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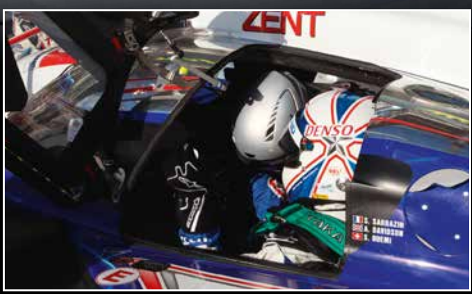

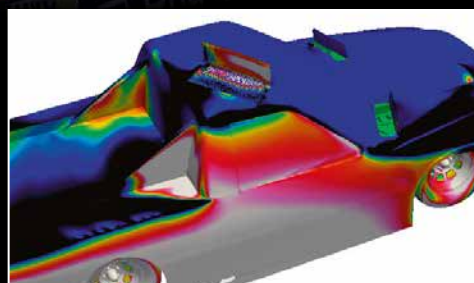

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Prism break

Did we lose something special when sponsors' liveries replaced national colours?

The colour of any object depends on both the physics of the object in its environment, and the characteristics of the perceiving eye and brain. So objects can be said to have the colour of the light leaving their surfaces, which normally depends on the spectrum of the incident illumination and the reflectance properties of the surface, as well as, potentially, on the angles of illumination and viewing.

A spectrum is a condition that is not limited to a specific set of values but can vary, without steps, across a continuum. The word was first used scientifically in optics to describe the rainbow of colours in visible light after passing through a prism.

While most humans are trichromatic (having three types of colour receptors), many animals, known as tetrachromats, have four. These include some species of spiders, most marsupials, birds, reptiles, and many types of fish.

We see a range of wavelengths from about 390 to 700nm (nanometers). In terms of frequency, this corresponds to a band in the vicinity of 430 to 770THz, although birds and bees can see frequencies starting from 300nm, well into the ultraviolet range. Flowers can have ultraviolet markings, which are invisible to us, but they are very useful for the birds and the bees.

Racecars are usually painted, or more usually now wrapped, in a palette of colours covering our visible range. But in the past they had quite well defined hues which depended on the country they represented.

Hue and cry

This all started out when Count Eliot Zborowsky suggested that each national team competing in the 1900 Gordon Bennett Cup be allotted a distinguishing colour; France getting blue, Germany white, Belgium yellow. Britain came to the Cup in 1902, and could not use its usual red, white or blue, as they had previously been allotted, and so it chose to paint its Napier in olive green.

The following year, when the cup was held in Ireland, this morphed into Shamrock green, which came down in various shades through the years. Italy adopted its classic racing red only from 1907, when a FIAT won the Peking-Paris in that shade. We can also see here that real racing from those days was not the short sprints GPs are today. Probably something to do with limited attention spans.

By the '20s the Association Internationale des Automobile Clubs Reconnus (AIACR), the forerunner of the FIA, had accepted colours for each nationality, this maintaining the original Gordon Bennett Cup colours, the German white seemingly morphing into silver by the 1930s, as seen on the Mercedes and Auto Union grand prix cars of the time.

'30s shades of silver

The Silver Arrows, as they became known, were silver basically because the cars had bare aluminium finishes, which gave birth to the legend that it had come about by stripping the paint to bring them down to the weight limit. This is probably apocryphal, as they were racing like that in 1932, and the limit did not come in until 1934. Some later cars from Germany reverted now and then to white.

Although some of the colours were rather arbitrarily assigned, others took cues from national colours, like the 'bleu de France', which is a colour traditionally used to represent France, and has been used in the heraldry of the French monarchy since at least the 12th century. Any team representing the nation, be it in football, ping-pong or any other sport is colloquially know there as 'Les Bleus', even if they are not using the blue livery.

XPB

French racecars, such as this 1920s era Bugatti Type 59, always raced in blue before the advent of major sponsorship in motorsport

Similarly Argentina's blue and yellow, Brazil's pale yellow and green, Australia's green and gold, as used on Brabhams, were official national colours.

Japan was assigned white with a red circle, identical to the national flag that has been used since 1854, when during the Tokugawa shogunate, Japanese ships were ordered to hoist the Hinomaru to distinguish themselves from foreign ships. This was seen on the first Honda F1 car in 1964.

The Netherlands was given orange, historically the colour of the Huis van Oranje-Nassau, a branch of the German House of Nassau, which has played a central role in the political life of the Netherlands since William I of Orange organized the Dutch revolt against Spanish rule, which after the 80 Years War led to an independent Dutch state. This orange was most recently used on the Spyker in F1.

The USA, had two variants, blue with white stripes – used by exponents such as AAR Eagle, Ford, Shelby, Scarab, Chevrolet – or white with blue stripes, commonly known as Cunningham colours, but also used by Ford, NART, Shelby and Chaparral. And I can still see the list in my 1977 copy of the FIA's Yellow Book, despite it authorizing other colours for sponsors liveries from the spring of 1968, South Africa's Team Gunston being the first to sport sponsors colours at that year's South African GP.

The number of primary colours being limited, combinations thereof were used on the latecomers, often as a basic plus a stripe, or body with different bonnet colour. Bulgaria was green and white, Cuba yellow and black, Switzerland red and white, Czechoslovakia white and blue with white bonnet and stripes, Denmark silver-grey with the national flag on bonnet, Spain red and yellow, and so forth. Probably the most unusual colours were the ones given to Jordan, a muted brown, and one I have not seen on any racecar, Egypt's violet.

Note that the convention was based on the original Gordon Bennett Cup rules, being that the colour was attributed by the team's nationality, not the car's or driver's, thus Team NART Ferrari F1 running at the 1967 US GP in white and blue.

The colour of money

Commercial sponsorship eventually took over the previous mono- or bi-chromatic bodyworks and to be fair it has brought some now iconic liveries, such as the JPS Lotus, with its black and gold, and the McLaren Marlboro white and red. The national colour tradition still remains in some liveries, though; note the silver on the Mercedes F1 car.

But I still hanker after the days when cars were monochromatic-ish, when often ill-advised combinations did not obscure the true lines, the '90s being the worst time for the multiple paint buckets thrown over the racecar syndrome.

Design convergence being what it is, maybe today's F1 liveries at least enable you to differentiate which car you are looking at, for I suspect if they were all of a single colour they would be very difficult to separate nowadays.

Jordan was given a most unusual national colour, a muted brown

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Data protection

Should drivers be allowed to keep their fast-lap secrets from their team mates?

It's fair to say Lewis Hamilton is known for making comments that are sometimes controversial, frequently confusing and sometimes downright irritating, but happily it's also true that the real racer that he is generally shines through.

A recently expressed opinion of Hamilton's struck home with me and encapsulated much of the issues surrounding modern motor racing. Referring to his objection against data-sharing between team-mates, he made the observation that this can make it too easy for new drivers to come into F1 and quickly be up to speed. I particularly appreciated Lewis' additional points. 'For example, when we're driving we're picking out braking points, bumps, tyre rubber marks on the track, all these different things to help get you through the corner quickest. You've got to find the limit yourself, that's the whole challenge of being a racing driver,' he said.

Maybe it reassured me that at least some things in race driving haven't changed, that it hasn't been totally reduced to a kind of robotics.

Share issue

On a less subjective level, this matter of data-sharing between drivers does offer food for thought. Whether it's F1, Indycar, LMP, GT or whatever, one might argue that professional drivers are paid employees and as such should carry out the team's bidding, the aim of which is to achieve the best result – for the team.

On the other hand, like any craftsman, a driver works hard to learn the skills of his or her trade. This has often been gained over years spent clawing a way up the racing ladder. Put yourself in this position and it is not hard to understand the reluctance in giving this personal intellectual property away to somebody who, after all, is focused on trying to beat you. In endurance racing, with two or three drivers per car, you would perhaps find it easier to accept data-sharing if it succeeds in speeding-up co-drivers and bringing about a better race result. However, there will always be some trick relevant to car, circuit or conditions that a driver will want to keep back – who doesn't want to be the fastest?

I guess one should pause and more closely break down the term 'data-sharing'. The traditional form of this involves car set-up; aero, suspension, ride heights, tyre pressures and for some time now engine and transmission modes. As a way of rapidly obtaining feedback and general direction at the track, this makes sense and benefits both drivers.

However, when it comes to revealing turn-in points, lines, throttle/brake control, carrying speed into and through corners and other subtleties of the driver's art, it is maybe a different matter.

During my own modest racing career, before even basic data-acquisition had become the norm, I certainly observed other drivers' lines etc, on and off circuit. On at least one occasion it definitely helped me to a last-lap race win (thanks always, rain-master Jacky Ickx), but this is rather different from studying in-depth data on screen or print-out.

In Moto GP in 2010, there was a Donald Trump-style 'Mexican wall' between Valentino Rossi and Yamaha team-mate Jorge Lorenzo, as their relationship broke down completely. However, it is virtually impossible now with the degree of data-logging and analysis going on for a driver or a rider to prevent cross-over, as it is the engineers who hold sway over the data.

XPB

Lewis Hamilton thinks data sharing between team-mates makes it too easy for some to get up to speed: 'You've got to find the limit yourself,' he says

Information overload

For a long time I have grouched about the excess of information-gathering and analysis that commonly takes place in many forms of racing. I have even called for the banning of all telemetry, taking the pragmatic view that if modern science and engineering can't design and make something that can last a race – even a 24 hour one – without constant nursing then we've gone a bit wrong somewhere. Okay, with complex power units on board now I can relent a little and let some of the techys keep their monitoring jobs; I admit that few things are more disappointing than to see a good battle spoiled by a failure in one of the cars, thankfully much more rare nowadays.

But what's wrong with a mandated reduction in the number and type of sensors that can be installed on a car in its entirety, allowing only potentially highly damaging, hazardous or race-stopping faults to be detected and acted upon from the garage? Permit only a small number of additional dedicated channels, meaning that teams will have to decide their priorities of use. Data-sharing between drivers might then no longer be an issue if the engineers want this limited amount of data-logging and acquisition capability for more critical, analysis and activation purposes.

Feelosophy

There will be the additional knock-on effect that most racers, excepting engineers, want to see happen – more of the control of the racecar reverting to driver skill and courage. I have yet to see or hear anything other than exhilaration from modern drivers who experience racing cars of the past and the visceral *feel* of them, so absent from current breeds of machinery in which that direct physical and tactile contact with all that is going on in chassis and engine is lacking. There is always great respect for those who raced these machines and – apart from the issue of safety – a significant air of envy is clearly detectable.

As in many other human activities, we have let technology take away as much, if not more, than it gives. A bit more driving by the seat of the pants, bending car and track to your will and talent and you to the challenges that they present, is a hell of a lot more satisfying than the equivalent of painting by numbers, which high-level racing has to an uncomfortable extent become.

Hopefully, in F1 at least, this trend may be about to be stopped, even reversed. One hopes so. Let's get the feeling back into race driving.

Bending car and track to your will and talent, and you to the challenges that they present, is a lot more satisfying than the equivalent of painting by numbers


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Grip it up and start again

There's change aplenty in Formula 1 this season – but will it be for the better?

Here we go again! The anticipation is higher than usual this year, stoked by the promise of more exciting racing and more dramatic cars. And yet, as the new cars have appeared – and they really do look better proportioned – we have two wise, experienced engineers making deflating comments, even before they turned a wheel:

Adrian Newey: 'I don't know, it's a very subjective thing, but being brutally honest I think kind of trying to introduce the illusion of speed by having swept front wing, swept sidepod front and swept rear wing endplate is kind of just a bit Wacky Races.' Patrick Head: 'If anybody was thinking of these rules with the aim of closing the field up then they've got rocks in their head.'

Not such a good start. But what is the reality, as revealed by eight days of pre-season testing? For 2017, the cars are longer, wider, bigger-winged, bigger-tyred, and have freed up key aero areas such as the front wing and sidepods. But they are heavier and only have the same rate of fuel burn as 2016, although they can use five per cent more fuel during a race. They are inevitably faster. However, speed through the corners, better braking, and better traction, while delighting the drivers, benefits who else? Will a faster, more physically demanding F1 car be more spectacular? More to the point, will it allow closer, less predictable racing and, whisper it, overtaking. I see no reasons why it should, and several why it will not.

Passing comment

If, and that is a big *if*, it is precisely known what effect on drag, downforce and centre of pressure the car ahead has on the following car as a function of the distance between the cars, then it is relatively straightforward to make a simulation of the overtaking manoeuvre for any given corner and following straight. It is also straightforward to model what advantage in tyre performance, or aero downforce, drag, power, weight etc., the following car needs to execute an overtaking manoeuvre by the braking point at the end of the following straight, for all types of corner. The physical advantage needed can then be translated into a lap time advantage; currently this is of the order of 1.5s/lap, depending on the circuit. No car of a lesser performance advantage will be able to overtake, let alone an equal car, such as Hamilton versus Rosberg last year, on the same tyre strategy.

If downforce is increased along with drag, the wake of the car ahead is almost inevitably going to become more 'disturbing'. If X per cent energy is lost at any given position in the wake, then the higher the downforce of the following car, the bigger the loss of vertical load on the tyres. Hardly a recipe for easier overtaking. By the time the cars return to Europe in May we shall know, if not sooner.

Apart from the plethora of, oh-so-vulnerable turning vanes, slots and widgets that make up the wings and body of the current Formula 1 car, the thing that has caught my attention is the comment that HPP's Mercedes engine is approaching 1000ps. Let us examine that more closely.

XPB

Formula 1's Barcelona tests can only tell us so much and a clearer picture will not really emerge until the new cars go head to head in the grands prix

A year ago, Andy Cowell, managing director of HPP, indicated that the 2016 engine was approaching 50 per cent thermal efficiency. Based on the gasoline specific energy figure used by the FIA-regulated WEC fuel (F1 does not specify this parameter), this translated into 840ps without drawing energy from the battery. A figure of 1000ps would mean that the thermal efficiency had been raised to 63 per cent!

Record breaker?

It is not clear whether the quoted figure related to the maximum power available at the flywheel and included energy drawn from the batteries to top up the contribution from the MGU-K to the maximum of 120kW. This would account for a maximum addition of around 30kW or 40ps; 960ps would be 60.5 per cent efficient. The world's best purely internal combustion, 4-stroke engine is the Finnish Wartsila 31, a 520-litre, V-16 turbo diesel producing 9760kW (13,000ps) at 750rpm and 52 per cent thermal efficiency, which is made for ships.

Has HPP bust this record? Probably not. F1 does not regulate the specific energy of the permitted fuels, preferring to tightly control the constituent hydrocarbons. It is very likely that Petronas, working closely with HPP, has maximised the specific energy within the regulations, and thus, without knowing the actual figures, we cannot calculate the real thermal efficiency. It is unlikely that the chemists found a legal 20 per cent increase in specific energy, and that the 1000ps figure is therefore probably wrong. For sure, HPP and Petronas' chemists have worked tirelessly on efficiency, as it is the mechanism by which more power is produced under the current powertrain regulations, with the additional advantage of avoiding dissipating excess wasted energy via radiators, thus providing advantages for the aerodynamics as well.

Woking's woes

What is clear is that, of the competing engine manufacturers, Ferrari is getting closest to Mercedes although we won't know how close until the opening races of the season. What is also remarkable is Ferrari's new approach to testing and communication, as displayed in Barcelona. It appears to have undergone a character transplant over the winter, and is now looking like the most professional of the UK teams.

As for McLaren Honda, I refer readers to the paragraph I wrote in my 2015 Formula 1 review: 'The Honda organisation today is very different from the one that dominated F1 with Williams and McLaren in the late 1980s and early 1990s. Mechanical ingenuity allied to high RPM, developed by a well resourced, dedicated racing R&D department, with support from the highest levels in the company were the foundations of its earlier successes. The experienced racers have retired and been replaced by managers who appear to believe that F1 can be run just like any other R&D programme. To have two cars on the back row of the grid in the 17th race of the year is really unacceptable progress for a partnership with the history of McLaren-Honda. Something is

Will a faster, more physically demanding Formula 1 car really be more spectacular? More to the point, will it allow closer, less predictable racing?

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Pirelli's new fat tyres help make the cars look cool but it remains to be seen whether they will improve the show

terribly wrong and whether it can be rectified, as all and sundry within the two organisations keep telling us is about to happen, I'm not sure. I do not yet see the scale of change that is necessary. Once again, I hope I am proved wrong.'

Nothing much seems to have changed except the bosses. I really do hope to be proved wrong.

One aerodynamic factor that has been subjected to close attention by the FIA during testing is the influence various teams' suspension systems have on ride height, and therefore downforce. It is known that Red Bull and Mercedes ran sophisticated systems last year, but not exactly what they achieved. Ferrari subtly probed their legality over the winter by requesting an FIA opinion on various configurations, which it hoped included their competitors' arrangements, and it would thus obtain a judgement on them.

Suspect device

The issue of devices that move relative to the sprung part of the car and have an aerodynamic influence has been taken to the limit since Gordon Murray put a fan on the Brabham BT 46 and claimed it was part of the engine cooling system. That was nearly 40 years ago! In the early 1980s, active suspension provided exactly what was needed to take control of the attitude of the car relative to the road surface, and provide engineers with the means to tune downforce independent of the airspeed and acceleration forces on the car.

At the end of 1993, Max Mosley put a stop to that; or at least he nearly did. Unfortunately F1 engineers had tasted the benefits of sophisticated suspension control, and 25 years later are still trying to apply ever more esoteric and ingenious interpretations. It would appear the systems that employ hydro-pneumatic time delays – storing and releasing energy over a period of time to change the spring characteristics of the suspension, resulting in both ride/grip and ride height changes, have been developed, but are now banned by the FIA. Whether Red Bull's difficulties in setting up its car in Barcelona are a result of this is not clear, but Ferrari's ascendancy may well be a result of its winter's negotiations with the FIA. Intriguing.

Slick work

And then there are the tyres. They had to be bigger to accommodate the greater downforce and weight, the 2016 tyre having proved to be on the limit. The increased sizes have proportioned F1 cars in a much more pleasing way, however they have really only retained the status quo. Much more significant are the tread compound changes that Pirelli has introduced on request. Instead of compounds that rise to an optimum temperature and then, if heated further, fall permanently away forcing drivers to manage them precisely, the 2017 compounds simply degrade progressively from their optimum, as they wear.

The previous compounds were Pirelli's answer to a request to produce cars that resulted in drivers that were at different stages of tyre degradation at different times, depending on strategy. This enabled overtaking between cars of similar fundamental performance, but equalised competitiveness over the span of a race.

The interesting thing is that Pirelli, even before Barcelona testing showed its new compounds achieved their objective, prepared 2017 tyres with the old compounds as an option. It foresees that the consistent tyres will lead to less overtaking and less entertaining races, and Pirelli is so convinced that it has taken precautions.

What I find so baffling is that virtually all the changes for 2017 benefit the engineers – new regulations mean lots of lovely R&D – and the drivers, who complained the cars were not exciting or challenging enough to drive. These are the people who are paid to participate, and paid very well. Whether these changes are beneficial to the fans – those who *pay* – will probably be the real talking point of 2017.

A figure of 1000ps would mean that thermal efficiency had been raised to 63 per cent!

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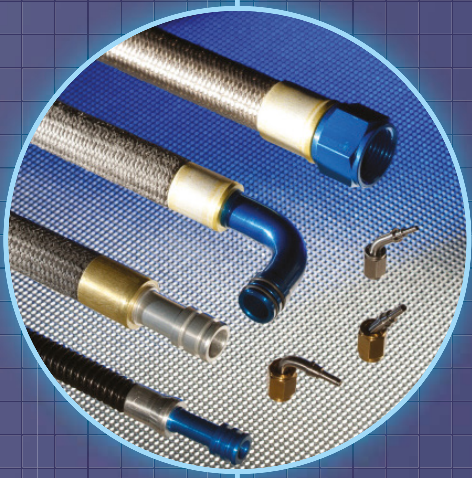

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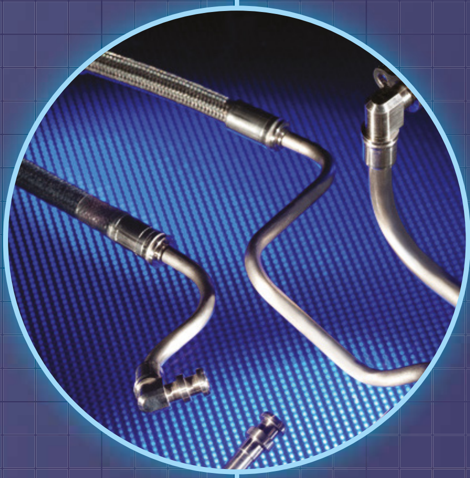

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Prime mover

With its LMP1 programme consigned to history the DTM is now Audi's flagship motorsport campaign – so it will be relying on its striking new RS5 to deliver in Europe's premier tin top series

By SAM COLLINS

In 2012, ITR, the promoter of the DTM, forged a deal with GTA, the promoter of Super GT, in order to unify the technical regulations of DTM and GT500. This agreement aimed to cut costs for both classes and ultimately create a new top level global racing category called Class 1.

But things have not gone to plan, or schedule, and the two series have yet to fully merge. However, there have been some moves toward unification in recent times. Both GT500 and DTM have used the same basic package of control parts, including the transmission, brakes and the monocoque, and the same basic technical regulations in other areas of the car.

This year had at one point been targeted as the year that the two series would have fully harmonised regulations, though only after the original target of 2014 was missed. That revised target has again changed and now the vague hope is that the two series will unify in 2019, so while they remain two very separate entities the two classes continue to head in the same direction in terms of technical regulations.

Partly in order to keep speeds under control on some of the smaller Japanese tracks such as Sportsland Sugo, and partly in order to improve the races in DTM, it was agreed by both sides to try to reduce the downforce levels of the cars by 25 to 30 per cent ahead of the 2017 season.

To achieve this, new aerodynamic regulations have been introduced which see the overall length of the car reduced, with the front

'First we had to get the shape of the new production car in good time, then we had to scale it. But that was the easy bit'

The new Audi RS5 racer will go head to head with BMW and Mercedes in this year's DTM. New aerodynamic regulations were meant to bring the DTM closer to Japan's GT500

TECH SPEC

Audi RS5 DTM (2017)

Vehicle type: DTM touring car

Chassis: Carbon fibre monocoque with integrated fuel cell, front, rear and lateral CFRP crash elements

Engine: Normally aspirated petrol 90-degree V8, four valves per cylinder, mandatory intake air restrictors (2 x 29mm)
Engine management: Bosch MS 5.1
Engine lubrication: Dry sump
Cubic capacity: 4000cc
Power: More than 500bhp
Torque: More than 500Nm

Drivetrain/transmision: Rear-wheel-drive
Gearbox: Semi-automatic 6-speed gearbox with paddleshift
Differential: Adjustable plate-type limited-slip differential

Clutch: four-plate carbon clutch

Steering: Servo-assisted rack and pinion

Suspension: Independent front and rear suspension, double wishbones, pushrod system with spring/damper unit, adjustable gas pressure dampers

Brakes: Hydraulic dual circuit brake system, light alloy monobloc brake calipers, ventilated front and rear carbon fibre brake discs, infinitely manually adjustable front and rear brake balance, electromagnetic start valve

Wheels: Forged aluminium wheels **front:** 12 x 18in;
rear: 13 x 18in

Tyres: Hankook **front:** 300-680-18; **rear:** 320-710-18

Weight/dimensions: Length 5010mm (including rear wing)
Width: 1950mm
Height: 1150mm
Minimum weight: 1120kg (including driver)

Fuel tank: capacity 120 litres

overhang becoming notably shorter. The area of design freedom at the rear of the car has been reduced and the diffuser height has been more than halved, all to cut down the downforce.

RS 2017

The first car built to the new DTM rules is the Audi RS5, which was revealed at the Geneva Motor Show in March. Taking advantage of the opportunity offered by the new regulations Audi has introduced a new base model, the latest generation of its RS5 production car (which was launched alongside the DTM racing version at the Swiss show).

Having both race and road versions appear at the same time raises the possibility of some joint development having taken place between the production car design team and the motorsport department, but as head of Audi Motorsport Dieter Gass explains, this was not quite possible this time: 'I would love to have fed input into the design of the production car so the shape was perfect for racing, but that has not happened as yet. We do have close discussions, so this could happen in future. There was a suggestion of doing it quite a long time ago, but at that time the racecars were homologated and frozen and we could not do it.'

In both DTM and GT500 manufacturers take a production car design, and manipulate the shape in order to fit the very tight dimensional requirements laid out in the technical regulations. This ensures that while the base

2016 DTM car was used as an aero test mule. Most of the major mechanical parts on the RS5 have been carried over from last year


Control rear wing now has flap-style DRS (as used in F1) rather than the entire wing moving, as was previously the case


Front overhang is now smaller, with a shorter splitter. The ride height has been raised while the car's length has been reduced

The area of design freedom at the rear has been reduced as part of new DTM rules brought in to cut the downforce

models have differing front and rear overhangs and very different aerodynamic performance the scaling process ensures that once homologated for DTM or GT500 they all have the same frontal area, the same overhangs and the same baseline aerodynamic performance.

Between the lines

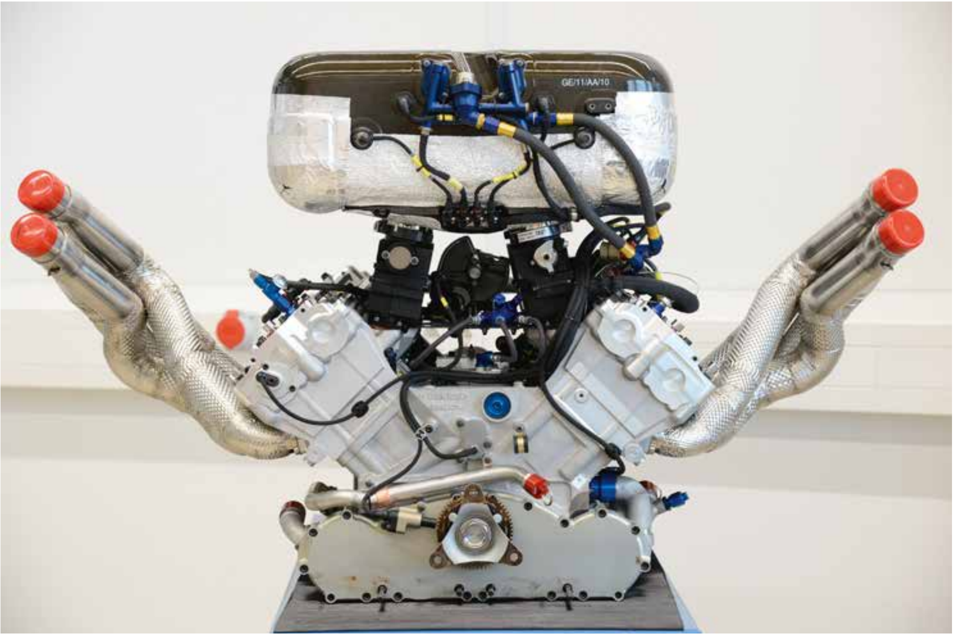
But there are some regions of total design freedom on the cars. Looking at the car from the side, there are essentially two main areas, divided by an imaginary 'design line' running along the top of the wheel arches and about halfway down the door. Above this line, the standard body shape of the base car must be used, albeit in manipulated form as described above. The only freedoms above that line are with the bonnet surface and the wing mirrors.

'First we had to get the shape of the new production car in good time, then we had to scale it, but that was the easy bit,' Gass says. 'The hard bit came after that when we had to start from zero in the free areas, and that was because we have a new floor, front splitter and diffuser this year, they are all control parts. We are still using the Sauber wind tunnel at 60 per cent to develop the car and we use both Audi and Sauber CFD capability. If we needed to use some of Sauber's facilities and personnel we could, but I don't think we will need to as what they can offer we are already well capable of.'

The RS5 which appeared at Geneva was what Gass calls 'test specification' and he hints it has been run in that trim. 'The final version of the bodywork will appear in Vallelunga for the first test,' he says. 'We have already run the car in this specification but it is just a test car. The final car is already homologated, but we did not want to show everything yet.' The car which appeared at Vallelunga did indeed feature a substantial aerodynamic upgrade, including revised cooling ducts, side panels and rear bodywork.

In mechanical terms most of the major components used on the RS5 carry over from 2016, meaning that the weight distribution remains almost identical year on year, and that created something of a challenge for the Audi engineers. 'The rules have changed the aerodynamic balance of the cars, mostly because the new floor features a thicker skid block, that has raised the ride height, and on its own that has shifted the balance, so we have done what we can to get it back to where we want it to be,' Gass says. 'With the weight distribution remaining the same you have to try to get everything the same, but you may want to react to the tyre behaviour and that I think will be crucial this season.'

While the DTM rules are restrictive, with onboard pick-up points, dampers and bars all defined by the control parts package, engineers still have some freedom to tune the car. 'The suspension is a common part



Audi's 4-litre V8 will produce over 500bhp for the first time this year after DTM lifted some engine restrictions

RS5 was launched with this side panel but it had been replaced by the time of Vallelunga test (see below)

Design is free between imaginary lines running along the top of the arches and about halfway down the door

'The suspension is common parts but the geometries are free and there is scope for some adjustment'

but the geometries are free and there is scope for adjustment,' Gass says. 'It was a joint development so every one of us fed into the project. I think every manufacturer can run the geometries that they want, pretty much. The uprights are different car to car, different wishbones, different brake cooling, that is an area of freedom we can work on. From the inboard attachment points it is all new this year, for instance. So I think we have enough freedom to play in the set-up area, it allows us to adapt to what we want to. Obviously if you did it yourself, with complete freedom, you would make something a bit more sophisticated, but with common parts there is no point as there is no competitive advantage and that is where the money is saved, and that is the real target of these rules,' Gass says.

DTM uses a single make tyre provided by Hankook and for 2017 this features an entirely new compound and construction, seemingly to replicate the performance of the tyres that are used in Super GT a little more closely. 'We are no longer using tyre blankets and the tyres have been specifically designed for this, so they warm up well,' Gass says. 'But these new tyres also feature significant degradation, too, so I think this season will be a lot about tyre management, both in qualifying and the race. Hankook has given us the standard tyre data from the manufacturer as you would expect, and we have been testing on the new tyres for quite some time now.'

Straight talking

Super GT also has a ban on tyre warmers in place, but is a full tyre war class. The new generation of GT500 cars have already been testing for some time now and the results show that the cars corner a little more slowly but have a slightly higher top speed at some tracks such as Fuji Speedway. But Audi's early testing suggests something of a different result for the German package.

'Even with the loss of downforce I'm not sure we will see an increase in top speed, because you lose the downforce from under the car and that does not make a big impact on the drag overall,' Gass says. 'However, we do have a new rear wing as a common part, and the DRS function is a bit different to how it was. Now only the flap will move like in F1, not the complete rear wing, and this should increase its

The engines are perhaps the biggest single sticking point at the moment with regard to any joint GT500 and DTM race

effectiveness, but I do not think the top speeds will be massively different. I do think that the cornering speed will increase, though, because the new tyres offer a bit more grip when they are up to temperature.'

V8 debate

Another reason for the increase in performance DTM will see in 2017 is a modest improvement in power output. For years the engines used in DTM have been frozen, resulting in all three brands in the championship running obsolete 4-litre V8s with port injection. There has, however, been a very mild thaw in the restrictions and this has allowed Audi (working with NBE) to get the engine to deliver over 500bhp for the first time. The base engine itself is the same (most major parts remain frozen) but the 2017 version does feature a new airbox and cooling system. The two air restrictors have been opened up slightly from 28mm to 29mm. Other detailed improvements have been made, though Audi was not forthcoming about exactly what, only stating that these changes are generally for reasons of reliability.

Engines are something of a bone of contention in DTM and perhaps the biggest single sticking point at the moment in regard to any joint GT500 and DTM race. Ever since 2014 GT500 has used modern 2-litre turbocharged 4-cylinder engines featuring direct injection. DTM too was meant to adopt a similar engine formula but development work on the new units was frozen, and remains so. Discussions have begun once again in Germany about a new DTM engine formula for the 2019 season, but there is clear frustration from Gass about their progress. 'We need the 2019 DTM engine to be confirmed, for me it is obvious that we must go for the 4-cylinder engine we were already on the test bench with,' Gass says.

But if the 4-cylinder engine is introduced it would need to be installed in the new RS5, a car which has now been optimised around the much larger V8 engine. 'I don't think a new car is certain for 2019 for us. The common target will be to keep things as frozen as possible from now,' Gass says. 'We would like that the aero homologation stays the same and adapt the new bodywork into the existing homologation. Mercedes did that a few years ago and I think BMW will have to do that, too. For us it was just luck that the new bodywork came at the same time as the new production model. So we would have to just deal with the change to the weight distribution if the 4-cylinder is introduced. We are not planning to make major changes, to the monocoque or transmission. We will of course have to change the cooling package, but those changes should be as small as possible and if the weight distribution is shifted then that is just how it is. You can react to it with mechanical balance things, perhaps a bit of aero. It will be a challenge.'

State of the union

Without DTM adopting the 4-cylinder it seems unlikely that there will be any chance of a unified series and, Gass thinks, even a non-points balance of performance challenge race is also unlikely. 'I like positive surprises, not negative ones. I would like it to happen but I don't think it will,' he says. 'It's not just the overall lap time or the track it might happen on. If you look at the start of the Super GT races, you can see the difference in how the torque develops, it could cause some pile ups at the start. I'm confident that once that new engine is in the car then a challenge race could happen at any time, but before that I can't see it happening. I don't think you could find the right BoP between the V8 and the 4-cylinder; its too difficult.

'There are still some other differences, they may seem small but they are important and the tyres are a big factor in that,' Gass adds. 'To run against GT500 on their tyres is pointless, if you had to have a common race the tyres would have to be the same. It's a very difficult situation. I have lost track of the GT500 regulations, last year when we decided on the new common components we kept up with it. We targeted that Super GT would introduce the changes for 2017, but I'm not certain of the extent that they are using the same parts in 2017.'

Life after Le Mans

When Audi Sport quit the World Endurance Championship, and its sister company VW quit the WRC, at the end of the 2016 season it left the Audi competition department in something of a state of turmoil, and a major restructuring was needed, with Deiter Gass replacing Wolfgang Ullrich, who retired as the head of the department. 'It is a bit early to understand the feeling within the organisation,' Gass says. 'Obviously there was a lot of disappointment after the WEC announcement and that lasted a while. But over the last three months we have been restructuring. We call ourselves Audi Motorsport now, and operate within Audi Sport.

'Internally we have been called that for some time. In a big company you have to attend a lot of meetings to get the head counts confirmed and have all the details confirmed by the various committees, but that is all done now and the new structure became active on 1 March. People from Motorsport are now moving within the company are transferring to the R&D department, for example, and we now start working as a new team.'

Audi's withdrawal from LMP1 had left the company's racing department in turmoil but things are starting to settle now

The RS5's diffuser was revised in time for Vallelunga test. It's not the same control part that's used in GT500 www.hankooktire.com/uk

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Big in Japan

The GT500 category continues to grow in popularity in Asia but does its future lie in a mooted new Class 1 world championship?

By SAM COLLINS

Lexus impressed in testing but this was hit by bad weather so the true pace of all the cars remains unclear

The 2017 season sees the Super GT championship in Japan going in to something of a new phase. It has adopted new aero regulations following the same overall dimensional changes and aims as the DTM series in Germany (see previous feature) and this has resulted in a rebalancing of power in its premier GT500 class.

The introduction of the new regulations has seen TRD switch to the new Lexus LC500, while Honda has also switched to a new model, although less obviously. In 2014 Honda used the NSX Concept car as the basis of its GT500, but now the production model is on sale it has switched to it, though it remains a mid-engined car. Nissan has decided to continue with the R35 GT-R. As with DTM the base cars are scaled to fit the regulations so in basic terms they remain the same as their German counterparts.

'The entry list for GT500 in 2017 remains at 15 cars,' GTA chairman Masaaki Bandoh says. 'Once again we have six Lexus, five Honda and four cars from Nissan. One team has left the series, Ryo Michigami's Drago Modulo team, but Mugen will run an NSX this season so the total number of cars from Honda remains the same.'

In a year where big name drivers, including a former F1 world champion, are rumoured to be making guest appearances, while the series its gaining a growing international presence, Bandoh's answer to what he's most looking forward to this season is something of a surprise.

'The tyre war,' he states firmly. 'It remains all-out war, even more intense than last year. Team Mugen has opted for Yokohama tyres, meaning that one car from each brand is on Yokohama tyres and that is going to be interesting. Michelin remains only on its two Nissan GT-Rs and Dunlop supplies only a single Honda, everyone else is on Bridgestone.

'The competition among the tyre makers will be more clearly shown this year with the supplies being a bit more balanced. I think the tyre war will be really interesting through the year as the tyres are developed, and I don't think it will be predictable at all,' Bandoh adds. 'Dunlop has struggled a bit with results in recent years but I have heard it has a good budget this year and could produce something really special. This tyre war is something really unique and special about Super GT.'

Snowed off

In pre-season testing the new Lexus LC500 proved to be the most competitive car, but the conditions were not ideal when the cars were out in track, and temperatures were very low to the point where the second full day of testing at Fuji Speedway was snowed off, so how much of an advantage Lexus has is not fully clear. 'At the last round of the 2016 season an upgraded engine saw Lexus become very strong indeed, this year the new car seems to be even stronger,'

Lexus LC500. Under the new bodywork the main mechanical components remain, though the engine is substantially updated while cooling has been revised by TRD

After using the Concept version of the NSX last year Honda switches to the production car as the base for its 2017 challenger, which also features an all-new engine. Five NSXs will race in 2017

Nissan is sticking with its R35 GT-R for 2017 but there are rumours that it intends to switch to a new model for 2018. There are four Nissans in this year's GT500 field

The 2017 GT500 diffuser differs to that used in DTM but retains the same dimensions. The rear wing is also different; GT500 using a single plane whereas DTM uses a DRS-fitted dual-plane item

Bandoh says. 'The new model of Lexus seems to have suited these new regulations well.'

Looking over the new GT500 cars it becomes clear that, unlike in 2014, not all of the control parts are identical between the Super GT cars and those used in DTM. The rear wing is a single plane design in the Japanese series and does not feature DRS like the twin-plane design used in Germany. The diffuser differs between the two classes, too, though shares the same dimensions, and the wheels themselves have become a control part in DTM but in Super GT they remain free with wheel manufacturers like Wedsport being major team sponsors in GT500.

'It is clear that we are going in the same direction with the new rules, but when and if we have a joint race we will run the same parts,' Bandoh admits. 'One of our major targets is to have a pair of finale races to start this collaboration, one in Japan and one in Germany. These will be exhibition races. All the cars will be on the same tyres, wings and things like that.'

So it is clear that the original idea of a joint DTM and Super GT race is still very much on the table with the 2019 season remaining the target, but there do remain some sticking points between the two series, such as Honda's use of a mid-engined car, and the ethos of freer technical development in Japan.

However, Bandoh clearly feels these points can be overcome. 'In Japan we will not stop technical development, because that is the ethos of the series. Why would we stop that? But when the common races happen we have to run the same specification, so it is fair. Some things will remain different though, the wheel rims for example in DTM are single spec, but we will not have that kind of thing. But we will have the same diffusers, floors and engines, of course.'

World championship?

But the unification between the two series was never meant to stop at just a handful of exhibition races, entertaining though they would be. A full united championship called Class 1 was always the intention, and it appears that despite repeated delays in the full unification taking place it's still on the agenda.

However, complicating things somewhat are insistent whispers from Europe that the FIA is proposing that the World Touring Car Championship in its current form concludes at the end of the 2017 season, takes a year off in 2018, and returns as a new World Championship running to Class 1 regulations in 2019. But this time-scale seems optimistic considering some of the hurdles still to overcome for full unification to take place. 'We have thoughts about the future as GTA [promoting body], we want to look at more things, about how a Class 1 series could work, I have heard the rumours about the WTCC proposal, but I have yet to meet Gerhard Berger [new DTM boss] or the FIA and discuss the way forward. There are some ideas about this of course, but it is a bit too early to reveal too many details yet.'

So it seems clear that in the coming months an attempt at putting together a joint plan will happen. What form it will take and whether it will succeed remains to be seen.

It's clear that the idea of a joint DTM and Super GT race is still very much on the table, with the 2019 season the target

Sizzling sibling

Some might view GT300 as a poor relation of Super GT big brother GT500, but with a wide variety of racecars and cleverly devised technical regulations it's a 'super' series in its own right

By SAM COLLINS

Subaru campaigns a JAF GT300 spec BRZ which is powered by a WRC-derived 2-litre engine

Bentley is to race in GT300's GT3 class in 2017. With three different classes and an ongoing tyre war, BoP is a difficult task

GT300 MC GT86. The growth of the Mother Chassis class has meant a resurgence of pure race engineering skills in teams

Unlike DTM, Super GT is a two class championship. Its second tier class, GT300, is also looking to grow internationally and collaborate with other major series including some from Europe. The class is, for many, the more entertaining of the two and it has wide technical variety with three sub classes of car, FIA GT3, JAF GT300 and the GTA MC 'Mother Chassis' GT300.

The first of these is exactly the same as GT3 everywhere else in the world: a pure BoP based class, while JAF GT300 and MC are both based on detailed technical regulations. The former of these two car classes is quite similar to GT500 from some years ago, some production parts must be used in the creation of the car (though very few) and the engine must come from the same manufacturer as the chassis. In the past this has seen LMP2-engined Honda CR-Zs and currently a Toyota LMP1 V8 engine found in the back of a Toyota Prius, while Subaru uses a WRC-derived 2-litre flat-4 in its BRZ.

GTA's Mother Chassis sub-group of car features a single make composite monocoque, engine and transmission, as well as a kit of other parts, but leaves many areas of the car, including the entire body, free for development.

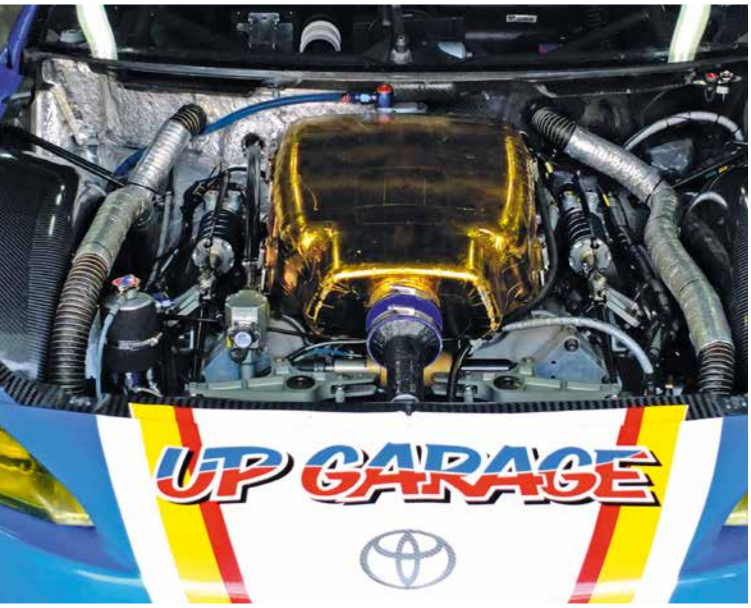
BoP stars

All three groups of cars are performance balanced together so they race well among themselves as well as with the faster GT500 cars. The responsibility for sorting all of this falls to Claude Surmont of SRO, who also does the BoP for the Blancpain series in Europe, among others.

'In GT300 we will continue working with SRO for the Balance of Performance,' explains Masaaki Bandoh, chairman of GTA, Super GT's promoter. 'We also have a new GT3 machine in the Bentley and it is already proving very popular with the fans. We have nine different GT3 models and they are seen as exotic cars here in Japan. The JAF GT300 class remain as in 2016, with the two Toyota Prius, one on Bridgestone, the other on Yokohama tyres, while the third JAF GT300 car, the Subaru BRZ runs on Dunlops. Finally there are the Mother Chassis cars. We have six of them this year including the new Toyota Mark X, the mid-engined Lotus Evora, and four Toyota GT86s.'

Making sense off all of these different cars is complicated by the fact that there are moving goal posts to contend with. 'The BoP is very tough to do in GT300, as there are the three different car types, but also a tyre war,' Bandoh says. 'When BoP is done for the GT3 cars in Europe it's all done on the same Pirelli tyres, but here the tyre war means that not only are there three tyre makers in GT300, but also a mix of commercially available tyres which any team can buy and use, plus development tyres supplied to specific teams. On top of that is the fact that the JAF GT300 cars have in-season development, while the GT3 cars are fixed specification.'

Watching the Super GT races, the BoP seems to be working reasonably well and no one



Mother Chassis (MC) GT300 racecars all use this GTA-branded V8 engine and a single make transmission. They also use the same type of composite monocoque

Lotus Evora MC. MC rules allow for development of many areas of the racecar, including the entire body. Super GT says MC cars could become part of a pan-Asian feeder series

type of car, and indeed no one model of car, dominates. In 2016 a Mother Chassis car took the championship and this was an indication to Bandoh that this new type of car is ready to expand internationally, which was always the intention when it was first announced.

Mother's day

MC has been attracting new blood from further afield, too. The appearance of an MC Toyota GT86 run by Panther Team Thailand as a full season entrant is perhaps a surprise at first glance, as the team had only ever competed in one of the races in its home nation, and GT300 is already oversubscribed with Japanese teams. But when you explore the concept of these cars it begins to make sense. 'They got a special wild card entry into the series as they are a foreign team and we want to encourage them,' Bandoh says. 'GTA keeps two slots on the entry list for foreign teams to compete. We are communicating with Asian countries to see if any other team wants to participate [and] there is interest.

'We are trying to lower the cost of racing for teams but also let them increase their engineering capabilities,' Bandoh adds. 'The [capability] of the teams has fallen a bit as a result of the growth of GT3 in Japan and South East Asia,' Bandoh adds. 'In the past when development was open the GT300 teams had a high level of technical capabilities, but when they all bought GT3 cars and had fixed specification they lost that ability. The Mother Chassis cars should bring some of that back, but we have not yet seen their full capability. If more Mother Chassis cars are built, perhaps it would be possible for a new class of race to start limited to just Mother Chassis cars, it could be like a Super GT junior series to develop young drivers and teams. Perhaps South East Asian teams could join Super GT initially by racing with GT3 cars, as many already do in series like GT Asia and Blancpain Asia, then stepping up to the Mother Chassis, which will improve their technical ability, and finally they could qualify into Super GT itself.'

The reason that new teams buying a Mother Chassis car, or indeed a JAF GT300 or GT3 car, could not expect to go straight into Super GT is quite simple – the series is oversubscribed.

Tiers for fears

'We received 48 entries for the 2017 Super GT series, and have 45 cars at each race and will restrict it to that,' Bandoh says. 'Even then we have to lose one car from the race at Sportsland Sugo because of the size of the pitlane there. So we have seeded all of the teams in the series into three tiers: tier A consists of all the GT500 teams and 13 cars in GT300, the remaining GT300 cars are in the B tier apart from five or six of them which are in the C tier. The allocation of the tiers has been based on past performances. At Sugo the C tier team with the fewest points will not get an entry to that race. In the near future the teams list will be fixed and made permanent with a kind of franchise system. This means that if a new team wants to join Super GT they will have to contact an existing team and buy its entry. It's something I have wanted for Super GT for a long time. I have tried for perhaps 10 years to bring this in and now I have finally achieved it.'

There may be other outings for GT300 cars beyond Super GT. Mother Chassis cars have already raced in a domestic series in Thailand and others may follow. Additionally it has been announced that 2017 will be the final running of the Suzuka 1000km race, and in 2018 a new 10 hour GT race will be run at that circuit instead with GT3, GT4 and GT300 cars taking part.

'This will not be a Super GT championship round,' Bandoh says. 'For some teams the cost is quite high as it is such a long race, so we have to be careful about that. Another issue is that the intercontinental challenge GT3 teams are more like works teams, and the Super GT GT3 teams are not like that, they are privateer teams, so it is not racing like for like, so that too we need to be very aware of. I watched [a race] at Sepang, where GT300 cars raced with GT3 cars, last year and the works-backed GT3 teams are really very fast. It was clear to me that if you mix up the Super GT GT3 cars and Blancpain Asia with the intercontinental GT3 teams that it will not be a very even fight.

'There is still some work to do on this race at Suzuka to make it the best it can be. I don't really want the Super GT teams to be a second tier, so we are discussing all of that,' Bandoh adds. 'Then on top of those things there is the issue of the Prius. For many people it is very strange to see a Toyota Prius overtaking a Ferrari going down the main straight. The pure fans like to see it as they are passionate and understand the cars, but it is still really a strange sight for most people. Stephane Ratel has said to me and others that it is not good to see a Prius beating a Ferrari, politically it is not good to see that.'

GT300 seems to be a category which is gradually but undeniably growing, and like its big brother it could eventually expand internationally, even beyond Asia.

'Then there is the issue of the Prius. For many people it is very strange to see a Toyota Prius overtaking a Ferrari going down the main straight'

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A smarter dummy

How Toyota's FE model of the human body (THUMS) has helped the FIA in its study of spinal injuries from frontal impacts in the WEC

By PETER WRIGHT

Back in 2012 Anthony Davidson suffered an injury to his spine after this accident. His Toyota LMP1 was hit by the Ferrari and rolled before clouting the barrier. The injuries Davidson sustained, and those from other crashes, prompted the FIA to look at seat safety

It was less than five hours into the 2012 Le Mans 24 hour race. Anthony Davidson's Toyota TS030 hybrid LMP1 car attempted to overtake one of the AF Corse Ferrari 458s, and was hit by it in the rear left suspension. The Toyota slewed sideways and took off. After a combined end-over-end and roll, the car landed on its left rear corner and slid head-on into the tyre barriers. Davidson extracted himself from the car, but only made it on to the sidepod before realising he had injured his spine, and then decided not to move further. It transpired that he had crushed vertebrae T11 and T12, just above the interface between the thoracic and lumbar sections of the spine.

While it was not clear which of the series of impacts had caused the damage, the vertical landing or the frontal impact, the FIA Institute was already alerted to a problem in LMP cars by the Guillaume Moreau head-on crash in an LMP2 racecar, at the Le Mans test that very same year. He too had injured his T12 vertebra, in a purely frontal impact.

Spinal injuries are very difficult to research using anthropomorphic dummies (Hybrid III and THOR) and Hi-Ge sleds, as the dummies were not developed for such research and the representation of the spine is not particularly biofidelic; the rigid mechanism used prevents flexure other than for adjusting seating posture.

With the above in mind the FIA Institute approached the Toyota Motor Company (TMC) through its motorsport arm in Cologne, seeking cooperation to research the cause of spinal injuries in frontal impacts, using TMC's sophisticated FE model of the human body: Total Human Model For Safety (THUMS).

By the time you read this, Toyota will have presented a paper to the SAE World Congress,

As LMP1 cars employ two or three drivers for each event, a small and a large driver were modelled, along with their seat mouldings

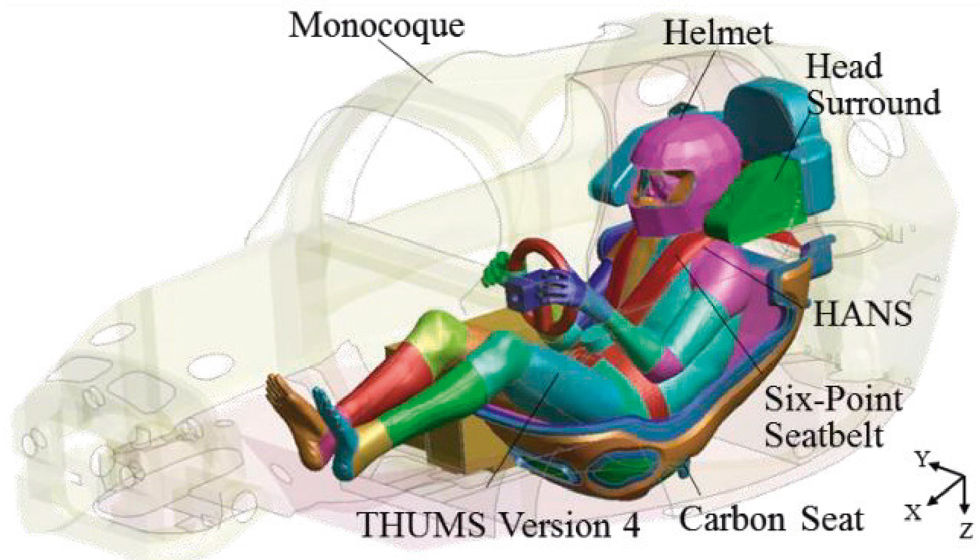

Figure 1: The THUMS driver in the LMP1 cockpit with his restraint system (*SAE Paper 2017-01-1432*)

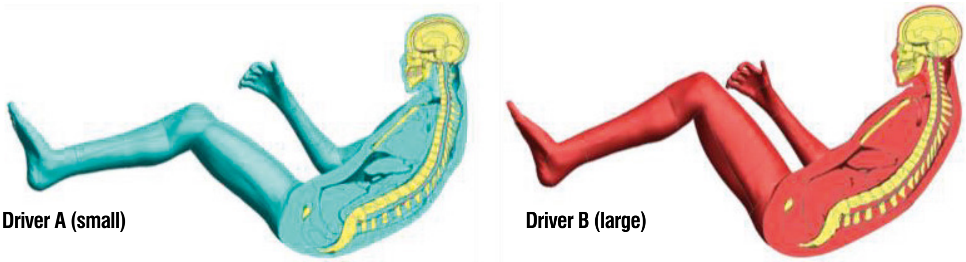

Figure 2: The two drivers evaluated in the simulations; A is based on Davidson, B on Wurz (*SAE Paper 2017-01-1432*)

Table: 1. Comparison between Driver A and Driver B and 50 per cent THUMS human model

	THUMS Version 4 AM50	Driver A	Driver B
Height [cm]	177	160	185
Weight [kg]	74	55	80

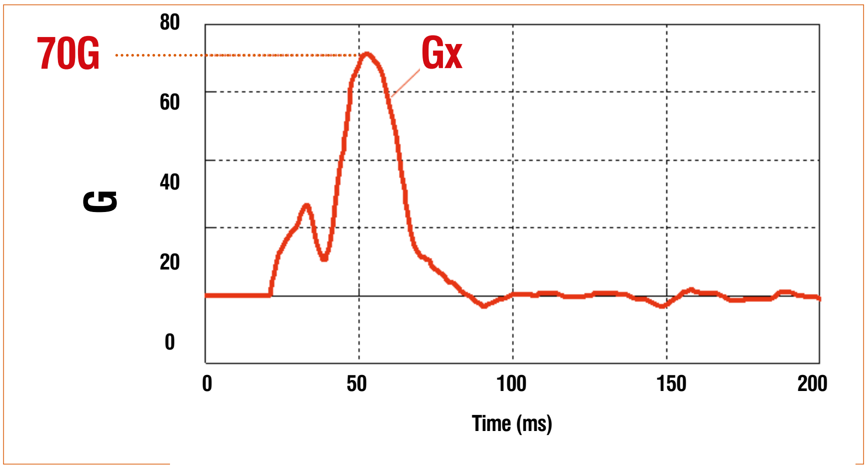

Figure 3: SFI Spec 38.1 crash pulse was used for this study (*SAE Paper 2017-01-1432*)

which describes the work carried out by TMC in this cooperation: *SAE Paper: 2017-01-1432: Analysis of Driver Kinematics and Lower Thoracic Spine Injury in World Endurance Championship Race Cars during Frontal Impacts*. Authors: Tadasuke Katsuhara, Yoshiki Takahira, Shigeki Hayashi, Yuichi Kitagawa, Tsuyoshi Yasuki.

Some 6500 spinal injuries occur in car crashes annually in the United States, according to the NSCISC (National Spinal Cord Injury Statistical Center), and there is a tendency for these to occur in frontal impacts, it reports. In motorsport the overall injury rate is much lower, but Dr Terry Trammell *et al* have reported that in IndyCar, a high proportion of injuries are spinal injuries, particularly in front and rear impacts into the relatively stiff walls of high-speed ovals.

Driver models

With the difficulties experienced when using dummies for spinal injury research, driver kinematic models such as MADYMO have been employed in simulations. While useful in studying the kinematics and loadings they do not possess the detail necessary to evaluate the stresses and strains on individual bones or organs that allow injury severity to be assessed. TMC has created the industry standard FE model of the human body, THUMS, in a joint development between Toyota Central R&D Labs Inc. and Toyota Motor Corporation, over a period of more than 20 years. THUMS is used widely by the automobile industry in its many versions.

THUMS Version 4 was employed in the WEC research, scaled to driver size and incorporated into an FE model of the cockpit, including:

- **Seat and head surround**
- **Harness**
- **Helmet**
- **HANS**
- **Steering wheel**
- **Pedals**

The total number of elements used in the model was 2.2 million.

As LMP1 cars employ two or three drivers for each event, a small and a large driver were modelled, along with their seat mouldings. The seating positions of the drivers, and most importantly their initial spine geometries were established by MRI scanning Anthony Davidson and Alex Wurz (little and large), whilst they sat in their correct driving positions.

In the initial study, a number of deceleration pulses were evaluated, combining vertical and longitudinal components. For the work covered by the SAE paper, the SFI Specification 38.1 pulse is used, Peaking at 70*g* longitudinal deceleration after around 50ms, this pulse is used as a certification pulse for testing most

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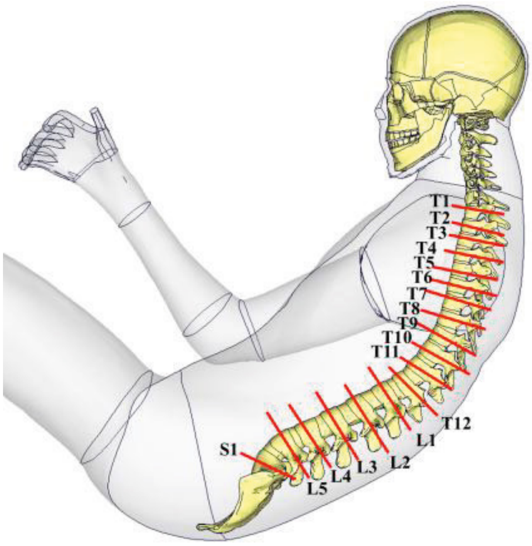

Figure 4: Positions of the thoracic and lumbar vertebrae (*SAE Paper 2017-01-1432*)

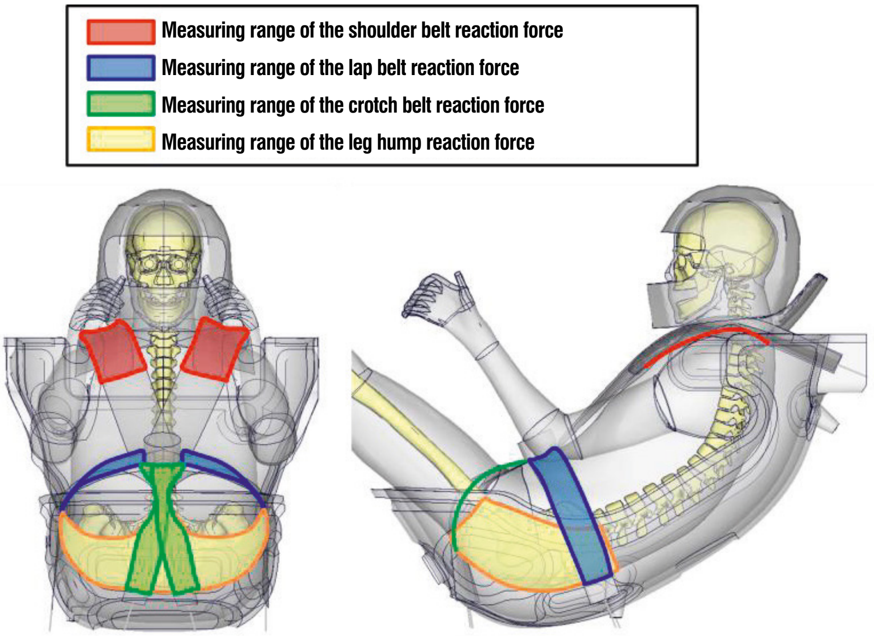

Figure 5: Measuring range of the reaction forces (*SAE Paper 2017-01-1432*)

Table 2: Cockpit and restraint geometry for initial runs; Driver A and Driver B

Case No.	1	2
Driver	Driver A	Driver B
i) Shoulder belt angle	-20 deg	-20 deg
ii) Seat back angle	35 deg	35 deg
iii) Crotch belt anchor position	Rearward	Rearward
iv) Shape of leg hump	Decline (40 deg)	Decline (40 deg)
v) Seat pad thickness	60 mm	None
vi) Seat pad stiffness	0.3 MPa	None

Table: 3. Maximum excursion of head, chest and pelvis of Driver A

x-axis	y-axis	z-axis	
Head	250mm	10mm	110mm
Chest	150mm	20mm	100mm
Pelvis	100mm	5mm	-25mm

top-end race driver safety equipment, and thus is judged to be survivable without serious injuries, providing the approved equipment is fitted correctly, of course.

Slow motion replay

A single run of the simulation, which lasts around 150ms in real time, takes about 24 hours of computational time. The output of the model includes the motion of each component of the skeleton and the organs, the forces and pressures and – particularly relevant to spinal injury – the axial force and bending moment of the spine. The cross-sectional area and section modulus of the cortical bone of each vertebra was calculated for each of the two race drivers, and thus the actual force and bending moment components of the spine stress could be calculated, and finally the spine stress of each individual vertebra. Based on biomechanical research on bone fractures it was postulated that bony fracture occurred when the ultimate strain of the shell element of the cortical bone exceeded three per cent.

The harness, HANS, and seat provide the reacting forces to restrain the body masses. The forces in the system and how they are applied to the body are also input to the THUMS model.

The base parameters for the initial runs are shown in **Table 2**:

The main difference between the two drivers' seating positions is the foam seat insert. With a prescribed eye height and pedal position, Davidson had to stretch himself out, straightening his body by raising his backside.

The results indicated T11 and 12 fractures on the small driver, giving confidence that they correlated with Davidson's actual injuries. Of concern were the results for the large driver, which suffered fractures of T11, T12, L1, L2 and L3. The simulations graphically showed why these injuries were occurring and the mechanisms that caused them. Time histories of the motion of the head chest and pelvis, in three dimensions, show that there is almost no motion for the first 30ms (peak *g* at 50ms). They reach their most forward position at around 70ms. Maximum excursions for the small driver in each of the three axes are shown in **Table 3**.

Figures 6 and **7** show that the pelvis is restrained in the x-direction by the seat ramp and rearward mounted crotch belts, the ramp causing the pelvis to rise. The chest moves forward and downwards, causing the spine to flex, reacting against the relatively unmoving pelvis to add the compression force. The combined flexure and compression concentrates the stress on the anterior (forward) part of the vertebrae around the area of maximum flexure – the interface between the thoracic and lumbar spines. Forward movement of the shoulders under the shoulder belts creates tension loads in the belts, the result of which is a downward force almost directly along the spine. This creates the compression force that ultimately does the damage to the lower spine. When the spine is straight it is able to withstand the compression without damage.

The larger driver was susceptible to greater compression and bending loads. The partial reason for this is his greater mass.

The development of countermeasures focused on three key features that it was considered contributed to the high bending and compression loads:

- **Pelvis restraint**
- **Seatback angle**
- **Shoulder belt geometry**

The larger driver was susceptible to greater compression and bending loads. The partial reason for this is his greater mass


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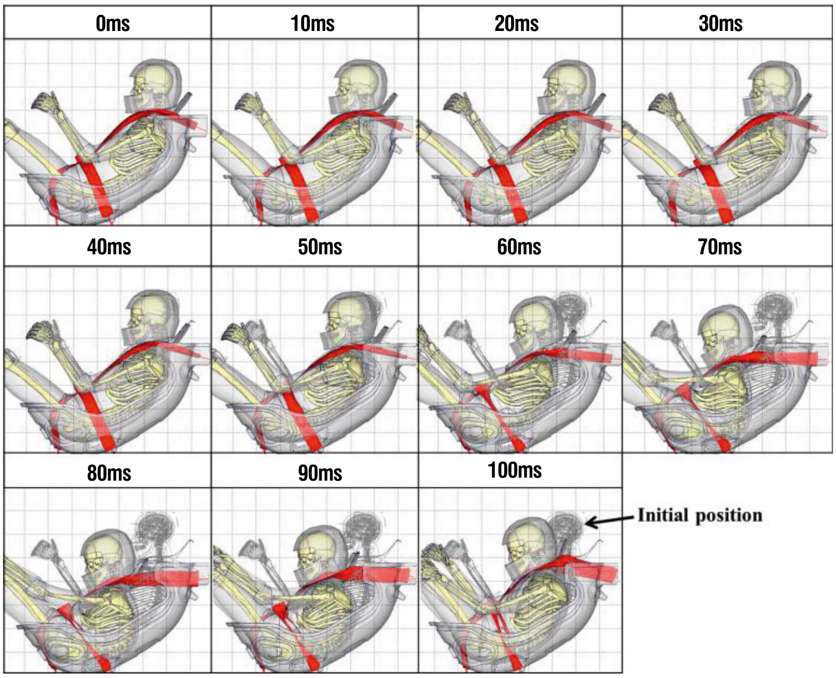

Figure 6: Kinematics of Driver A (*SAE Paper 2017-01-1432*)

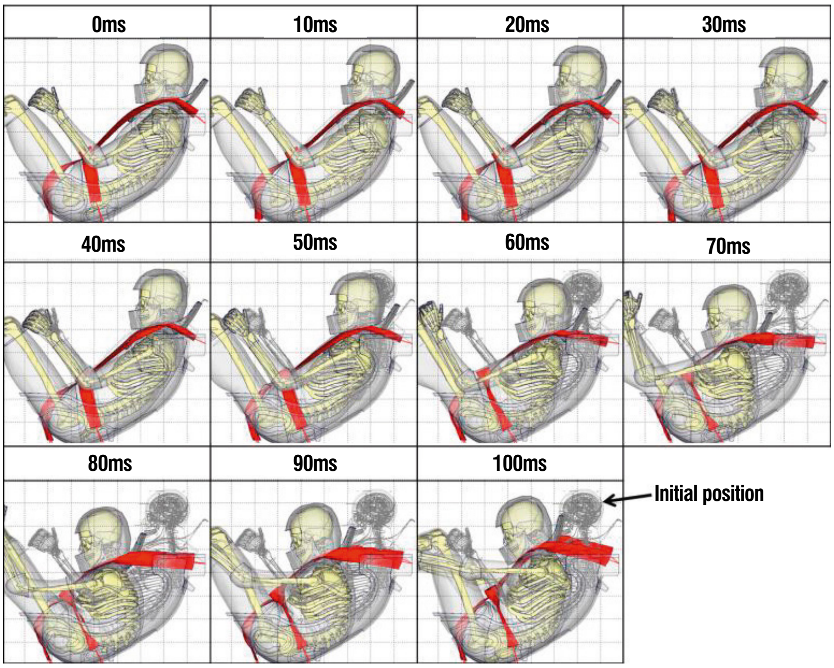

Figure 7: Kinematics of Driver B (*SAE Paper 2017-01-1432*)

Allowing the pelvis more forward motion, reducing the forward motion of the torso, and reducing the downward component of the shoulder belt loads should reduce the likelihood of spinal injury.

A series of cases were developed (**Table 4**), concentrating on the smaller driver, but with the larger driver assessed at the end once a solution for the small driver had been achieved.

The optimum set-up, Cases 9 and 10, with horizontal shoulder belt mounting; 55-degree seatback angle; forward crotch belt mounting; and the seat ramp retained, but with a thick, soft cushion to allow movement, generated no spine fractures in either the small or large driver.

Maximum spine stress was reduced by 32 per cent for the small driver and 62 per cent for the large one. Note that in Cases 6 and 7, where the seat ramp has been flattened to horizontal, all the restraint of the pelvis is provided by the crotch belts, and results in fracture of the pelvis.

Road car value

This work reached a satisfactory conclusion and has deepened the understanding of spinal injury mechanisms in motorsport, particularly in frontal impacts with reclined seating positions. It'll be some years before it can be seen statistically whether the countermeasures prevent such injuries, but perhaps the greatest value of such cooperative work lies outside motorsport, so highlighting how the sport can make a significant contribution to road car safety.

Toyota has spent two decades developing the industry standard for an FE model of the human body for vehicle safety research; it has been widely adopted by the industry and research labs and is now replacing the anthropomorphic dummies for R&D, if not yet for certification. It is of enormous benefit to motorsport safety to be able to make use of this simulation model.

In return, motorsport provides specific and highly detailed cases of accidents and resulting

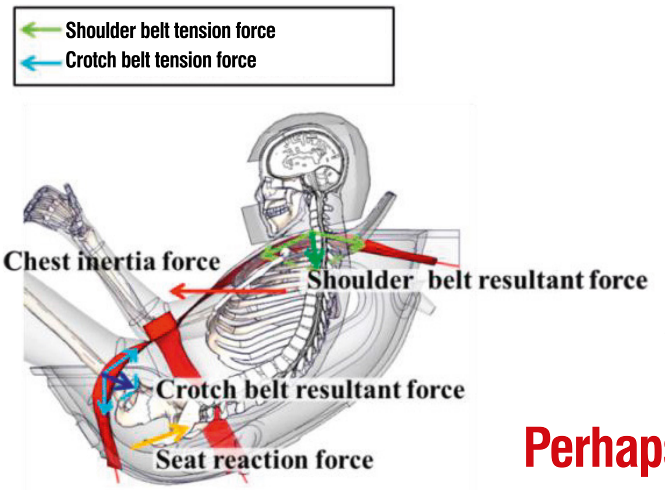

Figure 8: Shoulder belt force (*SAE Paper 2017-01-1432*)

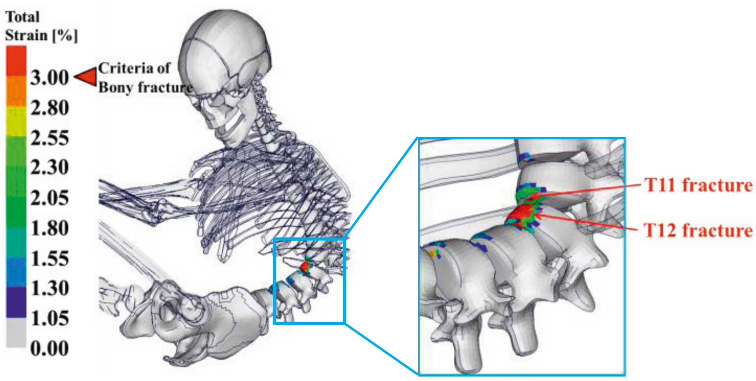

Figure 9: Peak vertebra strain: Case 1, Driver A (*SAE Paper 2017-01-1432*)

Perhaps the greatest value of such cooperative work lies outside motorsport

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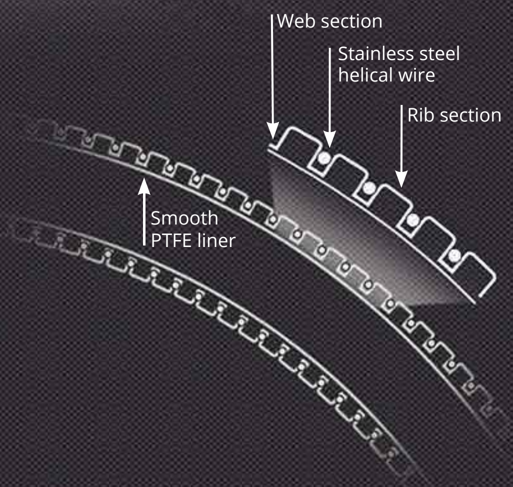

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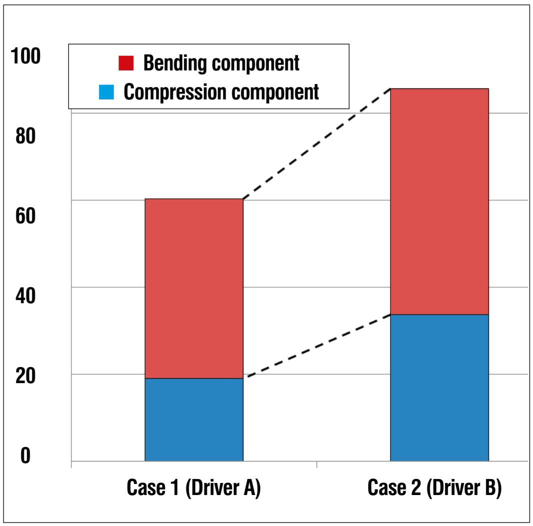

Figure 10: Comparison of maximum T12 stress, Driver A *v* Driver B

injuries. The vehicle and driver are instrumented, and there is often video footage of the accident, sometimes even high-speed video of the driver dynamics. Detailed medical data concerning the injuries is usually available and the driver nearly always cooperates in any post-accident investigation, maybe involving MRI scans.

All combined, these cases present an opportunity to validate THUMS analysis and will inevitably contribute to the further development of THUMS. The accelerations and forces generated by motorsport impacts are at the upper limit of survival and generate extreme conditions for the simulation.

The cooperation between TMC and the Global Institute, which has succeeded the FIA Institute, will continue in order to widen the knowledge of spinal injury causes across all forms of motorsport.

Racecar Engineering ***says: this could have implications across all forms of motor racing, with the WEC delaying the introduction of new chassis from 2018 to 2020. Single seat race cars from IndyCar to Formula 3 will also have to pay close attention to these findings.***

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For more on this subject please see Racecar Engineering *August 2015 (V25N8).*

Table 4: Number of bony fractures and maximum value of T12 stress for all cases

Case No.	1	2	3	4	5	6	7	8	9	10
Driver	**Drive A**	**Driver B**	**Driver B**	**Driver B**	**Driver B**	**Driver B**	**Driver B**	**Driver B**	**Driver B**	**Driver A**
i) Shoulder belt angle	-20 deg	-20 deg	0 deg	-20 deg	0 deg	0 deg	0 deg	0 deg	0 deg	0 deg
ii) Seat back angle	35 deg	35 deg	35 deg	55 deg	35 deg	55 deg	55 deg	55 deg	55 deg	55 deg
iii) Crotch belt anchor position	Rearward	Rearward	Rearward	Rearward	Rearward	Rearward	Forward	Forward	Forward	Forward
iv) Shape of leg hump	Decline (40 deg)	Decline (40 deg)	Decline (40 deg)	Decline (40 deg)	Decline (40 deg)	Flat (0 deg)	Flat (0 deg)	Decline (40 deg)	Decline (40 deg)	Decline (40 deg)
v) Seat pad thickness	60mm	None	None	None	76.2mm	76.2mm	76.2mm	76.2mm	76.2mm	76.2mm
vi) Seat pad stiffness	0.3 MPa	None	None	None	0.3 MPa	0.3 MPa	0.3 MPa	0.3 MPa	0.2 MPa	0.2 MPa
Chest deflection rate	5 %	6 %	6 %	5 %	10 %	12 %	18 %	15 %	16 %	15 %
Number of spine fracture	2	5	5	5	4	3	2	1	0	0
Pelvis fracture	None	None	None	None	None	Pelvis fracture	Pelvis fracture	None	None	None
Maximum spine stress	60.0 MPa	85.6 MPa	77.6 MPa	72.3 MPa	68.7 MPa	68.4 MPa	49.3 MPa	41.4 MPa	40.9 MPa	32.6 MPa

SEEN: Toyota TS050 Hybrid

Toyota presented its 2017 Le Mans challenger, the TS050 Hybrid, as *Racecar* was closing for press. It made its track debut at the pre-season test at Monza and will race in the World Endurance Championship this year. The car has a new 2.4-litre V6 engine with a higher compression ratio compared to the 2016 unit, while the MGUs have been reduced in size and weight. The front splitter height has been increased by 15mm in combination with a narrower rear diffuser in line with new regulations. The suspension geometry has also been optimised to accommodate the new tyre regulations which sees a reduction in the number of sets available during a WEC race weekend.


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Baby **boomer**

Onroak thought long and hard before committing to LMP3, but the commercial success of its Ligier JS P3 has more than vindicated its decision to go ahead with its 'baby prototype' programme

By LEIGH O'GORMAN

Ligiers to the fore at Sebring, where a JS P3 LMP3 won both of the IMSA Prototype Challenge sprint races. The racecar has also been a great commercial success for its maker, Onroak

When the ACO conceived of the LMP3 class to bridge the gap between LMP2 and CN-class machinery, many in the motorsport industry applauded the move. And among those happy to see the emergence of this new 'baby prototype' was French motorsport powerhouse Onroak, which soon got to work on a new car for the class.

The car that emerged was the Ligier JS P3 – loosely based on its bigger pre-2017 LMP2 class brother, the Ligier JS P2. Benoit Bagur, manager of Onroak's LMP3 project, remembers that while the concept of the new category made sense for the market, It also fed directly into a gap for the French manufacturer. 'The idea [from] the ACO was to create an intermediate category with an intermediate and accessible cost for the car and the season to pass from CN to LMP2,' says Bagur. 'There was nothing in between in the endurance racing world, and it was a very big jump in terms of performance and cost to reach LMP2 level.'

However, as Bagur reveals, not all elements of the concept were welcomed. An initial cost cap of €190,000 and weight limit of 900kg raised eyebrows and questions, forcing incoming manufacturers to press the ACO to reconsider both the cost cap and minimum weight. 'It was one of my concerns at the beginning,' he says, adding: 'With the weight of the car and the cost of the car inside the rules, it was not possible [to meet the regulations], so the difficulty of this car was to combine these aspects, because we need to have compromises in technical [quality] to meet the cost.'

Following some negotiations, the minimum weight was raised to 930kg and the cost cap was raised to a more manageable €206,000, although Bagur contends that this still leaves a very tight margin [for profits].

'We had to create an LMP3 car more than twice cheaper than an LMP2 car. At the beginning it was a hard decision to do this Ligier JS P3, because the price is very low, so it was very difficult for us to decide to put the investment required to build a reliable and [well] performing racecar,' says Bagur.

'With a cost cap category, the business model relies on the aftersales services and spare parts,' Bagur adds. 'In 2015 it was a

Onroak was expecting approximately 15 sales per year, yet in just 18 months it has delivered 80 Ligier LMP3s

An initial cost cap of €190,000 and weight limit of 900kg raised eyebrows and questions

tough decision to take, since the LMP3 market was obviously just in its early days.'

Due to the structure of the technical regulations, it is no surprise that the JS P3 shares many commonalities with the Ligier JS P2. However, Bagur tells *Racecar* that the main difference lies in the flat bottom, which is completely flat within LMP3, rendering it somewhat less efficient compared to LMP2.

Despite regs designed to keep costs low, there are still some small areas where freedom persists. 'We decided to use the rear gurney, because this and the dive plane at the front are the only parts that you can remove or [change] in this category. The concept of the front splitter is quite similar with the experience we have with the Ligier JS P2, and with the diffuser we have much less liberty compared to the LMP2. All the rest has to stay, as it is homologated.'

Yet as Bagur reiterates, finding a compromise between keeping the costs and the weight low defined much of the concept of the Ligier JS P3. 'The target was to reach the maximum aerodynamic performance, using reduced cost bodywork based on the LMP2, but with fewer parts and simpler parts.'

Aero smiths

While many of the aerodynamic principles were carried over from the Ligier JS P2, the optimisation of the JS P3 was done in CFD in conjunction with EXA, with the collaboration focusing on areas where the LMP2 and LMP3 regulations differ, such as the floor, while additional changes were made to optimise external airflow. However, Bagur says that the collaboration with EXA did not stop there. 'We also worked together on the internal airflow [and] driver's ventilation, a very important asset for the Ligier JS P3. Onroak Automotive and EXA engineers work in close collaboration, and we have a real and efficient partnership that started with the Ligier JS P2 and has continued with the Ligier JS P217 design.'

The wheelbase of the Ligier JS P3 came to 2860mm, although the design team was limited in their options. 'The overall front and rear was limited and the maximum length of the car is limited, as all the chassis are to be used by very tall drivers, up to 1m95. So that [tall drivers] can buy the car, we have set this to what is the maximum permitted by the rules.'

Inner space

With larger drivers still in mind, the regulations also made sure there would be ample space and ventilation in the cockpit. For Bagur, the principal effort was determining space in the frame for longer legs to increase comfort for the taller drivers. 'It was clear the rules with a minimum dimension for the cockpit help a lot for this. The very efficient ventilation system developed for the Ligier JS P3 in partnership with Stand 21 and EXA is also an important asset in term of comfort and security.'

While many areas of the car are effectively locked-in by the regulations, Bagur feels that Onroak has made significant gains with regards to weight optimisation of the Ligier JS P3, as well as its ease of maintenance. Yet these too were advantages born out of a careful balance. 'It was a compromise between cost and the weight of parts, and in this we did a good optimisation with our partner, HP Composites in Italy, to study the chassis with good weight and good cost.'

Bagur claims that the running costs are cheap with this car, too. 'We can assume excellent LMP3 running costs per km. It is lower compared to the CN. The engines do 10,000km now; the gearbox reaches the same amount of kilometres before a big rebuild and the cost of a rebuild engine is €15,000, so compared to other categories in endurance, it is very cheap.'

Baby brother

The Ligier JS P3 uses plenty of technology from its LMP2 sibling, such as wheel bearings, uprights and driveshafts. 'The Ligier JS P3 mechanic parts are robust and reliable, so there are rarely changes needed,' Bagur says.

Under the hood – as it were – the series has mandated the use of the Nissan VK50 engine. The 5.0-litre V8 power unit produces 420bhp and possesses a maximum torque of 540Nm (400lb.ft). Supplied by ORECA, the engine is mated to a 6-speed sequential mid-engine longitudinal transaxle gearbox from Xtrac, which uses a semi-automatic paddleshift system. The powerplant is managed by an ECU provided by Magneti Marelli.

Suspension for the Ligier JS P3 was designed in-house at Onroak's design base in Le Mans and produced at its Magny Cours factory. The optimised suspension geometry is a double wishbone, pushrod and spring-damper combination, with an adjustable anti-roll

TECH SPEC

Ligier JS P3

Chassis: carbon monocoque by HP Composites	
Engine: Nissan VK50 V8; 5.0-litre. Max power: 420bhp. Max torque: 550Nm. Developed and supplied by ORECA	
Engine management: Magneti Marelli	
Transmission: Xtrac 6-speed sequential gearbox, semi-automatic paddleshift; Oil-exchanger-cooled gearbox	
Suspension: Double wishbone, pushrod and spring-damper combination; three-way latest generation of dampers; Adjustable anti-roll bar system; third element front and rear	
Steering: hydraulic power steering	
Brakes: 6-piston calipers; 14in steel discs front and rear	
Wheels: Oz magnesium 18in diameter; front width 12.5in; rear 13in	
Fuel tank: ATL, 100-litre capacity	
Weight: 900kg (homologation weight)	

Ligier JS P3 shares some technology with its big brother, the pre-2017 LMP2. Yet while many of the aerodynamic principles were carried over from the JS P2 much of the aero optimisation of the P3 was completed in CFD in conjunction with EXA

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‘We want to expand the LMP3 market in Asia and North America’

system and third elements front and rear. The wishbones are steel welded, while the uprights are aluminium casts. All of the welded parts of the suspension are made internally .

Brake balance

The Ligier JS P3 uses brakes from Brembo. ‘We asked for the strongest performance from AP Racing, Brembo and Alcon, and Brembo was the best compromise in terms of cost and performance, so we chose it,’ Bagur says.

The car uses wheels supplied by OZ Racing, the rims of which are of magnesium alloy construction. They are 18in diameter and have a front width of 12.5in and rear of 13in.

As with the brakes, plenty of consideration was required when it came to selecting a steering system. While much of the design philosophy behind the Ligier JS P3 is based on balancing cost versus weight and practicality, Bagur believed that spending more on a higher-grade steering system would provide plenty of benefit for those behind the wheel in terms of both the performance and the reliability, not to mention driver safety. ‘We chose to use a hydraulic system,’ he says. ‘We know with electric steering, if you put in a lot of cost, you can have very good steering, but the risk with a cheaper system is to have some problem of performance when you need a quick change of [direction].’

Bagur also points to a lack of testing time forcing Onroak’s hand when a decision needed to be made. ‘There was no time to do some tests and to consider this choice with the timing, so it was possible to make a mistake and have technical problems, so for this reason we chose to go with a hydraulic system.’

At events where its LMP3 cars are in action, Onroak offers a dedicated support solution for its customers. Alongside a traditional aftersales service in each of its workshops, Onroak also offers a global technical support solution and season-long dedicated service. ‘We have developed a travelling support in Europe, North America and Asia,’ Bagur says. ‘Technicians and engineers, and trucks with spare parts and material, travel to many events.

‘With a dedicated and appropriated version of this travelling support service, we are able to follow and accompany our clients on a lot of series, for example the V de V Endurance Series, the European Le Mans Series, the IMSA Prototype Challenge, the Asian Le Mans Series and Sprint Cup, or the FRD LMP3 Series in China.’

Tub is by HP Composites, and cockpit is roomy. There’s little in the way of freedom for aero development at the rear in LMP3

Onroak opted for hydraulic power steering. Suspension is double wishbone pushrod and spring-damper, with third element

Exceeded expectations

Both the Ligier JS P3 and the LMP3 concept as a whole has surpassed Bagur’s expectations. At the launch of the category he tells us that Onroak was expecting approximately 15 sales per year, yet in 18 months, the company has delivered 80 Ligier JS P3s and have more in production for the coming season.

So Bagur has good reason to set his sights high. ‘For 2017, we obviously hope to continue like 2016 in terms of sales figures. To that end, we want to expand the LMP3 market to Asia and North America. Therefore we opened a workshop in January in Sepang Malaysia and just opened in October our facilities in North America. These markets represent a very important part for our development, but also are the keys of the success of the LMP3 as a world sport prototype category.’

Onroak’s American adventure began successfully at Sebring in March, at the first IMSA Prototype Challenge event at the track to feature LMP3 cars in sprint format. The Ligier JS P3 took victory in both races. ‘We believe that the LMP3 category has a lot of advantages for the North American teams and drivers,’ says Bagur. ‘Also, mid-May, there will be the first race of the FRD LMP3 series in China and we shall see how the category will be received there. Yes, we can say that the Ligier JS P3 exceeded our expectations, as we were not expecting this, just like anybody to be honest, including the ACO.’

Bagur added: ‘We can see that the investment is worth it because the LMP3 category is growing and we managed to build a reliable and performing Ligier JS P3, easy and comfortable to drive, and one that respects the philosophy of a cost cap category, with low running costs for the teams.’ All *bon*, then.

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The X-raid Mini finished sixth on this year's Dakar, its debut on the gruelling event. The car is based on the new John Cooper Works version of the Countryman

Dune tune

Racecar traced the development of X-raid's Mini Countryman F60 and discovered that building a Dakar entry is as much about making a tough racecar as a fast one

By LEIGH O'GORMAN

Peugeot's domination of the 2017 Dakar Rally may have garnered the headlines in early January, but X-raid's performance with the new Mini Countryman F60 was also a worthy effort. In a carefully crafted opening chapter for the latest Mini John Cooper Works Rally, Orlando Terranova and co-driver Andreas Schulz took sixth place, albeit almost two hours off the winning pace.

Speaking just prior to the South American adventure X-raid CEO Sven Quandt, a former rally raid competitor himself, made it clear that neither he nor Mini were expecting an easy ride, but that getting to the end was a priority. 'To finish the race is number one – first you have to finish before you can finish first, as it is said. Dakar is not necessarily dependent on the fastest car. You have to finish and that means you have to have a super reliable car, and this is what we hope we have got.'

But prior to the cars leaving Europe there was a less-than-ample amount of testing in conditions similar to that expected in South America: 'When we got the car we had no high temperatures [in Europe] anymore, so we had to wait to see if all the cooling and aerodynamics would work as we thought [in South America],' Quandt says.

X-raid had enjoyed Dakar success with the previous-generation Countryman, but its latest

Torque comes in very low for a diesel engine, but this does make the Countryman easy to drive in very difficult circumstances

challenger is in the form of the new F60 model, which was launched in Los Angeles last year. 'It is the first time in history that a racecar is presented together with the standard car when it's launched. Our relationship [with Mini] is quite a good one. We are not married and not divorced,' Quandt joked.

Having previously run the BMW X3 and X5, X-raid originally swapped to the Countryman to help showcase the Mini's abilities off-road with a more muscular machine, but the racecar is actually a similar size to the road car: 'It looks bigger, but it is not bigger. It has got only a wheel extension and a little bit more suspension travel, but the size of the car is more or less very, very similar to the original,' Quandt says.

The F60 also has some parts from the original road-going machine, but most of its kit is bespoke for rally raids, including a tubular frame and a carbon body, a 3.0-litre twin-turbo diesel engine from BMW, SADEV gearbox, Xtrac differential and 25cm of suspension travel.

All in, the weight of this new Mini Countryman comes in at approximately 1960kg.

The development process for the car began in June. Following some basic aero measurements, the bodyshell was calculated in CFD. 'We mounted the new body pieces on the car, then went back to the wind tunnel to see if we have the result that we thought,' Quandt says. 'In the end, we got a good result, with more downforce on the car. We have never really used aerodynamic devices and this was the biggest step forward, to have aerodynamic forces working on the car in the way we wanted. It was both wind tunnel and CFD.'

Following this, aerodynamic components for the F60 were developed at BMW Motorsport in conjunction with Magna Steyr, while production and fitting of components was done in partnership with Karcher. 'Aerodynamic wise, [the F60] is a big improvement. Basically four companies are involved in the development of the body to get the aerodynamics in place and make them producible, because some of the areas that were designed, we could not make them in carbon,' Quandt says.

Despite the aero development, Quandt says there were no major changes on the bodyshell, although several minor areas were tweaked to make them more serviceable. 'You can see that

The Mini is built around a tubular chassis made from aerospace standard steel and clothed in composite bodywork panels. Much of the weight has been moved down low in the car

Optimising the cooling has been a huge part of this project, with controlled ventilators for the brakes, turbos, gearbox and engine

in some areas the finish is different. Because the body parts were quite big we made some of them a bit smaller, or divided them. For parts that would easily break, we made them smaller, so that we don't have to change a whole side.'

The body of the car can now be taken off in 30 minutes if necessary and in events like the Dakar, these modifications can save significant time. 'It fits better, is more easy to work on. We just put all of our knowledge, and all that we had previously got wrong and made not so good, and tried to make it better,' Quandt says.

The chassis was made at CP Autosport in Germany from 1.77 steel, or what Quandt refers to as 'aerospace steel'. 'It's basically the best that we can get for this with different tube sizes. It's quite some metres, I can tell you, in this frame, and the frame is extremely strong. Most of the Mini's we built are still running, and even after some crashes you can always repair them.'

The work on the F60 frame has allowed space for three spare tyres to be placed underneath the chassis frame, instead of two, and Quandt says: 'In the greenhouse, there is no weight, except the heads of the people. The rest is the tubes and the body. But all the weight is below this area, which is quite a difference. We moved about 50kg in the car 50cm down.'

High performance

The engine is a 6-cylinder BMW 3.0-litre twin turbo, derived from a standard BMW, but the mapping system received quite a lot of attention, especially with regards to performance at higher altitudes. 'We have quite a good mapping, even at 4000m where it is not so easy, because we start at more or less sea-level and we go up to the highest stages at, I think, 4700m,' Quandt says. 'This was our big target really, over the whole race, with the differences in altitude, to always have good response and good power, which is not easy to do, so this was our focus this year.'

Torque comes in very low for a diesel engine, but this does make the Countryman easy to drive in very difficult circumstances. 'This is a big advantage of the car, as you have quite a band for driving and can drive up to 4500m without any problems; you have a driving band of around 1500 to 4500rpm, which in off-road terms makes it relatively easy to drive. This is a big plus with this engine'

There was also a concerted effort to reduce fuel consumption through the mapping programme, particularly at higher altitudes, with the X-raid team proving its developments in an altitude chamber. 'We worked with an absolutely standard BMW computer and only the mapping has changed. A lot of teams have hi-tech motorsport computers, but we use a standard one, which gives us a possibility to use all the standard features as well from the mapping device, which is positive.' Quandt does concede that this can have a drawback, though, as fewer inputs are available to the team.

Hot and cold

Thermal management is another area affected by altitude, with particular attention paid to brakes, engine, gearbox and turbochargers, and the ventilators for these areas are temperature controlled. At the front, the ventilators only run for the water and air coolers for the turbochargers. At the rear, the ventilation system for gearbox and brakes is closely monitored with temperature gauges. This can be varied to match the conditions, which change throughout the event. Inside the cabin, there is an air conditioning system, which has been improved to ensure the drivers and co-drivers are not overcome in the conditions.

There were also developments to the exhaust system, supplied by Slovenian

The body of the car can now be taken off in 30 minutes if necessary

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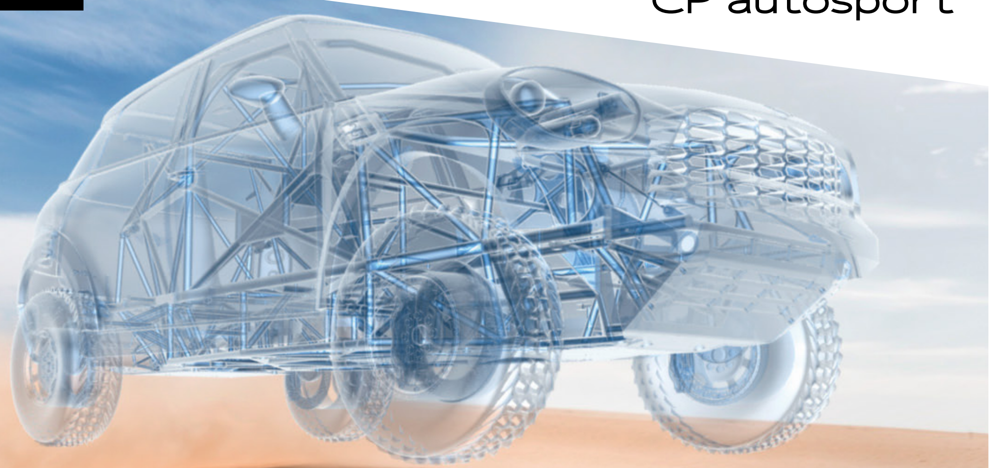

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The F60 Mini benefited from more aero work than predecessor, both in CFD and wind tunnel. This found useful downforce

TECH SPEC

X-raid Mini John Cooper Works Rally

Chassis: Tubular steel with composite bodywork.

Engine: BMW Group TwinPower turbo 6-cylinder diesel. Power: 340bhp at 3250rpm. Torque (approx): 800Nm at 1850rpm. Capacity: 2993cc. Air restrictor: 38mm.

Suspension: Reiger. Double shock absorber with coil over springs and an additional reservoir for oil cooling.

Transmission: SADEV 6-speed sequential; Xtrac differential.

Brakes: AP Racing. Six-piston calipers (air cooled front, water cooled rear). Discs: 320 x 32mm.

Tyres: BF Goodrich 245/80R 16

Fuel tank capacity: 385 litres.

Dimensions: Length: 4350mm; width: 1999mm; height: 2000mm. Wheelbase: 2900mm. Track width: 1736mm.

Weight: 1952.5kg.

The suspension has been developed for X-raid by Reiger and is double dampers all-round. Its travel is 25cm, as shown above

An air-conditioning system makes the Mini's cabin bearable for the crew during hot desert stages

company Akrapovic. The output was routed to the rear of the F60, having previously been located at the tail end of the side of the previous Countryman. For Quandt, this was a significant mod: 'It was always our problem, we had it always to the side and there were a lot of issues with the temperatures on the side when the gas came out, so we had to cool it down. That's why it is now running at the rear.'

On balance

One area Quandt does feel X-raid loses out on is balance of performance. The Countryman F60 weighs in the heaviest when compared to the works Peugeot and Toyota, but enjoys the least horsepower. One of the ways performance is balanced is through the use of air restrictors (the F60 has a 38mm restrictor), but Quandt feels that despite efforts to create some sort of parity, the F60 may still fall short. 'We have got 1960kg, four-wheel-drive and about 340bhp. The Peugeot has got about 1400kg, [and up to] 360bhp and the Toyota has got 1900kg and has 400bhp, or probably even more, we calculate, what with the new restrictor. On paper, we are probably the most underpowered car compared to the others. But what helps us a little bit is the good driveability we have.'

X-raid uses standard Euro-Diesel fuel that can be found in petrol stations across the continent. 'Luckily, since last year, you can also buy this as well in South America, except Bolivia, where we have to bring it into the country with our trucks,' Quandt says.

The suspension system – provided by Reiger – is double shock absorber, with coil over springs and an additional reservoir for oil cooling. The relationship with Reiger is a vitally important one, Quandt says '[It] is 20 years now that I am working with Reiger. We are on their development list as a number one. Basically it is Ford and us – Ford on WRC and [X-raid] on cross-country – so we get the highest level of suspension, which everyone else gets one or two years later, so we are quite happy with that.'

Providing the stopping power for the F60 are AP disc brakes. The rears are water-cooled and the fronts air-cooled, but it is unnecessary to run the cooling all of the time, due to the improved ventilation feed. 'The rear brakes – which were always a problem, most of the time they were the ones that got hotter easily – we have a water cooler in the caliper, plus an air cooler inside the disc.' The discs are pre-bedded, allowing for greater grip from first running.

Sand 'box

The gearbox unit comes from SADEV – another long-term partner of X-raid. The F60 utilises its latest 6-speed sequential 'box, which weighs in at some 5kg lighter than the previous version which X-raid first ran two-and-a-half years ago. 'The development was made together with SADEV and us. It's faster shifting; [and helps get] better mileage out of the gears and the AP clutch. We have used the AP clutch for many years and it has been very reliable; it is a standard clutch that you can buy off the shelf.' The differential, from Xtrac, has also been the subject of development, with modifications helping to extend the mileage.

The F60 runs with Goodrich tyres, which have been developed for cross-country competition. Development began in 2015 and X-raid used them for the first time in 2016.

Despite all of the developments on the Mini John Cooper F60 Countryman, X-raid's efforts fell short on this year's Dakar. But it got to the end, which is half the battle on this gruelling event. As the man said, to finish first, first you must finish. So, second, you must win. We'll have to wait until later in the season to see whether X-raid can build on the progress it's made, and topple Peugeot from the top spot.

'You have to finish, and that means you have to have a super reliable car'

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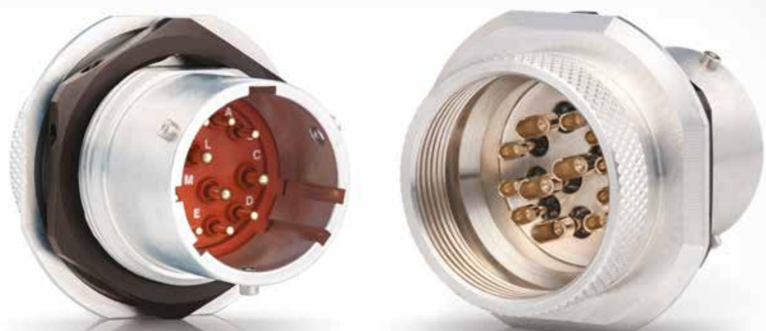

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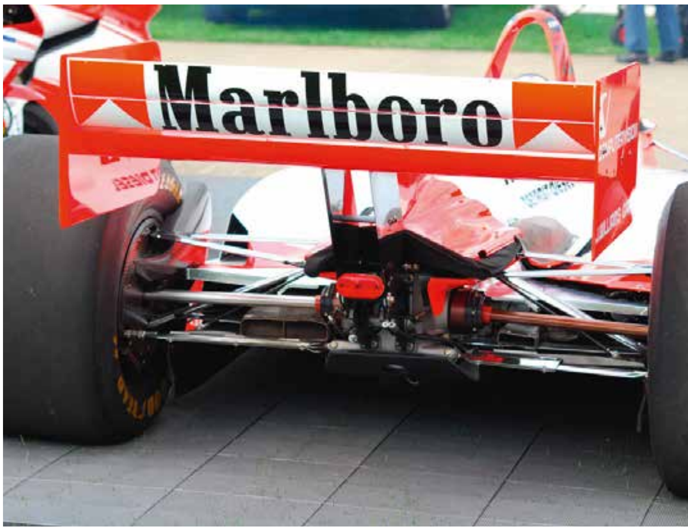
Restoration man

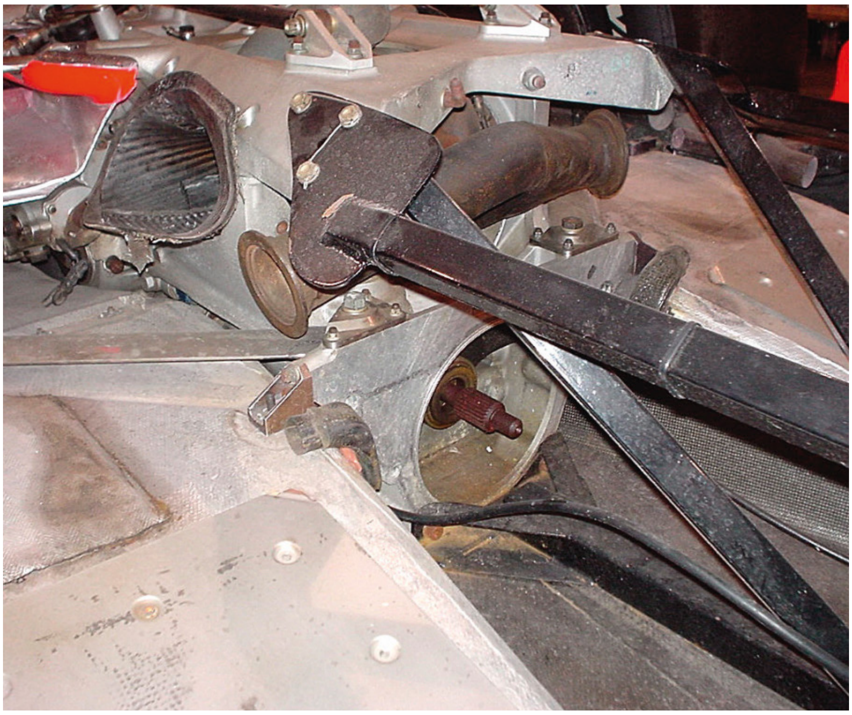
The Penske PC-23 is one of the most successful Indy racers of all time – but that's not the only reason a former IndyCar race engineer decided to rescue and perfectly restore one of these very special cars

By RICH HOWLETT

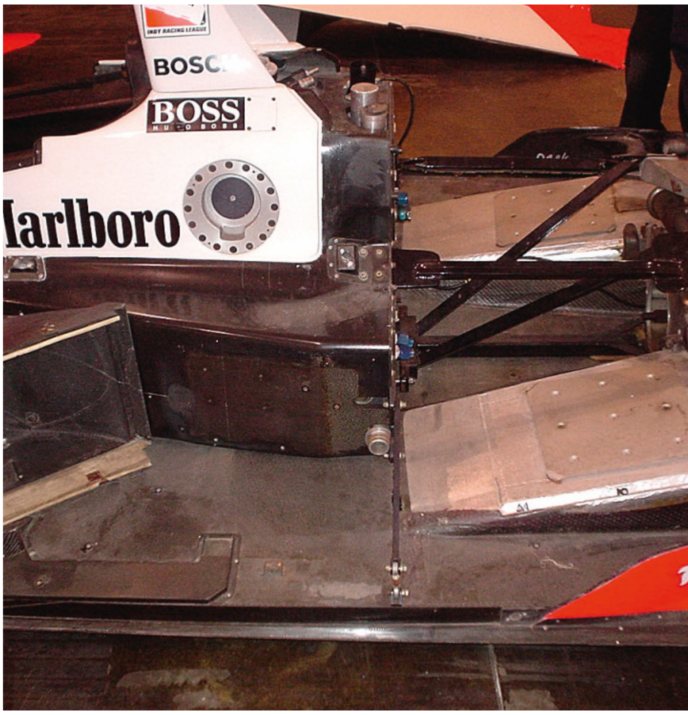
Penske PC-23 chassis 08 has been restored to state it was in when raced by Fittipaldi in 1994



Rather large rear wing betrays the fact that the car is now in road course configuration

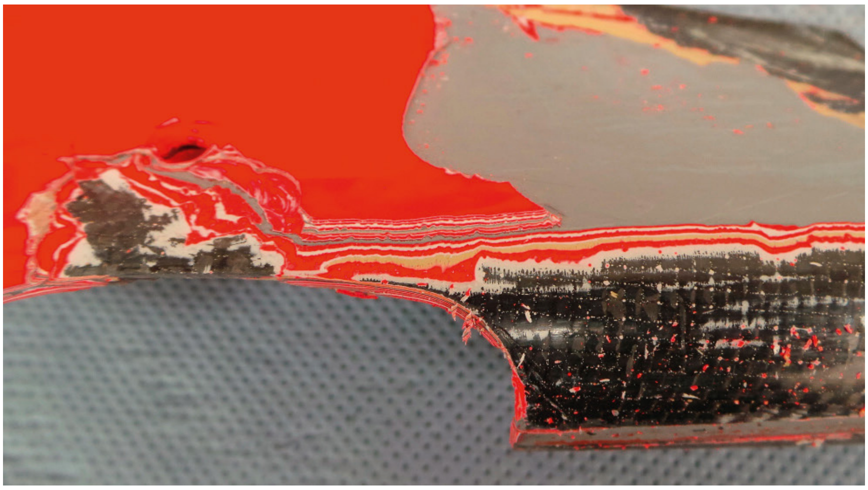


This was state of the chassis when it arrived in the UK after being shipped from the States

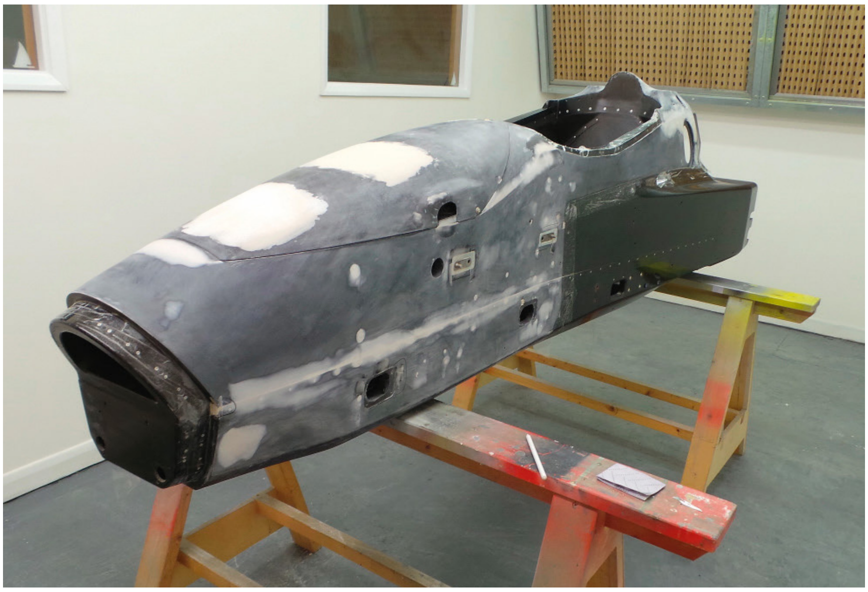


Chassis 08 prior to its strip down. The complete renovation took four and half years

'This restoration was a challenge because of the number of parts missing, and the condition of some of the parts that were there'



3mm thick layers of paint were stripped from the car and this amounted to a weight reduction of about 20 kilos



Here the stripped down Penske PC-23 monocoque is being prepared for its fresh coats of red and white paint

Bodywork mock-up prior to repairs. Note that Penske was ahead of F1 2017 back in 1994 with that dorsal fin

If you're going to renovate an Indy car it might as well be one of the best, so the choice of the iconic Penske PC-23 as a project is not surprising. But for former IndyCar engineer Patrick Morgan there was a little bit more behind the decision than that; this was not all about the car's performance and its winning history, there was also a very tangible emotional attachment, too.

For Morgan, his ties with the PC-23 (called a Champ Car in period) actually go back to 1994, when he was just 15. After school he would help out at the business of his Dad, the late Paul Morgan, building and machining parts for race engines at Ilmor Engineering in Northamptonshire (Morgan is the 'mor' in Ilmor, the Il is from Mario Illien). At the heart of the PC-23 is an Ilmor engine, and the link to his father, who died in a plane crash in 2001, is very much part of the appeal of this project. 'I would rather have my Dad, but I can't have that so I guess you have to make the best of what life throws at you,' he says.

And he has certainly made the best of this project. This racecar is an absolute work of art; the attention to detail in every area of this rebuild is absolutely staggering. The car is chassis 08 in Penske numbering. It is restored with a correct engine for the period, the Ilmor 265D, 2.65-litre single turbo V8 producing 850bhp at 12,700rpm (not to be confused with the secretly-developed 265E Indianapolis special, see box out). The gearbox is a Penske casing with Xtrac internals and the limited slip diff, as fitted for road course racing, is also from Xtrac. It also has an original Penske carbon monocoque.

Emmo-tive project

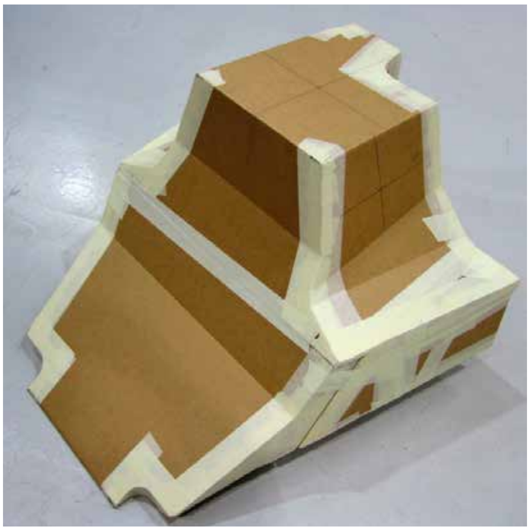
Chassis 08 was raced by Emerson Fittipaldi in '94, and was then passed on to the Bettenhausen team in 1995. Morgan takes up the story: 'They had a decent season with Stefan Johansson taking a podium at Nazareth Speedway. But the final outing for this racecar was at the ill-fated US 500 on the 26th May 1996 at Michigan International Speedway when Gary Bettenhausen, who was drafted in to drive, avoided the crash just before the start, but hit the wall on lap 79. From there chassis 08 was stripped out and became a show car. It was repainted numerous times, and had a tough life.'

For Morgan the restoration project began in 2011, when he purchased Penske PC-23 chassis 08 from Chuck Sprague, who had been team manager at Penske Racing back in 1994. The racecar was very loosely described as 'complete', as it was missing its engine, gearbox, cooling system, and it had no internals.

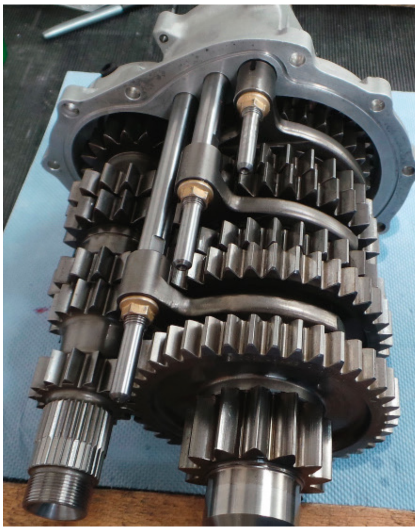
The restoration plan was to source and retain as many of the original parts as possible

'These racecars are beautiful, brutal, and fast, and they represented the pinnacle of a golden era in motor racing'

Engine cover after its initial re-skin. Note heat shielding on the underside of this intricate piece of bodywork



This is a mock up of the fuel cell. While original parts were sourced where possible sometimes they needed to be made



The gearbox cluster with road course ratios fitted. 'Box is a Penske casing but internals are by Xtrac

Front anti-roll bar with moveable blades. Suspension needed lots of work to get it back to '94 condition

and then refurbish them to maintain the originality of this iconic racecar.

Crack testing confirmed that the uprights were all in good condition, so just refurbishment for these items would be required. The suspension wishbones and pushrods, however, were a different story and would all need replacing. The bodywork was also in a very poor condition with many layers of paint having been applied over the years. This would all need to be stripped back to the carbon. Prior to stripping, the panels were weighed and then weighed again after stripping, revealing a total weight reduction of 20 kilos from the 3mm thickness of paint removed. Once prepped all panels would then be re-skinned in carbon to retain their originality, and then finished in that original and iconic Marlboro livery.

Chrome zone

'At the time I bought the car it was stripped down in a race shop owned by Don Hoevel over in Illinois,' Morgan says. 'Don bolted the car back together as best he could, with so many parts missing. It was then put on a pallet and flown to Heathrow. Normally it takes us a few weeks to strip a car. They don't typically come with an instruction booklet so any information you can take from measurements is often invaluable. In this case it took about two days to take apart as there was so little there. What was there either needed a lot of work or was no good.'

What was there also included an awful lot of chrome. 'The wishbones had been chromed, which is not ideal as there is a chance of hydrogen embrittlement creeping into the welds,' Morgan says. 'This is where, during the plating process, hydrogen atoms wedge themselves between the steel molecules at and just below the surface of the weld which raises the surface stress making it more likely to crack when more stress is applied … Talking of chrome plating, the brake discs had also been chromed, too. Chrome is not terribly well known for its high friction properties!'

Road trip

There are essentially three specs of Champ Car suspension and aero packages from the '90s era: road course, short oval and superspeedway. Chassis 08 had speedway wings, although the rear wing was off another car, but it was fitted with a road course/short oval underwing.

'We had to make a decision as to what set-up to work with, with the car,' Morgan says. 'I opted for road course for several reasons. Most importantly, that is the configuration Emerson raced the car in. Then, being in Europe where road courses are prevalent, a road course seemed sensible. Lastly, although I'm not really

'The wishbones had been chromed which is not ideal as there is a chance of hydrogen embrittlement creeping in to the welds'

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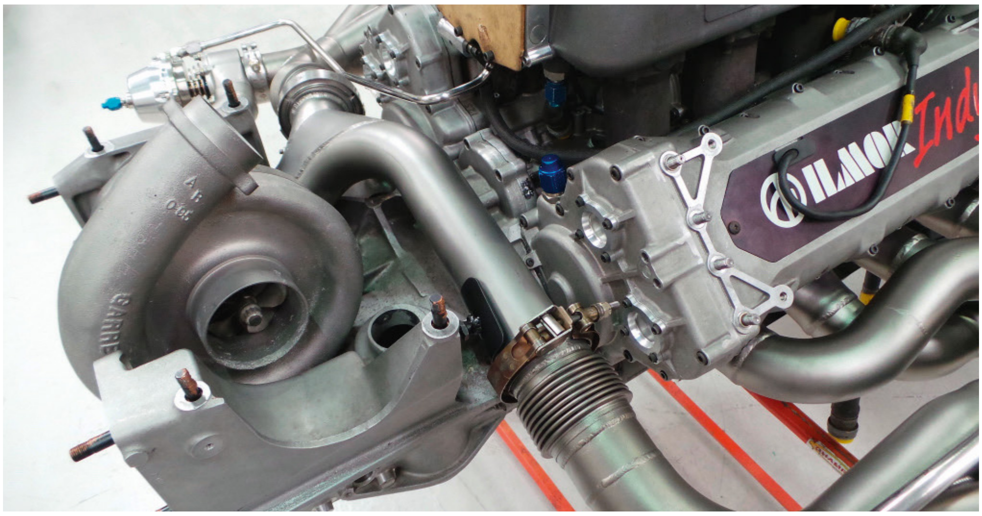
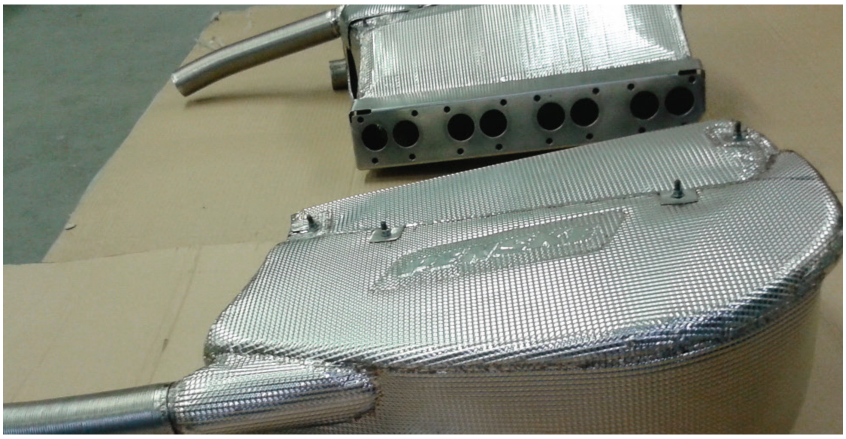


Turbocharger mock-up fitted to engine. The Ilmor 265D 2.65-litre single turbocharged V8 produces 850bhp at 12,700rpm



Header bags were recreated at Historic Fabrications, which also did wishbones and turbo heat shielding

Tub after painting. Carbon work was entrusted to MCT Composites, which spent three months fixing the rather battered car

a race driver I felt that I would like to drive this car, because it has a lot of sentimental value to me, and there's no doubt a road course is by far the safest place to start with a car like this.'

Carbon omissions

But the challenge of driving the car would come later (see box out). First there was the challenge of sourcing the parts. 'This restoration was difficult because of the number of parts missing or the condition of those that were there,' Morgan says. 'The carbon work had taken a lot of abuse and had also only been loosely repaired after the crash back in 1986. But we did have an original engine, which was good, as most of the 265Ds had been upgraded to D+ or IC108 spec, as we later discovered.

'After the car had been stripped we set about replicating the wishbones. This was done by Ady Matthews at Historic Fabrications. Ady was a fabricator at Penske Cars in Poole, Dorset, and would have made wishbones in period, and so he was the closest thing I could get to the original parts. Ady also made the header bags and turbo heat shielding, which is nothing short of a work of art,' Morgan says.

Carbon mating

Early on in the process it was decided that the carbon would need specialist attention. 'The chassis was assembled and sent to MCT Composites in Daventry,' Morgan says. 'It was there for over three months. I guess if there was a low point it was during this time. Nearing the end of the bodywork fit I visited MCT, which I was doing twice a week, and was taking in some of the detail work near the bottom of the engine. I then noticed that the lower part of the engine was not flush with the rear bulkhead, so much so that the fuel pump drive would not engage. It turned out the lower engine mount, an aluminium billet that is bolted to the front of the engine, was not correct. We quickly made a new mount but then a good deal of the body fit had to be done again.'

But it was not all bad news during the build. 'In terms of finding parts I got lucky,' Morgan says. 'I found a pallet of parts in Australia that had been left to satisfy the import/export paperwork back at the start of 1994 [when Champ Car raced at Surfers Paradise]. The

Beauty in the Beast

Back in1994 a collaboration between Penske Cars and Ilmor racing engines led to the development of one of the most ground-breaking racecar and engine packages that had ever been seen at the Indianapolis Motor Speedway.

Throughout the development of the Ilmor 265E pushrod engine, secrecy was paramount; only a handful of people knew about the enormous task they were undertaking in such a short time-frame, and most of them thought it was completely impossible. Their mission was to exploit a rulebook loophole that would allow them to design from scratch a race engine that would produce 150 to 200bhp more than its closest rivals. This was the fabled Ilmor-developed 265E 3.4-litre V8 turbo, reportedly good for 1000bhp.

This monstrous unit, officially called the Mercedes 500I, was developed to compete in the 1994 Indy 500, where Penske fielded three PC-23s for Emerson Fittipaldi, Al Unser Jr and Paul Tracy. The 265E-powered PC-23 was an immediate success with Unser taking pole and going on to win the race. It might have been even better for Penske, as late in the race two of the PC-23s were running in one-two formation. However, Fittipaldi – looking for two wins in a row at the Brickyard – hit the wall.

Such was Penske's utter dominance that year that Unser lapped the entire field, except for Jacques Villeneuve in second.

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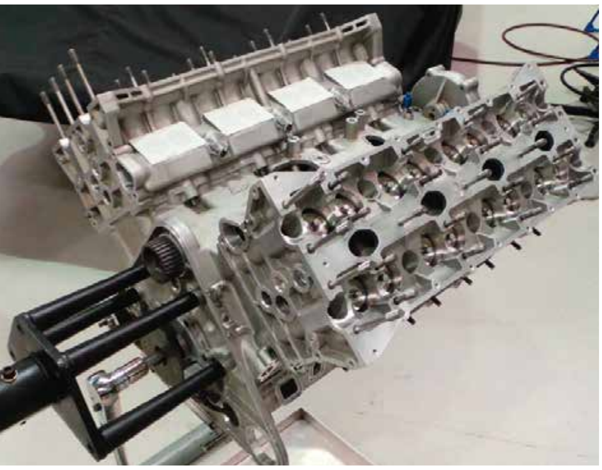
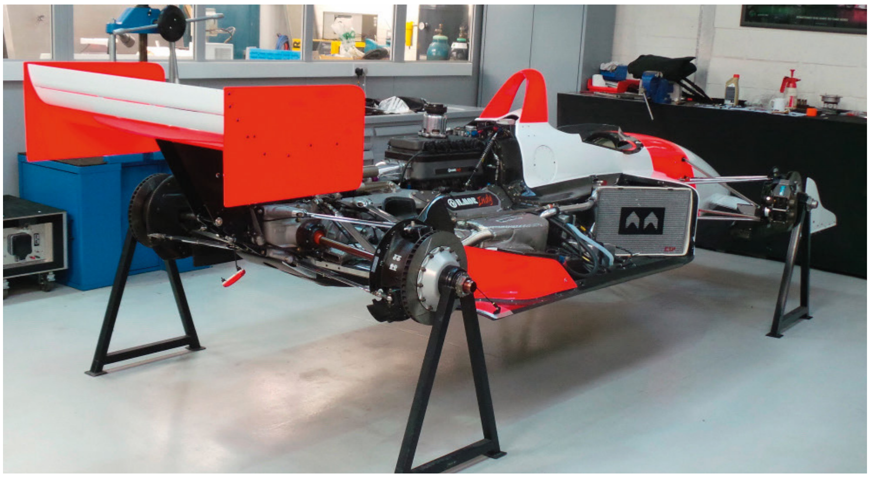
The attention to detail in every area of this restoration is absolutely staggering



The Ilmor 265D V8 powerplant rebuild approaching completion



One problem was getting the engine to fit flush with the rear bulkhead, but that's now a distant memory

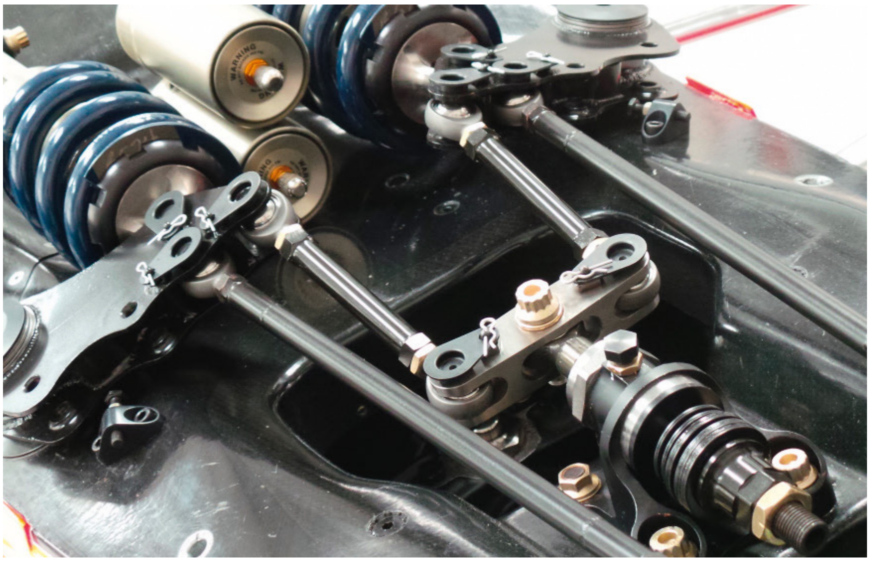
Behind the wheel

'I'm not a racing driver and anything I'm doing in the car is totally different to going for the last two tenths of a second or battling wheel to wheel,' says Patrick Morgan. 'But I can draw some comparisons. It accelerates harder than an F1 car of the same era, and as a manual sequential gearbox you have to take your hand off the steering wheel, which is noticeably more difficult than with an older H-pattern F1 car, as the steering effort is so high. The sequential box is, however, much easier to use than the H-pattern in the 1990 Penske I also have.

'The drivability of the engine is excellent, much better than I expected. There is some turbo lag but it's largely masked by the superb mid-range of the engine. The later Ilmor/Mercedes engines I've driven are a lot more focused on the top end and only really get going with 3000rpm to go before the rev limiter kicks in. The situation is further helped by the, what was then unique, mono-bump system, which is essentially a third spring. This system makes this chassis remarkably tractable.

'I can't tell you too much about the handling just yet as we need to go to a race track, but I can tell you the brakes are very good. They maybe don't have the 'hit you with a sledge hammer' effect that the 1997 PC-26 has, but they are really progressive and give more feel, which for someone at my level of skill is ideal. It's monstrously fast, but in such a way that it does what the very best race vehicles do; it inspires confidence and makes you feel a part of it, as if it is an extension of your body.'

Perfectly restored cockpit; note roll bar adjust levers on the left



Penske PC-23 features this mono-bump third spring system front suspension, a unique set-up back in 1994

parts included most of the cooling system, some peripheral engine parts, and many other brackets and other bits and pieces.'

There was also welcome help from across the pond. 'John Cummiskey in the US was a huge help with parts and also advice,' Morgan says. 'We also had another stroke of luck off the back of a tragedy. Penske Racing's Reading PA shop was flooded in 2006. Some of the inventory was essentially given away or auctioned to team members rather then put in the skip. By that point any PC-23 parts were 12 years out of date. The guy who had bought some of it contacted me to ask if I was interested in any of it. Needless to say I took as much as I could, and it really helped with some of the detail.'

Moment of truth

Finally the day came to run the engine in PC-23 08. 'The real high was the first time the engine fired in the car. We had some electronics issues to do with modern lead-free solder not mixing with old leaded solder on a PCB, that meant we were well behind on starting the engine. We were all rather surprised and extremely relieved when it fired up. The shakedown was pretty nerve wracking, or at least the lead up to it was. But it could not have gone better.'

And Morgan now owns a fully functioning piece of history, not to mention a tangible connection to his father's work. 'That season in 1994 was the only year an Ilmor engine ran under its own name; fortunately it was a good year to choose as PC-23s won 12 of 16 races and finished one-two-three in five of those. I was seconded to Penske Racing for a few months in 1997 and loved every moment of my time there. Then there is the Greg Moore connection, which I was unaware of when I bought the car [Morgan worked with Moore, who was killed in a crash in 1999. He also once tested this chassis].

'Essentially, for me, if there was just one racecar I could own, the PC-23 is it,' Morgan says. 'They are beautiful, brutal, fast and represented the pinnacle of a golden era in Indy racing, and in my view motor racing as a whole. Over-regulation was just around the corner, but had not really happened at that point.'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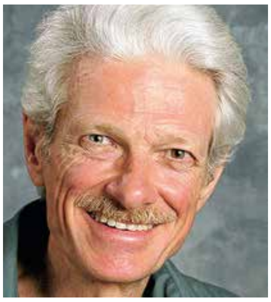

Making sense of the nonsense in Formula 1

Has the FIA muddled its list of non-compliant suspension traits?

QUESTION

What do you think of what the FIA is telling the Formula 1 teams about what suspension systems will be allowed in 2017, as was widely reported in the lead up to the season's start.

THE CONSULTANT

I don't want to be unfair to the FIA, or go off half-cocked based on a possibly erroneous media report. But I have asked the FIA for comment on the accuracy of a report on this that I have sent to them. At the time of writing I am still waiting for a response. If I find out that the report was inaccurate, I will amend my comments. For now, I will comment on the FIA's actions as reported. Here's whats been said.

'The FIA has told some of the Formula 1 teams they could be asked to remove their suspension systems if they fail to prove aerodynamic performance gain is not the design's primary purpose. The FIA picked out five key characteristics or components that it will deem non-compliant.' See below.'

- Any system that changes how the car responds to body accelerations.
- No direct coupling between the ride height function and the braking system or the steering system.
- Ride height control via self-levelling.
- Direct coupling between the roll and heave parts of the suspension.
- The storing of energy for delayed deployment or any system that would result in non-incidental asymmetry in the response to changes in load applied to the wheels.

The most recent revision of the FIA regulations is dated January 24, 2017. This doesn't include any of the above points. But It does include the FRIC ban: **10.1.2** Any suspension system fitted to the front wheels must be so arranged that its response results only from changes in load applied to the front wheels. **10.1.3** Any suspension system fitted to the rear wheels must be so arranged that its response results only from changes in load applied to the rear wheels.

I don't see any ambiguity in the regulations as currently published. I definitely would have problems with the reported policies, however. First of all, it is very often impossible to say whether aerodynamic gain is the 'primary purpose' of a suspension design. One of the fundamental facts of suspension design for at least the last three decades has been that the parts of the car close to the ground need to be held in as nearly a fixed relationship to the ground as possible, to prevent uncontrolled variations in downforce and downforce distribution. This inherently flies in the face of the need to let the suspension move to minimise tyre load variations due to road irregularities. Modern tracks are pretty smooth, and it helps the aero guys if the car is a go-kart, but the track still has bumps, crests, dips, and kerbs, so some compromise is necessary.

Primary purpose

It is simple to single-mindedly produce a suspension whose 'primary purpose' is aerodynamic advantage: just make the springs ridiculously stiff. But if we're intelligent, we try for a better blend of aerodynamic consistency and wheel load consistency over bumps. If we come up with a clever way to do that, is our idea's 'primary purpose' improvement of aerodynamic consistency for a given level of wheel load consistency, or is it improvement of wheel load consistency for a given level of aerodynamic consistency? It's impossible to say. The question is then fundamentally nonsensical.

Any system is prohibited that changes how the car responds to body accelerations? Compared to what? Doesn't anything we do to the suspension affect how the car responds to accelerations? Isn't the whole idea to optimise that?

Direct coupling between the roll and heave parts of the suspension is prohibited? Maybe that's a typo. Absence of direct coupling would be unconventional. Ordinary suspension springs create coupling of the suspension's roll and heave properties: they resist both roll and heave. Any rising-rate springing or any anti-roll bar with rising or falling motion ratios creates ride height changes with roll. A system with completely separate springing and damping for synchronous and oppositional motions of the two wheels, as recently used in LMP by Porsche and Audi, would be unusual. That is sometimes called decoupling of the modes.

Direct coupling

No direct coupling between ride height and steering? Does that mean the pushrods or pullrods cannot connect to the uprights? Does it mean there can't be any steering offset (scrub radius), steering axis inclination, caster, or trail? With most combinations of these things, the car goes up and down when the front wheels steer.

So we have rules that have been reported that are nonsensical. And we also see that, also reportedly, the burden of proof is to be on the entrant to prove compliance with the nonsensical rules – with those who wrote the rules as the arbiters of whether the burden of proof is met. If this is factual, it's worthy of Franz Kafka or Lewis Carroll. If it turns out to be fake news, I'll let you know.

Some media reports have quoted new rules with regards to F1 suspension, aimed at getting rid of pseudo-active systems, that appear to make little sense, says Ortiz

XPB

Does this mean the pushrods or pullrods can't connect to the uprights?

Independence on the ovals

Examining the suitability of independent rear suspension for a dirt track racecar

QUESTION

My father has been racing short track dirt oval for the past 20 years in South Africa, and I have just recently built him a new car running single piece wishbone independent front and rear.

As I understand it, anti-squat is like longitudinal anti-roll, which we can use to control rear bite. However, 'power anti-squat' comes from the differential centre and 'geometric anti-squat' comes from the locating linkage angles. I guess some power anti-squat is also transmitted via the stub axles. On an independent suspension the two are separate; we only have geometric anti-squat to adjust.

I designed the car with zero anti-squat and anti-dive. Anti-squat will create very unpredictable wheel movement in the sense that caster, camber and toe will change as the wheel moves through bump and droop travel.

When looking at our car from the side the chassis mountings do permit for adjustment, but if I start mounting the upper A-Arms at angles, this will cause bind, unless I used a 5-link type set-up. (A-arm rose joint mounting bolts run parallel to the longitudinal centreline of the car. I did this to prevent roll steer).

For this car I used a toe link at the rear of the lower A-Arm, which is equal in length to the lower A-Arm. Some of the documentation I've seen recommends that I should have used a longer toe link to induce dynamic toe-in during bump and rebound as to have toe-in at the rear is more stable.

The main advantage is reduction of unsprung mass, improving the ability of the wheels to follow road irregularities

Independent rear suspension systems work very well in off-road racing, rallying and rallycross (pictured) but could such a set-up pay dividends when applied to a short oval dirt track racecar?

THE CONSULTANT

I think independent rear suspension (IRS) can work great on dirt. It certainly has in off-road racing, rallying and rallycross. There has been little opportunity to explore its potential in American oval track racing because for many years there has been no class that allows it.

If we are designing an IRS system, rather than working within the limitations of one that already exists, we can obtain any amount of anti-squat desired, with just about any bump steer properties we want. We can do this with wishbones or with individual links. The questioner is correct that we have only thrust (geometric) anti-squat to work with, but we can get as much of that as we want. An exception may occur if we have drop gears in the upright, as on Humvees and old VW Transporters. In that case we can get lots of torque (power) anti-squat. But unless we need drop gears for ground clearance, we are better off without them, so an oval car would not have them.

With any suspension, the longitudinal jacking coefficient at any wheel depends on how much the contact patch moves longitudinally as the suspension displaces. With independent suspension, when the engine's off, brakes are off, and car's in gear, when testing the car statically the wheel does not rotate in side view as the suspension displaces, even if the upright does rotate. Contact patch displaces longitudinally at the same rate as the wheel centre. Anti-squat then requires the wheel centre to move rearward as suspension compresses and forward as it extends.

The main advantage of IRS on dirt tracks is reduction of unsprung mass, improving the ability of the wheels to follow road irregularities. This advantage is enhanced if the brakes are inboard. If the brakes are inboard, it doesn't matter whether the upright rotates in side view as the suspension moves. The anti-lift in braking only depends on how the wheel centre moves. The jacking coefficient for braking will be similar to that for propulsion. The contact patch will move with the wheel centre if the suspension is displaced with the transmission in neutral and the brakes locked, same as with the brakes off and car in gear.

However, if the brakes are outboard, when the brakes are on and the trans is in neutral the wheel rotates if the upright rotates. If the upright rotates in side view as the suspension displaces, the jacking coefficient for braking is different than for propulsion. This can be an advantage in a dirt car. It is common for dirt cars to run a lot more rear brake than pavement cars. If we have a lot of anti-lift, this can result in wheel hop in braking when the track is tacky. We can avoid this by having the side view instant centre behind and below the wheel centre: the side view projected control arms both slope up toward the front, the upper more steeply than the lower.

But again, this only works with outboard brakes, so we have to decide whether we want to be able to do this badly enough to accept the unsprung weight penalty.

The questioner does not mention what sort of car the system is going on, or what sort of bodywork or bodywork rules it has. Some dirt cars definitely have suspension systems intended to influence their aerodynamics. Whether this is desirable depends on the bodywork and the rules of the series.

Dirt Late Model racecars have large, slab-sided bodies that can generate considerable aerodynamic lateral force when running at large aerodynamic yaw angles. The rear suspensions are designed to create large amounts of roll oversteer and make the left rear corner jack severely. This strategy works because of the bodywork rules, combined with rules that some sanctioning bodies have regarding how much the right and left wheelbase measurements can differ statically. Incidentally, sprint cars are not designed to do the same thing.

With independent suspension, the rear wheels can be aimed any way we want statically, without any need to lead or trail either rear wheel. We can also make either rear corner jack up or down as desired, in response to cornering and/or braking and/or propulsion. Whether we want to do these things will depend on the rules.

CONTACT

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Under study: floor flow on a BMW

Our 1 Series aero investigation concludes with the car's underside

Singapore-based Giti Tires' decided to test itself in motorsport by entering the Nurburgring 24 Hours, as well as competing in some other well-known endurance racing arenas. It chose UK-based Saxon Motorsport to prepare the BMW 1 Series racecar obtained for the programme.

But first it had to qualify to run in the Nurburgring event with the selected 5-litre V10 engine. This entailed competing in three races with a 2-litre engine (250bhp) before switching to the 500bhp V10, an experience that brought drag as well as downforce into consideration.

So, part of the reason for this wind tunnel session was to examine drag and downforce in different configurations, as well as evaluating configurations that met the different rule sets the team will encounter in other series.

Prior to our wind tunnel session the team had not raced with a flat floor and diffuser. However, keen to evaluate its effect, Saxon Motorsport installed a full flat floor on the same plane as the front splitter panel, along with a prototype rear diffuser. The intention was to try the car with and without the full floor to investigate the effects on the aerodynamic data. With the MIRA wind tunnel's fixed floor, as well as the car's quite low ground clearance (55mm at the front splitter in baseline trim), it was going to be interesting to see how the data responded.

Rake change

Some basic rake angle changes were made with suspension adjustments, going down 10mm at the rear and then up 10mm, relative to the baseline set-up, to gauge response. Altering ride heights thus required raising the car on pneumatic jacks, so car alignment had to be carefully checked each time the jacks were lowered again. The data are shown in **Table 1**, as absolute numbers and as Δ (delta) values in counts, where 1 count is a coefficient change of 0.001, to show the changes.

The car's responses to 10mm rear ride height changes in either direction were basically equal and opposite, and more rake was beneficial, with increased front downforce and better balance. Although drag increased with greater rake, the downforce to drag ratio of the change was almost 4:1, an efficient adjustment. By way of comparison one of the BTCC cars that we previously tested showed, at 10mm rear ride height increase, a 26 count front downforce increase with a 10 count rear downforce increase. So the front gain was comparable but the rear gain was greater than the BMW. However, in the BTCC car's case the front ride height was simultaneously adjusted to maintain constant splitter ground clearance (at the regulation 60mm, so higher than our BMW), whereas the BMW's splitter clearance reduced with the rear ride height increase. This would have reduced mass flow under the BMW, which might account for the smaller gain in rear downforce, and why the front gain was not greater than it was.

Turning next to the diffuser, the angle of the BMW's prototype item was adjustable.

Table 1: The effects of rake adjustments

	CD	-CL	-CLf	-CLr	%front*	-L/D
Baseline	0.469	0.345	0.089	0.256	25.69%	0.735
RRH down 10mm	0.462	0.321	0.066	0.255	20.56%	0.695
Δ, counts, rel. to baseline	-7	-24	-23	-1	-5.13%	-40
RRH up 10mm	0.476	0.372	0.113	0.259	30.42%	+45
Δ, counts, rel. to baseline	+7	+27	+24	+3	+4.73%	+45

Absolute rather than relative difference in percentage front

The Giti Tires/Saxon Motorsport prepared BMW endurance racecar. Rake changes were made with suspension adjustments at the rear; down 10mm and then up 10mm

Baseline diffuser angle was six degrees and this was ratcheted up in 2-deg increments

The flow emerging from the BMW's diffuser lacked energy, even right in the centre

Table 2: The effects of increasing the diffuser angle

	CD	-CL	-CLf	-CLr	%front*	-L/D
6-deg	0.510	0.381	0.140	0.242	36.66%	0.747
8-deg	0.511	0.381	0.138	0.243	36.22%	0.746
10-deg	0.510	0.382	0.139	0.244	36.26%	0.749
12-deg	0.512	0.387	0.141	0.246	36.43%	0.756

**Absolute rather than relative difference in percentage front*

Table 3: The effects of removing the floor (except for the splitter panel)

	CD	-CL	-CLf	-CLr	%front*	-L/D
With full floor	0.483	0.495	0.224	0.272	45.15%	1.026
Floor removed	0.483	0.490	0.235	0.255	47.96%	1.016
Δ, counts	-	-5	+11	-17	+2.81%	-10

**Absolute rather than relative difference in percentage front*

Table 4: The effects of raising the car 10mm with the full floor fitted

	CD	-CL	-CLf	-CLr	%front*	-L/D
Full floor, baseline RH	0.483	0.495	0.224	0.272	45.15%	1.026
Full floor, +10mm	0.491	0.505	0.229	0.276	45.35%	1.029
Δ, counts	+8	+10	+5	+4	+0.20%	+3

**Absolute rather than relative difference in percentage front*

Table 5: The effects of raising the car 10mm with the floor removed

	CD	-CL	-CLf	-CLr	%front*	-L/D
No floor, baseline RH	0.483	0.490	0.235	0.255	47.96%	1.016
No floor, +10mm	0.494	0.501	0.247	0.254	49.25%	1.014
Δ, counts	+11	+11	+12	-1	+1.29%	-2

**Absolute rather than relative difference in percentage front*

The baseline angle was six degrees and it was increased in two-degree increments up to 12 degrees, with the results shown in **Table 2**. The starting configuration was different to that in the rake trials we outlined earlier.

Heads were scratched on seeing this data emerge, for it appeared to show almost no changes until the diffuser was adjusted to 12 degrees, at which point total downforce increased only very slightly. How do we explain this lack of response? First, the prototype diffuser was quite narrow, and although the centre section of a flat bottomed car is where the fastest airflow usually occurs, a wider diffuser (if practicable, given the rear suspension proximity and short rear overhang) would possibly have had a bigger influence. Second, a diffuser exit as far aft as the BMW's would be beyond the lowest base pressure in the wake, so would miss the strongest extraction potential; and it would also feel low pressure on the upper surface of the diffuser roof. Third, it was evident from the smoke plume that the airflow emerging from the diffuser was unusually lacking in energy, even in the centre. So it seems that the performance of the floor of the BMW was compromised, and the assertion in the previous section about blockage under the car, given the wind tunnel floor's boundary layer, may also have been instrumental in masking the underside's true performance. Having said that, when we tested the Ferrari F430 GT3 in 2010, with a splitter ground clearance of around 50mm, diffuser and underfloor performance were notably good (and it responded to rake changes).

Floor removal

With some trepidation, the BMW racecar's floor was removed leaving only the splitter panel under the engine bay and **Table 3** shows the results and the changes relative to the car's starting configuration.

In a nutshell, removing the entire floor made only a small difference to total downforce, with front downforce actually increasing and rear downforce decreasing. This again suggests that mass flow under the car was being restricted by the flat floor rather than improved, but the result was probably, at least in part, peculiar to being measured in a stationary floor wind tunnel.

As a last quick evaluation at the end of our session, the wind tunnel boundary layer theory was tested by raising the car 10mm front and rear, with and without the car's floor installed and the results are shown in **Tables 4** and **5**. In both cases there were modest increases in downforce and drag from raising the car by 10mm, so clearly the wind tunnel floor's boundary layer was at least partially responsible for suppressing the forces and responses in our underbody experiments.

Noteworthy, though, was that **Table 4** showed minimal balance shift with increased ride height, whereas **Table 5** showed a balance shift. This suggests that the car's floor and diffuser were bringing benefit; it's just uncertain by how much.

Next month we'll start a new project.

Racecar's thanks go to Martin Gibson at Giti Tires Europe and Nick Barrow, Jon Taylor and the team at Saxon Motorsport.

Removing the entire floor from the BMW made only a small difference to the total downforce

CONTACT

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

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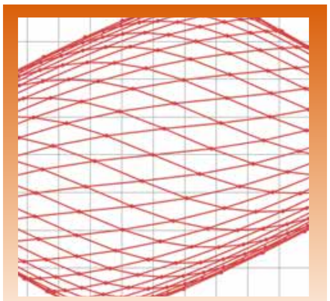

Slip Angle provides a summary of OptimumG's seminars

Getting to grips with your yaw moments

In the first instalment in a new series OptimumG vehicle dynamics engineer Claude Rouelle takes us through some yaw angle basics

One important part of a racecar performance engineer's job is lap time simulation. Simulating and comparing the effect of car design and set-up parameters on the lap time is essential. With the many inputs and outputs that exist in such simulation, it is always worth having metrics other than the lap time to know if and why we improve the car's performance. Metrics such as grip, balance, control and stability on entry and at the limit issued from the yaw moment versus lateral acceleration method, created by Bill Milliken in 1953, provide such criteria.

Let's start with a question here. What is the yaw velocity of your car on a skip pad (circular handling pad)? Many Formula Student participants in design judging and even several professional race engineers incorrectly answer this question. Most of the time their answer is 'zero'. Wrong. That is because they mix the definition of the yaw velocity and the speed of the CG slip angle ß (the speed at which, in top view, the angle of the car's longitudinal axis changes with the tangent of the trajectory). On a skid pad we can assume that the yaw angle (some could call it the car attitude angle) is constant and therefore the yaw angle speed is zero. But despite very similar words used in their description, 'yaw angle speed' and 'yaw velocity' are not the same entities. To help students rethink their answer about skid pad yaw velocity, we can ask them to simply wonder if 360 degrees (one skip pad lap) divided by their car lap time could be the right answer …

Let's go back to the basics. We know that **$A = V^2/R$** (1), A being the car lateral acceleration (in m/sec^2), V the car speed (in m/sec) and R the radius of the skip pad (in m). We also know that **V= rR** (2), r being the yaw velocity (in rad/sec). If we put equations (1) and (2) together we get that **r = A/V** (3). Equation 3 is in fact incomplete. A more accurate definition of the yaw velocity is **r = A/V + dß/dt** (4), ß being the chassis slip angle (in rad). dß/dt, will be given by the derivative of the signal of the slip angle sensor.

On a skip pad we can assume we are in steady state condition and that V, A, and R are constant, that the chassis slip angle ß is constant too and dß/dt = 0.

Therefore, the yaw velocity r is constant too. If the yaw velocity is constant, the yaw acceleration must be zero.

Figure 1a shows a simplified mass point car on a skid pad. **Figure 1b** shows a car with a constant slip angle ß. **Figure 1c** shows the same car on the same

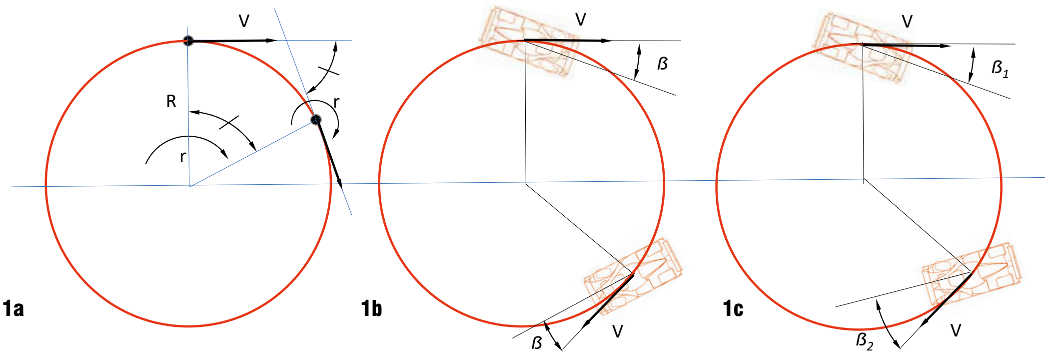

Figure 1a: Skip pad. Steady state mass point. Constant speed V, radius R and yaw velocity. The yaw velocity is nothing else than 360 degrees divided by the lap time
Figure 1b: Skip pad. Steady state vehicle. Same as 1a: constant yaw velocity r and constant CG slip angle ß. This is showing a racecar exhibiting a constant slip angle
Figure 1c: Skip pad. Transient vehicle. A, V and R are constant, CG slip angle varies

Here OptimumG has installed one of its slip angle sensors on the back of a GT car

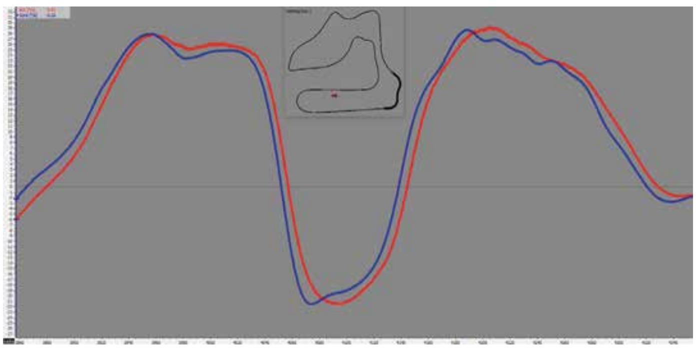

Figure 2: The difference between A/V match channel (the red trace) and the gyro signal (blue trace) is the slip angle speed dß/dt

Yaw angle speed and yaw velocity are not the same entities

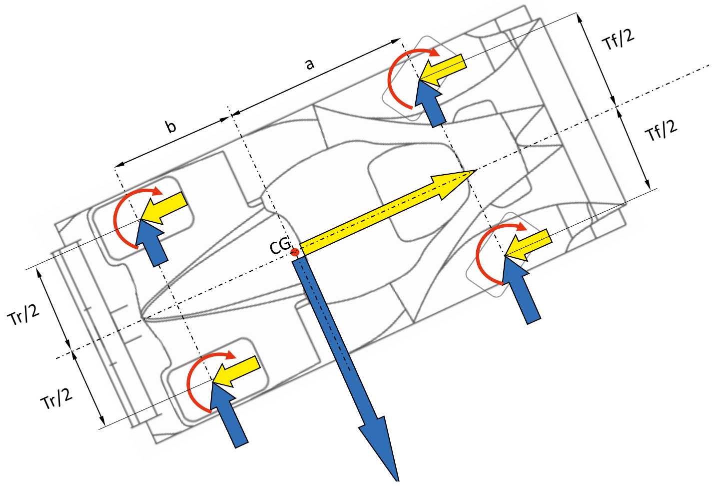

Figure 3: The 12 causes of yaw moment: four tyre lateral forces Fy, four tyre longitudinal forces Fx, and four tyre self-alignment torques Mz

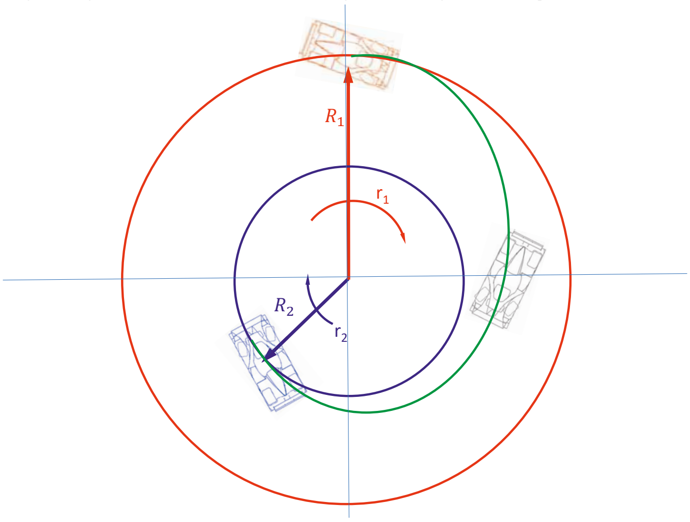

Figure 4: Going from one pad to another requires yaw moment N = Izz (dr/dt)

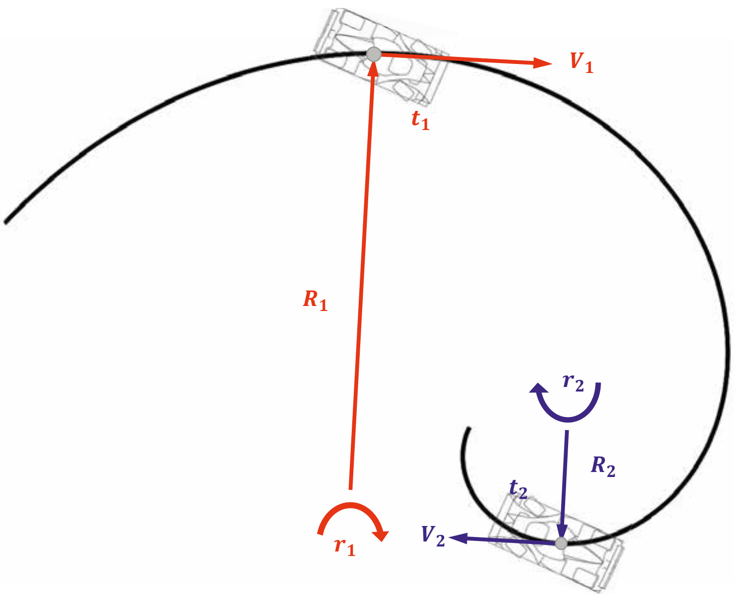

Figure 5: Same concept as Figure 4 but two skip pads do not have the same centre. Several iterative calculations can be made between points 1 and 2

skip pad but with a variation of the chassis slip angle. If in all three cases the lap time is the same (360 degrees in the same amount of time), the yaw velocity is different in the third case because of the variation of the chassis slip angle ß.

Figure 2 shows the difference between the math channel A/V (in red) and the gyro (in blue).

Let's now look at the yaw moment. The rotational perspective of the Newton second law **F = ma is N= Izz (dr/dt)** (5) where N is the yaw moment (in Nm), Izz is the yaw inertia (in kgm^2) and dr/dt is the derivative of the yaw velocity or the yaw acceleration.

Equation 5 could be written as **N = Izz [d(A/V) / dt + d²ß/dt²]** (6).

Theoretically, the yaw moment should be zero on the skid pad. A, V, R, ß and r are constant, or close to constant if we ignore the slight steering and throttle changes made by the driver. The car behaviour on skip pad is the closest situation of the steady state definition.

The steady state skip pad example is quite theoretical. No track is perfectly smooth, no driver input constant, wheels are never perfectly balanced and tyre grip (mainly temperature sensitive) is never constant. The reality is a car is practically in a transient state most of the time. So, two questions arise: how much is, or should, the value of the yaw moment be in transient and what are the parameters that influence the car yaw moment?

Yaw move

There are 12 causes for the yaw moment: four tyre lateral forces Fy, four tyre longitudinal forces Fx, and four tyre self-aligning torques Mz **(Figure 3)**. Looking at the car from the top, if we choose the car CG as a reference and we calculate the yaw moment around that point, distance a (from the front axle to the car CG) will be the leverage of the front tyre lateral force Fy (let's be careful to input the component of the front tyre lateral force that is perpendicular to the chassis longitudinal axis, not perpendicular to the front wheel), distance b (from the car CG to the rear axle) will be the leverage of the rear tyre lateral force Fy and each ½ track will be the leverage of each respective tyre longitudinal force Fx.

To answer the question on what should the yaw moment in transient be, let's imagine a car that is in steady state at a speed V_1 on a skip pad of a radius R_1, with a lateral acceleration Ay_1 and a yaw velocity r_1 **(Fig 4)**. We will now ask the driver to go as quickly as possible without *under* or *oversteer* to another skid pad that has a shorter radius R_2 on which he will reach another steady state with a speed V_2, a lateral acceleration Ay_2 and a yaw velocity r_2. Practically the driver must find the right combination of steering torque and brake pedal pressure to get the maximum deceleration and the yaw moment needed at any time.

Yaw moment

Going from a Speed V_1 to a Speed V_2 in a minimum of time Δt implies a longitudinal deceleration **Ax = (V_1 - V_2)/Δt.** Also, the car will go in this minimum amount of time Δt from a yaw velocity r_1 to a yaw velocity r_2 which implies a yaw acceleration **dr/dt = (r_1-r_2)/Δt**. Multiply this yaw acceleration by the yaw inertia and we get the yaw moment that is needed. We could imagine a similar transient behaviour in acceleration from skid pad two to skip pad one in acceleration.

We do not race on skid pad or skip pads, nevertheless the principle remains the same. If a driver follows a given trajectory (**Figure 5)** there will be changes in speed V, changes in radius R and therefore changes of yaw velocity, thus a need for a different yaw acceleration.

An understeering car has a deficit of yaw moment, an oversteering car has an excess of yaw moment.

The goal that racecar engineers and race drivers try to achieve is double; exploiting the tyres' potential forces and moments to get the best possible lateral, longitudinal or combined accelerations, and also to get the yaw moment they want, when they want it.

The reality is that a racecar is practically in transient behaviour most of the time

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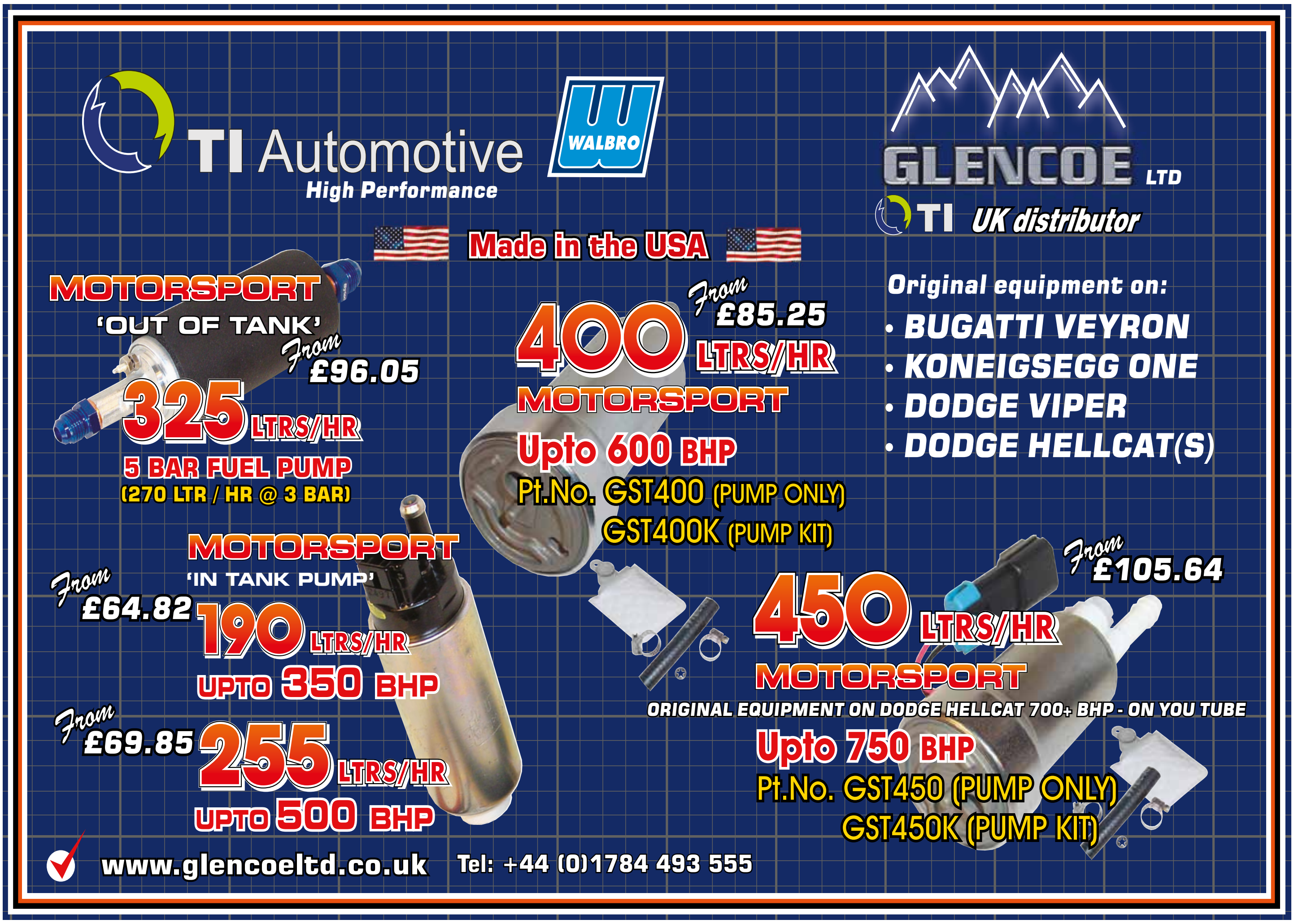
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Xfinity and beyond

NASCAR's ongoing mission to improve its racing and safety through aero development continues – here its lead R&D engineer brings *Racecar* up to speed on Xfinity Series drafting and lift-off crashes

By ERIC JACUZZI

There are many things NASCAR could be accused of, but resting on its laurels is not one of them. With a raft of safety and performance related changes in 2017, the season is off to a great start. On the aerodynamics side, there are two major thrusts for this season that began last year: improving lift-off performance of all three national series race vehicles, and focusing on track specific improvements to racing quality.

Both are focused on drivers and fans – in one case, keeping them excited about typically difficult tracks for NASCAR to race on, and the other to keep them safe when things go wrong on track. Both have involved the full gamut of CFD, wind tunnel testing, track testing, and immense collaboration between NASCAR R&D and the industry to hopefully deliver a safer, more entertaining NASCAR in 2017.

To begin with, let's look at the Xfinity Series. Since 2012, NASCAR's second tier series has joined the Cup at the prestigious Indianapolis Motor Speedway. This unique 2.5-mile track with four identical quarter mile turns and banked at only 9.2-degree has always presented a significant challenge to stock cars to put on a good show. The narrow width of the track and low banking angle means there is a narrow preferred line through the corners – the first driver to Turn One often begins to march away from the rest of the field as they battle for position running less than optimal lines.

With multiple packages having been attempted over the years, the one recipe NASCAR has not attempted is one out of the open-wheel book: wide open throttle and improved drafting. Grip limited cornering coupled with high rates of acceleration on the straights has been the mainstay in both Xfinity and the Cup, and while there have occasionally been exciting battles, generally Indy has not delivered the type of excitement this storied venue deserves.

NASCAR arrived at Indianapolis on an unseasonably warm day in September with three teams in tow to evaluate multiple aero and engine packages. A key concern of having track-specific regulations is the impact on team budgets. Currently, teams have two engine packages – intermediate and the restrictor plate version of the intermediate engine which is run

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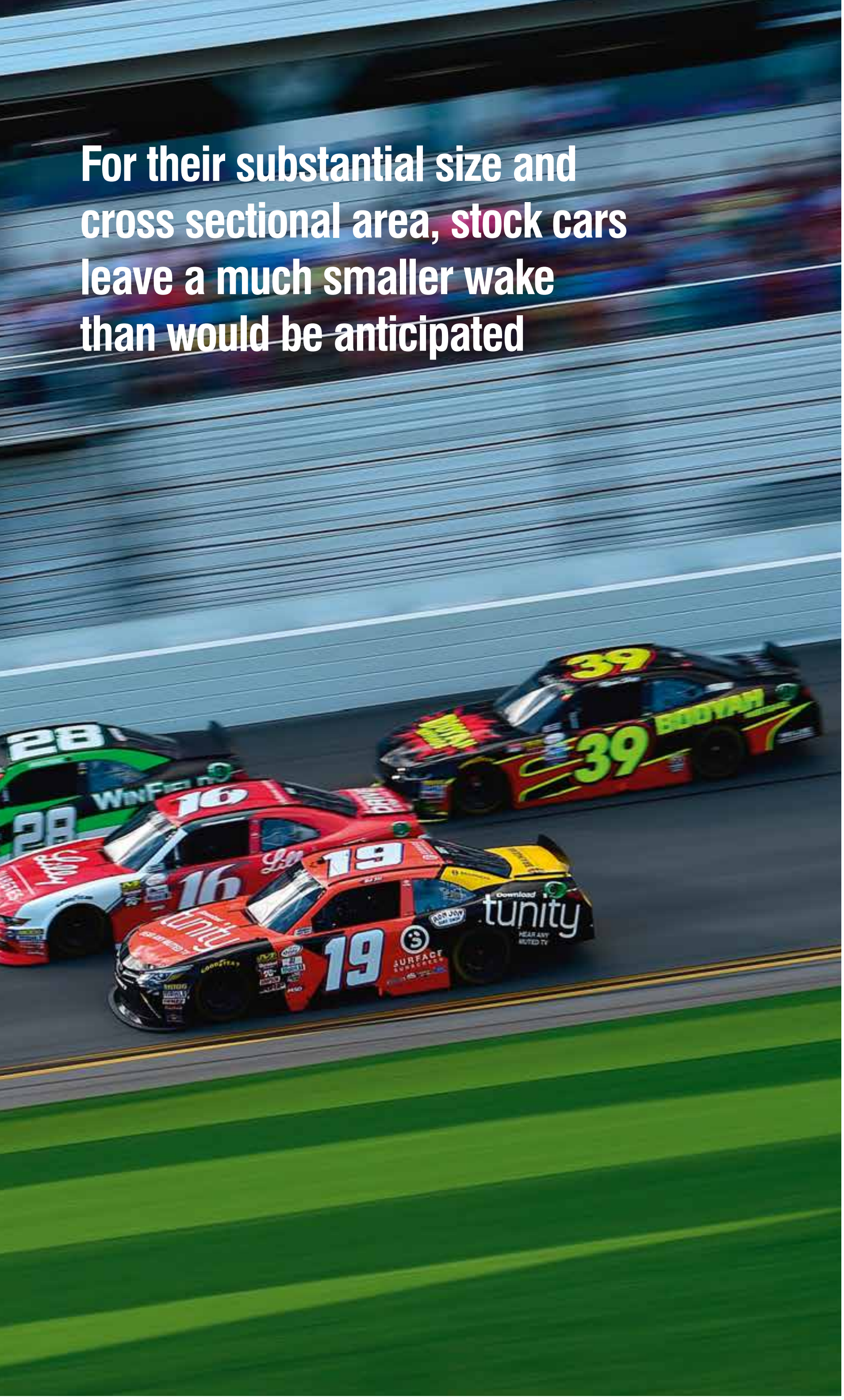


at superspeedways. There are not significant differences between the two. However, deciding to run an intermediate power level between the two currently, or drastically changing the lap profiles, could result in unanticipated development. It is a similar story with the car itself – there are hundreds of things that could be attempted, but the practicality of implementing it for one race and keeping teams from spending unnecessarily is another story entirely. So it was critical to arrive at a solution that worked within these parameters to make it a viable option for 2017.

The objective was to utilise 2016 downforce levels in the series (approximately 2700lbf at 200mph) and assess cornering speeds. Based on driver simulator work by Richard Childress Racing and past test data, this appeared to be around 170mph at Indianapolis. Reducing power from the current 600+ bhp to the restrictor plate engine power of 430bhp gave a straightline speed of under 175mph while maintaining that same corner speed. The car was still at the limit of handling in the corner, but the driver was able to hold 90 per cent or greater throttle through each of the four turns.

The second part of the equation was increasing the drafting potential of the cars. For their substantial size and cross sectional area, stock cars leave a much smaller wake than would be anticipated, particularly in comparison to an open wheel car. Additionally, sedan body types being basically bluff bodies on wheels means that as they approach a car from behind, they work to pressurise the tail of the lead car, lowering its drag and basically pushing the car away. These two factors make a meaningful draft a very difficult proposition. But that does not mean it's not worth pursuing, especially at a track like Indianapolis that has 1.5 miles of straights.

Initial investigations focused on many areas, including adding drag increasing appendages. However, from previous experience in trying to add drag via the spoiler, these types of items do not always lead to increases in drafting and can have significant effects on handling and stability. Adding drag generating devices to the front of the car was attempted, but each time the result led to significant changes in downforce and balance. An example is something like a wicker on the front fascia – while it does add drag to the car in isolation and increases drafting at several car lengths spacing, it also caused a significant loss in front downforce via the low pressure region behind the wicker. This meant that as a trail car entered the wake of a lead car, drag would be reduced but aero balance shifted forward as the suction behind the wicker was relieved. Furthermore, adding drag to the front of the trail car increased fascia pressure, exacerbating the pressurisation of the tail of the lead car from distances closer than one car length. Our potential drafting aid had become even more effective at pushing the lead car away!

Fresh fascia

Another approach was clearly in order. From the previous work on eliminating bump drafting, we knew the wake shape and its energy level, particularly on the front fascia, played important roles in determining whether a trailing car had a drag advantage or disadvantage. So reversing this thinking, a wider wake should give a better drafting environment. But how to achieve this without ridiculous appendages? The answer came via a conversation between Scott Miller, senior vice president of Competition at NASCAR and driver Brad Keselowski, who told Miller that he thought the cars had much less of the 'basketball effect' – the drag reduction on a lead car by the trailing car approaching it – at tracks like Watkins Glen where full brake cooling was utilised. Front brake cooling in particular is capable of exhausting a significant amount of air through the front wheels and out of the wheel openings.

Coming up with a solution for the Xfinity Series was aided by the use of a common lower fascia. For all three manufacturers, the lower half of the fascia is identical. Since the lower fascia and fender profiles are sensitive aerodynamically, standardisation of the lower fascia allowed for confidence in developing manufacturer identity into the upper fascia while honing

NASCAR Xfinity Series Ford Mustang showing the common lower fascia and brake ducts. The upper portion of the fascia is free for the three NASCAR manufacturers to style as they wish

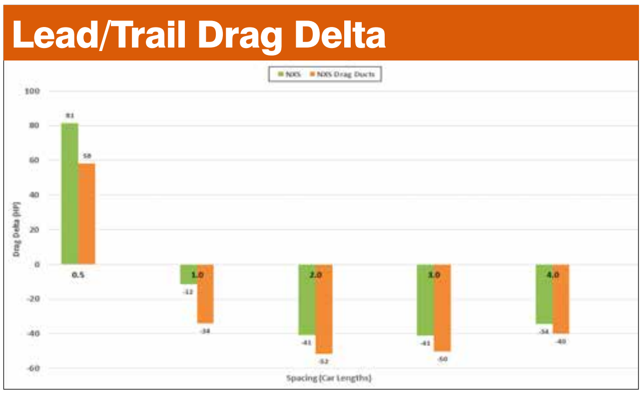
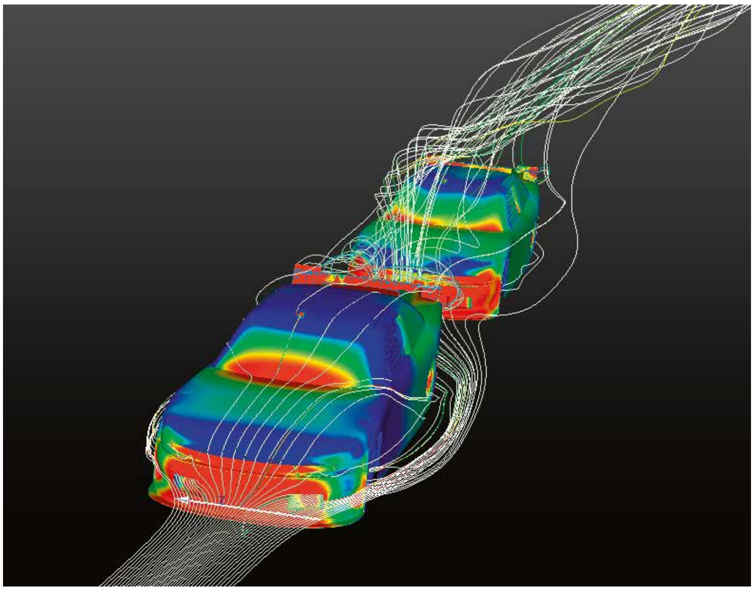


Figure 1: CFD prediction of drag duct drafting improvement on Xfinity cars

Delta showing the drag duct's effect on widening the wake out of the front tyres



Wake streamlines at a half-car length spacing. Note the airflow blown out of the wheel opening

The danger that lift-off poses is that it can take a relatively benign incident and turn it into something much worse

the aero homologation process now used in all three NASCAR major series. The standard lower fascia means the radiator opening and brake duct areas are all in the same place (an Xfinity lower fascia is shown at top of this page).

Utilising the common brake openings, ducts were designed at NASCAR R&D to take in air at these openings and blow a sheet of air out of the front of the wheel opening. The effect widens the wake at the front of the car, enhancing drafting by greater than 25 per cent according to CFD results at the critical one-half car length distance **(Figure 1)**. It is at this point that a passing manoeuvre is most likely to stall as the driver pulls out to pass. The ducts also have the benefit of increasing total downforce by around four per cent without impacting aero balance. The ducts are very efficient at generating downforce, with a minimal impact on total vehicle drag. The tortuous path of the airflow is designed to avoid the existing splitter structure so they can be installed on existing cars without modifications.

Experiments aside, the ducts had to deliver concrete gains on track. One of the difficulties of CFD work on drag is assessing how much of an improvement is noticeable on track. The test was formatted to allow short practice sessions with each package, followed by a five-lap mock race. The initial package was the restrictor plate engine only. The three cars at the test were able to stay within a car length each other, but there were no passes for the lead of the race and minimal passing throughout the field.

The next package added in the drag ducts, and had multiple passes throughout the field and for the lead over the course of the five lap race. Drivers commented that the drag basketball was greatly reduced and handling in the corners was not compromised beyond normal aero effects. It was certainly a welcome sight to see three cars racing together for several laps, instead of slowly spreading apart. Discussions are still ongoing as to whether to implement the package for the race in July.

Safety: lift-off

When most people think of aerodynamics and racecars, they usually think of how aero impacts performance – reducing drag, increasing downforce, etc. Few outside of the various sanctioning bodies have likely ever given any thought to the amount of work that goes into reducing aerodynamic lift-off during crashes. With fans close to the action at nearly every one of our tracks, NASCAR has been battling the forces of nature to keep cars on the track since the very first stock cars set foot on a paved oval.

Body shape

NASCAR racers are inspired by production shapes, with the recognisable and significant greenhouse. In the Cup Series, the body shape is inspired by the typical American four-door sedan, with current racecars based on the Ford Fusion, Toyota Camry, and Chevrolet SS. The most significant common areas of the cars are the wheel openings, skirts, tail outline, and the greenhouse and deck lid.

The significant greenhouse is great for accommodating the family and cargo, but is a significant aerodynamic hindrance at racing speeds. This is doubly true once we start to consider cars in various yaw conditions and attitudes associated with crashing.

The most obvious danger that lift-off poses is that it can take a relatively benign incident and turn it into something much worse.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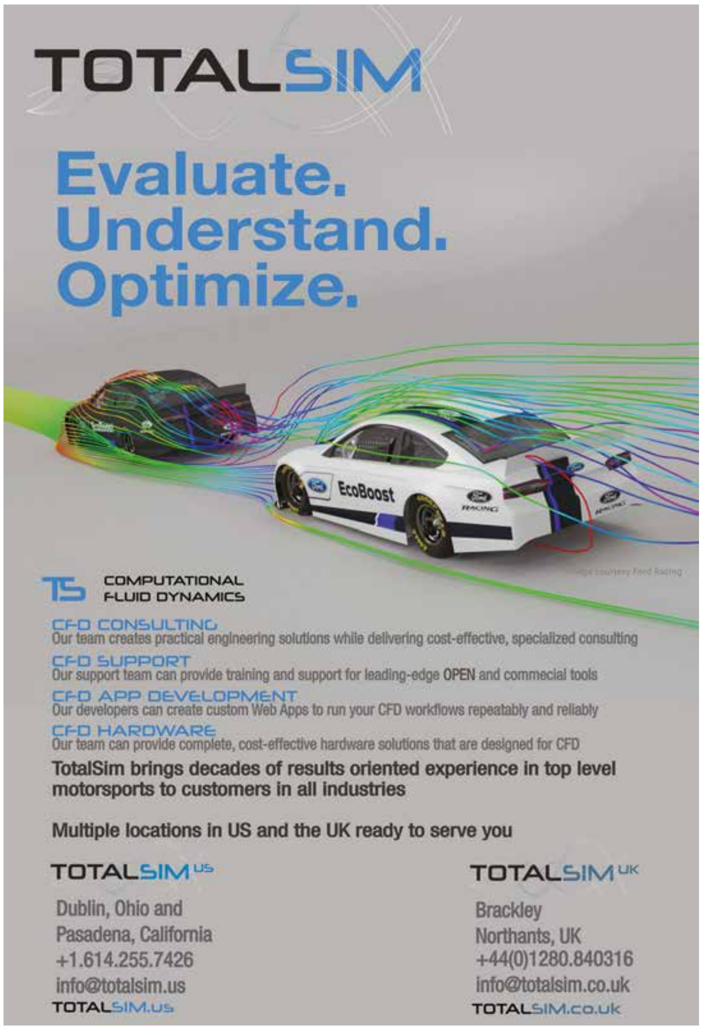
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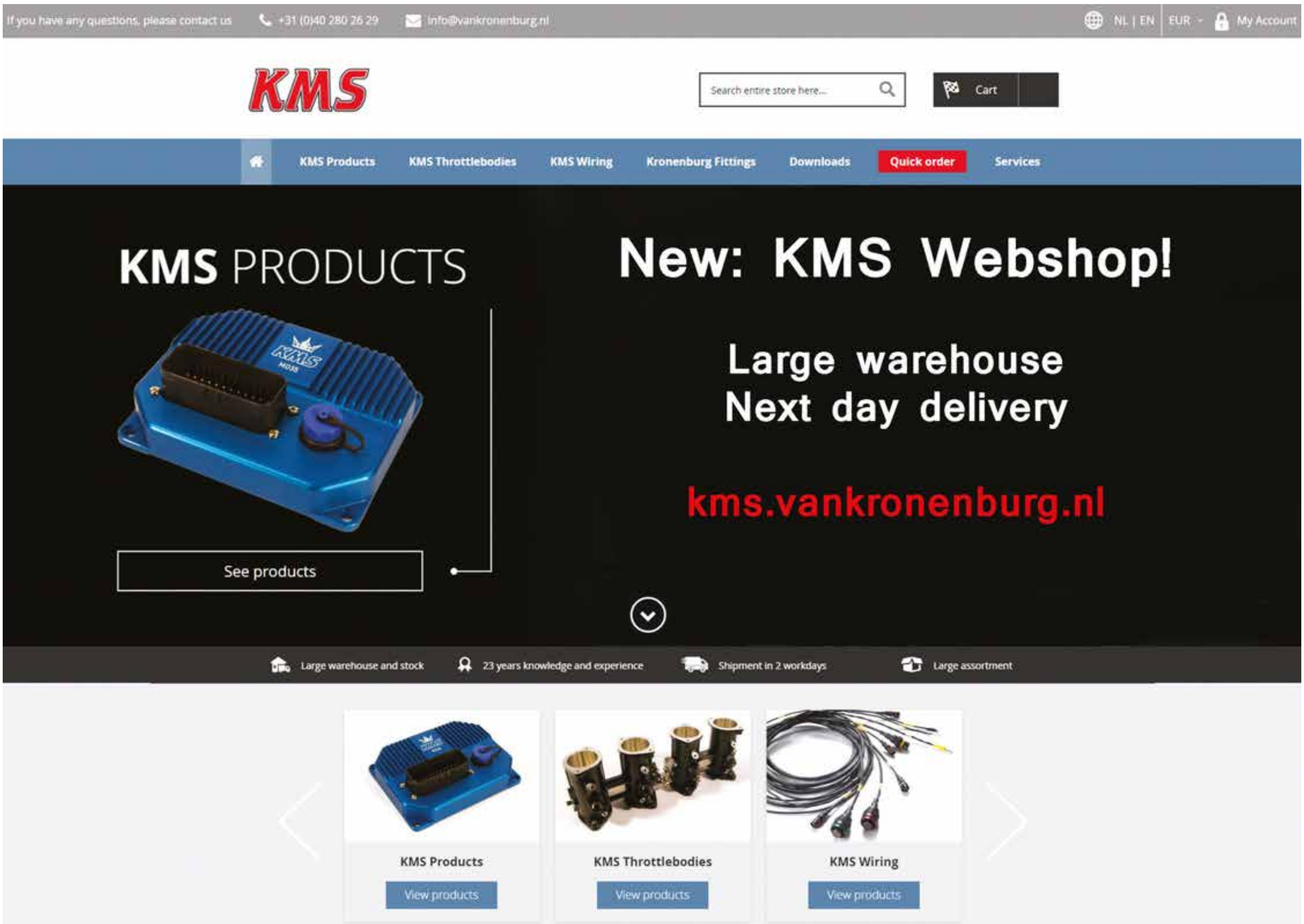
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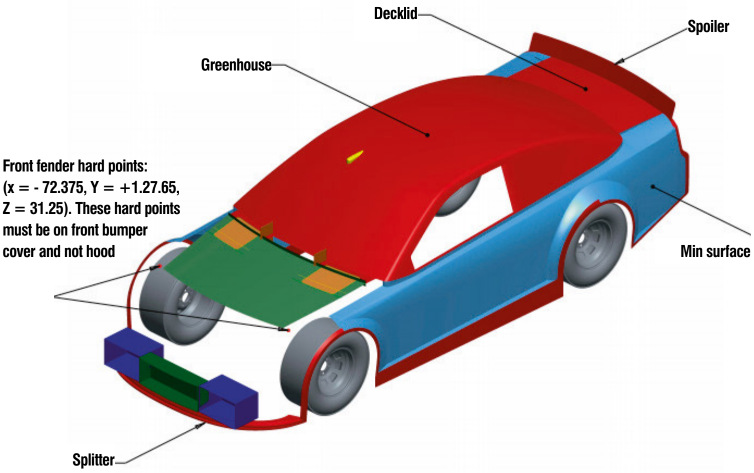
Here's a close up of the drag duct installed on the right hand side of an Xfinity Series stock car

Adding the drag ducts to the cars for a five-lap mock Xfinity race at Indy led to multiple passes throughout the field including overtakes for the lead of the race



Monster Energy NASCAR Cup Series body common areas, here shown in red. The blue portions show the maximum inward deflection a stock car body design can have. Brake duct and radiator air inlet locations are permitted within the coloured boxes at the front

Lift-off panel will simulate car with rear tyres four or five inches off the ground

Barriers meant to catch a car on the ground are suddenly bypassed as a car takes flight, slamming into unforgiving catch fencing or even worse – the seating areas. A simple spin at high enough speed is enough to send any car airborne. The question is: how fast is the car capable of going relative to its lift-off point, and what measures are onboard to attenuate lift-off?

In addition to sedans (Cup) and coupes (Xfinity), NASCAR also has the NASCAR Camping World Truck Series (NCWTS), which races American style pickups. As we will see, this unique body style presents several challenges to attenuate lift-off. Recently, two trucks became airborne at the season-opening race at Daytona. This prompted NASCAR R&D to look for some lift-off improvement solutions.

Analysing a spin

While all crashes present their own challenges, in terms of aerodynamic lift-off for NASCAR, high speed oval tracks definitely present the greatest risk to both drivers and spectators due to proximity and speeds. These tracks are 1.5 to 2.5 mile in length with a counterclockwise lap, with straightline speeds between 185 and 210mph. Typically, spin events are also counterclockwise in direction as well, although this is not always the case.

The NASCAR safety department expends considerable effort analysing every incident on track, with both collected data from event data recorders and the full barrage of television recordings from every race weekend. Lift-off events have generally been categorised into pure aerodynamic lift-off or aerodynamic lift-off with vaulting or ramping.

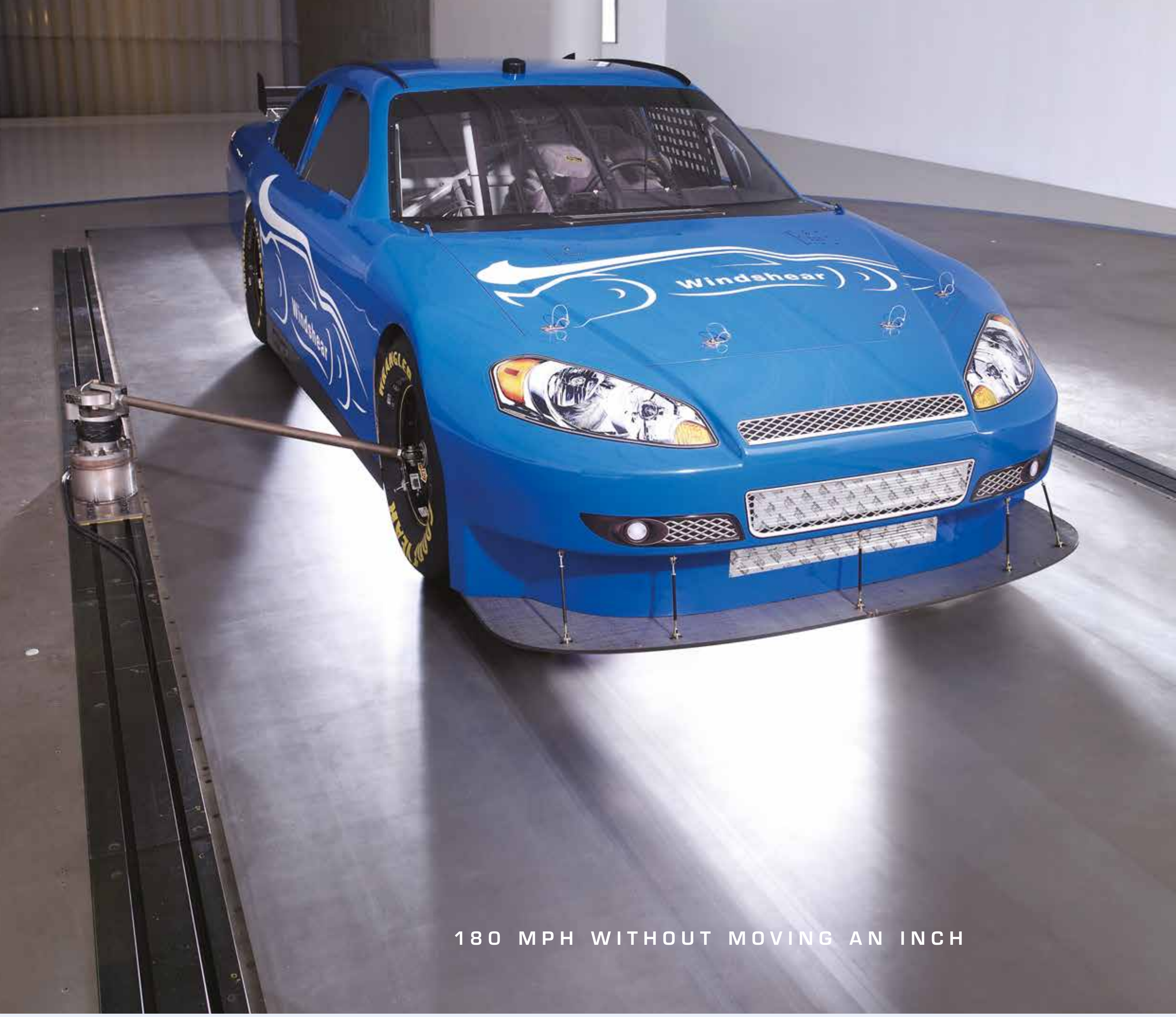
Pure aerodynamic lift-off is exactly as it sounds – the vehicle spun or was coaxed into a rearward yaw angle, but the contact did not contribute to the lift-off the vehicle then experienced. An example of this would be a racecar spinning at the end of the straight on track. Fortunately, thanks to the prior work to minimise lift-off effects NASCAR's done, these types of lift-off events are rare.

Both the Cup and Xfinity cars have fortunately had few pure aero lift-offs in the past several years, due to the effectiveness of the lift-off measures in place. These include lower tail extensions for Daytona and Talladega, and cowl flaps, large deployable roof flaps and vertical fins at all other tracks. Incidents involving airborne cars in these two series have typically been attributed to either ramping or tumbling. Ramping is where the car's tyres, usually the fronts, drive over the bodywork of another racecar, propelling it into the air. Tumbling is when the car trips on its own tyres due to landing in a sideways position, or vaults its own tyre that has been damaged.

In these instances, little can be done to prevent the car from becoming airborne, but any improvements to lift-off will help get the car back on the ground as quickly as possible.

The effectiveness of the roof flaps is such that there is not much room for improvement on the greenhouse. One area revealed in CFD studies was the change in floor pressures during a spin – significant pressurisation of the underbody was occurring as flow stagnated under the open bottom of the car. To combat this, various panels and radii were evaluated on the tail of the car. These panels simply close off the open areas of the floor, maintaining lower pressure under the car and providing a surface for the low pressure to act on. CFD results indicate approximately a 15 per cent reduction in lift at the most critical ride heights.

Wind tunnel validation is upcoming, including running with the car elevated at



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NCWTS Lift-off at 185mph

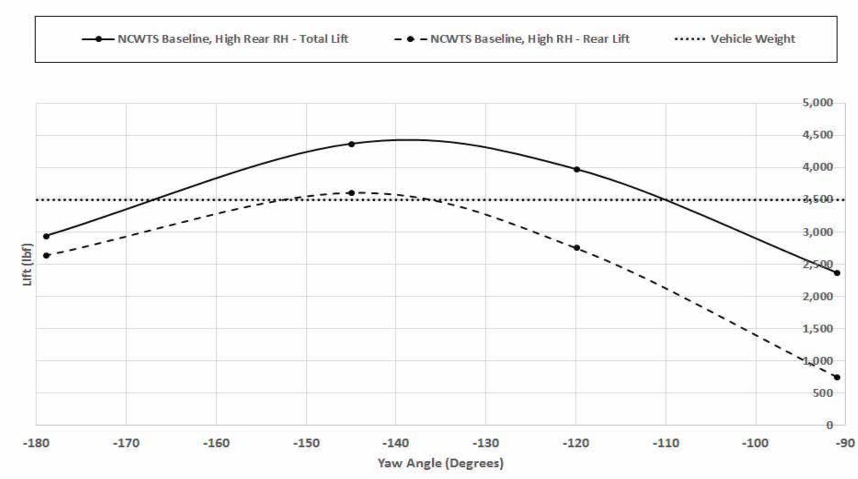
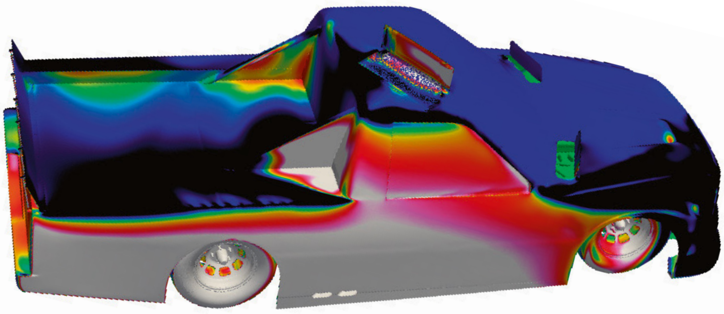
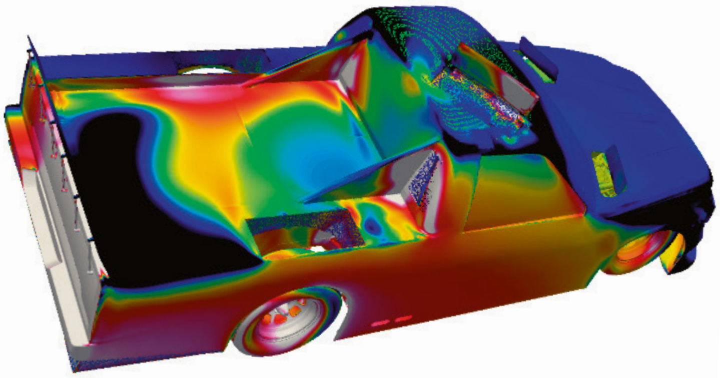


Figure 2. Truck lift at 185mph as shown on the CFD model through yaw sweeps at highest rear ride heights

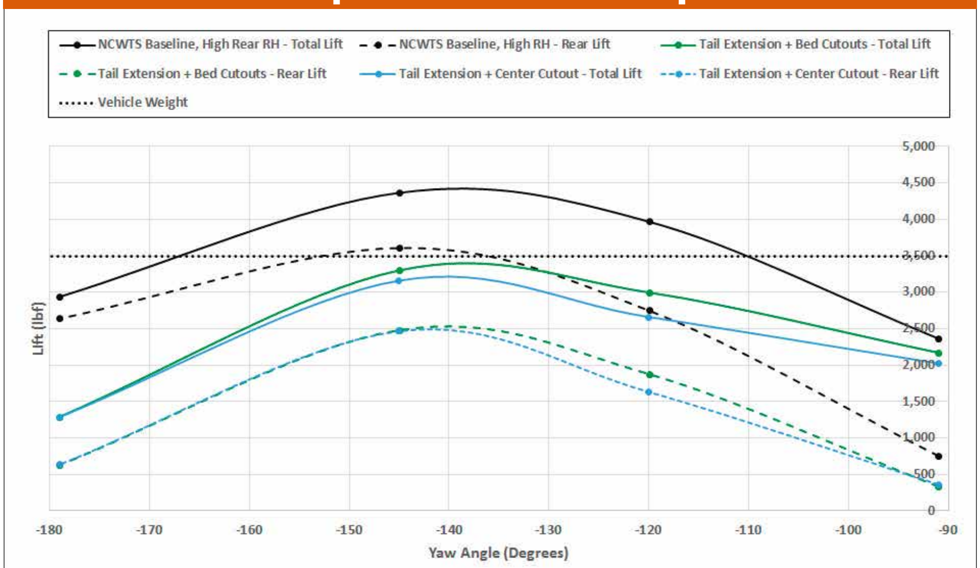
CFD surface pressure plot for -145-degree yaw angle. The blue/back regions are extremely low pressure



Wheel top cut-outs; showing reduced low pressure region



NCWTS Lift-off Improvement at 185mph



Lift reduction on the trucks via the proposed cut-out solutions. These steps are now to be evaluated further by NASCAR R&D

the rear to simulate a car with the rear tyres four to five inches off the ground.

As previously mentioned, the Daytona Truck race saw two trucks involved in lift-off events that thankfully did not result in any injuries. The No.4 truck and the No.88 truck both experienced airborne events that were deemed to be aerodynamic lift-off by the NASCAR safety and aero teams. The team quickly constructed a lift-off CFD model of the truck and ran through a yaw sweep of -90-degree to -180-degree. As expected, lift-off performance was worse than either the NASCAR Xfinity Series or Monster Energy Cup Series cars, even considering the slower speeds of the trucks. Lift force on the CFD model is shown in **Figure 2** through the yaw sweep at the highest rear ride height.

In past wind tunnel testing, earlier NASCAR R&D teams found that vertical fins were not as effective at reducing lift as they were on the cars, and the **Figure 2** plot shows why. The airflow acceleration over the bed and around the cab generates a significant lift in those regions. This is why early investigations of large deployable fins found them to be ineffective, as it simply exacerbated the flow acceleration in this area, making marginal contributions to changing the overall lift on the vehicle.

More promising avenues involve bleeding higher pressure into the low pressure region on top of the bed via cut-outs. Two proposed solutions to be tested in the wind tunnel in April are creating openings over the rear tyres, and separately, creating a cut-out over the centre of the rear axle. The results of the whee top cut-outs solutions is shown on the left.

Improvements of over 1200lbs of lift with the wheel top cut-outs and even greater with the centre cut-out were observed. To mitigate downforce loss, sealing flaps will be used on the centre cut-out, similar to the cowl flaps on the underhood region. These are lightly held down by springs under the flap just enough to keep them from bouncing during normal running, but they will still be able to open quickly when the pressure difference between the top and bottom of the flap dictates. For the wheel top cut-outs, louvred panels will be evaluated, as CFD indicated a significant reduction in straight ahead downforce loss. The louvres did appear to impact lift-off performance, so that will now be further evaluated and considered after the wind tunnel test is concluded.

Working with team partners and manufacturers, NASCAR will be able to quickly arrive at an agreed solution and implement it prior to the October Truck race at Talladega.

In conclusion, the improvements to both the racing product and new safety measures are now in full swing, at the time of writing early in the season. Hopefully, the fruits of this labour are successful and achieve our goals. Longer term work continues in both areas to ensure NASCAR is continuing to improve on the experience for fans and drivers alike.

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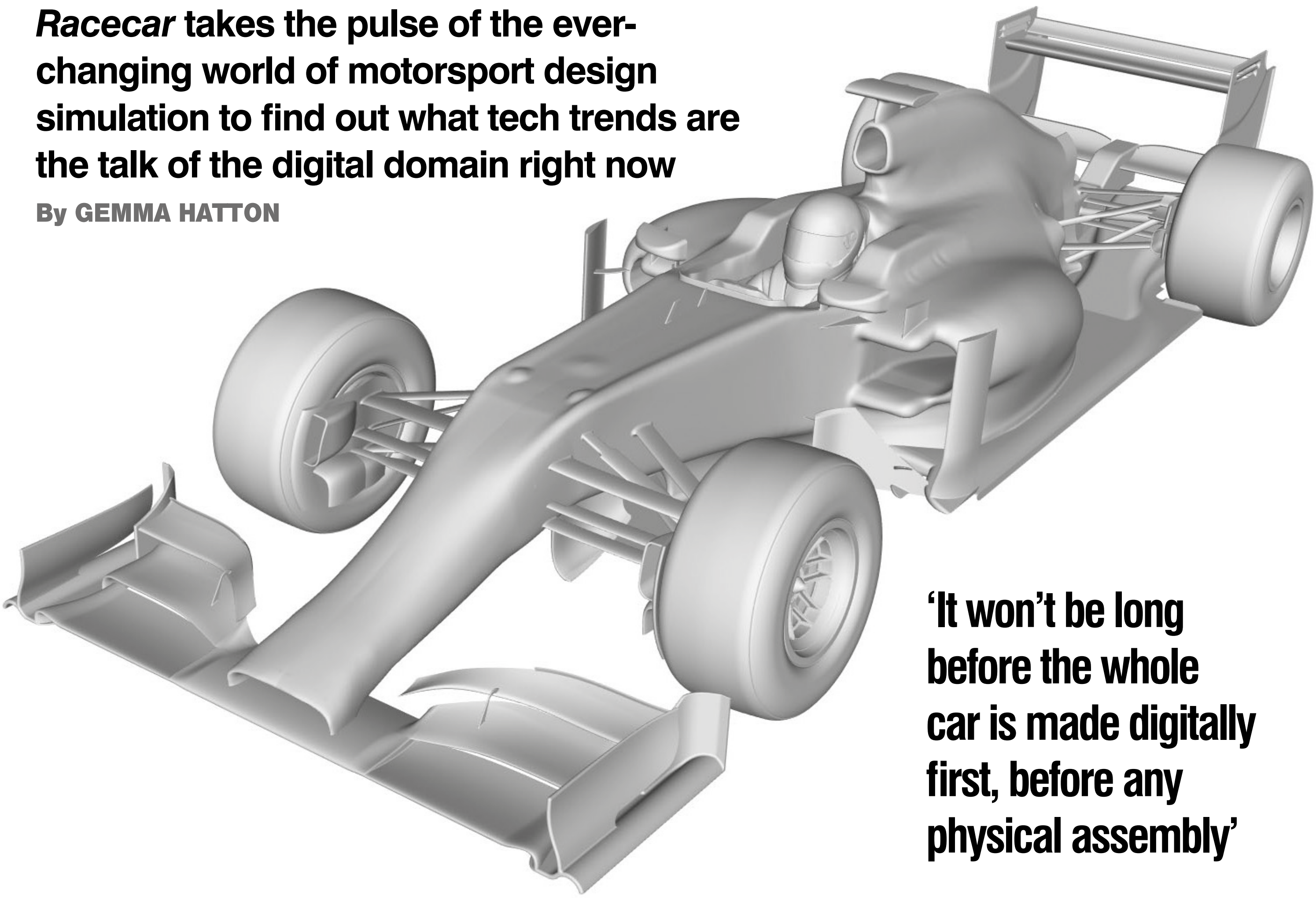
The state of the art

Racecar takes the pulse of the ever-changing world of motorsport design simulation to find out what tech trends are the talk of the digital domain right now

By GEMMA HATTON



'It won't be long before the whole car is made digitally first, before any physical assembly'

What is the first thing you do in the morning? The modern answer is most likely 'check my phone'. Today's diverse array of social media platforms and their ability to bombard you with endless notifications, messages and information is persuading us to develop a technological twitch.

The daily developments on these social media platforms mean that news travels faster than ever before and that people are now more connected, interactive and digitally accessible. This shift in lifestyle offers huge potential for any developing industry and explains why companies will be spending over $35bn globally on social media advertising this year.

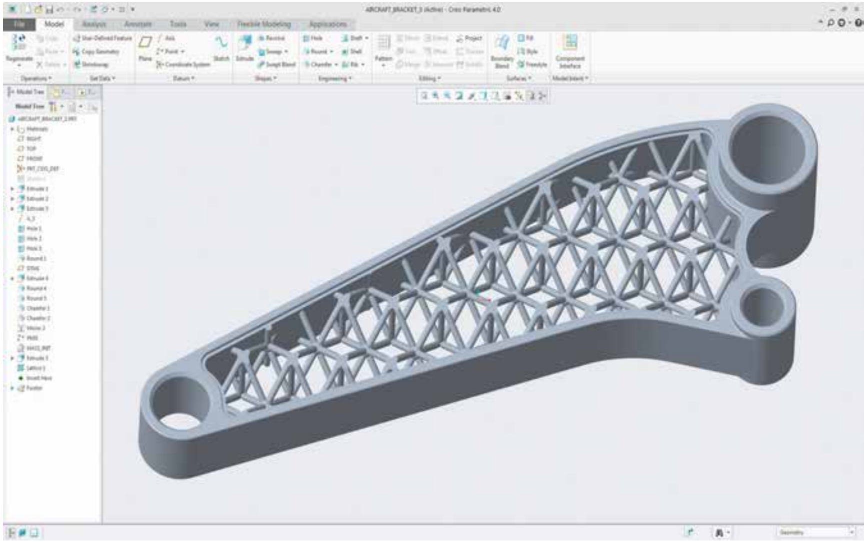
However, this worldwide social network cannot only be used to promote products and services, but also to develop them. And this is where world leader in engineering simulation, Dassault Systemes, has been gaining what it sees as a competitive advantage.

Connected design

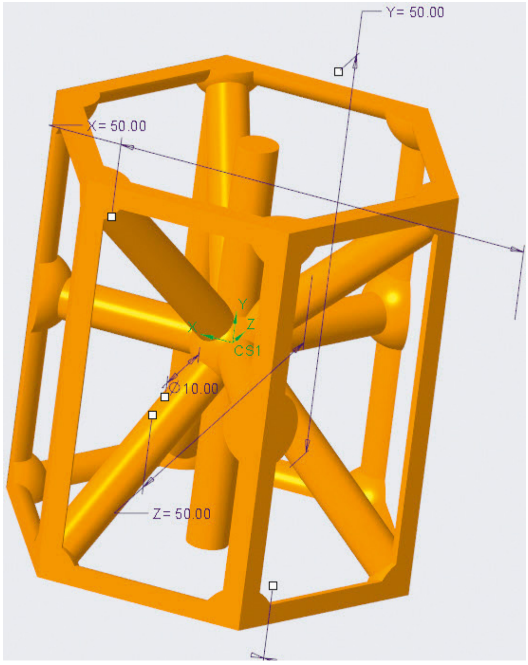
In motorsport, Dassault Systemes is well-known for its CATIA Design and digital mock-up applications, which in previous years has been used by 80 per cent of Formula 1 teams. However, this now forms just a small part of a much more advanced digital architecture.

'We have developed CATIA into a concept called the 3DExperience platform. This is a platform that powers our product portfolio in one common place and allows us to connect with the expertise inside and outside of our company,' explains Jonathan Ruffley, EuroNorth senior technical specialist at Dassault Systemes. 'Take the analogy of catching a taxi. Traditionally, you would wave a taxi down on the street and then find they don't take credit cards. Now, we use Uber which uses a platform on your phone to connect you with a driver. Other platforms include Amazon and eBay, but what we haven't had up until now is a platform for people who make things – this is what the 3DExperiecne concept is.'

This platform, just like your phone, has a wide variety of applications (apps) which include every possible required task to take an initial idea right through to final manufacture. CATIA is an example of one of these apps, along with SIMULIA, which conducts the Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD) simulations, as well as

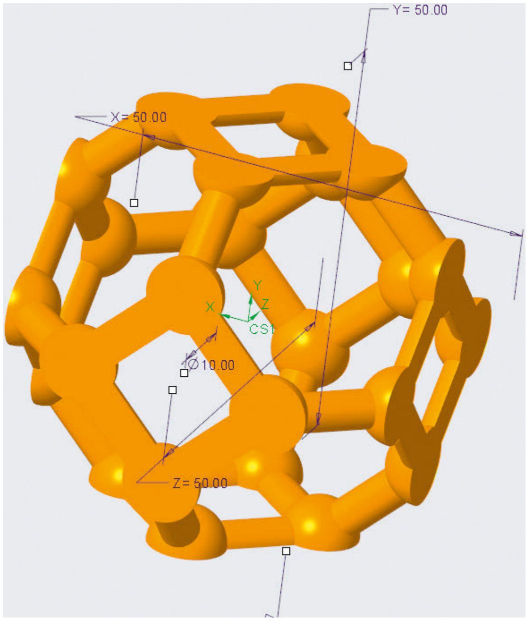


Triangular lattice structure, which reduces mass within the part while maintaining the exterior shape (PTC)



PTC builds up parts in layers with building blocks of cells (PTC)

Left to right shows progression from a traditional bracket to one that has been milled to reduce weight, then finally on the right the organic shape resulting from the topology optimisation approach (Dassault Systemes)



This shows octagonal cell while picture above is hexagonal (PTC)

project management and digital manufacturing processes. By using these apps to connect people and companies from all disciplines on one common structure, it allows a more fluid transfer of information. Consequently, because everyone is involved right from the start, the design can be driven by all of the requirements. This avoids having to continuously optimise an initial design based on feedback from manufacture. The 3DExperience platform creates a social collaboration throughout each stage of the innovation process.

'There is now a social part of the software which allows us to capitalise on the expertise of people who aren't necessarily designers,' Ruffley says. This feature allows you to connect to various 'communities' whilst designing, and resembles common social media timelines where people post images and videos of their related proposals. When you start thinking of an idea, it is a very fluid thing. You need suggestions from everyone involved to ensure that you have specified all the design requirements. Take F1 designers as an example; they have to be project managers as well. They need to collate information from the race team and other departments to optimise their design before passing it through to engineering. This platform is an approach that now allows them to do that efficiently.'

Within the platform you can also 'tag' roles to a design which essentially assigns tasks to the overall project and gives the necessary individuals access to your work. These roles can be anything from electrical design to simulation. By maintaining this information in one location, everyone can track which roles are required and when, ensuring efficiency for each individual to get their specific job done. This infrastructure of integrating the various roles, together with the range of apps, ensures that every aspect of a product's development cycle is considered, resulting in an 'end to end' approach – the core philosophy behind the 3DExperience platform.

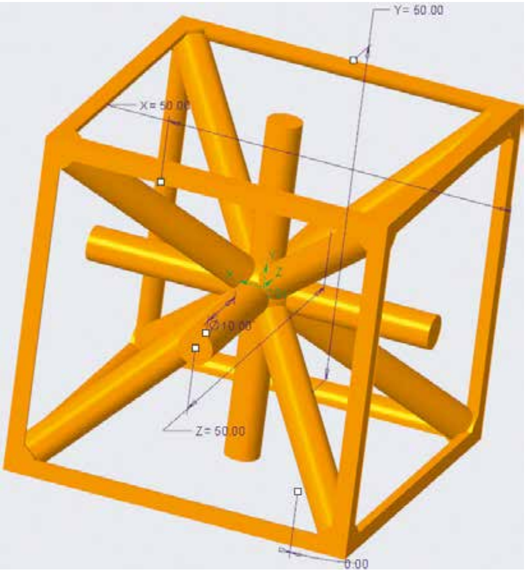
'Traditionally, companies work with a range of different systems which are usually quite isolated and so have poor efficiency and communication,' explains Ruffley. 'By connecting all the systems and tools with all the people, we can facilitate things more effectively. Our

'There is now a social part of the software which allows us to capitalise on the expertise of people who are not necessarily designers'

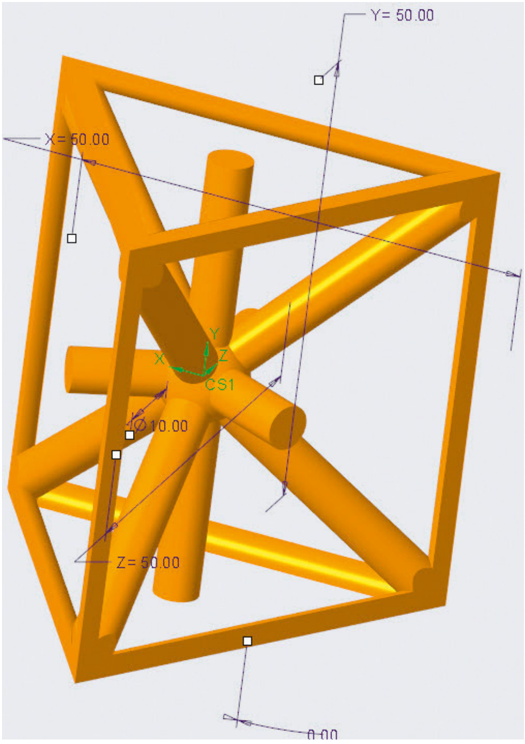
The trend of software companies integrating all their applications into a centralised digital architecture is set to continue

aim is to fully simulate the entire product before the manufacturing process starts.'

This idea of a unified architecture is a trend that other software companies have also been shifting towards over the last eight years or so. 'We have always had a very powerful portfolio of applications, but when we re-branded from ProEngineer to Creo in 2010, we made the conscious effort to develop a common platform for all our technologies,' explains Mark Fischer, director of Creo Product Management from PTC. By relating all the applications to a centralised platform, it means that data created in one application can be used in all the other applications. Therefore, there is no need to perform an import or export operation for Creo data which could result in data loss. Having this wide variety of standalone applications that work seamlessly together provides a powerful solution for our customers from concept design through to parametric modelling, analysis, and manufacturing.'



Square cell. CAD cells come in many different shapes (PTC)



Triangular cell from PTC; which has marketed Creo since 2010

Time saver

The original ProEngineer software, established 30 years ago, revolutionised the industry by being the first to introduce feature-based parametric solid modelling. Previous to that, 3D model or 2D drawings were not associative, which required users to find and update each source individually for every change. 'We automated the whole process, allowing our customers to make changes quickly and have the confidence that those changes would be reflected throughout. This allows our users to spend more time on innovation versus updating their models,' Fischer says.

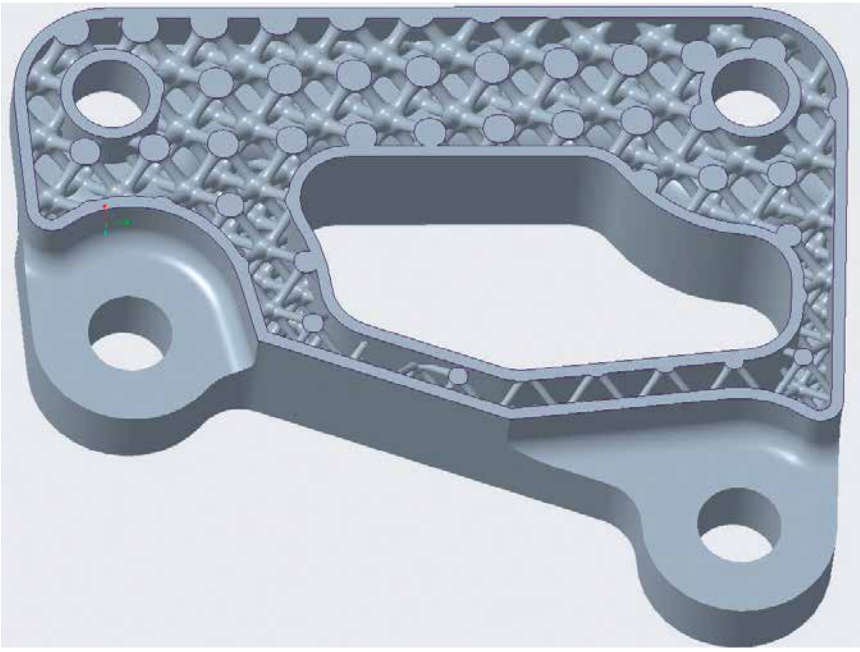
This time saving is proving invaluable in motorsport, where every millisecond counts, both on and off the track. 'The biggest challenge we have is the lead-time between generating the complex parts within the 3D model and physically bolting that component to the car. Compressing that lead time definitely gives us a competitive advantage,' says Rick Simpson, design engineer for Aston Martin Racing. AMR utilised Creo Parametric software along with its Advanced Assembly Simulation and Mechanism Analysis Extensions to design its cars. PTC's platform approach also helped to integrate this CAD design into its Product Lifecycle Management software, Windchill. This resulted in launching the Vantage GT3 from a piece of paper to the track in just nine months – which is half the usual lead-time.

This trend of software companies integrating all their applications into a centralised digital architecture is set to continue, too. 'There needs to be a connection between the digital component and the physical component,' Fischer says. 'We will be introducing some new technologies in Creo in the near future that will bring these two environments together. Essentially, data collected from on-track sensors will be collated into a central database where our predictive analytics software can determine any trends or issues which can then be fed back into Creo. This information can then be used for FEA simulations to represent real-world conditions – not just guestimates.'

'The end-to-end approach of the 3DExperience Platform from Dassault Systemes means we can complete this entire process within the platform and that's an opportunity that needs to be grabbed by all industries,' Ruffley says. 'I think this is going to revolutionise how we create things in the future.'

Additive manufacturing

As well as improving efficiency, the unique 3DExperience platform also improves design capabilities and is starting to shift the order of traditional development methods. Take the example of a roll hoop; it needs to be an exact strength in a certain direction to ensure that it fulfils its function of protecting the driver. However, it also needs to be as light



Octagonal cell lattice structure. Additive manufacturing has brought new possibilities for CAD world (PTC)

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‘Rather than starting with CAD and working through simulations for optimisation, we can now actually start with simulation’

as possible to reduce the mass high up on the car. Therefore, you are trying to find the optimal point where the part will become light enough but remain strong enough, which are essentially opposites. This process usually uses an optimisation loop to generate iterations of the design until the best case is achieved and is then machined out of solid. Machining from solid is a limiting factor in itself, so although you may have refined your design to perfection, it might be impossible to physically make. This is where additive manufacturing comes in.

‘In essence you use lasers to melt and solidify metal powder in layers to build up a part,’ Ruffley explains. ‘Dassault Systemes now has a common basis which allows the simulation of this manufacturing process, so you can take a new innovative approach when designing. Rather than starting with CAD and working through simulations for optimisation, we now actually start with simulation. We consider an initial block of space and simulate the required loads in the required positions for the desired part. The application then removes chunks of material to achieve the optimised design and because we’re using additive manufacturing, any shape can be created. In this way, the design of the part is driven purely by its function and the necessary parameters rather than by any preconceptions. It is then essentially designing without a designer.’

This is an example of a ‘bottom-up’ concept called ‘topology optimisation’ and usually results in very unique and organic shapes. Amusingly, even the stringent mindset of an engineer prefers an aesthetic design over a fully functional one, and so will use CATIA to add material back on and generate smooth and more familiar surfaces. However, this can potentially be quite time consuming as the topology optimisation results are usually in a tessellated format. Therefore, the designer has to rebuild the true CAD geometry around this tessellated framework.

To avoid this potential time loss, PTC has decided to follow a more conventional approach of building a part up in layers and optimising its internal structure.

‘The Creo package also utilises tools such as Lattice creation, allowing designers to define 2.5D or 3D lattice structures within their part,’ explains Fischer. ‘In this way, the mass is reduced and the rigidity is maintained whilst the exterior is visually the same.’

However, the designed lattice has to then be optimised through simulation to ensure that the part meets the structural, thermal and other

Case study: Team Delft

This is a slogan found on the walls of the engineering offices of one of the most innovative Formula Student teams; Team Delft: ‘If it’s not in CATIA then it doesn’t exist.’

‘It’s really true,’ says Pietro Areso Rossi, Delft’s team manager. ‘Until you import a part into the main assembly in CATIA, you have no concept of how that part will actually work on the real car. We use CATIA as the most up to date and realistic documentation of the entire car until we have a physical assembly in our workshop.’

Delft has been at the forefront of the electric car competition in Formula Student since 2011 and the combustion competition previous to that. It has worked with Apollo to develop its unique tyre design, is famous for its inner wheel all-drive concept and last year achieved an aerodynamic package that generated the same cornering *g*-force as a GP2 car.

Despite the mass penalties associated with electric racing, Delft has always accomplished its demanding weight targets, with its 2016 contender weighing in at 159Kg – the lightest in the competition. This can only be achieved by taking an exhaustive approach where every component is extensively scrutinised using the SIMULIA Abaqus FEA application from Dassault Systemes. ‘Once a part has been designed in CATIA, the load case is applied in Abaqus and it either fails or not,’ Rossi says. ‘Put simply, if it fails we add more mass, if it doesn’t, then we remove mass and we continue this optimisation loop until it comes to a point of diminishing returns. This is how we are able to eliminate the weight, especially during the initial iterations of our design.’

Power Electronics software helps teams to design wiring configurations. This also shows just how effective 3D models can be for visualising assemblies (Dassault Systemes)

Looming large

A further challenge of building an electric racecar is developing the complex wiring harnesses. However, by utilising the Power Electronics applications of Dassault Systemes’ 3DExperience platform, Delft has revolutionised this tedious process whilst saving huge chunks of time. ‘Wiring is one of those areas which sneakily cost a lot of time and effort,’ explains Rossi. ‘In the past, we would use string to visualise all the various wires once the car was assembled and determine their length. But with CATIA we have already been able to do this and spot any potential installation issues. The wiring design of the car is extremely difficult to document without a tool like CATIA.’

Team effort

The social collaboration enabled by the 3DExperience platform offers further advantages when trying to manage a large team of innovative and dedicated engineers. It avoids issues surrounding conflicting copies and it allows several engineers to modify their parts within the main assembly at the same time. ‘This means that everyone is collaboratively working with the most up to date design within the same space. Not only does this reduce potential error, but it increases overall efficiency and is how we managed to design, build and test the 2016 car in just eight months,’ Rossi says.

Wing work

The impressive 3.5*g* recorded during cornering is down to a highly tuned aero package which again was only achievable by utilising innovative software. The STAR-CCM+ CFD package from Siemens works seamlessly with CATIA; allowing the different wing configurations generated by the CFD to be easily imported into the main assembly.

‘We are constantly running different aero configurations with STAR-CCM+ to optimise our drag and downforce results,’ Rossi says. ‘By importing these configurations into the main assembly, we can see how our aero package evolves each day and how it changes the overall car.’

The software also allows a large degree of customisability; the mesh and surrounding finite points can be modified to the specific requirements. ‘We were very happy with the program’s efficiency and because it wasn’t as taxing on our hardware, it meant we could run more simulations than before, whilst achieving higher accuracy,’ Rossi says.


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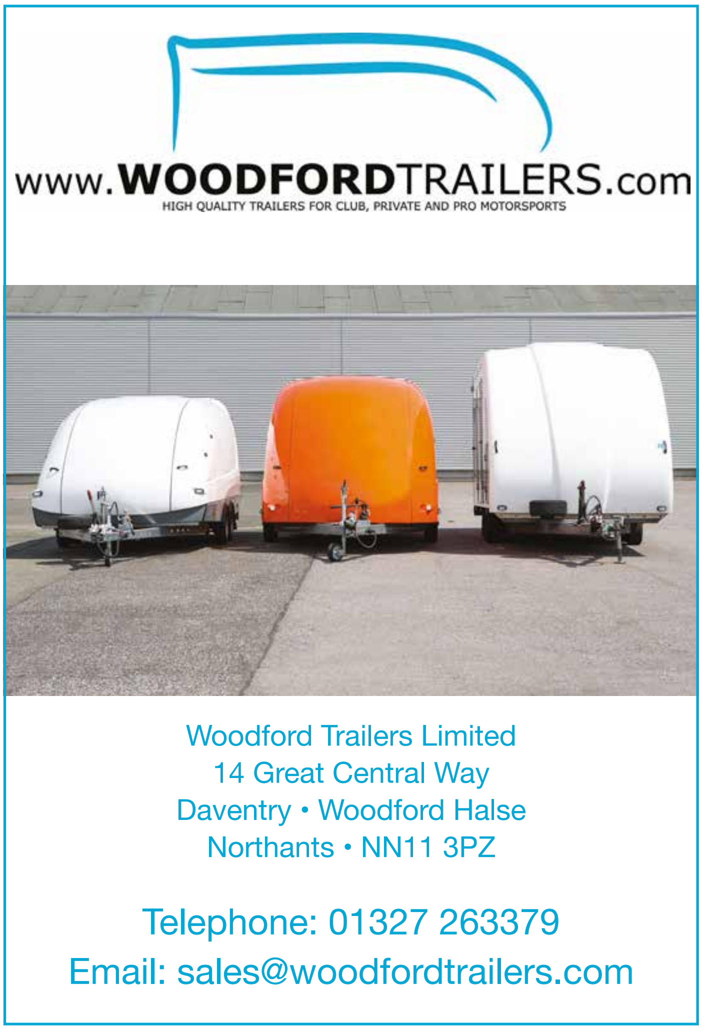
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'It is likely that 2D drawings will become redundant in the near future'

Complex modern parts require complex modern design software

design requirements. 'By using our other tools, the thickness, position and concentration of the lattice can be refined, ensuring confidence that the part will not fail,' Fischer says.

The vast capabilities of additive manufacturing, combined with the ability to virtually validate the manufacture, is now making previously unrealistic designs possible. Designers are not as restricted as before, which is why both PTC and Dassault Systemes have completely different approaches in their additive manufacturing simulation tools. However, add the possibility of using composites as well, and suddenly there are infinite opportunities. 'If you are using isotropic materials such as metals, where the properties are the same in all directions, it is a design challenge to determine the optimal geometry to give the desired performance,' explains Ed Bernardon, vice president, Strategic Automotive Initiatives for Siemens Specialized Engineering Software. 'Composites are anisotropic and allow you to modify properties in a particular direction, so the optimisation challenge for designers increases. However, by controlling the direction of specific material properties, it is possible to optimise and get even closer to the ultimate solution. This challenge is something that definitely must be addressed.'

3D future

As well as redefining its digital architecture, Dassault Systemes has also been advancing its individual apps such as CATIA, which has led to another shifting trend in CAD design. Within the application, parameter based features are utilised to generate the desired shape and surfaces. These can then be brought together, creating assemblies and the resulting technical drawings required for manufacture. However, the growing capabilities of modern design and manufacturing techniques mean that parts are continually increasing in complexity – making it difficult to visually convey this information via traditional 2D technical drawings.

'It can take a long time to put a drawing together for a part that may only be machined a few times. We're finding that our clients are using 3D annotated models more and more and it is likely that 2D drawings will become redundant in the near future,' explains Ruffley.

CATIA Composer is used to annotate the design with dimension and tolerance information and animation is added to demonstrate the process of assembly, all in 3D. 'The technician can see how all the parts come together – it's like a virtual 3D Haynes manual. It also minimises errors from interpreting complex technical drawings. Also, as full-scale car mock-ups continue to reduce, it won't be long before the whole car is assembled digitally first, before any physical assembly,' Ruffley says.

Complicated composites

Composite components now account for 85 per cent of a modern F1 car, yet only 20 per cent of its weight. The majority of these parts make up the exterior of the car and are usually the first to make contact in a crash, so teams need to be prepared with an assortment of spares.

Composite parts also see the most development during and between races, as the aerodynamic set-up is continually adjusted to exploit the characteristics of each track. Quite often in the European races, data from Friday running will be used to develop composite parts and will be delivered to the track on Saturday. Therefore, increasing the accuracy and reducing the time of designing, analysing and manufacturing composite parts is essential to staying competitive.

Products such as Fibersim from Siemens now allow the end-to-end design and manufacture process of complex composite parts to be simulated.

Composite parts are fiendishly complicated in modern F1 so design simulation is a great help in this area

These composite designs are referred to as 'data rich' because each individual ply can contain up to 150 attributes that must be associated to the geometry. But with a carbon fibre monocoque comprising of hundreds of plies, ensuring an accurate simulation whilst considering all these variables is not an easy task.

Expanding CAD

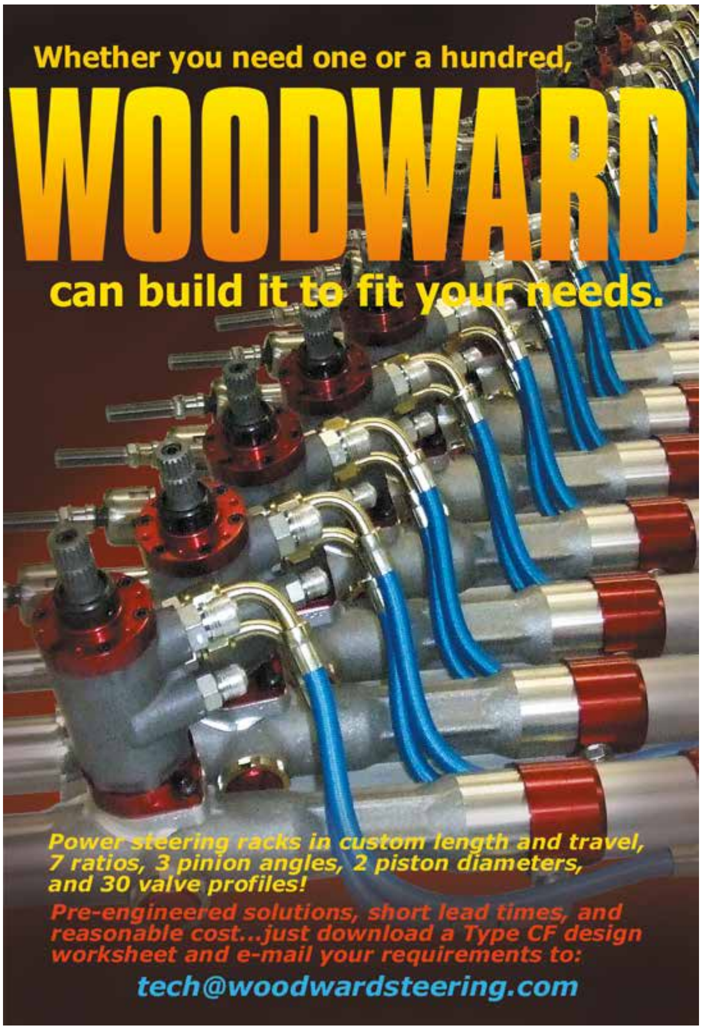
'Fibersim is integrated into the CAD system such as NX, CATIA or CREO,' says Ed Bernardon, vice president Strategic Automotive Initiatives for Siemens Specialized Engineering Software. 'The software essentially expands the CAD system into a composite engineering environment where engineers can trade off geometry and material against the producibility of a part. In Formula 1 the primary manufacturing process for composites is hand layup and you are usually working with shapes with complex compound curvature. Therefore, the fibre paths over these complex surfaces tend to deviate from the designer's desired orientation, which will impact performance. You may also get wrinkling and bridging of the fibres, which will effect producibility.

'In the past, you would have to wait until your design was actually laminated before all these issues were discovered and then begin redesigning. Fibersim simulates the hand layup process and predicts the resulting deviations in fibre paths as well the manufacturing issues. Consequently, instead of iterating through several prototypes, you usually achieve the producibility of the part first time. You also improve analysis of part performance, based on the actual fibre orientations after manufacture, rather than idealised ones,' Bernardon says.

Although this is where it saves most time in the development process, the software's philosophy of automation, leads to further time savings which all add up. For example, once a component has been designed and optimised for manufacture, a 'plybook' is automatically generated for the laminator. 'This is an instruction manual detailing the 2D shape and specific 3D location of each ply,' says Bernardon. 'Fibersim also automatically generates data for laser projection equipment which projects a line onto the 3D tool to guide a laminator placing plies.'

Mixing it

The engineering opportunities of composite components mean that there will always be a future for this technology in motorsport. Current trends are also integrating composites with other materials, such as metal, to make parts lighter whilst maintaining strength. 'One of the greatest benefits of composites is you can combine a variety of materials in a variety of ways to optimise and achieve desired performance,' explains Bernardon. 'At the same time, determining exactly how to combine these materials to achieve this goal is the greatest challenge in designing with composites. As composites are combined in multi-material designs with metals and even 3D printing, the use of simulation to optimise a design will become even more challenging. However, we are already seeing this challenge in Formula 1, and as always, racing is a great place for us to develop new ideas in engineering software.'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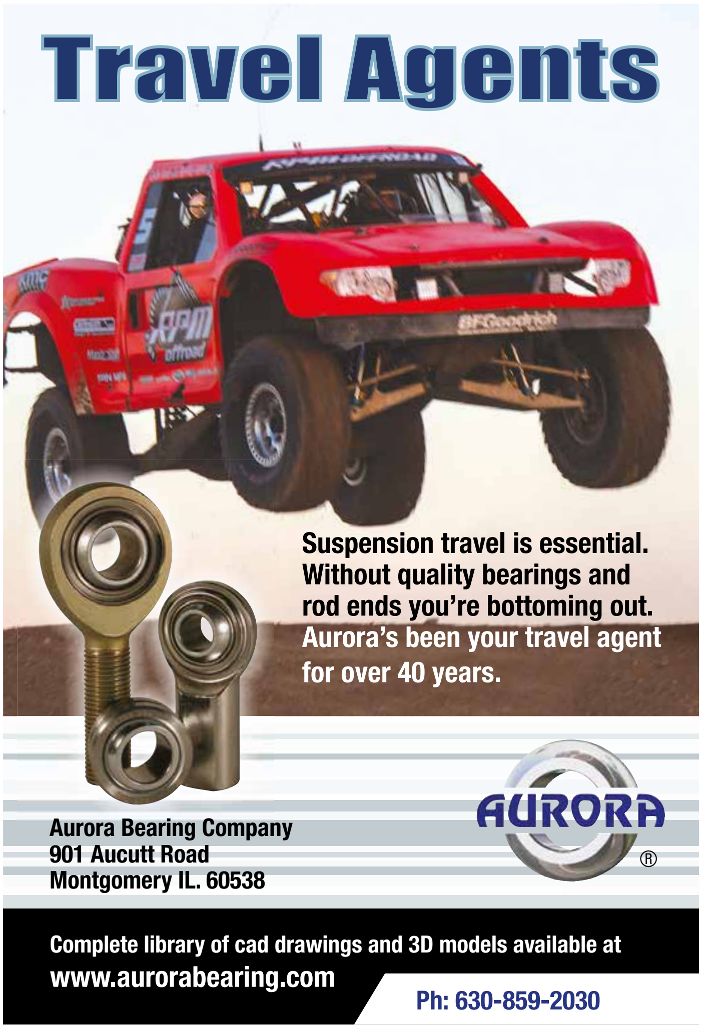
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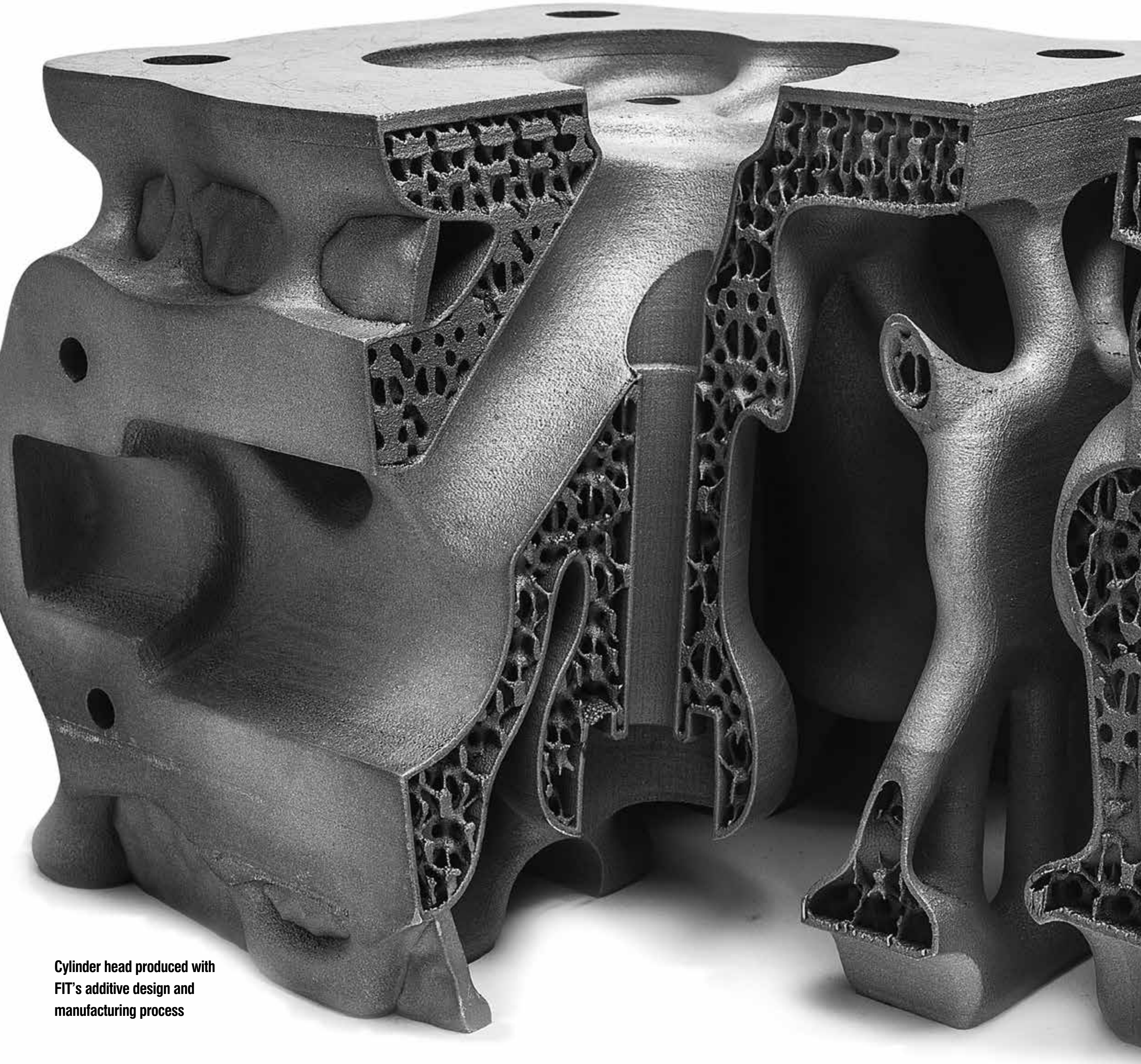
FIT for purpose

Additive manufacturing might have been invented for the exacting demands of high-end motorsport – we visited FIT, a German company at the cutting edge of this rapidly evolving technology, to find out more

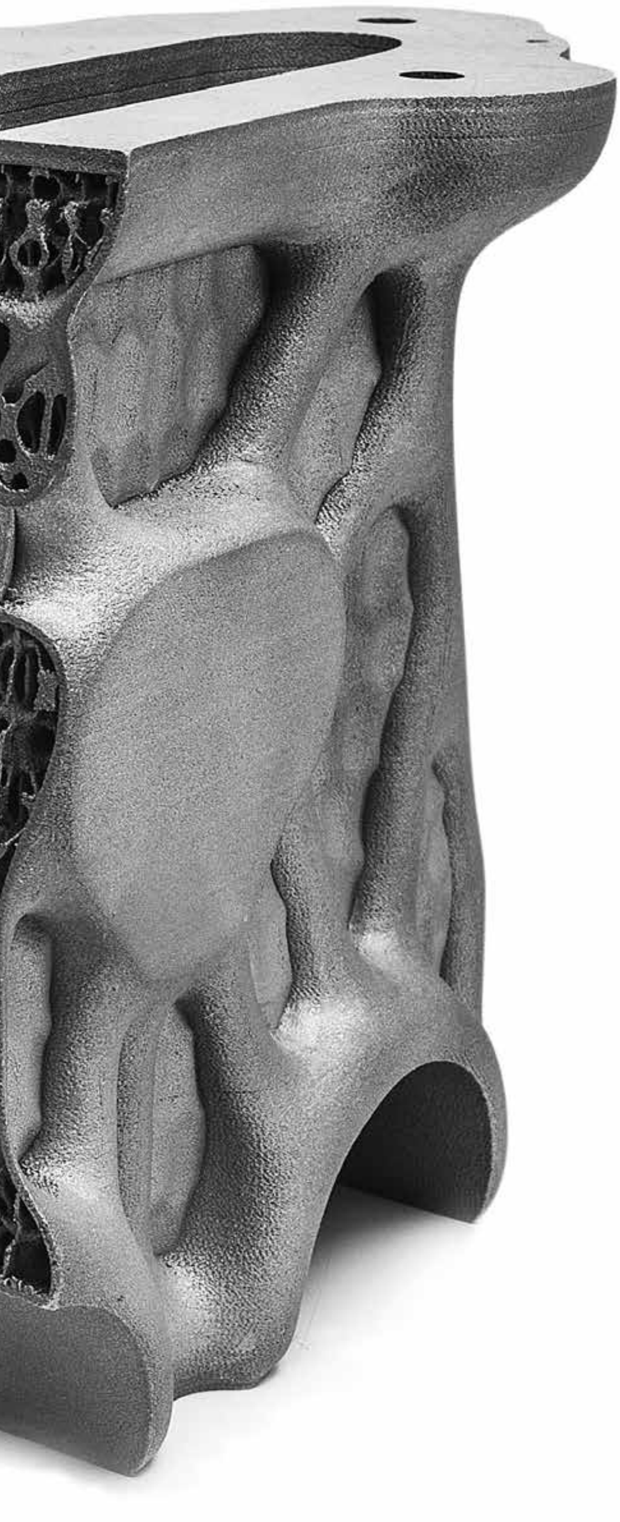
By SAM SMITH

All images: FIT AG www.fit.technology



Cylinder head produced with FIT's additive design and manufacturing process

‘There is an incorrect perception that there is quite a simple and magic formula that you just feed in to a machine and out pops a complex part’



Time and cost are two words that are inexorably linked when it comes to engineering in any technical discipline, but particularly in the world of motorsport. But when you involve a third word in this mix, *weight*, then a mystical spell is cast, and this explains the growing interest in the highly advanced and ever evolving sphere of additive manufacturing (AM).

One ambitious and leading exponent of additive manufacturing capability, skill and delivery is the FIT Group. Based in Lupburg, Germany, the company was founded by its charismatic and visionary leader Carl ‘Charlie’ Fruth back in 1995. Since those early days of rapid prototyping, and being a leading pioneer in additive manufacturing solutions, FIT has gone on to lead the way with ever more complex free-form 3D components.

Motorsport is now seeing more and more AM parts on its designs, with weight, cost and time being three key performance indicators which attract engineers and designers to the technology. But what is equally important to Fruth and his team in Lupburg is the philosophy behind this fascinating, progressive and constantly evolving aspect of this technology.

Race FIT

‘[In] most of the other industries, the people doing the work take responsibility in manufacturing but in some other industries, like medical or aerospace, there is no one who takes the real responsibility,’ says Fruth. ‘To make a simple design change you need 30 departments to sign, 30 departments need to analyse and they say: “oh is that good for me, is that good for my network, is that good for the department I am working for?”

‘This means you have 30 bottlenecks,’ Fruth adds. ‘Can you imagine what comes out of 30 bottlenecks? It is not pretty and it is actually very time consuming and tedious. But that is not what you have in motorsport. You have always small teams to communicate and find solutions. This is attractive for companies like us because we react quickly and we deliver quickly.’

Additive manufacturing is crossing all frontiers because when people understand the technology they know they can get a faster product and ultimately a better, lighter product. Lighter and stiffer, in fact. It will do all the things you want it to do while only using as much material as you need, so there is no downside.

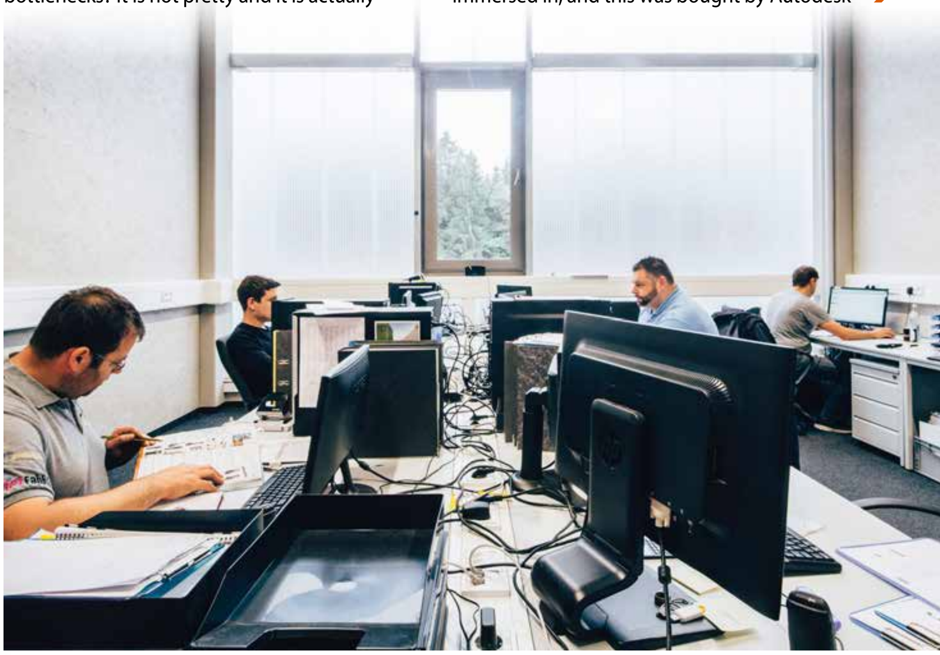
But Fruth admits that it’s not always cheap. ‘Obviously, some bits can be expensive but then you can’t compare part for part because they are not the same, you don’t make the same part as a casting as you do an additive, because if you do then there is no point, because you won’t be cost effective,’ he says.

Good FIT

The high level of prototype parts FIT produces means it is hard to quantify the percentage of business it does for the motorsport industry, but it is contributing significant parts to both the F1 and WEC grids this season. Additionally, FIT has recently employed the consultancy skills of former McLaren, Williams, Lola and Red Bull engineer Chris Saunders, who’s brought his expertise and contacts to the company.

However, at the present time, the majority of the work done at FIT is for the automotive industry and most is prototyping through additive design and manufacturing (ADM).

The really big push forward for the company came in 2015 when FIT announced a new €20m factory to service high volume metal and plastic components. But the platform for the unveiling of the new factory came years earlier when Netfabb GmbH was founded. Netfabb is the software which additive manufacturing is immersed in, and this was bought by Autodesk



Data is prepared for processing in the design office. FIT uses Netfabb additive manufacturing software

The level of technology is impressive and includes four Arcam EBM (electron beam machining) titanium production units

‘There is so much we are yet to understand about the possibilities of metal AM and where it can go’

in 2015. Autodesk also acquired a 10 per cent shareholding in FIT Group, and facilitated the finance to help realise Fruth’s vision of creating a new additive manufacturing capability.

The philosophy of working in small teams runs like strata in the bedrock at FIT’s Lupburg bases.When *Racecar Engineering* visited the new facility recently the headcount was at 250 and the key areas of focus were ADM, Prototyping and R&D of materials.

Template facility

Fruth says his company’s new factory is a template for future FIT sites that will be bigger and service more businesses on an outsourced basis. The thrust behind this thinking again comes down to engineering philosophies, as Fruth believes that AM has a different method to other manufacturing approaches.

‘There is a perception that this is quite a simple and magic formula that you just feed in to a machine and out pops a complex part,’ says Fruth. ‘Nothing could be further from the truth, actually. The machine is not as important as the human input. It is important but it has to be integrated properly and with skill and thought in to the whole process. That is why big companies come to us. They want to work in conjunction with us on R&D and understand what the best solutions are for the future.’

The equipment on show at the Lupburg facility is very impressive. The factory boasts 20 selective laser melting machines, three EOS machines and four Arcam EBM titanium production machines. The way the machines are fed their ‘nourishment’ of metal powder is ingenious. A continuous supply is networked via overhead pipes from a ‘mothership’ source in the factory. These are managed by pressured pipes to control the temperature and to avoid any risk of cross-contamination. In addition to this FIT has an in-house T6 heat treatment capability.

Quality controlled

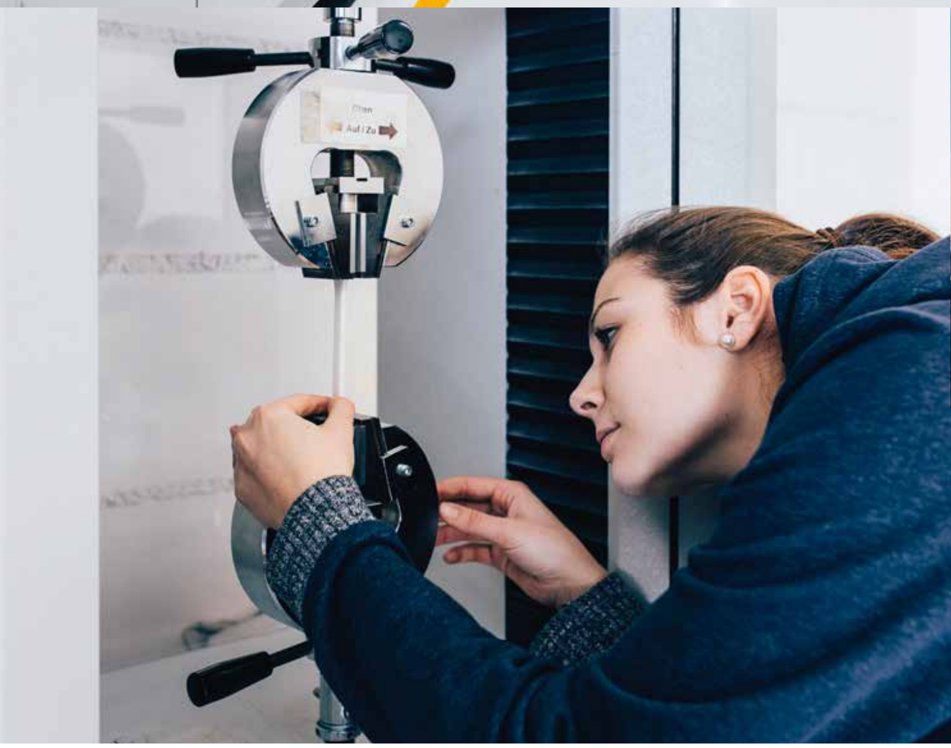
One of FIT’s more recent acquisitions is a CT scanner, which was installed at the new facility in November 2016, to be used by the firm’s quality assurance department. The company’s other measuring implements non-contact and non-destructive analysis of inner and outer structures created by FIT. Any minuscule cavities, fissures or shape distortion will then be traced using the new CT scanner.

Colour analysis can illustrate geometric flaws when comparing scan data of a part to the original CAD model, and dimensional tolerances can be reliably verified even for highly complex and bionic structures.

‘The adoption of in-house CT scanning allows for high precision quality control in-line with our manufacturing processes, increasing our efficiency and reducing lead time for our customers. At the same time, production processes can be improved continuously and significantly through this same data evaluation,’ Fruth explains.

SLM (selective laser melting) units. All the machines in the facility are supplied with metal powder via carefully monitored overhead pipes

Optimal results of cross sectional views are achieved using high resolution (up to 5μm) at a maximum acceleration voltage of 240kV. A 3K detector provides a third higher resolution when compared to standard detectors. 3D analysis is compliant to VDI 2630. The CT scanner is equipped with a reflection radiation



Traditional quality control methods (above) are backed up with a recently installed state of the art CT scanner

Top: Selective laser sintering machines are at the very heart of the AM process. SLS units bind the powdered metal into a whole
Above: FIT has invested around 20 million euros in its new facility, which is in the company's home town of Lupburg, in Germany

and target power of 300 Watt. Maximum size of the parts is 550mm (diameter) x 700mm.

This expansion in capability mirrors FIT's creator's vision. For Fruth his hope for the future of digital manufacturing is a mix of pragmatic technical development and an ethos of the simple symbiosis of human and machine.

'If we need to improve the process, we need to understand the problem,' he says. 'As soon as people are involved mistakes come in and if you ask whose fault it is, well it will be the machine, the supplier, the material … It's never the human's fault! We need to get an excellence [in] an understanding of the process otherwise there will be no progress.

'Look at McDonald's, they always do six hamburgers. Never two, never four, but always six,' Fruth continues. 'If someone is not able to make six burgers at once after one day of training then they are out. They don't need a brilliant chef who can do 10 or 12 at once, the people that are running the show know that six is an efficient number for the average person to do without mistakes.

'This is the kind of excellence which will improve the quality of the product,' Furth adds. 'That is why we have a consistent work space here. In digital manufacturing this is challenging because you have this digital backbone which is less tangible than an assembly line.'

Future FIT

Predictions in engineering are often futile. But in AM there is scope for a high quality industrial partner with some revolutionary plans which could shape higher volume manufacturing in the years to come. But with such ideas must come a level of patience, as well.

'There is so much we are yet to understand about the possibilities in metal AM and where it can go,' says Fruth. 'What we are trying to do is to be the best in finding the right path and then imparting the knowledge to industrialisation of this technology in the coming years. Motorsport gives us a good partner in to which we can push back the boundaries and understand quickly what can be achieved.'

Fighting the corner

With the growth of driver in the loop technology some say that lap time simulation is now irrelevant. Not so, argues *Racecar's* wizard of sim

By DANNY NOWLAN

Having been the principal of ChassisSim Technologies for some years, and having worked as a race and data engineer across many different formulas, I have had a unique front row seat on how simulation has been applied in motorsport. It's fair to say that the world of motorsport has always had a love/hate relationship with lap time simulation. Also, with the emergence of driver in the loop simulation, it would appear lap time simulation has run its course. This is most decidedly not the case, and we'll be discussing this in depth in this article.

To frame this discussion let's look at how lap time simulation came to pass and how it was rolled out. Lap time simulation, in particular pseudo static lap time simulation, started to emerge in the mid 1990s and became commercially available in the mid to late 1990s. In a nutshell the way that pseudo static simulation works is it uses the d'Alembert static equilibrium approximation to use static analysis to piece together what the car will do over the lap. At the time it was emerging everyone thought it was rocket science and it was going to transform the world. But while it certainly proved useful it wasn't the transforming technology everyone thought it was going to be.

But what pseudo static simulation does very well is it gives you a good indication of your static first order parameters. Where pseudo static simulation fits into the pecking order is it takes you beyond an Excel force balance sheet, such as the one illustrated in **Figure 1**.

Pseudo static

Pseudo static simulation can trace its DNA to the point made above. Given a second order traction circle radius *vs* load tyre model with pseudo static simulation (provided you use local grip scale factors) it will provide good correlation. It will also give you a good indication of what gears and aero you should be running.

It will also start to give you a good idea of what to expect in terms of set-up sensitivity for springs, bar and bump rubbers. It is not going to be exact, but at least it gives you something to get your head around.

It also executes very quickly. With racecars with very high levels of downforce (for example Formula 1, LMP1 and DTM) pseudo static simulation does a reasonable job, since the first order static effects, in particular aerodynamics, will dominate the set-up.

But where pseudo static simulation falls flat on its face is with transient behaviour, which is such a critical element of what we do. The tyre load plot in **Figure 2** is a classic case in point.

The final plots are load and as you can see the tyre loads are all over the place. In this situation a static approximation is useless. Given my background in flight mechanics and control I looked at this in the mid 90s for about 15 minutes and figured this has a snow flake's chance in hell. As an interesting side note, due to its transient nature, grip factors in ChassisSim are actually trim tabs, and this was added in to ChassisSim 10 years a go, because in most cases back then they were not required.

Pacejka model

The other thing that muddied the waters was that back then we all plunged head long in to using the Pacejka tyre model from the road car community. While the Pacejka model does a reasonable job of ensuring your grandmother's Fiesta doesn't swap ends on the motorway it struggled with motorsport set-ups. A classic case in point is why you need to run such a high front roll stiffness on high downforce open wheelers, which is dictated by thermal effects. Back then we were aware of it but couldn't quite get our heads around how to quantify it. This is no longer the case with thermo tyre models such as the Michelin TaMe tyre model and the ChassisSim v3 tyre model now available.

So, what happened is that motorsport people, being motorsport people, all dived headlong into it without really understanding what it was. Also, on top of that we all expected miracles and so when things didn't quite pan out as expected a lot of people got their noses out of joint. To add insult to injury we did a pretty poor job of explaining why this was so. I often say that pseudo static simulation is my greatest asset and biggest liability all rolled into one.

The other thing that lap time simulation did a pretty poor job of was predicting drivability. I'm guilty as charged with everyone else, albeit ChassisSim is slightly better due to its transient engine. However, it will still favour grip over drivability. The reason for this I discussed at

XPB

With racecars that boast very high levels of downforce, such as LMP1, pseudo static simulation will do a reasonable job

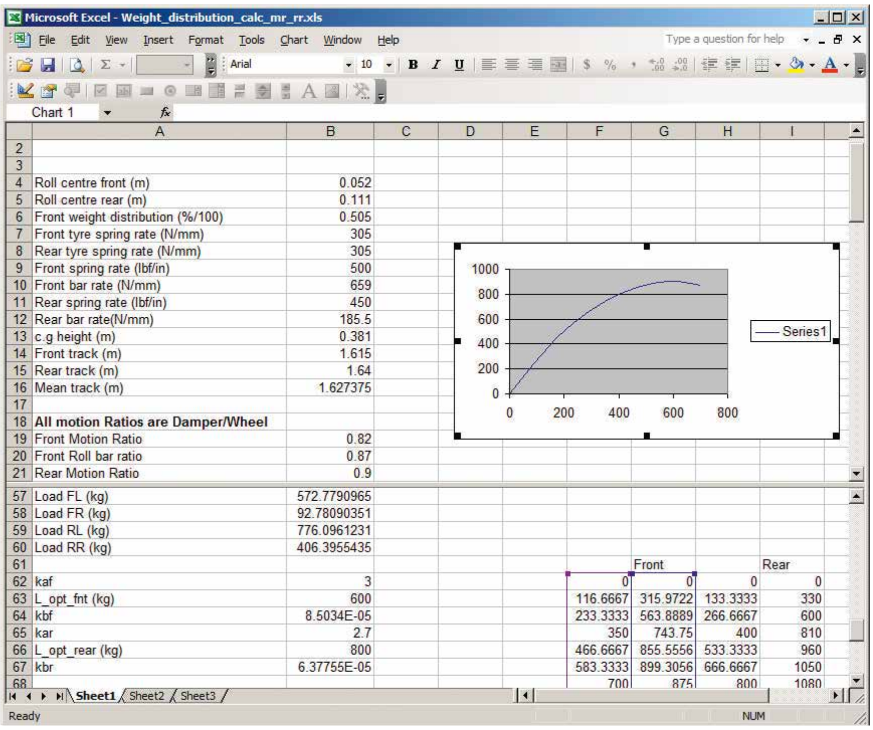


Figure 1: Pseudo static simulation helps because it takes you beyond an Excel force balance sheet such as this

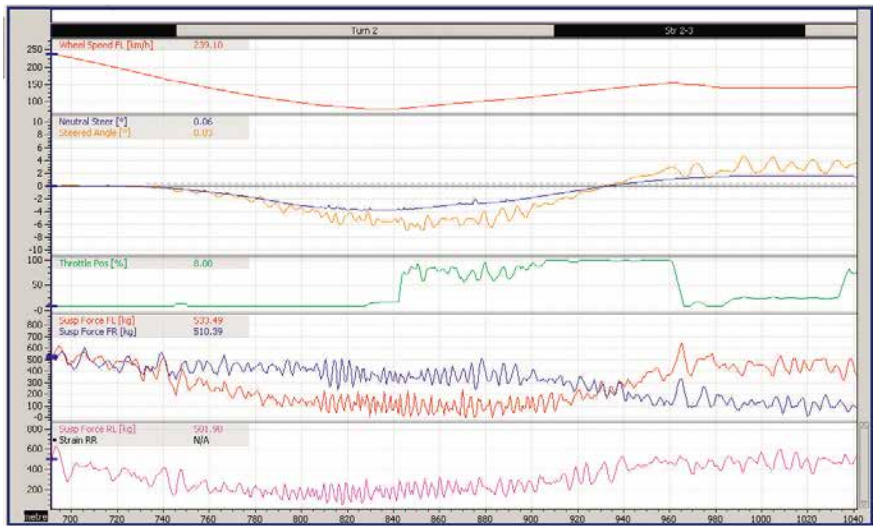


Figure 2: Speed and tyre load plot for a V8 Supercar showing the load variation as the car goes through a turn

length in my article on applying the stability index to lap time simulation (March issue, V27N3). However to refresh everyone's memory, turn to **Figures 3a** and **3b**.

As can be seen the grip isn't changing that much, but the stability index changes wildly. The lap time simulation companies, including my own, were very slow to recognise this. I can't speak for my competitors, but this has been addressed since ChassisSim v3.30.

Sanity clause

That all being said, lap time simulation has a valuable role to play, and if you're serious about getting the most out of your racecar you ignore a tool such as this at your peril.

Why? First things first, the critical role your lap time simulation package has is it is the ultimate sanity check of what your car is doing. This is graphically illustrated in **Figure 4**. This is an overlay of a high downforce car running on an oval. As can be seen the front dampers are okay but the rear dampers are way off. Most people look at that and figure their lap time simulation package is useless. That is rubbish. What this has shown is that there is a hole in the aeromap. This is the knowledge that sorts out the top teams from the also-rans.

Secondly, when using lap time simulation you have to look at the data in a slightly different way to race data. I was as guilty of this as anyone else, but my Australian Dealer Pat Cahill really pointed this out to me in no uncertain terms. The reason you have to look at simulated data in a slightly different way to race data is twofold. First, the simulator always knows where the grip is and it will drive to it. In contrast, a driver has to over step the boundaries, and this is why race data can vary so much. Second, a simulator has zero regard to its own mortality. So when looking at simulated data you need some rules of thumb to go by, as presented in **Table 1**.

When you actually look at a tyre model and throw some changes at it this is where the

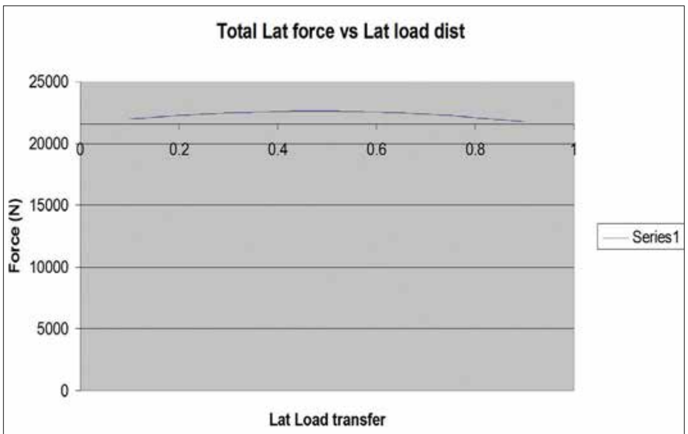


Figure 3a: A plot of grip *vs* load transfer shows that the grip is not changing too much

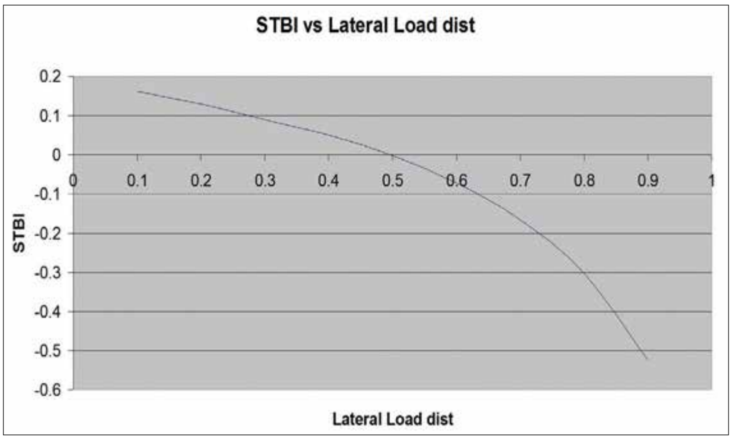


Figure 3b: But a plot of stability index *vs* load transfer shows big changes in the STBI

Pacejka's model does a reasonable job of ensuring your grandmother's Fiesta doesn't swap ends, but it struggles with motorsport set-ups

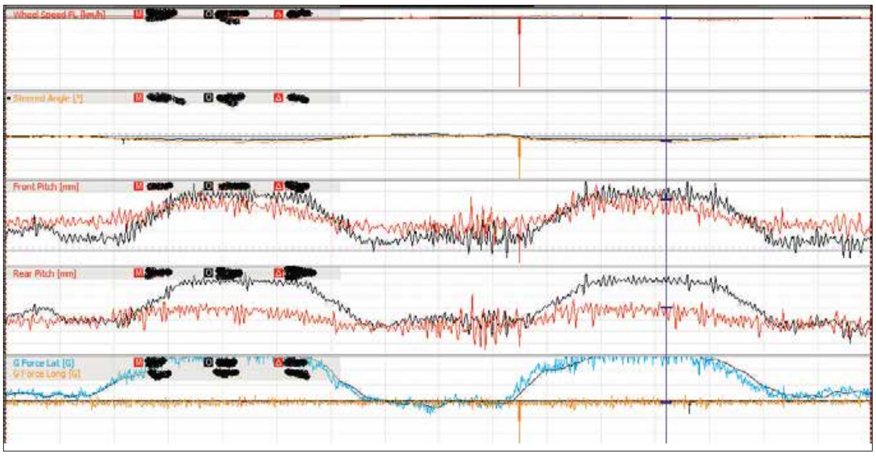


Figure 4: Apparent disparity with the rear dampers is not a sim problem but is actually a hole in the aeromap

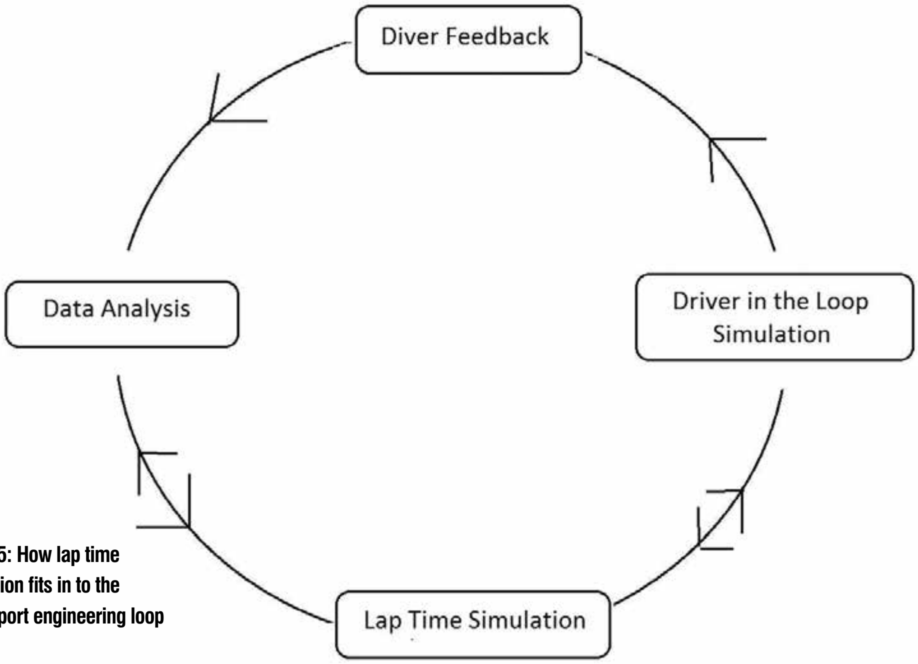


Figure 5: How lap time simulation fits in to the motorsport engineering loop

Table 1: Magnitude of speed changes to the severity of the set-up change

Change Delta	Severity
0.1 to 0.2km/h	Mild
0.2 to 0.6km/h	Moderate
0.6km/h +	Severe

Table 2: Rough rules of thumb for lap time simulation correlation

Corner speed	Delta
80 to 120km/h	1 to 2km/h
120 to 160km/h	2 to 3km/h
160km/h +	3 to 4km/h

A lap time simulator is a closed loop solution, so to get perfect correlation your tyre model and driver has to be spot on

numbers fall. In the static case they are a little lower than this but the magnitude is about the same. Also, where you will see the changes is not in driver throttle and steering application, but you will see it in cornering speed. We actually discussed the why for this in depth in my article on how to use simulation (January issue V27N1).

Also, for completeness, one of the big suck- you-ins you see with lap time simulation is that you get so focused on correlation that you actually forget to use it. Go to **Table 2** on the left for some rough rules of thumb for what you should be looking for here.

Remember, a lap time simulator is a closed loop solution. Consequently, in order to get perfect correlation your tyre model and driver has to be spot on. If you don't recognise this you will waste a truck load of time. Let me give you a war story to illustrate this.

About six years ago I did some modelling work for a race team. I performed all the ChassisSim modelling, and while the trends were great they where consistently 1 to 2km/h quicker than the actual driver. I then made a critical mistake. I trusted the racecar driver. Anyway the team got to their first race meeting and they got blown away. In a move of exasperation/desperation I was given the data of the front runner and it matched the original tyre model perfectly. The moral of this tale is don't get too carried away with perfect correlation.

As a side note, the exception to the above is with oval racing, because you need to ensure you have the loads matched up, since you are looking for very fine changes.

Looping the loop

Finally, we need to recognise where lap time simulation fits in to the motorsport food chain. This is presented graphically in **Figure 5**, which shows four steps. Step one is running the car and listening to what the driver/nut behind the wheel had to say. Step two is reviewing the data and figuring out what the racecar is doing. Step three is lap time simulation, and step four is driver in the loop simulation.

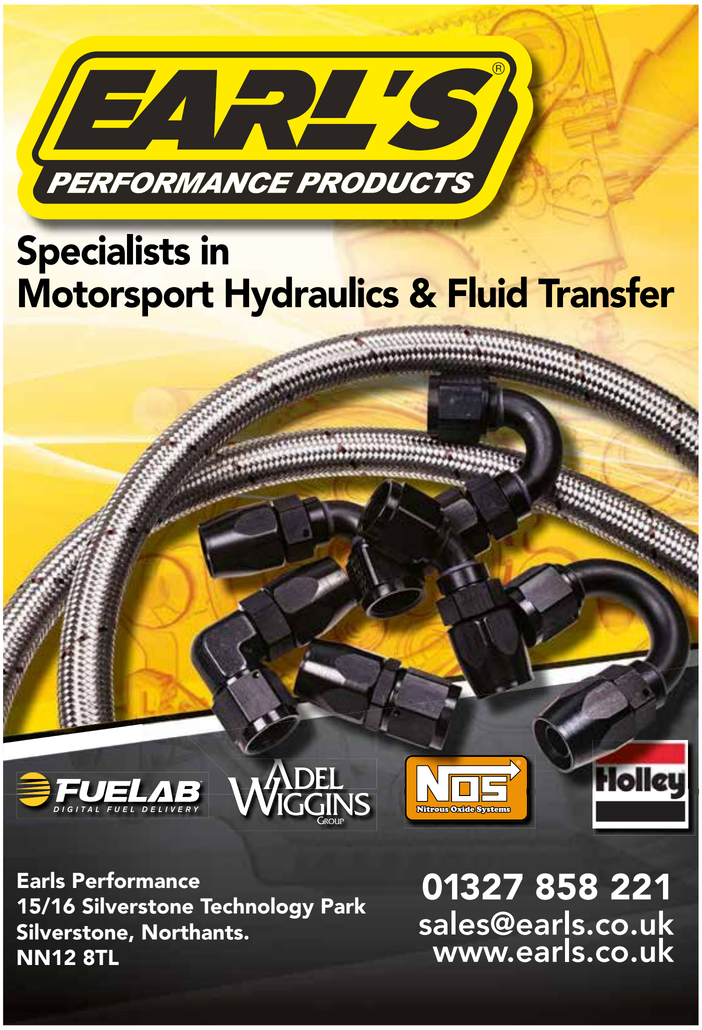
Of all of these links the lap time simulation is a great enabler for a number of very good reasons. Firstly, when you are dealing with transient simulation it will help you make sense of the data that you are looking at in step two. The reasons for this we discussed in depth in **Figure 4** with the aero discrepancy. The other impact it has is it prepares you for step four.

Sim-biotic

Lap time simulation allows you to quickly and thoroughly sort out the options you will test in driver in the loop simulator. This is for a number of very important reasons. Firstly, a lap time simulation will allow you to run through an option quicker than with a driver. Before you all state this is irrelevant because it's a simulator, the driver will still need a couple of laps to sort out what a change will do. A lap time simulator will tell you instantly. The second reason is that it gives you the time and space to actually look at and review what you have tried. Once you have a driver in front of you, while you don't have the same commitments on track, you still have a driver with finite time that you need to make use of. Consequently, if you are using driver in the loop exclusively for set-up work you won't have the time to complete the quality analysis you could do with a lap time simulator.

In closing, lap time simulation hasn't been superseded by driver in the loop simulation. If anything these tools are not just complementary they make each other much more effective. Not only does lap time sim help you make sense of race data and allows you to fill in the blanks, when used appropriately it makes what you do with driver in the loop and the race engineering process much more effective. However, there's the key word, used *appropriately*.

As we discussed with pseudo static simulation and how to use lap time simulation, there are tricks of the trade and things you need to be aware off. Remember, it's a calculator and not a magic wand. If you stick to that then this is a tool you won't want to be without.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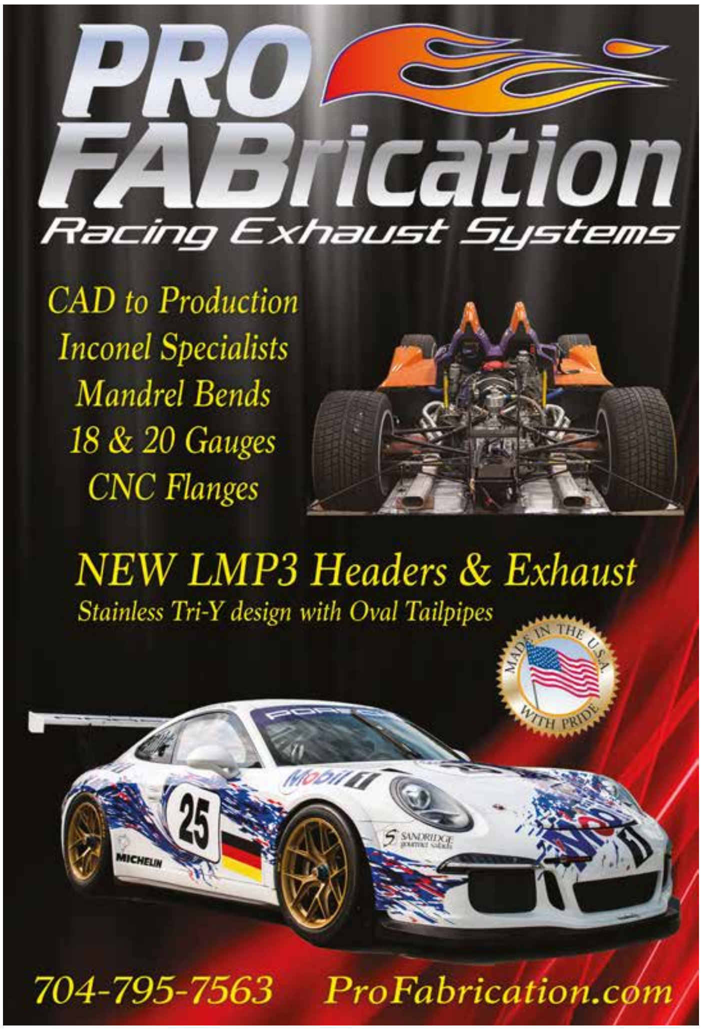
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Shades of grey

There may be new tech rules in F1 but there are also new uncertainties – we examine the issues that were the talk of the paddock at the start of the season

By SAM COLLINS

Whenever a major new rule set is introduced in F1 it creates opportunities in terms of technical innovation, but also possibilities that those innovations will fall foul of the rule makers. Unsurprisingly, this has already started in 2017, with a number of areas open to different interpretations.

During winter testing there was something of a flurry of technical directives from the FIA to the F1 teams, and it continued right up to and through the Australian Grand Prix weekend. The most widely reported of these related to the suspension systems used on many of the cars, which have for some years been increasingly designed to suit aerodynamic demands .

Suspended animation

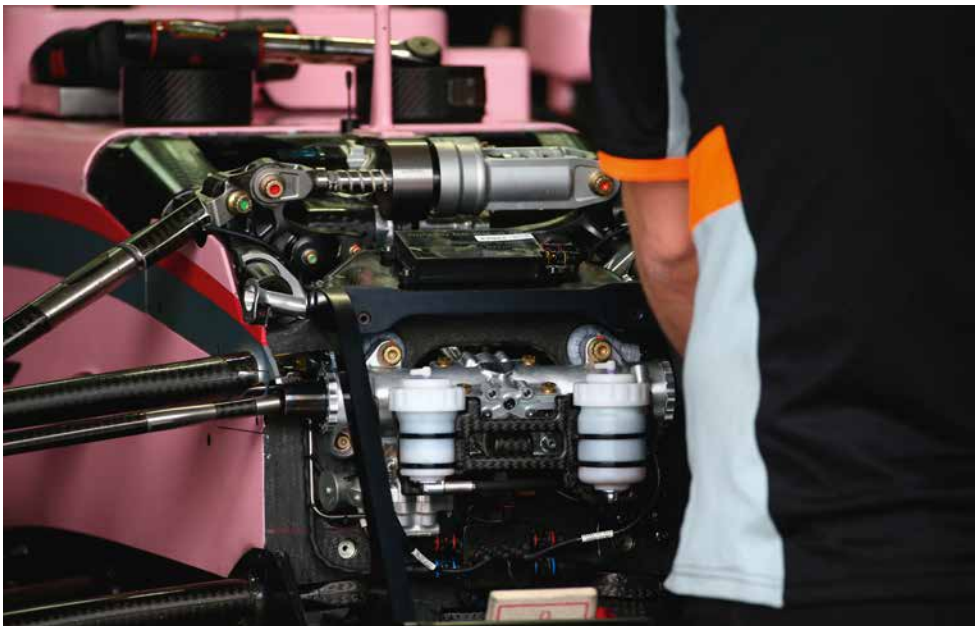
Two days before the first pre-season test at Barcelona, and after a number of cars had already run on track, the FIA issued a significant technical directive relating to the design and operation of suspension systems in F1.The details and implications of that directive are covered by Mark Ortiz (*The Consultant*, P49), but the key phrase in the directive was as follows: 'Any suspension system unavoidably influences the attitude of the car above the ground which in turn has an effect on its aerodynamic performance, such effect must however be wholly incidental to the main purpose of the suspension system which is to insulate the body/chassis unit and the driver from undulations in the road surface.'

This is at odds with the general suspension design concept of most cars on the grid, which are clearly about creating a stable aerodynamic platform. 'The primary aim of a formula 1 car suspension is to optimise the aerodynamics, despite what the rule makers would like us to believe,' a suspension designer from one team told us. 'The front wing operates very close to the ground and has a high sensitivity to ground proximity so generally teams run the front end ultra-stiff – some even try to run negative stiffness systems to raise the rear of the car at the end of the straight to allow the front to run lower in the middle of a low speed corner. The rear suspension is primarily designed around optimising the aeromap and allowing the car to run around the area of 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 car sits up at low-speed and then squats down at high-speed. Teams will 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 they will keep the rear up in the air to maximise downforce.'

On numerous occasions engineers have openly stated that suspension design in Formula 1 is primarily about aerodynamic demands, so it is no secret that this is what every team has focussed on, but according to the FIA's Charlie Whiting this may have to change. 'We've been aware of hydraulically operated suspension systems on cars for some time but it became clear they were being used for purposes other than suspension. So under the regulations where you are not allowed to have a suspension system that affects the aerodynamic performance of the car in anything other than an incidental way, we don't allow it,' Whiting says. 'We wanted to see whether suspension is genuinely suspension or whether it's there predominantly to affect the aerodynamic performance of the car. That's the change effectively, and we have been focusing far more on that this year. We think that if a suspension system behaves asymmetrically there is not a very justifiable reason for behaving like that. So if a suspension system goes down at one speed and comes back at a different speed, there really shouldn't be any reason for that.

'Also, if there is any attempt to store any of the energy for later deployment, then we feel that's not really part of a proper suspension system and it is being done for other reasons,' Whiting adds, before clearly placing the responsibility on teams. 'The onus is being put on the teams to demonstrate that their system

'The primary aim of a Formula 1 car suspension is to optimise the aerodynamics, despite what the rule makers would like us to believe'



Suspension systems are a matter of much debate in Formula 1 at the moment with the FIA insisting these must not be used for aerodynamic gains. The Cambridge inerter seen here on a Force India VJM10 has seemingly been deemed to be legal

'The use of oil as fuel is prohibited by the F1 technical regulations'

has an incidental effect only. If they are not able to convince us of that then they can't use it.'

The technical directive issued ahead of the pre-season test and later clarifications have still left something of a gap between what the teams are really doing and what the rule makers would like them to be doing, it seems. However, the FIA set about checking the design of every system on every car in Barcelona and continued the process in Melbourne. As a result Whiting felt that he had prevented any protests or disqualifications taking place; 'Marcin Budkowski, FIA head of the F1 Technical Department and Jo Bauer, FIA Formula 1 technical delegate did a lot of work in Barcelona going through all the systems and the ones we've inspected so far have all been as we expected to be here, so we do not anticipate any problems,' Whiting said.

However, there were still rumours in the paddock at Melbourne that at least two teams had indeed had to change their suspension systems to some extent to stay legal.

Oil be back

Another unresolved issue relates to the power units in the cars. This actually first reared its head in 2013 as the power unit designers explored ways to improve efficiency in a formula where efficiency equals performance. It is worth noting here that F1 cars do not use catch tanks, rather excess oil is recirculated into the combustion chamber. In an era where fuel flow and total fuel consumption is limited additional combustible hydrocarbons entering the combustion chamber could theoretically boost efficiency and in turn performance.

When this potential loophole was identified a number of teams asked the FIA to clarify what was and what was not allowed. In an F1 Technical Working Group meeting in 2013, Whiting stated unequivocally that he thought 'that the regulations could explicitly prohibit the use of oil for power', and went on to clarify that 'the use of oil as fuel was not permitted'.

The problem then was one of enforcement. How could the FIA police the use of oil as a fuel? After all, some oil would invariably find its way into the combustion chamber due to the layout of the engines. Mercedes suggested limiting the maximum capacity of oil tanks to five litres, but this was rejected. Fabrice Lom, the FIA's head of powertrain, stated that he felt that 'five litres was not a real restriction but that it would be difficult to set a much lower limit due to the engine oil consumption natural variation.' Lom suggested a 'common sense' approach should be used to police the use of lubricant as fuel.

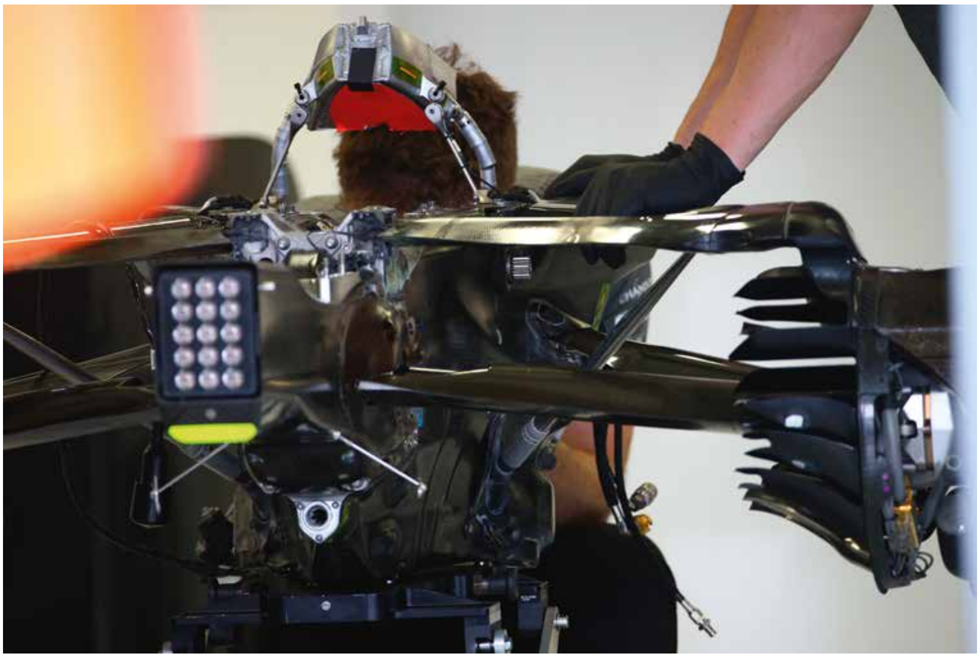
There the issue seemed to have been left until early in 2017 when just before the first pre-season test at Barcelona Paul Monaghan of Red Bull Racing queried whether the use of oil as fuel remained prohibited. The FIA's response was circulated to all teams and simply stated: 'It is our view that the use of oil as fuel is prohibited by the technical regulations.'

However, Charlie Whiting said in Melbourne: 'I wouldn't say it's an area of concern; it's an area of interest and we are monitoring it. We did quite a lot of work on that in Barcelona. We're going to inspect all the oil systems here and we're going to randomly check oil consumption to make sure it's not being used as fuel.'

Wobbly Haas

The appearance of winglets at the rear of the car has also caught the eye of the rule makers. In Melbourne the winglet on the Haas was visibly flexing and wobbling (as it had done during testing) and the team had to briefly remove the devices until it found a way to strengthen them. In 2018 it seems likely that such devices will be outlawed altogether, according to Whiting. 'I think there's quite a strong chance that the loophole allowing them will be closed; there appears to be quite a few people who think they're a bit of an unsightly thing. I personally don't have anything against them and I think the reaction of everybody against them was unexpected, to be honest with you.'

Other areas which received clarifications during the flurry of technical directives included clutch paddle travel and the shape of the lower part of the front of the monocoque.



Rear suspension components are buried in the transmission casing (McLaren gearbox pictured) but the FIA has inspected all car layouts and said they meet the regulations. Yet rumours persist that two teams have had to modify their suspension

Haas winglet wobbled excessively and had to be stiffened. These parts, also called 'T-wings', are likely to be banned in 2018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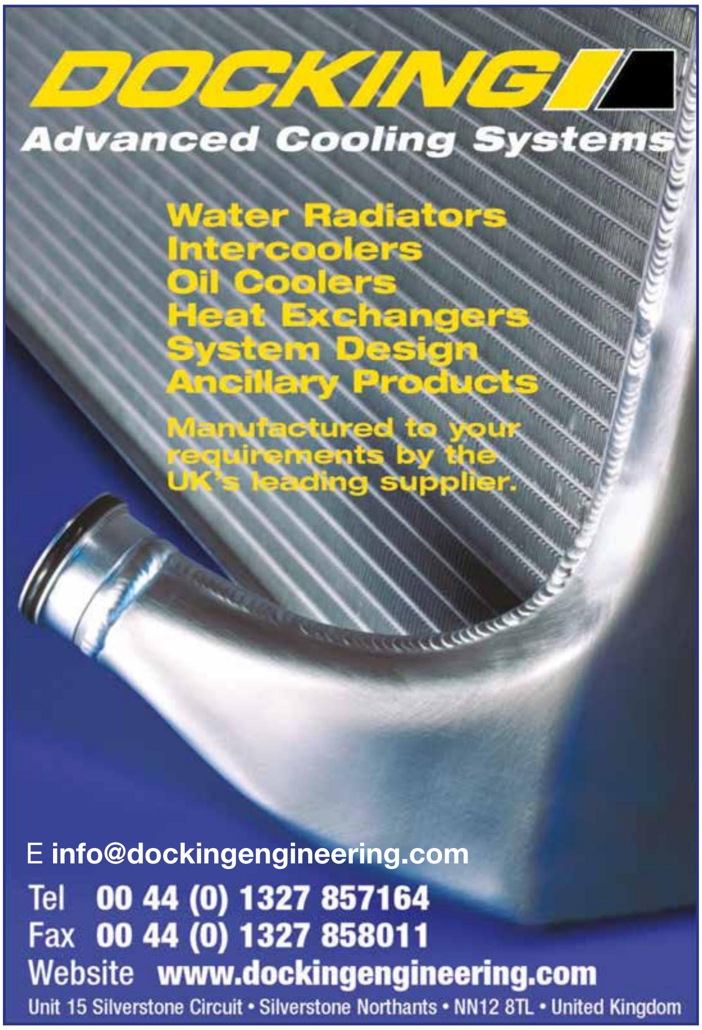
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John Surtees 1934-2017

Tribute to a racing great

John Surtees will always be remembered for his feats on two wheels and four, but he was also an enthusiastic engineer, as *Racecar* discovered in 2015

By MIKE BRESLIN

XPB

'If I hadn't been a rider I would have developed a career in engineering'

John Surtees died on March 10 at the age of 83. There were the usual obituaries, tributes, and recollections of races valiantly won, gallantly lost. But Surtees was a bit more than just a bike racer and a driver, as he was always hugely interested and involved in the engineering side of the sport. In fact, when *Racecar* interviewed him two years ago, he told us: 'If I hadn't been a rider I would have developed a career in engineering.'

Surtees' love of engineering began at the end of WWII when his father, a well-known motorcycle racer before the war, returned to London – and racing – after his Army service in the north of England. 'I was there in the evenings trying to help him and learning how to use some tools, and also the cleaning rag! He came home one day and he said: "Lad, those boxes are for you." And there were some tea chests full of parts. He said: "Put it together and you can ride it". It was a very early single-speed speedway Blackburn. So that was it, that's where it started. I put that together, I rode it, and it went on from there.'

As did his engineering: 'I didn't carry my schooling forward, instead I went into an apprenticeship at Vincent HRD, which was back then one of the premier motorcycle companies in the country. I served my apprenticeship there, during which time my racing career also developed.'

Constructor

His story from then on his well-known – seven world championships on bikes, one in cars (1964, for Ferrari), and six Formula 1 grand prix wins – but what is sometimes brushed over is Surtees' time as a team owner (in Formula 1 from 1970 to 1978), and even racecar designer. 'I did some of the outline work, I didn't get involved in sitting down and doing the details. We had a nice little team of youngsters who came along and joined us to do that. We didn't have any established people there because we were a young team, but I had specific ideas about what I think worked and what didn't work, and that was it. And also, of course, you had to trim your ideas to fit your pocket. You couldn't just go along and say this is exactly what we want, we must do this.'

That said, he was too good a driver himself not to realise you needed someone quick in the cockpit: 'I normally tried to make certain I always had one driver in a seat who was a fully paid and contracted driver, and we would also have to have drivers who gave us some support. But we always had one person in the team who was there purely on merit.'

Like many F1 outfits both then and now the Surtees team often suffered through lack of funds, despite some creative sponsorship deals in the 1970s, often brokered by Surtees himself – such as Brooke Bond Oxo, Matchbox (mainly in F2) and, of course, the at-the-time controversial tie up with condom manufacturer Durex. But it was another, unnamed, sponsor that ultimately led to the closure of the team. 'We were at the point where we were getting podiums, we were right there, even though we didn't have the benefit of lots of engines and things like this and we were working on relatively small budgets. Then we were severely restricted when there was a major problem, which was the sponsorship that didn't pay. And that's the thing that I fought for about three years in the courts, and it ran us dry. That's why I had to call an end to the team.'

The really sad thing is that the Surtees team was on the verge, he believed, of something rather good. 'The ground effect car which we developed with Southampton University was so very, very promising. It was going to be the TS21. We built [an interim version based on an existing car], which we called a TS20-Plus, which we in fact ran in some Aurora [British Formula 1 Championship] races. It won at Silverstone [in 1979], went like a rocket, and it would have been very high on the British Grand Prix grid that year with the times it did there. When I tested it I think I set the fastest lap which had ever been achieved around Goodwood [Surtees tested his cars long after he retired as a race driver]. So it was very promising, but there's no point if you don't have the finance.'

What if …

With an effective ground effect car in 1979 Surtees might well have done a Williams, to which it sold its FOCA licence that year. Williams became a leading team on the back of its success with the FW07 in 1979, so it' not too much of a stretch of the imagination to suggest Surtees might still be a feature in grand prix racing today, if the TS21 had lived up to its promise. Mind you, Surtees was not completely taken with present day F1, so perhaps it was not too much of a regret: 'At times there's a

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difference between what is good relative to the advancement of technology, and what is good for motorsport. For instance, we are bugged in Formula 1 these days with too many regulations, and perhaps a rather restrictive formula,' he said.

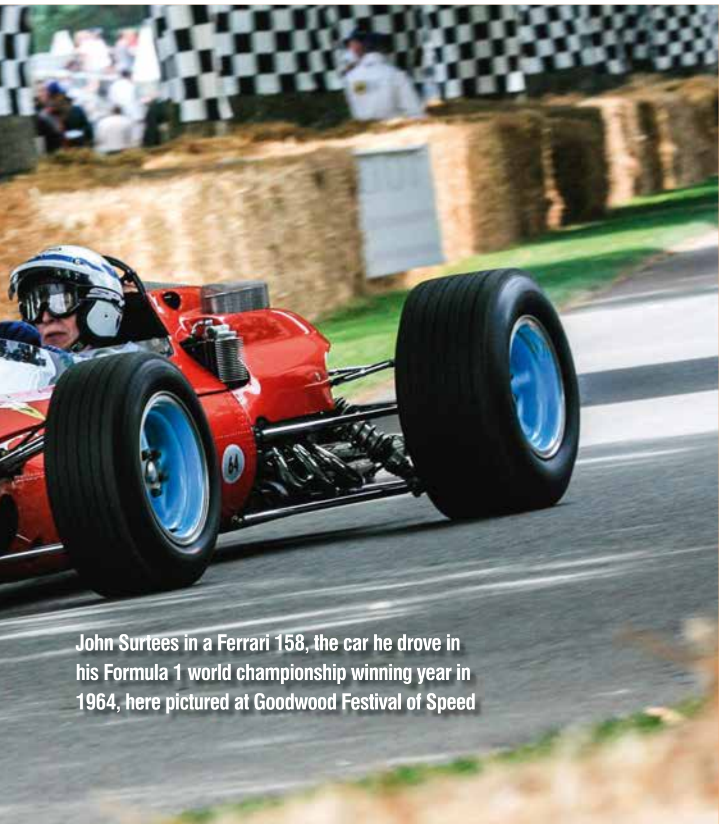
What might have been if Surtees had stayed in F1 is just one of very many 'what ifs' in our sport, but you can't help thinking that the engineer in Surtees would have loved a constructors' crown to add to the riders' and drivers' titles he is so famous for.

The Foundation

More recently Surtees had been heavily involved in the Henry Surtees Foundation, which was set up in the immediate aftermath of the death of his 18-year-old son, Henry – killed in a Formula 2 accident at Brands Hatch in 2009. 'Basically it was born on the day we had the service,' Surtees said. 'We had so much generosity from people who donated cash instead of flowers and that went to a project called Headway in Tunbridge Wells, a charity for head injuries. I hadn't thought about it before, but it grew, and the Foundation became an official charity the following year.'

Since then the Foundation (to give to the charity go to henrysurteesfoundation.com) has raised well over a million pounds, which has been donated to a number of good causes, including air ambulance charities, while there is also an annual karting competition which offers useful prizes to help cash-strapped racers. The event, the Henry Surtees Challenge, is held at Buckmore Park, where Surtees also stepped in to help the venue in a time of need, taking control of the kart track when its future looked uncertain to ensure that racers at a grassroots level are still able to compete.

And in the final analysis competing was what it was all about for John Surtees, getting the very most from a machine, and the very best from himself, at the world's most challenging circuits during motor racing's most dangerous era. As he told us: 'Places like the Nurburgring and Spa, probably two of the most challenging circuits, as they were. Spa because of its speed, and the speed of the corners. Because you didn't have the things to slow up circuits, chicanes and things like that, like you do now, so Spa was somewhere where you got a lot of satisfaction when you got it right. Because you'd have time to see; you got a corner right going on to a straight and you'd see how much benefit in the revs you got going down the straight, just because you got the corner right. That was good.'



John Surtees in a Ferrari 158, the car he drove in his Formula 1 world championship winning year in 1964, here pictured at Goodwood Festival of Speed

RACE MOVES

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Pirelli has restructured its Formula 1 operations and its racing department with long-time motorsport boss **Paul Hembery** now having moved to a new post as CEO of the Italian tyre giant's Latin American business. Hembery will, however, remain in overall charge of motorsport activities. Mario Isola has now taken on the new role of head of car racing.

Pasquale Lattuneddu, a well-known face in the Formula 1 paddock and often referred to as **Bernie Ecclestone's** right hand man, has now left F1. He filled a number of roles, including handling media accreditation, the layout of the paddock, and looking after VIP guests.

Nick Portlock is now the commercial director at UK sportscar and racecar constructor Ginetta. Portlock, who is a former Caterham racer, has been tasked with overseeing the globalisation of the brand alongside technical director **Ewan Baldry** and production manager **Simon Laughlin**. Portlock takes over the role from Ade Barwick, who has now left the company.

Well-known New Zealand race engineer, team manager and racecar designer **Alan McCall** has died at the age of 76. McCall worked at Lotus on Jim Clark's Cortinas in the 1960s before moving to McLaren. He also managed the Hexagon Formula 1 team in the early '70s and designed the Tecno PA123 F1 car. He subsequently went on to build up a business in historic race preparation based in the United States.

Pit Crews in the Australian Supercars Championship are to fight it out for a A$25,000 prize this year as part of the 2017 Pirtek Pit Stop Challenge, which will award points for the speed of the stops during the races. The top four teams will then take part in a live televised final during the build-up to the Bathurst 1000 at the end of the season.

Warren Scott, the boss of Factory-backed Subaru BTCC outfit Team BMR, is to step down from touring car driving duties this season to concentrate on his work behind the pit wall. The former Superbike racer will not turn his back on driving completely, however, and he has lined up a seat in a Citroen DS3 Supercar in this year's British Rallycross Championship.

Pat Symonds, the former Williams chief technical officer, has now joined UK broadcaster Sky Sports F1 as a technical analyst and commentator. Symonds' three-year spell at Williams came to a close at the end of last year, when he left to make way for incoming new tech boss **Paddy Lowe**.

Julie Conlin has been promoted to senior account manager at US motorsport PR firm Sunday Group Management. She has been at the company since 2011 and is now responsible for its clients active in IMSA, including Visit Florida Racing, Michael Shank Racing, Stevenson Motorsports, Change Racing and TeamTGM. Meanwhile, experienced race driver **Maddie Komar** has joined the Indianapolis-based concern as communications coordinator.

It's been widely reported that Honda has parted ways with consultant **Gilles Simon**, the engine guru who headed up Ferrari's powerplant operation during the Scuderia's dominant spell in the first half of the 2000s. Simon joined Honda in 2013 after a period working at the FIA.

Australian actor **Hugh Jackman** has been linked with the part of Enzo Ferrari in the long-delayed biopic of the founder of the famous marque's life. Jackman is now the third high profile actor mentioned in connection with this role, **Robert De Niro** and **Christian Bale** are the other two. The movie's director **Michael Mann** is thought to be due to shout 'action' on the film production sometime next year.

Former F1 driver Berger takes on top DTM role

Gerhard Berger has been appointed chairman of DTM organising body ITR following a management reshuffle.

The Austrian succeeds DTM founder Hans Werner Aufrecht, who has now stood down.

Hans-Jurgen Abt and Walter Mertes have also resigned from the ITR board. Mertes will stay on at ITR in his role as MD of ITR's F3 GmbH branch, which promotes the Formula 3 European Championship. Abt will remain in the DTM series in his position as the boss of his eponymous Audi-running team.

As part of his new duties, Berger will be tasked with enhancing the series' long-term appeal.

Berger said of the appointment: 'I started my motor racing career in touring car racing and always followed DTM with a lot of interest. It is a top-class product with independent, powerful regulations, with strong manufacturers, top sponsors, important international partnerships and many fans.

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Gerhard Berger is now chairman of ITR, which oversees the DTM

'This is a good starting point with great potential for the future,' Berger added.

'The first task I will focus on in the coming weeks is gaining a deeper insight into the details with the support of my colleagues. We will then use this strong basis for creating a joint strategy for the future.

'While doing so, I consider the further development of our international partnerships – also with regards to new manufacturers – spectacular racing cars that also command the drivers' respect as well as a format combining both sport and entertainment as particularly important,' Berger said.

Liberty F1 chooses new base and bolsters marketing team

Liberty Media has chosen a new location for the headquarters of Formula 1.

Chase Carey, the CEO of F1, announced that Liberty was on the lookout for a new HQ when its buyout deal was finalised, saying that the Princes Gate, Knightsbridge, offices long used by Bernie Ecclestone were now 'too small' for F1. Formula 1 is now to move in to the fourth and fifth floors of the St James' Market development, a $500m project on Regent Street, London.

Meanwhile, the new owner of F1 has also bolstered its communications and marketing departments, promoting former McLaren PR boss Norman Howell to Formula 1's director of Global Communications.

Howell brings more than 30 years' experience in international sports communications to the role. For the past two years he has held the post of head of Digital at F1, coordinating digital and social media output. He will report to Sean Bratches, managing director, Commercial Operations.

Bratches said: '[Howell's] extensive and demonstrated experience leading communications strategies for many of the world's most prestigious motorsport brands, together with his background as a journalist and social media specialist, align well with our objectives to broaden Formula 1's appeal and proactively engage the marketplace to elevate the exciting changes that we are envisioning and implementing.'

F1 has also hired Murray Barnett as global head of Sponsorship and Commercial Partnerships, and Matthew Roberts as global head of Research.

Barnett is a sports marketing professional with over 20 years' experience in media, marketing and sponsorship worldwide.

XPB

Norman Howell has taken up the director of Global Communications position at Formula 1

Roberts will head up F1's commercial research division, looking at existing markets where the sport has a presence and identifying new marketing and sales opportunities. He will also examine how Formula 1 can improve its presence across digital, broadcast and commercial areas.

RACE MOVES – continued

XPB

Four-time F1 world champion **Alain Prost** is to act as a special advisor to the Renault Formula 1 squad throughout the 2017 season. Renault, for which Prost drove in the early '80s, says it hopes to draw upon his experience both as a former grand prix driver and team boss – he ran his own eponymous F1 operation, after taking over the Ligier team, from 1997 until 2001.

NASCAR has announced the 20 nominees for its Hall of Fame Class of 2018. The management and engineering side of the sport is well represented, with car owners, crew chiefs and engine builders named; including **Ray Evernham**, **Ray Fox**, **Joe Gibbs**, **Harry Hyde**, **Roger Penske**, **Jack Roush**, **Waddel Wilson** and **Robert Yates**.

Randall Burnett, the crew chief on the JTG Daugherty Racing No.47 Monster Energy NASCAR Cup entry, was fined $65,000 and suspended for three races after the Chevrolet he tends was found to be running with improperly installed lug nuts at the Atlanta Motor Speedway round of the championship. **Ernie Cope** was drafted in to take his place for the duration of Burnett's suspension.

Casey Folks, a well-known figure on the US off-road racing scene, has died at the age of 72 after suffering a stroke. Folks founded and owned the Best in the Desert Racing Association, while he was also a successful off-road competitor in his own right.

Joe Gibbs Racing NASCAR Xfinity Series crew chief **Scott Graves** was fined $10,000 following the Atlanta Motor Speedway round of the second-tier NASCAR series after the Toyota he is responsible for failed the post-race front body height inspection.

Former Peugeot LMP1 driver **Nicolas Minassian** is now the sporting director at US LMP2 outfit Dragonspeed, which competes in the ELMS and is due to make its Le Mans debut this season. In his new role Minassian will work with the team's drivers while he will also help to develop the business.

Mika Hakkinen has rejoined McLaren, the team that took him to two world championship crowns in 1998 and 1999, in what's being called a 'partner ambassador' role. McLaren says he is to work alongside executive director **Zak Brown**, dealing with the team's sponsors.

Crack NHRA drag racing team John Force Racing has swapped crew chiefs and pit crews on its two lead cars. The crew of team owner and driver **John Force**, led by crew chief **Jimmy Prock**, will now switch to **Robert Hight's** Chevrolet Camaro SS Funny Car, while Hight's crew, headed by **Mike Neff**, will now tend Force's similar entry.

Ekrem Sami has left his position as McLaren Marketing CEO. He had been with the company for 35 years, but now intends to ply his trade in the 'wider sports and entertainment sector'.

Jeff Stankiewicz, the crew chief on the No.23 GMS Racing entry in the NASCAR Camping World Truck Series, was fined $7500 after the Chevrolet he tends failed to pass ground clearance inspection measurements, and was also discovered with improperly installed lug nuts, in Atlanta.

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Caddy lacking? Very little

The Sebring 12 hours saw the three Cadillac DPi V.Rs walking away with the race, finishing first, second and third, with the fourth placed car two laps down, and two of the three Caddys dipping into the 1m49s in race conditions, the only ones to do so. One senior IMSA official actually apologised to me for coming to Florida to see the spectacle of them falling short in the BoP process, for which emergency meetings were scheduled in order to rein in the Caddys. Clearly, IMSA has more data from which to work than we do, and they didn't like what they saw, but racing cars are fickle things, and there were a number of mitigating circumstances that I think warrant a mention.

Pre-race, the Cadillacs were awarded a smaller air restrictor, down from 33.1 to 31mm, which the teams claimed cost them 70bhp, and which actually put the 6.2-litre engine 30bhp down on the Gibson when looking solely at peak power. However, there is no substitute for cubic capacity, so the saying goes, and the torque produced by the Cadillacs meant that, particularly in traffic, the cars were untouchable.

The cars were also given a reduction in fuel capacity, down from 75 to 68 litres, but that didn't seem to have much of an effect on the competition, with the cars pretty much pitting at the same time as the WEC-specification cars. If that is the case, how much were they really hiding at Daytona? Regardless, the Cadillacs have the torque and the fuel economy of their competition despite these restrictions, but already the Cadillac teams were getting twitchy about their reductions in performance.

The torque of the Cadillacs meant they were untouchable

Neel Jani put the ORECA WEC-spec Rebellion on pole position for the 65th running of the endurance classic which, according to some teams, was a likely outcome. It was quick at Daytona, and the Cadillacs were pegged back since then. However, Cadillac's Christian Fittipaldi was on a lap at the end of qualifying that would have challenged, if not beaten, Jani's time, but he ran out of fuel and couldn't complete the lap.

There was one more point we should note, and that was the introduction of the new Continental tyre for Sebring. While in Europe the P2 cars are able to choose from three compounds of slick tyre, in the US, just one has to do the whole season, including road courses, part ovals, street tracks and a multitude of different surfaces and ambient and track temperatures. So, while some may draw comparison between the Dunlop test at Sebring in December, and the race (a difference of around three seconds), to do so is futile.

The Continental tyre was designed around the new LMP cars, but as is the case with the tyre manufacturers in Europe, and actually in F1 also, there was a problem; no cars on which to test it. Continental did buy old LMP2 cars and ran them with higher downforce levels, and actually had load data from the Daytona Prototypes from which to guess on sidewall stiffness, but when it came to actual testing, they had to go with the only chassis that was available: the Dallara Cadillac.

That said, the Cadillacs actually wanted to go softer on the rear tyre at Sebring, but Continental didn't allow that – it felt that to do so would have compromised lateral stability for the remaining races in the schedule. 'You have to be careful to make sure that you are centred on every chassis, so that one chassis doesn't pay a price in one part of the country in one set of conditions,' confirmed Kevin Fandozzi, Continental's Tire Product manager, IMSA, IWSC and ISTSC. 'There must be some small weakness that is more on one car than another. The key for us is to make the window as big as we can so that even if there is a slight difference in chassis we can adapt to it. Our goal is to make sure our tyre is peaky and responsive enough but operates in a large window. We provide all the data to the teams. A DPi running a Cadillac motor, when we get to Laguna Seca and we are coming out of T14 and it's hot, they will have problems putting the power down because they have so much torque. We have to be responsive to the paddock. This chassis we think is going to be in the centre of the window, and that is what it is designed to.'

The tyres were designed to cope with low and high temperatures, low and high grip levels from the circuit, new cars that were not run until September, and starting with a 24-hour race at the part-oval Daytona, where temperatures dipped close to freezing in wet conditions (it can only do one spec of wet too). It's second race was an old, bumpy airfield in 80degF temperatures. And, there was no data on how the tyres would perform during a race weekend, with support series, and multiple stints run by cars on the same, and other, rubber (GT LM runs Michelin).

With the WEC-spec cars also running into reliability issues, any car that came close to the Cadillac pace effectively took itself out of the running, and made the Caddys look that much better. I am not entirely sure what we saw at Sebring. Was it a mistake in the BoP? Was it that the Cadillacs have a performance advantage that cannot be controlled? Is it the chassis, engine, or tyres that gives it such superiority? Whichever it was, the other teams that are competing in the IMSA championship have to step up their own games and reach their own maximum before they start to complain. Or, IMSA has the answers already. Whatever the outcome of the emergency meeting post-Sebring, we'll find out very soon.

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