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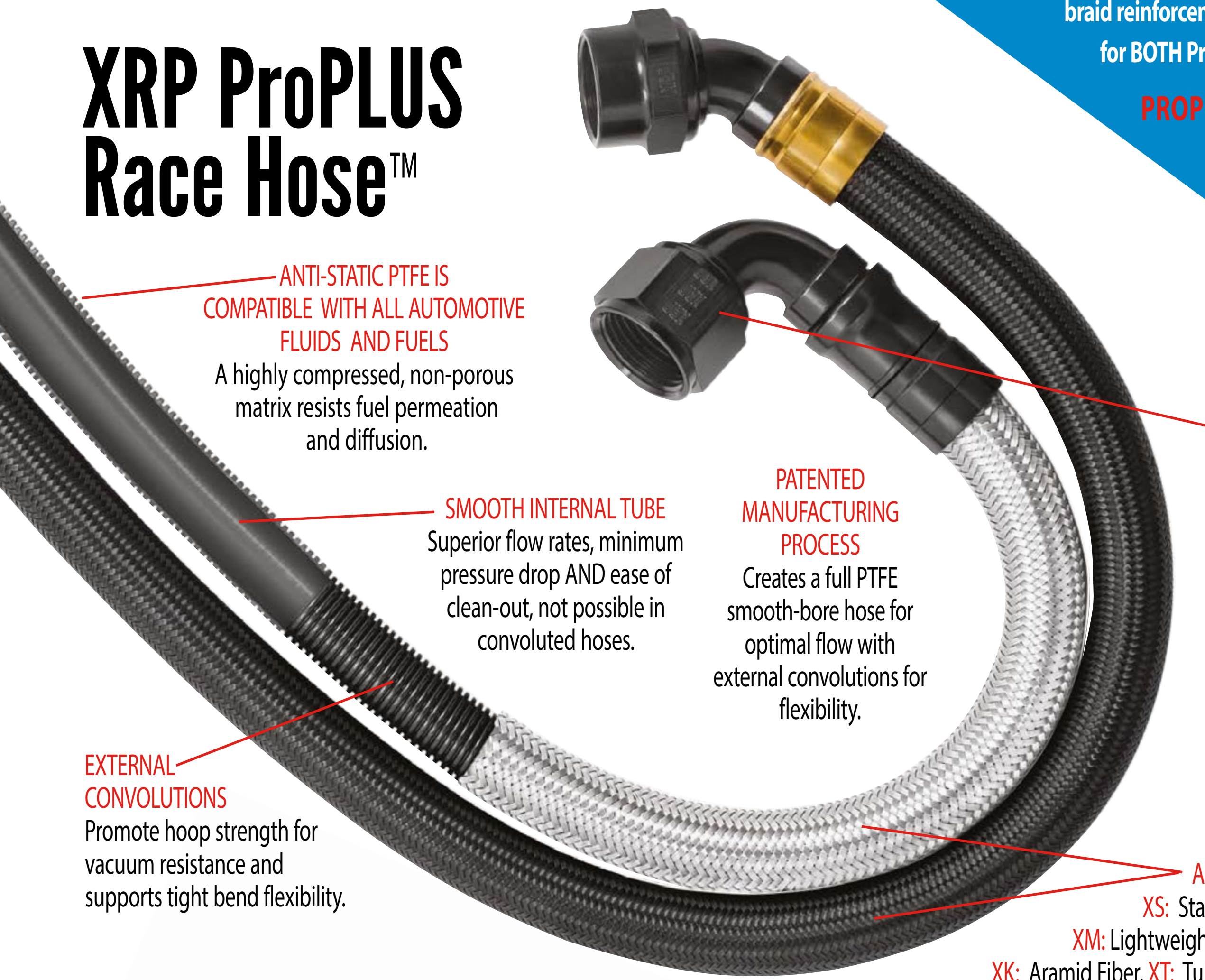

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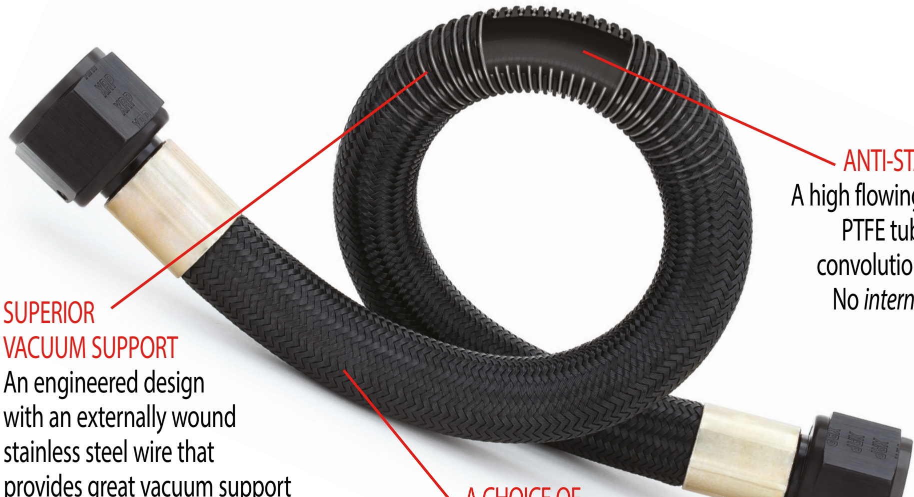

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As always Macau provided drama in spades this year, and not a little controversy. Turn to Bump Stop at the back of the mag for the inside story

Come the revolution

In a time of massive political upheaval could motorsport be next in line for change?

The Norse Eddas speak of Urth, Veroandi and Skuld, the Norns, maiden giantesses who see the past, the present and the future. 'Thence come the maidens mighty in wisdom. Three from the dwelling down 'neath the tree; Urth is one named, Veroandi the next. On the wood they scored, and Skuld the third. Laws they made there, and life allotted to the sons of men, and set their fates.' Quite. Presumably, if we ask them what the near future brings, we would be warned that a revolution is coming. But do we know what a revolution is? It used to be seizure of power by popular forces aiming to transform the nature of the political, social, and economic system, according to some dream of a just society.

Norse power

Today, we live in an age when rebel armies come sweeping into a city, or mass uprisings overthrow a dictator, but not necessarily with the consequences of a just society. On the other hand, the rise of feminism led to a profound social transformation, which took an entirely different form and tends to influence the basic fabric of society. As H Rap Brown noted: 'Revolution comes when human beings set out to correct decadent institutions.' One thinks the Norns watching the world would say what we have seen with Brexit and the American election, and worldwide political unrest, are but the reflection of a fundamental malaise in all systems, which are the result of old management and business models that are still governed by geriatric and entrenched powers.

Revolutions are thus planetary phenomena. And there is more, for what they really do is transform basic assumptions about what politics and society are ultimately about. In the wake of a revolution, ideas that had been filed as lunatic fringe quickly become the accepted currency of debate.

Before the French Revolution in the 1790s, the ideas that change is good, and that government policy is the proper way to manage it, and that governments derive their authority from an entity called 'the people', were considered the sorts of things one might hear from the tinsel-hat crowd and demagogues, or in the best interpretation a handful of freethinking intellectuals who spend their time debating in cafes.

There is a caveat, as always: 'Every revolution evaporates and leaves behind only the slime of a new bureaucracy,' said Franz Kafka, and Ludwig von Mises went further: 'Economically considered, war and revolution are always bad business.' The arch-revolutionary Lenin was blunt in 1918: 'It is impossible to predict the time and progress of revolution. It is governed by its own more or less mysterious laws. But when it comes it moves irresistibly.' And more bluntly yet: 'You cannot make a revolution in white gloves.'

Looking at the motorsport scene, there are a plethora of warning signs. These are more pertinent precisely because what is accepted as the modus operandi is directly related to the society it is embedded in. As global society increasingly becomes more integrated, these societies respond the same way. Immanuel Wallerstein noted that by the time of the French Revolution there was a single world market, and increasingly a single world political system as well, dominated by the huge colonial empires. Globalism is not new, just more visible. So the storming of the Bastille in Paris could well end up having effects on Denmark, or even Egypt, which were just as profound as on France itself—in some cases, even more profound.

No public, no sponsors. No sponsors equates to the death of the business

XPB

These days Russia has a grand prix (pictured), but 100 years ago it was on the verge of revolution. But is motorsport now facing a revolution of its very own?

Revolutionary zeal

The world revolution of 1789, the revolution of 1848, which saw revolutions break out almost simultaneously in 50 countries, from Wallachia to Brazil, none of which were successful in seizing power, gave rise to an acceptance of institutions inspired by the French Revolution, notably, universal systems of primary education which were put in place everywhere. The Russian Revolution of 1917 was a world revolution ultimately responsible for the New Deal and European welfare states, as much as for Soviet Union communism.

My own generation's revolution in 1968, much as 1848, broke out almost everywhere, from China to Mexico, seized power nowhere, but nonetheless they changed everything in the end.

It was a revolution against state bureaucracies, and for the inseparability of personal and political liberation, whose most lasting legacy will likely be the birth of modern feminism.

As I noted earlier, revolutions are planetary phenomena. What they really do is transform basic assumptions about what politics and society are ultimately about, and the same applies to the world of motorsport and its society.

As I also noted earlier, in the wake of a revolution, ideas that had been considered veritably lunatic fringe quickly become the accepted currency of debate.

To the barricades!

A generation later, even the stuffiest magistrates, priests, and headmasters had to at least pay lip service to the ideas of the French Revolution. Before long, we had reached the situation we are in today: that it's necessary to lay out the terms for anyone to even notice they are there. They've become common sense.

But the participants in motorsport are so busy devising ways to go faster and beat the opposition that they end up being like the general public in countries who are not involved in the governance, and are subject to private agendas of individuals. And, in the case of motorsport, much like the world, the interests of global companies prevail over the good of the sport, which depends ultimately on the paying public.

The steady loss of audience reflects the state of the business. No public, no sponsors. No sponsors or investors, equates to the death of the business.

So, all you citizens of motorsport, hear my cry: 'To the barricades, and make motorsport great again!' Oops, maybe this is not exactly the phrase one should use right now.


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The departed

In the wake of Audi's withdrawal from the WEC, what next for the top prototype class?

I began writing this column celebrating what is currently another golden age of Endurance racing, with the close battles between Audi, Porsche and Toyota works teams in the WEC, Ford *v* Ferrari again after half a century, plenty of drama, fantastically, close finishes, and heroic pitwork .

Then I read the bombshell news of Audi pulling out of the WEC. Perhaps not surprising really – there must be a limit to the returns to be gained for a high-volume car manufacturer after such a very long run of success. In Audi's case, other factors contributed to the decision, not least a desire to placate workers and shareholders following the massively expensive 'dieselgate' scandal in the USA for parent company VW, meaning something had to be seen to be done re cost-cutting. Audi's recent participation has all been centred on diesel power – perhaps something the VW board didn't think needed over-emphasising at present – and any automotive giant might well query why a second race programme competing against another group company – Porsche – can be justified without different technologies being employed.

Diesel genes

Although Toyota and Porsche still remain, this means only four manufacturer cars (an outside chance of six) taking part, not many when you consider the attrition rate common in the Le Mans 24 Hours. However, the deeper inference of Audi's withdrawal is of course the potential knock-on effect concerning these two LMP1 marques.

The ACO has, from bitter past experience, been aware of this threat. It has been trying to bolster the non-hybrid LMP1 privateer ranks, but has so far offered too little, too late, even with measures including advantageous aerodynamics and freed-up engine regulations plus a slight weight-break being introduced for 2018.

That the ACO and the FIA together conceived energy-based power unit regulations resulting initially in very different concepts proving highly competitive with one another was an amazing feat. It's claimed that these regulations encouraged Audi and Toyota to continue and Porsche to re-enter, creating the great racing that I started out by praising. But these LMP1 cars are wastefully heavy, complicated, very expensive and supposedly not viable to supply to non-works teams. With diesel engines removed from the mix, plus Toyota having converted from atmospheric to turbocharged engines and exchanging supercapacitors for batteries, therefore coming into line with Porsche, this variety of technologies has now reduced significantly. As is usual in motor racing, over time certain technical solutions come to the fore and become universally adopted, possibly negating the likelihood of any other manufacturer entering the WEC in order to show off its different approach.

ICE breaker

Ironically perhaps, the drive to smaller internal-combustion diesel and petrol engines enhanced by forced induction is starting to look less, not more, relevant to passenger car development. A recent Reuters news agency release stated: 'Tougher European car-emissions tests being introduced in the wake of the Volkswagen Group scandal are about to bring surprising consequences – bigger engines! Automakers are now being forced into a costly U-turn as more realistic on-the-road testing exposes deep flaws in their smallest engines.'

XPB

With Audi's announcement that it will no longer take part in the WEC the variety of competing technologies in LMP1 has been diminished

So it could be that the move to little internal combustion engines augmented by turbochargers is a bit of a blind alley after all. Coincidentally, and as in F1, it appears that the development of the complicated electric hybrid aspect has plateaued considerably, pending dramatic battery technology breakthroughs for which the timeline is as yet unknown. Instead, the major gains in efficiency overall are coming from developments in the internal combustion engines which still form the basis of the current power units. Pre-chamber and part-compression ignition, lean-burn technologies and advanced anti-knock, all directly applicable to the improvement of road vehicles, are where it's at. There is no doubt that the adoption of the fuel flow meter has focused the attention of the engine designers into optimising the energy potential of every fuel droplet, with dramatic results. This actually has been the real game-changer, first proposed by Keith Duckworth many years ago.

The hard cell

The ACO says it wants to encourage fuel cell-powered cars to enter and to lead more advances in technology, but it must be beware of following this philosophy too passionately. Being in line with a changing world is necessary, but there is a fine line between this and retaining full capacity quality grids and exciting racing. I have every respect for the success and nous of the ACO in maintaining and enhancing the prestige and value of Le Mans over so many years, but perhaps another re-think is necessary. As with F1, especially, chasing manufacturer entries and green credentials might on the face of it be laudable, but if this reduces the competition because of excessive cost and the spectacle by too much technological excellence, what has been achieved? One should always remember that the core activity is motor *racing*.

Bruno Famin of Peugeot has stated that the WEC is not sustainable, even if the spirit of the rules is good. He suggests a dramatic lowering of the minimum weight that currently stands at 875kg as one means to achieve this. (Question: as long as the same safety requirements are demanded and certain uber-expensive materials and processes are banned, should there be a minimum weight limit at all?)

Famin says: 'There are three [now just two] major manufacturers who want to show off their innovation and the technology they have developed, but the costs are so high no one else will join them in those conditions. I would like to propose a different way of achieving efficiency, namely minimum weight reduction. If you want to reduce emissions and fuel consumption, there are ways of doing it without using hybrid systems.'

Such observations, from a manufacturer with a great history at Le Mans, and a potential returnee if conditions are right, should not be ignored.

Being in line with a changing world is necessary, but there is a fine line between this and retaining full capacity quality grids and exciting racing

Blockbuster

It may act the film star on Gymkhana Nine, but at heart Hoonigan Racing Division's Ford Focus RS RX is a 100 per cent full-on rallycross machine, as *Racecar* discovered

By LEIGH O'GORMAN

Despite the short sharp shock nature of Gymkhana videos, and rallycross racing, aerodynamics still play a decisive role

For Derek Dauncey, team director of Ken Block's Hoonigan Racing Division, getting the Ford Focus RS RX prepared for filming Gymkhana Nine, the latest in Block's hugely popular stunt driving internet films – which at the time of writing has accumulated 14.5 million views – was a fairly straightforward job.

Following Block's participation in the FIA World Rallycross Championship in Canada, the team made straight for the outskirts of New York, where the video was to be filmed and immediately began preparation. 'We left Canada and went straight down to Buffalo, did the livery change, did some repairs and we changed the settings and that was it; we went and did the filming,' Dauncey says.

But while the RS RX may garner attention due to the Gymkhana films, the project was always at heart a rallycross car, and there was rather more to this project than simply putting a new livery on a Focus, as Dauncey explains: 'We had been running a Fiesta for a few years and we had been courting Ford about going into the [2016 Rallycross] World Championship. They saw the opportunity of assisting us with designing a brand new car.'

Race bred

The platform for the RS RX was the Focus RS rally car. However, when Hoonigan Racing completed an evaluation of the RS with M-Sport, it became clear that was precious little that could be carried over. But this did nothing to deter Dauncey and his team.

'We wanted to try to take some engineering advantage. We were in discussions with Ford and Ford worked with M-Sport [based in Cumbria in the UK and known for its Ford WRC programme] and they built the current car,' Dauncey says, adding that the chassis configuration of the RS RX is completely new, allowing Hoonigan Racing to develop a car almost specifically for rallycross competition.

Dauncey also explains that the gearbox tunnel on the rallycross car is much bigger than the RS rally car, as both the exhaust and propshaft run through that area.

The Ford RS RX rallycross car also runs with double wishbone rods. 'For the size of the car, we believed the double wishbone would have an advantage, so that was the way it went forward. There's hardly anything that carries forward [from the Fiesta] – maybe brake pads and the turbo. That's about it really. The whole design and theory was to basically not carry

While this Focus RS RX is known to millions for its exploits in Gymkhana Nine it was built with its day job in mind – racing in the World Rallycross Championship

anything over from the other car, but to revisit everything once the installation started.'

Powering the RS RX is a 2.0-litre Ford engine, which was developed by M-Sport and Ford Performance. Dauncey notes that the powerplant does have some carry-over from the engine's original concept, and with over 600bhp and more than 650lb/ft of torque, the unit has certainly delivered.

The engine has been mounted transversely in order to help with weight distribution and centre of gravity. 'When they did that in the installation, they changed quite a few items on the car to assist the angle of the transmission and steering,' says Dauncey. 'We kept that in the whole philosophy. Some said we would never make a transverse car work, but we could see the benefits of it and we liked the idea of making it with the Sadev gearbox.'

It is one thing to be quick, but for Block's Gymkhana films the car needs to be spectacular, too

Feeling that it was a package that worked well in the Fiesta, Dauncey's team worked hard to finely tune the centre of gravity and he feels that the success of the RS RX has changed some preconceptions regarding the weight distribution of transversely mounted cars. 'We looked at every option to help us off the line and where we want that weight off the line, so it's a slightly different way of thinking, but that was the direction we took.

'There's been some pretty good tricks done with the engine, but fundamentally it's just a 2.0-litre engine that's very similar to what we used before, but much more advanced.'

The RS RX utilises a 6-speed sequential gearbox by Sadev, as well as a Sadev rear differential and centre differential release unit. Already having an existing relationship with Sadev from the Fiesta, Dauncey decided to stick with the French company. 'We have a very good working relationship with them,' he says. 'The gearbox is slightly refined from what we had before in terms of gear ratios, gear widths, and we carried all that forward. We control it with a centre differential release hand-brake unit and a Sadev rear differential.'

Run via a slightly modified clutch system from AP Racing, the package has proved extremely strong, especially when considering the abuse it takes when getting off the line.

Cross-code

Of course, it is one thing to be quick, but for Block's Gymkhana films the car also needs to be spectacular. But Dauncey says that there was no trickery as such involved in making the car look good on film – just solid engineering and good driving. But there are some changes when it comes to the Gymkhana spec. 'We've had a specific turbo made that spools up quickly and gives you a quick throttle response, so if you are sliding, you can accelerate out of it. We've done a fair bit with suspension, as in really not making the dampers work as efficiently as they can, so that they allow the car to slide more, so that was basically carried over from the Fiesta. To be fair, the platform itself with the double wishbone

This picture: Rallycross action can be none too subtle and using strong parts is a prerequisite
Left: Ford performance has helped Hoonigan Racing with the aero development of the Focus RS RX – which is optimised for low speed rallycross tracks

works very well and we adopted the car a lot quicker than expected for the Gymkhana Nine filming. I think we had just three or four hours testing on the morning before we started shooting,' Dauncey says.

Dauncey adds that the team used harder tyre compounds during filming to not only help the car slide, but also to generate dramatic shots of smoking tyres. 'You always want to able to rotate and slide the car quite quickly from a very quick braking point, where the car falls off the tyre, and the Focus does that quite quickly.'

'The whole design and theory was to basically not carry anything over from the other car'

Electronics come courtesy of Cosworth. However, due to tight regulation in rallycross governing electronics, Hoonigan is limited in what it can do under racing conditions. 'We find the software to meet the regulations for what you are allowed to monitor and what you are not allowed to monitor. You are not allowed to take a lot of data out of the car in theory. They [the FIA] try to stop any possibility of manipulation on the track with traction control, engine cutting or anything like that.'

The data that is logged is strictly policed by Magneti Marelli and the Italian company monitors this after each race to ensure all competitors comply with the regulations as set. 'You have to homologate the set of software at the start of the year and the way it acts, you can't change it. You can do small parameter changes in the mapping, but nothing other than that, so that's being continually checked at every race.'

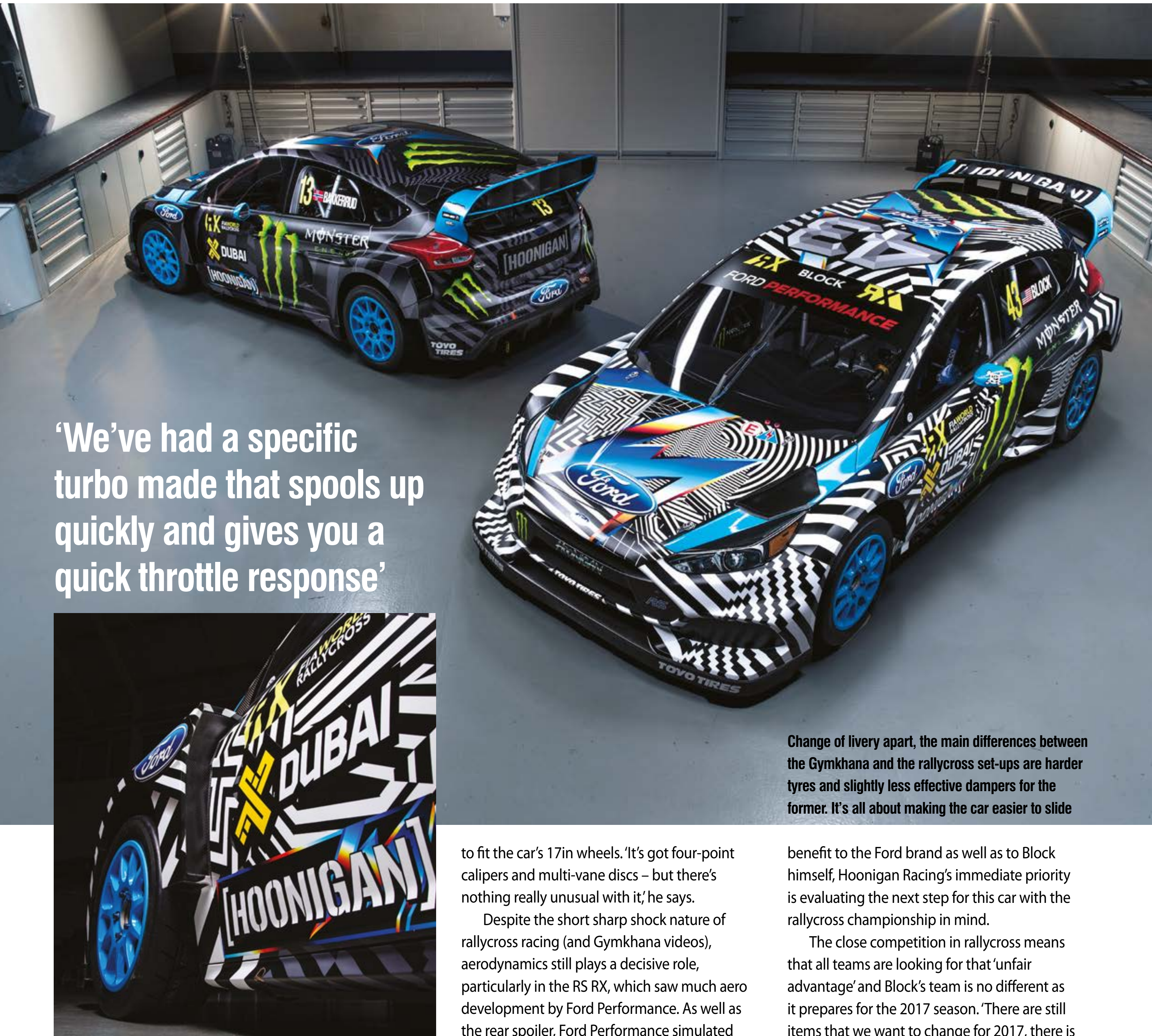
Block and load

The RS RX is fitted with Reiger dampers – a Dutch-based organisation that has been a partner with Hoonigan Racing for a number of years. Yet despite the closeness of the relationship, Dauncey was not in a position to reveal details of the machine during the design consultation. 'They were given the scope for the design without us telling Reiger what it was for initially, because we were trying to keep the project as quiet as possible,' he says.

The suspension as a whole is similar to units Hoonigan has used previously. 'The only difference we have now is that the double wishbone arms are fairly short,' Dauncey says. 'It took us some time to understand that in the real world. It's all been done on CFD and simulation, but in the real world we're still learning with that car and what we can do with it.'

The roll bar is multi-adjustable, while there's the option to change multiple components to suit specific race tracks, grip levels or the actual surface of the tarmac – also taking into account the weather conditions on race day.

The RS RX uses Brembo brakes, but has two choices of set-up and disc size depending on the circuit. However, for filming the Gymkhana video, Dauncey used the larger disc options



‘We’ve had a specific turbo made that spools up quickly and gives you a quick throttle response’

Change of livery apart, the main differences between the Gymkhana and the rallycross set-ups are harder tyres and slightly less effective dampers for the former. It’s all about making the car easier to slide

TECH SPEC

Ford Focus RS RX

Body: 2016 Ford Focus RS, seam welded and reinforced; M-Sport designed homologated FIA-spec roll cage; body design by Ford Performance and M-Sport. Bespoke underbody protection.

Engine: M-Sport/Ford Performance designed 2000cc, 4-cylinder, Garrett turbocharger. Power: 600bhp; Torque: 650lb/ft. Car capable of 0-60 mph in under two seconds.

Transmission: Sadev 6-Speed sequential along with Sadev rear diff and centre diff release unit. AP Racing clutch

Suspension: Double wishbone; Reiger multi adjustable dampers; multi-adjustable anti roll bar

Brakes: Brembo

Interior: Recaro seats, Cosworth engine management and data logging, M-Sport multi-function bespoke steering wheel.

Wheels: OZ 8in x17in.

Tyres: Avon rallycross controlled tyre.

to fit the car’s 17in wheels. ‘It’s got four-point calipers and multi-vane discs – but there’s nothing really unusual with it,’ he says.

Despite the short sharp shock nature of rallycross racing (and Gymkhana videos), aerodynamics still plays a decisive role, particularly in the RS RX, which saw much aero development by Ford Performance. As well as the rear spoiler, Ford Performance simulated many key elements including the bumper profile, the front splitter to the undertray underneath the front bumper, the sump guard in the rear bumpers, the rear wing outlets and the side vents. ‘We don’t see massive lateral slides, only at a couple of events, but they try to look at the courses that we visit and come up with a compromise that works at a low a speed as possible, but also at some of the higher speed [circuits] like Hockenheim,’ Dauncey says.

‘They’ve spent a long time giving us the optimum set-up and looking at the results, the minor changes that we have made pre-season have been pretty interesting, to bring that across to rallycross,’ Dauncey adds.

Dauncey feels that there is still more to come from RS RX, but while Block’s Gymkhana films rustle up the big numbers on YouTube, a clear benefit to the Ford brand as well as to Block himself, Hoonigan Racing’s immediate priority is evaluating the next step for this car with the rallycross championship in mind.

The close competition in rallycross means that all teams are looking for that ‘unfair advantage’ and Block’s team is no different as it prepares for the 2017 season. ‘There are still items that we want to change for 2017, there is some design work going on already with that,’ Dauncey says. ‘We are looking at increasing performance with Ford’s support and the engine department at Ford Performance, and everybody’s looking to try and come into 2017 with a quicker and a better handling car.’

Cross channelled

Often sessions in world rallycross competition end with large portions of the field covered by a second or less, a factor made even more impressive when one acknowledges the many different approaches to the packages available. There is little doubt that Dauncey hugely relishes the challenge this brings. ‘There’s no way to stand still, you have got to be looking to gain bits here, there and everywhere to try to be competitive,’ he says.

Mother of invention

Dome's updated Mother Chassis for the GT300 class of Super GT has now hit the race track. But can the MC86B tempt more teams in to embracing this neat common components platform?

By SAM COLLINS

Super GT is Japan's premier race series. In recent years it has been going through something of a transition, with a raft of new regulations. But it has always had a two-class structure, with each category having its own ethos.

The top class, GT500, is essentially still a playground for manufacturer teams, with Toyota, Honda and Nissan fielding cars. In 2014 new rules were introduced which are largely harmonised with those of DTM, and for this year these have been further updated. Meanwhile, the second tier class, GT300, has always been more about pitting cars developed by smaller Japanese tuners against the best customer cars Europe and North America have to offer.

The global rise of GT3 over the last decade, however, has seen the balance of the class shift dramatically, as the majority of teams have opted to use the cheaper and more widely available European cars instead of developing their own. For some time GT300 even looked like becoming just another GT3 championship.

Japan's motorsport industry was unhappy with this situation and in an attempt to resolve it it set out to create a new type of GT300 car, using a set of off-the-shelf components including engine, transmission and chassis.

The idea was that there should be enough single specification kit parts so that the costs were kept low, while still leaving a large degree of technical freedom for the tuners to create their own cars from the base package.

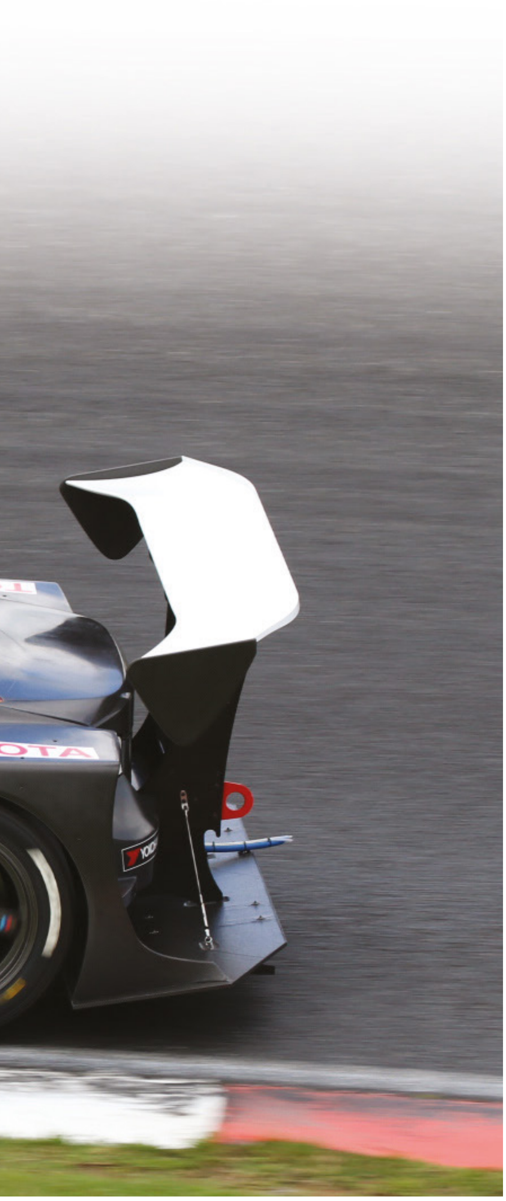
Usage of this new package was not mandatory, and the expensive but very competitive JAF-GT300 cars such as the Subaru BRZ and Toyota Prius would still be permitted, as would GT3 cars, but the new breed of cars should, in theory, be just as fast, if not faster, and more cost effective than either of those options.

Dome alone

Dome, Japan's top motorsport engineering company, was commissioned by GTA, the promoter of Super GT, to create the basic package, which had a carbon fibre monocoque chassis at its core. The original Dome designed and built MC86 was the first of this new breed of so-called 'Mother Chassis' cars to be built.

To ensure that the car was not massively more competitive than something that a small private tuner could create the initial bodywork used was designed more for aesthetics than performance, Dome opting not to use its wind

Main picture: The second version of the Dome-built MC86 GT300 car has been unveiled in Japan. The MC offers a platform for private tuners to build on
Right and below right: The Dome MC86B racecer features new bodywork which is aimed at improving both the aerodynamic package and the car's cooling



tunnel or large CFD capability to develop the best design possible in terms of performance.

Since the initial development of the MC86, however, the ownership of Dome has changed hands, its wind tunnel sold to Toyota, and its composites facility to Toray, and the company is now housed in an all-new technical centre next door to the JR R&D facility in Maibara, Japan, where the next generation of the iconic Shinkansen (Bullet Train) is being developed.

Dome's new owners felt that it was time to update the MC86 and improve its performance. So part way through the 2015 season an R&D project was launched with the ultimate goal of creating a B spec MC86. Dome's Takuya Nakamura, who headed up the project to develop the original MC86, was once again in charge. 'The main project goal was to increase the overall aerodynamic performance,' Nakamura says. 'We started the bodywork design last year, and did a lot of CFD on it. So we decided not to do a new production car as a base but to improve the one we had, that allowed us to compare old and new. Mechanically there was not really a lot of difference. All we really changed on this car was the bodywork. We did a few bits mechanically, too, though, but they don't change the performance, but the reliability is improved in some areas, as is the total life.'

Cool mother

One example of the mechanical changes made to the car can be found in the fuel tank. Nakamura says: 'The car uses a Fuel Safe cell from the USA, but on the new car we have changed the internal parts a bit, things like the fuel collectors. That is the sort of thing we have done, just to improve everything slightly.'

The new-look MC86B features a completely new set of body panels with substantially revised cooling, and bodywork which has clearly been tidied up in many areas. At the time of writing it had only raced once, in Super GT's only overseas race of the 2016 season, held at the Chang International Circuit in Thailand. Run by a local team with technical support from Dome, the car's overall finishing position was nothing particularly special, and it was easily outpaced by the original MC86 (which went on to win the race). However, this is not really the full story, according to Nakamura. 'We were very encouraged by the car performance in that race, one of the drivers in the car was a 50-year-old local amateur,' he says. 'His first time in the car was in qualifying and he got through to Q2 and ended up in 10th position, that is remarkable in such a competitive class. We were really surprised. We didn't think it could be that fast

'The main project goal was to increase the overall aerodynamic performance'

The carbon fibre tub is fitted with a very sturdy steel roll cage. Dome says that its torsional testing shows that the chassis of the MC86B is actually stiffer than its big-brother DTM-based GT500 cars. This is largely due to the thicker bulkheads used

MC86B has its V8 engine mounted in the front yet in the Lotus Evora version of the MC the powerplant is mid-mounted, as it is in the production car. The Mother Chassis is designed to take all configurations, which gives the teams more car options

While the Mother Chassis rules are generally quite open, a Hewland gearbox is one control part. Dampers are free, though, yet while Dome has its own four-way shock absorber many of the teams operating the chassis tend to use Ohlins dampers

straight out of the box. So we think that the car could be a quite something.'

Despite both old and new spec cars having now raced on the track together, Dome was unable to compare the performance of the two versions empirically, Nakamura says. 'We didn't have the right sensors on the car in testing or at the Super GT race in Thailand, so we can't do much comparison that way. But we now feel confident that there is a lot of potential in the new package, and our CFD says so, too. We did no wind tunnel on this new specification, just CFD, but we compared both old and new bodies and found the new design to be much better. The biggest difference was to the overall drag of the car, the new car is much better and without a loss of downforce, so it is much more efficient. The CFD claimed an improvement of 20 per cent.'

Mother's ruin

Not everyone is quite so pleased about the potential of the MC86B. Some of the GT300 teams running GT3 specification cars feel that the Mother Chassis cars have a big advantage in terms of tyre performance. Indeed, in some of the shorter 250km races such as the one in Thailand, it was possible for the MC86s to run the full distance without a tyre change, gaining a substantial advantage in the pit lane. 'The thing about these cars keeping the tyres alive is that they are 200kg lighter than GT3 cars in terms of the minimum weight,' Nakamura says. 'Our cars also have an aerodynamic package, too, which is quite different to GT3 and is easier on the tyres in terms of wear. The tyres on the MC cars are perhaps also slightly softer too as a result.'

The MC86B is the third car built on the Mother Chassis platform, the others being the original MC86 and the striking mid-engined Lotus Evora. Takuya Yura's Mooncraft organisation has done a substantial amount of wind tunnel testing on the Lotus, and it's partly because of the gains in performance with this car that Dome felt the need to upgrade its MC86.

Mother nature

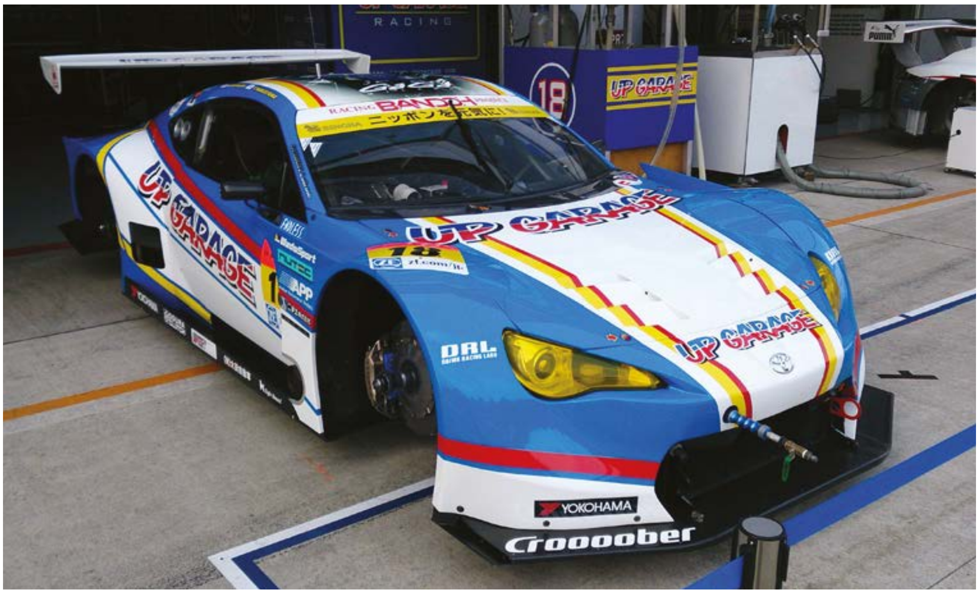
By regulation, the engines fitted to GT300 cars must be located in the same position as they are in the production version, so while the Lotus is mid-engined, the MC86 has its V8 engine mounted in the front, yet both racecars actually share an identical chassis.

The carbon fibre tub is fitted with a steel roll cage, as is the case with the single specification DTM/GT500 chassis. However, Nakamura believes that the mother chassis has some advantages over the German-designed monocoque used in the more powerful class. 'The stiffness of these MC cars is substantial. We have done torsional testing several times, we have compared it to other car types and it is much better,' he says. 'We suspect that this GTA monocoque is a fair bit stiffer than the DTM based GT500 chassis too, and the weight is similar. I think if you look at the monocoque the

Some of the GT300 teams running with GT3 specification cars feel that the Mother Chassis racecars have a big advantage

DTM has, the front and rear bulkheads are a bit too thin. If you look at our design the chassis is bigger in these areas and obviously that brings stiffness gains. In terms of weight, the chassis weighs 63.5kg, and with the cage it is 83kg. It is both lightweight and strong.'

One of the reasons for the thicker bulkheads is that the whole concept of the mother chassis was that it would be able to accept a wide variety of different car concepts and power units. To date all the MC cars built have used the same 4.5-litre GTA engine supplied by the promoters of Super GT. However, it is known that there is only one of these engine supply deals left available for the 2017 season, so if more than one organisation decides that they want to develop a new mother chassis car, or if Dome sells another MC86, then a different engine would have to be used. With this in mind, Nakamura has been evaluating the options that are available. 'By design the chassis should be able to accept most engines up to a certain size,' he says. 'The LMP3 engine, which has been mentioned, for example, we found that it might be a bit of a challenge to mount to the chassis as it is quite a long engine and quite heavy. While you could fit something small, like the 2-litre NRE engine used in GT500, the cost is very high and the mileage is not great; it's really a works engine. Right now we are still evaluating options and discussing it with GTA.'



The original MC86 (compare with the new car below). So far five Mother Chassis cars have been built, three of the first spec of MC86s plus the mid-engined Lotus Evora version, and one new MC86B. A sixth chassis has also been built up as a spare

One aim of the MC86B is to tempt the GT3 teams away from their exotic machinery. The MC86 can be updated to the B-spec car thanks to a kit available from Dome, and the GT300 organisers are hopeful teams running the car will make use of this

Shocks away

GTA's boss Masaaki Bandoh hopes that more Japanese teams and tuning companies will join the GT300 class using the Mother Chassis, in some cases potentially trading in the GT3 specification cars which they have currently. The ethos remains one of encouraging smaller concerns to develop their own cars rather than just buy in an off-the-shelf product.

'There is freedom for teams to develop on their own, many parts of the car can be changed,' Nakamura says. 'They use the dampers they like, for example, but most teams run with Ohlins. They do not use the Dome damper. We have a suitable four-way damper, but it is too much money for most of them. We offer a two-way damper as well, which is in the price range, but all the teams want four-way dampers so they buy Ohlins. I'm not sure why they choose Ohlins over other suppliers, I think someone used them once and was fast and ever since it's the damper to have. Most teams don't even consider alternatives. They also offer good track support in Japan, I think that is important.

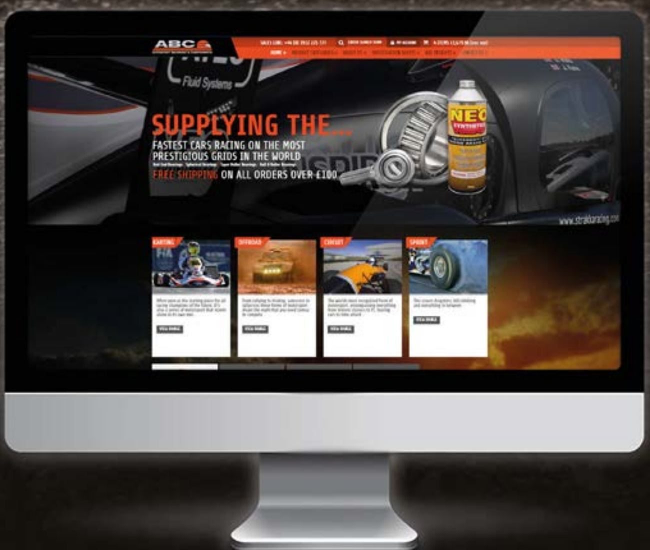
'Most of the teams have kept a lot of the parts in the package, the uprights for example,' Nakamura adds. 'They can change it but they don't they really have a reason to.'

Mother freezer

Not all areas of the Mother Chassis rulebook are so liberal. Some have been deliberately frozen, essentially to prevent European firms fighting expensive development wars in Japan. 'Teams are restricted to using the Hewland transmission; there is no reason to change that,' Nakamura says. 'We have no company in Japan able to offer such a unit, the Toda Racing gearbox, for example, is only really suitable for smaller capacity engines. The GT cars have too much torque and power for that unit. At the start of the project we compared all the units from the European suppliers in terms of cost, design and support and Hewland seemed the best, and that is what everyone must use.'

To date five Mother Chassis cars have been built. Three are the original MC86, plus the Evora and the new MC86B. A sixth chassis has also been built as a spare, or in case any team wanted to build a new car at short notice. The original spec MC86s can also be upgraded to the new MC86B, with a kit of parts from Dome. It's thought that some of the current Mother Chassis users will take up this option.

NEO SYNTHETICS
HPCC#1 GREASE
High Performance Calcium Complex Grease
NEO SYNTHETICS
75W90 RHD
HIGH PERFORMANCE SYNTHETIC GEAR OIL
SUPER SPEEDWAY GEAR OIL
Designed for Extreme High Speed, High Load Racing Applications
1 US Gallon - 3.785 liters



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Surf's up!

When Supercars squad Triple Eight Racing decided to pay homage to the legendary Holden Sandman it could hardly have guessed at the potent track-rides machine that would be the result

By STEFAN BARTHOLOMAEUS

For those who already think Aussies are slightly bonkers, this story's for you. It's the tale of a race team that decided to take a Supercar, one which contributed to Jamie Whincup's 2013 championship win, no less, and recreate a 1970s icon.

The team in question is Roland Dane's category-leading squad Triple Eight Race Engineering, and the icon is the quintessentially Australian Holden Sandman. This was the ultimate expression of the panel van craze of the '60s and '70s ,which brought together the load carrying capacity of a ute (or pickup) and the enclosed protection of a wagon (or estate). An ability to fit surfboards on the roof and a mattress in the back ensured panel vans proved particularly popular with the era's increasingly adventurous youth market, and in 1974 Holden created the ultimate van in the form of the Sandman, which mixed various features from the Monaro – including a V8 engine – with typically loud '70s colours and graphics.

The 40th anniversary of the Sandman in 2014 saw Dane approach Holden with the idea of converting a current specification Supercar into a Sandman tribute, which would serve as the car for the team's passenger ride programme. It already had a perfect donor car waiting in the wings in the form of the chassis that Whincup had raced during the opening nine events of the 2013 season. But although it won eight times and scored a total of 15 podiums from its 27 races, the car's inconsistent responses to set-up changes triggered a back-to-back test with Craig Lowndes' sister entry.

'It had been very successful, but pre-Sandown we did a test where we back-to-backed the two cars and, I don't believe in ghosts, but they weren't handling the same for a given set-up and tyres,' says Triple Eight team manager Mark Dutton. 'We decided the day after that we were going to take a new car to Sandown. We built that car from a bare shell in the shortest time we've ever built a car. Our previous best was 11 days and we built it in three and a half. Then we managed to win the Sandown race with the new car.

'That left the old car there with a question mark over it,' Dutton adds. 'We could have sold it, but RD [Dane] saw the benefit of doing something special for Holden, and ending up with a dedicated ride car.'

Designs for the Sandman began in May, 2014, with external sketches undertaken by in-house Holden designer Tom Grech. Holden also supplied various CAD files in order for Triple Eight's head fabricator, Jason Briggs, to design and manufacturer the internal structure that would turn the racecar into a Sandman.

The car's rollcage, which is a control item among the Supercars field, is unchanged, save for modifications to the left-side door bars in order to create a bigger opening for passengers. 'We grafted pieces of the original car, pieces of

Triple Eight Race Engineering team boss Roland Dane had the idea of making a Supercars version of the Holden Sandman. The outfit ended up with a very special passenger ride car

Team driver Craig Lowndes says the Sandman oversteered wildly before Triple Eight fixed a rear wing to it. The surf van does 4000 passenger ride kilometres each year

a ute and of a wagon together in order for the finished product to match the drawings as closely as possible,' Briggs explains. 'It's got the rear quarter glass from the Ute and then the basis of the rear structure is essentially the wagon road car. None of it went together perfectly, especially the Ute parts.

'On one side we used the actual quarter glass and on the other we had to manufacturer a polycarbonate panel because it also incorporates the spike cone for the air jack system,' Briggs adds. 'We also made some solid steel panels to fill in where the windows would be on a wagon. That was the fun part, and something very different to what we normally do. It was a little bit of trial and error to make everything fit and look nice, but we were all very happy with what we ended up with.'

A team of three fabricators took two months to make the conversion, with progress stopping and starting around their usual workload as part of the Supercars race team.

A team of three fabricators took two months to make the conversion, with progress stopping and starting around their usual workload as part of the race team

Shifting sands

Beyond the body, the most notable difference between a standard Supercar and the Sandman is the addition of a paddleshift mechanism for the control Albins transaxle gearbox. Despite the proliferation of paddleshift gearboxes on performance road cars, Supercars continues to use a sequential stick-shift. 'We figured that at some stage it will come online, so why not be able to test some things and, when the time comes, be able to offer it up to Supercars as a package?' Dutton says. 'It's not about putting us further down the track than other teams, because it's not a system that you develop as a performance tweak. It'll have to happen at some stage because paddleshifts are extremely common in performance road vehicles. For me it's a funny system. It's pneumatic, but I believe we'll soon see that stuff go away from pneumatic and become electrical. But you have to have a fair bit of force in them for a solenoid to do that. Some of the parts of it are really beautifully designed, for a racecar, and some are from show cars with air suspension that bounce up and down. So the compressor and reservoir are quite literally chrome-plated, which doesn't normally go on racecars. But the solenoid, which is an off-the-shelf part, is really nice. The actual switches that the paddle are attached to are a smart design and have a good tactile feel. The whole system works pretty faultlessly.'

Implementing the system required working closely with Supercars control ECU supplier Motec, and some track testing with Lowndes. 'It took us a while to get the auto-blip right for downshifts and to fine tune the mechanism for the upshift,' said Lowndes. 'It took a couple of days to get the electronics right and what we ended up with feels really nice. It's perfect to make driving a little easier on a ride day.'

Dutton stressed that he hopes any eventual move to paddleshifts can be done with a fully electronic system, which may also one day be tested on the Sandman. 'We've looked at a different actuator, but we haven't gone to the electrical yet,' he says. 'If we got it working it would be a better 'fit and forget' because you don't need a second reservoir to store the air and a compressor, which is weight. And as much as you can avoid having a compressed gas cylinder in the car, even if it is only full of air, the better, because compressed things can explode if they go wrong. It's in the boot area and it's totally safe, but if you can avoid it then that's better.'

Triple Eight and Motec also developed a fly-by-wire system for the car as part of its nod to the category's likely future. Fly-by-wire was introduced on the new Mercedes-AMG Supercars in 2013, but soon ditched by the Erebus team as it worked through a variety of issues on its German-made equipment.

Surf and girth

The engine itself is essentially a Supercars motor with a stroker kit that takes it from 5.0 to 5.5 litres, and from 645bhp to 707bhp. Achieved with a longer stroke and shorter conrod, the car also runs 11:1 compression instead of the category-mandated 10:1.

The motor was built by Triple Eight's Supercar race engine supplier, KRE, which has carved a reputation as a class leader in the touring car category. 'The good thing about the horsepower upgrade is that the passenger can get a better feel of what the racecar is like when you don't have the extra weight of the passenger,' said Lowndes. 'I remember doing a ride day at Sandown and I passed Warren Luff in one of the Holden Racing Team cars down the back straight. He rang me up that night asking what the hell we'd done with that car. The lack of aero helped it go faster as well, it just meant the corners were a bit of a problem.'

The car had its first run in Sandman form at the relatively tight driving training course in Norwell, Queensland in October, 2014, ahead

The Triple Eight passenger ride car is based on the 1974 Holden Sandman panel van, as seen in the rear of the picture. The modern version packs a 5.5-litre Holden V8 race engine, a paddleshift sequential gearbox, and two surfboards on its roof!

of its public debut at the Gold Coast street circuit race later that month.

While the extra horsepower and absence of a rear wing made it oversteery at every venue, it wasn't until the car was run at the high-speed Sydney Motorsport Park (SMP) midway through the following year that the lack of downforce really became apparent. 'Coming down into Turn 1 it reaches a speed, over 200km/h, where it's got all the front downforce but nothing at the rear. The rear just goes into this crazy oversteer into the corner,' says Dutton. 'The drivers are good enough to catch it, but they came in with eyes like saucepans and said "mate, that's actually quite dangerous". It was that loose.'

Board room

Dutton set about designing a wing for the Sandman which utilises the same main element seen on the racecars, and although it was not taken through the usual CFD process for aerodynamic parts, Lowndes says it does the job perfectly. 'Without the wing the car looked very slick but it wasn't very practical in terms of driving. It wasn't a pleasant experience,' Lowndes says. 'The wing transformed the car. It was an unknown at the time, we didn't know the first time we ran it if it would fall off or what, but it settled the rear down perfectly.'

A somewhat unique aero issue on the car is that of the roof-mounted surfboards, which Dutton affirms wreaks havoc with downforce. 'We ran it at SMP without the surfboards because of the importance of the aero, but we run the boards everywhere else,' he says. 'The boards probably take away 85 per cent of the wing's benefit, but because it didn't need it to begin with at the other tracks, it's not a problem.'

The engine is essentially a Supercars motor with a stroker kit that takes it from 5.0 to 5.5 litres and from 645bhp to 707bhp

Damper van

After the initial fabrication work had been completed, the car was built up under the direction of mechanic Ty Freele. Now number one on Whincup's racecar, Freele was at the time heading up the team's ride car programme and says he relished the opportunity to build something out of the ordinary.

The key elements are, however, standard Supercar, including the double-wishbone front end and independent rear suspension. But it's not just a Supercar. 'It's not full of old Supercar bits, it's got brand new everything,' Freele says of the Sandman, which at 1374kg without fuel or driver is slightly heavier than the standard car. 'And when you have a lot of resource and no rules to follow, there's a lot you can do.

'On the racecars we're restricted where we can use carbon, but here we could dream of whatever you wanted. We went a little bit further with things like suspension parts that normally you wouldn't powder coat or paint due to weight and crack testing,' Freele adds. 'The Sandman doesn't see the kilometres that a racecar does so the crack testing isn't as crucial. We powder coated all the suspension arms. It looks like a show car that you might see at a car show.

'Whatever I could think of or dream of I took to RD and he'd either say yes or no, so it was a very fun project,' Freele adds. 'Things changed as we were going. We looked at everything and said how can we make it lighter or shinier or better looking. And everyone chipped in. When the boys would finish their racecars they would come and help out on the Sandman.'

Dutton says that the attention to detail brought a strong reaction from the rest of the Supercars fraternity when it was unveiled at the Gold Coast event. 'Normally you don't look at other people's racecar, but they wanted to see this and we welcomed them over,' he says. 'They were looking at it and saying "this is prepared better than our racecars, when do you find time for these things?". We never did it to play mind games with people, that wasn't the motivation, but it kind of did because they were thinking "how can we compete when our racecars aren't as good as your side project?". It wasn't worth doing it just for that, but you do feel pretty good when other teams give it that much respect.'

Gold coaster

Naturally, this attention to detail didn't come without cost. 'It's the most expensive car we own,' says Dutton. 'It's hard to put an exact figure on it due to the labour, but it would have cost a couple of hundred thousand more than a Supercar. It'd be close to A$750,000 [£450,000].'

The need to have the car ready by the Gold Coast 600 ensured that not all of the original concepts for the van made the finished product. 'We were busy racing and trying to win a championship, so there just wasn't time to do everything,' Dutton says. 'It was a project of passion type of thing where a lot of the work was being done after hours. We had a firm deadline to be ready for the Gold Coast race. But it's like racing. Nothing is perfect on the racecar, because it has to be ready to go racing.

'The original design from Tom included a two-piece tailgate, like the original Sandmans have, but time meant we ended up going with the hatch,' Dutton adds. 'We'd also planned different wheels, but when we got them there were some clearance issues and, being different sizes front and rear, it would have been more expensive to have to keep buying the tyres.'

Initially run on Michelin rubber, the team was eventually granted permission to use the leftover stock of its Dunlop race tyres. 'Because it handles nothing like the racecars you get to the point where you say "we have all these Dunlops that we scrap that have enough meat on them to be used on a ride car",' Dutton says.

'The Supercars guys have been smart enough to understand that it's not a racecar and we don't have all the performance sensors on it,' Dutton adds. 'We could, because it's not a registered Supercar, but it won't teach us anything so we don't need to be collecting data for the sake of it. That's good, because it saves a lot of cost in running it.'

The Sandman is regularly driven by Triple Eight's regular Supercars driving trio of Lowndes, Whincup and Shane van Gisbergen for its approximately 4000km worth of ride duties across Australia each year. Sadly, the rooftop surfboards are not used quite so often.

Charged up

As Formula E switched on for season three *Racecar* plugged itself in to the technical and operational developments that have been the buzz of the FE paddock

By SAM SMITH

The amusement always runs high among members of the media at the Donington tests every year as each team so valiantly attempts to pull down a veil of secrecy on its motors, inverters and transmission options for its new models.

This year, though, there is little in the way of change in the regulations for season three, but some teams have opted to subtly alter things, in particular Renault, Audi and Venturi, while others have gone for more wide-ranging set-ups, such as DS and NextEV. With the regs staying stable, the grid has closed up, and on the evidence of the Hong Kong opening round, probably three-quarters of the grid are in with a chance of winning a race this season.

With some drivers having expressed concern about the longer races, which have become a feature of the all-electric championship in season two and in to season three, harvesting of energy will go up from 100Kw to 150Kw for the current season. Teams and drivers now have to carefully balance their use of energy as the extra regeneration escalates thermal temperatures in the battery cells.

Reigning champion Renault e.dams finished season one with the Zytek built motor atop a two-speed gearbox wrapped up in a complex carbon casing. Sebastien Buemi and Nicolas Prost used the first gear at the start and then never again. But in season three it appears that the unit has gone and that the differential is driven directly by the motor, meaning now that a gear change is not needed by the drivers. It remains unclear, though, just how Renault is using its intricate cooling system so effectively.

The challengers

The ABT squad now has added Audi-ness to its armoury, with the announcement the German manufacturer is to take on a bigger involvement, but little has really been changed over the season two to season three break. The package, which uses a Schaeffler designed motor and inverter, is still believed to be encased in a non-carbon transmission system incorporating three gears. This has been optimised this year, but only in a packaging sense. The team is known to be focusing on its solutions for season five, where Audi's recent shift in its motorsport outlook – which includes quitting LMP1 and the World Endurance Championship – should ensure its move from title contender to the title favourite for the 2018/19 season.

The Chinese-owned Techeetah team has gone with the regulated cost-cap customer option with one of the manufacturers. Naturally, it's chosen Renault and a supply of the title-winning ZE16 set-up, including the all-important Renault software. The only problem appears to be on the operational side, after a myriad of issues at the season opener.

The DS Virgin Racing team has started from a clean sheet of paper and has changed more or less everything within its design layout. The twin-motor YASA design has gone and has been replaced by a single motor/single gear straight to diff solution. The packaging of the DS powertrain features a carbon case in which

On the evidence of the Hong Kong round, probably three-quarters of the grid are in with a chance of winning a race this season

The DS Virgin Racing team has started from a clean sheet of paper and has changed more or less everything within its design layout

the inverter is positioned. So far the design has shown well and could be the most consistent to challenge the Renaults – Sam Bird could have taken a win in Hong Kong with the DS but for a software glitch during his car-swap pit-stop.

Magnetti Marelli's expanded presence in FE sees it working with several teams with its new motor. Mahindra, Dragon and Andretti are all using the MM product, which drives a twin-speed 'box attached to the diff. The two inverters are contained inside the carbon housing.

The Chinese owned, US based, EV company Faraday Future is working on a season five powertrain for Dragon Racing and as a stop-gap measure it has acquired powertrains from Mahindra. The team has expanded hugely after the big money Faraday deal and has employed experienced engineer Jacky Eeckelaert to work with double Formula E race winner Jerome d'Ambrosio.

The only team using an updated and modified original FE McLaren motor is Venturi. *Racecar* believes that a modified inverter is being used by Venturi, which announced a major partnership with ZF just before the season started. The Monegasque concern has also confirmed it will use Silicon Carbide conducting tech on its cars, too (see box out).

The Renault e.dams outfit is still the team to beat in FE. For season three is has switched to a direct drive transmission after previously using a two-speed gearbox, where first gear was only used for starts. It also has a very intricate cooling system

Cat-licked converter

New kids on the block Panasonic Jaguar Racing had a low-key debut in Hong Kong, but this is not surprising since it is taking an initially conservative approach to playing itself in to the championship, it has said. In partnership with Williams Advanced Engineering, Jaguar has opted for a single motor which lies longitudinally turning a twin-speed gearbox to the differential. Like some other teams it has opted to place the inverter above the battery.

FE is all about data and operational efficiency as well as tech development. So Jag will be doing well to score points in its first season and Hong Kong reflected that. What it has on its side is two excellent drivers in the shape of Adam Carroll and Mitch Evans, as well as a strong engineering unit including Okan Tur and Carroll's race engineer Patrick Coorey.

Andrett-E

After the nightmare of its abortive ATEC-01 powertrain, which was ditched at the start of season two, Andretti has chosen the Magnetti Marelli package. It has stuck with a relatively conventional Hewland gearbox, though, and two inverters located on top of the battery.

Meanwhile, sticking with its convictions for innovation in trying to make a twin-motor system work, the Chinese NextEV operation has, unlike DS Virgin, stuck rather than twisted. It has refined its package and altered the layout – now transverse with a single gear and an inverter atop the battery. The team is still working with Omni Gear and Rational Motion (based in the Toyota Motorsport GmbH facility), but is now also in partnership with Shanghai Magelec Propulsion, which has an R&D facility in Zurich. The results have been encouraging for NextEV with a front-row lock out in Hong Kong but its energy efficiency waned in the race. The team has also been rocked by the loss of one of its driving forces, former Ford of Europe boss Martin Leach, who died recently.

After the Hong Kong opener Formula E visited Marrakesh, and was then to go on to Buenos Aires, Mexico City, Monaco, Paris, Berlin, Brussels and New York, before finishing its season in Montreal in July of 2017.

SIC notes

The Venturi FE team hopes that the introduction of a new advanced technology can help it to join the front running teams in the championship this season, with new semiconducting silicon-carbide (SIC) diodes being used on the Venturi VM200-FE-02 in an effort to improve efficiency.

Developed by global technology company ROHM, the special SIC diodes have made the Venturi's inverter 2kg lighter, with electric efficiency being increased by 1.7 per cent, and the volume of heat extraction components has been reduced by 30 per cent. The material is believed to be capable of withstanding higher electric fields than conventional silicon, which results in extremely low losses of power and higher temperature resistance.

Unveiling the new technology in Hong Kong, Venturi technical director Frank Baldet said: 'We are very proud to be co-developing our powertrain with ROHM's silicon carbide technology, which can be used to create a great solution for our inverters. FE is all about power management, and the partnership with ROHM, the leader in power semiconductors, improves the overall electronics of our car so we can reach higher performance with our electric motors.'

With the challenge of FE being to find the most efficient way of using the energy provided by the battery and applying it on the road, Venturi believes that the new semi-conducting technology will give it an advantage.

What is SIC?

SIC works by making power electronics smaller, stronger and faster. Silicon carbide is a compound of silicon and carbon. It is produced using a crystal growth process of sublimation and exposure to high temperatures of about 2000degC.

Using this technology in power devices, ROHM has achieved lower power consumption and more efficient operation. There are several benefits compared to conventional silicon.

Firstly, it is smaller – system miniaturisation means reduced size and weight, which then allows for improved weight distribution in motorsport and less power consumption in general.

Secondly, it's stronger. Devices with SIC can work with higher voltages and currents, which increases power density and reduces switching losses even under high temperatures.

Thirdly, and in this application perhaps most importantly of all, this technology is faster.

Electrical blueprint

The new Formula E season not only brought news of further manufacturer interest but also a plan for the technical future of the electric race series. *Racecar* went to the Hong Kong ePrix to find out more

By SAM SMITH

The sense that the FIA Formula E Championship had properly arrived was palpable at the inaugural Hong Kong ePrix as season three of the all-electric championship whirred in to life in October. Quite apart from the phalanx of manufacturers joining the show, the imposing high-rise edifices of Hong Kong and the impression that the series is now making it on the global stage, FE has fast-tracked itself into setting out and finalising its technical roadmap until season eight, which will be in 2021/22.

This technical road map, which was seen for the first time in Hong Kong, details a plan which embraces high-end development within a generous time-frame. A new spec chassis and spec race battery from season five will pave the way for an eventual marketing race for the automotive and EV manufacturers (Renault, BMW, Mahindra, Faraday Future, Audi, ZF, Schaeffler, Jaguar, DS and NextEV) to tuck in to a projected 41 million EVs (according to a report in *Bloomberg New Energy Finance*), which are projected to be sold by the year 2040.

The rub-off for motorsport? A key marketing tool for the manufacturers and electrical engineering giants, which is set to be enormous, and potentially industry changing.

The FE roadmap

Plans for active braking to be allowed from season five and a brake by wire initiative have both now been detailed. These would also dovetail brake bias with regeneration levels.

Looking even further to the future, the FIA roadmap, which is being led by Professor Burkhard Goeschel, president of the FIA Electric and New Energies Championships Commission, is evaluating multiple options such as a front MGU. The much discussed use of torque vectoring and active bodywork are also being carefully analysed as the Formula E series looks to advance its technical credibility.

'We are looking to lead and drive electric technology because in racing the pressures and detail of the work means that the pace is greater for automotive to learn from,' Goeschel says. 'The most important season will be season five, because the target is to race with one car only for one driver. Our focus in Formula E is not aerodynamics and not chassis technology. It is solely electrical powertrain engineering.

'We have already opened the doors for the inverter and the motors,' Goeschel adds. 'There are different configurations the teams apply, [it] is totally free and this is one area which is very interesting. Specific technologies like silicon carbide will also come on stream and I think that Formula E will be a very nice compromise between sensible costs and innovation in interesting areas.

'We are having very detailed discussions with the car manufacturers about battery technology and where we go with it in the future,' adds Goeschel. 'The key is that it stays relevant for what the manufacturers want but very importantly it should not become too exotic of a solution. It has to benefit the future customer in cost and range.' So it looks like FE knows just where it's going, then.

The future looks bright for FE with new manufacturer interest. The series unveiled its technical plans (below) in Hong Kong

FIA Formula E technical roadmap: season four to season eight

	S4 (two cars)	S5	S6	S7	S8
Battery	28kWh	54kWh	54kWh	54kWh	54kWh
Max power (quali)	220kW	250kW	250kW	250kW	250kW
Max power (race)	180kW	200kW	200kW	200kW	200kW
Max power (Fanboost)	220kW	250kW	250kW	250kW	250kW
Max power MGU front	0kW	0kW	0kW	0kW	0kW
Max power regen	200kW (0.8)	250kW (0.8)	250kW (0.8)	250kW (0.8)	250kW (0.8)
E-diff / 1 MGU per wheel / TRQ Vectoring	No	No	No	No	No
Braking	Classic	Active	Active	Active	Active
Transmission	RWD	RWD	RWD	RWD	RWD
Chassis/aero	Dallara (SRT01)	Chassis FIA01; bodywork EVO	Chassis FIA01; bodywork EVO	Chassis FIA01; bodywork EVO	Chassis FIA01; bodywork EVO
Tyres	Michelin	Michelin	New tender	New tender	New tender
Weight (with driver)	880kg	888kg	888kg	888kg	870kg

The world's fastest Mini

With a 970cc engine and the aerodynamics of a furry brick the original Mini Cooper is not your ideal record car – but that did not stop a group of intrepid New Zealanders taking one to Bonneville

By DR CHARLES CLARKE

'Rocket car? I thought you said pocket car'. This little Mini Cooper achieved big things at the Bonneville Speed Week in the summer

The Project '64 team was founded in Nelson, New Zealand, in 2010 with the object of taking a 1964 Mk1 Mini Cooper 970 S to Bonneville Speed Week. Bonneville was a bucket list thing for Guy Griffith and Garry Orton, and they decided that competing was so much better than spectating. So things wouldn't get too serious, they also decided, over a couple of beers, that they should compete in something a little ridiculous, which is how the Project '64 Mini was born.

Griffith and Orton are the owners of Victory Motorsport, which runs international and local drivers in the NZ Toyota Racing series, as well as building and maintaining classic racecars for themselves and customers.

Project '64 – 1964 was the year the car was born – is privately financed through fundraising and sponsorship. Burt Munro's grandson, Rob Henderson, unveiled the Mini at a fundraising event in September 2011 – Munro, also from New Zealand, broke the land speed record with a 47-year-old Indian Scout motorcycle in 1967 and his story was the basis of the Anthony Hopkins film *The World's Fastest Indian*.

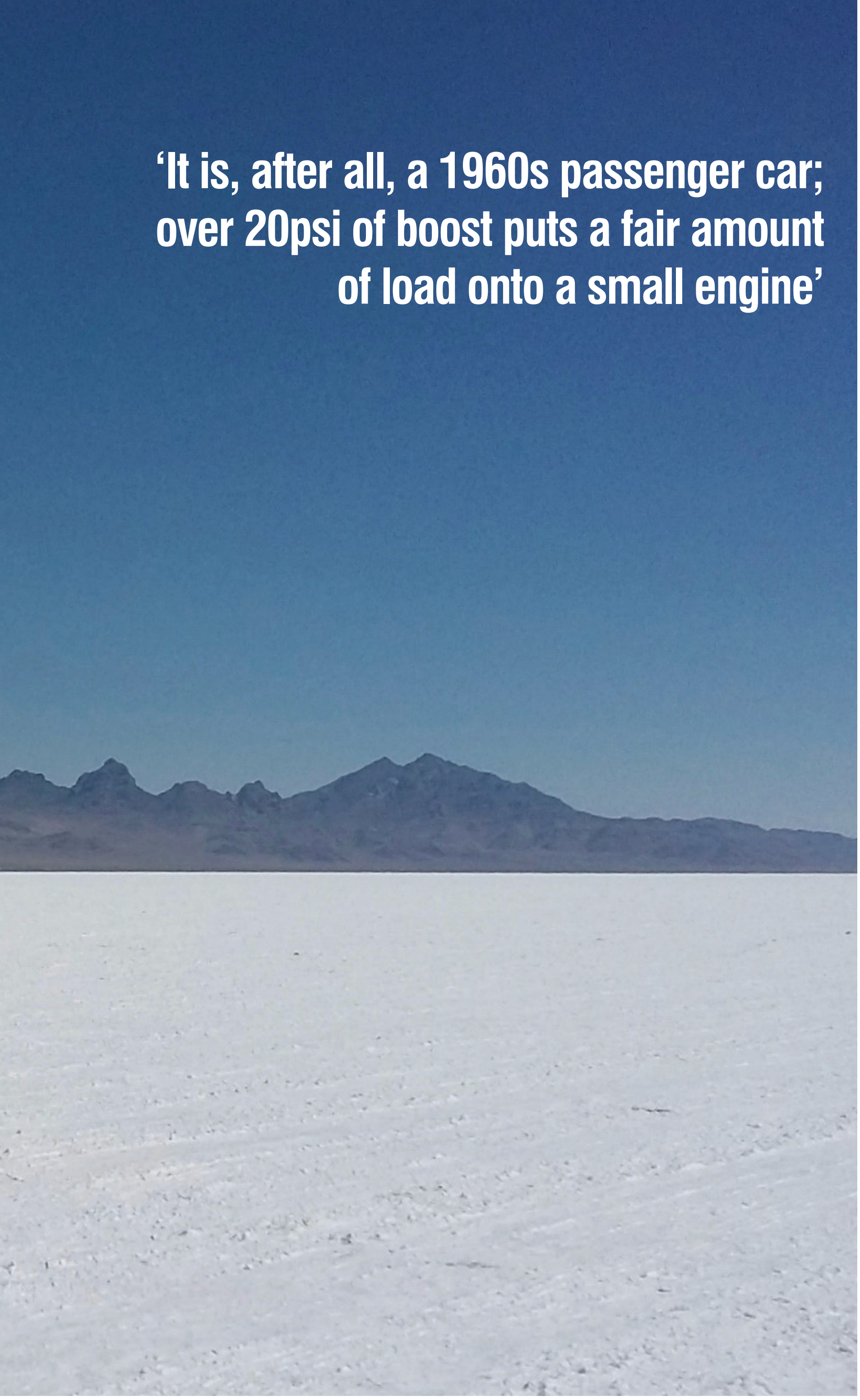
The Mini was built from a rusty Cooper S, with a replacement bodyshell coming from a similarly aged Mini 850. A rollcage to conform to SCTA (Southern California Timing Association) requirements for Bonneville was added. The short-stroke 970 A-Series Cooper S motor was modified using a BMW K100 motorcycle twin cam, multi valve cylinder head (see box out), a billet steel crankshaft, fuel injection, and a perfectly tuned turbo and intercooler supplied by Steve Murch at MSE Turbos. Many of the car's parts were supplied by volunteers from around New Zealand, with a considerable amount of the engine bits coming from Larry Mulholland of Swift Tune in Christchurch NZ.

In 2012 the modified engine delivered approximately 300bhp on pump fuel and 340bhp on methanol at sea level in NZ. This increased in 2016 to approximately 350bhp on pump and 375bhp on methanol.

Mini adventure

The basic aerodynamics of the Mini are generally regarded as awful, which was a big part of the attraction. The body was stock, apart from a front air dam, smooth undertray, modified grille and ducting for the air intake. It used 12-inch Yokohama tyres, rated for speeds up to 150mph (240kph) and for 2012 the car was

‘It is, after all, a 1960s passenger car; over 20psi of boost puts a fair amount of load onto a small engine’



TECH SPEC

Project ’64 Mini Cooper S

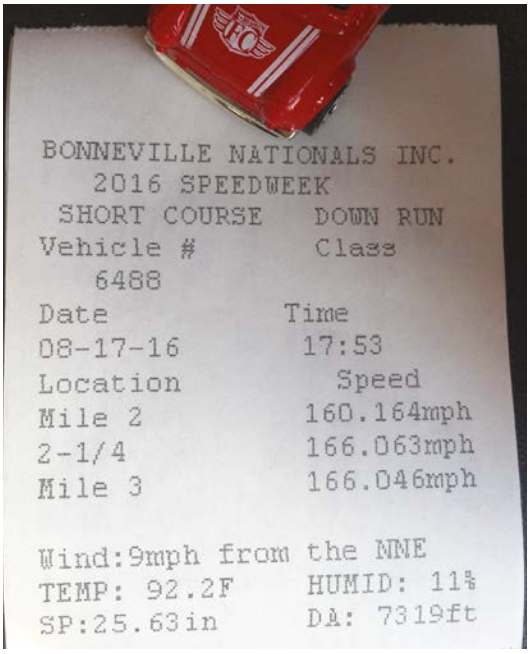
Chassis and bodywork: Mini 850 bodyshell (replacement for original Cooper shell); SCTA-approved rollcage; front air dam, smooth undertray, modified grille; ducting for air intake

Engine: A-Series 970cc Mini Cooper S block developed by Hartley Engines; BMW K100 motorcycle twin cam multi valve cylinder head; billet steel crankshaft; fuel injection; turbocharger and intercooler plus modern engine management. Power: 370bhp on methanol

Transmission: conventional straight cut close-ratio Mini gearbox; long diff ratios for high speeds

Suspension: Standard Hi-Lo adjustable rubber coned system with new uprated shock absorbers

Tyres: 12in Yokohamas shaved for speed by Nate Jones Tires



Speeding ticket: 166mph in a 970cc 52-year-old Mini Cooper is pretty impressive. Surely this has to be the fastest Mini (with an original A-Series engine and standard bodyshell) in the world?

entered under the SCTA I/BGCC class rules. I – for vehicles with an engine capacity of between 751cc and 1000cc; B – for blown engines (turbo or supercharger); G – for Gasoline; CC - for Competition Coupe; this category allows body mods like lengthening or chopping the roof.

Cooper-charged

In 2012 the team returned from Bonneville triumphant. ‘Despite a massive learning curve and losing both our engines as a result of oil starvation, we had managed to break our way into the record books,’ says Mike Wilson, media and sponsorship manager at Project ’64. ‘The plumbing was revised and a third engine was built from the remains of the first two, then a record top speed of 156.6mph (252.02 kph) was set in I/BGCC. Before that, the fastest A-Series powered Mini to be recorded on ‘The Salt’ was Don Racine’s 121mph (194.73kph).’

The team initially intended to return to Bonneville for 2014 Speed Week, but with the car not quite being ready and the weather marginal (it was eventually cancelled due to rain) Project ’64 decided on 2015 instead.

Its two new engines were a step up, with more power and better reliability, featuring two new billet crankshafts developed by Costa Mesa and Marine Crankshafts in California, USA, but there was still plenty of work to do before the planned 2015 runs. ‘One of our main concerns was eliminating harmonics from the three-bearing crankshaft at over 10,000rpm,’ said Nelson Hartley of Hartley Engines (see *RE* March 2016, V26N3), the Project ’64 Mini driver and engine builder. ‘It is after all a 1960s passenger car engine; over 20psi of boost puts a fair amount of load on a small engine.’

Then, while the team was in transit from NZ for Speed Week 2015, the event was cancelled, again due to bad weather. But a year later, when the team arrived in Los Angeles in early August 2016, one of their first jobs was to retrieve the Mini from storage. It made sense to store the Mini in California rather than ship it back. A couple of jobs left over from 2015 were done before the road trip to Utah. ‘Nate Jones Tires did their magic shaving our tyres, Burt Munro style, to lower their rolling resistance and raise their speed rating to 180mph,’ says Wilson. ‘On paper that was what the Cooper was geared for.’

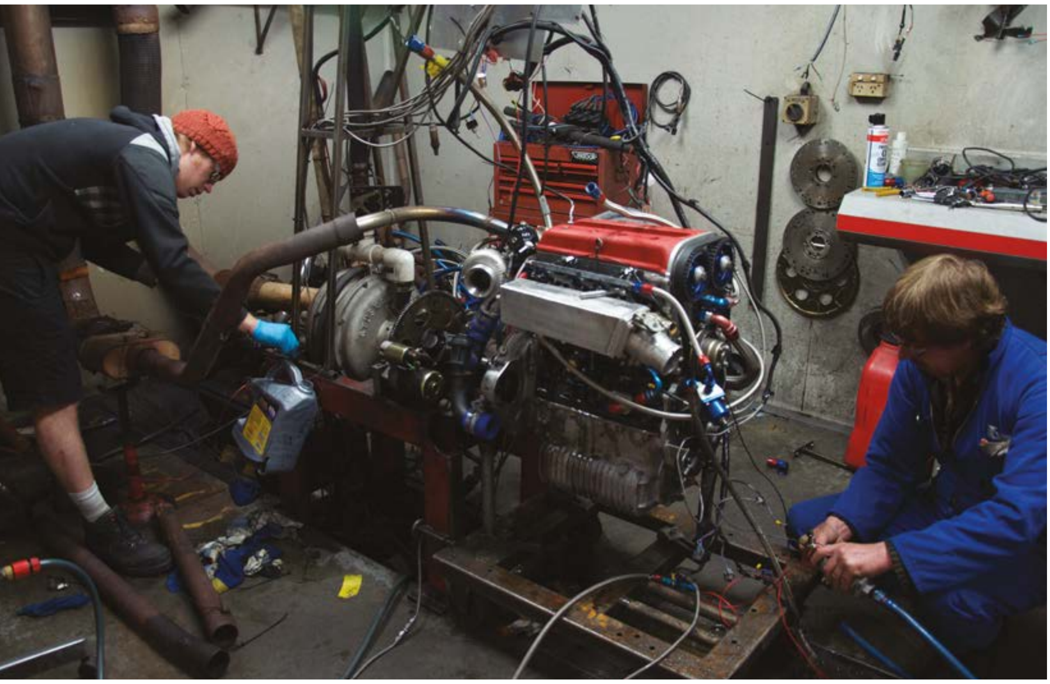
But while the Mini was in storage all the braided fuel lines had perished. ‘We went to fire it up on the Saturday morning before we were due to go for a run and fuel came out everywhere,’ says Hartley. ‘We pulled all the fuel lines out and replaced them and at this point, bits of the old fuel lines had clogged up all the injectors, so we lost a day there. Then we

While the Mini was in storage all the braided fuel lines had perished

wasted a couple of runs just trying to get the engine to run properly. We must have cleaned the injectors out three, maybe four, times. Bonneville is in the middle of nowhere, and we had no way of road testing the car. I think we managed to break a record with it running lean on about 30 per cent fuel!'

After setting a new record in the class for I/BGALT ('ALT' for 'altered', where you can change a limited amount of bodywork) at a disappointingly low 144.033mph (231.799 kph), the team then realised that the fuel available in Bonneville was too different from the fuel they had tuned the engine for in NZ for them to be able to get enough power in the time available. Without having access to a dyno they were relying on tuning the car on the track, but they could only get two or three runs a day.

In order to ensure that 'speeders' weren't running prohibited exotic fuels the SCTA supply controlled fuels, but the US gasoline in Bonneville was completely different to the gas they had used in NZ. 'They gave us this gasoline for turbo engines which, we assumed, was similar to what we used back home,' says Hartley. 'It turned out that it was a competition gasoline developed for extreme applications like dragster racing where the engine had to use petrol rather than some of the more exotic fuels. It was about 110 octane, which wasn't really much different to the Avgas we were using.'



The powerplant was prepared at New Zealand company Hartley Engines. The original A-Series 970cc unit showed an astounding 375bhp on the dyno when run on methanol. A BMW K-Series head was a vital part of the power package

Fuelled again

But the way fuel is rated in the US is completely different to NZ. 'We didn't know this at the time, but it turns out that this turbo fuel needs an extra 100degF to atomise effectively, so with our set-up we spent two days not being able to get the engine to rev past 8000,' says Hartley. 'Because our basic set-up was wrong for this fuel, we then went straight to methanol. And methanol is pure alcohol in any language. So what we tuned on in NZ was more or less the same as the methanol in the US.

'The US turbo fuel was probably awesome gasoline, if we'd known what it was and if we'd had a chance to tune the engine beforehand,' Hartley adds. 'Some people who use it get good results with it. [They] have fuel heaters in the car, even when the ambient temperature is high.'

On a tuning run for methanol, the car broke the 140.458mph (226.045kmh) class record with a speed of 158.039mph (254.339kmh). But it was unable to back this up by a second run due to a hose fault on its next attempt.

But once the problem was fixed it went out again and qualified at 153.710mph (247.372kmh), and backed it up the next morning for a record result in I/BFALT of 156.006mph (251.067kmh) – this new class, I/BFALT, is where F stands for Fuel (or free fuel, in this case a change from petrol to methanol).

Super Cooper

In the process the team managed to qualify for a third record, in the I/BFCC class which they had hoped to convert the next morning. 'On our first outing we ran 157.213mph, almost 3mph faster than the record set that same week by The Hudson Boys [a group of enthusiasts who have raced at Bonneville since the 1960s] in their streamlined Geo,' says Wilson. 'But when we returned to impound, we found a tiny error on our paperwork, one letter transposed, and the run didn't count. With no time to waste, we went out again and managed to slip in one last run at the end of the day.' This eclipsed all previous efforts by reaching an astounding 166.046mph (267.225kph) into a 9mph headwind.

The following morning the Cooper lined up for its last run on the Salt regardless of the outcome. It was the final day of racing. 'Any speed over 150mph would mean we would leave with a third record,' says Wilson. 'I remember watching from out on the return road; Nelson was going to pull the parachute one last time and I wanted photos from as close as I could get. Three miles away a small red

Cooling was a headache and the team fabricated this huge heat exchanger that sat within the car instead of relying on a conventional air to water radiator – it was filled with ice minutes before each run. Otherwise it's a classic race Mini interior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The Mini gets a nudge start, as wheelspin on the salt was a constant problem. To reach the high speeds attained with the standard gearbox some fairly long diff ratios had to be used

Much of the extra power was found through the use of the turbocharger, but it was a major challenge to eliminate the harmonics from the three-bearing crankshaft at over 10,000rpm

car came into focus through the haze and the glorious scream of its little engine pierced the peace of the Salt Flats. Then silence. The engine had finally let go. Nothing spectacular. Just a sudden drop in oil pressure, at 144mph. The little Mini arced off the course across the rough salt and drew to a stop.'

In the end the Project '64 team left Bonneville Speed Week 2016 with two world records and a fastest run of 166mph (267kph). 'We were planning for 170mph plus on our last run,' Hartley says. 'The conditions were perfect and we had finally found the sweet spot on the tune, but the little 970cc BMC A-Series motor said "enough" half way through the final run. We had pulled out the pin on this 370bhp hand grenade at the start of the week, and we had no intention of putting it back. At the end a lack of oil pressure stopped our last run.'

Salt shaker

It wasn't just the engine that caused problems for the Project '64 team, though. With such a compact car the wheelbase and the track are not ideal for straight-lining at an average speed of 251kph on salt. 'This Mini was not designed to travel at more than 80mph (128kph),' says Hartley. 'It all starts getting serious at 240 to 250kph, when the car really starts moving from side to side.'

'The engine had finally let go. Nothing spectacular. Just a sudden drop in oil pressure, at 144mph'

Suspension was the Hi-Lo adjustable rubber coned system that was used on all early Minis, but with new uprated shock absorbers added. The body and chassis was near-standard, with a flat floor and undertray

Keeping the car on the salt and not leaving the ground, was also a challenge, but the answer was keeping things simple. 'We tried to keep the silhouette as standard as possible as well as the suspension side of it,' says Hartley. 'We had a flat floor and undertray, with just an air dam at the front. We really went to a lot of effort not to change the car too much, so that it would be as recognisable as any other road going Mini. We just modernised the drivetrain to include turbos, fuel injection and modern engine management to get more power.

'The suspension was the Hi-Lo adjustable rubber coned system prevalent in 1964 with new uprated shock absorbers,' Hartley says.

Worth its salt

'We made as many components in house as we could,' Hartley adds. 'Everything had to be strong and, as mentioned before, getting rid of the harmonics from a three-bearing crankshaft at 20psi of boost and 10,000rpm is never easy. With pure methanol fuelling we made just over 375bhp on the dyno in NZ, not bad for an engine that started life with roughly 60bhp.'

The BMW K-Series cylinder head is actually a readily available kit from Specialist Components (see box out). 'The kit isn't really intended to produce much more than about 150bhp,' says Hartley. 'To get it up to 350-plus we had to beef everything up and we elected to make our own cams and produce our own inlet and exhaust manifolds. All that coupled with packaging the turbo, intercooler and heat exchanger under the hood of a standard Mini, was a bit tricky, but it was probably the temperature control that had us the most concerned.'

Instead of relying on a conventional air to water radiator the team fashioned a massive heat exchanger positioned inside the car next to the driver, filled with ice minutes before each run. The engine water ran from the engine bay, to the cabin, then back to the engine bay.

But the component that eventually let them down was the generic BMC A-Series oil pump. For those readers who know the A-Series, this is the peculiar eccentric lobe device on the back end of the camshaft. Because the cylinder head was swapped out for a BMW K-Series twin cam cylinder head, the old A-Series camshaft was retained as a jackshaft just to drive the oil pump.

Fine whine

The gearbox was also a conventional straight cut, close-ratio Mini gearbox that is fairly common in classic Mini motorsport circles. That, coupled with some fairly long diff ratios, allowed the Mini to achieve reasonably high speeds. In the picture at the top left of this page you will see the car getting a nudge start as wheelspin on the salt was a constant problem. Because of the frictional characteristics of the salt there's not a lot of load on the transmission, so wheelspin, when it comes on boost at 100mph in the third gear, was not uncommon.

The crank is a chrome moly billet crank and it was machined as a five-bearing crank even though the A-Series engine only uses three. By machining it with five-bearing counterweights it was easier to balance and smooth out the harmonics that occur at high revs. This kind of thing has been done for years with MGA and MGB engines, where a five bearing crank was used in a three-bearing block.

The main bearings were stiffened by using steel bearing caps throughout with a centre main strap in the classic A-Series tuning fashion, using a piece of inch-square section, high tensile engineering steel (EN24T or similar) and longer main bearing bolts. This allows the engine to rev comfortably to 10,000 with no dramas. 'In truth the engine was built to last about eight to

'We took a tiny, much-loved car and we broke land speed records with it'

For the record: driver and engine builder Nelson Hartley (with the New Zealand flag) and the Project '64 crew after the team's Mini Cooper S broke two class records at the Bonneville Speed Week

10 runs,' says Hartley. 'We didn't expect it to last much longer. The way things panned out we ended up doing about 12 runs before it expired … We kept qualifying for record attempts with the high-speed runs we were putting in,' Hartley adds. 'At Speed Week every time you hit a personal best, it usually qualifies you to enter the car under another category to chase another record. Because we were going so well, we ended up getting two records and qualifying for a third when we only really went there for one.

'By the time we got to putting some boost into the engine and running it properly we'd almost worn the thing out,' Hartley says. 'Our top speed 166mph run was still only a moderate run for us. We had another 10 miles an hour left, easy – we just weren't able to do it.' The reason? 'We wasted too many days trying to tune the engine for the conditions. Which is why we will be taking a portable dyno the next time we go to Bonneville Speed Week.'

'It wasn't just the difference in fuels,' Hartley explains. 'It was much hotter on the Salt and the air at altitude was a lot thinner. The only way we could tune the car and check it was to do high-speed runs, but there was no facility on the lake for people to do test runs alongside the main speed circuit. The organisers couldn't really afford to do that as there would be 400 or so entrants all wanting to do test runs; it would be chaos. So in the two days we wasted we only maybe got in three test runs.'

Pass the salt

But Hartley admits that this is par for the course with this kind of competition: 'I don't know if anyone gets a perfect run in Bonneville, something always seems to go wrong or the conditions aren't quite right. You spend all day tinkering until things are running the way you want them to and then the wind gets up. Or the winds die down and the track falls apart. Or you get halfway down the strip and the engine starts to lean out – it's actually a long way and you have to queue for five hours just to get one run. There's a lot of hanging around in Bonneville.'

The only departure from a standard mini silhouette was a snorkel poking through the front of the bonnet, to get undisturbed air in to the turbo. This was done by intuition rather than hi-tech CFD and it probably needed a fancy venturi at the intake end, but it seemed to work. 'Much of the project was calculated guesswork, which is why when we go again, we'll do some proper CFD work before we start,' says Hartley. But where can this project go from here?

'It would be nice to give the new Mini a go, but so much depends on what commercial arrangements we can make,' Hartley says. 'It would be really nice to go with a car manufacturer, but it's still early days yet.

'There are also some basic things that we need to know,' continues Hartley. 'Things like how much energy is required to get the vehicle up to a certain speed on salt, exactly what point it starts to lift, and where the best place is for us to position the air intake.

Maxing a Mini

Hartley adds: 'I don't know what sort of speed we're going to aim for in the next project because it's probably going to be dictated by the type of car we take,' Hartley says. 'There are lots of different categories there and some are more popular than others.

'But we have such a strong team, the Project '64 brand is really cool,' Hartley says. 'We were easily one of the favourites amongst the crowd, and we put on a really professional show. It would be nice if we could turn this in to a marketing tool for a manufacturer, whilst also achieving something for ourselves.'

Wilson is philosophical about the project: 'It's easy to focus on the "what might have beens". If we had more time the spare motor would have been put in the car and we would have gone again; if we had got the paperwork right first time we might have had the record on that last run; if we had entered a more modern car it all would have been easier. We prefer the facts: we took a tiny, much-loved car, that was designed for economy and known for being quick around corners, and we broke land speed records. We took a car that people love to claim has the aerodynamics of a brick and without resorting to swapping in a modern powerplant, took it to 166mph. We took a Mini to Bonneville, and we had a great time.'

Special K

The cylinder head for the Project '64 Mini is taken from the BMW K series range of motorcycles that were introduced in 1982 and manufactured until early 2000. It is an all alloy twin cam construction with both 8v and 16v versions available. The block modifications are the same whichever option is chosen.

It is a fairly standard, twin overhead cam, modification for the A-Series engine. The heads are available in kit form with most things included in the kit. This kit has become popular because the BMW head is dimensionally very similar to the A-Series block and the combustion chambers have similar volumes to the A-Series head. In fact, three of the A-Series head studs can be left in place at the front of the block to locate the other head stud drilling locations. All the new water jacket drillings are located using a template from the kit.

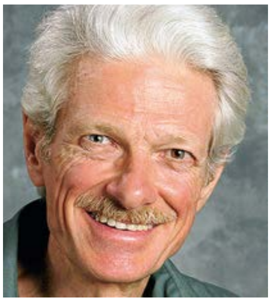
Hands on deck

It's not exactly an operation for a DIY weekend warrior, but most engine tuners and tuning shops would have few problems with it, and it represents about three hours work for a well stocked machine shop.'You leave the front three stud holes alone,' says John Kimmins of Specialist Components, which makes the kit. 'Then plug everything else up; waterways, push rod holes and other head studs. If you are using an external oil feed, the oil transfer hole needs to be blocked up too. We use head studs for blocking the old stud positions and threaded bar for the other holes. We supply a drilling template, which you use to mark out all your new positions. It has small holes for centre-punching through.

'If you are going dry deck, like the Hartley engine is, you just have to drill and tap new head studs,' Kimmins adds. 'If you want a wet deck you will need to drill all the new waterways to match up with our custom alloy/copper head gasket.'

For the wet deck you need to weld up the front piece of the cylinder head where the chain used to run, as well as welding up the two oil drain holes at the back and tap a 3/8in BSP hole for a new oil drain system. The front of the welded head needs to be flushed off for the CAM sprockets backplate to seal against. 'Our gasket matches the BMW waterways with the new waterways in the block,' says Kimmins. 'If you want a dry deck you need to weld all the waterways up in the head too.'

Specialist Components has been doing these engine conversions for 11 years and it is a one-stop-shop for everything, including custom ECUs. It also supplies wiring looms, exhaust manifolds, cams, big valves, ported heads and billet heads.



Keeping a sense of proportion with brakes

What effect does a brake proportioning valve have on a racecar?

QUESTION

I have been an enthusiastic reader of *The Consultant* and your newsletters since 2000. But another subject I get excited about is brakes. I captured the data pictured (below right) in support of my proportioning valve discussion, which involves a proportioning valve in the rear brake line.

This allows the car to have more rear brake on a gentle application than it has on hard application. This is particularly helpful when it is raining

There's also the case where, as the brake pedal is released during trail braking at corner entry, the brakes bias more toward the rear.

As a school of hard knocks kind of guy with a few years under his belt, I have an observation that you may appreciate. I suspect that this is why you typically see the inner rear wheel lock on corner entry on a traditional tin top (proportioning valve). And you typically see the inner front wheel lock on corner entry on a traditional formula car (bias bar).

I would be grateful for any comments you could give on these observations.

THE CONSULTANT

This chart (bottom right of this page) appears to be a data acquisition plot from a real car, set up for 50 per cent front brake or at least identical front and rear line pressure, when the proportioning valve is below the knee point – a 400psi knee point – and about four-sevenths, or 57 per cent, pressure reduction beyond the knee point.

The data appears to have been taken with the car stationary and the brakes applied and released more gradually than would actually be seen when racing, to show the action of the proportioning valve more clearly.

If the racecar was actually racing, we would expect to see a much more abrupt brake application and also a brake release lasting a lot less than nine seconds, unless the car is on a large oval track.

Anyway, the hysteresis effect – higher rear brake pressure during release than during application – is real, and is widely recognized. On the next page there is a chart from AP Racing (this is available for free download at their website, incidentally). This shows an idealised graph of input and output pressure of one of its proportioning valves. The AP graph illustrates a similar effect to the traces below. For a given input pressure, the output pressure is higher during brake release than during brake application.

The AP graph shows no drop in output pressure as the input pressure first decreases, but it shows the output pressure starting to drop before it is completely equal to input pressure. The trace actually does show a slight drop in output pressure when input pressure first begins to decrease, but then output pressure holds steady while input pressure drops from 1500 to 1000psi. The 1000psi point is where input and output pressures are equal during release. They are only equal up to 400psi during application.

At around 16.5 seconds, which is during release, the input pressure is around 1300psi and output pressure is 1000psi. During application, output pressure doesn't get that high until input pressure reaches 1800psi. A 1300psi input pressure on application produces only 800psi output.

AP notes that the hysteresis effect is quite variable. It is affected by where the knee point is set. An earlier knee point results in more hysteresis. It is also affected by the fluid volume required to operate the brakes.

AP doesn't say, but I would expect that larger cylinders, more fluid displacement, and lower pressures would increase the effect (and would certainly require a lower knee point pressure for a given application, which alone would increase the effect).

Does this mean we shouldn't use proportioning valves in racecars at all? Or, if we do use them, what are the effects on racecar behaviour and what allowances for those effects are appropriate?

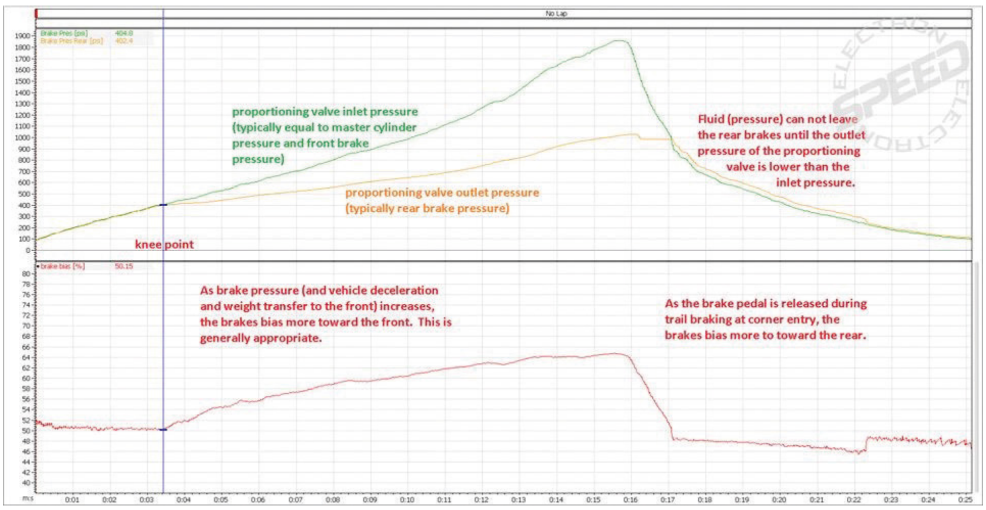
Even without hysteresis, just having more rear brake on light application than we would have with only a balance beam makes the car freer (adds oversteer) when trail braking.

The hysteresis further exaggerates this. But is that really so bad? For trail braking into a high speed sweeper, maybe.

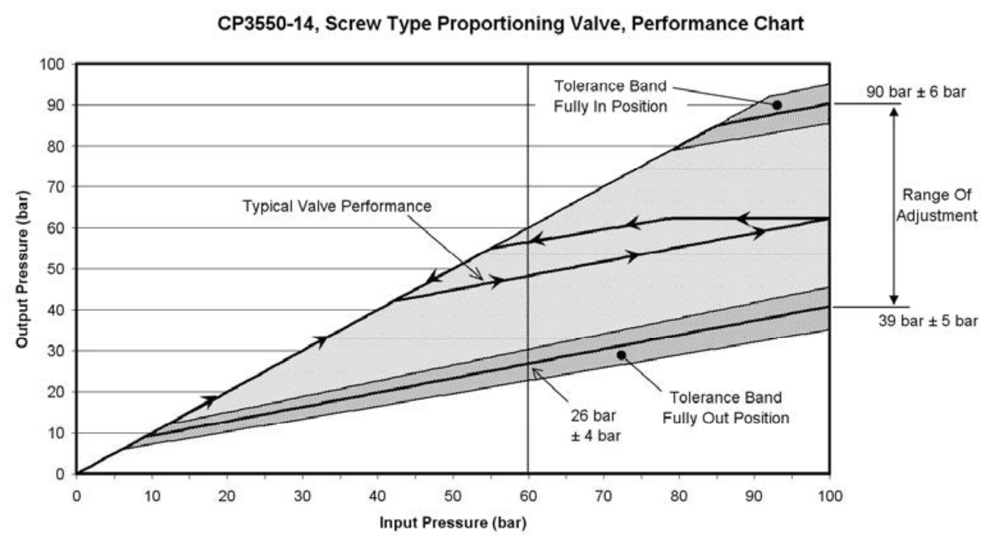
On the other hand, for a situation where we want to toss the racecar in to the corner with the brakes, to use the brakes to make the car rotate, as in autocross or rallying, it may be an advantage. In most cases it will require a later knee point than would be needed if hysteresis were absent.

Can we tell if a car has a proportioning valve based on whether the inside rear or inside front wheel locks first in trail braking?

Does this mean we shouldn't use proportioning valves in racecars at all?



The data presented here appears to have been taken with the car stationary and the brakes applied and released more gradually than would actually be seen when racing – to show the action of the proportioning valve a bit more clearly



GRAPH NOTES:
HYSTERESIS IS GREATER WITH THE CAP IN THE FULLY OUT POSITION AND IS AFFECTED BY THE REAR FLUID DISPLACEMENT.

AP graph shows that for a given input pressure the output pressure is higher during brake release than brake application

Not necessarily. That will really depend on the lateral load transfer distribution as well as the brake force distribution, and how the racecar's brake bias is overall.

However, it is certainly true that a racecar with a proportioning valve will have more tendency to lock the inside rear, and less tendency to lock the inside front, than the same racecar with only a balance beam, with all other things being equal.

Would it be possible to eliminate hysteresis? Perhaps. I don't know if this has been tried, but it would be possible to create a knee in the rear brake pressure curve with a return spring at the rear master cylinder, arranged to only operate once the piston has moved to a particular displacement. This spring could be either inside the cylinder or outside, perhaps coaxial with the push rod. This would have no hysteresis.

It would create a knee point that would depend on master cylinder piston travel rather than line pressure. I am not sure whether this would create unwanted changes in the knee point in actual use. Probably an external spring would be better than one inside the cylinder, to allow for knee point adjustment.

In any case, it is definitely possible to race successfully with a proportioning valve, but it is necessary to understand the device's properties and effects, including hysteresis, and tune around them.

CONTACT

Mark Ortiz Automotive is a chassis consultancy service primarily serving oval track and road racers. Here Mark answers your chassis set-up and handling queries. If you have a question for him, get in touch.

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Shaving drag from a Formula Ford

Our quest for a super-slippery Swift SC92F continues

When the Swift SC92F that is the subject of our current investigations was originally constructed, Formula Ford had already been in existence for 25 years, so the designers of this, and other marques, had had plenty of opportunity to minimise frontal area and drag coefficient. But did they leave any stones unturned in the quest for optimum sleekness? We put the writer's hillclimb variant to the test in the MIRA full-scale wind tunnel to find out.

Other than the timing strut on the nose this car is representative of pre-1994 Kent engine Swifts and indeed Formula Fords worldwide. And apart from the wider sidepods that house lateral intrusion structures on later Formula Fords, it's not too different in overall aerodynamic concept from any Formula Ford racecar. Thus, with no downforce generation permitted in the rules, aerodynamic improvement is solely down to minimising drag. Given the reasonably sleek shaping, any improvements were thought likely to be small, so the overall gains found throughout our session were actually a pleasant surprise.

Last month we used the MIRA smoke plume and wool tufts to visualise and identify areas that might yield drag reductions, and there were several areas where improvements looked achievable. In this issue we'll examine the initial batch of improvements made, but first let's look at the baseline data and compare it to the Spectrum Formula Ford we examined in 2007, a car that featured the aforementioned wider sidepods and lateral intrusion structures.

In order to directly compare the data we will be using CD.A and CL.A figures, that is, coefficients multiplied by frontal area, as these are directly proportional to the measured aerodynamic forces at any speed and also eliminate any discrepancies in the measurement of frontal area.

So if there was any doubt that the earlier car had room for drag improvements then **Table 1** must surely eliminate this, for despite the somewhat wider sidepods the Spectrum's drag was more than 15 per cent lower than the Swift's, suggesting the intervening 15 years of development had yielded aerodynamic fruit.

Interestingly, the Spectrum also developed greater rear lift than the Swift; lower drag and higher rear lift may not be unrelated if both arose from sleeker shaping at the rear. However, the focus here was squarely on examining drag reductions as being the only legitimate and worthwhile way of improving aerodynamic performance, so let's not dwell

Would the writer's 25-year-old Swift SC92F respond to our drag reduction measures?

Table 1 – Baseline data on the 1992 Swift SC92F and the 2007 Spectrum FF

	CD.A	CL.A	CLf.A	CLr.A
Swift	0.495	0.175	0.140	0.035
Spectrum	0.428	0.261	0.140	0.120

Table 2 – The effects of taping over the radiator inlet

	CD.A	CL.A	CLf.A	CLr.A
Baseline	0.495	0.175	0.140	0.035
1 strip	0.493	0.173	0.138	0.035
2 strips	0.485	0.165	0.132	0.033
3 strips	0.483	0.163	0.133	0.030
Δ, counts	-12	-12	-7	-5
Δ, %	-2.4%	-6.9%	-5.0%	-14.3%

The Spectrum we tested back in 2007 had lower overall drag than the earlier Swift despite the presence of those wider sidepods, which house lateral intrusion structures

Strips of race tape were applied incrementally to the radiator inlet ducts of the Swift

Blanking plates were fixed to radiator exit apertures to mask a quarter, then a half, of area

Would these shaped inlet reducers prove more efficient than the simple race tape?

Table 3 – The effects of blanking the radiator exit apertures (inlets still taped)

	CD.A	CL.A	CLf.A	CLr.A
No blanks	0.483	0.163	0.133	0.030
¼ blanked	0.478	0.162	0.134	0.029
½ blanked	0.475	0.158	0.131	0.028
Δ, counts	-8	-5	-2	-2
Δ, %	-1.7%	-3.1%	-1.5%	-6.6%

Table 4 – The effects of the radiator exit blanks alone, compared to the baseline

	CD.A	CL.A	CLf.A	CLr.A
Baseline	0.495	0.175	0.140	0.035
½ exits blanked, no inlet blanks	0.478	0.162	0.133	0.029
Δ, counts	-17	-13	-7	-6
Δ, %	-3.4%	-7.4%	-5.0%	-17.1%

Table 5 – The effects of shaped inlet reducers, when compared to the race tape inlet blanks

	CD.A	CL.A	CLf.A	CLr.A
Using tape	0.475	0.158	0.131	0.028
Using reducers	0.476	0.162	0.133	0.029

on the fact that both these racecars actually created modest lift forces.

The race tape is generally only brought to bear at the end of a session, but as the Swift had been run with more than half of the radiator inlet ducts taped over for the past two seasons (to prevent over-cooling and hopefully to reduce drag), this was the first configuration change in this session. Three strips of tape were applied incrementally, the third diagonally at the outer, lower corner of the duct inlet, and **Table 2** shows the results along with the overall changes, expressed as 'Δ' (Greek letter delta) values in 'counts' (1 count = 0.001 in a coefficient) and percentages. The '%front' and 'L/D' values usually reported in these tables have been omitted because we are not looking at either the balance or the efficiency of downforce, as we normally do.

Blank tape

Once more race tape proved its worth then, with a useful drag reduction and, as a bonus, a significant lift reduction, too. In addition to tape over the inlet ducts, roughly half of the cooling exit apertures had also been taped over for the past two seasons. How much drag was this worth? Panels were taped in place to incrementally mask a quarter, then a half, of the exit apertures, and the results are in **Table 3**.

Further benefits were achieved with the exit blanks then, and in combination with the inlets being taped over, a worthwhile 20 CD.A counts or four per cent drag reduction was achieved by partly blanking the cooling exits. And again there was the bonus of lift reductions that amounted to almost 10 per cent in total. It was also noteworthy that the wool tufts on the vertical face of the sidepod downstream of the radiator duct exit showed that the flow was faster and better attached with the blanking plates fitted, suggesting better acceleration (and extraction?) of exhausted cooling air.

But what would the radiator duct exit blanking panels achieve on their own? The tape was removed from the radiator inlet apertures and the car was run again; results in **Table 4**.

We can see that most of the benefit of blanking both the inlets and outlets was achieved by just blanking the outlets. This points to somewhat different mechanisms that were clearly not additive. Individually, comparing Table 4 with Table 2, blanking the exits achieved a better drag reduction than blanking the inlets, while the changes to lift were very similar. However, the drag (and lift) reductions were greater when using both inlet and exit blanking.

Radiator inlets on most racecars have generally been well designed with nice, radiused lips to encourage clean flow into the ducts, and your writer has always frowned upon the use of tape to blank them off (despite using the technique himself) because flow separation is likely to occur at the sharp edge.

Shaped reducers

Surely properly shaped inlet aperture reducers would function better and yield further improvements? With this in mind reducers comparable in coverage to the three pieces of tape were hand-shaped from polyurethane foam block, with radiused lips and tapered internal faces, and taped in place, with the exit blanks still affixed. **Table 5** shows the results.

Rather frustratingly, the results with the shaped inlet reducers were certainly no better than using the tape, and may even have been a little bit worse! Perhaps the workmanship was not quite up to standard here?

Next month we'll look at more ways in which drag was reduced on the Swift; some were surprisingly successful, some less so.

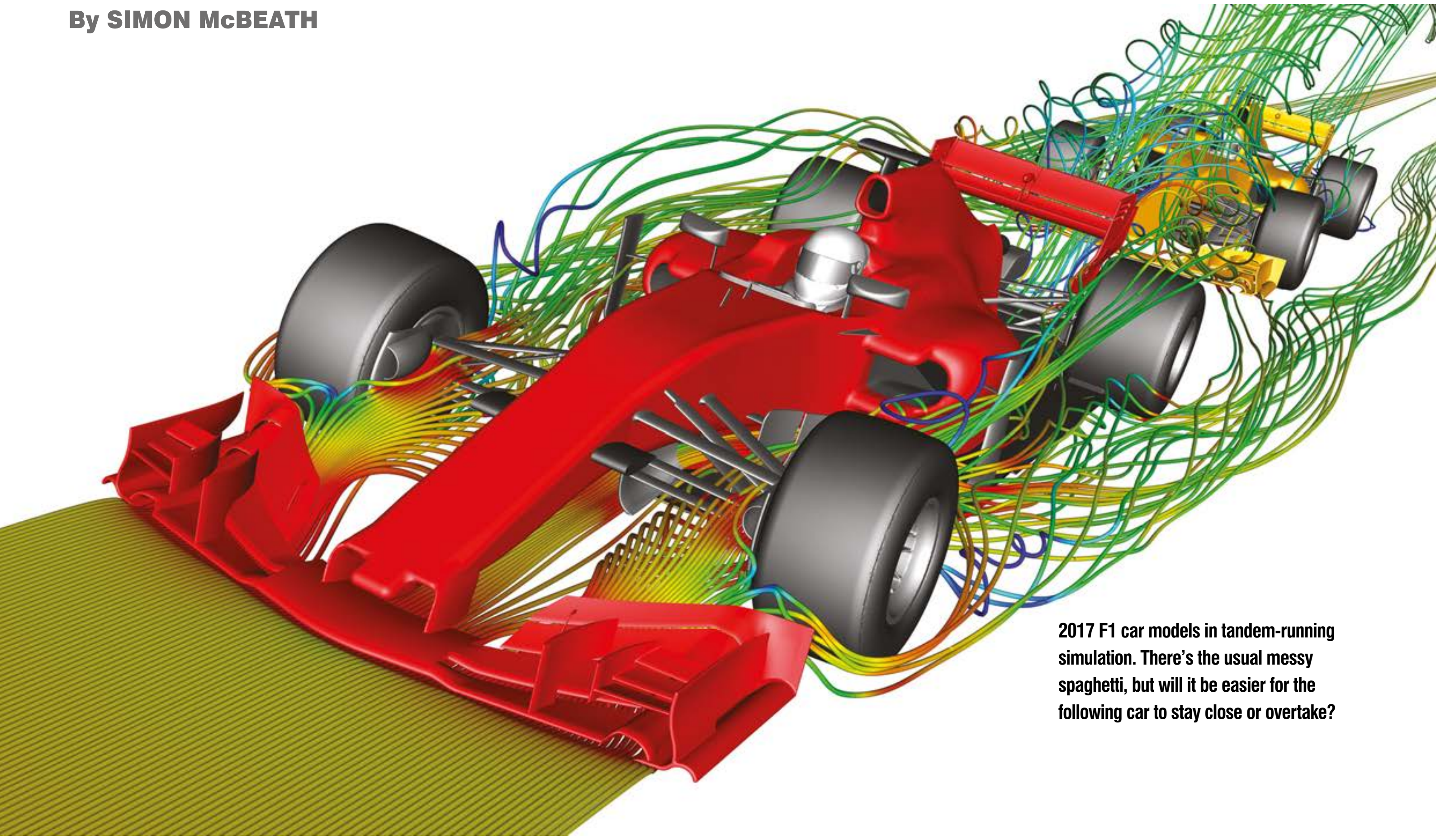
The overall gains we found throughout our session were actually a pleasant surprise

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

Follow the leader

Downforce is set to increase in Formula 1 in 2017 but will the new regulations improve or reduce the ability of cars to run close together or overtake?

By SIMON McBEATH



2017 F1 car models in tandem-running simulation. There's the usual messy spaghetti, but will it be easier for the following car to stay close or overtake?

With official F1 testing scheduled to take place at the end of February, time is now short for the teams to complete the build of their initial aerodynamic packages to the new regulations that come into force for 2017. And with limits on the amount of wind tunnel testing and CFD that the teams are permitted to do under the Resource Restriction Agreement, it is improbable that any of them have indulged in the relative luxury of running their new designs in multi-car scenarios to see how they will perform in traffic. Their focus will inevitably have been on hitting the track with a package designed to achieve the best lap time, and one which will form the basis for ongoing developments.

However, with designs and CFD services provided by Miqdad Ali (MA) at Dynamic Flow Solutions, *Racecar Engineering* can show the results not only of optimisation work on the 2017 rules model introduced in our December issue (V26N12,) but of running that car in two-car line-astern drafting scenarios that we can compare to the similar trials we have conducted in the past 18 months.

The rationale behind our line astern two-car simulations has been that the effect on the aerodynamics of a following car has an enormous influence on a driver's ability to get close to the car in front. And being able to get close is the essential preliminary to being able to overtake, which definition here excludes artificially assisted passing manoeuvres that use DRS, or 'push to pass' engine modes, or the release of stored energy. The FIA's passing reference (pun intended) to the topic of overtaking was seemingly just to request that the new rules should not make the current situation any worse. Now we can demonstrate what the initial 'following car' simulations on our 2017 rules model have indicated, and our findings are surprising indeed. But first, let's look at the optimisation work that MA has performed on the new 2017 car model to bring its balance and downforce closer to expected levels so that he had a good basis on which to conduct the line astern simulations.

Improvements

The 2017 rules model introduced in last month's issue did not quite achieve the desired aerodynamic balance or the expected total downforce level in initial simulations. With the statutory weight distribution in F1 requiring around 45 per cent of the weight on the front axle, the aerodynamic balance target was also to have 45 per cent of the total

Now we can demonstrate what the initial following car simulations on our 2017 model have indicated, and our findings are surprising indeed

Table 1: The basic aerodynamic parameters on our baseline 2017 FIA rules F1 model at 50 per cent front balance level			
	CD	-CL	-L/D
2013	1.17	3.94	3.36
2016	0.87	2.84	3.27
2017	1.20	3.91	3.26

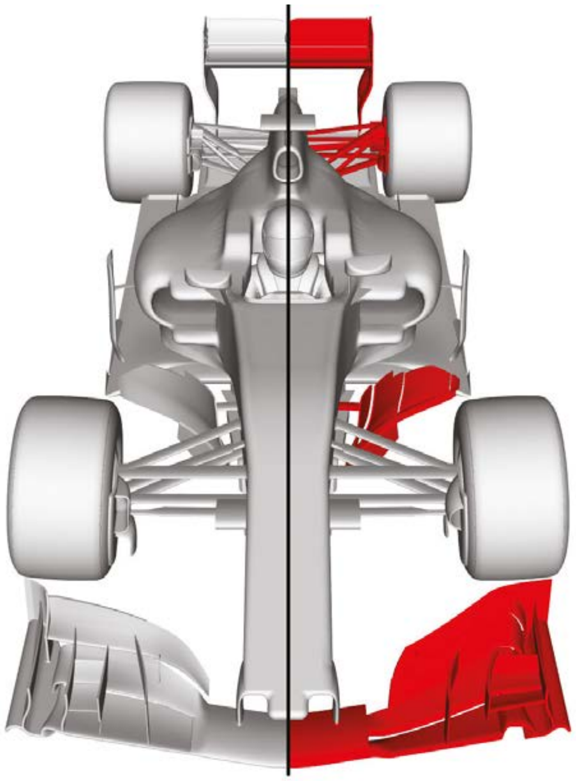


Figure 1: Areas optimised on our 2017 model are highlighted in red. The front wing, bargeboard, rear wing flap and rear wheel brake duct cascade were all re-designed

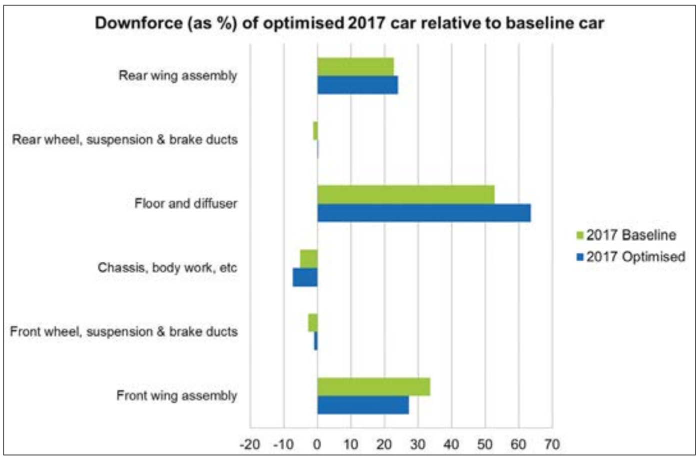


Figure 2: The effects of our optimisation work on the 2017 Formula 1 racecar model. Gains in downforce were made from the underbody and the rear wing areas of the car

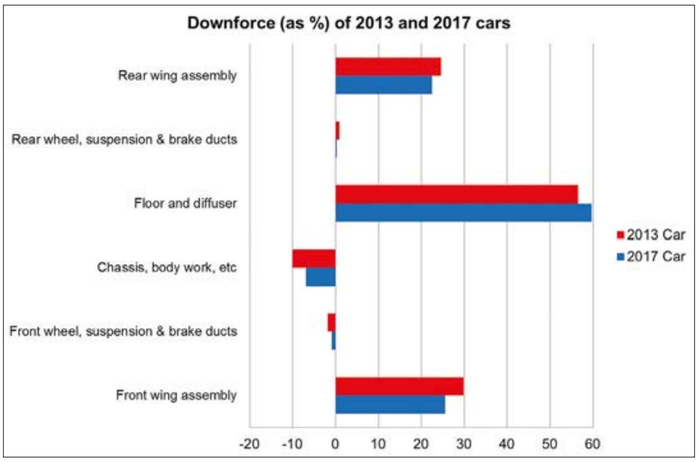


Figure 3: Comparing downforce contributions with our 2013 model. It's clear here that the underbody of the car has become even more important with the 2017 configuration

downforce on the front axle. In its first design iteration our model generated a 50/50 per cent split in downforce, so clearly more work was required to generate some more rear downforce, and/or to reduce front end downforce. At the same time MA was also looking to achieve greater total downforce, as he explained: 'In the previous feature we compared three cars at equivalent balance levels of roughly 50 per cent front and that gave us an idea of where things were, as shown in **Table 1**. The next target was to optimise our 2017 car both for balance and downforce. We also wanted to compare the optimised 2017 car with our earlier optimised 2013 car (at 45 per cent front), against which our following-car simulations on various design configurations have been compared in previous articles, and run the optimised 2017 car at various separations behind a leading 2017 car to see how it performed when following. This would give us an idea of how it compared to the 2013 racecar at various line astern separations and whether the 2017 rules had made things any better.'

MA continued: 'To improve both balance and increase downforce there were several things on the baseline 2017 car which obviously needed work straight away. One would expect this anyway when you make simple changes to a car which works well under one set of regulations to meet a different set of regulations. The first thing to address on the 2017 baseline model was the size of the front tyre wake. The results and visualisations showed that the baseline front wing and its endplate did not do a good enough job of diverting the airflow outboard of the wider front tyres. Secondly, the 'y-250' area [where the neutral section of the front wing terminates, 250mm from the centreline] of the 2013 front wing worked well with a raised nose where the resulting y-250 vortex interacted well with the vane-vortex coming from the under-nose turning vane. The lowered nose on the 2017 car changed the flow in that area considerably. We were not getting the flow conditions needed for producing efficient downforce. There is also the presence of the bigger bargeboard, which would need careful placing in the context of all the other flow structures around the area. Also, the baseline front wing produced more downforce than required.

'A new front wing was designed to address the above issues. The outboard section diverted the flow around the front tyres a lot better, resulting in a smaller front tyre wake. A reduction in chord length of the main element reduced front wing downforce by the required amount. The strength of the y-250 vortex was increased through the use of smaller flap elements at higher AoA. Moreover, the y-250 vortex was moved outboard (to y-320) (through reduced span of the flap elements) and worked better with the bigger bargeboard in deflecting the front tyre wake away from the underfloor. All these produced a more favourable flow condition behind the front wing which helped the underfloor produce more downforce and shifted the balance to the rear.

'To improve the underfloor further, several vertical slots were added to the bargeboard, which kept the flow attached to the inner face of the bargeboard; this in turn kept the pressure low and improved mass flow in that area. It also increased the strength of the bargeboard vortex (which added downforce in the

The visualisations showed that the baseline front wing did not do a good enough job of diverting the airflow outboard of the wider front tyres

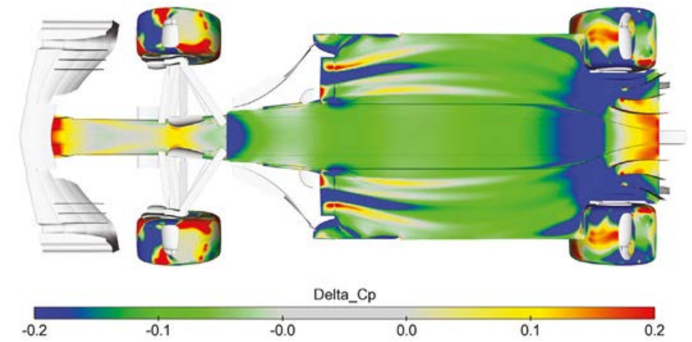


Figure 4: This delta-Cp plot shows where pressure reductions were achieved with optimised 2017 model, leading to downforce gains, especially in the rear underbody

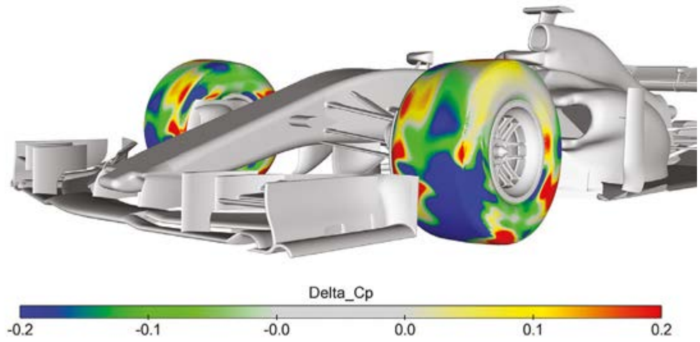


Figure 5: Turning the airflow more effectively outboard around the tyre also produced reductions in front tyre drag, as shown by the pressure reductions (blue) on front of tyres

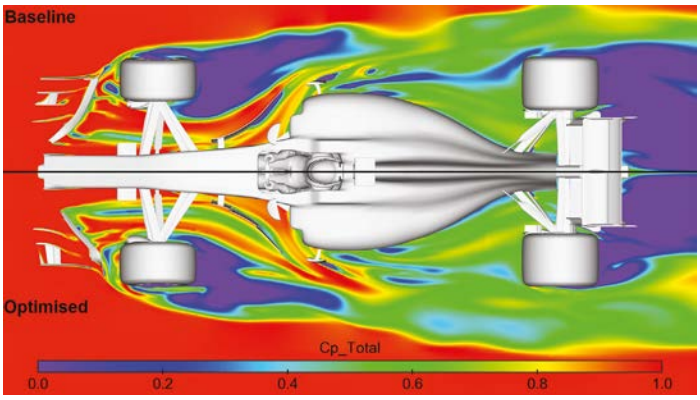


Figure 6: A total pressure slice taken 200mm above ground level clearly shows the reduced front tyre wake on our optimised 2017 Formula 1 racecar model

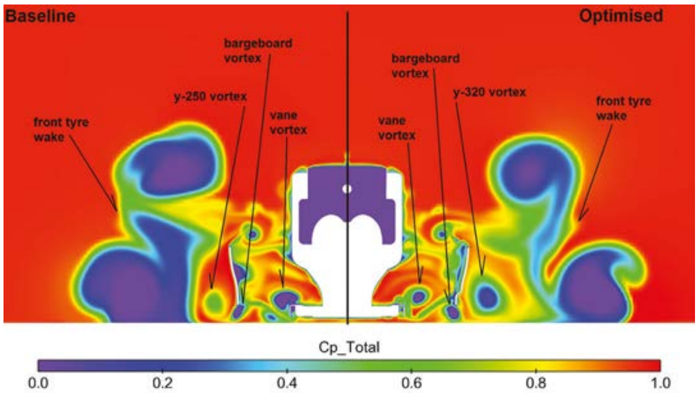


Figure 7: A total pressure slice 900mm behind the front axle line shows how the flow structures were modified by the optimisations; note the front wheel wake reduction

Table 2: The basic aerodynamic parameters on our optimised 2017 FIA rules Formula 1 model compared with our earlier 2013 Formula 1 model racecar

	CD	-CL	%front	-L/D
2017 optimised	1.20	4.31	45.0%	3.59
2013 optimised	1.17	3.89	45.0%	3.32

forward underbody) due to a bigger pressure difference across the two faces of the bargeboard.

'Moving to the rear of the car, minor changes were made to the rear wing flap profile, reducing its camber to fix some trailing edge flow separation. The slot gap between the main element and flap was reduced from 12mm to the minimum permitted 10mm. And gills were added to the rear wing endplate leading edge to deal with flow separation there. Rear wheel/tyre assembly lift was reduced via the use of brake duct cascades. All these changes increased overall downforce by over 10 per cent over the baseline 2017 car, with a desired downforce balance of 45 per cent front and 55 per cent rear,' **[Figures 1** to **7]**

Table 2 shows the basic aerodynamic data for this optimised 2017 model and compares it to our earlier optimised 2013 rules model. The 2017 model now generated over 10 per cent more downforce than the 2013 model. Given that the 2014 to 2016 regulations caused a marked decrease in downforce compared to the pre-2014 rules, it looks as though our optimised 2017 model was producing significantly more downforce than our 2016 model would have done at the same balance level, had it too been optimised.

From this we might conclude that, following the optimisation work MA carried out, our model may not be too far from expected Formula 1 aerodynamic performance levels amid the reported predictions by F1 insiders of up to 25 per cent more downforce in 2017 than in 2016.

Tough act to follow

So, coupled with increases in mechanical grip from the bigger tyres being imposed for 2017, Formula 1 lap times will certainly decrease for cars running in isolation. But how will following cars in line astern formation fare? We have seen in our various studies over the past 18 months that the car's basic aerodynamic configuration can alter the total downforce and aerodynamic balance that a following car can generate. MA created one configuration, among others, that saw zero balance shift on the following car across the range of longitudinal separations from eight car lengths to half a car's length, and another that saw much reduced total downforce losses when following, although achieving both certainly looked like the search for the Holy Grail. Meanwhile, out on track in all the recent rule-defined aerodynamic configurations we have seen how cars have suffered from aerodynamic understeer when closing on the car in front, and our simulations on models to recent rule sets have shown this rearwards shift in aerodynamic balance at ever closer line astern separations too, which has made it manifestly difficult for following cars to close up on the car in front.

It was felt that minimising or eradicating this rearwards shift in downforce balance was key to mitigating the problem of being able to follow closely, and we saw in V26N2 (February 2016) how increasing the influence of underbody aerodynamics was one of the important factors in minimising balance shift on the following car. The 2017 rules enable a greater downforce contribution from the underbody, so could we be optimistic of change for the better?

The data from our 2017 rules model in two-car line astern is outlined below, and **Figure 8** illustrates the changes to the usual aerodynamic parameters across the range of horizontal separations from half a car's length to eight car lengths. It is immediately obvious

It was felt that minimising this rearwards shift in downforce balance was key to mitigating the problem of being able to follow a car closely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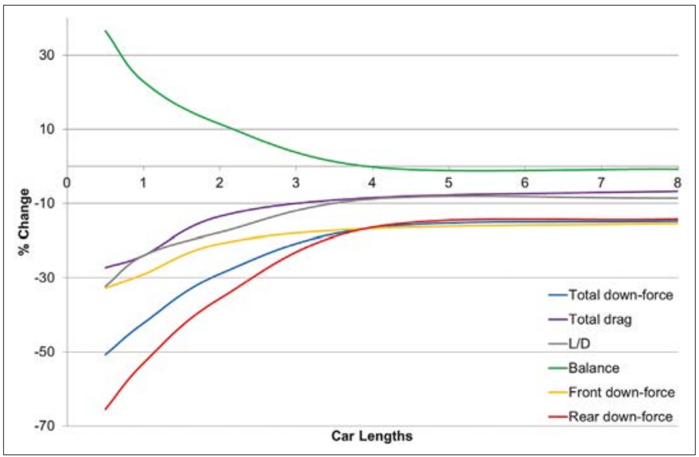

Figure 8: Changes to the principal aero numbers on optimised 2017 car when following

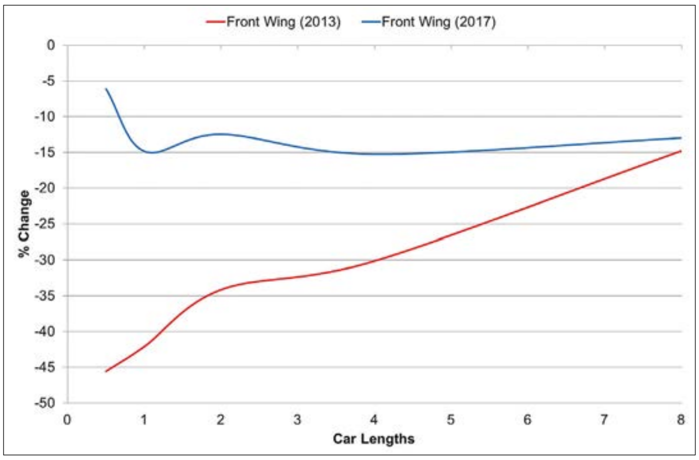

Figure 9: Changes to front wing downforce on our optimised 2017 car when following

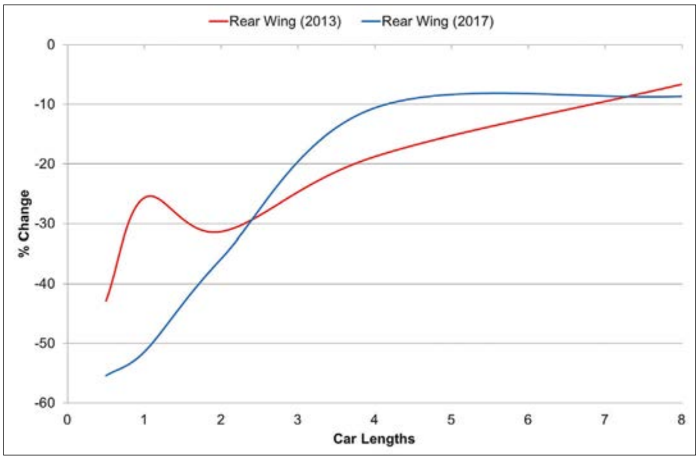

Figure 10: Changes to rear wing downforce on our optimised 2017 car when following

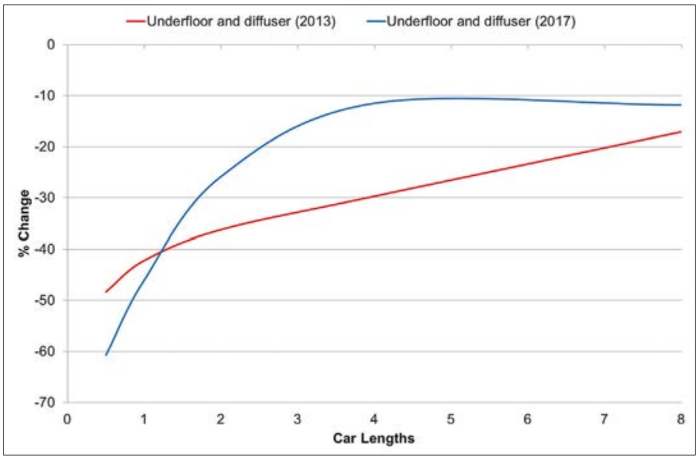

Fig 11: Changes to underfloor, diffuser downforce for optimised 2017 car when following

that there are some major and very surprising differences with this 2017 configuration. The most obvious difference is in how the aerodynamic balance on the following car changes across the separation range.

Initially there was zero balance shift at eight and four car lengths separation, which does indeed give ground for optimism that cars could run closer. This minimal balance shift at these separations, combined with just a modest initial decline in total downforce, and the increased mechanical grip of the 2017 cars, should make things easier for the following driver as he first starts to close on the car in front.

However, the subsequent forwards balance shift at closer separations is the complete opposite of what we have become used to and is an intriguing and – if it translates to reality on track – a slightly worrying response for the closer separations.

The plot lines in **Figure 8** showing the front and rear downforce changes with car separation confirm the forwards balance shift, with front and rear downforce declining similarly and modestly from eight to four car lengths separations, but at closer separations both ends declined further, but rear downforce declined much more.

Translating the relative data in the graph to absolute numbers, what we saw on our model was the balance figure change to about 50 per cent front at two cars' separation, 55 per cent front at one car's separation and about 61 per cent front at half a car's separation, compared to the 45 per cent front figure on our model in isolation and at eight and four car lengths' separation. If this were to transfer out on to the track, what we could see in 2017 when cars try to run close together in line astern through 'aero speed' corners is that the following car might initially be able to get closer more comfortably than in previous configurations but then, as it closed more, become prone to aerodynamic oversteer. This may simply manifest itself as just that, oversteer. But could it be that drivers will risk spinning off if they get too close to the car in front?

The detail

Figures 9, 10 and **11** isolate the downforce changes of the front and rear wings and the underbody across the range of longitudinal separations to help understand why our 2017 rules model responded the way it did. In contrast to previous car configurations, with our 2013 rules model shown here for comparison, the 2017 model's front wing maintained a good proportion of its downforce at all separations. This in isolation was quite a step forwards; previously the loss of front wing downforce as cars closed up on the one in front was the dominant cause of rearwards balance shift and aero understeer when following through a corner. But our 2017 rules model did not suffer this to anything like the same extent as we had seen on earlier models, and had this been the whole story then we might be contemplating – indeed celebrating – a scenario in which balance shift when following closely was minimal.

It was unfortunate, then that, after the initial modest downforce losses at eight and four car lengths the rear wing then lost considerably more downforce as the car got closer to the one in front. A not dissimilar pattern affected the underbody, and the rear wing's losses will have been directly related to the underbody losses because of the interaction between the two; once the rear wing lost downforce, so too did the underbody. Thus we appear to have a

This may simply manifest itself as just that, oversteer. But could it be that drivers will risk spinning off if they get too close to the car in front?

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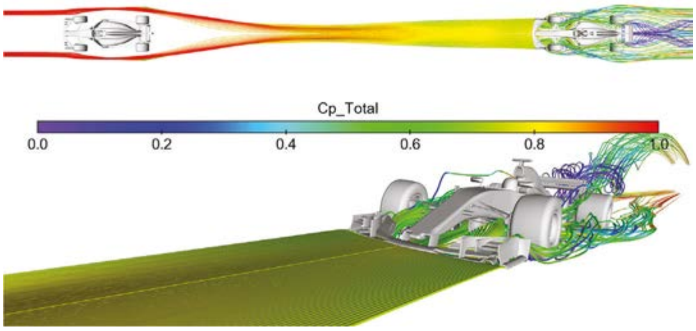

Figure 12: At four car lengths separation the front wing of the following racecar received a reasonably energetic and a well aligned airflow

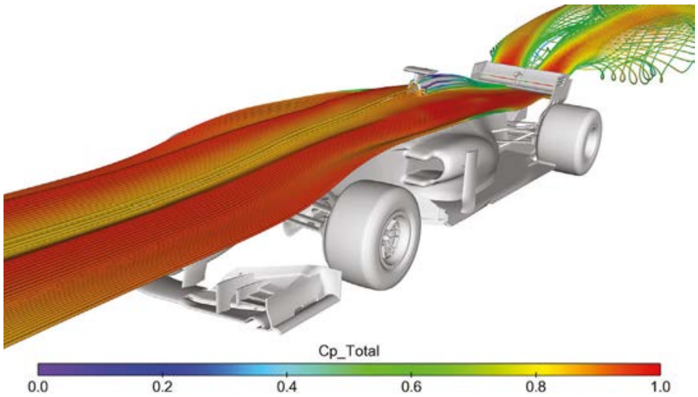

Figure 13: At four car lengths separation the rear wing of the following racecar also received a reasonably energetic and a well aligned flow

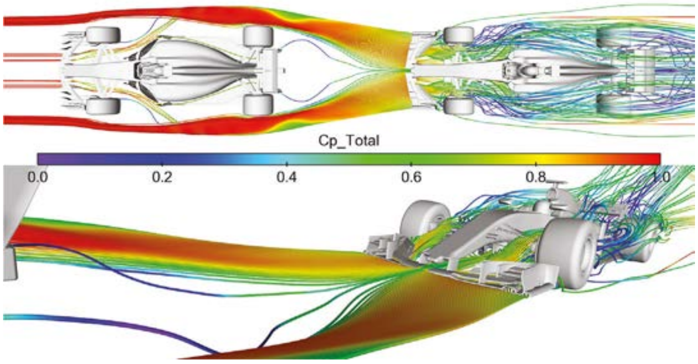

Figure 14: At half a car's length the front wing of the following car still received decent airflow; in fact the swept back shape seems to align with the onset airflow

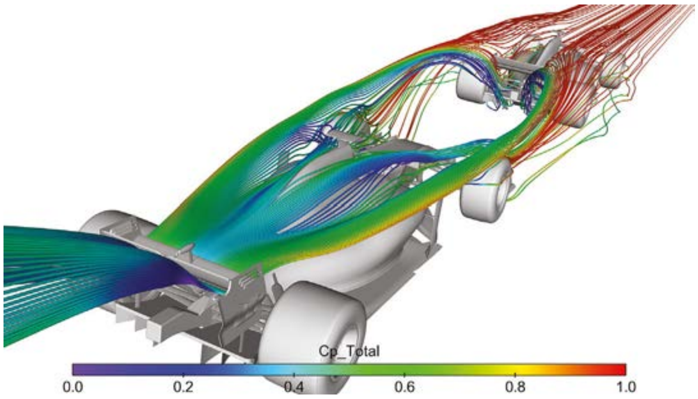

Figure 15: However, the rear wing did not fare quite so well at closer separations, receiving lower energy and a disturbed airflow

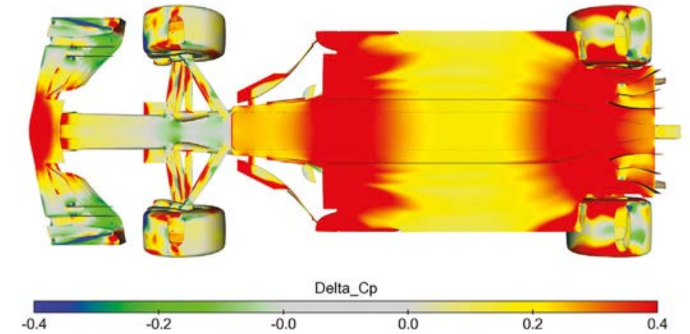

Figure 16: Here the delta Cp plot of the underside at half a racecar's length separation shows that the front wing incurred relatively minor pressure changes

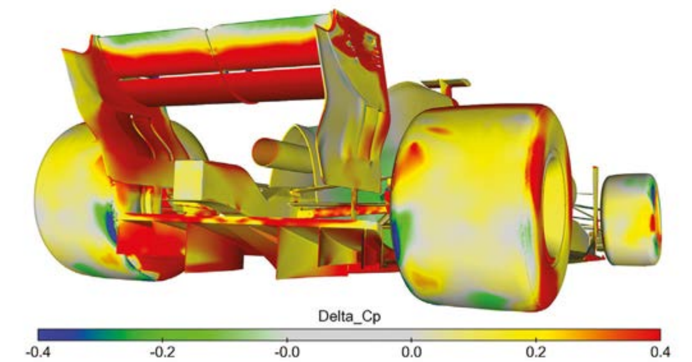

Figure 17: At half a racecar's length separation the rear wing saw pressure increases on its suction surface that created significant downforce loss

configuration that saw this forwards balance shift at close quarters. The question is, why did it happen?

Looking first at streamline images of the wings at four cars' length separation, in **Figures 12** and **13** we can see that both the front and the rear wing of the following car received flow with reasonably high total pressure, or energy, as shown here by the relatively high coefficient of total pressure. Furthermore, the flow direction was reasonably well aligned with the ideal. Thus, the wings were able to generate a high proportion of what they would have generated when the car was running on its own.

If we now look at **Figures 14** and **15** at half a car's length apart, in the case of the front wing we can see that streamlines impinging on it were not just reasonably high energy but also had reasonably good flow directionality, too. MA picked up the explanation here: 'When we look at the streamlines approaching the front wing at half a car's length we can see that most of the flow was high energy coming from outboard of the lead car thanks to the in-wash caused by the highly cambered rear wing, which is a lot closer to the ground [than under 2016 rules] and therefore so was the in-washed flow to the front wing. This helped the front wing keep its performance. Furthermore, the swept back nature of the 2017 front wing worked well with the in-washed flow since the flow direction was aligned with the front wing. In fact, the front wing only lost six per cent of its downforce at half-car length whereas the rear wing lost around 55 per cent. When we look at the delta Cp plots in **Figures 16** and **17** we can clearly see that the front wing maintained most of its downforce since the pressure changes were less, whereas the rear wing showed significant changes in static pressure.'

Looking at **Figure 15** showing the streamlines impinging on the rear

The wings were able to generate a high proportion of what they would have generated when the racecar was running on its own

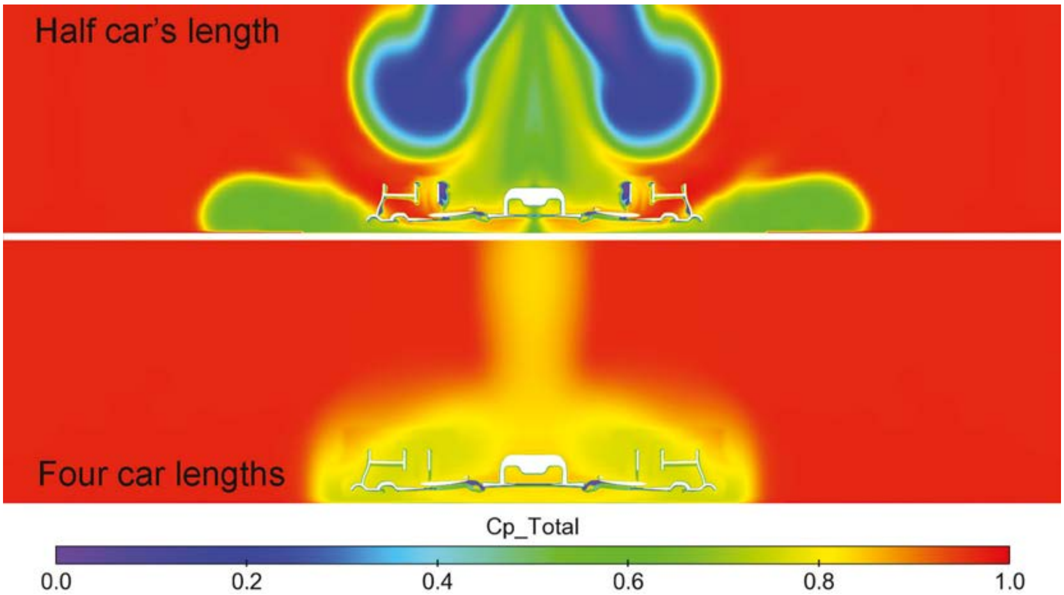

Figure 18: Energy of airflow impinging on front wing leading edge didn't change much from four car lengths to half a car length

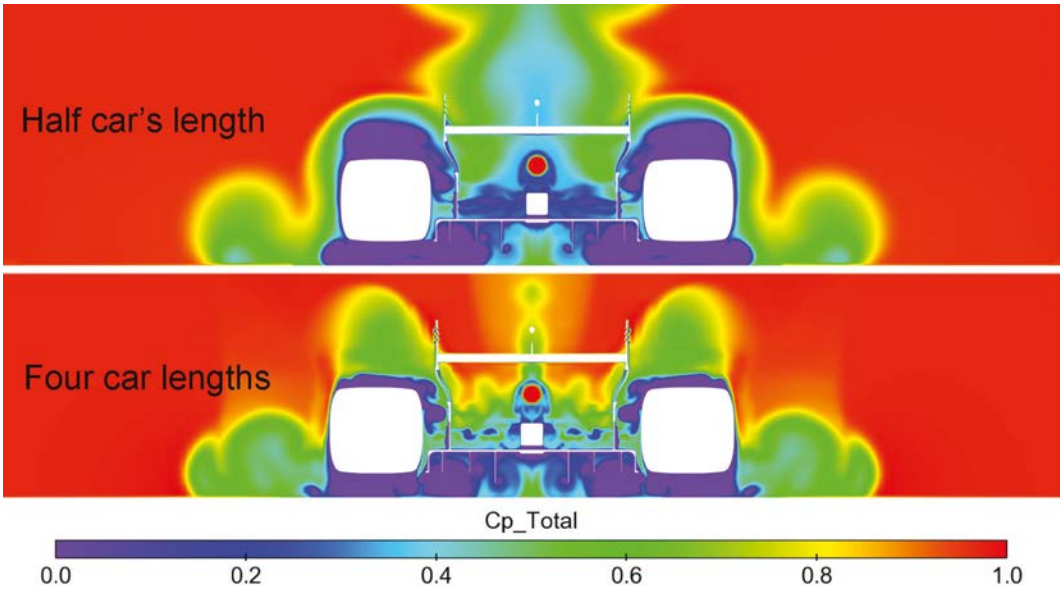

Figure 19: Here it can be seen that the energy of the airflow impinging on the rear wing's leading edge was much reduced at half a car's length separation compared to the situation at four car lengths separation

Dynamic Flow Solutions

Dynamic Flow Solutions Ltd is an aerodynamics consultancy led by director Miqdad Ali, ex-MIRA aerodynamicist, who has performed design, development, simulation and test work at all levels of professional motorsport from junior formula cars to World and British touring cars, Le Mans prototypes, up through to Formula 1 and Land Speed Record cars.

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Ex-MIRA aero man Miqdad Ali ('MA'), is boss of Dynamic Flow Solutions

wing of the following car at half a car's length separation the story was quite different, as MA related: 'The in-wash which was beneficial to the front wing also had to go around the front tyres. The resulting front tyre wake headed to the rear wing along with the rear wing vortex coming from the lead car. The streamlines approaching the rear wing clearly show this. By the time the flow reached the rear wing it had lost a significant amount of energy and the direction it approached from was not ideal either.' Thus, the relatively benign situation at eight and four car lengths' separation had turned into a significant and intrinsically unstable forwards balance shift at separations of two lengths and less.

Total pressure slices in line with the front and rear wing leading edges at four car lengths and half a car's length separation **(Figures 18** and **19)** complete the story and show how the energy of the airflow encountering the front wing remained high even at the closest separation, whereas that which impinged on the rear wing had lost significant energy at half of a racecar's length.

Cause for optimism?

Could our findings just be a particular characteristic of our interpretation of the 2017 rules, or is the forwards balance shift at closer separations likely to be a generic effect? MA commented that 'our model has the same basic architecture as the cars will have, with the bigger wheels and tyres, and the wings to the sizes and in the locations they have to be, so the main flow structures will be pretty similar. But I'm optimistic that things will be better in 2017, and it looks as though the initial response when closing will be to allow the cars to get closer more easily – I hope so anyway!'

So now we wait to see what happens when the cars hit the track, and in all likelihood it won't be until the first race of 2017 that we get an idea of how running in traffic has or has not changed. It will be fascinating to see if the new aerodynamics and mechanical layout do provide any help to drivers trying to close up on the car in front through a corner. The FIA's brief to the rule writers was to not make 'the overtaking problem' any worse. Would the response we have seen here fit that requirement?

In one sense perhaps it would, although it might simply change the reason for the fact that the underlying problem, at least in part, remains! But let's remain optimistic that what looks to be at least a partial fix for the aerodynamic reasons for the difficulty in following closely, combined with an increase in mechanical grip, will improve the situation overall.

Could our findings just be a particular characteristic of our interpretation of the 2017 rules?

Dimple minded

Ever wondered what impact the use of dimples or rough surfaces has on the aerodynamic performance of a racecar? One Cranfield student was determined to find out. Here are his findings

By MATTHEW R THOMAS

What impact would dimples or irregular surfaces have on the aerodynamic performance of a competition car? It is a question which will inevitably crop up among motorsport engineers when chatting, but it has never really progressed much beyond that stage.

Matthew R Thomas, a Motorsport Engineering and Management MSc student at Cranfield University, decided to try to answer that question with his thesis: *The Use of Dimples to Improve the Aerodynamic Performance of Aerofoils used in Motorsport*. This thesis is thought to be the first serious work of its type, and the article which follows is based on it.

Flow attachment and separation

The objectives of the research were to validate the hypothesis that dimples can reduce drag on aerofoils used in motorsport applications, and investigate the effect on lift, particularly at steep angles. Being able to manipulate the point at which laminar/turbulent boundary layer separation/re-attachment occurs at varying *Re* and angles of attack is useful in controlling (and giving predictable) lift and drag characteristics.

Over the years a number of solutions have been used in F1 for this purpose including using serrated trailing edges on the rear wing to promote reattachment of the flow when the DRS closes. Trailing edge blowing has at least in some form been tried out in F1. An inverted version of this device shown in **Figure 1** can be seen in the 2015 F1 'S' ducts placed in the nose, for example, on the Mercedes, Red Bull and Toro Rosso. This technique has also been applied to the front wing of the 2012 Mercedes linked to the DRS to de-activate it when the DRS is enabled, and so improve front-rear aerodynamic balance and give an overall drag reduction.

A variation on this theme is the use of blowing air on to the aerofoil surface to cause separation and drag reduction, such as used in the now banned F duct.

Vortex generators are commonplace in many areas of a modern F1 car. However, over the years other less common approaches have been proposed and even trialled. Vortex generation using tangential blowing was investigated in the past, including on a 1999 Ferrari rear wing. This showed an improvement in performance by prolonging attachment of the airflow, but as far as the author is aware, did not make its way onto an F1 car.

Boundary layer suction has also been proposed but in reality it's application, be it active or passive, is difficult to implement. Any porous surface would be difficult to maintain in an F1 environment where there is significant amounts of debris collected on the external surfaces of the car during a race.

One technique which is particularly interesting is the application of 'Riblets' by 3M

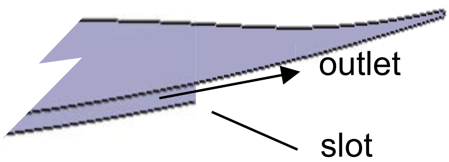


Figure 1: Trailing edge blowing

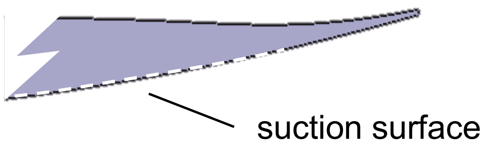


Figure 1.1: Suction

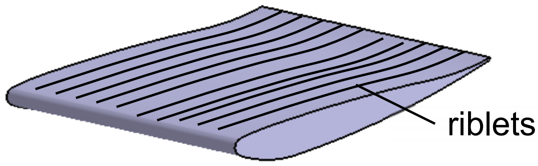
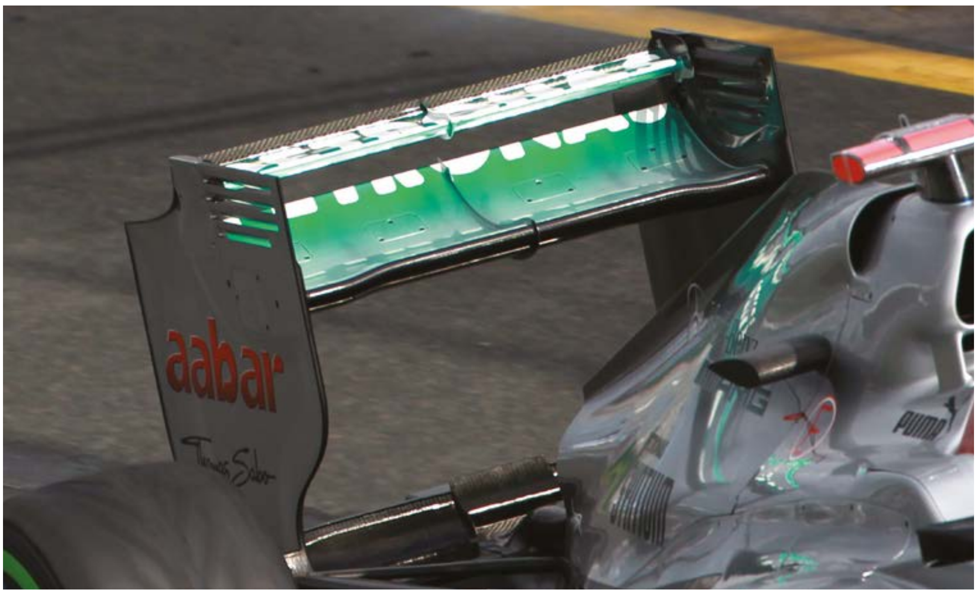


Figure 2: Riblets



In 2012 Mercedes used serrated trailing edges on the rear wing to promote reattachment of the flow when the DRS closes

in the Americas Cup (**Figure 2**). Studies have investigated the use of riblets and their ability to reduce drag by up to 11 per cent on a test subject. The grooves found in shark skin are similar to these riblets and are thought to be more effective, but are harder to manufacture.

At the other end of the spectrum, very smooth surfaces could also in theory improve performance but a technical report into this approach by Boeing has said that smooth surfaces have little impact in comparison to other techniques, and they are difficult to maintain in real life (e.g. insect impacts).

Neither of these approaches have been used in F1, for practical reasons of manufacture or maintenance – although the use of non-stick coatings could prevent the build-up of debris.

However, the flow control potential of dimples has yet to be fully evaluated, at least for this application. It is the use of dimples (and

Using dimples for aero gain has been experimented with many times

bumps) which this study set out to understand. The effect of surface roughness on the drag of spheres has been well documented and related research includes the use of dimples to aid heat transfer, some of which also documented the impact of dimples on drag in fluids.

Dimples and aerofoils

The benefits of reduced drag due to dimples on golf balls, and the use of raised dimples (bumps) to improve heat transfer, are well understood.

However, their application to aerofoils, both generally and in motorsport, has not been as well researched in comparison to more conventional flow control techniques, such as wedge shaped vortex generators.

Using dimples for aerodynamic gain has been experimented with many times and in particular on Tour de France bike frames and wheels, but not all of the data from these trials has been published. It's worth noting that a number of leading cycle teams continue to experiment with surface roughness of both the bicycles and the riders' clothing to reduce drag.

Although the use of dimples appears to have potential it has not been extensively used in motorsport or in automotive engineering. But an attempt to demonstrate the reduction in drag using dimples on a car was made by Hyneman and Savage. This showed an overall reduction in drag, but was not aesthetically pleasing and it lacks scientific rigour. For example, the reduction may have been caused by the dimpling edge at the trailing edge of the roof/boot enabling the airflow to stay attached for longer or, alternatively, acting like a gurney flap, rather than due to a reduction in drag along the main surfaces.

Dome, in Japan, constructed a very high efficiency version of the Honda Insight in more recent times which featured some dimpled surfaces, but the firm has not revealed its research to date.

Willem Toet, the former head of aerodynamics at the Sauber F1 team, claims that he has investigated the impact of dimples on a Formula 1 car as recently as 2012. However, he remains unconvinced, saying: 'Covering a whole vehicle with any single treatment would not be practical or beneficial. We have invested in this research in the past and spent some money and energy on it again in 2012, but this did not lead to an improvement. From time to time we believe that, due to new information, we have a chance to improve performance in this way. However, so far we have not found permanent improvements using this technique.'

However, some years ago one of the organisations conducting aerodynamic research for cycling teams spoke out in *Racecar Engineering,* wondering if there was more to it: 'I wonder if dimples may only increase skin friction drag at high speed, but possibly increase downforce and reduce drag at low speed?'

This comment, combined with the experimental results which shows lower drag in certain circumstances for dimpled spheres, and the lack of detailed work in their application to aerofoils, suggests that there is scope for further work in this area of dimpled surfaces, which

An inverted trailing edge blowing device as used on the Toro Rosso S duct sited in the nose of the 2015 car

Dimpled surfaces are used widely in cycle racing having been pioneered by Zipp Speed Weaponry

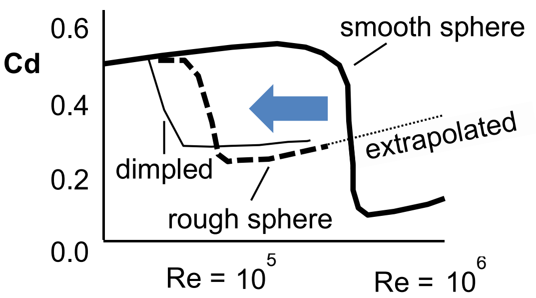


Figure 3. Drag for smooth and rough spheres at differing ***Re***

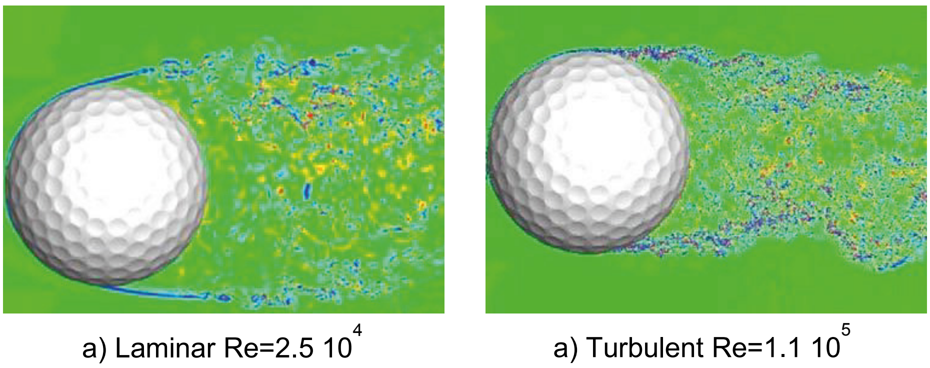
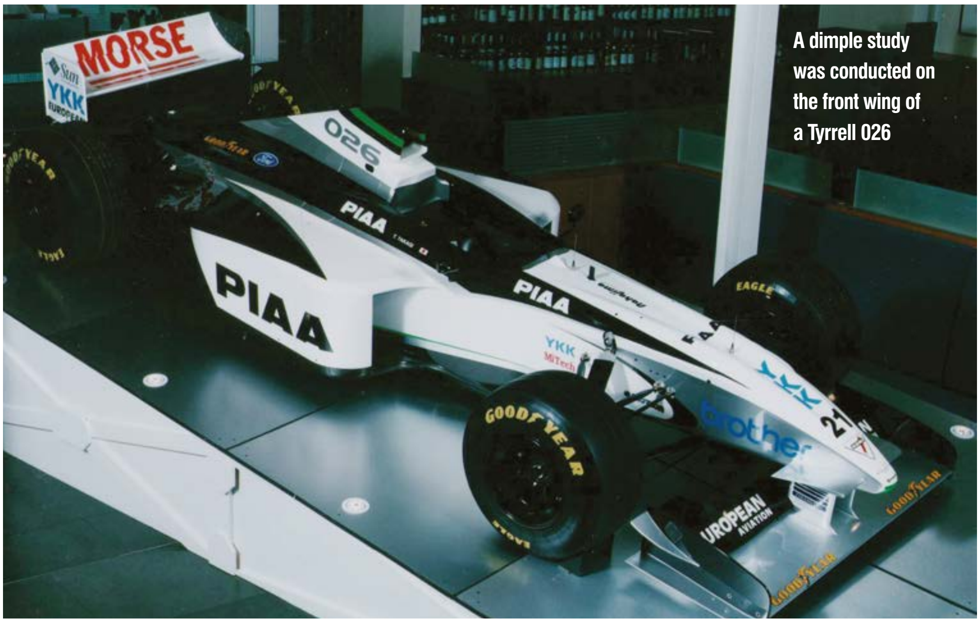


Figure 4. Laminar and turbulent flow field around a golf ball



A dimple study was conducted on the front wing of a Tyrrell 026

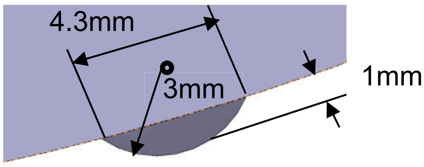


Figure 6: Dimple/bump geometry (cross section)

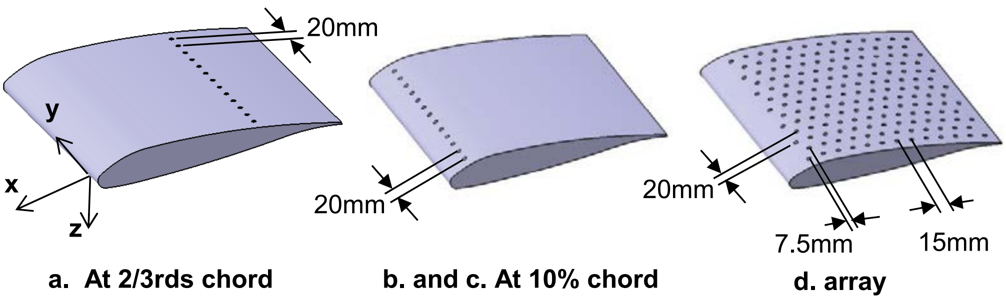


Figure 5: Positioning of bumps or dimples on wing as seen from below

provides the motivation for the new research, which we will pick up here.

Adding dimples

Adding dimples to the surface or increasing the roughness of a sphere reduces the drag in the region of *Re* 0.5 x 105. This is based on experimental data from previous research and is reproduced in **Figure 3**. Note how the whole drag/*Re* curve shifts to the left due to the early onset of turbulent flow caused by the surface roughness/dimples. Just like golf balls, using dimples may have the potential to reduce the drag of aerofoils which operate across this *Re* range. Dimples also have a key benefit of being insensitive to flow direction, unlike more conventional fixed vortex generators.

The drag reduction due to dimples or surface roughness is achieved due to the early transition to turbulent flow, which enables the airflow to remain attached around the sphere for longer. This in turn reduces the unattached low pressure area behind the sphere and reduces the pressure drag **(Figure 4)** which more than offsets the increase in friction drag.

This suggests that the use of dimples and bumps could be a useful flow control technique. For example, in curved areas with adverse pressure gradients, such as aerofoils and diffusers. They may also be an appropriate replacement to vanes, such as those found on the upper surfaces of radiator inlets on F1 cars. Another interesting application could be in MotoGP, where aerofoils are banned from 2017, but there are a number of curved surfaces on the bike fairing and the rider's protective gear.

Tyrrell study

Using the front wing of a Tyrrell 026 as a test subject a study was conducted using a CFD RANS (Reynolds Averaged Navier Stokes) solver with a k-ω SST (Shear Stress Transport) turbulence model. Various types and layouts of dimple were tested at a variety of wing angles and the results compiled.

The primary aim of the study on the Tyrrell wing was to quantify the effectiveness of dimples on aerofoils used in motorsport as a way of improving drag and lift performance across its operating range (i.e. speeds of 70mph-200mph). The objectives were to validate the hypothesis that dimples can reduce drag on aerofoils used in motorsport applications, investigate the effect on lift, particularly at steep angles of attack where separation is likely, and to characterise the key design parameters of dimples for this purpose. The methodology relied on the use of CFD modelling calibrated against known experimental data for a motorsport aerofoil (hence the use of the Tyrrell wing). This was to allow a range of different dimple locations to be tried which would be more difficult to achieve as cheaply and quickly using wind tunnel models. The CFD model was then applied to a number of dimple configurations from which results are extracted and used to deliver the report objectives.

Four sets of dimples/bumps were modelled for comparison with the plain unaltered aerofoil which acted as the reference base case. For this report, a bump refers to a raised dimple. The four models consisted of:

- A row of bumps at 2/3rds of the chord length, 20mm spacing in the *y* direction **(Figure 5a)**.
- A row of dimples at 10 per cent of the chord length, 20mm spacing in the y direction **(Figure 5.b)**. This is to compare the effect of dimples *vs* bumps and check the hypothesis put forward in some previous non-motorsport research that bumps work better than dimples (although the advantage is small; 10 per cent to 20 per cent). Any difference is useful to know as it is felt that it would be simpler (and therefore cheaper) to add bumps rather than create indents.
- An array of bumps in the horizontal *x-z* plane, with a line of bumps every 20mm in the *y* direction. This row of bumps is repeated in the *x* direction, with spacing every 15mm, starting at 10 per cent of the chord length and continuing until the trailing edge is reached. Every other *x* direction row is displaced by 7.5mm in the *x* direction to give a pseudo random effect **(Figure 5.d)**.

The height of vortex generators are typically set at a boundary layer thickness б = 100% but can be between 10% and 50% of б for low profile devices (i.e. a range of 10% to 100% of б). For the speeds used in this analysis (30m/s to 90 m/s), the turbulent boundary layer б ranges from 1mm at 10% of the chord, to 6mm at the trailing edge (0.5mm to 1.7mm for laminar). б is based on formula shown in **Equation 1** and **2**.

For this analysis, a dimple/bump height of 1mm was used, which equates to 100% of бvturbulent at 10% chord, falling to 17% of бturbulent at the trailing edge (200% to 67% for бlaminar). This range (200% for бlaminar down to 17% for бturbulent) is outside the range of 10% to 100%, but is recognised as a

Dimples also have a key benefit of being insensitive to flow direction

Table1: Speed and Reynolds Number

Speed v m/s	30	60	70	90
ditto mph	67	112	157	201
Reynolds Number Re	0.44m	0.73m	1.03m	1.32m

Table 2: Angle of attack

Angle of attack°	-0.55	3.45	7.45	11.45	15.45	19.55	23.454
Zerihan Equiv.[5,31]	-3	1	5	9	13	17	21

Equation 1

$$\delta_{turbulent} = 3.7\ L / Re_L^{0.2}, \qquad \delta_{laminar} = 5.2\ L / Re_L^{0.5}$$

Equation 2

$$Re_L = \rho\ L\ u / \mu \quad \text{(where } \rho\text{=density, L=length, u=velocity, } \mu\text{=viscosity)}$$

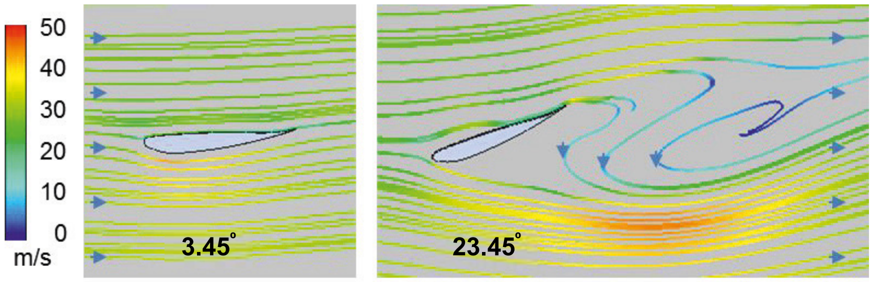


Figure 8: Streamlines for the plain aerofoil, 30m/s

Table 3: Summary of scenarios modelled

Dimple confgurations		Angles°		Speeds m/s
Base case - no dimples		-0.55		30
A. Bumps at 2/3rds chord		3.45		50
B. Bumps at 10% chord	x	7.45	x	70
C. Dimples at 10% chord		11.45		90
D. Bumps across surface		15.45		
		19.45		
		23.45		

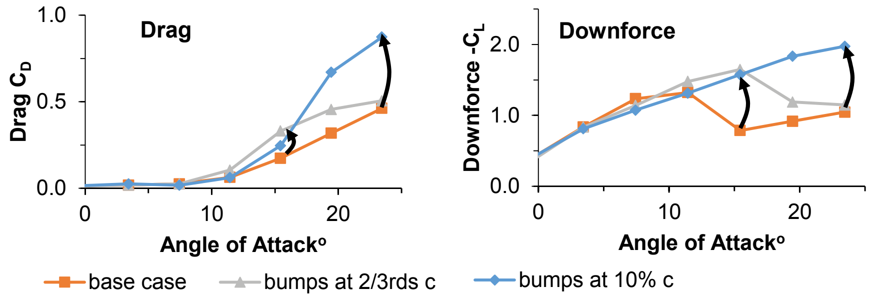


Figure 9: C_D and C_L with bumps at 10 per cent and 2/3rds chord, 30m/s

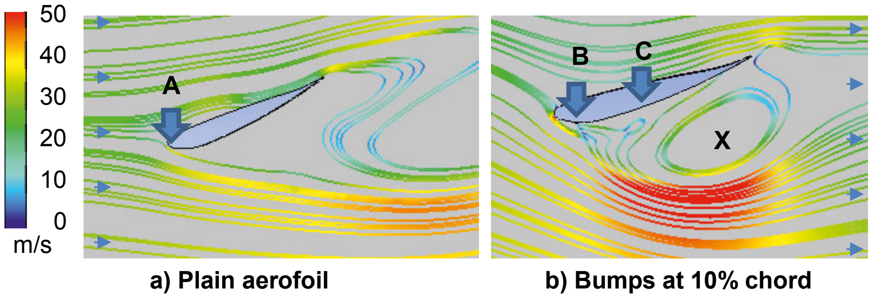


Figure 10: Streamlines at 10 per cent chord, 23.45-degree, 30m/s

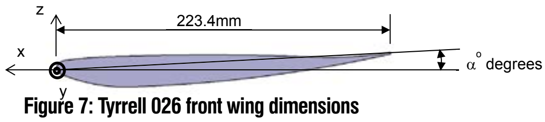


Figure 7: Tyrrell 026 front wing dimensions

compromise to deal with the range of speeds and positions used. Note that *L* is the distance along the chord from the leading edge, and *ReL* is the Reynolds number at this position.

Geometry of the dimple/bump is shown in **Figure 6.** This was created in CATIA as a sphere of radius 3mm, set into/out of the wing by 2mm to leave a bump/dimple height/depth of 1mm.

Angle of attack

A number of aerofoil angle of attack positions and speed settings were analysed for each of the dimple/bump configurations. The aim was to generate as many data points as possible, within the computational resources and time available, to generate useful results without significant data gaps.

The speed boundary conditions were set to emulate those seen in motorsport and to align with published experimental data. This gave a speed range from 30m/s (as used in the published data) to 90m/s. The speeds used are set out in **Table 1** along with the Reynolds number calculated for the Tyrrell 026 aerofoil length of 223.4mm.

The angle of attack α **(Figure 7)** was increased every four degrees from -0.55-degree to 23.45-degree in line with data published in a paper by Jonathan Zerihan detailing the wing's function (*Aerodynamics of a single plane wing in ground effect*) and as per **Table 2**. Note that the data used by Zerihan shows the end plate angle to which 2.45-degree has to be added to get the equivalent chord angle of attack. The aerofoil angle was emulated by vectoring the inlet and outlet air velocities relative to the aerofoil.

Other reference parameters include a pressure of 101,325Pa and temperature of 300k (27degC). For an ideal gas (p=ρRT), this gives a viscosity μof 1.7894e-05 kg/m-s and a density ρ of 1.1767 kg/m3. The default turbulence of five per cent was used to reflect external rather than wind tunnel conditions. The *Re* number shown in **Table 2** was derived using this data, length l being the chord length 223.4mm using **Equation 2**.

Finally, it is worth noting this simple comparison of the streamlines at low and high angles of attack on the wing **(Figure 8)**. Both angles are for air speeds of 30m/s. The left hand picture shows the air remaining attached on the underside of the aerofoil. The right hand side picture shows how the airstream has become fully detached at the leading edge with a larger wake region downstream of the aerofoil.

Results

The results cover a number of configurations and operating parameters as set out in **Table 3**. The five configurations at seven angles and

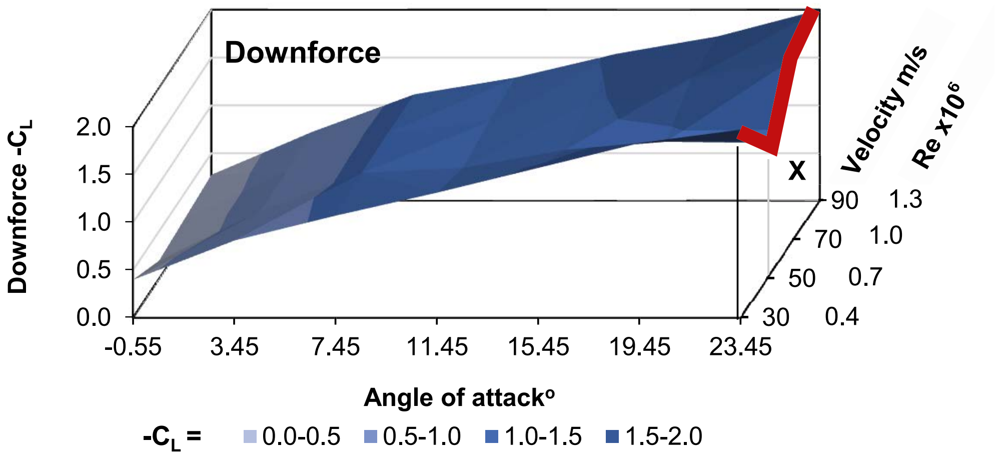


Figure 11: Downforce results, bumps at 10 per cent chord

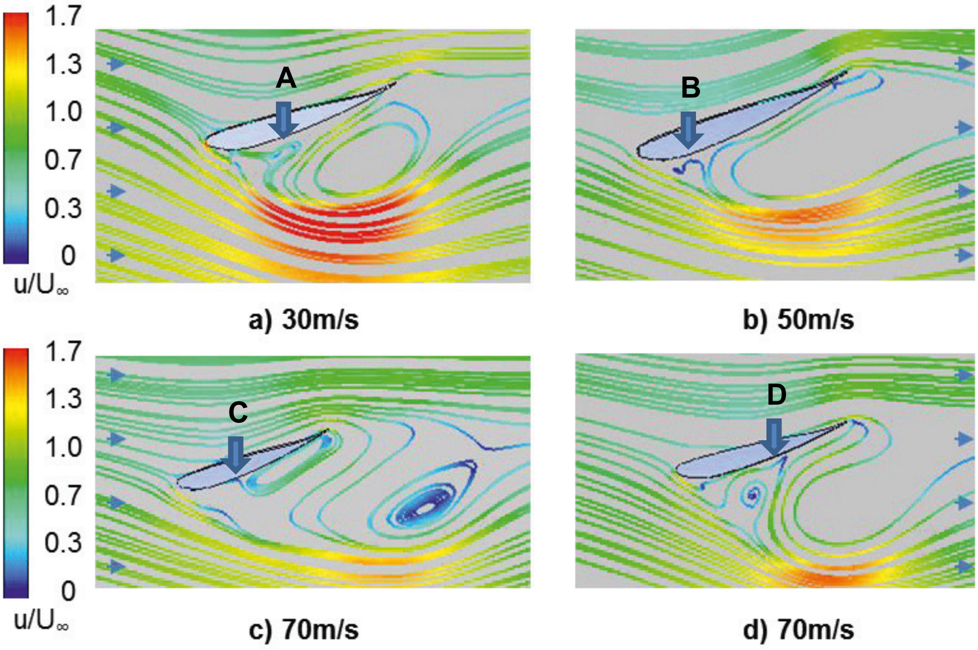


Figure 12: Streamlines *vs* speed, bumps at 10%c, 23.45-degree

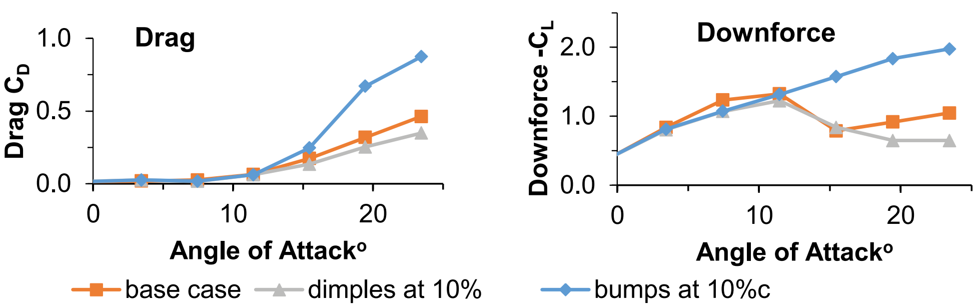


Figure 13: Streamlines *vs* speed, bumps at 10%c, 23.45-degree

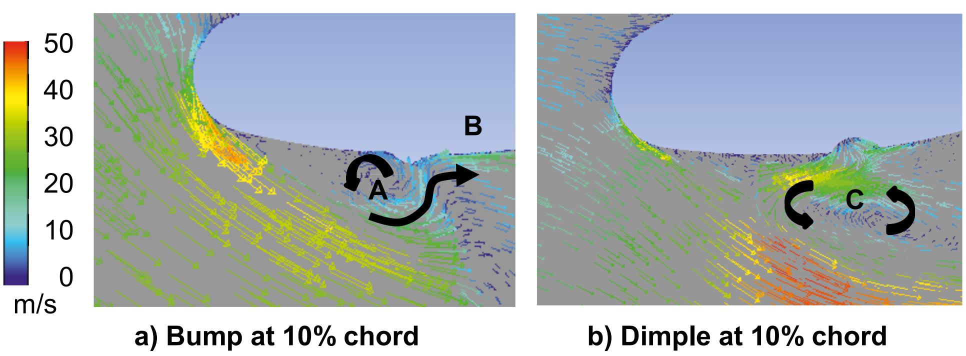


Figure 14: Velocity vectors for bumps and dimples, 23.45-degree, 30m/s

three speeds required 105 separate CFD runs of between 1500 and 4500 iterations each. These 105 runs took ~840 hours (35 days) of computational time on the Cranfield Astral cluster. This excludes the time taken for carrying out the mesh set-up and validation studies. These time constraints meant that additional data points (e.g. speeds of 40, 60, and 80) were not carried out and the number of dimple cases and other parameters such as dimple shape/height/placement were also not explored in more detail, which leaves plenty of scope for further experiment.

Bump it up

The addition of bumps to the aerofoil increases the downforce at steeper angles of attack (right hand diagram, **Figure 9)** by, it is assumed, changing the point at which separation occurs. Placing the bump at 10 per cent chord has a bigger impact than at 2/3rds chord as the effect is felt across most of the wing (90 per cent) rather than the final third. This higher lift result is consistent with the use of vortex generators. In terms of drag compared to the plain aerofoil the results show similar levels of drag, which then increases more sharply as the stall angle is reached (left hand side diagram of **Figure 9**).

As a result of this analysis and other data used for comparison, the expected reduction in drag was neither proven nor disproven. The supporting evidence which argues that a reduction in drag is possible is enough for the author to recommend further work is carried out in a wind tunnel. The author also recognises that it may be that the benefits of drag reduction only work within a narrow set of operating parameters (e.g. aerofoil shape, dimple height and position, airflow speeds) which may be why conflicting results are being seen. For example, moving the bumps forward to 10 per cent chord and reducing their height had little or no effect compared to the base case.

For the plain aerofoil, separation occurred at the leading edge as shown by point A in **Figure 10**. The effect of including dimples at 10 per cent chord is to cause re-attachment at point B with separation occurring a point C. This delay in separation results in a less dramatic fall off in downforce as the separation point moves towards the leading edge in a progressive manner compared to the plain aerofoil. However, the creation of a vortex centred on point X is thought to be the cause of higher drag compared with the plain aerofoil at the same angle of attack.

As the speed increases, there is a dip in downforce at 50m/s before climbing again as the speeds increase still further (point X in **Figure 11**). This becomes more pronounced at angles of attack above 7.45-degree and can be seen most clearly at 23.45-degree.

Looking at the streamlines in **Figure 12**, the point of separation appears to move forward towards the leading edge as the speed rises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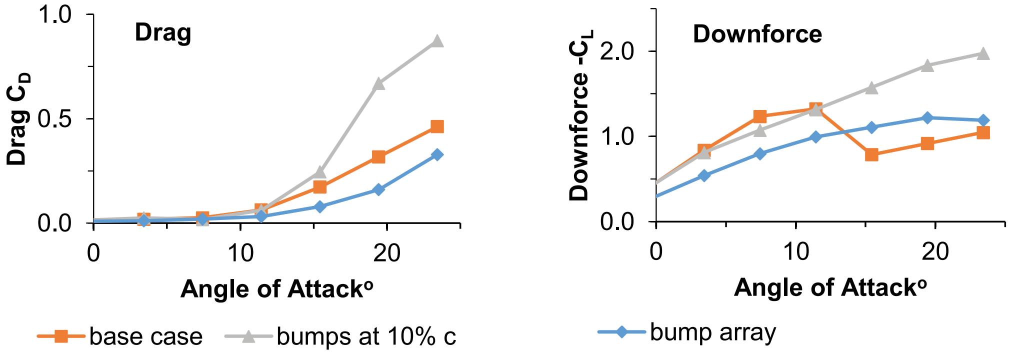

Figure 15. Results for bumps at 10 per cent chord *vs* bump array, 23.45-degree, 30m/s

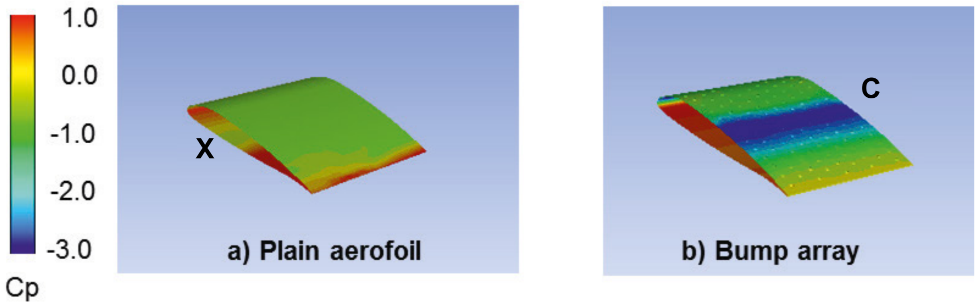

Figure 18. Bump array Cp plot (inverted aerofoil), 23.45-degree, 30m/s

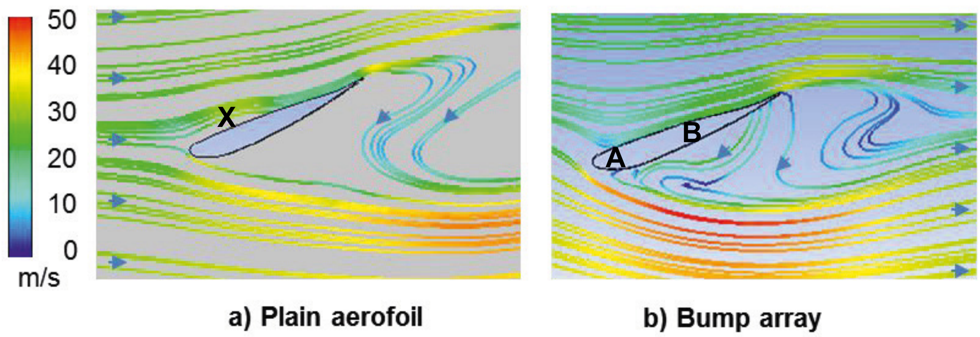

Figure 17: Bump array streamlines, 23.45-degree, 30m/s

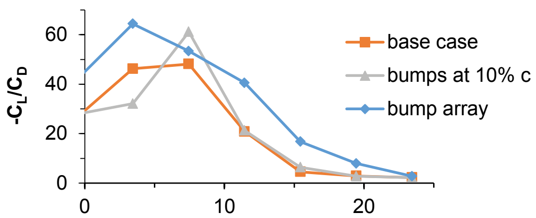

Fig 16. Downforce to drag $-C_L/C_D$ ratio performance, 30m/s 30m/s

from 30m/s to 50m/s, before moving back again above these speeds. This effect was only seen with this set of results i.e. bumps at 10 per cent chord. This change in performance suggests that the flow structure is affected by air speed and could be considered unstable and/or only work within narrow operating conditions.

Bumps *vs* dimples

The analysis of using recessed dimples, shown in **Figure 13** closely matched the results for an aerofoil with no dimples rather than the bump (raised dimples) results. This is in contrast to the analysis by other non-motorsport research which showed that dimples gave noticeable effect with similar results to bumps; with the bumps performing slightly better (10%-20%). However, those studies used a CFD technique which may miss the true effects if the boundary layer was not sufficiently resolved.

Further insight can be found by looking at the velocity vectors **(Figure 14)**. The bump (raised dimple) appears to set up a recirculation pattern ahead of the bump around point A, which causes the flow to re-attach after the bump at point B. In comparison, the dimple results in a re-circulation point around point C which prevents reattachment. From this and past work the author infers that the creation of multiple dimples could create a recirculation pattern which results in re-attachment. This would require further work to verify.

The re-circulation around the raised bump causes quite sharp changes in flow direction around A in **Figure 14**. The point of recirculation is also nearer to the bump than leading edge. It is possible that moving the position of the bump and altering its height could improve the performance further, particularly if the sharp changes in direction could be reduced to give an extended region of attachment.

Using an array of bumps is seen to reduce the drag across the range compared with the base case, avoiding the sharp drop off in downforce seen in base case, but giving a lower downforce per angle of attack compared to the single bump at 10 per cent chord **(Figure 15)**.

Looking at the downforce to drag performance **(Figure 16) ,** it can be seen that the bump array outperforms (is higher than) both the base case and the single line of bumps at 10% chord. So although the downforce is lower by ~35% compared to the single line of bumps for at 19.45° angle of attack, the drag is ~50% lower **(Figure 15)** giving a net benefit.

The effect of the bump array is to draw the air flow towards the leading edge A (**Figure 17)** which combined with the turning of the air around point B **(Figure 17)** leads to a low pressure area C **(Figure 18)**. This in turn results in increased downforce and reduced drag when combined with the improved airflow on the upper surface, point X **(Figure 18)**.

Do dimples work?

The results have shown how the use of a simple row of bumps (raised dimples) extends the downforce performance at high angles of attack. This is achieved by delaying the point at which separation occurs and altering the flow path, changing how the pressure across the aerofoil surface is coupled to the downstream wake and far stream air flows. Bumps also reduce the rate at which downforce is lost at steeper angles of attack. These findings suggest that bumps could prove to be a useful flow control mechanism, particularly around aerofoils and diffusers. Using an array of bumps gave the same characteristic as a single line of bumps, but with reduced drag and downforce. Although downforce and drag was reduced, the bump array gave a higher downforce to drag ratio (i.e. more efficient), with bumps having a much stronger effect than the use of dimples.

The analysis did not show a marked reduction in drag in the way predicted by research into golf balls and spheres with rough surfaces. However, experimental work by a group at Cambridge University in 2011, also on a Tyrrell 026 wing using three rows of recessed dimples, did reduce wake, and by inference, drag. This, together with the findings in this report, implies that getting the golf ball effect is sensitive to size of dimple, position, number of rows and whether the dimple is raised as a bump or recessed. These range of sensitivities drive complexity, which may be why the use of dimples is not widespread.

Further experimental work is clearly required, not least to try out a variety of patterns, sizes and shape of bump. This study had a number of limitations based around resource and time. For example the CFD techniques used may not be totally accurate in terms of absolute drag and downforce, but they are considered adequate as a comparative study about how the different dimples and bumps behave.


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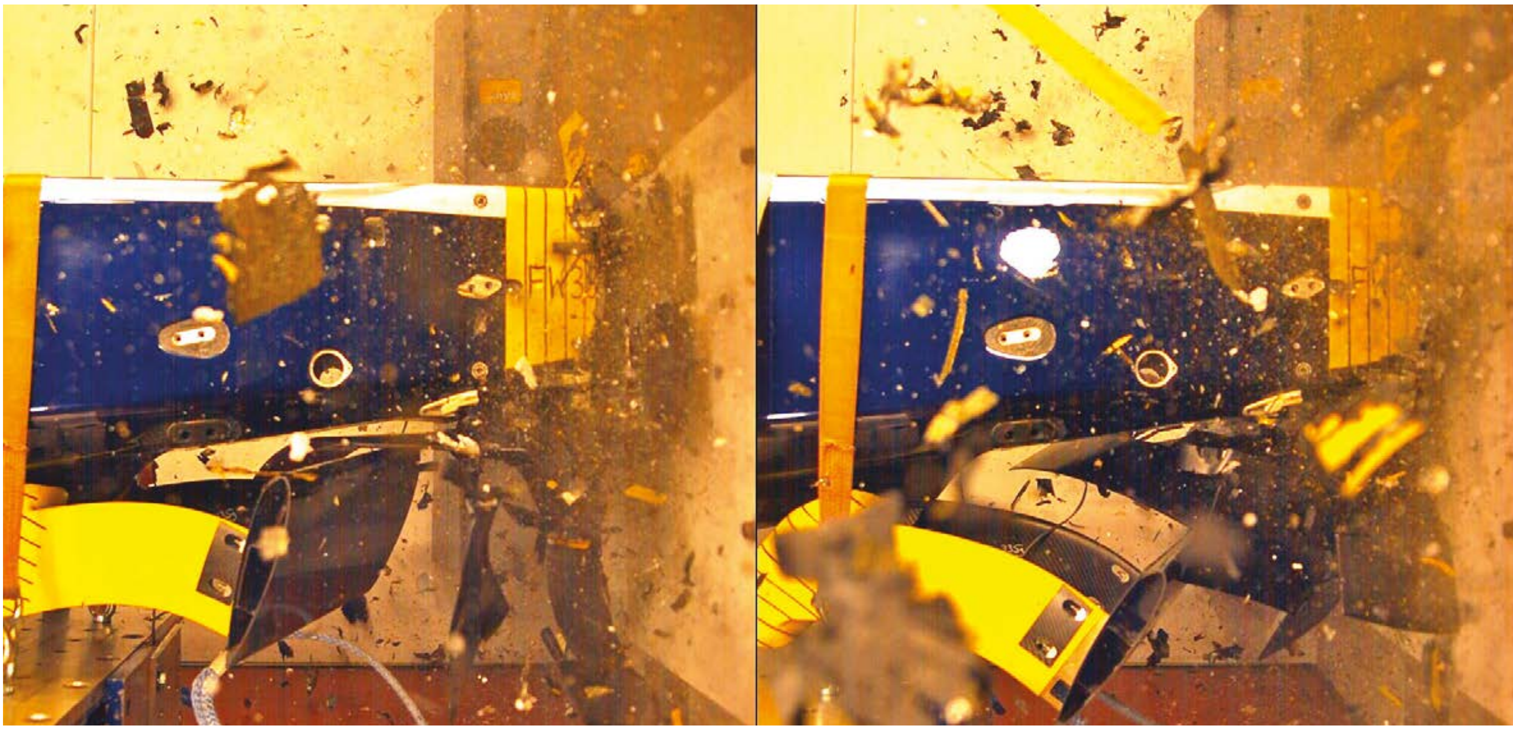
Making an impact

Chassis impact testing has been a part of Formula 1 for more than 30 years, and one Williams engineer has been involved since the start. Brian O'Rourke talks us through the history of this life-saving science

By SIMON McBEATH



Williams FW33 (2011) nose-box at point of impact. Crash-testing has improved F1 driver safety immeasurably and the lessons learnt from it have percolated down through to other formulae

Recent moves towards the seemingly inevitable adoption of cockpit protection into F1 chassis design have highlighted an aspect that has not, thus far, been covered by the technical regulations. Precisely what, if any, form of additional cockpit protection will ultimately be mandated remains unknown as this is written in November 2016, as too does the form of testing that will apply. However, what is crystal clear is that the previous three decades since chassis testing first began have produced colossal improvements in the rest of the cars' design with respect to driver safety.

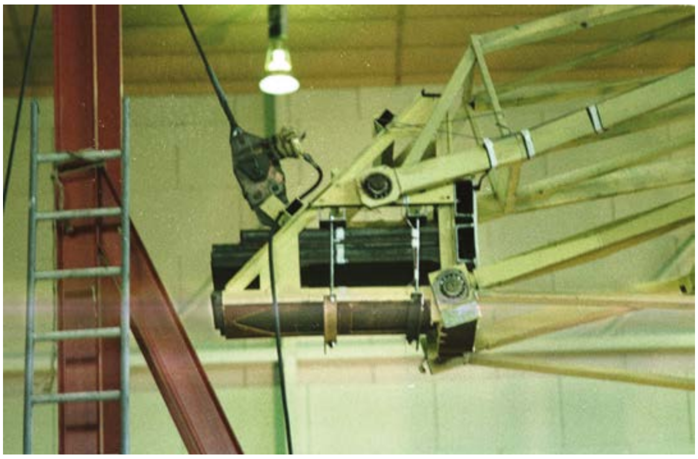
Racecar Engineering has once again been privileged to speak with Brian O'Rourke, who, as chief composites engineer at F1 team Williams, after being recruited from the aerospace composites industry 35 years ago, has since supervised the design and testing of all the team's composite structures. This, then, is O'Rourke's condensed retrospective on 'The testing years' to date.

As always O'Rourke's forthright views are rooted not only in the wealth of knowledge he has amassed during his time at Williams but also in his cross-sector experience as the MIA's representative on the UK government's Department of Business, Innovation and Skills (BIS) Composites Leadership Forum, established to foster knowledge transfer within the UK composite industry. 'The current discussion in Formula 1 on improving head protection has highlighted that open cockpits are almost the only aspect of the cars' structural design not covered by previous legislation regarding "crashworthiness",' he said. 'It has always been a fact – and one that I have pointed out whenever there was an opportunity, publicly, to do it – that F1 racing involves open wheels and open cockpits, so the laws of both physics and statistics will eventually apply. Today's long anticipated discussions, therefore, are necessary.

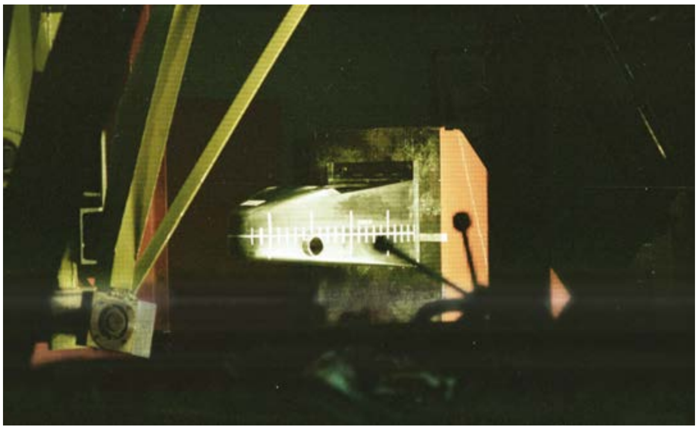
'However, looked at from a different perspective, the present situation does tacitly acknowledge that massive strides have been made with the remainder of the cars' design in terms of driver safety. This has not happened overnight; what is seen today is the culmination of over 30 years of incremental changes to the FIA's requirements for crashworthiness and, equally, a great deal of hard work on the part of the – still – small number of engineers whose job it is to achieve them. Whilst never claiming to be an 'expert' in this field (the analysis and design of structures built from composite materials are subjects that only the foolhardy would say they have fully mastered), I have been closely involved in the design, build and testing of chassis and impact absorbers since the introduction of the first crash test ahead of the 1985 season. That has included the supervision and witnessing of every

'The stress engineers are probably the most stressed engineers of all'

The 1985 trials on the Williams FW09 Formula 1 car. These early impact tests were between a mass swung on a pendulum and the solidly fixed nosebox structure



Pendulum ready for release. Then, as now, Williams' tests were carried out at Cranfield



The time is up for this F1 part: the pendulum is about to impact the FW11 nose-box

This shows the same moment of truth. It was a destructive but highly effective method

The pre-'85 nose test energy absorption requirement was 39kJ. This sample absorbed 50 per cent of that; 'meeting the requirement was not going to be easy,' O'Rourke said

FIA test of Williams structures from that day to this; in crude terms, watching several hundred tests and an awful lot of wilful destruction!'

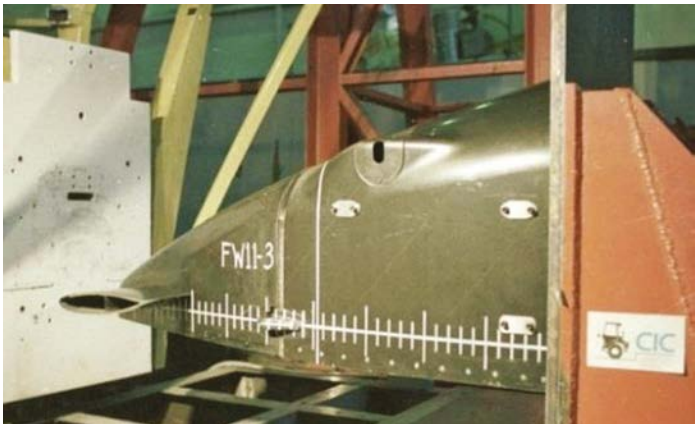
Structural design

It's probably fair to say that the topic of structural design is under-reported in the general and specialist media compared to, say, aerodynamics in F1 in particular. O'Rourke says: 'Some of us have that perception, yes. Okay, we all understand that aero has a direct bearing on the speed of the car but remember, if crash-tests are not passed we will not be racing anyway, so everything else that might follow it is academic. This is a complex, difficult field of study and achieving an effective but weight-efficient result that satisfies all of the requirements for the structure is vital to competitiveness on the racetrack.

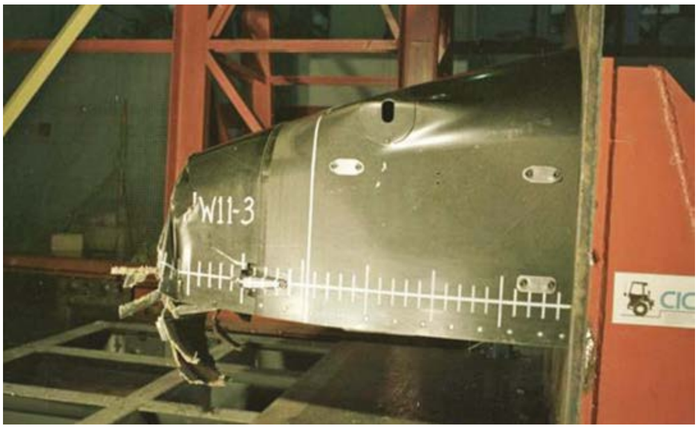
'Very much in parallel with aerospace structural design, in F1 an optimum balance between stiffness, strength and minimum mass is not easy to realise – with the addition of impact alongside static and cyclic loading. To stress engineers, the old dilemma is alive and well: "If it breaks, it's your fault; if it doesn't break, it's too heavy – and that's your fault instead". The same expectations also apply to structures remaining in one piece when needed – the reason why stress engineers are probably the most stressed engineers of all.'

So, what is required of an F1 car's structure? 'In its early decades, this question was left entirely to the imagination, experience, competence and conscience of those involved in its design, leaving much to chance for the drivers – over-used quotations about a racecar having done its job perfectly if it disintegrated as it crossed the finish line in first place betray the naivety, or arrogance, that must have prevailed in those times, particularly when knowledge of fatigue behaviour in metals was at an early stage,' O'Rourke says.

Looking through historical F1 technical regulations there was little specified in terms of structural requirements until the early 1980s when specific features – longitudinal box members and foot-well forward extensions – started to appear. Representative testing of structures was, no doubt, done by some teams but data was lacking at the time, particularly pertaining to inertial or



A Williams FW11 F1 nose-box in 1986 testing, moments before it takes the impact



This shows the same after the impact. Things had clearly moved on from pre-1985

Here a panel penetration test is about to take place. These tests came in to F1 in 1995

The panel penetration test rig with its a solid metal cone, designed to act as a nose-box

Aftermath of the panel penetration test; 500mm by 500mm panel was clamped down

aerodynamic loading, and the facilities needed were limited, too.

'The safety record of F1 racing in those earlier days was, as everyone now recognises, abysmal. Using the analogy of a 'system', an examination would reveal that all components – other than driver ability – were deficient. Circuits featured high speeds and challenging corners but the failure to meet a challenge would find little trackside protection to help the situation. The cars were fast but their structures were only designed to carry the loads input to them whilst working on the track and offered little to protect the driver when unintentionally leaving it. That added up to fast corners at which the chances of error were high, but with little protection for the driver when things went wrong.

'As we know, in the 1970s big improvements were made in the provision of barriers to contain cars leaving the track, but injuries and fatalities continued until the early '80s. The cars themselves had progressed – seemingly – little.'

Testing times

All this was about to change when, for the 1985 season, F1 teams were required by the FIA to demonstrate the integrity of their structures through testing. Initially, this comprised just one test, a frontal impact to a nose and forward chassis section. And teams would not be allowed to participate in grands prix unless the deceleration pattern and damage containment satisfied specified targets.

Initially this represented a difficult task to achieve. O'Rourke: 'Viewed from today, it is hard to convey just how insubstantial some of the F1 structures of that time were. Composite materials had arrived, but composite chassis design and manufacturing methods were at an early stage. In 1984 some cars still had metal chassis; sandwich panel construction of course, but their aluminium skins were typically less than 1mm thick. In the case of composite materials, mechanical properties are [in part] a function of the manufacturing method used and in all but a few cases these were being processed without pressure-curing, as autoclaves had not yet become standard equipment. In addition, as I learnt to my consternation, knowledge of the analysis of redundant semi-monocoque shell structures amongst Formula 1 designers in those days was – to put it politely – limited, and such calculations that were done might best be described as cursory.'

Meeting the requirements of the front impact test, and in particular the nose-box crush targets, was a challenge. But a secondary effect, and one which O'Rourke suspects was not anticipated by some, was that the overall strength of the monocoque itself needed, in many cases, to be substantially improved.

So the impact test requirement had a significant beneficial knock-on effect for the whole structural assembly. O'Rourke continues: 'This was the real reason that such improvements were seen in the

If the crash-tests are not passed then we will not be racing anyway

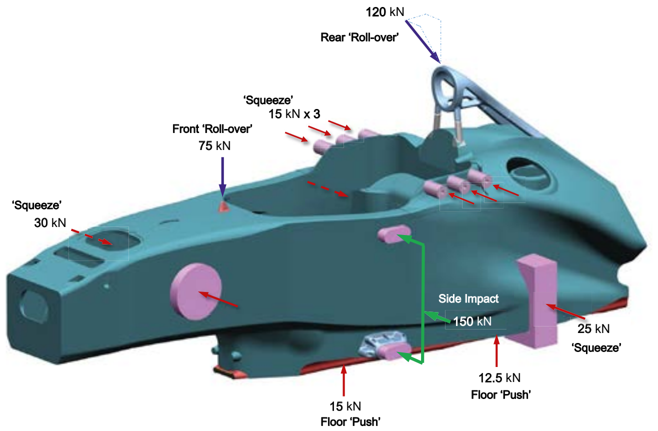


Figure A: Summary of 2016 static load test requirements

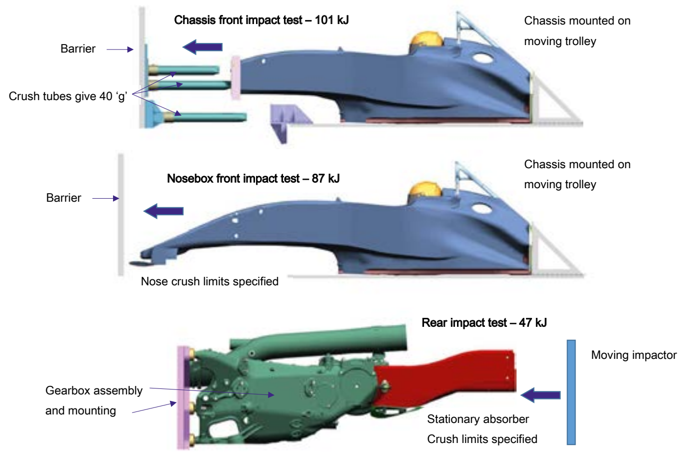


Figure B: Summary of 2016 impact test requirements

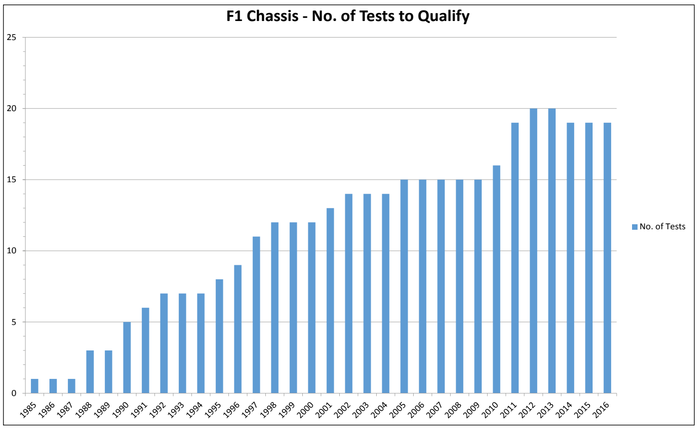


Figure C: The number of FIA tests has steadily increased since the first test in 1985

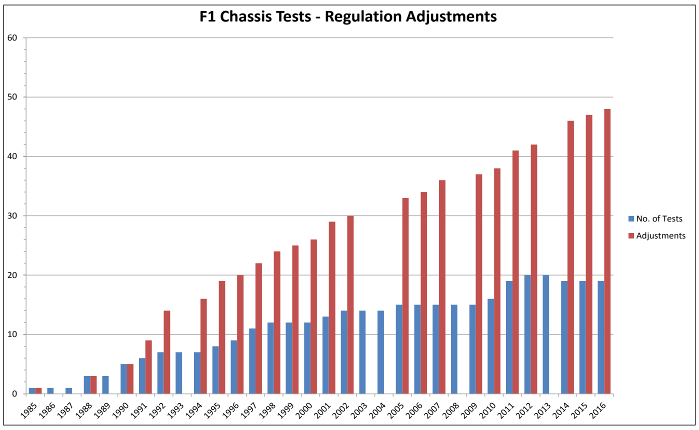


Figure D: Number of regulation adjustments has climbed faster than number of tests

seasons immediately following the introduction of testing, a fact I feel cannot be over-stated. At Williams, we had proof of how things had moved on through major accidents to both Nigel Mansell, in Detroit and Paul Ricard in 1985, and Nelson Piquet at Imola in 1987, the latter being regarded as severe by the standards of the day, the positive outcome even drawing tributes from sections of the press. People were starting to take notice that things had changed – and very much for the better.'

Senna effect?

O'Rourke was keen to highlight this early progress, and put to bed a misconception: 'There seems to be a perception amongst F1-watchers today that car strength improvements only really started to happen after the tragic events of 1994 when, in reality, the most meaningful increment of change occurred in the previous decade. It was, in fact, a true step change and from 1985 things did not stand still. Further tests were introduced in 1988, which were the first of the static squeeze loads intended to demonstrate side-crush strength of the chassis in the cockpit and tank bays. Research ahead of them showed that there was room for improvement and, accordingly, this was made,' O'Rourke says.

'With regard to roll-over protection the regulations at that time had really been left behind by the way the cars had developed. In earlier days, F1 cars usually incorporated roll-over hoops made from tubular steel. The technical regulations, even in 1990, still made the assumption that they would be of that form since they requested that constructors presented the FIA with a certificate from the hoop supplier as proof of its integrity. Unusually, load cases for the main hoop had been specified for some years and so teams – or supplier companies – really had no excuse for not testing them.

Was this not always done? Perhaps, but from 1990, the FIA introduced a demonstration test for the roll-hoop installed on the datum chassis with a combined, angled, load case of 72kN (about 7tonf); a very effective solution.'

A problem remained, however. The squeeze test was only required to be demonstrated on one datum (or reference) structure; there was no requirement to check every example built. So this rule was altered for 1991 to include all chassis built to ensure their repeatability. Why the change? O'Rourke: 'Opinions vary but clearly a loop-hole existed allowing teams – should their consciences tolerate it – to qualify one design of structure and then build others differently – in order to save weight, perhaps? It may have been fiction, of course, but suggestions persisted that this was a reason behind the outcome of an infamous accident in 1990.'

Feeling the squeeze

These squeeze tests were, additionally, now carried out in four locations along the tub and a new push load was introduced to the bottom of the tank bay. Contemporaneously the first of a series of front impact speed increases took place from 10m/s up to 11m/s. This was now carried out on a full monocoque which had to have completed all of the other tests first. The following year the tub and nose had to be mounted on a moving trolley and contain a 75kg dummy plus a fuel tank full of water, so giving 780kg combined mass, and continual progression towards realism.

O'Rourke says: 'That was the state of the test requirements when we reached 1994. Teams were required to test every chassis with four squeeze loads and a tank-bay floor push, a roll-over load followed by front crash case, the nose-box of which had previously been subjected to a side push-off load of 30kN (3tonf). And things were not standing still because for 1995 a side impact test had been specified for the first time. 'The media coverage of the events at

'There seems to be a perception that F1 car strength improvements only really started to happen after the tragic events of 1994'


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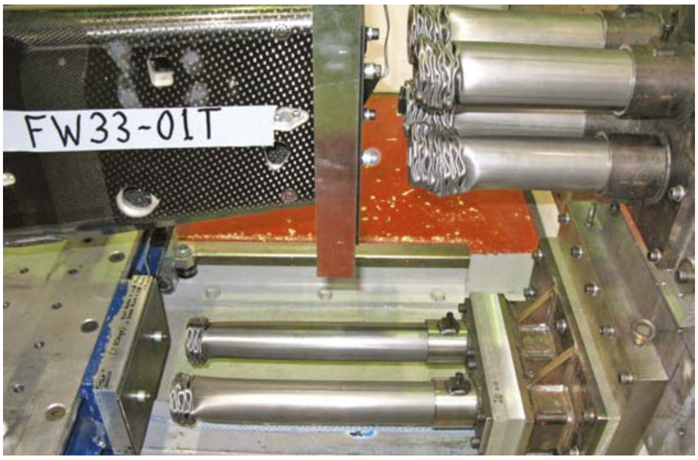
Table 1: A summary of the changes made to the FIA rules for structural testing in Formula 1

Year	Test Additions	Test Changes
1985	Font impact	
1988	Chassis squeeze loads (2)	
1990	Main roll-hoop, Nose push-off	
1991	Tank bay floor push	Front impact increased, full chassis Chassis squeeze loads (4)
1992		Front impact on moving trolley Chassis squeeze loads increased (3) Nose push-off increased
1994		Chassis squeeze loads increased (3)
1995	Side impact	Front impact increased Nose push-off increased
1996	Rear impact Cockpit edge squeeze	
1997	Steering column impact	
1998	Forward roll-hoop	Side impact increased
1999		Front impact increased, criteria added
2000		Front impact increased
2001	Penetration panel	Main roll-hoop increased Side impact increased
2002	Rear impact push-off	Penetration panel increased
2005	Side impact rearwards push-off	
2006		Rear impact increased
2007		Front impact criteria altered Rear impact decreased, criteria added
2009		Cockpit edge squeeze increased
2010	Chassis-only front impact added	
2011		Cockpit edge squeeze (3)
2012	Side impact upwards push-off	
2014	Chassis side impact crush load	Sided impact push-off increased (2) Side impact test deleted
2015		Front impact criteria added
2016		Cockpit edge squeeze increased (3)

Chassis without nose is impacted into an FIA-specified tubular metallic energy absorber which provides a standardised 45*g* deceleration; no damage is tolerated.



Here it can be seen that the Williams chassis remains undamaged after the impact test

Imola, of course, inevitably brought a renewed focus on driver safety. Naturally, it is difficult to put into words the effect on a team of the loss of a driver, particularly one with the profile of Ayrton Senna. For anyone who was closely involved with the car's safety provision it was a difficult time, despite none of the existing test specifications, or the performance of the car in satisfying them, having been brought into question.

'The evidence is that the survival cell in that accident had done its job; the injury was caused by a suspension component external to it. However, there is, even today, a general belief that impact and other testing in F1 really only began as a result of that accident, that is, in the years after Senna. This is a misreading of the reality. Vast amounts of work had been done over the preceding nine years. Perhaps paradoxically, the changes to the testing for 1995 – other than an increase in front impact speed to 12m/s – had already been planned before those events occurred.'

Test improvements

Test upgrading was continual. In 1996 a rear impact test was introduced. In 1998 the side impact energy was doubled and a front roll-hoop test added (75kN or 7.5tonf).

Then 2001 brought major changes, including another doubling of the side impact energy; the main roll-hoop load increased by 65 per cent (to 120kN); and the front impact speed was raised to 13m/s. Significant also was the introduction of the side penetration test. O'Rourke expands on this: 'There had been a fear from around 1995, when F1 cars adopted high noses, which were aligned with the driver's thorax, that a T-bone collision between two cars could result in a nose penetrating a cockpit side panel. Whilst chassis were regularly subjected to 30kN as part of the squeeze test, an impact such as this would result in a considerably higher load. A regulation was added, therefore, asking constructors to build chassis sides with a sandwich laminate capable of withstanding 250kN of load. This is proven by the preparation of a 500 x 500mm panel, clamped around its edges, and a solid metal cone, loosely representative of a nose-box, driven through it. Once a solution has been arrived at, this is an impressive – and extremely noisy – demonstration,' O'Rourke says.

Table 1 summarises the new tests and test changes introduced down the years and clearly illustrates that the work does not stand still. The tests currently in place in 2016 are summarised in **Figure A** and **Figure B**, the complete set comprising some 19 tests (see also **Figure C** and **Figure D**). 'When it does happen,' O'Rourke says 'the introduction of cockpit protection will require radical changes to the current list.'

Bigger picture

'A cross that every stress engineer has to bear' says O'Rourke, 'is that they seldom get to determine the best shape for the structure they are trying to size. Racing cars – in common with aircraft – have external surfaces that are shaped for other functions, typically aerodynamic ones. Whilst ultimately the stress designer determines the absolute minimum that a section can be – for reasons of stiffness or strength limits – usually it is a case of having to make a less-than-ideal shape work somehow; one that, by definition, is less efficient. All design is a compromise. In common with every other component on the

In 1996 a rear impact test was introduced. Then in 1998 the side impact energy was doubled and a front roll-hoop test was added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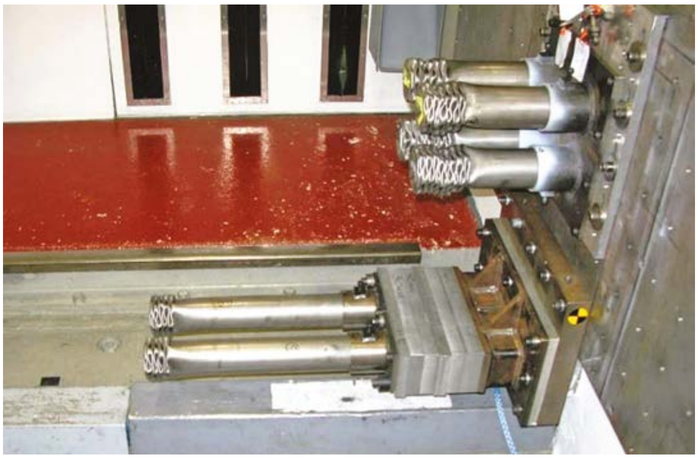
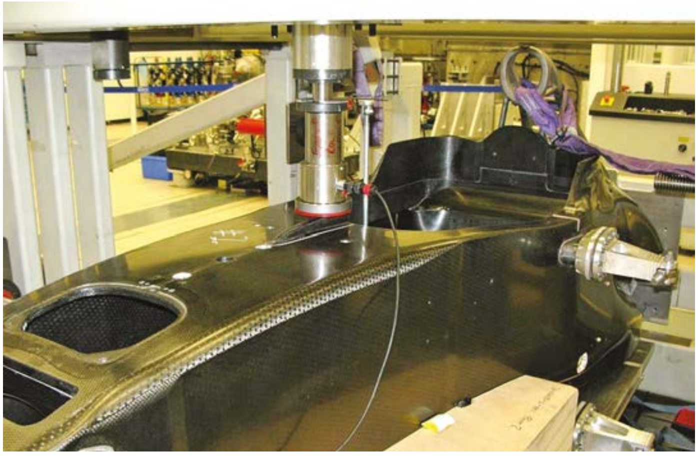
The 2016 test chassis is ballasted to 900kg, which includes the water-filled fuel tank,and is then propelled at the impact absorber on a trolley at 15m/s, which equates to 101kJ



These tubular energy absorbers have clearly done their job; note the deformation

The additively-manufactured titanium main roll hoop undergoing its 120kN push test



The front roll protection structure on the Williams chassis is subject to a 75kN push test

car, impact absorbers are always built to be of the minimum mass possible. This can bring design conflicts as there is pressure on an engineer to make the crush performance of an absorber to exactly match the FIA requirements and provide nothing extra. Imagine, then, how it feels to have to perform iterations of a design – and the expense of re-testing – in order to save a few grams of mass, only to see it put back again as ballast in close proximity to where it has just been removed! Every time the phrase "Safety is always the first priority" is uttered in F1, realists will know that the truth is somewhat different; it's car performance every time.'

Against this background of an increasing number, and increasing severity, of tests to qualify an F1 structure, some anomalies inevitably appeared. 'There came a point when incompatibilities appeared between requirements,' O'Rourke says. 'Most obviously, nose-boxes that were now capable of absorbing greater energy became stiffer and a point was reached at which this exceeded the ability of the chassis side penetration laminate to contain an impact with one. Alongside this, some designs of nose, and rear impact structure, began to feature spiky geometry which would behave differently from that of the test cone shape. This was firstly addressed by regulations defining nose front cross-sectional area and secondly by a limit on the *g* level measured during the first part of its crush during the impact test. In time, however, impact testing of nose cones into real monocoques was carried out by the FIA, and this told some worrying truths. What resulted has had far-reaching effects for car design and testing costs,' O'Rourke says.

Peak practice

'Crash test regulations had always been quite simple in terms of pass criteria,' O'Rourke says. 'Constrain the average deceleration to less than a specified level and contain the damage within the absorbers. In 2008 a major transformation was imposed, however, when there was a change from using average *g* figures to those of peak deceleration; this was a whole new challenge.

'By this stage, prediction of crush behaviour using dynamic Finite Element Modelling had reached an advanced stage at Williams and was very useful in establishing the shape of the [energy] absorption curve,' O'Rourke says. 'Predicting peak loading, however, is altogether more difficult because of the variability inherent in composite materials. No two structures will crush in precisely the same way and so designing to keep decelerations below peak targets is very difficult. A statistical approach to testing has been adopted by teams in response: if the first one doesn't pass, keep using identical specimens until one does. Not an ideal approach but the only one possible.

'A further safety device was also added on the cars for the future,' O'Rourke adds. 'Upon the successful conclusion of the entire set of crash and squeeze testing, each monocoque has bonded to it a set of FIA-defined secondary intrusion panels (these being made from a composite including Zylon, a high tensile-elongation fibre type). This is a belt and braces approach, but a way of ensuring a minimum level of penetration performance is provided, and one undoubtedly contributing to further driver protection.'

Inevitably, the crash test rules have been tweaked in recent years with small additions intended to prescribe a set deceleration pattern along the length of each structure.

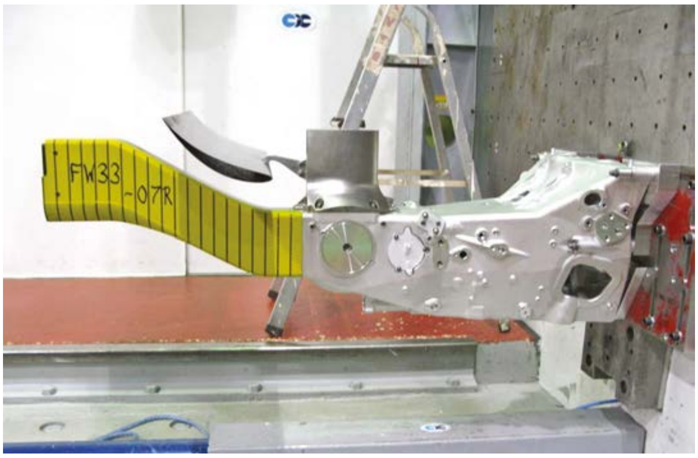
This has reached the extent that, for front impact, it is now necessary to satisfy seven different criteria in order to pass the test. Consequently the amount of work – and the cost – required to fully qualify a new Formula 1 design has increased hugely over the last eight years, ironically in parallel with a stated

'In common with every other component on the racecar, impact absorbers are always built to be of the minimum mass possible'

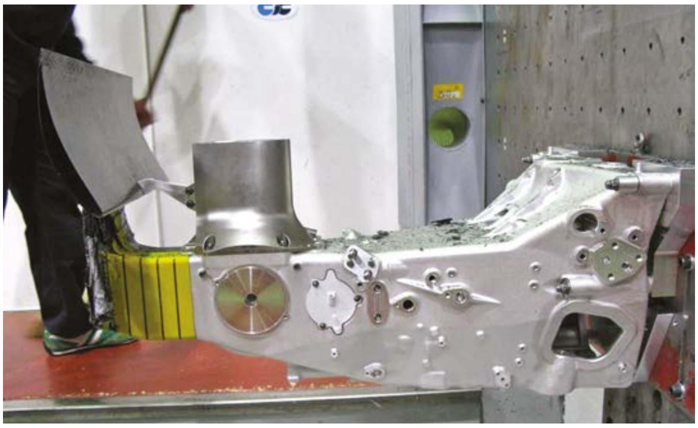
IMAGES: B O'ROURKE

Here the Formula 1 chassis with nose attached is impacted into an immovable barrier

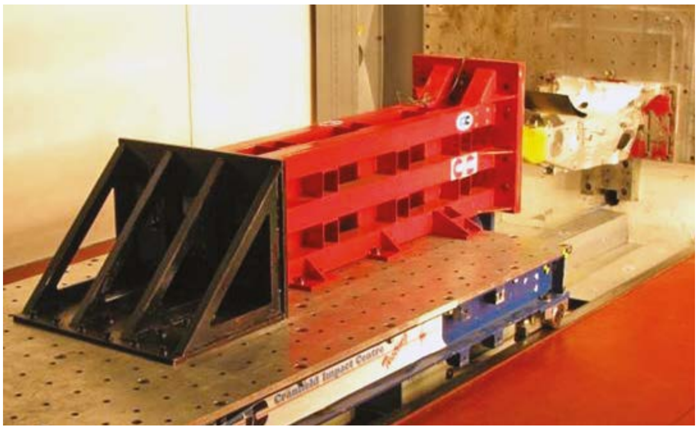
For the nose crush test the structure weighs 780kg and is impacted at 15m/s (88kJ). Six different deceleration parameters must be met, and no chassis damage is tolerated



Rear impact structure about to be tested. Testing of the rear of the car came in in 1996



Rear impact structure after the test. The effectiveness of the deforming area is clear



Rear impact test rig. The car's tail end is subjected to a 40kN push-off load these days

objective from the FIA that F1 should be made cheaper. The tests currently carried out on Formula 1 cars in 2016 are as illustrated in **Figure A** and **Figure B**.

Test chassis are now ballasted to 900kg. In addition, there are push-off loads for each of the energy absorbers: 40kN (4tonf) in the case of the rear impact structure (RIS) and nose-box, 100kN rearwards and 35kN upwards for the side impact structures (SIS). The side impact test, introduced in 1995, improved for 1998 and then, more effectively, for 2001, has now disappeared. 'As time went by the energy absorber solutions evolved by teams resulted in minimised designs and eventually these became textbook examples of items designed to pass a test but not be of much use in real life,' O'Rourke explains. 'Eventually agreement was reached for a common design to be applied to all cars, maybe still not the best solution but one that would be tolerant of at least some off-axis loading. So, actual tests on the cars were deleted in favour of a maximum side impact load squeeze test across the cockpit bay of each design amounting to 250kN (about 25tonf)'.

What next?

O'Rourke expressed puzzlement at some current developments in F1. While expecting that a cockpit protection device, be that the Halo or some variation along those lines, will provoke a re-think on the chassis loading test cases, he also says: 'An allowance will have to be made for increasing car performance. In 35 years of working in Formula 1 I have become used to very many changes in regulations. Overwhelmingly, these had one of five objectives: to improve driver safety; to slow the cars down (in order to effect the same); to improve overtaking;to reduce cost (occasionally); and to improve fuel efficiency, although the change to 3.5-litre engines in 1988 did precisely the reverse and appears bizarre when compared with today's units.

'The 2017 regulations appear to run completely counter to one point above as, for the first time, there is an attempt to actually make the cars faster. Are the circuits that much safer nowadays to justify reinstating some of the risks deemed unacceptable in the past? The newer ones might be perhaps, but others? Time will tell.'

Summing up

Thirty-plus years of increasingly severe test requirements and a great deal of hard work by the teams in F1 has seen substantial improvements in driver safety, not only in F1 but also, through dissemination of knowledge, in other formulae. But O'Rourke summed up with a note of caution: 'There is almost a presumption that drivers will walk away from accidents that once would have had serious consequences, and that's gratifying. But it's been put to me on several occasions that the apparent safety of the racecars has prompted drivers to take risks which they might not take otherwise. Is there something in that? Whatever else we are required to do in the cause of further improvements, it must be remembered that the principles of physics and statistics will always still apply.'

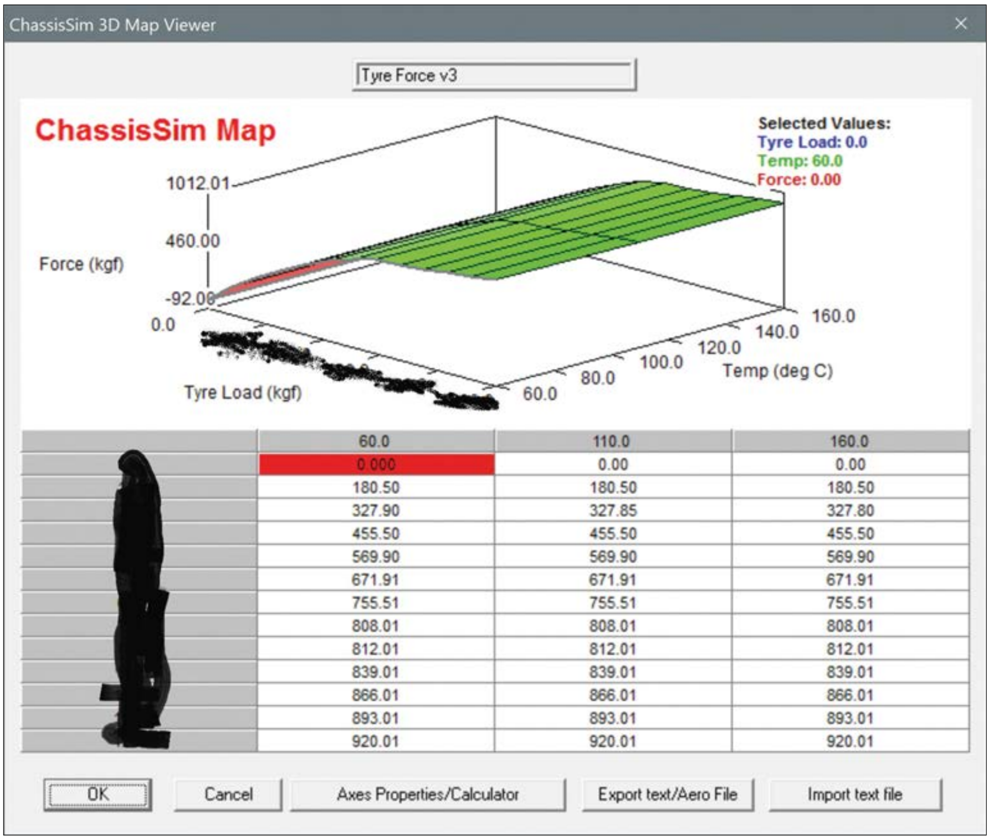
It is necessary to satisfy seven criteria to pass the front impact test

Simulation in action

Using chassis simulation in the workshop is one thing, but how would it stand up to a day at the races? *Racecar's* numbers man packed his laptop and went to the Sydney World Time Attack event to find out

By DANNY NOWLAN

The NA AutoEng WTAC Mitsubishi Evo 6 with driver Nick Ashwin (left) and our very own Danny Nowlan. The team placed third in Sydney World Time Attack event



	60.0	110.0	160.0
[redacted]	0.000	0.00	0.00
	180.50	180.50	180.50
	327.90	327.85	327.80
	455.50	455.50	455.50
	569.90	569.90	569.90
	671.91	671.91	671.91
	755.51	755.51	755.51
	808.01	808.01	808.01
	812.01	812.01	812.01
	839.01	839.01	839.01
	866.01	866.01	866.01
	893.01	893.01	893.01
	920.01	920.01	920.01

Figure 1: WTAC tyre model; without this the NA AutoEng team would have been completely lost when it came to simulation

It's not that often I get to comment on what goes on in my own backyard, let alone when I'm an active participant. However, on October 13-15, 2016, the stars aligned and I engineered a customer's car at the 2016 World Time Attack Challenge in Sydney. If you ever wanted a flashing neon sign to show what simulation can do in the right hands, then this weekend was the perfect example. I engineered the NA AutoEng Mitsubishi Evo 6 entry in the open class. Last year it placed 17th. With an aero package from AMB Aero and chassis tuning courtesy of ChassisSim, this year NA AutoEng placed third. This is the story of how we did it.

The reason I'll be going into depth about this is to disprove two of the biggest misunderstandings about simulation; that you need terabytes of data to do it, or it can get shuffled off as a low priority. Bottom line, these are excuses. I can tell you right now had NA AutoEng not had access to a tool like ChassisSim they would have struggled to crack the top 10. Also, when I was engineering the car, the vehicle dynamics knowledge I had built up over the years came into play. If you're serious about results, ignorance is not an option. If you want to take your results to the next level, read on.

Evo solution

The Sydney weekend also illustrated the great cancer that has infected our sport. This cancer is the view that in order to level the playing field we need to tightly regulate the cars. For all its faults World Time Attack Challenge shows the utter foolishness and intellectual bankruptcy of this. Without this technical freedom the car I was engineering wouldn't have got onto the podium.

Like all Time Attack cars, the Evo started its life as a standard car, then had a new motor put in and aero stuck to it. If there is a racecar equivalent of the Millennium Falcon then this car is it. To quote Han Solo, it doesn't look like much, but its got it where it counts and that is speed. Anything else is rubbish. As can be seen in the picture above it has a front splitter and an ample rear wing courtesy of AMB Aero. Extracting the most out of this package was ChassisSim's job.

The foundation of what we were able to achieve this weekend was in the tyre model

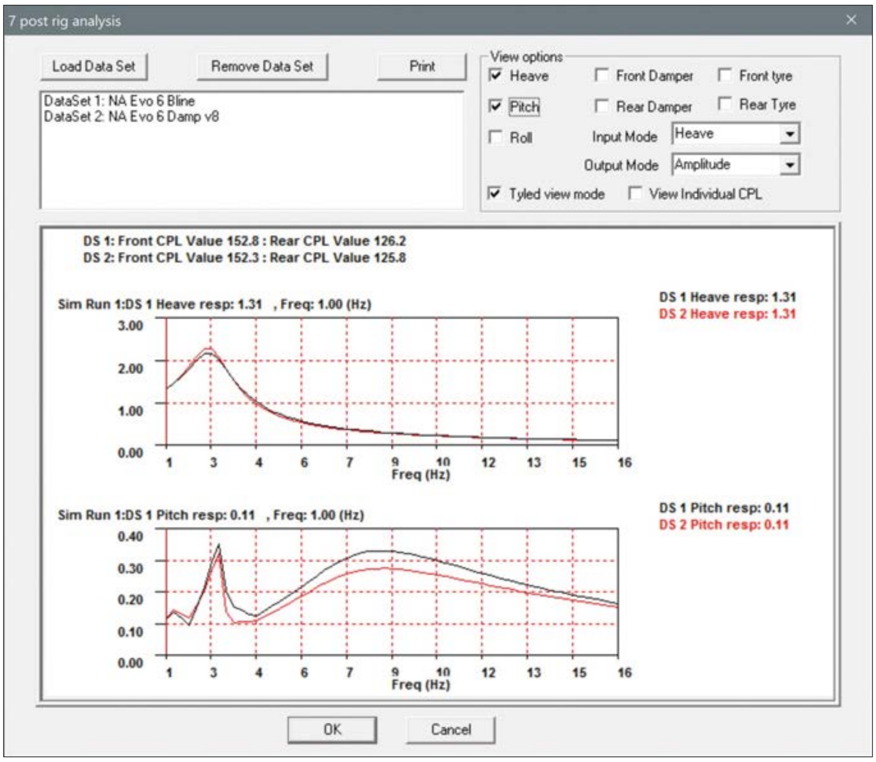


Figure 2: Example of using the ChassisSim shaker rig toolbox – one of the key building blocks for the weekend

Table 1: Aero numbers for NA AutoEng Evo

Aero paramater	Value
CLA	3 +
CDA	1
Aero balance	45%

Table 2: Rough outline to damping ratios

Damping Ratio Range	What this applies to
0.3 – 0.4	Ideal for filtering out bumps
0.5 – 1.0	This deals with body control.
1.0 +	This deals with extreme body control/ driving temperature into the tyres.

Table 3: Rough values for damping ratios

Damper section	Damping ratio value
Low speed bump	0.7
High speed bump	0.4
Low speed rebound	0.4
High speed rebound	0.4

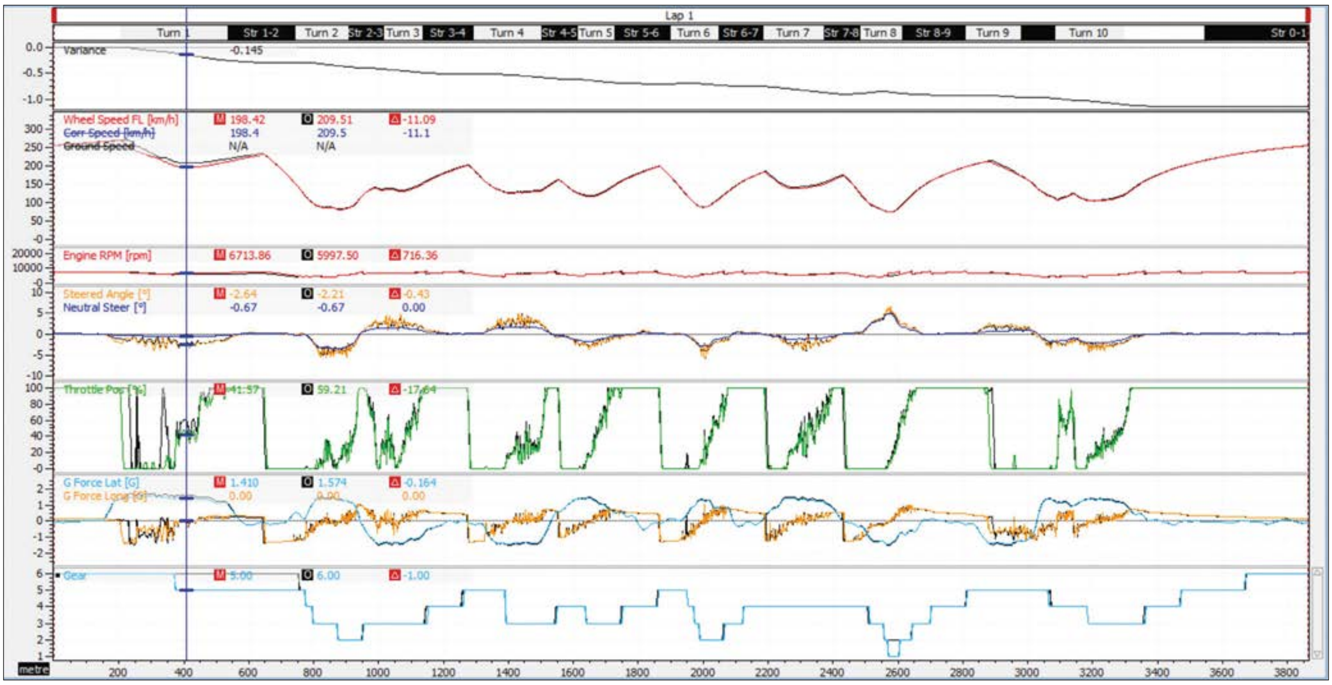


Figure 3: Front dive plane change. Coloured trace is set-up baseline and black trace is the dive plane change with the spring change the team was also planning to make

that I discussed in a previous feature on World Time Attack challenge (*RE* V26N11). Using the ChassisSim tyre force modelling toolbox the World Time Attack tyre was constructed from race data. This is shown in **Figure 1**.

In the previous article on World Time Attack I discussed this in some depth, but one thing I will add here is that some of that data was coming from cars that where falling apart. So this shows you don't need perfect data to get the job done. I can also add that without this we would have been completely lost.

Where this job started was with hand calculating the aero of the car from last year's data and also confirming this from the first day of running. It gob-smacks me why 95 per cent of race and performance engineers don't do this. Without this we would have been flying blind. The approximate aerodynamic numbers for this car are shown in **Table 1**.

This racecar had a weight distribution of 60 per cent. The full significance of this number would become apparent later.

The next job was specifying the dampers. When we talk about setting up dampers we are all convinced this is rocket science that requires an IQ of at least 300. The reality is somewhat different. The first port of call was using the damping ratio guide that I have discussed on a number of occasions here. But to refresh everyone's memory there are some rough rules of thumb shown in **Table 2**.

Damper ratios

So, all that had to be done was determining the transition between the low and high speed section of the damper and specifying the damper ratios. To that end the damping velocities from a smooth circuit simulation filled in these blanks very nicely.

Once that was determined then all that had to be determined next was the damper

The simulated baseline was a 1:31.0s lap. The simulated change was a 1:29.5s lap. My first thought was this was too good to be true

ratios. The approximate values are shown in **Table 3.** Anyone familiar with this will realise this is textbook stuff, from my first ever *Racecar* article on how to select damping ratios.

Solid platform

The next step was to refine this damping ratio selection using the ChassisSim shaker rig toolbox. The priority here was using the shaker rig toolbox to minimise contact patch load variation, and given how aero sensitive these cars are we also concentrated on minimising the cross pitch mode in heave. **Figure 2** is an example of the analysis that was done.

As you can see, there is no rocket science here and I do not have to solve a 15th order differential equation. I'm just following a simple process and sticking to it. All of this was critical because the car now had a solid platform that was well controlled. This was one of the key building blocks for the weekend.

The next step was race engineering the car. The ability to listen and having the vehicle dynamics knowledge was critical. The first question I asked the driver/owner Nick Ashwin was: what is your biggest problem? The answer to this was mid-corner to turn-exit understeer.

At this point, because I knew this was where the peak loads were, I knew the areas to focus on were springs and bars and the rear ride height. The springs and bars controlled the distribution of the load transfer. The rear ride height controlled the aero platform, in particular the aero distribution. The reason I could make these decisive calls was because of the decades of vehicle dynamics study I have had, that now boiled down to one day. Also, we didn't do anything silly. It was one change at a time, confirmed by looking at the data.

Dive planes

While we had made progress the inherent understeer in the car still hadn't been dialled out, and it was here ChassisSim came to the rescue. When we concluded the first day's running Ashwin said to me: 'We have dive planes that we can use at the front if you need them'. I was almost going to wait until midday Saturday to try them, but then it hit me in the eyeballs. Hang on, this isn't a spec formula. I can do what I want. So I ran the numbers in ChassisSim and the end result can be seen in **Figure 3**.

The coloured trace was the set-up baseline from the end of Friday's running. The black was the dive plane change with the spring change we were going to do. The simulated baseline was a 1:31.0s. The simulated change was a 1:29.5s lap. My first thought was this was too good to be true. But then I noticed how consistent the compare-time plot was and how consistent the speed differences were. So, first thing on Saturday morning I called the change.

While by modern spec formula standards this was a Hail Mary pass it worked exactly as expected. NA AutoEng's best time until this point was a 1:32.00s lap. When this was put on the car it was a 1:30.26s lap. The next lap would have been a sub 1:30s, but the car was held up in traffic. The comparison between actual and simulated data is shown in **Figure 4**. As always actual is coloured and simulated is black. I'm the first person to admit this is far from perfect and needs dialling in. However, the trends are undeniable and it shows you how far you can get with a model that is not actually perfect.

The other revealing thing about the weekend is what I discovered about what happens when you have significant technical freedoms to play with. When I started engineering the racecar during the test day and the first day of running, I approached it with the mindset of a spec car. That is, being very careful with the car and being very deliberate with the changes. That in itself is not a bad thing, because it ensures you don't get lost. However, the sim work on the Friday night showed what you can do when you do have those technical freedoms to play with. Unfortunately, it's a skill set that we are on the verge of losing.

Free formula

The other huge takeaway of this weekend was recognising the complete and utter intellectually bankruptcy of motorsport regulatory bodies' restrictions on technical freedom. To be quite honest this is technophobia run amok, that borders on complete hysteria. The critical tweaks for this weekend was the use of ChassisSim, the aero package from AMB Aero, and the front dive plane that provided the finishing touches. So to get this matter resolved once and for all let's break down the costs: shown in **Table 4** and quoted in Australian dollars

All up price is $7000. This enabled an amateur driver like Ashwin to keep a pro driver (who would eventually win the event) awfully honest. So, I have a simple question to any motorsport regulator or any motorsport red neck reading this. How exactly does technical freedom spoil the show or not allow low budget small teams to compete with their more resourced counterparts?

In closing, the NA AutoEng Evo 6 is the perfect case study of what happens when you have technical freedom and a tool like ChassisSim at your disposal. Using tools such as the ChassisSim tyre force modelling toolbox, the damper guide, and the shaker rig toolbox laid the foundation. All that was left was to use the ChassisSim lap time simulation to harness the aero package from AMB Aero. Without all these tools this podium would have been impossible and this shows that you ignore tools like ChassisSim at your peril.

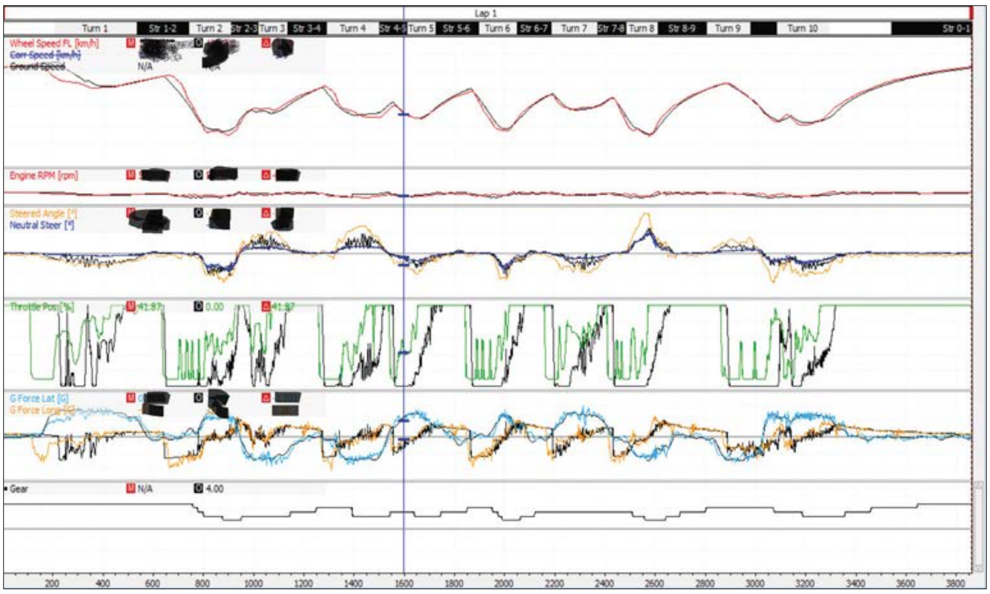


Figure 4: Comparison between actual (coloured) and simulated (black) data for the NA AutoEng Evo 6 World Time Attack car

Table 4: Costings of NA AutoEng tweaks for the Evo 6

Item	Cost
AMB aero package	$5000
ChassisSim set-up service	$1500
Front dive plane	$500

Liberty's Formula 1 purchase plan facing investigation by UK government body

It has emerged that the planned acquisition of Formula 1 by Liberty Media could be the subject of an investigation by the UK's Competition and Markets Authority (CMA).

Liberty Media has agreed to become F1's biggest shareholder through the purchase of shares from Formula 1's current owners, chiefly majority shareholder CVC Capital Partners. Liberty intends to initially acquire 100 per cent of the shares of Delta Topco, the parent company of F1, and completed an acquisition of an 18.7 per cent minority stake for $746m (£560m) in September.

This was followed up with a further $13m in late October, which secured an extra 0.4 per cent, increasing Liberty's share in Delta Topco to 19.1 per cent, with the remainder of the buy-out scheduled for the first quarter of 2017.

Liberty Media has not, at the time of writing, bought any of CVC's shares, as it awaits regulatory and shareholder approval.

However, the CMA – a UK government department responsible for anti-competitive activities – has now stepped in, and has said it is considering whether the deal was in contravention of the UK's anti-competition laws. The CMA also called on any party concerned about Liberty's acquisition of F1 to submit information to it before the end of November. The CMA said in a statement: 'The CMA is considering whether it is or may be the case that this transaction has resulted in the creation of a relevant merger situation under the merger provisions of the Enterprise Act 2002 and, if so, whether the creation of that situation has resulted, or may be expected to result, in a substantial lessening of competition within any market or markets in the United Kingdom for goods or services.'

The CMA has said that it will make a decision on whether it will take the matter any further on January 5 2017.

Liberty Media said when it announced its plans that, 'the completion of the acquisition is subject to certain conditions, including the receipt of certain clearances and approvals by antitrust and competition law authorities in various countries, certain third-party consents and approvals, including that of the FIA'.

XPB

UK government could rain on Liberty Media's Formula 1 buyout parade with the possibility of an anti-competition investigation

Volkswagen Audi Group culls top-level motorsport programmes

Two of the most successful international motorsport programmes in the sport's recent history have been cut with the surprise announcements that Volkswagen is to cease competing in the World Rally Championship while Audi will now no longer race in the World Endurance Championship, or at Le Mans.

VW broke the news soon after it clinched its fourth straight World Rally Championship drivers' and manufacturers' crowns, and the decision was seen as especially surprising as the company has recently finished developing its Polo for the new 2017 WRC technical regulations.

Volkswagen says it will now focus its motorsport efforts on customer-based competition, with its Golf TCR and the Beetle GRC rallycross car. It will, however, return to rallying at a lower level following the development of an R5-specification Polo in 2018.

Frank Welsch, VW board member responsible for technical development, hinted that part of the decision was down to the dieselgate scandal that rocked the company in 2015, as well as a desire to market new electric cars rather than ICE vehicles: 'The Volkswagen brand is facing enormous challenges. With the upcoming expansion in electrification of our vehicle range we must focus all our efforts on important future technologies. At the same time, Volkswagen is going to focus more on customer racing,' he said.

Meanwhile, Audi has announced it will pull out of the WEC and Le Mans after an 18-year involvement in the premier sportscar racing category.

Audi chalked up 13 Le Mans victories and the WEC drivers' and manufacturers' titles in 2012 and 2013 during its LMP1 programme, but it now says it is to realign its motorsport business to concentrate on Formula E with the Abt-Schaeffler team.

Audi chairman Rupert Stadler said: 'We're going to contest the race for the future on electric power. As our production cars are becoming increasingly electric, our motorsport cars, as Audi's technological spearheads, have to be even more so.'

The company also hinted at a need to reduce its motorsport budget by stating that the decision needed to be understood 'in the context of the current burdens of the brand', seen as a clear reference to the financial liabilities that are likely in the wake of dieselgate throughout VAG.

Audi's decision also comes against the backdrop of falling sales of turbodiesels road cars, which is the technology it chose to showcase in the WEC.

VW has quit the WRC, finishing on a high by clinching its fourth straight title, while sister marque Audi has left the WEC

XPB

US F4 chassis maker bought by Onroak-led motorsport group

French racecar constructor Onroak has acquired well-known US chassis builder Crawford as part of a recent expansion that has also seen it snap up engine builder Sodemo and top French racecar manufacturer Mygale.

Onroak, which produces the Ligier LMP2 car, has bought Crawford – which currently builds the US Formula 4 car and has a history in Daytona Prototypes – partly because it was looking for a base in the US.

Onroak Automotive will now operate directly from Crawford's base in North Carolina for all its Ligier LMP2, DPi, LMP3 and CN activities in North America. The Crawford F4 spec chassis programme will also continue.

Onroak founder Jacques Nicolet said of the Crawford acquisition: 'Since 2014, we've been looking for the right place, but mostly the right people, to base our activity in the USA. Onroak Automotive will pursue the development of the existing Crawford Formula 4 programme in the USA and will establish its sales and support services for its range of prototypes for the North American market.'

Max Crawford, the founder of his eponymous company, has now taken on the role of Onroak's North American general manager.

French firm Onroak has, since September, been run under the umbrella of the newly-named Everspeed Motorsport group (formerly known as the JN Holding Group), which also now controls Mygale, Sodemo and Italian-based carbon specialist HP Composites.

Everspeed's purchase of Sodemo was announced in October. Following the acquisition Nicolet said: 'What we're aiming to do at Everspeed is to offer the widest possible range of services in the industrial and the motorsport sectors through companies between which we can optimise synergies. Sodemo's expertise has been acknowledged in motorsport, among other areas, for more than 25 years, and its activities in the engine and electronic sectors will dovetail perfectly with the services we provide in our motorsport branch.'

XPB

Onroak is already responsible for the Ligier LMP2 (pictured) and has now added US F4, Mygale and Sodemo to its business portfolio

Russian manufacturer to end its World Touring Car programme

Lada has axed its World Touring Car Championship (WTCC) programme and will no longer compete in the series after the end of this season.

The Russian marque first entered the WTCC in 2008, and it has competed on a full-time basis since 2012, in the past two seasons with its Vesta model.

Alexander Bredikhin, marketing director for Lada's parent company AvtoVAZ, confirmed the news after it was initially broken by works driver Nick Catsburg.

Francois Ribeiro, the head of WTCC promoter Eurosport Events, said of Lada's decision: 'Manufacturers will always come and go in motorsport and the current period is definitely not an easy one for those world championships in which car manufacturers are directly involved as factory teams.

'Even though Lada's domestic market share is holding up with a new range of products, the Russian automotive market has declined by 50 per cent over the last two years,' Ribeiro added. 'The WTCC has certainly helped Lada to transform its image and positioning and we wish to thank them for their long-term support of the championship.'

Lada has had its best season in the WTCC to date this year; with the first wins for the Vesta coming at its home track in Moscow in the summer.

The firm's withdrawal will leave just Volvo and Honda as manufacturers active in the WTCC next season, following Citroen's decision to quit touring car racing in 2017 in order to concentrate on the World Rally Championship.

It has been reported that Lada will now build a Vesta to TCR regulations, which will be entered in the Russian Circuit Racing Series, the RSKG, next season.

AvotVAZ is controlled by Alliance Rostec Auto BV, which in turn is 67 per cent owned by the Renault-Nissan Alliance.

XPB

Lada is to pull out of the WTCC and the Russian company now intends to concentrate on its domestic TCR series

SEEN: ORECA 07 LMP2

ORECA has unveiled its 2017 LMP2 contender. The French constructor says the new ORECA 07, which is based on the ORECA 05 monocoque, benefits from radically different aero as well as significantly increased efficiency and downforce. ORECA has also revealed that the car is well below the 930kg minimum weight for the new LMP2 class, and hence carries substantial ballast. The new car, powered by the one-make Gibson LMP2 V8 engine, undertook its first test run at Paul Ricard in November.

David Floury, technical director at ORECA, said: 'The ORECA 07 was conceived around the ORECA 05's monocoque and shares a certain number of the 05's mechanical components. The idea was to build on the success and the quality of the ORECA 05 while developing performance. Our concept was to design a completely new car around a base of existing components thus allowing the teams who own an ORECA 05 to update it to the 07, by trying to control the cost of conversion. This is in keeping with the philosophy of cost cap and allows the teams to pay off their investments over a longer period.'

The ORECA is the third of the 2017 LMP2s to break cover, after the Dallara and the Ligier (see RE V26N11). The last of the 2017 cars – just four companies are now licensed to build the new LMP2s – will be the US-built Riley-Multimatic.

Malaysian Formula 1 race in the balance

The future of the Malaysian Grand Prix is in doubt after the country's sports minister admitted that it could be dropped in the face of diminishing interest in F1 in Malaysia and ever-rising race hosting fees.

Malaysia has hosted a round of the Formula 1 world championship since 1999, but now its sports minister has cast doubt on its continuation and it has been reported that it is looking at dropping the race.

However, Malaysia and GP venue Sepang are said to have a 'watertight' contract with Formula One Management (FOM) to host the grand prix until 2018. Yet as *Racecar* went to press it was reported that a meeting had been set up with the intention of ending the contract next year.

It has been reported in Malaysia that hosting fees have continued to rise by 10 per cent every year, while ticket sales have declined since 2014 by a similar amount – almost 10 per cent year on year.

This prompted Malaysian sports minister Khairy Jamaluddin to Tweet: 'When we first hosted the F1 it was a big deal. First in Asia outside Japan. Now so many venues. No first mover advantage. Not a novelty.

'Formula 1 ticket sales are declining, the TV viewership is down,' he added. 'Foreign visitors down because they can choose Singapore, China, Middle East. Returns are not as big.'

Meanwhile, MotoGP is riding high in Malaysia and it has recently signed on with the premier motorcycle racing category to stage a GP at Sepang until 2021. Razlan Razali, chief executive at the Sepang International Circuit, said: 'It's not very difficult to convince the Malaysian government to support the Malaysian [MotoGP] Grand Prix because we achieve record-breaking crowds every year. MotoGP is no longer just a spectacle for Malaysians, it is now a platform for young Malaysian talent to compete in the world championship and on home ground. I think that is key to the Malaysian GP.'

Sparse crowds in the grandstands at Sepang – is the end in sight for the Malaysian Grand Prix after 17 years in Formula 1?

SEEN: Porsche 911 RSR

Porsche has unveiled its new GT racer for 2017, which head of Porsche Motorsport Dr Frank-Steffen Walliser says is 'the biggest evolution in the history of the top GT model'. It will compete in the WEC and IMSA.

The new 911 RSR features the flat-six engine positioned in front of the rear axle. The car is said to be a completely new development: the suspension, body structure, aerodynamic concept, engine and transmission have all been designed from scratch, we're told. The engine concept has enabled the designers to install a larger rear diffuser, while there is also a top-mounted rear wing adopted from Porsche's LMP1 prototype racecar, the 919 Hybrid, which should raise the level of downforce and improve aerodynamic efficiency.

'For the 911 RSR, we deliberately focused on a particularly modern and light normally-aspirated engine, as this gave our engineers immense latitude in developing the vehicle,' Walliser says. 'Apart from that, in principle, the LM-GTE and GT Le Mans class regulations stipulate the absolute equality of various drive concepts, as the torque characteristics of turbo and normally aspirated engines are aligned.' The car will debut at January's 24 Hours of Daytona.

Upturn in profit for Prodrive Motorsport

Famed race and rally preparation business Prodrive Motorsport has released encouraging financial results for 2015.

The UK-based company posted operating profits of £1.9m for the year ending December 2015, which is a 305 per cent increase over its 2014 operating profit of £632,000. In the same period turnover increased by 7.3 per cent, from £27.5m in 2014 to £29.5m in 2015.

Prodrive put its success down to 'the continued efforts and results of the introduction of incremental race programmes and our engineering projects during the last few years coupled with tighter cost control'.

It also states that the experience and skills it has accrued since it was founded in 1984 has played no small part in its success: 'The company's continued success in motorsport is primarily due to the extensive experience, skills and resources it has developed over the last 30 years. This allows the company to undertake the complete design, engineering and development for almost any class of competition race or rally car.'

There was a small change in the workforce between 2014 and 2015, with a decrease from 142 to 138. Broken down further this is 128 working on the engineering and technical side (129 in 2014) and 10 in sales and administration (13 in 2014). The Prodrive group as a whole, which encompasses Prodrive Advanced technology, employs over 500 people.

Prodrive's main motorsport business continues to be running the Aston Martin Racing team on behalf of the manufacturer as well as supplying Aston Martin GT cars to series worldwide. It also built and developed the VW Golf that competes in the Chinese Rally Championship.

Last year also saw Prodrive Motorsport move in to a new purpose-built motorsport-engineering facility in its home town of Banbury.

Prodrive Advanced Technology operates out of Milton Keynes and now accounts for over half of the Prodrive group's turnover.

The Aston Martin race programme is a key element in Prodrive Motorsport's success as a business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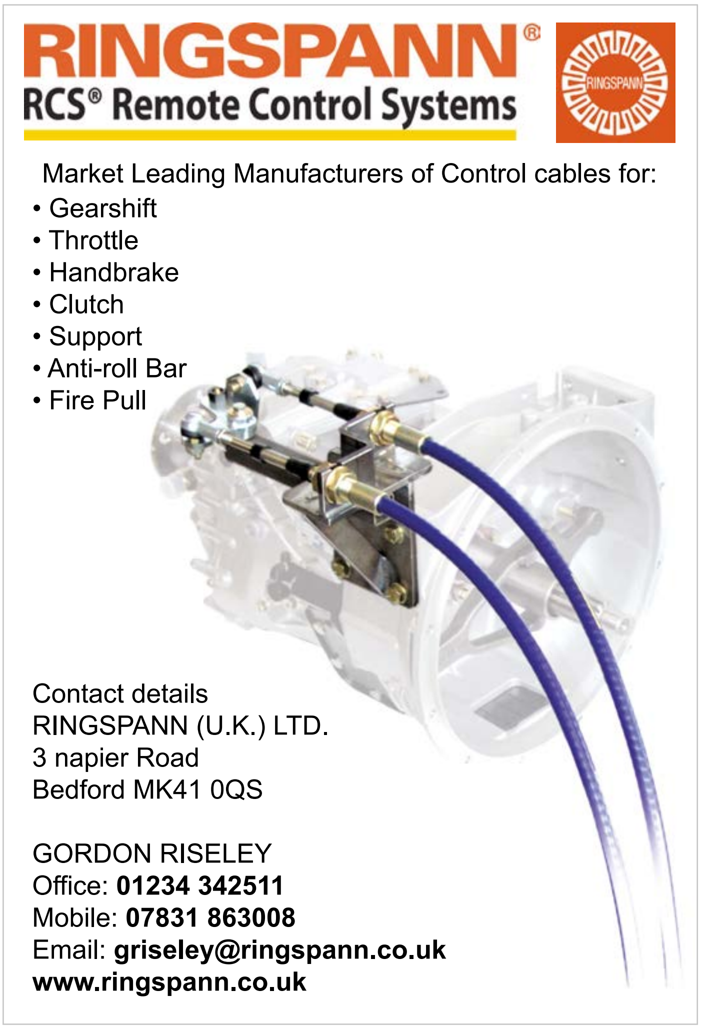
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INTERVIEW – Rene Rosin

Rosin bloom

In 2016 Prema Powerteam has won almost everything worth winning in sub-F1 single seaters. The Italian operation's boss tells us the secret to its success

By MIKE BRESLIN

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'Let others think it was due to the investors. But it was mainly due to the way we are working'

There are some standout candidates for having had the best 2016: Leicester City football club, the Chicago Cubs baseball team, or maybe Donald J Trump, for a start. But when it comes to motorsport you would be hard-pressed to find a season to compare with the one Italian single seater outfit Prema Powerteam has just experienced.

The northern Italian company, which is based near Vicenza, has campaigned in GP2, European F3, and F4 in Italy and Germany, winning the teams' title in all four and the drivers' title in all but Germany – GP2 had yet to be sealed at the time of writing but it was between the two Prema drivers. Yet, despite this wide breadth of championships, scratch the surface and what you see is at heart a Formula 3 operation.

'Our history is Formula 3,' team boss Rene Rosin says. 'When Dad [Angelo Rosin, who set up Prema with Giorgio Piccolo] started in 1983, it was F3, and always it has been Formula 3. In our heart it has always been a focus on Formula 3.'

Ladder to F1

Clearly, this focus is not at the expense of the other categories, as Prema's winning return to GP2 (it was last in GP2 in 2009) shows. This also gives it a useful selling point when it comes to attracting drivers, says Rosin: 'Now we have stepped up in to GP2, on our ladder we can bring drivers from karting to F1.'

Yet ironically, Prema's latest graduate to Formula 1 has made the jump straight from Formula 3, European champion Lance Stroll signing up with Williams for 2017. Stroll also points to one of the big talking points in F3 over recent seasons. His billionaire father, Lawrence, backs Prema – which with Van Amersfoort Racing and Hitech GP is one of the three F3 'superteams'. Some say this had led to a drop off in entries in F3, with drivers not being able to find a seat in one of these top teams electing to go to another category – this year the grids have been around 20 cars, down from around 35 in 2015. This has now led to an FIA clampdown, with a ban on wind tunnel development, plus a new set of control aero parts from Dallara for 2017.

However, Rosin insists the dominance of teams such as Prema is not the real reason for the reduction in the number of drivers. 'The number dropped because we lost drivers coming from new markets, like China,' he says. 'We lost six drivers like that, more or less. On top of that there's been the rule that drivers can not repeat F3 for more than three years [now four].'

But with the above in mind, are the new aero restrictions a waste of time then, merely bringing the famously free – in terms of engineering – formula closer to a spec series? 'The FIA decided on this to stop teams with a very good financial base getting an advantage,' Rosin says. 'So, this is a positive step. The engineering push will now be on the mechanical side [suspension and dampers remain free]; and the study for this can cost much less than aerodynamics. With aerodynamics to find something very, very small means you spend a lot of money. It is sad to say, but this was the right choice. I fully agree with the FIA because we cannot keep pushing on aerodynamics. This year we have Prema, Van Amersfoort, and Hitech that was allowed, due to their [backers], to do this aero development. But to be honest there is not much to gain from it anyway. If you see the cars, they are all pretty similar.'

In one respect, they are identical, in fact. Despite the odd interloper – such as the Russian ArtTech last year – F3 is now a Dallara F312 lock-out, for one very good reason. It's just a great car. 'At the moment Dallara has such exceptional technology,' says Rosin. 'I think if there is a new car from someone else it won't be until 2020 [the end of the current chassis cycle]. There are difficulties for manufacturers to come in; because Dallara has the facilities to design and build a car that for other companies it is very difficult to replicate. The big teams, like us, have done aero development. But nobody has really changed the car, because Dallara has done such a great job with it.'

Grand Prema 2

Dallara also supplies the spec chassis for GP2, of course, the GP2/11, which has been raced for six seasons now. This year GP2 made the decision to postpone the introduction of a replacement for the dated-looking chassis until 2018, rather than 2017. Rosin believes this was the correct decision. 'When we heard that it was not now going to happen until 2018, from an economical point of view we were happy … I think that the car itself is a pretty good car; the package is quick and reliable, and so it is good that we have it for another year.'

When the new car does come along, if all goes to plan, it

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should also be known as Formula 2. This, says Rosin, will be a good thing. But he also believes the FIA should go further, even to the point of getting rid of GP3, he hints. 'I am always telling them that there are too many categories around, so if the FIA can agree to just do the ladder, Formula 4, Formula 3, then Formula 2, then Formula 1, then somebody for sure will suffer, but we cannot have everybody happy.'

Power team

As far as Prema's own ladder is concerned, Rosin is team principal for the GP2 team and team manager for F3 – his father Angelo oversees the F4 efforts. There is also a staff of around 50 – in fact, in terms of number of employees and its resources, Prema claims it is the third Italian race team after Ferrari and Toro Rosso. This staff is also critical to its success, Rosin says: 'One factor we have in our favour is stability of team personnel. Since 2009 we achieved stability, that has helped us a lot. I try to have around me people who I trust and who I can rely on. If I find these people, I try to keep them, because it's quite difficult to find really good people. We also try to grow people within the organisation, they come up through all our categories.'

It's actually this that makes Rosin believe that the new F3 aero restrictions for next year will not hit Prema hard. 'We will see now, with these new aero kits, whether they will shuffle the field a bit. But in the end, even if we don't go to the wind tunnel, even if we end aero development, what will count is the way a team works; the way the team is organised. Our team will still do a great job. Let the others think it was due to the investors. But no, it was mainly due to the way we are working.'

Beyond single seaters Rosin says he would love to one day run an LMP programme, at Le Mans in particular, but adds that Prema would only really contemplate this if it was in partnership with a manufacturer. Any new project would also involve new staff, too. 'I cannot add any workload to my guys, because then we will lose performance, and when we lose performance we will lose everything,' he says.

In the shorter term Rosin has something else to worry about: 'Next year will be difficult,' he says. 'Because we want to do better than this year.' Now that will be quite a challenge …

Italian single seater outfit Prema Powerteam has had an amazing year in 2016, winning titles in Formula 3 (pictured) GP2 and F4

RACE MOVES

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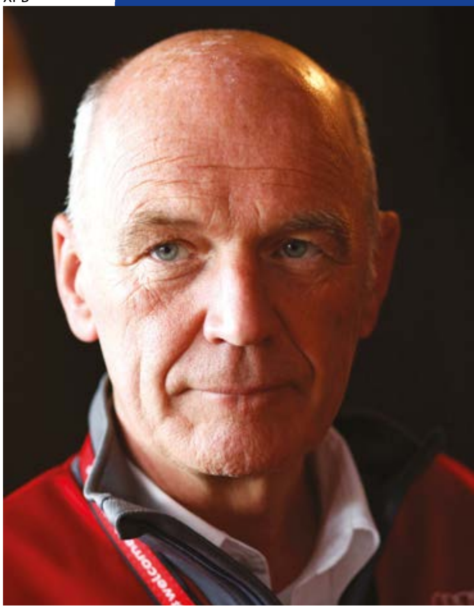


Wolfgang Ullrich, the long-time boss of Audi Sport, is to retire at the end of next year. He has also announced that he will hand over his duties to current Audi DTM head **Dieter Gass** at the end of this season, and then work alongside him throughout 2017. Ullrich joined Audi as head of its motorsport department in November 1993.

Colin Folwell, the founder of respected competition seat concern Corbeau, has died at the age of 77 after a short illness. A former club racer, he started his well-known race seat business in 1963.

Supercars driver **Todd Kelly** changed his race engineer at the Gold Coast round of the Australian race series, the Nissan works team owner/driver's car now being tended by **Blake Smith**, who takes over from **Matthew Rumfield**. This is the second engineer change for the Carsales Nissan this season, and is an interim appointment while the team looks for someone to fill the post full time.

NASCAR Sprint Cup crew chief **Greg Ives** was fined $10,000 when the No.88 Hendrick Motorsports Chevrolet he tends was found to be running with improperly installed lug nuts at the Kansas round of the series.

Brad Jones has been re-elected as a member of the Supercars Commission Board, the body which represents the team owners in the prestigious Australian tin top championship. Meanwhile, Holden Racing Team's managing director **Adrian Burgess** has been officially elected to the board an as alternate commissioner.

A member of the Mercedes Formula 1 team was robbed at gunpoint during the Mexican Grand Prix weekend. The unnamed man was said to be 'shaken up' after he was targeted by thieves just after he had arrived in Mexico City. The team member, who lost his wallet and watch in the incident, elected to stay with the team throughout the race weekend rather than returning to the UK.

Gerard Lopez, the former owner of the Lotus Formula 1 operation – which now races under the Renault name – is set to buy French football club Losc Lille, it has been reported. Lopez is still a minor shareholder in the Enstone-based Renault team.

The F1 in Schools World Finals 2016 was won by a team from Athens, Greece. Infinite Racing, from Mandoulides School, took the World Champions crown and lifted the Bernie Ecclestone trophy. Australian team Infinitude was the runner-up, with Endeavour from Germany taking the third podium place.

Sam Michael, the former Williams technical director and one-time McLaren sporting director, has joined Australian Supercars team Triple Eight Racing. He will take up what's been described as a 'part time mentoring role' at what will be the sole Holden works outfit next season. Michael also worked with Lotus and Jordan over the course of his two decades in Formula 1. He left McLaren and F1 at the end of the 2014 season.

Ludo Lacroix, who has been technical director at Australian Supercars squad Triple Eight Racing since 2003, has left the team. Lacroix, who was also the race engineer for **Craig Lowndes** at Triple Eight, will be moving to DJR Team Penske for next season. He is now on gardening leave and **John McGregor** has stepped in to cover the race engineer duties for Lowndes.

Robert Yates, the NASCAR engine builder and former team owner, has been diagnosed with liver cancer and has now begun treatment, his son **Doug Yates** has announced. Robert Yates spent 21 years as a team owner in NASCAR's top level series, earning 57 race wins, 49 poles, and the 1999 championship. His cars also won the Daytona 500 three times while those packing his engines have scored 77 top-line NASCAR victories.

Audi man signed up as Sauber technical director

Jorg Zander, formerly the technical director at the Audi LMP1 operation, has now taken on the same position at the Sauber Formula 1 team.

Jorg Zander has left Audi, where he was technical director, to take up the same post at Sauber in Formula 1

Zander, who left Audi in the wake of its withdrawal from the World Endurance Championship, will start work at the Swiss F1 outfit next year. He previously worked at Sauber's base in Hinwil as the chief designer for BMW Sauber between 2006 and 2007, and has also worked with Toyota, Williams, BAR, Honda and Brawn in Formula 1.

He said of his return to F1: 'The new Formula 1 regulations offer a great opportunity to point the way with innovations and technical creativity. One of my tasks will be to define a stable and efficient technical organisation that evolves the potential of creativity and, therefore, the basis for the development of successful F1 cars. Initially we obviously want to improve and establish ourselves as a team in the midfield. Overall it is a challenge which I await with excitement and enthusiasm.'

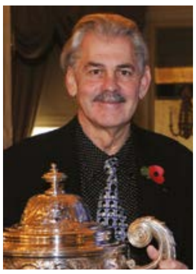
Sauber team principal Monisha Kaltenborn said. 'Zander fits well into our team, he has a lot of know-how in F1, as well as in motorsport in general. As technical director he will have the overview as well as the responsibility for all technical departments.'

Zander's appointment is the latest in a series of signings since Sauber was bought by Longbow Finance in the summer. Chief amongst these was Nicolas Hennel de Beaupreau's hiring as new head of aerodynamics and Xevi Pujolar as head of track engineering.

Former motorsport boffins scoop top RAC tech prizes

A company headed by Former F1 designer Gordon Murray has won the Royal Automobile Club's prestigious Dewar Trophy, while one-time Formula Ford designer Hugo Spowers has been presented with its Simms medal.

The Dewar Trophy was awarded to the Gordon Murray Design founder, and former F1 designer at Brabham and McLaren, for his team's development and application of the innovative iStream chassis concept, including its use in the Global Vehicle Trust OX all-terrain vehicle – which tackles crucial transport challenges in the developing world, by offering a cheap, versatile and durable flat-pack truck.



Gordon Murray has picked up the Dewar Trophy for his ground-breaking iSteam chassis concept

An iStream-constructed chassis is at the heart of the OX, featuring steel tubes bonded together by plates. In more expensive vehicles, these plates would be carbon fibre, but in the OX they are 'engineered plywood', a strong and cheap material that helps contribute to the truck's 1900kg payload capacity.

John Wood MBE, chairman of the Dewar Technical Committee, said: 'Gordon Murray Design's iStream technique presents a completely new way of thinking about vehicle construction and manufacture … It's a genuine innovation that could positively affect the lives of people in some of the world's poorest areas.'

Meanwhile, Hugo Spowers – who is known in motorsport for the radical Prowess Formula Fords he designed in the 1980s – picked up the Simms Medal for Riversimple, the company he founded, which has developed its Rasa as an affordable and usable hydrogen fuel cell vehicle.

Innovations used in the Rasa include an ultra-lightweight carbon fibre monocoque, four in-wheel electric motors, a bank of super-capacitors and regenerative braking that captures more than 50 per cent of kinetic energy.

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Matt Borland is to return to crew chief duties in the NASCAR Sprint Cup next year, tending the No.27 Richard Childress Racing (RCR) Chevrolet. Borland, who will take over from interim crew chief **Danny Stockman**, who in turn is expected to switch to RCR's Xfinity operation, comes to RCR from Stewart-Haas Racing, where he was vice president of technology – a role that involved liaising with the Haas Formula 1 operation.

RACE MOVES – continued

It has emerged that former Mercedes F1 boss and one-time Ferrari technical director **Ross Brawn** – who won the championship with a car bearing his own name in 2009 – has been taken on as a consultant to help Liberty Media navigate the rocky waters of Formula 1 as it continues to progress with its purchase of F1 from CVC Capital Partners.

Michael Mallock is now the chief executive at RML Group with company founder **Ray Mallock** electing to fully focus on his role as chairman of the well-known motorsport and high performance engineering concern.

Former Prodrive electronics expert **Richie Frost** has joined EV maker Detroit Electric as chief technology officer. Frost started his career in motorsport in 2001, delivering electrical systems into Formula 1, before joining Prodrive in 2005. In January 2011 he founded Frost EV Systems, an engineering consultancy specialising in low carbon vehicles.

Ricky Brooks had been appointed technical director for the TA2 class of the US TransAm Series. Brooks has been recruited to the championship as the class prepares to invest in its technical compliance and cost control.

McLaren Automotive has made key appointments in the areas of social media and product communications within its Global PR team. **Paul Chadderton** joins the company as global product communications manager, while **Hunter Skipworth** will take on the role of social media communications manager.

Former V8 Supercars driver and team owner **Allan Moffat** has been named an ambassador for the Confederation of Australian Motorsport, a role which will see him supporting its efforts to promote motorsport in Australia.

Dr Martin Leach, the boss of the NextEV Formula E team, has died at the age of 59. Leach, who was a karter in his youth, was for many years an executive in the automotive industry, and held high level positions at Ford, Mazda and Maserati. Electric car company NextEV, of which Leach was a founder, took over the Team China FE operation in 2015.

Long-time club motorsport reporter **Bill Henderson** has died at the age of 92. Henderson started writing race reports and taking photographs from Scottish venues, mostly for *Autosport* magazine, in 1950.

Frank Williams has been discharged from hospital and is said to be well on the road to recovery after contracting pneumonia. He was taken ill during the Italian GP weekend and was later admitted to Oxford's John Radcliffe Hospital. Williams Deputy team principal **Claire Williams** missed five grands prix in order to be close to her father during his illness.

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AUTOSPORT INTERNATIONAL
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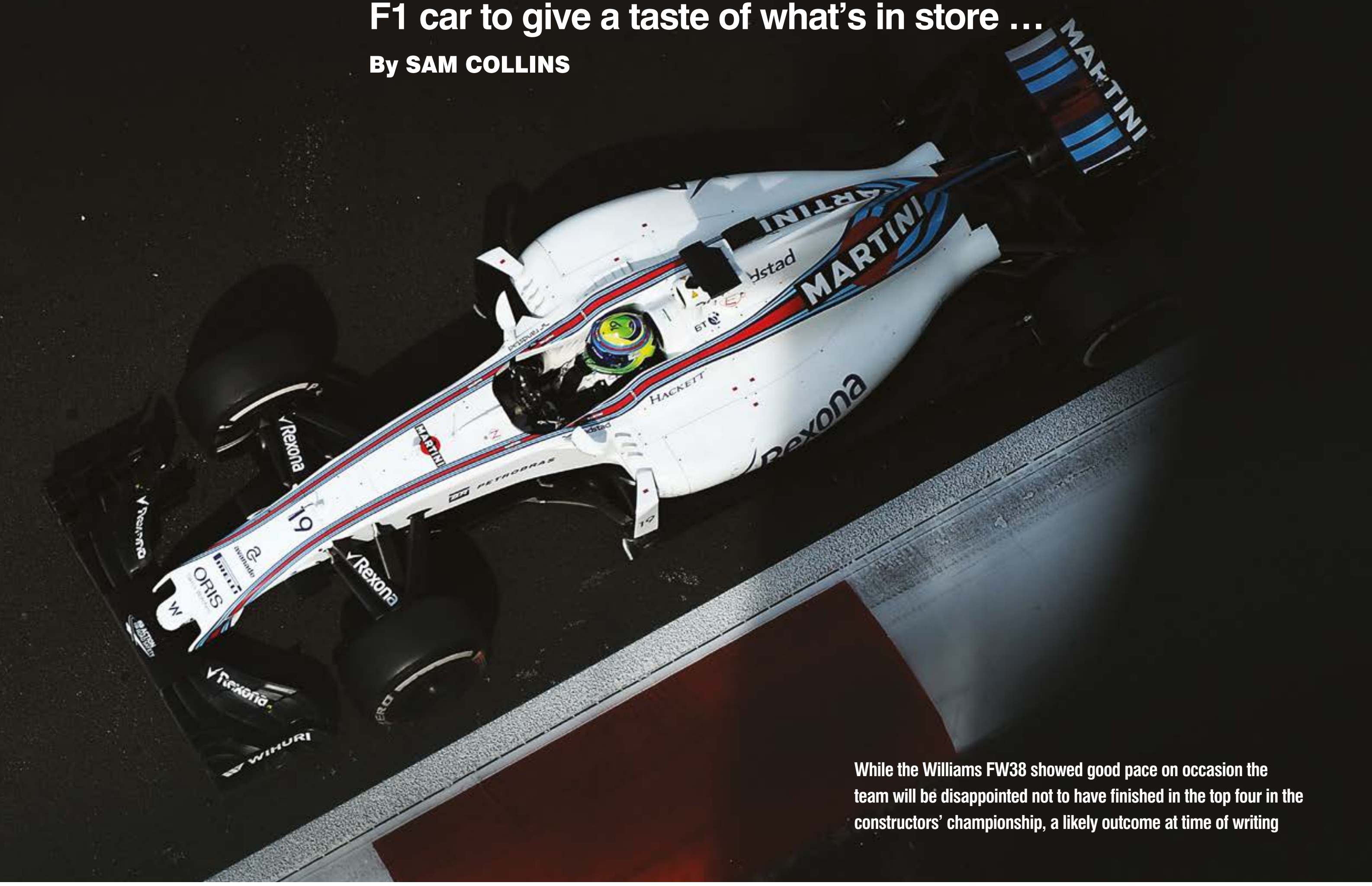
Forty years of racing history

Williams is to celebrate its 40th birthday with a special display at the Autosport Show. We unwrap its present F1 car to give a taste of what's in store …

By SAM COLLINS



While the Williams FW38 showed good pace on occasion the team will be disappointed not to have finished in the top four in the constructors' championship, a likely outcome at time of writing

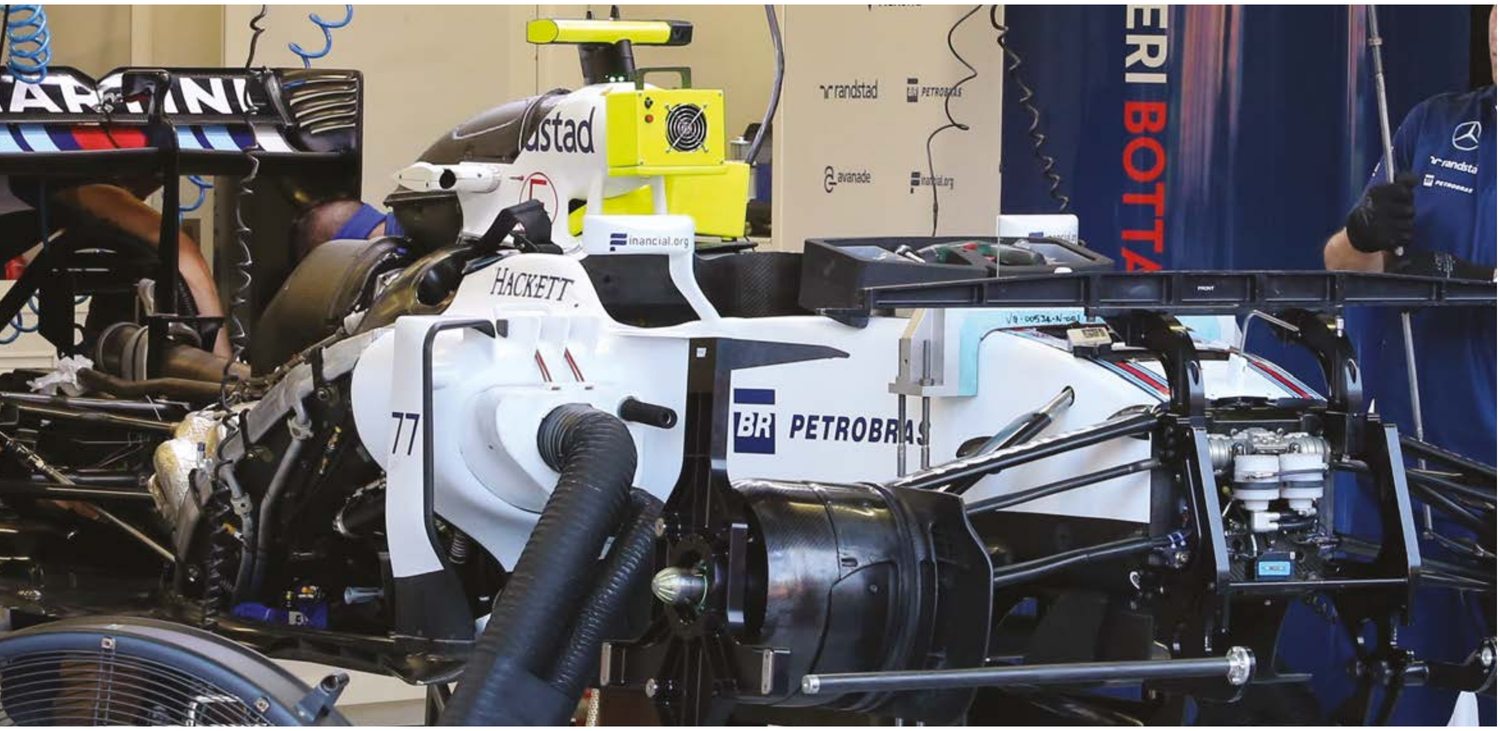
They're the star cars that took some of the Williams team's most famous and important victories, including the team's first ever win. Now, as part of its 40th anniversary celebrations, visitors to Autosport International in January will be able to get up close to these iconic F1 machines.

And likely to be among the racecars on display is the 2016 design, the Williams FW38. The car was launched online just before the start of winter testing in Barcelona – this the first 2016 design to be shown – and at first glance it was a very close iteration of the 2015 FW37.

The overall car layout is indeed essentially the same, with pushrod actuated torsion bar suspension at the front of the car and pull rod at the rear. Power comes from the 2016 specification Mercedes power unit driving through an aluminium cased transmission of Williams' own design. Something which gives the team complete freedom in terms of its rear suspension layout (other customer teams tend to buy in a transmission casing).

But there are many small refinements and revisions across the whole car. For example, the forward upper leg of the front wishbone sits slightly further rearwards relative to the front of the bulkhead on the FW38 than it did on the FW37. This change is perhaps a small indicator of the direction taken by Williams with the 2016

Power comes from the 2016 specification Mercedes power unit driving through an aluminium cased transmission of Williams' own design



A half naked Williams FW38, showing pull rod rear suspension and the very neatly packaged cooling system. The car is in many ways an updated FW37, but with many refinements

Williams has opted for the far less common AP Racing calipers on its FW38, using 6-piston calipers at the front end, 4-piston at the rear, and carbon discs and pads

The front bulkhead and the steering rack. The suspension layout is essentially the same as the FW37, with pushrod actuated torsion bar at the front of the car and pull rod at the rear

car. 'The FW37 was a pretty effective car and so we concentrated on understanding the areas where we could improve it without losing the attributes which made it effective,' technical director Pat Symonds says. 'It is no secret that the low speed performance of the FW37 didn't match its high speed performance so a lot of time was spent looking into why this was and subsequently making changes, which we [hoped would] improve the situation. On top of this we looked at the normal physical obstacles to development that one always meets during the life of a car and tried to push those barriers back.' Symonds had earlier described the FW37 as a 'bloody good all rounder.'

The new car featured higher and tougher cockpit sides as a result of a rule change introduced for the 2016 season. The roll hoop concept, however, was a continuation of that used on all of the team's designs since the FW35, though it must be assumed that the design has been improved since its introduction.

Aero package

In terms of the aerodynamic package a lot of work was carried out around the rear of the racecar, while the sidepods and internal cooling were completely reshaped, as well.

Early in the season the team also adopted a new front impact structure, which improved air flow around the front of the car.

Initially the performance of the car was acceptable but as the 2016 Formula 1 season drew to its conclusion the Williams team was fighting a seemingly futile battle for fourth place in the constructors championship, and for the badge of honour as the best Mercedes customer team. Force India's substantial rate of improvement during the season had seen it overhaul the nine-time champion team.

'I think that most of our competitors improved more than we expected,' Symonds says. 'We made the improvements that we more or less had expected to make. We probably didn't set the targets high enough. Some of our competitors have improved a lot. But a huge factor also was that the power units got much more equal – and that is eroding some of the advantage that we had with the FW37.'

A number of other famous cars from the history of the Williams F1 team will be

In terms of the aerodynamic package of the Williams FW38, a great deal of work was carried out around the rear of the racecar


PRO FABrication
Racing Exhaust Systems
CAD to Production
Inconel Specialists
Mandrel Bends
18 & 20 Gauges
CNC Flanges
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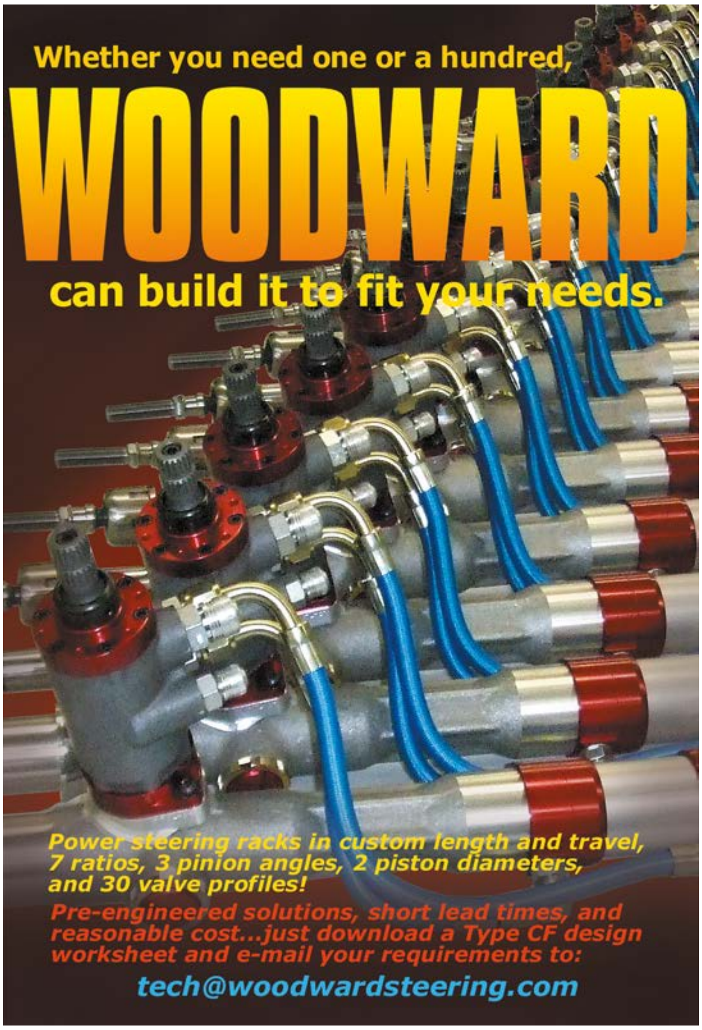
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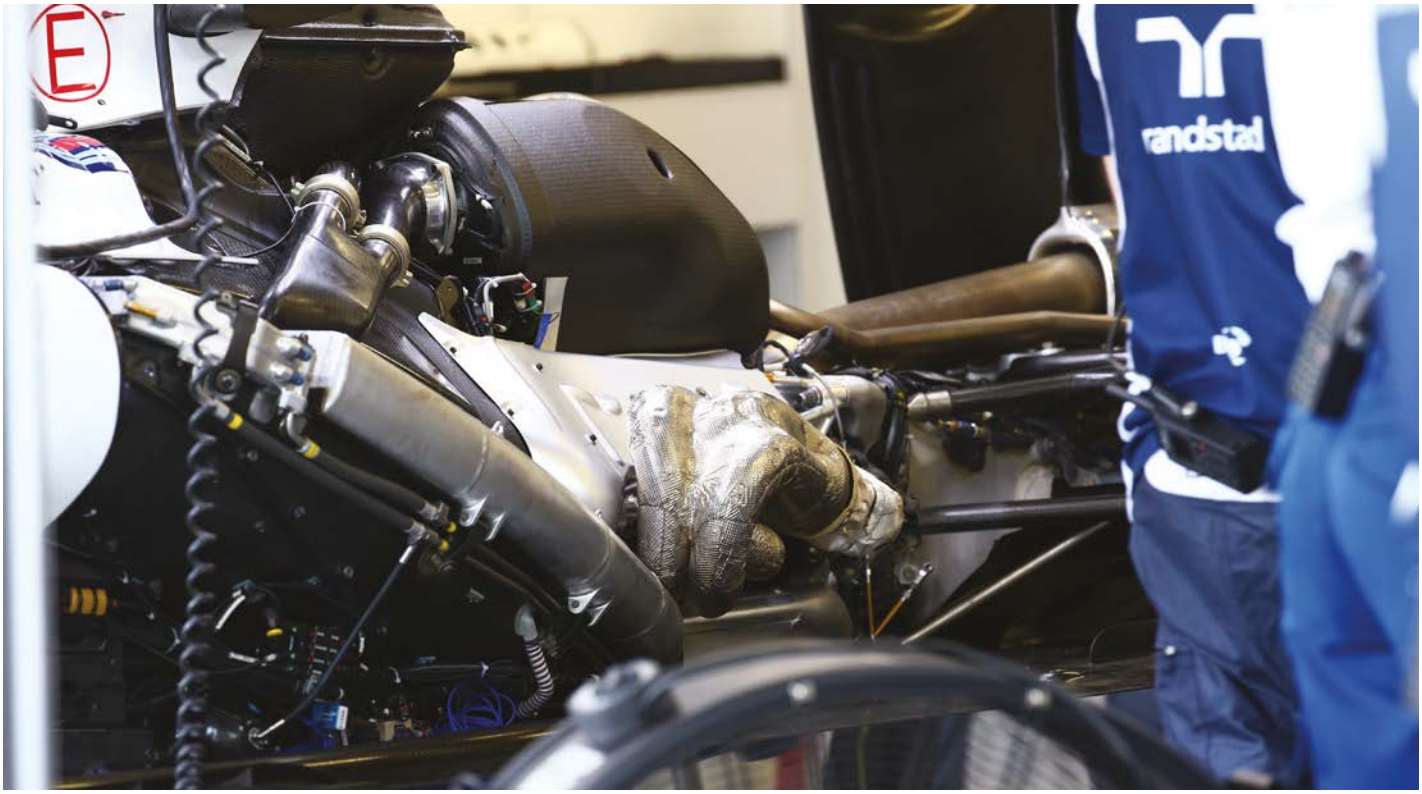
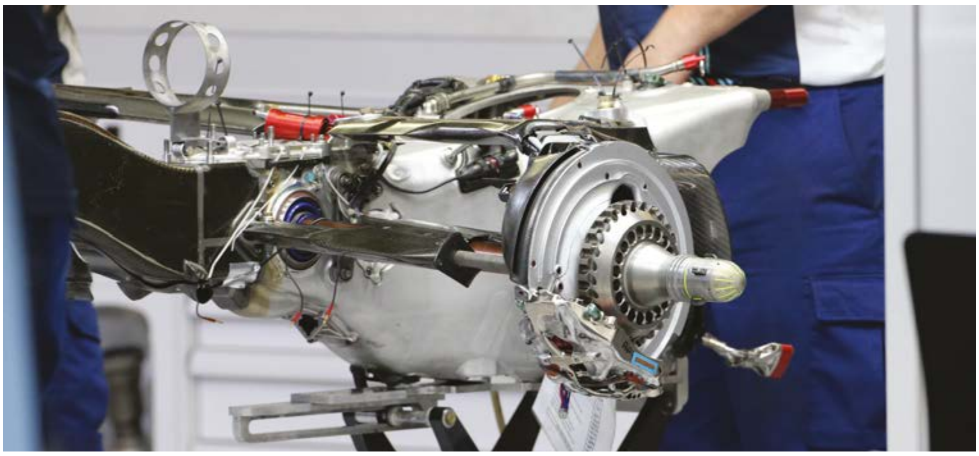


The FW38 packs the all-conquering Mercedes power unit – although technical director Pat Symonds says the advantage this potent powerplant gives was narrowed in 2016

The roll hoop concept is a Williams trade mark and a continuation of that used on all of the team's designs since the FW35 of 2013, though it is highly likely that the design has been improved subtly since its introduction three years ago



Williams uses its own aluminium cased transmission, which gives it complete freedom in terms of the design of the rear suspension layout on its cars, a luxury many customer teams do not have. It also supplies its gearbox to the Manor team

on display at the show, including the FW07, the car which scored the team's first grand prix win at Silverstone in 1979, and the most technologically advanced car of its time, the FW14B; which featured a semi-automatic transmission, active suspension, traction control and anti-lock brakes. These will be joined by the 1996 title-winning FW18 and the BMW-powered title runner-up FW25 of 2003.

Diverse display

Alongside all this will be displays giving visitors an insight into the world of Williams Advanced Engineering, the division that transfers technology from Formula 1 to market sectors as diverse as defence and renewable energy. In addition, visitors will be able to learn about Williams Heritage, the team's historic racing division, which restores and fully supports Williams racecars for private owners.

'We get such great support from the fans and we can't wait to be able to give something back. We're looking forward to showing off some of our most famous racing cars from the past four decades. It's also a fantastic platform for us to showcase Williams Advanced Engineering and Williams Heritage,' said Claire Williams, deputy team Principal at Williams.

'We get great support from the fans, and we can't wait to be able to give something back'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Show and sell

January means just one thing for the global motorsport industry – the Autosport Show at Birmingham's NEC

The 2017 Autosport Engineering Show is nearly upon us. *Racecar Engineering* will, as usual, be represented by the jovial staff of the Chelsea Magazine Company, who are keen to get your feedback on the magazine. Alongside the editorial team, our commercial team will be on hand to discuss opportunities to boost your business. Feel free to visit us on stand E290 in Hall 9. But to get you in the mood first, here's a taste of some of the not-to-be-missed products and happenings you will find in the halls of the NEC in Birmingham.

Variohm EuroSensor

Variohm EuroSensor, one of the UK's leading sensor manufacturers and distributors, will be showing off its 'puck and magnet' design option that's been added to its well-proven Euro-X programmable angle sensor range.

The new Euro-XPK is a fully non-contacting two-part design: a high accuracy hall effect sensor element encapsulated in a high-grade sealed plastic housing and a separate magnet, available in three size options.

Throughout the Euro-XP series the specification includes dual-redundant factory programmed angles from 20-degree to 360-degree in 10-degree steps with a ratiometric output from a 5V DC supply (+/- 0.5V) for both measurement range and characteristic curve.

Aimed at motorsport, construction and agricultural angle sensing applications, such as steering, sequential gearbox and throttle etc., the Euro XP series also suits industrial high duty cycle angle sensing for harsh environments.

Magnet options for the Euro-XPK include small and large rectangular designs as well as an encapsulated M10 bolt version.

The puck sensor may also be supplied separately for use with the customer's own magnet design preference. Standard versions are supplied with cable connection, but custom options with connectors, or with adapted mountings, are available on request.

Stand E280

Greenpower Education Trust

The Greenpower International final was held at Rockingham recently, with over 130 teams from around the globe, including, Brazil, Portugal, Poland, Ireland and USA, taking part.

The Greenpower challenge, which is to design, build and race a single-seat electric car, provides young people with a unique, hands-on opportunity to engage in engineering.

A regular exhibitor at Autosport International, Greenpower's mission is to change current perceptions about engineering by presenting it as a fascinating, relevant and dynamic career choice for any young person.

Furthermore, the education trust's aims are to demonstrate the importance of engineering to solve problems faced by societies, particularly in sustainability, and to help address the UK's need for 830,000 new engineers by 2020.

Please make sure you visit Greenpower at Autosport International in Hall 9, and talk to the team about how you can get involved in inspiring new engineers.

Stand E1255

Listsa storage

Lista is one of Europe's most recognised businesses for workspace and storage solutions, and boasts a long list of well-known customers in motorsport, including F1 team Red Bull. Its newest product is the L3627 Workshop Trolley, which it says offers a high level of flexibility for race teams and workshops.

The trolley boasts a load capacity of 40kg per drawer, which can be fully extended to ensure easy access without any wasted space. It also runs on two fixed and two swivel casters, meaning in can be transported from the pit garage to the truck with ease, while the central locking and single drawer opening prevents accidental opening during transit.

Depending on use and individual requirements, the basic models can be flexibly expanded in many ways by means of optional accessories, and Lista's experts will once again be present at Autosport International to showcase its versatile and modular solutions.

Stand 7500

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12-15 JANUARY 2017

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TRADE TICKETS

TRADE	Advance price	Door price
Adult	£28	£30
MSA members	£23	£25
BRSCC members	Free	Free

Tickets do not include access to LAA (Live Action Arena), which is sold separately at £11 (advance and on-site)
Each ticket includes a Trade Directory (value £10), collectable on the day.

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The flip side of flipping

The crowd in Macau are a passionate bunch. They get fully engrossed in the pantomime of racing, and on the Saturday of the Macau Grand Prix in November, I would fancy that the motorbike race had some of them go hoarse. Then, when Laurens Vanthoor crashed his Audi in the GT World Cup race after just two racing laps, clipping the inside kerb at Mandarin which then fired him into the retaining wall on the outside, at which point his R8 performed a slow backwards flip and skidded down the track on fire, there was a hue and cry as the crowd feared for his safety. That sound was then matched by the roar of approval as he climbed from his stricken car, more shocked by the sight of the rest of the GT World Cup contenders bearing down on him than by the accident itself.

However, it was what happened afterwards that got the crowd really in a lather. Up on the big screen flashed the message that the race would not be restarted. The booing was probably audible in Hong Kong, an hour's ferry ride away. Porsche's Motorsport boss, Frank-Steffen Walliser, refused to comment on the result. 'I'll let them do the talking,' he said of the noise. His driver, Earl Bamber, had passed Vanthoor with a clean move before the accident, although was carrying a five-second penalty for pushing Mercedes driver Maro Engel into the wall at the first start and so was a Kiwi in a hurry. Later, Walliser suggested it might have been right to do one lap behind the safety car, meaning that Vanthoor would not be declared the World Cup champion but his driver, Kevin Estre, who was third at the time of the crash, would win.

Two World Cups on the same day could have been a mistake

The crowd had made their feelings known, but then, so had the motorsport bosses of Porsche and Audi who, like Lamborghini and Mercedes, had each paid a total of €42,000 for an entry into the race for their two cars (BMW had just one car), and all had paid freight and travel costs. They were also trying to work out had there ever been a race declared with a full result after just two laps of green flag racing?

While the arguments raged, the organisers were creditably open. The FIA's Christian Schacht was on hand to comment on the failure to complete any more laps. Once Vanthoor was out of the car, the clean up job was relatively quick. But there were issues that caused the GT World Cup to be declared after so few laps. The primary problem was time – the Formula 3 World Cup was due to take place immediately after the GT race, and single seaters don't have headlights. This issue was raised following barrier repairs during the preceding TCR race, and the first FIA GT World Cup encounter when a seemingly innocuous crash led to more lengthy repairs, and delay.

With two World Cups in one day, which was the headline event? Was it the GTs, into which the manufacturers had paid, or the F3, for which the Macau Grand Prix (now the F3 World Cup) is famous? Running two World Cups consecutively, could have been the mistake, given the unforgiving nature of the circuit. So what if the FIA does indeed introduce a touring car World Cup to the schedule?

As Vanthoor showed, the Macau circuit is unforgiving. John Watson is always clear when it comes to track limits – put up a wall and if the drivers hit it, they have been proven to exceed the track limits and pay the fine. I presume Macau is therefore his ideal track. As is Monaco, Detroit and Long Beach. The fact is that the manufacturers and the FIA agreed to host the World Cup in Macau, and the circuit did not just materialise in a black box, contents unknown, before the decision was taken.

Stephane Ratel added that the Macau Grand Prix is special, with a following from a passionate audience, and the circuit is incredible. The World Cups could be held in Europe, but would anyone show up to watch?

Under the FIA's watch, the number of cars for the GTs and touring cars is dropping, while the TCR series was furious at its treatment. The Chinese Touring Car Championship was mixed in with its race, and post race it issued an extraordinary apology. 'Maybe you have remarked [on] the absence of any reference to TCR in the official communications and press releases,' said its director of communications Fabio Ravaioli in an email to the press. 'This was done against our own will and despite our protests. The last insult was to hear from the timekeepers that they were told on Saturday morning not to show the TV graphics with championship points, after this had been done during the practice sessions. Once again, I apologise on behalf of all our staff. And I'm sure you do understand our decision not to bring the series back to Macau next year.'

Has the FIA helped to grow the international appeal of this event, or would it be better for it to rethink and host its World Cup in Europe, and allow Macau to return to its traditional roots? The Formula 3 boys preferred the 'Macau Grand Prix' title to the 'F3 World Cup' anyway.

I left Macau on the ferry on the Sunday night after the event worried that the tentacles of the FIA are stretching into a culture that it does not understand. The Macau Grand Prix this year was a bit of a mess. Even with a passionate and loyal crowd, they need to sort this out, quickly.

ANDREW COTTON Editor

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