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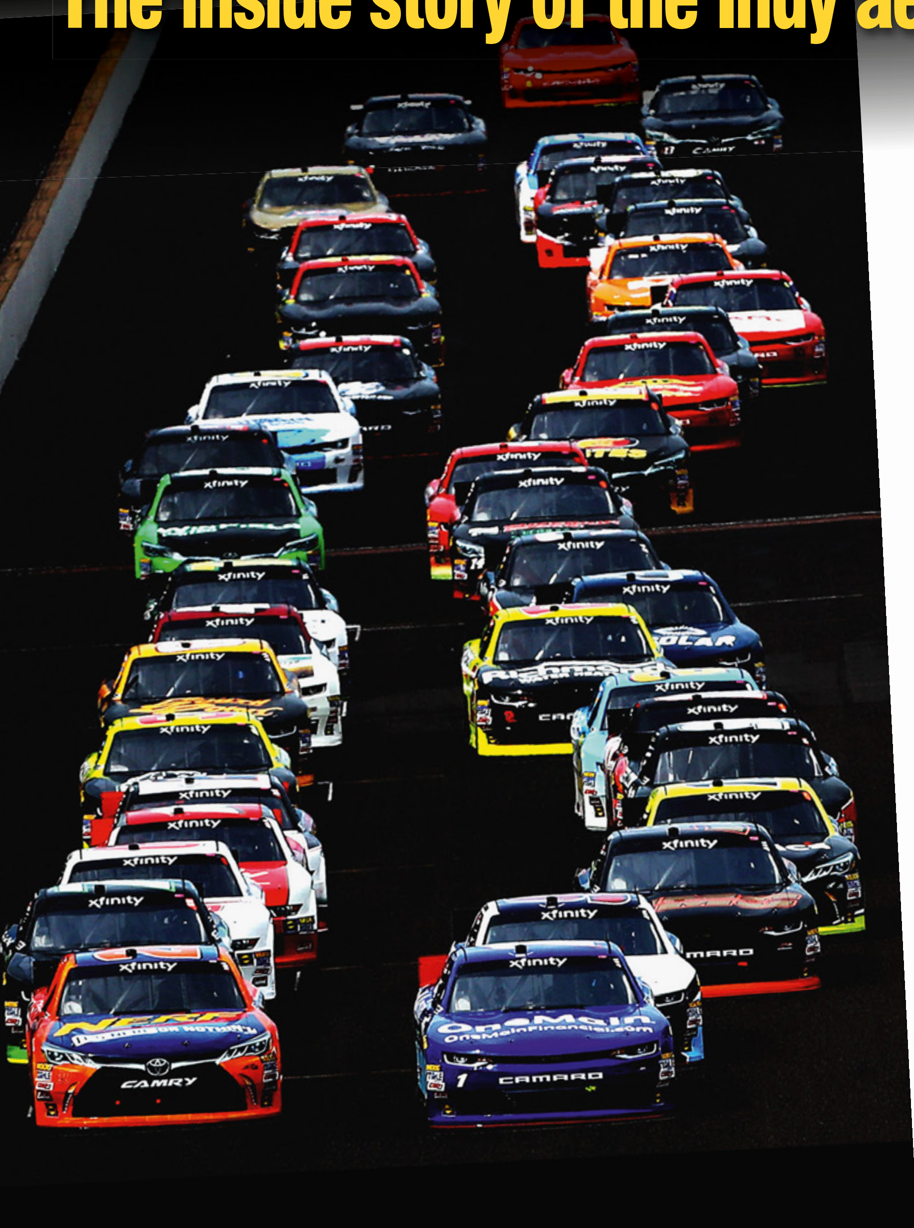
NASCAR Xfinity Series

The inside story of the Indy aero tweaks



The Baja 1000

Improving safety in the world's wildest race

Force India F1

Up close and personal with the rapid VJM10

Formula 2 2018

Full technical analysis of Dallara's new F2/18

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Kicking up dust in the desert. The Baja 1000 celebrates its golden anniversary this year and it should be a lot safer than in the past. Turn to page 46 to find out why

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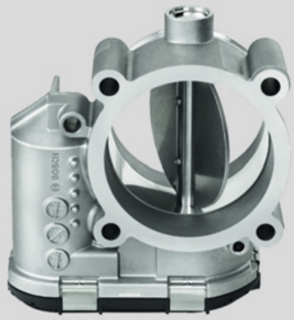

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Hyper inflation

Are the makers of mega-money hypercars too fixated on those *really* big numbers?

Regular as clockwork, manufacturers come up with another supercar, some just show cars to pump up the image, but some as production cars. Some of those actually jump into another group, the hypercars, like the 1479bhp at 6700rpm, peak torque 1600Nm, from 2000rpm all the way to 6000rpm, Bugatti Chiron, with a limited top speed of 261mph, and a projected production run of 100 cars. Apart from the performance figures, it also ticks the really essential big number: $3.38m.

A well know syndrome in teenage boys is the word-exempt conversation they tend to indulge in, with a sprinkling of numbers and of course letters, exemplified in this sample: 'Ah, the 3000YZ 3-litre triple-turbo; zero to a 100 in 3.5 seconds, DOHC desmodromic cams, 500bhp, paddleshift, rheostatic dampers, active differential beast.'

To be answered with: 'The 114 W16 can beat it easily, 600bhp DIN double manifold flux-capacitor with nuclear mega tonnage capability and a state of the art air conditioner, capable of 48,000 BTUs of heat extraction. And holographic mirrors. Can't beat those.'

Figures of speech

These conversations do not only involve cars, they also apply to stereo equipment, planes and of course, weapons. I am not immune to this either, but at least it is part of the job description. But sanity should return to the populace at large and principally to the motoring press, who act as porn merchants to this syndrome. It is time to acknowledge that this sort of performance is not really usable anywhere, save dedicated high-speed test ovals.

One company car I used was a Lamborghini Diablo. It had more blind spots than Stevie Wonder, a clunky gearbox, pedals that required truck driver muscles, an air conditioner that couldn't cope with the half-acre of glass so you would fry in summer, while it was impossible to pay Autostrada tolls without opening the door and getting out.

So why do they exist? Well, we can class them in the jewellery category, like watches, where you can find examples like the Graff Diamonds Hallucination at $55m; the Breguet Marie-Antoinette Grande Complication Pocket Watch at $30m; or the Richard Mille RM 56-02 Sapphire Tourbillon at a mere $2m. The high price tag is the reason to buy it.

But engineering is not supposed to be a wallet advertiser, and we can tell the time on our smartphone these days. And considering that what used to be the open road is now a hunting ground for radars to increment the state revenue, call it indirect taxation, the concept of a car that can go over 200mph is frankly ridiculous, and not many hypercar buyers even regularly take them to a track day to exploit even part of their performance.

Engineers can be forgiven for these cars, perhaps, as part of their motivation is to improve the breed. But it is time to admit that improving the breed does not mean more horsepower or more speed, but rather more efficiency, more usefulness, and better energy consumption?

That there will be a market for a couple of thousand supercars or hypercars is clear, given the world's fleet of approximately 1.3bn cars, but it does not need the slavish hyping of it by the motoring press. And this applies also to more mundane cars.

Why would you need an 8-speed 600bhp 4WD Audi RS6 station wagon? Considering that it will spend most of its life trundling around small towns or cities, or at best in the suburbs on the school run, it does smell a bit of overkill. It's a nice car, yes, but not really pertinent to real life. But it is a mega car to drop into a conversation in a pub, or for getting one-up on your neighbour.

The Bugatti Chiron costs $3.38m, yet a 300kg 0.4-litre car could be a more attractive solution. And Gordon Murray drives a Smart

Handy Murray

Probably the premier designer of my generation, Gordon Murray, has said: 'I've driven a Smart car for the last 13 years.' After designing F1 cars that won the world championship, producing the McLaren F1 supercar that won Le Mans at its first attempt, we can assume he knows cars, be it for the road or race track, and he loves driving and all that goes with it. So he's worth listening to.

And where is Gordon Murray now? Well, if you are in the business, you should know he is still very active indeed, be it with designing town cars, or creating manufacturing methods to be more reactive, downsized and ecological.

I have ranted on for years about the incongruity of using a two-metre wide, four-metre long, ton-and a-quarter of metal object to transport 80kg of me around. For more than ample performance this will have to have something in the region of 300bhp, giving a power to weight ratio of 5kg per HP.

Hyper-active

Let us take a small run down memory lane. What is accepted as the first car was the Benz Patent Motorwagen of 1886, with a 560W (0.75hp) 954cc engine and an empty weight of 265kg, giving a power to weight ratio of 353.3kg/hp. It could easily be outperformed by a horse.

Okay, as we progressed we then went from a 1908 Ford Model T 2.9-litre flex-fuel, at 27kg/hp, to today's base saloon of around 150hp with a power to weight ratio of 8.8kg/hp.

The high-performance car could be exemplified in 1984 by the Ferrari Testarossa, with 390bhp and P/W ratio of 3.86kg/hp, or in 2007 with a Porsche 911GT2 with 523bhp and 2.75kg/hp. Today's La Ferrari with 950bhp clocks in at a P/W of 1.66kg/hp, just slightly worse than a 1936 Supermarine Spitfire with a P/W ratio of 1.57. We will have to go a bit further to reach the highs of a Boeing 747 (0.548kg/hp), but we're not too far away from the first of Audi's diesel Le Mans winners, the 2006 R10 TDI at 1.43.

But what we need is a measure of usable performance, and as such we need to parse in the other factors, such as what speed we really need to go, what fuel consumption and pollution is acceptable, and what the car is to be used for, plus what it will cost to scrap and maintain. We do not need a bling advertiser and bird puller, women are much more sensible than that.

We can build sane cars easily. It will weigh more than a bare bones early 20th century cycle car, but given the materials we have now, putatively 50 per cent efficient ICE engines, one can design and build a 300kg carbon aluminium 0.4-litre engine 100bhp car that will outperform all the iconic sportcars we had drooled over in our teens (or later for the incurably car-struck) and reduce pollution, use less space and accelerate very quickly.

The sole drawback is having to share the road with Ms Doe taking the kids to school in the 3-tonne, 9ft high Toyota Tyrannosaurus SUV. I do love cars, honest, guv, but some sanity please.

Improving the breed does not mean more horsepower or more speed

Fatal distraction

In the rush to diversify have some F1 teams lost sight of what really matters?

Commitment in motor racing is generally identified with a driver's determination to keep hard on the throttle into fast and risky corners where the consequences of misjudgment are likely to be severe. But there are other forms of commitment that play a massive part in our complex business and sport.

Liberty F1's Sean Bratches recently stated that it is committing to street races for the additional grands prix it wishes to establish. One can see the marketing logic, and there is a place for such events in F1, as has always been the case. Monaco has been a *sine qua non* of the world championship since its inception; Singapore has presented a real challenge over the past decade. Nonetheless, should the ratio of street to purpose-built tracks begin to approach half, there is a real risk of Formula 1 losing its core identity.

No 'round-the-houses' (or should this be 'round-the-skyscrapers'?) circuit can ever equal the majesty of Spa or Suzuka, where cars and drivers can stretch their proverbial legs and exercise the full extent of their capabilities, and spectators can view more than just one corner. If Liberty sticks to its promise of protecting the traditional venues, all well and good, and we will have to accept the necessity of more street races to maintain the health of grand prix racing. What bothers me and, I'm sure, many others who love the sport, would be for Formula 1 to gradually become a grown-up version of Formula E, focused on city centres, even if, praise be, it retains the internal combustion engine at its heart. Commitment to success is vital, but Liberty must be careful not to destroy the foundations of grand prix racing as a consequence.

XPB

Two once great teams battle for scraps in the Singapore GP. Have Williams (foreground) and McLaren both been overly-distracted by non-F1 projects?

Out of focus group

Also on the subject of commitment, given McLaren's current woes and its need now to hurriedly form a relationship with a new power unit supplier (which is rated as only third best), I find some of Zak Brown's recent pronouncements puzzling. Following Alonso's beautifully-executed 'compensation treat' in the Indy 500 this summer, Brown was adamant about a future McLaren entry in IndyCar. Just recently, he made a similar comment in regards to a Le Mans LMP1 project.

Assuming that this isn't just hubris, does he really believe that they can succeed in their stated task of bringing the Formula 1 team back to its glory days while diverting resources and concentration to these other demanding disciplines?

Horsing around

McLaren should take heed of Ron Dennis' throw-away comment, way back when McLaren were top of the heap, that 'F1 isn't enough'. While McLaren's subsequent ventures in supercars and a variety of technologies has been very successful, for the F1 operation it's been downhill ever since. Even back in motor racing history, Ferrari's grand prix efforts always suffered when winning Le Mans was seen as a priority. That lesson was taken on board eventually and the Prancing Horse has not had a factory presence outside of F1 since the mid 1970s, a decision endorsed by the many races and world championships won subsequently. Imagine now, with F1 competition infinitely more complex technologically and logistically, how much greater is the necessity for McLaren to commit absolutely 100 per cent to the single aim of winning again, without any distractions at all along the way. How else to compete with Mercedes and Ferrari, both of whose formidable organisations are totally committed to the one objective of being top of the heap, also against Red Bull and upcoming Renault?

Doubt also enters my mind about the real commitment to winning displayed by Williams. As a publicly-listed company, one understands that it has a duty first to maximise assets and profits for its shareholders. However, in recent years this certainly appears to have dented Williams' long-held reputation for always favouring talent over budget, despite protestations otherwise.

This principle became compromised when the team began employing drivers with lesser ability but bringing big bucks sponsorship. Obviously funding was the issue that necessitated this change of philosophy, but since then Williams has experienced a steady decline with only the occasional flash of speed to remind one of the heady years of the past decades. In terms of constructors' points payments and sponsorship revenue lost, one wonders how the scales might have weighed overall regarding this sacrifice of performance in exchange for money? Maybe there was no choice, but despite the increased financial health of the company, the taking on of Lance Stroll – talented but raw and inexperienced – together with the demands of a massive testing programme coming as part of the deal, must inevitably be a distraction for the management of the organisation, no matter how lucrative.

Lowe and behold

In just this year alone the organisation of the extensive Williams 40th anniversary Silverstone event, the attendant book and film, all takes the operation's collective eye off the ball, which must inevitably detract from the business of winning.

Allowing Paddy Lowe to buy into the operation implies more of a return to the 'real racers' tag that used to define Williams, but unless he can inject a massive kick up the backside to this lack of real commitment, Britain's favourite F1 team will continue only as a racing company earning enough to maintain itself as a viable business – but no more.

Much like Sauber, whose decision, despite a big new backer, to use year-old Ferrari engines and accept pay drivers, I criticised pre-season as displaying a real lack of commitment. Completely uncompetitive in almost every race so far, it is to be hoped that the recent signing of Fred Vasseur as team principal will turn this around. Only total commitment to win can exist in a team intent on not just making up the numbers.

While McLaren's ventures in supercars and a variety of technologies have been very successful, for the Formula 1 operation it's been downhill ever since

Engineering a race

With Xfinity races at Indianapolis tending to be lacklustre affairs NASCAR R&D set itself the task of spicing up the show with some cunning one-shot aerodynamic developments – its lead engineer gives us the inside story

By ERIC JACUZZI

It was an overcast Saturday at Indianapolis Motor Speedway on July 22, a welcome break from the usual scorching temperatures for the annual summer NASCAR race at the track. On the grid 40 cars prepared to roll off for the start of the race, while five nervous NASCAR R&D engineers and fabricators huddled near the centre of pit road.

As the cars started their engines, a procession of NASCAR officials came by to collect a curious looking package with carbon fibre bits protruding from each end of the bubble wrapped exterior – the back-up ducts. Once finished, the officials took their posts and the R&D staff returned to the office of NASCAR Xfinity series director Wayne Auton to see whether nearly a year's work would result in a thrilling race. This is the story of how the Xfinity series race package came to be, and the results of NASCAR's grand experiment.

Indy beginning

As previously outlined in the May 2017 issue of *Racecar Engineering* (V27N5), NASCAR conducted a test in October 2016 to evaluate a new race package for Indianapolis. The package itself began as a question – what would a successful race on the challenging 2.5-mile, low banked oval look like? The iconic venue has hosted the top-tier Monster Energy NASCAR Cup Series for the Brickyard 400 since 1994, with the NASCAR Xfinity Series joining in 2012.

With its historic significance to racing, the Indy event is considered one of NASCAR's crown jewel events, though racing heavy stock cars on the track has always proven a challenge. The task was handed to NASCAR R&D to determine if there was a way to deliver a more consistently exciting race for fans at this historic venue.

Racing these heavy stock cars on the Indianapolis track has always proven to be a challenge

NASCAR R&D's efforts led to close racing at the Brickyard, where the Xfinity Series put on what was generally agreed to be its best Indy race to date

The staff at the R&D centre knew that slipstreaming had to play an important role in keeping the cars close and mitigating losses in the corners due to the single lane nature of the track. That meant eliminating the typical 40 to 50mph difference observed between the apex and end of straight speeds in the top tier Cup series. The recipe called for the greatest cornering speed an Xfinity car could achieve while limiting the end of straight speed as much as possible – essentially running flat out or very close to it. Driver simulator work showed that using the 2016 aerodynamics package along with the current restrictor plate power level would achieve this goal. It was then a matter of maximising the slipstream effect to ensure the cars could actually capitalise on their closer proximity and make passes on track.

Bubble trouble

CFD work commenced, analysing how to improve the slipstream and reduce the spike in drag on a trailing car in the half- to one-car length region. This effect is inherent to most typical automotive shapes running in close proximity outside of open wheel cars. The approaching trail car effectively lowers the drag of the lead car while experiencing an increase in drag itself, resulting in what drivers refer to as a drag bubble. Analysis of the CFD results revealed this increase in drag occurred primarily on the front fascia of the trailing racecar, accounting for nearly all of the total drag increase the trail car experienced.

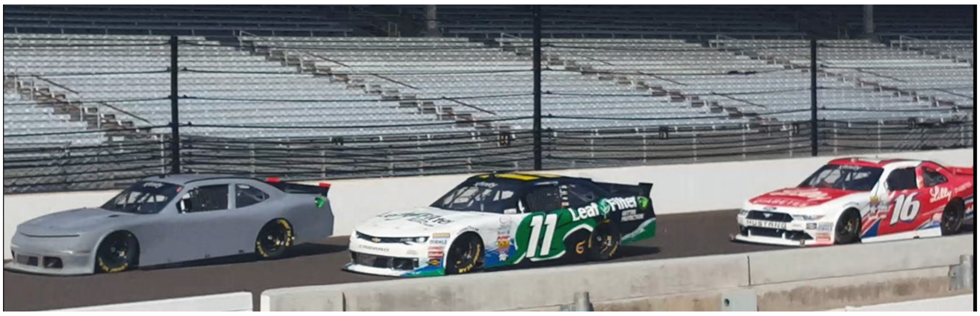
The effect appeared to be due to the wake inwash of the lead car impinging on the front fascia of the trailing car, resulting in higher fascia pressures and thus higher total vehicle drag. This led to attempts to widen the wake using

It was decided that with the stakes as high as they were, we simply could not afford to be conservative in our approach

various devices with varying degrees of success, but ultimately paved the way to finding the successful solution of ducting air from the front fascia and blowing it outward from the front of the wheel opening. The effect of the ducts was pronounced in CFD in both single car **(Figure 1)** and in multi-car runs, with a 25 per cent reduction or more in drag on the trailing car between zero and four car lengths. The question remained – would this be enough to make a noticeable difference on the track?

The teams of Richard Childress Racing, Roush Fenway Racing and Kaulig Racing tested

Figure 1: CFD velocity delta plot showing the wake deficit created by ducts. White/red shows high velocity air exiting ducts



The October 2016 Indianapolis test. The day was structured to allow 30 minutes of practice laps followed by a mock race

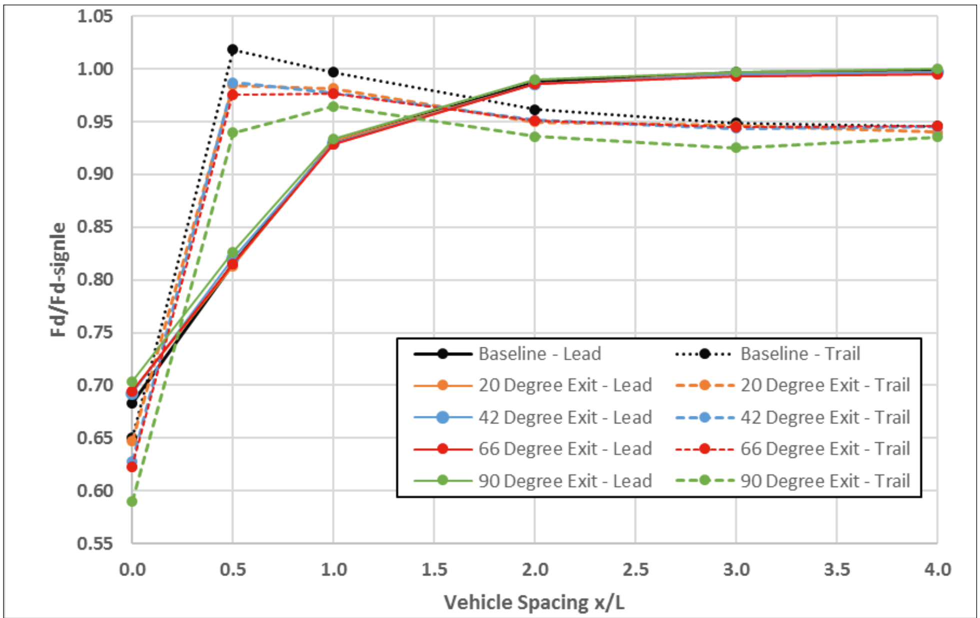


Figure 2. Normalised results for lead and trail car total drag for various duct exit angles at a constant inlet/exit ratio

a package that included a targeted 2700lbf of downforce at 200mph, higher grip Goodyear tyres, a restrictor plate cutting engine power to approximately 430bhp and the first version of aero ducts. The test was structured to allow 30 minutes of practice followed by a mock race for the various configurations, allowing NASCAR and the teams to assess the cars in both individual and race states. The package without the aero ducts featured close racing with the group of three unable to separate; however, passing was extremely difficult. Adding the aero ducts led to significant passing on track, with drivers reporting that they could slipstream and complete a pass much easier than without them. Watching from the pit road, the action was exciting (especially for a test session!) with a very different look and feel to the typical Indianapolis on-track action. The package was obviously ready for prime time.

Rubber stamped

After presenting the test data to NASCAR management and the technical directors of the Xfinity Series teams, NASCAR's top management made the call to proceed with the race package in January 2017. As with all decisions made in NASCAR, team costs are of paramount concern, especially with the lower budgets in the Xfinity Series. This meant that NASCAR footed the bill to produce the aero ducts for the package – and also meant is was able to maintain control over the ducts. The ducts would not be made available to teams for wind tunnel testing, and geometry would not be provided to the teams, other than the relevant hole patterns.

Prime fascia

At R&D, the green light on the package meant a final push in CFD to analyse the best possible configuration for the ducts. An additional complication was that the front fascia of the Xfinity car had seen a change in the off-season, with the front splitter height lowered one inch to bring it in line with the Cup Series cars. It was also decided that with stakes this high, we could not afford to be conservative in our approach to this – every risk within reason had to be considered to make the package a success. This meant reviewing our assumptions and trying to fine-tune as much benefit as possible into the final duct design.

An advantage of my current doctoral studies in the department of Mechanical and Aerospace Engineering at North Carolina State University is the ability to call on the expertise of my adviser, Dr Kenneth Granlund. Dr Granlund is an assistant professor in the department, with a background in vehicle dynamics and aeronautics from the Royal Institute of Technology, Sweden. As a PhD student at Virginia Tech, he worked on aero/hydrodynamic stability of manoeuvring airships and submarines. He currently teaches automotive and aerospace engineering courses and directs

Adding the aero ducts led to significant passing on the race track

basic and applied research projects in subsonic and supersonic experimental unsteady fluid mechanics supporting US Air Force and Army, as well as working with NASCAR R&D.

Dr Granlund was of great assistance in helping to analyse the sensitivities of the ducts from the original work. We studied a variety of parameters and their effect on the cars such as duct exit height, inlet/exit ratio, and exit to angle to arrive at the best compromise. It was found that the lower the ducts were to the track and the greater the exit size, the better they performed at both increasing single car downforce and improving slipstreaming. Exit angle was also crucial; a perpendicular duct exit offered the best slipstreaming but actually hurt downforce, while shallower duct exit angles still offered good slipstreaming performance yet increased downforce. Normalised results for the lead and trail car drag are shown in **Figure 2**.

From a rule-making perspective, adding a device that hurt downforce and added drag would motivate teams to sabotage our efforts. It was decided to maximise the exit area by widening the duct to the absolute limit allowable for tyre clearance and choose the most practical exit angle of 42 degrees from the longitudinal axis. The overall height of the duct was also shortened, since the height study showed better performance lower to the track and eliminated the need to trim the flange between the upper and lower fascias. The exit of the duct was shortened to move it closer to the front of the car to avoid the need to scallop the duct for tyre clearance when turning, but it would still be a close fit. The ducts still needed to clear the splitter structure without drastic changes in volume throughout the duct; the design CAD is shown in **Figure 3**. The differences in design between the test and the race version are shown at the foot of this page.

Finally, there was the small matter of building the finalised ducts. NASCAR solicited bids from several composites manufacturers in the industry, ultimately choosing Crawford Composites of Denver, North Carolina. Crawford utilised multiple tools to produce the ducts, ultimately supplying 56 sets to NASCAR for the expected field of 40. The ducts were drilled and fitted with nutserts and lovingly boxed into four pallet-sized boxes for the journey to Indianapolis, with the human cargo not far behind. With the rulebook updated for the race weekend, there was no turning back now.

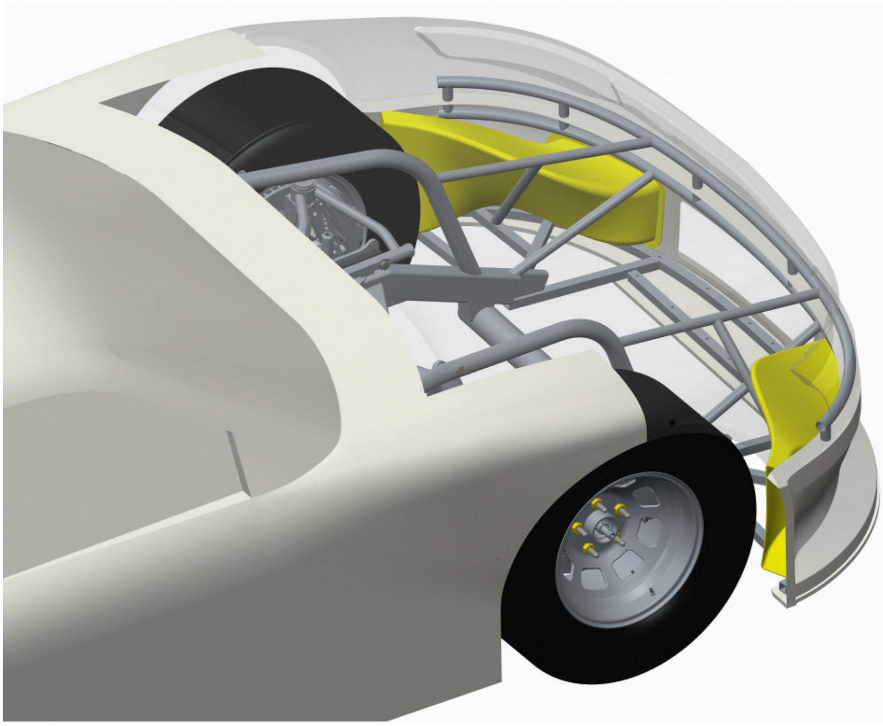


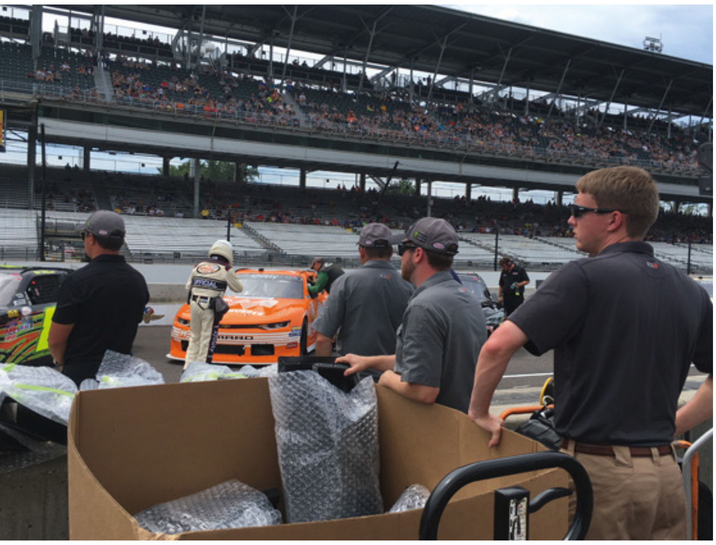
Figure 3. Final duct design in yellow, also showing surrounding structure

The race

The R&D team arrived early to the track on Friday and took up position near the garage entrance to distribute the ducts to each team's crew chief. For many, this was the first time they had laid their hands on them, but installation went remarkably well thanks to the efforts of the series staff to provide templates and test fit them at team shops (they were not allowed to keep them). There was some initial concern over tyre clearance to the ducts, with teams worried the tyres would rub the ducts during sharp cornering in the garage area, but this ultimately proved unfounded.

First practice took place in the early afternoon on Friday, with peak temperatures around 90degF and the track surface in a green state. Drivers were unsettled about how slick the track was – they were not able to run flat out even with clean air ahead. Apex speeds were lower than expected, likely attributable to the higher ambient and track temperatures compared to the test conditions. But by second

The differences in design between the test version (left) and the version-two duct used in the race (right). Crawford Composites was hired to manufacture the race ducts for NASCAR



Preparing to hand out the back-up duct sets to NASCAR officials before the race

Start of the race. The R&D department looked on anxiously as its package was put to the test

William Byron wins with Paul Menard just 0.108 seconds adrift

Post-Indy wind tunnel testing at Aerodyn Wind Tunnel with the No.1 Chevrolet of Elliot Sadler

practice things were looking up – packs of 15 to 20 cars were snaking down the straights in an unusually aggressive practice session. Teams had used the time between practices to make adjustments that had moved the needle toward the type of on-track behaviour expected from the test. At the flag for practice two, 25 cars were on the track attempting to learn as much as possible about what lay ahead in the race.

On Saturday, qualifying took place shortly before the race, with the No.9 car of William Byron taking pole at a speed of 165.283mph. It was obvious that there were divergent aero strategies at play, with some top organisations running more downforce (and resulting higher drag) with the hopes of an advantage during the race, while others focused on minimising drag. With the spoiler size set by NASCAR, tweaks to the downforce and drag levels of an individual racecar is largely left to teams by optimising the body within the allowable tolerances, as well as splitter angle settings on the front of the car.

Final draft

The race itself was a whirlwind for the R&D staff, who watched from the series director's trailer that features live feeds of 20 track cameras as well as the broadcast feed of the race. On track, groups of cars were racing together as hoped – not a pack consisting of the entire field, but smaller groups of three to five cars. The leading car proved unable to escape into the distance in clean air as commonly seen at Indianapolis. At one point, the No.18 Toyota of Kyle Busch took a several-second lead after a double-file restart, but was run down within two laps by a group of charging cars. Blocking was prevalent throughout the race, making the straights nearly as exciting as the corners, which at times featured three-wide racing on the narrow track. The finish of the race featured a shoot-out between Byron driving for JR Motorsports and veteran Cup series driver Paul Menard, who battled for several laps before finishing 0.108 seconds apart. Immediately after the chequered flag, the R&D team assisted competition officials in collecting the ducts back from the teams. Overall, only three sets were lost due to crash or debris damage.

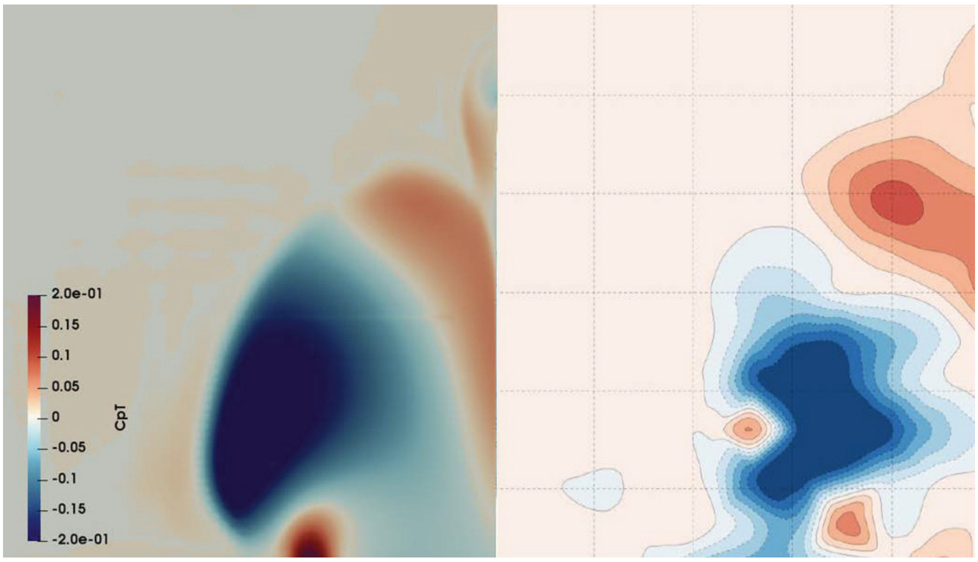
The NASCAR R&D team didn't have much time to rest after returning from Indianapolis, with a scheduled wind tunnel shift to validate the duct performance on the No.1 Chevrolet of Elliot Sadler. Because of the secrecy involving the actual duct design and the tight window teams had to prepare their cars prior to the race, it was not possible to test the ducts on a car in the wind tunnel before the race. The results of the test correlated well with CFD (**Table 1**), with a downforce gain of 94lbf predicted in CFD *vs* the measured 100lbf. In the race tape

Given the success of the race, the Indianapolis race package will live on in the NASCAR Xfinity Series next season

Table 1: Wind tunnel deltas compared to CFD predicted values. Full tape refers to the radiator opening being covered completely (no cooling flow)

Run	Drag (lbf)	Total Lift (lbf)	Front Lift (lbf)	Rear Lift (lbf)	L/D
Duct delta – race tape	30	-100	-64	-36	-0.03
Duct delta – full tape	36	-115	-74	-41	-0.02
CFD predicted delta	26	-94	-52	-42	-0.03


The accuracy of the CFD-predicted wake change was assessed by fitting a Kiel probe array to the racecar in the wind tunnel



CFD predicted Cp at Kiel probe rake location (left) *vs* measured Cp. Measured pressure coefficient correlated well with CFD

Table 2: Race metrics from the Lilly Diabetes 250

Criteria	2017	3-Yr avg	2016	2015	2014
Number of unique leaders	8	4.7	2	6	6
Green flag passes for the lead at timing loops	29	9.7	10	10	9
Quality passes	518	396	251	449	488
Number of lead changes at start/finish line	16	6	2	8	9
Margin of victory	0.108	0.56	0.411	0.421	0.833
Average time between 1st and 5th at S/F Line	2.5	8	8.9	7.7	7.3
Fan action score	8.1	6.8	5.5	7.4	7.4

The race broke previous records for number of unique leaders, green flag passes for the lead, number of lead changes and margin of victory

configuration the L/D correlation was spot on with a -0.03 improvement. Force levels are all scaled to 200mph, as is the standard practice in the NASCAR racing world.

In addition to validating the forces on the car, the accuracy of the CFD-predicted wake change was assessed using a Kiel probe array, custom designed by the R&D Centre team. Probe density was focused around the higher delta regions predicted by CFD. The measured pressure coefficient correlated well with simulation, showing a large wake deficit region running along the side of the car created by the ducts. The lateral expansion of the wake was slightly less than CFD, though this is most likely attributable to the wall proximity at Aerodyn.

A good race?

Analysing the quality of a race as a spectator is a difficult thing with each fan's opinion varying on what makes for a good race. Is it a close battle for the lead? Lots of passing or crashes, or maybe simply their favourite driver winning? So, instead of relying solely on qualitative analysis, including fan opinion, NASCAR has attempted to create quantitative metrics that are analysed after each event. **Table 2** shows a selection of statistics from the race in 2017 as compared to the three-year average and past data from the last three races. The race broke previous records for number of unique leaders, green flag passes for the lead, quality passes, number of lead changes, margin of victory, and the average time between first and fifth place under green flag conditions. The margin of victory (0.108 seconds) was a NASCAR Xfinity Series track record at Indianapolis. On the qualitative side, the fan action score is a metric culled from a pool of fans who sign up at the beginning of each season and are randomly polled on the race in the immediate aftermath. The 8.1 rating ranks near the top of the charts for all Xfinity races in a season, and handily beat the 5.5 rating of the 2016 race. Another data point comes from journalist Jeff Gluck of www.jeffgluck.com and his popular 'Was it a good race?' Twitter polls, with 87 per cent of fans voting affirmatively.

Up for the Cup?

Given the success of the race, the Indy race package will live on in the Xfinity Series next season with discussion of possibly expanding its implementation. Application in the Monster Energy Cup Series is possible in the future, though the process would be slightly more complex due to the higher degree of design freedom in the body styling. But it will not be an insurmountable challenge to design ducts that achieve the same result while affecting each manufacturer's car in an equal manner.

One of the peculiar facets of working for the sanctioning body is we don't often get to feel the thrill of victory that a team gets when it wins race. But on an overcast Saturday at Indianapolis, we came pretty close.

Fourth India

It's not just the pink livery that makes Force India's VJM10 the stand-out car in the Formula 1 pack, for as we discovered the team has also produced what is probably the best racecar outside of the big three F1 operations

By SAM COLLINS

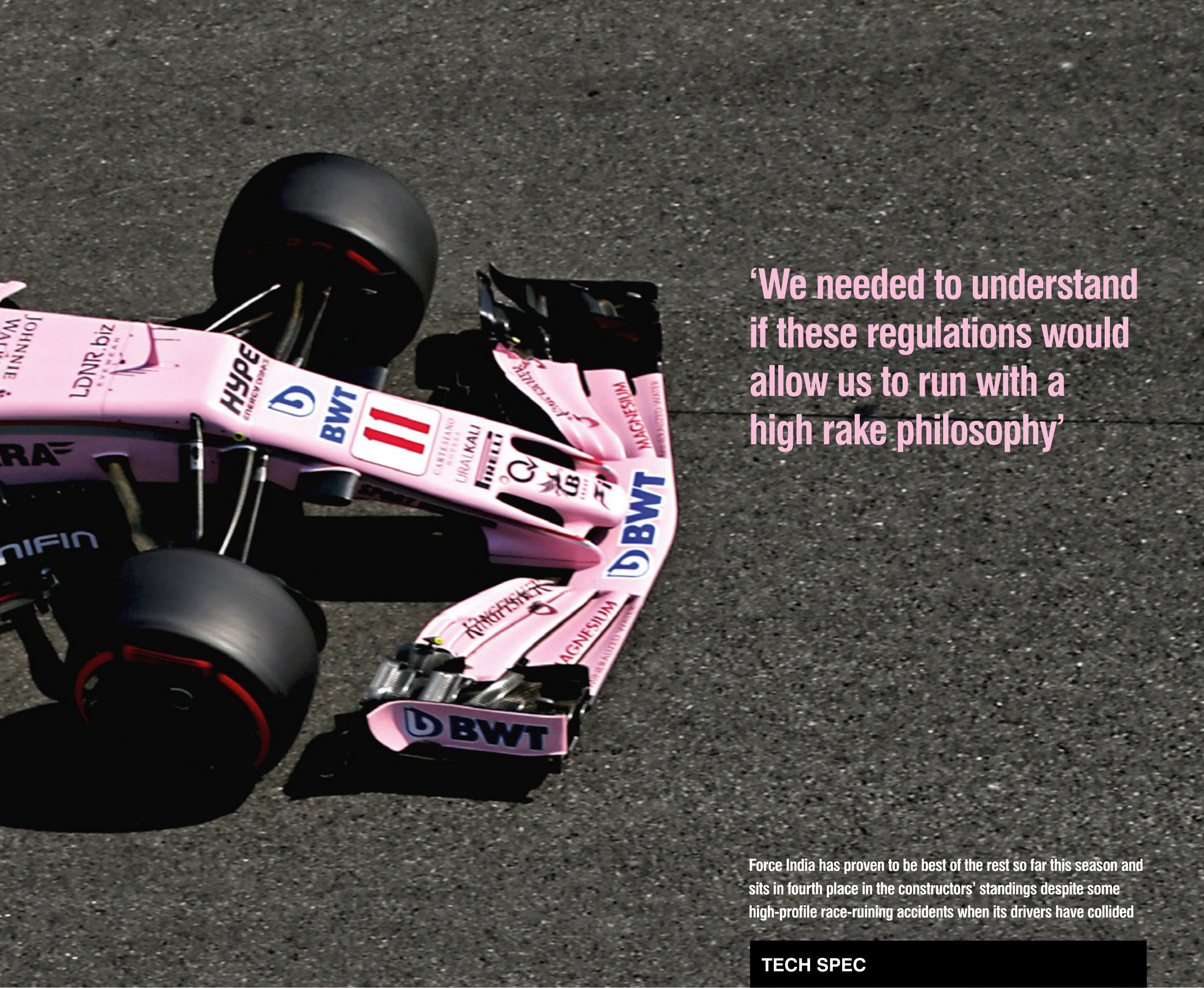
When asked about his favourite feature of the 2017 Force India, the small Silverstone-based outfit's technical director, Andy Green, jokes 'the colour!' The VJM10 is, indeed, one of the most distinctive cars in Formula 1. But it's not only that bright pink paint job, it also has an eye-catching design with a unique nose treatment, but more eye-catching for most of the team's rivals is its solid fourth place in the constructors' championship.

Design work on the VJM10 started before the 2016 season got underway but still perhaps later than Green would have liked. This was due to a lack of clarity over the 2017 regulations, which only started to be really firmed up during pre-season testing in 2016. As has been detailed previously (see V27N4) the new rules included a more potent aerodynamic package with a much larger diffuser, swept back wings and the bargeboard area freed up for open development. In addition to this, mechanical grip would increase with much larger tyres.

A number of cars in Formula 1 in recent years, including the recent line of designs from Force India, have run with a high rake angle for aerodynamic reasons, with the rear of the car sitting higher than the front, but it was not clear to the Force India designers if this would work with the new rulebook. 'When we first got the regulations through it was about trying to understand what concept we thought would work and what, if anything, we could carry over from our previous year's car philosophy,' Green says. 'It was the first thing we looked at from a performance perspective, we needed to understand if these regulations would allow us to run with a high rake philosophy, and whether that was the route we want to be heading down for this year and beyond.

'That was the first real litmus test of where we were going to go. All those simulations were coming in and all the preliminary answers were telling us that we could continue to run a high rake,' Green adds. 'As it did not look like there would be any issues we pressed the button and went with that approach.'

With that key decision taken the preliminary aerodynamic work on the VJM10 was undertaken at the TMG wind tunnel in Cologne,



> 'We needed to understand if these regulations would allow us to run with a high rake philosophy'

Force India has proven to be best of the rest so far this season and sits in fourth place in the constructors' standings despite some high-profile race-ruining accidents when its drivers have collided

where Force India uses a 60 per cent scale model. 'Once the aerodynamic guys had started work our attention turned to the structural side of the car,' Green says. 'We had to estimate where we were going to be aerodynamically at the end of the season and what the loads would be. Trying to predict that 18 months to two years in advance is a big question, and hard to answer, but it is a fundamental question and one you have to ask as that is the car you are designing the structures for, not the one you launch. The aerodynamic team then gave us some early indications of where they thought that they would start the season aerodynamically, then we looked historically at our development rate following a big regulation change. That gave us an idea of what level of development we could see during the season and allowed us to try and predict where the car would be by the end of the 2017 season in Abu Dhabi.'

After analysing the results of that very early work the team at Force India discovered that one track in particular would define what the structures that make up the VJM10 would have to withstand. 'We ran some simulations, sweeps through some of the critical tracks, to try to understand where we would see the peak loads,' Green says. 'It became quite apparent that Eau Rouge at Spa-Francorchamps was a stand-out corner, so the car had to be fundamentally designed to take that corner.'

Gripping mystery

As was the case with all teams developing cars for 2017 there was one area where information was severely lacking – again due to the very late confirmation of the rule changes. 'The biggest catch to understanding all this was the tyres, we had no visibility of what Pirelli were going to bring for 2017,' Green says. 'In fact, Pirelli didn't know what they were going to bring. There was no point in asking them as they were still developing them. We had to make assumptions about what they were going to do, where they were going to set the compounds. We needed to know how quick they were going to be; that makes a huge difference to the car you design.'

The problem was that Pirelli had only done limited running using fairly unrepresentative mule cars which did not generate the same

TECH SPEC

Force India VJM10

Chassis: Carbon fibre composite monocoque with Zylon side anti-intrusion panels.

Power unit: Mercedes AMG High Performance Powertrains V6 Turbo 1.6-litre with ERS

Suspension: Front – aluminium alloy uprights with carbon fibre composite wishbones, trackrod and pushrod. Inboard chassis mounted torsion springs, dampers and anti-roll bar assembly. Rear – aluminium alloy uprights with carbon fibre composite wishbones, trackrod and pullrod. Hydro-mechanical springs, dampers and anti-roll bar assembly.

Transmission: Mercedes AMG F1 8-speed, semi-automatic seamless shift.

Wheels and tyres: BBS forged wheels; Pirelli tyres

Fuel and lubricants: Petronas

Brakes: AP Racing / 920E calipers with carbon-carbon friction material.

forces as the 2017 cars would. 'We needed to not underestimate what Pirelli could bring, because they could bring some really aggressive compounds and completely change the loads on the car,' Green says. 'So we had to anticipate that happening, and once we had all of that information we could start to build a picture of what the car would look like and structurally what it needs to be. Then we can work out how big all the wishbone legs need to be, how strong all the attachments need to be, and how stiff we need to make the chassis. It's a long process when you're starting from scratch like that. It's a big drain on our resources.'

'We are far better off running a slightly heavy car rather than one which needs to be redesigned'

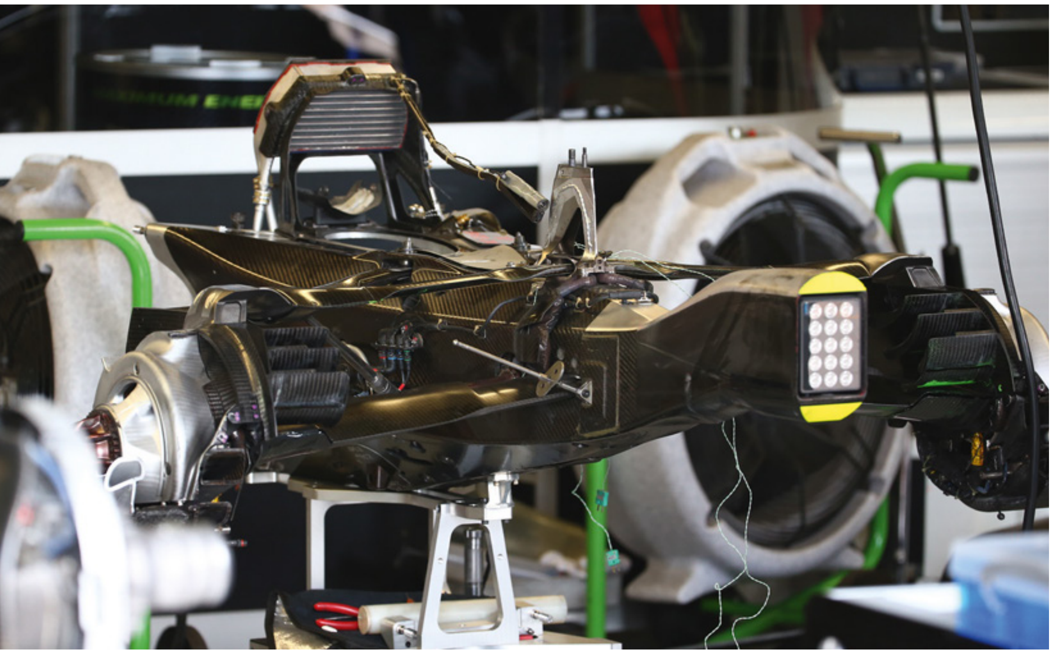
Design dilemma

Not knowing any real details of the tyre performance left Force India with something of a dilemma: design the car to be the lightest it could be but marginal in terms of withstanding loads, or play it safe and risk being overweight. 'We can't afford to underestimate that, as we are not a team that can get halfway through a season and start redesigning the suspension or the chassis to try and cope with a load increase,' Green says. 'It would absolutely destroy our development capability if we realised at the start of the season we had made a mistake on the performance of the car and had to start redesigning fundamental components. That would see our development budget gone, so it is one or the other. We are either developing a car structurally or developing a car from the performance perspective, we can't do both. That's life as a small team. That means giving ourselves margin with the peak loads we think we are going to see.'

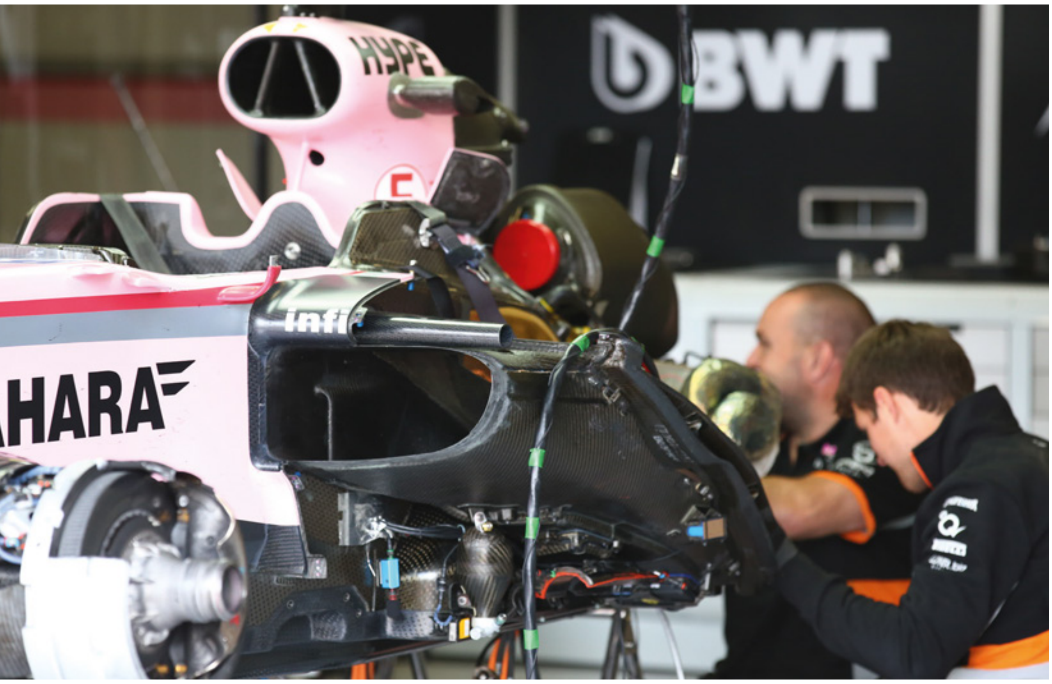
The risk of playing it safe in terms of being able to cope with the loads through the car is that components end up being over-engineered and in turn overweight. 'We are trading grams and sometimes kilograms, we are far better off running a slightly heavy car rather than one which needs to be redesigned,' Green says.

It is clear that the VJM10 was marginal in terms of weight during its development, despite the fact that in 2017 the minimum weight of the cars is the heaviest it has ever been at 728kgs. 'It was tight but the guys did a great job,' Green says. 'In winter testing the car was over the limit, but by the time we got to [the first race at] Melbourne is was just under. We can slowly trim weight off throughout the season.'

With getting the car underweight proving a bit of an issue, getting full movement within the regulated weight distribution limit was a problem, too. The limit is a minimum of 330kg on the front axle and 391kg on the rear, giving a window of just 7kg. 'We don't have full movement in the window, that was one of the issues we had,' Green says. 'So we made a decision on where we wanted to put the weight distribution, then run the car on the new tyres and see what they needed. It turns out we guessed right, and I think a lot of teams did, to be honest. We are pinned at one end of the range but we are happy with that.'



VJM10 uses Mercedes 'box, but as it's designed for a lower rake car some compromises have been needed at the rear end



The VJM10 struggled to meet the new, heavier, weight limit during development but achieved it by the start of the season

Nose picking

In general terms the design of the Mercedes-powered car is relatively conventional with pushrod actuated front torsion bars suspension, and pullrods at the rear. However, a notable area of difference is the nose, which features a continuation of Force India's unique approach to the front crash structure regulations – but more notably a rather unfortunate looking hump at the rear of the nose structure. This covers some of the inboard front suspension components, which are mounted on top of the monocoque.

'That is to do with the stiffness targets we set ourselves,' Green says. 'We are very sensitive to how low we can run the nose of the car so front stiffness is important to us and we decided that we didn't want to compromise on it at this early stage. Aerodynamically it is neutral putting it all on the top of the chassis and having that shape on the nose. The other alternative was to lower it all and add additional weight to the racecar. It was a basic decision; do we make the car look a little bit nicer and lower the pushrods, but to get the stiffness back again we would

have to add a kilogram of weight to it. That was an easy question to answer, then, we had to keep the weight down on all those little areas. It is easy to add a few grams, but they all add up, and then you are in big trouble.'

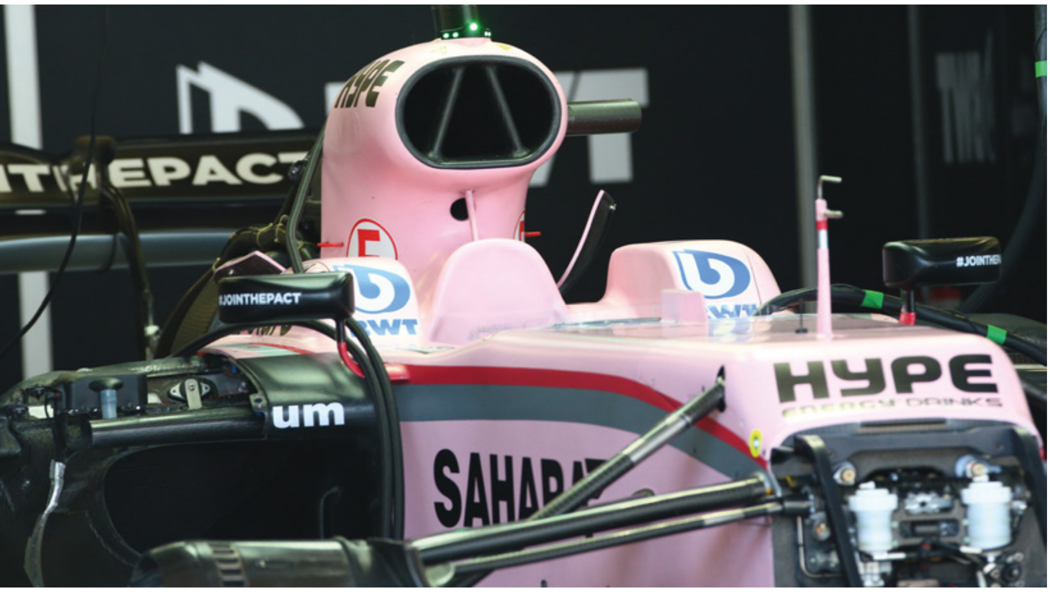
Boxed in

Force India utilises not only the Mercedes power unit but also its transmission. 'There is a big area of the car we have very little control over, including the power unit and the gearbox main-case,' Green says. 'That means we are obliged to run the Mercedes pickup points.

'We are very sensitive to how low we can run the nose of the car so front stiffness is important'

They do compromise their design to allow us to run the suspension and ride heights that we run, because ours is quite different to theirs. While they do help us and allow us to do that, the fundamental pickup points are designed for a low rake car, and so we would prefer to have some things in different places, but that is just one of the compromises we have to live with, we are not in a position to design and manufacture our own gearbox.'

The rear suspension of the car was, as was common with all 2017 designs, something of a point of interest early in the season as a result of the FIA's rules clarification on collapsible elements (see April 2017 V27N4) which allow the car to vary rear ride height depending on aerodynamic forces. Force India was not one of the teams required to make changes and according to Green the clarification did not stop the team doing what it intended at the rear of its car. 'At the time we were not that happy about the way the rules were going, but it's all been clarified, what we can and can't do, and the FIA are happy about what the teams are doing,' he says. 'We still manage to shed ride height to get the drag down going down the straight. One of the main issues of a high rake car is that it tends to be draggy, but we can do things to make that less so. We didn't need to change our concept.'



Roll hoop contains segmented air intakes with outer portions for the cooling while inner section directs air for combustion

With a lack of new regulation data pre-season, peak suspension loads were formulated with Eau Rouge at Spa in mind

In the pink

Despite the consistent form of the cars the engineers at Force India are not content, even though the team is on target to match its best ever World Constructors' Championship finishing position of fourth and there is still a lot of work to do. 'The cars tend to get more complicated as they develop and generally more complicated components are heavier,' Green says. 'We are always developing the suspension and that tends to get heavier, not lighter. The car tends to gain weight naturally if you just let it develop. Every year you have to drag the weight down again. Every single time a part gets made, we are looking at ways of making it lighter without losing performance. It's continual and it is always at the forefront of everyone in the drawing office's mind.'

This mission to cut the weight of both the VJM10 and its 2018 successor has reached an extreme level of detail. 'All the departments look at materials specifications, asking themselves if they are using the right material, is there something better,' Green says. 'They ask is there a material that allows them to maintain stiffness and reduce weight, things like that. That is especially true in the composite department where there is so much more freedom to look at different materials.

'They are always looking to see if some material can be taken out of a component,' Green adds. 'If you take that material out it makes it lighter; [and] it might make it more flexible before it makes it slightly less strong.'

Material world

Force India's constant quest to get the best materials is to an extent reliant not only on finding new solutions but also proving manufacturers' claims. 'We tend toward a lot of static testing to validate materials, rather than rely on simulation or the stated properties,' Green says. 'You find materials at the trade shows or in magazines are so new that the availability is very small, so we have to wait months or even years for these to become available to us in the quantity we need. Sometimes there is a big lag between seeing the materials and having a part ready to run on the car. Also, bigger teams often get the parts ahead of us as they are willing to pay a premium. We have to wait a season or more to get it.'

Detail designs are then constantly adapted on the VJM10 in order to further reduce its weight. 'Things are always being remade to save weight,' Green says. 'It's big parts, too. The floor, for example, is one of the heaviest components

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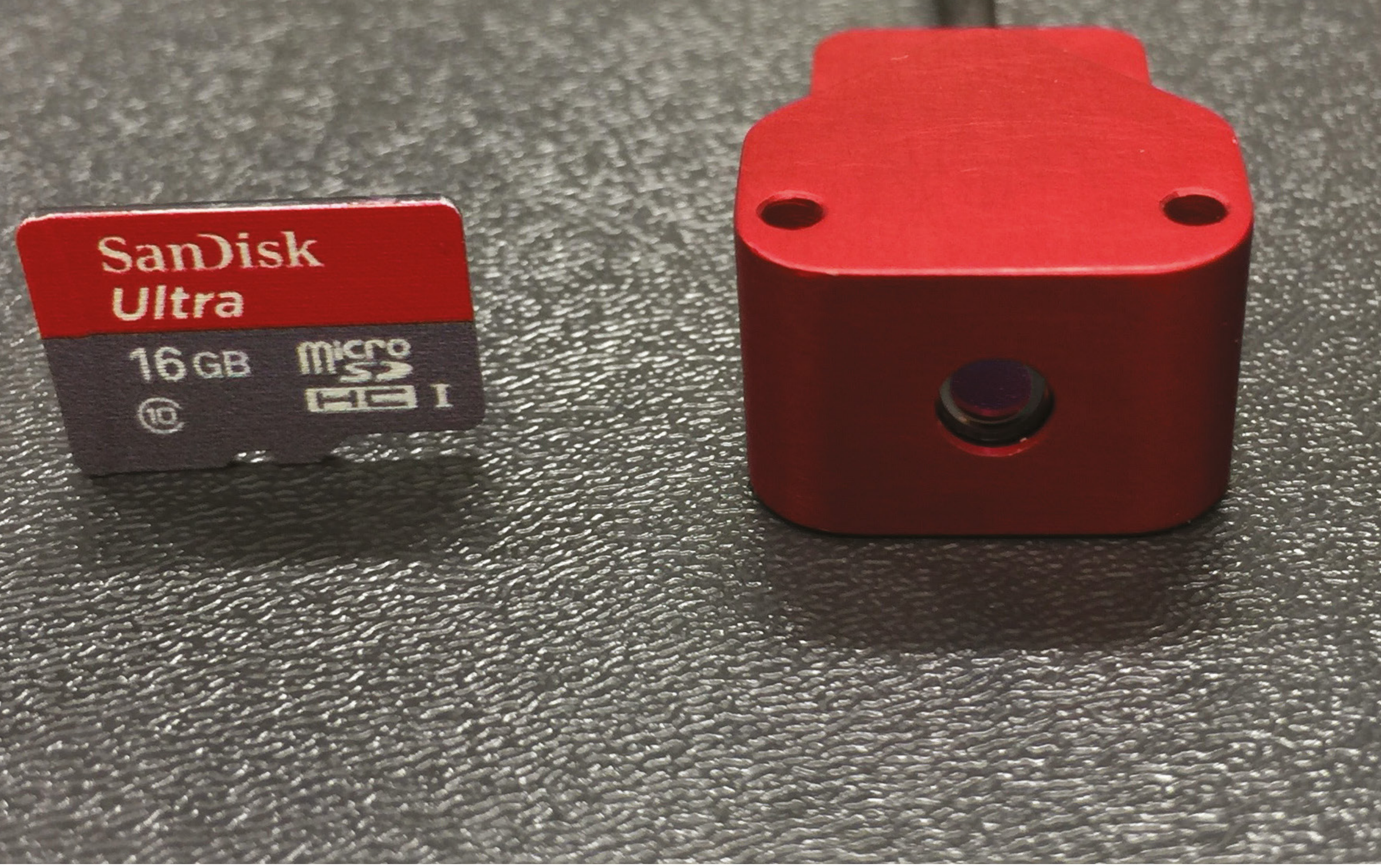

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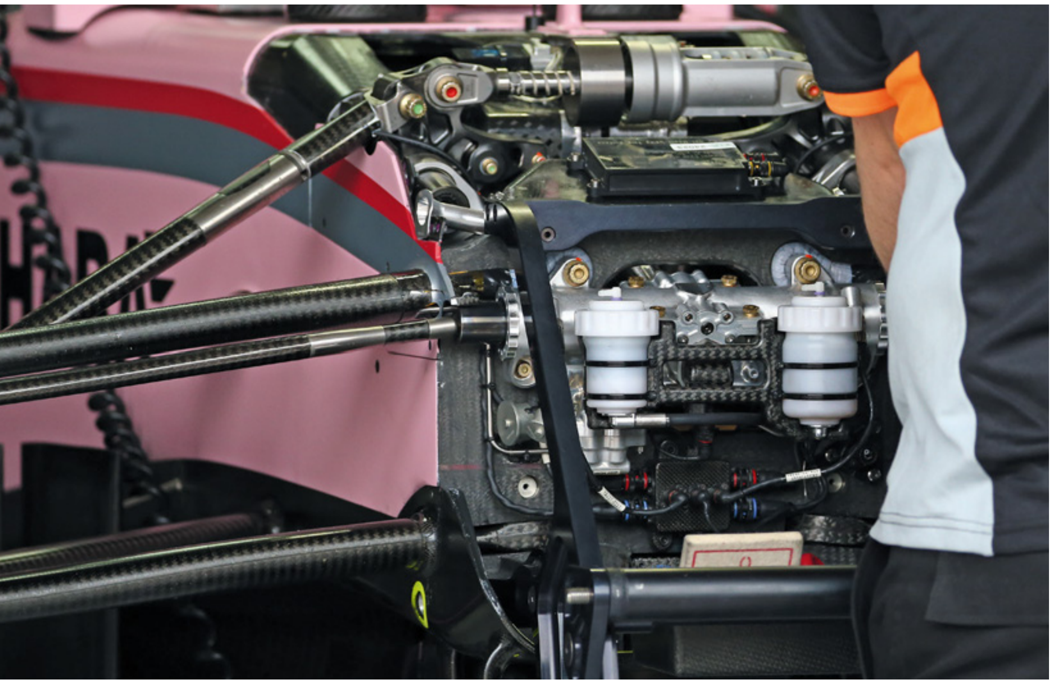
on the car, and we are always looking to try to take weight out every time a new one is made. We look at everything, even down to the way we paint the car – is there a lighter weight pink paint we can use? Do we have to have metallic elements in the paint which we might be able to get rid of, that alone could save 300g. It's even down to the thickness of stickers on the livery.'

The Force India weight loss project is only set to get harder in 2018 with the addition of the new Halo cockpit protection device. 'With the VJM10, if we want to reduce the weight of the car much more we are moving into fundamentally redesigning the structures of the car,' Green says. 'But for next year knowing what the loads are we can now optimise and start to reduce weight for that design. However, the weight of the Halo and the mounting of it far exceeds the increase in minimum weight, so we have to make big reductions again. It is 100 grams here and 50 grams there, luckily there is some margin to get weight out. So our target is again to get the car on the weight limit and that is a big challenge, probably a bigger challenge than it was this year.'

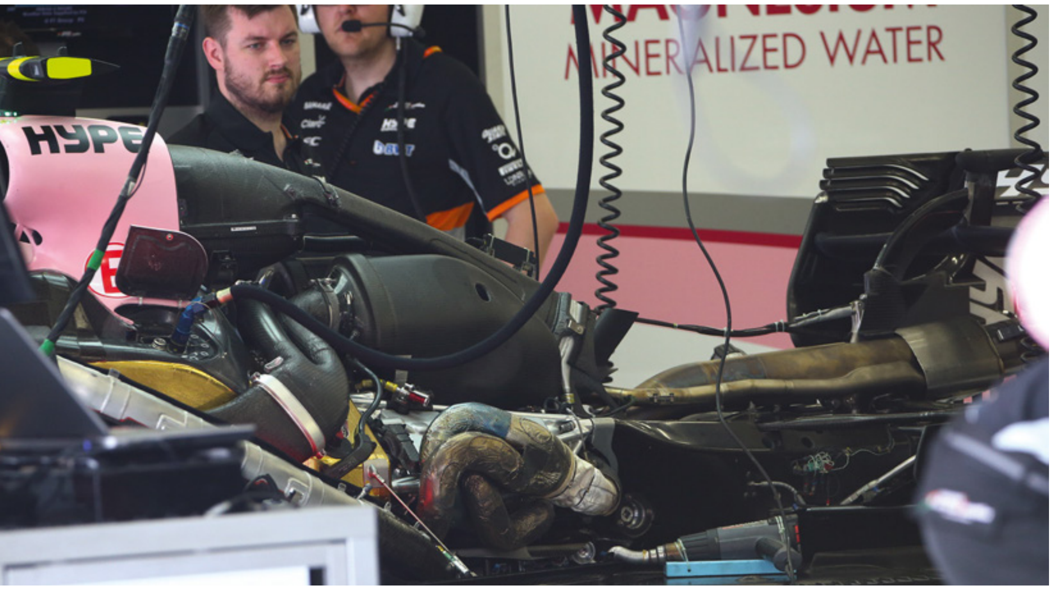
'We still manage to shed some of the ride height to get the drag down going along the straight'

Data-driven

For the engineers, one element of the design of 2018's car is somewhat easier than that of 2017, though, in that they have real data to work from now. 'Now we have done it, and are on to the second iteration we are a lot more comfortable with what we are seeing,' Green says. 'We have got data, and as we are a very data-driven team that is a good thing. We have gone through the first half of the season, we have gone through Spa and we know what loads we have seen, we now know aerodynamically where we sit, we know where Pirelli have put the tyres and where on the compound range they sit, and we have some idea what they are doing next year, going one step softer. Next year is looking a lot better in terms of the accuracy of the data we are working with and we are also starting to get some carry-over parts which is good for a team like us as we can start pre-season testing with existing components, and it lets us bring an update package earlier on in the season.'



The reason for the ugly nose hump is that suspension parts are placed on top of the chassis in a quest to maintain stiffness



Force India uses the Mercedes power unit. Rear suspension is conventional, with pullrod-activated inboard torsion springs

Room to improve

Green struggles to think of any part of the car he is really proud of in isolation. This is not because he thinks that there is nothing on the car to be proud of, rather that he thinks the team simply could do better. 'I look at almost every part of the car and think "I could have done that better". I think everyone in the team does that, too. I wish we didn't have the T-wings on the car, I think that was a bad regulatory mistake, that really annoys me when I look at the car. Actually, the VJM10 looks old to me now, I'm used to working with the new concept for the 2018 car. There are so many areas where we know we can do better, but we are reasonably happy with the compromises we made. There is nothing on the car which makes me think "that was a really bad call". There is nothing stand-out, either, I just see everything and know that we can do a better job, but the car was the best we could do in the time we had and with the data we had.

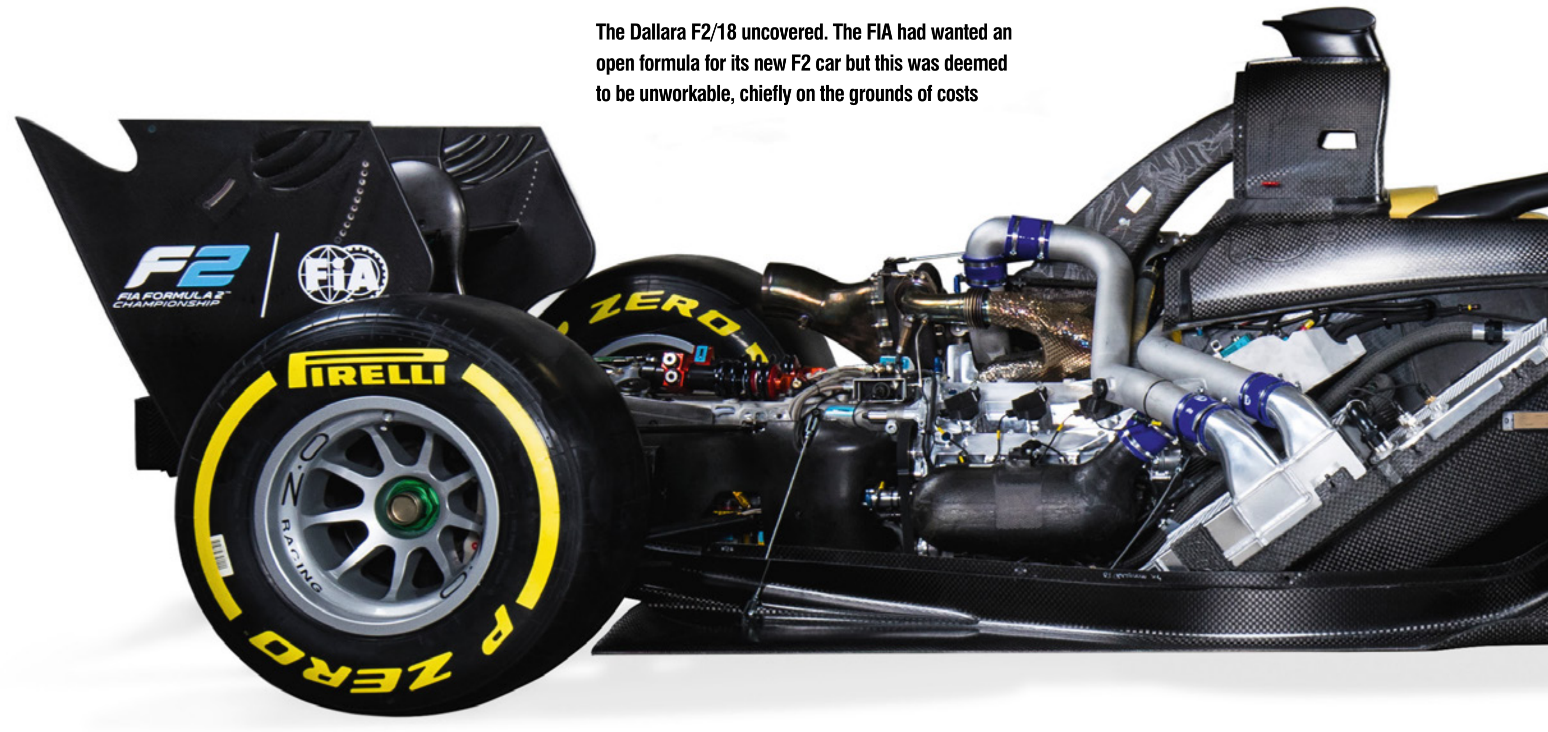
'There are nice details on the car, a lot of them you would never see, they are all under the skin,' Green adds. 'Some of the most amazing detail only ever gets seen in the sub assembly area. You look at one of the uprights, the machining from a solid billet, you just think that is a lovely piece of work. But to say I am I proud of any particular element, well I don't think we really think like that, I don't think there is anyone who would look at any component of the car and say we have done a fantastic job, it's a perfect concept … We look at our car and know we can do better, but we look at some of the other cars, and we see the amazing detail on some of the big teams' cars, sometimes we are in awe of what they can do, the level of detail they can put into some of the components – something we just cannot do.'

With solid performances all season long and a excellent reliability record, the VJM10 is set for a very creditable fourth-place finish in the world championship, but despite this Green already has his sights set on the future. And knowing this is sure to have those working at rival Formula 1 teams not a little concerned.

Finishing school

The 2018 F2 car is a far cry from the FIA's original intentions for its feeder category, but will the Dallara F2/18 still deliver where it matters – preparing drivers and engineers for F1? *Racecar* investigates

By SAM COLLINS



The Dallara F2/18 uncovered. The FIA had wanted an open formula for its new F2 car but this was deemed to be unworkable, chiefly on the grounds of costs

One of the longest serving open-wheel racecars of recent years will be officially retired at Abu Dhabi in late November. Dallara's GP2/11 is to be replaced in the FIA Formula 2 championship by an all new design from the Italian constructor, called the F2/18.

Formula 2 was relaunched by the FIA at the start of 2017, essentially a re-branding of the existing GP2 Series. But when the tender for a promoter for the 'new F2' was first announced in 2015, the proposed technical regulations were very different to that of GP2. Indeed, it called for a multi-chassis, open wheel series using hybrid powertrains. 'The tender had to change, it needed to be a single make chassis rather than an open class,' Didier Perrin, technical director of F2 says. 'It is the most efficient way to do affordable motor racing. Open championships cost so much more and there was no possibility to have an open championship at this level, the costs would be too high, so the tender reverted to a single make category. Also, to have a hybrid, it's difficult to do it in a cost effective way, so we didn't even look at it with the new car.'

Key criteria

With a single make series confirmed the task then fell to Perrin and his staff to define what exactly the car would be, and after some contemplation three key criteria were set. 'From the beginning the main aim was to increase the safety standards, as we wanted to be the ultimate in safety, then the second most important element was the show,' Perrin says. 'The cars must be able to follow each other and race, that is the key aim with the aerodynamics. In an open championship the aerodynamics are developed to produce the most efficient package possible in terms of performance, but in a one make series the emphasis must be in allowing the cars to follow.

'The third objective was controlling the cost and keeping this as low as possible,' Perrin adds. 'When I talk about the cost I'm not talking about the purchase cost of the car, I'm talking about the operating cost, that is what really makes the difference. That impacts the budget the driver has to pay to race for a season, so a key point is that the car must be reliable and easy to run with a limited number of people. That must be in mind from the beginning of the design process. If the car is too complex or needs too many people to run it, there is no way that you can have an affordable racing season.'

One additional criteria for the chassis was also set to deal with a trend among young drivers, and is something that is intended to increase the size of the talent pool. 'It may sound minor, but something we had to deal

Just like its predecessor the F2/18 has been designed to look like an F1 car. Formula 1 will also be running with the Halo next season

‘The cars must be able to follow each other and race, that is the key aim with the aerodynamics’

While the chassis has been built to 2017 F1 safety standards it’s similar in concept and uses the same materials as the GP2/11 it will replace in F2 next year

Above: The cockpit features extra Zylon panels which has had the knock on effect of increasing the car's weight. It has also been designed so that taller race drivers can be accommodated **Right:** The Halo fitted on the launch car was actually a dummy. The car was not originally going to include the new safety device and Dallara has had to design-in extra hard points on the chassis

'As our first aim was to improve safety we had to build the chassis to the F1 2017 safety standards and pass all of the same tests'

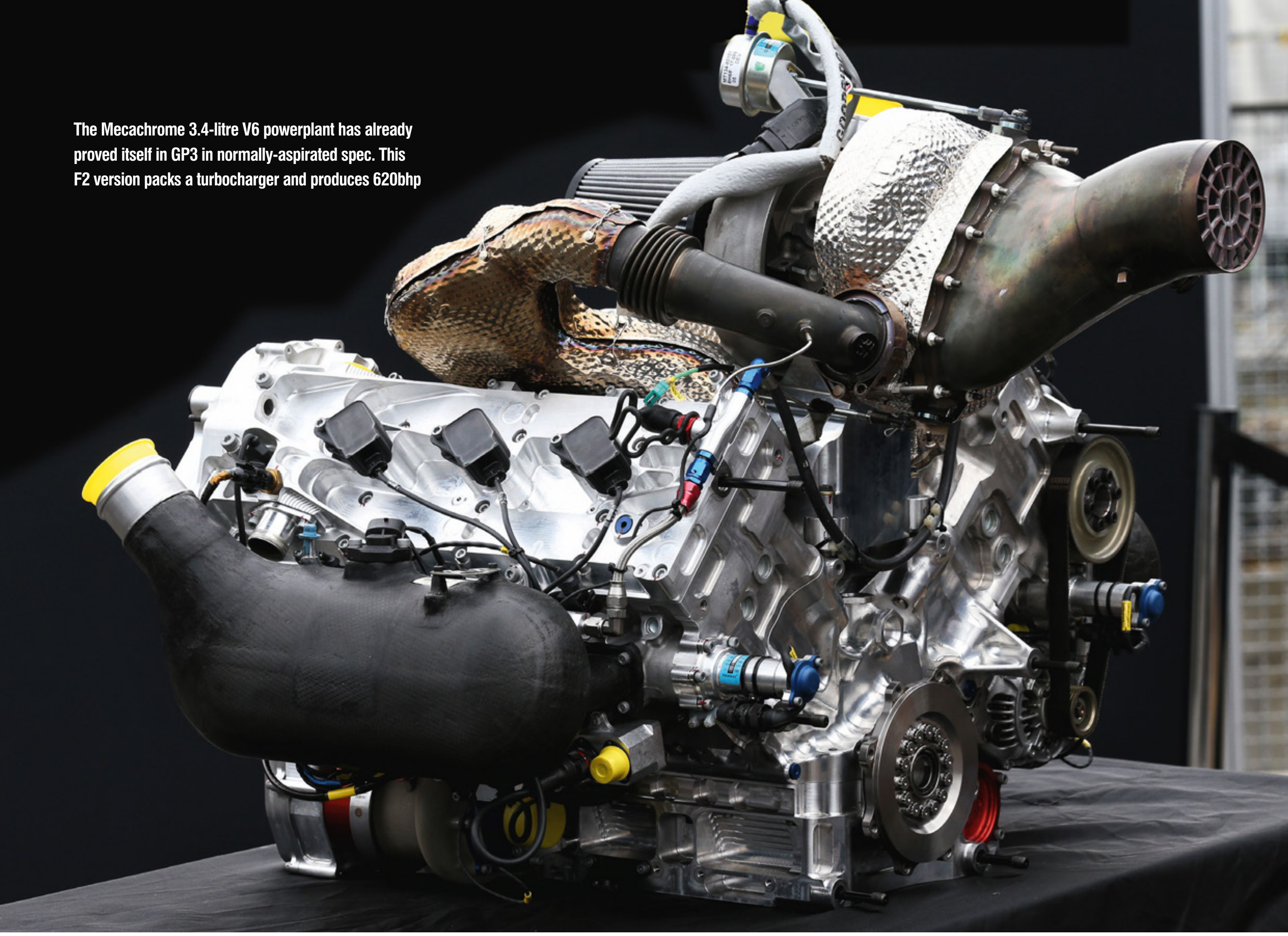
with is that drivers are getting taller, on average,' Perrin says. 'We started to have some issues with the old car and tall drivers. It's something so simple, but we needed to change the chassis so tall drivers could fit, so with those criteria decided we set that out to all of our suppliers.'

In terms of those suppliers it is clear that continuity was an important factor, too, with Dallara leading the project, Mecachrome supplying the engine, and Hewland the transmission – as was the case with the current GP2/11 that races in F2 now. 'As the first aim we were set was to improve safety we had to build the chassis to the Formula 1 2017 safety standards and pass all of the same tests,' Luca Pignacca, chief designer at Dallara explains. 'This had an impact not only on the technical content of the car but also the appearance of the car. So it has a low nose, which according to the FIA is safer, so we had to follow this path.'

Tub concept

While Dallara is very familiar with the current Formula 1 safety standards and chassis construction techniques, as it also builds the chassis for the Haas F1 Team, according to Pignacca not all of those methods were applicable with the F2/18. 'The chassis is not completely different in terms of concept compared to the old one,' he says. 'We decided to use the same materials as we did with the GP2/11, and those materials are not the same standard as you would find in Formula 1. We did this for cost reasons, so in structural and conceptual terms the new monocoque is pretty similar, we just had to add more material and design it in a slightly different way.'

As a result of this approach, and the somewhat larger cockpit required for taller drivers, the new monocoque is notably heavier than the design it replaces. It features a lot more Zylon (anti-intrusion) panels compared to the old one, too. 'As is the case with current F1 cars the whole front of the cockpit is clad with panels and this alone accounts for 7 to 8kg. Then we have the Red Bull style side impact structures and that adds weight too,' Pignacca says. 'The new engine is also a bit heavier, with the turbo



The Mecachrome 3.4-litre V6 powerplant has already proved itself in GP3 in normally-aspirated spec. This F2 version packs a turbocharger and produces 620bhp

F2/18 features a Formula 1 style swept back front wing which has been optimised to minimise the wake effect – the quality of the racing was one of three key criteria for Dallara when it was designing this car

'The car must be reliable and easy to run with a limited number of people'

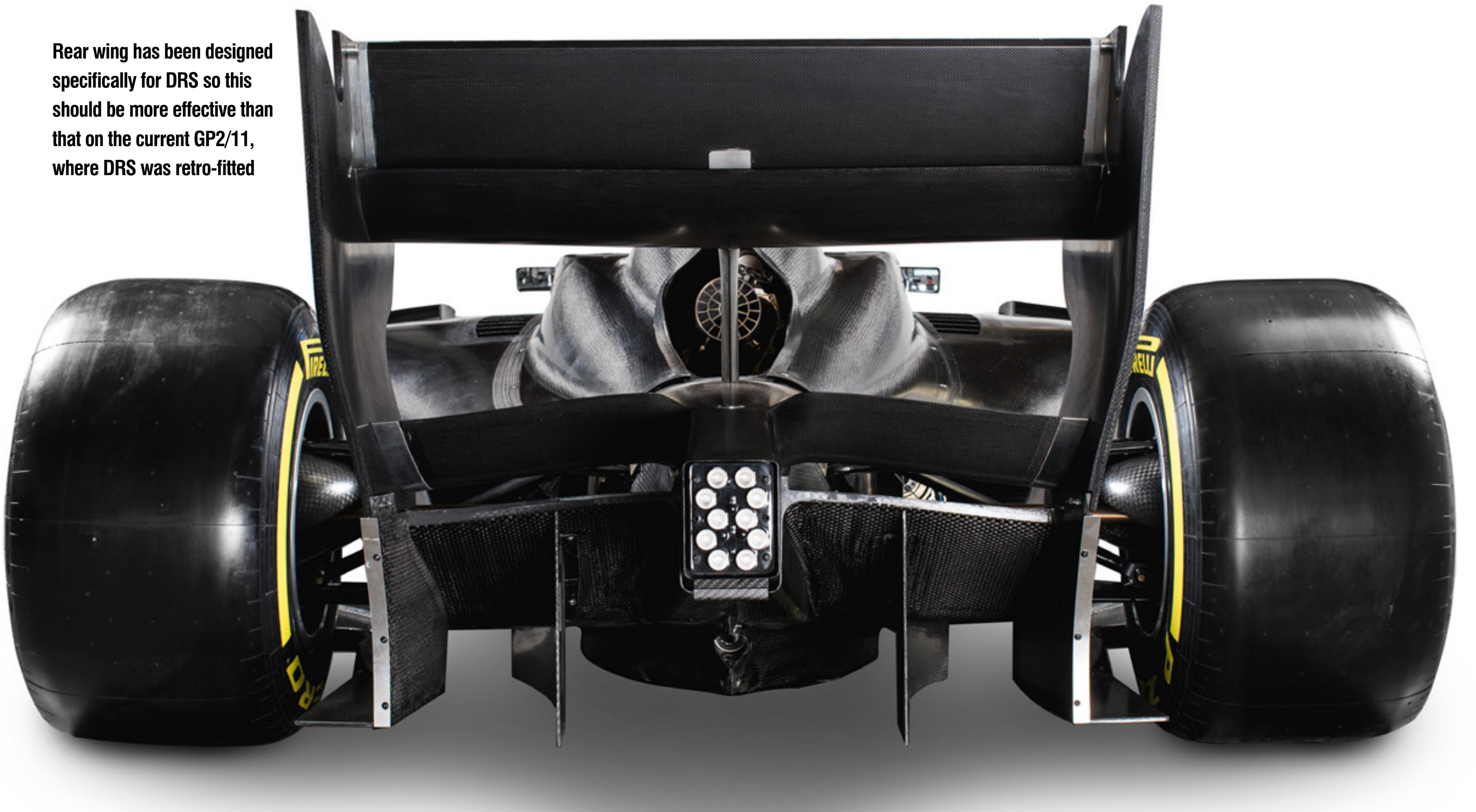
and intercooler the weight distribution is moved slightly rearward, but with the extra safety measures we have actually seen the overall balance move a bit more towards the front.'

Halo there

One of the most distinctive features of the Dallara F2/18 is the Halo cockpit protection system which, of course, will be a feature of all Formula 1 cars in 2018, too. However, when the racecar was designed it was not thought that it would feature at all, leaving the Dallara engineers with something of a headache.

'While the shape of the tub was conceived to fit the Halo in the first place, when we started this project over two years ago, we then decided that it would not feature it after all,' Pignacca says. 'Luckily we retained the shape but the structure was not there for its mounting. Because we didn't think there would be Halo we didn't put in all the extra material and inserts it needs. So we started production on the chassis without the Halo mountings, and actually the first three chassis we made did not have the mountings, but then the FIA decided that the car should feature it after all. To install it you need a lot more carbon fibre, and also hard points which those first chassis did not feature. Now we have some very nice show cars!

'The loads the structure has to withstand are massive and it was a very difficult challenge



Rear wing has been designed specifically for DRS so this should be more effective than that on the current GP2/11, where DRS was retro-fitted

for us to fit it to the chassis and pass the FIA crash tests,' Pignacca adds.

The car seen in the pictures on these pages is one of those first three chassis built, which will be used for initial testing but not racing. 'We have not yet received the definitive Halo,' Pignacca says. 'The one on the launch car is a dummy, but looking at the CAD we believe that the extra weight due to the device itself and the mounting points and extra material required in the chassis is around 10 to 12kg. The F1 guys have to do the same, but the weight will be a bit lower as they are using better materials.'

One of the reasons for the uncertainty surrounding integration of the Halo was down to the fact that Formula 1 was experimenting with a partial canopy during the mid part of 2017, and at one time this looked more likely to be used in both F2 and Formula 1. 'Going to the screen was not as difficult as the Halo,' Pignacca says. 'As the structure and its design did not require such a high proof load. With the screen we would not have needed to modify the shape or structure of the monocoque. You would have to add some brackets and fairings but not much.'

Turbo power

As the chassis design and development was ongoing, Mecachrome was developing an all new turbocharged V6 engine to power the new car. The base 3.4-litre engine made its race debut in 2016 fitted to the GP3 series cars, albeit in normally-aspirated trim. In Formula 2 specification with its single turbocharger the unit delivers 620bhp at 8750rpm.

'One of the reasons we have a turbocharged engine in F2 was due to the fact that we wanted to have something that really prepared the drivers for Formula 1,' Perrin says. 'In Formula 1 with the current hybrid power units, you have a lot of torque. That means that the power curve of an F1 car now compared to five years ago is much flatter, and one way to have this, other than having a hybrid system, is to use a high capacity engine with a turbo. This is why we moved to the current engine; we needed a power curve as close as possible to a F1 power unit curve. In fact, this engine was defined four years ago for F2, but the same base unit was also used for GP3. That has allowed us to check the base unit to see if it is reliable. It is.'

The reliability of the engine will also be put to the ultimate test in 2018 when it is fitted to the new Ginetta LMP1 chassis, although with some specification differences. 'The engine racing in LMP1 will have direct injection and a different turbo to the Formula 2 car, but is otherwise the same,' Perrin says. 'So that along with the performance in GP3 this year shows that this is a very reliable engine. Mecachrome have done a very good job.'

Perrin's second biggest objective was perhaps the hardest for Dallara to achieve; to ensure the racing was good and that the cars could pass each other. 'Overtaking is very complicated,' Pignacca says. 'If I knew exactly how to design a car so it overtakes well that would be priceless. It's not just aero, it is a combination of things, like the tracks for example. We know very well that some cars can race well on some tracks but not on others; the power, the weight, it all plays a role.'

'One of the reasons we have a turbocharged engine was due to the fact that we wanted to have something that really prepared the drivers for Formula 1'

F1 lookalike

The F2 organisation wanted its racecar to look like a current Formula 1 car so it features a swept back front wing, large bargeboards and a low and wide rear wing, featuring DRS.

'We can control some of the factors which influence overtaking,' says Pignacca. 'We did a lot of CFD work to make sure it was no worse than with the old car which actually works pretty well in terms of overtaking. So with the new front and rear wings we ensured that there was no real difference in the wake of the car. That was key; the wake of the car and how the following car reacts to it. The DRS carries over in terms of the mechanism and it is the most effective thing at making overtaking happen, that is clear. Actually, the DRS on this car is more powerful than the old one. The reason for this is that the old car was not designed with DRS, the wing had to be adapted to take it, it was retrofitted, but this wing is designed specifically to have DRS, so it is much more effective.'

The aero package is significantly more potent than that of the GP2/11

TECH SPEC

Dallara F2/18 Formula 2

Monocoque and Bodywork: Survival cell, sandwich Carbon/aluminium honeycomb structure made by Dallara. Front and rear wing, carbon structures made by Dallara. Bodywork, carbon/Kevlar honeycomb structures.

Engine: V6 3.4-litre single turbocharged Mecachrome engine; 620bhp at 8750rpm; drive-by-wire throttle; rebuild after 8000km; maximum Torque 600Nm.

Transmission: 6-speed longitudinal Hewland sequential gearbox with electro-hydraulic command via paddleshift from steering wheel; ZF SACHS carbon clutch; anti-stall system; non-hydraulic ramp differential.

Electronics: Magneti Marelli SRG 480 ECU/GCU including data logging system; Magneti Marelli PDU 12-42 power supply management unit; CAN data acquisition pre-equipment; Beacon receiver.

Suspension: Double steel wishbones, pushrod operated, twin dampers and torsion bars suspension (F) and spring suspension (R); adjustable ride height, camber and toe; two way (F), four way (R) adjustable Koni dampers; adjustable anti-roll bar (front/rear).

Steering system: Non-assisted rack and pinion steering system; XAP steering wheel with dashboard, gear change and clutch paddles, plus marshalling and VSC display.

Brakes: 6-piston monobloc Brembo callipers; carbon-carbon brake discs and pads.

Wheels and tyres: F1 2016 standard wheel dimensions; OZ Racing magnesium rims; F2 specific Pirelli slick/wet tyres.

Fuel cell: FIA Standard Premier FT5 125 litres.

Dimensions: Overall length: 5224mm (was 5065mm); overall width: 1900mm (unchanged); overall height: 1097mm including FOM roll hoop camera (was 1072mm); wheelbase: 3135mm (was 3120mm).

Weight: 720kg (including driver).

Performance: Acceleration: 0 to 100km/h, 2.90s; 0 to 200 km/h, 6.60s. Maximum speed, 335km/h (Monza aero + DRS); max braking deceleration -3.5g; max lateral acceleration +/- 3.9g

The aerodynamic package of the F2/18 is claimed to be significantly more potent than that of the GP2/11, but the overall performance is expected to be similar. 'The brief was also to improve aerodynamic performance to offset the weight increase, but the weight penalty is pretty big so we will not be faster than the old car,' Pignacca says. 'The power level is about the same but with better torque. Then there are the tyres. My impression is that these tyres are better for overtaking than the wide ones used in F1, but tyres are critical and if you lose [performance] by locking up, then drivers don't take risks for overtaking. I'm quite curious to see how the tyres work with that extra torque.'

Slick work

As is the case currently, the tyres on the F2/18 will be supplied by Pirelli, and will be the same size as those used on the GP2/11. 'We get data from Dallara, and we saw no reason to change the size of the tyres,' Mario Isola, Pirelli's racing manager says. 'I think this is the right size and I believe we have a good product so there is no need to make something completely new. We will have to look and see as there will be some impact from the new engine. Obviously, because of the different torque level and the weight distribution change we will have to do some fine tuning to get the best product.

'When we started in Formula 1, it became very apparent that the torque level had an impact on the heat level at the rear, especially on the centre of the tread,' Isola adds. 'We had to modify the profile and the construction so the tyre could cope with that a bit better. I think we can transfer that experience to the F2 tyre.'

The third of the objectives for the Dallara F2/18 was to keep running costs as low as possible for the teams and that has resulted in much of the mechanical design of the car carrying over from the GP2/11.

'We did not want to make a completely new car, we wanted to carry over some components from the old car, for example the hubs,' Pignacca says. 'We are aware that teams are under budget pressures so we tried to change as few of the parts as possible to help the teams keep costs down. The rear dampers, for example, are a direct carry-over, but the uprights, for instance, have a slight modification to increase their life. They are interchangeable with the old ones, though, so the teams can keep the old ones as emergency spares. The gearbox main-case carries over, too, along with the internals, but the bellhousing has had to be changed as you would expect to accommodate the new engine. The rear crash structure is the same, as is the suspension geometry.'

Switching over

Not everything on the racecar is a carry-over, of course, with Perrin deciding to make a significant change and upgrade to the latest specification electronics package from Magneti Marelli. 'It has a lot more potential to introduce things like electronic marshalling, VSC [virtual safety car] conditions, and in general there is a lot more scope for development and upgrade,' he says. 'The previous system had about reached its limit in terms of capability.'

The first F2/18 chassis has completed its initial track running in private with further tests scheduled for the winter when teams start to receive their cars, and there seems to be some optimism about its performance from those who created it, even though it may be slower than the car it replaces. 'When we specified the F2 car we believed that the performance level, in terms of lap time was about right,' Perrin says. 'It's what we need to prepare drivers for Formula 1, so we did not ask for a faster car. We are not looking for the optimum, the last two or three tenths per lap, we don't care about that, all we need is a good tool to prepare the drivers for Formula 1 at the same time as providing a good show on track. It's clear to us that this car has a lot more development potential than the old one, and it is more versatile.'

It might not be the F2 first envisaged when the FIA decided to relaunch the category, but the Dallara F2/18 is certain to play a key role in the future careers of many drivers, and indeed engineers, in the years to come. If it is useful in this respect, then as a feeder formula car it will surely be seen as a success.


Windshear
180 MPH WITHOUT MOVING AN INCH

Style with substance

The face-lifted 2018 Dallara DW12 IndyCar has been widely praised for its sharp looks, but it also packs some serious safety and aero-performance improvements. *Racecar* took a closer look

By MARSHALL PRUETT

‘When it became clear that we were going to do new bodywork we said that we should work to improve the side impact structure’

Improving the aesthetics of the five-year-old DW12 design was a priority with the UAK18 bodykit. Road course package is shown

The process of remodelling IndyCar’s Dallara DW12 with new bodywork for 2018 goes well beyond a beautification project that was long overdue. For hidden beneath the new panels that surround the 2012-era tub, wholesale changes to driver protection materials and methodology have also been made.

Externally, a reversal of the DW12’s sidepod layout with the upcoming UAK18 (universal aero kit 2018) has produced a proper ‘Coke bottle’ profile. Unlike the stock Dallara DW12 sidepods (2012-2014) and custom Chevrolet and Honda aero kits that replaced it (2015-2017), the UAK18 will now employ a wide structure alongside its drivers that provides ample structure to crush.

IndyCar aerodynamic director Tino Belli, charged with the overall rethink on the DW12’s UAK18 kit, performance levels, and safety improvements, talked *Racecar* through the formidable redesign process that will keep the chassis in service through to at least the 2020 season. ‘When it became clear that we were going to do new bodywork, [IndyCar engineering director] Jeff Horton said that we should work to improve the side impact structure beside the monocoque because it had been a little bit of an Achilles’ heel with the DW12 from the beginning,’ Belli says.

Side impact

The problem was that with the narrow radiator inlets next to the cockpit feeding oil and water coolers positioned almost parallel with the DW12’s rearmost bulkhead, the vertical walls enclosing each driver were asked to withstand an impact with minimal *g* deceleration.

Injuries suffered by Sebastien Bourdais in 2012 and Justin Wilson in 2013, where heavy objects pushed in a cockpit wall, led to the series mandating more cladding with Zylon panels for 2014. Strengthening the cockpit ring was also completed to bolster the primary aperture against deformation. Faced with adding more Zylon and more weight to address the problem, Belli, Horton, and Dallara took a clean-sheet approach to the UAK18’s sidepods.

‘Part of our requirement immediately was we wanted to move the radiators forward for aerodynamic reasons but also to get them in to help absorb some energy in the side impact,’ Belli says. ‘Dallara did do some side impact tests on radiators full of water at a FIA-sanctioned crash testing station in Turin. And Jeff determined that although the tests look quite spectacular, the video looks spectacular, the energy absorption from the radiator on its own was not sufficient.

‘We had the accelerations you got from the radiator. And really the radiator crushes too fast

New road course aero package is capable of generating 5300lbs of downforce, which is a step down from the amount generated by the manufacturer kits; around the 6800lb region

and then gives you a high peak right at the very end of the crash; obviously the art of energy absorption is to try and avoid the high peak *g*-loading. You really want a nice, steady, even peak *g*-loading.

'So Jeff concluded that that wasn't sufficient,' Belli adds. 'He was pretty sure before we did that test that that would be the case. The other problem you often have with just radiators is, in a pure side impact, they crush, but when you get slight oblique impact they just lay over. That really doesn't do you any good whatsoever.

'Then we took the FIA side impact criteria. We adjusted them a little bit to the higher loads that we see. Then we asked Dallara to design the leading edge of the sidepod so that it would absorb more loading to satisfy the FIA tests.

'One of the [different things] that we did here, was when an engineer picks up, you give him test criteria. [He will] then design just to pass that test, so you're once again back into pure side impact, and the structure, which is basically the top of the side part, would've acted perfectly. But if you had a slight angle to the impact, up or down or forwards or backwards, it would probably just take that structure and snap it off, which we wanted to avoid.'

Crushable structure

Dallara's UAK18 solution was to create a large, dense, leading-edge sidepod structure to be retrofitted, that will compress and act as a proper crushable structure. Repositioned radiators, which now fall in line with the driver's upper torso, will also help to dissipate the energy in an impact. The u-shape UAK18 sidepod structures replace the crushable 'teeth' that were used throughout 2017.

'So we had a meeting in May before the Indy 500,' Belli says. "[IndyCar doctor] Dr Terry Trammell, Jeff, myself, [IndyCar colleague] Bill Pappas, where we instructed Dallara that we wanted the side impact structure that they had designed for the top bonded to the bodywork that goes on the side, and come all the way down into the feed load, into the lower skin of floor of the tub.

'And that's what we have,' Belli adds. 'We've tried to put as much load as we can into the dash bulkhead, into the seat-back bulkhead and then into the floor of the tub. So that if the car gets up and hits at a bit of an angle, which does happen, we just wanted as good a structure for different directions of impact.'

Crash testing

Rigorous side impact crash testing for the UAK18 will now become standard fare, too. 'What we will plan to do, and we haven't done it yet because you're always battling time, is to do the side impact tests from a number of angles,' Belli says. 'And then over the next year or two we will be comparing test results *vs* actual results. Which should give us a much better picture of what we need to achieve when we do our next racecar. It's a constant evolution.'

The DW12's new sidepods are a maze of packaging and multi-purpose serving of needs. Walls separating the radiators from the tub are used to feed air and cooling to the 2.2-litre twin-turbo V6 engine and various electronics. The radiator ducting also carries miscellaneous electronic boxes as safety, heat rejection, drag, and downforce intermingle.

Pipe dream

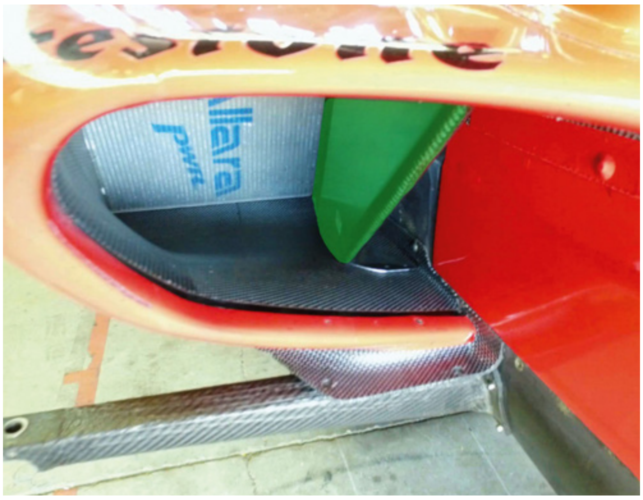
'At one time we were going to have a common turbo inlet duct and a common filter, turbo, pre-turbo filter,' Belli reveals. 'But to not add a lot of cost on the engine side, we didn't want to relocate the positions of the turbos. The difference is, Honda has a turbo which is quite forward and low and Chevy has one which is mid-engine and a bit higher.

'We came to the conclusion very early on that it was going to be almost impossible. So the inlet to the turbo and the water piping and the oil piping are the lifeblood of the engine as Marvin Riley, our engine director, says. He thought it was better to allow the engine manufacturers to design their own lifeblood.

'We left a gap between the radiator and the side of the monocoque and we said, "Hey your turbo inlet has to come through this gap." And then we also specified that the turbo inlet mustn't be visible, when looking at the car from the side. With no shuttering on the radiator inlet,' Belli says. 'We did that because we didn't want them making the turbo inlet come all the way down to the front suspension.

'After that, they're responsible for the cooling of their electronics which fits behind

'We've tried to put as much load as we can into the dash bulkhead, into the seat-back bulkhead, and then into the floor of the tub'



Dallara created a large leading-edge sidepod design that will compress and act as a crushable structure. Repositioned radiators, designed to be in line with the race driver's upper torso, will also help to dissipate energy in an impact. New sidepods are now packed with parts, while walls between the sidepods and the tub are used to channel cooling air to engine

the radiator instead of beside the radiator.' Belli adds. 'And they have to take the air for cooling of the electronics and for the turbo inlet through this gap that we gave them down the side of the radiator and tub. So as of now we don't know that it'll be amalgamated with the engine. The designs are not final. [This is] something you will see probably in the New Year.'

Aero tweaks

Ridding the DW12 of its limited visual appeal was the first priority for IndyCar. Second came the desire to carve a significant amount of potential downforce from what the Chevy and Honda aero kits produced. With side impact improvements duly made, and the overall look of the car vastly enhanced, Belli and Dallara went to work on the UAK18's aero performance in and around the new sidepods.

'The interesting thing is, in moving the radiators forward we've got a much gentler Coke feed in the back of the diffuser,' Belli says. 'Initially, without the tyre ramps that Coke shape actually didn't work very well. When we re-introduced the tyre ramps, which we needed to do on the super speedways for drag because we're trying to hit similar speeds in qualifying to what we have now, maybe a little bit slower, they energised that Coke shape.

'They push the air down, up over the underwing and then the efficiency of the car was very, very good,' Belli adds. 'And removing the rear wheel guards, that was a significant drag increase. So hitting that drag number was probably our hardest target. When we put the tyre ramps back in, in fact, in speedway format, it was too efficient early on. The car would have been too easy to drive in the race. Our target for Indy was to keep it the same. I think we had very interesting, very competitive exciting racing there. We had to play around to get those numbers to be the same.'

Maximum road course downforce for the Chevy kit, which topped the Honda by a modest margin, came in at 6826lbs, according to a leading race engineer with knowledge of both of the kits. Restoring lift/drag sanity was always on the cards for the UAK18.

Clipped wings

'The maximum downforce for the car, we really wanted to bring it down and we targeted 5000lbs,' Belli says. 'It's capable of 5300 with everything. We had a bit of luxury in that area that we could generate more downforce from the floor. So we filled in the hole near the leading edge behind the front tyre which had been introduced with the aero kits. Mainly because the manufacturers have done a better job than anticipated and we had to take some downforce away from them. And we had the luxury of putting the strakes and the sidewalls back in because once again, we took them away for the aero kits because their numbers were really just way too good. We managed to put a lot more downforce onto the floor.'

'Front road course flaps are about 73 per cent the size of current flaps'


Performance
comes from
within

Top pictures: The difference between the sidepod leading edge treatment on this year's version of the DW12 (left) and the new bodykit. Bottom two pictures show the super speedway configuration of the new and old (top) kits. IndyCar was pleased with the way the racecar performed at the Indianapolis 500 this year and wanted to retain a similar aero performance

Adjustments to the sizing with some of the topside wings helped pare the downforces and drag figures down to IndyCar's new goal. 'The front road course flaps are about 73 per cent the size of the current ones,' Belli says. 'The rear one's a lot smaller. We've used things like that. Obviously we had the ability, because we write the rules. We widened the rear wing a little bit, which is always good. Aspect ratio's always good. We widened the front wing main plane flaps a little bit to try and get the front downforce without so much flap angle.

'We lost a little bit off the front,' Belli adds. 'We raised the endplates a little bit because we'd been wearing them away and we wanted to reduce the amount of wear that we get on them. So they're a little bit higher next year. It was playing with all those bits and pieces. Essentially the car, in road course trim ,if you look at the efficiency line, the L over D line, it's identical. It's identical until you get to maximum downforce and then you just can't quite get as much maximum downforce out of it as you did with the manufacturer aero kits.'

In concert with changes to the floor in road course configuration, the rebalancing of downforce has boosted top speeds by as much as 10mph. Despite the slower cornering speeds due to losing more than 1500lbs of downforce, the straightline gains have kept lap times nearly identical to the DW12 in 2017 trim.

'The thing that happened with the DW12 when it first came out was the underwing was widened to the maximum width of the car to try and prevent interlocking wheels, which I think it's been very successful at,' Belli says. 'As a consequence of that, the way the car produces its downforce is not with very high amounts of suction. It's been quite low amounts of suction but on a large area. I wasn't around when the DW12 was conceived, so I don't know if it was intentionally conceived that way. But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'Right from the beginning we have been considering the aeroscreen and making sure that aerodynamically it is adaptable to this car'

it's produced a very benign car. I think a lot of that is down to a large area and not very low coefficients of pressure on the floor of the car. When we opened up the hole in the floor for basically the 5-degree nose-up condition [test] in the back flips of Indy, we noticed that we really didn't lose anywhere near the amount of downforce that we were expecting to lose. Part of that is because the floor is so wide and long at the front that the underwing wasn't really sucking through and using that as a proper diffuser. The DW12 floor is also low; lower to the ground at the front than it used to be with the previous Dallara chassis.'

Choke point

Beneath the new side impact structures, IndyCar has inserted a diffuser into the revised forward floor section – where the large hole will be used on the superspeedways – to re-energize the air. 'Part of that is just that the wide floor of the front is choking,' Belli says. 'So by adding that slot [we can] get some of that air out of there, and pull the air through that front part, the front part of the floor is working a lot harder. That was an objective that we had. We wanted to try and get as much front downforce from the underwing as we could within the constraints of using the same underwing. And therefore reduce the inter-dependency on the front wing.'

With the UAK18's fresh forward floor, sidepods and crush structures sorted, the final area of exploration has come with IndyCar's development of an aeroscreen for the car. Ongoing plans to test the DW12-specific solution remain; whether it will be approved for competition is another matter.

Screen saver

'Dr Trammell and Jeff Horton have obviously investigated [different solutions], as they're part of the safety commission that they work with in Europe,' Belli says. 'So they have looked obviously very hard at the Halo. And they've also looked at aeroscreens, and have come to the conclusion that in our situation, an aeroscreen is a better possible solution for us.

'So, right from the beginning of the UAK18 kit, we have been considering the aeroscreen and making sure that aerodynamically it is adaptable to this car. We tested it in the winter. One of the good reasons for moving the air intake from the roll hoop area to the cockpit, to the inlet ducts, the radiator inlet duct area, is obviously the aero screen is less likely to affect the airflow into the engine. And it obviously doesn't affect it at all on the UAK18.'

Issues with air curling over the top of the aeroscreen and building pressure behind the driver's helmet is the current dilemma to solve. 'We have done CFD studies on helmet buffeting and head pushing, so we were not surprised when F1 tested it on [Sebastian] Vettel's car and his [head] had pushed forward,' Belli says. 'We're currently working on helmet solutions to fix that problem. In Indy configuration we check the car five degrees nose up, nine degrees of yaw, 135 degrees yaw, 180 degrees of yaw. We checked those configurations to make sure that we haven't lost stability in any of them.

'From that point of view we're okay to go. Jeff has checked the visibility of the windscreen in the simulator. And the next phase is to get it on a car and start track testing it. Obviously, there's still quite a few checks and balances that have to be done on a system like that. You've got reflections, you have fogging, oil, water, racing at night under the lights, going from dusk to dark. We need to make sure that we have a handle on them before we press the button on that proposed project,' Belli says.

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Seoul music

Hyundai's rasping WRC powerplant has impressed this season, powering the i20 to three victories. *Racecar* traces the development of the Korean firm's first wholly in-house built engine

By MARTIN SHARP

Hyundai's time-scale for setting up its motorsport operation was nothing if not ambitious. Announced at the Paris Motor Show in October 2012, the budget allocation was in place when team principal Michel Nandan joined the company in January 2013. At that time building work was just under way at the Alzenau, Germany HQ.

An i20 World Rally Car had already been designed and built at Hyundai's Research and Development Centre in Samyang, South Korea, and, as more Hyundai Motorsport employees were taken on at Alzenau, major revisions to evolve this car took place in Germany; ostensibly to improve reliability and component access, but also to aid its competitiveness.

But the Korean company's stated intention had always been to create an autonomous

Hyundai's 1600cc turbocharged engine was built for the new-for-2017 WRC regulations. It produces 380bhp at 6500rpm and 450Nm of torque

The new engine is adapted to suit the increased inlet restrictor diameter, meaning combustion chambers and pistons are different

SARAH VESSELY, HYUNDAI MOTORSPORT

motorsport facility at Alzenau. The plan involved the entire design and manufacture of its World Rally Cars under one roof. This objective encompassed the WRC engine, too, but in the very short time available between early establishment of the HQ and the first i20 WRC's debut rally, available engine engineering personnel and facilities were lacking.

Which is why the first engine development was therefore undertaken at Hyundai's Samyang R&D base. This powerplant was then honed to world rally competitiveness in Alzenau, through three initial iterations before homologation of the fourth version, by Hyundai Motorsport's fledgling engine department under its then-boss Stephane Girard, who joined the operation in April 2013. Girard is a highly-regarded engine engineer, who started with Citroen Sport, then moved to Prodrive and went to Hyundai after five years experience of working on Peugeot Sport's LMP1 engines. By November 2013 he had six people working for him in the Hyundai Motorsport engine department and was actively recruiting to at least double this headcount.

To begin with Girard worked with the Research and Development department in South Korea, but more closely still with Hyundai Motorsport's French partner, Pipo Moteurs – 'for reasons of logistics,' Girard said back in 2013.

Early days

At that time there was no exact timing to get the engine department fully up and running with Girard more concerned with not rushing the process, as he said then: 'I don't want to rush anything on that – it's easy to rush and make a mistake, so as it is a long-term project we are building up slowly.'

During these early days of engine development Girard spent one-third of his time at Alzenau, one-third testing and one-third at Pipo. Team Principal Michel Nandan says of that time: 'In fact, for the engine of the first car we asked for the help of Pipo Moteurs because I had only Stephane [Girard] and a few guys to do proper engine engineering and we had no dyno; we had nothing, so it was the only way to get a competitive engine quickly.'

Just 12 months after starting with effectively a clean sheet of paper, the new team went into its first WRC season, in 2014. Podiums in Mexico, Poland and a one-two in Germany indicated that things were heading in the right direction.

The following season, 2015, saw the team take podiums in Sweden, Sardinia and Spain while Hyundai just missed out on second place in netting third in the manufacturer rankings.

The Hy' life

But that first engine was to last just two years, as the New Generation i20 road car would appear for 2016 and a completely revised power unit was planned for the first New Generation World Rally Car. This was developed during 2015 by the Alzenau engine department, once again also in collaboration with Pipo Moteurs.

Straight out of the box, on the first rally of the season, Monte Carlo, there was a debut podium. Hayden Padden then dominated Argentina, scoring the New Generation car's maiden win. Then Thierry Neuville took the new car to victory in Sardinia. In total two victories, 12 podiums and 47 stage wins for the year boded well for the next new car built to the all-new 2017 FIA WRC technical regulations.

Between the end of 2015 and the beginning of 2016 the team installed its first engine dynamometer test cell, then a year later a second dyno unit was installed; this one being equipped with altitude/climate simulation facilities. Around the same time as the appearance of the second dyno the entire engine department was up to speed, with six engine engineers, seven workshop personnel and the personnel to run the dynos; in total around 25 people.

To give scope for Hyundai Motorsport to develop the 2017 WRC engine in-house, build work of 2016 engines became split between Alzenau and Pipo, with Pipo doing six event units, Alzenau six, and so on. But all the 2017 engine development work was done at Alzenau.

By 2017, Hyundai's objective of taking full control of its engine development was achieved, with all engine development and assembly for this year's three-door i20 Coupe WRC now completed in-house. Having hit this objective, engine department boss Girard then decided to take up an offer from ORECA in France to head-up its engine department.

Hyundai team principal Nandan is very happy with all the work Girard had contributed

The new powerplant has been effective – a win on Rally Poland one of three victories for the i20 in 2017, at time of writing


Michel Nandan says engine development is ongoing

to the team effort but, with Girard's family living in France and him working in Germany, Nandan fully appreciates his desire for better family arrangements. Julien Moncet now heads-up the engine department, having joined Girard's early engine team from Toyota's F1 programme.

Hyundai is not totally on its own with its engine, though, and Pipo is still involved with the operation; completing a limited amount of parallel work on the 2017 WRC engine, while also building Hyundai Motorsport's customer R5 engines and its TCR engines.

New formula

The 2017 Coupe WRC car is, naturally, a new homologation and its 36mm inlet-restricted engine (which is up from 33mm on the previous WRC units) is said to be a 'completely new' design; although using the bore and stroke of the 2016 unit, so components such as the crankshaft and connecting rods could be carried over to the current engine.

While the cylinder block exhibits some similarities to that used in 2016, the machined from solid alloy unit is a new design, optimised to integrate components and reduce weight. Of course, the new engine is adapted to suit the increased inlet restrictor diameter, meaning combustion chambers and pistons are different, as is valve lift and geometry.

The very first i20 WRC engine ran with Magneti Marelli fuel injectors, but Bosch units were installed for the new engines in 2016 and for this year, managed by Magneti Marelli electronics. Nandan explains: 'We compared both together and we still compare both types in order to get the best choice, and on last year's engine we had Bosch … and we still selected Bosch ones [this year] because we had better performance with them.'

With the restrictor change for 2017 comes a new Garrett turbocharger. By allowing more air to mix with fuel in the combustion chambers a more volatile mixture is produced. But the FIA rules have not changed the maximum allowed 2.5bar absolute WRC boost pressure. The net result is more maximum power at higher rpm but no big change in maximum torque figure. Both maxima are produced higher in the rpm range; but just slightly higher than before for the torque, while max power is rather further up the range. A less 'driveable' power curve for most WRC engines is the result.

Nandan says: 'It's true that in the beginning the drivers were not really used to using the higher rpm, so yes they had to get used [to it] because in the end you can't really change anything – it's due to the restrictor size. The only thing we were trying, was to try to get a still wider range of the torque, in order that it is much easier to use it. But for sure the fact that they have to go higher in rpm, then it is more [up to] the drivers to [adapt to] that [than adapting the rpm range].'

Development

Nandan also says that his engine team is constantly working on improvements. A July joker saw the introduction of a revised, more durable, exhaust manifold after earlier cracking problems were identified. Then, for Rally Germany in August, another engine joker was spent on revised Bosch injectors with different spray patterns. This improved power, and the nature of the engine's curve.

Thus far the engine has powered Neuville to three WRC victories (in Corsica, Argentina and Poland) and at the time of writing the Belgian driver was second in the World Rally Championship, while Hyundai was also lying in second place in the teams' standings.

For Rally Spain in October a third engine joker is planned. At press time it's work in progress, but the intention is to improve combustion further, most specifically through changes to piston design.

Corridors of power

Hyundai's Alzenau-based in-house engine department comprises engine engineers and designers and, of course, engine builders.

Building a complete new engine requires about a week's work, but then post-event rebuilds can take around the same time. In addition to the dedicated engine build team, engine department staff at Alzenau remain on-site during tests and rally weekends constantly monitoring and analysing the performance of the power units. These people deal with any real-time issues arising, while also feeding back to colleagues on the event any improvements that may be of benefit to the team.

Sometimes there are just two weeks between WRC rallies, so post-event engine rebuilds must be both swift and methodical.

The process is a full strip-down, a check, and then all the consumables are replaced. Here, liaison between the team's parts manager and its purchasing department is crucial to ensuring that the correct engine parts are available at the right time to be fitted within the very tight time schedules the WRC demands.

Once complete, a just-built or rebuilt engine will go to the dynamometer for checking, then back to the engine workshop for a final pre-event check.


After each rally the engines are fully stripped down at Hyundai's Alzenau HQ

When the dust settles

How one man's terrifying experience changed the approach to safety on one of the toughest motorsport adventures of them all – the Baja 1000

By DON TAYLOR

Some accidents change a competitor's attitude to motorsport safety forever. Here's the incident in 2010 that did it for Roger Norman, then a Trophy Truck racer in the Baja 1000:

'I was running at 120mph and he [a motorcyclist] was going about 25mph. I was getting ready to pass two other Trophy Trucks. He thought it was clear because two trucks went by, and he didn't realise that there was a third truck that was going way faster than the first two. And I hit him … I only saw him for maybe a half second, not enough time do anything on a narrow dirt road … [I] knew he was dead.'

A sobering incident, but before we look at the implications, a little Baja background might be in order. In a world of ever-safer racecars and carefully architected circuits with generous run-off areas, The Baja 1000 is one of those crazy motorsport throwbacks, like say, the Isle of Man TT, that you sometimes can't quite believe still take place. It is a non-stop, all-out run down the Baja peninsula of Mexico, a thousand miles through the desert. It was started by a group of adventurous California enthusiasts and this November will mark the annual contest's 50th consecutive running (see box out).

Desert dust-up

Last year, 26 classes competed, with the participants aged from 16 to 79-years-old. That added up to more than 1100 drivers, co-drivers, and riders taking part, with some of them sharing driving stints, while others did it Iron Man style, without relief. The vehicles include a wide variety of trucks, buggies, ATVs, UTVs (Utility Terrain Vehicles), quads and motorcycles, broadly varying in size, weight, and speed.

With a low barrier to entry, people can take their old motorcycle or UTV and join in. There are some riders and drivers coming over with Dakar experience and many from other forms of racing give it a try as well. But compared to the Dakar Rally, this event is a non-stop, non-staged affair that runs through the night, over terrain that often requires plenty of suspension travel.

The route is changed from year to year, making every race different. There is a time limit, set at 36 hours in 2016. That year it took about 17 straight hours of non-stop driving to win.

For decades the Baja races have been sanctioned by SCORE-International (Southern California Off Road Events). The storied Baja 1000 is the Big Kahuna of the annual SCORE

Trucks mix it with bikes and quads on the Baja. This has led to fatalities in the past but now the race organiser has brought in new safety measures

Lights and sirens are often lost in the huge dust clouds and engine noise

series, which is bundled with a handful of other, shorter desert races, also in Mexico.

As Norman, who is now the owner of SCORE, says: 'Our races are unique and very dangerous. Every single race mile is different. We've had racecars go into the ocean, 27ft under water. We've had racecars go off 300ft cliffs.'

And it's had trucks hitting bikes, as we learnt in the opening to this piece. So what happened next? Well, the rider was not dead after all, to Norman's immense relief and surprise. Norman was able to get him evacuated by helicopter and then to hospital. The rider did fully recover, a major achievement for the man, considering he endured the mending of 28 broken bones and underwent some 30 surgeries.

But while Norman was physically unharmed in the incident, it certainly had an impact. 'The accident with the sportsman motorcycle rider in the dust shook me to the core. I have been devastated and demoralised since Saturday's race,' he told fellow competitors at the time. 'I can tell you that until you run someone over, while in the dust of another Trophy Truck, at over 100mph, you will simply not understand the devastating feeling.

'The next guy will not be so lucky, and I want to avoid any of you from having this pain and fear I have felt,' Norman added. 'The incident could have happened to any one of us, and unless *we* do something to force the issue, then nothing will be done.'

Loving the sport as much as he does, Norman continued to race in the Baja for several years, but was now consumed with the goal of improving its safety, while he and the downed rider, Tim Nugent, became best friends, with a shared purpose. 'He and I tried to change the sport, not to change the tradition of the sport, but to figure out a way to make it safer … And we were not successful,' Norman says.

Wealth and safety

They made a lot of noise, but little changed, as most participants liked the spirit and tradition of a wild-ass event of few rules and restrictions, a real test of man against the elements, in a country not known for road safety.

And then, with long-time SCORE owner/promoter Sal Fish retiring in 2013, SCORE, and the Baja 1000, was up for sale. Norman, a real estate development entrepreneur in everyday life, saw an opportunity. He saw an opening to grow the series, and perhaps more importantly,

‘We’ve had racecars go into the ocean and finish up 27ft under water. We’ve also had some cars go off 300ft cliffs’

finally be in the position to make it safer. ‘How do you fix it?’ Norman says. ‘You buy it, and then make the changes. I had to buy it to fix it.

‘We have a lot of challenges when it comes to safety, and making changes without changing the tradition of the sport, and not ruining what made it great,’ Norman adds.

With the takeover completed in December 2013, in addition to all the challenges of transforming himself from racer into series owner, operator, promoter, and sanctioning body head, the question then became: where do we start on improving safety?

For an engineer, the first response may be to take a mechanical approach, engineering a solution to a problem such as developing the Halo for open cockpit cars, a stronger chassis structure, better energy absorbing zones and materials, or adding protection from penetration, all aided by data gathered from crash recorders and test sleds.

Motorsport’s safety improvements in recent decades have been driver protection centric, physically protecting the driver within a safety capsule, reducing extreme forces from reaching the driver, though while also protecting the spectators with walls and fences. But in off-road racing the safety challenges are different.

Desert dangers

Generally, today’s caged, four-wheel, desert racing vehicles are relatively safe as they are, at least for the drivers. Their rollover protection, seats, and belts have evolved to be very protective. Appropriate driver safety gear is mandated, including a frontal head restraint. In fact, Norman tells us: ‘There have only ever been three deaths in roll-caged vehicles in the Baja, over these last 49 years.’

But motorcycles and quads cannot incorporate the same driver protection, and he admits: ‘A lot of the deaths come from motorcycles, spectators, and chase trucks.’

So attention was given first to those three groups. In those areas, realistically, few of the safety problems could be solved by mechanical/hardware means. But rather, SCORE’s approach was through assessing the overall situation, and with the use of electronics, social media, plus the old standby of common sense, new sporting rules, and penalties.

For example, in addressing the problem of motorcycles being overtaken by faster, four-wheeled vehicles, stricter rules were the first action taken. It became mandatory that motorcycles had to let faster vehicles pass, under threat of a penalty.

‘If any of the motorcycle racers caused a problem, with not moving out of the way, that would be a disqualification,’ Norman says. ‘When I was racing, I would come up on motorcycles, and I would literally be one foot off of their rear tyre at 90mph for 20 miles … and this would be near the finish line in La Paz, after I’ve been driving for 19 hours, without getting out of the car, and I’m not at my sharpest, and neither is he. But now we have a reason for him to get out of the way, because all I have to do now, if I was racing, is get his number, and he’s done.’ Meaning the rider is disqualified.

Dust to dust

This year SCORE has also adopted an electronic technology solution, with the use of the Stella III, which is a GPS tracker, as well as a vehicle-to-vehicle signalling device. This is a product developed for off-road and rally racing by Anube Sport America. It radically reduces the unknowns in the passing of motorcycles, but also for passing any other slower competitor, as every vehicle racing, large or small, fast or slow, must be so equipped.

Basically, Stella III is a dash-mounted box with lights and buttons that has the ability to send basic messages between vehicles, be used for tracking and scoring, and, if necessary, it can send an SOS to race control.

Norman says: ‘There’s a blue button that allows you to warn the person ahead of you that you’re passing, and if they, say, are on a motorcycle then they have to get out of the way. So if they hit their blue button, basically they’re saying they’re clear, they’re off the course, go! It’s just the cars in your class that don’t want to

It takes at least 17 hours or so to complete the Baja so some night driving is inevitable – which explains all those spotlights

It can be difficult to see other, sometimes vulnerable, competitors such as bikers in the dust that’s thrown up during the Baja

get out of the way. You just have to prove you're actually fast enough to get by them.'

In that case the traditional 'I want to pass you' signal, which is to give a stiff love tap to the other car's rear bumper, can be used. This is actually often necessary as lights and sirens, which are also used as alerts, are lost in the huge dust clouds and the engine noise.

The Stella 3 can also tell approaching racers if there's another vehicle stopped up ahead, or if they are about to enter a limited-speed zone, so they can prepare to slow down.

As for chase vehicle safety, new guidelines are also in place regarding driver and crew behaviour, with the possible consequence of team disqualification if they're not followed.

But it's not just vulnerable competitors and support crews that need protection, there are the Baja spectators to think about, too. Providing spectator safety is critical in all types of racing, and the responsibility lies with everyone involved in conducting the event.

What makes this a little challenging on the Baja is that the spectators have been known to get a little actively engaged, and while in Formula E fans might vote for a favourite driver to get more power-to-pass, Baja racing fans are much more hands on. Literally.

'There's a blue button that allows you to warn the person ahead of you that you are passing'

The spectators are in a safe area here as they watch a Trophy Truck fly, but that's not always the case over a 1000 mile course

When then truck racer Roger Norman (left) hit motorcyclist Tim Nugent (right) in 2010 his attitude to safety on the Baja changed

Norman says: 'Our spectators are interactive. It's not like at other sporting events, where the spectators are just sitting there in seats watching, our spectators like to get involved, and help make jumps to make the racing more exciting, or dig ditches, or pull some old junk car out on to the course. You have to deal with booby traps. Crazy things like that have happened.' You can also add to that the chance of encountering a large farm animal.

Matador madness

With 1000 miles of track you can't provide a continuous barrier, of course. At the Baja start and finish line areas, spectator fences are erected. But elsewhere spectators can stand at the edge of the course or even right on it, playing a game of chicken, messing with the drivers and riders. Much like The Running of the Bulls in Pamplona, the goal is to move out of the way at the last instant, while touching the speeding beast as it goes by. Except in this case the bull is a 7000lb race truck.

Besides digging holes, and placing obstacles on the course, fans can also become engaged by moving the directional signs along the course, trying to lead drivers astray (though this is much less effective in these days of GPS).

What has SCORE done to discourage these dangerous shenanigans? As mentioned, walls are out, and you can't post marshals every hundred metres. But one tool SCORE uses comes from the soft sciences, and that is using social media for education and for peer pressure.

'We do a lot of things on social media, like videos where our racers are talking about safety and asking the fans to stay off the course,' Norman says. 'It's helped a lot.'

He adds: 'We've created a group called *Afficiano Responsible.* It has about 12,000 members all throughout Baja.' The campaign is basically "Don't do something stupid", reinforced by the serious fans of the sport. 'They post the dumb things that happen at each race and make fun of the idiots who are doing these stupid things,' Norman says. 'So it's made it very unpopular to be an idiot in Baja, and that's done an awful lot, just by people seeing this, and by promoting that these people are not cool. It's not cool to do that kind of stuff.

'Of course, what happens, happens in the middle of nowhere, and no one has control of people out there. But fortunately more people are taking it on themselves to be much more respectful of the racecars.'

The Baja region does appreciate having the race, with the business and exposure it brings, though, and that helps. 'We're getting a lot more help from the military, and the police, federal, state and local agencies down there. We have about 20 meetings now, per race, regarding safety,' Norman says.

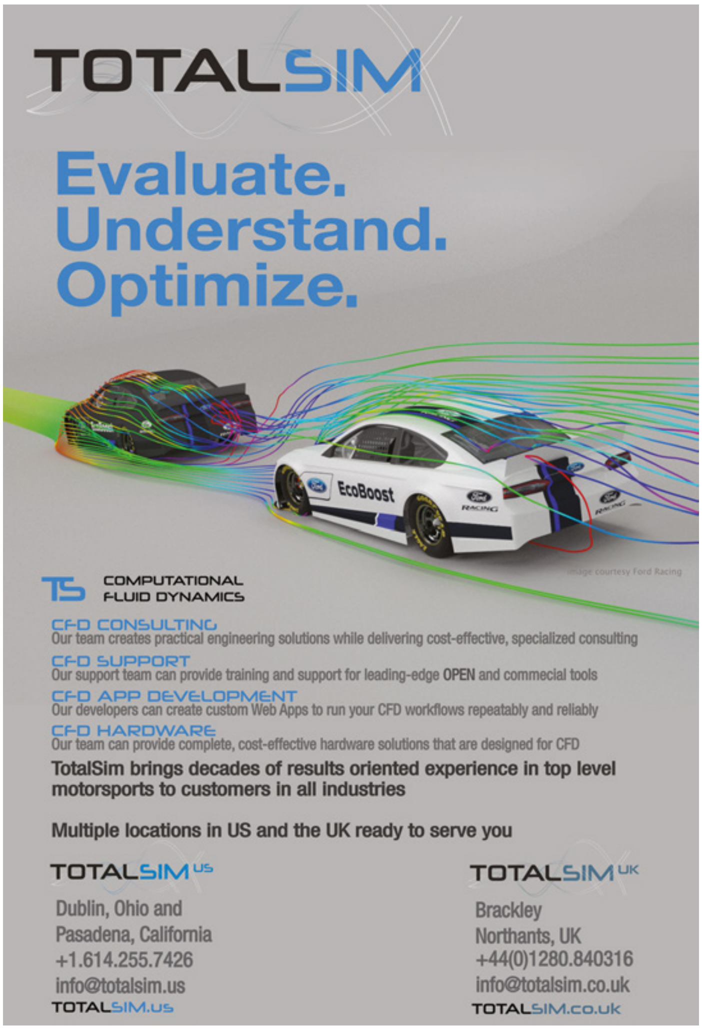
To help control spectators, unlike in the past, there are also now enforceable laws against interfering with the race course and vehicles.

Emergency cover

Improving medical resources and responses has also been a high priority for Norman. 'We want to provide medical, life, and unlimited para-medivac service,' he says. 'When we started this, we found out that every ambulance had less-than-basic life support. When I was a racer, I thought, that's great, they've got an ambulance there. Then when I took over, I found out that the guy who was getting the money for it, was just taking the money, and they didn't have anything to save a life, not even a Band-Aid.' As soon as he took charge Norman made it a priority to upgrade all of the ambulances to provide life support capability.

Emergency response is now centred around Cruz Roja, the Mexican version of the Red Cross, and its volunteers, who also cover the public roads. Each unit on average responds to two head-on collisions per month, keeping them on top of their game. Many of the Cruz Roja units had no Jaws-of-Life rescue tools, so

Baja race trucks pack sturdy cages. There have been just three fatalities in caged vehicles over past 49 years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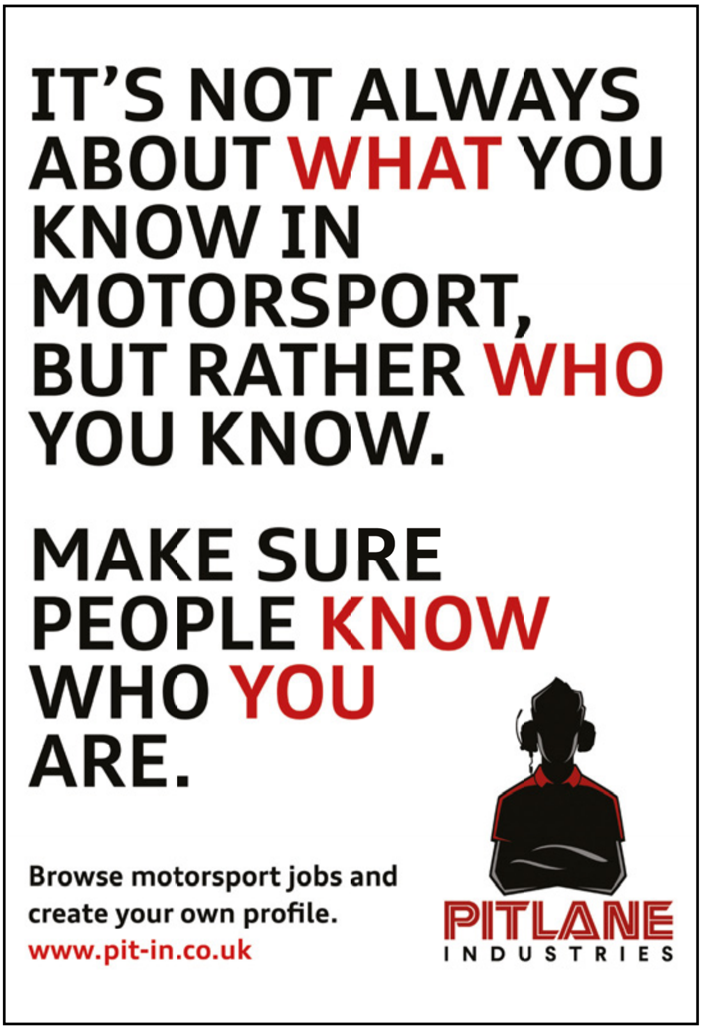
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SCORE bought them dozens. 'The nice thing is anything we buy them saves lives throughout all the year. It's not like we're just buying it just for our organisation,' says Norman.

Norman's personal paramedic from when he was racing, plus many other volunteers, also come down from the US to assist Cruz Roja in training workers before events.

'We have a rescue helicopter, we have a rescue airplane, and we have about 23 ambulances. But it can be an hour for someone to get to you, especially at night, because nobody's allowed to fly at night, by law.'

To help themselves after an incident – before other assistance arrives – all teams are required to carry emergency signalling devices, survival supplies, and a first aid kit aboard their vehicle. But the first one on the scene is most often another competitor and one of the many things that Norman has implemented is a Good Samaritan rule. When other teams stop and render service to downed riders or crashed trucks there is no penalty for lost time. There is an adjustment made to their total elapsed time.

Much like The Running of the Bulls in Pamplona, the goal is to move out of the way at the last instant

Roadside assistance

That provides an incentive for racers to stop, and with the Stella III system, Race Control knows pretty quickly who had the problem, who stopped to assist, and for how long. 'We know within five to ten minutes what we are crediting those people. That allows teams to not worry about stopping, because it's a timed event. Every race we have one or two cars stop to help somebody. All we then have to do is verify that the accident really happened, and that they were really stopping to help, not to work on their car. We haven't had a problem with that yet, but we do watch for it just in case.'

With such devices, SCORE Race Central can simultaneously track the location of all vehicles on the course, whether moving or still, and whether they need medical assistance.

It should also be noted here that as well as the previously mentioned Stella 3 signalling device, riders and drivers are encouraged to also be equipped with a SPOT Personal Tracker device. Used by outdoor adventurers and workers, it is a GPS tracker, plus an emergency-signal sender. It can also send pre-recorded messages to friends and family.

To reinforce SCORE's safety message to competitors, in July, Norman, acting in partnership with the Stand 21 Safety Foundation, presented a "Second Annual SCORE Safety Conference". It brought in such motorsport safety experts as Dr Steven Olvey, veteran IndyCar medical adviser, who talked about concussions, explaining how the teams could do a quick field assessment, and what to do next if concussion is suspected.

Final SCORE

After four and a half years of hard work to improve his sport's safety, Norman now says: 'Everything looks easy on the outside, and then once you get in then you realise how much harder it is, and what a difficult job it was, and why they didn't make changes. Because change is always hard, and sometimes it's not accepted, even though everyone knows it's going to save lives. Everyone has the expectation that it's dangerous, and should never change.'

Yet he believes that it's a challenge that's been met. 'We've been able to make some changes to improve safety without changing the tradition. That's what it's all about.'

This year's event is the 50th running of the race, and there will be a great deal of attention on it. With all of the exposure, it is critical that this event is run as safely as possible. When the Mariachi bands play on, and government officials smile, as those 400 to 500 vehicles leave the starting line, with all the sound and fury of a *Mad Max* movie, on the golden anniversary of the original running, all that Roger Norman and his team have done to improve safety on the Baja 1000 will be put to the test.

The Cruz Roja has benefited from its involvement in the Baja race, with SCORE donating much-needed life-saving equipment

Just deserts

This year's 50th running of the world's oldest, longest and continuously held desert race, will get more attention and up-close coverage than ever.

On top of this a new movie about the race has been made by noted Hollywood director Dana Brown. He returns to the desert with *Dust2Glory*, a documentary film project as a follow-up to his original 2005 *Dust to Glory* film.

Qualifying for the Trophy Trucks takes place on October 31, 2017, at the Las Vegas Motor Speedway, during the annual SEMA Show in Las Vegas, which attracts over 150,000 attendees. The race itself starts in Ensenada BC, Mexico on November 16, 2017, and concludes in La Paz BCS, Mexico with awards presented on November 18, 2017.

This year sees the 50th running of the Baja 1000. Race organiser SCORE also runs similar events such as the Baja 500 (pictured)


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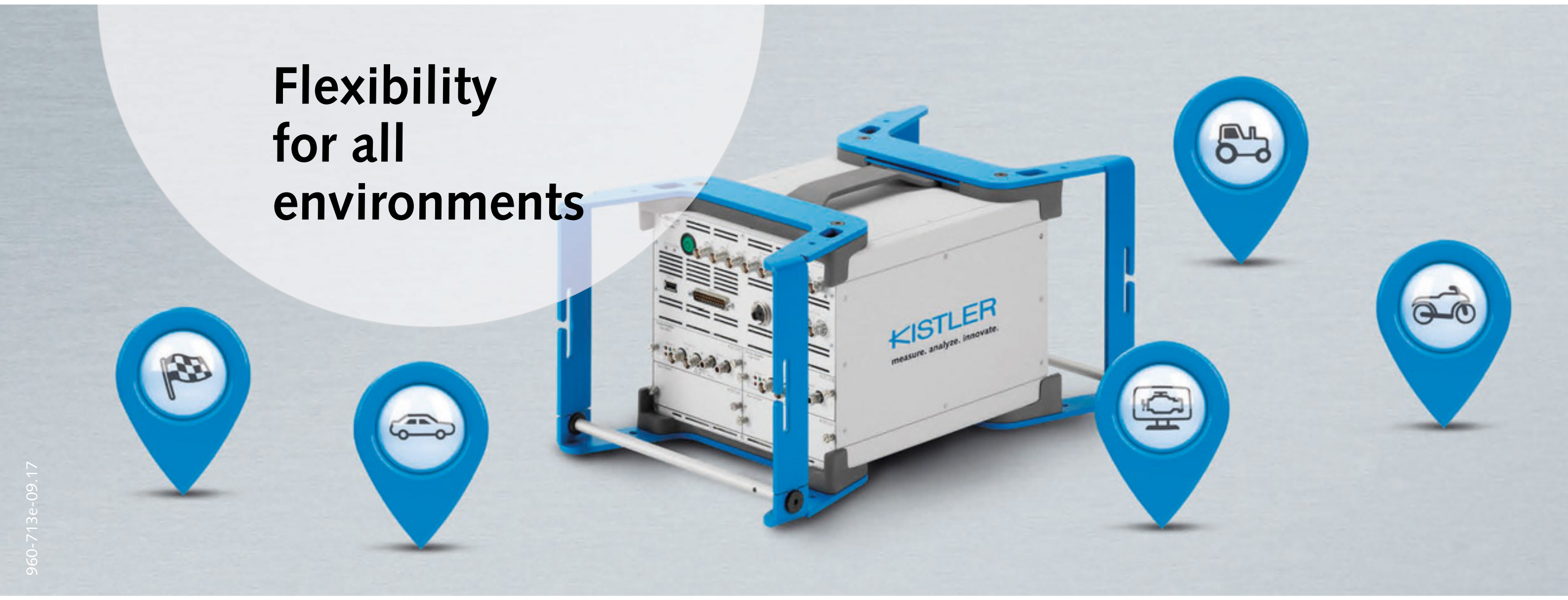
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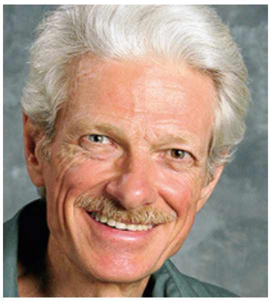


Torque wedge and links on an Aussie V8

Optimising the suspension for a big-power V8 Supercar

QUESTION

We run a car here in Australia based on an earlier generation V8 Supercar chassis, with equal length four-link and a watts linkage. Usual set-up is parallel arm geometry, with a slight amount of nose-down which gives a small amount of pro squat. The car has approximately 640lb/ft at the flywheel, and runs a 330mm wide rear tyre.

I have a question in three parts for you. A: We race against some TransAm racecars which almost all run a three-link, with quite long lower arms. What are the relative advantages of four- versus three-link in this tarmac racing application?

B: The second part of the question is about minimising torque wedge. We have been experimenting with running a stiffer rear anti-roll bar with a lower roll centre, based on what I read in one of your previous articles. Obviously there is a finite limit for rear roll centre as the rocker will hit the ground. Is there a point where lowering the roll centre and running a stiffer rear anti-roll bar will start to impact corner exit, even though the roll stiffness remains the same, more or less?

C: My final question is; is a three-link better than a four-link for minimising torque wedge? And what, if anything, can we do with arm angles that may help with this?

THE CONSULTANT

The main advantage of the three-link over the four-link is that we can have some anti-squat without having the suspension bind in roll or creating roll oversteer.

The disadvantage of using more elastic roll resistance and a lower roll centre is that there is more wheel load change over one-wheel bumps. However, there is also less lateral displacement of the contact patches with respect to the frame over one-wheel bumps. This matters more when the tyres have a lot of lateral stiffness.

As for effect on inside wheel loading when exiting turns – or any other time – the total load transfer (excluding the unsprung component) is always the total roll resisting moment divided by the track width, regardless of what portion of the moment comes from geometry and what part comes from the springs, bars, and dampers. It also doesn't matter what portion comes from what kind of spring (an anti-roll bar being a type of spring).

A basic three-link can completely or partially cancel torque roll and torque wedge. This involves either offsetting the top link to the right or angling the top link in top view so that the front of the link points to the right. If the top link is on centre and is not angled in top view, the three-link does not reduce torque wedge.

Creative torque

What we are doing with the offset or top-view-angled link is creating a leftward roll moment in the suspension under power, using axle torque. This counters the rightward moment resulting from driveshaft torque.

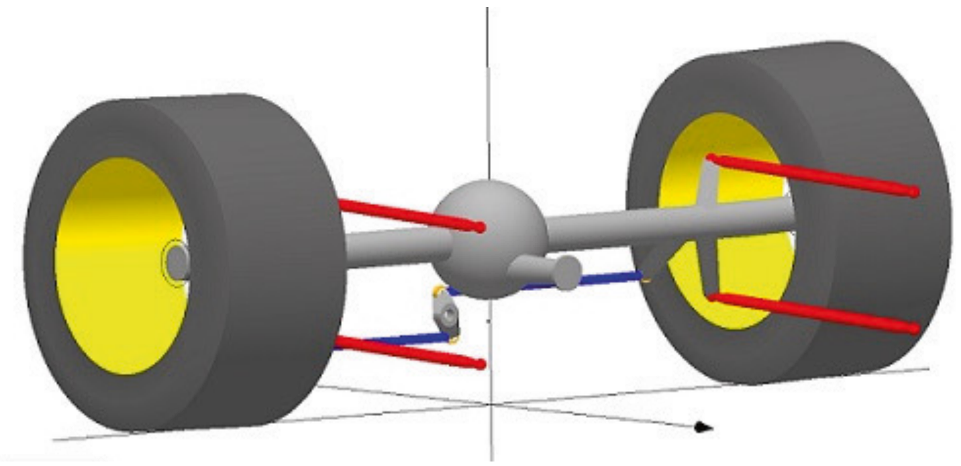
The usual problem with fully or partially cancelling torque wedge that way is that we also create a rightward roll moment in braking, when there is no driveshaft torque that we need to cancel. The geometry then needs to be a compromise, in which we accept some roll and wedge in braking in return for partial cancellation of roll and wedge under power.

The way out of this, rules permitting, is to make braking torque react differently through the linkage than propulsion torque. This usually involves mounting one or both brake calipers on birdcages or brake floaters.

A birdcage is a bracket that can rotate on the axle tube, carrying two longitudinal links. A brake floater is the same thing with just one link. There are also some other possibilities involving push bars or pull bars: links that only work in one direction. In some cases these solutions may be legal when birdcages and brake floaters are prohibited.

Lower roll centres

If torque wedge can be entirely cancelled, the need to maximise rear elastic roll resistance goes away. There is no longer any need to get the rear roll centre extremely low. However, if desired, there are ways to get the roll centre a bit lower than is possible with the layout shown below, while still using a Watt linkage. It is possible to turn the rocker ninety degrees and lay it flat. This is common in TransAm cars. Usually, the rocker is mounted horizontally to the underside of the diff. Structural constraints permitting, there is a case for mounting it to the frame instead, as in the layout below. That makes the rear roll centre rise and fall with the sprung mass, which is similar to the behaviour of an independent front suspension. It is necessary when using a horizontal rocker to make sure not to run the rod ends out of travel.



Structural constraints permitting there is a case for mounting the rocker to the frame as in the layout shown here. This makes the rear roll centre rise and fall with the sprung mass, similar in behaviour to an independent front suspension

A three-link can completely or partially cancel torque roll and torque wedge

Springs, bars and caster jacking

The pros and cons of installing an anti-roll bar system

QUESTION

I have a small formula car. It started life as an F-440. I started rebuilding it a few years ago. It had rubber shock absorber type units for suspension. I removed those and fabricated in coilovers. The car has a solid rear axle, no differential. I run 10 degrees positive caster; lots of positive caster helps transfer the weight such that on cornering the inside rear tyre is unloaded, allowing it to slip more easily as it needs to travel a shorter distance than the outside rear tyre. My question is, would installing an anti-roll system front and rear be counter-productive?

If not, how much would you run in such a set-up – same as if the car had a differential, or some percentage less than that?

When a racecar has a lot of downforce and under-car aero is sensitive to ground clearance stiffer springs can be fitted, and then ARBs are used for fine-tuning

THE CONSULTANT

If the objective is to maximise the de-wedging effect from caster jacking, anything that makes the suspension stiffer in warp will help. Warp is roll or oppositional displacement in opposite directions at the front and rear. With conventional springs and anti-roll bars, anything that adds elastic roll resistance makes the system stiffer in warp. With more innovative systems that connect front and rear wheels, this does not necessarily hold true.

What part of the roll resistance should come from the bars and what part from the springs? For a road car or a racecar with little downforce, as much as half can be from the bars, or maybe even a bit more. This allows the car to ride many types of road irregularities better than with stiff springs, while providing the necessary roll resistance. When the racecar has a lot of downforce, and particularly when the under-car aero is very sensitive to ground clearance and pitch angle, it then becomes necessary to use stiffer springs. The bars then become more of a fine tuning tool.

There is also some advantage to running stiff springs in a racecar without significant downforce: the car can run with lower ride height, when it is limited by scraping the ground in dips. This will come at the cost of increased wheel load changes over bumps, so the setting will be a compromise.

This is less true for a car that has to run on the street. There, ground clearance requirements are primarily determined by the need to clear obstacles at low speed. Assuming we are not limited by available suspension travel or fender clearance, that situation favours soft springs and stiff bars.

Bar work

On racecars, and sometimes on street cars, we can adjust the anti-roll bars, either by adjusting arm length or something else in the linkage, or with a rotating blade. When the bars are stiff relative to the springs, the car becomes more sensitive to these adjustments. This is usually not a problem – just something to be aware of. In some cases it can be a problem. If the bars are very soft, it may be necessary to change bars to get a sufficient change in car behaviour. If the bars are stiff and adjustment can only be made by coarse increments, we may find we'd really like a setting between two available ones. But such situations are fairly rare.

Caster jacking is affected not only by caster angle but also by front-view steering offset or scrub radius. It is fairly common on karts to adjust caster jacking via spacers on the front spindles. This is particularly useful on a vehicle with no suspension, but it works with suspension too.

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, don't hesitate to get in touch.
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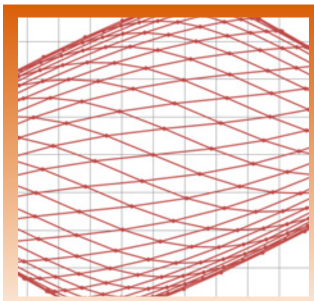

Slip Angle provides a summary of OptimumG's seminars

The four secrets for chassis happiness

Claude Rouelle explores the possibilities of qualifying and quantifying a racecar design or set-up through grip, balance, control and stability

In the racing industry, I often find engineers that perform simulations in the same way barmen create cocktails: by (sometimes randomly) mixing ingredients and varying quantities until they eventually find something that matches their taste. From weight distribution to springs and aerodynamic balance, everything is changed to, after numerous consecutive approximations, find the best possible outputs, the most important one being the lap time.

The barman approach has two main problems. First, simply varying inputs and observing the changes in outputs without understanding the real reason behind those changes can be very time consuming, since it involves lots of trial and error. There must be other methods that allow us to walk less in the dark. Second, an engineer may spend hours and hours to find a set-up that works perfectly in his computer, only to be told later by the driver that the car is undriveable. A set-up that exploits 75 per cent of the car performance can be, on the track, quicker than a set-up that exploits the performance at 95 per cent. We need a set of criteria to link the perspectives of the driver and the engineer. That is why the concepts of grip, balance, control, and stability are useful. To define these concepts, we need to look at the yaw moment diagram.

The metrics

Figure 1 shows a typical constant-speed yaw moment diagram. As explained in previous articles in this series, the yaw moment diagram is a representation of all the possible states of the vehicle during a corner at a given speed. Even though we simulate all the combinations of steering wheel angle (δ) and chassis slip angle (β) within a range, most of the time we are interested in only a few points of the diagram. Point 2, for example, represents the maximum lateral acceleration of the car while having zero yaw moment. It corresponds to a situation where the vehicle is at the apex of a corner. The overall maximum acceleration that the car can reach at a given speed is represented by Point 3. Notice that, at this point, the vehicle has a positive resultant yaw moment. In other words, when the vehicle is at the limit of its performance, the tyre forces and moments result in too much yaw moment. As mentioned in previous articles, this is what we defined as an oversteer behaviour. We give the name of grip and balance to, respectively, the lateral acceleration and the yaw moment of Point 3. The grip is a rather obvious performance metric of the car; as you maximise the lateral grip of your car, it can drive faster in corners. The balance is a good indicator of how oversteer or understeer will exhibit at the limit of the car's lateral performance: the more positive the value is, the more oversteer the vehicle will have; the more negative the value is, the more understeer the car will have.

Take a look now at Point 1 of **Figure 1.** This point is the intersection of the isolines of zero steering wheel angle and zero chassis slip angle. It represents the car going in a straight line, where both lateral

There must be other methods that allow us to walk less in the dark

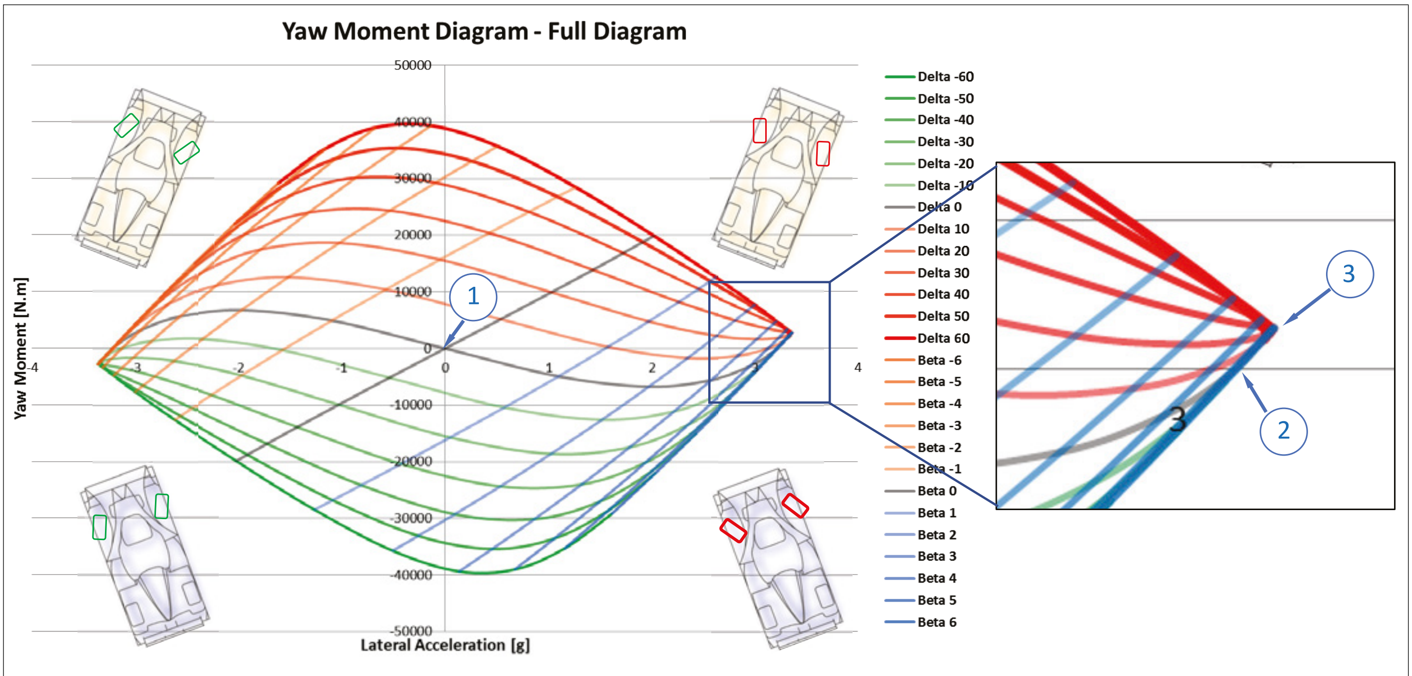

Figure 1: Yaw moment diagram at constant speed with CG slip angle (ß) and steering (ō) isolines. We are usually interested in only a few points on the diagram

acceleration and yaw moment are zero (if the car is symmetric, of course). When the driver turns the steering wheel to enter a corner, he creates slip angles in the front tyres, which will generate lateral forces and aligning moments. These forces and moments will then result in a yaw moment in the car, which will be different than zero. This is where the definition of vehicle control comes from; it is the change in resultant yaw moment as you vary the steering wheel angle by one degree. The control can be calculated in the yaw moment diagram as illustrated in **Figure 2a**. By following a line of constant chassis slip angle (in this case, β = 0), we can calculate the variation of yaw moment as we travel between the lines of steering wheel angle δ = 0 and δ = 1. Here resultant control is equal to 24.7N/deg.

Degrees of stability

The concept of stability is derived in an analogous way. We start off again with the vehicle going in a straight line (Point 1 of **Figure 1**), then we give it an increase in one degree of chassis slip angle (β). This increase come from a disturbance such as a bump on the track, a gust of wind or, worse, another car hitting it. Wherever the disturbance comes from, we always want the vehicle to go back to its trajectory instead of spinning. In other words, the tyres must generate forces and moments which will result in a negative yaw moment, and rotate the car back to its original slip angle. The stability is defined as the change in yaw moment as you vary the chassis slip angle by one degree. Therefore, it represents the capability of the vehicle to return to its trajectory after a disturbance in its orientation. In the yaw moment diagram, this situation is represented by **Figure 2b.** The stability is calculated as the variation of yaw moment as between two lines of constant chassis slip angle (β) as you go along a line of constant steering wheel angle (in this case, δ = 0). In the given example, the stability is equal to -3156Nm/deg. The vehicle is more stable when the stability value is lower (i.e. more negative).

It is important to mention that the notions of control and stability can be applied not only to the

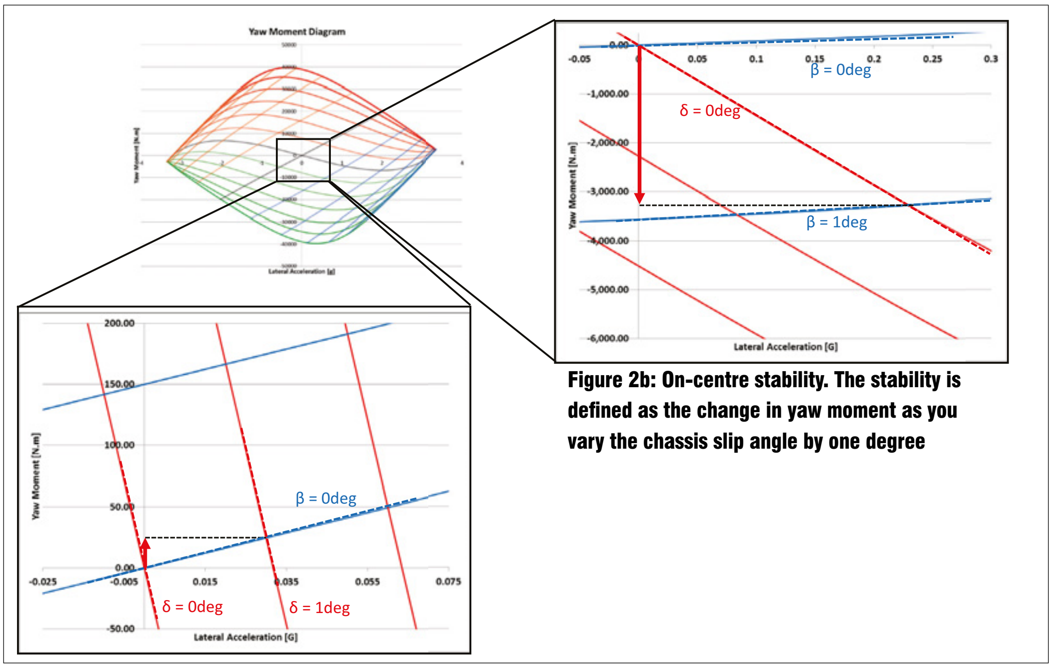

Figure 2b: On-centre stability. The stability is defined as the change in yaw moment as you vary the chassis slip angle by one degree

Figure 2a: On-centre control. Control is the change in resultant yaw moment as you vary steering angle by one degree

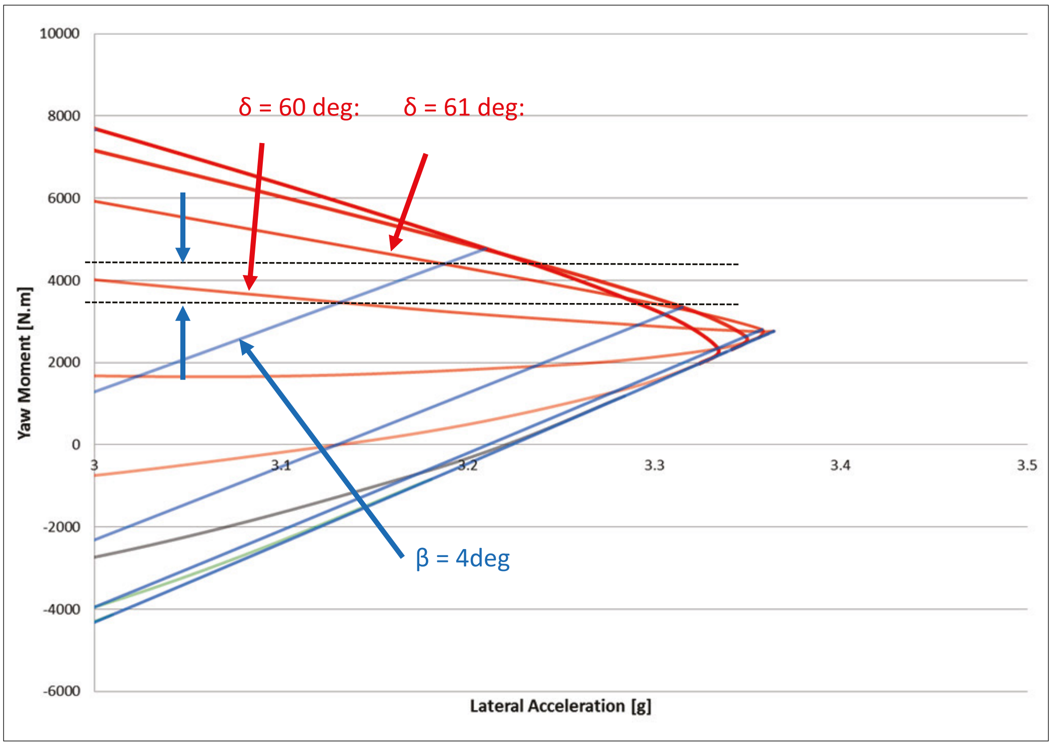

Figure 3: Control and stability can be applied at any point of the yaw moment diagram. This shows 400Nm of yaw moment variation at four degrees of CG slip angle (β) with a steering angle variation (б) from 60 to 61 degrees

centre, but to any point of the yaw moment diagram. **Figure 3**, for example, shows the calculation of control for a steering wheel angle of 60-degree and a chassis slip angle of four degrees, which can represent an instant when the vehicle is approaching the apex of the corner.

Once we have very clear notions of vehicle balance, grip, control, and stability, we can start associating these calculations to data and comments from the driver.

Driver input

During a free practice session, an engineer usually gets many comments from the driver about the vehicle and various parts of the track. The job of the engineer is to be able to gather all these comments (as well as vehicle data) and quickly make decisions about which parameters of the car will be changed. In the consulting projects that OptimumG performs at the racetrack, we always ask the race drivers to rate the performance of the vehicle, at each corner (or even at each section of each of the corners), in three criteria:

1. Control. How well, for a given amount of steering input, the

We ask drivers to rate the performance of the car at each corner

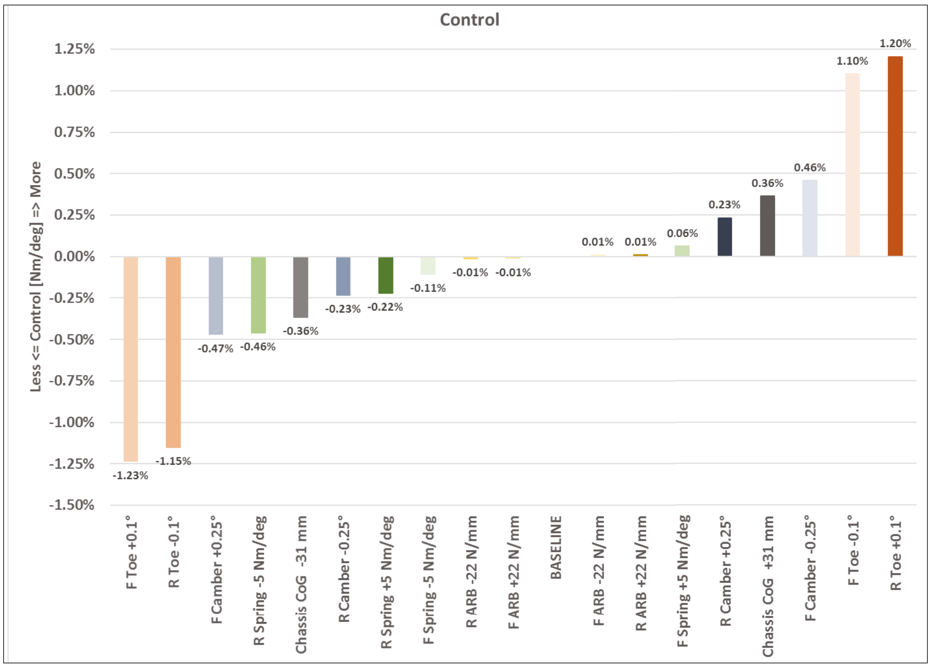

Figure 4: Accessing simulation data. This shows the effect of various set-up parameters on entry control

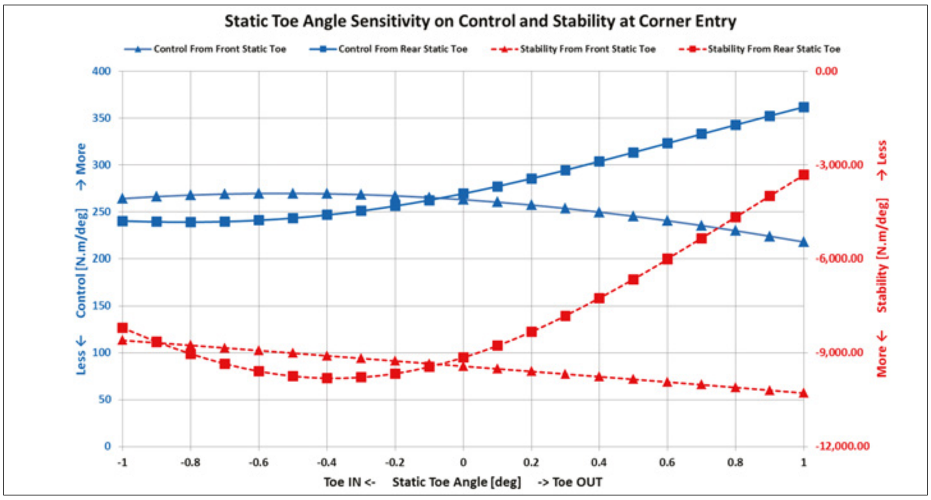

Figure 5: Varying parameters. The effect of front and rear toe control and stability on corner entry

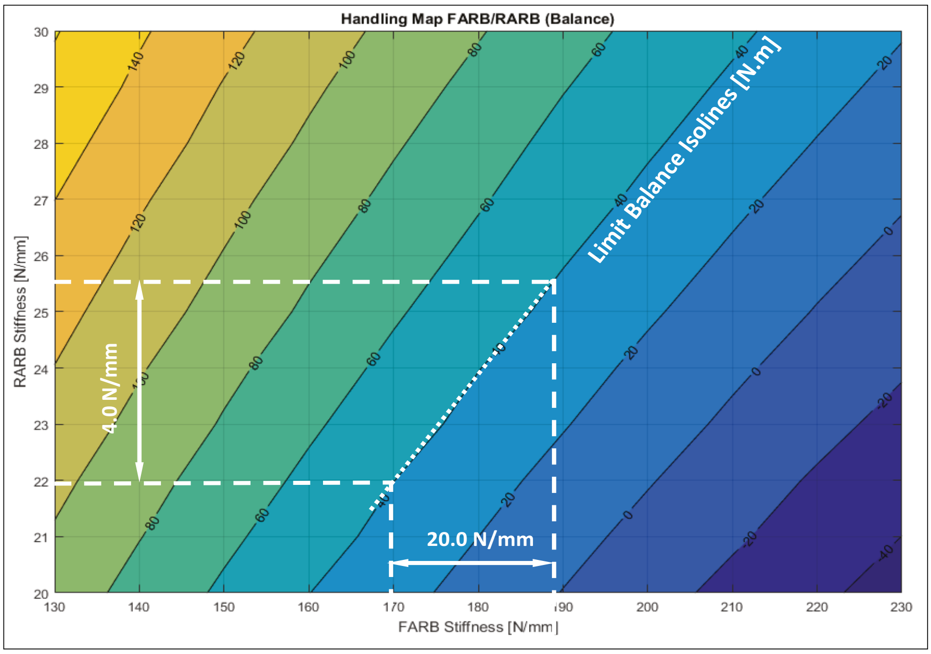

Figure 6: If the race engineer wants to change the front anti-roll bar (ARB) stiffness by 20N/mm while still keeping the same balance in the racecar, then a change of 4N/mm is required in the front ARB

racecar goes where you want it to go. This is rated from 0 to 10.

2. Stability: How well the vehicle is capable of staying in its trajectory during the corner. Rated from 0 to 10.
3. Balance: Does the vehicle understeer or does it oversteer? Rate it from -5 (understeer) to 5 (oversteer).

Organising the driver feedback according to this set of criteria helps the engineer to decide the changes he will make in the set-up. Of course, he must have done simulations prior to going to the race track.

Target values

Let's imagine a situation where the driver rates the car control as 4/10 and the engineer knows that, according to simulations, the current vehicle set-up has a control of 150Nm/deg. By accessing the history of previous testing sessions, the engineer finds out that the driver had given a rating of 9/10 for a set-up that had a control of 220Nm/deg, so he knows what his target value is. The question now is; which changes will he have to make to reach the target value? This is where simulation data becomes crucial.

Being able to access and visualise simulation data is as important as performing the simulation itself. A chart such as **Figure 4**, for example, can help the engineer not only decide which parameter to change, but also the amount of the change. Since much of the behaviour of the car is often very non-linear, it is also interesting to calculate metrics as you vary certain parameters within a range, as shown in **Figure 5**. If you want to observe the interaction between two parameters and one of the metrics, a chart like that shown in **Figure 6** can be very useful. It displays the value of balance as you very the stiffness of the front and rear anti-roll bars.

Useful tool

As I've been saying during this series of articles about the yaw moment diagram, this simulation method is not perfect for many reasons (for example, the fact that the calculation is steady-state based). In fact, with so many parameters involved, all simulation that you try won't be perfect. However, some of simulations can be useful, and I can say that the yaw moment *vs* lateral acceleration method is one of them. OptimumG's successful experience in many championships has proven it.

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Flaps, flouts and flups on a hillclimber

Our DJ Firestorm aero study concludes with some front wing tweaks

In this final instalment of our wind tunnel study on the latest variant of the DJ Firestorm UK hillclimb car, which uses the compact, lightweight 2.5-litre V6 Cosworth KF ex-DTM engine for nimble handling and a compact overall package, we focus on the front wing and efforts at gaining more aerodynamic efficiency. With a power deficit to the competition, efficiency was felt worthy of emphasis, along with the usual quest for a good aero balance.

Flaps up

The new Firestorm featured a not quite full span single front wing flap in baseline configuration, there being a narrow gap between the mounting plates under the nose. In a CFD study in our April 2014 (V24 N4) issue we saw that narrower span flaps (with a bigger central gap) lost front wing downforce but enabled more underbody downforce to be generated, thus achieving similar total downforce but with improved efficiency. However, balance shifted rearwards.

So, with this in mind, for our wind tunnel trial we decided to use a pair of slightly narrower flaps each side of the nose in the hope of improving downforce efficiency without a rearwards balance shift. **Table 1** illustrates how the data from this set-up compared with the baseline configuration.

Note that the data on the two narrow flaps arrangement followed an upper front flap adjustment to bring total downforce to a similar level to the baseline – by happy chance it created exactly the same total downforce. Drag was very similar, perhaps a tiny bit more, so efficiency was a little bit lower. What did change though was the balance, there being a 79 count gain at the front and a 78 count loss at the rear (1 count is a coefficient change of 0.001), resulting in a 4.2 per cent front increase.

So this was a rather different result to the CFD trial, in that to retain the same downforce level the balance shifted forwards, but efficiency did not improve.

However, as discussed in our previous instalments on the Firestorm, underbody downforce seemed to be suppressed by the combination of low dynamic ground clearance (the car visibly compressed its suspension as air speed increased) and the wind tunnel's stationary floor boundary layer. So perhaps out on track the two front flap arrangement would yield better downforce and efficiency.

In a further front wing CFD study in our March 2017 (V27 N3) issue we saw that directing more air outboard of the front wheels with devices attached to the front end plates could increase underbody downforce. So two devices were made for our wind tunnel trial to see what the effects would be. The first of these were 'flip outs' or 'flouts', curved vertical plates that were attached to the outer face of the front end plates that were intended to simply steer more air outboard of the front tyres. The changes (Δ or delta values) are shown in counts in **Table 2**. Although a drag reduction was achieved with the flouts, there was a clear (balanced) reduction in total downforce and also a reduction in efficiency.

Flip side

Moving swiftly on to the next trial then, two variants of front wing end plate flip ups, 'flups', were tried next, one was tapered, the other was a simple rectangle. **Table 3** shows the results.

These were rather more beneficial modifications, with modest drag reductions,

The flip ups proved to be rather more beneficial modifications

The DJ Firestorm was subjected to front wing tests in the MIRA full-scale wind tunnel

This two-flap arrangement was compared to the baseline single flap set-up on the car

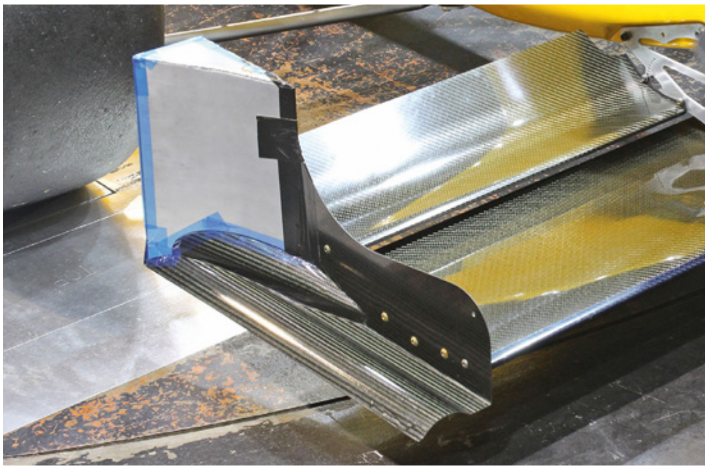
Table 1: Baseline data compared to the data with a pair of narrower front flaps each side fitted

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Baseline	0.775	1.892	0.547	1.345	28.9%	2.443
With two narrow front flaps	0.778	1.892	0.626	1.267	33.1%	2.433

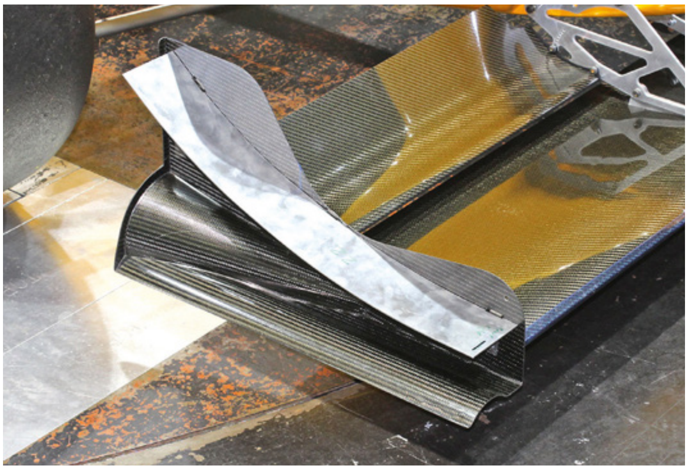
Table 2: The effects of 'flouts' on the front end plates compared to the baseline

	Δ CD	Δ -CL	Δ -CLfront	Δ -CLrear	Δ %front*	Δ -L/D
With flouts	-8	-37	-11	-26	nil	-24

*Absolute rather than relative difference in percentage front.



Flip outs (flouts), designed to steer more air outboard of the front tyres, were investigated

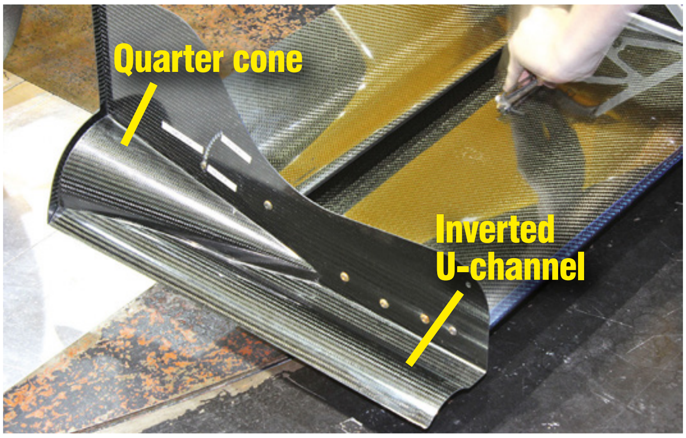


Two types of 'flups' were tried. The tapered variant was half-width at the leading edge

Table 3: The effects of 'flups' on the front end plates compared to the baseline

	Δ CD	Δ -CL	Δ -CLfront	Δ -CLrear	Δ %front*	Δ -L/D
With tapered flups	-6	-1	+37	-37	+2.0%	+18
With rectangular flups	-11	+4	+55	-52	+2.9%	+40

*Absolute rather than relative difference in percentage front.



VEEPs (vortex entraining end plates). This combination of designs worked very well

Table 4: The effects of VEEPs compared to flat end plates

	Δ CD	Δ -CL	Δ -CLfront	Δ -CLrear	Δ %front*	Δ -L/D
With VEEPs	+4	+297	+183	+112	+3.6%	+375
Change, %	+0.5%	+20.1%	+31.1%	+12.5%	-	+19.5%

*Absolute rather than relative difference in percentage front.

Table 5: The effects of quarter cones and inverted U-channels in the VEEPs

	Δ CD	Δ -CL	Δ -CLfront	Δ -CLrear	Δ %front*	Δ -L/D
¼ cones only exposed	-1	-3	-3	-1	-0.1%	-2
¼ cones and inverted U-channels exposed	+3	+32	+35	-4	+1.4%	+32

*Absolute rather than relative difference in percentage front.

It is abundantly clear that the VEEPs benefitted more than just the front wing

up to 10 per cent more front downforce, useful forwards balance shifts and up to 1.6 per cent improvement in efficiency (-L/D). It is noteworthy that the gains in front downforce (in counts) were almost exactly matched by the losses of rear downforce. It isn't possible to know exactly from where the benefits accrued in the wind tunnel, although simplistically the flups will have been acting like simple inverted wings and generating their own increments of downforce. However, in our CFD trials earlier in the year it was evident that the wing's own downforce was also increased by flups, as was that of the underbody.

VEEP treatment

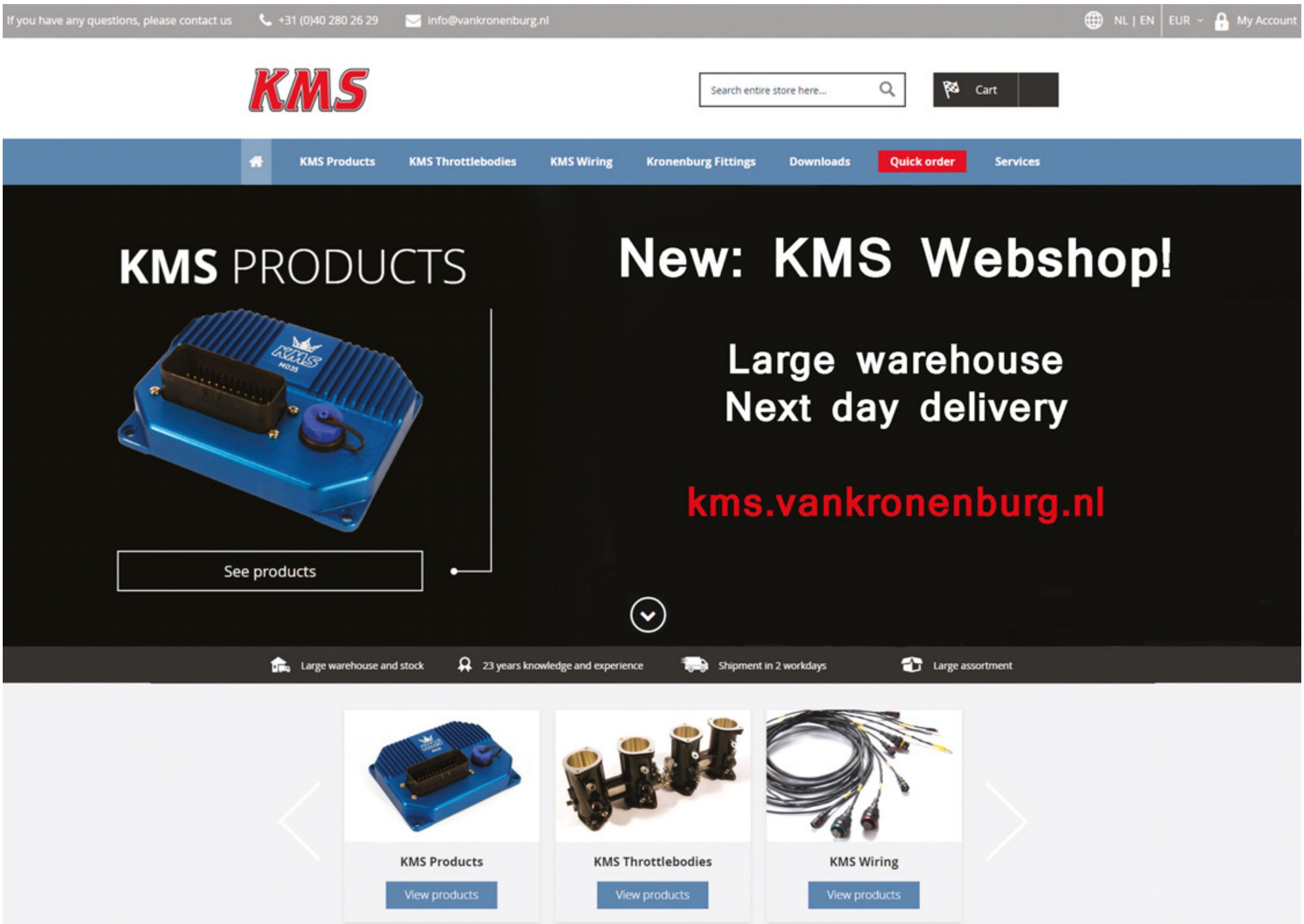
When we tested the original DJ Firestorm in the MIRA wind tunnel six years ago (issues V21 N3 to N5) we compared simple flat front end plates with so-called VEEPs or vortex entraining end plates. The VEEPs were 100mm wide each side, bringing the front wing assembly up to the maximum permitted 1500mm front wing width, and featured a longitudinal inverted U-shaped channel in the horizontal foot plate, and a quarter cone at the rear, lower corner. The results were pretty extraordinary, and are repeated in **Table 4** for reference. It is abundantly clear that the VEEPs benefitted more than just the front wing.

In our CFD-based feature in V27 N3 we saw that one effect of the quarter cone was to eradicate partial stall on the outer part of the flap and increase front wing downforce. The longitudinal inverted U-channel was not evaluated in that exercise. So could we isolate each of these features in turn in the wind tunnel and measure their effect? We first of all covered the quarter cones and the inverted U-channels to create a flat footplate; then in turn the quarter cones were uncovered and then both the inverted U-channels and the quarter cones were uncovered, with the results relative to the flat footplate shown in **Table 5**.

This was a surprising result in that exposing the quarter cones alone appeared to have a small negative effect. However, exposing the combination of the quarter cones with inverted U-channels had a beneficial effect, with seven per cent more front downforce, a useful forwards balance shift and 1.3 per cent better efficiency. Perhaps one difference between our wind tunnel trial and our earlier CFD trial was that the flap angle tested in the wind tunnel was not steep enough for outer flap stall to occur, and hence the quarter cones brought no advantage. Further investigation is warranted.

Racecar's thanks goes to Richard and Alex Summers and the DJ Engineering crew.

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



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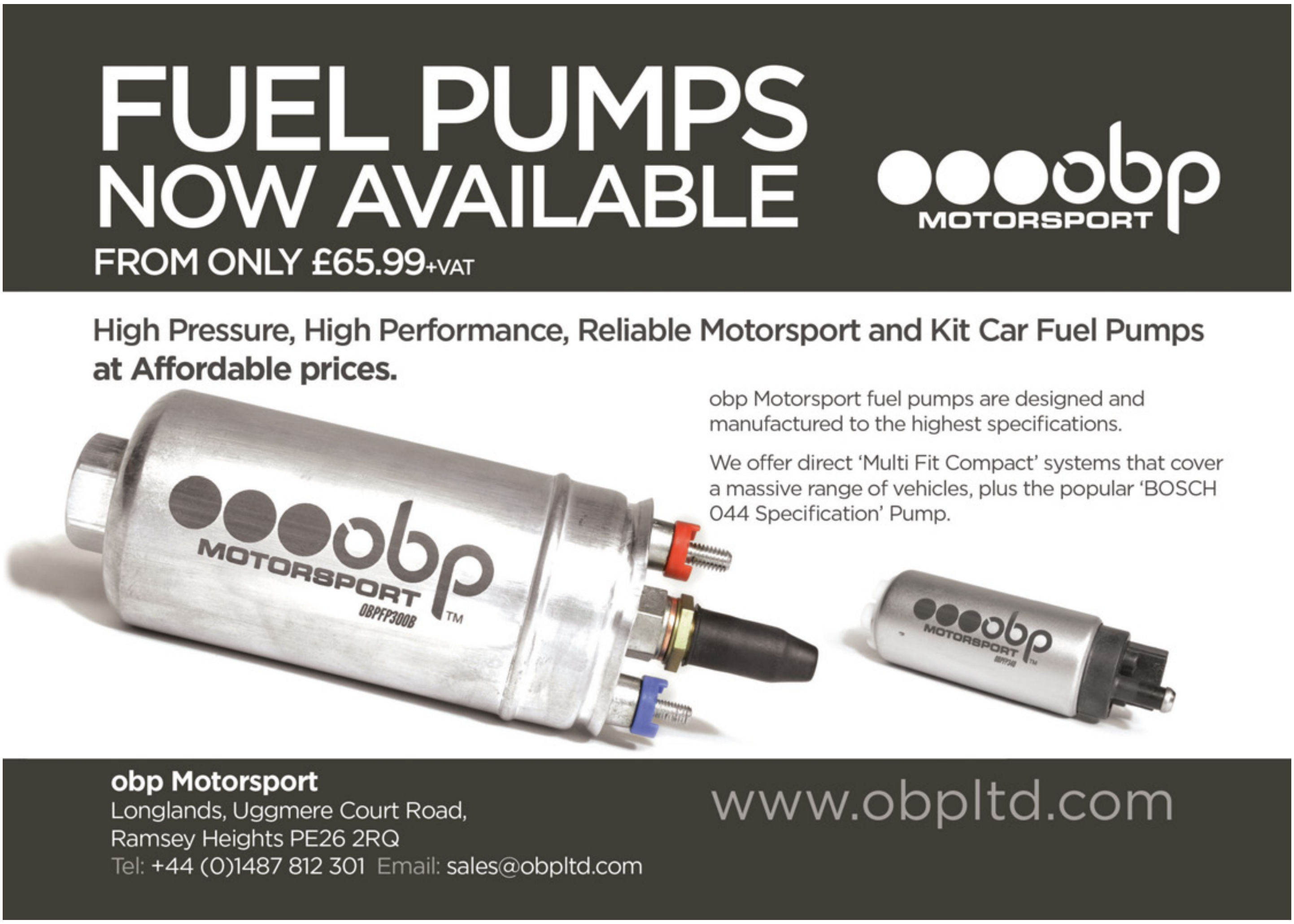

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Disc world

The demands placed on motorsport brakes and braking systems have never been greater, but thankfully the development of retardation technology is – ironically enough – unstoppable. *Racecar* investigates

By GEMMA HATTON

Brake-by-wire was introduced in F1 together with the revolution of the 1.6-litre V6 turbo powertrains back in 2014. These dramatic rule changes allowed a maximum of 2MJ of energy per lap to be recovered through the rear brakes and so the engine manufacturers developed their own MGU-K (Motor Generator Units – Kinetic). These systems can transfer a maximum of 4MJ per lap from the energy store back to the drivetrain during acceleration, which equates to approximately 160bhp for 33 seconds each lap.

To achieve this, the braking system has two hydraulic circuits, with a separate master cylinder for the front brakes, and another for the rear. The front brakes operate conventionally; where the driver pushes the pedal with a force of 160kg, applying pressure to the fluid in the master cylinder. This fluid is used to actuate the six pistons within the caliper which clamps the brake pads to the carbon disc with around five tonnes of pressure; reducing the speed of the wheels through friction.

The rear brakes, though, have an additional master cylinder which is electronically controlled. Therefore, during braking, the fluid is moved through the rear master cylinder as normal, but the MGU-K then determines the amount of pressure applied to the rear calipers. In this way, the energy from the rear brakes is recovered, but once the 2MJ limit has been reached, the rear brakes operate conventionally.

Point brake

The biggest challenge with this system, is tuning all the various brake maps so that the driver gets consistent feedback of retardation versus pressure regardless of whether the rear brakes are being controlled electrically, or purely hydraulically. These maps also have to balance the energy used from the rears with the energy that is being recovered and ensure that there is no remaining force when the driver releases the pedal, which could lead to the wheels locking.

This year's wider tyres and higher downforce has increased the wheel torque by roughly 20 per cent, demanding more from the brakes. Therefore, the carbon discs are wider on both the front and rear, with an increase in thickness from 28mm to 32mm. The aluminium lithium monobloc calipers are larger, each weighing an extra 300g, as the wider tyres allow more space for the inner wheel assembly. Each carbon pad has also increased in width by 2mm. The brake-by-wire system on the rear means that the front axle experiences the most braking performance, therefore the rear calipers are smaller, operating only four pistons and the diameter and thickness of rear discs have reduced by seven per cent.

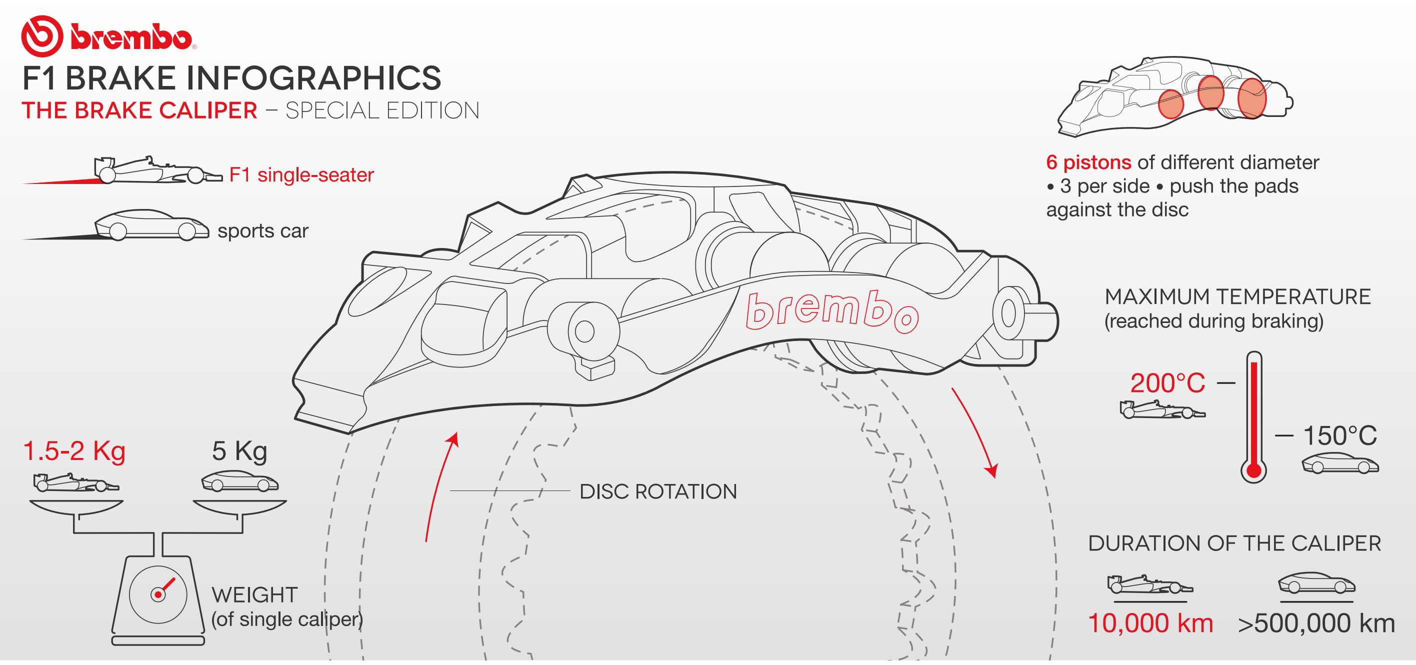
This year wider tyres and higher downforce in Formula 1 has increased the wheel torque by roughly 20 per cent, demanding more from the brakes

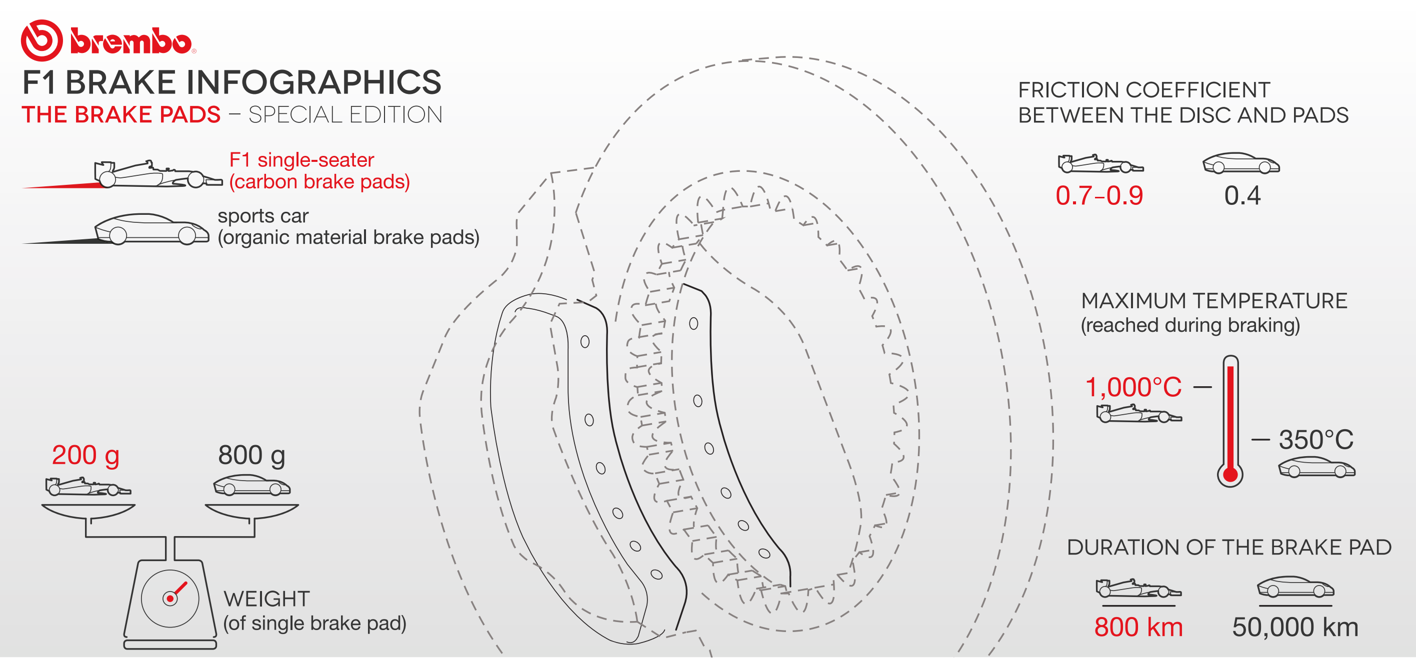
Cool pad

The wider discs also allow for improved cooling, which is essential when the friction on the discs can generate temperatures up to 1200degC – which is similar to the temperature of molten lava. To dissipate this heat, the carbon discs have ventilation holes that are between 2.5 to 3mm in diameter and the number of holes is inversely proportional to the diameter of the disc. With each circuit demanding different performance from the brakes, Brembo supply three types of discs, each with a different level of cooling to suit particular tracks. For example, the low cooling discs only have 500 ventilation holes and so would be used at Silverstone, Spa, Sao Paulo and Suzuka, where the average braking demands are relatively low, whereas, Singapore, Monza and Canada require a lot more performance and so would use the high cooling disc, with 1300 ventilation holes.

Maintaining the brakes within the optimum temperature window is one of the race engineer's main challenges and is a balancing act. The pads and discs need to be hot to give the brakes 'bite', which is why at the start of most races, when the brakes are cold, drivers often struggle around the first few corners, until the brakes are up to temperature. The heat generated from the brakes can also be used to increase tyre temperatures via complex air

F1 carbon brake discs can reach 1200degC. That's why each disc can have up to 1300 ventilation holes in it to help to dissipate heat





Brembo sees the worth of its involvement in Formula 1 both from a technology development and PR point of view and is always keen to show off the capabilities of its brake systems

ducts. However, it's also important to keep the brakes cool, as this slows the rate of wear. 'It's very important for teams to experiment with the set-up of the car during FP1 and FP2 to define the optimum working range of temperatures for the brake discs and pads,' says Andrea Pellegrini, Brembo F1 engineer. 'If initial temperatures are too low, under 250degC, then the drivers can glaze the disc which decreases the life. However, if temperatures are too high, above 600degC, then you can have high wear.

'They also have to keep in mind that during the race weekend, brake temperatures will continue to increase due to track evolution and also at the start of the race when the car is heavy with fuel,' Pellegrini adds. 'Therefore, the engineers need to continually adjust the margins of their defined temperature window.'

Each team's braking system differs from the other as every driver's preferences are different and so is the team's design approach. 'Every team has a dedicated front and rear caliper design because some teams prefer stiffer, but therefore heavier and larger calipers, and there are other variances in terms of the weight of the rim and the installation,' Pellegrini says. 'Stiff calipers and an overall stiff system gives consistent feedback to the driver from the beginning to the end of the race, but of course this compromises the weight.

'There are some drivers who prefer braking with a long pedal, and so require shorter master cylinder travel, and others that drive better with a shorter pedal,' Pellegrini adds. 'So the size of the master cylinder is also different between teams, but the discs are usually the same.'

Brake test

In the dry, the braking points in circuit racing remain the same each lap as the track exhibits a relatively consistent level of grip, aside from a small improvement in track evolution. Of course, there will be variations in driver style and car performance, but these are relatively minor. However, in the world of rallying, loose surfaces such as gravel, snow and sand are continuously changing and the unknown grip level around each corner is one of the main challenges. This

'Every F1 team's car has a dedicated front and rear caliper design'

Top four images: Brembo F1 monobloc brake calipers are made from aluminium lithium and take around 40 hours to machine. They use six pistons to apply approximately five tonnes of pressure onto the pads. Bottom image: Alcon's R5 4-piston monobloc rally caliper has internal passageways for fluid cooling

WRC drivers left foot brake to instantly load up the front tyres to stabilise the car on ever-changing surfaces

is why rally drivers are masters of the art of left foot braking, because by continually balancing the throttle with the brakes, they can instantly load the front tyres to stabilise the car, regardless of the available grip.

Unlike circuit racing, where the different demands of each track usually require modifying the brake operating temperature window slightly and adjusting the cooling strategy, rally stages present a whole host of other issues that the brakes have to cope with. Continuous sequences of corners subjects the brakes to high loads as the drivers are continually modulating the pedal to stabilise and adjust the position of the car and therefore there is no time for this heat to dissipate.

Furthermore, most stages experience changes in altitude, such as the Ibarilla special stage in Mexico, where drivers descend 534m over 20km, increasing the stress on the brakes. There is then the issue of thermal shock, which occurs when the cars race across fords or snow and can initiate cracks on the discs and ultimately the pads detaching. Depending on the surface and individual demands of each stage, different size discs are used. For example, on asphalt rallies where there are usually several 90-degree corners, larger discs up to 370mm in diameter and 30 to 32mm in thickness are used, whereas unpaved stages use smaller discs at 300mm diameter and 25.4 to 28mm thickness.

Brake bias

Jonathan Edwards, sales director at Alcon, says: 'Feel and consistency of the brakes is key for drivers to have the confidence to push to the maximum in varying conditions. The braking systems are typical hydraulic systems with dual master cylinders on a balance bar to provide a front and rear split. There is also a hydraulic handbrake via a long lever with a low friction master cylinder for maximum efficiency.'

Rally brakes use iron discs which are resistant to cracking and coning; aluminium grade (typically 2618) 4-piston calipers and metallic pads. 'The latter vary from driver to driver according to their preference and these high friction pads experience minimal wear. The material must be able to work well when the pads are cold, but be sympathetic enough to the disc to avoid cracking due to the sharp thermal gradients,' explains Edwards.

The heat is on

The cooling strategy for the brakes used in rallying is similar to most forms of motorsport where cool air is fed through the brake ducts into the eye of the disc and the caliper body. As well as ventilation holes, the discs also have a vane design to further dissipate heat, which is particularly important for tarmac. Some teams also have liquid cooling systems for the calipers via a closed loop internal design.

The future of brake technology in rallies will centre around light-weighting and innovative materials. However, regenerative braking is also a potential technology. 'It would be similar to other forms of motorsport where it would likely require an active brake-by-wire system to allow the teams to blend the friction brakes with the regeneration torque. This would mean there would be a natural downsizing of the friction brakes due to their lower utilisation,' says Edwards. 'The main difference for rally would depend on how the electric drive system would be applied to a 4WD. For example, the rear-wheel drivetrain could be replaced entirely by electric drive. With a brake-by-wire system this would eliminate the need for a hydraulic handbrake circuit and the handbrake would likely become an electronic potentiometer. In lower friction situations such as gravel or snow, this may also eliminate the need for rear friction brakes entirely.'

'Feel and consistency of the brakes is key for rally drivers to have the confidence to push to the maximum in varying conditions'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Road works

How well-known engineering wizard Ricardo has taken the lead in developing motorsport technology that has transferred to road cars

By GEMMA HATTON

Work in progress at Ricardo. Helical gears, a shaft of which can be seen here, are primarily used in transmissions

Car manufacturers are now no longer using motorsport purely for their brand awareness

The competitive nature of Motorsport provides the perfect platform to develop innovative technologies which, once proven, filter down into other industries. One of the most successful examples of this is the Kinetic Energy Recovery System (KERS). First introduced in F1 in 2009, recovered braking energy was used to generate an extra 80bhp for the driver to deploy throughout six seconds per lap. Four years later in 2013, Volvo reported that KERS improved fuel consumption by 25 per cent on its S60 model. Today's Formula 1 Energy Recovery Systems (ERS) are now even more efficient, with the MGU-K and the MGU-H combining twice the power whilst improving fuel consumption by 35 per cent.

The spectrum of transferable technologies and processes from the race track to the road has become the backbone of companies such as Williams Advanced Engineering and McLaren Applied Technologies. Through their work with other sectors, these companies have generated the revenue to then support their partner F1 teams. This technology life cycle has become so successful that car manufacturers are no longer using motorsport purely for brand awareness. Instead, they are investing in areas of racing which could see the next innovation; as demonstrated by the nine manufacturers

‘Ricardo invented the viscous coupling which was adopted by virtually all of the Group B rally cars back in the 1980s’

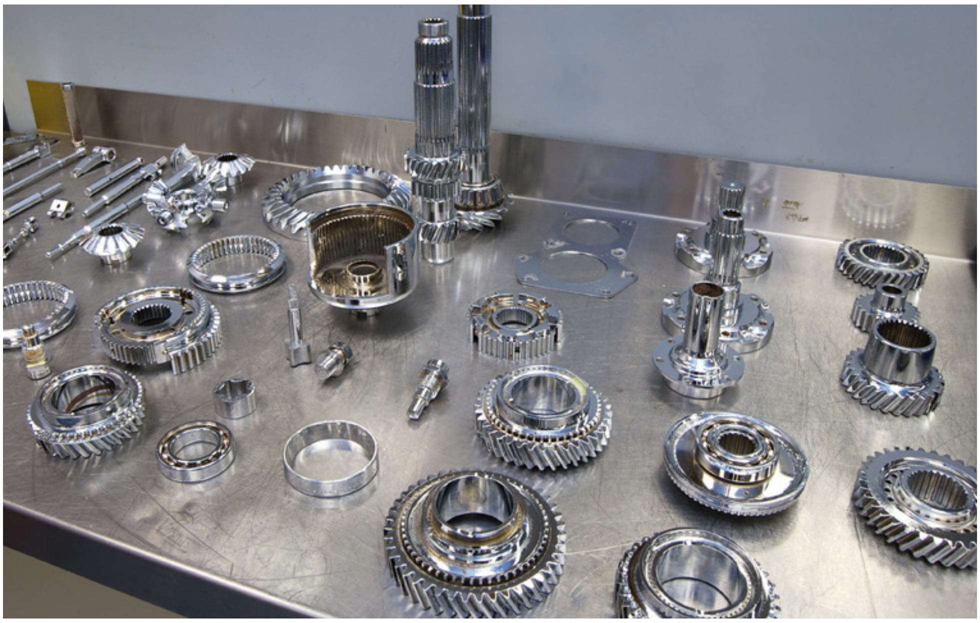
competing in Formula E in its fifth season (2018/19), with Porsche and Mercedes also joining the series the season after that.

It is a similar story for many of the industry’s suppliers, where products designed for racing have found their way on to road cars. This has been the case for Ricardo, whose first transferable technology dates back to the 1960s when Harry Ferguson, one of FF Developments’ original founders (it was acquired by Ricardo in the 1990s) developed a four-wheel-drive Formula 1 car; the P99. Once driven to victory by Sir Stirling Moss, the technology was later developed and applied to the 1966 Jensen FF, which many cite as the first ever road car to feature four-wheel-drive.

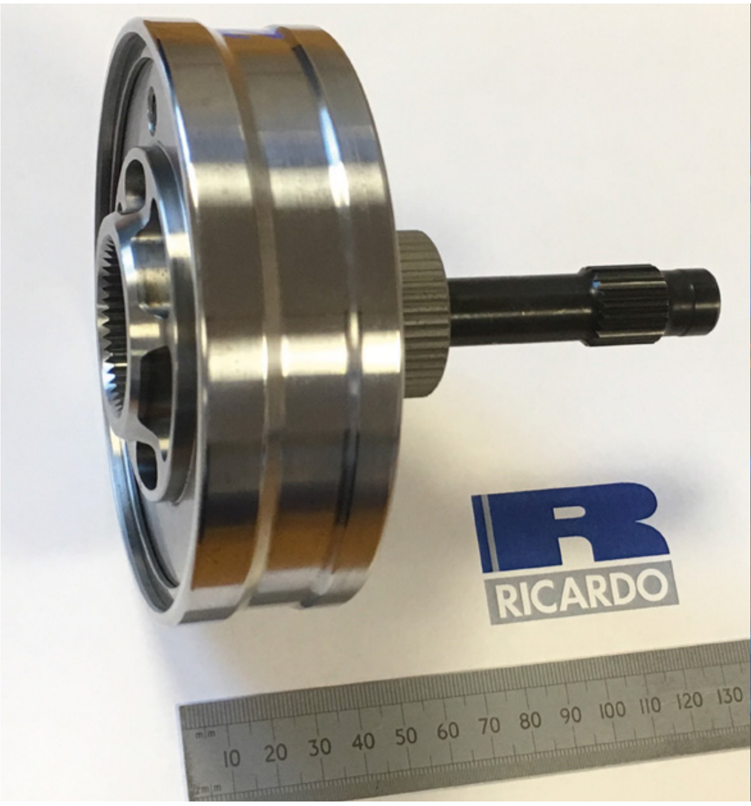
With this sort of background Ricardo was more than ready when rallying embraced 4wd. ‘The mid 1980s, with the Group B rally cars was one of many of Ricardo’s successes in motorsport,’ says Steven Blevins, project manager of High Performance Transmission Products for Ricardo. ‘We invented viscous coupling which was adopted by virtually all of the Group B rally cars at that time and the technology can still be seen in some road cars.’

Viscous coupling, in principle, is similar to a limited slip differential (LSD, see box out) in that it achieves independent rotation at the wheels, whilst also locking; to allow the transfer of torque to both wheels to overcome low traction conditions. However, viscous coupling is usually used to link the two axles, for 4wd cars, so if one set of wheels starts to slip, torque is transferred to the other set. Each coupling consists of a series of plates which are connected to the driveshafts and are immersed in a viscous fluid. When one set of plates starts to rotate at a higher speed, the viscosity of the fluid increases, generating friction which then drags the slower set of plates up to the same speed. In this way, torque is transferred to the slower moving wheels and the couplings become locked. Unlike normal differentials, which are torque sensing and can sometime be quite aggressive, viscous coupling is speed sensing, which allows for a much smoother ramp up in engagement.

‘One of the big advantages to viscous coupling is it’s relatively maintenance free,’



Components of a high performance gearbox. Ricardo has a long history of transmission innovation for both track and road



Ricardo developed viscous coupling, which is a type of differential that uses a viscous fluid to generate friction between plates and transfers torque between two driveshafts. On the left is the front assembly of an LMP1 spec viscous coupling while the image on the right shows the internals of the device. Ricardo first used this technology in Group B rallying

The knowledge: LSDs

The aim of a differential is to not only split the torque from the engine to both wheels on an axle, but also to allow each wheel to rotate at different speeds. This is essential when driving around a corner when the outside wheel needs to travel further than the inside wheel, and therefore rotate more. If both wheels were to rotate at the same speed, then one wheel would have to lose traction and slip to complete the turn. A gear assembly is used to rotate both the right and left driveshafts together (locked differential), as well as independently (open differential).

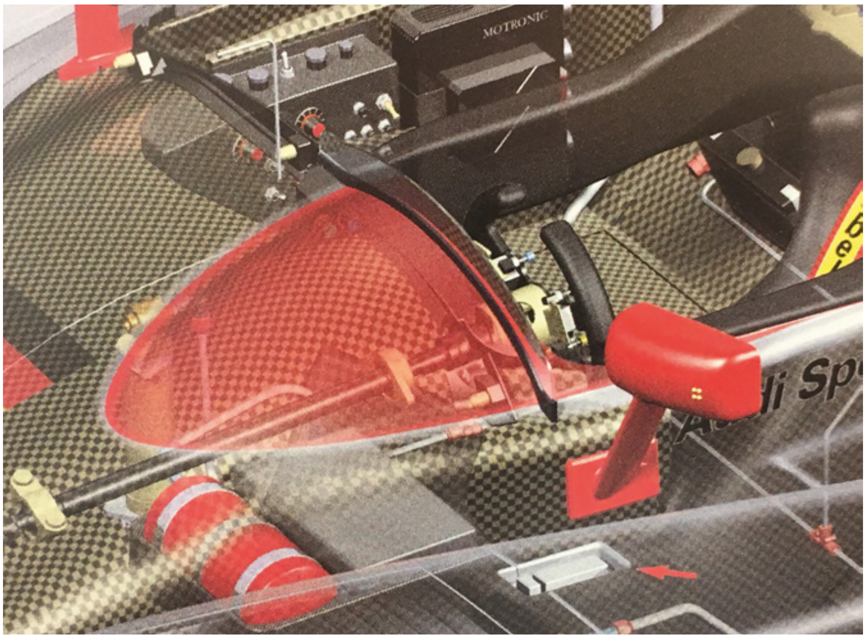
A more advanced system is a limited slip differential (LSD) which is designed to combine the benefits of both an open and locked differential. Therefore, when one wheel starts to slip due to a loss of grip, a small amount of torque is transferred to this wheel to help it overcome this lack of traction; acting like a locked differential. However, the majority of torque is still sent to the wheel with traction, to allow it to continue rotating independently; acting like an open differential.

This is often achieved through a clutch pack on each side of the gear assembly and consists of a series of friction plates that rotate with the differential housing and are interlaced with a series of clutch discs that rotate with the driveshafts. The two spider gears are connected by a set of planet gears which move under acceleration and braking, exerting a force, via a cross pin, on the ramp plates which either compresses or releases the clutch packs.

Ramping up

The amount of force exerted is dependent on the working angle of the ramp plates fitted to the differential. Therefore, during acceleration, the planet gear moves and exerts a force on the ramp plates, which compresses the clutch packs and locks the differential. Under braking, the planet gear is moved in the opposite direction and the ramp angle results in a lower force on the clutch packs, so that the wheels can rotate independently, but some torque is still transferred to provide an element of locking; preventing either wheel slipping excessively.

The amount of torque on the differential when accelerating from a relatively low speed is approximately 1g, whereas under braking, the torque transferred is around 0.3g. To avoid the wheels slipping at all, a pre-load is also applied to the clutch packs when the diff housing is first assembled, therefore, this resultant torque needs to be overcome before either wheel starts to lose grip. The amount of locking is a balancing act, but one that engineers can use to tune their car set-up to suit particular tracks.



Ricardo designed pneumatic paddleshifts for Le Mans to reduce driver fatigue and avoid over-revving which helped the transmissions to survive 24 hours of racing. Audi's R8 won five Le Mans with Ricardo paddleshfts

Mark Barge worked closely with Audi Sport, developing the transmission for the Audi R8 in the early 2000s, which was also used in the Gibson LMP2 chassis until 2016. Ricardo also has experience with spec formulae

'A lot of development went into the paddles themselves, to try and provide the driver with some feedback'

Blevins adds. 'The plates in normal differentials wear after about 1500 to 2000km, particularly in rally and circuit racing applications. The driver can feel this wear in the differential as a delay between locking between drive and overrun, so you almost get this free-wheeling type situation. It's for a very short amount of time, but enough to unsettle the driver. Whereas viscous coupling has no mechanical contact within any elements of the disc because of the fluid. In sportscars, we used to service the viscous couplings once a year and when you think that includes the Le Mans 24 hours, you are looking at about a service every 12,000km, compared to every 2000km with a plate differential.'

Visco-mechanical

Ricardo also developed a visco-mechanical differential which was used by Audi in its sportcar programme. This essentially combined a mechanical plate differential with a viscous coupling to try and achieve a unit that had the advantages of both, without the negatives.

'This design could essentially achieve 100 per cent locking through the plate differential, but the viscous coupling also provided an element of damping,' says Blevins.

Ricardo's next motorsport innovation that was quickly integrated into road cars was the paddleshift developed for Audi during its domination of Le Mans in the early 2000s. 'The typical characteristics of Le Mans in those days in round figures was 5000km in 24 hours which equates to roughly 20,000 gear shifts,' says Mark Barge, managing director of Performance Products at Ricardo. 'The transmission is actually a key structural component of the car and is subjected to all the suspension loads and stresses, so a lot of development work had to be done to ensure it survived the 24 hours.'

The Audi R8R and the R8C debuted at Le Mans in 1999, with the former featuring a pneumatically-actuated gearbox with paddleshifts and the latter using the traditional manual gearbox with a lever. In 2000, Audi debuted the famous R8, which claimed five

‘There’s a real skill in getting these sections down to the minimum’

Le Mans wins and used a Megaline pneumatic paddleshift system. Ideally, drivers want to keep their hands on the wheel at all times, which is one of the benefits of using paddles, while they also reduce driver fatigue, which is critical in endurance races such as Le Mans.

Shift work

‘These systems reduce the risk of getting the gearshift wrong and damaging the gearbox or miss-timing the shift and over-revving the engine,’ explains Blevins. ‘Not only can the system prevent the driver from shifting down too early, but it is also clever enough to realise that two upshifts within half a second is probably wrong, which can happen if the driver goes over a bump and accidentally pulls the paddle. Therefore, this system was one of the main drivers for increasing the reliability of the gearbox to get it through the 24-hour race.’

The Megaline paddleshift system is electronically controlled, but pneumatically driven. A gearbox control unit (GCU) consists of an electronic control unit, a compressor and a pressure reservoir which is connected to the valve block that is secured to the gearbox. The electric compressor and an accumulator supply this pressurised air to the valve block which opens pneumatic valves to feed the air behind the pistons, which changes gear.

‘Although it’s a small part of the system, a lot of development went into the paddles themselves to try and provide the driver with some feedback,’ says Blevins. ‘There is actually an over-centre action within the paddles, so the driver knows the change has been made, and this feedback can be felt in the paddleshift systems of road cars.’

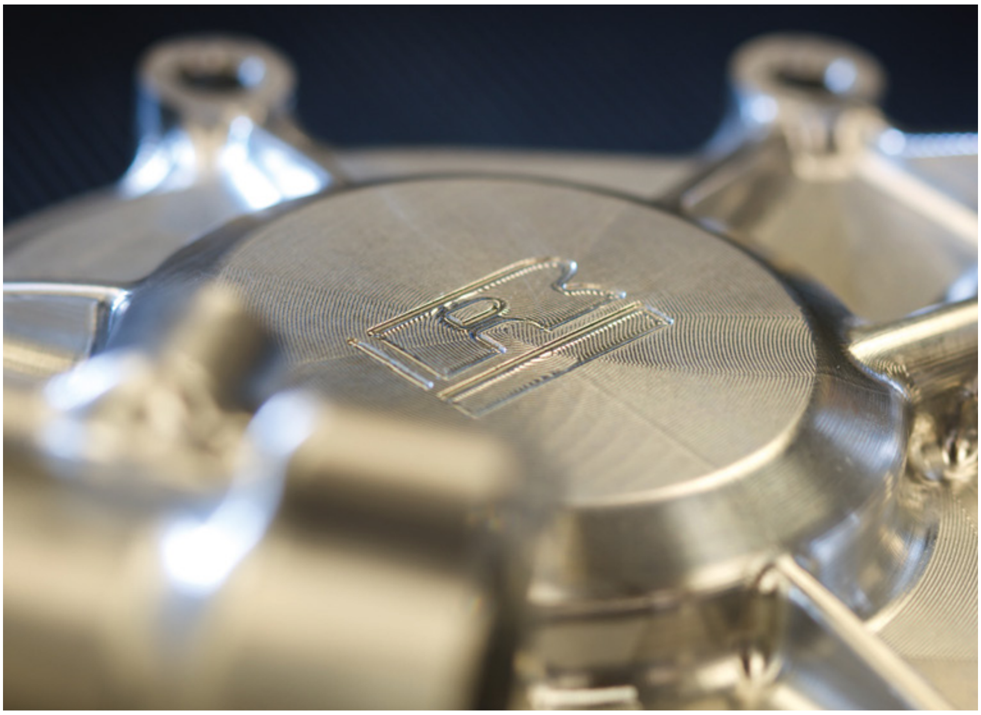
Today’s gearshift systems are now predominantly electric as it avoids the inefficiencies associated with converting energy between pneumatic and mechanical. These are also much smaller, with the components for the pneumatic system replaced by essentially one circuit board and a stepper motor.

From 2005 onwards, Ricardo shifted focus to F1, where the challenge was centred around material science and exploiting manufacturing processes. ‘Although advanced aerospace materials were understood, they weren’t commercially available,’ says Barge. ‘However, the demands of F1 teams put pressure on material manufacturers to create alternative steels along with the development of thin section aluminium, titanium and high strength magnesium. This flows all the way to the present day where it’s now quite normal to have the transmission structure made from carbon fibre with other specialised materials, with these lightweight structures becoming increasingly common in high performance roadcars.’

F1 intricacies

The complex and intricate designs of Formula 1 components also demands new manufacturing processes to cope with the required accuracy of the machining features that had to be achieved within a small area. ‘It would be quite normal for some complex housings to be machined for more than 40 hours non-stop, which is more than enough to machine an entire clay model of a whole car,’ Barge says. ‘Yet, it’s not about the amount of removed material, as there is minimal waste, it’s all about achieving those intricacies that requires an almost dentistry approach. There’s a real skill and experience in getting these sections down to the minimum, which defines Formula 1 really.’

The transfer of technology is not always from motorsport to road car. When Ricardo became the sole supplier for some single make series, it needed the manufacturing expertise used in automotive to cope with the increased production numbers. ‘To supply a championship, you need the best from both worlds: you need to engineer high performance components and yet be able to manufacture them on a production line,’ Barge says. ‘To produce parts to the expected standards, we’ve had to really focus on production methodologies such as design control, quality control and full component traceability, but on a much larger scale. No driver can have an advantage so performance, reliability and quality needs to be exactly the same – despite how much each team wants you to gain them a performance advantage.’



Some complex F1 housings can be machined for over 40 hours – enough time to machine an entire clay model of a road car

Formula E

To keep up with the development of electrification, Ricardo is working with some Formula E teams, supplying their transmissions for Season 5 onwards. Efficiency has become an essential requirement in any category of motorsport, however, with teams restricted by the capabilities of battery technology, efficiency can be the difference between a winner and a loser in Formula E.

‘Recently, we completed a research project for one of the teams to determine the efficiency improvement of a particular concept. We worked with them for around four months to produce a single set of parts which they then tested on their dyno,’ explains Blevins. ‘The new concept achieved less than a per cent efficiency gain throughout the driveline. Now, to you and I that is a small number, but the team was more than happy, because they had predicted an improvement of around that figure. Despite this minute change, it was still worth pursuing. Those are the sort of margins we are dealing with in Formula E.’

The gearbox for these electric racecars couldn’t be simpler; a single speed gearbox is all that is necessary, as the motors can reverse and there is no need for a clutch. However, this drive for efficiency means everything has to be as lightweight as possible and so despite the simplicity of the concept, a huge amount of technology is invested into the gear geometries and finishing techniques, for example, to reduce weight.

Shocking news

Racecar's numbers man dispels some damper myths while also showing how shocks can be used to help fine tune a chassis

By DANNY NOWLAN

The writer brought his damper wisdom to bear when sorting the handling of a Lamborghini GT3 such as the one pictured

Since I have been contributing to *Racecar Engineering* one of the subjects I've covered that always gets a response is damping. Given that damping is a critical but very poorly understood area of racecar engineering this is not surprising. However, one thing that I have not yet addressed is what part of the damper do you need to adjust to get a desired result. This is what we will be discussing at length in this article.

Before we begin we need to deal with one great myth about dealing with racecar damping. This is to do with the peak force *vs* peak velocity graph. This is illustrated in **Figure 1**. The biggest suck-you-in with racecar damping is that if the curve in **Figure 1** moves up and down then everyone thinks the damping has been increased/decreased. This is complete nonsense.

The thing that drives damping behaviour is damping rate. This is the slope of the graph and you'll see an illustration on how to calculate this on the chart. Typical racing numbers are in the order of 3000 to 20000N/m/s. All damping behaviour stems from here. Some might point out that regressive damping disproves this. However, once you dig beneath the surface it is actually the exception that proves the rule. Why this is so we'll discuss at another time.

To kick this discussion off we have to review some basics first, and this starts with the quarter car model. The reason we review the quarter car model is because it's a very simple and instructional tool to educate us as to where to start. Just to refresh everyone's memory the quarter car model is shown in **Figure 2**.

The parameters of the model are:

m_B = Mass of the quarter car (kg)
m_T = Mass of the tyre/unsprung mass (kg)
K_B = Spring rate of the body (N/m)

You have to always remember that it is the damping rate as opposed to the magnitude of the damping force that drives damping behaviour

With the quarter car, given a damping ratio we can then calculate the damping rate

C_B = Damping rate of the body (N/m/s)
K_T = Spring rate of the tyre

The key thing to recognise here is that all spring and damper rates are specified at the wheel. So you will have to take into account the motion ratios. Also, work this in strict SI units. I know that if you are based in North America this will annoy you, but if you go down the Imperial road you will get lost.

The great thing about the quarter car model is we can break the car down into natural frequencies and damping ratios. I've gone into the proof of this in past articles, but let's get to the results. All damping behaviour can be summarised by **Equation 1**:

$$C_B = 2 \cdot \omega_0 \cdot m_B \cdot \zeta$$

$$\zeta = \frac{C_B}{2 \cdot \omega_0 \cdot m_B}$$

Here the terms of the equation are:
C_B = Wheel damping rate of the spring (N/m/s)
m_B = Mass of the quarter car.
ω_0 = Natural frequency (rad/s)
ζ = Damping ratio

The power of the quarter car is that given a damping ratio we can readily calculate the damping rate we want. Once we know the damping rates we want we can then turn around to a damper builder and specify that this is the damping curve we require. This is why this technique is so powerful, and it goes back to our earlier point that it is the damping rate as opposed to the magnitude of the damping force that drives damping behaviour. Remember, the damping force is a consequence of the damping rate, so keep this in mind.

However, once we understand second order time based frequency response we can actually use the damping ratio to tune the response we want. This is illustrated in **Figure 3**.

As can be seen, when the damping ratio is greater than 0.5 this is ideal for body control and when it is between 0.3 to 0.4 it's ideal for riding kerbs. This has led to my damping ratio selection guide that I first discussed back in 2008 (**Figure 4**). While this isn't the last word on where you select your damping, the power of

Figure 1: Peak force *vs* peak velocity graph

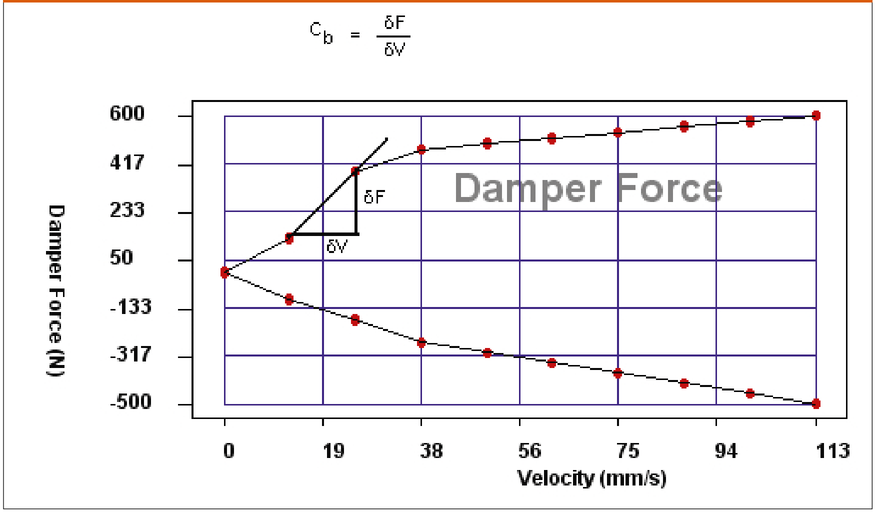


Figure 2: Quarter car model

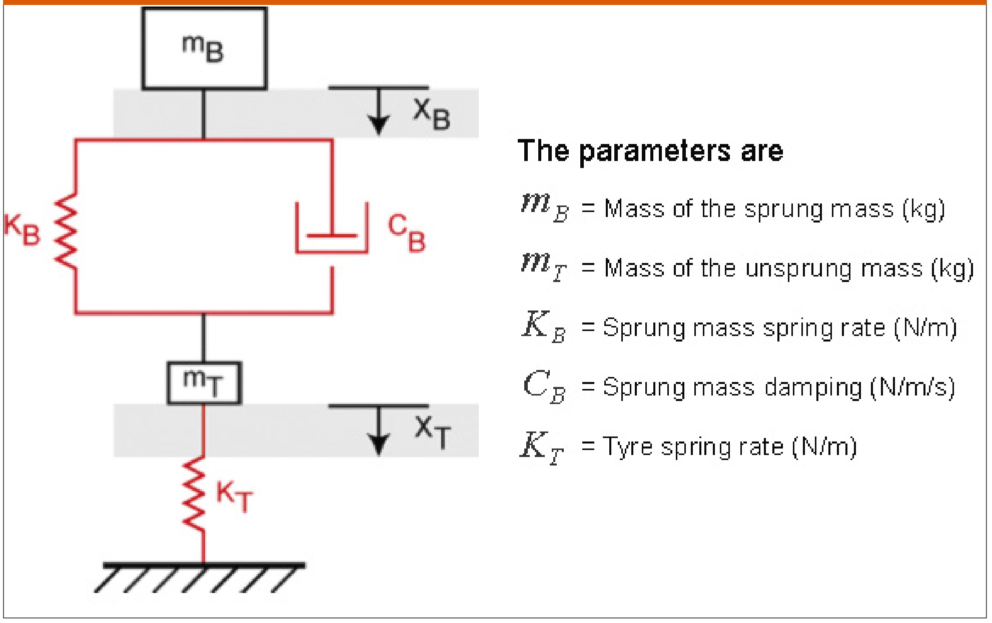


Figure 3: Second order system response by damping ratio

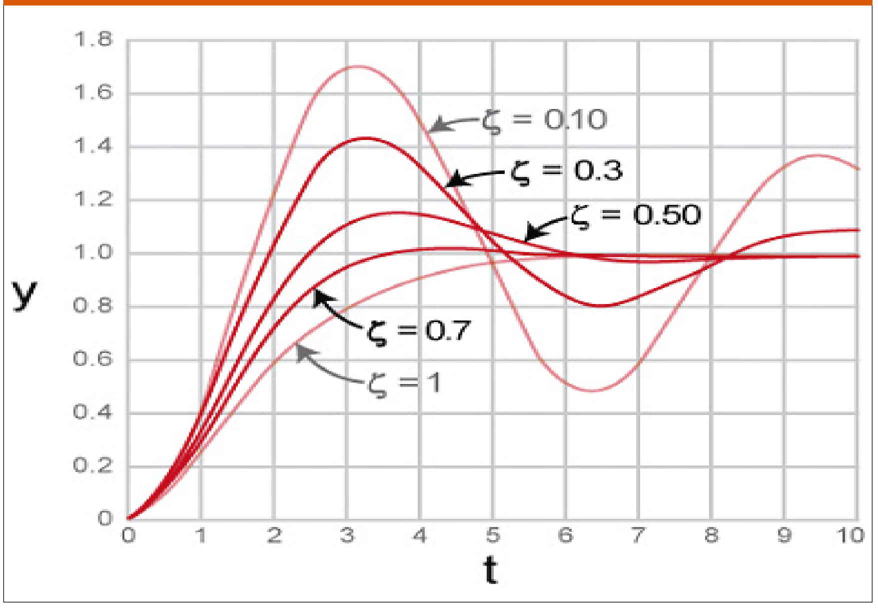


Figure 4: Damping ratio selection guide

Region	Value
$\zeta_{LS-Bump}$	This is body control so, if it is a bumpy circuit the ratio is 0.5. If the circuit is smooth choose 0.7. If the tyres need to be worked hard then choose 1.2.
$\zeta_{LS-Rebound}$	This will be dependant on a number of factors. Where body control is not significant use 0.3. However where body control is significant use 0.5 to 0.7.
$\zeta_{HS-Bump}$ $\zeta_{HS-Rebound}$	This is the high pass area of the damping curve. The values here should be 0.3 to 0.4

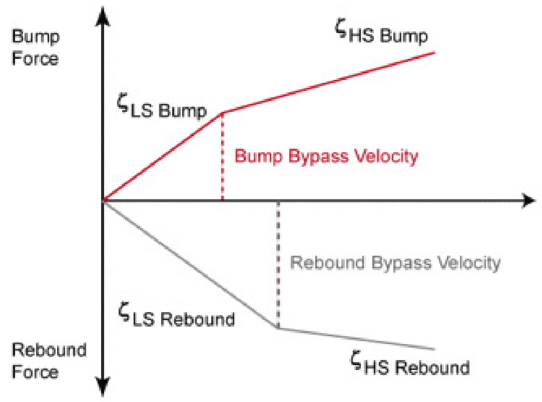


Figure 5: Beam pogo stick approximation of the racecar

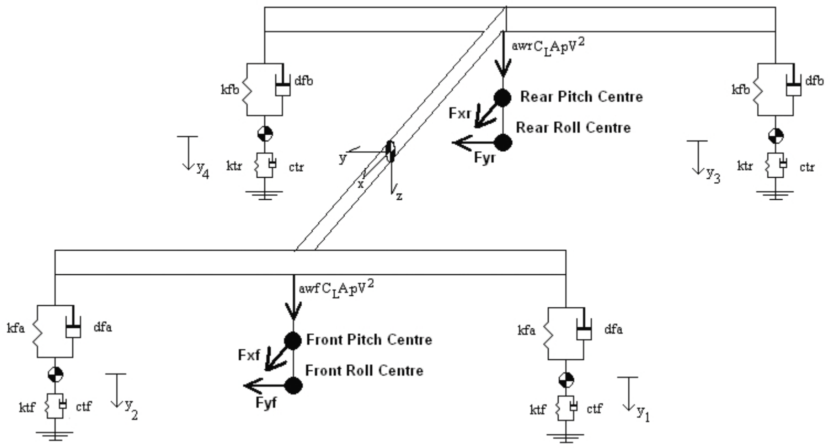
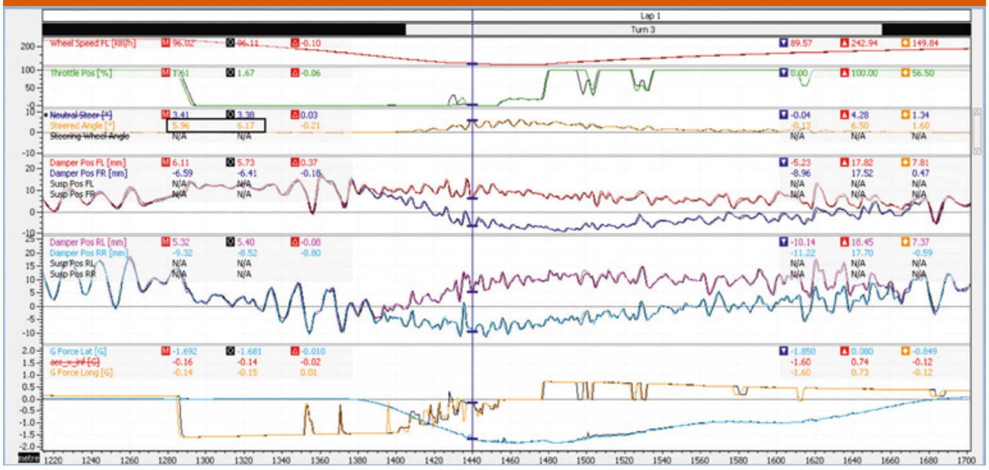


Figure 6: Increasing low speed bump at the front



The Lamborghini was exhibiting borderline turn-in oversteer so the first step was to increase the bump at the front of the car

While it has a big impact on overall performance we should not use a damper to correct a problem we should be correcting with something else

Figure 4 is it gives you some rough numbers to hang your hat on. Also, combined with **Equation 1**, it gives you the metrics to understand what you have in front of you.

The next step in understanding damper behaviour, or more importantly what to do with it, comes in understanding the beam pogo stick approximation of the racecar. This is shown in **Figure 5.** While this will not win any prizes for technical drawing it illustrates all the key aspects of racecar behaviour. For example, if you hit the brakes and you need to keep the nose up, what do you do? You increase front spring rate. Guess what the damping equivalent of this is; you increase the front damping rate, particularly in bump. Also, at the rear as the rear squats and you want to keep the rear up, you increase rear spring rate. What is the damping equivalent? You guessed it, you increase the rear bump rate.

Damper curves

One thing to keep in mind, just remember your base damping curve will be a compromise. It will be a trade-off of body control, and how the car rides the bumps and the frequency behaviour you want from the car. You start this process with damping ratios, you dial this in with a tool like the ChassisSim shaker rig toolbox, and then you go to the track to test. The combinations thereof will settle on what the mid-range damper curve looks like.

That said, there is quite a bit of on-track tuning you can do with dampers and here are some rules of thumb that over the years have worked very well for me:

- **If the dampers are wildly oscillating and the car is undriveable – increase the damping.**
- **Turn-in understeer – decrease front bump and rear rebound. Reviewing the beam pogo stick model, this will force the car to pitch.**
- **Corner exit understeer – increase the rear bump. This is effectively adding transient rear spring.**

Also, it goes without saying that if you have the opposite condition the inverse applies. I should also add that for an aero car these effects become even more pronounced.

Bumped up

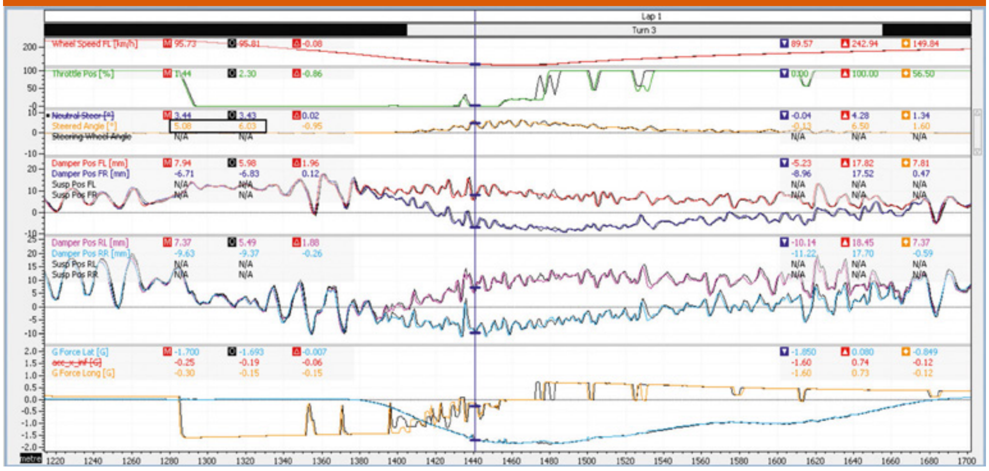
To work through some examples of this let's do some simulations using ChassisSim. The reason we are using ChassisSim is that its lap time simulation is transient. Consequently we can actually simulate the effect of dampers on the vehicle's performance and ultimately lap time. This is a key distinction that separates ChassisSim amongst its contemporaries, but we will discuss the whys of this another time.

For the purpose of this study we will focus on an Lamborghini LP560 GT3 around Willowbank/Queensland Raceway in Australia.

This car was borderline turn-in oversteer so for our first change we increased the front bump.

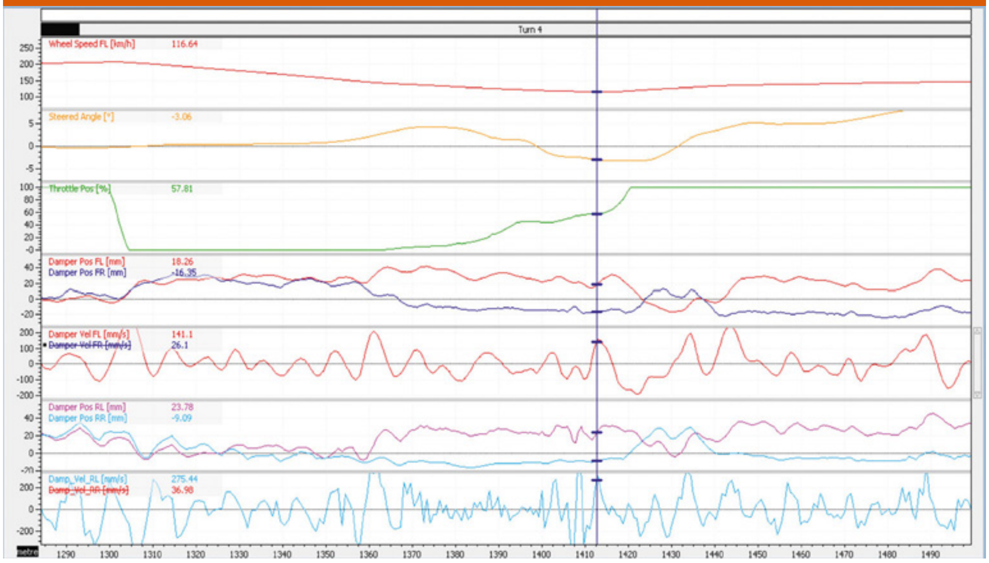
These are all the things you would expect from softening the rear spring on a racecar, but this time we have done it with a damper

Figure 7: Decreasing low speed bump at the rear



The second step in the damper tuning of the Lamborghini was to decrease rear bump to help sort out corner-exit oversteer

Figure 8: Where to tune for damper velocity



To find out where in the curve you need to tune you have to plot corner speed, damper movement and the damper velocity

Gaz coilover shocks. Dampers are a potent tuning tool in their own right, but to get the very best from them you need to use them appropriately

The results of this is shown in **Figure 6**. The baseline is coloured and the simulated is black. As can be seen it has had a marginal increase in steer angle which is the effect we are after. It has gone from 5.96-degree of steer to 6.17-degree of steer. Also, the front pitch was decreased by 0.5mm. Ultimately this actually increased the car's lap time, but on the other hand it did have the handling effect we were after.

Bumped down

The second change was to decrease the rear bump to help with rear turn-exit oversteer. The results are shown in **Figure 7**.

As before coloured trace was the baseline, the changed was black. Looking at the data a couple of things are apparent. The steering lock has increased marginally from five degrees to six degrees, the rear dampers have squatted by an extra1mm on average, and you have more throttle application. These are all the things you would expect from softening the rear spring, but this time we have done it with the damper.

As we review the data we need to keep in mind a couple of things. Firstly, because these are simulated changes the magnitudes of the changes will always be far more subtle than with an actual driver. However, this also illustrates that a damper is a fine tuning tool and while it has a big impact on overall car performance we need to be very mindful not to try and use a damper to correct a problem that we should be correcting with something else.

Also, to wrap up this discussion, where in the damper curve should we actually be tuning? The answer is readily found by plotting corner speed, damper movement and damper velocity. This is illustrated in **Figure 8**.

So, in this particular example the front dampers are relatively well controlled but the rears need work. In this case you simply read off the damper velocity which here is 275mm/s, and that is where in the damping curve you should apply all your efforts.

Shock tactics

In closing there are some very simple techniques that can be applied to tune the racecar using dampers. The first step in the process is to understand the quarter car model and know what your damping ratios are.

Then, using the beam pogo stick model as a visualisation tool to help you and exploring this with software like ChassisSim, you can refine the transient handling using dampers. Once you get your head around this you will find just what a powerful tuning tool dampers are, provided they are used appropriately.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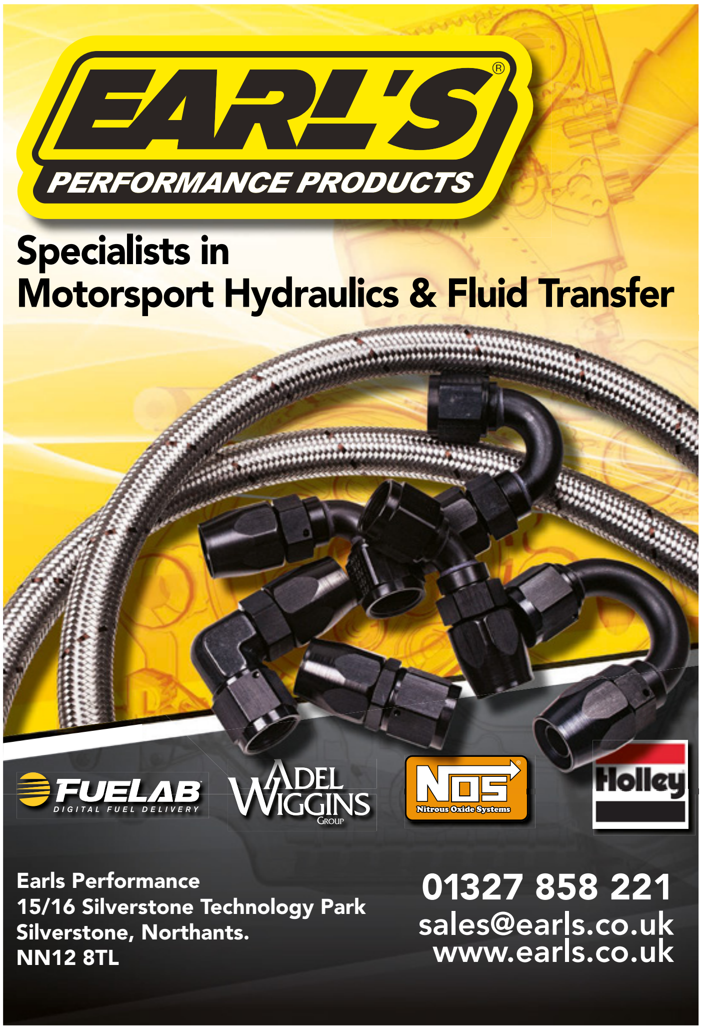
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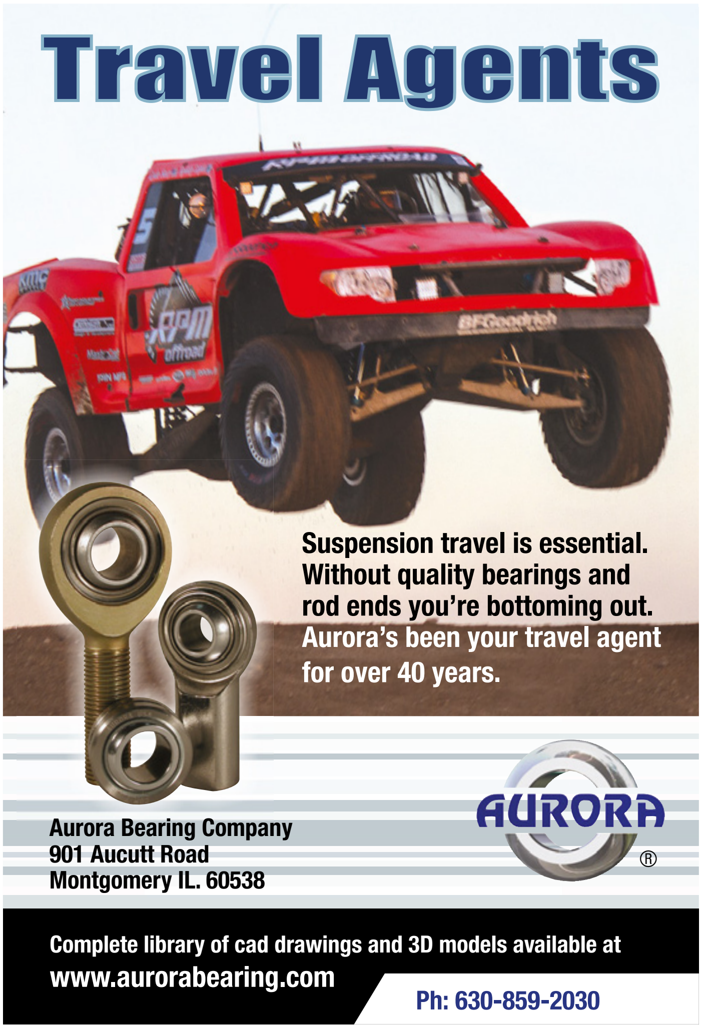
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Eyes on the prize

The ACO has reacted to the bombshell of Porsche's withdrawal from LMP1 with a new set of technical regulations for the class

By ANDREW COTTON

Following Porsche's announcement that it will withdraw from the World Endurance Championship, the ACO has finally announced its 'Plan B' for the future of LMP1 regulations. Gone is the plan to complete 1km on electric power only at Le Mans, and crucially gone too is the necessity for a manufacturer to compete with a hybrid in the top class. The new-look LMP1 cars will run in one class, and will be balanced for lap time only, with the expectation that hybrid will be used for economy rather than power, and so will go longer on each fill of fuel. That means that any incident or delays that occur early on in an endurance race will be easier to mitigate than later in the race, when strategy will have less of an impact on the overall result.

The decision to not implement the rules that were announced at Le Mans in June was designed to bring in new manufacturers. The plug-in hybrid idea was conceived by the FIA through Lindsay Owen-Jones, President of the Endurance Commission, and agreed by Toyota, Porsche and Peugeot, if it would help to bring in the French manufacturer. However, the argument remains that the Le Mans regulations should have been designed to attract new manufacturers, and not just Peugeot.

'Having Porsche leave at an unexpected time, it is an opportunity to be attractive so you re-open the door and make the category easier to access for other manufacturers,' said the ACO's sporting director Vincent Beaumesnil. 'We are convinced that this is the right plan now.'

The decision to open the regulations up to manufacturers competing in the non-hybrid class, and balanced by fuel flow, means Toyota could be competing against a rival that is spending significantly less. The manufacturer is unlikely to spend money developing a new car with a lower hybrid capability, and will certainly not compete with no hybrid power.

P2s thwarted

The insistence that cars be balanced with a fuel flow meter effectively rules out the LMP2 teams that considered moving to LMP1 with their current cars unrestricted. Without ballast, and with the engine increased in power, teams believe they could lap at Le Mans in 3m20s, and use less than a litre more fuel despite the extra power. With confidential tyres, banned in LMP2, and with aero development, the cars could compete with modification to the bodywork to reduce length by 100mm.

However, the fuel flow meter also rules out DPi teams and manufacturers competing in the US from coming to Le Mans in the top class with their IMSA-specification engines. Teams are still hopeful that, in these turbulent times, the ACO will change course and allow in the non-fuel flow meter cars, and it seems likely that the US and European rules may come together in the next rule set due in 2020.

The fuel flow decision means that the ACO has put its faith in the new LMP1 cars that are currently under construction at Dallara, for the SMP and ART teams, and Ginetta. Nicolas Perrin, who also had an LMP1 car in design and is ready to build one, says that there is more supply from manufacturers than demand from customers, and so has stopped his programme for next season as an agreed contract fell through.

What the rules do is open the door to Peugeot, which now has everything that it wants to compete; a lower-capacity hybrid system, a lower budget and equal opportunity to compete. However, the French manufacturer was in September accused of its part in an emissions scandal that, according to *Autocar* magazine in the UK, could cost the manufacturer €5bn. The claims against PSA are published in a report from the European Union's directorate-general for competition, consumer affairs and fraud prevention, according to *Autocar*, although the PSA group says that it complies with regulations in every country where it operates.

For Toyota, which objected to the increase in the number of races and the introduction of the third ERS but was over-ruled in both matters, the decision on whether or not to compete under the new regulations will come in October and it has asked directly whether or not Peugeot will come and if so, when? 'We need to understand where the calendar goes, if competitors are coming and based on that where the regulation goes,' said Toyota's team principal, Pascal Vasselon. 'These are the three things; calendar, competitors and regulations. We need to have some indications that new competitors are coming.'

The regulations should have been designed to attract manufacturers

Interview – Alan Gow

Ready steady Gow

The boss of the BTCC talks TCR, touring car 'cultures' around the world, and the place of hybrid power in future British Touring Cars

By MIKE BRESLIN

XPB

'At the end of these current regulations we might look at incorporating hybrid into the next'

If a touring car series promoter had a wish list it would read something like this. Full grids; lots of marques; close competition; stable and cost-effective regulations; a long term TV deal; and grandstands packed with spectators. But for Alan Gow, long time boss of BTCC promoter TOCA – and also the outgoing chairman of the MSA and president of the FIA Touring Car Commission – this is not so much wish list as reality.

The BTCC now hosts 10 car makes (with Alfa Romeo returning as a dealer team entry with Handy Motorsport next year to make it 11); at Rockingham qualifying it had 27 cars covered by a second; and it has crowds of 30 to 40,000 at its events, plus TV coverage that's locked in until the end of 2022. Then there's the highly successful NGTC regulations, which are in the first year of a five year extension.

It's actually this last, the regulations, that Gow believes provides the bedrock to the BTCC's success, largely due to the pack of standard components that's at its heart. 'It's cost effective and it gives everyone an equal chance at success, and that's the most important thing,' Gow says. 'It doesn't rely on an expensive homologation process of standard cars, and it doesn't rely on production components, so it's not about whether one car has got a better suspension system than another, or whatever. It takes out all those variables and gives every car an equal chance of success.'

Which suits the teams, and also the manufacturers that back many of them, usually on a sliding scale of works involvement. 'Some of the teams are manufacturer backed,' Gow says. 'But there is no such thing as a race team run out of the factory anymore. We have teams that are financially and technically supported by manufactures, such as BMW and Honda, but I can't think of a touring car manufacturer who runs a team from inside the factory walls – except maybe Audi in DTM. But then Mercedes [DTM] farmed all their stuff out to HWA. It's very rare that a manufacturer has an in-house race team.'

Team works

Gow will not mind that the manufacturers are not heavily involved, though, as a reliance on works teams has bitten the BTCC before, during its Super Touring era, when costs went through the roof and many of them then departed. 'That's the same in any series,' Gow says. 'LMP1 is going through that exact same process now, and so is DTM. When you're reliant on pure manufacturer participation that's always a problem, because understandably manufacturers go in and out of a programme, no different than them going in and out of advertising on a certain TV programme. They will change their marketing, they will change their advertising, they will change their PR focus, they don't do the same thing forever.

'But that's why our regulations are very good,' Gow adds. 'Because they are team based regulations, and the teams become the constructors. The teams homologate the car, if you like, so it's based on the teams, and the teams do all the work, and the manufacturers then end up supporting them.'

And for those teams it's the costs that keeps them in the BTCC. 'The cost of competing hasn't gone up since NGTC started [iaround £400,000 a car per season] because the cost of the cars and parts haven't gone up,' Gow says. 'Running a car is always based on the cost of parts, the cost of tyres, the cost of fuel, the cost of brakes; they all remain the same. In our contract with our suppliers – like RML, AP and Xtrac – they are fixed on the prices over five years. So it can only go up by inflation.'

TCR threat?

But while the NGTC concept has worked well, it's not the only show in town when it comes to touring car categories, and next year TCR, with its manufacturer-friendly customer racing approach, is coming to the UK with a brand new British series. Some have seen this as a challenge to the BTCC's hegemony when it comes to top-line touring car racing in Britain. Gow, however, does not see it as a threat, and responds to TCR's claim that it has big grids for next year already with: 'No they haven't. To be honest I'll be surprised if they can find that many people willing to spend £200,000 on doing a season of TCR, which are basically club races.

'I think you will find there's simply no room for it,' he adds. 'I don't think it will have any traction, because it's not cheap. If you have a look at the costs of running the TCR races, teams are quoting £200,000 to do 14 races. Well that's the same price as doing the BTCC [33 races over 11 events], but without the spectators and without the TV the BTCC has.'

Gow also believes TCR has no place in the UK anyway, as it's not the sort of place it will thrive. 'It does well everywhere

Honda, MG and BMW battle it out at Knockhill. Plenty of marques and stands full of spectators are hallmarks of the BTCC where there is no strong domestic touring car championship,' he says. 'All it is doing is plugging a hole, in those countries that don't have a touring car championship.'

In fact, Gow believes that no touring car formula can offer a truly global solution, a one spec fits all sort of thing, because different countries or continents have different car cultures, which he maintains has a strong influence on the type of tin tops people like to watch.

'You can't take one global view because touring car means different things in different regions,' Gow says. 'In Australia touring cars are all about big V8 saloons, in Germany it means much more hi-tech coupes, in Britain it means what we have in the BTCC, you will never find one form of it to fit the whole world, it's a cultural thing. In Britain we drive cars that are about the same size as those we are racing in the BTCC, in America they don't. What people watch is not only about motorsport, but what they actually drive on the road.'

Incidentally, Gow actually believes that DTM is more hi-tech GT than pukka touring cars and he thinks that total convergence between it and Super GT – basically agreeing on a common engine package – is just a matter of time.

Hybrid future?

Of course, car culture everywhere is now changing. Under current proposals, the UK and other countries in Europe are set to ban new petrol and diesel cars sales by 2040, so the British-based championship will need to think about electric, and certainly hybrid, sooner rather than later.

'What we race has to reflect what's happening on the road,' Gow says. 'All technology gets cheaper every year. When there's a standard hybrid that we can attach to our cars, and where it's cost effective to do so, then we would look at it. We certainly wouldn't do it yet, it's too early, but at the end of these current regulations you would look at incorporating it into the next – which after this year is in another four years.'

Gow would also welcome an electric series on to the TOCA package of support races, he says. 'There are none on the horizon at the moment but then going forward all of motorsport is going to have to embrace what is happening on the road, so some form of electrification, with a hybrid system and all of this stuff, is obviously the way forward, and it will get cheaper and easier to do as each year passes.'

Whether the next regulations have hybrid or not, the next big challenge for the BTCC is getting them right once more.

RACE MOVES

XPB

Toro Rosso technical director **James Key** has extended his contract with the Italian Formula 1 team. The length of the extension has not been disclosed. Key joined Toro Rosso from Sauber in 2012, after entering F1 with Jordan in 1998 and staying on as it morphed through its Midland, Spyker and Force India identities. He left Force India to join Sauber in 2010.

Adrian Newey is to make his North American race driving debut in a car he designed and ran nearly 35 years ago in the Classic 24 Hour at Daytona in early November. Newey will be competing in one of his earliest projects, a March 83G Chevrolet, which is the same car he tended as it raced to a second-place finish at the Daytona 24 hours in 1983.

Martin C Klein is the new head of Recaro Automotive Seating Branding and Marketing and the Recaro Performance Car Seating business. Klein replaces **Markus Kussmaul** in the role, the latter having decided to leave Recaro to pursue other career opportunities. Klein has over 25 years of professional experience in the automotive business and has held various leadership positions at Daimler in both Germany and the United States.

Steve Horne has stepped down as chairman of the Supercars Commission – the body which manages and oversees the racing rules, regulations and formats and then passes on its recommendations to the board of Australia's premier motorsport category. The former IndyCar team owner has been the Commission's chair for the past four years.

Matt Bishop, the McLaren Technology Group's chief communications officer and group media, content and communications director, is to leave McLaren after 10 years with the firm.

Supercars outfit Prodrive Racing Australia has recruited NASCAR engine expert **John Grove**. Grove comes to Prodrive from Toyota Racing Development, where he worked on its NASCAR engine programme. The Australian already has experience in Supercars, having worked for Triple Eight's engine supplier KRE before he moved to the US two years ago.

NASCAR mechanic **Adam Wright** was killed in a car accident in North Carolina, in late August. Wright (33) was the son of **Pete Wright**, a long-time NASCAR crewman and a member of **Terry Labonte's** 1984 Cup-winning team.

Gilles Simon, who was a consultant with the Honda F1 engine programme until just before the start of this season, has now rejoined the FIA where he is its new technical director. Engine specialist Simon has previously worked at Ferrari and Renault in F1 and was the FIA's technical and powertrain director from 2010 until a switch to the stillborn Pure F1 engine project a year later. He became involved with Honda in 2015.

Former IndyCar crew member **Hardy Allen** has died. Allen worked in the 1960s and early 1970s for Dan Gurney's All American Racers organisation before moving to AJ Foyt Enterprises. He will be remembered as something of a trailblazer, as one of the first African-American men working in the sport.

The Motorsport Industry Association (MIA) is once again holding its successful School of Race Mechanics next year. Kicking off in January 2018, the course will host 20 students over a two-week, 120-hour period, and will be held at the Silverstone race circuit. The top five students are guaranteed a work placement with a race team for the 2018 season and for those remaining the MIA aims to secure industry opportunities. For more go to www.schoolofracemechanics.co.uk

NASCAR Cup Series crew chief **Mike Wheeler** was fined $50,000 and suspended for two races after the No.11 Joe Gibbs Racing Toyota he tends was found to be running with a rear suspension that contravened the rules at the Darlington Raceway round of the series. **Chris Gabehart** (the crew chief on JGR's No. 20 Xfinity Series car) was to replace Wheeler during the suspension.

Team bosses worried about too many Formula 1 races

Formula 1 team chiefs have said an over-expanded F1 calendar could push their staff to the limit and might lead to them having to hire more personnel, which will in turn push up costs.

Chase Carey, CEO of the Formula 1 Group, has recently gone on record as saying he's looking at increasing the number of races, possibly up to 25 a season, in future years – this year there are 20 grands prix with 21 set for next season.

But Red Bull team principal, Christian Horner, said he believes there will already be too many races in 2018: 'Look at next year's calendar; we've got a triple header followed by a double-header with a weekend gap in between, so already the calendar [I feel] is at saturation point; 21 races is, I think, the absolute limit.

'To go beyond that, I think we're pushing teams, we are pushing engineers, we're pushing travelling staff too far. So then you're going to end up in rotational shifts. As soon as you do that then the costs will become exponential with it because you'll end up with a much bigger workforce to accommodate that.'

XPB

Christian Horner thinks adding more races could push personnel to the limit

Renault managing director Cyril Abiteboul agreed, adding: 'I think it's all about quality over quantity and I would focus on quality rather than quantity. I think we need races that are absolutely iconic, huge races … In addition [there is] the economic factor which should not be underestimated with the cost to F1 and all the teams travelling.'

But Haas team principal Guenther Steiner thinks more grands prix could work, if changes were made elsewhere: 'One way would be to make a longer season, with also shorter race weekends, shorter events,' he said.

OBITUARY – Don Nichols

Former Shadow Formula 1 boss Don Nichols has died at the age of 92.

Once a soldier in the US Army, American Nichols served in both WWII and the Korean War before settling in Japan where he established a business selling American tyres and was also involved in Japanese motorsport, including playing a part in setting up the Fuji race circuit.

Returning to the States in the 1960s he founded automotive company AVS, which went on to build often innovative CanAm cars, including the radical Shadow Mk1 – known as 'tiny tyres' because of its kart-like wheels.

A tie up with fuel company Universal Oil Products (UOP) led to Formula 1 in 1973. The team shot to prominence at the start to the 1975 season when its DN5 looked to be the class of the field, but after a couple of pole positions the car lost its competitive edge, although Tom Pryce did win the non-championship Race of Champions that year.

There was one grand prix win, in 1977, when Alan Jones took a fortuitous victory at a wet Austrian GP, but the team was never quite the same after it lost its UOP funding at the close of the 1976 season. Shadow also won the CanAm championship in 1974.

The DN5 was Shadow's best F1 car, taking two pole positions during the 1975 season

With the core of the workforce splitting off to form Arrows in 1978 – which led to a copyright infringement court case over the Arrows FA1, which Nichols won – Nichols eventually sold the Shadow operation to Teddy Yip's Theodore concern in 1980.

A mysterious, quiet character, there were rumours that Nichols had a background in espionage – something hardly dispelled by the Shadow team's logo of a cloaked man …

Don Nichols 1924-2017.

RACE MOVES – continued

XPB

Dave O'Neill has left the post of sporting director at the Haas F1 operation, which he joined in 2014 with the brief of setting up the team in readiness for its debut season in 2015. He has now taken on a role with new firm DKR Technologies, alongside former Red Bull chief mechanic **Kenny Handkammer**.

Rory McDonnell has been appointed head of sales and marketing at UK sportscar maker Lister. McDonnell has a background in project management and has worked on several high profile international projects in organisations such as Siemens and the BBC. He has a keen interest in historic racing.

NASCAR operation Joe Gibbs Racing (JGR) is no longer responsible for the pit crews on the No.77 and No.78 Furniture Row Racing Toyotas in the Cup series. It previously provided crews as part of a technical tie-up. However, while decisions for the Furniture Row pit crews will now be made in-house, the crew members will still continue to train at JGR.

Williams deputy team principal **Claire Williams** will not be attending any more races this year as at the time of writing she was due to give birth. She has said that she will be working from home for the remainder of the season.

Sue Roethel, a long-time chief steward for the SCCA, has passed away. Roethel was one of only two SCCA members to have earned all three of the organisation's top awards – the Barnato, the Morrell, and McGill awards – and is said to have been the first woman to take on the chief steward role at a professional motor racing meeting in the United States.

Greg Ives, the crew chief on the No.88 Hendrick Motorsports car in the NASCAR Cup Series, was fined $20,000 and suspended for one race after the Chevrolet he tends was found to be running with the lug nuts improperly installed at the Darlington Raceway round of the championship.

Formula E champion driver **Lucas di Grassi** has been named CEO of Roborace, the autonomous race series that's to support FE in future seasons. Roborace demonstrated its DevBot test car at Marrakech, Buenos Aires, Berlin, New York and Montreal during the 2016/17 FE season and aims to continue its development throughout the 2017/18 season.

Roy Lunn – who is known for his part in Ford's GT40 project, which he oversaw – has died at the age of 92. An accomplished engineer, and also an RAF pilot during WWII, Lunn was responsible for a number of well-known automotive and motorsport projects, particularly for Ford in the US in the 1960s.

NASCAR Cup outfit Joe Gibbs Racing switched the pit crews from its No.19 car to its No.18 car as the series went into its Playoffs period in September. The No.18 Toyota, driven by **Kyle Busch**, qualified for the playoffs, but teammate **Daniel Suarez**, who is the driver of the No.19 JGR entry, did not.

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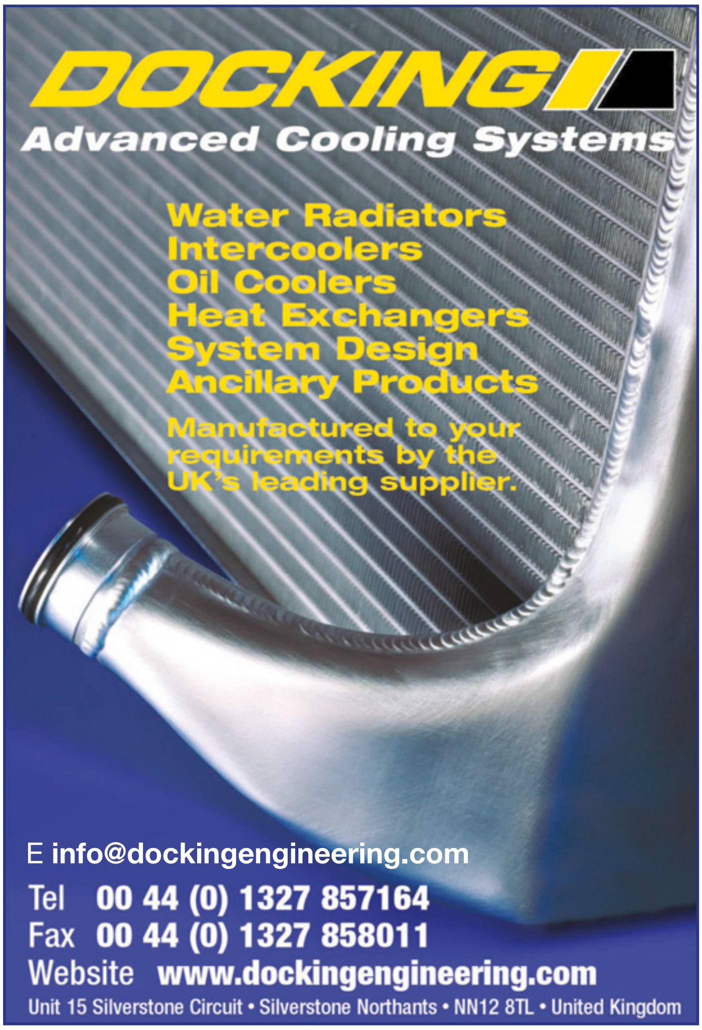
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European Formula 3 to go single-make in 2019

F3's long history as an open formula is to come to an end in 2019. Dallara's ubiquitous F312 is pictured

The FIA has confirmed that the flagship Formula 3 European Championship is to be a spec series from 2019 onwards.

This long-expected change was voted in at a World Motor Sport Council meeting in late September. Although it has not yet been confirmed, it's believed the new single-make category will take its place on the Formula 1 support bill alongside F2, probably replacing GP3, in 2019.

The car will be powered by a 350bhp engine, a big hike on F3's current 200bhp, and the FIA has invited racecar constructors to tender for the chassis contract.

While Formula 3 has always nominally been an open formula it's effectively been a Dallara lock-out for many years now, with the occasional interloper such as Mygale, Lola-Dome and most recently Arttech..

Grids for the new championship will be limited to 24 cars with eight teams running three cars each, while testing will be restricted in an effort to keep budgets down – current European Formula 3 base costs are between €600,000 and €750,000 a season.

There is also to be new regional F3 categories, which will be similar in concept to FIA Formula 4, where each series would be one-make, though using its own chassis/engine package. These are to be in the 200 to 240bhp-plus power range, very much like the MSV-run BRDC Formula 3 Championship in the UK and the recently announced US F3 series (see foot of this page).

SEEN: Megane TCR

Vukovic Motorsport has unveiled the Renault Megane TCR that has been designed and built by the Swiss-based company with the blessing of Renault Sport. 'The car has been developed to optimise the chassis qualities of the production model for an ultimate racing use,' it tells us. 'The combination of the standard suspension layout with the chassis optimisation on torsion and strength provides a large set-up potential.'

The outfit has attracted a number of technical partners, it says, including Bosch Motorsport for the electronics; 3 MO for the transmission; KW for the suspension; OZ Wheels for the rims and Lehmann Motorentechnik for the development of the 1.8-litre race spec engine.

BMW launches M8 GTE for WEC, IMSA and Le Mans

BMW used the Frankfurt show in September to launch its much-anticipated M8 GTE, which is to be campaigned in next year's GTE Pro division of the World Endurance Championship, in the IMSA series in the US, and at the Le Mans 24 hours.

The car will make its race debut at the 24 Hours of Daytona in 2018 in late January.

'The BMW M8 GTE is our new GT flagship and will go head to head with the strong opposition in this sector,' said BMW Motorsport director Jens Marquardt. 'The FIA WEC and the IMSA series in North America are a top competitive environment for our new challenger.

'With the BMW M8 GTE, we are bringing cutting-edge technology to the top international class of GT racing, whilst at the same time tying in with our tradition at Le Mans.' Marquardt added. 'The development of the BMW M8 GTE is on schedule, and we can hardly wait to see the car challenging for victories in 2018.'

The M8 GTE marks a return to Le Mans for BMW, which was last seen on the grid at La Sarthe in 2011, when there was an M3 GT2 in the field. Its best result at the great race was in 1999, when Yannick Dalmas, Joachim Winkelhock and Pierluigi Martini won in a BMW V12 LMR. The McLaren F1 GTR, powered by a BMW engine, had previously triumphed in 1995.

QUICK SPEC

BMW M8 GTE

Engine: 90-degree V8 with BMW TwinPower turbo; 3981cc; 500bhp at 7000rpm.

Body: Composite body with carbon core and DMSB-approved safety roll cage; CFRP outer shell with quick-change concept.

Chassis and suspension: Double wishbones on front and rear axle; 4-way adjustable shock absorbers at front and rear; anti-roll bars.

Transmission: 6-speed sequential motorsport gearbox; electric paddleshift system; limited slip differential.

Plans for all-new US Formula 3 series announced by SCCA and Onroak

The organisers of the US Formula 4 Championship are set to launch a new American Formula 3 series along the lines of the FIA's new vision for regional F3 (see lead story, top of page).

The championship will use an upgrade of the current Crawford/Onroak chassis – called a Ligier Crawford JS F3 – and a 270bhp Honda Performance Development version of the new Honda Civic Type-R turbocharged K20 engine.

The series is to be promoted by SCCA Pro Racing, as is US F4, and the car will be officially unveiled at the US Grand Prix in Austin on October 19.

'SCCA Pro Racing's introduction of an FIA F3 race series is a great opportunity for our partners and SCCA Pro Racing to reset the current paradigm of open wheel racing in North America,' said Steve Oseth, vice president/general manager of SCCA Pro Racing. 'Its introduction, combined with the steps above and below the F3 series, will work to greatly lower the running costs of open-wheel racecars.'

Ligier Crawford JS F3 is based on US F4 car

Max Crawford, general manager of Onroak Automotive North America, said: 'The F3 race series will feature the next generation of all-new FIA racecars, the Ligier Crawford JS F3, designed and manufactured in the United States, at Onroak Automotive North America's headquarters in Denver, North Carolina. The Ligier Crawford JS F3 is the next step up from Onroak Automotive NA's successful F4 car.

'The design team in Denver, NC, has worked comprehensively with the FIA on implementing all the requirements for the new generation of Formula 3 racecars, and this has enabled us to produce the new car at a level of performance and safety that leads the world,' Crawford added.

AUTOSPORT INTERNATIONAL
THE RACING CAR SHOW

Opportunity knocks

If you're looking for a career in motorsport engineering then ASI in January is simply a must-attend event

The face of motor racing is changing rapidly with the arrival of electric and hybrid systems in the past four years. In Formula 1, the World Endurance Championship, Formula E and the new Electric GT Championship, which will start in 2018, it appears that this technology is here to stay, and that means a whole new skill set to be learned for budding engineers.

For instance, in the German Formula Student competition in the summer of this year, engineers were already working on driverless car technology, and the UK competition next year will feature a category for autonomous cars, too.

That is not to say that the traditional technology is going to become less relevant. There are huge gains in efficiency that need to be found in the internal combustion engine, and CEOs of major car manufacturers have highlighted that there is still a future for gasoline and diesel technology.

All of this is just in the drivetrain technology, but throughout each racecar there are also opportunities to work with new materials and technologies, and companies are looking for young and talented engineers to do just this.

Motorsport companies are looking for the very best young and talented engineers

Recruitment drive

So it's good to report that at the Autosport International Show, visitors considering a future in motorsport or performance engineering will find a careers and education area, in partnership with a new recruitment platform, Motorsport Jobs. Each year, universities, colleges and specialist training companies alike all offer advice on how to find a route into the industry. New for 2018, this area of the show will also incorporate the Talk Shop stage, where experts from a range of disciplines within the industry will share their advice and offer insights. Motorsport Jobs will be just one of the exhibitors which will be taking the stage over the course of the event, talking about how to recruit in the digital age.

Meanwhile, throughout the Autosport Engineering Show, held once again in conjunction with us, *Racecar Engineering*, top firms will be in attendance not only looking to do business, but also looking for new young talent. As a student or as an engineer looking for a career in motorsport, don't forget to bring your CV, business cards, and make sure you've studied the show layout to see where the primary companies you want to visit are located. Bring your best sales pitch, too, and make sure you have knowledge of the companies you want to speak to.

Kate Woodley, show director, Autosport International, said: 'With the motorsport industry employing close to 50,000 people throughout the UK, this chance for prospective students and employees to meet such a wide range of companies and further education providers is invaluable.'

For a full list of exhibitors, visit the official website www.autosportinternational.com.

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11 to 14 JANUARY 2018

PUBLIC OPENING TIMES:
Saturday: 9:00am to 6:00pm
Sunday: 9:00am to 6:00pm

NEW FOR 2018, child ticket prices for those under 16 have been reduced. Full ticket price information is as follows:

Standard: Adult £35pp, Child (6-15yrs) £17

Ticket includes entry into Autosport International, the Live Action Arena and Performance Car Show (children under five years of age go for free). Ticket price includes the £2 booking fee per ticket.

Paddock Pass: Adult £46pp, Child (6-15yrs) £27.50pp

Ticket includes entry into Autosport International, the Live Action Arena and Performance Car Show (children under five years of age go for free). Access to backstage Paddock area in the Live Action Arena, Paddock Guide and access to driver autograph sessions.

Family Pass: £87 (2x Adult and 2x Child of 6-15yrs).

Ticket includes entry into Autosport International, the Live Action Arena and Performance Car Show. Valid for standard tickets only. The price includes booking fee charges.

VIP Club: £127 (no VIP Child ticket available).

Ticket includes entry into Autosport International, the Live Action Arena and Performance Car Show. In addition VIP Club includes free parking, seat at VIP enclosure in the Live Action Arena, complimentary drinks and canapes, VIP gift bag and much more.

For more, visit www.autosportinternational.com

Autosport Engineering is a great place to meet future employers. But don't forget to take your CV and business cards

The Performance Car Show tunes up

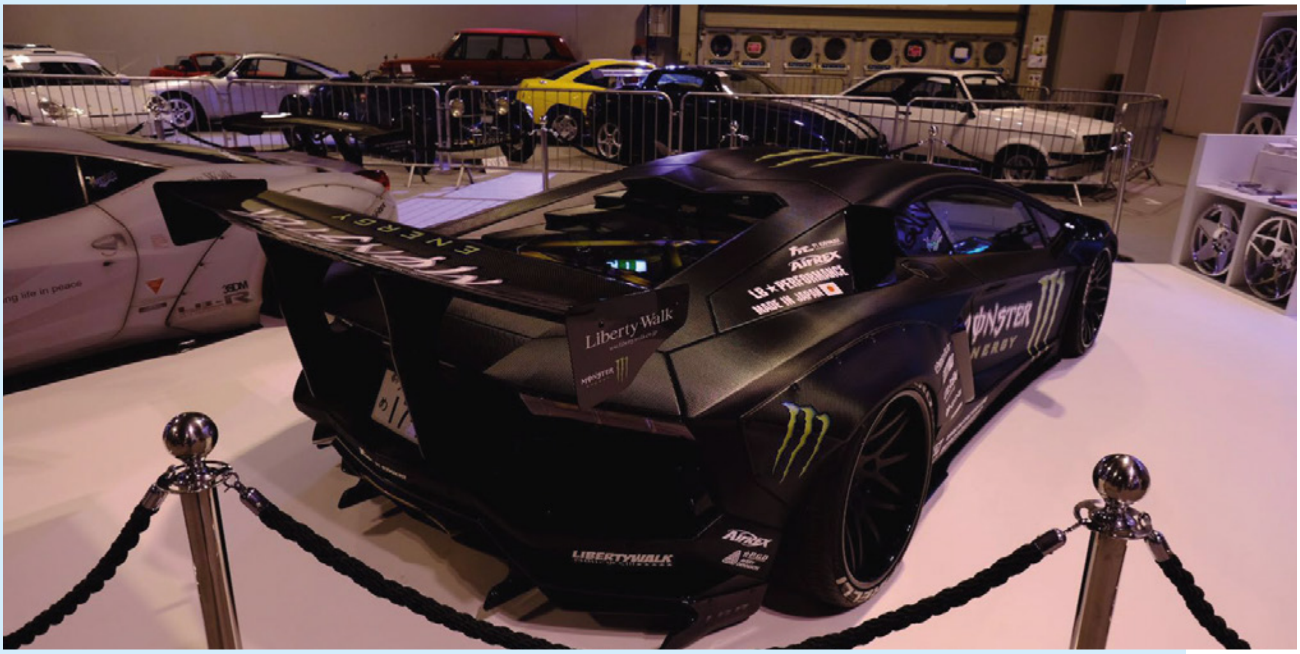
Once again the Performance Car Show area will feature a range of tuning industry-leading exhibitors who will showcase the latest products and technology, including numerous companies new to the event.

Among the companies attending is Knight Industries, which is the first UK company to offer both performance tuning and body styling upgrades for the MG3 and MG6.

Meanwhile, Newquay-based Celtic Tuning specialises in the development of engine management software, and will also be at the show, while joining it in the new show area will be Steeda UK, which provides performance parts, tuning and upgrades for the Ford Mustang, Focus ST and RS, Mondeo and Fiesta.

Also exhibiting is Magic Motorsport, from Italy, one of the world leaders in electronic programmers for ECU and TCU repair and tuning.

Keep up to date with the latest content at www.performancecarshow.com



The Performance Car Show, which runs alongside Autosport International, highlights the work of the tuning industry and is packed with very cool cars

Exhibitors and products at ASI

Advanced Fuel Systems

This specialist fuel safety cell manufacturer creates products for the marine, motorsport, aerospace and defence sectors.

One of its most notable recent projects is the monolithic FIA-approved fuel cells seen in the Bloodhound SSC car. The supersonic car, which has been designed to break the 1000mph barrier, has four of Advanced Fuel Systems safety cells, each containing 550 litres of jet fuel. The pumps are capable of delivering fuel at a rate of 20 litres per second to the jet engine.

Uniquely, Advanced Fuel Systems simultaneously manufacture both composite materials and finished fuel safety cells, so the shape of the cell can be moulded and optimised to customers' exact requirements. All current products offer improvements in durability, increased flexibility and weight reduction.

Visit Advanced Fuel Systems on **Stand E481** and read more about Advanced Fuel Systems pursuit of breaking records at: www.advancedfuelsystems.com/recordbreaking

OBP Motorsport

OBP Motorsport is now offering new aluminium fixed and adjustable camber top mounts.

The high-performance premium motorsport parts specialist has racing in its blood, providing parts like the V2 bias brake assemblies in the Mini Challenge cars, right through to electric car pedal boxes for Formula E teams and the Pro-Race Pedal Box in the VUHL 05RR raced by four-time Formula 1 champion Sebastian Vettel at this year's Race of Champions.

The latest top mounts from OBP Motorsport are manufactured out of carbon steel with a PTFE lined spherical bearing, which replaces the standard rubber mounts, improving the feel and precision of cars on track, the company tells us.

There is a choice of well-crafted 10mm, 12mm or 14mm Inserts created from lightweight aerospace grade aluminium.

To find out more about this interesting motorsport company visit OBP Motorsport at **Stand 7545** at Autosport International or check out all its kit at www.obpltd.com

Alcon

Highly acclaimed motorsport brake and clutch company Alcon has launched a brand new bespoke armoured vehicle brake caliper. The new CIR55 has been designed and developed to fit 8x8 type military vehicles operating at 30 to 40-plus tonne, incorporating a custom-designed eight-piston, four-pad configuration with an option for either 60mm or 64mm pistons.

The UK-based company has been sought out by global special forces manufacturers to provide bespoke material for the military industry, these companies include BAE, Ricardo and Jankel.

Increasing braking performance and reducing weight, the CIR55 is a cost-effective alternative to other products on the market, Alcon says. The bespoke caliper immediately offers a weight reduction of 50kg per vehicle and upgraded cooling. It boasts 11.5 per cent larger piston area; 34 per cent more pad area; 33 per cent additional torque capacity; and all delivered with a seven per cent weight saving over the nearest market leading alternative, we're told. www.alcon.co.uk

Pit equipment
Gunning for fast wheel changes

Sector expert Paoli has brought a new wheel gun on to the market, called the Hurricane.

The company says: 'The partnership with highly skilled technicians and top racing teams has allowed the development of an innovative, greatly performing and technologically advanced product.'

The Hurricane has been designed using CFD (Computational Fluid Dynamics), which, Paoli tells us, has allowed it not only to sharpen up the performance of the motor, but also to create a unique, fresh and well-finished design.

There's some nice attention to detail, too, particularly in the use of new technologies in the production area, such as in precision casting, which is intended to assure internal channels dimension repeatability and to guarantee homogeneity in performance.

Performance on loosening nuts has increased by 10 per cent with the Hurricane, Paoli tells us, while on the tightening side it has remained intentionally unchanged compared to the previous models, in order to avoid excessive tightening.

The new Hurricane is also suitable for Paoli's new Fast Shift system, which allows an immediate reversal to save time between the removal of one wheel and its replacement with a new one.

The selection of materials such as carbon, aluminium and aeronautical steel makes Hurricane a fast and extremely reliable wheel gun, Paoli says.
www.paoli.net

Fire suppression
Safety in numbers

Lifeline's fire suppression systems for 2018 and beyond puts driver safety into a new dimension, the company tells us.

With even faster and more efficient deployment of extinguishant, all systems have been tested to conform to either FIA Technical list numbers 16 or to 52, making them the most advanced in the world, Lifeline says.
www.lifeline-fire.co.uk

Heat management
Taking the heat

Hauck Heat Treatment provides a comprehensive range of heat and surface treatments to the engineering industry from multiple national and international locations.

It holds most major quality approvals which enables it to support customers in specialist markets including aerospace, motorsport and automotive. Check out its website at:
www.hauckht.co.uk

Electronics
Get yourself connected

Souriau 8STA connectors are designed for applications where high performance, small size and light weight are key.

They are used extensively in motorsport for engine control, communications and harnesses. Lane Motorsport can supply 8STA connectors, caps, gaskets, nut plates and heat shrink boots on very short lead times.
www.lanemotorsport.com

Set-up equipment
Wizzard kit

The innovative laser based wheel alignment system Setup Wizzard from CP Autosport ensures perfect suspension measurement of toe, camber, corner weights and ride height at the race track.

It can be used in almost every possible racing series there is, says CP Autosport, from GT3 to TCR, and from rallying to Formula E.
www.cp-autosport.com

Engine performance
The gold standard for cold air

To assist with keeping your engine's intake charge as cold as possible DEI has introduced the Cool Cover Gold air tube cover kit.

Cool Cover Gold is manufactured from high temperature metalised polyimide lamination, bonded to a robust heat-treated glass fibre base material that will protect and keep components cool in the hot engine compartment environment.

Cool Cover Gold features a hook and loop closure along the open edges for easy installation and is able to reflect direct heat up to 800degF (427degC) making it the perfect choice to keep air intakes cool and protected, DEI tells us.

Cool Cover Gold will fit air intake tubes up to 28in (71.1cm) long and 3in to 4in (7.62cm to 10.16cm) in diameter.

It is easy to cut or trim as necessary and at just .031in (0.7874cm) thick takes up negligible space around the intake tube.

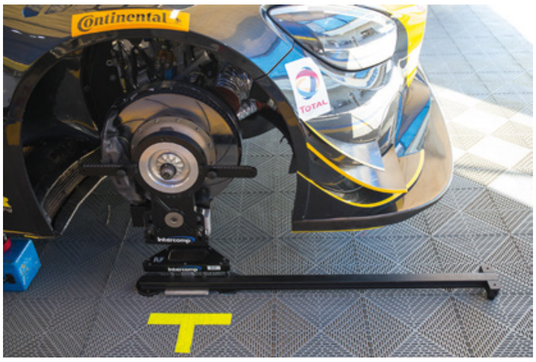
Cool Cover Gold has been tested and proved to FSTM 191.5100 and ASTM D1117 standards.

You can order this as part number 010486 at $83.55 plus shipping and import tax directly from DEI in the USA, or simply find your nearest dealer on the website below
www.designengineering.com

Set-up equipment
Plating up

Here's the RFX Wireless Precision Hub Plate Scale from Intercomp.

The scale measures corner weights with a bolt-on hub plate. Consistent and repeatable measurements are a reality thanks to its ball transfer bearings, which allow for up to 360 degrees of rotation.
www.intercomp.com



Sensors
Izze too hot?

Introducing Izze Racing, a US-based motorsport electronics manufacturer.

It specialises in the design, production, and distribution of multi-channel infrared tyre and brake temperature sensors. These have up to 16 channels per sensor at 32Hz via CAN and come either as a fully sealed aluminium enclosure ($300) or as PCB assembly ($175).
www.izzeracing.com

Electronics
Deutsch tech

The Deutsch ASDD Series connectors from TE Connectivity (TE) are a revolution in motorsport connector design, TE says.

They have almost double the number of contacts of standard equivalent shell sizes, we're told, and were developed to bring high density and high performance into the smaller wire sizes racing teams prefer.
www.te.com

Fluid transfer
Right tools for the job

Aeroflow is renowned for its premium quality, high performance fluid transfer products, which use lightweight alloys in their construction. It now provide the tools to fit them.

Aeroflow components are capable of repeated assembly and disassembly without degradation, providing these correct tools are used. The standard or double-ended wrenches provide a perfect fit and are made from materials with the same hardness rating as the components they are designed for, so they won't mark your fittings.

All Aeroflow aluminium wrenches are hard anodised black and size stamped. The spanners and wrenches are available individually or as a seven-piece set.
www.aeroflowperformance.eu

3D printing
The tough stuff

Windform SP composite material is the latest thing in 3D printing technology.

Windform SP is a carbon fibre reinforced composite material for functional 3D printing applications. It is a very light and strong material that can withstand the loads and vibrations of high speeds and rough tracks. It shows how far the technology has come that now this can be used for applications such as rallying.
CRP-group.com

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All change at the top

It wasn't widely reported, but the departure from the FIA of Bernard Niclot, the highly-regarded now former head of Technical at the organisation, is big news. Right now, Formula 1 and the WEC are looking to finalise far-reaching regulations that will bring stability and which will be embraced by teams and manufacturers, and this now falls under the guidance of Gilles Simon.

Niclot joined the FIA in 2010 and was responsible for ushering in the hybrid regulations that former president Max Mosley considered critical for manufacturers to meet their corporate responsibilities. Whether or not that sop to the manufacturers was actually the right thing for the sport is a much-debated topic. For some manufacturers, such as Porsche, the link between race and road has become strong, particularly in terms of personnel. In terms of actual technology, and the improvement of racing, the energy recovery systems have taken a back seat and are not reported, except in case of failure.

Yet, perversely it could be that the hybrid regulations, and the speed of change from 'conventional' power units to a more powerful electric element, may have caught the FIA by surprise. The rapid rise of manufacturer interest in Formula E, the announcement of plug-in recharging technology at Le Mans (now rescinded) the rapid advancement of hybrid capability in LMP1 and F1, Dieselgate in 2015 has certainly changed the look and feel of world championship racing.

An amalgamation of LMP1 and F1 engine rules is unlikely, but it is clearly on the table

Niclot was charged with bringing in the regulations to F1 and the WEC, and with Fabrice Lom, they also brought in fuel flow meters, introduced a new engine concept to F1, as well incredibly powerful hybrid systems into LMP racing. There were mistakes, clearly, including the accuracy of the fuel flow meters that ended up in court at the first grand prix of 2014, and more recently the balance of performance debacle in GTE that reached critical levels in 2016 and led to a whole new automatic system. It was an underestimation that LMP1 manufacturers would hit the 8MJ top limit so quickly. Most recently, Niclot was given the task of implementing the 1km on electric power at Le Mans each stint, but that plan was not clearly thought through as detailed in RCEV27 N8.

He was also tasked with working with the safety department to improve head protection in an open cockpit, and the Halo design seems to be the best that could be considered, as an elongated windscreen made drivers feel sick. It has been an interesting journey on which he has been, and arguably he was at the heart of the most technically advanced regulations ever introduced into the sport. His legacy will go far beyond the 2017 season, however.

As FIA head of Technical, he has also been in a key position to try to sort out the future of the engine regulations in both F1 and LMP. His successor has plenty of experience with hybrids and future technologies. Simon worked with FIA president Jean Todt at Ferrari in 1993 in the engine and electronics department; under Todt investigated new energies and environmentally friendly technology in motorsport in the FIA, and then went to work for engine manufacturer PURE, although its unit never made it into the sport. He was then hired by Honda but recently parted with the manufacturer to take up his place in the FIA. On paper, he is an ideal candidate and is clearly well connected. The FIA did not reveal why Niclot left and had not even prepared a statement regarding his departure, only the arrival of Simon into post.

Formula 1's 2021 engine rules are coming along, according to sources. It seems that twin turbo 1.6-litre engines, minus the exhaust energy recovery system (MGU-H) and with more from the MGU-K, while not decided are likely. Fuel flow will be increased, although how that will fit with the fuel limitation that plays a factor in certain races is yet to be revealed. But the key for them will be to improve the racing while also attracting new manufacturers.

For this, the FIA and the ACO are working together to try to finally amalgamate the F1 and WEC LMP1 engine regulations. Could Niclot's legacy be that manufacturers can, finally, switch between programmes or, better yet, run parallel programmes and amortise the cost? Under Bernie Ecclestone's rule, this could never have happened. There is only so much sport that can be broadcast over the weekend, and Bernie's position was always to have F1 as the motor racing product, and it had to be protected at all costs. That meant, for example, that manufacturers were encouraged, in the early 1990s, to build 3.5-litre engines for sportscar racing, that led Peugeot to enter F1. Under the new management, could this now be consigned to history, and manufacturers actually encouraged to run other programmes using the same powertrain?

Clearly, the demands are different and the regulations are too far apart for this to be a certainty and such an amalgamation of rules seems unlikely, but is clearly on the table and could benefit both series. It would clearly explain why the ACO is so against adopting DPi regulations, despite pressure from Ford and Lamborghini to do so.

ANDREW COTTON Editor


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