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Le Mans

Will Toyota's new TS050 finally bring 24-Hour glory?

Prius Super GT

The LMP1-engined hybrid GT300 that's wowing Japan

IndyCar makeover

How US series will improve car looks and racing in 2018

Manor Formula 1

What might have been for plucky British race team

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COVER STORY

COLUMNS

FEATURES

Top of page: Toyota's Prius as you've never seen it before. This LMP1-engined racecar is a firm favourite with fans of Japan's Super GT series. To find out why turn to page 16

TECHNICAL

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Baroque and roll

Is it time for Formula 1 to vastly simplify its restrictive aerodynamic regulations?

Baroque is a style of European architecture, music, and art of the 17th and 18th centuries that is characterised by ornate, intricate detail. The word comes from the French *baroque* which in turn is derived from the Portuguese word *barroco* which refers to a 'rough or imperfect pearl'.

The Palace of Versailles represents it in architecture, so does Christopher Wren's works in England. In music, the major composers include Vivaldi, Bach, and Handel. On the visual side Caravaggio and Rubens are baroque artists.

In informal usage, the word baroque can simply mean that something is elaborate, with many details, but baroque has a resonance and application that extends beyond a simple reduction to either a style or period.

Well, here we are in the 21st century, but if we look at a current F1 car we can classify it in that very same category, missing only the gilding for it to truly be ready to hang on a wall. But the proliferation of ornate intricate detail on the aerodynamic appendages is not due to any artistic impulses in current designers, but just the natural result of rules that try, King Canute wise, to reduce the dependency on aerodynamics.

Aero worship

Well folks, in F1 the jury is back, and it has pronounced aero the winner. One sorrows for the number of words wasted to frame the new rules. The proliferation of boxes and walls to endeavour limitation as to which spaces can be used to fit in aerodynamic appendages is reminiscent of the American attempt to wall unwanteds; equally expensive, ineffective and cumbersome. The loosening of some parameters to get more downforce in the interests of a faster car for more crowd appeal has left most confused. We are not impugning the work done by the aero bods, nor the methods and tools developed specifically for this. Ground proximity aero, be it either virtual, in CFD, or real, or in wind tunnels with 60 per cent models, has reached another order of magnitude.

The aerodynamics of single seaters are now the cutting edge of the art, that segment not being much pursued in Aerospace, by being a very small part of the flight envelope in planes and not considered at all in missiles, where 'ground' will be only interesting on impact. Not surprising, considering the finance thrown at it by the competing teams and the specificity of the rules which by their very definition are not pertinent to any other endeavour. The silver lining will always be there; the sheer depth of research in investigating flow and vorticity giving serendipitous tools that can be developed for common use.

We had successive limitations on aero. Tall upright-mounted wings were banned after a series of accidents, yet the culprit was neither the butler nor the wings, but common or garden-variety structural design problems. Then, when wing cars appeared with skirts and bumped the L/D to new peaks their ban did not bring us to sleek, lissom projectiles with burnished, exposed limbs, but to flat bottoms. In brief, once the original sin of applying Bernoulli, Navier-Stokes and all the accumulated data in aid of the new Golden Calf had cast us out of the paradise of internal-combustion power we had to clothe ourselves with the scraps of mandatory boxes that could be used for appendages.

XPB

It looks nice, but is it art? A 2017 F1 car displays so much ornate and intricate aerodynamic detail that it could be described as baroque

The seating position of the driver has pushed us into a dangerous configuration forced by the necessity of lifting their legs to enable a better flow of the front wing in single seaters, and likewise the front diffusers of endurance cars. The resulting position, inclination and flex of the spine are now dangerous, according to all the current biomechanical knowledge we have.

Diminished returns

In a time where the great cry is 'get the costs down' one of the heavy items on the budget was the building, staffing and operation of not one but sometimes two wind tunnels running in shifts 7/7, 24/24 to pan out the small nuggets of downforce of an almost depleted lode. Putting limits on this only diverted the resources to simulation, with that now in turn being limited to a given number of Petaflops. King Canute again. Then other heresies were conjured up to improve the spectacle, the obvious one being DRS. This, to me, seems the equivalent of shooting fish in a barrel. Giving extra performance to the following racecar to enable it to overtake in such an arbitrary fashion ethically feels like something where the attacked has no means of defence, thus it's intrinsically wrong.

Cold turkey

You might say that racing has an addiction to downforce. How can we define 'addiction'? The truest definition is that it's something you enjoy doing in the short term, which undermines your well-being in the long term, but that you do compulsively anyway. We're biologically prone to getting hooked on these sorts of experiences. If you put someone in front of a slot machine, their brain will look qualitatively the same as when they take heroin. We are engineered in such a way that as long as an experience hits the right buttons, our brains will release the neurotransmitter dopamine. We'll get a flood of dopamine that makes us feel wonderful in the short term, though in the long term you build a tolerance and want more. The same with designing, those extra points in downforce seem to be worth all the subsequent suffering.

But rather than going cold turkey and banning all aero, we should face up to the fact that things seen often cannot be unseen. Aero is here and the use of it is bound in with engineering tradition and practice.

So active aerodynamics, by all means, then. All aeroplanes change their configurations in flight for the different phases, flaps and appendages popping up and out, with landing gear appearing for the landing and ground phase. Racecars, which by definition need minimal drag for the straight lines, maximum for braking and maximum downforce for cornering, should likewise have the same in their bodywork configuration. Active suspension and attitude control for better aero? Same applies here.

Will it be expensive? Of course, but one suspects that what is being used to find the loopholes to best exploit the rules (think monkey seats, barge-boards and vortex conditioners) could be better used and produce more world pertinent solutions, and thus reward the ever-toiling aero bods. And maybe even produce prettier racecars.

You might say that Formula 1 racing has an addiction to downforce

Random thoughts

Why adding an element of uncertainty could heighten the drama in motor racing

To create more surprise, results in motor racing require a degree of randomness. This, joy of joys, is what we sometimes see when variable weather conditions catch out some drivers and allows the talent of those usually labouring under the shadow of uncompetitive equipment to shine through. Safety car situations can also upset the order, if not always for the best.

Some people have suggested that the amazing reliability of contemporary racing cars has encouraged predictable results, especially in F1 (until, gladly, maybe this season – at time of writing Ferrari 2, Mercedes 1). While this is partly true, racecars dropping out of races is surely the least satisfactory way of upsetting the form book. Understanding what goes into the preparation of car, driver and team up to the moment that the lights go green, only to see all that effort dashed away by sometimes just a trivial fault always stirs my disappointment and elicits my sympathy towards those afflicted – at any level, professional or club. It can also ruin an exciting race.

XPB

Formula 1 fuel stop from 2004. Might a return to refuelling bring about differing strategies and therefore introduce more variables into a race?

Playing the joker

In endurance racing, especially 24 hour marathons, generally enough curve-balls occur with strategy, changing weather conditions, day/night driving, safety cars and zones, reliability, traffic incidents etc to make the final result always in doubt. For a classic example refer to Toyota's failure to finish the final lap while leading last year's Le Mans. Cause: broken turbo/intercooler line.

For shorter events this is much less the case and it's difficult to introduce random effects without resorting to gimmicks, like the 'joker laps' now being promoted in the WTCC. This is okay, perhaps, for rallycross, whence it came, and events where entertainment more than out-and-out racing is the objective. I hold the same view about weight penalties and, to a lesser extent perhaps, 'push-to-pass', which is really just the same as DRS.

Maybe of greater preference in facilitating overtaking is an idea straight out of the early days of motor racing. At Brooklands, when cars of varying performance took part in the same races a means of handicapping was devised that consisted of having up to five chicanes constructed in parallel on a wide part of the concrete apron ahead of the high speed banking. The fastest cars had to negotiate the tightest of these, the slower the easiest, right down to almost flat out.

With overtaking still a hot topic, could a variation of this be an answer? Imagine, in this case however, identical mirror-image chicanes such as Monza's Roggia and Ascari 'piff-paffs'. The driver being bottled-up can try to enter and negotiate the alternate chicane at higher speed than the leader and exit with more momentum, allowing the cars to be side-by-side heading for the following straight. Could be fun, especially on the first lap.

Variable conditions

Somehow I don't see this happening, so perhaps rather than randomness more variables need to be introduced. Pit stops for tyre changes combined with different compounds to be run as in IndyCar, F1 and F2 do add to the racing, even if critics believe that it discourages on-track passing manoeuvres in favour of just waiting for the car ahead to stop first. But if the competition is close enough, such an easy option doesn't exist.

I favour fuel stops in certain categories, F1 most obviously, to encourage different race strategies and introduce an unknown factor to outwit rivals (as well as preventing hauling all that weight of fuel around from the start). In a previous column, I advocated points being awarded at half-distance for the race leader, to set up a nice strategy-call dilemma when it comes to fuel and tyre stops. Should the team strategists get too easily on top of this scenario, then the race lap number at which the points award is to be made could be changed – and if necessary not announced until just before the start. There's nothing like a bit of a flurry on the pit wall/in the garage to liven up the show and favour those who can think best on their feet – or, more aptly, use all the digital aids at their disposal. Indycar operates a similar points scheme in addition to fuel and tyre stops, but much more complicated – I'm all for keeping it simple, not least for spectators and viewers, including me!

I suspect that the difference between gimmicks and the use of variables is that the latter approach consists of setting targets to be achieved in order to win the race rather than a manipulation of the results. Strategy and tactical thinking have been key factors in the sport since it began; as long as it adds to the quality of the competition rather than detracting from it, then this is fine.

Thin on top

On a different tack, having spent some time at Silverstone's WEC opening round just prior to writing this, the paucity of LMP1 cars was noticeable, even though it's not easy to distinguish them from LMP2s (nor Toyota from Porsche for that matter, with regulations that virtually design the shape of the car aggravated by both manufacturers' similar colour schemes). The ACO has tried to boost the LMP1 privateer entries by a number of performance incentives, including remarkably free engine regulations.

Now I'm all for ridding motor racing from the dead hand of micro-regulation of technical matters, and this move presents independent engine builders with a golden opportunity to use some innovation and free thinking, but soon this will regrettably have to be restrained. Because? Should Red Bull or a similar high-wealth corporation – but not a car manufacturer – with the desire and marketing justification to succeed at Le Mans decide to invest enough to employ F1-level but non-hybrid engine technology, then it will be back to square one for all the other private teams.

Who would be a rule-maker these days?

There's nothing like a bit of a flurry on the pit wall or in the garage to liven up the show and favour those who can think best on their feet

Unfinished business

Last year Toyota came within one agonising lap of winning Le Mans. Has its new generation TS050 LMP1 got what it takes to lay that ghost to rest, and also win the WEC, this season?

By ANDREW COTTON

‘Our downforce last year was clearly too low, but we have been able to step up and we have more now’

On paper, it looks as though the Toyota TS050 has merely been through an update process; the monocoque is held over from last year, and it still runs with a 2.4-litre twin-turbo engine. However, this LMP1 car is anything but a simple update.

Although the engine retains its capacity and architecture, it has a completely different lean burn characteristic. The gearbox, too, is completely new, as is the front and rear suspension. The battery is designed to run with less cooling in mind, and therefore less drag, and the whole car has been optimised to accommodate new aero and tyre regulations.

In fact, the only thing that was missing from the raft of change is the monocoque, and that's only because the cost return on a new chassis is so limited that, as part of the cost-saving measures agreed in technical working groups, Toyota and Porsche agreed not to develop it until new regulations come into force in 2020.

The regulation changes introduced in 2017 were designed to slow the cars from 2016, reducing downforce by raising the splitter height by 15mm and narrowing the rear diffuser, while the tyre regulations see teams running just four sets, plus two 'joker' tyres to cover punctures, for qualifying and the race. Practice is governed by just three sets of tyres, too, limiting the amount of development that the team can do on a race weekend. That didn't stop Toyota's Kamui Kobayashi lapping the Silverstone race circuit in a time of 1m36.793s, almost three seconds faster than Brendon Hartley's fastest lap in the Porsche 919 in 2015 of 1m39.534s (the 2016 qualifying was damp).

'If you take the last values of last season's car, there are a few regulation changes that make a big gap,' says TMG's LMP1 project leader John Litjens. 'We checked in CFD to see where we lose performance and you see that the lower and top side is higher up, to steer the air under the car. You see the undercut of the sidepods and all has been done to recover [the lost downforce].'

This new route for the air is nothing new – Audi tried it with the Audi R15 in 2009 and that car featured downforce generators within

TECH SPEC

Toyota TS050 Hybrid

Type: LMP1-H (Le Mans Prototype – Hybrid)

Bodywork: carbon fibre composite; windscreen is polycarbonate

Powertrain: Toyota Hybrid System – Racing (THS-R). Hybrid power, 368kw / 500PS (front and rear combined); high-powered lithium-ion battery; front hybrid motor, Aisin AW; Rear hybrid motor, Denso; Inverter, Denso. Hybrid power, 368kw / 500PS (front and rear combined).

Engine: V6 direct injection twin-turbo; 2.4-litre. Power 368kw/500PS. Fuel, petrol.

Fuel capacity: 62.5 litres.

Transmission: 6-speed sequential transverse gearbox; aluminium casing; constant velocity tripod plunge-joint driveshafts; multi-disc clutch; mechanical locking differential.

Suspension: Independent front and rear double wishbone, pushrod-system; torsion bars; front and rear anti-roll bars

Steering: hydraulically assisted.

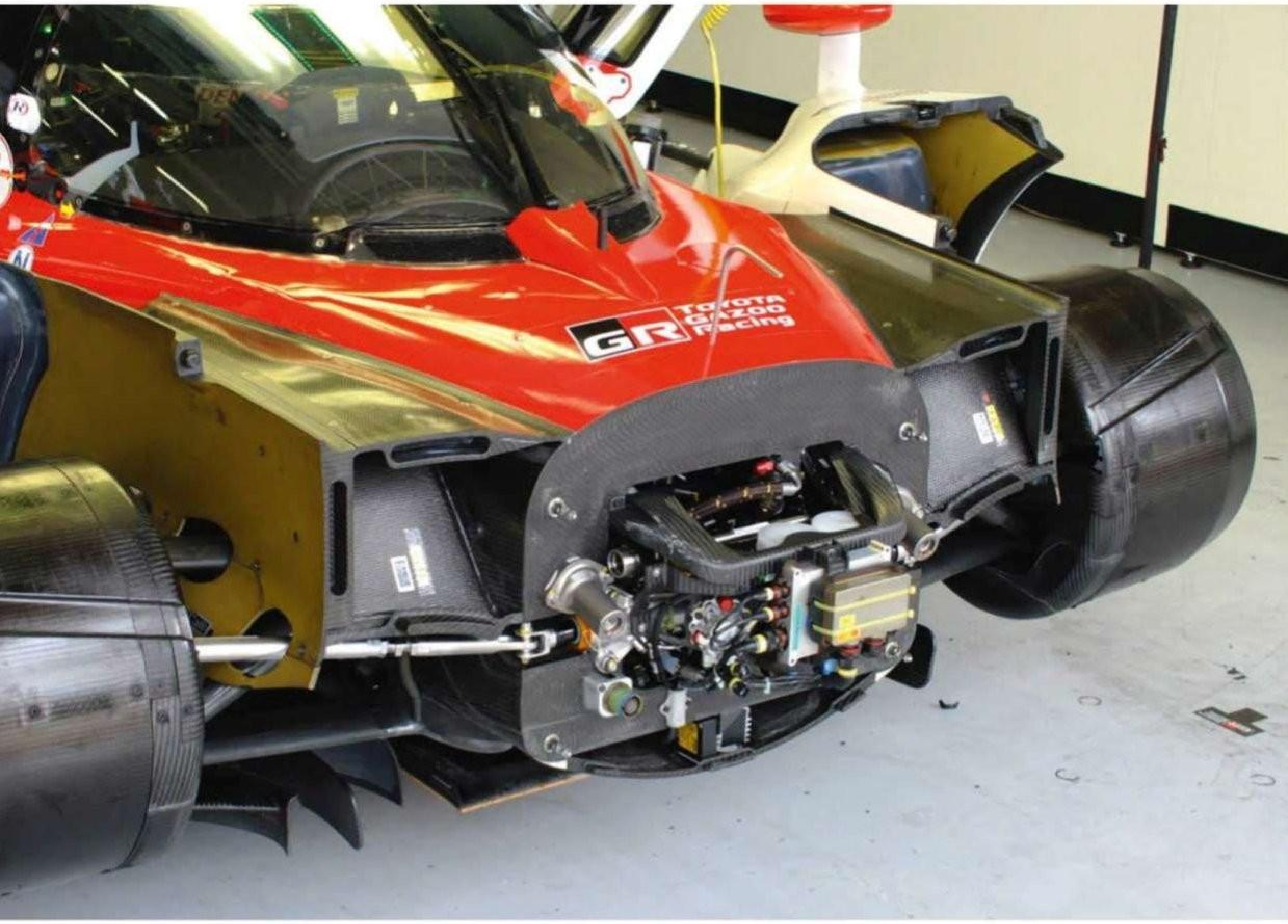
Brakes: calipers, Akebono mono-block light-alloy; discs, carbon ventilated.

Wheels: RAYS magnesium alloy.

Tyres: Michelin radial; front and rear, 31/71-18.

Dimensions: length, 4650mm; width, 1900mm; height, 1050mm.

Toyota's very heavily revised TS050 has undertaken close to 35,000km in pre-season testing as it gears up for another assault on the Le Mans 24 Hours. Could this finally be Toyota's year at La Sarthe?



Front bulkhead. The monocoque carries over from 2016 which has restricted development of the front suspension. Porsche and Toyota have agreed not to develop chassis until 2020

the tunnel that were protested by Peugeot in the week leading up to Le Mans. Both Toyota and Porsche have adopted a similar strategy with the airflow and there is no doubt that the two have worked hard to utilise the area within the racecar, while those who saw the stillborn Audi plans for 2017 say that the German manufacturer was looking for an even more extreme solution, with a very high nose.

Tightly packed

Toyota's solution means that the packaging had to be completely redesigned, including the gearbox internals and casing. Although the gearbox still retains its aluminium casing, rather than carbon, weight has been saved from the gears themselves. The team admits that delays in the engine development programme left it with few other options than to keep the casing material similar to last year. The oil tanks, breather tanks for the engine and the shape itself is all more compact to help with the aero. 'There is more through-flow from the front to the back,' confirms Litjens. 'The trend was already there, but now you are forced to review everything. You still have the limitation of the existing monocoque, so you cannot put the nose as high as you would like to go.

'The cooling air is now going up rather than from the top surface,' Litjens adds. 'The new engine means that we have a different cooling and for sure you had to do that with the packaging. The management of the engine is not the same as the old one, and that is one of the reasons we have a new gearbox as well. It is one of the reasons why we moved and we cleaned up the suspension area, and for a potential third ERS, to combine that with the new engine and rear suspension orientation.'

The 2017 version of the TS050 rear suspension features a cylinder that now sits transversely across the gearbox. Litjens confirmed that this cylinder was all part of the original suspension layout, but was previously mounted longitudinally. That was one of the changes for the third ERS that was due to be introduced to accommodate the new regulations increasing the maximum stored energy to 10MJ. Toyota had actually already started a recruitment programme to develop an exhaust-driven energy recovery system for 2018, before the decision came to delay the new regulations to 2020. By then, clearly, the new gearbox and suspension layout were finalised.

'As soon as you design a new block it is never the same length or fixation,' says technical director and TMG vice-president Pascal Vasselon, adding that with the gearbox: 'The internals of the gearbox are new but this is more [to do with] changing the casing. It is just the usual design work to fit with the new casing.'

Both Toyota and Porsche have worked hard on the suspension layout both front and rear to cater for the new tyre regulations that will see teams double-stinting each set for the shorter duration races (Le Mans has the same number of tyres as 2016). Previously, for the 6-hour races teams had at least six sets of tyres, and for new tracks eight. That meant at one

'No process can take care of quality issues that have not been seen before'

Sidepod shape from rear showing interaction with front wheel pod and nose ducts. Toyota says aerodynamic efficiency has improved

Sidepod undercut. Note the duct under the D of Denso. This feeds directly into the volume above the diffuser

stage during a race in 2016, the teams had to double stint one set of tyres at least once, which led to some interesting strategy decisions. Toyota, traditionally, was kind to its tyres and was relatively comfortable double-stinting, but still had work to do to ensure all new Michelin compounds could be double-stinted in 2017. The new gearbox casing means that the rear suspension can be mounted differently with a view to making the tyres last better, but the retention of the 2016 monocoque means that development of the front suspension was limited to outboard changes only.

At Silverstone, Michelin was delighted to report that the drop off in the second stint was around 0.6s, particularly as Porsche had come with its low-downforce kit to ready itself for Le Mans, preferring to leave its 'high downforce' kit development to at least the Nurburgring in July. This year, by regulation, the teams have only two kits, rather than three in previous seasons. Previously the first kit was usually a development of the preceding year's kit, the second a low downforce kit for Le Mans, and the third a high-downforce kit for the remaining races of the season. Cost control is the root cause of the change to two kits for 2017.

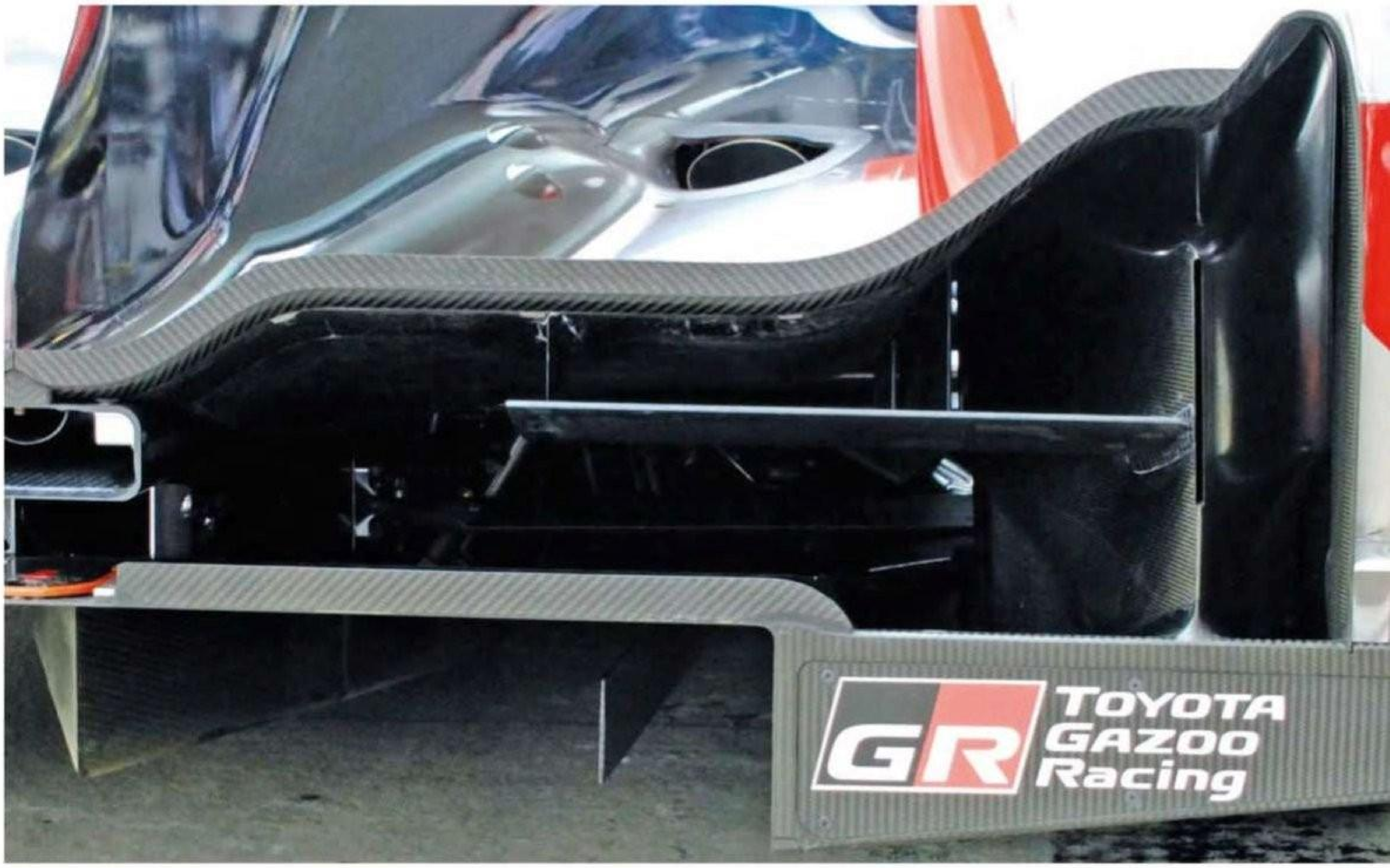
While Vasselon stated that the reduction in tyre allocation made life simpler, and that each set had to be double-stinted, Porsche pointed out that, in changing temperatures, making the correct tyre call was essential, and that if the wrong decision was made, it would affect performance over a double stint, or the tyres would have to be used again later in the race.

'With the new tyre regulations, everything was slung together, and we had to make sure that we were kind to the tyres, and with Michelin they had to produce less wear-sensitive tyres,' says Litjens. 'It still will be a challenge for certain races. We will see clearly less wear than last year.'

Drag and downforce

With the new route for the airflow, the target was clearly to claw back some of the lost downforce from the raised splitter and diffuser. 'The drag targets were kept the same, for sure when you start developing then you have to do

The 2017 Toyota TS050 LMP1 is anything but a simple update



Toyota diffuser and engine cover. Note daylight entering from the side and the air jack hole in the floor. Further aero benefits have been found with the battery, which requires less cooling

the compromising and run the simulation, [but] the drag is quite close to last year's,' says Litjens. 'You have the downforce [now], so we have to see if we have to run the wing angle steeper to get the downforce through the Porsche Curves, for example. I don't think that we will be much slower than last year.'

In spec 1 bodywork, nominally the high downforce kit that will see the car through the majority of the season, the change to the aero was clear, particularly at the rear of the car where the gap between the engine cover and the top of the diffuser was markedly different, with turning vanes within the diffuser area. Holes in the floor for the air jacks were clearly visible from the outside, such is the way the tunnels through the car are sculpted.

Battery development

One of the big aero changes for this year is the development of the battery, which is designed to run in hotter conditions, and therefore requires less cooling. 'The engine is smaller and lighter [than 2016], but the battery is similar [weight]' says Lijtens. 'We worked on the other hybrid components to make a step. The maximum energies are enforced by the regulations. The motors we took weight out of, but the development was almost all in the battery. You try to get cells that work at higher temperatures, so they need less cooling and so on. So far this has been successful. With the batteries last year, it was better than the capacity before, but we saw quite big degradation from new to the end of race, but now they did a good job there, so it looks stable. We want to do a few races with the battery. Two years ago we threw away the batteries after every race, last year we started like that, but we saw that they were quite good, so we did two races, and at Le Mans it was quite stable so we can do more races.'

Engine options

Engine displacement was also a topic for discussion pre-season, and project general manager Hisatake Murata confirmed that the team had actually experimented with a 2.1-litre engine, although there was some disagreement within the team whether or not the smaller engine had run only on the dyno, or in the car too. The new engine, in 2.4 litre guise, only arrived into the car late in the testing programme and much of the developmet work for the 2017 season was done with a re-mapped 2016 engine that therefore suffered failures.

Following an embarrassing 2015 season, in which Porsche and Audi took stunning steps forward with their cars while by comparison Toyota only took a moderate step, its engine development was therefore accelerated.

Toyota has two teams of engineers working in Japan, a young group of engineers who work on the future technologies, and an older, perhaps more experienced, set of engineers who work on the race engines.

Following Le Mans in 2015, where the team ran the normally aspirated 3.4 litre engine, the decision was taken to produce a new twin turbo engine that was being investigated by the young team ready for 2017, and introduce it instead for 2016. That engine was a masterpiece, one that almost delivered Toyota a Le Mans victory. 'We designed the engine with two lines of experience for the engineering team,' said Murata of the 2016 development programme. 'The experienced engineers make the development, and the second tier of engineers, the younger generation, do the other work. The 2017 engine was for the younger engineers as they were learning and studying, but I decided to bring the engine forwards and installed the top line engineers and the young guys to work together on the engine.

'Always, with the hybrid and the battery and engine calculation we are working in parallel in development, so that is the normal way. If

The aero solution means the packaging had to be completely redesigned

Note airflow routed upwards from the sidepod, and the tight packaging which is a stand-out feature of the revised TS050

The cylinder on the rear suspension sits transversely across the gearbox in preparation for a third ERS

we had some margin of performance we could develop the engine and the hybrid one by one, but at last year's [2015] Le Mans the difference in performance was huge, so we needed every component to be developed.'

The new engine has a much higher compression ratio this year, although the team would not reveal to what specs it is running.

2.4 to the fore

'Everyone said to me why is your engine 2.4 litres?' says Murata. 'So, that is why we tried to check the benefit, and on the final conclusion it is currently 2.4-litre for us. Time is a limit, and that is the reason why we could not do several attempts [with the smaller capacity engine], so we just checked the 2.1-litre. It was a theory, [that] thermal efficiency increased.'

Toyota has also remained with a twin-turbo approach, with a switch to single turbo only likely if the new ERS comes in. 'We tried several ideas for the ERS-H,' says Murata. 'If you look at single turbo or twin turbo it depends on your targets. Increasing the thermal efficiency, the single is better than the double, but if you aim at the turbo lag, the twin is better than the single.'

The battery is designed to run at an even higher voltage than in 2016. The limit by regulation is 1000V, but Toyota says that it ran at closer to 750V in the 2016 season.

One further change to the hybrid regulations is that the 300kW maximum energy boost is for the whole season, now, rather than just at the Le Mans 24 Hours. That makes little difference to the manufacturer, as neither Toyota nor Audi raced at more than 300kW leading up to Le Mans in 2016 anyway.

Engine timing

Back to the engine, one stand-out aspect of its development has been the tight time-frame Toyota has been working to over the last few years. 'We were discovering the technology and not everything was where we wanted it to be for the first engine,' says Vasselon. 'The planning of this engine has been extremely tight. [The decision] to go to turbo technology at Le Mans was, made in 2015. Everything was late, and then we have had another rush. The 2.1-litre engine was run. We keep in our minds the third ERS, but at the moment it is out of the way. The regulation has been shifted to 2020 at least. But we cannot say that many things have been steered by the prospect of the third ERS. We

Toyota has worked hard on the suspension layout, both front and rear

The front brake uses Akebono mono-block light-alloy calipers and ventilated carbon discs. Pad material changed mid-2016

have known for some time. [Now] it is all about thermal efficiency and fuel efficiency.'

What is the weak point of the Toyota LMP1, from Litjens' point of view? 'Difficult to say,' says the Dutchman. 'From last year, and with the rule changes it is the high downforce which was not enough. The whole thing is reshuffled again. Our downforce last year was clearly too low, and we were able to do the step up, and have more downforce, and we learn from that base. This is for me the biggest question mark, and there is no way to react anymore.'

Quality control

For Vasselon, the weakest point was clearly the quality control last year, and the team has taken steps to address that issue as it goes all-out for Le Mans victory in 2017. 'We are close to 35,000km [in pre-season testing], and it went well so far,' he says. 'Last year we had good reliability as well, except in the last five minutes [at Le Mans]. It is a process. In some parameters we didn't change the process as it was in place, and the part that failed last year passed the process. We have reduced the tolerances. We did not change the process in place, so if we roll out a car and do 800km on the first day, it works. No process can take care of quality issues that have not been seen before. The part that broke physically [at Le Mans] was a quality issue which was impossible to catch. Then we should have been able to handle this problem. Now, if we had the same failure, we would be able to do the last lap in four minutes. It was because we were running short of time and we didn't have the mode for the engine.'

One other area in which the team has worked hard is in qualifying. Traditionally the car has been significantly more competitive in race trim than in qualifying, but Kobayashi's time at Silverstone suggested that this had been a topic over the winter for the team. 'We have done a couple of simulations because it is one of our weaknesses so we concentrated on it a bit more,' confirmed Vasselon at the Prologue at Monza in April. 'We didn't need to do more long runs, so now it is time for us to prepare for the first race. We did not do quali runs before because we focussed on the race.'

Toyota believes that it has taken all the steps that it can to win Le Mans for the first time. Certainly the winter development has been extreme. But will it be enough?

The TS050 focusses on though-car airflow, hence the high nose treatment. The front impact structure is new

Grand **Prius**

Not a fan of the Toyota Prius? This mid-mounted LMP1-engined hybrid-packing rear-wheel-drive GT300 rocket might just change your mind

By SAM COLLINS

What is perhaps the most unlikely car in GT racing is set for another strong season in 2017

It's a Prius, but not as we know it. Japanese company apr has produced a pair of these 'Mega Prius' GT300 cars for the Super GT series

TECH SPEC

apr Prius GT300

Engine: Toyota RV8K, 3400cc normally aspirated V8, 2 x 28.32mm air restrictors, Pectel ECU, Total lubricants

Hybrid system: Production car based, with single MGU-K sourced from either Toyota Aqua or Camry.

Wheels: Rays

Tyres: 330/40R 18in front and rear (Bridgestone or Yokohama)

Brakes: AP Racing GT500 calipers, steel discs.

Suspension: Double wishbone all round. Ohlins dampers

Transmission: Hewland NLT with Ogura clutch

Dimensions: Wheelbase, 2700mm; length, 4620mm; Width, 1950mm; Height, 1150mm

Weight: 1100kg minimum

The finale of SRO's Intercontinental GT Challenge last year was held at the Sepang Circuit in Malaysia. Among the smattering of FIA GT3 specification Audis, Ferraris, Lamborghinis, Porsches and Aston Martins was a strange interloper, a Toyota Prius. This was no Uber driver having taken a very wrong turn somewhere. No, this was one of two highly potent GT300 specification mid-engined rear-wheel-drive Toyota Priuses built for the Japanese Super GT championship.

Super GT's second tier class GT300, so called as the cars are supposed to produce around 300bhp (though in reality they are substantially more powerful), is open to three distinct types of car, each with their own set of regulations. The most popular is FIA GT3, followed by the new Mother Chassis cars (see P24) and finally the least popular, but perhaps the most interesting, the JAF GT300 rules cars.

Left field

The JAF GT300 regulations basically allow tuners to develop a wide range of production cars into a GT300 competition car and over the years it has seen some oddities including a Subaru Legacy, and a Lexus IS350, but the Prius is perhaps the strangest car of all of them. Its creator, Hiroto Kaneso, and his apr team, based in Atsugi just south of Tokyo, Japan, has been responsible for a number of GT300 racecars over the years, including the Toyota MR-S and the rather unlikely Toyota Corolla Axio.

The racecar pictured on these pages is actually the second generation of the apr Prius. In 2012 the team built a GT300 car based on the third generation of Toyota's hybrid production car, the ZVW30. Taking advantage of the JAF GT300 regulations which allow for any engine from the manufacturer's range to be used, apr opted to install a Toyota RV8K engine, the 3.4-litre normally aspirated unit which has its roots in the firm's 2003 Indy 500 winning unit and has gone on to be used in GT500, Super Formula and in LMP1 in the Toyota TS030, Lola B08/60 and Rebellion R1.

Midshipmen

The engine was mounted in the centre of the car making the Prius mid-engine, rear-wheel-drive, or as the Japanese call it a 'midship' layout. Between 2012 and the end of 2015 the apr Prius proved to be competitive but perhaps a little inconsistent. During the 2015 season GTA, the organiser of the Super GT series, announced that the JAF GT300 rules would be changed and all cars would have to run with engines located where they were sited on the base production road cars. This essentially outlawed the mid-engined Prius. When the old car won on its final outing at Motegi in 2015, Kaneso was in tears. It looked like an emotional farewell.

However, in secret he had been developing a new car, again a Toyota Prius, but this new version was based on the fourth incarnation

'Having a midship car gives us better stability, we wanted to keep that'

Number 30 car being prepped for first race of 2017. The 3.4-litre normally aspirated Toyota V8 RV8K engine has been used at the very highest levels of racing, including LMP1. Regulations allow the use of any engine from the manufacturer's range

Gearbox is a Hewland NLT. The apr team is beginning to have some problems sourcing parts for this tough transmission

The headlight lenses and badge are part of a very small amount of carry over (as little as five per cent) from the road car

of the Prius (the ZVW50), which had only been announced in September 2015. Many were shocked when early in 2016 Kaneso took the wraps off his new GT300 car and they saw that again it was a mid-engined hybrid. It later transpired that because the ZVW50 had gone on sale in Japan a few days before the JAF GT300 rule change took effect, apr could keep its mid-engined layout, and the RV8K engine remained in the exact same position it had been in on the old car. What also shocked onlookers and the media is that two examples of the new car had been built, and both would race.

'Having a midship car gives us better stability, and we know it so well, so we didn't really want to change the layout at all,' apr engineer Tsubasa Yokomizo explains. 'Changing to a front-engine layout would have been a big step and we already have good performance with this Prius, so we managed to get this racecar approved just in time.'

Family resemblance

Looking at the new Prius GT300 many assume that it is a pure silhouette, merely styled to look like a Prius production car, as is the case with GT500 cars and the Mother Chassis GT300 cars. But, as Yokomizo explains, some parts do actually carry over from the road going production model. 'There is some production car in there, just not a lot, maybe less than five per cent of the base car is used,' he says. 'So we retain the A-pillar, about a third of the roof, the headlight lens [but not the internals] and the badge. We also use the production car front bulkhead, but we cut a lot of holes in that.'

The overall chassis structure is visually very similar to that of the older Prius, and it is a design concept that is more than well proven. 'Actually, under the skin it is almost the same as the 2012 car, and the main chassis concept is actually much older than you might think. It actually dates back to 2000 and the MR-S GT300,' Yokomizo says. 'In GT500 everyone is always trying to decrease the weight, even changing the material and bolts in the suspension, decreasing from an M10 to M8, but sometimes they push too far and it leads to unreliability. We don't have that philosophy really, we stick to what we know to be reliable and improve the base performance of the racecar in other ways. That's really why the concept has continued all this time.'

Prius-toric

Studying the No.30 Prius racecar it soon becomes apparent that this chassis is actually that used from 2012-2015, albeit in modified form, while its sister car No.31 is a new build. Kaneso told *Racecar* in the past that it would be possible to convert one of the Corolla Axio chassis into a Prius, but this seemingly never took place as the Corolla chassis still sits in storage at the apr workshop.

One of the biggest differences between the Corolla and the 2012 Prius was that the later car had to use thinner walled tubing in order to accommodate the added weight of the hybrid system fitted to the car, though this meant that the torsional stiffness was reduced. That has been addressed on the new Prius, according to Yokomizo: 'We stiffened the chassis over the engine and added some tubing in a few other places. It was possible because the hybrid system is a bit lighter on this car.'

Charge change

The new Prius is, of course, also a hybrid, but the system it uses is different to that used on the 2012 version. Indeed, the two new cars use different systems to one another, though like the older model the systems use modified production car parts. 'Actually, that is the biggest difference between the two cars racing this season. The hybrid systems are totally different, on the No.31 car there is a high power motor from the Camry Hybrid production car,' Yokomizo says. 'It deploys its energy more aggressively than the No.30 car. The No.30 has a different motor, from the Aqua production car. It uses its energy more steadily, so while it does not have that big power boost at some points on the track it has a constant deployment pretty much whenever the driver is on the throttle.'

With different motors the batteries used on the two cars differ from one another, too. The team is a little cagey about exactly what batteries are used, stating that they are from production cars, though it is not clear if they are the nickel metal hydride cells used in the current Aqua and Camry production cars, or if they are the lighter lithium based cells used in the 2017 Prius and on the forthcoming 2018 Camry.

'The batteries on the two racecars are different to each other and the cells come from the production cars, like the motors,' Yokomizo says. 'So the battery casings are a bit different, both sit in the 'passenger' area and the capacities differ. The total handicap weight plus hybrid system weight differs on each car too, but overall the weight is about 80kg, so that's pretty tough to accommodate.'

Sparking fine

Using production car parts does mean that some of the production car electronics have to be used, too, which creates something of a challenge when mating it to a motorsport electronics system. 'All the management systems on the car are from Cosworth electronics and the engine runs on a Pectel ECU, but the hybrid system electronics are the exception to that, it is still the Toyota production car system. We have a very clever electronics guy in the team and he

Hybrid system PCU (the silver component) is mounted in the space passenger seat would normally fill. It's from a road car but is mated to a Pectel ECU. The black battery pack is also visible; casing is bespoke but cells are from the production car

Rear suspension. Prius uses double wishbones and damping is courtesy of Ohlins. TRD has helped with suspension design

Front suspension. The car uses a third element on front and rear. Geometry differs on both cars due to use of different tyres

'Hybrid system electronics are from the Toyota production car'

‘When it’s raining we take a lot of photos of the car as you can see the flow lines showing in the dirt that’s on the bodywork’

got the Toyota production car system to work with the Pectel ECU. All the wiring we use is bespoke. Actually, we even support some of the GT500 teams on electronic things and even the Toyota production car engineers sometimes ask us for advice,’ Yokomizo says.

The overall weight of both the No.30 and No.31 cars is 1100kg, though that is often increased by the balance of performance process used in Super GT. At the opening round of the 2017 season the No.30 car ran at 1238kg and the No.31 at 1216kg, though, again, these weights are likely to change through the season as the cars accumulate success ballast and the BoP is adjusted as the year goes on. ‘The different motor and battery packages have different weights but it’s not a big enough factor to make a great difference in terms of weight distribution,’ Yokomizo says.

When the original Prius GT300 was launched it appeared with double brake calipers, in order to cope with the effect of the hybrid system harvesting on the brake pedal feel, however the car never raced with the twin caliper system and it did not return on the pair of new Prius GT300s.

‘There is actually not a link between the hybrid system and the brake system on this car,’ Yokomizo tells us. ‘So actually, the hybrid system harvests and deploys exactly the same way each lap, it’s essentially pre-programmed. The calipers we use actually are second hand parts, they are old GT500 calipers that TRD have given us. I think they are from the SC430 racecar, so our brakes are very conventional.’

Driver controls in the cockpit are similar to GT500. With different hybrid systems on both cars throttle response differs, too

AP racing brake calipers were previously used in GT500. There’s no link between the hybrid system and the braking system

TRD and tested

The close relationship between apr and TRD has also helped the team develop in another key area on the new generation Prius GT300, namely the suspension design. ‘The suspension geometry and the overall suspension layout have been developed over time,’ Yokomizo says. ‘Indeed, we changed it from the 2012 car to the 2016 one in quite a significant way. The basic suspension system is the same with a third element front and rear, but we did relocate the dampers and some of the mounting points. So for the ZVW50 Prius GT300 we looked at the whole layout and decided to change things around a bit. We used the Cosworth data analysis software, used linear pots and some track testing and fed all of that data as well as the overall design into some multi-body simulation software that TRD helped us with.’ TRD also allowed apr to use one of its seven post rigs to help the team understand the new car.

The final design saw the third element at the front of the car, which had been mounted transversely on the 2012-2015 Prius, mounted longitudinally, while the spring damper units which had been mounted vertically in the centre of the racecar were now moved to a horizontal position further rearward and just ahead of the front bulkhead. The wishbones have also been redesigned. At the rear the spring damper units are mounted longitudinally on top of the transmission.

Get a grip

According to Yokomizo, one reason that the suspension had to be reworked was that the two racecars use different tyres; the No.31 car uses bespoke Bridgestones developed specifically for the Prius, while the sister machine uses off the shelf Yokohamas. ‘It’s a bit political and there is a money element to it, too,’ he says. ‘The 31 car has special tyre war compounds while the 30 car has commercially available tyres. This means we have to run the two cars with totally different suspension geometries. The Bridgestone has a really high grip level and the construction means we can run quite stiff springs on that

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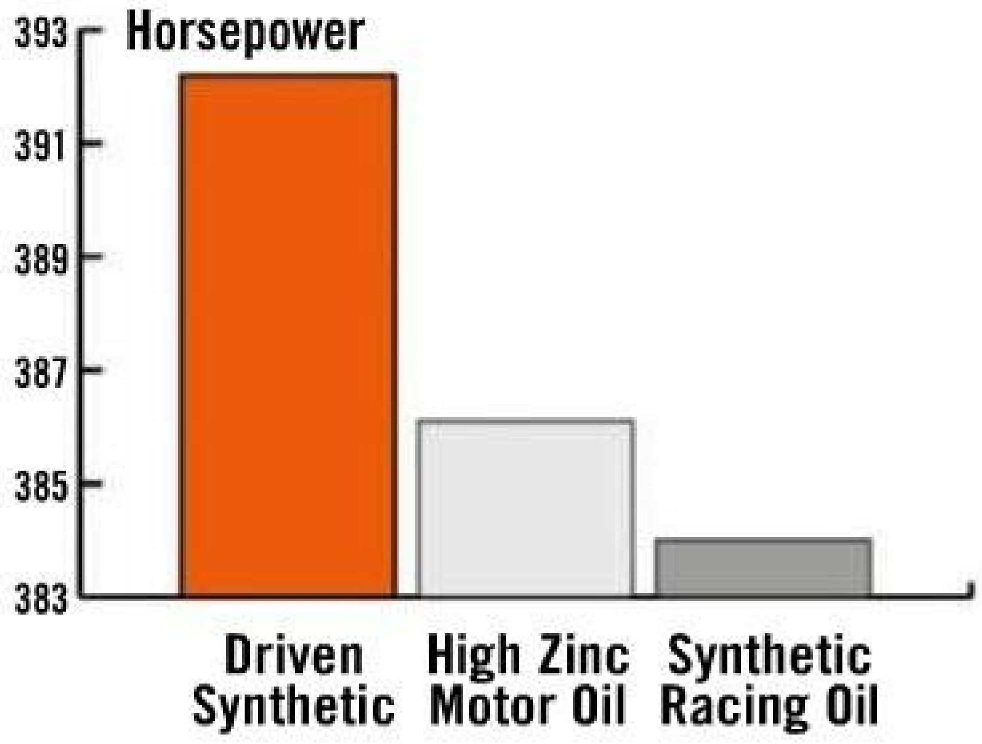

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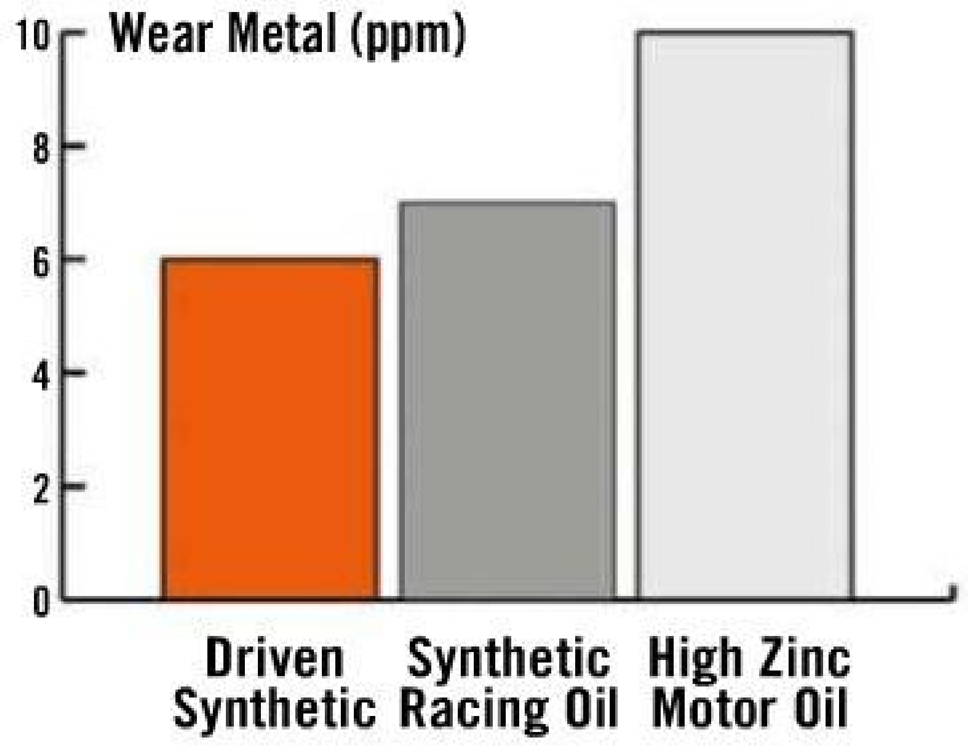

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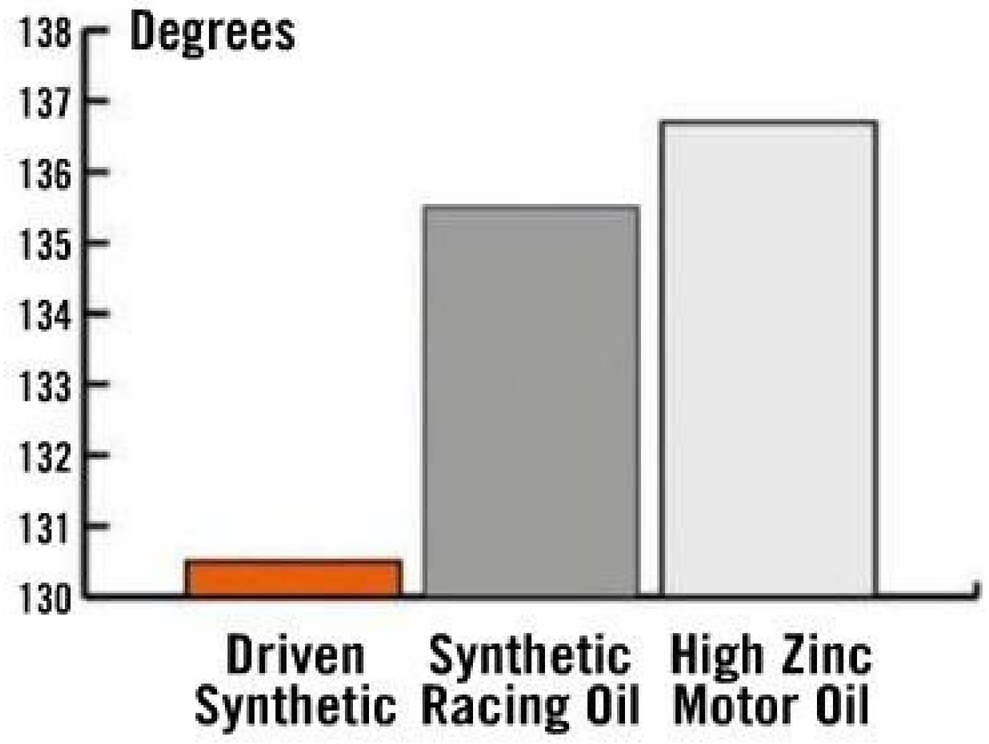

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Aero development was done on a very small scale using a mix of CFD, a little wind tunnel work, and the intuition of Hiroto Kaneso

The rear wing concept on the Prius dates back to the MR-S. The swan neck supports come from the previous generation Prius and they also bear a resemblance to the aero approach of Super GT's technical cousin, DTM

Exhaust exit. Intricate engineering is a hallmark of the apr team

'We stiffened the chassis over the engine and added some tubing in a few other places, it was possible because the hybrid system is a bit lighter on this car'

car, but the Yokohama tyre has a lower grip level and the construction means we run softer springs on the 30 car. One of the biggest advantages we have with this car is that it is very easy to change the geometry and to adjust things like anti-squat and anti-dive. So as the tyres develop we can react, it is a big advantage. When the new tyre comes they tell us about its performance, but we don't get it all written down as you might expect, so we have to work a lot out from track data and driver feedback, so we need that freedom of adjustment.'

Intuitive aero

One area where assistance might be expected from TRD but apparently is not forthcoming is in the aerodynamic development of the car. Indeed, some elements of the aerodynamic package such as the rear wing shape can be traced back to the MR-S GT300 of 2000. By regulation, and similar in concept to the DTM and GT500 cars, certain elements of the base car's styling have to be retained and so the profile of the car in the centre must be the same.

'Most of the aerodynamic design of the car came straight out of Kaneso's head,' Yokomizo says. 'We didn't have a huge amount of budget so we used a very small scale model in the wind tunnel, and we also used a fair bit of CFD, then finally we did full scale tunnel testing with the finished racecar. So once the car was built we had to tune it at the track. To work out the cooling flows, we again simply used Kaneso's brain and flow vis dye in testing. Actually, when it's raining we take a lot of photos of the car as you can see the flow lines in the dirt.'

As the car enters its second year of competition further major changes could be coming for the Prius, for while sticking with a tried and tested car concept brings reliability, that approach is also beginning to cause supply issues, most notably with the engine and transmission. The Prius is the last car to use the Toyota RV8K engine, though unlike other RV8K engines those used by apr are not tuned by TRD or even TMG. 'Ogura have tuned all our engines for nearly 20 years, so that continues with the RV8K, so they do all the checks and rebuilds rather than TRD,' Yokomizo says. 'Sourcing parts is becoming an issue now, however. I think some parts we use have been made just for us and that gets expensive.

'Perhaps we will have to use a different engine in future,' Yokomizo adds. 'But you have to remember this is GT300 and we simply don't have a huge budget. The transmission is an issue too, we are really struggling to get parts for the Hewland NLT. It gets really expensive as parts are hard to source. Our version of the NLT is just an off-the-shelf unit with slightly thicker ratios due to the style of racing we do.'

Mega Prius

The new Prius GT300 has performed well, winning on its third outing and finishing second in the 2016 championship. On its intercontinental GT debut the car only had average pace, though this was partially due to the fact it was running on different tyres to normal and that the BoP was quite harsh. However, it seems likely that the 'mega-Prius', as some fans call it, will again be seen outside of Super GT in the not too distant future.

Meanwhile, what is perhaps the most unlikely car in GT racing is set for another strong season in Super GT in 2017.

Great Xpectations

The Toyota Mark X is the latest car to take the Mother Chassis path into Japan's Super GT series – but this is no ordinary GT300 effort

By SAM COLLINS

The Saitama Toyopet Toyota Mark X is the first four-door saloon car to get the Mother Chassis treatment in Super GT. So far it's struggled for pace, but it's still early days for the project

TECH SPEC

Saitama Toyopet Toyota Mark X
Chassis: GT300 Mother Chassis designed by Dome and GTA, Carbon tub is made using male mould on to which pre-preg sheets are laid up. Steel roll over structure.
Engine: GTA-branded 4.5-litre V8, which gives around 430bhp, Normally aspirated
Suspension: front, double wishbone system. Rear, double wishbone system; mounted partly on bellhousing and partly on the transmission casing
Transmission: Hewland LLS 6-speed sequential gearbox with magnesium casing
Wheels: front, 18in/13J; rear, 18in/13J
Tyres: Yokohama
Brake system: Alcon 6-piston monoblock
Wheelbase: 2750mm
Weight: over 1100kg

The Toyota Mark X is a rather unremarkable luxury saloon. It features rear-wheel-drive or 4wd depending on the exact trim level chosen by the customer. It does not stand out in a crowd. Currently the car is only available in Japan and only via the Toyopet dealer chain.

At a stretch you could see it being adapted for use in VLN but certainly not GT racing. However, that did not seem apparent to Takayuki Hiranuma, the general manager of the Toyopet chain in Saitama, a suburb of Tokyo. In 2013 he launched a new racing team staffed entirely by mechanics from his service centres, believing that the best way to prove the abilities of his staff was to have them take part in motorsport while he could also take advantage of the marketing opportunities. Hiranuma himself would also get behind the wheel and try to realise his racing ambitions.

Initially the team competed in Super Taikyu in a Toyota GT86 as well as running a number of cars in one-make Toyota 86/Subaru BRZ racing. In 2016 it stepped up to the higher ST-3 class in Super Taikyu, essentially the Japanese equivalent of VLN. The new ST-3 car was based on the Mark X and was developed in-house by a team of eight dedicated staff.

But from the outset Hiranuma had his sights set on one championship; Super GT. When he had started out he had been unclear on quite how he would get his team into the GT300 class, at the time only buying an FIA GT3 car or developing a JAF GT300 car seemed likely

Mother's heart: the MC chassis showing Fuel Safe fuel cell. The Dome-developed monocoque uses coreless design and is said to be stiffer than the GT500 chassis

The 4.5-litre GTA engine is spec issue for Mother Chassis racers, but with the entry of the Mark X the supply of this unbranded unit has now dried up. Promoter GTA is looking for a new source

options. However, the former didn't do much in terms of promoting the technical skill of the Toyopet staff, and Toyota did not offer a GT3 car at that time anyway, and the latter option was prohibitively expensive.

But then the launch of the GTA Mother Chassis in 2014 gave Hiranuma an idea. He could use it to develop the Toyotpet chain's premier model, the Mark X, into a GT300 racecar.

Mother in law

The Mother Chassis GT300 rulebook is designed to allow small teams and tuners to develop a reasonably capable GT car on a fraction of the budget required for GT3 or JAF GT300, and it uses a large amount of standard components.

As the name suggests all cars share the same core chassis, a carbon fibre monocoque developed by Dome. To keep costs down the companies proprietary UOVA technique has been used in various parts of the tub, which sees a core-less structure used. While heavier than a conventional structure it can give more freedom in terms of mounting points and even torsional stiffness. Exact numbers are not available but it's claimed that the Mother Chassis, which weighs 63.5kg as a bare composite structure (and with steel roll cage fitted 83kg), is actually stiffer than the DTM-based chassis used in GT500.

The versatility of the Mother Chassis was one of the core aims of its design, and it is specifically engineered to allow a front- or mid-engined layout, both of which have already been done with the GT86 (front) and Lotus Evora (mid). The GT300 rules state that the engine position of the production car must be used, so the new Toyota Mark X GT300 would have to be front-engined.

As standard the Mark X comes with an option of two different Toyota V6 direct injection engines, with differing capacities, 2.5 litre and 3.5 litre, but under the Super GT Mother Chassis regulations there is only one option; an unbranded 4.5-litre normally aspirated V8. When the Mother Chassis package was introduced GTA (Super GT's promoter) secured a guaranteed supply of engines to cover six cars. With the entry of the Mark X in 2017 there are no more engines available. This means that GTA now needs to find a new supply of engines and there is no clear alternative available at the moment. The Toyota V6 used in the Interproto series is felt to be too heavy and underpowered, Nissan's LMP3 VK50 is also felt to be too heavy and also too long, while adaptations of the GT500 2-litre turbo engines are said to be too expensive. It is not yet clear what unit GTA will adopt for future Mother Chassis cars, but it is clear there will be more cars.

Mother superior

The GTA V8 is mated to a number of other standard parts on the Mark X, primarily the Hewland LLS 6-speed sequential transmission and the double wishbone suspension with pushrod actuated spring damper units all round. Indeed, under the bodywork the Mark X GT300 is mechanically identical to the Dome-Toyota MC86B (GT86) which made its debut in 2016, itself a mild update of the MC86 from 2014.

The Mark X is the first four-door car to race in GT300 since the Subaru Legacy B4 in 2011, and that was built to the JAF GT300 rulebook. But being based on the Mother Chassis package which works well for the GT86 and Lotus has created some issues for the Saitama Toyopet team. The GT86 has a production car wheelbase of 2570mm, but the Mark X has a wheelbase of 2850mm. The Mother Chassis cars, both GT86 and Mark X, have a wheelbase of 2750mm. The longer layout has been fairly effective for the '86 but with the Mark X it has created some issues with getting a good balance, as the rear overhang seems a bit too long.

While Dome supplied the Saitama based team with all of its mechanical parts, the bodywork was developed at least in part by Takuya Yura's Mooncraft company, which was also responsible for the Lotus Evora Mother Chassis car. Mooncraft has its own wind tunnel, a 40 per cent scale open section closed loop facility with an optional moving ground plane. With the moving ground plane operational the model is supported by three wires and the forces acting on it are measured via strain gauges. The tyres are independently supported and rotate on the belt with the resistance measures. Pitch and yaw can be adjusted remotely. The maximum flow speed is 40m/s.

Mother's ruin

While the Super GT balance of performance and success ballast will likely help, there is clearly some work to do before the Mark X GT300 is truly competitive. In pre-season testing it struggled for pace, and it was a similar story in the opening race of the 2017 season. A driver error during the race saw the car crash heavily, though this was a similar pattern to that of the GT86 when it started in Super GT races and now it is a highly competitive machine. Only time will tell if the Mark X can get up to speed.

Hiranuma launched a racing team staffed entirely with mechanics from his service centres

To the Manor stillborn

Just one championship point proved the difference between survival and failure for the Manor F1 team – but before it closed its doors work on its 2017 MRT06 was well advanced. Here's what might have been …

By SAM COLLINS

Before the 2010 season the FIA opened up the F1 entry list and four brand new teams entered the sport. Seven years later and every one of them has collapsed. USF1 never really got going, HRT collapsed at the end of the 2012 season and Caterham failed at the end of 2014. The last of this group of new teams, Manor F1, closed its doors in January 2017, but not before it had completed the design of a brand new car.

The team had been rescued from administration at the start of the 2015 season and looked to have a hopeful future. A small squad was put together blending youth and experience and things were looking up after it scored a point at the 2016 Austrian Grand Prix. This point elevated Manor to 10th in the championship and with this came the prospect of tens of millions of euros in prize money. But the team's hopes were dashed at the penultimate round of the championship, the Brazilian GP. Sauber, which had gone pointless all year, managed to get a car home in ninth and scored two points, relegating Manor to 11th.

Making the team's financial prospects even worse were a new set of criteria on driver Super Licences ahead of the 2017 season, which seriously reduced the pool of available race drivers with a large budget, an income Manor had relied on for some time.

Yet by the time the doors were finally closed and the assets labelled up for auction the design of the 2017 car had been completed and the first monocoques were ready to be built up. Details of that design can now be revealed.

Lords of the Manor

Created by a team of engineers headed by John McQuilliam (technical director) and Luca Furbatto (chief designer) with Nikolas Tombazis (chief aerodynamicist) and Tim Milne (head of aerodynamics, who was looking after the bodywork) the MRT06 was to have utilised a Mercedes power unit, so would have been widely known as a Manor-Mercedes.

Reportedly, the aim of the project was to ensure that the car was consistently competitive, not only so the team could recapture 10th in the championship, but perhaps move even higher up the order. The new technical regulations came as a great opportunity for the team especially considering that the MRT06 would have had what is generally considered to be the best power unit on the grid while its rival, Sauber, was stuck with an obsolete 2016 Ferrari unit. It was felt within Manor that the car should provide a much stronger aero platform in order to get the most out of the at least 25 per cent increase in downforce that the new rules would bring. Reducing the aerodynamic sensitivity of the racecar was another key aim.

With the weight limit increasing significantly to 728kg it was also clear that the car would have to come in comfortably below the limit while having full freedom to work within the mandated 7kg weight distribution window (330kg minimum front and 391kg rear), this was particularly important as there was some uncertainty about the new much wider Pirelli tyres (see April edition, V27N4).

Achieving this was probably easier than perhaps it would have been in the past when the weight limit was lower. Even so, the 2016 MRT05 was known to be underweight, thought to be by as much as 30kg – and that design even featured a large tungsten plate to protect the battery which weighed 20kg. However, an increase in loads through the car due to the much higher grip levels will have likely increased the size and weight of some structural parts.

Mind your Manors

During 2016 teams including Manor were expecting to see gains of about 0.5*g* in positive acceleration and a 1*g* increase under braking as well as a 0.75*g* increase in cornering at the start of the 2017 season, and an overall increase in loads of about 20 per cent. This led to a serious amount of structural work for all teams, looking at hard points on the monocoque with placements optimised to increase stiffness for a minimal gain in weight. Exact design details of the monocoque have not yet emerged but it was believed to retain the machined aluminium front bulkhead, which was a feature of the

About 90 per cent of the parts for the MRT06 were completed when the team entered administration

The pics seen here are the first detailed images of the 60 per cent model of the MRT06. Like many of the 2017 F1 cars the Manor would have used a dorsal fin, which is to help with stability in yaw. Its fin is not as large as those seen on other cars

Some components on the MRT06 are notably more substantial than those on the 2016 car, to cope with the increase in loads

MRT05 and the preceding MR03 chassis. The rear of the tub appears to have a large cut out in order to accommodate the ducting leading to the compressor, mounted at the front of the Mercedes V6. It also appears that the rear of the tub is asymmetric, with a cut out on the lower part of the left side, but it's not really clear what this would accommodate.

Some components on the MRT06, such as the wishbones, are notably more substantial than those on the 2016 car, also to cope with the increase in loads. But the overall design of them is primarily to meet aero demands, with work done to reduce unwanted compliances given the increased loads expected in 2017.

A focus on maximising mechanical grip was also part of the MRT06 project from the outset. While it was generally felt that the 2016 car was good in this respect, Manor decided that it would develop its own suspension in 2017, though Williams would again supply its aluminium cased transmission. Developing its own suspension freed up Manor's engineers to pursue some of their own ideas and concepts, rather than rely on what Williams offered them.

However, the suspension design and function of the MRT06 was still dominated by aerodynamic demands. This is because the front wing operates very close to the ground and has a high sensitivity to ground proximity, so generally teams run the front end of the racecar extremely stiff – it is thought that some even try to run negative stiffness systems to raise the rear of the car at the end of the straight so as to allow the front to run lower in the middle of a low speed corner.

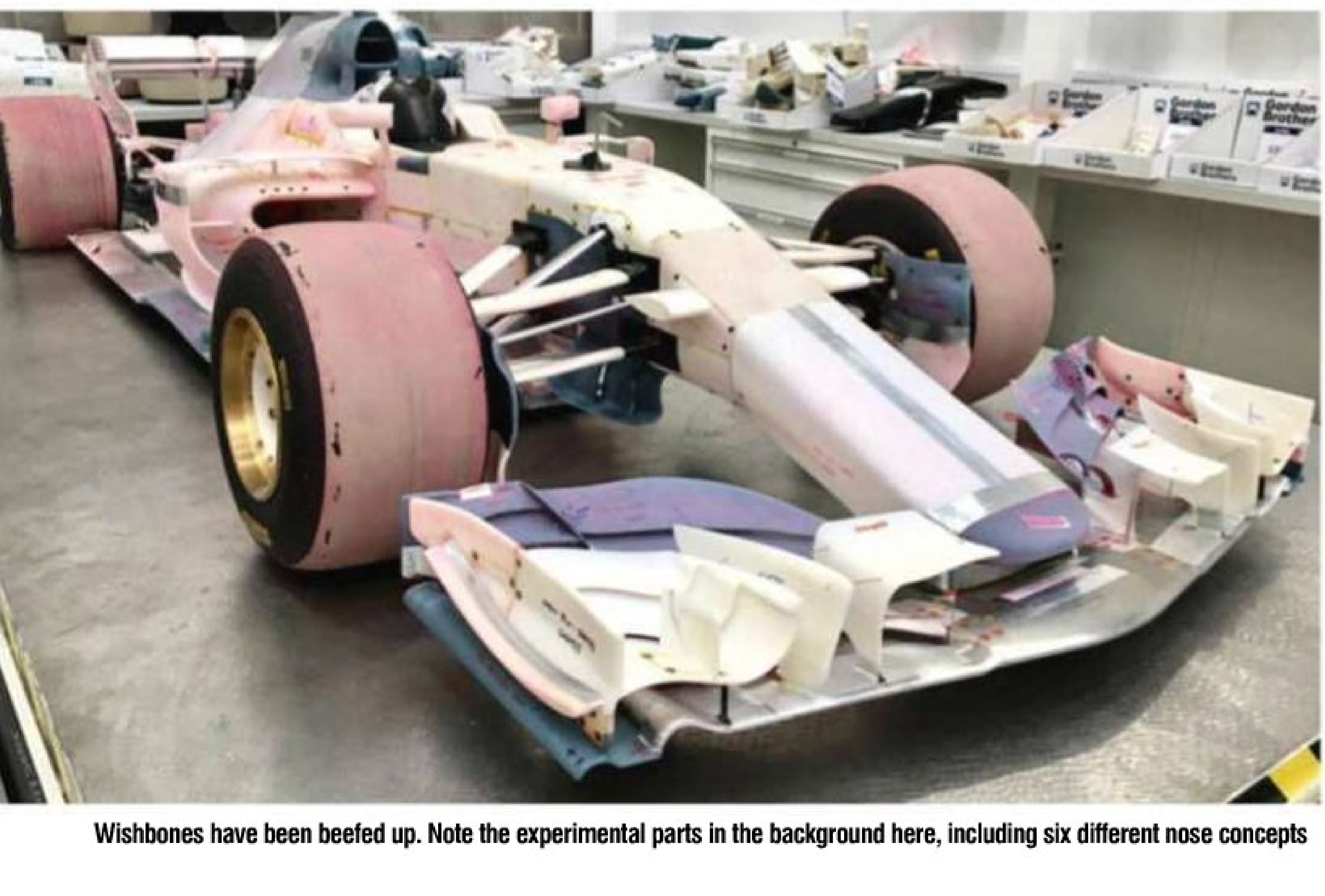
Swept back front wing is a result of the new 2017 regulations but also valuable lessons the team learned during the 2016 season

Trick suspensions

The rear suspension of the current generation of cars is primarily designed around optimising the aeromap and allowing the car to run with maximum rear downforce as it enters and exits the corner. The rear suspension must also allow the car to drop into a low-drag condition for high-speed straight-line running.

This means the rear of the racecar will sit up at low-speed and then will squat down at high-speed. Formula 1 teams tune the rate of rear ride height lowering depending on the track they are operating at – the more high speed corners there are, the longer the teams tend to keep the rear of the car up in the air to maximise the downforce.

On the MRT06 the general inboard suspension layout would have been fairly similar to that of the 2016 car, albeit developed to accommodate the 2017 regulations with the wider track and the increased loads mentioned earlier. It features torsion bars all round with pushrod actuation at the front and pullrod at the rear, as is common on modern F1 cars.



Wishbones have been beefed up. Note the experimental parts in the background here, including six different nose concepts

Elementary physics

The MRT06, like the MRT05, would have used third element bump stops, central springs, dampers and inerters, with all these functions carried out across two physical units at each end of the car. Third elements would only operate in pure heave so they could be tuned to optimise the aerodynamic and vertical ride aspects of the car, without compromising the roll and handling aspects of the racecar performance.

A stiff third element spring makes it possible to run the car very stiff vertically without having to run it stiff in roll. Clearly, from a weight point of view it is better to have as few units as possible but from a packaging point of view, it is apparently easier to spread the various functions across multiple units. F1 suspension specialists have told *Racecar* that it is also hard to measure the contribution from the different force generating elements if you have them all on the same physical unit.

Images of the MRT05 reveal that Manor would run a strain gauge on each third element unit. This is to measure the force it was generating to check it was performing as expected and to help identify failures early. It's likely this would have been used on the MRT06.

The rear suspension of the MRT06 was reportedly designed as a 'decoupled' unit where the roll and heave springing and damping is fully separated. The front suspension was to have been a more conventional arrangement with coupled torsion bars providing heave and roll stiffness, it also had split heave and roll damping. According to engineers with knowledge of current car design, the advantage of this type of damping arrangement is that it makes it possible to separate the damping needed for ride and aerodynamic performance (heave) and the damping which affects handling (roll). The roll dampers on the MRT06 were also thought to be adjustable to provide different corner entry and exit handling.

The increased loads and also the aerodynamic rule changes have also resulted in different suspension travel ranges. The ride height where the peak aerodynamic load occurs has changed and that, in turn, has meant that the rear suspension travel has increased on all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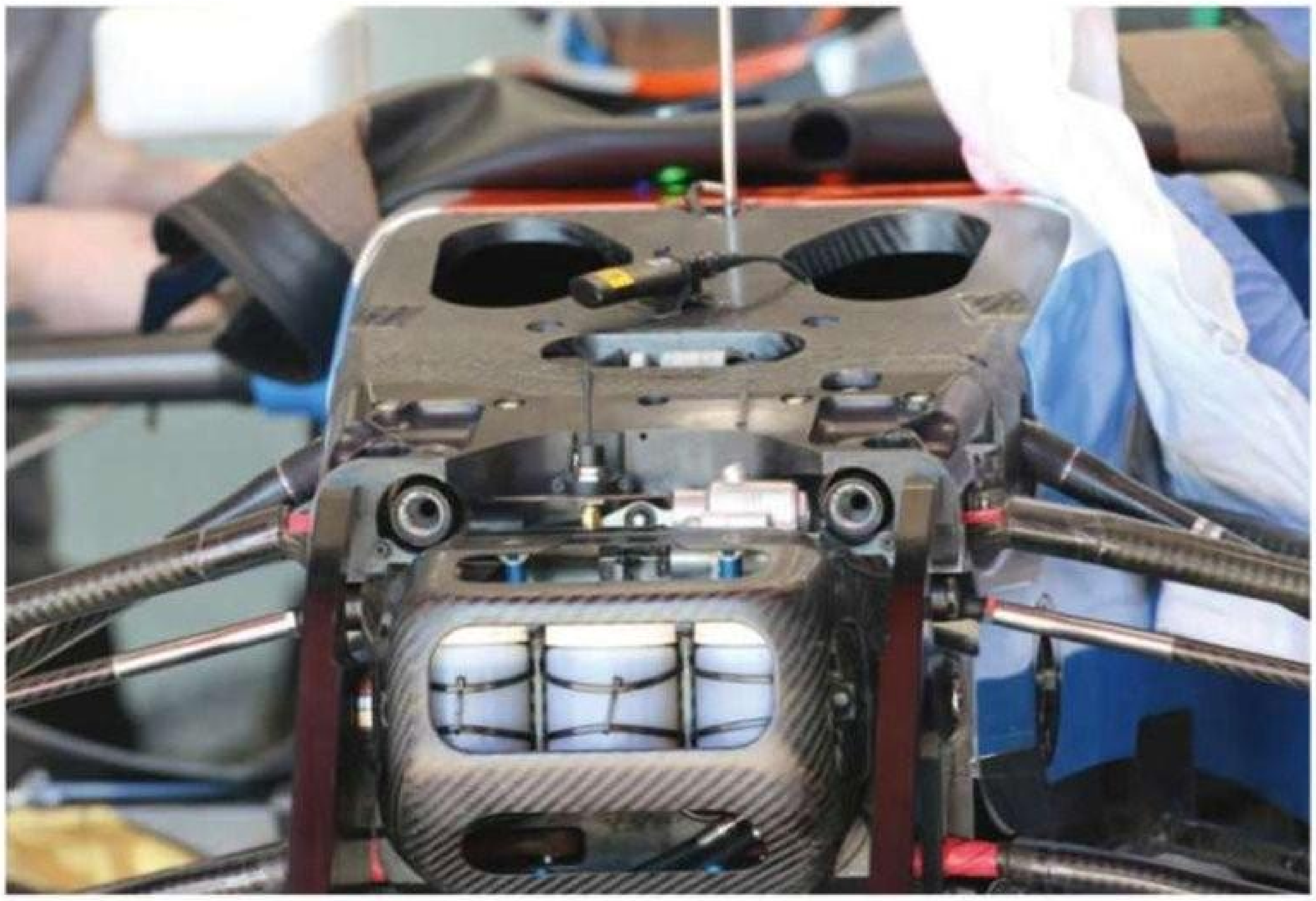

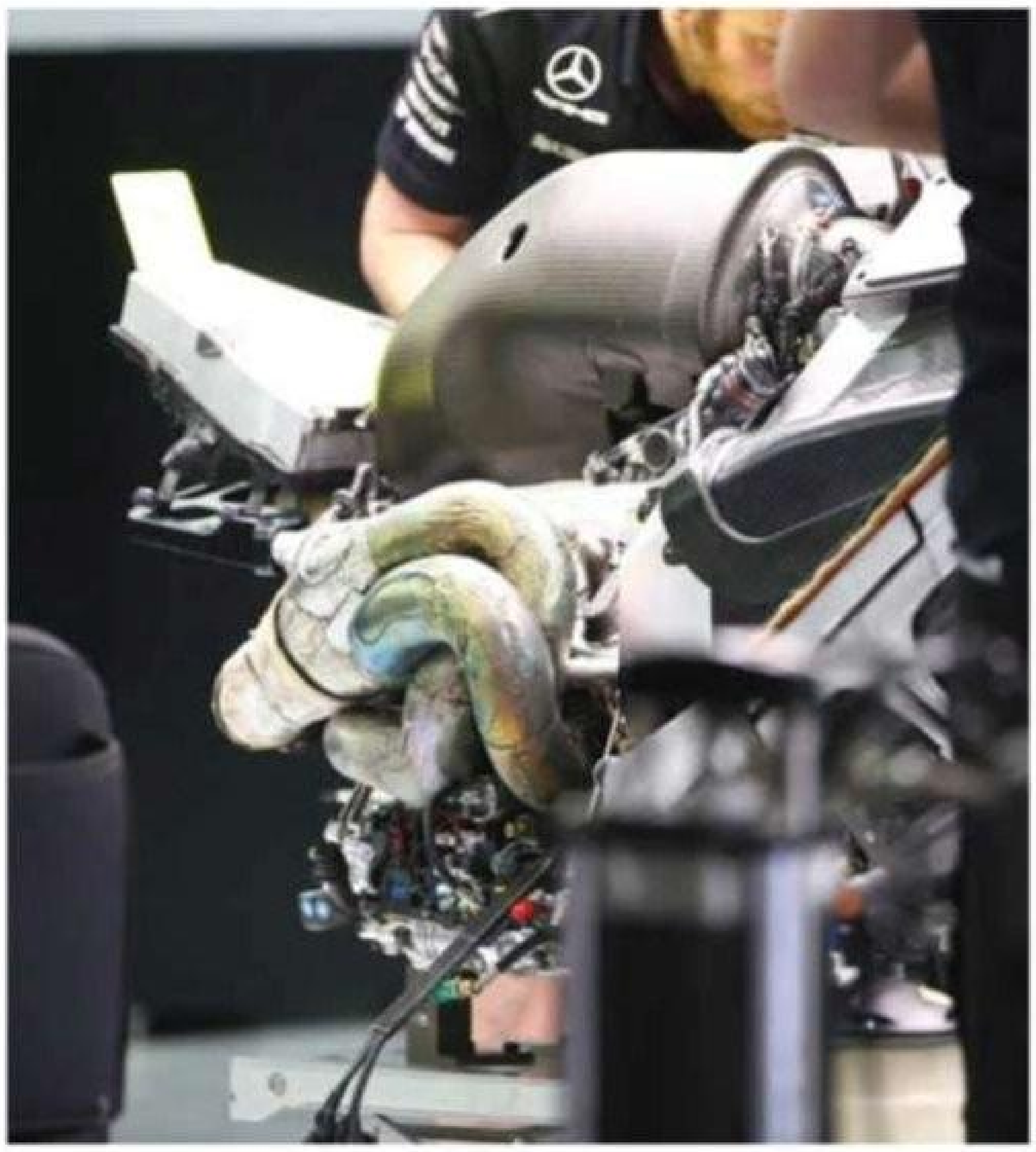

Above: Inboard suspension concept carries over from MRT05 (pictured) and features torsion bars all round with pushrod actuation at the front and pullrod at the rear, as is common on modern F1 cars. It would have also have used third element bump stops, central springs, dampers and inerters

Right: The MRT06 was to pack the 2017 Mercedes power unit which, even with the resurgence of Ferrari in recent races, is still regarded as the best engine package on the grid

Below: Wider tyres and more effective aero have increased torsional loads by about 20 per cent in 2017, and the size and weight of some structural parts would probably have had to have been increased

the 2017 Formula 1 cars compared to those used in 2016. This was something else that was accommodated on the MRT06 design.

Pirelli's tyres were a significant unknown during the design phase of the 2017 cars, with engineers from a number of teams saying the information received from Pirelli and the mule car tests was often inconsistent and contradictory. So with this in mind Manor engineers worked to create a suspension system which had the greatest amount of versatility possible, so it could react to how the tyres really worked with low compliances, sensible set-up steps, and large set-up range. This approach also resulted in the MRT06 having three different rising rate geometries for the rear anti-roll bar to change the roll balance with speed.

Apparently, one option kept the roll balance more or less constant with speed and the other two introduced different levels of understeer (more forward roll balance) as the speed increased. There were also to be collapsible rear anti-roll bar drop-links designed to improve entry stability and reduce mid-corner understeer, which are common handling problems for a modern Formula 1 car.

Wriggle room

At the time the suspension systems were being schemed, the aerodynamic maps were apparently not finalised for the MRT06, so the suspension design would have to ensure all bases were covered. In late 2016 Manor engineers discussed a big push to allow as many rapid changes to the car for in-session tuning and testing. One likely example of this is the adjustable roll and heave dampers.

Because of this uncertainty about the best way to operate the new tyres (which no team had run until the start of winter testing in late February – after Manor had already closed its doors) the MRT06 was designed with a number of rear camber gain options ranging from zero to 2deg/100mm of travel.

In general terms, across all of the 2017 Formula 1 cars the strict prescriptions imposed by Pirelli on end-of-straight camber levels have pushed teams towards lower camber-gain suspensions. This allows them to run higher levels of rear camber at low speeds, which is beneficial for low-speed rear grip.

The roll centres on the MRT06 were to be kept generally as low as possible to allow the springs and dampers to control the car, but there were reportedly quite large variations depending on which camber gain option was to be run, an unwanted consequence of packaging and aero importance in F1 suspension design.

Conventional design

While some of the aerodynamic detail of the MRT06 was revealed on social media by Manor team members on their last day at work before the team was shut down, more detailed images of the 60 per cent wind tunnel model have not cruden

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While many 2017 F1 cars feature ducted noses, the Manor does not

been available until now. The model was highly advanced by the time the team folded and had already conducted extensive running at the Mercedes wind tunnel in Brackley.

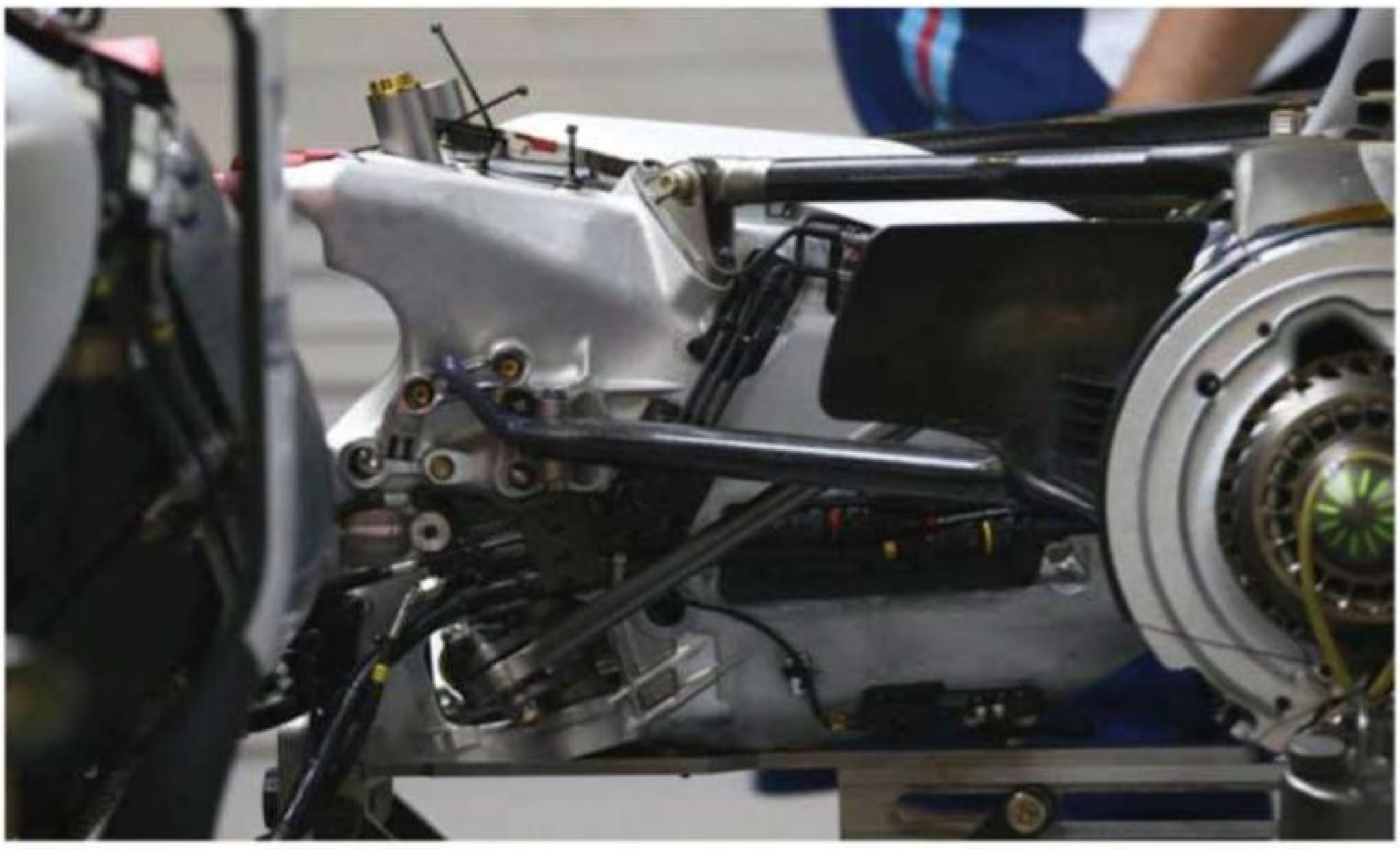
The overall design of the car seems fairly conventional by 2017 standards, but it's clear to see from the large number of experimental aerodynamic components available at auction (see panel at foot of this page) that a number of different concepts had been tried out in different areas of the racecar.

The nose of the car is largely an evolution of the concept used in 2016, the MRT05 was already at the minimum nose length so there was not much Manor could do in this area. However, looking at some of the lots available for auction it does seem clear that the team did at least evaluate a few different nose concepts for the car (see picture page 28).

The front wing is swept back, as this is mandated in the 2017 technical regulations. Manor developed its front wing extensively through the 2016 season and a lot of the lessons from that process have quite clearly fed into the 2017 wing design.

While many of the cars on the 2017 grid feature ducted noses, the Manor does not. According to some former team members this is because the aerodynamic department felt that the gain these ducts offer is too small for Manor to spend the amount of time and effort required to get it working properly.

The airbox and roll hoop concept of the MRT05 has clearly carried over to the MRT06, as has much of the cooling system. Team members reported that the MRT05 was actually slightly overcooled in 2016 so that layout was further optimised for the 2017 design. The sidepod ducts are, as a result, slightly smaller than those used on the MRT05 and they have been reshaped. Downstream of the rollhoop the MRT06 is fitted with a fin, like many other 2017 designs, in order to offer greater stability in yaw.



MRT06 would have used the 2017 aluminium encased Williams transmission (pictured) if the Manor team had not folded

Unfulfilled potential

Many former Manor staff have commented that they felt that the MRT06 might have been competitive and the fact that it will never race is something of a missed opportunity. According to senior members of the team about 90 per cent of the parts for the MRT06 were completed when it went into administration. At that point work on the 2017 car slowed and efforts switched to adapting the 2016 MRT05s to the new regulations so that an interim car could have been made ready for the Australian GP, while the MRT06 could have been introduced for the Bahrain Grand Prix in April. This work carried on even after the team had officially closed, but finally stopped when Manor's entry was withdrawn during the pre-season tests at Barcelona in late February.

The hoped for rescue package never materialised and Manor's assets now fill the catalogue of an auction house. Yet another F1 story of what might have been.

Garage sale

With the closure of the Manor Formula 1 team all of its assets are to be sold off in an online auction. The sale includes a large amount of the team's equipment and the 2017 wind tunnel model. A large range of 2014-2016 car parts feature in the auction, too, including at least three chassis, all of the pit equipment, test jigs and various pieces of high-end test and inspection equipment. For a full auction listing visit: www.gordonbrothers.co.uk/assets-for-sale/manorf1

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i-tech

Hyundai's i20 Coupe finally lived up to its promise by winning a WRC round in April – *Racecar* uncovers the secrets to this new-regulation Word Rally car's success

By MARTIN SHARP

TECH SPEC

Hyundai i20 Coupe WRC

Chassis: i20 Coupe; three-door body

Engine: In-line 4-cylinder, 1.6-litre, turbo direct injection. Bore/Stroke: 83mm/73.9mm. Power: 380bhp (280kW) at 6500rpm. Torque: 450Nm at 5500rpm

Transmission: Four-wheel-drive; Sadev sequential gearbox, six forward gears and one reverse, with paddleshift

Differential: Hydraulic active centre; mechanical with ramps at the front and rear

Clutch: Cerametallic twin-disc

Suspension: MacPherson struts; EXE-TC dampers

Steering: Hydraulic power-assisted rack and pinion

Brakes: Ventilated Brembo disc brakes (370mm on tarmac, 300mm on gravel); air-cooled 4-piston calipers.

Wheels and tyres: 8x18in for tarmac, 7x15in for gravel; Michelin

Dimensions: Length: 4100mm, width: 1875mm, wheelbase: 2570mm

Weight: 1190kg minimum; 1350kg with crew

Hyundai became the fourth of the four manufacturers currently involved in the World Rally Championship to chalk up a win with its new 2017 regulations Hyundai 120 Coupe WRC in Corsica in April – which means four different car makers were victorious in the first four events. But while this is great news for the WRC, after years of Volkswagen dominance, it was also a real shot in the arm for the Alzenau, Germany-based Hyundai Motorsport operation.

However, the win was perhaps not entirely a surprise for Hyundai – or even its rivals at Citroen, M-Sport Ford and Toyota – as the new car had already shown well. Indeed, on the championship-opening Monte Carlo Rally and the second round Swedish Rally the i20 of Thierry Neuville crashed out while leading. This lead seemed to prove that the team was thinking along the right lines about the design of its new car under the 2017 regulations, and the Corsican result has surely confirmed that.

As always, though, the path to Corsica glory was a long one, and had more than a little to do with doors. That's because one of the main differences between this year and last year's car – beyond the new rules package – is the fact that the new car is a coupe. Yet this move was

‘It’s not like a circuit car; you have to think that this car will be driven on gravel and on rough roads’

actually a year late. Hyundai planned initially to base its 2016 WRC on the three-door coupe version of the new generation i20. A prototype WRC based on the i20 coupe was built, but then a delay in coupe production indicated the standard model might not hit the minimum quantity required by the FIA in time. Hence, last year’s i20 World Rally Car was a five-door saloon.

Interim testing

Coupe production figures now comply, so the new 2017 WRC is based on that model. The team amassed experience and knowledge from running the original prototype WRC coupe with a 2017 spec 36mm diameter inlet restrictor during tests beginning in April 2016. Then the 2017 transmission was installed, complete with active centre differential. By the end of June the full, new, 2017-spec car was ready for test, minus this year’s bodywork. ‘We did things late for the bodywork just because of the regulations coming quite late, and I didn’t want to work on it before everything was fixed,’ explains Hyundai Motorsport team principal Michel Nandan.

‘We started to do a bit of work in June 2016, when the regulation was not fixed, but we really worked on it and designed it in July. Probably the biggest challenge was to work on the aerodynamics [for rallying use]. It’s not like a circuit car; you have to think that this car will be driven on gravel, on the rough, in Argentina and everywhere. You can lose a lot of parts so you have to be not too extreme; the parts have to be strong enough, and in case you do lose parts [then this should not] transform the car completely into an undriveable car.

‘It’s not so easy, it’s probably the more difficult thing to do, because, if you tell an engineer; “Okay you are allowed to do this”, then you can spend firstly a lot of money on aerodynamics, but you have to have it present in your head that this car has to be run on

New car's roll cage is very similar to the previous WRC Hyundai, while floorpans on the Coupe and 2016 car are the same

Front wheel arch area has been redesigned because of new suspension rules. Engine has new head and gives more power

The new aero package, including flick up rear wing, has been designed to be tough enough to survive rough WRC stages

gravel, or you will lose a lot of parts, especially at the front, and on the side, of the car.

'You have a fixed FIA profile for the wing,' Nandan adds. 'It is not so efficient, but now the wing is a bit higher [50mm] you can have some more downforce, but we're not talking about a big change of numbers. The more difficult thing is to get a good balance, because at the rear the wing can do something [but] on the front, okay you can do things, but it's a bit limited, so what we are trying to do is to get a good front-to-rear balance. Also you can do a [front] splitter, within some dimensions. Material is carbon composite – you can use it now for the bodywork. Before it was just one layer allowed,' says Nandan.

Eye to i

The rules controlling the roll cage and its structure have not changed since last year. Hence, apart from adaptations to enable it to fit within the coupe bodyshell dimensions, the new car's roll cage is effectively the same as that in the 2016 version. Plus, the five-door and three-door i20 floorpan platforms are exactly the same. Nandan admits these factors saved some design time.

'We redesigned the [front] wheel arch due to the change of the suspension regulation – because pick-up points would be changed,' Nandan says. 'This is the part of the car we redesigned, but most of the steel bodywork was kept from the five-door to the three-door, because they have the same platform.'

The suspension concept is the same, using EXE-TC dampers, but all suspension parts are new while, because maximum torque is similar to last year's output, the Sadev transmission remains some 80 per cent the same as it was in 2016, with just a redesigned casing to incorporate the new centre differential.

High range power

For 2017 there is a new global engine, based on the same concept of the 2016 engine. The cylinder block is machined from billet aluminium alloy, as was last year's, and the head is new, but bore and stroke, and some components such as crankshaft and connecting rods, are the same as before. 'We really worked on the engine for packaging, but it's the same concept as previously,' Nandan says. '[There is] more power because of the increase [in diameter] of the restrictor, but we are still at the limitation of boost, so the torque is similar to what we had. But the power is more on top [of the rpm range], so yes on the engine design you need to review completely all the timing. This is totally different because the [valve] timing for [a] 33mm [restrictor] is not suitable for 36mm. But also, because you are generally revving a bit higher, you should also consider this in the light of the [life of the] parts,' Nandan says.

Hyundai driver Hayden Paddon reckons the revised, wider, power curve of the 36mm-restricted 2017 WRC – with similar maximum

Hyundai scored its first win of 2017 in Corsica. Aero effect of the carbon front splitter is limited and a good balance across the car is the main objective

torque produced at around the same rpm and some 80bhp more max power produced at higher rpm than before – makes throttle control more difficult. 'Particularly when accelerating through the lower gears it can sometimes be more difficult to control wheelspin, but I don't think it's really a massive problem,' says Paddon.

Bar torque

Nandan says the fact that there is more power 'doesn't affect [the engine] too much. It would have been different if we could have had more torque, which means more boost, but the boost has not changed; it's still regulated to 2.5bar, so the torque is quite similar. The only increase is really in power. The power does not affect too much the handling behaviour, but it's affecting, of course, the tyre wear.

'The effect of more power is affecting not so much the balance of the car, but really affecting the grip: especially on gravel,' Nandan continues. 'So yes, of course we need to be a bit more careful with tyre wear, and we need to work constantly on the suspension.

'I think in some stages on some events the tyre wear could be brutal, but where already last year you had quite a big tyre wear it could be really, really more tricky than it has been. For example, Australia, with the warm temperature and everything, tyre wear was quite significant. For sure this year with more power, if we have the same number of tyres, it will be critical.

'Traction is a bit affected because you have more power and it's coming on a bit more suddenly,' Nandan adds. 'It means that you have to work much more on suspension, this is for sure. But given that, for sure tyre wear is increased. So it's a new parameter to introduce. But, of course, it is the same for everybody, but I think a car which has much better suspension in terms of grip will have less tyre wear.'

Greater freedom for the front suspension pick-up point locations provides the possibility to 'really optimise' the wheel travel. Specifically, Nandan points out that with last year's WRC car: 'We had to try to correct the problems we've had in exiting corners; where we were lacking grip in certain corners. We can do that now because of the increased freedom with the suspension pick-up points.

'Also, the understeer with four wheels locked together was difficult to sort out, but with the centre diff it's much easier,' Nandan adds, while also pointing out that this year, while drivers need to concentrate harder on tyre wear strategy, some aspects of the new regulations will help them. 'It's nothing revolutionary, but it allows us to adapt the car for the drivers much better. The centre diff helps here, but then there's the aero, which helps a bit, too. Okay, the car's wider, but that makes it much more stable. And, of course, with 80bhp more there's more wheelspin, but with an active centre diff it makes that easier, too.'

When asked whether he thinks the 2017 World Rally Car engines will exceed 400bhp maximum output the Hyundai team boss said,

'When accelerating through the lower gears it can sometimes be more difficult to control wheelspin'

with a knowing smile: 'For sure,' which might be further good news for rally fans.

Nandan is not only the boss of the Hyundai Motorsport team he set up from scratch in 2013, he is also a time-served rally engineer notably responsible for three-times world WRC winner, the Peugeot 206 WRC. With such a background he is understandably pragmatic about the new i20's performance thus far in 2017, and its potential: 'I have to say that the Hyundai seems homogenous in its operation,' he says, positively; yet with characteristic caution – which is no doubt born from experience.

ALL PHOTOGRAPHY: XPB

High-undai

The new for 2017 regulations were intended to inject a little more drama in to the sport. But it should not be forgotten that it's not just the cars and the drivers that build the narrative in rallying, it's the events themselves, too.

Take this year's Rally Mexico. The ambient temperatures on its high altitude stages were not as high as previously, yet all the top teams, apart from Citroen, suffered with over-heating engines.

The first six miles of Friday's opening 34.11-mile El Chocolate test were slow and twisty, while the road also rises to the highest altitude of the entire Mexican event: 2746m (9009ft – Britain's highest mountain, Ben Nevis, peaks at 4435ft). These thin air conditions caused high engine temperature warnings for the majority of new World Rally Cars not far into the stage.

And that included Hyundai. Neuville's i20 deranged its front bumper early in the stage, so the cooling flow – of thin air at low velocity – was impaired significantly; the engine overheated massively and automatically went into road-mode; hence it was *seriously* down on power.

To compound the issue a fuel filter problem later on hit all three works Hyundais. One of the fuel filters in all three of the cars picked up more dirt contamination than designed. This meant low fuel pressure into the two-bar direct injection fuel rail at high altitudes and high temperatures, which then resulted in misfires.

All the fuel filters were changed and, because of inconsistent fuel pressure, all the high-pressure fuel pumps were also changed, as a precaution. Post-event an investigation showed the cause was most likely a fuel filter manufacturing problem. Lessons learned.

Yet, despite these major frustrations, Neuville's i20 was third overall at the finish and earned maximum Power Stage driver points on the final test.

Body and soul

With its new-for-2018 universal body kit IndyCar intends to beautify its DW12 and spice up the show – but just how did it go about designing a package that would tick both these boxes?

By MARSHALL PRUETT

The first full-scale version of IndyCar's new-for-2018 universal bodywork package was expected to be revealed soon after *Racecar* went to press, and with it the series will present a vision for the future that is firmly rooted in its traditions.

It's also a vision that rejects the limited visual appeal that has plagued the series since the Dallara DW12 chassis arrived in 2012. Take one look at the current car in its manufacturer-based 'aero kit' guise and it's hard to see past the clutter: bulbous rear wheel guards, anti-wheel interlocking devices, and metres of carbon-fibre eccentricities in the form of flicks and ramps, and wings stacked upon wings, has ruined the basic beauty of the open-wheel arrow that lies beneath. Those aero kits, introduced in 2015 and built by IndyCar engine suppliers Chevy and Honda, ushered in record-breaking speeds on road and street courses while achieving an all-time downforce peak that surpassed the 5500lb mark. As well as the ridiculous cornering speeds that ensued, aero kits also exposed the differences between Chevrolet's aerodynamic design team and Honda's outsourced solution from Wirth Research.

New direction

With a new and widening competitive gap between the brands causing great concern for IndyCar, and the lack of interest shown by other manufacturers to join a series where funding engines and aero kits would be required, IndyCar competition president Jay Frye hit the proverbial pause button on the exercise in 2016. Citing the requirement to make IndyCar more attractive to new engine manufacturers, not to mention the need to redistribute the areas where most of the road course/short oval (RC/SO) downforce is produced on the DW12, the call was made to freeze aero kit development for 2017. This decision effectively ended the two-year aero kit experiment while giving Frye's technical department, led by race engineer-turned-aerodynamic development boss Tino Belli, the 2017 season to fashion new clothes for the DW12 that embraced sex appeal and performance in equal measures.

'We were working on it since April of 2016,' Frye says. 'So it's been ongoing for quite some time. We first had to work with the

Aesthetics was a top priority for IndyCar's new-for-2018 body kit and judging by this image of it in superspeedway guise it seems to have hit the mark

manufacturers and teams to freeze the kits for 2017, which we did. And then we came out with a five-year plan. Part of that is having the universal aero kit for sure for 2018, 2019 and 2020. That is all in motion.'

The series' present technical team, including Frye, Belli, Bill Pappas – and even the series CEO Mark Miles – came to IndyCar years after the DW12 was commissioned by their predecessors. It likely explains their collective detachment to the DW12 and the impetus to transform the Dallara into something that sheds the ugly parts while carrying forward better looking lines that hark back to the CART and Champ Car eras.

'There was a great reverse engineering approach to this car,' Frye says. 'We came up with a list of what we thought the car should look like. That was last spring. And we started with that, looking at cars from our history and then what is our identity, what is an IndyCar supposed to look like? It created a template and we started down a path.'

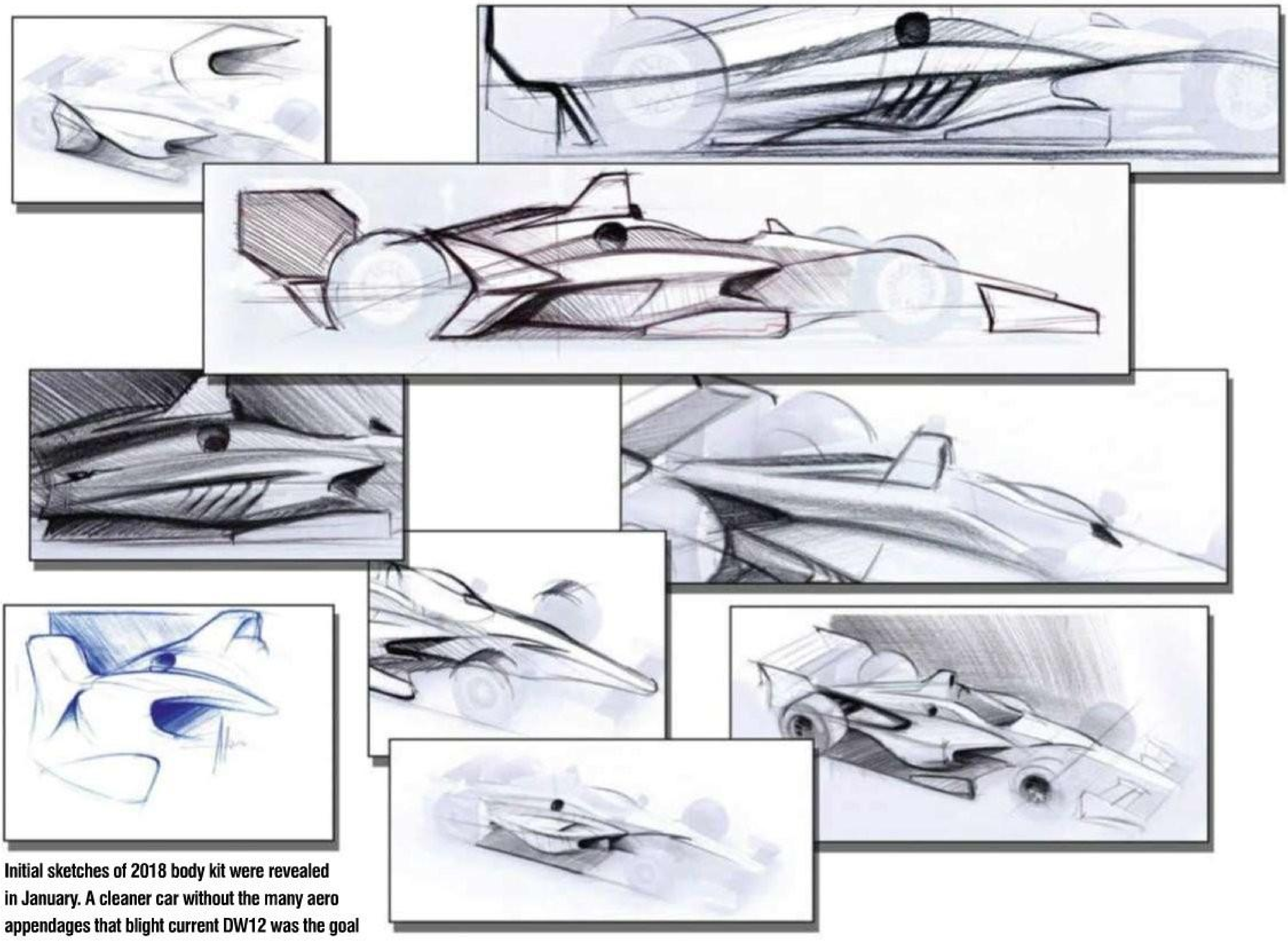
Pretty quick

With beautification as the first step in the process, IndyCar continued shaping the looks of its universal bodywork to satisfy the needs of its paddock before tasking Belli with applying the science and engineering to make the new lines and curves function in dynamic form.

Doing away with the Indy Racing League-era overhead air intake was among the first styling changes. Paring the excessive aero kit furniture from the car also took place, along with dumping the rear wheel pods and other ungainly items carried forward from 2012.

'Once we got the path defined, we were very conscious with the owners and the manufacturers on not only aesthetics, but how does this change what they have to market?' Frye says. 'We actually had an outside source take the current car to find out how much different it would be for sponsor signage with the changes we were looking to do in 2018 – especially in the engine cover area. That is a big spot for an IndyCar team to sell, and we were getting rid of that tall profile.

'They came back and said that this new bodywork is actually substantially better than the current car because it is cleaner. All the lines, you can see it flows very well, versus



Initial sketches of 2018 body kit were revealed in January. A cleaner car without the many aero appendages that blight current DW12 was the goal

the current version of the car, which has got some more pieces that are more [mixed up] together a little bit. It looks good, we think, and it will help the teams from a marketability standpoint. We couldn't have created something that the teams couldn't market.'

Form then function

Working from a close approximation of how the universal kit would look in its RC/SO form, and in its stripped down superspeedway configuration, Belli began the process of making the retro-modern designed bodywork comply with the requisite lift and drag figures for the diverse circuits on the IndyCar calendar.

'From a physics point of view, we set targets, our L/D minimums and maximums,' Belli explains. 'We wanted the racecar to look pleasing, and so we basically then joined the two needs together, to hit those targets and create a nice-looking racecar.'

Once the universal bodywork moved from its creative phase to a functional project for Belli, bringing Chevrolet and Honda closer into the process was required. With the 2018 bodywork meant to feed and cool their 2.2-litre twin-turbo V6 engines, working with Chevy and Honda on new methods to deliver air to each compressor and on new radiators was vital.

The choice to relocate the radiators from aft of the cockpit to a forward location alongside the driver – restoring the Coke bottle shape from overhead – helped cure some of the DW12's odd looks and added a secondary layer of protection in a side impact. Sliding the radiators forward also bought IndyCar much needed space to route new turbo inlet ducting that's carried inside the radiator ducts.

'We have a dedicated side-impact structure on this car, and the radiators have been repositioned to help with packaging,' Belli says. 'We have all the CAD of the existing aero kits, so we started off by running those configurations, via CFD and the wind tunnel, to measure all the airflow rates and the projections for what we currently have [for 2018]. In this kit, we made sure we exceeded those projections.'

Beyond the obvious styling exercise with the universal bodywork, IndyCar went to great lengths to advance the stability of the DW12 in a superspeedway spin. With the current aero kits affixed, Belli and the technical department solved the trio of flips and flights that marred practice for the 2015 Indianapolis 500 by incorporating dome-shape skids and rear beam flaps – identical in practice to NASCAR's roof flaps – for the 2016 running of the race.

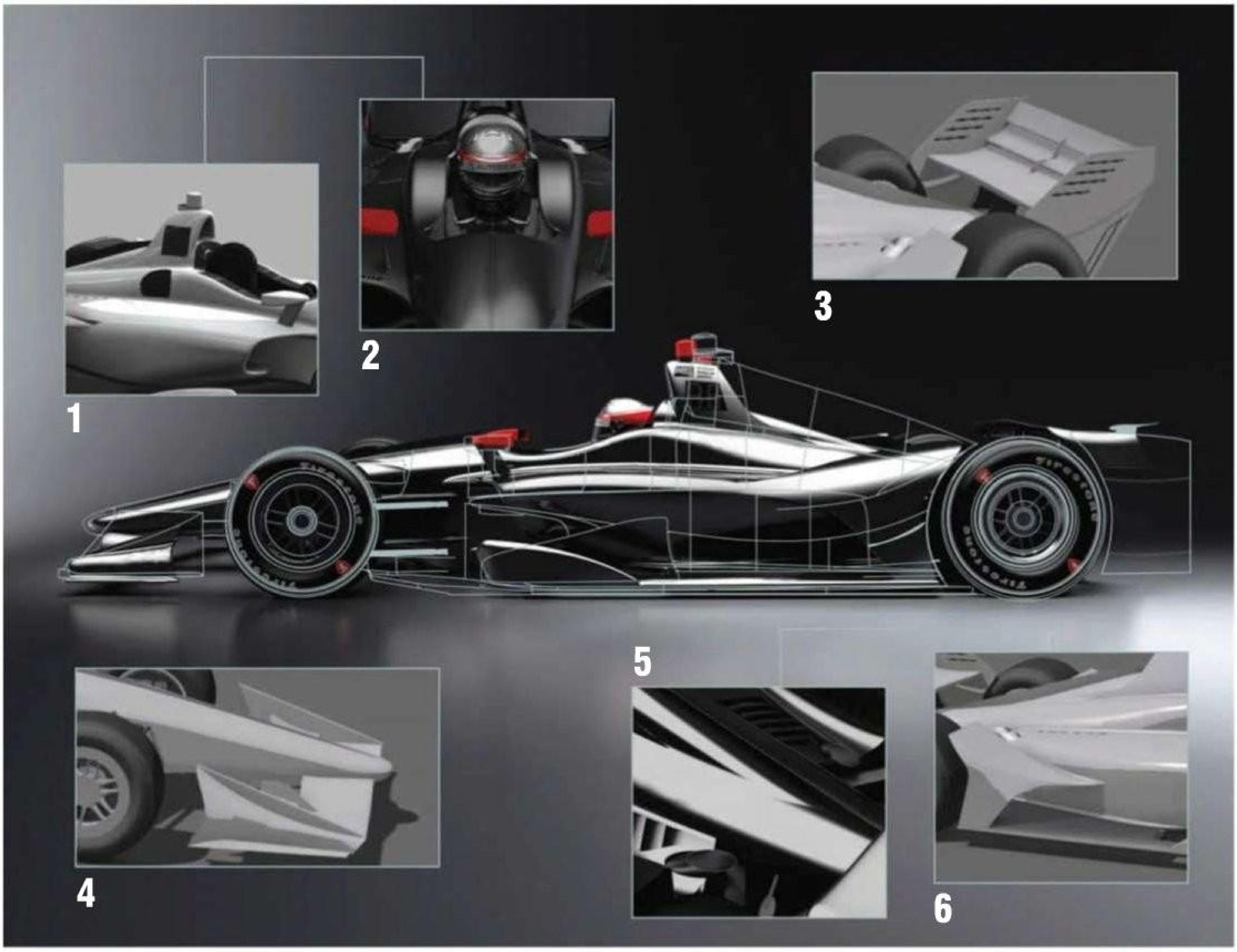
Safety fast

Those add-on safety items will continue through the final superspeedway race of 2017, and thanks to the successful exploration with the universal bodywork, the same spin stability and prodigious downforce production will be achieved without the dome skid and without the rear beam flaps. The rear beams and the wheel guards they carry will be gone by 2018, yet with the clear effectiveness of the flap system to consider, new units will be produced and fitted to the trailing edge of the diffuser. Like the current models, the universal flaps will deploy upward in a spin. 'It has not been easy,' Belli says. 'At various stages in development we had certain conditions where we said "what's going on here?" We had to do more CFD studies to understand. It should be very interesting.'

Prior to the commencement of track testing later this summer, Frye expects to keep CFD

'It looks good and it will help the teams from a marketability standpoint'


180 MPH WITHOUT MOVING AN INCH



1. Ridding the DW12 of the Indy Racing League-era overhead air intake was among the first of the styling changes **2.** Safety is paramount, but it remains to be seen where a cockpit protection system could fit with this new svelte design philosophy **3.** The road course aero package for the 2018 kit includes a triple element rear wing **4.** Indycar's working hard to ensure there's enough front wing downforce to keep centre of pressure stable. **5.** Smoothing out process applied to all areas **6.** Rear wheels are still protected from interlocking

server farms and wind tunnels busy with the final details of the RC/SO and superspeedway bodywork. 'Part of this too, obviously, is this has all been done in CFD before we hit the track,' he says. 'We still have all these digital assets, components and learnings that if we need to do something different, it is possible to make changes before we go into production and track test. Even then, we can make changes if we don't like something based on the performance numbers or a driver's feedback.'

Belli adds: 'We have tied up a CFD department for probably five months. We're at about 250 hours of wind tunnel. We'll probably be at 300 by the time we get it on track. And there are some areas where track data is more favourable for final sign-off. We're looking very carefully at brake cooling, for example.'

Kerb weight and weight distribution will change with the universal package. Eliminating the rear beam and wheel pods will help, and with fewer appendages found elsewhere on the 2018 bodywork, 20 kilos could be lost once the aero kits are replaced.

With most of that weight coming off the rear of the racecar, and with the radiators moving forward, drivers and engineers can look forward to having more load across the front axle to rectify some of the DW12's unexpectedly rear-heavy nature.

'So, yes, the rear guards, moving the radiators forward … we had informed all of our teams we were going to make this change,' Belli confirms. 'I think with the DW12, [the rear weight bias] was a surprise to IndyCar teams, and so we're trying to make sure this is not a surprise. As a consequence of that, the teams will have to run a more forward centre of pressure. Your CoP does follow your centre of gravity. Certainly, in the road course configuration, we are working very hard to make sure that we have enough front wing to be able to create that pressure without taking downforce off the rear of the car.'

Extreme makeover

With front and rear wings and all of the topside bodywork in between being redesigned, the only major piece of bodywork set to be retained is the Dallara floor, although it is also expected to receive some adjustments. The other significant task on Belli's list is to reduce the DW12's wake with the 2018 RC/SO aerodynamics, and to achieve those means stripping wings and drag-producing pieces from the top and increasing the floor's downforce capabilities has been a key initiative.

'It is a modification of the floor, which will be reworked along the leading edge,' Belli explains. 'We use a hole in the floor to shed the

'If you take a look at the three-year plan we have for this racecar, you will see there is a substantial downforce reduction to come'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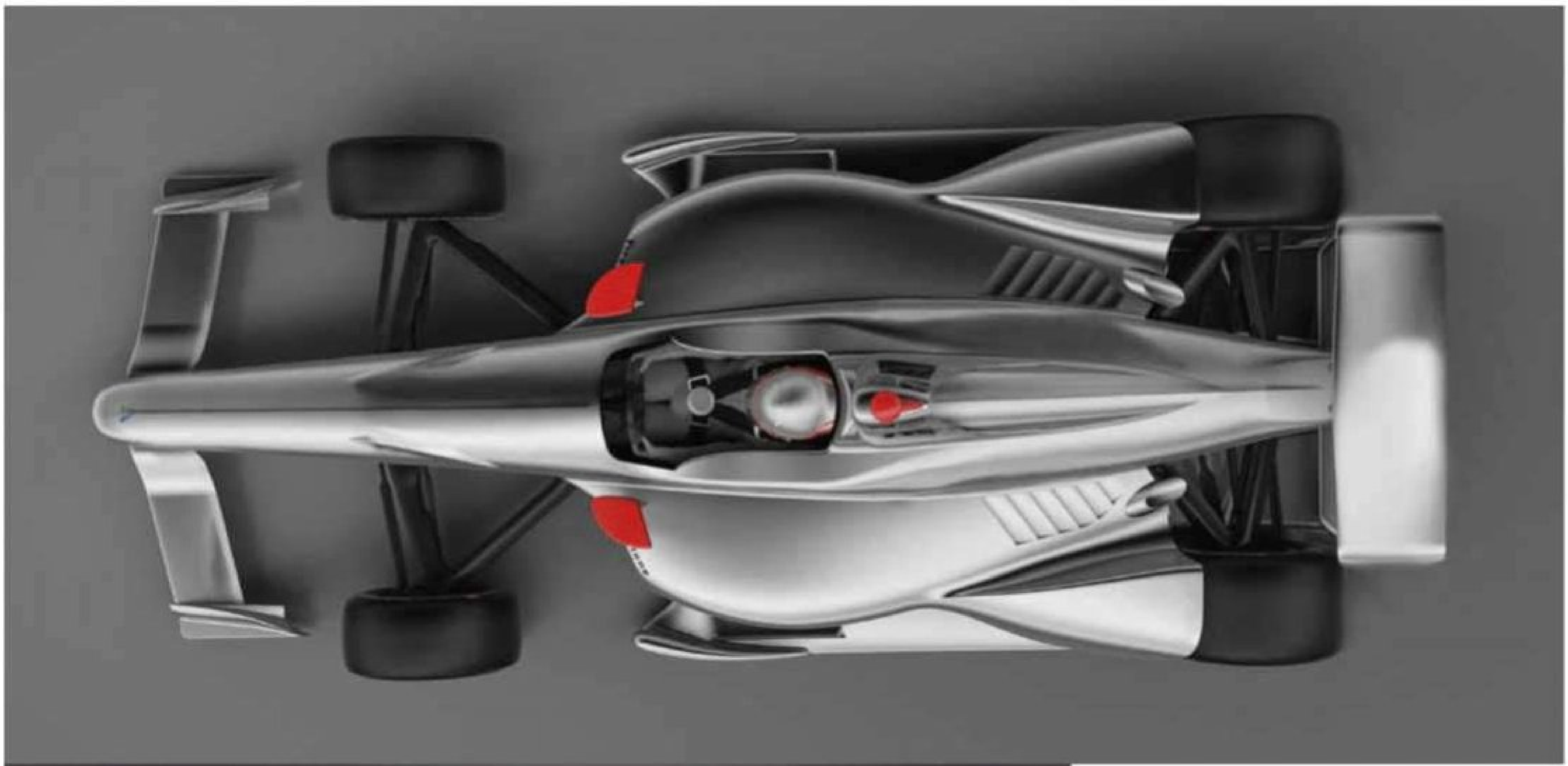
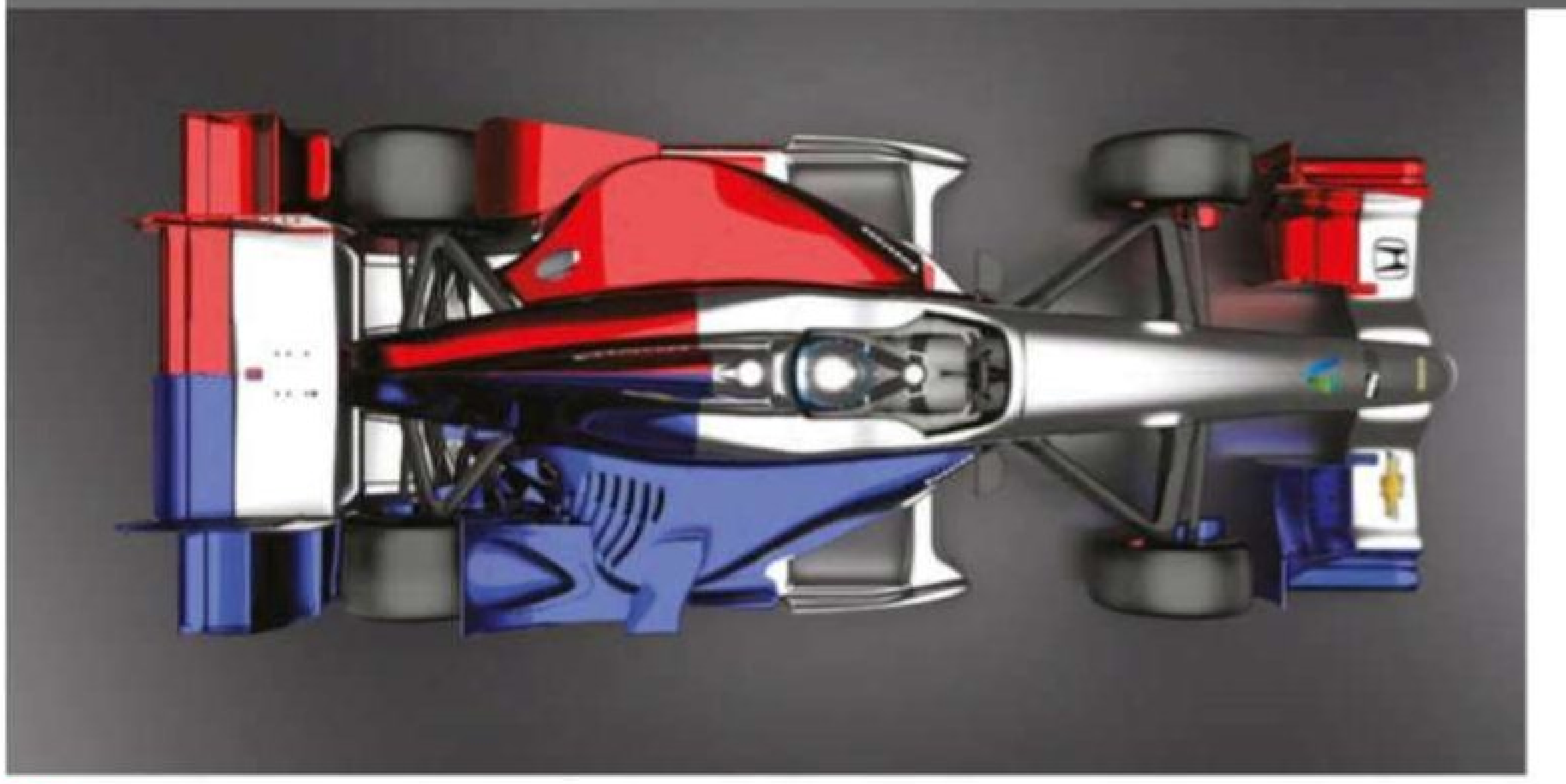




Top: Coke bottle shape has been restored, largely thanks to the repositioning of the radiators towards the front of the car
Above: Current car shown in both Honda and Chevrolet body kits. Costly aero kit development has been frozen for 2017

that it goes through. But I think one of the biggest things is the wake off the cars; there's not a wake off [the 2018] car like there is with the current Indycar. The racing is very good now, but this will help to enhance it even more.'

Race tests

IndyCar made headlines last year by trying something new ahead of the universal bodywork design project. In an attempt to quantify and measure what makes for good racing and improved passing possibilities through vehicle dynamics and driver feedback, the series used the Mid-Ohio road course and multiple car configurations to determine which items helped or hindered in a race simulation.

Drivers Tony Kanaan and JR Hildebrand carried out most of the testing with various wings and panels removed and, as a whole, most of the live running focused on cleaning up the topside aero and adding power to the floor. From the data generated by those runs, Belli was able to shape the direction of the universal kit. Once the 2018 aero is ready, a return to Mid-Ohio, among other tracks, is all but guaranteed to continue the live race development process.

'We did a test at Mid-Ohio last year where we took some components off and asked the drivers to follow each other and try and out-brake each other and find out which configuration was the best for competitive racing,' Frye says. 'We will try and do those tests again with the new car. A lot of people speculate about what makes good racing. There has been very little on-track studies ever done. We're trying to say: here's the theory, let's test it.'

But the real test will be when the new-look bodies hit the track next season.

downforce, and for the road course tracks the hole in the floor will be sealed.'

Full details on the underwing development have not been released, but the aforementioned work at the floor's mouth, sealed holes, and anticipated development with the diffuser should lower the reliance on the exposed wings to generate most of the aero grip.

Cutting downforce

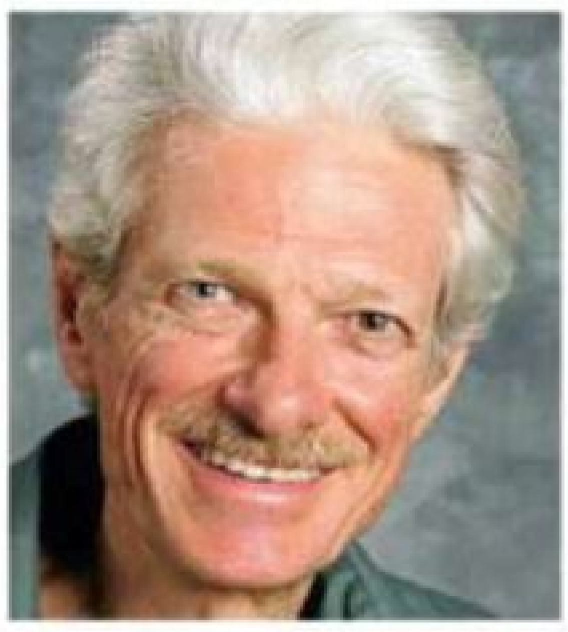
Starting in 2018, and continuing each year afterward with the universal bodywork, IndyCar will intentionally stray from the tyre-crushing aero kit downforce figures. Exact figures won't be known until the RC/SO package is finalised, but working from the 5500lb peak, Frye anticipates teams will have approximately 4700lbs of downforce to play with.

'That's not a bad number,' Belli agrees. 'While deciding whether to fill the hole in the floor, we did a test at Phoenix. We were looking at how easy it was for one car to follow another. And the distance a car could follow was halved with the same amount of total downforce, by shifting the downforce from the top onto the bottom. This [2018] car is a step in that direction. So we shifted even more of the downforce. The road course rear wing was actually smaller. The depth from top to bottom is also less to help hit our maximum downforce target.'

Gradual reduction

Rather than knock a large percentage from the total downforce available in one season, Frye prefers to ease the IndyCar Series towards a lesser reliance on aero-driven performance. 'If you look at the three-year plan for this car, there's a substantial downforce reduction,' he says. 'Part of the process is we reduce it again so it's not all at once. There's a certain progression,

'We have tied up a CFD department for probably five months'



Going to extremes to find the optimum

Could very big changes help you home in on the ideal set-up?

QUESTION
What do you think of the idea of 'bracketing the setting' – changing a chassis setting by a really big amount, probably an excessive amount, and then backing up?

THE CONSULTANT
It depends on the type of setting, and also how confident you are of the qualitative effect of the change. It can be a real problem if the effect of the change reverses when you go past a certain point, especially if you don't know that point.

Wing angle would be a setting where we pretty much know the effect qualitatively, and just want to find the optimum. We know that increasing attack angle will increase both downforce and drag, at least as long as we stay short of stall. We also know that when we do hit stall, we will see a big increase in drag and probably a reduction in downforce, and we know that increasing attack angle will lower the stall speed. So we know in general terms how a big change will affect the car. We know that if we increase the rear wing attack angle, that will add understeer. We can make a big change, and if the car has gone from too loose to too tight at high speed, we can go back part way. We can ask the driver, and/or look at the data, and decide whether to go back a third of the way, or half, or two thirds. We may very well be able to zero in on the optimum more quickly this way than by trying to sneak up on it.

Tyre pressure is different. There's a pressure where lateral grip or force capability is maximised, and the grip falls off both above and below the optimum. The same holds true for longitudinal grip, but the optimum pressure is generally lower.

Suppose optimum pressure is 38psi and we're at 34. If we try going all the way to 44 and the racecar is worse, do we conclude that we should go softer than 34 instead? That wouldn't be correct.

If we are reasonably close to a good setting, and we aren't even sure which side of optimum we're on, or indeed whether we're at optimum, then small changes make sense. If we make a change that's just big enough to produce a measurable or noticeable effect, and then the racecar gets better, then we can try another similar one and see if the trend continues. If the car gets worse, we try a similar change the other way. If the car gets worse both ways, we know we're close to the optimum.

Incremental changes
One advantage of making incremental changes is that it gives us a better picture of the 'shape' of the car's response. We can see when we're approaching optimum. We can eventually get a feel for how the racecar responds when it's close to, or far from, the optimum.

One disadvantage of making a lot of small changes is that over a large number of runs, just running the car may change it, or conditions may change. We may go slower no matter what we do, just because we're using up the tyres or because the weather, the track temperature, the amount of rubber or oil on the track, or something else changes.

The usual way to avoid being misled by such things is to start at a baseline setting and then return to that for the last run of the session. That will give us a reasonable read on the effect of changes in conditions or changes due to just running the racecar.

This is not totally foolproof, because more than one factor can change at once, occasionally with mutually cancelling effect, but it's good practice. It's a bit like balancing the books in accounting. If they balance, that's good, but it's still possible there's an error. If they don't, you know you need to correct something. If you go back to baseline and the results repeat, you don't know for sure that nothing changed in an uncontrolled manner, but if the results don't repeat, you know something other than your setting did change.

Sometimes, by going to extremes with wing angle you can zero in on a perfect set-up, but such 'bracketing' doesn't always work

Four better and four worse

Why four-wheel-drive on a powerful asphalt racecar requires careful consideration

QUESTION
I recently learned of the CERV II experimental vehicle that GM created back in the '60s. It was a rear-mid-engine sports racing car that had all four wheels driven, using two 2-speed transaxles, both with torque converters. The front transaxle was driven from the front of the engine. The engine was on-centre and there was no transfer case and no driveshaft alongside the engine. What do you think of this idea? Also, what are your thoughts on how to do all-wheel-drive for a powerful racecar that runs at high speed on pavement?

THE CONSULTANT
This car still exists. Zora Arkus-Duntov was heavily involved with it. The idea was to produce the car with and without drive to the front wheels. The transmissions were manual 2-speeds, but with torque converters, as used in the first Chaparral 2. Indeed, the two cars show similar thinking in a number of respects, although they share no parts except possibly the rear transaxle. Both have fibreglass monocoque construction. The very first Chaparral 2 had somewhat similar front end styling, and similar individual exhaust stacks

We'd like to be making nearly full use of all the tyres, and we'd like to at least know which end we're more likely to lose when we do hit wheelspin

(only straight, not megaphones). The front end was redesigned early in the Chaparral's development, due to problems with lift.

The front transaxle had a smaller torque converter than the rear: 10in rather than 11. The car was tested extensively, using a variety of front and rear gear ratios. Duntov was reportedly trying to get 35 per cent of the torque to the front wheels at low speeds and 40 at high speeds. Using a smaller torque converter at the front would have produced a higher stall speed for the front, and this would have caused the front to get a higher percentage of the power at high speed. However, it wouldn't be road speed that mattered for this, but rather engine speed, since the torque converters drive the transmission input shafts.

I don't know how the car scaled, but I've read the total was close to 1400lbs. However, just looking at the layout of the car, front/rear weight distribution would have to be similar to others of comparable layout. The engine was an experimental small-block with aluminium block and heads and titanium rods, but the rest of the car was also unusually light. That would mean the 2wd version would have had around 60 per cent static rear and the 4wd one perhaps 58 per cent. Wheels and tyres appear to have been equal size front and rear.

There are some obvious benefits with AWD, such as traction off the line. But it also adds weight and complication. This is a 1968 Hepworth-Ferguson 4WD

Roll play

Even on early '60s tyres, to avoid having excessive oversteer in a car that tail-heavy without larger tyres at the rear, the front has to have sufficient roll resistance to almost completely unload the inside front wheel. This would create a problem getting power down with the inside front. Solving this would require tyre sizes more proportional to weight distribution, or else a front differential capable of generating considerable locking torque at very low throughput torque, which tends to create undesirable forces in the steering.

I would consider 35 per cent of the power to the front to be reasonable for a car with 50 per cent static rear weight, not a tail-heavy rear-engine car. For best results in low-grip conditions, we want torque distribution similar to static weight distribution. However, for high speed work on pavement, the percentage of power going to the rear needs to be at least 15 percentage points greater than the static rear weight percentage. This is to allow the driver to control it with the throttle when cornering in a manner like a rwd car, and partly to allow for rearward load transfer under power.

If a car's c.g. height is 15 per cent of its wheelbase, 15 per cent of its weight transfers rearward for each *g* of forward acceleration. With modern tyres and all wheels driven, accelerations of well over 1*g* are possible, even without downforce. If we do have downforce, generally we want the percentage of downforce at the rear to be greater than the static rear weight percentage. Even if the car has two times its own weight in downforce, and enough power to use the tyres to the full, the rearward load transfer under power will still be something like 15 per cent of the tyre loading from gravity plus aero.

Reasonable people may differ as to whether we'd like the front tyres to break loose first under power, or the rears, but there is a strong case for not losing the ones we steer with first. In any case, we'd like to be making nearly full use of all the tyres, and we'd like to at least know which end we're more likely to lose when we do hit wheelspin.

Full-time scores

We also want the front wheels to help propel the car all the time, or at least whenever the rears are making forward force. The car will be fairly controllable if the fronts don't drive at all until the rears reach a programmed per cent slip, provided this is not a per cent slip that we will reach in normal throttle steering, and provided that drive to the front doesn't engage too abruptly. An on-demand four-wheel-drive system that just has a computer controlled clutch for the drive to the front, and no centre diff, can provide this if the programming is suitable. However, this way we are missing out on the gain in cornering power that all-wheel-drive can deliver, and the lateral acceleration capability, due to the added weight of the hardware to drive the front wheels.

Full-time AWD increases cornering power because it eliminates the need to transmit the power that drives the front wheels from the rear wheels via the road surface. Power to drive the front wheels, in a rear-drive car? Yes! Why? Because when the front tyres are running at a slip angle, as they must to make lateral force, they absorb considerable power. If there are no shafts driving them, that power must be transmitted to them from the road surface, and it must come from the rear wheels before that. This means that a portion of the friction circle of all four tyres is being used to drive the front wheels, leaving less of the tyres' force capability for lateral acceleration. This is why cars with AWD will often achieve skid pad performance comparable to rear-drive cars weighing two or three hundred pounds less.

Car diff' city

At the same time, we probably would rather not have the front tyres driving on deceleration, or at least not strongly. If we drive the front with just a viscous coupling, either the front wheels drive on decel' or they drag a bit when cornering when they are tracking on a larger radius than the rears, depending on tyre sizes and gear ratios.

Probably the best approach is to use an epicyclic centre diff that sends a fixed percentage of transmission output torque to the front and rear at all times, with the percentage of power to the rear at least 15 percentage points greater than the static rear weight percentage. There can also be some viscous limited-slip effect added to this. By juggling tyre sizes and front and rear gear ratios, we can make the viscous influence gently drive the front wheels and correspondingly retard the rears when coasting if we wish, and we can control this effect. A pure viscous limited-slip at the front is probably desirable as well. At the rear, all the diff choices that work with rear-drive are viable options.

To avoid needing to have the inside front wheel very light in cornering, tyre sizes need to be matched to front/rear weight distribution.

Even when all of this is fully optimised, there will still be considerable cost, weight, and packaging penalties, compared to rwd. The car needs to be very powerful for the benefits to outweigh the penalties.

CONTACT

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Tweaking a GT-R for the Nurburgring

We put a 1000bhp road-legal Nissan 'Ring racer in the wind tunnel

The Nissan R35 GT-R LM1 RS that we have evaluated in our latest MIRA full-scale wind tunnel project has been assembled and developed by UK-based Litchfield Motors for the car's London-domiciled Australian owner/driver Anthony Gaylard to tackle the Nordschleife circuit at the Nurburgring, Germany. The target is the symbolic seven-minute mark with the car technically road legal (it will even be driven to the fabled race track). This impressive Nissan boasts approximately 1000bhp, Ohlins-tuned suspension, Alcon brakes and it has an aerodynamic package based on a NISMO GT3 set-up.

Michael Krumm set 7m08.679 with a Nissan GT-R NISMO back in September 2015, one of the fastest laps of the circuit in a volume production car, which in that instance benefitted from 'track options for aerodynamics, suspension tuning, and weight reduction.' We will have to wait and see how our test Nissan fares. But in the meantime, some very interesting lessons were once again learned as we worked through our half day wind tunnel session.

Baseline configuration

The GT-R's baseline package included a reasonably large, curved front splitter with gentle integral front diffusers, aggressive dive plane pairs on each corner, louvred openings in the bonnet, a flat underside with a rear diffuser, and a full width, large chord dual-element NISMO wing. Up front were a large intercooler and even larger area water radiator fed from the front apertures, though with no ducting. Side inlets behind the doors fed additional coolers, with fan-assisted exits emerging in the rear panel.

As usual, a test plan had been put together ahead of the session. And, as often happens, the plan, or at least the order of tests, was shuffled immediately the baseline data appeared on the PC screen. Given that aero balance was unknown prior to this session, as a starting point the car arrived with its 1970mm (77.5in) span by 470mm (18.5in) chord wing set on maximum angle. A rearward bias in downforce was therefore anticipated, but as the data in **Table 1** shows, the balance was even more rear-biased than expected.

As delivered then, the GT-R had slight positive lift at the front, and quite a lot of

Table 1: The baseline aerodynamic coefficients and balance

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Baseline	0.543	0.896	+0.061	0.957	-6.78%	1.651

As delivered this GT-R had slight positive lift at the front and quite a lot of downforce at the rear – not a set-up conducive to fast lapping

This Nissan R35 GT-R LM1 RS is to tackle the famous Nurburgring Nordschleife so will need good, but above all, balanced downforce

The front end looked like an effective set-up but it took some work to realise its potential

The rear wing dominated the early runs and was over-powering the front end of the car

Table 2: Baseline data on the 2009/10 Ferrari F430 Scuderia GT3 compared to the Nissan GT-R's at the same balance level

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Ferrari F430	0.521	0.821	0.348	0.473	42.4%	1.576
Nissan GT-R	0.432	0.572	0.241	0.328	42.4%	1.316

Table 3: Baseline and optimised data on the GT-R from this session

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Baseline	0.543	0.896	+0.061	0.957	-6.78%	1.651
'Optimised'	0.426	0.561	0.241	0.320	42.91%	1.316
Δ, counts	-117	-335	+302	-637	+49.69%*	-335

Absolute rather than relative difference in percentage front

If the GT-R's splitter was lowered so that its underside was on the same plane as the main floor it would generate more front downforce

downforce at the rear, not a set-up conducive to fast lapping and likely only to exacerbate the car's apparently inherent mechanical understeer. The –L/D value looked quite good, but without a balance it rather flattered to deceive. Clearly in this configuration the rear wing was over-powering the front end, but it also looked as though the front was not achieving what it should, considering the effective-looking splitter and dive planes.

So the emphasis for most of the rest of our session switched to working towards a better aerodynamic balance. With a static weight split stated at roughly 50/50 front to rear, the aerodynamic balance target was around 45 per cent front. After 15 configuration changes a peak value of 43 per cent was achieved, demonstrating that even if the initial set-up is a long way out it is possible to achieve a workable balance in the wind tunnel. We shall examine the steps along the route to this much improved set-up in the next two issues of *Racecar Engineering*, but first let's just compare it to a known successful set-up to try and assess the GT-R's overall aerodynamic package.

A very effective GT3 car we tested in 2010 was the Ferrari F430 Scuderia. The baseline data that we published is shown in **Table 2**, along with the GT-R's data with an identical %front value from later in our session. Taking the coefficients at face value, the GT-R's CD was roughly 17 per cent lower and the –CL was 30 per cent lower than the F430's at this level of balance. One key difference between the cars was ground clearance, and especially that of the splitter. The F430's splitter was 50mm above the ground, whereas the GT-R's was 100mm at the outer ends and 140mm at the upturned central leading edge. The GT-R's floor was roughly 70mm above the ground along the main flat section in this configuration. The F430's splitter (and flat floor) would be generating significantly more downforce at this much lower ground clearance. So if the GT-R's splitter was lowered so that its underside was on the same plane as the main floor, then it too would generate more front downforce, and with plenty of adjustment to spare on the rear wing it would be simple to add some more wing or flap angle to re-balance the car at an overall higher downforce level more akin to that of the F430.

Favourable comparison

Moreover, if we now compare the two cars' CD.A and –CL.A values, that is, the respective coefficients multiplied by the notional frontal area values used to calculate the coefficients from the measured forces, it transpires that the GT-R actually generated 1.3 per cent less drag and just 17 per cent less total downforce than the F430 at this balance level. The CD.A and –CL.A values are directly proportional to the actual forces generated, so the –CL.A difference shows that the GT-R had a much smaller actual downforce deficit than the coefficient comparisons imply, and one that should substantially be addressable with the aforementioned splitter height reduction and wing angle increase (actual CD.A and –CL.A values have been left unstated to preserve confidentiality for the teams concerned).

Table 3 shows the baseline values on the GT-R compared to those at the highest %front value attained to summarise the overall progress made. The Δ or 'delta values', the differences between the baseline and optimised data, are given in 'counts' where 1 count is a coefficient change of 0.001.

Next month we'll focus on adjustments and alterations at both ends of the car in the quest for that all-important aerodynamic balance, with valuable gains at the front as well as necessary reductions at the rear.

Thanks to Anthony Gaylard and Iain Litchfield and all the team at Litchfield Motors.

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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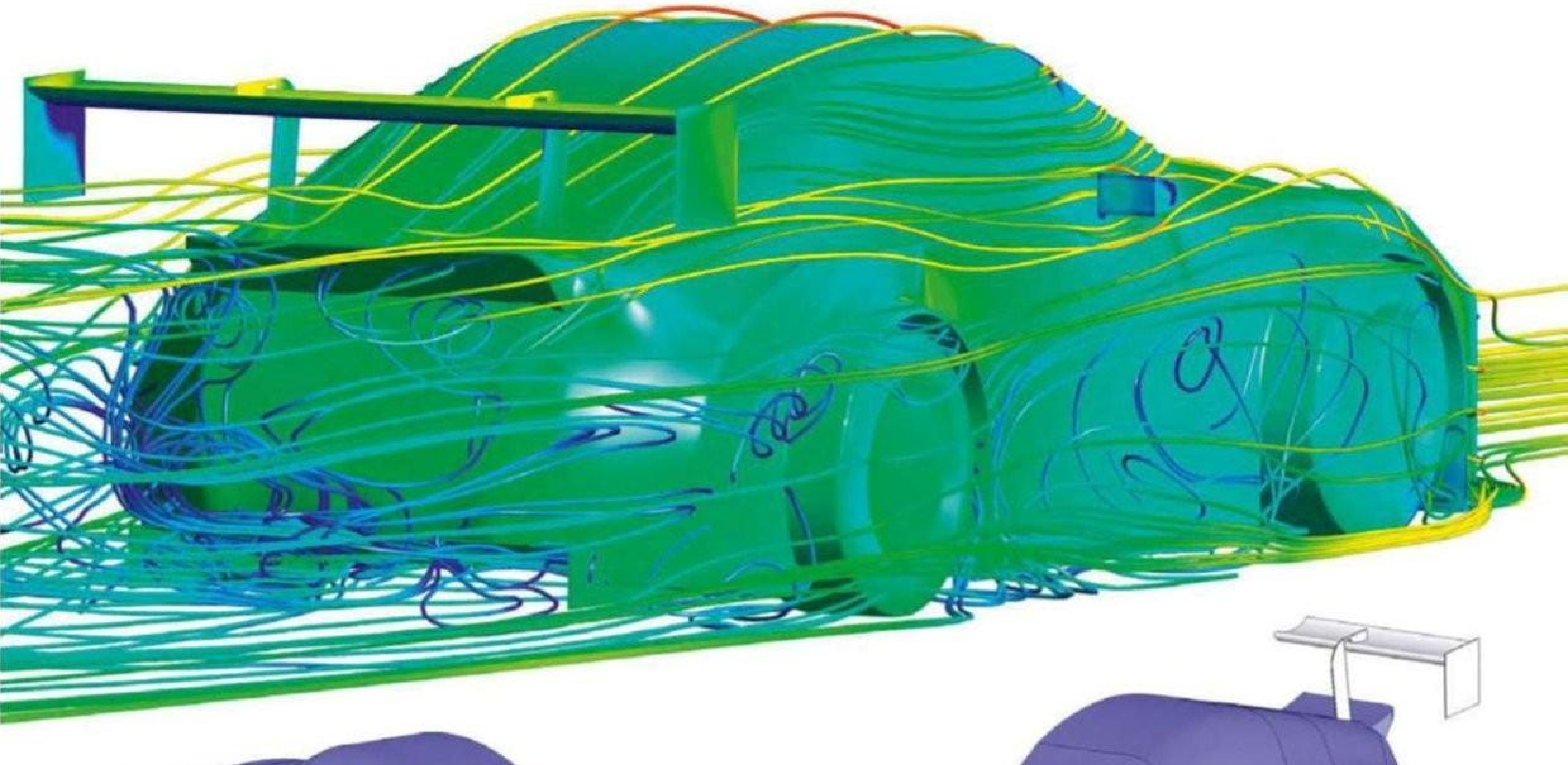
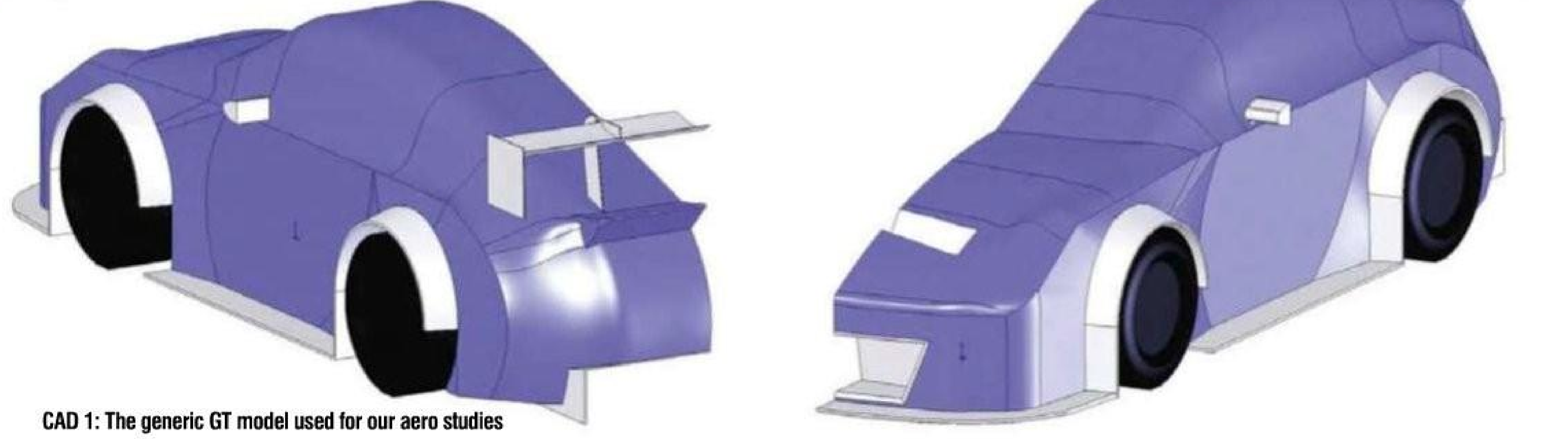
GT aero: the basics

With restrictive rules and large body shapes GT cars can prove challenging for aerodynamicists. We used CFD to get to the heart of the basic aero issues that are an inherent feature of these racecars

By SIMON McBEATH





CAD 1: The generic GT model used for our aero studies

It is something of a truism that the sessions we run in the MIRA full-scale wind tunnel for our monthly *Aerobytes* column generally produce at least as many questions as answers. This can be because, more often than not, our sessions are the first time that the subject cars have been aerodynamically investigated, and there just isn't time to examine everything on inevitably lengthy wish lists. And some modifications are just not practical to carry out in a relatively short wind tunnel session.

The key to maximising the benefit of time in the wind tunnel is to run through a slick programme of easy adjustments to gain the maximum knowledge from those precious few hours. So it's useful to be able to bring other tools to the party in order to examine aspects that we can't cover in the wind tunnel. ANSYS CFD is the tool in question, and following on from our occasional CFD studies of single seater and sports racer aerodynamics, this month we turn our attention to some of the basics of GT aerodynamics using a simplified CAD model of a generic GT car.

As always, the process started by working up a set of suitable CFD parameters that generated solutions in a sensible time frame and to an acceptable level of fidelity. And as usual it's fair to state at the outset that, like your writer's previous generic studies, these are not high level simulations; the model is simplified, the resources for performing CFD are basic, and the absolute results should be treated with a pinch of salt. The primary purpose here was to investigate

Table 1: Aerodynamic data on our CFD model and the Porsche 997 GT2 and Ferrari F430 in the wind tunnel

	CD	-CL	-CLfront	-CLrear	% front	-L/D
CFD GT starting	0.47	0.83	0.20	0.64	23.9%	1.84
CFD GT baseline	0.46	0.85	0.33	0.52	38.8%	1.87
997 starting	0.435	0.523	0.110	0.413	21.1%	1.203
997 optimised	0.439	0.705	0.245	0.460	34.8%	1.606
F430	0.523	0.805	0.317	0.487	39.4%	1.539

Sources of downforce and lift

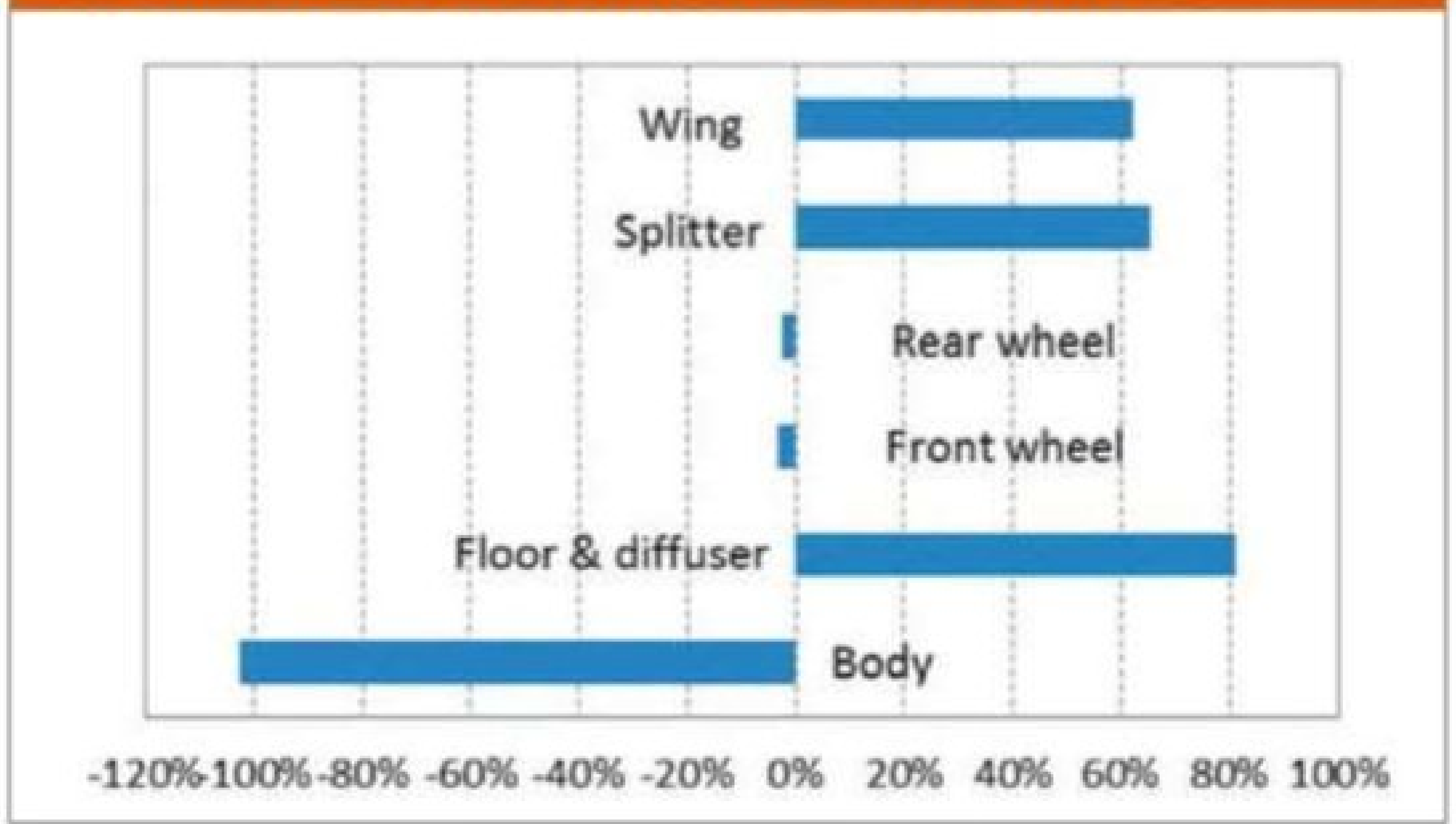


Figure 2: The lift and downforce contributions of the major components on our model

Sources of drag

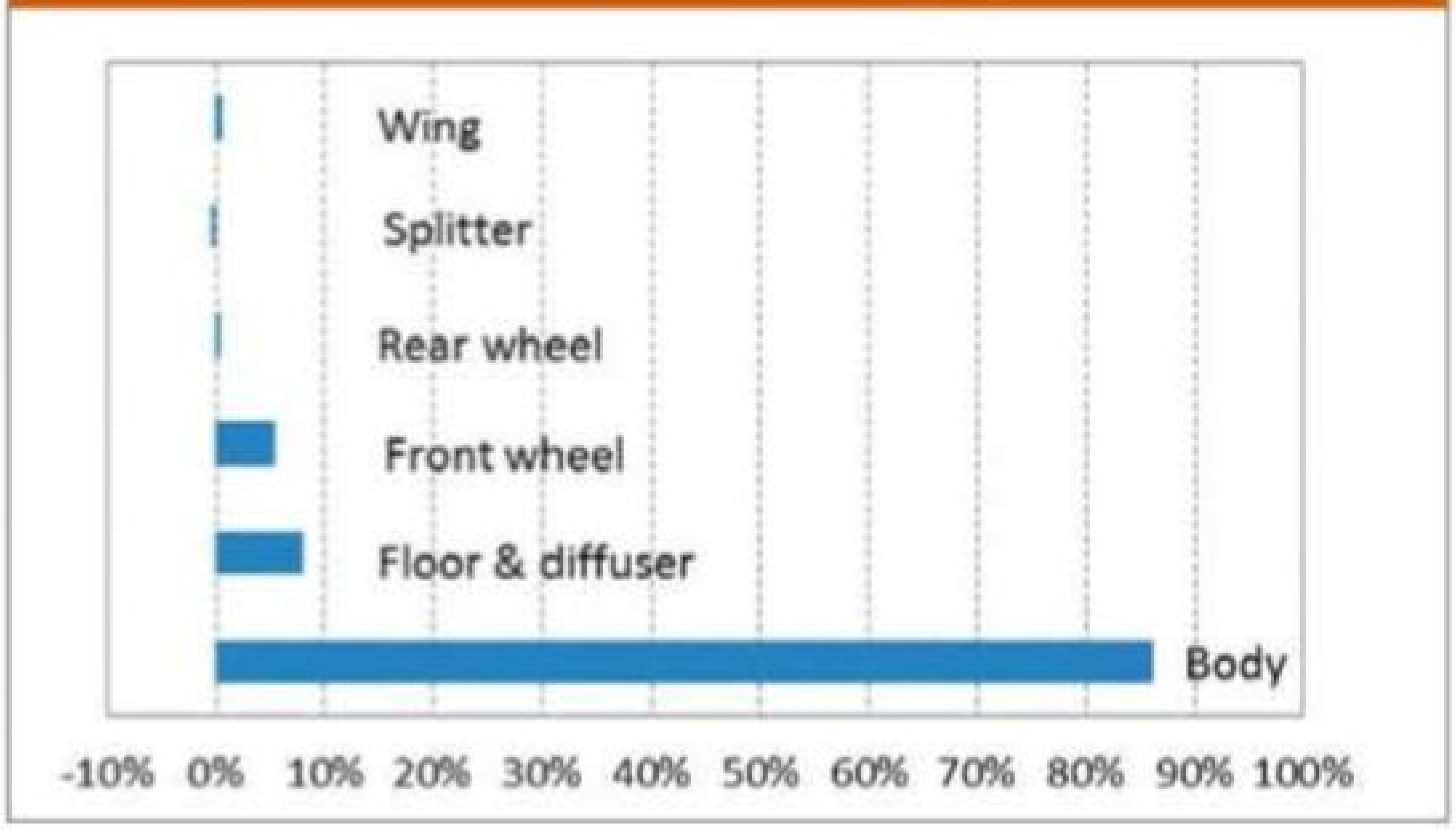


Figure 1: The drag contributions of the major components; the main source is obvious

The first run showed the front to rear aero balance to be just 24 per cent front, way short of the initial target of around 40 per cent front

the effects of fairly broad brush configuration changes to see what trends and responses emerged.

Having said that, it was gratifying that the aerodynamic coefficients that arose on our GT model were not so far from those of GT cars we have actually evaluated in the MIRA full-scale wind tunnel, and we are going to assume that was not entirely a happy coincidence …

The baseline

While working up the CFD parameters, adjustments were also made to the CAD model so that a suitably balanced baseline configuration was created. The starting configuration was actually based on a client's wing positioning study, but that featured a different wing configuration, so in this instance it proved necessary to carry out wing relocation and angle adjustments, plus some rake adjustments to achieve a reasonable balance.

The starting aerodynamic package featured a 150mm simple, flat splitter leading to a flat underside. This in turn fed a basic rear diffuser with the transition in line with the rear axle, a roof angle of 12 degrees, two pairs of fore/aft strakes, and a termination in line with the rear body. Initial ground clearance was 60mm front and rear, measured at the splitter/floor join at the front, and at the diffuser transition at the rear. The splitter underside was 5mm lower than the main floor. The single element wing, which was almost full car width, was one of the writer's own high downforce single element profiles with a chord of 300mm; initial angle was six degrees and it was set at roof height plus 40mm, with its trailing edge overhung by 175mm behind the rearmost line of the body.

The first run showed the front to rear aerodynamic balance to be just 24 per cent front, that is, the proportion of total downforce on the front was 24 per cent, some way short of the initial target of around 40 per cent front. Incremental adjustments were made to reduce the wing's angle to two degrees and to lower it to 40mm below maximum roof height and then forwards by 175mm so its trailing edge was level with the car's rear body. This yielded a balance of 28 per cent front. Finally, rake adjustments were made that lowered the splitter leading edge underside to 47mm ground clearance, kept the front ride height at 60mm but increased the rear ride height to 75mm (equating to 15mm rake on the flat floor), and the diffuser strakes were removed (see **CAD 1**). This then brought the balance to just under 39 per cent front, which was considered to be a suitable baseline to work from. We will revisit the effects of all these adjustment parameters in more detail later; the purpose at this stage was to achieve a balanced set-up, but nevertheless it was illuminating to see how the model responded to these early adjustments.

The aerodynamic coefficients of our starting and our 'refined' baseline configuration are given in **Table 1**, along with some comparisons with the Paragon Porsche ALMS GT2 Porsche 997 GT3RSR, and the MTECH Ferrari F430 Scuderia GT3, that followed the Porsche in *Aerobytes* (we wind tunnel tested both in 2010), the Ferrari having a similarly-balanced state to our baseline CFD model.

Note that coefficients have been given to just two significant figures on the CFD model. This is because, although the CFD solver was run in each case until the forces on the major components were deemed steady, there was a margin of error of up to +/- 2.5 per cent in some cases, and without time-averaged data sampling, as is done in the wind tunnel, the third decimal place was thought to be rather frivolous. Nevertheless, the drag of our model was in between the real 997 and F430. Downforce was somewhat higher than both real cars, which could be due in part to the wind tunnel's fixed floor suppressing underbody downforce, whereas the CFD simulations included moving ground and rotating wheels, and in part to the CFD model's simpler and essentially flaw-free shape. Real cars have panel gaps, door handles, seams, joins and all manner of defects that compromise aerodynamic performance whereas our simple CFD model is, relatively, very 'clean'. However, the values were comparable to the real cars, which gave some validity, even if our main aim was just to examine the effects of changes.

Baseline studies

It's worth pausing to look at the data and visualisations from this baseline model in more detail, to get an idea of how and where the aerodynamic forces were generated. Looking at **Figure 1**, it's very apparent what the main source of drag was, but that's scarcely surprising when the car body is the biggest 'component' of the model and constitutes most of the

The drag of our model was in between the real Porsche 997 and the Ferrari F430. Downforce was somewhat higher than both real cars

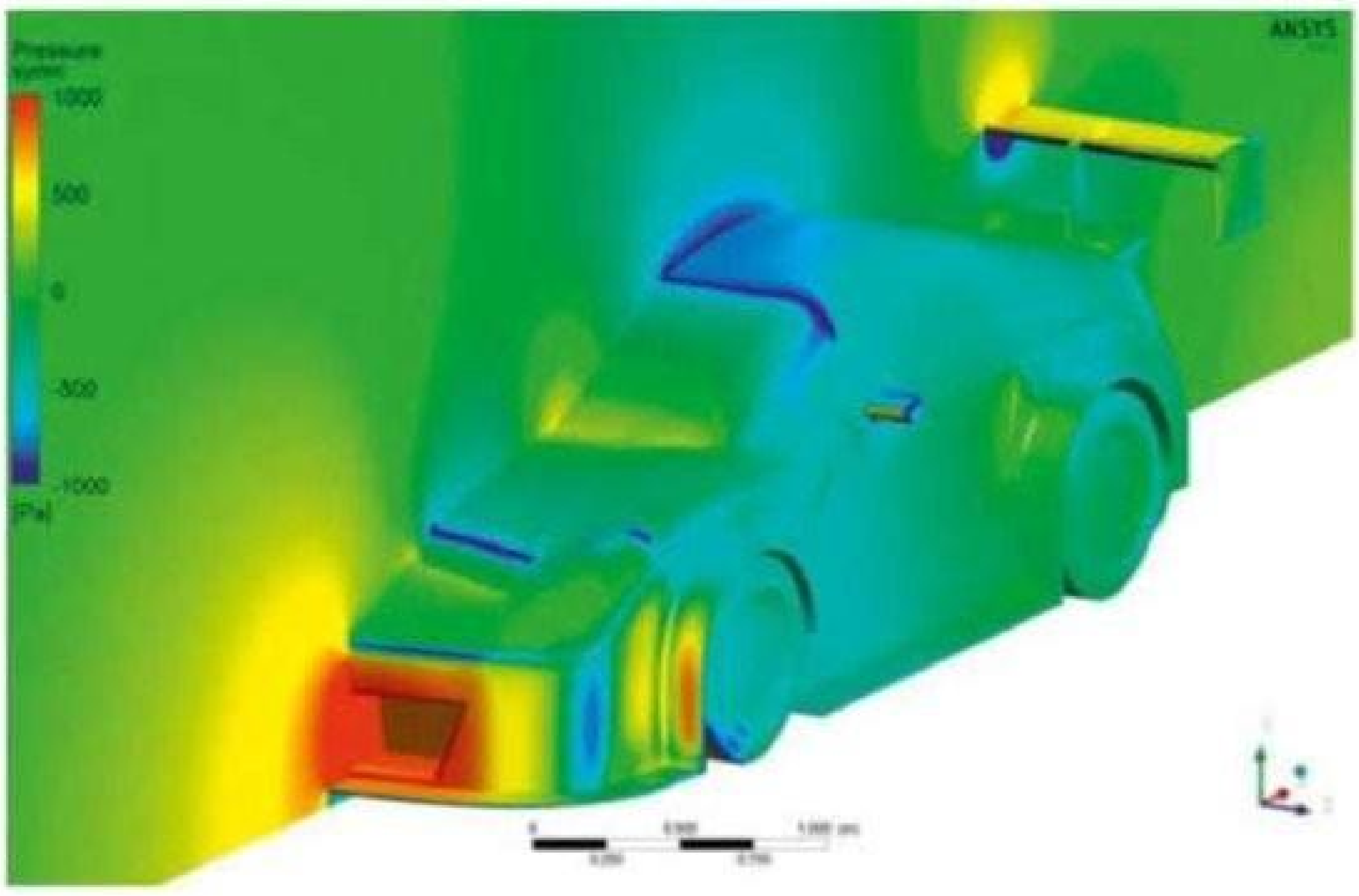


Figure 3

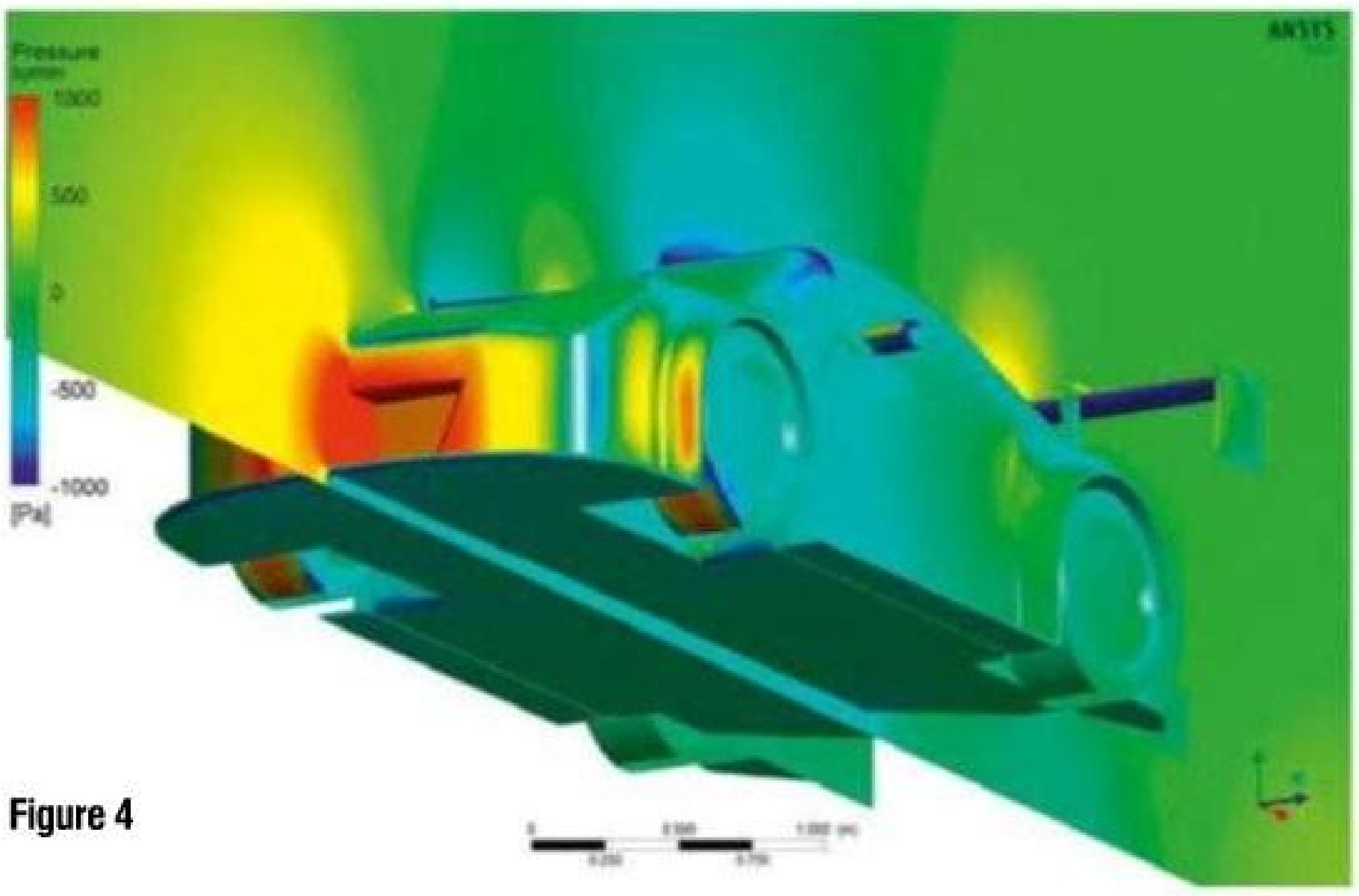


Figure 4

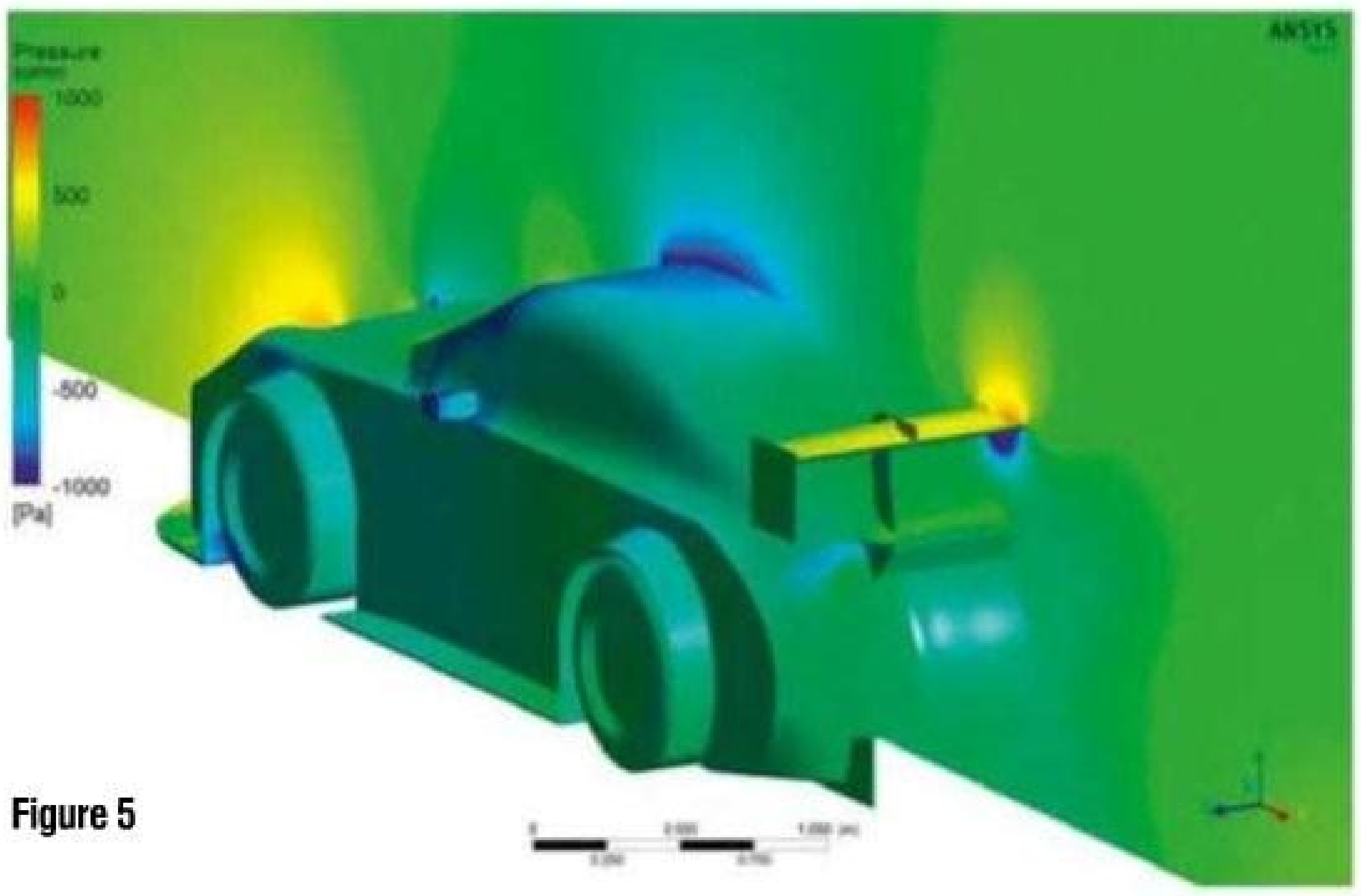


Figure 5

Figures 3, 4 and 5: The sources of drag, downforce and lift are evident from the pressure distributions. High pressure is red to yellow and low pressure green to blue

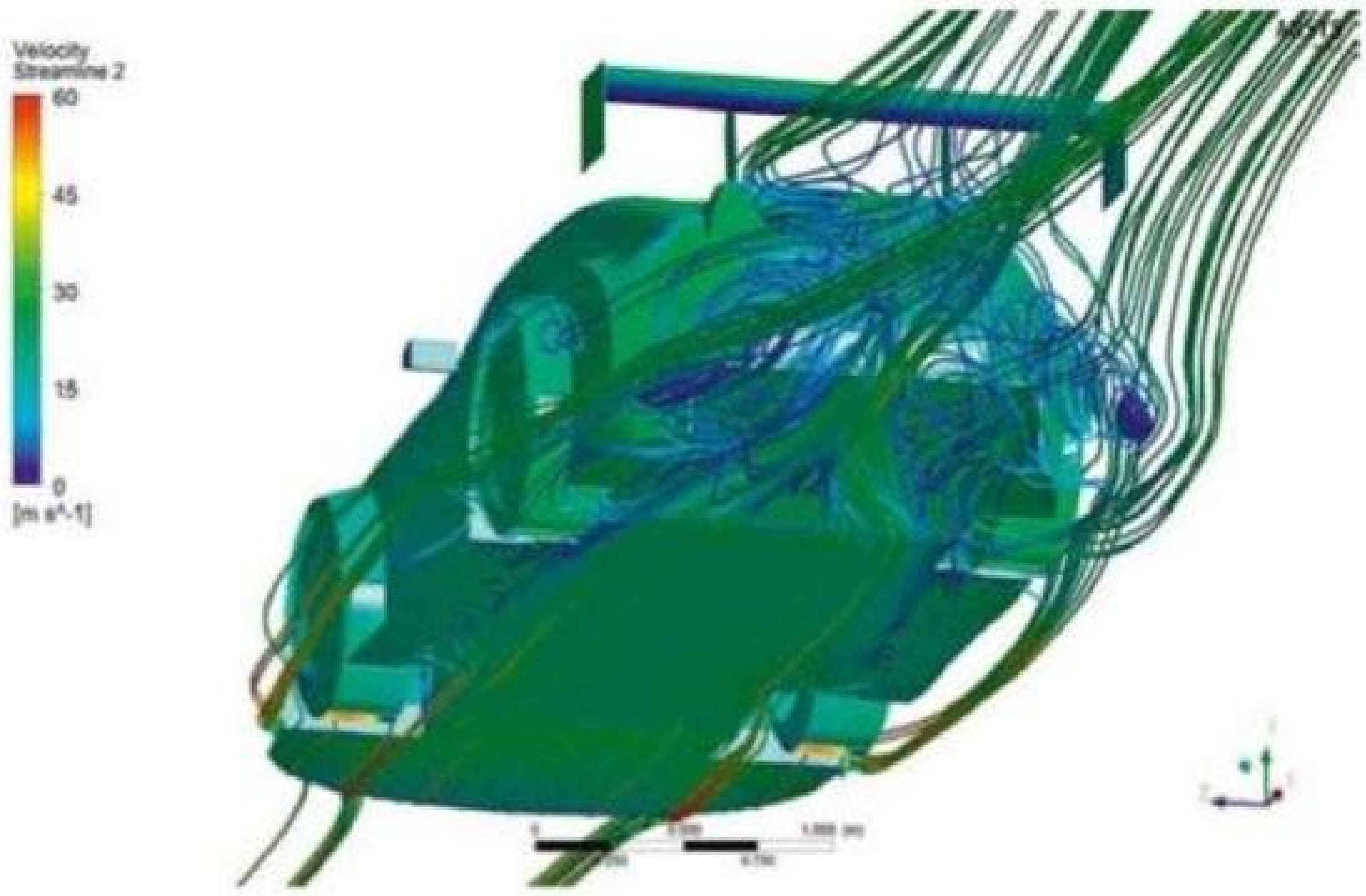


Figure 6: The streamlines reveal that the diffuser was almost stalling in the centre. Also, note that the streamlines in the outer sections of the diffuser appear to be disorganised

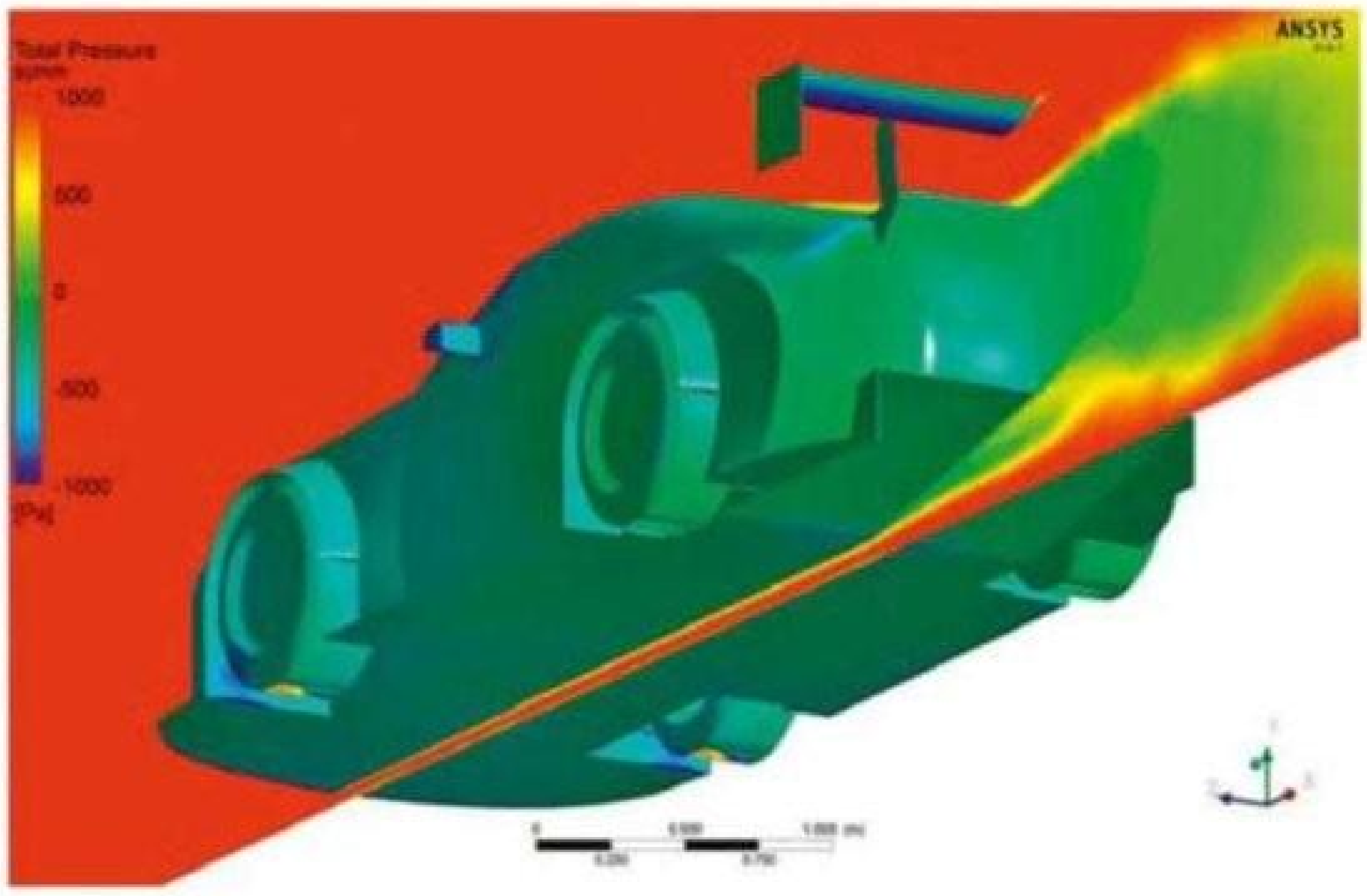


Figure 7: The total pressure plot on the symmetry plane of our GT racecar model shows energy losses in the diffuser centre, which indicates near-stall conditions

Table 2: The effects of reducing diffuser angle

Diffuser angle	CD	-CL	-CLfront	-CLrear	% front	-L/D
12deg (baseline)	0.46	0.85	0.33	0.52	38.8%	1.87
10deg	0.46	0.85	0.34	0.51	39.5%	1.87
8deg	0.45	0.91	0.36	0.55	39.1%	2.01
6deg	0.45	0.89	0.34	0.55	38.5%	2.00
4deg	0.45	0.89	0.35	0.54	39.2%	1.99

The GT model's floor and diffuser generated around 39 per cent of actual downforce

frontal area. The floor and diffuser (analysed as one component) and the front wheels produced the majority of the rest of the drag, while the rear wheels, the rear wing and the splitter made very small drag contributions. The splitter's essentially negligible drag contribution bears out wind tunnel findings that show little if any drag change when, say, a bigger splitter is fitted.

Figure 2 shows the sources of downforce and lift on the model. Here we see that the wing, the splitter, and the floor and diffuser were the downforce generators, offsetting and reversing the lift generated by the body and, to a much smaller extent, the wheels. **Figures 3** to **5** show the surface pressures on the model's surfaces and on the symmetry plane, with the pressure range set so as to emphasise the areas of high pressure (red to yellow) and low pressure (green to blue). It isn't hard to pick out where lift, downforce and drag respectively were generated, on and off the model's surfaces.

Note that the floor and diffuser generated around 39 per cent of the actual downforce, compared to 31 per cent from the splitter and 30 per cent from the rear wing, the floor and diffuser contribution falling short of equalling and reversing the lift contribution from the body in this specific configuration. Clearly, without the splitter and the wing the car body's lift would have been the dominant vertical force.

Having established a balanced baseline model, we then moved on to examine the effects of changes to the key parameters.

Diffuser angle

There were various aspects of the underbody and diffuser that needed investigating, among which were ground clearance, rake and pitch angle. But before that, the diffuser angle was examined. At 12 degrees on the baseline model, it appeared from views of the streamlines and of the total pressure on the symmetry plane that the diffuser was partially stalling in the centre, just aft of

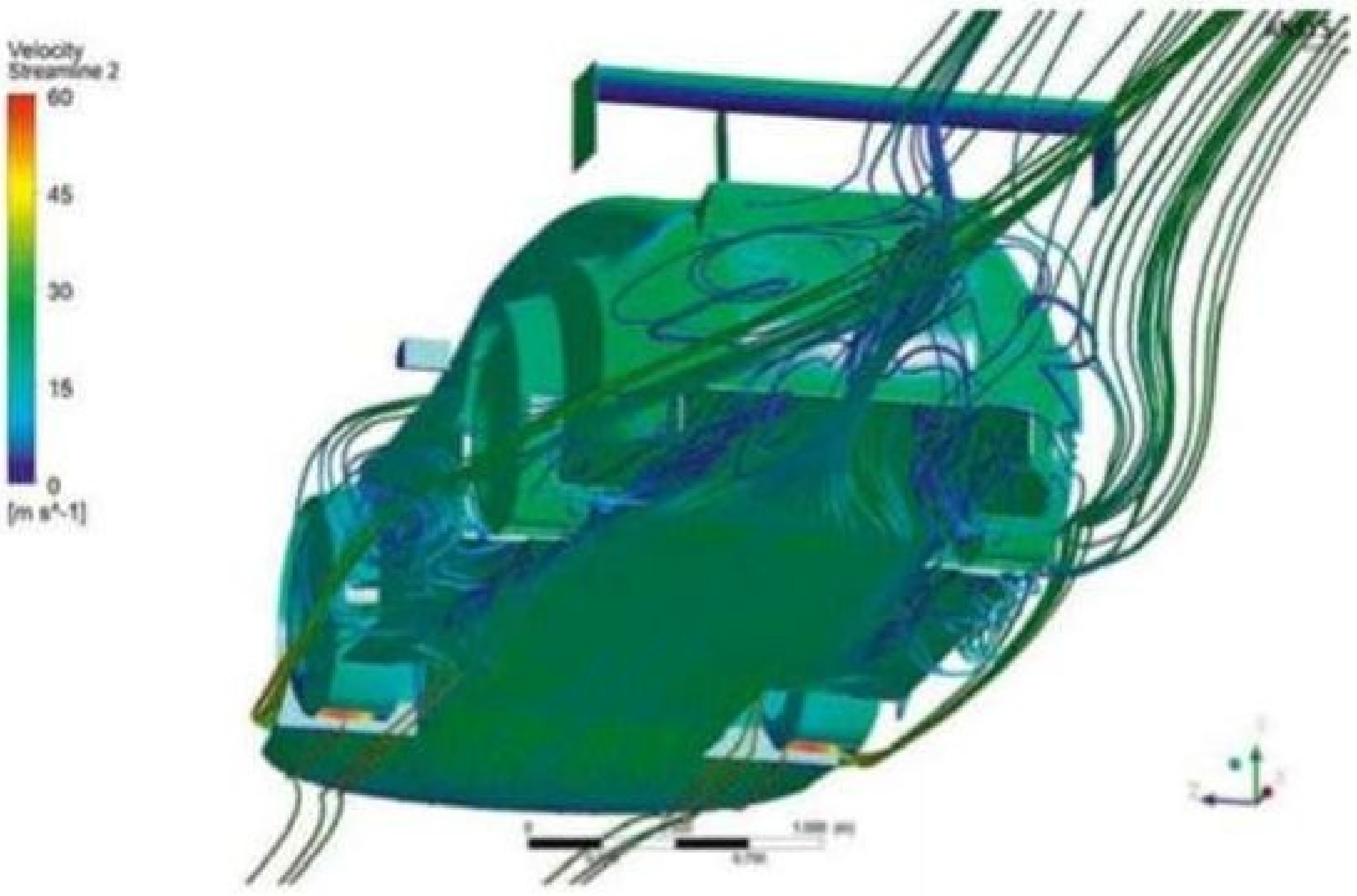


Figure 8: Reducing the roof angle of the diffuser to eight degrees eradicated the stall in the centre. The peak diffuser angle was lower than perhaps might have been expected

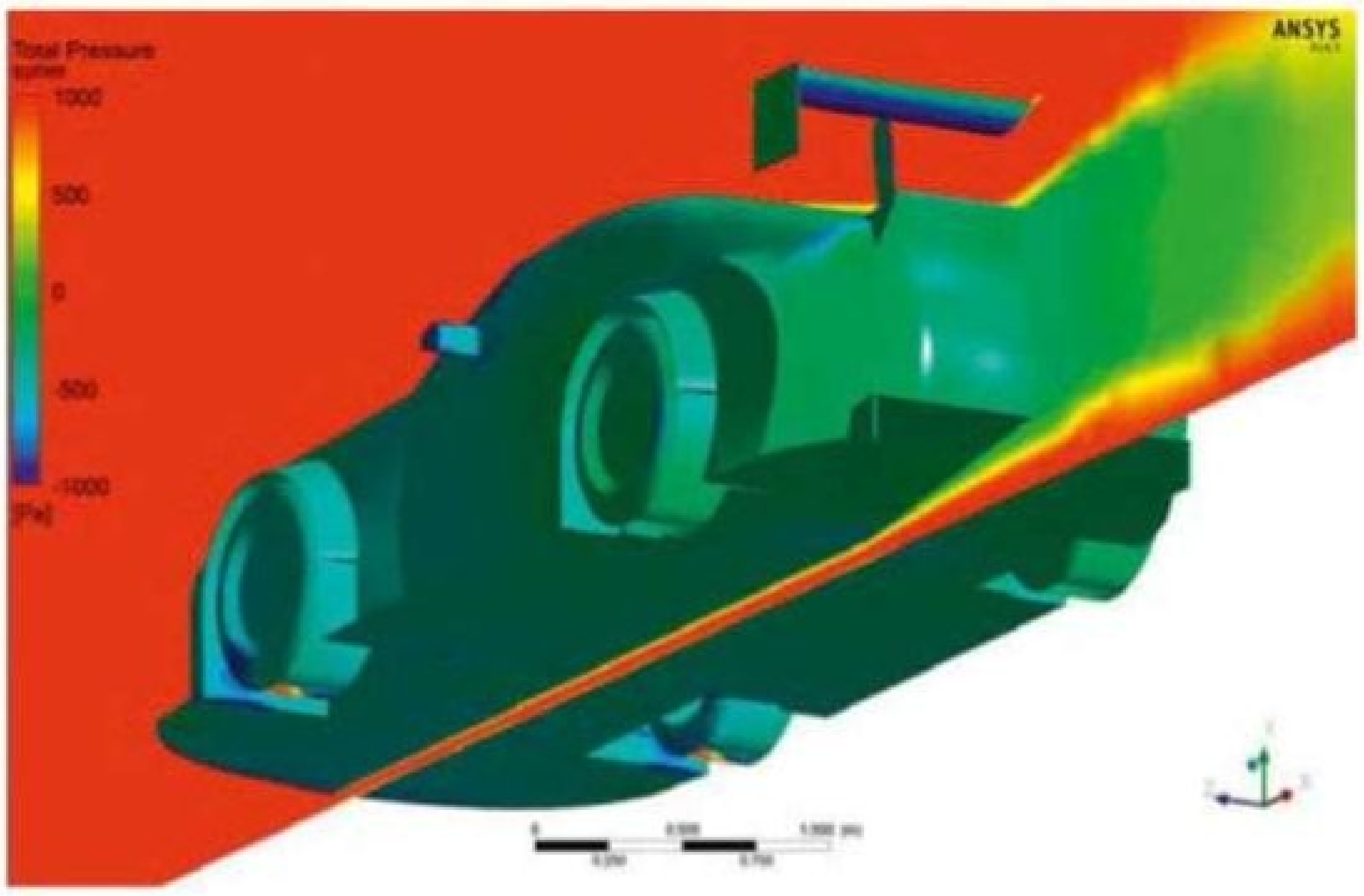


Figure 9: Comparing this with Figure 7 (see opposite page) you can see there was less total pressure loss in the diffuser centre when its roof angle was reduced

The flow from the Ferrari F430 Scuderia GT3's diffuser centre was seen to be tidy …

… While the flow from the outer diffuser sections was untidy, reflecting what the CFD simulations showed. This Ferrari was tested in the MIRA wind tunnel back in 2010

Table 3: The effects of changing ground clearance

	CD	-CL	-CLfront	-CLrear	% front	-L/D
-10mm	0.46	0.94	0.37	0.56	40.0%	2.06
Baseline	0.45	0.91	0.36	0.55	39.1%	2.01
+10mm	0.47	0.82	0.30	0.52	36.9%	1.74
+20mm	0.48	0.81	0.28	0.53	34.5%	1.70

the transition from the flat floor (see **Figures 6** and **7**). So a set of successively lower diffuser angles was run to enable the data and the visualisations to be examined. Go to **Table 2** to see the results.

Interestingly the responses to changing diffuser angle were not strong but there did nevertheless seem to be a gentle peak in downforce and efficiency (-L/D) at a diffuser angle of eight degrees. Furthermore, as **Figures 8** and **9** show, there no longer appeared to be any signs of stall in the diffuser centre at eight degrees. So it would seem that on this particular model, at this rake angle and ground clearance, and in a configuration that featured a low wing angle at this stage, the peak diffuser angle was lower than perhaps might have been expected. There are other variables that could influence this though so maybe the key lesson here is that it's unwise to make assumptions about any variable.

As an aside, if the streamlines in the outer sections of the diffuser in **Figures 6** and **8** appear disorganised, compared to the tidy flow that converged in the centre of the diffuser, then compare them to the pictures above, from the wind tunnel, which show typical flows emerging in this case from the exit of the Ferrari F430's diffuser. The CFD images give us a better idea of just why the flows emerging from this kind of diffuser look tidy in the centre but untidy outboard of that. The combination of the diffuser shape, the location of its transition, and airflow coming off the inside of the rear tyres, to name but three influential factors, create the messy conditions in the outer diffuser areas. We will return to this subject in a future study on our GT model.

Ground clearance

We rarely alter ground clearance (as distinct from rake) in our wind tunnel trials, except perhaps for a quick check on one or two alternative heights, partly because it's assumed that running a car as low as possible is the right thing to do, so why squander wind tunnel time? The opportunity to examine alternative ride heights on the CFD model was therefore worth taking. The 'new' baseline model with eight degree diffuser, 47mm splitter leading edge height, 60mm front ride height (FRH) and 75mm rear ride height (RRH) was lowered by 10mm and then raised by +10mm and +20mm, and the results are shown in **Table 3**.

In this instance then it would seem our assumptions about the effects of changing ground clearance were essentially borne out, with a general upward trend in drag and a downward trend in downforce with increasing ground clearance. Balance shifted rearwards as ground clearance was increased, primarily because splitter downforce declined. The responses were non-linear, with the biggest incremental changes between baseline height and +10mm on baseline, although it is unclear at this stage whether this response

In this instance then, it would seem our assumptions about the effects of changing ground clearance were essentially borne out

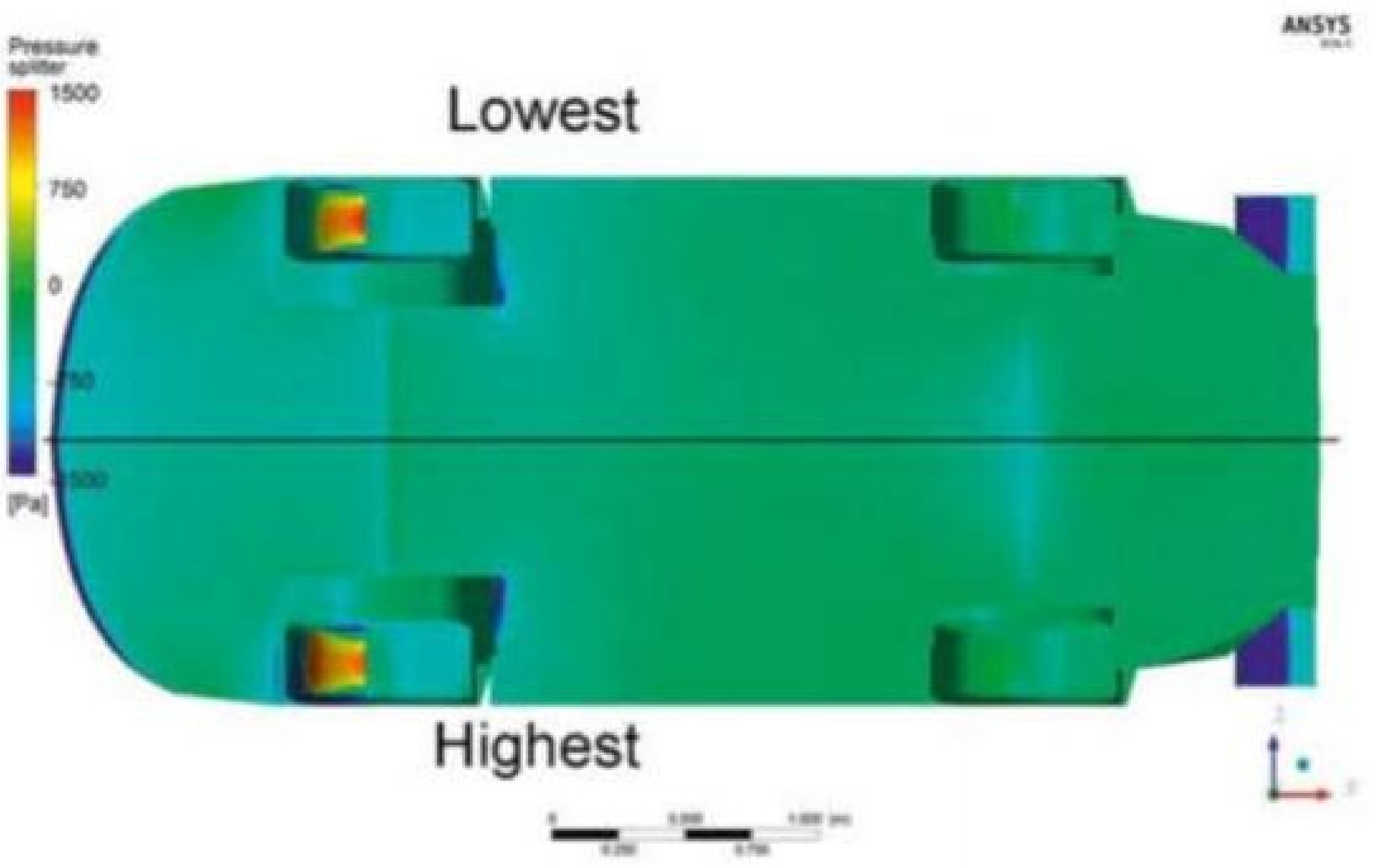


Figure 10: At the lowest ground clearance the pressure under the splitter was marginally lower, as shown by a subtle increase in the area of pale blue in the upper half of graphic

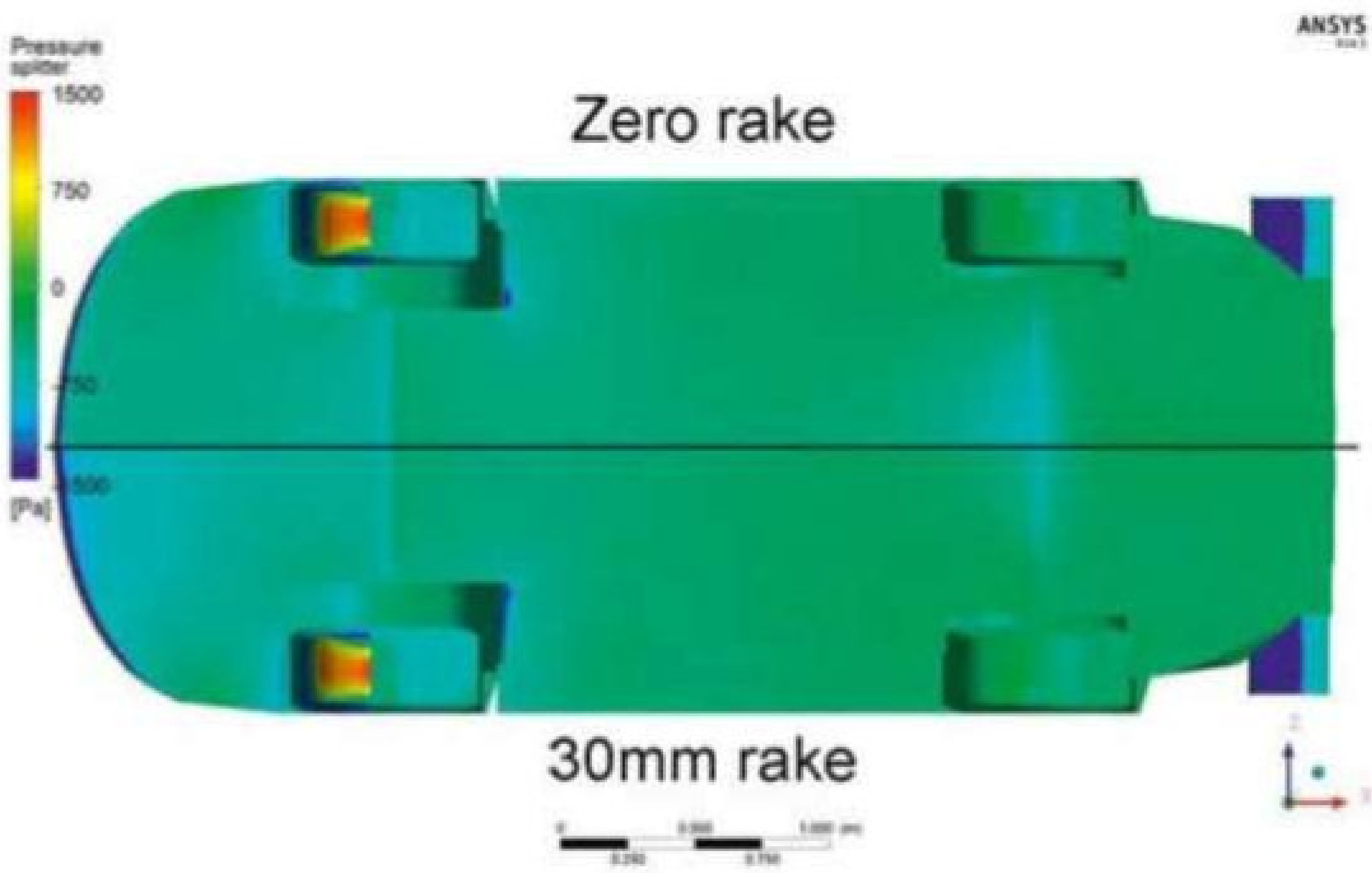


Figure 11: Rake change caused a forward shift in balance. The splitter panel exhibited greater pressure reductions at the highest rake angle compared to the zero rake case

Table 4: The effects of rake adjustments

	CD	-CL	-CLfront	-CLrear	% front	-L/D
Zero rake	0.44	0.88	0.30	0.58	34.0%	2.01
Baseline, 15mm rake	0.45	0.91	0.36	0.55	39.1%	2.01
30mm rake	0.46	0.92	0.43	0.49	46.4%	2.00

Table 5: The effects of pitch angle adjustments

	CD	-CL	-CLfront	-CLrear	% front	-L/D
Baseline, 0 pitch	0.45	0.91	0.36	0.55	39.1%	2.01
0.375deg pitch	0.48	1.05	0.52	0.54	49.0%	2.22
0.75deg pitch	0.51	1.27	0.76	0.51	60.1%	2.51

Proportions of downforce

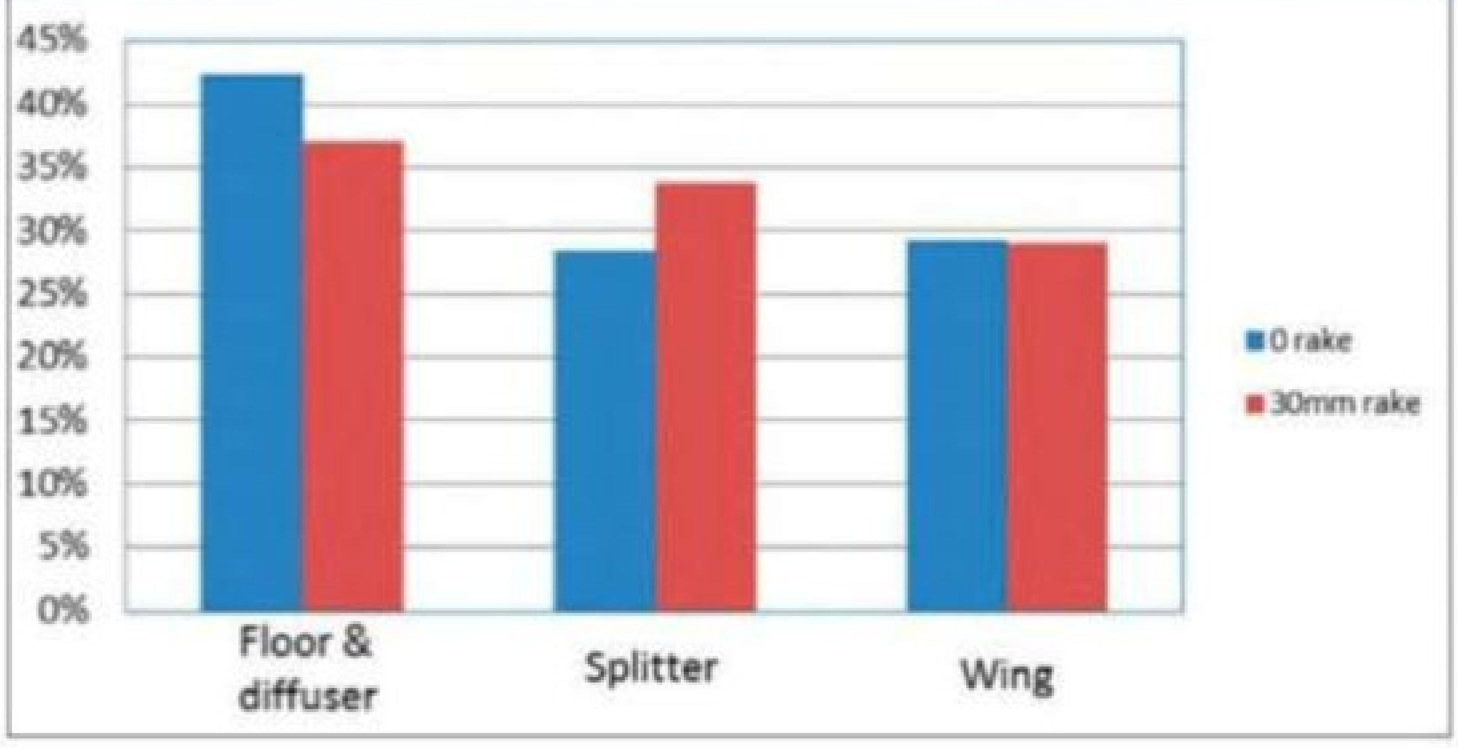


Figure 12: The contributions of the major component groups when the rake was altered

would be matched across the same ground clearance range in reality. **Figure 10** compares the surface pressures on the underside of the lowest and highest ground clearance models; the differences are subtle and concentrated mainly under the splitter panel, which extends back to in line with the front axle.

Rake angle

When rake is adjusted in our wind tunnel sessions, sometimes it's done with packers under the tyres, sometimes by adjusting the suspension. In the latter case it is possible, with preparation and care, to maintain a fixed splitter height and alter the car's rake angle by, effectively, pivoting the car about the splitter's leading edge. This is important if there is a minimum permitted splitter height. In CAD it's very simple to rotate the car model (independently of the wheels) similarly to maintain a fixed splitter height and achieve different rake angles. This was the basis of the next set of runs, and the 'new baseline' model was rotated to zero rake (FRH and RRH both 52mm) and to 30mm rake (68mm FRH, 98mm RRH). In each case the underside of the splitter leading edge remained at 47mm. The data are reported in **Table 4**.

There were some pretty clear responses in the coefficients to changing the rake angle. Drag and total downforce both increased by modest amounts as rake was increased. But front downforce increased by over 40 per cent over the rake range tested, while rear downforce decreased by 15.5 per cent. Balance moved more than 12 per cent forwards in absolute terms. And efficiency (-L/D) barely changed at all. So the predominant effect of increasing the car's rake was to move the balance forwards, and the modest total downforce increase was a secondary effect.

Figure 11 highlights where the surface pressure changes occurred on the underside; the splitter panel exhibited greater pressure reductions at the highest rake angle compared to the zero rake case; and the 'suction peak' at the diffuser transition was reduced in magnitude at the maximum rake. **Figure 12** illustrates how the proportions of downforce generation changed from zero to 30mm rake; the floor and diffuser's proportion reduced while the splitter's increased. The rear wing's downforce actually increased by a very small amount, this no doubt because of the small increase in its angle of attack, but its proportionate contribution remained unchanged.

Pitch angle

Whereas the results of the rake changes in the foregoing section could be regarded as indicative of steady state conditions in different set-ups, pitch angle is a parameter that changes dynamically on a fairly continuous basis in most competition scenarios. Our simulations are by definition steady state, but by applying different pitch angles to the model and comparing them with the baseline data we can get some idea of the changes in aerodynamic performance across a dynamic pitch angle range. So in this instance the baseline model was rotated about an imaginary pitch centre halfway along the wheelbase and at wheel axle height, and two angles were successively applied. 0.375 degrees changed the splitter leading edge height, front ride height and rear ride height from 47mm/60mm/75mm to 31mm/52mm/83mm, while 0.75 degrees changed them to 15mm/45mm/91mm. The data are shown in **Table 5**.

The responses in this instance were even stronger than when rake angle was adjusted. The dominant factor here was the increase in front downforce, which more than doubled from the baseline to the 0.75 degrees pitch angle, with a commensurate significant shift in the aerodynamic

The predominant effect of increasing the GT model's rake was to move the aerodynamic balance of the racecar forwards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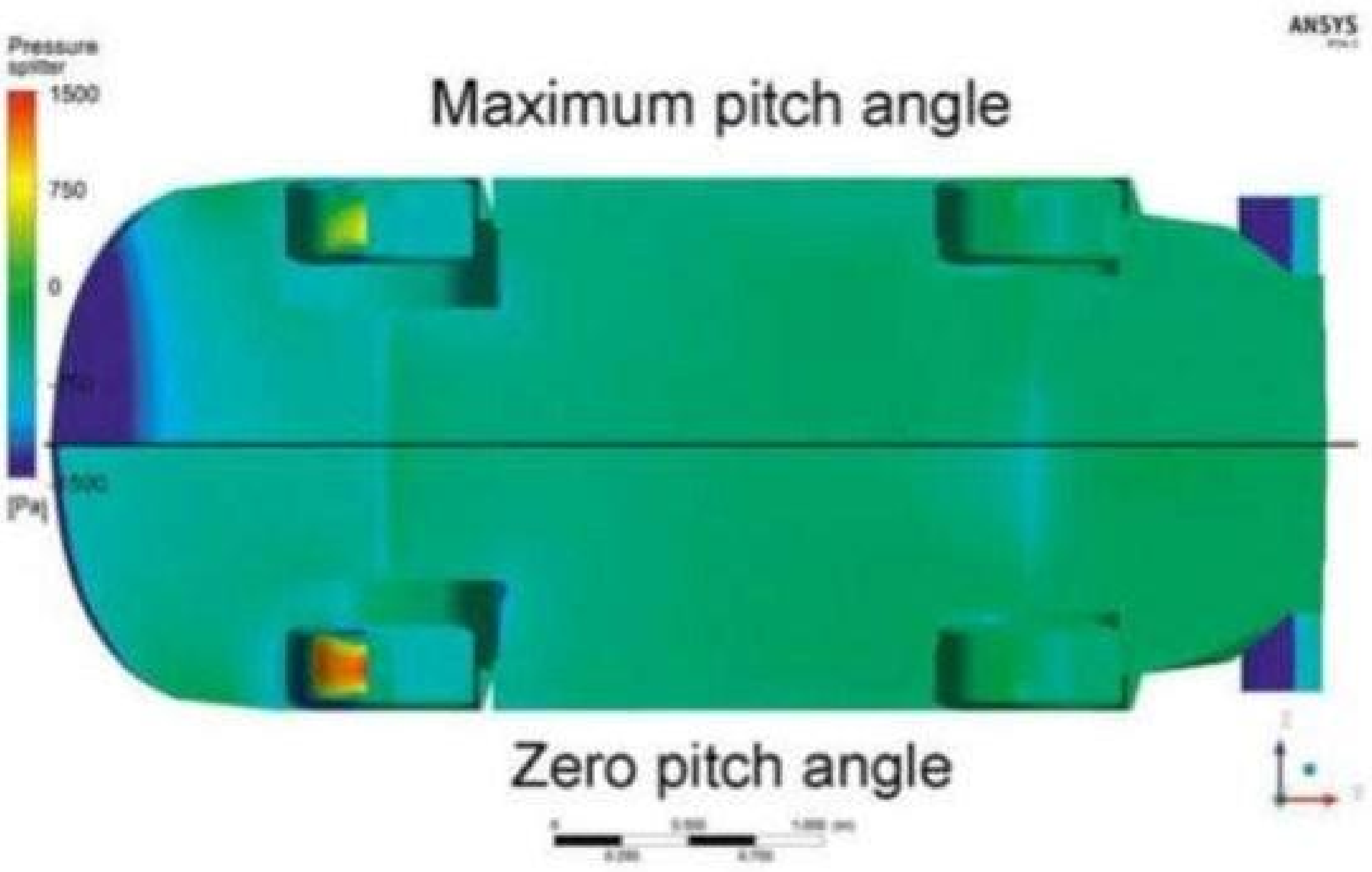


Figure 13: Pitch changes caused big shifts in pressure distributions on the underside

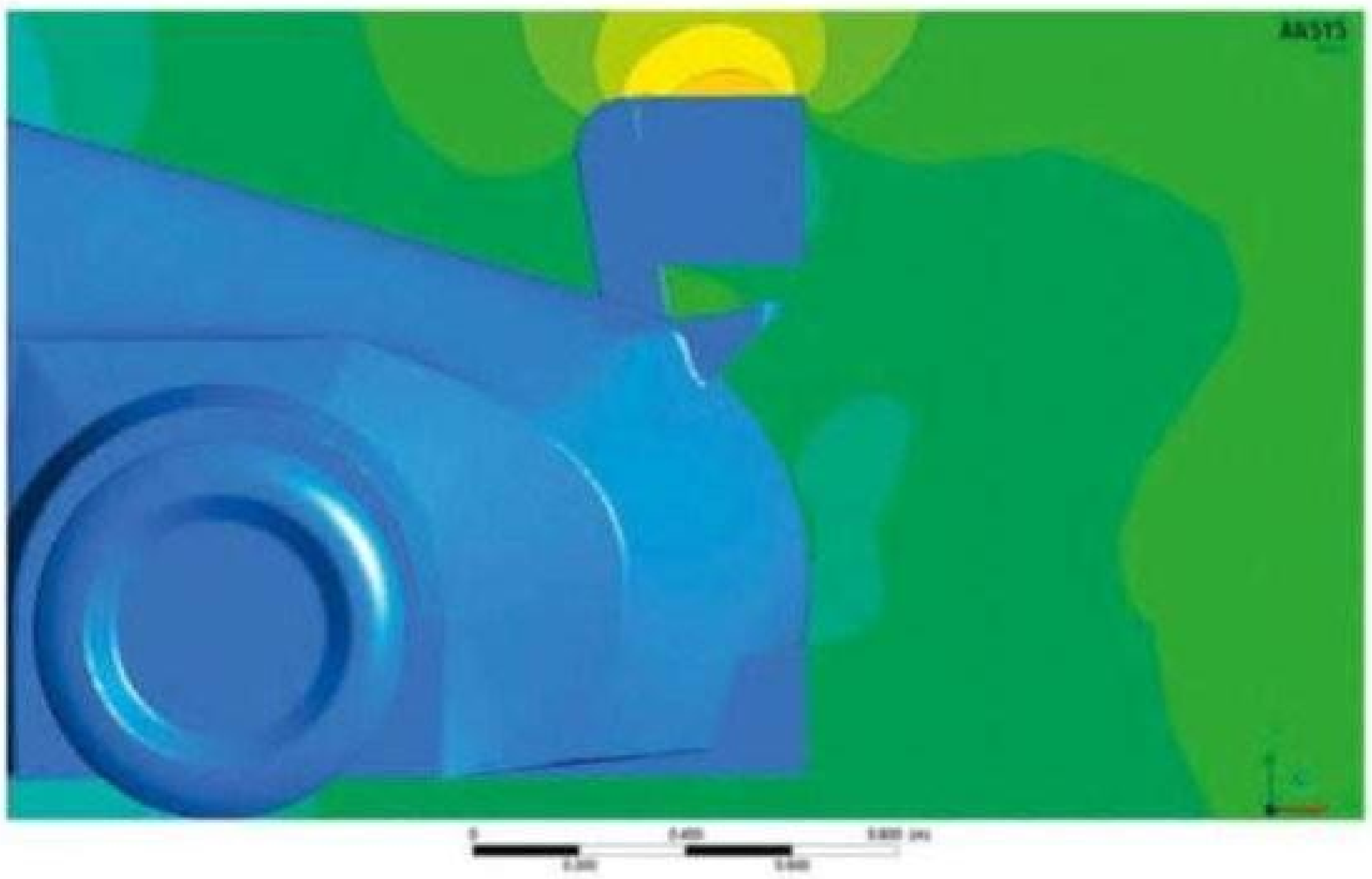


Figure 15: Diffuser overhang was also examined. Terminating the diffuser at the rear extent of the body ensured that the lowest wake pressure was exerted on diffuser exit

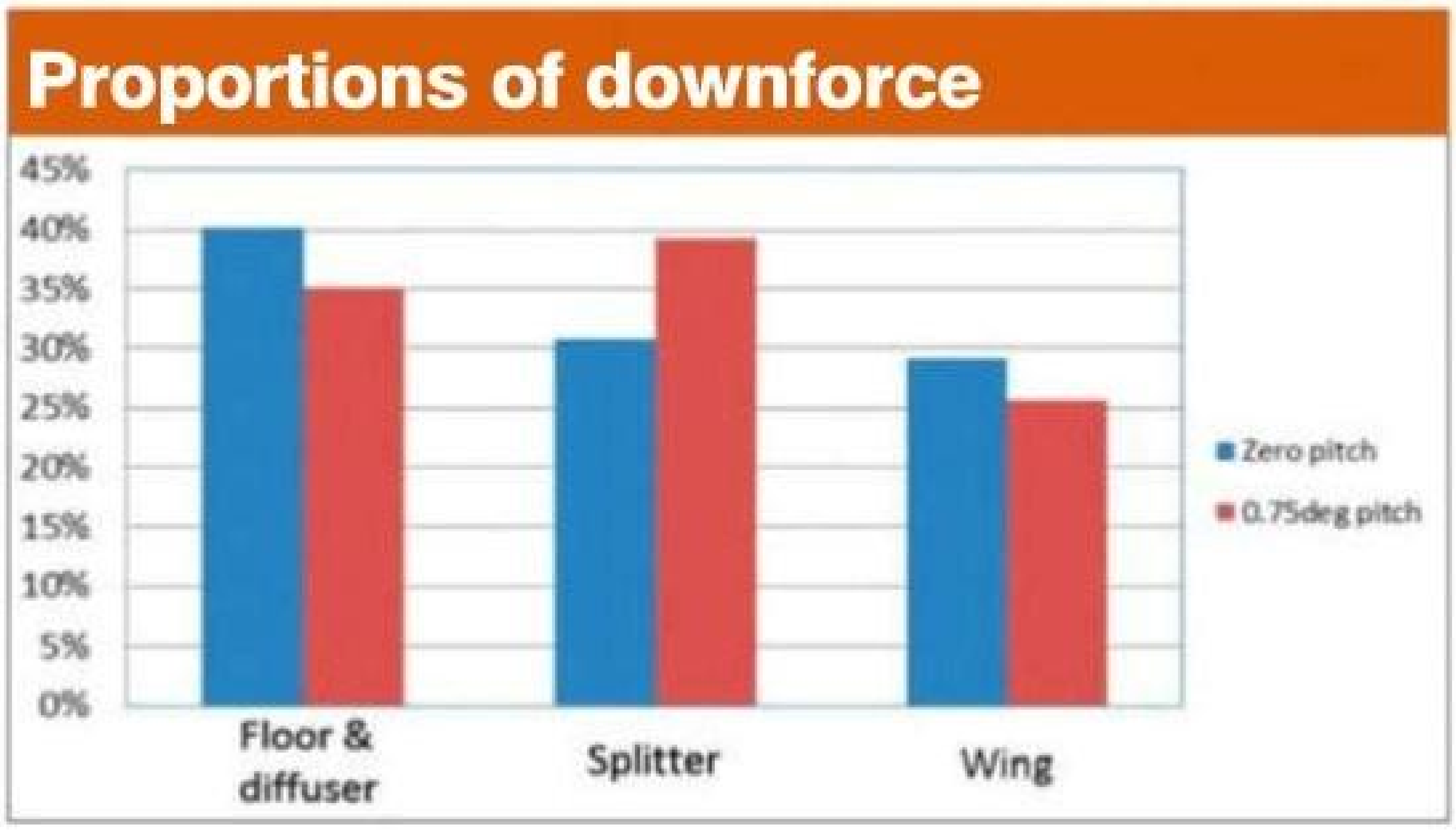


Fig 14. Pitch changes also caused some big shifts in the downforce contributions

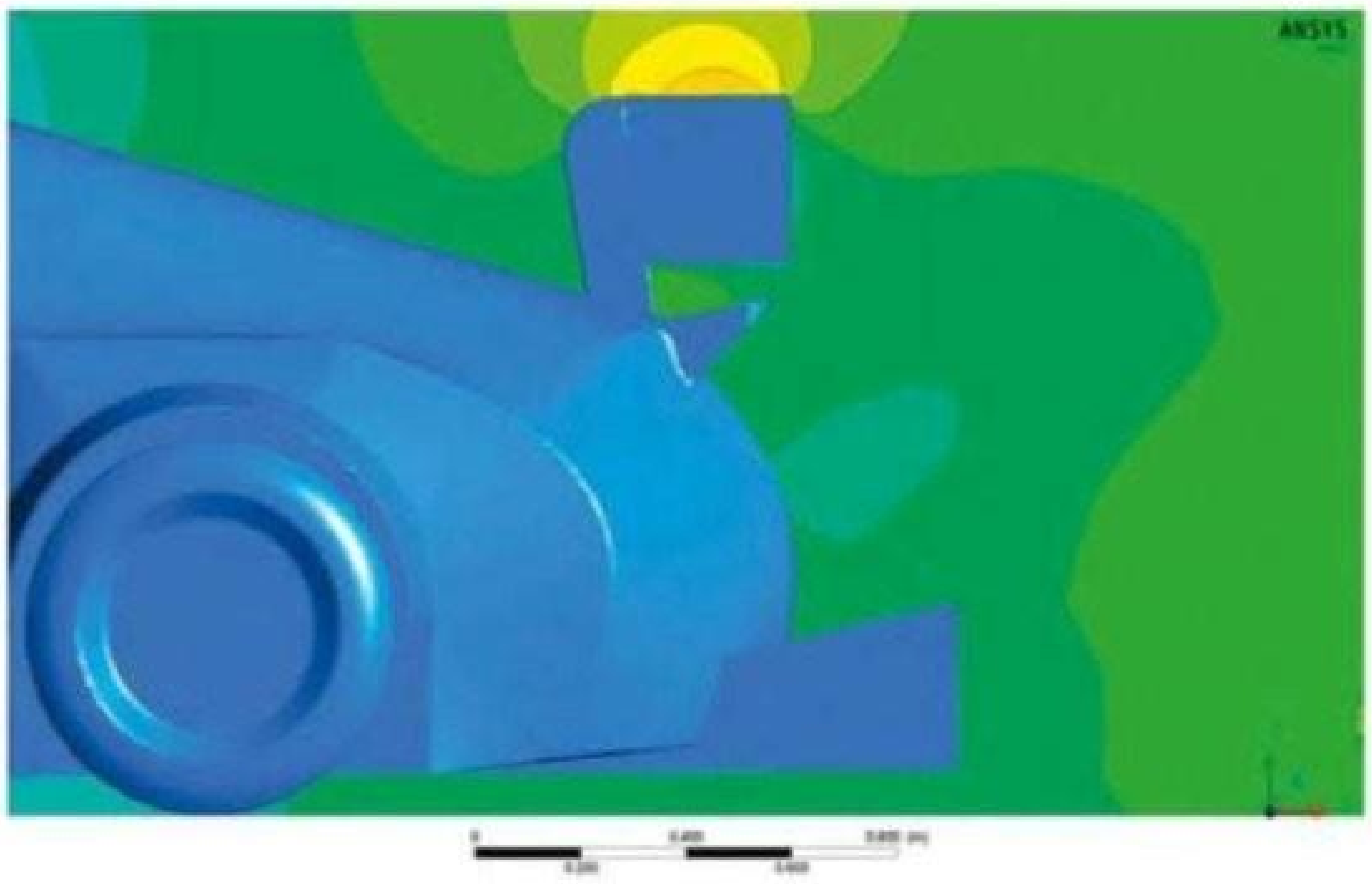


Figure 16: Extending the car's diffuser saw slightly higher pressures at the diffuser exit

Table 6: The effects of extending the diffuser

	CD	-CL	-CLfront	-CLrear	% front	-L/D
Baseline diffuser	0.46	0.85	0.33	0.52	38.8%	1.87
+100mm diffuser	0.46	0.84	0.33	0.51	38.9%	1.84
+200mm diffuser	0.46	0.84	0.34	0.49	41.0%	1.80
+300mm diffuser	0.46	0.86	0.34	0.52	39.2%	1.87

balance. **Figure 13** shows the surface pressures on the model's underside; the big increase in suction under the splitter is very obvious when compared with the zero pitch case. Note also other differences such as the change in pressures on the 'exposed' lower portions of the front tyres, and the reduced suction at the diffuser transition, both presumably the result of reduced mass flow under the car when the splitter was so much closer to the ground. **Figure 14** shows downforce contribution changes.

This kind of pitch change would occur under heavy braking, so the aerodynamic balance shift would reinforce the mechanical weight transfer during the braking phase. Whether or not this was deemed detrimental or beneficial would be a matter of driver and race engineer preference. Certainly the different aerodynamic loads at the different ends of this pitch angle range would see a significant difference in the vertical forces on the front tyres.

Diffuser overhang

A frequent question the writer gets asked is 'how far should a diffuser protrude at the rear when there are no rule restrictions?' In unrestricted categories, like Time Attack for example, diffusers that protrude well beyond the rearmost extent of the original bodywork are frequently seen, and this seems to prompt others to ask the question, or else follow suit on the assumption that it's the correct thing to do. Having had no opportunity to evaluate this in the wind tunnel, gut feel suggested that there would be trade-offs that would not guarantee additional downforce from a longer diffuser. On the one hand the diffuser volume would be greater but, on the other hand, would not the geometry of the underbody forward of the diffuser need to be configured to enable a bigger diffuser to be filled so as to provide a beneficial contribution? Furthermore, extending the diffuser rearwards may push its termination into areas of not such low pressure in the wake, when it is preferable to exploit the lowest wake pressures immediately aft of the car to help draw air through the diffuser. Extending the diffuser into the wake also subjects the top surface of the diffuser roof to the wake's low pressure, which would create an increment of positive lift that, at the very least, would negate any above/below pressure differential in the diffuser extension. And unless the rear wing is moved aft too, which may result in an undesirable balance shift, any positive interaction between the wing and the diffuser would most likely be weakened by the greater distance between the wing and the diffuser exit. Clearly these and other aspects could all be optimised as part of an initial design, but the original question remains: 'is it a valid generalisation that a longer diffuser will be better?' To find out, three longer diffusers were evaluated on our initial baseline model, and the results are shown in **Table 6**.

Gut feel suggested that there would be trade-offs that would not guarantee additional downforce from using a longer diffuser

The short answer then is that increasing the diffuser overhang had negligible influence on any of the key parameters, and there was no tangible change to the downforce generated by the floor and diffuser as its length was extended (see **Figures 15** and **16**). The caveat should be added that this trial was done on the original 12-degree diffuser so further work should be done on a better optimised diffuser.

This and other parameters will be examined in future issues.

Fluid situation

These days there's much more to CFD than just colourful spaghetti, as *Racecar* discovered when it talked to those at the cutting edge of this exciting design technology

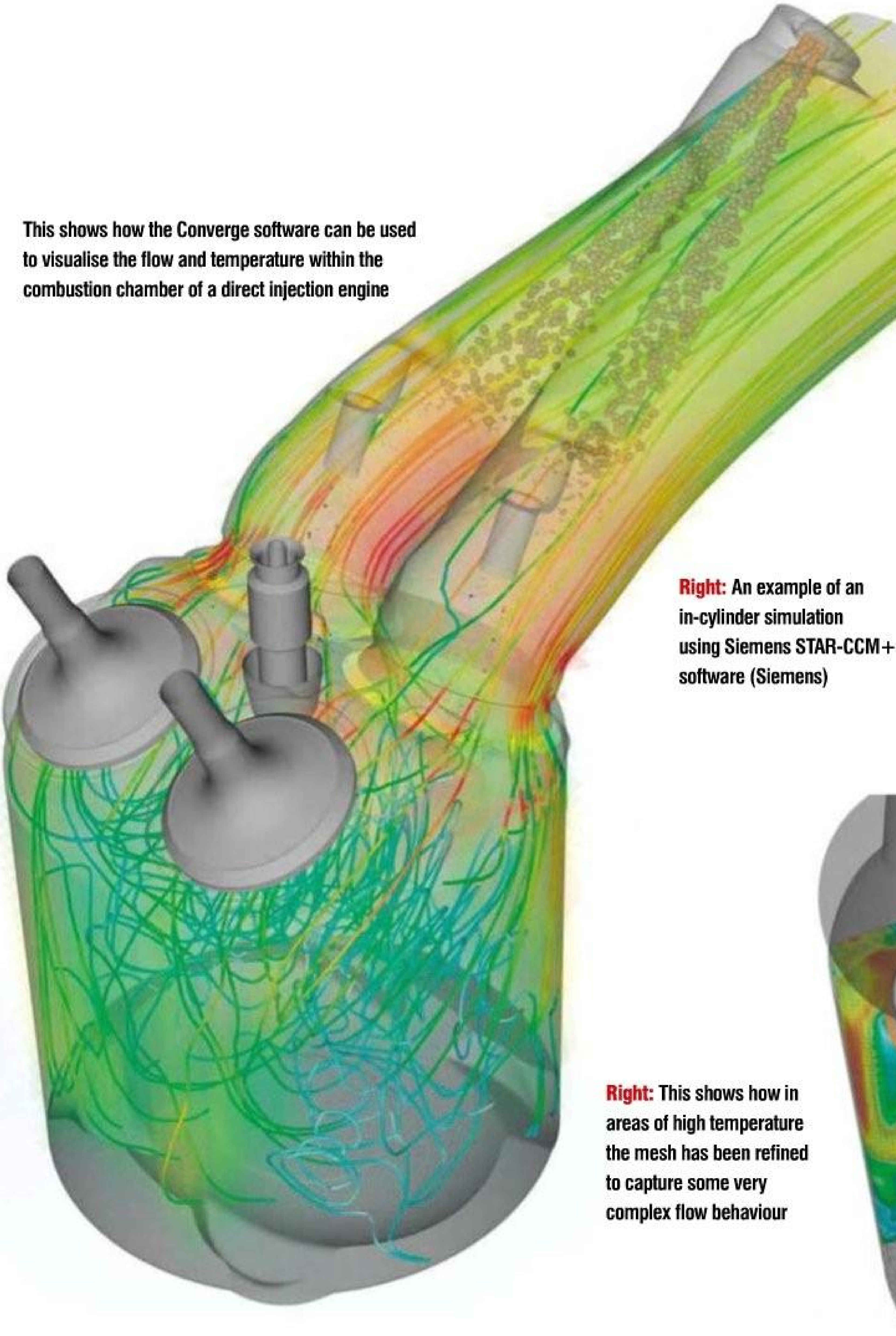
By GEMMA HATTON

To simulate the behaviour within an engine accurately, the CFD has to overcome more complex challenges than those found in general aerodynamics

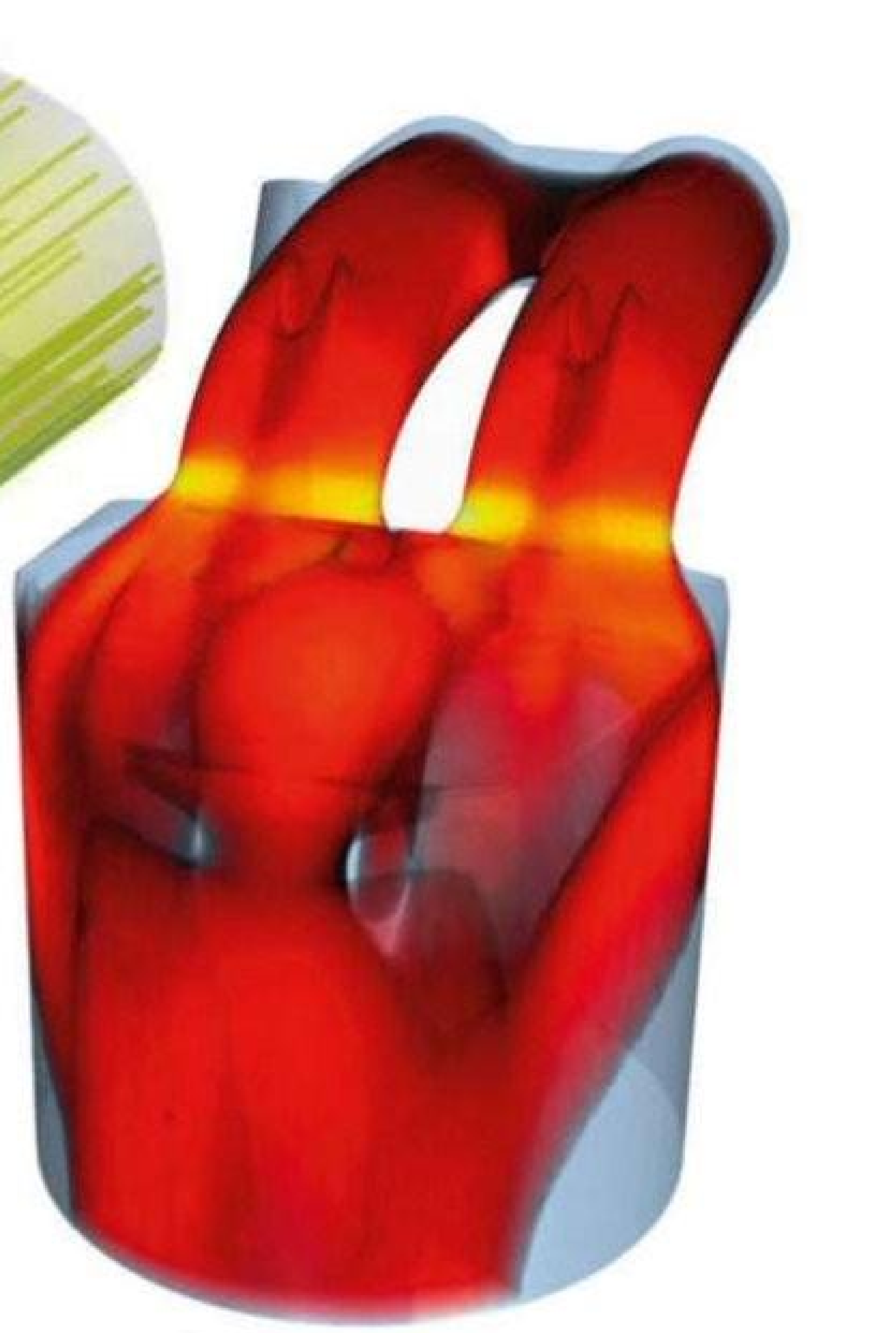
The Sahara Force India F1 Team filed a request to the FIA to modify the Sporting Regulations in favour of CFD last year. 'What we have today is a wind tunnel-biased formula, and what we are looking for is a CFD-biased formula,' explained Bob Fernley, its deputy team principal. 'We believe that in the foreseeable future – in three years or a bit more – there is a possibility that CFD could become the primary or only aero programme.' Although this was a strategic move to save millions on renting a wind tunnel, it does also demonstrate the importance of CFD. For a team who finished fourth last year to instigate F1's route to virtual aero development highlights just how realistic modern CFD software is becoming across all areas of the car.

We are all familiar with the mesmerising images of multi-coloured streamlines surrounding a racecar. What we don't often realise is that CFD can also be used to optimise internal flows within an engine to increase its performance and efficiency. 'Essentially, we use CFD to model the gas exchange and combustion processes within our direct injection engines,' explains Ian Whiteside, chief engineer of Advanced Projects at Ilmor Engineering. 'For example, we investigate the amount of turbulence generated in the combustion chamber, the interaction and distribution of the air and fuel mixture and the volumetric efficiency – all with the aim of optimising the combustion process and therefore generating more engine power.'

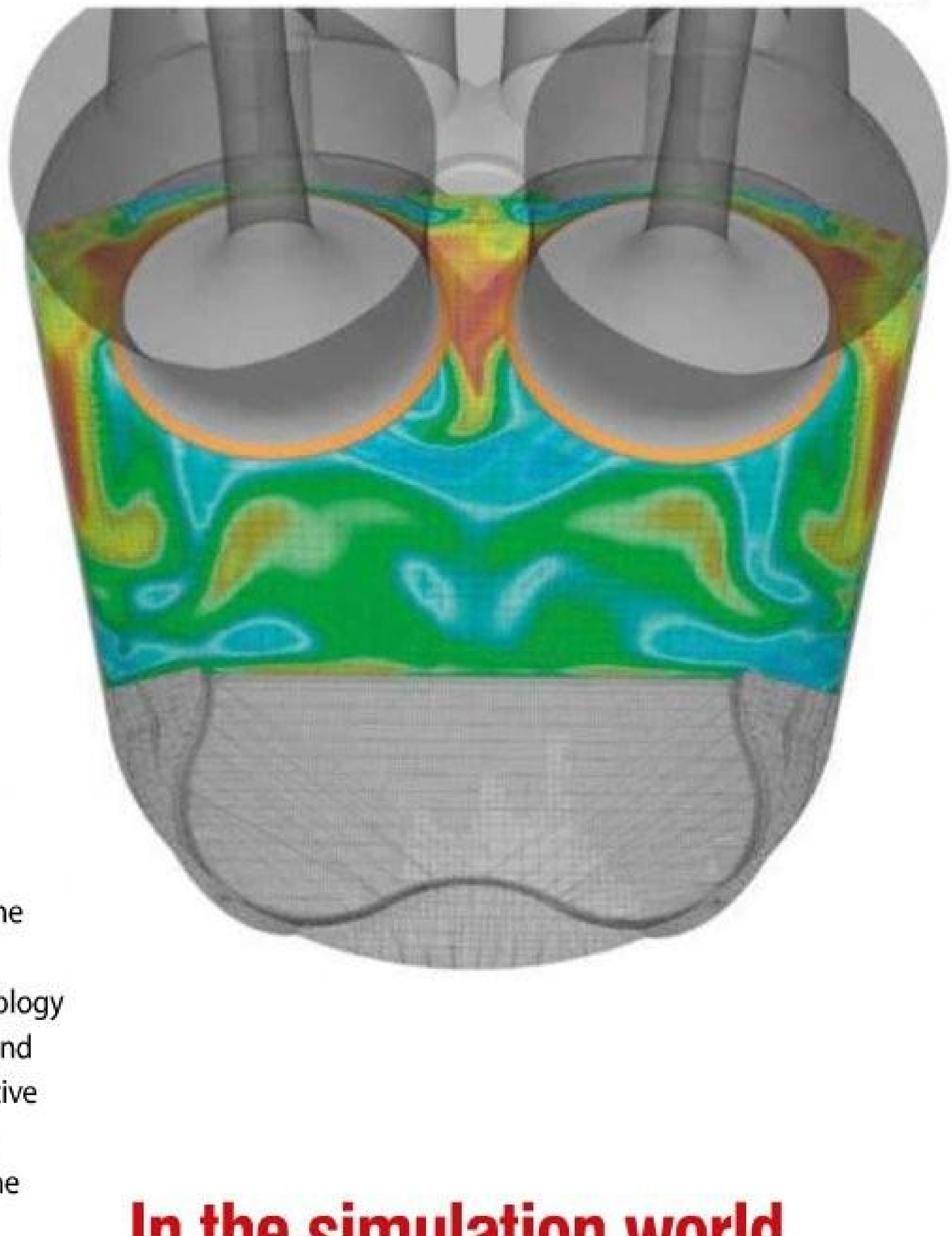
Ilmor is renowned for its high performance engines that have raced in an impressive array of championships including F1, Indycar, NASCAR and even the WRC. To maintain its competitive edge, Ilmor is utilising the advanced Converge CFD software to not only improve its technologies, but also to increase the efficiency of its development process. This is exactly



This shows how the Converge software can be used to visualise the flow and temperature within the combustion chamber of a direct injection engine



Right: An example of an in-cylinder simulation using Siemens STAR-CCM+ software (Siemens)



Right: This shows how in areas of high temperature the mesh has been refined to capture some very complex flow behaviour

what has been achieved, as Ilmor reduced its development time by 50 per cent which effectively saved eight weeks on the design and manufacture of the 2016 Indycar engine, whilst reducing prototype build costs by 75 per cent.

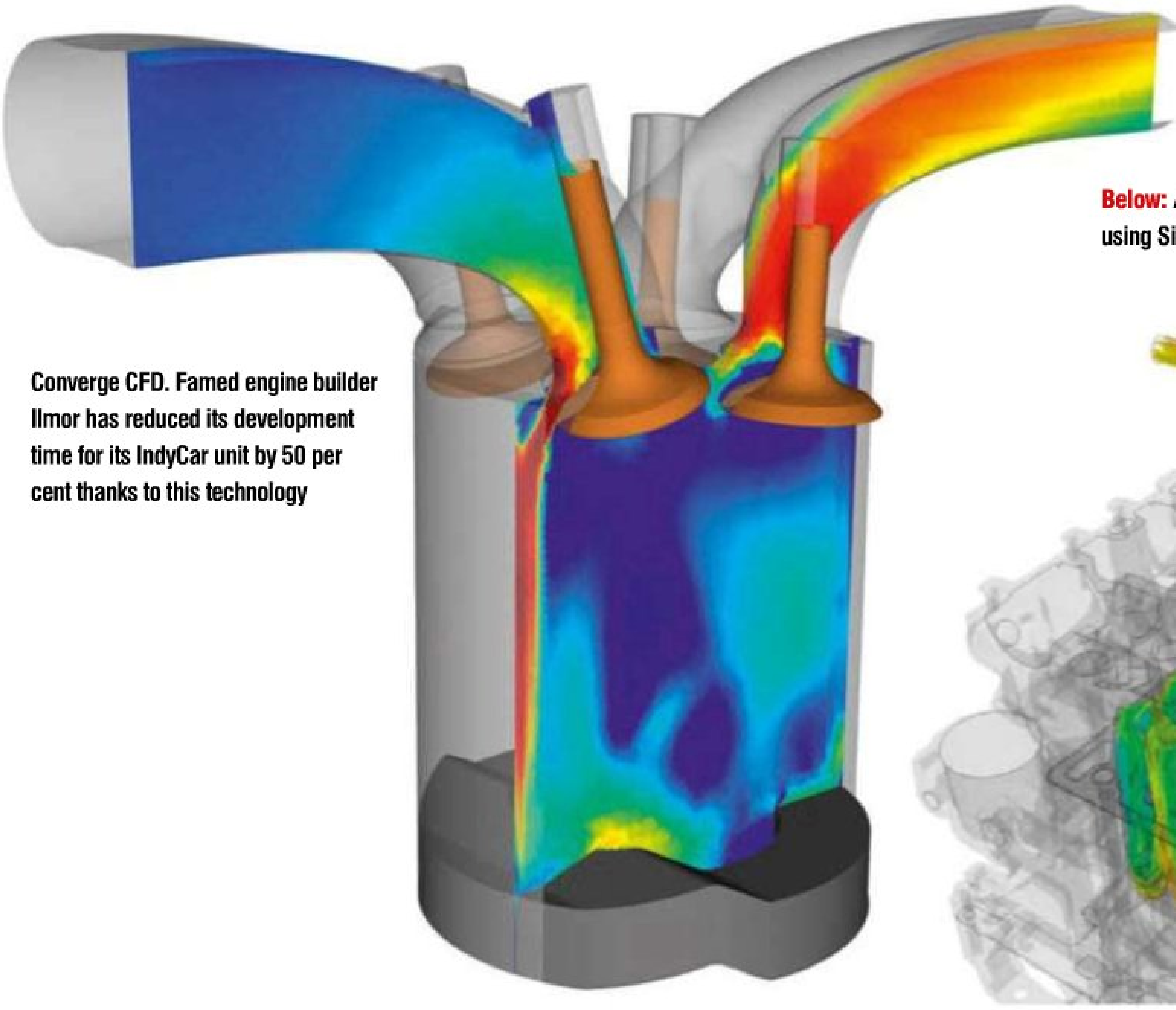
To simulate the behaviour within an engine accurately, the CFD has to overcome more complex challenges than those found in general aerodynamics. 'Firstly, the software has to model the movement of components with complex geometries such as pistons and valves,' explains Stephen Ferguson STAR-CCM+ marketing director, Siemens PLM Software. 'The second complication is simulating the complex physics of the combustion process and the reacting flows which needs to be modelled explicitly. You also have to determine the influence of the extreme heat generated on components and how to manage this by ultimately rejecting the heat to airflow in and around the car. In my opinion, engine simulation is one of the most difficult engineering problems that the motorsport industry has to face.'

One recent development in CFD technology which is proving invaluable for both aero and engine simulations is the concept of Adaptive Mesh Refinement (AMR). This is essentially automatic meshing which occurs during the run time of the simulation.

'For Ilmor, one of the main benefits of the Converge software is the automatic meshing,' Whiteside says. 'Our CFD experts determine the general grid size and define the areas where they want to refine the resolution of the mesh to capture complex flow physics. The rest is automated, which not only saves time from manually meshing, but also ensures that the same answer is achieved every run, regardless of who is controlling the simulations.'

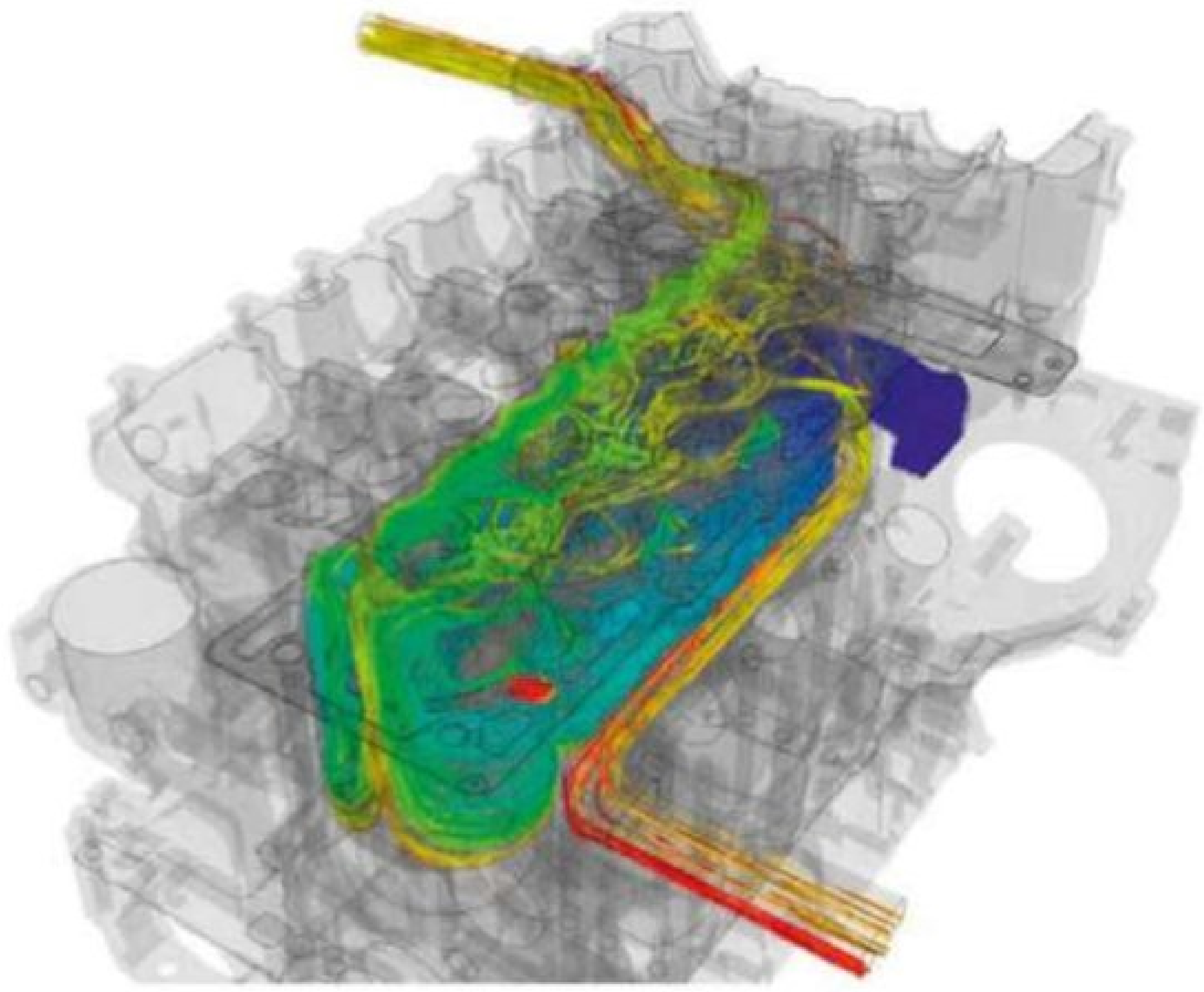
The Converge software uses an orthogonal mesh that is composed of cubic elements generated from the triangulated approximation

In the simulation world the Cloud's potential capabilities have been quickly realised and this is now leading to the evolution of a new simulation era



Converge CFD. Famed engine builder Ilmor has reduced its development time for its IndyCar unit by 50 per cent thanks to this technology

Below: An example of a water jacket simulation using Siemens STAR-CCM+ software (Siemens)



of surfaces found in standard CAD output STL files. AMR is also able to refine the mesh itself by subdividing the cubic elements in complex areas where the gradients are high. Therefore, the accuracy of the mesh can be greatly improved but only in areas where it is needed and only at the required times during the simulation. The benefits this gives are dramatic reductions in run time, enabling engineers to be more creative and investigate more ideas within the same time-frame.

For Siemens, highly automated meshing is one of the main reasons why its software is so successful within Formula 1. 'F1 is leading the way in terms of automation,' Ferguson says. 'Due to the hundreds of simulations run every day, the workflow has to be highly automated to ensure efficiency, so that highly trained engineers can focus their attention on analysing results rather than meshing, which is what our tools aim to achieve. The whole process of sourcing the CAD geometry, generating the mesh and making the simulation is best done automatically to ensure repeatability when comparing results.'

As well as automating a single run, additional optimisation tools such as HEEDS from Siemens allow you to automate a sweep of runs. For example, engineers define particular parameters such as a wing angle and HEEDS drives the STAR-CCM+ programme through hundreds or thousands of configurations and then post-processes the results into a report. Therefore, once up and running, the first time an engineer is involved in the process is right at the end when analysing the results.

With the continuing advances in computing power and simulation efficiency, a fully predictive CFD future is not that far away and, in some perspectives, it is already here

Design filter

CFD is still mainly used as a virtual filter to ensure that only the most effective designs are prototyped and tested. This is particularly true for engine simulations, where CFD is utilised in a more fundamental way as dyno testing occurs much later in the development process and can be extremely expensive. 'There are some subtle differences between the results from the engine simulations and the dyno, but overall we have a lot of confidence in the CFD,' says Whiteside. 'The question is, can you ever achieve 100 per cent correlation? I think it's unlikely, and although CFD is a fantastic tool for the overall process, Ilmor are still a firm believer that the dyno is the ultimate decider.'

However, with the continuing advances in computing power and simulation efficiency, a fully predictive CFD future is not that far away and in some perspectives, is already here. 'In F1, CFD is competing against wind tunnels and engine dynos,' Ferguson says. 'Therefore, in practical terms, it's accuracy only has to be as good as those test beds, so you could say that CFD tools are already fit for purpose. In general, CFD engineers are more interested in the resulting trends rather than actual values. Once they are satisfied with the accuracy of their CFD, they can then go on to simulating scenarios that cannot be tested in real life. For instance, a few years ago, Renault F1 were using STAR-CCM+ to test how hot exhaust plumes influence the rear end aerodynamics, which you would never be able to replicate in a wind tunnel. As the accuracy of the models and solvers continue to increase, engineers can now simulate on-track conditions, overtaking and cornering. Although these might not be 100 per cent accurate, neither are any other engineering tools.'

CFD for all

CFD is not just for F1 teams, though, and it is becoming more widely available, largely thanks to the Cloud. Traditionally, if you wanted to simulate the fluid flow around a racecar using CFD, you needed two things: 1) A license to use a software programme and 2) Access to high performance computing (HPC). Both of which are expensive, yet both of which can also now be avoided by using the Cloud.

'The whole process of purchasing a license, along with an advanced computer, and then installing the software is very time consuming and expensive,' explains Milad Mafi, academic program manager from SimScale. 'With SimScale, you simply log in on your web browser, upload your CAD STL file that you

want to simulate and everything else is stored and computed within the Cloud. This means you are no longer restricted, because you can work on simulations from wherever you are and on whatever device you want – you just need an internet connection.'

Access all aeros

This flexibility and reduced cost has opened the doors for smaller software suppliers, as well as customers and the keen individual, because now everyone can afford to run a simulation. It is this accessibility which is making Cloud based simulation solutions so successful. 'Our goal with SimScale was to make simulation accessible to everyone and you can clearly see the effectiveness of this strategy by the number of Formula Student projects we have on our platform,' Mafi says. 'These teams don't have the budget of an F1 team and we found that their biggest problem was, despite having access to the software, they had a lack of hardware and knowledge. Therefore, together with the organisers of the competition, we created a four day workshop, teaching the teams how to conduct a fluid flow simulation and then how to utilise this to improve the aerodynamic efficiency of their racecars.'

Over 40 Formula Student teams currently utilise the SimScale platform, which also enables a team to collaboratively develop their design, thus improving the team's efficiency.

The accuracy of the mesh can be greatly improved, yet only in the areas where this is needed

SimScale provides its CFD platform through the Cloud, thereby making this amazing technology available to all

Free flow

SimScale's ethos of accessible simulation is not only achieved through the convenience of the Cloud, but also the cost. For you or I to run a simulation, regardless of the complexity of the model or fluid behaviour, will cost us absolutely nothing. That's right – it's free, and your work will be automatically uploaded to the SimScale library. Cleverly, this has not only resulted in a vast database with hundreds of examples for users to read, but also stimulates further ideas for simulations. This perpetuating cycle means that whatever question you have or scenario you are trying to simulate, there is likely to be someone who has already solved your problem. In this way, the platform provides the answers, increasing your knowledge, which is another philosophy behind SimScale's platform.

However, when in competition, race teams are unlikely to want their designs available with a google search. Therefore, to ensure privacy, a professional subscription has to be paid. Regardless of your subscription type, everyone has access to up to 32 cores. A core is a processing unit which receives instructions and performs the necessary calculations, in CFD this is using equations to solve large linear algorithms. 'To run a CFD simulation, it will take a total amount of computational time and this depends on the complexity of your simulation,' Mafi says. 'For example, the higher the number of degrees of freedom or the finer the mesh, the longer the computational time. Let's say your simulation will take one hour when using one core. If you use two cores, it will take half an hour and so on. Usually, a full F1 car sim using 32 cores can take up to eight to ten hours, at the end of the day it depends on your required accuracy and how fast you need the results.'

To run a full car simulation, imagine that the CAD model is encased in a rectangular box which is the fluid flow domain. On one side there is the inlet to the system and on the other there is the outlet, both of which require specific boundary conditions as well as the floor. The relative velocities of the floor and wheels then need to be considered to ensure the car is actually driving through the air and the wheels are rotating. Many additional complexities can be added, such as the effect of the exhaust flow. It depends on how accurate you need to be.

'Most people prefer to run half car simulations and apply symmetry boundary conditions to save time,' Mafi says. 'We have three ways of meshing: tetrahedral, hexahedral and then both, so if necessary you can have control of every cell within the mesh to refine to your requirements. At the end of the day, all simulation users need to question whether they can trust the results. There is no point in saving money on simulation if you cannot make valid conclusions. SimScale uses the code based on an open source software called OpenFOAM which is used by the Mercedes and Sauber F1 teams. We have added our own GUI and integrated our own improvements.'

Clearly cloudy

Cloud based simulation solutions seem to solve many of the current issues found with traditional software programs. In addition to being accessible, it reduces costs, it is convenient, and even avoids the need for annoying updates, downloads or restarts, because every time you refresh your web browser you are using the latest version.

But there are always sceptics when it comes to new technology and in this case data security is the main concern. Yet data transferred between your computer and the platform is done via industry standard SSL encryption technology. External data centres and hard drivers on the company's servers are also encrypted by the same AES technology used to protect government documents.

Clearly, the Cloud is proving to be the next step in the evolution of simulation.

Best motion picture

Non-linear motion ratios will mean sums used for linear springs will be next to useless – luckily *Racecar's* numbers man has a few tricks up his sleeve

By DANNY NOWLAN

One of the most challenging areas of race engineering is how to deal with non-linear motion ratios. The reason it's such a very vexing question is because a lot of the assumptions and formulas that we use for linear springs go flying right out the window once non- linear motion ratios get introduced.

Fortunately, there is a way through the jungle, and we are going to discuss some techniques to help you not only to understand non-linear motion ratios, but also to use them to specify the lateral load transfer you are after.

Before we begin it would be wise to take a step back and consider the role lateral load transfer distribution at the front plays in race engineering. To make things simple we will focus on a symmetric set-up. So, to understand the role of lateral load transfer distribution let's consider **Figure 1** and **Figure 2**.

The magnitude and distribution shown in **Figure 1** is determined by the tyre characteristics which will dictate the spring and bar rates required to bring the tyres to temperature. The magnitude of **Figure 1** is also greatly affected by aerodynamics, race tracks, inertias, mass and ride height. Once we know the shape of **Figure 1,** then **Figure 2** will allow us to fine tune the front lateral load transfer distribution, since this will determine drivability.

I call this the racecar grip/balance equation. In all cases it is absolutely vital to have a good handle on the front lateral load transfer, which is what we'll discuss in depth in this article.

To kick this discussion off we need to define what front lateral load transfer distribution is. Mathematically this is defined as **Equation 1,** which, as far as equations go, is a pretty simple animal. But the details of calculating this are another story.

The linear version of **Equation 1** is very simple and to focus our attention I'll just look at the sprung mass load transfer. Also, to make this discussion simple I'm going to assume wheel rates. For a front and rear spring of *kf* and *kr* and bar rates of *krbf* and *krbr* it can be readily shown in **Equation 2**. At the wheel we have **Equation 3**. Manipulating **Equation 3** it can be shown as **Equation 4**. Doing some more manipulation of **Equation 3** and **Equation 2**, it may be shown as **Equation 5**.

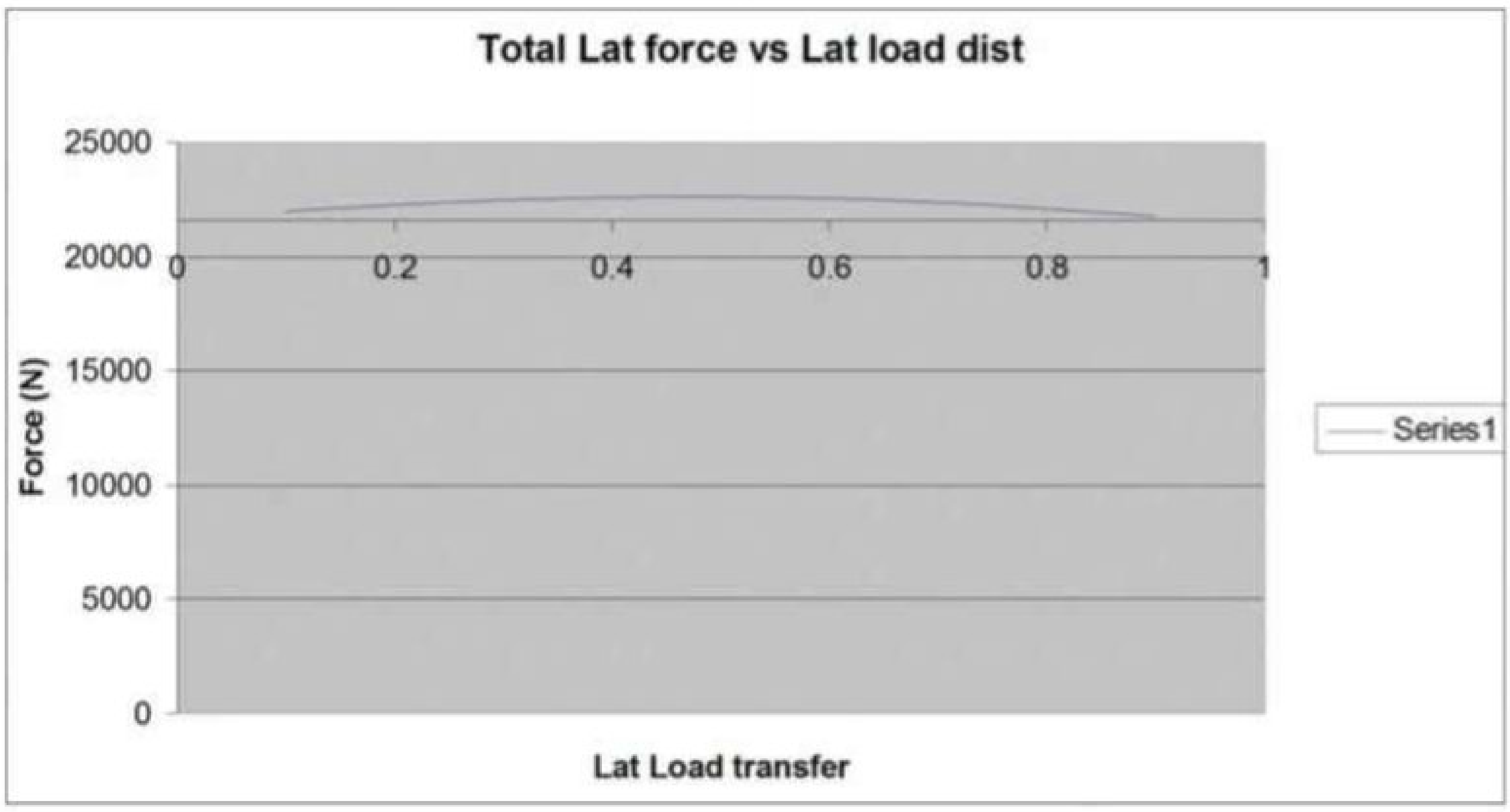


Figure 1: Total lateral force *vs* front lateral load transfer distribution. Magnitude is affected by tyres and many other factors

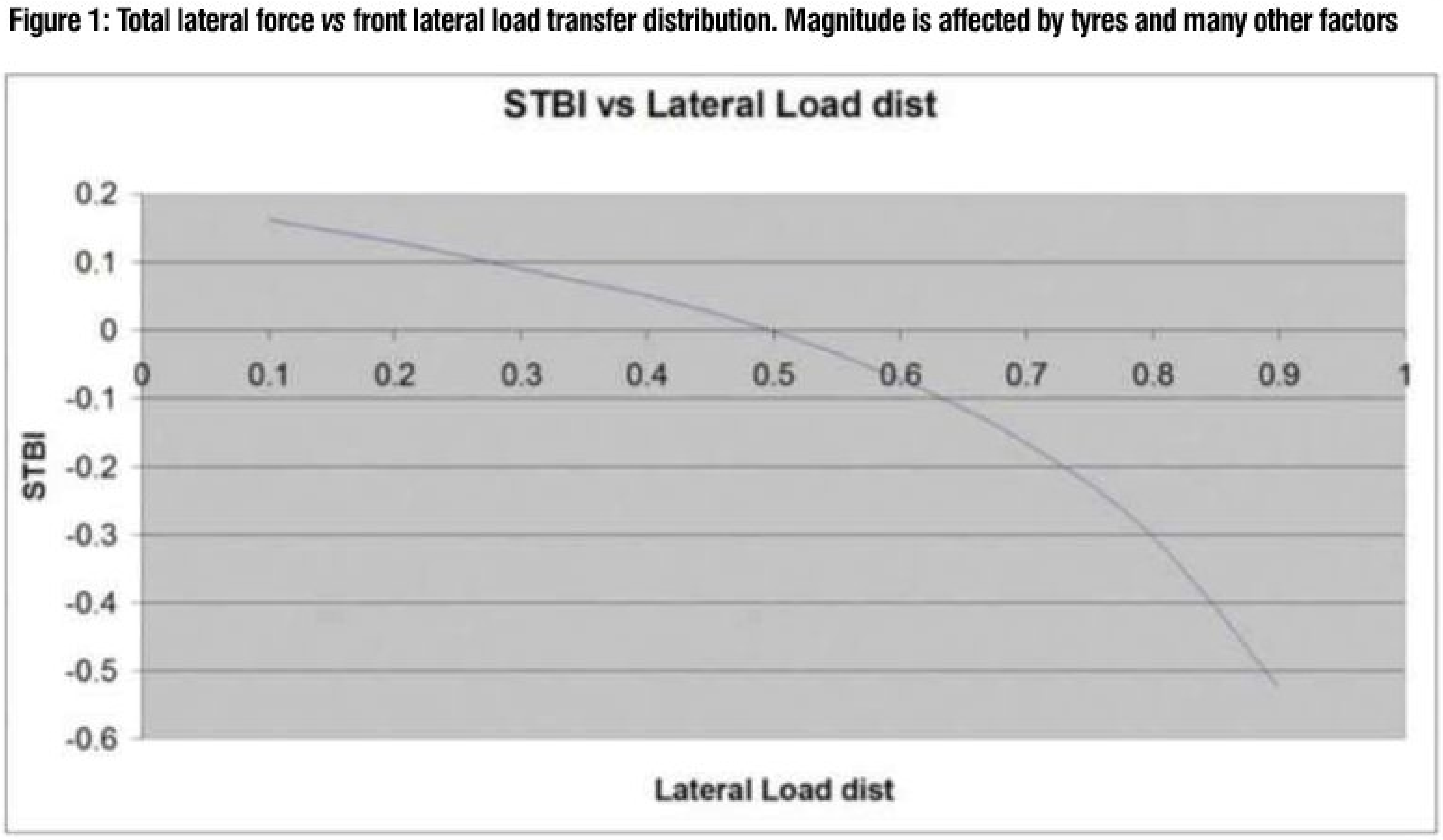


Figure 2: Stability index *vs* front lateral load transfer distribution. This allows us to fine tune the latter, and will show drivabilty

Non-linear relations

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.

Where things get tricky for the non-linear case is that the relation of spring rate times distance is now non-linear. For a given wheel movement the change in force for a change in wheel movement is given by **Equation 6**.

Here *MR* is the motion ratio (damper/wheel) and *x* is the wheel movement. Anyone who has been around differential calculus for more than five minutes will realise that to solve this you need to integrate it. So let's assume we have a non-linear motion ratio defined by **Equation 7**.

What this shows is that the wheel *vs* damper displacement curve is a quadratic, and it's amazing how far you can get along the road with something like this.

So putting **Equation 7** into **Equation 6** and integrating from 0 (full droop) to the sprung mass movement *sm*, shows **Equation 8**.

Believe it or not we can get something very useful out of **Equation 8**, but we need a magic trick. This magic trick is to define **Equation 9**. So using **Equation 9** and looking at **Equation 8** the effective wheel rate is given in **Equation 10**. Where k_{eff} is the effective wheel rate for a given wheel displacement *sm*. Note, to keep things consistent *sm*, the wheel movement from full droop, is in m.

Now this is where the rubber is about to hit the road. Recall **Equation 3**. Now plugging in the non-linear spring and not assuming a roll bar we have **Equation 11**. Solving for the wheel movements, we have **Equation 12**.

Here b_f and b_r are the pitch and heave movements of the front and rear of the car respectively, w_{m1} to w_{m4} are the wheel movements and k_{eff1} to k_{eff4} are the equivalent wheel rates for tyres one to four.

Where things start to get interesting is when we evaluate the loads. Plugging in the numbers this is seen in **Equation 13**.

So let's now define the relations given in **Equation 14**. Assuming that the sum of the effective spring rates are much greater than the difference, the lateral load transfer distribution is given by **Equation 15**.

Roll bars

So what happens when you throw in roll bars? To keep this discussion simple I will assume they are linear. In terms of wheel rates you will be looking at **Equation 16**. You then plug **16** into **15**. This is a bit of a dive for the deck. However I have validated it for a couple of settings so as an approximation it will get us by.

So how do we actually employ this? The best way to illustrate this is via an example. Consider a car with the parameters seen in **Table 1**. The non-linear motion ratio of interest is shown in **Table 2**. The first step in this analysis is to plot out wheel movement *vs* damper movement. We

We are going to discuss some techniques to help you not only to understand non-linear motion ratios, but to also use them to specify the lateral load transfer you are after

EQUATIONS

Equation 1

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

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 2

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

Equation 3

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

Here we have

k_{tf} = Front tyre spring rate (N/m)
k_{tr} = Rear tyre spring rate (N/m)
tf = Front track (m)
tr = Rear track (m)
w_{mf} = Front wheel movement (m)
w_{mr} = Rear wheel movement (m)
ø = Roll angle (radians)

Equation 4

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

Equation 5

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

Equation 6

$$\Delta F = k \cdot MR^2 \cdot \Delta x$$

Equation 7

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

Here we have

MR = Motion ratio
MR_0 = Motion ratio at zero wheel displacement.
MR_1 = Motion ratio slope

Equation 8

$$F = k \cdot \left(MR_0^2 \cdot sm + MR_0 \cdot MR_1 \cdot sm^2 + \frac{MR_1 \cdot sm^3}{3} \right)$$

Equation 9

$$F = k_{EFF} \cdot x$$

Equation 10

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

Equation 11

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

Equation 12

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

EQUATIONS

Equation 13

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

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

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

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

Equation 14

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

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

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

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

Equation 15

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

Equation 16

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

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

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

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

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_0	0.8
MR_1	1

Table 3: Wheel movement *vs* Damper movement

Wheel Movement (mm)	Damper Movement (mm)
0	0
20	16.2
40	32.98
60	49.8
80	67.2
100	85
120	103.2
140	121.8
160	140.8
180	160.2
200	180

Deducing the appropriate load transfer for non-linear motion ratios, while a bit tricky, is actually quite doable

We will need to correlate damper movement with wheel movement

need to do this because race data and simulators return damper movement not wheel movement.

For this analysis to work for us we need to correlate damper with wheel movement. So, all we do is integrate the terms shown in **Equation 2** and plot wheel *vs* damper movement. This is all shown in **Table 3**.

Lateral load

So how do we employ this to figure out the lateral load transfer distribution? The process is actually very straightforward:

- **Take all four damper displacements from full droop from either race data or simulation**
- **Use Table 3 to determine the wheel movement.**
- **Use Equation 10 and Equation 14 to determine the effective spring rates**
- **Use Equation 16 and 15 to figure out the Lateral Load transfer distribution.**

Let's illustrate this via example. For our racecar we had the wheel and damper movements that are shown in **Table 4**.

The next step is to figure out the effective spring rates. For brevity, I will just show this for the left front, as in **Equation 17**.

So the effective spring rate including the bar is shown in **Equation 18.**

In summary, the rest of the numbers are shown in **Table 5**. Finally the lateral load transfer distribution is given by **Equation 19**.

So, to validate 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 the simulation also takes into account damping, that is pretty good agreement.

Designing motion ratios

In order to automate this process rather than doing hand calculation you can incorporate all this into Excel and a screen shot of what I have been using is shown in **Figure 3**. It's not pretty, but it gets the job done.

To wrap up this discussion, how do you actually go about designing the motion ratios that you want? This is the procedure:

- **Go through your current damper displacements and play with the MRo and MR1 to dial in the lateral load transfer you want.**
- **Plug this into ChassisSim and run the simulation.**
- **Then, using an Excel sheet like in Figure 3,** see where you are at.

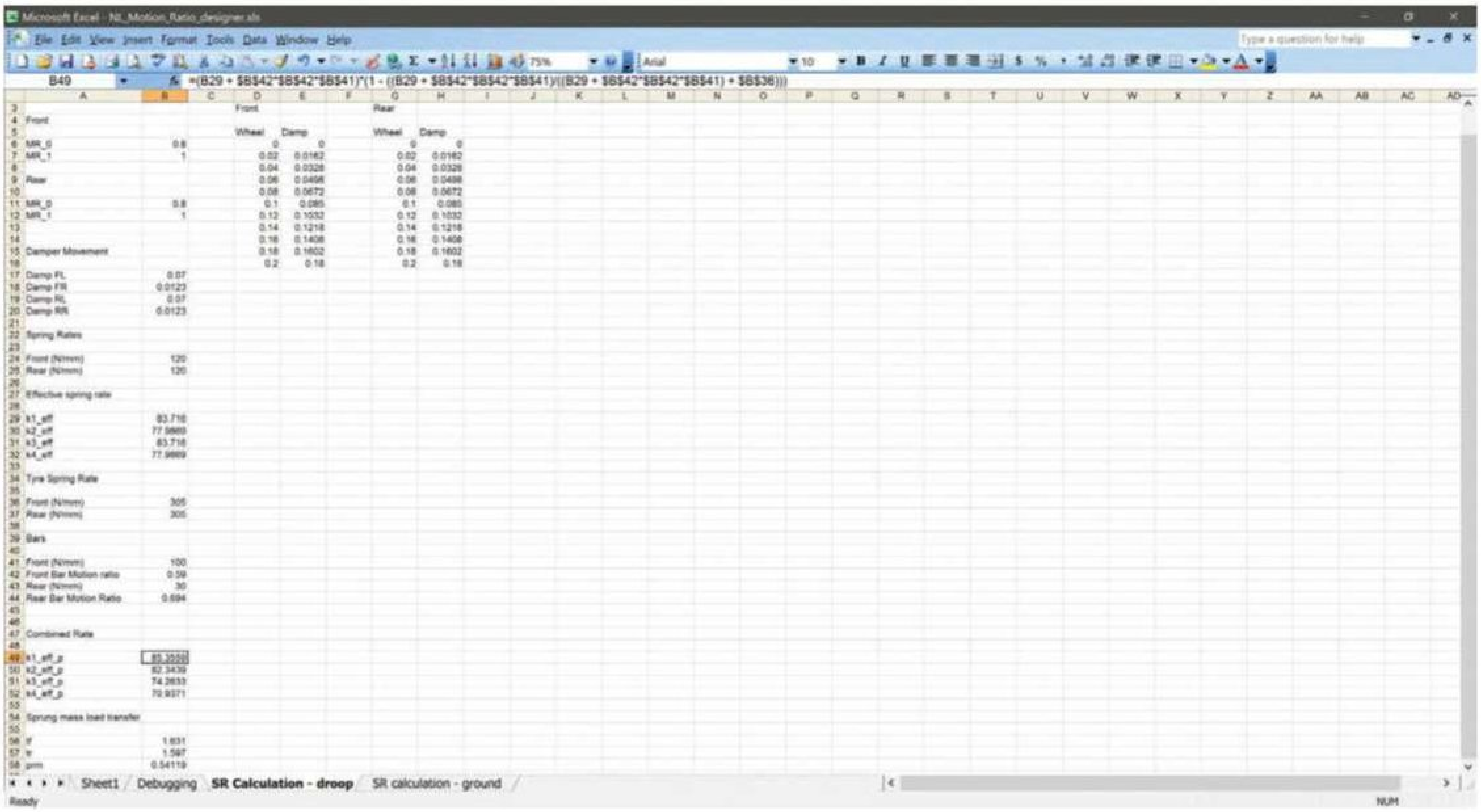


Figure 3: A screen shot of an Excel sheet used to calculate the non-linear motion ratios – this way you can 'automate' the process, cutting down on the many hand calculations

Table 4: 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 5: Effective spring rate numbers

	Effective spring rate
Left front	85.36N/mm
Right front	82.35N/mm
Left rear	74.26N/mm
Right rear	70.94N/mm

This is actually a really good example of how to appropriately use simulation, because now you are using it as a calculator, and used that way it's a very powerful tool indeed.

Summing up

In closing, deducing the appropriate load transfer for non-linear motion ratios, while tricky, is actually quite doable. The key here is to understand what drives it and then set up the appropriate tools in Excel. Then you use tools like ChassisSim to fill in the details.

This is where simulation tools make their presence felt, and if you're running a car with non-linear motion ratios you'd be crazy not to be using tools like this, and the analysis techniques we have just discussed.

EQUATIONS

Equation 17

$$k_{eff} = \left(MR_0^{\,2} + MR_0 \cdot MR_1 \cdot sm + \frac{MR_1 \cdot sm^2}{3} \right) \cdot k$$

$$= \left(0.8^2 + 1 \times 0.8 \times 0.07 + \frac{1 \times 0.07^2}{3} \right) \times 120$$

$$= 83.716 N/mm$$

Equation 18

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

$$= (83.716 + 0.59 \times 0.59 \times 100) \cdot \left(1 - \frac{83.716 + 0.59 \times 0.59 \times 100}{83.716 + 0.59 \times 0.59 \times 100 + 305}\right)$$

$$= 85.355 N/mm$$

Equation 19

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

$$= \frac{1.631 \times (85.36 + 82.34)}{1.631 \times (85.36 + 82.34) + 1.597 \times (74.26 + 70.94)}$$

$$= 0.5411$$

This is a really good example of how to appropriately use simulation

To boldly go

Ginetta swiftly recovered from the disappointment of losing out on the LMP2 contract and has bounced back with its own LMP1 design for 2018. *Racecar* took a peek at its plans

By ANDREW COTTON

Ginetta hopes that teams will be attracted to LMP1 over P2. The car is to go on sale for £1.34m, while the engine lease cost will be £594,000 a season

British firm Ginetta announced in January that it will launch a new LMP1 car that will be available for customers, and is eligible for the non-hybrid category at the Le Mans 24 hours in 2018, and the WEC. The company is planning to supply three two-car teams, each of the chassis powered by the Mecachrome turbocharged V6 engine that is derived from the new for 2018 Formula 2 (previously GP2) engine.

Despite losing out on the tender to become one of four LMP2 chassis manufacturers in 2017, Ginetta maintained a relationship with the ACO, having launched its LMP3. Then, when the new non-hybrid regulations were announced, it decided on the new LMP1 programme.

Gimmicks, including the moveable aerodynamic devices such as DRS, now appear to be off the table under the new regulations, which according to Ginetta are stable until 2022. As yet there is no word on the fuel flow limit that will be delivered to the French-built engine, but engineers are working to a power range of less than 700bhp, and a low chassis weight.

Classy chassis

Chassis construction is by ARS, which builds the Tatuus Formula 4 car, and its general manager, Piero Consorti, says that there is to be no scrimping on the design that Ginetta hopes will be on the grid for the opening round of the 2018 season at Silverstone. 'We have many solutions under development and we are clear that this will not be just another LMP car, it will be a real LMP1 chassis, so second to none,' says Consorti. 'In terms of lightness, materials used, capacity of manufacturing, only the best materials on the market will be used, and different options are under evaluation.'

Ginetta is targeting a minimum weight limit of 750kg, allowing up to 80kg of ballast, according to the regulations, and that will be used to help the front tyre to work effectively. A tyre development programme will be undertaken to produce tyres that are specific to a non-hybrid car, unlike the current LMP non-hybrid, which run Michelin front tyres derived from hybrid manufacturer spec that are developed to deliver around 400bhp from the hybrid system. Ginetta has a long-standing relationship with Michelin, but says that a deal is not yet done, while Dunlop is known to be keen on developing an LMP1 tyre too.

'I think that the front tyre is the challenge,' says Ginetta's technical director, Ewan Baldry. 'We want to make sure that we have something to be able to get the weight distribution forwards, and are looking at 46 to 47 per cent distribution towards the front and, if that turns out to be too much, then hopefully with the ballast we can move it back that way.'

To reach the low weight set, ARS says that it is using the latest in material technology, with the only limitation not budget, but availability. 'The main problems with the special materials is that they are limited in supply, so the best materials are usually a small quantity and we are trying to secure the right amount of those best materials,' says Consorti. 'At this time it is not a matter of price. This is an application where

Performance-wise Ginetta is looking to balance against the LMP1 hybrid cars, but with less than a tenth of their budget

Monocoque construction has been entrusted to ARS, which will be targeting a weight of between 54kg and 59kg for the chassis

The Ginetta P1 boasts a relatively high nose, which should bring aero benefits

Ginetta technical director Ewan Baldry says that getting the front tyres to work will be one of the major challenges with the new car

price is not the main problem. We are really analysing a lot of manufacturing techniques to deliver the final results. There is to be a good balance between high performance and weight and homologation.

'The chassis is designed by Ginetta, and what we are doing is the co-design, so the way that the manufacturing can apply to the design, and this is an important [point]. The designers want to design in their way, and manufacturing has other needs and they have to match. It will be a one-piece monocoque, and everything should be integrated, so no glue at all.'

Weighting game

ARS already has experience in the production of LMP1 and LMP2 chassis and crash structures, and will be targeting a minimum weight for the chassis of between 54kg and 59kg. The whole package will be, according to Ginetta, around 65kg lighter than a current P2 car.

Aero work is led by Andy Lewis, who previously worked on Porsche's aero package at the Williams wind tunnel, while Adrian Reynard's ARC company is handling the CFD for the programme. The team has elected to run a relatively high footbox, 275mm between the drivers' seat base and the height of the drivers' heels, offering significant aero advantages.

Mecachrome V6 is derived from the new-for-2018 Formula 2 unit but will be exclusive to Ginetta in DI form. It can run at hot water temps which brings aerodynamic benefits because of the lower cooling requirements

TECH SPEC

Ginetta LMP1

Chassis: ARS-developed

Bodywork: Advanced composite; carbon/Kevlar mix as appropriate. Windscreen, polycarbonate with hardened surface and heated elements.

Aero package adjustability: twin element rear wing; adjustable main plane and flap (independent); variable dive planes and tangency panels.

Engine (proposed): Mecachrome V6 Turbo GDI; performance determined by permitted fuel flow.

Transmission: Xtrac/Ginetta custom main case, 7-speed P1159 internals.

Brakes: AP Racing 6-piston monoblock caliper; adjustable sliding pedal box; Carbon/Carbon with spline drive discs.

Suspension: Torsion bars front and rear; Ohlins 5-way adjustable dampers.

Target L/D: 6:1 HDF, 5.5 LDF.

Dimensions: Length, 4650mm; width, 1900mm.

Predicted Weight: 760kg, allowing 70kg of ballast.

However, Ginetta says that it has a remarkable safety record, and intends to keep that in mind with the design of this new LMP1 car.

'The thing about Ginetta is that the safety angle is a huge thing for Lawrence [Tomlinson, Ginetta chairman],' says Baldry. 'You could take 50kg out of the chassis in the junior car that we produce, but you have 12-year-old kids driving them. Ginetta has an amazing track record for safety. They have had some huge shunts, particularly with the GT cars, and people have walked away from them. ARS has the challenge of delivering that [level of safety].'

Geometry set

The height of the nose, coupled with the need to work the front tyre under the new tyre regulations that permit only four sets, plus two joker tyres, for qualifying and the six-hour race, has clearly had an impact on the design of the front suspension, which will feature a standard torsion bar layout.

'It is not fixed yet, but relatively so because it is largely driven by the aero of the car,' says Baldry. 'We have not gone for the super high levels of the Audi [footbox] that never was, but we are significantly higher than the Porsche, and I suspect higher than the Toyota too, so there are challenges with the suspension geometry [from] having the raised nose. Because the wind tunnel programme has already kicked off in terms of the model manufacturing, we have had to nail that down. For this type of car, the suspension is conventional with torsion bars, Ohlins dampers and then an adjustable anti rollbar, third element, and we will package for inerters, but initially it will be conventional. Steering will be KYB electric power steering. We used it successfully in the G57, and have had discussions with them, and it seems that they are the logical solution.'

Customer service

The first chassis is due from ARS at the end of August, with track testing starting shortly afterwards. 'Our ideal scenario is that we have customers signed up and involved from the beginning,' says Baldry. 'We will have a test car, we have two drivers in Charlie Robertson and Mike Simpson, but we need to have someone experienced, too. We want to sign some customers early and have them involved. We had a chat with Rebellion and they were asking about the rear suspension geometry and whether we would give them the opportunity to adjust it, so I took that as saying they wanted some adjustability!'

The Mecachrome V6 engine is derived from the F2 unit but is exclusive to the Ginetta LMP1. Performance will be limited by the fuel flow meter, and Ginetta has yet to decide on which meter it will use, but in non-fuel flow format it has reached around 750bhp for the duration of the 7000kms completed on the dyno.

The engine is configured as a 'hot V', similar to the current F1 engines and the LMP engines from Porsche and Audi. Complete, the package is said to weigh in at 122kg. It can run at high water temperatures (120degC), offering further aero efficiencies due to lower cooling requirements. 'In terms of the fuel flow, it is a moving thing, and the one problem that they have is that they only have one car to play with and that gives some limitations,' says Baldry. 'We need to be lobbying the ACO in order to get a sensible fuel flow. The figure that has been mooted is 108 or 110, which we believe pushes us in the 600s in terms of horsepower.

'You can make some fairly generic suggestions where we will be,' Baldry adds. 'The car will be 65kg lighter than an LMP2 car, and the simulation says it will be quicker. We would be on confidential tyres, and the customer will decide on the tyre it will use.'

Cooling comes from long-term partners PWR and the current plan is for a water-oil heat exchanger for the engine. The team is planning an air conditioning package, too.

Bosch will supply the electronics and the suite of sensors is to be included in the price of the racecar. The whole package is for sale at £1.34m, with the engine lease package charged at £594,000 per annum.

The gearbox is supplied by Xtrac, and features internals taken from Rebellion's LMP1 programme in 2016, with an external casing

The whole package will be around 65kg lighter than a current LMP2 car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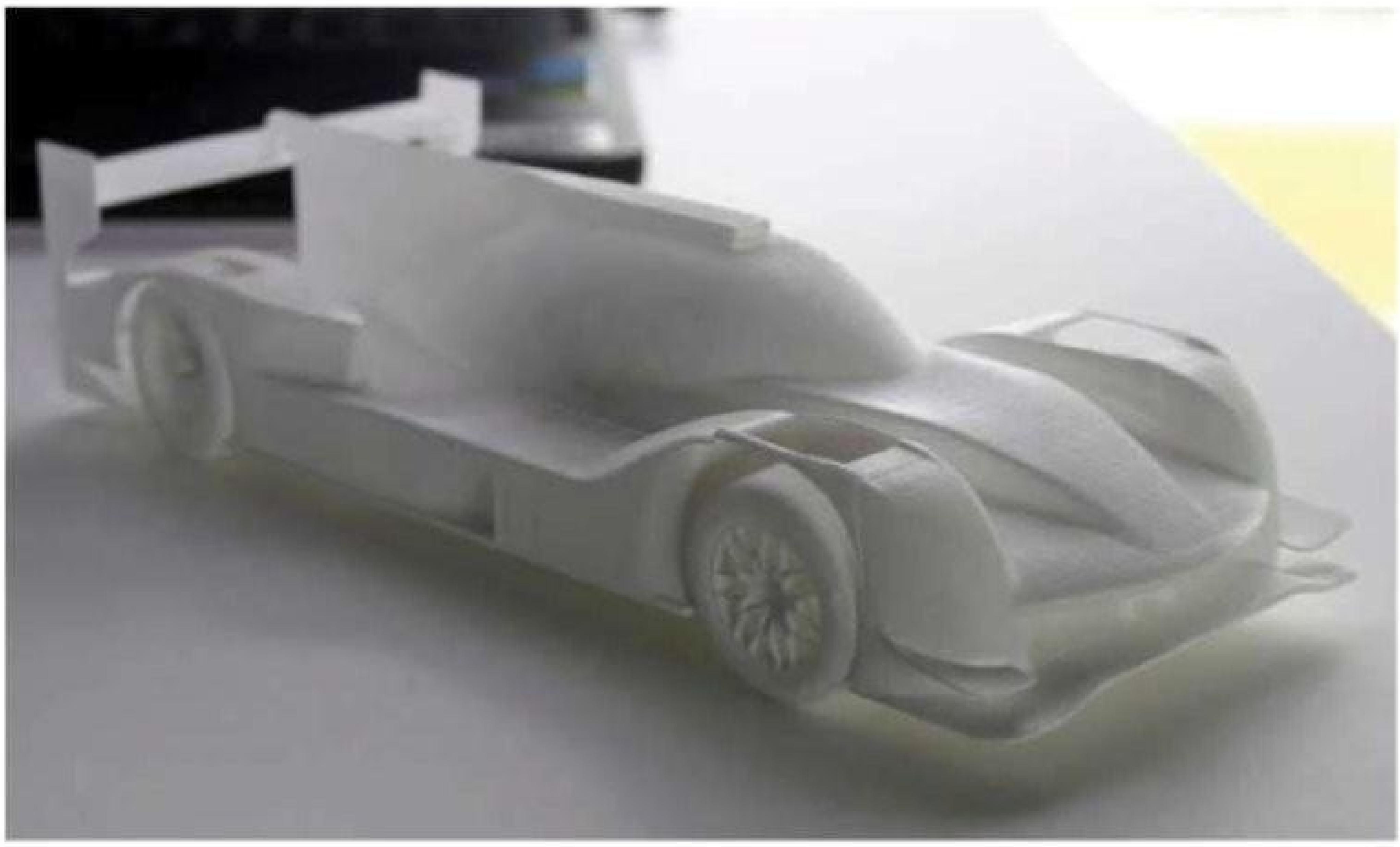
'Our ideal scenario is that we have customers signed up and involved from the beginning'

specific to the Ginetta programme. 'The box that we are using is what is used in three of the four P2 cars. So it was initially designed for Rebellion for the P1 application, and now used in P2,' says Baldry. 'We are only using the internals of it. The casing is of our design so all the suspension pickups are designed by us, and we can twist the internals so that they are lower and further forwards, and where we would have to have the off-the-shelf component we would need to have a bellhousing too, and that would compromise the stiffness and the weight. The main case is one piece that bolts to the back of the engine. Going back to the Peugeot LMP1 car, it was done like that. We will take up that space with catch tanks, overflow for oil, and things like that.'



Model for success? It's unlikely Ginetta will challenge the hybrid teams but its new LMP1 car could succeed commercially

Delicate balance

Performance-wise Ginetta is looking to balance against the LMP1 hybrid cars, but with less than a tenth of their budget. But it is difficult to see how the Ginetta could do anything other than finish behind the manufacturers. From an engineering standpoint, even with the reduction in aero for this year's LMP1 cars, the Toyota went faster at Silverstone than ever before, and politically it wouldn't do to be quicker than the big cash injectors.

'Chassis-wise, because we have certain breaks compared to the hybrid cars, although they clawed that back, we have potential advantages, such as a weight advantage,' says Baldry. 'There will be a lot of politics involved, it will conflict with Porsche and Toyota if a privateer car, at £2m a year when they are spending so much by comparison, [does better], so there will be a conflict, but I think that the ACO will use that fuel flow limit to put the car where they want it to be. Where they want it to be is uncertain, but around a circuit like Silverstone, the hybrids [might] be a couple of seconds up on us, which at Le Mans is four seconds, so that would put [us] three or four seconds quicker than the P2s.'

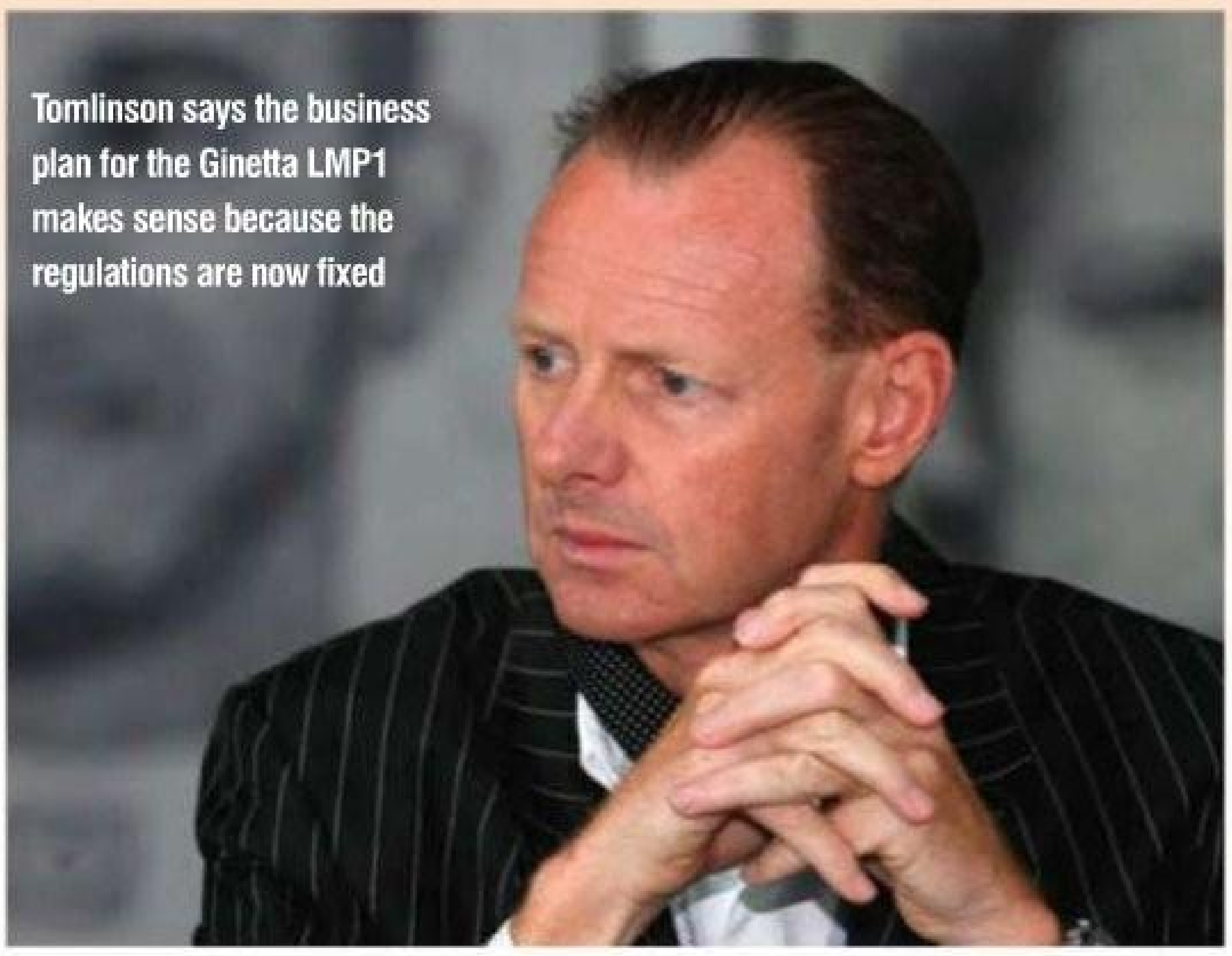
See P98 for the editor's comments on the Ginetta LMP1 programme.

Ginetta boss Lawrence Tomlinson talks LMP1

'I think it is an exciting project for us. Technically we worked with the ACO to develop the LMP3, and you could have said that could not have been a success. We saw sense in the business model, and we developed 15 cars. We worked hand in glove with the ACO to develop that category, but there are technical regulations that are open to everyone who wants to race in it. The ACO and the FIA say that the [P1] regulations are also fixed for a number of years so we are just working to build a car to those regulations, which seems to be a straight-forward job.

'Those will be fixed and there are technical working groups for LMP1, and we are part of LMP1. When you put your homologation form in, and pay the fee, you then go to the technical working groups. With the inside knowledge of being a member of the technical working group, we are happy to progress with this business plan because we think it makes sense. It is a great opportunity for Ginetta with the partners that we pulled into this programme. They are absolutely world-class, every one of them.

'We are keen to work with the ACO and the FIA to develop a sustainable category. Many people have come into LMP1 and spent huge amounts of money and not been overly competitive because the concentration has been on one or two cars. They have had to shoulder the whole of the development cost and made decisions based around designs by various different people with various amounts of success. Any partners that comes on board with Ginetta [will be getting] the Williams wind tunnel, Mecachrome, Paolo Catone, Adrian Reynard, Xtrac gearbox with specifically designed casings with reliable internals, we have 7000km on the engine on the dyno, it is not something that an individual would really take on. While we have these partners, we also have a huge team at Ginetta to manage the project. We are very skilled, and we have bolted onto that other aero specialists.



Tomlinson says the business plan for the Ginetta LMP1 makes sense because the regulations are now fixed

'There is one class that is LMP1 and the ACO and the FIA will come up with the technical regulations that will ensure the long-term sustainability of the category. Clearly, LMP2 cannot be LMP1, and it looks from all the indications that we get that they want LMP1 to be competitive and not have the situation that we had with the Ginetta Zytek 09S, where you knew that you were second class car in the P1 class. That was unsustainable, proved to be unsustainable, and people were spending huge sums of money and it didn't make sense. How do we make this make sense, and make LMP1 sustainable? The answer is this category and these regulations, which I think are very sensible.'

There is now a new Balance of Performance system for GTEs in the World Endurance Championship. It relies on race data being fed in to a complex algorithm

Sense of balance

The ACO and FIA have addressed the thorny old issue of a workable BoP in the WEC with a new automated system. *Racecar* investigates

By ANDREW COTTON

The continuing Balance of Performance (BoP) saga in the WEC has taken its next step as the ACO and the FIA have released more details of the automated system. Race by race, data will be fed into an algorithm that is available to all teams, allowing them in effect to check the BoP. Needless to say, this has led to a whole new world of complaints, although overall teams and manufacturers seemed to be in favour of the new system.

Opposition took two forms; one was that this was confirmation that the ACO and FIA had no control over the BoP in 2016 as suspected, and the other was that the success of the system was absolutely dependent upon there being an accurate starting position for the BoP.

The first point is now irrelevant, and the second will only be found out during the opening races of the WEC season.

The Le Mans 24 hours is outside the auto BoP, and the conditions under which the cars will race there will only be determined after the test early in June. The only exception to that is the performance of the Porsche GT3 RSR that debuted at Daytona and then raced at Sebring under the IMSA BoP system, which in turn was determined

The FIA will use race data from the opening round of the WEC at Silverstone (pictured is a Ford GT at this race) and the second round at Spa for this season's new auto BoP system

following tests at Ladoux, France, in September and during the winter months in the US.

The BoP is dependent on analysing the 60 per cent fastest laps of a race, if the right conditions are met for that race. The FIA was unwilling to hand out a copy of the algorithm, but says that it is comprehensive and was developed in conjunction with the manufacturers. There were more than 20 versions of the algorithm before it went live, and there is potential for more if anyone notices a glaring error in the system.

'The fact is that what is decided through this auto BoP is to consider first of all some conditions of eligibility of a race itself, to be suitable to provide some good view of the performance of the car,' says the FIA's Denis Chevrier. 'That depends on the conditions, climatic conditions, some expected lap times and everything, so there are some conditions to say that this race is eligible, to say that the auto BoP will be applicable.'

'The system was designed to recognise when a racecar is not performing to its full potential'

Data gathering

The first two races of the auto BoP system, at Silverstone and Spa, will be used solely to gather data, then the first auto BoP change will come at the Nurburgring in July. 'We see that from one stage of development, or understanding of the cars, there is a ramp of progress,' continues Chevrier. 'The knowledge of the car and management of the tyres [will be seen], which will be integrated in Le Mans 2017 BoP, and with the challenge to enter within that a new car.'

The auto BoP is clearly designed to avoid the sandbagging for which manufacturers are known, but the system was designed with the car makers and the FIA to also recognise when a car is not performing to its full potential. If one car is seen to be performing badly, it will be struck out of the system and it will be clear to all who have the algorithm to see why. 'What could be done by a competitor intentionally to hide some performance during the first two races, will be known by everybody,' says Chevrier. 'If some people are desperately slow, they go out of the eligibility of the performance of the car itself. We have talked about the eligibility of the race, but there is also the eligibility of the fastest car of the model of car, which is the one taken into consideration. If, for any reason, the fastest of one model of car is not at a reasonable level, it is not eligible. It is not possible that you are so bad. It is not a human input, it is automatic. In correspondence with an average car, yours is outside the capability.'

Florida key

To reach that all-important starting point, the FIA and ACO worked closely with IMSA, which itself had pre-season tests before Christmas and after the New Year before 36 hours of combined racing at Daytona and Sebring. It was not one-way traffic; IMSA also wanted to know what the FIA had done to the Porsche.

The two series have different styles of racing. In the WEC, cars are deliberately given more power than in the US, but while the US system is largely based on the last hour sprint to the

The new auto BoP algorithm is applied to a 60 per cent sample of fastest laps so anomalies due to driver errors, mechanical issues or lost time in traffic should not muddy the water

flag, in the WEC with the virtual safety car, any time lost from the green flag onwards must be made up on performance.

'We have some relationship first by the way the ACO is linked with IMSA, and the FIA, and we exchange data and points of view and have regular conversation between us,' says Thierry Bouvet, International Technical Delegate of the ACO who works closely with the FIA. 'In America with a full course yellow, it is more of a sporting thing, but here we have six hours of sprint racing and there is no need to wait for the final hour; everyone pushes from the beginning of the race, while in IMSA the game is to stay on the leader lap until the last hour of the race. Typically it is a sporting difference.'

The team acknowledges the political pressure that manufacturers are under to gain a cheap advantage

In terms of tyre usage there is another difference; in the pit stops US teams can change tyres and refuel at the same time, meaning that there is no loss to teams for single stinting their tyres. New rules in the WEC, which limit the tyre usage to four sets for qualifying and the race, mean that double stinting is necessary.

'If you do not take into account the way that they are capable of keeping the tyres consistent, you miss this, so that is why the amount of laps taken into account is better to distinguish a car that is capable of maintaining performance, despite the tyres getting old,' says Chevrier.

Window addressing

If there is a large discrepancy in the starting point of the system, the FIA has limited itself to a 10kW, and a 20kg adjustment window. The plan is to not have a pendulum effect of weight and power going on and off race-by-race. With the different nature of the circuits, and the different tyre usage by teams, the system is already retrograde enough. What happens, for example, if a car is more than one second off the pace and requires a large adjustment?

'Is there potential for that deficit?' asks Bouvet. 'After last year, with all the analysis that we have done, plus Sebring and Daytona for the Porsche as a new car, we need to level this car as a competitor. Everyone brought this year new tyres, so that is an unknown factor, but if we are talking one second, if you want to translate one second to kilogrammes, how much would that be? When we did the simulation we needed to add 100kg to a car to balance it, how many times did you see in the GT category that magnitude of change? Never. What we try to do with the chassis manufacturers, we try to integrate that one track would suit one car, for example, and we try not to overreact, otherwise it will be plus 100kg, or minus 100kg, so you need to temper that range.'

In the spirit of co-operation, the BoP for Le Mans in 2016 has been distributed to the

Ford (left) is expected to introduce an update kit for its GT next year and this will be treated as a new car for BoP purposes, with a performance estimation to be based on the current car. Completely new GT racecars will be much harder to quantify

teams and they have been invited to comment. However, the BoP team acknowledges the political pressure that manufacturers are under to gain a cheap advantage, but it says that it is protected from outside influence. Where the major problems lie is not in what it can see, but what it cannot see.

'What is clear is the consideration that there will always be a new entrant, with either one or two more cars compared to the previous year, so you cannot make everything as if it was a consistent field of competitors,' says Chevrier. 'It deserves some special care.'

New car issues

If an entrant brings an update kit, as Ford is expected to do in 2018, then it will be treated as a new car in the BoP. Ford will no doubt be invited to offer an estimation of improvement over the current car, giving the FIA an idea of what to expect. However, the real problem comes when a manufacturer arrives with a completely new car, such as BMW, with no previous experience, other than the adapted GT3 car that races in the US.

'It could come from a manufacturer who had a car before, it is capable of knowing the performance of its car compared to its previous car, but you can also have a completely new competitor, such as BMW, and it cannot tell us what percentage better than a previous racecar the new racecar will be, simply because they don't have one,' says Chevrier. 'And that is why we need the Le Mans test.'

As with all algorithms, there is a potential for making a mistake. 'It will happen,' says Nicolas Auberg, technical delegate of the FIA. 'The algorithm works well, and we won't make any big mistakes because we tested it and everyone had the opportunity to say that they are happy with it. In the end if there is a mistake, all the manufacturers know the philosophy that we have, and we have a lot of meetings, and if the algorithm doesn't show what we want it to, we have the power in the FIA and ACO to change it. The idea was to rebuild some lap times without any BoP to give a starting point for the auto BoP and test it. Everybody built the system together.'

The jury's out

'We started to have meetings with the ideas,' Auberg continues. 'And because we had the opportunity to test the 2015 and 2016 years, it was able to do as good as we did last year, even though we were not the best for BoP. At that point, everyone started to think that it was robust, looking at a difficult season with the tyres and sandbagging. The auto BoP was able to give good results that were even better than what we had. [But] we don't know how the manufacturer will behave with the auto BoP.'

This is a long game and the ACO and FIA won't know until the last race of 2017 whether or not their system is a success.

Where the major problems lie is not in what it can see, but what it cannot see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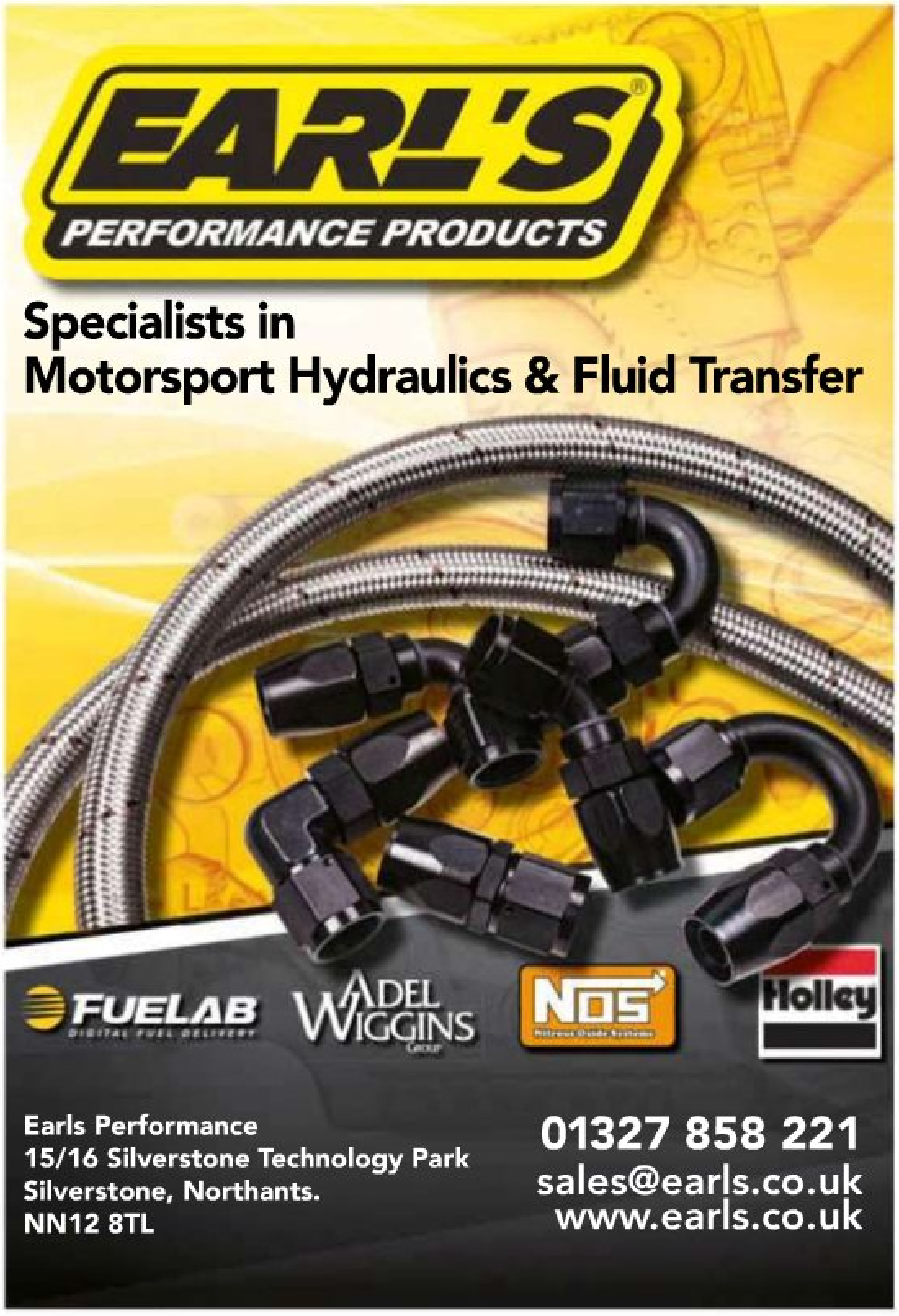
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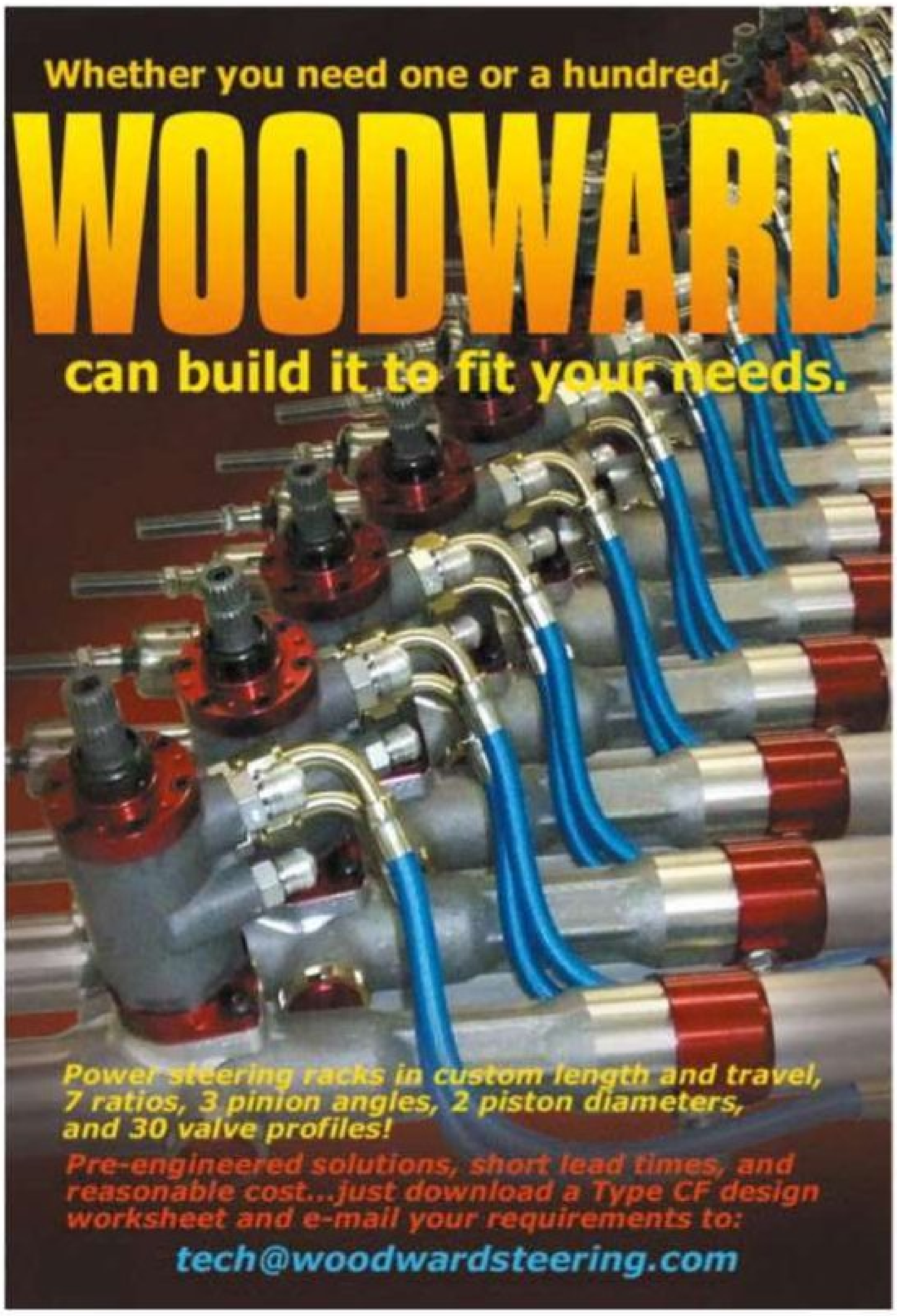
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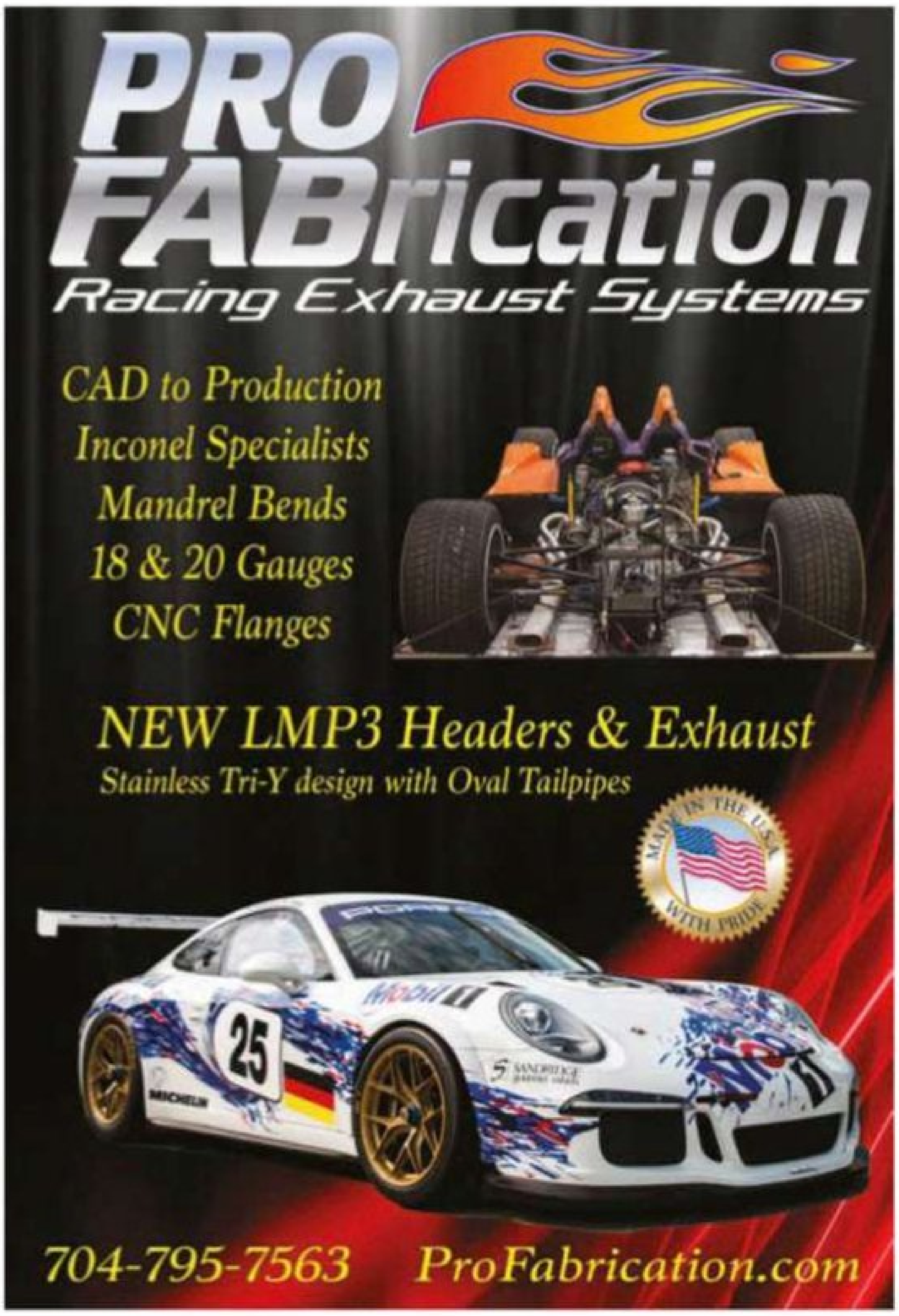
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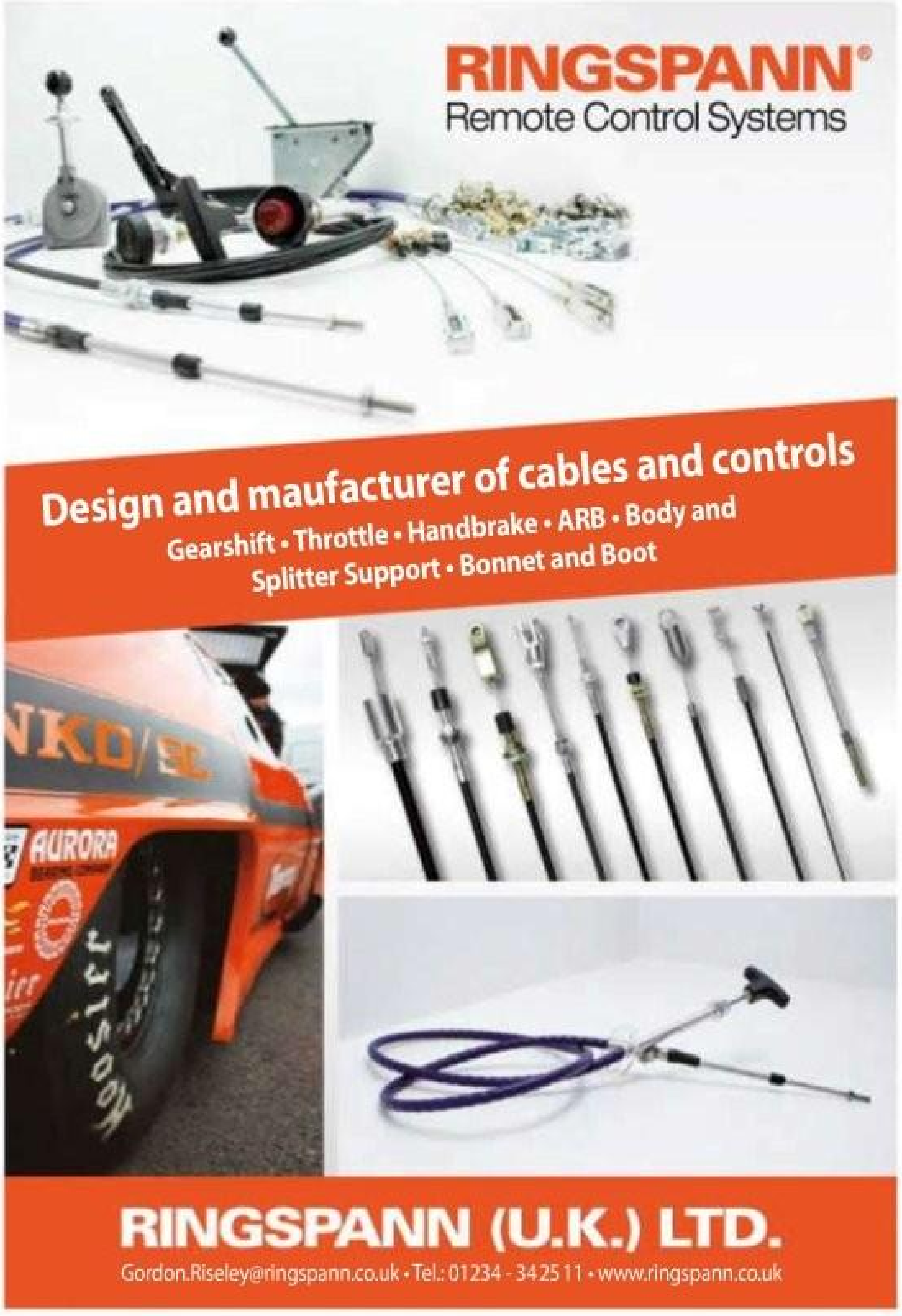
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Thundersteer

Can a Land Speed Record car actually be steered when it reaches jet plane velocities? Opinion seems to be split

Bloodhound is aiming to hit a cool 1000mph. But will the aerodynamic effects at such high speed actually overwhelm the mechanical steering making its pilot, Andy Green, little more than a passenger?

I have recently been considering the steering systems on Land Speed Record vehicles. Like Thrust 2, Bloodhound uses a rack and pinion steering unit. The unit in Thrust 2 was an Adwest built for buses, but with the length and stroke modified to suit and the power boost removed to increase steering feel.

A steering ratio of 25 to 1 was chosen for Thrust 2 that gave good results with both rubber tyres and solid wheels. Thrust 2 had a 60/40 weight distribution that put a static weight of 4800lb on the front wheels. Peak speed on Thrust 2 was 650mph, about 350mph slower than the projected top speed of Bloodhound. However, according to its designer Ron Ayers, at some specific Mach number the ground under Bloodhound will become fluidised and the car locked on course by aerodynamic forces that will overwhelm mechanical steering, so Bloodhound won't actually be steered at 1000mph, although its rack and pinion unit will be equipped with power boost. This raises the issue of whether at some point the need for steering feel becomes moot. I have, through building and driving my prop-driven car, some first hand experience with driving based entirely on visual cues instead of feel. Stan Barrett also steered the Budweiser Rocket car based entirely on visual cues.

It would seem that steering forces on a transonic or supersonic car might be a combination of mechanical grip, aero effects, and gyroscopic precession. In a CFD analysis it was proposed that cross-flowing air between the rear wheels on Thrust SSC generated the lateral force experienced by Andy Green.

In 1963 the Flying Caduceus was modified after computations had shown once the front wheels went through more than one degree of travel, they would cease to be effective for steering and slide over the salt while the car continued in the direction in which it was travelling. That car was equipped with a tail fin and rudder connected to the steering linkage so that for each one degree the front wheels travelled the rudder would move three degrees.

When the wheels were turned right the rudder would move left and vice versa. Using the rudder system, the driver made consecutive runs of 314, 350, 359, 354, and 355mph. From the 359mph run onwards the car was being run at full throttle but the engine was not indicating more than 90 per cent rpm.

Tom Burkland once described how in his streamliner, since the front wheels were driven, they were slipping to a degree that compromised their steering ability. So once, just for a test, he turned the steering yoke to the lock at 400mph to see how the car responded and got no reaction. Near maximum speed he could only place the car on the course within about 40 feet laterally (half the track width). It would be interesting to know whether Green had a similar experience with the diesel streamliner.

I remember reading comments by Green where he expressed some amazement at how Gary Gabelich was able to steer The Blue Flame with its high ratio of 90:1. The answer to that could be because The Blue Flame accelerated so rapidly, it was quickly in the window where aerodynamic forces overwhelmed mechanical steering. I'm sure you've seen or done the classic physics demonstration where a person sits on a revolving stool holding a spinning bicycle wheel and rotates in the same direction in which they lean the wheel. I'm not an expert on gyroscopic precession so, since that demonstration involves moving the wheel in a different axis than a wheel being steered on a Land Speed Record car, I'm not sure it directly translates, but mathematical analysis that accounts for this effect could be informative.

Franklin Ratliff, Florida, USA

ANDY GREEN'S REPLY …

Your letter raises a lot of questions! I can't really comment on the implied stability and control of the Burkland car without knowing more about the steered wheel deflection, likely aero effects of the steered wheels (from memory, the cars wheel fairings go almost to the ground) and some idea of the yaw static margin. I'm not convinced by the idea of putting full lock on at 400mph 'just to find out what happens' as part of a test programme. I wouldn't do that.

The only thing I can comment on is the line that 'near maximum speed I can only position the car to within 40ft'.

JCB Dieselmax was fully controllable throughout each run, up to a peak of 365mph, so it doesn't have to be like that.

You will not be surprised to hear that Dieselmax behaved exactly as predicted.

'The ground underneath Bloodhound will become fluidised and the car will be locked on course by aerodynamic forces'

Andy Green (left) says the Dieselmax was fully controllable for each run, even at peak speeds of 365mph. The fin at the rear of the projectile is for yaw stability at high speed

I was aware of crosswind effects, but they were easily controllable.

At an event like Bonneville Speedweek, it's easy to check for crosswinds, as there are lots of other cars running. Before each run at Speedweek, I spent about 10 minutes at the start line watching the cars immediately ahead of us – their salt plumes give a very clear indication of the wind behaviour down the track (until about Mile Five, when the plume is getting too far away to see, mostly due to the curvature of the earth). We didn't have this indication for the FIA runs with Dieselmax, but then we didn't really need them – we'd already proven the car's handling in crosswinds.

For Bloodhound, we're using some simple technology to monitor the wind. A network of solid-state anemometers down the track will give live crosswinds as we get ready to run, so I know what to expect (we will aim to run in limited crosswinds early in the programme, until the handling has been proven). We can also compare car handling on each run with the measured winds down the course. The network has already been tested – they took it down to the beach near Bristol last year; any excuse to get out of the office!

Wing Commander Andy Green, RAF. World Land Speed record holder

RON AYERS SAYS …

When Tom Burkland says that he can only place the car to 'within 40 feet laterally' at top speed, he does not say (and probably did not know) what the crosswinds were like. Travelling near maximum speed, and with maximum usable power applied to the wheels, adhesion will be so low that a crosswind gust can push the car violently sideways. It may not be obvious to the driver why any particular deviation occurred.

Fins in crosswinds

When Andy was driving Dieselmax, I positioned myself near the start of the measured mile. At that point I might reasonably guess that most cars were near the max velocity/limiting adhesion point. On that day there was a strong but steady crosswind (left to right across the track) that began around the measured mile start so I was well placed to observe what happened when the cars encountered this. Some designers had not worried about yaw stability and had fitted no fins at all. Most of the ones who were absolutely determined not to go unstable had gone to the other extreme and had fitted fins that were (to my eye) much too large. The results were rather as one would expect. On arriving at the crosswind 'channel of air' the big fin cars deviated to the left and the fin-less ones to the right – sometimes going outside the width of the track. I imagine that both groups of driver would afterwards say something like 'I could not place the car within 40 feet laterally'. The cars that appeared unaffected had modest sized fins.

During the design of Dieselmax I had discussed the yaw stability problem with Andy and we had agreed to aim at a yaw static margin of about two to three per cent of vehicle length. I had the advantage of using CFD so I could design to a specific yaw stability target, and the result appeared to be successful in that Dieselmax seemed to be substantially unaffected by the crosswind. I was still pioneering the use of CFD on cars at the time (only Thrust SSC had previously benefitted from it) so we also took a replacement (and larger) fin to Bonneville 'just in case' but did not need it.

Not many Bonneville designers have the resources to use either wind tunnels or CFD, so what should they do? Well, I would recommend the following. On a side-view drawing of the car, mark in the centre of gravity position. Now sketch in a fin size that moves the lateral centre of area some two to three per cent of body length behind the centre of gravity. You should now have a side view that an experienced designer would probably agree will look about right. I have frequently been complimented on the appearance of Dieselmax which is widely agreed to 'look right'. However, it had the advantage of having four-wheel-drive. I've not designed for front-wheel or rear-wheel drives so have not seriously thought about them.

Positive yaw stability

The reason for the success of having a small positive yaw stability is clear enough. When the car hits a crosswind gust it is knocked slightly head-to-wind and the driver just bears away instinctively to keep on track.

It is certainly true that by about 600mph the wheels on Thrust SSC were significantly under-speeding relative to the ground speed. After a high speed run, a glance at the track showed that the surface had been fluidised to a depth of several inches. Perhaps this should not be surprising since the inter-particle adhesion was never going to be very great and was easily broken by the mechanical trauma caused by a 10 ton vehicle charging overhead at sonic speeds accompanied by its ground-penetrating shock waves. However, the deduction that Bloodhound will be impossible to steer at higher speeds is, quite simply, wrong.

The primary side forces on the car will be aerodynamic. Thus the car, stabilised at the back by its large fin, will be steered in the normal way by the front wheels. However, the aero side loads could well be much greater than the sideways push on the sand particles. I have not yet got a clear idea of their relative importance. That is still on my 'to do' list, together with cross-wind gust sensitivity at up to 1000mph. Sadly, there is no prior art to guide me in these studies.

As far as vehicle dynamics is concerned, think 'supersonic hovercraft', or maybe 'supersonic hydrofoil'. Should be fun.

Ron Ayers, chief aerodynamicist Bloodhound SSC

> **'Once, for a test, Tom Burkland turned the steering yoke to the lock at 400mph, just to see how the car responded'**


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Interview – Dilbagh Gill

Indian summary

Mahindra Racing's team principal tells us why Formula E flicks all the right switches for the Indian car manufacturer

By MIKE BRESLIN

XPB

'When I asked for a reasonably big budget for this season, Mahindra did not question it'

There must be a warm feeling within Formula E right now. Because, whatever you personally think of it, there's no doubt the electric race series is now pretty much an established part of the international motorsport scene. Drivers are seeing it as an honourable and challenging alternative to other series – it even has its cadre of former F1 stars – and, much more importantly, manufacturers are beginning to flock to it, to the point where Formula E boss Alejhandro Agag is asking for its future 12th team to pay €25m for the privilege of taking part, while Mercedes and Ferrari are now both looking to join Audi, Renault, BMW, Jaguar and others on the Formula E grid.

Those manufacturers who were involved at the very beginning might be feeling a little smug right now, then. Companies like Indian car maker and leading exponent of electric mobility Mahindra, for example.

Dilbagh Gill is the team principal at Mahindra, and he says that the larger Mahindra group is benefitting from its faith in the series, having at once seen Formula E as a perfect fit for it: 'You have to bear in mind that Mahindra is one of the world's oldest producers of electric vehicles,' Gill says. 'We have been producing electric cars for over 20 years, and this is something that we increasingly see as a market to produce products for. Formula E was perfect, because we're expanding from our traditional markets of India, South Africa and Latin America, and this was perfect for us to show where we are going. By 2020, 25 per cent of the Mahindra product line will be electric, so Formula E fitted particularly well.'

Spark life

Formula E also ties in nicely with a new range of high performance electric production cars which is to come on the back of Mahindra's purchase of a very famous name in the world of car design. 'We are trying to upgrade our capability, firstly by acquiring Pininfarina last year. And with Pininfarina coming in we are going to be producing a high performance car, and Formula E will be providing the power. Mahindra has launched a company called Mahindra Electric, which will make the platforms for the entire range of Mahindra vehicles, and also adapt the powertrain from Formula E,' Gill says, adding: 'The formula E team has helped Mahindra with their understanding of high voltage systems.'

It's fair to say that Mahindra is happy with its involvement, then, and Gill emphasises this point quite succinctly: 'Well, when I asked for a reasonably big budget this year they did not question it.' He would not disclose Mahindra Racing's budget, but estimates for a season in FE for a team are around the area of €10m, and ever-rising, mainly because of the manufacturer involvement mentioned above – for with car maker kudos comes car maker spending.

'Costs are going up at a faster rate than we all wanted them to go up,' Gill says. 'But then again, a lot of the things that we are developing here are very relevant to a road car programme. If you look at the proportion to relevancy to what will turn up on road cars, it is much higher than other motorsport. That is important. The race to road technology is here, and for a company like Mahindra, that is huge.'

Currently, the technology being developed by the team is based around a single axial motor, mounted transversely and driving through two gears. It's a Mahindra-developed powertrain with Magneti Marelli motors, though Gill says: 'Magneti Marelli supply the motors and the inverter, but it is Mahindra designed. So the intellectual property of the motors and inverters is owned by Mahindra.'

Software updates

One of the frustrations for FE teams is that powertrain development is restricted in-season. The designs are locked in from the start of the competition, which has the knock-on effect that the development race focuses on software. 'On the electric powertrain a lot can be achieved through software, and we are getting most of our efficiency improvements this way,' Gill says. 'We are expecting improvements this year of between one and one and a quarter per cent, through software. There is continuous improvement in using the motors and inverters which can be altered through software. In addition to this we are also working on improving gearshifts.'

Race weekend set-up on the car is undertaken by personnel supplied by Campos Racing. 'The team is structured so that there are Mahindra engineers and Campos mechanics,' Gill says. 'So, what I call the heads of department, are all people from Mahindra; the chief engineer, the chief mechanic, simulation; they are all direct Mahindra people. So, today, we have eight

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people directly from Mahindra, and 30 people from Campos. Campos is responsible for running the car, the set-up etc.'

At the time of writing the team was fifth in the championship, but earlier in the season it was riding high in second place. A coming together between its two drivers, Nick Heidfeld and Felix Rosenqvist at the Mexico City round (which was caused by another driver) has knocked it back a bit – but the pace is undoubtedly there.

Electric avenues

But it's not just the team's performance that has improved, Gill insists, FE as a whole has come on in leaps and bounds and there's much more to come. 'The technology improvement over the last two years with the powertain has gone further than I think anyone expected at the start of the championship. We are ahead of where we wanted to be at this point in time, which is really good. But you will see a lot of exciting things happening in the next 18 months when we move towards what we call the season five cars; a single car that will last an entire race [rather than the current car change mid-race]. So in four years we have doubled the energy density and range, so we are going to have the same weight of a car running around for double the time, and that will be a significant achievement,' Gill says.

But while Gill is almost evangelical in his support for FE, he does admit that there is room for improvement, particularly when it comes to the calendar. 'We need to get a steady calendar, so that people know when a race is coming to their area. While we race in the heart of iconic cities like New York, Paris, Hong Kong, etc., there needs to be a fixed weekend for Formula E to visit a particular city. The gaps between races needs to be reduced to a maximum of three weeks, too. But being primarily a winter series is really good.'

Running over the winter is just one of the things that differentiates Formula E from other series, but perhaps the one subject that has initiated most debate in motorsport circles – at an almost existential level – has actually been Formula E's decision to run a series for autonomous cars as support races at its meetings, for many believe that Roborace – as it's called – is simply not what racing is about.

But Gill disagrees: 'Autonomous vehicles are the future, and we will all be using autonomous vehicles in the future. So I don't see why some people can't understand Roborace. Roborace is relevant. Okay, it's unique. But it is relevant.'

Which was the sort of thing people were saying about Formula E just four short years ago.

Mahindra was one of the first manufacturers to embrace FE and it is now the Indian car maker's flagship motorsport programme

RACE MOVES

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Well-known all-rounder and one-time Formula 1 racer **Stephane Sarrazin** has formed his own rally team, Sarrazin Motorsport, to run a Hyundai i20 R5 and a Skoda Fabia R5. While still maintaining his commitment to Toyota's World Endurance Championship programme, and competing in Formula E with Venturi, the 41-year-old intends to develop his motorsport preparation business from its base in Cevennes in France.

Alberto Bombassei, president of brake maker Brembo, has been nominated for induction into the prestigious Automotive Hall of Fame. Brembo was founded by Alberto's father, **Emilio Bombassei**, and his uncle **Italo Breda**. He has served in various roles at the company since 1961, and has overseen its expansion and research efforts, and has been involved in breakthroughs such as the design and production of the first aluminium calipers.

Steven Costello is now the series director of the Pirelli GT3 Cup Trophy USA, an all-Porsche multi-class series. Costello, whose time in motorsport started as a driver and mechanic in Formula Ford, has had a varied career which has included spells working in Formula 1, IndyCar and NASCAR.

Randy Buck has also joined the Pirelli GT3 Cup Trophy USA (see above). A long established driver coach and instructor, Buck is now race director for the series, with a brief to oversee the on-track activity during the 2017 season.

Jeremy Vaughan has been appointed head of motoring – previously known as motoring secretary – at the Royal Automobile Club. Vaughan has over 25 years of experience in media and events at Haymarket Media Group, where he helped publish magazines such as *Autosport*, *Classic & Sports Car*, *Autocar* and *F1 Racing*, before heading up Haymarket Publishing's activities in Asia and Australia.

Mike Collins is no longer president and CEO of SCCA Pro Racing, the SCCA Ventures Board of Directors has announced. Collins, a veteran of the United States Marine Corps, took over as president last September following the resignation of former IndyCar president of operations and competition **Derrick Walker** from the post.

Sam Ard, a former NASCAR Xfinity team boss and also a two-time champion in NASCAR's second tier series when it was known as the NASCAR Late Model Sportsman Series (winning it in 1983 and 1984), has died at the age of 78. He won three races during his six-year spell as a team owner, all at Martinsville Speedway.

Bo Beresiwsky, vice president Facility Operations at the famed Mazda Raceway Laguna Seca race track and the Sports Car Racing Association of the Monterey Peninsula (SCRAMP), has retired after 40 years with the track and its operating company. Beresiwsky's role included maintaining the entire facility, including the Laguna Seca Recreation Area.

Former Williams F1 aerodynamicist **Andy Lewis** has been appointed head of aero for the forthcoming Ginetta LMP1 project. In his new role Lewis will oversee the aerodynamic development of the Ginetta WEC LMP1 L, set to debut in 2018. Lewis comes from BAE Systems and has also worked at Porsche's WEC programme, where he focused on the aero testing of the 919 Hybrid LMP1.

Long-time Indianapolis 500 entrant **Dennis Reinbold** has teamed up with Mike Harding, of Indianapolis-based paving company Harding Group, to field a car in this year's 101st running of the great race. IndyCar veteran **Larry Curry** will be team manager and competition director at the outfit, called Harding Racing. **Matt Curry**, Curry's son, who worked for AJ Foyt Racing last year, is the team's lead engineer.

OBITUARY – Tim Parnell

Tim Parnell, who died recently at the age of 84, was the son of successful racing driver Reg Parnell. He started his career in motorsport behind the wheel, but was unable to find the success his father enjoyed and went on to make a career in F1 race team management.

Parnell junior raced in sportscars, Formula 2 and then Formula 1. He took part in four F1 world championship grands prix, the first in 1959, but only qualified for two of them and failed to score a championship point. His only finish was a 10th place in the 1961 Italian Grand Prix at Monza.

He then took over the running of his father's Reg Parnell Racing team following his death in 1964, the outfit then running ex-works Lotus chassis with BRM engines.

The team's best world championship F1 race result was fourth in the 1968 Italian GP, with Piers Courage driving its BRM P126. However, it closed its doors after the Monaco Grand Prix in 1969 and Parnell moved on to manage the works BRM team, overseeing the last four wins it scored in F1, including famous victories such as Peter Gethin's hair's breadth win at Monza in 1971 and Jean-Pierre Beltoise's surprise triumph in the rain at Monaco in 1972.

In later years Parnell was the vice-president of the BRDC.

Tim Parnell 1932-2017

RACE MOVES – continued

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The FIA is set to launch an official Hall of Fame later this year to help celebrate the great and the good of motorsport throughout its history, similar in vein to those run by NASCAR and the Indianapolis Motor Speedway. FIA president **Jean Todt** (pictured) has said it intends to open two halls of fame, in fact, one to be based in Paris and the other in Geneva.

The longest-running driver/engineer partnership in Australia's Supercars series was put on hold during the Tasmania round of the series at Symmons Plains after **Michael Caruso's** race engineer **Steven Todkill** stayed at home with his wife to await the birth of their first child. Todkill and Caruso have worked together since 2008.

Seth Barbour, the crew chief on the Roush Fenway Racing No.6 Ford Mustang, driven by **Darrell Wallace Jr** in the NASCAR Xfinity Series, was fined $5000 after the lug nuts were found to be not properly fitted to the car at Auto Club Speedway, California.

Joe Gibbs Racing crew chief **Dave Rogers** is taking indefinite personal leave from the Monster Energy NASCAR Cup Series team. Rogers is the crew chief on the No.19 Toyota, driven by series rookie **Daniel Suarez.**

Richard Usher, the former owner of the Blyton Park test track in Lincolnshire, UK, is to stay on as manager at the venue following its takeover by race and sports car manufacturer Ginetta.

Glyn Swift, well-known as a highly successful tuner of the BMC A Series engine that powered the original Mini, has died at the age of 73. His Swiftune Engineering concern, which was founded in 1965, provided the power for many Mini victories over the years, in both racing and rallying.

Brian Pattie, Roush Fenway Racing's NASCAR Cup crew chief on the No.17 Ford was fined $10,000 after lug nuts on the **Ricky Stenhouse JR** car were found to be improperly installed after the Texas Motor Speedway round of the series – $10,000 is the least harsh penalty available in the Cup following NASCAR's crackdown on this infraction.

Formula 1 has appointed **Ian Holmes** as its global director of Media Rights. He will lead a team which will be responsible for the licensing of F1 audio visual rights to third parties. His role will also involve managing the rights for archive footage, post-produced programming, the newly rebranded F2 (formerly GP2), GP3 and the Porsche Supercup.

Formula 1 has also named **Kate Beavan** global director of Hospitality, Experiences and Packages. She will be responsible for continuing to grow the Formula One Paddock Club as well as driving innovation in all aspects of corporate and fan packages. Beavan qualified as a lawyer in 1994 and has previously worked for the TWR Group and the Arrows Formula 1 team.

A bid to steal **Enzo Ferrari's** body and hold it to ransom has been thwarted by the authorities in Italy. Italian police say a gang in Sardinia were planning on taking the Ferrari founder's body from its tomb in Modena, with the intention of then demanding that a ransom was paid by the Ferrari family for its return. Enzo Ferrari died in 1988.

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

Final call for wannabe Formula 1 race engineers

Student engineers wishing to enter the Infiniti Engineering Academy, the talent search programme that offers the lucky winners paid work placements with the Renault F1 team, will need to get their skates on as the 20 May deadline is fast approaching.

This will be the fourth successive year for this unique recruitment programme, which, in Infiniti's own words, 'provides a money-can't-buy, fully supported, life changing career opportunity for seven world-class students'.

The academy offers seven engineering students the chance to work both at the Renault Formula 1 outfit and at the Infiniti motor company itself in a 12-month placement split between the two.

Infiniti's scheme has already proved successful in launching engineering careers, with Former Academy Engineers William Priest and Daniel Sanham both securing full time roles with Infiniti and the Renault F1 team respectively following their placement with the Academy.

The regions from which Infiniti is recruiting for 2017 are: Asia and Oceania, Canada, China, Europe, Mexico, Middle East and the United States, with each region to announce a single winner. The seven winners will then move to the UK with their prize package, which includes air travel, accommodation, access to an Infiniti company car, and a salary.

'I anticipated this experience to be absolutely amazing, but I still found myself blown away,' said Caitlin Bunt, Infiniti Engineering Academy US winner 2016, who is now doing her six-month placement at the Infiniti Technical Centre in Cranfield and will soon begin the second part of her placement with the Renault F1 operation in Enstone. 'I am participating in projects and gaining experience I never thought I would get to in my first six months. Being here, behind the scenes and contributing to these exciting projects is a dream come true.'

For further information on the Academy or to register to be a part of the class of 2017 visit website at academy.infiniti.com.

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There are worse racecars to start your race engineering career on – a work placement with Renault in Formula 1 is up for grabs


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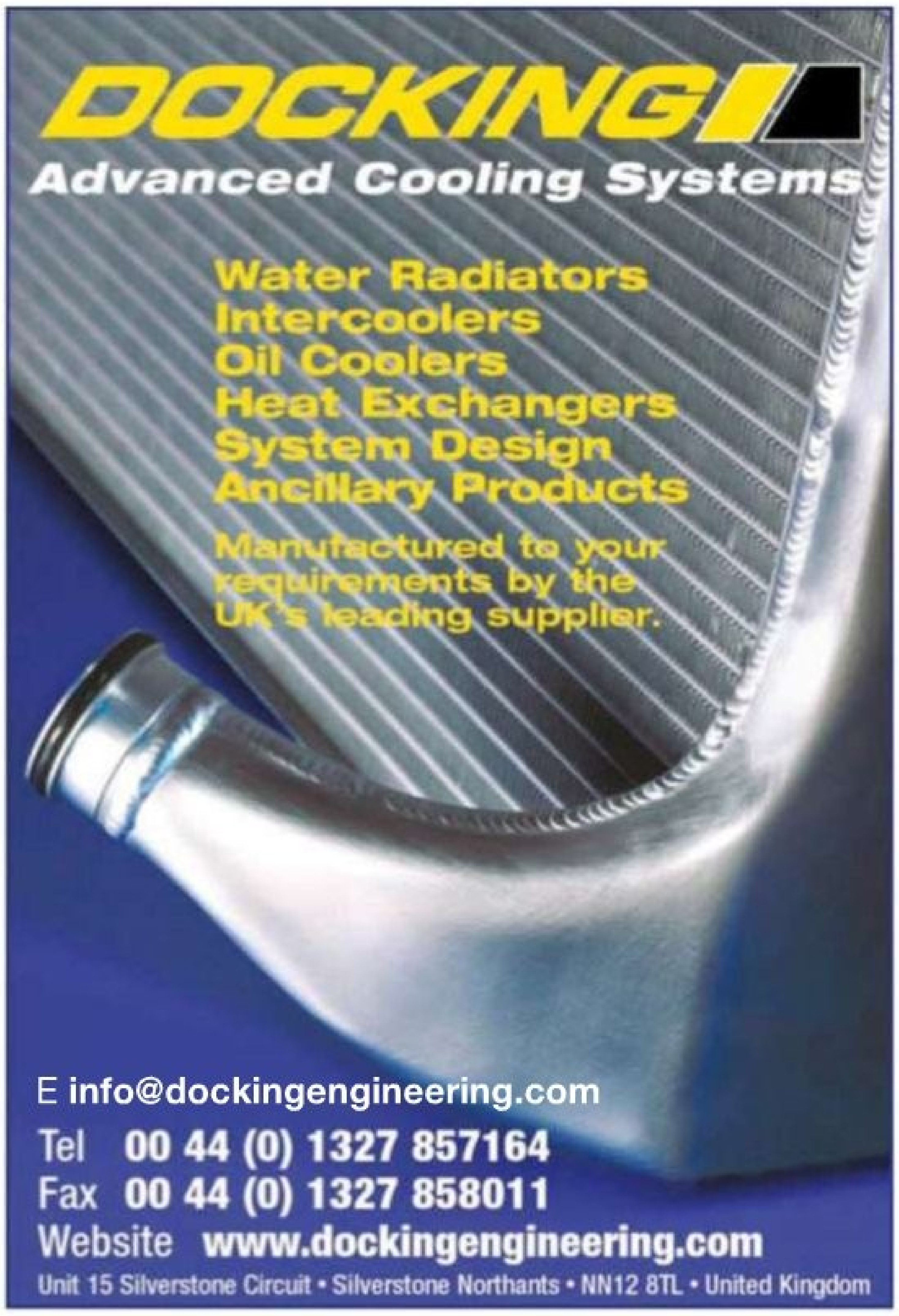
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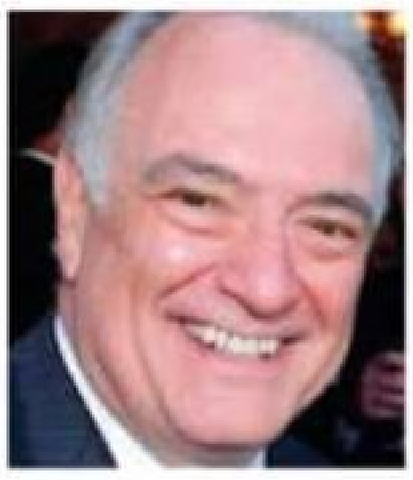

Provide and rule

The MIA's CEO explains how the UK government helps motorsport businesses

A really exciting Formula 1 season beckons; a close fight for leadership, overtaking battles, and close racing through the whole grid – a great start to the year. Alonso trying to win the Indianapolis 500 is a master stroke of positive publicity for Honda and McLaren. Having witnessed this great race a few times, I can't wait to see his undoubted skills being really tested.

Great viewing on TV is raising the profile of F1, while both the Alonso Indy challenge and Jenson Button's return at Monaco show how the new owners of Formula 1 can increase the popularity of our sport. We can look forward to welcoming new fans, new sponsors and so new income for the teams and their suppliers. This may well wake up other race series promoters to the commercial opportunities from attracting more fans on TV and at the track, and perhaps a better deal for the track owners too.

World Rallying is similarly unpredictable, close and exciting this year with four teams all winning, and the BTCC has never had such an exciting grid, with close battles throughout. It could be a very good 2017 ahead.

Uncertain times

The UK press gives full coverage to the uncertainty caused by our decision to leave the European Union, but when major changes occur, opportunities for success are everywhere. We now have a UK general election in June which should bring a more certain commitment for the future from whatever government, so I welcome the decision.

Currently UK trading figures are exceeding expectations – more people at work than for many years, GDP growth rate rising, exports booming – but how long will it last? My advice? Don't hang about – move fast and capture all the business you can. If you are not yet exporting, or believe you can export more, get going now as exchange rates can change quickly. Right now UK products or services have never offered better value all over the world.

The MIA wants to see Motorsport Valley companies build their international business. We are there to help and will answer any of your export questions, just contact us on www.the-mia.com

UK and overseas companies regularly ask me whether the UK government does a good job for motorsport and is this the reason we attract so much inward investment. I think the answer is yes. Only this month, new legislation was announced which will allow public roads to be closed for motorsport events for the first time for decades.

Once the local highways authority has checked all safety matters are in order and that the promoter has been authorised by the MSA, then we will be able to see races, sprints, hillclimbs and all manner of other motorsport disciplines right in the very heart of communities in Britain.

So motorsport will be taken to the people at long last. I fully expect to hear that Formula E will be on the streets of London, and the other cities will host high profile international races, too.

R&D tax credits from the UK government are really beneficial to motorsport

XPB

Rallying and racing could soon be seen on closed pubic roads in the UK thanks to new legislation. There are other ways the government helps motorsport, too

R&D Tax Credits from the UK government are really beneficial to motorsport and under review, and could be even more attractive soon. All part of a new Industrial Strategy for the UK which will bring many changes to boost business growth, particularly for those using R&D and 'experimental development'.

Vnuk ruling

Hundreds of millions of pounds of government funding is made available through Innovate UK, so check the website and take your share: www.gov.uk/government/organisations/innovate-uk. Many motorsport companies have benefited from millions of pounds and collaboration with innovative companies through this scheme.

We are also working closely with government to amend the infamous Vnuk insurance ruling from the European Union, following the recent consultation that attracted over 700 responses. The Department for Transport is actively trying to ensure UK motorsport can continue despite this misguided judgment from the European High Court of Justice.

The Apprenticeship Levy is now in force for England, aiming to attract millions of new apprentices by 2020. If you are one of the two per cent of UK companies whose payroll exceeds £3m – only 100 employees at an average of £30,000 per year – then you will pay a 0.5 per cent levy each month, offset by a £15,000 allowance, and can spend the levy on apprentice training and assessment provided by approved trainers.

The best news is that all companies below this payroll level will find that the government will pay 90 per cent of apprenticeship training and assessment, leaving most paying only 10 per cent.

The regulation makes it clear that apprentices can be any age, so anyone in middle age in employment can now up-skill themselves and move into other areas – which is an excellent idea.

Diary dates

There was a huge number of young people looking for jobs in motorsport at our recent MIA Jobs Fair at Silverstone, so we will be repeating this on 5 October and confidently expect over 1000 job seekers to attend. The companies attending not only recruited good people on the day but also created a data bank of potential future staff.

The UK government is steadily reducing Corporation Tax to reach just 17 per cent by 2020, one of the lowest rates in any country in the developed world, which adds to the reasons why Motorsport Valley continues to grow and attract investment and new companies into high performance engineering and motorsport.

Many international buyers will come to the British Grand Prix this year to attend the MIA Business Week, and our major Business Growth Conference on 13 July at Sahara Force India. This will focus on positive presentations from companies succeeding at this time of apparent uncertainty. Real business people who have overcome difficulties will share their knowledge with our audience.

This is a good time to be in the motorsport business, so plan to join us there. Check www.the-mia.com for details. Make the most of this period of change, grab all the opportunities you can.

Batteries
Charged up

RPS has launched a new battery for racing applications. It has been specifically developed for use with race engines up to 2000cc fitted with an alternator.

Compared to a production specification lead acid battery this lithium-ion battery enables the battery location to be changed to lower the centre of gravity. Since lithium-ion batteries are sealed they can be mounted in any orientation in the car, even flat on their side.

It has a nominal voltage of 13.2v and a nominal capacity of 16.0Ah (211Wh). The charge current is 40A and the pulse cranking current is 840A. The battery comes with M6 female terminals.

www.rps-battery.co.uk

Dampers
Shock of the new

UK suspension specialist Gaz Shocks has extended its bespoke custom build service to include monotube shocks.

The slightly confusingly named GAZ as-charged Monotube Coilovers are said to be far lighter than other types of coilover damper. The use of lightweight billet aluminium parts reduces unsprung weight, making them ideal for track day or competition use. They also react quicker, Gaz tells us, and can be used in an inverted position.

GAZ Monotube Coilover kits come with silicone chrome springs and the required mounting hardware. The spring platforms are adjustable to allow the ride height to be altered as required and the bump and rebound settings can be adjusted by means of a knurled collar at the top (or bottom if used inverted). Bespoke valving and spring rates are available.

www.gazshocks.com

Pit equipment
Jacks for all trades

Quick Jack's bl-3500SI, bl-5000SIX and bl-7000SIX12V family of portable lifting systems is designed to make vehicle maintenance, both on and off the track, convenient and fast.

Compact and transportable, these units are designed to replace floor jacks and jack stands, Quick Jack says. The jack frames are positioned under the vehicle and raised using a button on a remote hand-held control.

The units collapse to a 3in profile so they can fit in places where other jacks might not. Because the frames have no cross members they provide greater under-car access and can be installed at any width required, we're told.

Quickjacklift.co.uk

Set-up equipment
Weighty issues

B-G Racing's new Wireless Race Scale pads are produced from aluminium with a ribbed construction for maximum strength and almost zero deflection, we're told.

The wireless technology eliminates having cables all over the shop floor and allows free movement around your car, with a hand-held wireless control pad.

The pad displays the vehicle's four corner weights, the axle weights, the cross weights and percentages all at once. The control pad display and configuration can be changed to suit the user's preference and features a low power consumption level.

A mains power adaptor is included for the control pad (with UK and EU plugs) in the event of replacement batteries not being immediately available.

www.bg-racing.co.uk

Electronics
Cos' you're 'Worth it

Cosworth Electronics has launched its new Central Logger Unit (CLU), a single-box solution for motorsport logging and control which supersedes the well-known Sigma system.

Using the latest hardware, software and Cosworth's in-house electronics expertise, the CLU provides excellent memory capacity, bandwidth and logging rates. It features, fully customisable AutoCoded control strategies, synchronous logging with up to 32 16-bit analogue inputs, up to 12GB memory, up to 50kHz burst logging, up to 16,384 channels, and up to 8 CAN ports.

1GBit Ethernet is included and the unit has a 5V to 33V voltage operating range. It has an IP65 rated aluminium enclosure and weighs 470g.

Cosworth.com

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What future for LMP1?

There were two schools of thought at the WEC event at Silverstone as Ginetta launched its LMP1 programme for 2018. One was that this was going to be the future of the category, with a lightweight chassis, powerful engine and intelligent approach to aerodynamics. The other was that the programme could not succeed due to the costs involved in running an LMP1 campaign compared to LMP2. The key, I feel, is Peugeot, and the French manufacturer is playing its cards close to its chest. The guessing game is now on.

How can LMP1 be fixed, with Audi having left? By contract, the ACO and the FIA have agreed a minimum of three manufacturers in LMP1 hybrid to maintain a World Championship status. At least, that was the agreement in 2011 when the World Championship was close to being delivered. An exception was made when Peugeot pulled the plug on its programme in 2012, but Porsche was waiting in the wings and had already begun work on its 919 Hybrid. Testing started in 2013, the car raced in 2014.

Fast forward to the present, and with Audi gone, even if Peugeot agrees to return, it won't join before 2020. The FIA and ACO reacted at Silverstone by signing a new three-year agreement for the World Championship. That announcement provided the security that the series needed, but doesn't address the problem; where will that third manufacturer come from, if it is not Peugeot. Or, have the ACO, FIA, Porsche and Toyota all agreed that they will stomach the cost of Audi's withdrawal?

Even if Peugeot agrees to return, it won't join before 2020

Ginetta's announcement came on the Thursday before the Silverstone season opener, by regulation one year before the car competes in the WEC for the first time. At £1.3m and with a service contract that takes it closer to £2m for a season, before actual running costs, it is already more than three times the price of an LMP2 car. And, at best, the LMP1 privateer car will be finishing around the same place as an LMP2. So, the programme, from a financial point of view, makes little sense.

Peugeot, likewise, made the comparison. With a difference of just a few seconds between LMP1 hybrids and the fastest LMP2s, even if an LMP2 car cost €4m for the season, it pales by comparison to an LMP1 hybrid budget, which is estimated at around €50m to €70m just to get the car to the track (including facilities, engineers, wind tunnel time, testing, designing, developing and so on). Peugeot boss Bruno Famin, who was at Silverstone, made the point, and then smiled and shrugged, and then left for a pre-arranged meeting with the FIA, ACO, Porsche and Toyota.

There are many ways that the costs can be reduced. Signing the document ruled out one of them; getting rid of the World Championship status, which means that the series would not need races on three continents, and nor would it need that third manufacturer. However, such a radical move would leave other problems, including the GTE Balance of Performance issue. A reduction in the number of races is clearly an option, as is a reduction in test days, wind tunnel time, long-term use of a monocoque and so on. With wages and travel of engineering personnel alone, it costs on average €1.3m to attend a WEC race. That's before freight and running costs of the car, although teams are widely agreed that labour is the largest single cost to an LMP1 team during the season.

Others also spoke, as I have, about the need for the series to improve communication and marketing value. That would all help to raise the bottom line for a programme, whether the team competes in LMP or in GT. One suggestion was to make the tickets free for the WEC races, except for the Le Mans 24 Hours. Everyone remembered the 2008 WEC race at Silverstone where no one could believe the crowd figure of 50,000 to watch Peugeot and Audi compete for overall victory.

I think it is down to the marketing for one very simple reason. If Ginetta's plan is to work, there needs to be a return for a team. And it is not only Ginetta. If BR, Dome, Gibson or anyone else wants to build a car, their options are limited and no longer include LMP2. With that in mind Formula 1, Formula 3 and LMP1 are pretty much their headline targets which are not single chassis supply, and even those are all highly limited.

I do believe that the ACO and the FIA have a responsibility to ensure the long-term future of the LMP1 privateer category, and not only for the fact that this has been the backbone of endurance racing since the beginning of time. This is to ensure that manufacturers that want to go racing have a platform to do so. Adrian Reynard is involved in the Ginetta programme and, with Lola during the 1980s and 1990s, his company provided a sound school of learning for many budding engineers and designers, not to mention such non-race track dependent skills such as model making. Racing is in danger of losing these core skills, and so Ginetta's programme must be given a high priority.

The cost target for the Ginetta programme was welcomed by everyone in the paddock, but the category has to be given more than LMP2, which itself has struggled to sell into the WEC and this year the grid is full of ORECAs only. Will the organising body allow that to happen, and if they do, what will the teams that have just invested in LMP2 make of it?

ANDREW COTTON Editor

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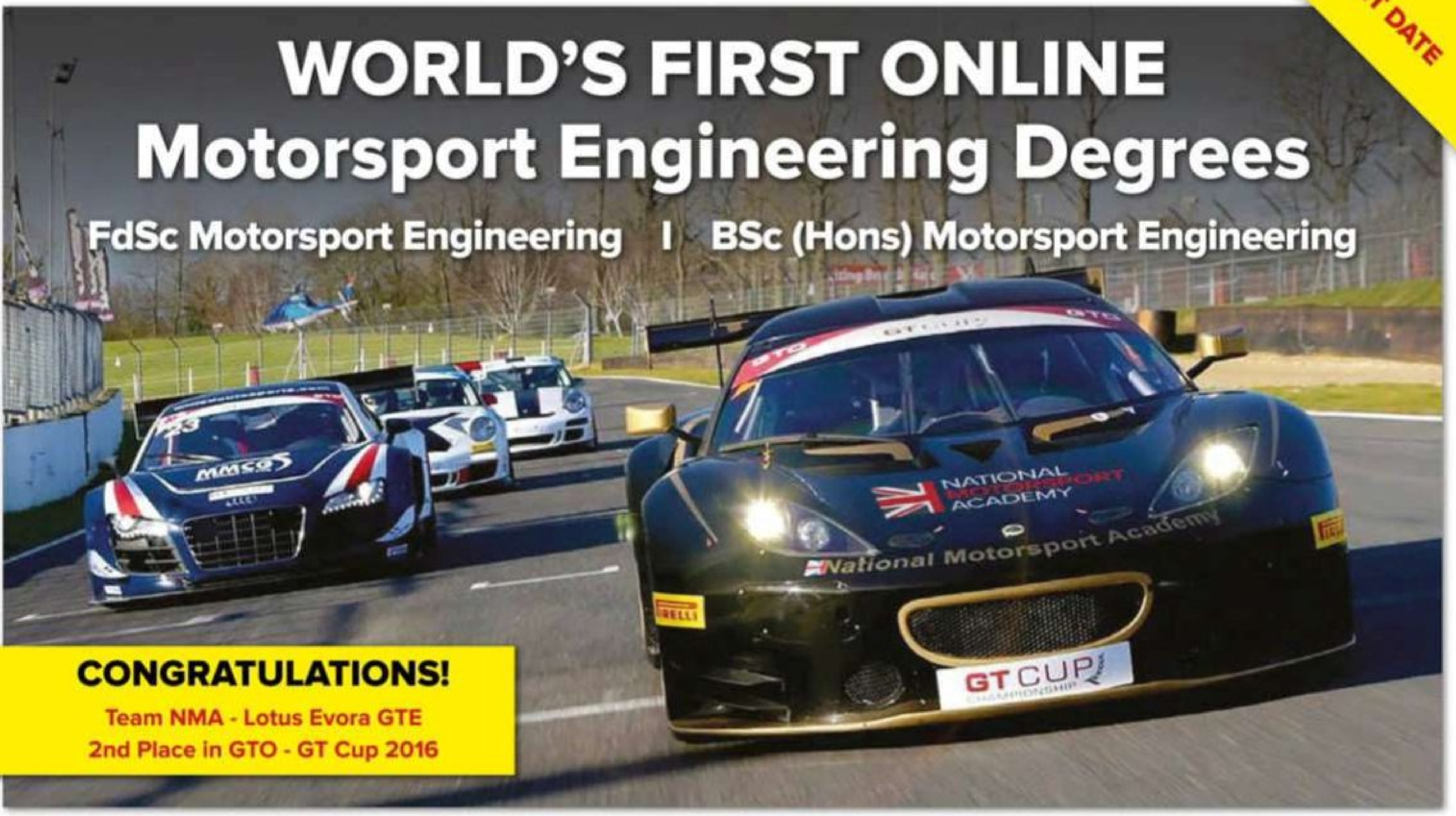

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