the facility is already up and running but I'd expect the full facility to be functional by August to September.'

Power play

One of the major sticking points with the introduction of Class 1 was the engine specification, and the DTM manufacturers have been slow to catch up with their Japanese counterparts. GT500 has used a version of the Global Race Engine concept since 2014, with 2-litre turbocharged in-line 4-cylinder engines featuring direct injection. It is also a fuel flow limited class, using a fuel flow restrictor rather than the flow meters utilised in WEC and Formula 1, and this has seen a huge emphasis placed on combustion efficiency. Indeed, when Honda returned to Formula 1 in 2015 it based its V6 combustion chamber on that of the GT500 engine as extensive work had already been conducted and aside from the fuels used the concepts were directly applicable to the F1 power unit. More recently the three Super GT manufacturers have introduced pre-chamber ignitions systems. This work has given the Japanese manufacturers a substantial head start over their new German rivals, who have only just introduced their 2-litre, 4-cylinder engines.

The DTM manufacturers wanted to keep the specification of their engines frozen once homologated and tried to convince Super GT to do the same. But while this technology freeze may be acceptable in the marketing department-led DTM, in Super GT the R&D departments of the manufacturers hold sway and any kind of technological restriction is anathema. A compromise had to be struck, and while the exact details are not finalised it is clear that engine development will continue in Super GT. Initially, pre-chamber ignition systems were to be outlawed, but it seems that they may have been given a stay of execution.

'For us motorsport is very important for the production car R&D philosophy, but it goes beyond that, it creates the emotion and technology of the car, and Toyota wants all of that to feed into production cars,' Nagai says. 'It is the same for the other manufacturers, so together with GTA [Super GT's promoter] we have created what we call the 'Class 1 Plus Alpha' regulations. This gives us some more technical freedom, maybe five per cent.

'It was actually really a question of how to allow some development in the engine, whether

Global Supra-mecy

Toyota has put the Supra at the heart of its motorsport activity and it is likely that a number of competition versions will appear in the near future.

Perhaps surprisingly, the first official racing version of this car is running in the NASCAR Xfinity Series, but this is clearly just the tip of the iceberg, as the Japanese brand has been dropping heavy hints about a number of other Supra projects.

Left: A version of the Toyota Supra is already being raced in NASCAR's second-string Xfinity Series

In 2018 a Supra-based LM-GTE specification concept racecar was shown off at the Geneva Motor Show, but this really was little more than a design study. Based on a pre-production chassis the show car was built using a few genuine parts, but with no real intention of ever taking it on track. Indeed, the car was not even fitted with an engine, just a small electric motor so it could be manoeuvred around the show stands.

However, at this year's Geneva Show an FIA GT4 specification version of the Supra was shown off, and this was a far more serious project than the 2018 car. This Supra featured a fully developed aerodynamic package with front splitter and rear wing (both made from natural fibres rather than from conventional carbon fibre).

The production car's MacPherson strut front and multi-link rear suspension design is carried over, but with the addition of competition springs, shock absorbers and anti-roll bars. Competition specification Brembo brakes are fitted. By regulation GT4 racecars must use the engine fitted to the production car so the BMW-derived turbocharged 2-litre, straight-six engine is fitted, though coupled with a motorsport electronics package.

All the other motorsport specification equipment you would expect to find was installed in the show car, including a bespoke roll cage, FIA certified fuel cell, OMP harnesses and a dry-break refuelling system. Details about the transmission were vague, other than that it had a limited slip differential and motorsport specification driveshafts from Pankl.

Toyota officially claimed that the car was a 'design and engineering study that explores how the newly launched fifth generation of the legendary Supra sports car might be developed as a competitive machine for international GT4 racing'. But sources within Toyota claim that this GT4 car is just waiting for formal sign off before being homologated in late 2019, and then being made commercially available in 2020.

Left: LM-GTE Supra concept from 2018
Below: GT4 Supra might race in 2020

The Supra that was campaigned in GT500 in the 2000s. Next year the new version will replace the Lexus brand, which has represented Toyota in the Super GT series since 2014

'For companies like Toyota being able to develop the new technologies like advanced combustion is really important'

the combustion technology was fixed or open for development,' Nagai adds. 'In Japan we need it to be open, for companies like Toyota being able to develop technologies like advanced combustion is really important. If it's restricted or one make, what is the point of taking part in racing? So we insisted on leaving the development open and so engine development will continue. I don't know the real performance level of the DTM engines, so it's hard to judge the relative performance levels compared to us, but I think we will be stronger.'

Another major sticking point between the DTM and Super GT has been the tyres which will be used; Super GT has a full blown tyre war going on while the German series runs on control rubber from Hankook. After a lot of negotiation it has been agreed that the two challenge races will be run exclusively on the DTM tyres. But during these races the Super GT teams will be running in their full 2019 specification which, as mentioned, has a much higher downforce level than seen in DTM, along with the Japanese specification engines which are a lot more powerful as things stand. Each manufacturer was given a single set of Hankooks to test at Fuji Speedway recently in two secret 30-minute sessions following the general pre-season tests at the track.

'In the first joint races, I don't think it will be all that close,' Nagai says. 'The GT500 cars will be running 2019 aerodynamics, which means they will have a lot more downforce, and also the 2019 open development engines, which means they will have a lot more power too. In fact, our only disadvantage will be the tyres, as all the cars will be using the DTM Hankooks, and we have only used these tyres briefly. We are not sure if we will get any more chances to test the DTM tyres, we only had one car, and one set of dry tyres for it to use, so there was not a lot of data, or [much time to] do much in terms of performance work. The real priority was to ensure that these tyres can withstand the loads of our cars without failure, as a tyre failure at Fuji Speedway can be a big problem.'

Fully loaded

Looking ahead to 2020 a not unrelated issue also has to be faced by the GT500 manufacturers. Under the Class 1 regulations all the racecars will feature a common suspension design, but the components have been designed for the lower downforce, lower grip DTM cars, and while the GT500 cars will lose a lot of downforce in 2020, they will retain the far more grippy tyre war rubber.

'The idea is to use the same single spec suspension which DTM is using currently, but we are still not certain that it will be able to take the loads of our cars,' Nagai says. 'So there is a question about the safety of it at the moment, so we need to finalise that still. If the suspension is spec, then it means that the tyre companies will have to get their products to work with that suspension. Right now our engineers optimise the car around the tyres, so it will be something of a change in the way we work. It's a big project, and of course we still have not finalised the suspension [rules], so that work can't really get going yet.'

Despite this Super GT engineers from TRD Japan are already looking to widen their knowledge base so that they can learn how to optimise the car set-up to get the most out of the tyres with fixed suspension. 'TRD USA has some good capabilities and knowledge on this from NASCAR, actually our staff have just gone there to study how they do things,' Nagai says. 'Also, Super Formula, where all the cars are identical, is another place where we can learn, it is a one make tyre yet with our cars there is a one second time gap from fastest to slowest. That comes from the car set-up, and getting the most out of the one make tyres is crucial. Those skills from Super Formula could really aid the GT500 teams next year.'

The 2020 Toyota Supra GT500 is likely to shakedown for the first time in August or September, with development continuing into the new year. Rumours of it making a guest entry in the Fuji Speedway challenge race in November to see how it compares to the DTM machinery are thought to be wide of the mark, though sources at TRD refuse to firmly rule it out. If this does not happen then the Supra will make its race debut at Okayama in April 2020. And Nagai's target for it is quite simple: to win the Super GT championship.

Single minded

Dome was determined to build a brand new F3-level single seater, even if it meant promoting its own championship to create a market for it, and now its F111/3 Regional Formula 3 racer is set to see action next year. *Racecar* visited the firm's base in Japan to check on its progress

By SAM COLLINS

Formula 3 was once a core part of the international motor racing scene, with most nations having competitive championships. But in recent years interest in the category began to dwindle, with national championships seeing shrinking grids, and the international series drivers opting to race in GP3 instead. When the once great British F3 series was suspended a few years ago alarm bells started to ring at the FIA.

Change was needed, and ultimately GP3 morphed into FIA F3 International, while a new class for national and regional championships was introduced called Formula 3 Regional (F3-R). It's the creation of this latter category that has given Japanese constructor Dome its chance to return to F3 after a long absence.

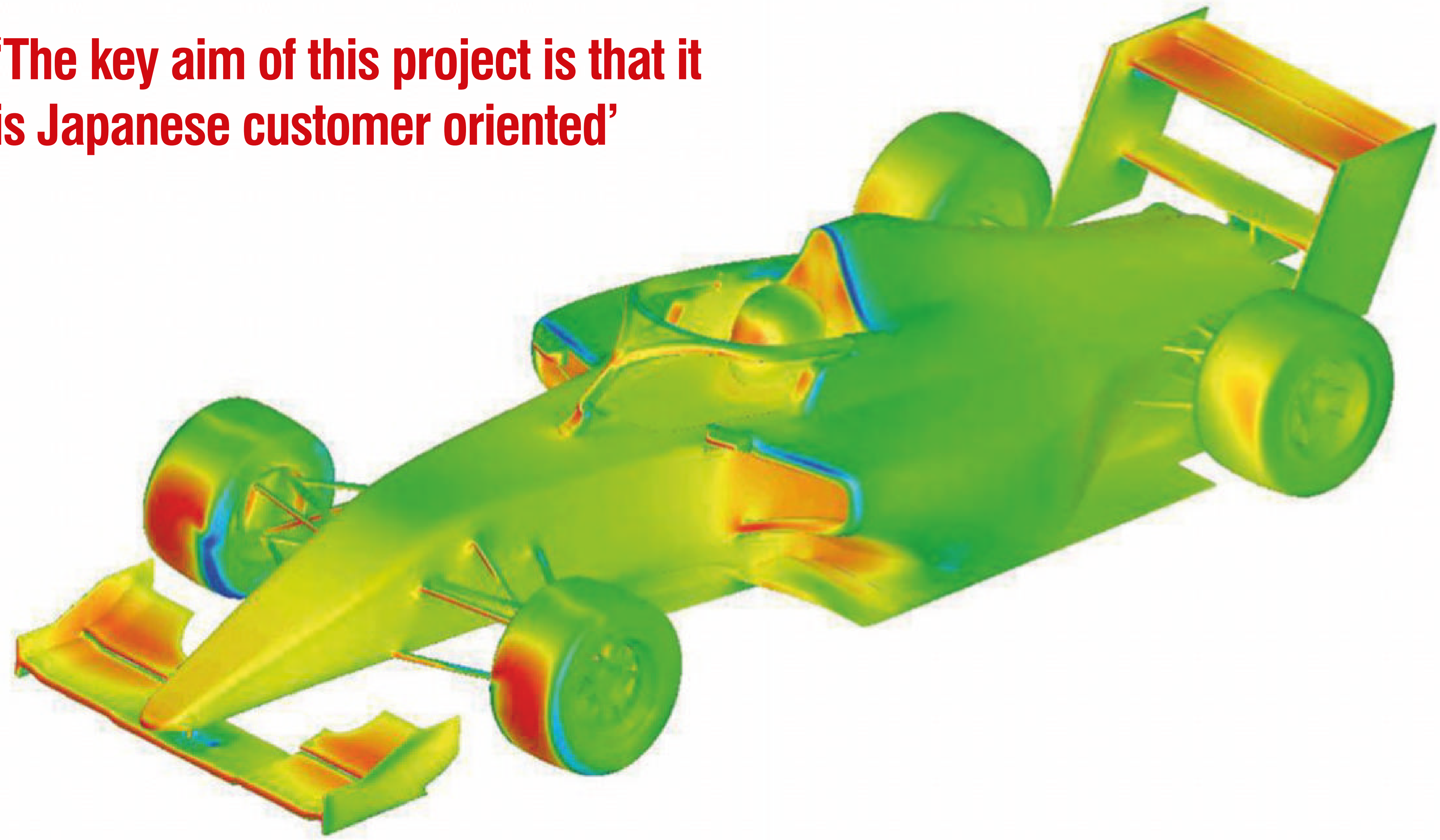
Dome first entered F3 in collaboration with British constructor Lola, working together to create the Lola-Dome F106 in 2003; the partnership ended as scheduled with each constructor building their own new designs for 2005. Dome's new car, the F107, only ever raced in Japan, to the relief of Dallara, the dominant force in F3, as it recognised that the Japanese car was extremely fast. But after two seasons the F107 was retired and Dome turned its attention to Super GT, Le Mans Prototypes and later F4 cars. It was only with the recent changes that it started to look once more at Formula 3.

'From the first day that the FIA started to discuss the whole new structure for open wheel racing we were looking at it,' Yoshinori Arimatsu, the general manager of Dome says. 'But when the pyramid reached F3 and it was clear that the GP3 would turn into the new international F3 and then F3 Regional [F3-R] would be introduced, we and a lot of other manufacturers threw our hands up and cried "oh no". For us this was not Formula 3 at all, the regulations were not at all what we considered to be Formula 3.'

Three thinking

Because of this Arimatsu admits that Dome was not completely won over by this new F3 to begin with. 'At first it was not easy for the FIA to bring it in, as people were sort of brainwashed with the long standing Formula 3 concept, a Dallara style chassis, and a normally aspirated engine with an air restrictor,' he says. 'So we had been thinking that the new F3 would be

'The key aim of this project is that it is Japanese customer oriented'



Dome's new Formula 3 chassis will race in its own championship in Japan in 2020. The company has focussed on making this an easy car for teams to service and repair

Dome's first involvement in Formula 3 was with the Lola-Dome F106, which was built in collaboration with Lola back in 2003. The new F3 project is to the FIA's Regional regulations

an update of that concept but what we got was something completely new – the name is Formula 3, but everything else is different.'

Despite its misgivings about the new rules Dome decided early on that it would build a racecar to these regulations, whatever they would be. This is because the company had been looking for a new project since missing out on the Gen2 Formula E contract and pulling out of its planned LMP3 project.

'Even when the discussions about the rules were ongoing, and even before the final technical regulations were fixed, we decided that we would go for it,' Arimatsu says. 'We didn't actually know from a business point of view how we were going to do it but we were doing it anyway. We had no idea how many customers we would get but we felt it was the future so we would have to push ahead with it regardless.'

Dome alone

Before working for Dome Arimatsu ran Toyota's young driver programme and he now believes that the new series is the logical progression for Japanese drivers completing in the two very successful Japanese Formula 4 championships. Dome faces a slight problem, however, in that Japan already has its own F3 championship, and its promoter is far from keen on adopting the new F3-R regulations and it intends to stick with the older cars.

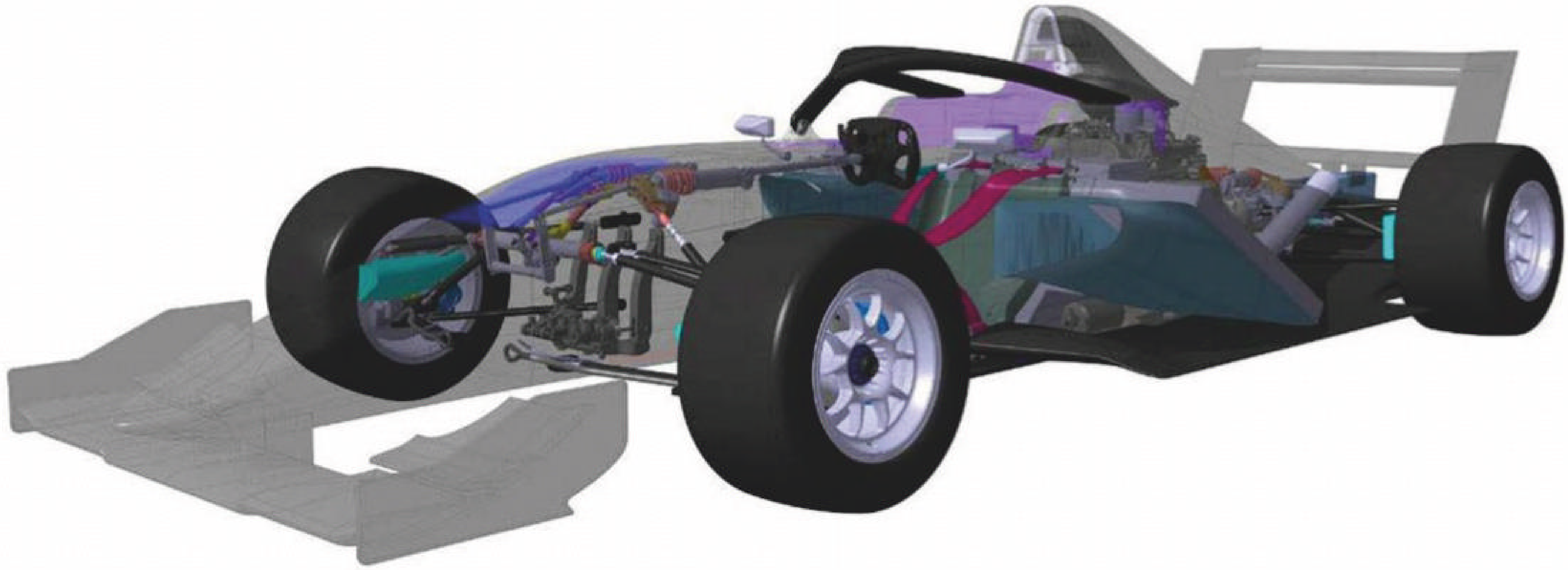
'There was no promoter who would take a risk on this, so we have now also become the promoter of a new series,' Arimatsu says. 'I can't tell what the future will bring, but for now we are going it alone. The existing F3 promoter is really confident that they can organise a series like Formula European Masters [which was to be based on last year's FIA Formula 3 European Championship], but since that series was cancelled [due to lack of entries] perhaps the landscape is changing a little.'

Once the regulations were finalised Dome started work on what would become the F111/3, but as under the new rules all F3-R championships would be run as one make classes the company decided to take a very different approach to the car design. 'The key aim of this project is that it is Japanese customer oriented,' Arimatsu says. 'In the past the cars raced in Japan have really had a European-centric design, cars from Dallara, Reynard, Ralt, even Dome's approach was that of European teams. With this car we started off by going to all the potential customers and we got their feedback about what they want from a car.'

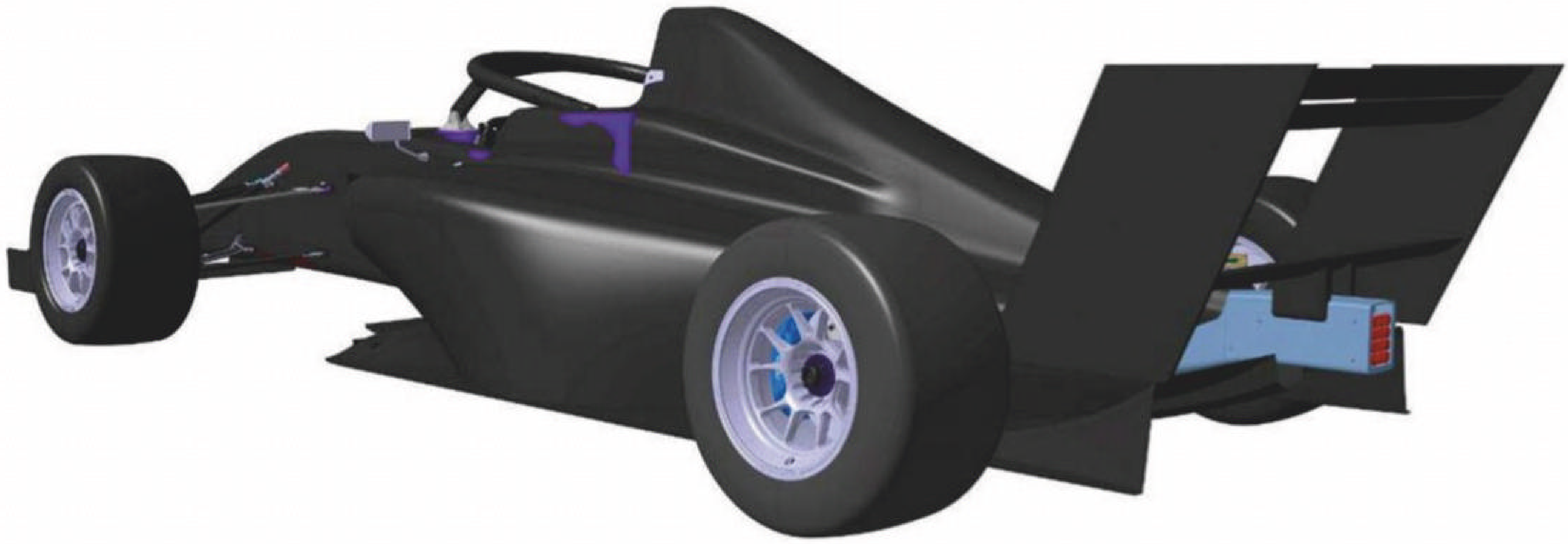
This feedback had a fundamental influence on the way the car had been designed, along with the fact that it will be racing in a one make championship. 'It is the first time we have taken that approach with a car and it makes it a bit different to the other cars out there,' Arimatsu says. 'One of the key design targets fed back from the customers was serviceability. Let's say there is typically a half hour break between sessions on track, we need to let the mechanics get as much done in that 30 minutes as possible. With no competition between chassis constructors in the series it means that not every component needs to be optimised for the best lap time, instead you can find other things to focus on, and with this car that is making it easy to work on. You will see this in a number of areas of the car, for example the pushrod. You could make it fairly flat to reduce drag, with the adjustment inboard and shrouded, that would be the normal way to do it. But with this car the adjustment is exposed to the airflow, which is slightly more draggy, but makes it much easier and faster to adjust as there is no bodywork to remove to get that job done. The camber shim as well can be adjusted much faster than on a normal car. With features like this you can get through more set-up changes in a given time, and in addition to that it is far more adjustable than a conventional car. We have targeted a 20 to 30 per cent time saving in adjustments over a conventional car like the F110 [Dome's current FIA F4 car]. That was a key factor in the monocoque design. This is very much a customer-driven monocoque.'

Dome's studies into the current junior single seater market involved interviewing drivers who

'We had been thinking that the new Formula 3 would be an update of the old concept, but what we got was something completely different'



Cutaway of the F111/3. As it's a spec racecar a great deal of effort has gone into balancing the front aero loads with the suspension geometry to avoid over-heavy steering



The F111/3 from the rear, although at the time of writing the bodywork had yet to be finalised. Engine cooling rather than generating downforce is the current priority for Dome

have competed in other manufacturers' designs, and noting all the positives and negatives. 'One of the interesting things with this type of car is that you can get quite good downforce from it,' Arimatsu says. 'But we had some feedback from drivers in other series who complained about the steering being very heavy. So we wondered what that was all about. Our conclusion was that most other cars had a slight mismatch between the front end geometries and the downforce level. If you look at something like a Mercedes road car, it makes a slightly funny movement when you turn the steering wheel a lot, the chassis moves upwards then downwards slightly due to the caster as the front wheels turn. On production cars there is power steering so the driver does not really notice this behaviour, but in a single seater with downforce, if you do that with the caster then the driver is essentially fighting both the weight of the front of the car and the downforce acting on the front. This makes it very heavy.'

The regulations stipulate all cars have to have double wishbone suspension with pushrod actuated dampers all round. Only twin damper layouts are permitted, with monoshock layouts and third elements outlawed – anti-roll bars are permitted. Dampers and rockers must also be mounted on top of the monocoque, while the dampers themselves must be conventional hydraulic single tube units with a single piston and two-way adjustment. Only conventional coil springs are allowed.

'The power unit will be made specifically for us, but will not be something re-badged, this will be a bespoke Dome engine'

Made to measure

The F111/3 has been tailor-made with Asian drivers in mind, making it a true regional car. 'The shape of the Japanese body is different to Europeans,' Arimatsu says. 'Around the top of the leg and the lower abdomen the length is a little different, it is longer. It's a genetic difference maybe, but it's also down to the diet of Asian people, because we eat more vegetables we need a longer intestine to digest it. So as a result of this a car designed around a European driver is perhaps a little uncomfortable for Asians. So we have designed the car to have a monocoque that is a bit longer to allow for that extra length, so the drivers can have a better position.

'We actually have tried out a lot of different drivers in the mock up to get it right,' Arimatsu adds. 'We had a W Series driver [the new women-only Formula 3 level series] in the mock up of the car and she gave us a lot of input, but we also put in a driver who was 190cm tall into the car to get feedback too. We also worked on

the steering column layout and pedal position, for it to be better for Asian drivers.'

The monocoque has also been designed to be some way above the required safety standards, while it features side impact structures and a Halo. 'We originally planned to make our own Halo, but we will buy one in instead, because it's a bit cheaper and it does not make a difference if we make our own,' Arimatsu says. 'We could make it ourselves but we would have to go through the crash testing and homologation of that, which would just add cost and not really bring a benefit.'

Halo Kitty

When the Halo was first introduced for F1, F2 and the new Formula 3 International class along with Formula E, there was only one specification; the one used in Formula 1. But as more lower level series have started to adopt the safety device regulations the FIA has moved to allow cheaper versions for such categories.

The F1 specification Halo is made from titanium, but the version used on the F3-R car is made from steel, and is built to these new lower cost Halo regulations. The device looks the same as the F1 version but weighs almost twice as much at 13.5kg. But like the F1 version, all Halos have to pass stringent tests at the Cranfield Impact Centre, and then once approved they can be made commercially available.

'When the Halo was announced for F1, we started to study what would happen in terms of aerodynamics, as we already had the templates from the FIA,' Arimatsu says. 'We found out that the impact was not good for Formula 3, it was a big disadvantage for a normally aspirated car as the flow would impact the intake badly. Our simulations suggest that if you put a Halo on the current Dallara, the car would be heavier and slower. If you try to make up for that weight, and get the same lap time, then you need at least 20 to 25bhp more than the engines have now. That is not really possible with the normally aspirated air restricted rules, even 1bhp is hard to find.'

The F3-R regulations in terms of the chassis are fully detailed, as you would find in the rules for a fully open category (like the 'old' F3), with tight regulations governing the car's overall dimensions, front and rear wings and the bodywork around the front wings.

Where things do differ, however, are with the engine regulations, or rather the lack of them. Indeed, the regulations just govern a number of voids in the car to accommodate the engine and the exhaust. Instead of a rulebook relating to an engine, a power to weight ratio of the complete racecar including the driver – limited to between 2.4 and 2.6kg/hp – is given, along with power and torque curve templates.

Dome's answer to this has been a decision to use its own engine. 'I can say now that the car will not be fitted with a power unit you can see at the moment in Japan,' Arimatsu says. 'It will be a Dome power unit. This is something new for us. But our wish, our vision for this company, is to become similar to ORECA. If you look at the LMP3 car they do, our plan is similar. So the power unit will be made specifically for us, not something re-badged, this will be a bespoke Dome unit. It's a turbocharged in-line engine, and it really has to be turbocharged to meet the power and torque templates. The regulations mean that we have to design the car to accept any homologated engine, so if another series wants to use this car then maybe they could use a different engine. Those engines all have to meet a template so they can all fit in every chassis built to the F3-R regulations.'

Only sequential 6-speed longitudinal transmissions may be used in F3-R, with steel ratios. Transverse gearboxes are forbidden. 'We have selected the internals from our supplier, but the casing will be a bespoke Dome component,' Arimatsu says. 'Actually it is a pre-existing cluster, as there was no point in changing something which does the job and is reliable. So we are just changing the casing.'

Dome economics

The make or buy strategy adopted by Dome for the F111/3 is also slightly different to what it has done previously, where it often used as many Japanese made components as possible.

'We have done a lot of make or buy analysis, and I would say that this car is a kind of fusion car,' Arimatsu says. 'We have taken away limitations such as we must make everything in Japan, or only buy from certain countries in Europe. So now we are going to go to wherever the quality and price is right.'

There is, in fact, a new approach to doing things throughout the Dome factory in Maibara, Japan, a facility which has seen a huge amount of investment in recent months, with a brand new composites facility and machine shop. The number of staff has also been increased and the company is going all out to demonstrate its skills with the F111/3.

'This monocoque has probably had the highest level of computer power applied to it in the history of Dome,' Arimatsu says. 'I think it will be the best and most advanced monocoque Dome has ever built. It is a big jump for us. The F110 was a quite neat and nice car but the F111/3 is going to be a real milestone in the history of Dome. When we look back in 10 or 20 years this car will be a real transition point for the company.' Incidentally, Dome plans that the monocoque will eventually also be adapted into the F111/4 , so it will then replace the current Dome F110 F4 chassis.

In the meantime Dome has re-acquired its well regarded 50 per cent wind tunnel from TRD just in time to use it to finalise the F111/3 bodywork. 'On the aero we are taking it quite easy, as there is no chassis competition, so another focus is on getting the power unit to cool properly rather than chasing downforce,' Arimatsu says. 'Once the design is finalised we will go into the wind tunnel to tune it all.'

The Dome F111/3 is likely to hit the track for the first time this summer, and will start its racing career in early 2020.

QUICK SPEC: Dome F111/3

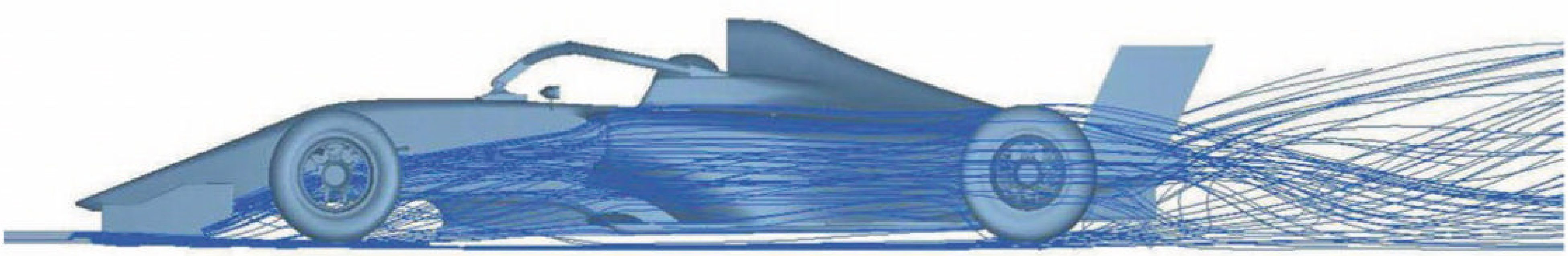
Chassis
Carbon fibre monocoque with side impact structures and AFP Halo. Front and rear crash boxes.

Engine
Dome turbocharged, in-line; power, 265bhp; torque, 370Nm.

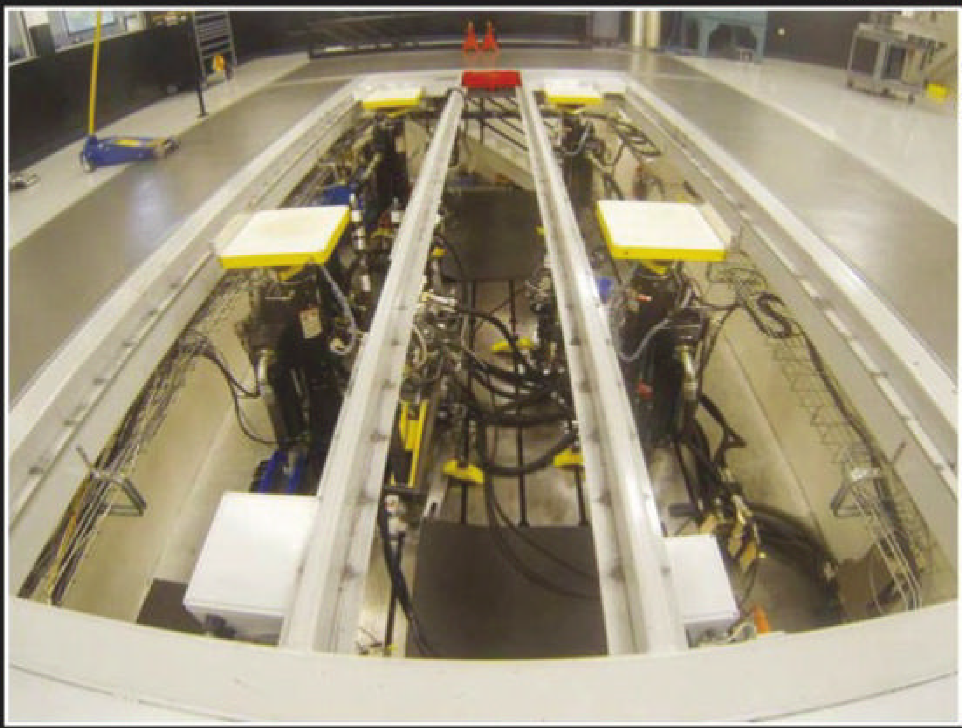
Dimensions
Height: 960mm; width, 1850mm; length, 4940mm; wheelbase, 2950mm; track, 1200mm (min).

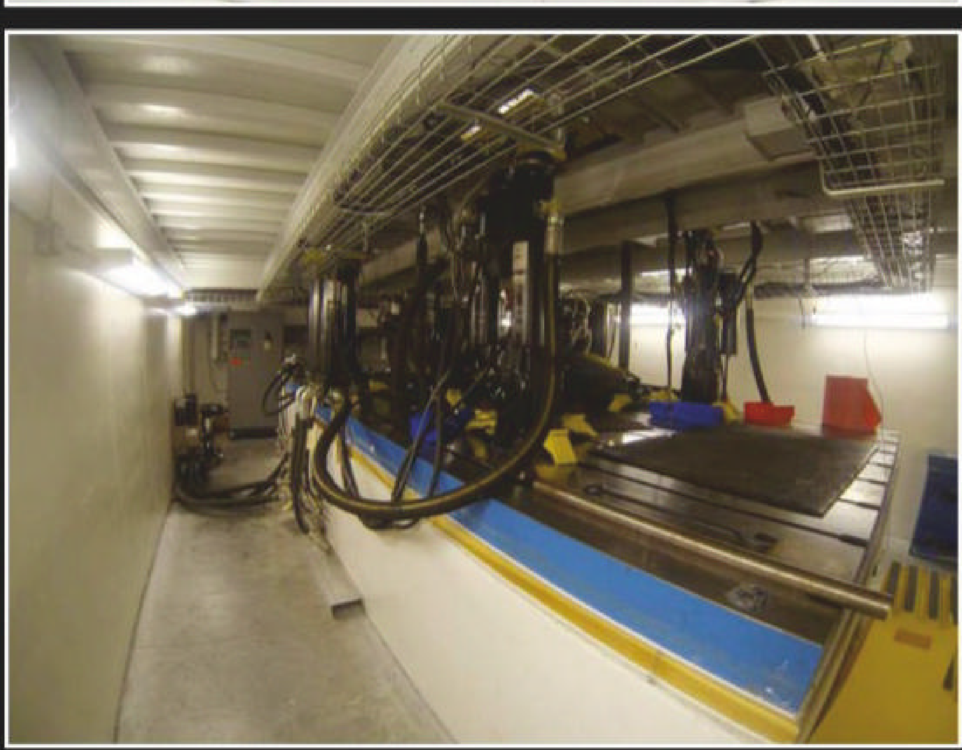
Weight
650kg (min).

'The F111/3 monocoque has probably had the highest level of computer power applied to it in the history of Dome'



To date all of the F111/3 aero development has been done in CFD but the racecar will go in the wind tunnel soon. Dome has recently re-acquired its 50 per cent facility from TRD



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ULTRA

Race against time

‘It was a late decision to build the new car, it is normally a good five to six month project’

Champion team West Surrey Racing had won a race even before the lights went out to signal the start of the BTCC season, rising to the challenge presented by a late call to switch from BMW's 1 Series to its 3 Series for 2019. Here's the inside story of an epic car build

By ANDREW COTTON

The introduction of new machinery into the British Touring Car Championship is always welcome, and never more so than when it marks the return of an old favourite. So when it was announced that champion team West Surrey Racing (WSR) was switching from the BMW 1 Series to the new version of that BTCC stalwart, the 3 Series, it went down rather well.

But this was no easy task for WSR. The decision to make the switch wasn't made until October 2018, giving the team a very short time-frame. It started its design work based on the CAD files from BMW, but the actual physical job of building the racecars could not start until the end of November, when the chassis from the production line were first delivered to the team's base, although they also had to go off-site for the stripping of the shells and fitting of the roll cages before WSR could get stuck in.

Powering on

In order to achieve the build in the short amount of time available before the season opener in early April the team took some short cuts, including carrying over the B48 engine from the outgoing 1 Series car, as there is little point in investing too much cash in developing the powerplant anyway, because of the balancing of the power units in the BTCC.

'If you develop the engine too much, the organisers turn the engine down,' says team owner Dick Bennetts. 'They monitor every car's cylinder head with an intake manifold flow test, which is when your base boost is determined and then they monitor on track performance on acceleration in third and fourth gear, and that's how they equalise the engines.'

Despite the short-cut with the engine the rest of the car still required a lot of work – and still does. At the time of writing the team has yet to perfect the set-ups; this includes anti roll, anti dive and anti squat, as well as roll centres, which can also be adjusted track to track.

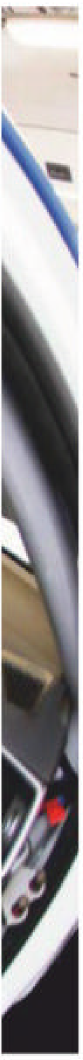
'Only the TOCA parts are carried over [from the BMW 1 Series racer],' Bennetts says. 'We redesigned the front, so everything away from the subframe and suspension is all new. It was a late call to build the new car, it is normally a good five to six month project, and we got the green light on October 1, but the 3 Series was launched on March 9, [though] we got the shells on November 29, and then they get dipped to get the glue off them from the road car, then we put in the roll cage, got them built and painted, it was a lot of work.'

Weighting game

The first job for the team was to make the most of the larger cockpit area the 3 Series bodyshell provided, and move the driver towards the rear of the racecar to help with the weight distribution. There simply wasn't the room to do this with the BMW 1 Series and so the team took full advantage of this new opportunity.

'Only the TOCA parts are carried over from the 1 Series, we redesigned the front so everything apart from the subframe and suspension is new'

WSR has made the most of the larger cabin and has moved the driver towards the rear to improve the car's weight distribution



TECH SPEC: NGTC touring car regulations

Engine
Turbocharged 2-litre 350+bhp; direct-injection engine; fly by wire throttle control. Common Owen Developments turbocharger and PWR intercooler.

Bodyshell
Base vehicle must be freely on sale in the UK through the manufacturer's normal dealer network at time of homologation. Open to two-, three-, four- or five-door bodies with a minimum 4.4m length (two- or three-door cars must share the same basic body profile as the 4/5-door model); equalised width of 1890mm; stylised front and rear wheel-arch extensions; side exhaust permitted.

Drivetrain
Xtrac 6-speed sequential-shift gearbox and differential; AP Racing carbon clutch with steel cover. Drivetrain layout front- or rear-wheel drive, as per base vehicle.

Aerodynamics
Specified front aerodynamic device incorporating flat floor, apertures for radiator, brake cooling ducts, intercooler and side exits; specified rear wing profile.

Suspension
RML-designed full front subframe incorporating suspension, brakes, transmission and engine location that attaches to specified roll cage locations; multi-adjustable double wishbone suspension with SPA Penske coil-over dampers. RML-designed rear subframe that attaches to specified roll cage locations; multi-adjustable double wishbone suspension with SPA Penske coil-over dampers. Hydraulic power steering.

Brakes
AP Racing specified package and AP Racing specified pedal-box.

Wheels/tyres
Rimstock 18in centre-lock wheel; Dunlop 265/660 R18 tyres. Three tyre compounds: Soft, Hard and a specific compound used at Thruxton only.

Safety
Latest specification FIA homologated seat; Lifeline fire extinguisher system.

Electronics
Cosworth Electronics specified package incorporating ECU, dash, data-logging and scrutineering logger; data channels limited to 16; common power management box and switch panels; common Cosworth wiring loom design; judicial camera system run on all cars.

Fuel
Carless supplied petrol; 80-litre ATL fuel tank.

Weight
Equal base vehicle weights for front- and rear-wheel drive: 1280kg.

WSR also designed much of the switchgear to make it more driver-friendly, and added smaller details, such as moving the electrical connections to the outside of the tubular chassis frame to help with the downloading of information when the car pits.

Longer wheelbase

The wheelbase of the BMW 3 Series is also longer than the 1 Series, something that should help with high-speed stability but which may hurt the car on the smaller, twistier circuits due to the need to change direction quickly. 'We are still not sure on the wheelbase, but it is not hurting us at the moment,' says Bennetts, who was actually speaking to *Racecar* as the cars tackled the wet conditions at Brands Hatch.

There are also differences with the aero on the new car. The 1 Series sported the widest wheel arch extensions that could be imagined in professional motorsport, but the new car already has wider bodywork and so the team believes that it is already a step further forwards with it. 'We figured that the cars with biggest top speed had a boot on,' says Bennetts. 'It has a longer wheelbase and that was my only nervous area, but it is proving to be okay. So far, in the damp conditions it gives the drivers more confidence than the 1 Series.

'The new BMW 3 Series road car is quite wide as a production car, so the wheel arch extensions are quite small,' Bennetts adds. 'The 1 Series had big wheel arches because the cars run to the same maximum width, so we will have a slightly bigger frontal area on the top of the car, and the lower half will be the same. Because we have smaller wheel arches that should help us aero wise.'

The Holy Grail of touring car racing is low cost, high entertainment, and the British Touring Car Championship has achieved this target, with a stable set of chassis technical regulations first introduced in 2011. The Next Generation Touring Car regulations had an initial five-year homologation period, but these were extended for a further six years in 2016, when RML was introduced as the new technical partner for the subframes, suspension and hydraulic power steering (see tech spec, left). It's a formula that has led to a very wide diversity of racecars on the grid, and the new BMW 3 Series is a more than welcome addition.

The wheelbase of the BMW 3 Series is longer than the 1 Series, something that should help with high-speed stability

The longer wheelbase gave the drivers a more stable platform in the wet conditions of the BTCC's Brands Hatch season-opener

Whale tale

When Porsche pushed the Group 5 regulations to their breaking point in the late 1970s the result was the outrageous 935/78, better known as Moby Dick. Here's the story behind the development of an endurance racing legend

By **WOUTER MELISSEN**

For GT racing, the 1970s were simpler times. The use of terms like balance of performance, sandbagging or waivers were still a thing of the future. Homologation was the key word then, and a level playing field was created by a minimum weight bracket that was related to the size of the engine. Manufacturers could request an exemption to be made, but unlike today's waivers, these could then be applied to all cars. So engineers with a knack for reading and the gift of creativity were clearly at an advantage. Perhaps the most talented of these engineers was Porsche's Norbert Singer.

Singer had been responsible for the all-conquering 934 and 935, which were raced in the Group 4 and Group 5 classes respectively. Both were based on the 911 Turbo, which was known internally as the Type 930. While the 934 and the various evolutions of the 935 were capable of class wins at best, another read of the regulations had Singer convinced that a 935 could be created that would be capable of winning Le Mans outright. To do so, it would have to beat the purpose-built Group 6 prototypes, which were restricted only by a 3-litre displacement limit. Among the new-for-1978 935's chief rivals would be Porsche's equally appropriately named 936.

Open book

The Group 5 regulations were very lenient but still required several crucial components to be carried over from the homologated road car. But for the 1978 season subtle changes were made to the regulations, which now stipulated that only the cockpit had to be retained, which effectively meant the front windshield, the roof line, the rear window and the doors. As per rival BMW's request, the floor could now also be raised to the level of the sills. This was asked for to make room for the exhaust of the Munich company's 320i Group 5 racer. There was, however, no reason for another manufacturer not to take advantage of the same exemption in the regulations. And these two changes in the rulebook were the impetus for Singer to create the Porsche 935/78.

As per the regulations, the Porsche engineers started with a bare 930 shell. All the metal fore and aft of the cockpit was cut off and replaced with lightweight, tubular subframes. At both ends of the cockpit the frames were bolted to the roll-over bars, effectively creating a single spaceframe inside the original 930 shell. While reducing weight and improving torsional rigidity, the new chassis also provided much more freedom to relocate suspension points and optimise the geometry. This was certainly called for to deal with Singer's next trick. He had the sheet steel floor cut out and replaced by a glass-fibre reinforced plastic floor that was installed at

Norbert Singer was convinced that a 935 could be created that would be capable of winning Le Mans outright

sill level, a full 75mm higher than before. This in turn allowed the car to be dropped by about the same distance, lowering its height and centre of gravity and also reducing the frontal area.

At the front of the car the McPherson strut suspension was modified to allow for a significantly wider track. The rear end received more substantial modifications with the original trailing arms replaced by purpose-built, aluminium forked semi-trailing arms in order to reduce the unsprung weight.

Blisteringly fast in a straight line and relatively heavy, sufficient braking was already of paramount importance with all previous 935s and this was addressed with large ventilated discs originally sourced from the 917 sports prototype. But Singer believed that these were no longer adequate and specified larger still ventilated and cross-drilled discs to be fitted. The 935/78's new discs had a diameter of 430mm and were 32mm thick.

Head start

In addition to the cockpit, major engine parts like the crankcase, crankshaft and cylinders also had to be carried over. Crucially, the list did not include the cylinder heads. As chance would have it, Porsche engine wizard Hans Metzger was in the process of developing a new twin-cam, 24-valve head for the 936. With relatively few modifications this could also be used for the 935/78. But while offering obvious advantages, switching to a twin-cam head also forced Metzger to rethink the engine cooling layout.

As it turned out the new heads and particularly the centrally-mounted spark plug proved virtually impossible to cool with air alone, as had been Porsche's practice for over two decades. Instead, the new heads were water-cooled, while the cylinders and block relied on an old fashioned fan. No longer required to cool the heads a smaller fan could be used, which drained just four bhp at the engine's red line. The four camshafts were driven by gears from the crankshaft and were housed inside magnesium covers. The valves were mounted at a relatively tight 30-degree angle.

Mounted on either side of the 930-derived crankcase were cylinders with a bore and stroke of 95.7 and 74.4mm respectively. This gave the Type 930/71 engine a total displacement of just over 3.2 litres. Taking into account the 1.4 x equivalency formula applied to turbocharged engines, this placed the 935/78 in the over 4-litre category, which had the minimum weight set at 1025kg. Singer was convinced that the 750 to 800bhp produced by the new twin-turbo unit would more than make up for the added weight – particularly at Le Mans, where top speed was key to achieve fast lap times.

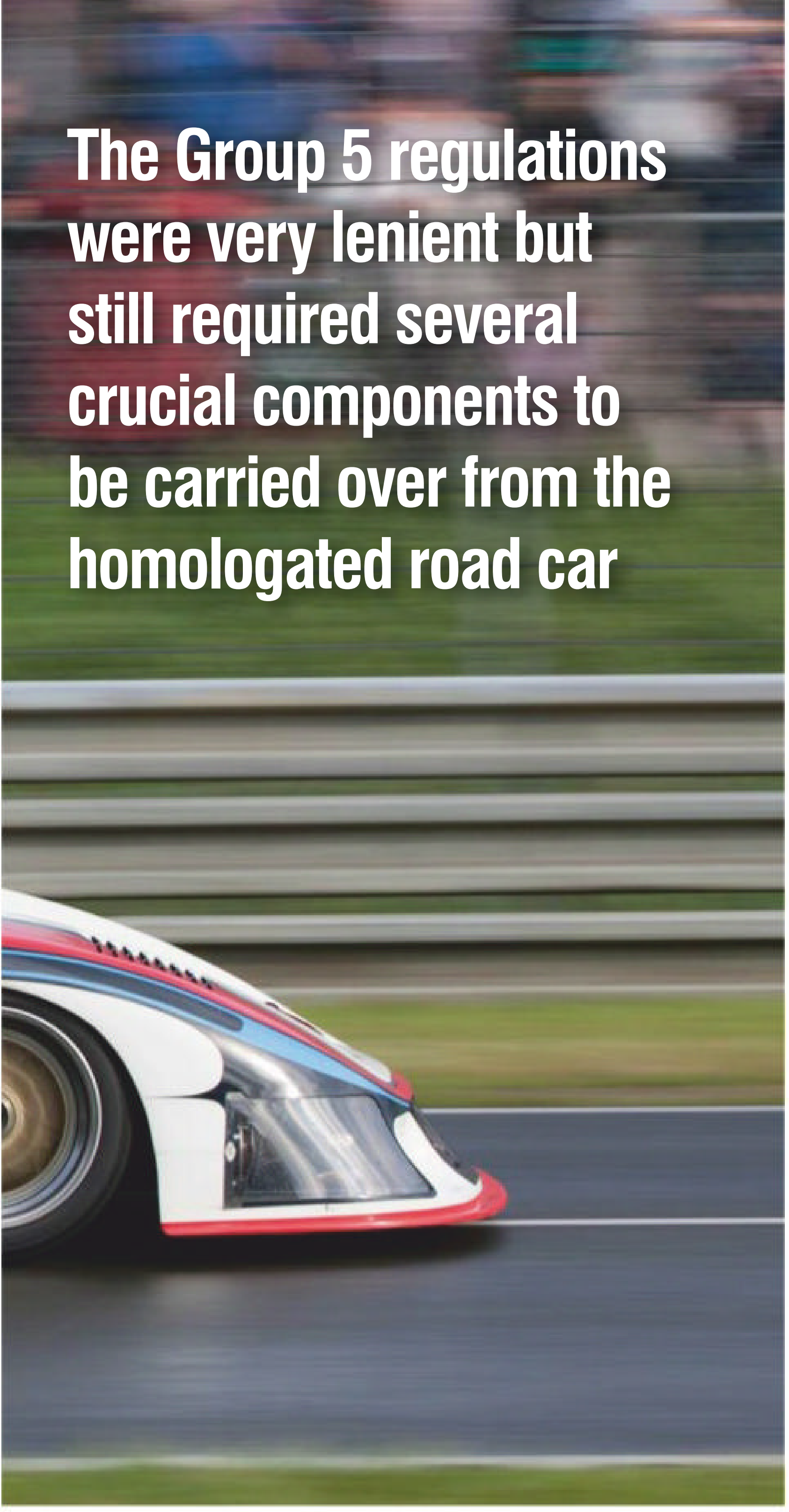
'Box of tricks

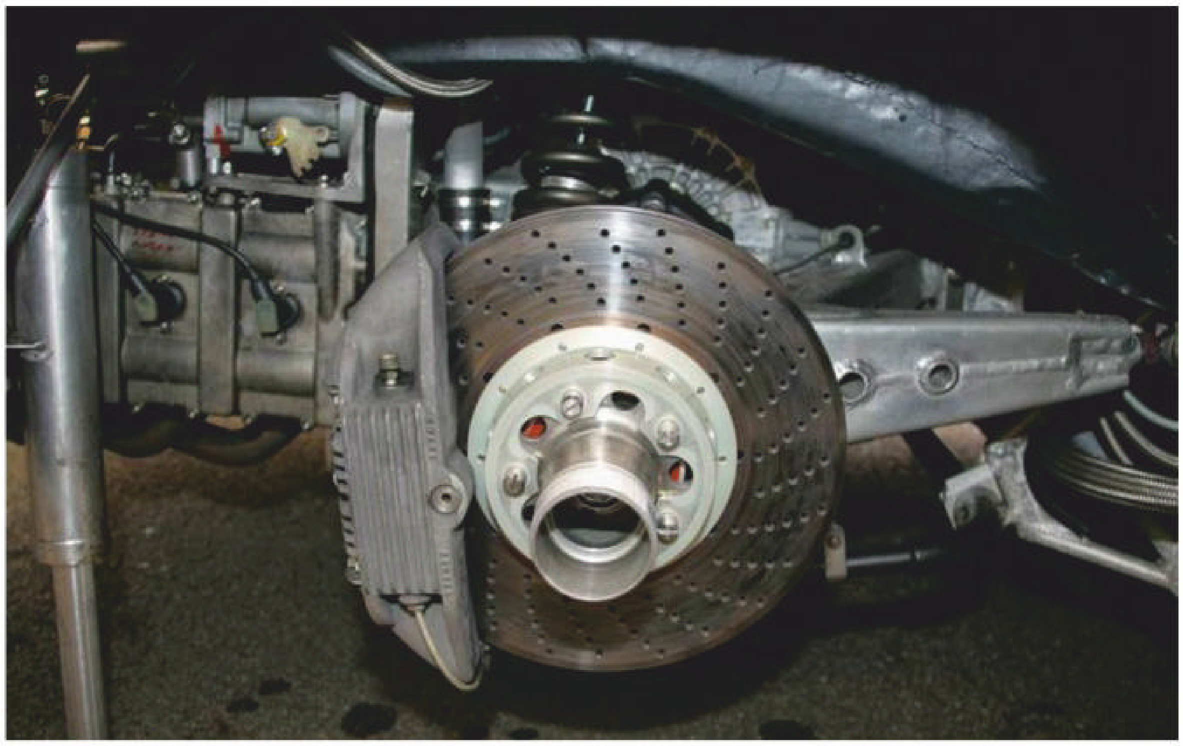
With the entire chassis lowered compared to the wheel centreline, there was a potential issue with the acute angle of the driveshafts if a conventional gearbox was used. Instead, Porsche's tried and trusted 5-speed gearbox was turned upside down. It was not quite this simple, however, as the Porsche engineers did need to hastily re-cast the gearbox casings and the engine bellhousing to make it fit. This upside-down gearbox approach would later be adopted by many sportscar designers, even for cars not powered by Porsche engines.

Despite reading the rulebook very diligently, Singer could not find any mention of how long the car's nose and tail was allowed to be – naturally, he decided to use that to his advantage. The 935/78 was fitted with a relatively long, wide and low nose in order to reduce drag and force the air over the car to

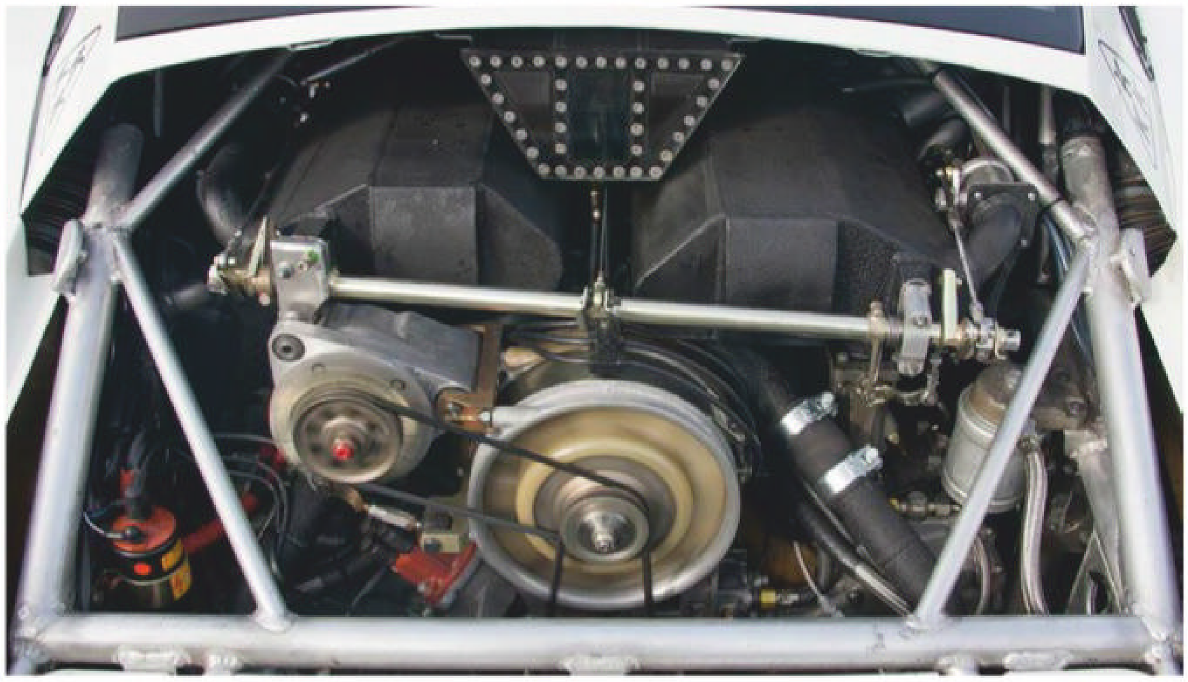
Porsche's tried and trusted 5-speed gearbox was turned upside down

The Group 5 regulations were very lenient but still required several crucial components to be carried over from the homologated road car





The 935/78's discs were an improvement over the standard 935 spec, with greater diameter and thickness



Above: The extraordinary lines of the Porsche 935/78 are best appreciated in profile. It was raced for just one year in 1978

The twin turbo engine with its new twin-cam, 24-valve, cylinder head produced in the region of 750 to 800bhp

Because of a regulation change Porsche was allowed to raise the floor to the level of the sills. The shape of the cabin had to remain the same as the road going 911

The Porsche 935/78 is justly famous for its slippery shape. The relatively long, wide and low nose was designed to reduce drag and to force the air over the body to the rear wing

the rear wing with help of a splitter. The wing was mounted at the tip of the elongated tail, which again was designed to reduce drag. With the front and rear fenders wider by quite a margin than the 930 it was based on, the 935/78 featured cowlings on the original doors to further clean-up the airflow. Wide and low, the car quickly received the nickname 'Moby Dick.'

Lose the blubber

Although the 935/78 was due to run in the 1025kg category, Singer made sure the car was as light as possible. In addition to the lightweight spaceframe chassis and the fibreglass floor, a lot of weight was saved by making the entire body from fibreglass and carbon fibre composite. As a result, the finished machine tipped the scales at just 960kg. This provided the team with 65kg of ballast that could be carefully placed to further improve its weight balance. For this reason alone, Porsche's works drivers quickly discovered that Moby Dick was, by far, the best handling of all 935s.

Shortly after the first 935/78 was completed, inspectors from the sport's governing body visited Porsche for a closer examination. They were quite taken aback by Singer's interpretation of the regulations. While, according to most accounts, the inspectors had no option but to approve of the design, they did require Porsche to make modifications to the doors and the rear wing. They stipulated that the doors not only had to be present but also had to be visible, so sections of the cowlings were removed to reveal the original sheet metal. The rear wing could no longer be visible from the front, so it had to be slightly narrowed. But to maintain its effectiveness it also had to be raised by quite a bit.

Fuel tank is in the nose. The car was designed to win Le Mans but an oil leak ruined its only attempt in 1978

Porsche's works drivers quickly discovered that Moby Dick was, by far, the best handling of all 935s

Racing record

Although designed specifically for the Le Mans 24 hours, Porsche decided to debut Moby Dick at the Silverstone 6 Hours as a final test. Jochen Mass and Jacky Ickx were called upon to drive it and they did so formidably, grabbing pole with a lap that was well over 1.5 seconds faster than any of their rivals. In the race they cruised to victory with an average speed of 202km/h and a seven-lap margin over the second-place 935. This was one of the latest customer cars built by Porsche and was driven by Bob Wollek and Henri Pescarolo, underlining just how much progress had been made with the 935/78.

For Le Mans, the car was entered for Manfred Schurti and Rolf Stommelen, along with three 936s. In qualifying it was beaten only by one of the 936s, and the fastest of the Renault-Alpine Group 6 cars. By comparison, the second fastest Group 5 car, a regular 935, was nearly 20

The rear wing had to be narrowed so that it was not visible from the front of the car, and it was then raised so that it would remain effective. From this angle there's very little 911 left

The 911 doors were originally hidden behind cowlings but the rule makers told Porsche to get rid of these

The 935/78 proved an inspiration for Porsche's customers to further develop their own cars

seconds slower. Porsche was no doubt helped by the startling 368km/h (229mph) top speed down the Mulsanne straight.

The race, however, was a disappointment, as the car was forced to slow down after an oil leak was discovered. This was later found to be insignificant and would have most likely not have caused any problems. The 935/78 was classified eighth overall and third in class. The race was won by one of the Renault-Alpines.

Porsche then fielded the car in the Vallelunga 6 Hours, where it once again was the class of the field until the fuel-injection belt snapped. Moby Dick was also raced at the Norisring but again failed to reach the finish. That would be the final outing of the year for the 935/78 with Porsche probably realising that the car would only snatch the limelight and victories from its own, paying customers. At the end of 1978 the Martini sponsorship money dried up, which brought an end to Porsche's works efforts. As a result the construction of a second Moby Dick, due to be raced in 1979, was also halted.

Leading the way

Although not raced again, the 935/78 proved a source of inspiration for Porsche's customers to further develop their own cars. Much of its aerodynamics were incorporated into Kremer's 935 K3, which won Le Mans outright in 1980. Joest went one step further by building a pair of replicas using the drawings kindly provided by Porsche. These cars were raced on both sides of the Atlantic with some success. None of these privateer cars, however, featured the mighty 24-valve engine of the original Moby Dick.

While ultimately not a success on the race track, Singer's Porsche 935/78 remains as a fabulous example of what can happen if the regulations are bent close to their breaking point. A Le Mans win was certainly on the cards, though, and this provided enough inspiration to Porsche's privateers to keep the 935 very competitive well into the 1980s.

Involved in all of Porsche's first 16 Le Mans wins, Singer remained on top of his game for many more years. His keen reading skills resulted in the 1994 Le Mans win after he had convinced the governing bodies that a 962C was really a GT car. He also kicked off the GT1 craze of the late 1990s with the 911 GT1 of 1996, which, in more ways than one, was the spiritual successor to the legendary Moby Dick.

Of the two 935/78s built, the car that was raced during the 1978 season (chassis 935-006) was retained by Porsche and has been on display in the company's museum. Following a recent restoration, it has also been regularly demonstrated at events around the world.

The second, uncompleted, chassis (935-007) was sold along with a large number of parts to an American enthusiast. After struggling to find parts he eventually passed the project on to Freisinger Motorsport. It managed to find the elusive Type 935/71 engine and by the early 2010s the car was finally ready to be used in anger. Among its subsequent outings was an entry in the 2012 Le Mans Classic.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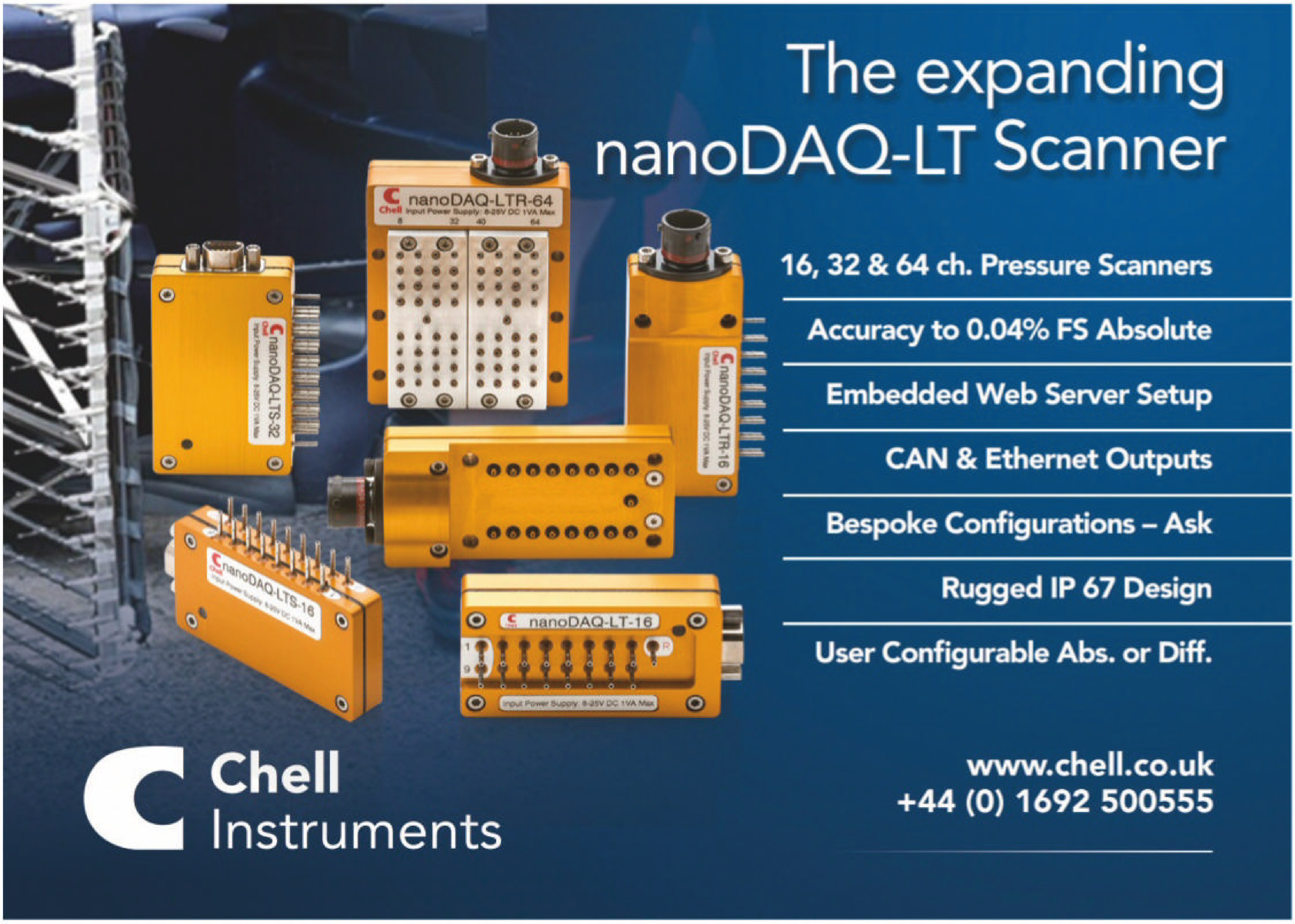
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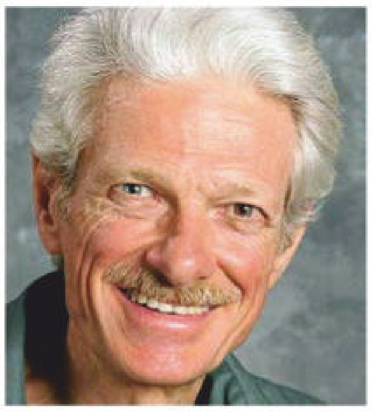

Joining the chain gang with a Formula Student project

Is it a good idea to use a chain-driven beam axle on an FSAE car?

IMechE Formula Student

To get the very best from any Formula Student car you need a compliant rear end, but also a driver who is able to turn the car in on the brakes to help counter understeer

Q We are considering using a chain-driven beam axle at the rear of an FSAE [Formula Student] car. Do you have any suggestions as to how to approach this? And how do you determine the anti-squat and the anti-lift with chain drive?

THE CONSULTANT

A The first question calls for a fairly lengthy response, so I'll address the second one first. Assuming that the driven sprocket is on the axle, the run of chain that's under tension acts like a link under tension. If the engine is ahead of the axle, that will be the upper run of chain when we are under power. Interestingly, but probably less importantly, on deceleration engine braking puts the lower run under tension instead. So we have two distinct geometries, depending on the direction of engine torque, although we are mainly interested in just one of them.

The system acts like a three-link axle (three trailing links plus something for lateral location). The other two effective trailing links are whatever locates the axle longitudinally. The simplest possibility is two trailing arms or radius rods. Ordinarily, these will need to be able to swivel a little horizontally at the rear to prevent bind in roll, because the horizontal distance between the front ends changes a little as the car rolls. Alternatively, we can have compliant bushings at the front ends of the arms, or we can have them converge to a single pivot in the middle of the car, although this latter option is hard to package in a low car.

However, it's just about as easy to have birdcages and four trailing links.

It is highly desirable to have the chain centred in the car, or at least close to centre. If it is significantly off-centre the jacking force from the chain will change the car's diagonal percentage under power.

Chain of command

Two questions come up immediately: first, are we going to have a differential, and if so what kind and how do we arrange it? The second question is; how do we do the brakes?

Based on personal experience with FSAE, the tyres used are not very load-sensitive, meaning that it takes a big change in roll resistance distribution to produce a relatively modest change in handling. Even with a diff, the cars end up cornering with the inside rear tyre very lightly loaded in order to combat understeer due to off-tracking in the very tight turns.

Therefore, for steady state cornering, it should actually be possible to run a completely locked axle. This has been done with moderate success in FSAE, and it certainly benefits mechanical simplicity. The main problem is that the car tends to push on corner entry. It gets reasonably free once we've got it rotating in yaw and have lateral load transfer, but we have to get it to turn to reach that state. This can be dealt with via driving technique and brake bias.

The driver has to toss the car with the brakes to get it rotating. For really tight turns this is the norm with karts, which practically always have locked axles. However, it takes some practice for a driver accustomed to ordinary cars to get used to doing this, and do it with control when the cones are close. If we have two drivers with

If the chain is significantly off-centre in the car then the jacking force from it will change the diagonal percentage under power

An example of a beam axle for a Formula Student project, as used on the car designed by Australian team Edith Cowan University last year. This clever rear suspension system also featured a heave spring

It probably makes sense to have a De Dion suspension; a beam axle with a sprung differential driving the wheels through jointed shafts

karting backgrounds, that helps. We would use these drivers for the autocross and endurance events. We need four drivers in all, but the ones we use for the acceleration and skid pad events wouldn't need kart experience.

Most successful FSAE cars do run with differentials, either clutch pack Zexels or worm gear Taylors with viscous fluid. If we're going to do that, it probably makes sense to have a De Dion suspension; a beam axle with a sprung differential driving the wheels through jointed shafts as with independent suspension. This is probably easier than trying to design an axle incorporating the diff. It also saves unsprung weight, and it no longer matters whether the chain is in the middle of the car. The frame design gets more complex, unless we mount the diff to the engine; which is actually fairly appealing, even with independent suspension. We do have to come up with some way to adjust chain tension, but that's not really harder than it is with the diff and engine mounted separately to the frame.

Another advantage of a De Dion is that we can incorporate some means of static toe adjustment. It is very common in FSAE to run static toe-out at the rear, to combat understeer. With a simple open tube axle, we can't do that.

It is somewhat easier to get roll oversteer with a beam axle. It is possible with independent suspension as well, but that entails making each wheel toe out any time that wheel's suspension compresses and toe in any time that wheel's suspension extends. The toe of each wheel relative to the other therefore changes a lot with ride or two-wheel heave motion. With a beam axle, the toe can be made to stay constant in ride while the rear wheels still both aim out of the turn when the car rolls.

Take a brake

With an open tube axle we can use a single rear brake. We do need a way to react the brake torque without creating change in diagonal percentage. We can do that with the caliper on one birdcage, provided that we use parallel (not necessarily horizontal) trailing links.

We can also use a single rear brake with a differential, but only if it acts through the diff carrier, not just on one wheel. The diff also needs to generate substantial locking torque in braking. Otherwise, if the rear tyres are unequally loaded or have unequal grip for any reason, we risk failing to lock both rear wheels in the brake test during tech inspection.

A De Dion suspension allows us to run a bit of static negative camber if we wish. An open tube axle does not allow that. Beam axles do not require as much static negative camber as independent suspensions, however, because (disregarding the roll component due to tyre compliance) they achieve 100 per cent camber recovery in roll. This also makes beam axles potentially attractive for the front suspension.

Lateral location doesn't need to be anything fancy; a single link is fine. Watt linkages and other more complex options will work, although there needs to be some packaging advantage to justify the added complexity.

CONTACT

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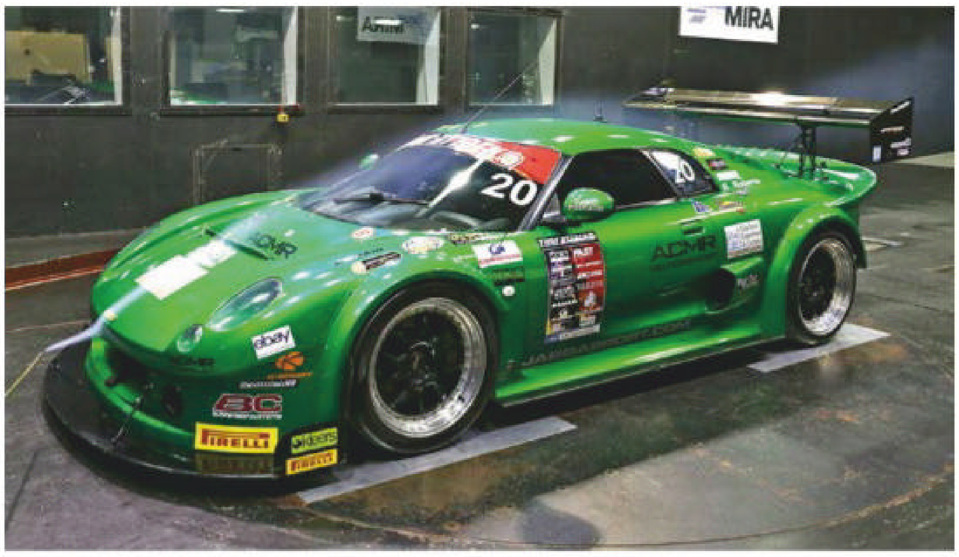
Noble cause: honing the aero package on an M12

Our two-car Time Attack wind tunnel study comes to an end with some front end tweaks and rake changes on the Noble



The Noble M12 RSR is well-developed and produced good, balanced downforce

The Caterham had modest downforce figures, despite a recently fitted wing package

In our current wind tunnel project we have been studying two racecars that represent the smaller, lighter, nimbler approach to Time Attack, which in the UK's upper echelons at least still seems to be dominated by bigger, heavier but potent turbocharged saloons. The Caterham R400 here belongs to David Long, who won the 2018 Super Lap Scotland Pro class, while the Noble M12 RSR took Simon Roberts to the 2017 UK Time Attack Club Pro class title and runner up spot in 2018. Having focussed on the Caterham last month, we will round off the project in this issue with a closer look at some of the key aero features of the Noble.

As a quick recap **Table 1** gives the coefficients (multiplied by the frontal area to enable direct comparison) for each car in best in session configuration. The Caterham's recently installed wing package achieved quite modest downforce, 6.4 per cent of car weight at 100mph in fact, and as described last month still needs refinement to achieve an aerodynamic balance nearer to its 48 per cent front to 52 per cent rear static weight distribution. The well-developed Noble achieved quite high downforce, 30 per cent of car weight at 100mph, with an almost ideal balance in relation to its 38 per cent front to 62 per cent rear weight distribution.

Front tweaks

The Noble started our session as raced in 2018, and proved to have a very good balance of just under 35 per cent, which tallied well with driver feedback. We started by looking at the contributions of two of the front end devices; the front diffusers under the splitter and the splitter end fences. By panelling over the front diffusers results 'with' and 'without' were obtained, and are shown as simple coefficients in **Table 2**. The differences (delta or Δ values) are also shown in counts, where 1 count is a coefficient change of 0.001, and percentages. As the data shows, with minimal change to drag the front diffusers provided a significant chunk of additional front downforce that brought the %front figure up to its well-balanced level of around 35 per cent. Note that there was only a small decrease in rear downforce.

Some even simpler devices attached to the front were the splitter end fences. With the front diffusers now in play, the splitter fences were removed to examine their effects, and the data is in **Table 3**. The responses here were different; the fences generated more drag than the front diffusers, although really very little extra, and the gain in total downforce was more modest.

However, the principal effect was to add downforce to the front at the expense of a downforce reduction at the rear. In this respect these fences behaved very much like large

Table 1: Baseline numbers on our test cars

	CD.A	CL.A	CLfront.A	CLrear.A	%front	L/D
Caterham	0.866	-0.318	-0.083	-0.234	25.9%	-0.368
Noble	1.446	-2.571	-0.914	-1.657	35.6%	-1.779

Table 2: The effects of front diffusers

	CD	-CL	-CLfront	-CLrear	%front	L/D
With	0.695	1.157	0.404	0.754	34.9%	1.665
Without	0.691	1.099	0.335	0.764	30.5%	1.590
Δ, counts	+4	+58	+69	-10	+4.4%*	+75
Δ, %	+0.6%	+5.3%	+20.6%	-1.3%	-	+4.7%

* Changes in %front are absolute, not relative.

Table 3: The effects of splitter end fences

	CD	-CL	-CLfront	-CLrear	%front	-L/D
With	0.695	1.157	0.404	0.754	34.9%	1.665
Without	0.687	1.120	0.286	0.834	25.5%	1.630
Δ, counts	+8	+37	+118	-80	+9.4%*	+35
Δ, %	+1.2%	+3.3%	+41.3%	-9.6%	-	+2.1%

* Changes in %front are absolute, not relative.

Rear downforce was now needed to bring it back to the well-balanced value we started with

Table 4: The effects of a taller front radiator exit Gurney

	CD	-CL	-CLfront	-CLrear	%front	-L/D
2018	0.695	1.157	0.404	0.754	34.9%	1.665
Taller	0.701	1.173	0417	0.756	35.5%	1.673
Δ, counts	+6	+16	+13	+2	+0.6%*	+8
Δ, %	+0.9%	+1.4%	+3.2%	+0.3%	-	+0.5%

* Changes in %front are absolute, not relative.

Table 5: The effects of rear ride height increases – changes are relative to the previous configuration in each case

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Before	0.701	1.173	0417	0.756	35.5%	1.673
+19mm RRH	0.711	1.243	0.492	0.751	39.6%	1.748
Δ, counts (%)	+10 (+1.4)	+70 (+6.0)	+75 (+18.0)	-5 (-0.7)	+4.1 (-)*	+75 (+4.5)
+38mm RRH	0.726	1.307	0.555	0.752	42.5%	1.800
Δ, counts (%)	+15 (+2.1)	+64 (+5.1)	+63 (+12.8)	+1 (+0.1)	+2.9 (-)*	+52 (+3.0)

* Changes in %front are absolute, not relative.

Table 6: The effects of increasing rear flap angle by two increments

	CD	-CL	-CLfront	-CLrear	%front	-L/D
+38mm RRH	0.726	1.307	0.555	0.752	42.5%	1.800
R/flap +2 holes	0.773	1.375	0.489	0.886	35.6%	1.779
Δ, counts	+47	+68	-66	+134	-6.9%*	-21
Δ, %	+6.5%	+5.2%	-11.9%	+17.8%	-	+1.2%

* Changes in %front are absolute, not relative.

dive planes. But the net effect, especially to aerodynamic balance, was highly beneficial and there was still a modest gain in aerodynamic efficiency, as given by the L/D figure.

The leading edge of the radiator exit duct in the front clam shell featured a fairly prominent Gurney. The height of this was increased by about another 10mm to see if there would be any adverse effects, with the results in **Table 4**. Although the effects were relatively modest, there was another small gain in %front, and perhaps most interestingly no reduction in rear downforce, as had been expected (by disruption of the flow over the car to the rear wing), but instead a small increase.

New angles

Having assessed components of the existing aerodynamic package, we then moved on to trying to find further improvements. Roberts had found that rake angle changes made noticeable differences to the car's behaviour on track, so two increases of rear ride height were tried (using shim plates under the tyres) to gauge their effect, with the results shown in **Table 5**. The major effect of these rake angle changes then was significantly to increase front downforce with very little change of rear downforce, thus increasing the %front value. Modest increases in drag also occurred. The effects with the two equal ride height increments were non-linear and tailing off. Furthermore, the extent of the second ride height increase was probably beyond what was practically achievable but at least a response curve had been gleaned.

Such was the effect of increasing the rear ride height on front downforce that more rear downforce was now needed to bring the balance back to the well-balanced value we started with. Time being tight ahead of this final run there was no chance of mapping a range of wing angles, so with fingers crossed the rear wing flap angle was increased by two

These simple splitter end fences proved to be potent devices

adjustment holes. The final results, shown in **Table 6**, show the balance was very close to the 2018 figure but with 18.8 per cent more downforce and 11.2 per cent more drag. Efficiency (-L/D) was also 6.8 per cent up on the 2018 figure, but had come down by 1.2 per cent with the last rear flap angle increase, which suggested this set-up was just past peak efficiency for the car in its current guise.

However, given that the maximum practical extent of rear ride height increase would be somewhat less than the 38mm tried with tyre shims, the extent of the required rear flap angle increase would be commensurately smaller too, which would hopefully put the set-up even closer to peak efficiency.

Next month we'll start a new project.

Racecar's *thanks to David Long and Simon Roberts for providing their racecars.*

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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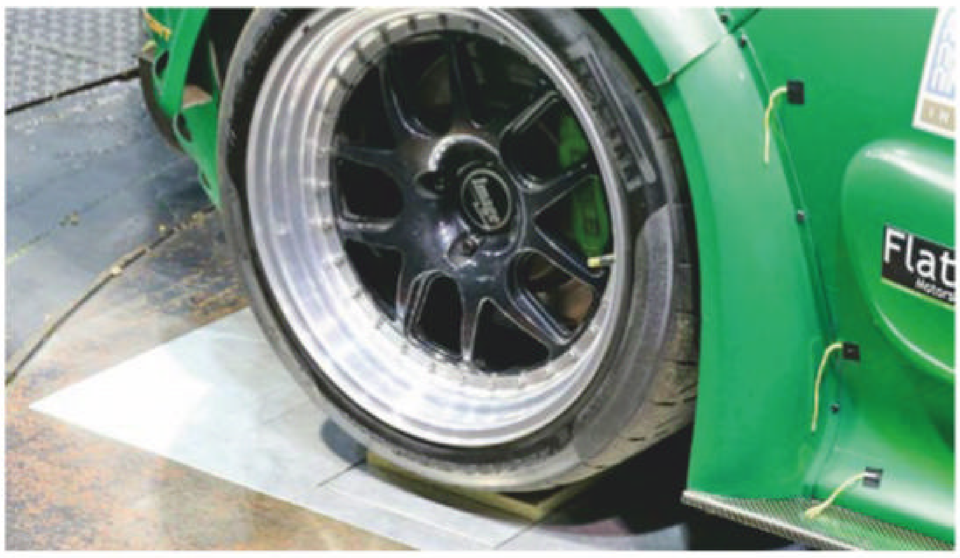
The radiator exit duct, which is situated in the front clam shell, has a prominent Gurney



Raising the rear ride height to increase the rake angle was a very productive experiment

What might have been

The Penske PC27 pictured in superspeedway spec in 1998

The last Indy car Penske ever built bristled with innovative engineering and yet it failed to win a single race. John Travis, its designer, talks us through some of the finer points of the PC27 – and also reveals why the project was doomed from the outset

By SIMON MCBEATH

Team Penske enjoyed a long spell at or near the top in CART-sanctioned Indy car racing as a constructor and, for the most part, the sole entrant of its own cars, taking its first series title in 1979, with further titles in 1981-'83, '85, '88 and '94.

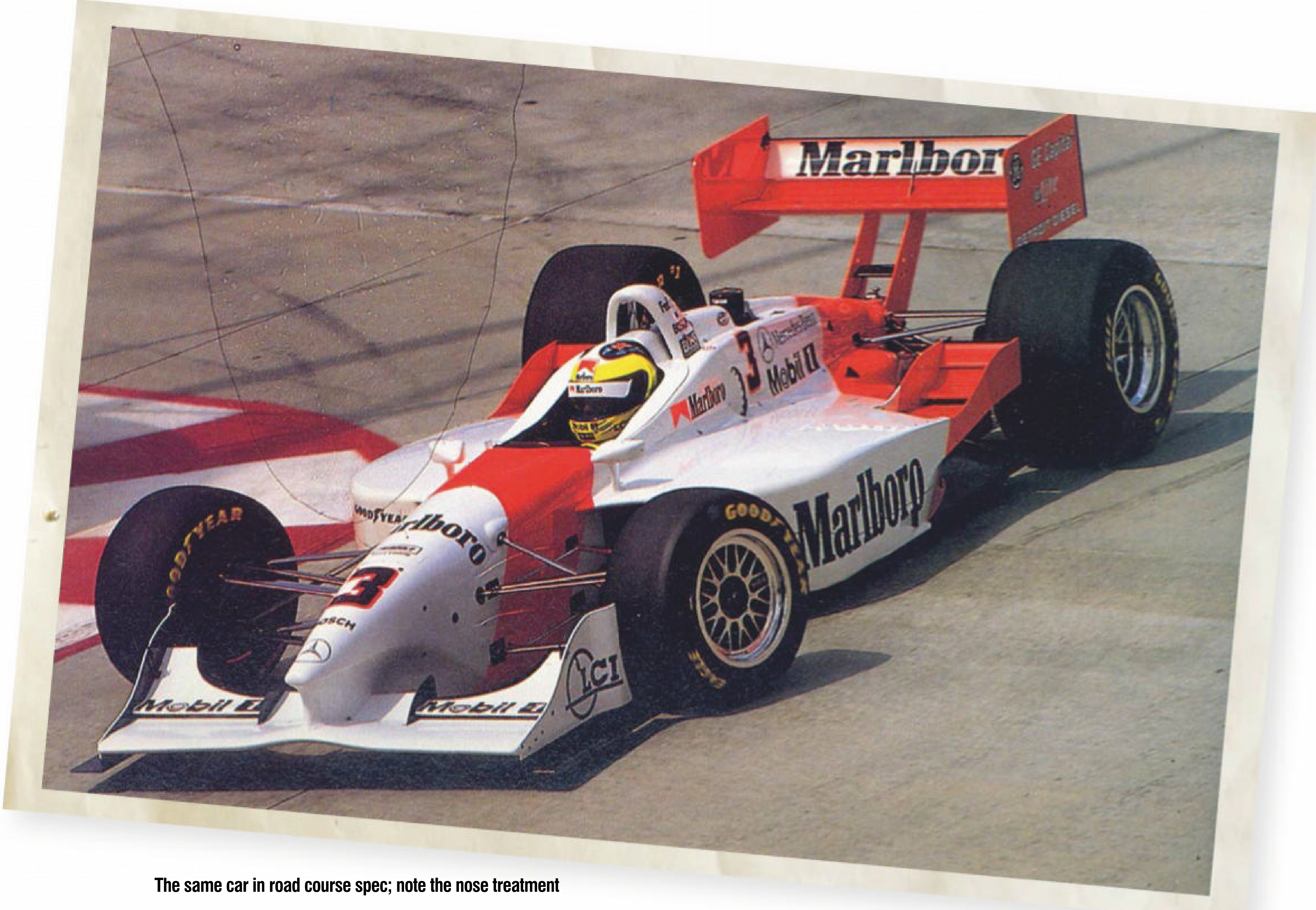
Penske Cars in Poole on the south coast of England was responsible for the design and build, engines aside, and Team Penske ran the cars out of its Reading, Pennsylvania base in the USA. The well-resourced F1-style operation thus enjoyed the luxury of being able to design and engineer its cars for just its own drivers rather than a number of customer teams. But after those five titles in the 1980s, only one more as a constructor followed in a dominant 1994 season that saw 12 race wins. The 1995 season produced five wins, 1996 was winless, and there were just three early season victories in 1997. On that purely statistical basis the operation seemed to have passed its zenith.

The car that took those last three wins in 1997 was the Nigel Bennett-designed PC26, which, according to this magazine's Class of '98 special feature (V8N5), could trace its origins back to the successful PC22 of 1993, and the mildly altered and dominant PC23 of 1994. But then Bennett, who had been with Penske Cars since 1988, decided he was going to retire, so in 1996 John Travis was hired from Lola to work alongside him for a year before becoming chief designer for 1998, and pen the PC27.

Indy beginning

Travis is these days busy re-forming his consultancy company after working for Wirth Research, but in 1996, on his arrival at Penske, he was initially involved with the PC25 and PC26. The PC25 was the 1996 car, while the PC26 was being designed for the 1997 season.

Travis's first impressions of the Penske organisation were mixed: 'The factory and the



The same car in road course spec; note the nose treatment

'The general architecture and driver positioning were novel, and how we got the aero to work was good'

people in Poole were second to none but the technology was behind. When Reynard arrived [in Indy car] in 1994 they raised the bar. While I was at Lola we had to raise our game and it took until the '96 car to get there. So now I had to do the same at Penske. They had perhaps been a bit complacent, maybe resting on their laurels? There was none of the wind tunnel programme or testing capacity in place. Aerodynamicist David Johnson-Newell was manually entering wind tunnel data into a spreadsheet. The wind tunnel model, which was largely made of wood, was pretty dire … So I discovered that the job was not just about designing the new car but revamping the capabilities too.'

The Formula 1-inspired Ilmor engine that powered the PC27 was shorter, narrower and lower than the unit that was in the PC26

One of Travis's first improvement projects was an independent survey by a professor of aerodynamics at the RJ Mitchell wind tunnel at Southampton University. It concluded that considerable upgrade work was needed on boundary layer control, temperature control and working section flow quality. Penske invested around a quarter of a million pounds in the upgrades, including new suction boxes to improve the (moving ground) boundary layer, air condition, a new Pi Aero data acquisition system, a new stiffer model support strut that allowed improved access under the model, laser positioning, steering angle control, and a new high accuracy model, with bodywork in carbon composite, that also featured engine flows. The improvements were said to make it one of the best wind tunnels in the world at that time.

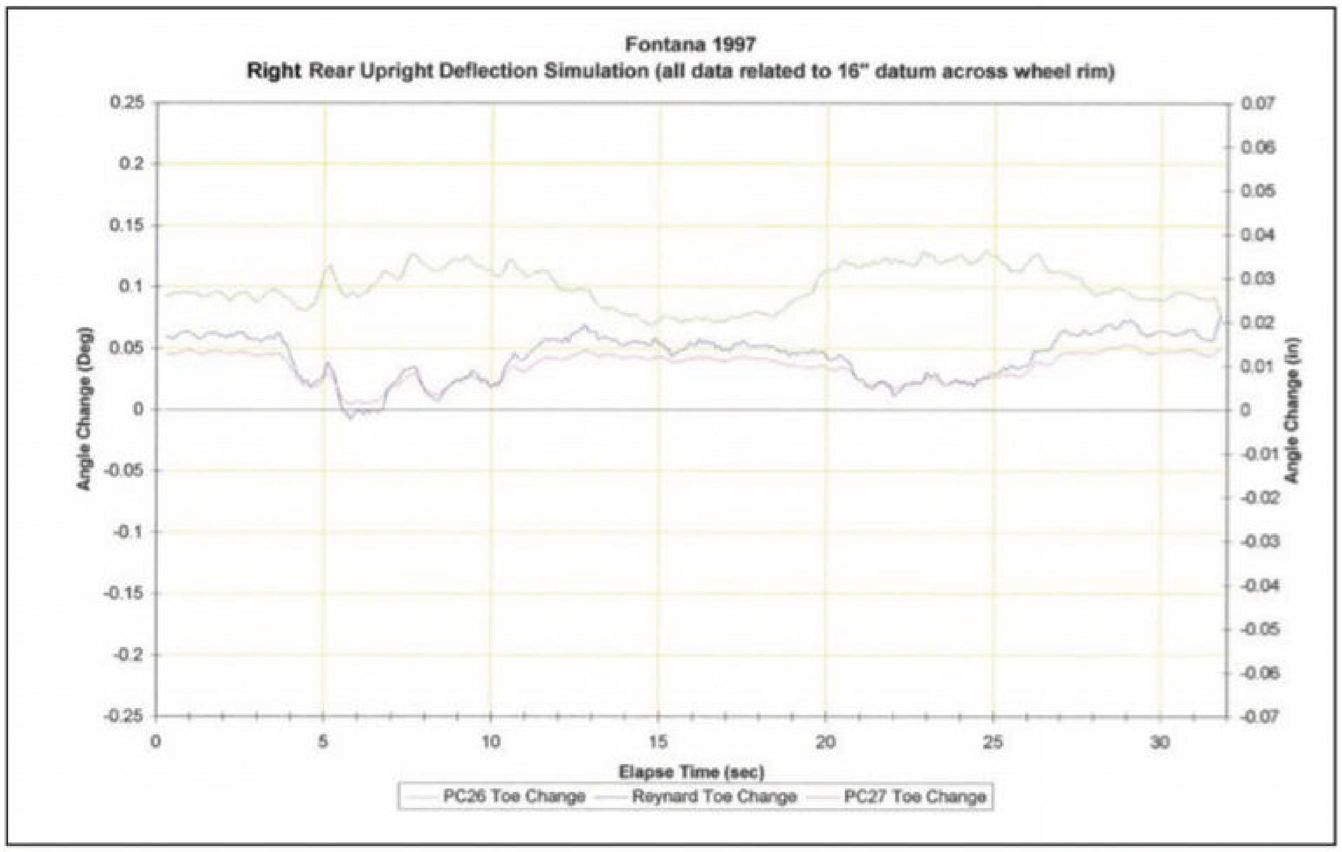
'This was during 1997 while I was working on the PC26 development and the capability upgrades were happening in parallel,' Travis says. 'With the wind tunnel sorted I moved on to the composites shop, or rather the drawing office/composites shop interface. They were great people but the processes had sort of frozen in time. I brought Dean Basford in and we basically changed how things ran to include lay-up books, and generally improved the quality of the processes. [Managing director] Nick Goozee was very supportive; he had to push RP [Roger Penske] to enable these big changes in a short period. And it was quite painful.'

Fresh start

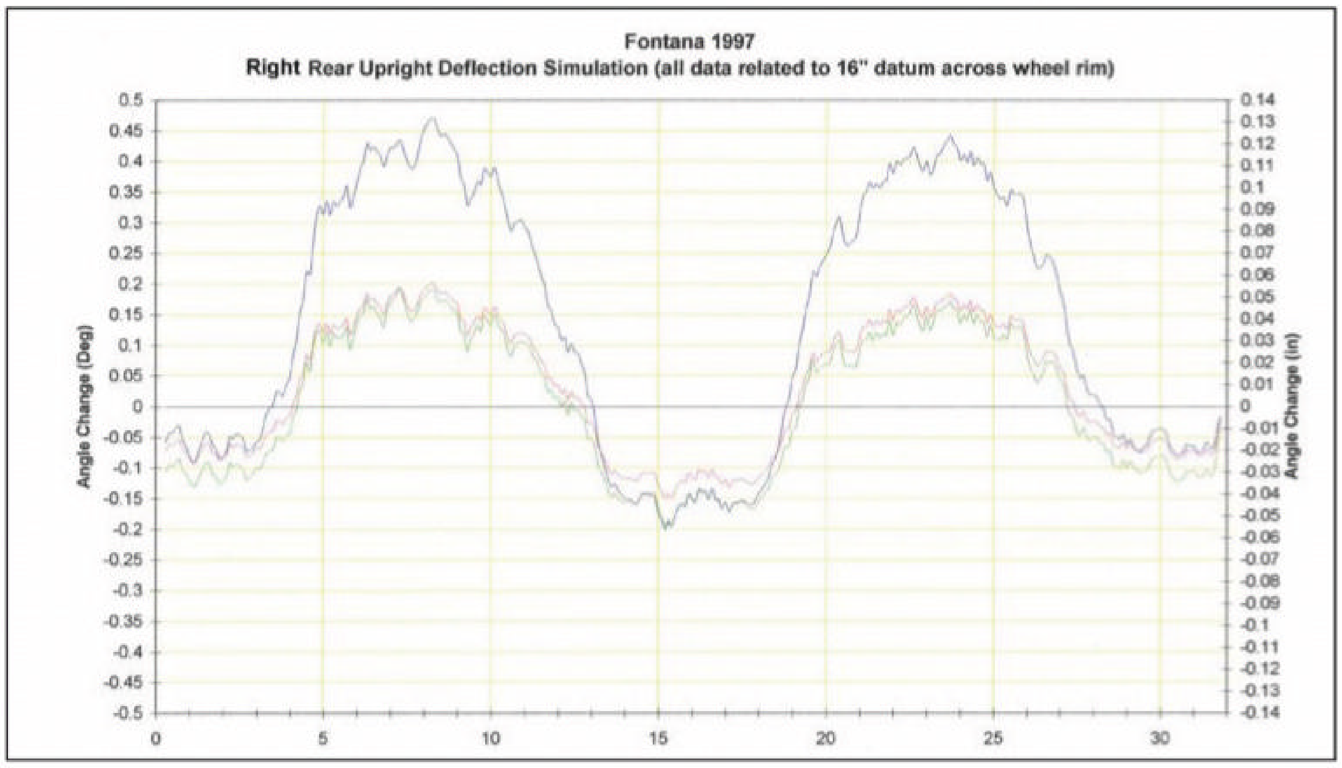
Following a pretty disappointing 1997 season with the PC26 Travis started with a clean sheet of paper for the PC27. Some design decisions address the shortcomings of a previous design; others are evolutionary, while still others represent genuine innovation. There was almost zero carry over of parts from PC26 to PC27, suggesting that evolution played little part in the PC27's design. But there were some major shortcomings that had to be addressed, not all of which were under Penske's control. And there was also considerable innovation.

'The biggest issue was the Goodyear tyres,' Travis says. 'The PC26 won on short oval courses but not on road courses and Goodyear were lost as to how to make competitive compounds. Firestone were using synthetic compounds and produced consistent and durable performance;

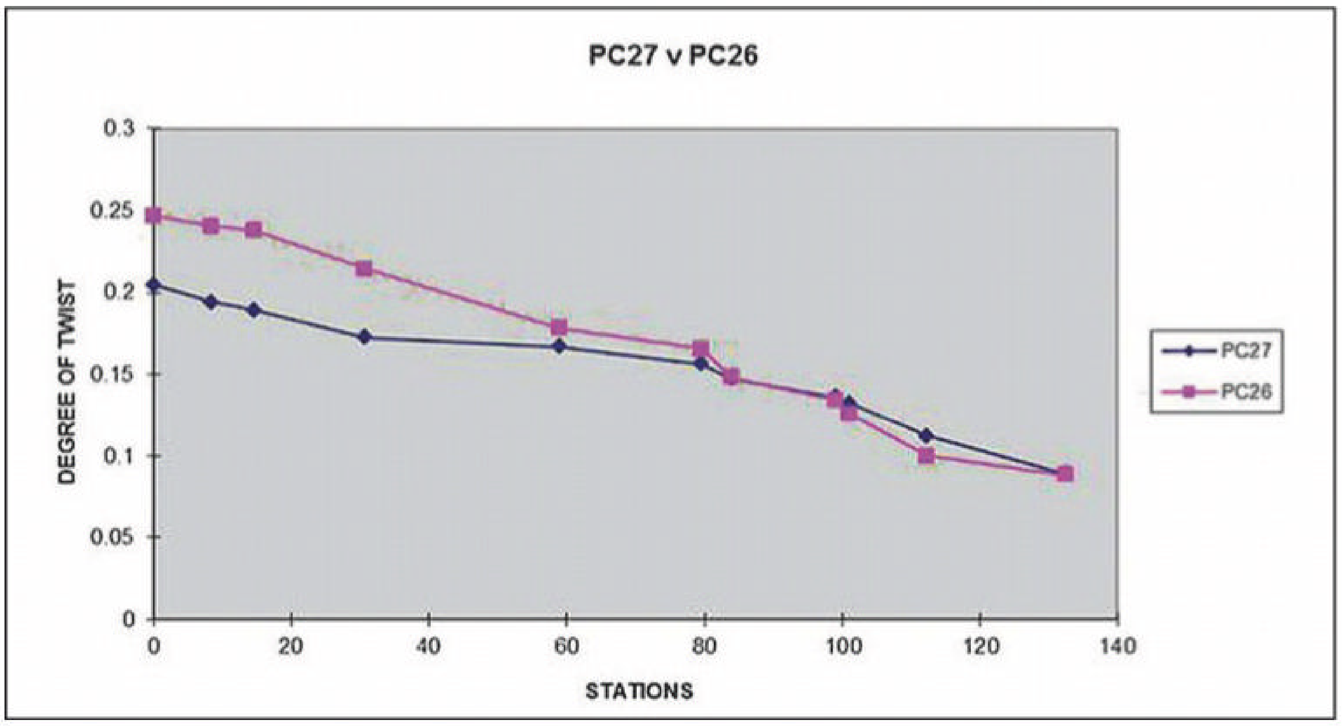
‘Roger Penske had one of the biggest Goodyear dealerships on the United States west coast and he wasn’t going to race on Firestones’



Deflection tests using load data from Fontana revealed that the PC26 rear upright (green line) suffered from excess toe steer



Camber deflections for PC26 and PC27 right rear uprights were both good when compared to the Reynard (the blue trace)



Monocoque stiffness was improved by 97 per cent on the PC27; this is a comparison with the PC26 (pink) along car lengths

Goodyear were using traditional raw materials and after the tyres had peaked very early in their life they then fell off [in performance]. But we were stuck with them because RP had one of the biggest Goodyear dealerships on the US west coast and he wasn’t going to race on Firestones.

‘The only suspension geometry programme the company had was one that didn’t even have an option to change the pushrod attachment point, giving the wrong motion ratio for suspension movement,’ Travis adds. ‘So I brought in Karl Nikalass, whom I had worked with previously, to develop geometry and chassis dynamics software. Goodyear were very good at providing data including Pacejka coefficients for our simulations, and we did our best to improve the use of the tyres but we couldn’t make up for their poor performance. We were in a tyre war, and when you’re losing you keep producing new tyres. That meant we had a different tyre for pretty much every track, so we had to run simulations with different data for each track.

‘The PC26 also did some unusual things at the rear on ovals,’ Travis adds. ‘It needed a *lot* of toe-in, and we couldn’t figure it. I had learned at Lola that you need to perform stiffness tests on components, but Penske didn’t have the facilities, so we had to set up an R&D department to test parts. Nigel Goozee got a unit around the corner from the main factory, we obtained a surface table, and we built various test rigs. Among other things we found that the PC26 rear upright was deflecting and giving toe steer. The rules mandated ferrous materials for the suspension so we started with steel billets and used EDM – electrical discharge machining, or spark erosion – to manufacture them. We had started to use FE analysis as well, and Marcel Staniak was brought in to do that.’

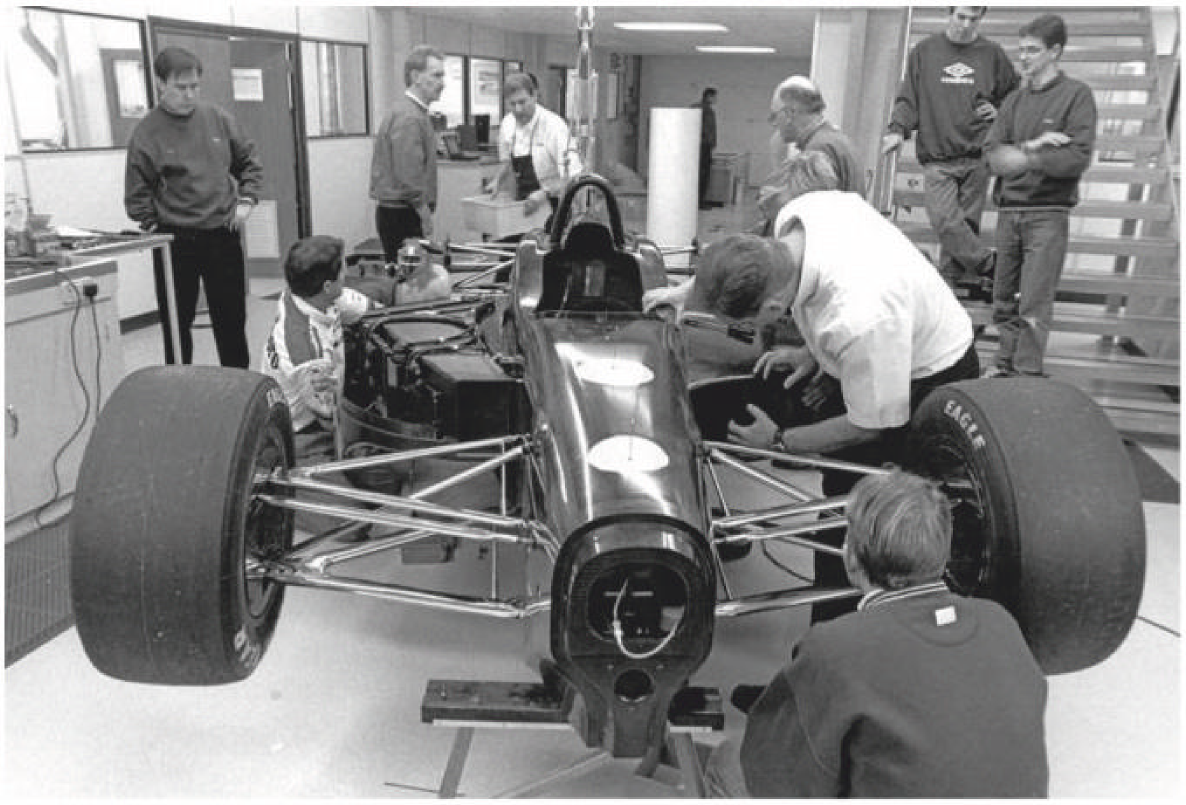
Knock-on effects

Other design criteria (of which more shortly) also meant that the rear dampers were low mounted on the gearbox, which made the pushrod angle shallow, in turn dictating that the pushrod had to attach to the upright. So, because of the distance between the wishbone pick up and the pushrod pick up, there was an additional toe steer force.

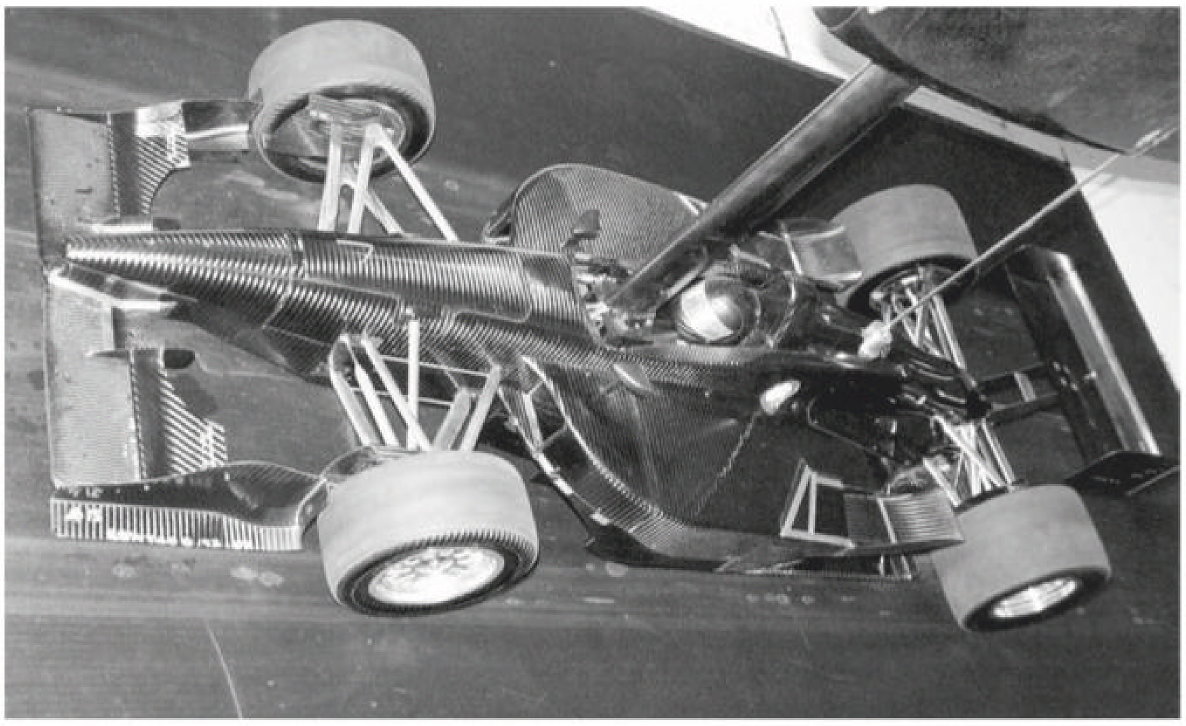
‘Anyway, given that we were stuck with Goodyear tyres, we had to look at what we *could* do to try and make up performance,’ Travis says. ‘It came down to aerodynamics, component stiffness, the right weight distribution, and the ability to alter that weight distribution.’

A major influence on the decision to start afresh on the PC27 was that Ilmor had been developing the replacement for its successful 1997 engine, the IC108D. At this time it was making strides on F1 engine design for McLaren,

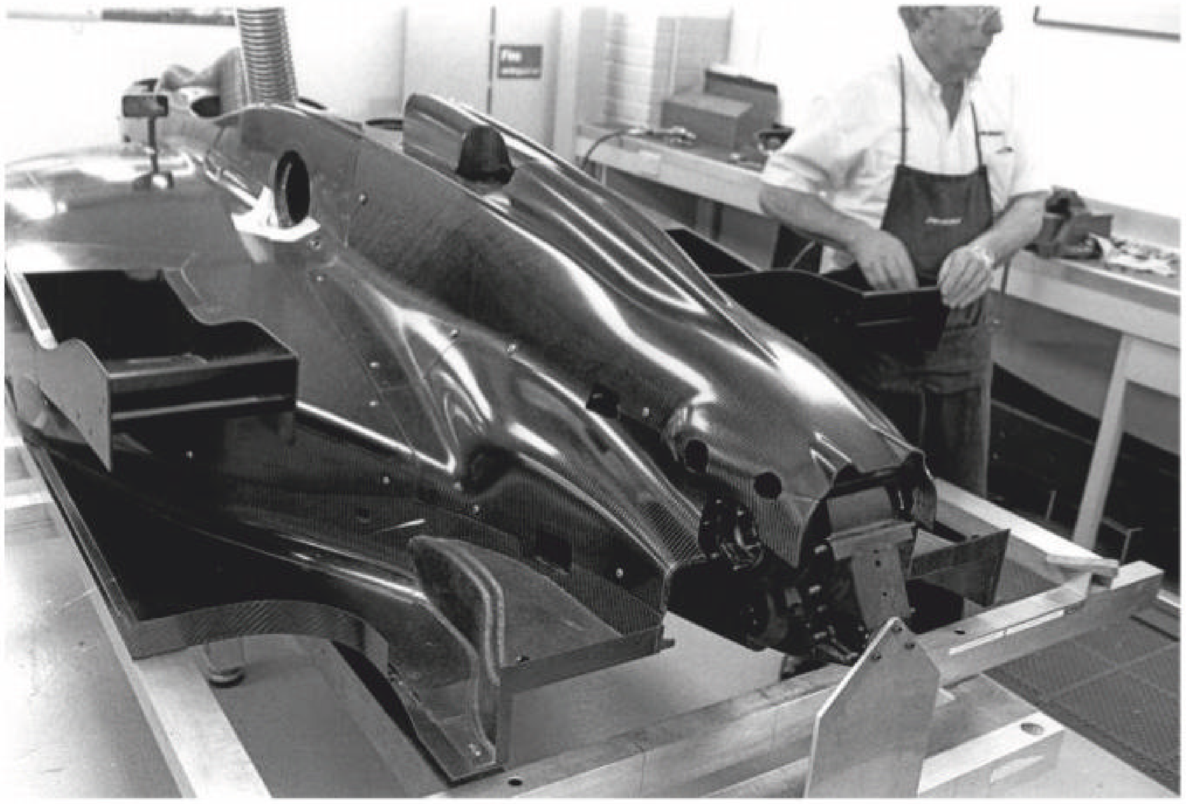
The small engine brought weight reduction and lowered CoG benefits, and also provided the opportunity to lower the central upper surfaces



The PC27 nearing completion at the Poole, Dorset (UK) factory with John Travis (third from left) supervising



The 40 per cent scale model of the Penske PC27 in the University of Southampton's R J Mitchell wind tunnel



The PC27's body assembly jig in Poole. Here the late Don Berrisford is taking a hands-on approach to the job

Black and white photos: Tony Matthews

and inevitably that led to similar concepts being adopted for its new Indy car unit. Pretty basic changes to the engine's architecture were made, the influential parameters for the Penske designers being that it was 95mm (3.74in) shorter, 65mm (2.56in) narrower and 39mm (1.54in) lower than its predecessor. It also weighed 23kg (50lb) less and the crankshaft height was 19mm (0.75in) lower.

'Our fundamental decision was: did we use the old chassis style or re-design to fully exploit the new engine?' Travis says. The decision was clear cut. 'The new engine was *tiny*, so we had to look at the rest of the car to take full advantage. We started with the ergonomics.'

Driver friendly

The small engine not only brought weight reduction and lowered centre of gravity benefits, it also provided the opportunity to lower the central upper surfaces, which would give obvious aerodynamic advantages. But unless the ensuing driver position was usable this would not be a viable quest. Formula 1 may have moved to lower driver positions, with a high foot position and the now ubiquitous raised forward chassis but, as Travis points out: 'Driving Indy cars was very physical on the bumpy road tracks, with no power assisted steering, yet on ovals and super speedways it was all about absolute finesses. We were dealing with two different car concepts.'

So the design team started with a full-size adjustable ergonomic model of a PC26 (which could be turned on its side to simulate one 1*g* cornering load), strain gauged the steering and brakes and brought driver Paul Tracy over to perform all the driver functions while remaining comfortable. They then lowered the seat back, moved the bulkheads, and rotated the driver position and repeated the driver function and visibility tests. This exercise then provided the basic architecture of the chassis.

'Then we worked our way back to the gearbox,' continues Travis. 'We had been using an inboard transverse gearbox, but its width was impinging on the tunnel exit volume, and we were constrained to a mandatory tunnel exit width. So to minimise the intrusion we devised a longitudinal inboard concept with a reversed gear arrangement that put the smallest diameter layshaft gears at the rear of the gearbox, allowing a tapered cone shape to the bottom, rear of the casing.

'We also dispensed with step down gears so we could run the "change gears" at engine speed,' Travis adds. 'This reduced the torque on them, which allowed narrower gears, enabling a smaller package again [Travis explained that the pinion gear on the main shaft drove a gear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on a cross shaft, and that cross shaft had a straight cut gear that drove the final drive gear, so there were two reductions to the final drive output. There were two final drive ratios, one for speedways and one for road tracks]. The casing was then "wrapped" around the gears. We then decided the casing would form the wetted underbody surface, so the inboard sides of the underwing slotted into tongue and grove joints in the side of the casing. The gearbox thus slid off the back of the car for ratio changes without the removal of the underwing. We made a big step aerodynamically with this gearbox. The wind tunnel model had an accurate model of the engine and the gearbox.'

Clear thinking

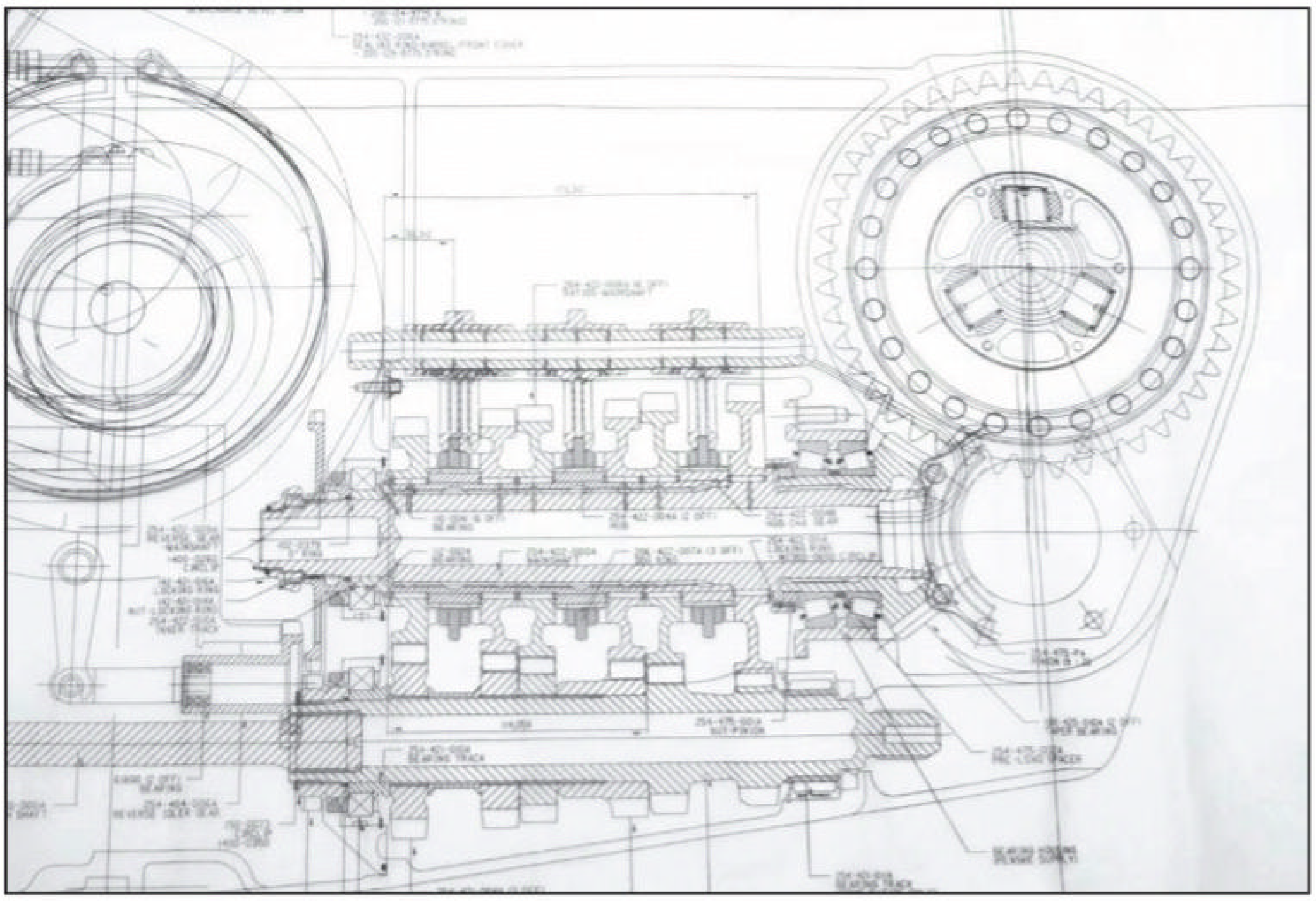
The gearbox design was a joint project between Penske (and more specifically Geoff Ferris) and transmission specialist Xtrac. The next issue with it was how to scavenge the gearbox oil. 'Xtrac made a translucent rapid prototype case with all the gears inside it and they then ran it up, unloaded, on their dyno to see where the oil went,' Travis explains. 'Basically it ended up on one side in between the two principal shafts, and it needed an inverted catching rail to collect

We had some catastrophic failures where two gears had engaged simultaneously

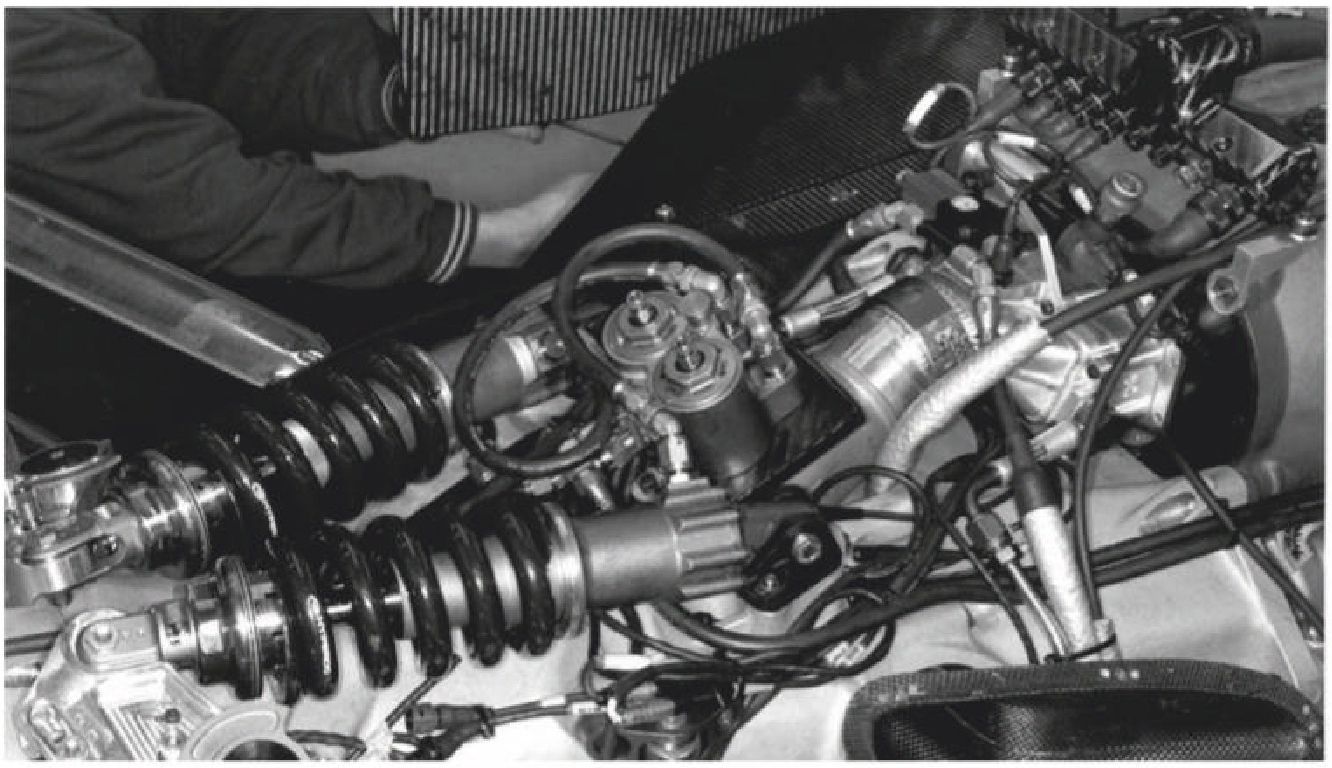
and scavenge the oil. It had to be inside or the exterior would be compromised.

'Ultimately it was the low gear cluster that meant the top of the gearbox was low, which in turn led to the low damper height and shallow pushrod angles and hence the pushrod location on the rear upright,' Travis adds.

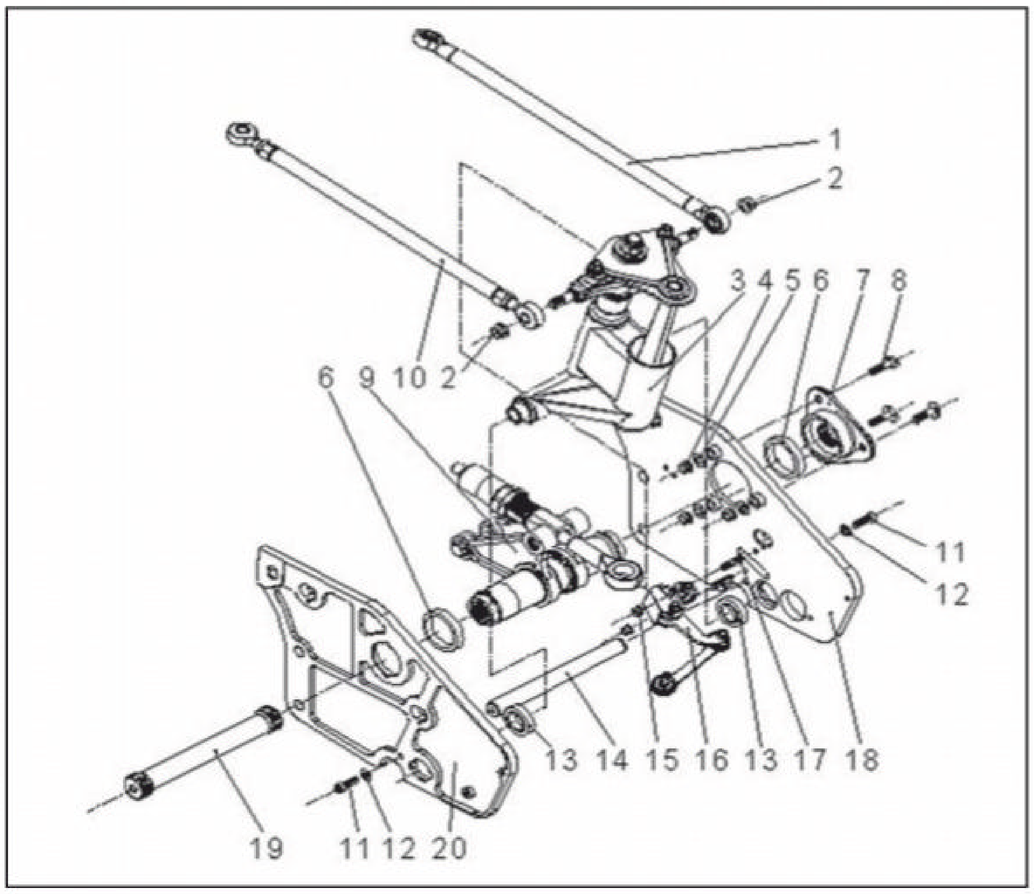
A number of non-finishes in 1998 were attributed to transmission failures, though. 'Yes, there was criticism about the gearbox's reliability,' Travis says. 'But you don't get the people at Xtrac scratching their heads wondering what's going on without there being a peculiar reason … We had switched to Magneti Marelli engine and gearbox controls on the PC27, with a flat shift system, but initial problems with this had been eliminated. Yet we had some catastrophic failures where two gears had simultaneously engaged. We made stiffer selector rails in case they were flexing, but that wasn't it. However, we were running very close dog clearances. Then I saw a gearbox being stripped, in the US, and I noticed that the selector fork bush, which should have been a tight fit in the casing, almost dropped out. It transpired that these had been pulled out and



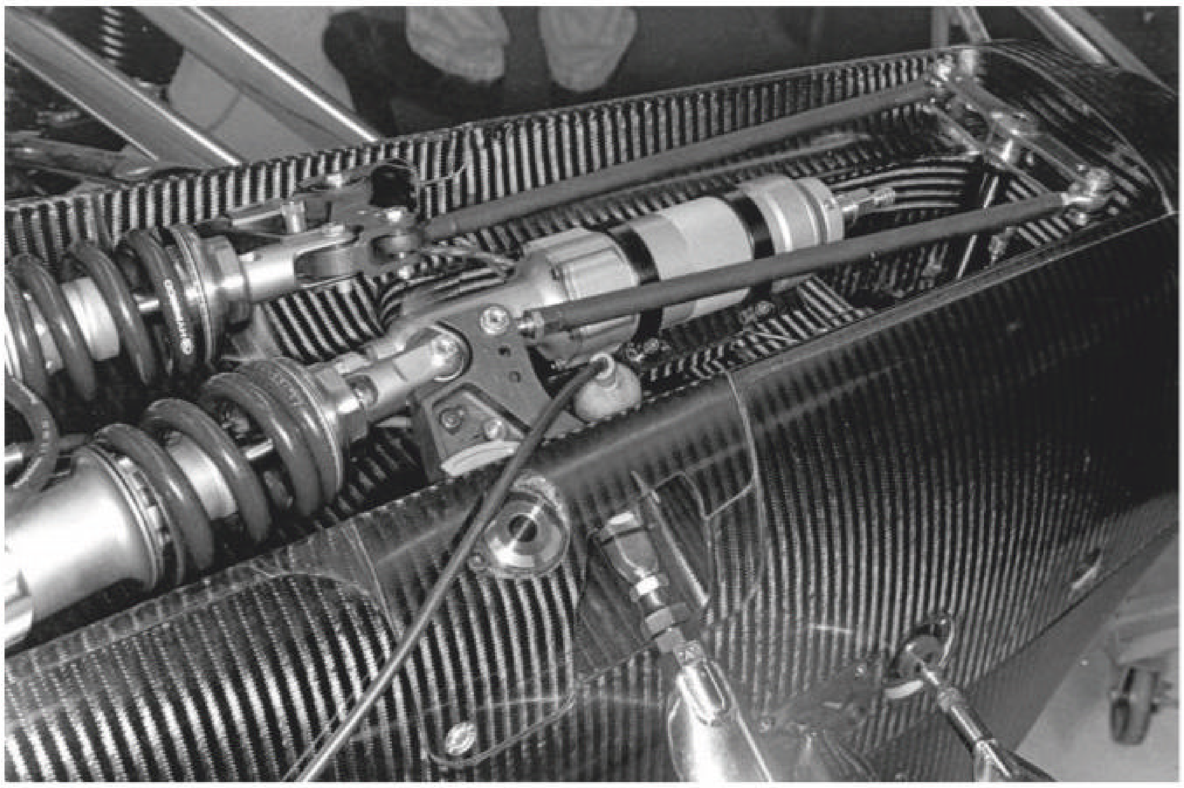
This schematic of the PC27's gearbox shows how the internals were arranged to create the three-dimensional rear taper



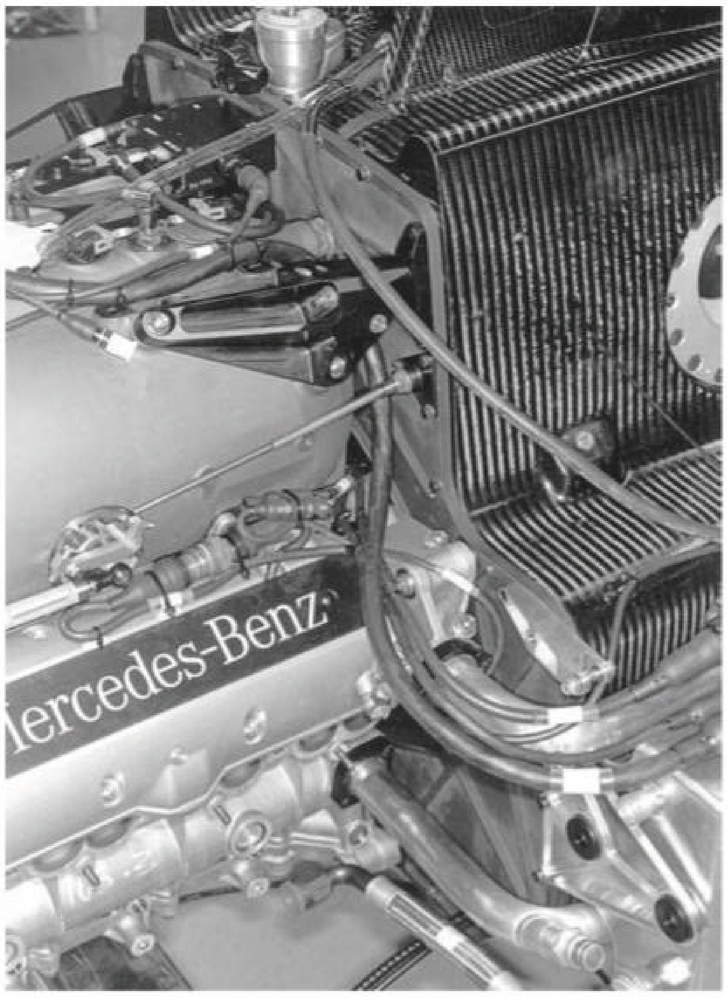
Rear dampers were hydraulically cross-linked via an adjustable valve block. PC27 was the first racecar to use this set-up



Exploded drawing of the mono-blade rear anti-roll bar with torsion bar third spring and damper. This was installed between the wing mounting plates



The front third element damper was hydraulically, not mechanically, connected to the main spring/dampers



Engine/chassis interface was partly via cast magnesium plenum

There was almost zero carry over of car parts from the Penske PC26 to the PC27

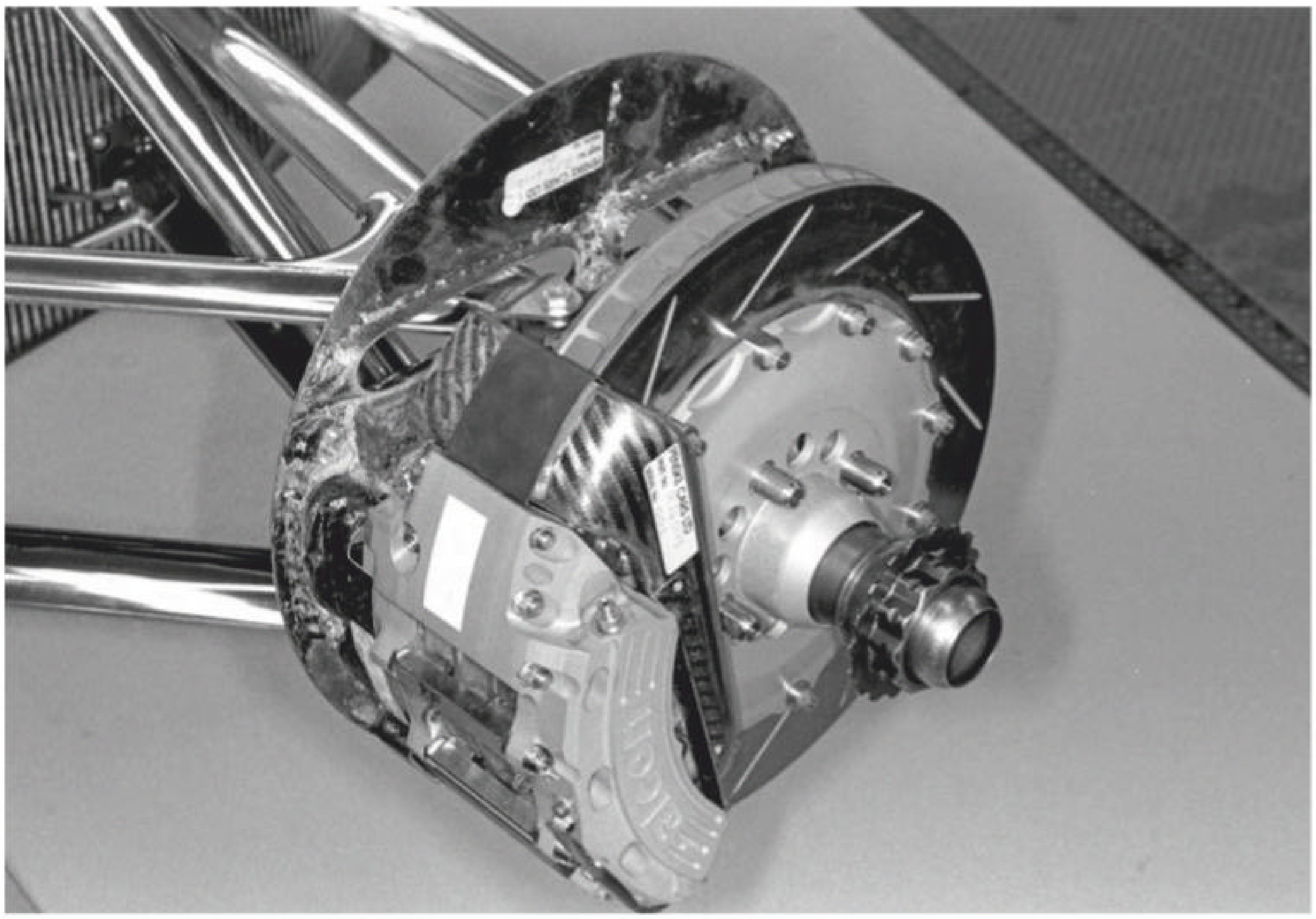
externally finished to facilitate their replacement during rebuilds. But this also allowed them to float, which enabled the selector forks to move and pick up another gear! When this assembly problem had been eliminated it worked fine. I got lambasted by RP for the gearbox being complicated. But it wasn't complicated at all.'

Cross-linking

Travis believes that, in association with Penske Shocks, the PC27 featured the first cross-linked suspension ever to be raced. 'On bumpy road tracks we didn't run anti-roll bars. And while drivers don't really notice the amount of total roll they certainly feel the *rate* of roll, so we needed control of low damper shaft speeds to deal with chassis transients.' To that end the dampers were connected to cross-linked remote reservoirs that gave control over low speed damping characteristics.

'We used very unconventional hydraulic third elements too, with no mechanical connections to the main spring/dampers, but this was a problem at the rear because of high temperatures expanding the oil, thus changing the ride heights, and was abandoned,' Travis says. 'However, our solution was a real work of art to fit in the restricted space. It comprised a torsion bar third "spring" dealing with the heave mode that had a small damper that was only activated when the torsion bar, which had an adjustable engagement point, was engaged. It all fitted in between the wing mounting plates on the back of the gearbox.'

Much of the re-packaging of the entire car was to narrow the rear end, not just within the rear underbody as has been mentioned, but also the cockpit and engine cover to improve flow to the rear wing. This caused some heat issues but



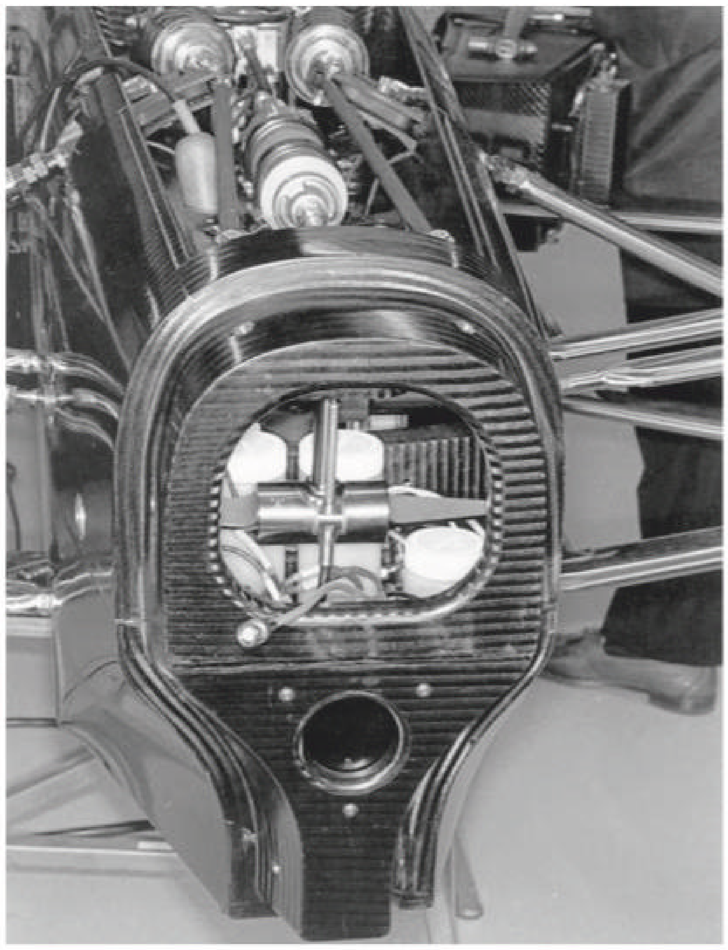
Front upright assembly. The outboard carbon shroud has a PC26 part number, one of very few carry overs from the '97 car

The wheel includes paddles for hydraulic corner weight jackers

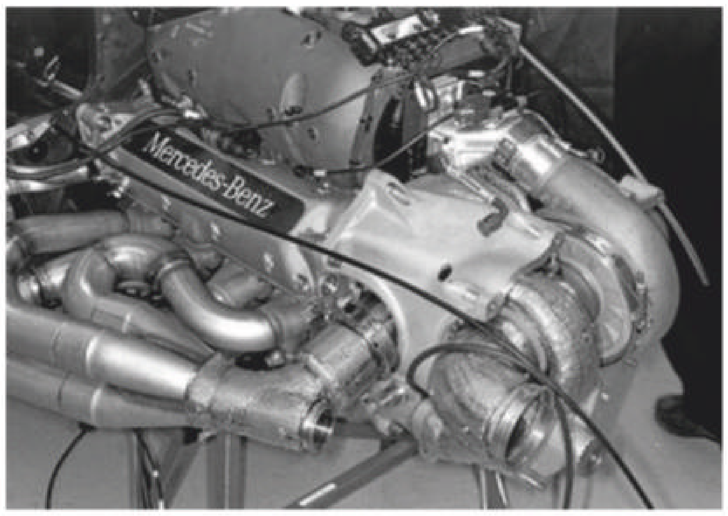
they were circumvented. Helmet integration was also improved to reduce buffeting.

'The other novel thing was the nose, with its raised, single pillar mounting. This was difficult to get to work structurally. We had to meet the rules on minimum width at the front bulkhead interface and the under-surface angles of the nose, which were a maximum of 10deg for 15in then a maximum of 5deg to the front of the nose, so this controlled the lower nose height, hence the speedway nose. But what you did above this was open, and led to the road course nose. The aim was to increase mass flow to the underwing and into the big scalloped underbody inlets, with their vortex generators.

A view of the underside of the road course nose and wing assembly reveals the cutaway and the central keel



Scalloped cutaway is visible at the bottom of the forward chassis



Engine was down on power. Note turbo assembly in bellhousing

'However, we had two noses, one for superspeedways, which easily passed its impact tests, and the new road course/short oval nose, which was a nightmare to get through tests. Stiffness was an issue too. We were up against time constraints and we tested at Phoenix pre-season with cables between the nose and the wing. Dean Basford and Marcel Staniak worked on the composite lay-up with the help of FE to improve the stiffness of the wing interface and to pass the crash tests, which we duly did.'

The challenge of designing and making two different nose shapes was compounded by the need for the speedway nose to have what Travis called 'rabbit ear extensions' on the rear, lower sides to fill in the chassis scalloped cutaways that were a continuation of the road course nose to direct air into the underbody.

'The underbody inlet area was interesting; and we tuned the vortex generators according to circuit type and ride height requirement, as well as having two completely different underbodies, one for road track and one for ovals and speedways. The main thing with these cars though was to minimise rear end sensitivity, so controlling pitch and heave was important. Prior to the PC27 aero programme we also made a new carbon wind tunnel model of the PC26 as a new reference for the PC27.'

A couple of years later, Penske decided to run Reynards instead of building its own cars, and the chance to compare some numbers from the Southampton tunnel arose. 'The Reynard R2KI 2000 was a very good car so it makes an interesting comparison with the PC27,' Travis says. As **Table 1** shows, the PC27 produced 7.5 per cent more downforce for 5.3 per cent less drag than a car designed two years later.

History shows us that the PC27's best result in 1998 was second place for Al Unser Jr, in Round 2 at Motegi in Japan. But by the year's end Penske had shrunk its Indy car operation to a single car for 1999 and reduced staff levels both in the UK and in the US. There was criticism that Travis had pushed Ilmor too hard to make the engine so compact and that this limited the ability to make gains from plenum and intake tuning. But Travis disputes this.

'We didn't drive the engine size, Ilmor did that,' he says. 'We only asked if we could use the cast magnesium plenum structurally to help with beam stiffness and provide a multi-point connection to the engine bulkhead. But had Ilmor asked if they could increase the plenum size to give us more power then of course we'd have modified the engine cover and so on to suit. But we never had such a request.'

Which begs the question of whether the engine *was* down on power, and if so why? 'It couldn't reach the design RPM, they couldn't control the valve train at design speed, so we didn't have the absolute power,' Travis says. 'Add that to the problems with the Goodyear tyres and we were doomed.'

Final flourish

Notwithstanding the outcome Travis has positive recollections of his Penske Cars tenure. 'I have to give credit to the skills at Penske, you couldn't ask for better people,' he says. 'These were born and bred Penske people on the south coast, not ones that had moved from the traditional motorsport regions. And it's only when you leave a company that you realise how well it was run; Nick Goozee gets credit for that. We were sometimes at loggerheads, but he set standards that have stayed with me to this day.'

Al Unser Jr has described the Penkse PC27 as 'my favourite racecar … a dream to drive. With the right tyres and engine it would have won many races.' And despite the factors that ultimately hobbled the PC27, Travis has a fierce pride in this particular racecar. 'The general architecture and driver positioning were novel, how we got the aero to work was good,' he says. 'We kept the weight right down so we could move ballast around. In fact, we ended up adding weight by making the lower half of the engine bulkhead in stainless steel to get the car *up* to weight. The whole package went together well. It was such a different challenge. I put my head on the block and had it chopped off. But I had to do what I did, and we could all have been heroes.'

Table 1: Comparison between PC27 and Reynard R2KI aero data (150mph, 12.5mm ride height)

	Drag, lb	Downforce, lb	%front	L/D
Penske PC27	884	2807	41.7	3.175
Reynard R2KI	933	2612	42.1	2.800

'The Penske PC27 was a dream to drive and with the right tyres and engine I believe this car would have won many races'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Material benefits

How Williams Advanced Engineering has developed a brace of new Formula 1-inspired technologies that could lead the way in providing affordable, weight-saving composites for road car manufacturers

By SAMUEL COLLINS

The automotive industry is currently facing a period of great change as various legislation will force the vast majority of production cars to be hybrids or EVs within the next decade. Other legislation will see the remaining combustion engines limited to ultra low emissions. At the same time consumers demand that their new cars are spacious, safe, comfortable and come equipped with advanced and high quality entertainment and navigation systems, all things which add considerable weight.

Hybrid systems also have considerable weight penalties as well as an increase in complexity, which in turn adds further weight. Meanwhile, for cars fitted with combustion engines the regulations are also getting ever tighter, and for 2021 the European Union has set a stringent fleet-average CO2 target of 95g/km for all car manufacturers. This has placed a lot of pressure on them to reduce component weight. Discussions have also started about reducing that to as low as 75g/km in 2025.

Pole position

All of this has put the motorsport industry in a key position. With its expertise in lightweight materials and highly efficient power units its ideally placed to step in, and many well-known racing teams have started to offer their expertise to help with projects away from the race circuit. Indeed, as the new Williams FW42 made its race debut in the Australian Grand Prix, back at the factory Williams Advanced Engineering revealed details of two new composites which have their roots in Formula 1, but have been adapted for use in wider applications. Both of them have been used in the Williams FW-EVX, a technology demonstration electric vehicle platform, designed to provide a lightweight and safe basis for production cars.

Carbon trading

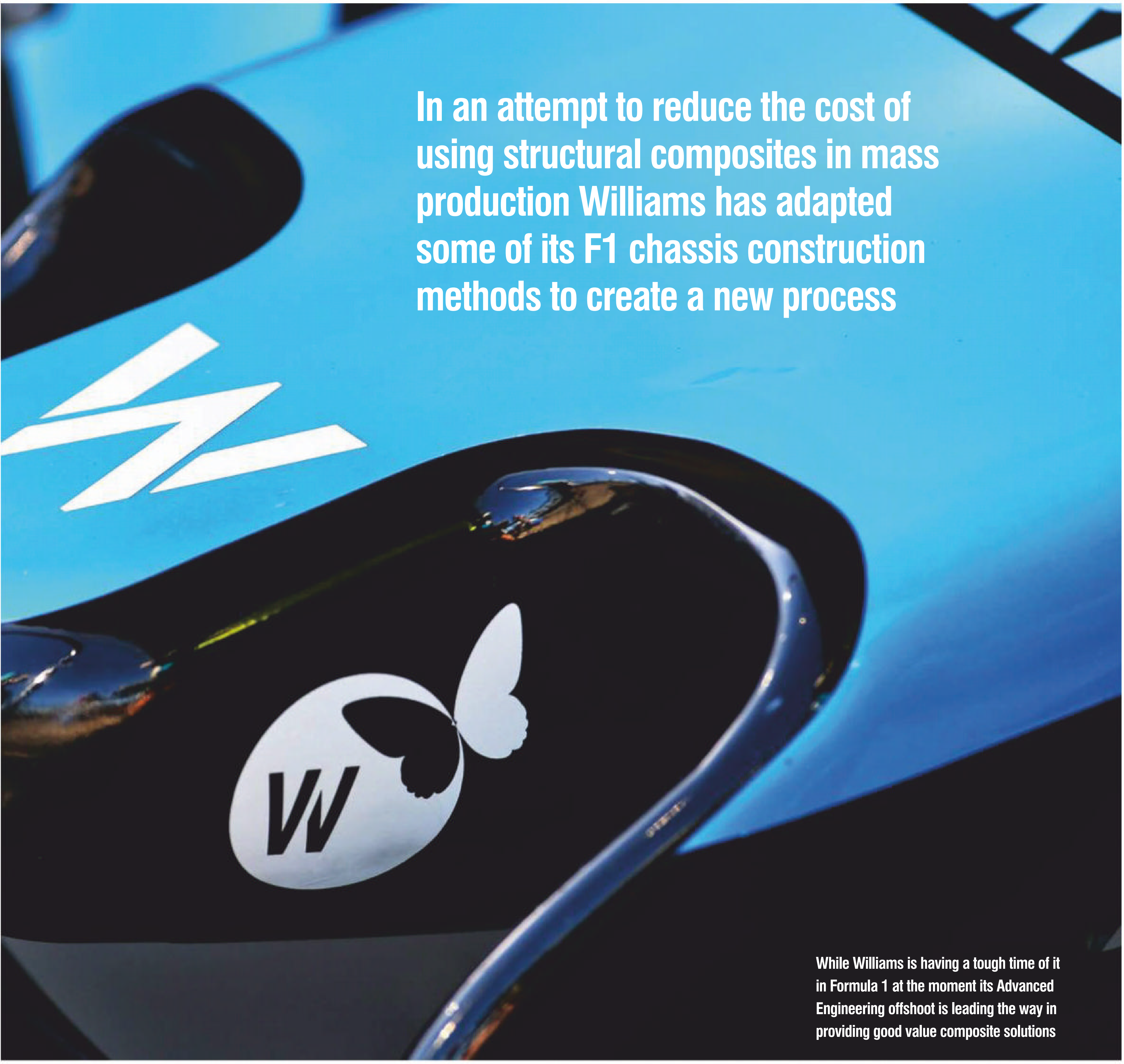
Using composites to reduce weight is nothing new, but to date the production processes have proved prohibitively expensive, with traditional composite production methods involving costly materials and lengthy process times. They also incur a relatively high scrap rate (typically around 30 per cent), compounded by the challenges of recovering the carbon from pre-preg off-cuts, and of finding value from the material at the end of the product life.

As a result, structural composite parts have really been confined to niche applications. In the automotive sector, for instance, a car body structure produced with traditional composite techniques is typically around 60 per cent lighter than one manufactured in steel, yet around 20 times the cost. This has limited its application to low volume or high cost cars, or to where the vehicle manufacturer subsidises the process as part of its learning around new technologies, as is common in racing.

In an attempt to reduce the cost of using structural composites in mass production Williams has adapted some of its F1 chassis construction methods to create a new process it calls '223'. It was conceived as a method of creating three dimensional composite structures from a two-dimensional form. Essentially this is a flat pack car. Its creators claim that it is ideal for box-like geometries, such as battery containers for electric vehicles, or potentially even complete vehicle monocoques. It could also have a notable relevance for some sports and racing car constructors who in the past have struggled with the cost of composite structures.

The name is from one of the defining features of this process. While composite components generally have to be laid up in their final geometry, 223 allows them to be created initially as two-dimensional parts before being folded into three-dimensions; 'two to three'.

The European Union's 95g/km legislation has placed a great deal of pressure on road car manufacturers to reduce weight



In an attempt to reduce the cost of using structural composites in mass production Williams has adapted some of its F1 chassis construction methods to create a new process

While Williams is having a tough time of it in Formula 1 at the moment its Advanced Engineering offshoot is leading the way in providing good value composite solutions

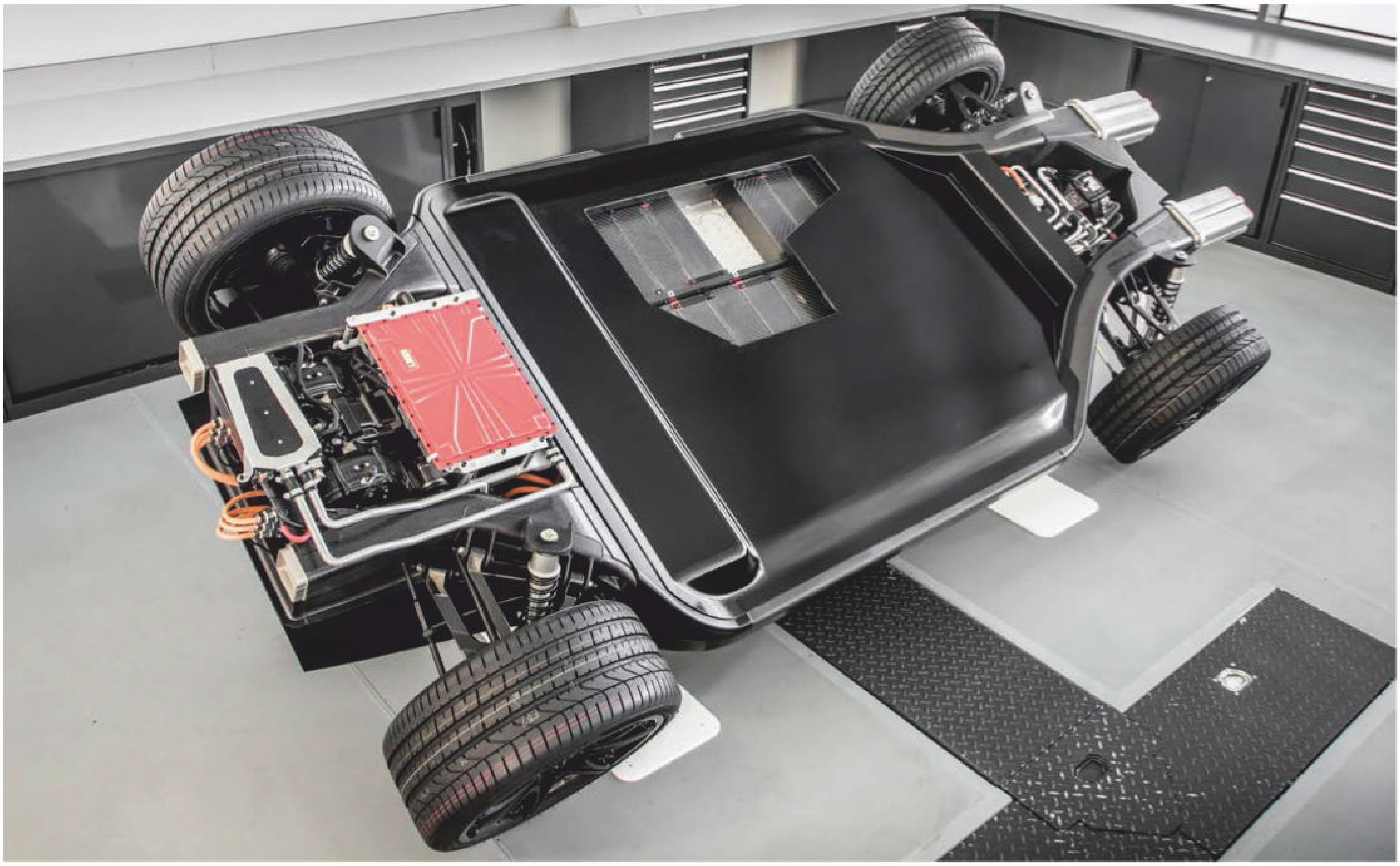
A potential application for this is a production car body-in-white (the stage when a cars body has been completed, which in steel terms means welded together) which typically consists of around 300 metal pressings, made with perhaps 600 different tools – a vehicle bonnet alone may require four different press operations. Using the Williams 223 process, the number of pressings could be reduced to around 50, all created on a single machine with a significant reduction in the tooling cost.

'We estimated that a weight saving of around 25 to 30 per cent could be achievable on a car's body-in-white, compared to an equivalent aluminium alloy structure,' a white paper from Williams Advanced Engineering states. 'With 223, this could be delivered in higher volumes and at a lower cost than a traditional composite solution. Where less strength is required, further cost savings could be made by specifying lower cost materials, for example glass fibres, while alternative resins can be specified to increase toughness and heat resistance.'

Trade secrets

Williams is not willing to disclose the full details of the 223 process, or the exact materials involved, but states that it uses a 'radically different' process for the integration of woven, dry fibre reinforcement sheet with a separately-prepared resin matrix. The technique is said to provide a great deal of freedom to optimise both elements to the specific requirements of a design across the component. For example, a design may employ high-strength carbon fibres as the reinforcement in some structurally critical areas, while low cost glass fibres could be used in others. Costly materials are used only where their benefit is required, and local strength can be provided without the cost of additional reinforcing components. This allows the full benefits of directional fibres to be used, rather than the often derided 'black-metal' approach where designers use composites as if they were traditional steel or aluminium.

The 223 process begins with an automated cutter trimming the flat sheet of woven fibre into near-net shape. The excess material from this process is dry, untreated fibre, which is substantially easier and more cost effective



Both the 223 and the Racetrak composite technologies have been used to great effect in the Williams Advanced Engineering-developed FW-EVX electric vehicle platform concept

to recycle than traditional pre-impregnated materials. At this stage, other components can be easily embedded, such as printed electronics and energy absorbing materials.

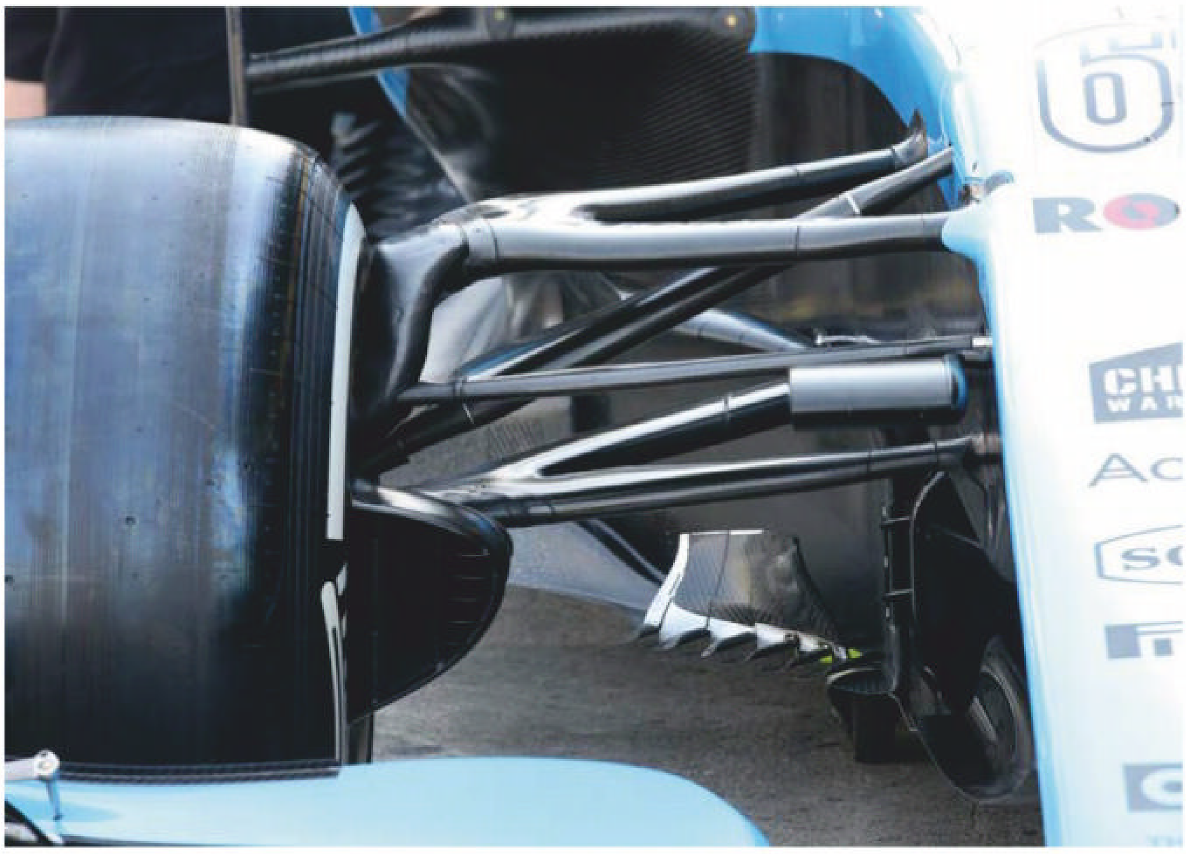
Next, the matrix is applied using an automated process that enables the composition of the resin to be specified locally across the part, allowing properties such as toughness and thermal conductivity to be varied across the component.

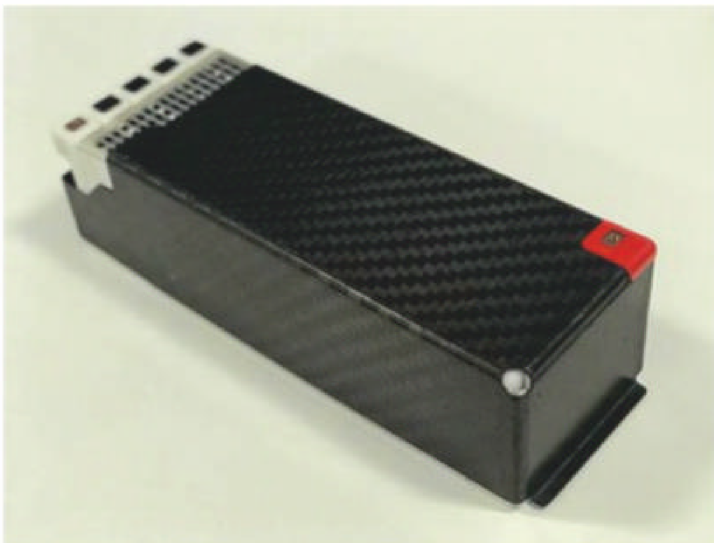
At this stage the pre-form is still a flat, two-dimensional sheet, like a cardboard box that has yet to be folded – think Swedish furniture.

Williams estimates fibre deposition rates of up to 500kg per hour. 'Overall, including other areas of process time saving, 223 is up to around 50 times faster than traditional aerospace-grade methods, which lay down material at roughly 10 to 20kg per hour,' the white paper states.

The pre-form is then fed into an industrial press, where a carefully-controlled force and temperature is applied. This cures the sections that are destined to form the faces of the box, while leaving the hinge areas between them flexible. 'Thanks to snap curing resins, the pressing process can be accomplished in around three minutes and with a high degree of automation,' the Williams paper explains. 'Energy, cost and time savings are also evident from the ability to maintain the press at a constant temperature, where otherwise the autoclave or press would traditionally go through a temperature cycle, adversely affecting the operational efficiency. Again, this is a further benefit of the process.'

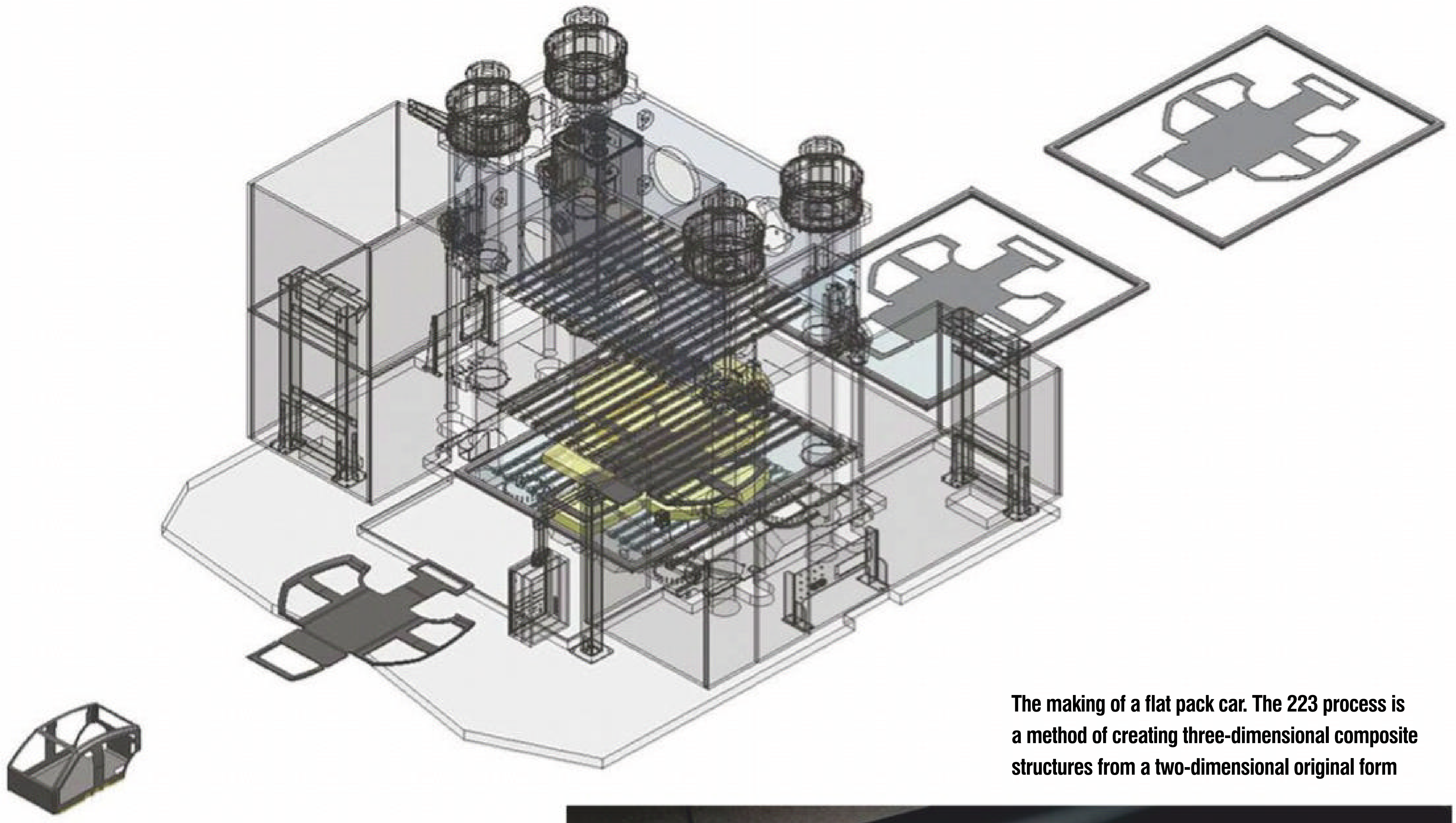
Once removed from the press, the cured areas have sufficient structural strength for additional manufacturing steps to be performed. The flat pack components can at





Above: The FW-EVX battery box is made using the 223 process. It's possible 223 could also be used to make complete car bodies

Left: Williams has extensive experience in composites and has based its new techniques on those used to make its Formula 1 parts, such as the wishbones shown here on the Williams FW42



The making of a flat pack car. The 223 process is a method of creating three-dimensional composite structures from a two-dimensional original form

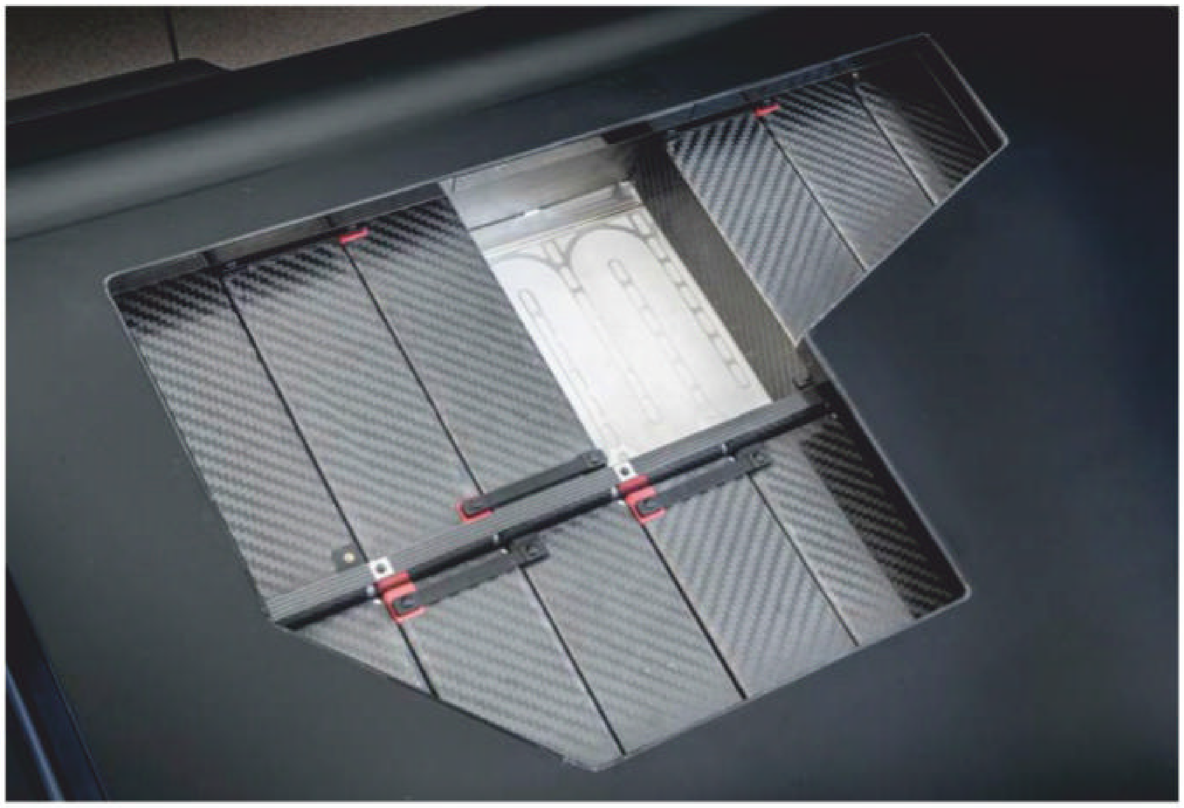
this stage be transported and stored, something which could offer companies logistical advantages. It's claimed that these flat packs are able to be stored for up to a year before the final curing stage is carried out.

For this final stage of the 223 process the component is placed in a jig, where it is then folded into its finished three-dimensional form. It then undergoes a final curing stage, which solidifies the hinges and seamlessly joins the edges of the adjacent panels.

Scrap value

Another benefit for mass production manufacturers is the low level of waste that's a result of the 223 process. Conventional techniques for manufacturing composite components (such as autoclave) typically result in upwards of 25 per cent scrap, because it is generally uneconomical to recycle pre-preg. This is because extracting the fibres requires a complex procedure to separate them from the resin, typically involving pyrolysis or solvolysis chemical decomposition, which consumes energy, incurs additional cost and increases the overall carbon footprint of the process.

But because off-cuts from the 223 process are dry, without resin around the fibres, they can be simply fed into a carding machine (a drum with internal spikes in which the material to be recycled is tumbled). This allows them to be easily converted into a felt-like non-woven material with carbon fibres a few millimetres long. The random direction of the fibres means the recovered material is not suitable for high strength applications, but the toughness, lightweight and acoustic damping characteristics make it ideal for applications such as door casings and instrument panels, or as a core within a laminate to improve noise, vibration and harshness resistance.



The 223 battery boxes fitted in the FW-EVX. Box-like containers like these are a perfect application for 223

In the 223 process more costly materials are only used where they are needed

Racetrak ready

Williams has also revealed a second new composite manufacturing technique which is suitable for highly loaded parts like wishbones. According to its promotional literature it has named this process Racetrak, explaining that that is 'because the continuous loop of fibre around the load bearing area resembles a race track when viewed from above.' Parts made using the Racetrak process consist of three main components: a core of low cost, non-woven bulk material, a loop of unidirectional carbon fibre, and on both sides of this a protective shell made from die-cut woven fibre sheet.

Notably, the manufacturing process is highly automated, with the unidirectional loop robotically wound to create precise, repeatable tailored fibre placement. This reinforced material

Wishbones could be turned into calibrated load cells that can transfer load data back to the vehicle via wireless electronics

pre-form is then placed dry into a tool, which applies a light shaping pressure to create a removable cartridge. This is then placed into an industrial press, where a vacuum is applied and the resin is injected into the heated mould. Under these conditions, the resin takes about 90 seconds to cure. It is then ejected from the machine and a fresh cartridge is loaded.

'With a cycle time currently at just 120 seconds, a single press using this process can produce more than 500,000 units a year,' the promotional documentation from Williams claims. 'The composition of the system also contributes to an attractive price/performance ratio as the most costly materials – notably the unidirectional carbon fibre – are used only where their unique mechanical properties are required to deliver high local strength, for example to link anchorage points. The woven shell increases load distribution across the component and enhances both sheer strength and damage tolerance.'

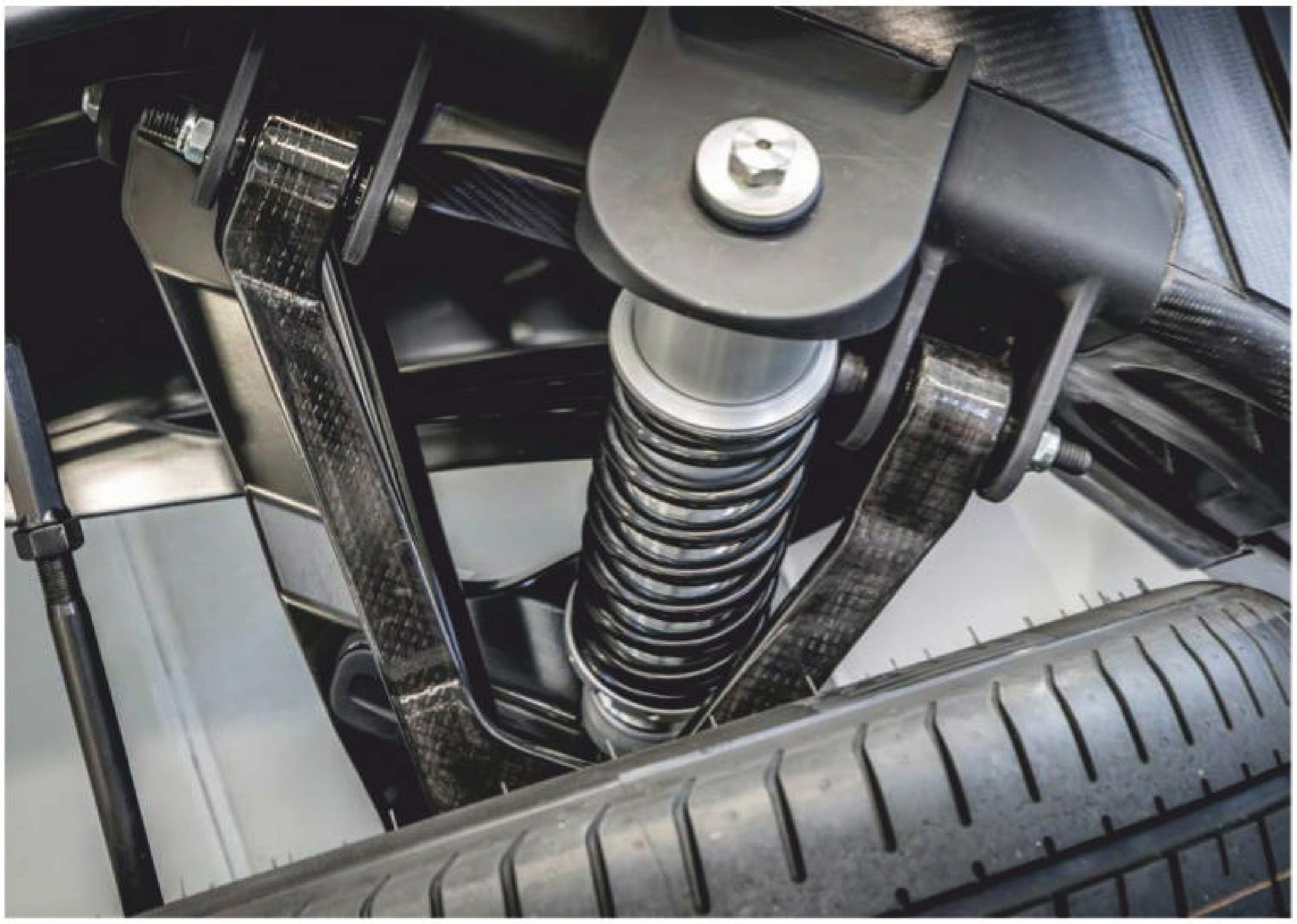
The Racetrak system allows for a choice of resins, for example polyurethane instead of the more conventional epoxy resin, which has different properties and a lower cost. Alternative fibres can also be integrated into the resin matrix, too, such as glass to provide it with additional strength and toughness.

Embedded electronics

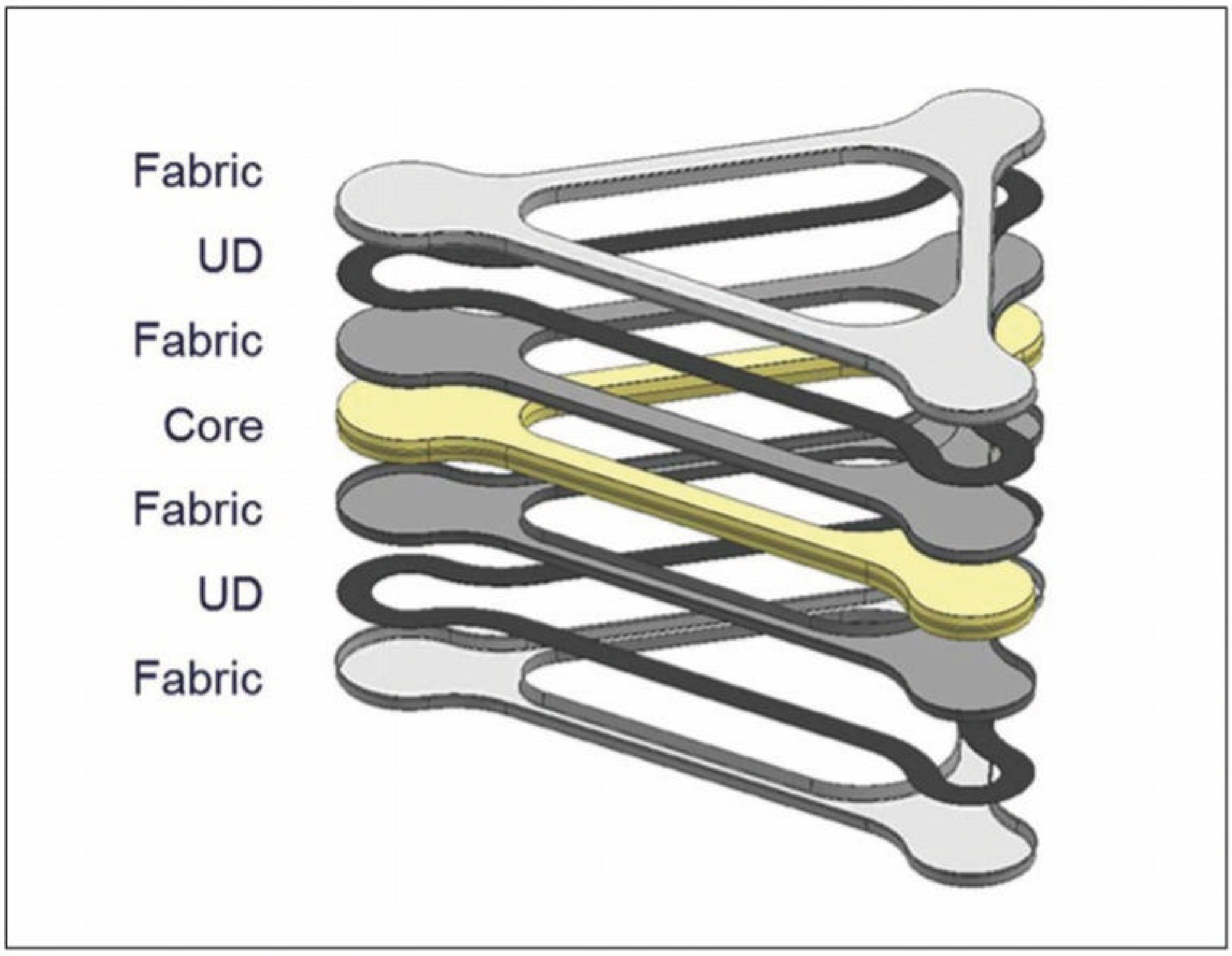
A further advantage is the potential for the integration of electronics into the structure. 'It has the ability to embed components such as thin film sensors, which can be just 6µm [micron] thick, and bearings, effectively removing another step from the current production process. Thin film sensor could, for example, be used to measure torque or to identify internal failures resulting from out of tolerance stress,' Williams tells us.

This creates the potential for turning wishbones and other composite components into calibrated load cells that could transfer load data back to the vehicle via wireless electronics. This would not only allow a car manufacturer to capture usage data, but would also have practical applications at a vehicle level, measuring real-time loads applied to a component. An example is a wishbone providing data that can be used to measure the lateral grip, which the car's stability control system could then make use of.

These techniques are already available and in use in a number of applications, both on and off track. Williams is very cagey about exactly where either process is being utilised, though it has hinted that they are in use in defence applications and aviation already, but it is willing to highlight one application beyond FW-EVX.



Williams Advanced Engineering's Racetrak is ideal for composite parts such as wishbones; as seen here on the FW-EVX



Racetrak's core is a non-woven bulk material. Unidirectional carbon fibre layers are sandwiched between woven sheets

'We are currently involved in developing a novel wind turbine blade design, which features a rigid spine with a flexible textile covering,' says Williams Advanced Engineering technical director Paul McNamara. 'The Racetrak process is being used to create a series of ribs that will sit along the main spar, giving the blade its aerodynamic profile. In addition to the excellent mechanical properties of the finished parts, the inherent flexibility of this process allows the engineers to subtly vary the rib geometry along the length of the blade using relatively soft tooling to generate further savings.'

This application of knowledge derived from Formula 1 that is shown here is very likely to be simply the tip of the iceberg, as various industries look to motorsport to find ways to hit very tough government targets.

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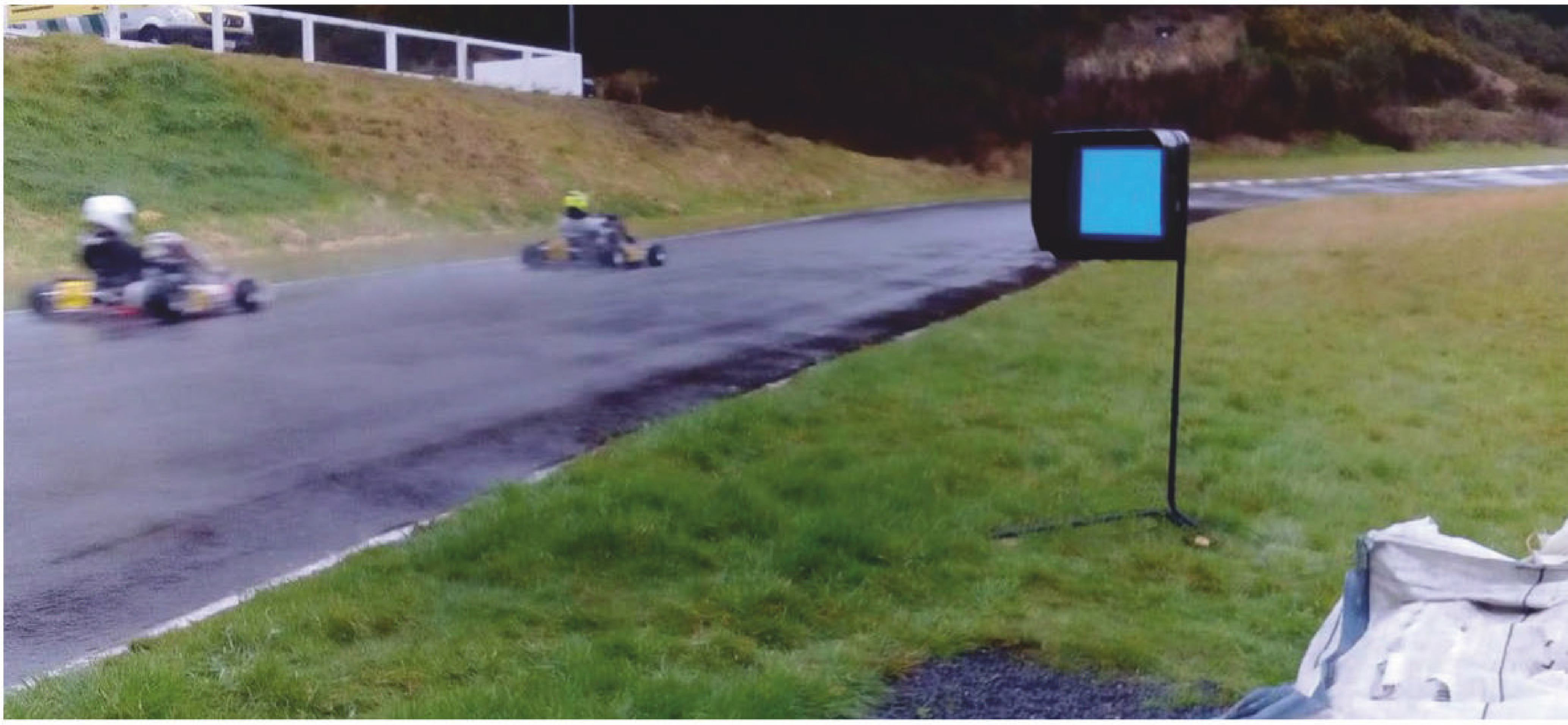


Mimirbox being track tested at the Kaitoke kart circuit in New Zealand. The system is especially adept at differentiating between the karts, which is vital in blue flag situations

Robo-marshal

With fewer people willing to volunteer their services to marshal at race meetings might military grade technology have the answer? One New Zealand company believed so and its Mimirbox system is the result

By DR CHARLES CLARKE

Because it's tucked half a world away from the centre of the racing action in Europe and the USA, New Zealand has a long history of ingenuity, often coming up with solutions that match or even exceed the best on offer anywhere else. Couple that with world class manufacturing skill and you get products like Mimirbox.

Mimirbox is the brainchild of Darren Conway, a keen karter and former weapons engineer with extensive experience implementing major military and commercial systems. Conway recognised that the number of volunteers willing to donate their time at circuits is dwindling, and many existing volunteers are retiring. Without theses volunteers circuits have to choose between the high on-going costs of paid officials and marshals, or implementing technology based solutions like Mimirbox – named after Mimir, a figure in Norse mythology renowned for his knowledge and wisdom.

Conway also recognised that while new electronic systems would be relatively expensive to purchase to begin with, they are cheap to run and much more reliable. Electronic systems don't get bored, don't need feeding, they don't need sleep and they don't get sick.

Marshal law

The traditional approach to motorsport applications is to have a collection of systems that operate standalone. The timing system, event registration, track signals, incident response, pit control and others are traditionally separate systems. These standalone systems require dedicated people to operate them and coordinate information flow. This is labour-intensive and can be prone to error.

Many motorsport software applications already have Application Programming Interfaces (APIs) that allow integration with other applications, but there are no industry standards for APIs. The only practical solution is to use another integrating application that translates APIs from one application to the next. This integrating application can then be used to communicate with, and control, connected applications through their APIs. When different applications are integrated, they can provide features not available on standalone systems.

Mimirbox was specifically designed to be an integrating application from the outset. It is modular and uses internal APIs to communicate and control different parts of the system.

Mimirbox has already been successfully integrated with the Alpha-Timing system and more are planned, including Mylaps. The modular architecture allows for system modifications and upgrades to meet current and future needs. Everything in Mimirbox is written in Java and both the internal and external APIs are language agnostic. The control server runs on Linux for improved reliability.

Electronic systems like Mimirbox will never get bored, they don't need feeding, they don't need to sleep and they don't get sick

The Mimirbox system design is based on Conway's experience with implementation of advanced military systems. The military implement command, control and communications (C3) systems, which integrate widely varying connected systems. C3 systems gather, filter and present real time information to users to maintain situational awareness and enables them to make good decisions based on valid and up-to-date information.

A Mimirbox C3 system for motorsport is implemented in different layers. The communications layer gathers and distributes information to integrated applications. The control layer displays information to officials and implements control over the management of the event and track. The command layer provides the race director and senior officials with a real time flow of key information to enable informed decision making and overall management of the event.

It takes less than two minutes to train an official in the basics of Mimirbox electronic flag control

Kart driver level view of a 'red flag'. The technology is based on military command, control and communications systems

Flag martial

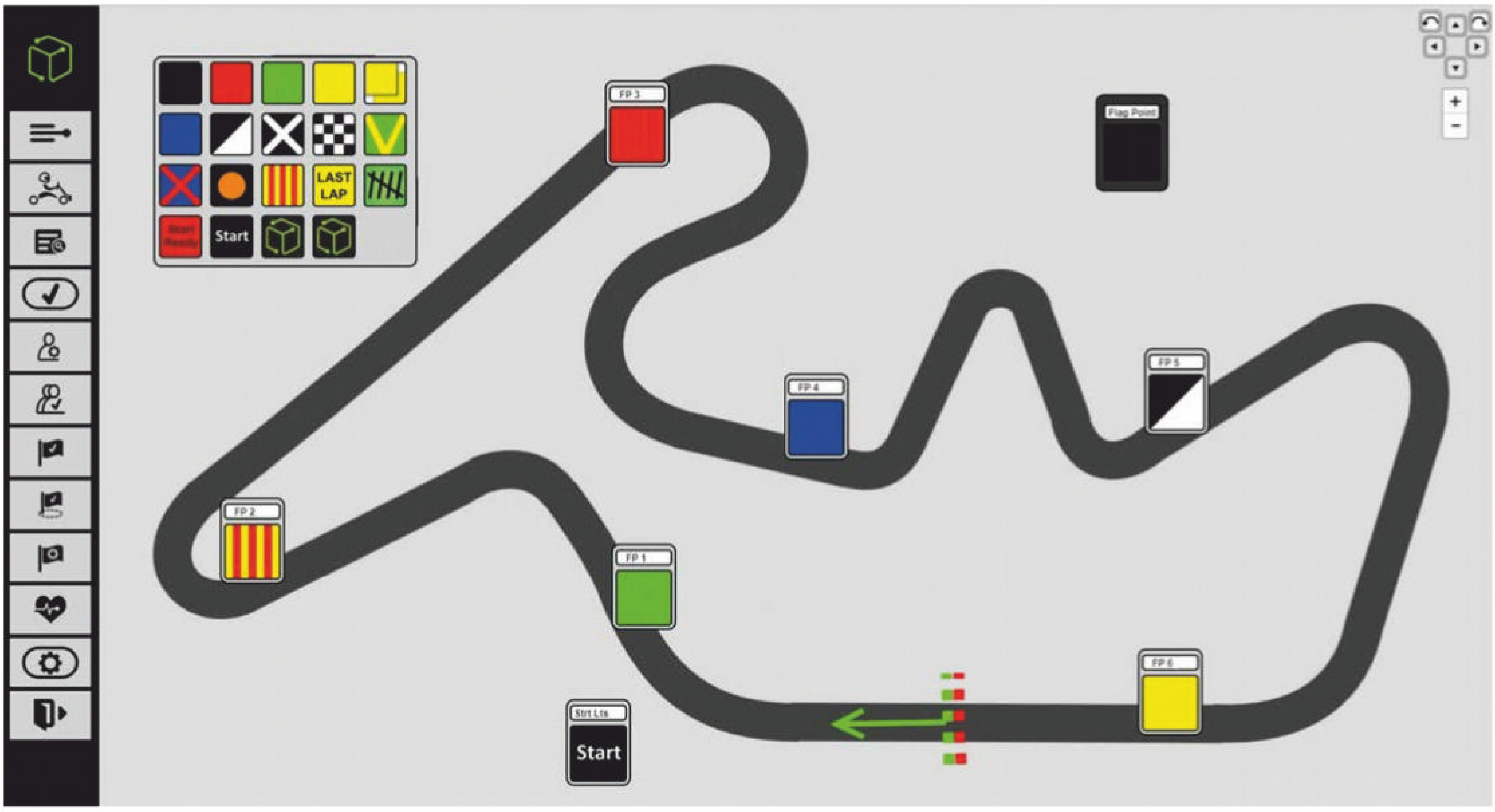
Conway's military background means that he understands what is needed to make a system rugged and simple to operate while also being safe and secure. It takes less than two minutes to train an official in the basics of the Mimirbox electronic flag control. Achieving this simplicity of operation requires a very smart system design. Displays automatically configure themselves based on their location by GPS. The wireless mesh communications network is robust and self-healing. Permissions for individual officials can be set to control which flags they can show on displays at specific locations. The system is continuously monitoring its status and operational health.

The operation of Mimirbox has proven its popular with drivers and users. Mimirbox appeals to younger users, because it is like a super-sized computer game. Also, practical experience has shown that concentrating the operation of electronic flags to a small number of dedicated and self-motivated Mimirbox users significantly improves the quality and therefore safety of the signals seen by the drivers.

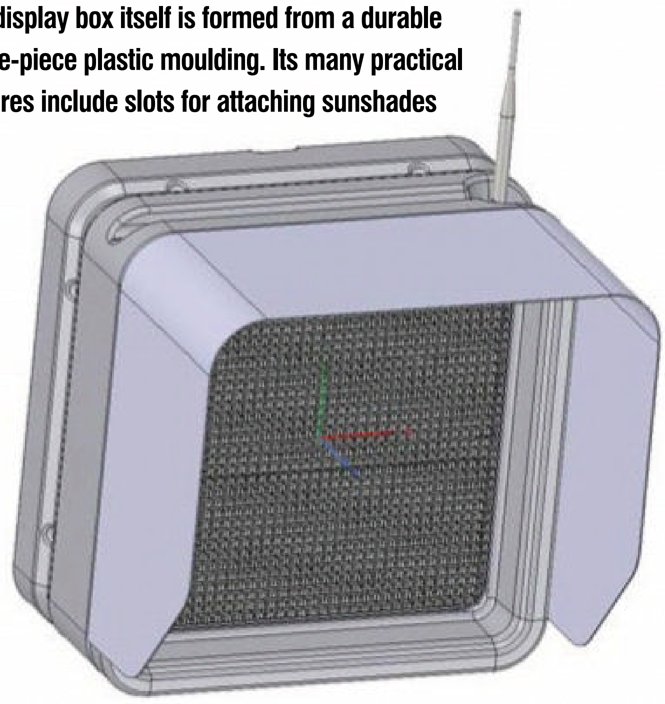
Blue on blue

Whilst at university, Conway developed a system with joystick control that simulated the ability of radar to track an aircraft or missile, and then predict its future position to meet anti-aircraft fire. The mathematical methods applied to the simulation are directly applicable to tracking racecars and predicting where they will meet out on the circuit, to signal a blue flag automatically to the car about to be lapped. Automatic blue flags illustrate what can be achieved when you are integrating a timing system with a smart track signalling system.

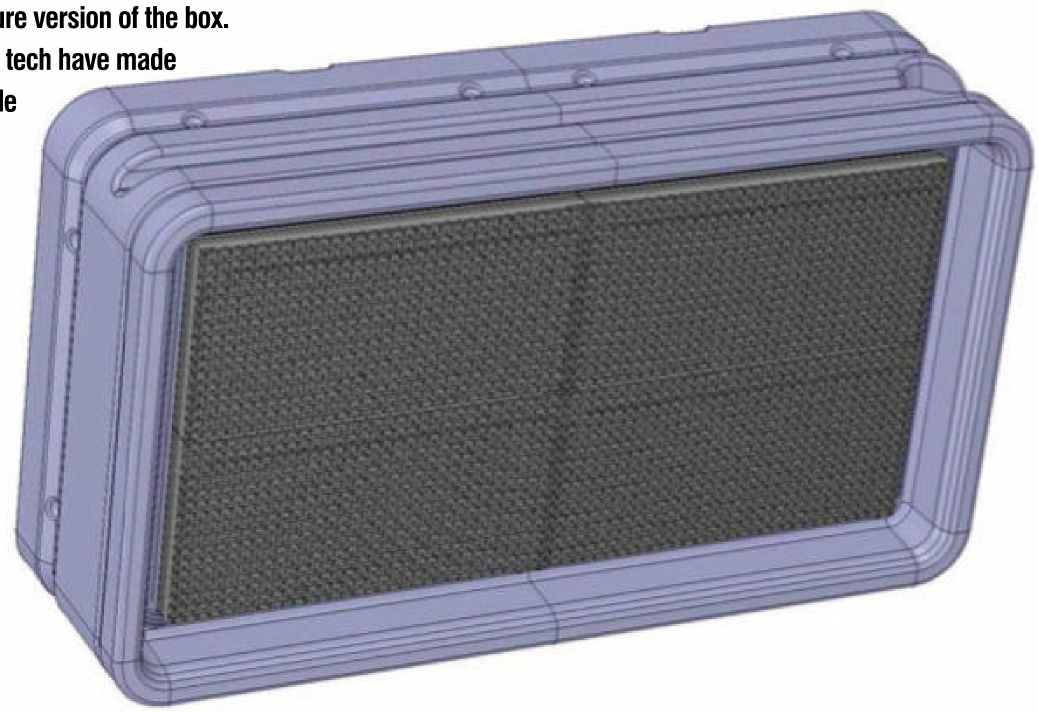
'When I started to investigate LED technology it wasn't bright enough, it was too expensive and there wasn't the demand for electronic flags,' Conway says. 'In the last couple of years there's been significant alignment of the technologies to make LED displays a feasible proposition. There is an increasing demand from tracks for electronic displays because of the diminishing pool of volunteers and increasing



The main flag control screen is designed to be very simple to operate. It shows a menu of pages down the left side plus a circuit map with the position of each box clearly marked



The display box itself is formed from a durable single-piece plastic moulding. Its many practical features include slots for attaching sunshades



A double-enclosure version of the box. Advances in LED tech have made Mimirbox possible

'All the software resides on a purpose-built Mimirbox microcomputer server'

focus on safety. LED displays now make good economic sense and the interest from the user community is now growing.'

Most of the companies offering this kind of equipment had some kind of fabricated sheet-metal or off-the-shelf plastic electronic box enclosure that did very little other than support the display and provide location/fixing for the box. Mimirbox, on the other hand, is a custom single piece plastic moulding designed for durability and convenience. Visually, Mimirbox looks like the durable military style flight cases you see being loaded onto Humvees in war zones, so it looks like it will survive the rigours of the garage, paddock or pit lane.

Months of design effort went into incorporating useful features moulded into the enclosure that you don't see in other products, such as slots for sunshades, a framed recess to protect the LED panels, indents for straps and indents for light sensors for automatic brightness control, to give a few examples.

All the edges of the enclosure are rounded and it is made from durable high-density non-splinter plastic for safety. A carry handle is also moulded into the enclosure and there are grooves all around it to allow it to be slotted easily into a low-cost tubular bracket (similar to TV aerial support tubing), which has standard scaffold pipe clips fitted to its attachment ends. The enclosure can also be ratchet strapped to racetrack catch fencing or posts while there are also threaded inserts moulded-in, so it can pretty much be bolted to any fixing.

In order to bring the product to market in New Zealand Conway established a distribution agreement with Alpha Timing, a UK company best known for its timing software. All except one affiliated kart club track in the UK uses Alpha-Timing software. The combination of Alpha-Timing and Mimirbox provides a complete race event management and control system that replaces Orbits and interfaces directly to Mylaps hardware. Alpha-Timing is an easy to use system that includes on-line registration, live results feed and now integration with Mimirbox.

'All the software resides on a purpose-built Mimirbox microcomputer server,' Conway says. 'There is no software to install on a user machine and no limit on the number of connected users. Any authorised user with network, or even internet access, to the server can run Mimirbox. You log in to the server with any device running any operating system to get full access. The Mimirbox system looks like a private, secure website to the user.'

The modularity in the software is defined by internal and external interfaces so new functionality can be added or substituted just like Lego bricks. To give an example, when Mimirbox is displayed on a mobile phone, a specific version of the graphical user interface (GUI) is automatically substituted to work with the smaller screen size.

All software development and integration is done remotely via the Internet from the UK, Australia, the Philippines and New Zealand. Alpha Timing was able to log into the system in New Zealand over the Internet and develop its API and related software in the UK.

Real time

With a Mimirbox electronic pit board integrated with the timing system you can display the current lap information immediately after the car or kart has crossed the start and finish line. You don't need to wait to finish another lap before reviewing the previous lap's time. The timing display is immediate, there is no need to input the timing results into a different system. This is real time information that does not require anything extra to be installed in the racecar itself. It relies on information passed from the timing system as the car passes over the track loop at the start and finish line.

The box is easily slotted into bespoke low-cost tubular brackets

Conway is now working on a customized LED display, which uses the same dies, templates and tooling that the larger display uses. This panel is over twice as bright as equivalent off-the-shelf panels and it uses less power. Power is really important in these kinds of applications as the power loading defines the size of the battery, which has cost implications. All the Mimirbox displays use high quality EV type lithium batteries.

There is also a development that will allow users to inspect the state of charge of the battery inside each display and be informed of the remaining capacity. This is important as lithium batteries tend to have a very short twilight charge, so the power output fades quickly. The battery monitoring electronics are very sophisticated and this allows for things like battery age and the discharge profiles over time. The battery fuel gauge indicator is said to be a very reliable measure.

If there is a problem with a display, it only takes seconds to swap in a fresh one. When a display is introduced into the network, it is automatically configured. There is no need to address each display individually.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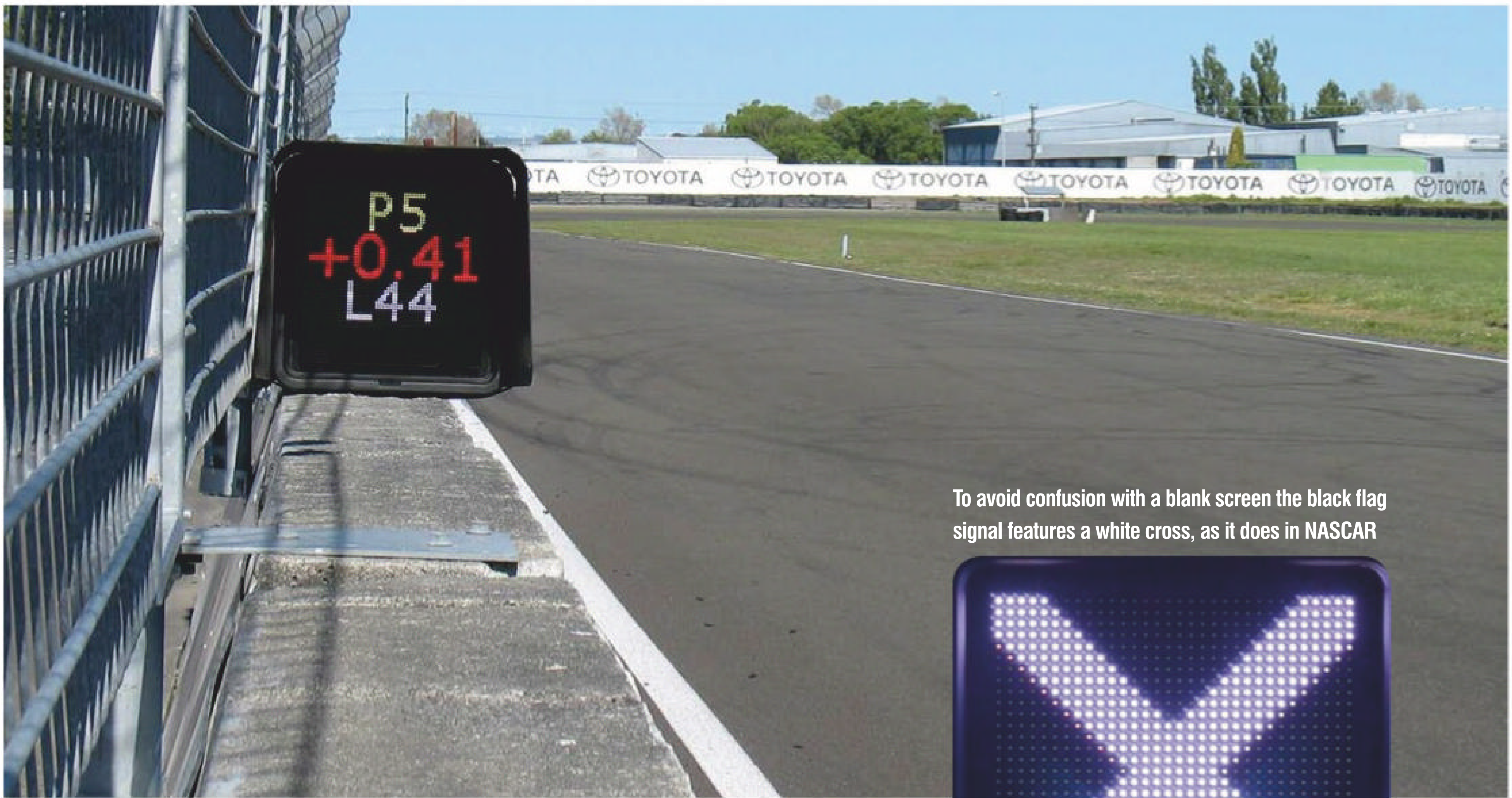


The box can also be used as a pit board, with the added advantage of conveying bang up to date information

To avoid confusion with a blank screen the black flag signal features a white cross, as it does in NASCAR

Single yellow flags are shown as a slow flash, while double yellows are a fast flash

The main flag control screen is designed to be very simple to operate. The interface shows a generalised track layout with a menu of pages down the left side. These menus provide a range of smart configuration options to define how the system is set up. Each flag point is identified around the circuit. One or more displays can be manually or automatically assigned to a selected flag point with a simple point-and-click interface. Each Mimirbox is shown as a small icon on the circuit map.

One or all flags can be changed with two mouse clicks. Where appropriate, flags will alternate with a race number to identify a specific car. Single yellow flags are shown as a slow flash, while double yellows are a fast flash.

Mimirbox has a full library of all the known worldwide motorsport signal flag sets. Additional flags and/or custom flags can be added as required. This can include sponsors logos to provide tracks with an additional income stream. This custom flag feature can also accept text, movies, JPEGs and bitmaps for static or animated custom displays.

Safety protocol

The elements of safety engineering that are incorporated into the design of Mimirbox are largely invisible to the user of the system, but the benefits are not. As part of the safety protocol, when a flag is assigned to a flag point it doesn't change colour on the main flag control page immediately, it goes to a darker half-tone and then changes to the assigned flag. The message is sent to the display, as part of the safety protocol the display acknowledges that it's received it (with the half-tone) and the action is completed (with the full-tone). In addition to these safety aspects, the user will be given continuous visual confirmation that the display is working properly.

If the display has failed, there would be no reply and the icon would remain in the intermediate half-tone state. Failure to complete the message transaction would be clearly indicated to the user. This fail-safe response to a transactional message sequence is one of the features of a safety engineered system. The benefit to the user is that they don't need to see the display to be confident that it is working and showing the correct flag.

If a display loses contact with the server, the Mimirbox logo is displayed rather than a blank screen. This display, as it's not a racing flag, is a clear message to drivers that the display has malfunctioned; another example of fail safe behaviour built into Mimirbox.

Incidentally, to prevent ambiguity with a blank screen, the traditional black flag is displayed as a white diagonal cross on a black background, similar to the NASCAR version.

The server is user configured so that specific displays can only show the flags appropriate to their location. For instance, a start and finish flag point can only display the start and finish flags. The different zones also dictate which kinds of flags can be displayed at each point. The system is smart enough to only allow safe configurations of the flags in use.

As well as being a smart C3 application the Mimirbox system is also economical, as it was originally designed for karting. Kart racing circuits don't have a lot of disposable funds, so the systems must work and be affordable.

One quite tricky aspect with Mimirbox is getting prospective users to look past the fancy box with the pretty flashing lights and consider the software. This is a sophisticated C3 software product first, with hardware attached. By virtue of its flexibility, its applications are only limited by the users' ability to think outside the box. The modular design of both the hardware and software make it readily adaptable and configurable.

A motional rollercoaster

Racecar's wizard of sim does the maths to help explain one of the trickiest vehicle dynamics properties of them all – non-linear motion ratios

By DANNY NOWLAN

One of the most difficult things you will ever deal with in racecar vehicle dynamics is non-linear motion ratios. With linear motion ratios, calculating what the car will do in terms of load transfer and pitch behaviour is easy. But when we move to non-linear motion ratios things become very messy, very quickly.

Fortunately there is a way through the jungle. Here I'm going to revise an article I did two years ago on this matter and fix up some mistakes and omissions. Since that time I've added some data acquisition channels to ChassisSim that will greatly aid in our understanding of what is going on with non-linear motion ratios. This will help put you in a position to make some very solid calls when it comes to these.

To understand what we are dealing with we have to go back to the fundamental core of how motion ratios tie into the forces on the car. To make a simple visualisation let's say our motion ratio is connected via a vertical pushrod and bell crank, as shown in **Figure 1**.

When we do the force derivations for this, the force at the wheel for the linear spring and linear motion ratio will give us **Equation 1**.

One thing I have been very deliberate about doing in **Equation 1** is writing it as MR·(MR·w) as opposed to MR^2. This was the big mistake I made in my article from a couple of years ago. For linear motion ratios you can completely get away with this, but for non-linear motion ratios you don't. It's a suck-you-in that can trap the best of players, and that includes me.

The reason you can't use MR^2 at will is due to the fact that damper movement is the integral of motion ratio. That is, the movement at the damper is given as **Equation 2**. You get away with this in the linear case since the integral of a constant is MR·w. But for a non-linear motion ratio this all goes flying out the window.

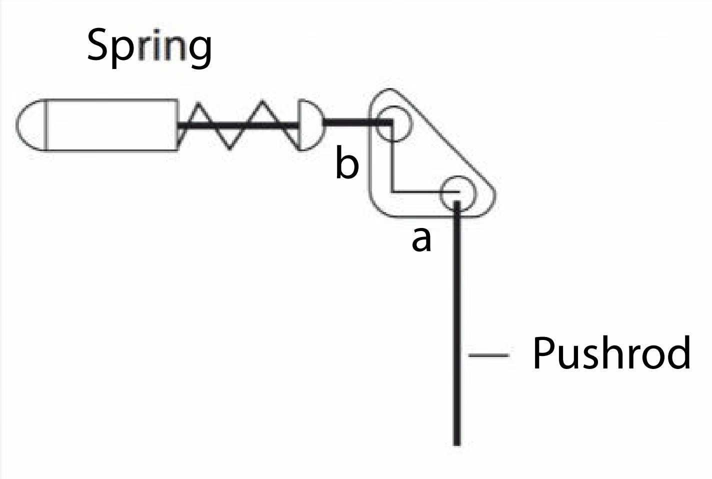
Wheel rate

So our first step in understanding non-linear motion ratios is to figure out what the instantaneous wheel rate is. This task is not as onerous as you might think, because if we re-write **Equation 1** we have **Equation 3**.

So the wheel rate is the derivative of Fw with respect to wheel movement. This is a simple product rule derivation and it leads us to **Equation 4**. But a couple of observations here. Firstly, unless you want to completely confuse yourself, work this in metric. Also, you are doing all these calculations from full droop. But the real power of what you have in **Equation 4** is that it gives you something you can very easily plot in Excel to provide you with a feel for what you are dealing with. Finally, you can deal with the non-linear spring case quite elegantly. In this case **Equation 3** can be re-written as **Equation 5**.

This is still a product rule derivative, but you now have to be a little intelligent about what you do with the k(x(w)) function. You might want

Figure 1: Bell crank motion ratio



EQUATIONS

EQUATION 1

$$F_w = MR \cdot (MR \cdot w) \cdot k$$

Where:
- F_w = force at the wheel (N)
- MR = motion ratio specified as damper/wheel
- w = wheel movement (m)
- k = spring rate (N/m)

EQUATION 2

$$x(w) = \int MR \cdot dw$$

Where:
- $x(w)$ = movement at the damper (m)
- dw = increment of wheel movement

EQUATION 3

$$F_w = MR \cdot x(w) \cdot k$$

EQUATION 4

$$\frac{\partial F_w}{\partial w} = k \cdot \left(\frac{\partial MR}{\partial w} \cdot x(w) + MR^2\right)$$

Where:
- $\frac{\partial F_w}{\partial w}$ = the wheel rate in N/m.

EQUATION 5

$$F_w = MR \cdot k\big(x(w)\big) \quad (5)$$

Our first step towards understanding the non-linear motion ratios is to figure out what the instantaneous wheel rate is

EQUATIONS

EQUATION 6

$$LLTD_F = \frac{L_1 - L_2}{(L_1 - L_2) + (L_3 - L_4)}$$

Where:

$LLTD_F$ = front lateral load transfer distribution
L_1 = load on the left front tyre
L_2 = load on the right front tyre
L_3 = load on the left rear tyre
L_4 = load on the right rear tyre

EQUATION 7

$$\Delta L_F = 2 \cdot (k_f + k_{rbf}) \cdot (0.5 \cdot tf \cdot \phi - w_{mf})$$
$$\Delta L_R = 2 \cdot (k_r + k_{rbr}) \cdot (0.5 \cdot tr \cdot \phi - w_{mr})$$

Where:

k_f = front spring
k_r = rear spring
k_{rbf} = front anti roll bar
k_{rbr} = rear anti roll bar
tf = front track (m)
tr = rear track (m)
w_{mf} = front wheel movement (m)
w_{mr} = rear wheel movement (m)
ϕ = roll angle (radians)

EQUATION 8

$$k_{tf} \cdot w_{mf} = (k_f + k_{rbf}) \cdot (0.5 \cdot tf \cdot \phi - w_{mf})$$
$$k_{tr} \cdot w_{mr} = (k_r + k_{rbr}) \cdot (0.5 \cdot tr \cdot \phi - w_{mr})$$

Where:

k_{tf} = front tyre spring rate (N/m)
k_{tr} = rear tyre spring rate (N/m)

EQUATION 9

$$w_{mf} = \frac{(k_f + k_{rbf}) \cdot (0.5 \cdot tf \cdot \phi)}{(k_f + k_{rbf} + k_{tf})}$$
$$w_{mr} = \frac{(k_r + k_{rbr}) \cdot (0.5 \cdot tr \cdot \phi)}{(k_r + k_{rbr} + k_{tr})}$$

EQUATION 10

$$k_{eff\_r\_f} = \frac{(k_f + k_{rbf})k_{tf}}{(k_f + k_{rbf} + k_{tf})}$$
$$k_{eff\_r\_r} = \frac{(k_r + k_{rbr}) \cdot k_{tr}}{(k_r + k_{rbr} + k_{tr})}$$
$$\therefore LLTD_{f\_sm} = \frac{tf \cdot k_{eff\_r\_f}}{tf \cdot k_{eff\_r\_f} + tr \cdot k_{eff\_r\_r}}$$

Where:

$k_{eff\_r\_r}$ = effective roll rate at the rear
$k_{eff\_r\_f}$ = effective roll rate at the front

A racecar's suspension is subject to varying forces when it's on the limit in a corner, from full compression to full droop

to look at differentiation by substitution. For any engineering students or recent graduates reading this that is your cue to do some work.

The above covers the instantaneous spring rates, but what about the question of load transfer? To do this we will now need to revise a few things we have discussed previously on this matter. Mathematically load transfer is defined as shown in **Equation 6**. This, as far as equations go, is pretty simple. But the details behind calculating it are another story entirely.

As noted, the linear version of **Equation 6** is very simple and to focus our attention I'll just concentrate on the sprung mass load transfer. Also, to make this easy I'm going to assume wheel rates. This can be shown by **Equation 7**. While at the wheel we have **Equation 8**.

By manipulating **Equation 8** we then get **Equation 9**, while some further manipulation of **Equation 8** and **7** gives us **Equation 10**. This is the sprung mass component of the lateral load transfer distribution that we have all come to know and love. The reason I've presented an abridged proof of the linear version is that in order to understand the non-linear sprung mass load transfer we need to understand the derivation process for the linear case. Also, because it is linear all the numbers work out simply. Let us now review what happens in the non-linear case. For a given wheel movement, then, if you will recall **Equation 3**, we now have **Equation 11**. So let's assume we have a non-linear motion ratio defined by **Equation 12**.

In order to get wheel movement or the x(w) function we need to integrate **Equation 12**. This then gives us **Equation 13**. So plugging **Equation 13** into **11** gives us **Equation 14**.

We still need to evaluate **Equation 6** and here we are going to pull a rabbit out of the hat. We define the effective spring rate of our non-linear spring as **Equation 15**. So using **Equation 15** and looking at **Equation 14** the effective wheel rate is **Equation 16**.

Evaluating loads

So why do we need to bother with all this? Well this is where the rubber is about to hit the road. Recall **Equation 8**. Now plugging in the non-linear spring and not assuming a roll bar we have **Equation 17**. And solving for the wheel movements we then have **Equation 18**.

Where things start to get interesting is when we evaluate the loads. Plugging in the numbers we see **Equation 19**. The following relations are then defined in **Equation 20**.

So, assuming that the sum of the effective spring rates is much greater than the difference, then the lateral load transfer distribution is now given by **Equation 21**.

So what happens when you throw in anti roll bars? To keep this discussion simple I will assume they are linear. In terms of wheel rates you are looking at **Equation 22**. You then simply plug **Equation 22** into **Equation 21**. This is a bit of a dive for the deck, however, I have validated it for a couple of settings, but just as an approximation it will get us by.

So how do we employ this? The best way to illustrate this is via an example. Consider a car with the parameters in **Table 1**. The non-linear motion ratio of interest is shown in **Table 2**.

One of the great things that has just been added to ChassisSim is that you can now log motion ratios and you can see what the wheel movement is and you can now toggle between seeing this in droop and on the ground. For this particular car in the mid corner condition the numbers are illustrated in **Table 3**.

The next step is to figure out the effective spring rates. For brevity I will just show this for the left front, see **Equation 23**. So the effective spring rate including the bar is shown in **Equation 24**. The great thing here is that all of this can be combined in an Excel sheet. The rest of the numbers are summarised in **Table 4**. Finally, the lateral load transfer distribution is given by **Equation 25**.

EQUATIONS

EQUATION 11

$$F_w = MR \cdot x(w) \cdot k$$

EQUATION 12

$$MR = MR_0 + MR_1 \cdot w$$

Where:

MR = motion ratio
MR_0 = motion ratio at zero wheel displacement
MR_1 = motion ratio slope

EQUATION 13

$$x(w) = MR_0 \cdot w + MR_1 \cdot \frac{w^2}{2}$$

EQUATION 14

$$F_w = MR \cdot x(w) \cdot k$$
$$= (MR_0 + MR_1 \cdot w)\left(MR_0 \cdot w + MR_1 \cdot \frac{w^2}{2}\right) \cdot k$$
$$= \left(MR_0{}^2 \cdot w + \frac{3}{2} MR_0 \cdot MR_1 \cdot w^2 + MR_1{}^2 \cdot \frac{w^3}{2}\right) \cdot k$$

EQUATION 15

$$F = k_{eff} \cdot w$$

EQUATION 16

$$k_{eff} = MR_0{}^2 + \frac{3}{2} MR_0 \cdot MR_1 \cdot w + MR_1{}^2 \cdot \frac{w2}{2}$$

EQUATION 17

$$k_{tf} \cdot w_{m1} = (k_{eff1}) \cdot (b_f - 0.5 \cdot tf \cdot \phi - w_{m1})$$
$$k_{tf} \cdot w_{m2} = (k_{eff2}) \cdot (b_f + 0.5 \cdot tf \cdot \phi - w_{m2})$$
$$k_{tr} \cdot w_{m1} = (k_{eff3}) \cdot (b_r - 0.5 \cdot tr \cdot \phi - w_{m3})$$
$$k_{tr} \cdot w_{m2} = (k_{eff4}) \cdot (b_r + 0.5 \cdot tr \cdot \phi - w_{m4})$$

EQUATION 18

$$w_{m1} = \frac{k_{eff1} \cdot (b_f - 0.5 \cdot tf \cdot \phi)}{k_{eff1} + k_{tf}}$$
$$w_{m2} = \frac{k_{eff2} \cdot (b_f + 0.5 \cdot tf \cdot \phi)}{k_{eff2} + k_{tf}}$$
$$w_{m3} = \frac{k_{eff3} \cdot (b_r - 0.5 \cdot tr \cdot \phi)}{k_{eff3} + k_{tf}}$$
$$w_{m4} = \frac{k_{eff4} \cdot (b_r + 0.5 \cdot tr \cdot \phi)}{k_{eff4} + k_{tf}}$$

Where:

b_f = pitch and heave movements of front
b_r = pitch and heave movements of rear
w_{m1} to w_{m4} = wheel movements
k_{eff1} to k_{eff4} = equivalent wheel rates for tyres 1 to 4

EQUATIONS

EQUATION 19

$$L_1 = k_{eff1} \cdot (b_f - 0.5 \cdot tf \cdot \phi) \cdot \left(1 - \frac{k_{eff1}}{k_{eff1} + k_{tf}}\right)$$

$$L_2 = k_{eff2} \cdot (b_f + 0.5 \cdot tf \cdot \phi) \cdot \left(1 - \frac{k_{eff2}}{k_{eff2} + k_{tf}}\right)$$

$$L_3 = k_{eff3} \cdot (b_r - 0.5 \cdot tr \cdot \phi) \cdot \left(1 - \frac{k_{eff3}}{k_{eff3} + k_{tf}}\right)$$

$$L_4 = k_{eff4} \cdot (b_r + 0.5 \cdot tr \cdot \phi) \cdot \left(1 - \frac{k_{eff4}}{k_{eff4} + k_{tf}}\right)$$

EQUATION 20

$$k_{eff1}' = k_{eff1} \cdot \left(1 - \frac{k_{eff1}}{k_{eff1} + k_{tf}}\right)$$

$$k_{eff2}' = k_{eff2} \cdot \left(1 - \frac{k_{eff2}}{k_{eff2} + k_{tf}}\right)$$

$$k_{eff3}' = k_{eff3} \cdot \left(1 - \frac{k_{eff3}}{k_{eff3} + k_{tf}}\right)$$

$$k_{eff4}' = k_{eff4} \cdot \left(1 - \frac{k_{eff4}}{k_{eff4} + k_{tf}}\right)$$

EQUATION 21

$$LLTD_{f\_sm} = \frac{tf \cdot \left(k_{eff1}' + k_{eff2}'\right)}{tf \cdot \left(k_{eff1}' + k_{eff2}'\right) + tr \cdot \left(k_{eff3}' + k_{eff4}'\right)}$$

EQUATION 22

$$k_{eff1}' = (k_{eff1} + k_{rbf}) \cdot \left(1 - \frac{k_{eff1} + k_{rbf}}{k_{eff1} + k_{rbf} + k_{tf}}\right)$$

$$k_{eff2}' = (k_{eff2} + k_{rbf}) \cdot \left(1 - \frac{k_{eff2} + k_{rbf}}{k_{eff2} + k_{rbf} + k_{tf}}\right)$$

$$k_{eff3}' = (k_{eff3} + k_{rbr}) \cdot \left(1 - \frac{k_{eff3} + k_{rbr}}{k_{eff3} + k_{rbr} + k_{tf}}\right)$$

$$k_{eff4}' = (k_{eff4} + k_{rbr}) \cdot \left(1 - \frac{k_{eff4} + k_{rbr}}{k_{eff4} + k_{rbr} + k_{tf}}\right)$$

Table 1: Car parameters

Parameter	Value
Mass	1500kg
Unsprung mass front	101kg
Unsprung mass rear	120kg
Spring rates front and rear	120N/mm
Tyre Spring rates front and rear	305N/mm

Table 2: Car non-linear motion ratios

Parameter	Value
MR_o	0.8
MR_1	1

Table 3: Damper and wheel movements

	Damper movement (mm)	Wheel movement (mm)
Left front	61.147	70
Right front	10.55	12.3
Left rear	61.118	70
Right rear	8.87	12.3

Table 4: Effective spring rate numbers

	Effective spring rate
Left front	87.134N/mm
Right front	82.65N/mm
Left rear	76.225N/mm
Right rear	71.286 N/mm

EQUATIONS

EQUATION 23

$$k_{eff} = \left(MR_0^{\,2} + \frac{3}{2} MR_0 \cdot MR_1 \cdot w + MR_1^{\,2} \cdot \frac{w^2}{2}\right) \cdot k$$
$$= \left(0.8^2 + 1.5 \cdot 0.8 \cdot 1 \cdot 0.07 + 1 \cdot 1 \cdot \frac{0.07^2}{2}\right) \cdot 120$$
$$= 87.174 N/m$$

EQUATION 24

$$k_{eff1}' = (k_{eff1} + k_{rbf}) \cdot \left(1 - \frac{k_{eff1} + k_{rbf}}{k_{eff1} + k_{rbf} + k_{tf}}\right)$$
$$= (87.174 + 0.59 \times 0.59 \times 100) \cdot \left(1 - \frac{87.174 + 0.59 \times 0.59 \times 100}{87.174 + 0.59 \times 0.59 \times 100 + 305}\right)$$
$$= 87.134 N/mm$$

To validate all this I ran a simulation using ChassisSim with zero roll centres and used the loads to cross reference the lateral load distribution, and it came out at 0.539. Given that the simulation also takes into account damping that is pretty good agreement.

However, one thing to note is that you always validate with simulation results. The reason for this is that when we are evaluating any actual real life racecar the joker in the pack is that the spring always interacts with the tyre. The approximations we have used have certainly got us in the ballpark, and that is a good thing. But as the loads start to change then the tyre compression also changes, which impacts on the sprung mass. Consequently, while we have some excellent rules of thumb which will get us in the ballpark, you will always need to cross validate with the simulation results.

EQUATIONS

EQUATION 25

$$LLTD_{f\_sm} = \frac{tf \cdot \left(k_{eff1}' + k_{eff2}'\right)}{tf \cdot \left(k_{eff1}' + k_{eff2}'\right) + tr \cdot \left(k_{eff3}' + k_{eff4}'\right)}$$

$$= \frac{1.631 \times (87.134 + 82.65)}{1.631 \times (87.134 + 82.65) + 1.597 \times (76.225 + 71.286)}$$

$$= 0.5403$$

You make use of hand calculations and Excel to inform your instincts

Reality checks

What we have just illustrated here goes to the very heart of how you use simulation. You make use of hand calculations and Excel to inform your instincts. You then run the sim results to double check them. This way, when you get out on to the circuit, you don't have any nasty surprises.

It would also be very useful here to show you some of the logged data you have in ChassisSim which can make your life far easier with regards to non-linear motion ratios, and the appropriate log is shown in **Figure 2** below.

In the bottom eight traces the wheel position at the damper movement and at the wheel in droop can be seen (this is indicated by suspension position front left to rear right channels). The bottom four traces are the motion ratios in damper on wheel. That quantised nature is an idiosyncrasy of the simulated data interacting with the data analysis software used and is not worth losing sleep over. However, the nail here is that you have everything at your fingertips to truly understand what your non-linear motion ratios were doing.

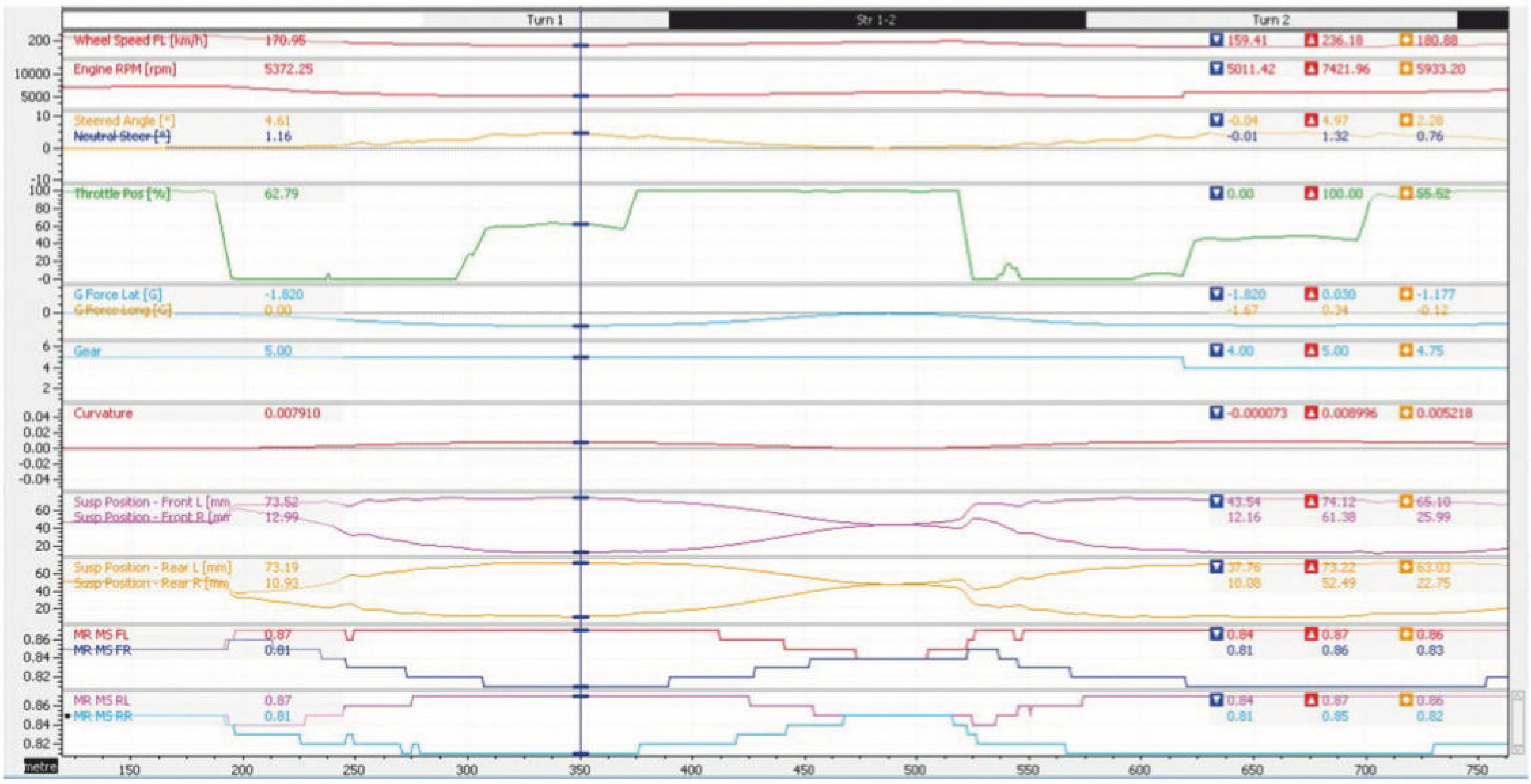
Summing up

To wrap up this discussion, just why would you want to use non-linear motion ratios in the first place? Using our Excel sheet, if we increase the rising rate of the non-linear motion ratio from 1 to 7 our lateral load transfer will jump from 0.54 to 0.59. It's quite a marked increase and it gives you a powerful tool if you need a continuous way of ramping up the support on the car, or if you need to change the balance.

For example, using non-linear motion ratios to change the lateral load transfer distribution was a party trick used by a colleague of mine, the late Tim Wardrop, when he engineered IndyCars. He knew his stuff and I never really appreciated this until I fully understood what you could do with non-linear motion ratios.

In closing, while non-linear motion ratios pose their challenges there are ways around these. There are hand calculation approaches that you can use to help you quantify what a non-linear motion ratio can do. Then, using the logging tools from simulation packages such as ChassisSim, you can fill in the blanks. Once you approach it with this mindset you can make the most of the benefits to be had from understanding these properties.

Figure 2: Motion ratio and wheel position log



Interview – Andrea Adamo

Heart and Seoul

Hyundai Motorsport's new boss tells us how he's bringing a fresh approach to the Korean manufacturer's World Rally Championship operation

By MIKE BRESLIN

'To win the World Rally Championship you have to be competitive on every event and we are working to make the Hyundai i20 fast everywhere'

Hyundai has done quite well in the World Rally Championship since it entered in 2014. For the past three years it has finished in second place in both the manufacturers' and drivers' standings, winning 11 rallies along the way. But for a global corporation the size of Hyundai, second is simply not good enough.

Something had to change then. So out went Michel Nandan, who had masterminded Hyundai's entry into the WRC and the setting up of the Hyundai Motorsport headquarters in Alzenau, Germany, and in came Andrea Adamo to take his place as team director, the man who was, and still is, in charge of the organisation's burgeoning customer racing department. And one thing was different from the very start; unlike Nandan Adamo will not be drawn on matters of a technical nature. Which given his background is perhaps surprising.

'My father worked in the Italian ASN as a technical scrutineer so it [motorsport] was an environment that surrounded me while growing up,' Adamo says. 'At around 14 years of age I decided that I wanted to be a motorsport engineer. I attended technical school before going on to study engineering in Turin.

'While I was a student, I was already co-operating with Abarth on rallying and racing,' Adamo adds. 'I was then a junior aerodynamicist in the DTM before starting to work in super touring. I was a race engineer in Italian and Spanish championships with Super Touring cars. I was with Fiat Group until 2008 when they decided to reduce their motorsport activities. I then became a consultant working for many companies, including a Lotus rally car project, as well as N Technology until 2012 when I moved to Honda Racing to work on WTCC until 2015. At the end of that year, Hyundai Motorsport contacted me, and the time was perfect for a new challenge.'

Customer focus

That new challenge was the Customer Racing Department, which sold more cars in the first two months of this year than it did throughout 2018. 'When I joined there were just three of us, and the focus was on the R5 programme,' Adamo says. 'We had to create the entire department from scratch, building and developing a car, and growing a customer base in a short space of time. It was an ambitious, tough target but we achieved it. Since then we've added a successful TCR project, which – alongside WRC and R5 – is helping us to create a strong reputation for the Hyundai name in global motorsport.'

Now Adamo is running both the customer sport and the WRC programmes, something that he says is working out well. 'It is difficult, but it is not something that I would describe as too difficult, because I have already spent so much time planning my agenda, to make sure that my time with the different people is dedicated to them. But I am happy, and I am lucky because I am working with very good people, and when you are working with good people everything is easier.

'I am now the one person who is responsible for both the problems and the people, to integrate much better the processes and optimise better the costs, and restructure a bit the responsibilities, and I hope then that I can manage these things from this point of view because I have a task ahead, which is to win,' Adamo adds.

Winning is, of course, where Hyundai has been falling short in the WRC, in championship terms at least, and its former boss Nandan has admitted to this magazine that it's i20 has not performed so well on tarmac, while its known that Rally Finland is a bogey event for the Korean manufacturer. Adamo, however, says this has to change. 'I think to win the championship you have to be competitive everywhere, and my engineers and technicians are working to make the car fast everywhere,' he says. 'We are planning on improving every aspect of the car.'

Many WRC bosses talk about improving aspects of the calendar, too, Adamo among them. 'In my opinion the current number of rallies is a bit over the reasonable, one less would be much better, but I am totally against an increase in the number of rallies,' he says. 'We are not Formula 1.

'We have to go to the countries where we are welcome, but we have to use a bit of common sense,' Adamo adds. 'But this is not something that has to be driven by the promoter, it has to be driven by the manufacturers. I think the manufacturers have to be more and more involved in the choices, because at the end we are running the show. Without the manufacturers there is no World Rally Championship.'

But as a life-long fan of rallying, how does Adamo think the WRC might be improved? 'I think they need to bring the people a bit closer to the drivers; I have a feeling that we have to do something to get people closer. But also, we must see that now

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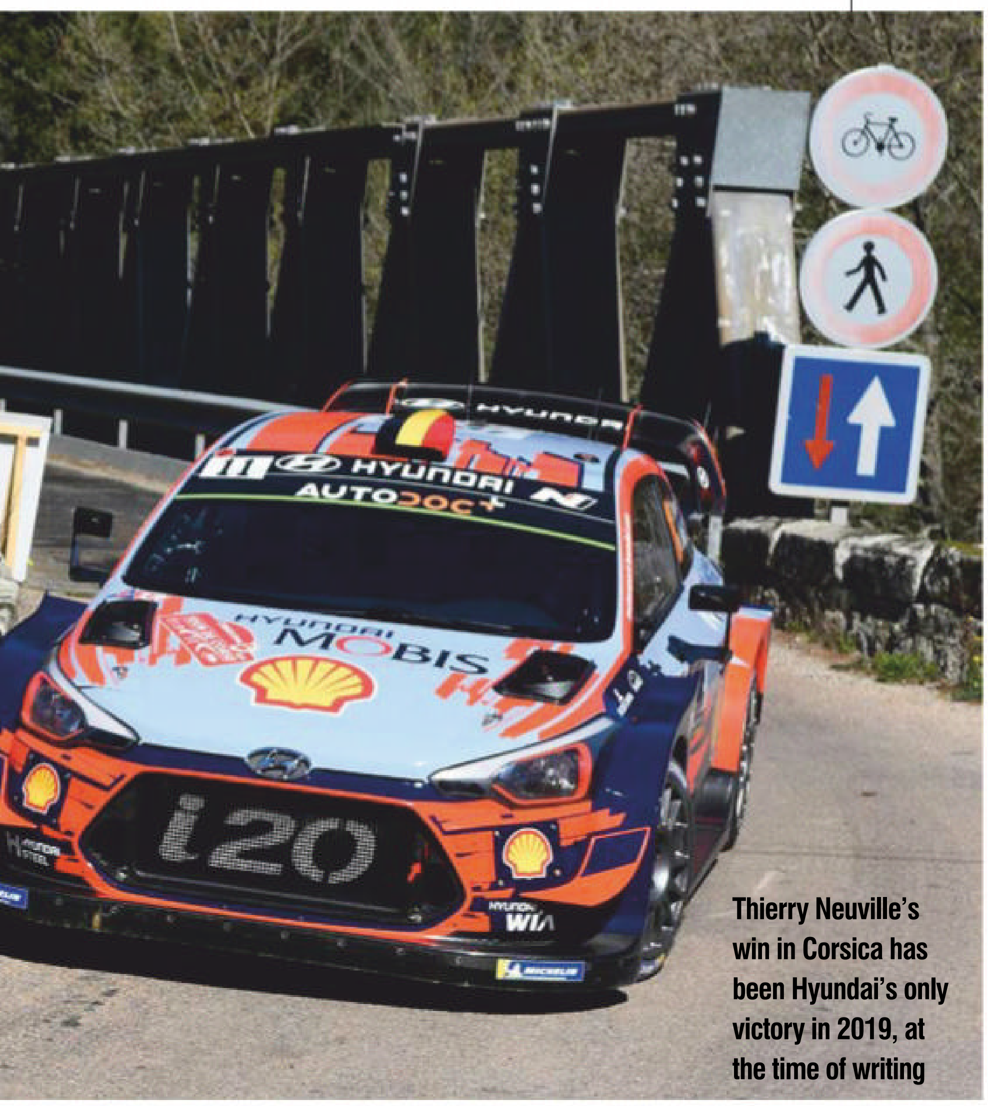
it's a different generation. We once had people spending the night on the Col de Turini, but now, if I asked my niece, who is 23, to do something like that she would ask me if I am totally crazy or drunk! But maybe we could have a different type of service park, maybe having the drivers more in contact with the people, that would be much better. But I am really against the way Formula 1 is managing the paddock.'

Hybrid future

Even if the service park stays as it is one change that does look likely is the move to some form of electric aspect in the powertrain from the 2021 season onwards, something that the four manufacturers involved in the WRC – Hyundai, Citroen, Toyota and Ford (M-Sport) – are clamouring for. 'I think it is the only way that we can go, as manufacturers. But also for Hyundai, [because] if we do not like it after 2022 it will be difficult for us to remain in the championship. For me, we need some hybridisation. We are discussing with the FIA between all the manufacturers, we have agreed in the working group, it is also common sense that we don't need complication, we don't need something like Formula 1, we need something easy, something electric that gives some power improvement. But we are not interested in something that will double the cost for WRC. We need something which is reasonably cheap, we need something that is easy to use, but it also needs to bring to motorsport the same technology that we are using on the road car.'

But talk of a fully electric WRC is premature, Adamo believes. 'For WRC that is something that is too far from reality now. In Africa they used to say that to eat an elephant the only way is bite by bite, so before you are doing something that it will not be possible to have on the car in 2022 it is better to keep your feet well on the ground, make something that is feasible and makes everyone happy, and start from there. Before you dream about the moon, you have to climb a mountain.'

While the Hyundai i20 has had a tough start to the season, with just one – perhaps fortunate – win in Corsica to shout about, the car is to get a new homologation in July, and perhaps it's only after this that Adamo's impact will be able to be fairly assessed. The question is, will Hyundai have climbed further up the mountain to championship success?



Thierry Neuville's win in Corsica has been Hyundai's only victory in 2019, at the time of writing

RACE MOVES

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World Touring Car Cup racer **Rob Huff** has partnered with Teamwork Motorsport to set up his own team to compete in this year's TCR UK. The Volkswagen Golf-running outfit has entered the series as Teamwork Huff Motorsport, with support from British Touring Car Championship operation Ciceley Motorsport. Huff will still also continue to drive for the Sebastien Loeb Racing VW team in WTCR this year.

Casey Lane is now chief revenue officer for Hulman Motorsports, the company which owns and runs the Indianapolis Motor Speedway and IndyCar. A veteran sports business executive Lane joins Hulman after nearly a decade with Professional Bull Riders LLC. His duties will include sponsorship sales for both the track and the series.

Jason Overstreet, the car chief on the No.20 Joe Gibbs Racing Toyota in the NASCAR Cup, was ejected from the Texas Motor Speedway round of the series after the car twice failed inspection before the start of qualifying.

NASCAR has indefinitely suspended **Jeffrey W Merritt**, a mechanic on the No.22 AM Racing entry in its Truck series, for violating Section 2.11.a of the rulebook, which is to do with people involved in NASCAR notifying the governing body within a specified time if they have been charged with a violation of the law or misdemeanour.

Former Sprint and Indy car builder **Bobby Hillin** has died at the age of 79. The Texas oil man bought into a USAC Sprint-car team in 1974 before starting his own operation, Longhorn Racing, in 1975. By 1978, winning at Indianapolis had become his goal and to help achieve this he hired the then Williams F1 designer **Patrick Head** to create the Longhorn chassis, which achieved a best Indy 500 finish of fifth in 1982.

Thierry Koskas, who had been set to take over from **Jerome Stoll** as president of Renault Sport Racing before he left the company, has now resurfaced at Groupe PSA, where he is vice president of sales and marketing. Koskas, who had worked at Renault for over 20 years and was latterly its executive vice-president of sales and marketing, replaces **Alberic Chopelin** in the PSA post.

Father Glenn O'Connor, who was the Catholic chaplain for the IndyCar Ministry organisation and the Indianapolis Motor Speedway, has died after a brief illness. The IndyCar Ministry is a not-for-profit organisation which provides spiritual support and counselling to drivers, teams, officials and staff in IndyCar and its support series.

Tom Purves is the new chairman of the Motorsport Council. This was previously the decision-making arm of the governing body, Motorsport UK, but it has now taken on a more advisory role. Purves, once a director of Motorsport UK and a chairman of the Royal Automobile Club, takes over from **Tony Scott Andrews**, who was chairman of the Motorsport Council for nine years.

BTCC racer **Colin Turkington** has a new race engineer for this season after **Kevin Berry** – who had engineered the reigning champ' for the past six years – left BMW works squad WSR to take on a new role with the Lynk & Co effort in the World Touring Car Cup. **Dan Millard**, who previously worked at Subaru-running squad BMR, has replaced Berry.

Pam McCarthy, for many years the coordinator of the popular MG BCV8 Championship in the UK, has died. As a sign of respect all competitors at the opening round of this year's championship at Silverstone got out of their cars and stood at the front of the grid for a minute's silence.

Jim Russell, the founder of the racing school that bore his name, has died at the age of 98. After serving in the RAF, Russell started racing at the age of 32, and had some success in single seaters, but he called time on his career after a serious crash at Le Mans in 1959. He founded the Jim Russell Racing Drivers' School at Snetterton in 1956 while he was still active as a driver, and it went on to have offshoots in north America. The school also ran its own teams in F2 and F3.

Head returns to Williams F1 team in consultancy role

Patrick Head, the co-founder and former technical boss of the Williams F1 team, has returned to the organisation in what's been described as a 'short-term consultancy' role in a bid to help it sort out its current problems.

Head returns to the team after eight years on the side-lines.

This follows the departure of chief technical officer Paddy Lowe at the start of the season, which came in the wake of a disastrous start to the year for the Grove team, with the FW42 comfortably the slowest car on the grid and Williams admitting the chassis has a 'fundamental' issue.

Head, who has remained a minority shareholder in Williams, was engineering director at the team until the end of 2011and his return comes as part of a wider reshuffle within the organisation which has also seen Adam Carter appointed as head of design and Dave Robson being promoted to acting chief race engineer. Doug McKiernan continues as design director.


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Can Patrick Head help sort Williams FW42 problems?

Williams said of Head's return: 'We can confirm that Sir Patrick Head is currently offering some support to our engineering team on a short-term consultancy basis.'

Head, who is now 72, was in the paddock for the Chinese Grand Prix but was not on the pit wall and he is not expected to take a place there later in the season, either, his role being seen as largely informal.

Infiniti Engineering Academy 2019 is up open for entries

Nissan's prestige car division is calling for applications for the sixth of its motorsport engineering talent searches, the Infiniti Engineering Academy, which aims to give the very best student engineers a way into Formula 1 via a work placement with the Renault F1 team.

The scheme has been in existence since 2014 and 50 per cent of all winners have accelerated their careers by securing full time positions at either Infiniti or in Formula 1 following their placements, Infiniti tells us.

Tommaso Volpe, director of motorsport and performance projects at Infiniti Global, said: 'At Infiniti, we believe that human talent is the driving force behind technology and we constantly strive to keep our talent pool revitalised. The Infiniti Engineering Academy, as a global talent search that successfully mixes multi-culturalism with academic and engineering excellence, helps us do this.

The 2019 scheme is now open for applications and Infiniti is looking for seven winners from seven different regional competitions. The prize, which is six months working with Infiniti plus six with Renault in Formula 1, comes complete with travel, accommodation, an Infinti company car and salary.

Marcin Budkowski, executive director at the Renault F1 team, said: 'Attracting top new talent is crucial for success in F1, and the Infiniti Engineering Academy contributes a great deal in that respect. It's a fantastic initiative that takes recruitment in F1 to a new level, and brings new and diverse thinking to the sport. The Infiniti Academy engineers bring fresh ideas and different perspectives to the team, which are key to our continued progress.'


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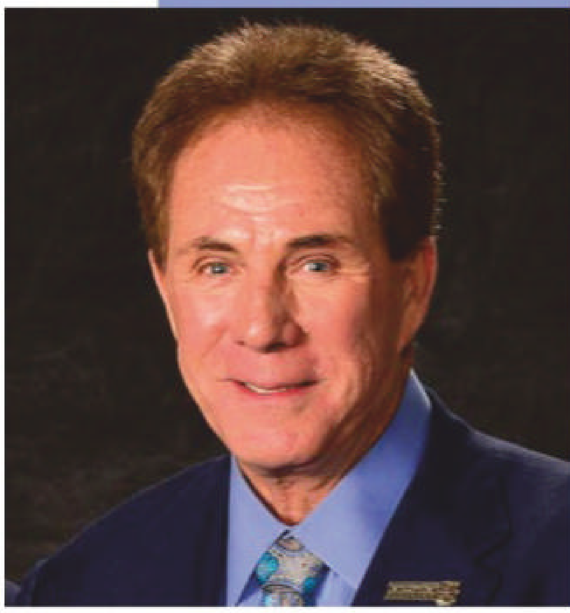
The scheme gives students the chance to work in F1

For more information or to apply, check out: academy.infiniti.com

RACE MOVES – continued



Darrell Waltrip, the former NASCAR racer turned commentator whose trademark 'boogity boogity boogity' catchphrase has become a feature of the Cup's TV coverage over the past 20 years, has decided to retire from his post with Fox Sports, and will turn in his microphone after the Sonoma Raceway round of the NASCAR Cup at the end of June. As a driver Waltrip, who is now 72, won the Cup title three times and chalked up 84 wins at the top NASCAR level.

A group called Stig Investments Inc has successfully bid $1.67m to purchase the renowned Bondurant Racing School in the US. The three partners in the group, **Bruce Belser**, **Jeff Hunter** and **Pat Velasco**, are all graduates of the school, which filed for bankruptcy protection in the autumn. Belser was set to become CEO at the time of writing.

John Klausmeier, the crew chief for the No.10 Stewart-Haas Racing car in the NASCAR Cup, was fined $10,000 when a lug nut was found to be improperly secured on the Ford he tends following the Texas Motor Speedway round of the series.

The Joe Gibbs Racing-run No.11 and No.19 Toyotas in the NASCAR Cup fell foul of lug nut regulations at post race inspection at the Bristol Motor Speedway race. As a result **Chris Gabehart**, the crew chief on No.11, and **Cole Pearn**, the crew chief on No.19, were each fined $10,000.

The Chip Gannasi Racing NASCAR Cup operation reshuffled its pit crews for the Richmond round of the top level US stock car series. **Bryan Jacobsen** moved to front tyre-changing duties on the Ganassi No.42 Chevrolet, having previously served in that role on the No.00 Chevrolet of StarCom Racing, which has a developmental pit-crew partnership with Ganassi. Jacobsen replaced **Steve Price**, who then took Jacobsen's place on the StarCom car. Meanwhile, **Daniel Kincaid** has replaced **Ken Pozega** as front tyre changer on the No.1 Ganassi Chevy driven by **Kurt Busch**, and **Cory Baldwin** is now rear tyre changer on the same car.

Dick Jordan (75), who has worked in a variety of roles for American race organising body USAC since 1969, has been recognised with an award from the Indiana Racing Memorial Association, which has presented him with a plaque that will be erected in the shadow of the USAC offices, situated close to the Indianapolis Motor Speedway.

Australian Supercars outfit Kelly Racing recalled **Steven Todkill** to replace **Giovanni Colombo** as engineer on **Gary Jacobson's** car for the Philip Island event after Colombo suffered a hand injury. Todkill's day job is now in the transport industry after he left the squad, where he had worked for six seasons, at the end of 2018.

Nicolas Todt, son of FIA president Jean, has signed up Ferrari Formula 1 junior and Prema Racing Formula 3 driver Marcus Armstrong to his All Road Management stable. Todt currently also has **Felipe Massa**, Toro Rosso's **Daniil Kvyat**, WEC racer **James Calado**, three-time World Touring Car champion **Jose Maria Lopez**, and reigning French F4 champion and Renault F1 junior **Caio Collet** on his books.

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The Monza lottery

The opening round of the Blancpain Endurance Series at Monza was fascinating in that any strategical decision that looked plausible, logical or fast was wrong. It wasn't just me looking at it like that, teams all made the wrong choices too. Well, most did, and one of those that didn't came from 22nd on the grid to win the race overall, on its debut in the series.

Motor racing needs some factor to make the result uncertain and at Monza it was the weather, and how teams dealt with and prepared for this. In Formula 1, meanwhile, they are making a lovely job of stacking the odds in Mercedes's favour as Ferrari makes mistake after mistake.

As a side-thought, I found it quite stark that the only time we have really discussed hybrid in Formula 1 recently was when it cost Charles Leclerc a race win in Bahrain. This put the technology into a negative light. No one ever wins a race because their hybrid system is better, according to the global press. Likewise, when the entire MotoE bike field was destroyed in a fire at Jerez, it was the first many had heard of the series in the wider motorsport community. It happened as I was at the Sebring 12 hours in March, and it led to a discussion on how electric mobility is being portrayed. Even in Formula E spectators are not allowed into the paddock until the racecars have been made safe. How does that look to the wider public to whom they want to sell electric cars?

But I digress. For the Blancpain Series race at Monza, the result was unpredictable because of the weather. The GT3 cars are now well sorted, and reliable, and so even with the new 'evo' cars that added another element of uncertainty, it really is down to teamwork to deliver a result. A morning of heavy rain made qualifying a painful experience for some, while those of us watching wandered off in search of coffee as the plethora of red flags elongated the session to seemingly half the day.

By race start, it was still raining but, happily, no one really invests in weather forecasting companies. Instead, weather forecasting websites are searched, discussed among teams, and then largely ignored as they are all different. This makes it all much more fun than the now common F1 radio call: 'we expect rain in four minutes, to last 10 minutes.' At Monza, teams risked trusting their phones, and believed that the race would dry out in the final hour. Some set their cars up for dry running at the end, which was their first mistake.

Others opted for a soft, wet weather set-up, and launched their cars at the first corner hoping for the best. It has to be said that the drivers were very well behaved, and the majority of cars finished the opening hour in one piece. There were a few spinners, and the third placed Black Falcon Mercedes was one of those which sustained front-end damage having been tapped into a spin and hit by another car.

The interesting bit was what happened in the second hour. The track looked dry, and drivers on wet tyres were searching out the damp patches in a bid to keep their rubber cool. Any sane team would have switched to slicks now, and many did, but Monza has a weird track surface in these conditions. Even though it looked dry, the track actually retained an element of moisture that meant with a soft set-up and careful driving, the wets could survive. Conveniently-timed safety cars helped to keep the temperatures down a little, but the interventions had the opposite effect on the slick shod cars; Raffaele Marciello leading the race in his Mercedes dropped through the order like a stone at a restart because he just couldn't generate the heat in the second cycle.

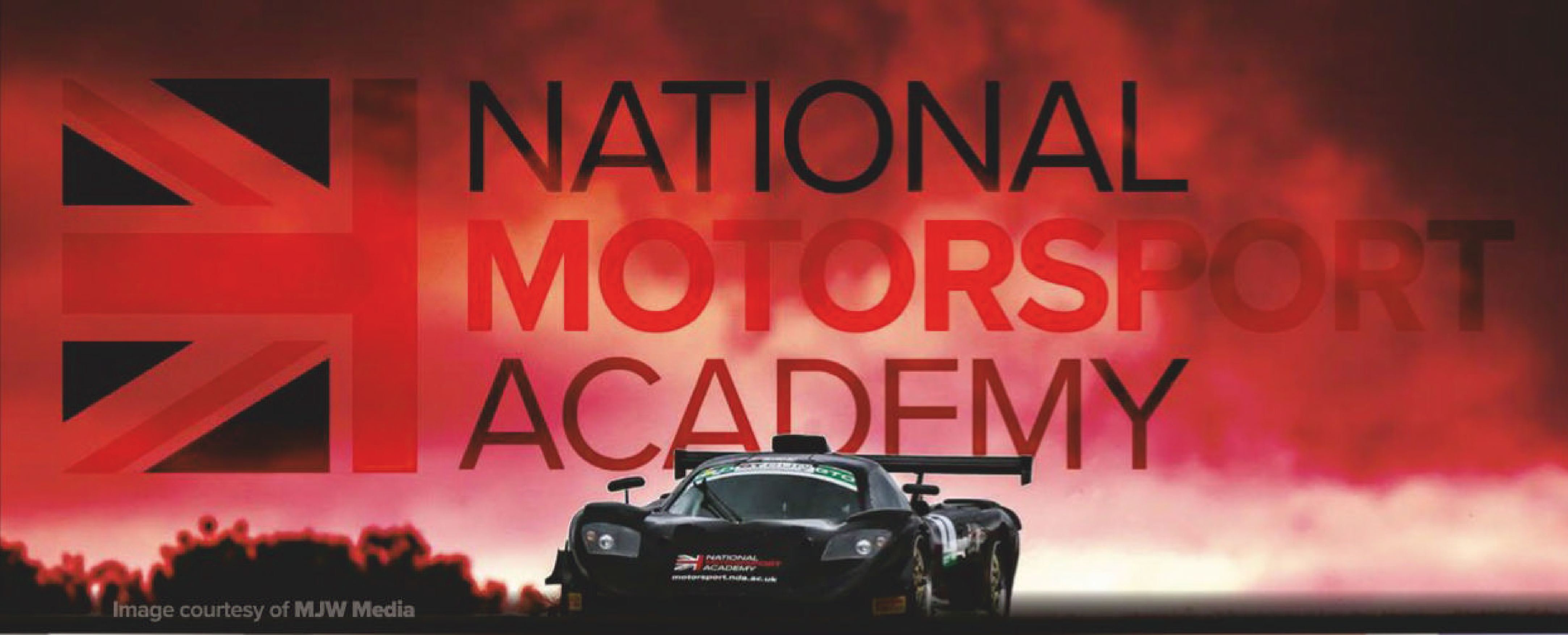
> **The track looked dry and drivers on wets were searching out damp patches to keep their rubber cool**

Sven Muller, in the new Porsche GT3, led, but when he handed over to Romain Dumas, the tyre pressures were too low by around 0.4bar, and so Dumas reversed impressively through the field, eventually finishing up outside the top 20, his demise helped by a puncture. 'We put one tyre on with the right pressure, and I was as fast as the leaders,' he said. For those who opted to stay on wet tyres throughout, well they did alright, thanks.

What was also noticeable was the amount of left rear punctures throughout the field. This, clearly, was a problem with Pirelli, wasn't it? No, the teams set their cars up for dry running, put wets on, and then simply drove too fast, destroying the tyres. At Monza, the left rear is heavily loaded, and they overheated and broke.

With all the intrigue and entertainment, the paddock is full, the grid of 48 cars looked spectacular, and promoter Stephane Ratel's oft-repeated mantra, that the days of a multi-million euro, multi-year racing budget signed off by a manufacturer are long gone, looks correct. His series is based on customer racing. It may not be sexy to the wider world, but it works. Monza threw up a lot of challenges, and the teams rose to meet them. Some did better than others, and no one predicted a Porsche win, but that's what we got. There was no need for anything other than good strategy and skill on the pit wall as well as in the cockpit. It was perfect motor racing.

ANDREW COTTON Editor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