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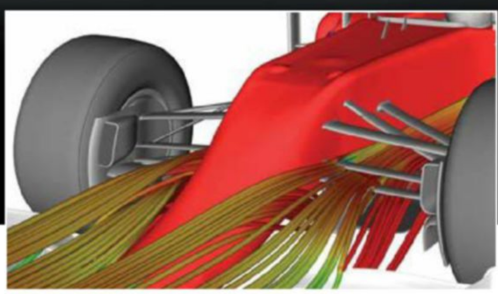
Lifting the lid on the Ferrari-inspired design that's shaken up F1

Canadian Formula 4

The home-built racecars spicing up entry-level racing



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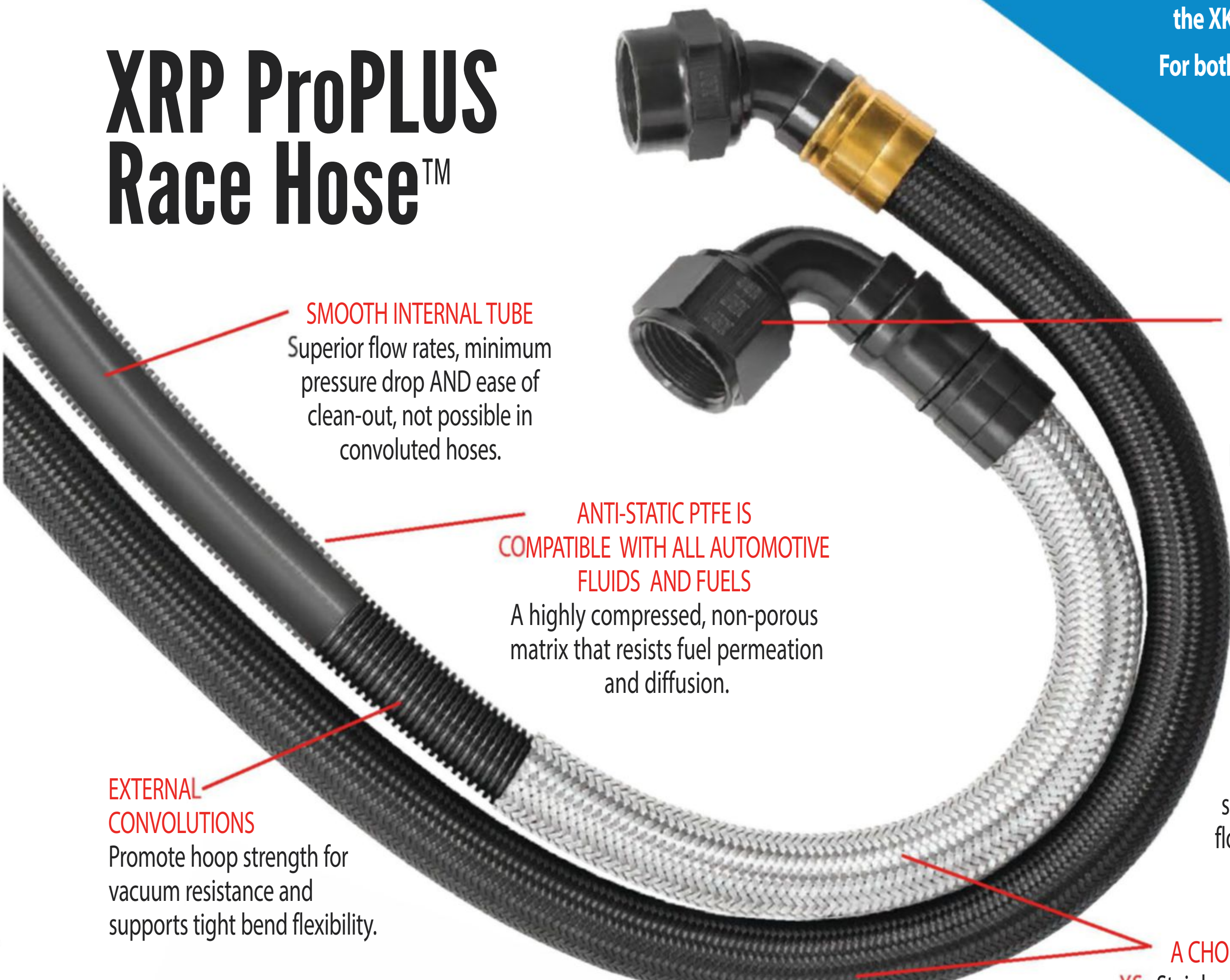

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THE XTREME IN RACECAR PLUMBING

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Thunder steer: beneath the heavy metal there's some very clever race engineering involved in truck racing. Turn to page 44 to find out more

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The pace of change

In an ever-faster world what does the future hold for the business of speed?

It is a sobering thought that when Wolfgang Amadeus Mozart was my age, he had been dead for 36 years. But there is an advantage to longevity; one does get to see the amusing circus that is human existence, and the constant return to scenarios we have seen before.

Politics does go off in unexpected directions, some of it due to the usual mess caused by good intentions having unintended consequences, one not being paranoid and adhering strictly to Hanlon's dictum: 'Never ascribe to malice that which is adequately explained by incompetence.'

The US, and the UK in particular, that being our Anglophone sphere of interest, but also other countries, are a good example of what that can bring, and the ensuing mess that seems to be the status quo is more about trends in society, demographics and the march of, what shall we call it, progress?

It really boils down to change, and the spread of ideas happens much faster and has quicker consequences than in the day of the horse-drawn post, plus information about reality is more accessible to a bigger slice of the public ('Reality is that which, when you stop believing in it, doesn't go away,' said Philip K Dick) despite the efforts of the popular press and spin doctors.

Net benefits

The sheer speed and the huge volume of information sparks off innovation and new ways of doing things. When major retailers are being slayed by internet shopping, and you can call an Uber cab to collect you at a good price, nobody questions the fact that all that has emerged and become dominant in a surprisingly short period of time.

The other side effect is that several generations of human beings now suffer from phototropism, also known as vidiocy – the irresistible compulsion to pay attention to lighted screens.

The internet has gone from being a Net, created in 1969 for the US defence department. Funding from the Advanced Research Projects Agency (ARPA) allowed researchers to experiment with methods for computers to communicate with each other.

The corollary of AI and deep learning will impact all sectors and activities at a bigger rate than the industrial revolution, and all this is happening 10 times faster and at 300 times the scale, thus it is a 3000 fold disrupter. One does not need to remind you of the effects of the revolution in society, for nations and commerce, not to mention conflicts and other interactions.

And that poses a problem, as for society in general there has been opposition to every innovation in the history of man, with the possible exception of the sword, a clear example of 'the devil you know', and a blissful ignorance of the speed at which things happen.

The view of the past being inevitably seen through rose tinted glasses, there will be a tendency to either want to go back to it or at the least to want to keep things as they are. On the other hand, there is a growing group of people who are against the status quo, either because they feel they are being left behind or because it does not suit their interests, or they are unhappy with the product.

The pessimistic view would be that machines will take all the jobs

XPB

With the rise of computers, the ancient art of wielding a spanner may be in decline. But just how much will AI affect the future of the sport's workforce?

The results of this are reverberating in politics and, want it or not, when you are embedded in a society you, too, will be affected by it.

Bling dynasty

We have the same situation happening in motor racing. The previously successful growth of the sport, at least in the upper echelon, generated an industry, which really should thrive on innovation, and yet it is still governed by obsolete mind-sets and business models.

Perception of cause and effect is sometimes clouded. How will F1 tyres be seen by the consumer if it is known that they are Chinese? (Pirelli has been owned by ChemChina since 2015), a fact that has escaped most race fans. The particular needs of China and India for transport in their environment will eventually re-shape the car into something we probably would never develop in a European or American setting. Money has long been known to provide unusual bedfellows.

Speaking about money is now civilised, but perhaps it is really an indication that the level of civility has declined. The flashing of bling and flaunting of expensive toys is not intrinsically linked to the value of what you have, but more an indication of wealth that shows you can buy it.

The fact that it pushes unwary blingsters into debt is something they will rue later, and provides incomes to leech-like investment groups that suck money from several sources, including motor racing. They not only worship the golden calf, they barbecue it for lunch.

Presumably the invisible hand of finance available will eventually redress this, but I'm not holding my breath.

Race relations

We shall now venture into the minefield of race and religion. This, of course, has had a long and illustrious story, probably beginning with the first time dinosaurs had saddles thrown on their backs and early humans raced them to show their superiority. This scenario only holds if you are a religious fundamentalist and believe dinosaurs and men are coeval (of course, this paragraph covers these two subjects, religion and race. You didn't really think I would touch those two third-rail subjects in earnest, did you?).

So what is the outlook for those starting out in motor racing? The pessimistic view would be that machines would take all the jobs. However, the opposing view is that technology actually eventually creates more jobs than it destroys.

Looking at an average team in any class now, the clear response is that actually working hands-on on a vehicle is now turning into the minority, there being a increasing number of software dedicated work in all departments. IT biased groups are increasingly doing even the logistics of the team. Precisely the ones that will be impacted by AI.

One would predict that in the future, for those who are in the schooling process, that it will not be a introduction into working practice, but a life-long endeavour. You just have to keep on being curious and learn as much as you can.

Failing the driving test

A visit to the recent Silverstone test highlighted some key faults with modern F1

That rarest of happenings these days – a Formula 1 test – took place at Silverstone after the British Grand Prix. Accordingly I took the opportunity on the Tuesday to catch up on seeing the latest machinery first-hand.

The morning had dry running. The initial impressions of amazing braking and acceleration registered as usual, more so than the cornering speeds. LMP1 cars earlier in the year were more impressive, even if this is illusory (but they do have a lot of downforce and much better tyres).

After a while, however, watching became rather boring frankly, except when a driver (rarely) overstepped the limit. As has been a widespread lament from aficionados for a considerable time, there can be no question that the engineers have severely reduced the spectacle. These cars are just too tamed, too clinical. This is an unchallengeable fact. At least the exhaust note was better than when last heard, but still not the noise that gives goose bumps, as used to be (and should still be) the case.

Damper testing

Rain fell in the afternoon, which made it more interesting. Not because the cars moved around more (sadly they didn't), but because, spectating overlooking the tight Vale/Club chicane before The Wing pits complex, the differences in the exhaust notes were very noticeable. With track conditions changing, together with varying tyre choices and of course no way of knowing the power unit modes or fuel loads at any one time, it was pointless corner-timing, but experienced eyes and ears are still sufficient to spot certain features.

Not surprisingly, the Mercedes power unit, regardless of chassis installation, was the smoothest and most-efficient sounding, more like a road-going supercar. No apparent wasted energy here, either on the overrun and part throttle, or on acceleration, just a seamless transition all through. In contrast, the Honda in the McLaren was popping and banging and changing note through the throttle transition phase, with a completely different sound – rather waspish – when the revs first picked up. One very much gained the impression of far from perfect power and torque control throughout the process, and of a waste of usable energy as a result. A lot of work still to be done here, clearly. Perhaps Ron Dennis, the suggestion of him attending a driver/engineer briefing having caused much mirth from Jenson Button on TV, should listen to his drivers first-hand, not through the medium of engineering reports wherein important details can be lost?

The Renault unit was in-between, closer to the Mercedes with a sometimes flat but deeper note but still not as smooth or efficient-sounding. As for Ferrari's power unit – well, possibly my imagination – but it seemed to be what you'd expect from the Italian stallion, with a note of urgency and a bit of a growl. Overall, one could understand, even from this one corner, the advantage that those drivers equipped with progressive Mercedes torque enjoy over their rivals. Oh, and the banning of traction control – there's more than one way to get around regulations and it might be called another name, but traction control there certainly is. What would you describe, for instance, software-cancelling of three of the six cylinders, rather than the driver using his right foot, when limited torque delivery is required? Give me a break!

XPB

Unfamiliar helmet, familiar story: Esteban Ocon at the wheel of a Mercedes at the Silverstone test, where the sight and sound of F1 failed to impress

Torque radio

Between the showers topics included the level of information permitted by radio communication. To many – but not to all I spoke to – it's essential that the driver should drive the car unaided. At the recent British GP, Nico Rosberg should have had the nous to change gear through seventh straight to eighth without radio intervention from his engineer. Other than when a real safety issue is involved, or to avoid a certain DNF, messages to drivers should perhaps not contain more information than can be put on a regular-size pit board. In the case of Lewis Hamilton at Baku, his confusion over settings surely indicates that the number of functions that the driver can alter should be much more severely limited, also the variety of 'sub-functions'. For example, if the argument is that these very complicated power units need to have multiple adjustable engine modes available to the driver, then the answer is to design them so that they don't. Same for everybody, and maybe a performance-leveller. This needn't interfere with driver talk being aired, especially choice Raikkonen-esque comments, which ought to be maintained because we all enjoy this.

Tech tonic?

There's a fairly recently-established opinion that motor racing has to be very hi-tech to attract younger fans. I don't entirely buy that. LMP1 and F1 in particular do need a certain level of advanced technology, but not to the extent of further degrading the spectacle. Among the least technology-focused yet popular sports worldwide are football and basketball, and I don't see any diminishing of youthful interest in these. If more technology is needed it should better be concentrated, as has been argued for a long time, on how the sport is presented.

The criticism over the Silverstone GP starting behind the safety-car highlights a fundamental subject. This procedure now seems to be the norm for every 'declared-wet' race, ostensibly for drivers to note surface conditions prior to going racing. This appears to have been an unannounced policy recently made by the FIA, because the same decision was taken for the start of June's Le Mans 24 hours (the first time ever under safety-car).

But unless the track is obviously flooded, what's wrong in allowing two unrestricted reconnaissance laps in advance of the start procedure? This way, the drivers find the puddles okay, the spectators are not denied what is often the most exciting part of the race – a full-on standing start– and it permits wet-weather driver skill to upset the usual order. It's not a new solution, either.

There can be no question that the engineers have severely reduced the spectacle, the cars are just too tamed, this is an unchallengeable fact

Gene-etic engineering

Haas might have scored points in its first grand prix with its VF-16, but being a US-owned British-run team with an Italian-built car using Ferrari parts presents its own problems, as *Racecar* discovered

By SAM COLLINS

‘We don’t have a history to refer back to, just numbers that are floating around in the heads of our people’

Haas enjoyed one of the most successful starts for a new team for many a year. Despite its close ties with the Scuderia the front end of the VF-16 actually looks quite different to the front end of the Ferrari SF16-H

The Haas Formula 1 team was born in a North Carolina steakhouse, when Gene Haas met Italian Formula 1 engineer Guenther Steiner for the first time back in 2010. It was not long after the collapse of the USF1 team, which had been located nearby.

The failure of USF1 actually served as a lesson for many considering an entry into the top level of motor racing, and certainly put more than a few investors off getting involved in Formula 1. But it was also as a direct result of that failure that Haas found himself in that steakhouse. ‘USF1 and Ken Anderson [one of the founders of the stillborn team] kind of lit the fuse of my interest in Formula 1, I went over there a few times and had a look,’ Haas says. ‘Ken asked me to get involved but I felt that I didn’t have the time to commit to it.’ A little over half a decade later and the all-new Haas VF-16 finished sixth in this year’s first F1 grand prix in Melbourne.

The creation and technical model of the Haas F1 team mirrored that of the Haas CNC NASCAR Cup team in many ways. In NASCAR Haas has, since its inauguration in 2002, bought most of its components, including the chassis and engines, from Hendrick Motorsports. It is a model which has delivered two Sprint Cup titles and a host of race wins. Perhaps it is no surprise then that Haas has adopted an almost identical model in Formula 1. It buys in almost the entire car from Ferrari, with the components being of largely similar specification to those used on the works SF16-H run by the Scuderia.

The creation and technical model of the Haas F1 team mirrored that of the Haas NASCAR Cup team in many ways

Taylor two cities

The areas of the car which cannot be purchased directly, namely the monocoque, front impact structure and all the bodywork and wetted surfaces, had to be bespoke. But even here Haas partially sub-contracted the work. Dallara was contracted to design, develop and build the car in collaboration with engineering staff employed directly by Haas. Heading the programme would be Rob Taylor as chief designer. Taylor has a good pedigree in F1, having worked for Ferrari, Arrows, McLaren and Red Bull, amongst others, over the years.

‘When Guenther first called me about the project I didn’t believe him, I thought it was just a chat – and then I found myself with a job,’ Taylor says. ‘I was then in the middle of this very complex web we have weaved for ourselves, with staff in Italy, England and the USA.’

The main focus for Taylor and Dallara was the development of the VF-16’s chassis, and with the unusual approach taken by Haas it provided some equally unusual challenges. ‘The chassis is fairly conventional in design terms but the process to create it differs in that some of our design team come from Maranello,’ Taylor reveals. ‘They are not literally part of the team but what they do has a big impact on what we do; such as milestones like getting the fuel tank defined, a key thing for the chassis design. That’s really the difficult bit about doing things this way. It was like the fuel cell design was being done somewhere else, by someone else, a bit like having a bunch of sub-contractors designing it. It was a double edged sword, using someone else’s fuel cell, you simply have to wait for them to finish it and you don’t see that process. If you were doing it yourself you would see the design change and develop, but all the while you are aware of those things and can react to them, but on this car we were just less aware of what we were going to get and some of it comes as a surprise.’

Half Haas approach

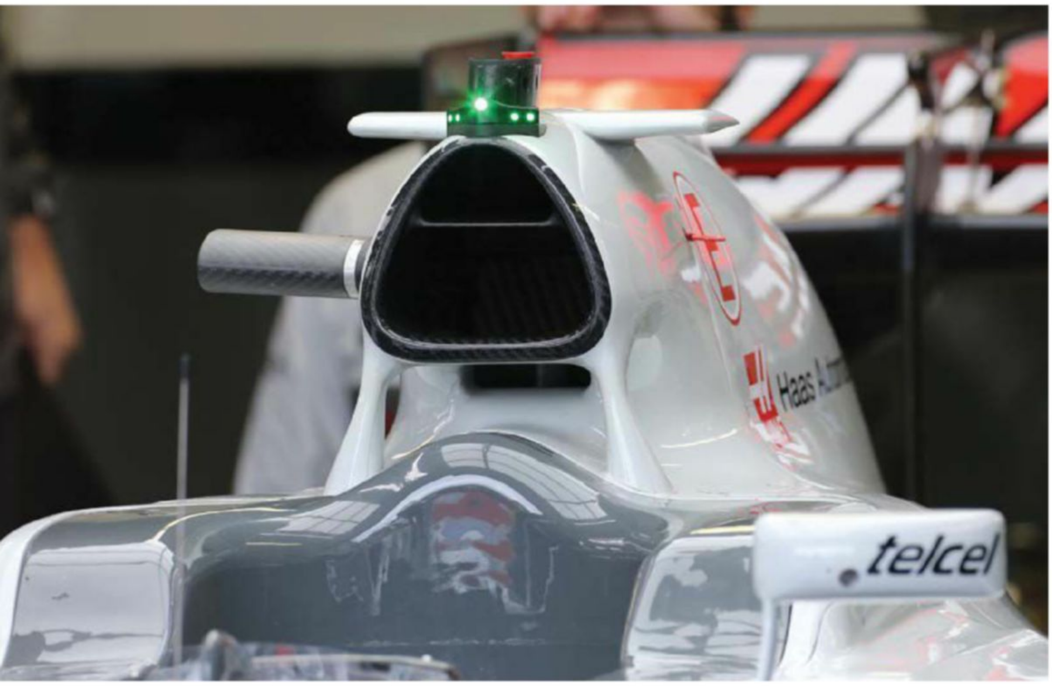
Working with Ferrari, and having most of the major elements supplied, does require a change of approach in the day to day attitude of designing a new car, but perhaps not the process overall, Taylor says. ‘The methodology of design does not change really, you just get fewer snapshots of what you are aiming for. You have meetings in Maranello and design updates, but it’s not the same as being able to walk across the office to the guy who is designing it and look over his shoulder and have a chat about it. It’s challenging in its own way, but it all works.’

The front of the chassis had little or no Ferrari influence in terms of overall shape, and that is obvious when comparing the VF-16 to the 2016 Ferrari. The tub is clearly the work of the joint Haas and Dallara team, which was starting from a clean sheet of paper. Despite this, Taylor claims that there is not all that much in it and that a lot of the tub shape is defined elsewhere. ‘The aero guys chip in with comments round the front of the car, perhaps asking to move the leg box up or down a few millimetres, for

Working with Ferrari and having most of the major elements of the racecar supplied does require a change of approach

example. The suspension guys then also make their own demands, but in general the front of the racecar is really defined by the regulations, as to what shape it is,' Taylor says.

That does not mean that there is no chassis design freedom in modern Formula 1, though. A quick look at the roll hoop designs on display up and down the grid proves that there is. Of particular interest here are the solutions used by Sauber and by Ferrari itself, which share the same power unit. Yet both are very different to each other and to that used by Haas. The American-owned, Italian-built, British-run car, has twin sculpted forward roll hoop supports and three separate ducts, the uppermost of these feeds air to a charge air cooler, the lower one in the hoop provides the combustion air itself, while a third duct below the main intakes is thought to cool some electrical components at the front of the power unit.



VF-16 has twin sculpted forward roll hoop supports and three separate ducts. The uppermost inlet feeds air to a charge air cooler, the lower one in the hoop provides the combustion air itself, a third below these probably cools electrical components

The VF-16 shares much of its engine installation and cooling philosophy with the Ferrari SF16-H (pictured). This is not really surprising as Haas buys most of its components from the Scuderia. Its links with Ferrari caused controversy last season

'The roll hoop is a big test still,' Taylor says. 'It's high up so it's prime real estate for getting weight out of it as a component. With anything that's high on the car, especially rear wings and roll hoops, a lot of the challenge is to take weight out. That means that you never really repeat a roll structure, carrying it over year to year, as you are always morphing it somehow, looking at ways to get weight out.

'We defined what it needed to do based on experience really,' Taylor adds. 'We don't have a history to refer back to, just numbers that are floating around in the heads of people. All we could benchmark against was knowledge and experience, over the years there are numbers that kind of get embedded, which tell you what you expect to see from structures like that.'

Haas you like it

One area where the VF-16 is quite distinctive is with its front bulkhead, following the trend started with the Marussia MR03 of 2014 (and also adopted by Red Bull in 2015 and 2016) the monocoque is fitted with a machined aluminium front bulkhead.

'It comes and goes into fashion, doing it this way, it's nothing new,' Taylor says. 'If you backtrack some years, we saw metallic bulkheads bonded into carbon chassis. It makes some of the carbon parts easier, strangely, as it leads to a re-distribution of the joint lines and gives access to the moulds when you are laminating. So it is a swings and roundabouts situation. In terms of the stiffness and weight of the chassis it is probably neutral compared to a carbon fibre bulkhead.

'One advantage of doing it this way is that it kind of takes away some of the risks involved,' Taylor adds. 'The structure of the front end of a tub is basically completely made up of inserts and adhesive. When you look at the insert count, the front 100mm of the chassis was turning into a solid mass of machined inserts all joined together. So you ask yourself, why not just machine it all together as one single part? We did a crude model in CAD, looked at the numbers, and found that it kind of worked. What we have done is do away with all the separate inserts and replaced them with one big insert. The benefits come all over the place, but not one of them is a key driver. It's just a big billet of aluminium and with modern machine tools it's not really that difficult to do. But as a component it does look very complex.'

The front end of the VF-16 was partially defined by the layout of the Ferrari SF16-H, as both cars share uprights, outboard suspension elements, inboard suspension parts and the

entire brake set-up. This means that just like the red car the Haas has push rod actuated dampers on the front and pull rod on the rear, but the way each uses the hardware is different.

'In that respect we are completely separate to Ferrari,' Taylor says. 'While we have the same geometric structures and hardware we have a totally different knowledge base. That's all our own work and it's been difficult. Selecting tyres was a bit of a problem. But people in the team had knowledge.' But managing the tyres and getting the best out of them has not been entirely in the hands of the Haas and the Dallara engineers, mainly as a result of the hardware all coming directly from Maranello.

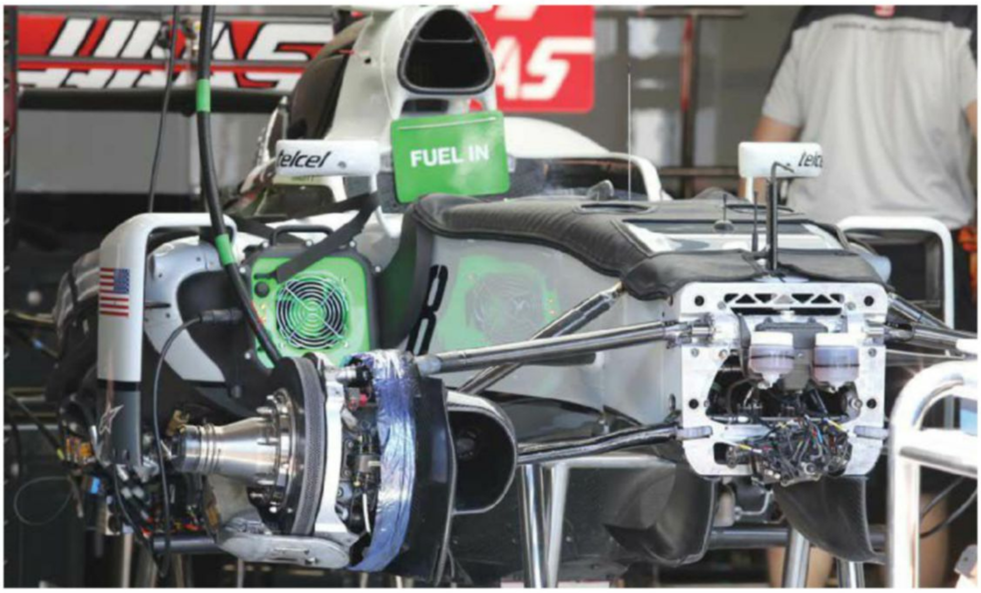
'It was a little bit difficult at first, not being in charge of your timescales, especially with the suspension where you are not using an evolution of something you knew before,' Taylor says. 'But at the end of the day it is still just two wishbones, a rack, some rockers and a push rod, how different can it be? There are differences between different teams, each has its signature bits. Force India, for example, has its spline drive, not peg drive, wheels, that has been something they have been doing for years, but beyond those signature bits, in general most things are basically the same.'

How it Haas to be

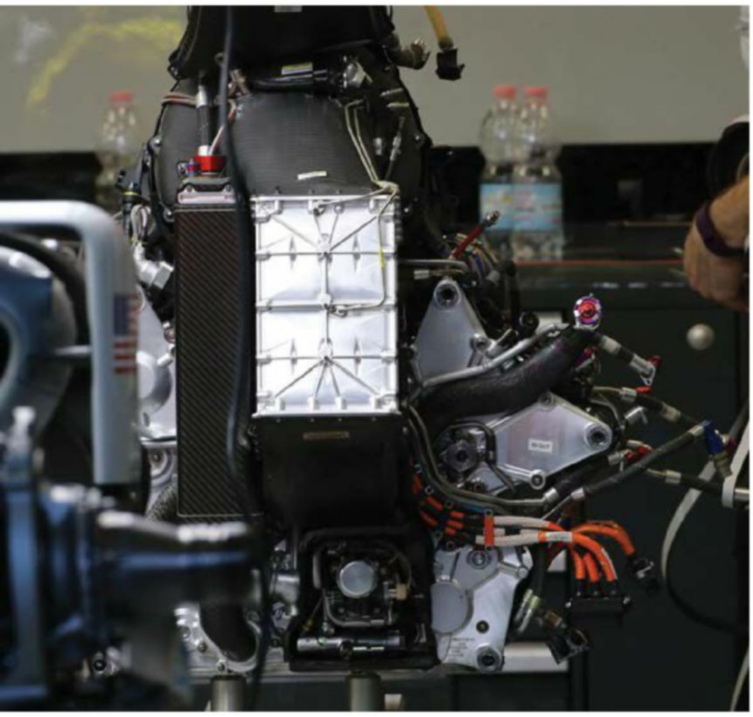
While the exact wheelbase of the VF-16 has not been revealed it is likely to be similar to that of the Ferrari SF16-H (also not revealed). After all, both cars share the complete suspension system and transmission casing. 'When you start a car development, every year you are not sure what your wheelbase will be,' Taylor says. 'There is always an aero guy asking to do an experiment in the wind tunnel to see what might happen if we pushed the wheels forward or something. But there is a generic number, and I would think everyone in the pit lane is within 50mm of that number. There is always a thought about moving the wheels forward or back for one reason or another, push them forward you get an aero benefit, push them back you get a weight saving, that kind of thing. At the rear you have to look at that to re-balance the centre of gravity, so there is always something going on. The point when you decide what to do and stick with it comes surprisingly late, but the reality is that the benefits coming from changing the wheelbase are not that great.'

'The rear half of the car these days is just a whole load of packaging numbers,' Taylor continues. 'The number of coolers and things there are, it is all fairly well crammed in there. There other things like changing the packaging of the cooling system which are more important than the overall wheelbase, the prize for them is much greater than changing that. The wheelbase really is just a number. There are trade-offs which will force you to

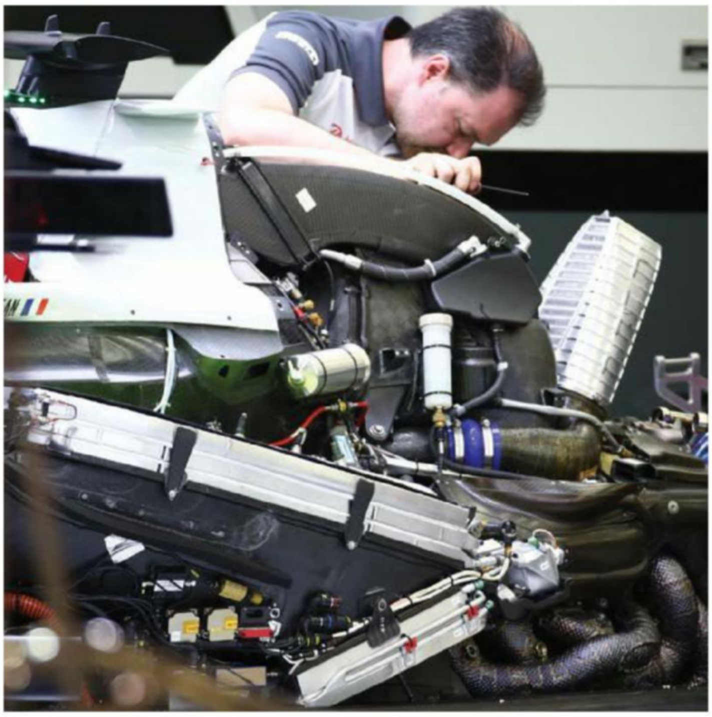
'When you start a car development, every year you are not sure what your wheelbase will be'



Haas has followed Manor and Red Bull down the machined aluminium front bulkhead route. The team says this does not give it a benefit in terms of chassis stiffness and weight over a carbon example but that it does simplify this area of the car



Ferrari power unit in the back of the VF-16. This shows charge air cooler, oil tank and cylinder head. Use of proven technology has helped the Haas team to shine this year



Cooling system uses three coolers stacked on top of each other within each sidepod with a fourth mounted further back forming a V-shape. Again this is similar to Ferrari's system

change it, but in reality really it is just a number and that is all there is to it.'

On the subject of cooling, The VF-16's layout is fairly unusual, with only the Ferrari SF16-H adopting the same approach – three coolers stacked on top of each other in each sidepod, with a fourth mounted further back in a mirror image of the upper units, forming a kind of V shape. 'If you look at the coolers relative to the crash tube you can see that it's no higher than others on the grid and it has no big impact on C of G height,' Taylor says. 'But the layout has changed the underbody aerodynamics slightly, from a conventional layout, and the centre of gravity has perhaps moved forwards a little as the tail of the radiator is kind of swung underneath. Through history, if you look, it's actually not too unusual as a configuration. The interesting thing is that there is a more challenging duct design, but with modern analysis techniques, so our ability to predict the function of the flow through the ducts is much better than in the past, so the risks of doing a more complex duct design are lower. This layout delivers some advantageous things.' But what these actually are, Taylor would not divulge.

The aerodynamic development of the VF-16 was conducted at 60 per cent using Ferrari's wind tunnel in Maranello. Haas could have used its own 100 per cent scale wind tunnel in North Carolina but due to Formula 1's ban on any testing over 60 per cent scale this would have required substantial adaptations and also re-calibration, while Dallara's tunnel is only 50 per cent. CFD work was conducted using the former Marussia F1 cluster in Banbury, but driven by operators in Concord, NC.

Scuderia Haas?

With former Ferrari aerodynamicist Ben Agathagelou running the programme in Italy, a number of teams were uncomfortable about the close relationship between Haas and Ferrari. Throughout 2015 the two were free to share aerodynamic data, and while both parties deny any direct data sharing, many in the paddock believe that there was little or no confidentiality between the two. This situation came about as Haas was not an entrant in the 2015 World Championship and so it not only did not have to abide by the aerodynamic testing restrictions applied to those who were, but also would have been free to share any data it wanted.

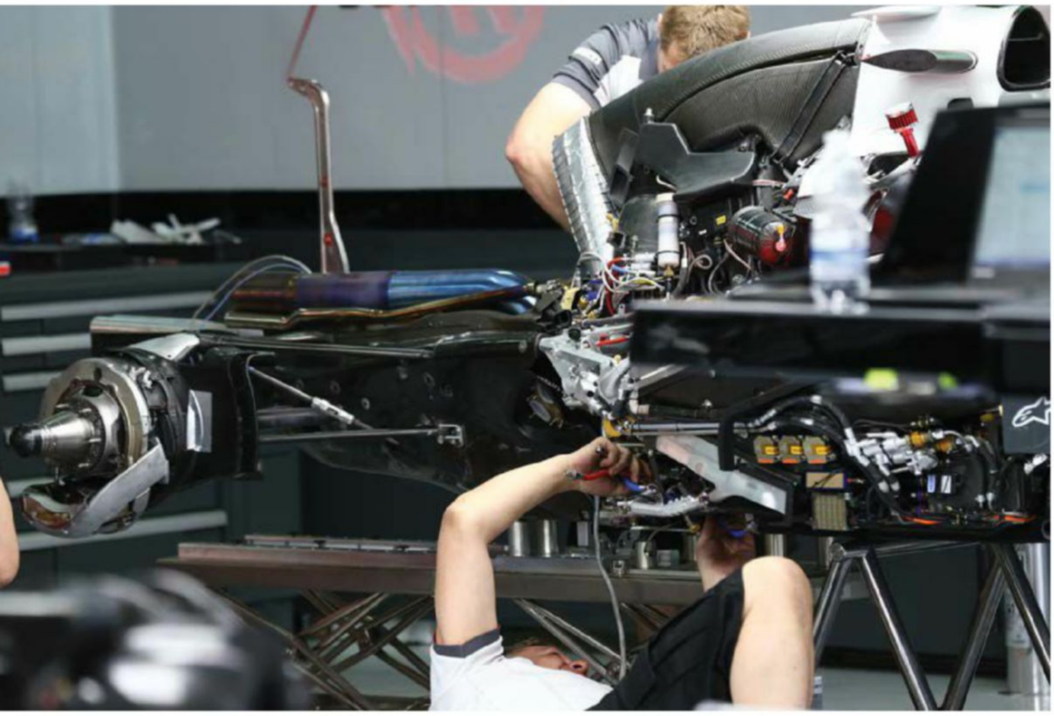
This was a situation that eventually led to a formal request for clarification from the Mercedes team. The Stewards at last year's Abu Dhabi Grand Prix found that nobody had done anything wrong, yet a rule was changed to prevent the two teams working so closely together from that point on. By then, though, it did not matter, as most of the aerodynamic concept of the car was complete. Yet the similarities of some parts on both the SF16-H and the VF-16 are undeniable – especially the cooler layout, front wing and diffuser.

New car Haasle

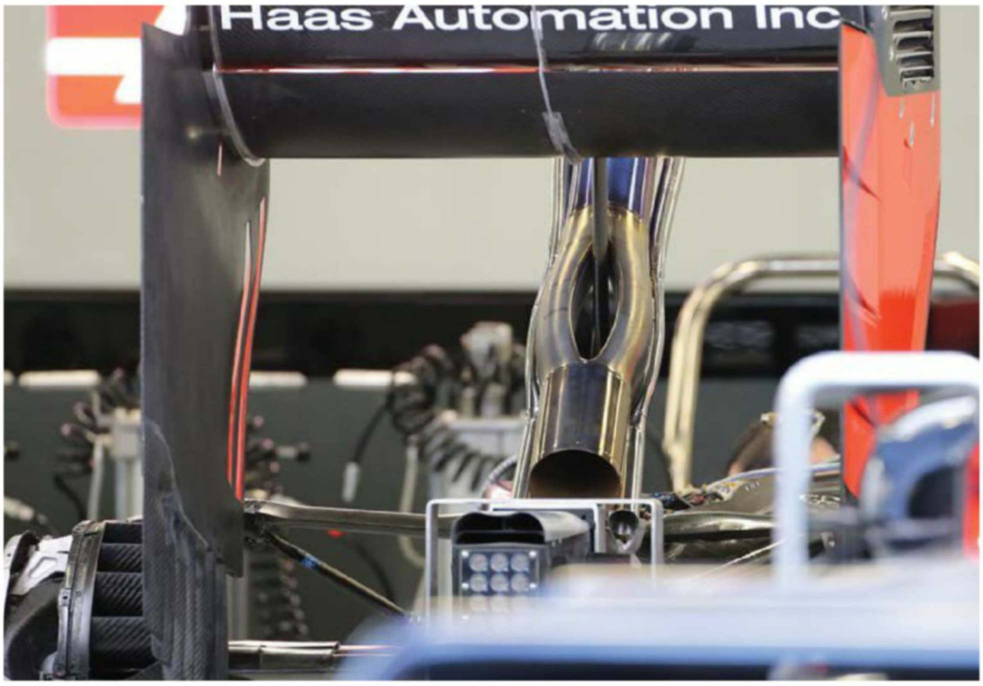
A new rule book will be introduced in 2017 and that will reset much of the car's design, and Haas will again have to start from a clean sheet of paper. But in some ways that could favour the newcomers. 'Going into 2017 I think we will use the exact [design strategy] template we used in 2016, because the 2016 car part catalogue becomes obsolete it's the same [situation] again and it worked okay this time,' Taylor says.

Haas still eventually intends to relocate its engineering efforts to its North Carolina home, but not until the time is right. After all its unusual approach to building a racecar paid off quite well in NASCAR, and seems to be working out in Formula 1 now, too. Perhaps in future other new teams will follow its lead?

Haas still eventually intends to relocate its F1 engineering efforts to North Carolina



The rear end showing the Ferrari transmission. Haas shares uprights, outboard suspension elements, inboard suspension parts and brake set-up with Ferrari. The VF-16 also has push rod actuated dampers on the front and pull rod on the rear



The Haas has the rear wing pylon passing through a split exhaust tail pipe. This is actually a solution pioneered by the Toro Rosso team which is now becoming popular up and down the pit lane. Aero development of VF-16 was done at Maranello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Class action

This year's UK Formula Student competition at Silverstone had it all: a big field, technical innovation, some startling performances out on track, and not a little controversy

By JOSH KRUSE

This year's UK Formula Student event saw more than 130 teams from over 30 countries gather together at the Silverstone race circuit to put their designs to the test against one another in the usual static and dynamic competitions.

While the weather teased the paddock with gloomy grey skies and a brief shower on the Friday, there was for once no rain interruption on Saturday or Sunday, which helped to make this yet another successful event. This year was so successful, in fact, that for the first time in any Formula Student competition, 75 cars competed in the endurance event on Sunday, and while only 37 of these saw the chequered flag (and five were later disqualified, of which more later), the number of cars out on track easily beat the previous record of runners in the endurance and efficiency test.

The acceleration event on Saturday showcased the EVs particularly well, as every car which qualified for the top six run-off was propelled by electric motors. The usual suspects of Delft, Zurich and Karlsruhe all went into this final session, which for the first time counted towards the overall points tally. Joining those three were the cars from Amberg-Weiden, Darmstadt and the Norwegian University of Science and Technology. The typically tiny car from Delft registered a seemingly unassailable time, but after a short delay the world acceleration record holders, ETH Zurich, pipped their Dutch rivals by just 0.0136 seconds.

Student protest

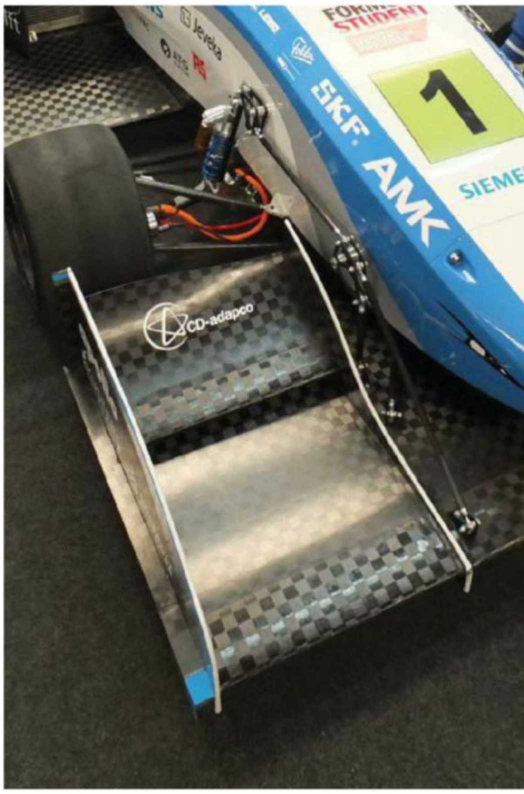
Up next was the sprint, held on the Saturday afternoon on a course laid out around Silverstone's Copse corner, where again the electric cars proved to be very strong indeed. But the combustion engined machines now staged a fightback with the E85 fuelled cars from Stuttgart and Karlsruhe posting times to match those of the best EVs. Reigning champions Delft topped the time-sheets while rival ETH Zurich found itself rather slower than expected and just outside the top 10.

As always the final and toughest hurdle for teams at Formula Student is the 22km Endurance and Efficiency event. Following an amusing on-track scrap between the top UK teams, Hertfordshire and Bath, the car from Oxford Brookes university set some extremely fast times before bursting into flames. On a day where the temperatures were approaching 30degC it was clear that it was not just the pace which was going to be hot.

Of the favourites, ETH Zurich was the first to run, a consequence of its poor showing in the Sprint the previous day, but its lap times were astonishing, five seconds a lap faster than anything that had run earlier in the day. The car completed the event and had a very comfortable first position.

But it seemed that the times set were too good to be true, and the Zurich students had in fact made a rather elementary mistake. The

TU Munich turned up with what some in the paddock called the most aerodynamically advanced FSAE car ever. The team was one of those caught up in controversy later in the event



Delft's front wing was twice found to be oversized, firstly during initial tech inspection when it was deemed to be 1mm too high and the team was forced to trim it slightly

Bath was once again the best of the UK teams and it missed out on a podium finish by just one point

Aerodynamic detail reached new levels at this year's event, as this very neat sidepod ducting work on the RWTH Aachen entry shows. Cooling has also become a key battleground in Formula Student competition

team had actually set the power mode to the German Formula Student setting, which allows for a maximum power of 80kW. The Silverstone maximum is 60kW. Zurich was subsequently disqualified from the endurance test while the event was still taking place, promoting Rennteam Stuttgart to first place overall, just five seconds clear of Delft.

It was at this point that controversy struck the Formula Student paddock with a vengeance. In the post-race technical inspection, it was found that a number of cars had run non-compliant bodywork in the endurance test. The exact details of the discrepancies from each of the disqualified teams had not been disclosed as *Racecar Engineering* went to press, however, Delft, Amberg-Weiden, Universitat Stuttgart, and TU Munich were all excluded from the endurance event. At the time of the disqualification, Delft had been on course to achieve a strong position in the overall standings, while Amberg-Weiden was also enjoying an extremely strong performance up until its exclusion from the event.

An appeal was lodged by all of the offenders, as each team believed their indiscretions to be of such a minor significance that it wouldn't have affected the result. As the scrutineers and officials discussed the appeals from the teams, confusion around the paddock arose, and the awards ceremony was delayed as a result of the various the appeals from the teams.

But, after almost an hour of careful deliberation, the appeals were not upheld and the disqualification for all the teams concerned stood. This left Rennteam Stuttgart with its F0711-11 easy winners of the competition ahead of the Karlsruhe combustion car and the car from TU Graz, all the top four cars packing combustion engines. Meanwhile, for the second year running, the University of Bath finished in fourth position by just one point.

Degree of change

It's all change for Formula Student next year with tighter aero parameters plus new combustion engine rules which will allow the use of larger units

By JOSH KRUSE

Formula Student 2017 will see a number of new regulations in force, and some of these are sure to have teams rushing back to CAD suites around the world to reconsider various elements of the car designs, as Andrew Deakin, the chairman of Formula Student has explains: '2017 FSAE is a major rules change year, the rules that we ran under this year just had typo corrections and safety critical changes, but for 2017 we spent a lot of time looking at certain areas.'

Deakin outlined a number of changes to the safety regulations including revisions to the impact attenuator rules, as well as mounting points on monocoque chassis. Teams were also advised that it was felt there was an over reliance on FEA. The rules on aerodynamic devices were in the spotlight this year, and Deakin also revealed that there would be some revisions to these in 2017. 'In terms of aerodynamic device locations, since we introduced the rules a few years ago, a few teams are pushing the boundaries so some clarifications will be introduced. Looking at the front wing end plates, there is currently a grey area in the rules, it was a mistake in the original rules and it was never the intent as the rule was written, so the rule has been rewritten. For any portion of the front wing that's above 250mm, that's now restricted to a single vertical surface per side, and that must obstruct no more of the front tyre than 25mm of width,' he said.

But the above paled into almost insignificance with the next change; the arrival of larger and more powerful engines to the class. 'We're increasing the allowed capacity from 610cc to 710cc, the restrictor sizes will remain unchanged,' Deakin said. 'The engine capacities are creeping up and it's becoming more difficult for teams to find economical sources to find 600cc engines, so by opening it up to 710cc we want to try and keep it as cheap as possible for teams who want to run the larger 4-cylinders to carry on competing.'

However, this also opens up the possibilities for teams to use larger more powerful engines such as the 670cc triples from Triumph, or the Ducati 696cc air-cooled Monster engine. This increase in capacity could well also increase performance for the combustion engined cars relative to the electric cars. Formula Student combines the EV runners and the combustion cars in a single class and uses an equivalence of technology to attempt to ensure parity between the power sources, although Deakin also explained that this area is being looked at to ensure that it is as fair as possible: 'We are looking at efficiency scoring, particularly when you have combined events with electric and combustion cars running together.'

'We're increasing the allowed engine capacity in Formula Student from 610cc to 710cc'

Next year Formula Student intends to tighten up the regulations concerning the front wing end plates while there will also be new rules pertaining to the mounting points on monocoque chassis and revisions to the impact attenuator regulations

Static moves

Some of the static events will be revised in the future too, though the timescale is not clear. 'We are looking at a major revamp of the cost event, so we'll address the design for cost, the design for manufacture, and sustainability and design, and also we're open to suggestions [the teams] might have. If they can see a way to improve the cost event to try and make it more relevant to the educational-giving of their schemes.

'There are some teams who are always struggling, or feel like there is an injustice, and there isn't a sufficient penalty in cost report for those guys who have expensive cars,' Deakin added. 'Possibly the most contentious point, which caused a lot of uproar in the States, was a redistribution in the points for the events in the draft rules. The points for design were proposed to be increased to 200 from 150, and the extra 50 points were to be based on pre-event submissions rather than on-the-day assessment on the design judging. That was to try and reduce the many subjective elements in the design scores and make it as objective as possible with those extra 50 points that were applied. It's a very contentious issue. Rather than push the rule changes through, we've chosen to pause and consider. We will send an email to all the faculty advisers and we'll be looking to get input and feedback on increasing points for design, or how we might choose to trade off the points distribution in all areas.'

The final 2017 rules will be announced some time in the next few months. They will also feature revised noise limits and a number of other detail changes which will make the task of designing a new car harder for students next season it seems, with less of the previous year's project able to carry over.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Among the aerodynamic developments on this year's Stuttgart car were a new concept front wing plus a fourth element fitted to the rear wing

German wings

Rennteam Stuttgart took overall honours at this year's FS UK thanks to some clever aerodynamic developments on its F0711-11 challenger. We took a close look at this finely optimised machine

By JOSH KRUSE

The well-established Rennteam Stuttgart won its fourth Formula Student UK event with its F0711-11, a car that was developed with downforce very much in mind. So it was no surprise that the aerodynamic package has changed considerably from last year.

Stuttgart actually originally planned to use some concepts from last year's car, but during simulations it found it was left with an aero package which excelled in straight lines, but fell short in the corners. To fix this for the new car the aero balance was shifted with a new concept front wing. Also, following the lead set by Oxford Brookes in 2015, a fourth element was added to the rear wing in front of the DRS (which results in the car having 30 per cent less drag). This is to aid the car through corners, yet it has no effect on the aero in a straight line.

Also new for this year's car is an added adjustable front wing flap designed to assist the driver's set-up of the aerodynamics and make driving the car a more stable and comfortable experience – an important mod given that the team doesn't have experienced drivers.

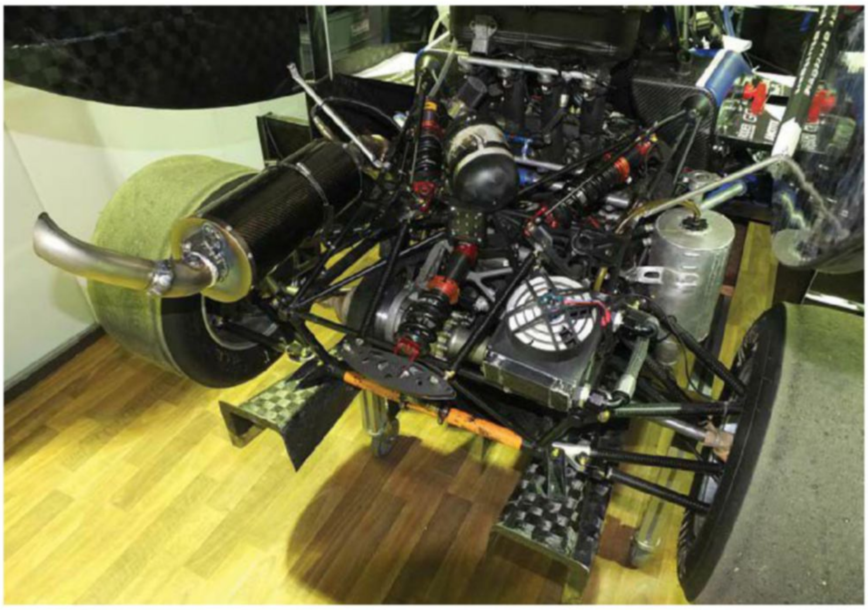
'The extra adjustable flap on the front wing doesn't make the car go faster, because when it goes down you lose downforce on the front and don't gain much back, but the driver feels much more comfortable and can drive faster and better with the car, so it's a feature for the driver feeling and not for the car itself,' says head of suspension Lars Altseimer.

'Whenever we changed something we then simulated it in three different stages: straight line, cornering and cornering with different angles and wheel positions, so we lose about 0.1 to 0.2 CLA CD on the downforce in cornering,' Altseimer added. 'The leading edges, the fourth flap on the front of the rear wing, everything is optimised for cornering. In the middle we have an extra flap on the front wing which is an active aerodynamic balance system, so we can adjust the aero balance from rear to front, or from front to rear, while driving. So we can have it more on the front on tight corners or more on the back for wide and fast corners.'

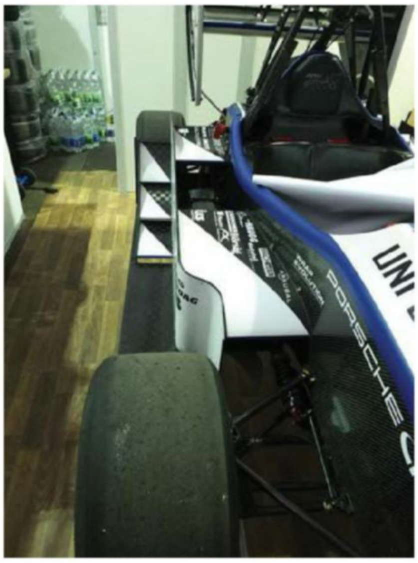
Swabian knights

The team re-located the cooling system by splitting it on the two separate sides to optimise the air flow around the car. The same reasoning is behind the positioning of the oil cooler, which they have placed at the back of the car because it's an area where it does not have such an influence on the aerodynamics.

The chassis consists of a CFRP-monocoque and a steel tube rear frame to ease maintenance on engine and drivetrain parts as well as the rear frame's wiring harness. In total the car weighs in at 191kg, slightly higher than the team's previous design (which won at FSAE in Michigan earlier in the year) due to the considerable



The gigantic rear wing assembly on the F0711-11 sits atop a Yamaha YZF-R6 499cc in-line four engine. Note the third element suspension, with its heave spring to support the racecar's ambitious aerodynamic package



The Stuttgart team has worked hard on aero details and on the location of cooling system components

amount of added wings to the aero package. 'We had a really detailed lap time simulation, and we found that a few kilograms more in weight is worth the downforce that we can produce with it. We drove both cars on track and it's faster,' team Leader Joscha Haupt said.

'We tried once building a car with a full monocoque,' Haupt added. 'But it's hard to get to the engine and in general really hard to service, so this way, with the rear steel frame, we are able to change the clutch in maybe 30 to 40 minutes. We have more freedom for the suspension attachment points, so we get better compliance with the suspension and aerodynamics.'

A key feature of the F0711-11 is the rear suspension with its heave spring to support the aerodynamic package. The team created aerodynamic maps for roll, pitch and steer to optimise the heave spring layout in order to not lose downforce when the car rolls or pitches, which, according to Haupt, took a lot of alterations and adjustments to get right. This allows the car to have a constant ground clearance. Altseimer says: 'We used the heave spring system for the first time last year and we learned a lot about it. It's a really complex system to set up and to get the car running and driving smoothly. But we did it last year which was pretty good, and we optimised a few things that we learned about the system then developed it in to a better one. Everything works together, that's the real deal of the car.'

Warming device

The F0711-11 also features a driver-adjustable anti-roll bar at the front so the driver can warm up the tyres in the first stint of the autocross and then adjust it to get more out of the car in the second stint. These additional features on this year's heavier car are manufactured as lightweight as possible, so that the weight penalty is in turn as small as possible.

'All the parts are optimised for weight,' Altseimer says. 'Our steering rack and complete steering assembly is self-developed, so we can adjust steering play and still have optimal feeling. We use aluminium brake discs on the rear, we tried it on the front but we aren't finished yet so this is now something for the near future. We designed our hubs with this in mind so there's a possibility we will introduce the aluminium brake discs on the front at Formula Student Germany. I hope we can, because they save a lot of weight.'

The car is powered by a modified Yamaha YZF-R6 four-stroke in-line four which the team developed with aerodynamic performance as well as engine performance in mind. A new oil system has been installed while the lower crankcase has been reduced in size to allow the whole engine to sit slightly lower in the car. 'We chose the petrol engine because it's much more reliable and it's also about the feeling,' Haupt says. 'We try to be as efficient as possible, for example we could use a 1-cylinder engine with a turbocharger or something else, but we decided to stick with the 4-cylinder engine, which is heavier, but is easier to drive and get more power. We don't have experienced drivers so we have to train them. So we're going for power in the engine department, because everyone can use power. Driving with aerodynamics is a little more sophisticated, and we try to train our drivers to do that, but the easiest way is to have more power.'

Well tested

One of the reasons behind Stuttgart's strong performance throughout the Formula Student weekend was its impressive testing programme. The team clocked up 1800km with the car and made it relevant to the goals it was trying to achieve, making many alterations of set-ups of suspension and aerodynamics. But before this, by loading the logging data from the Silverstone track used in last year's event, it simulated laps on the track in the different dynamic events and chose the 10 best suspension set-ups. Then it took to the track to test them and perform some fine tuning.

'It's a big step that we've done this year, Haupt said. 'And it made our testing much more efficient, so we can go more for driver training and less for set-up. So the suspension set-up is done without the driver even noticing it. It's a complete set-up and it's not just a one screw after the other sort of set-up.'

The triumphant Stuttgart team will go on to contest all the other major FSAE competitions with the new F0711-11, until its successor is rolled out next summer.

TECH SPEC

Rennteam Stuttgart F0711-11

Length: 3060mm,

Width: 1200mm

Height: 1370mm

Wheelbase: 1630mm

Track (front/rear): 1140mm/1120mm

Weight of car (no driver): 185kg

Weight distribution including 68kg driver (front/rear): 125/128

Suspension: Double wishbone front and rear, pullrod actuated front, pushrod actuated rear, modular third spring/damper system

Tyres: Hoosier R25B, 7.5inx18in

Wheels: Rennteam Stuttgart-designed Hybrid Rim, Carbon fibre rim well, aluminium wheel star

Brakes: ISR Calipers, aluminium brake disc on front

Chassis construction: single-piece monocoque with steel rear frame

Engine: Yamaha YZF-R6 four-stroke in-line four. Bore: 65.5mm; stroke: 44.5mm; 4-cylinder, 499cc

Fuel type: E85

Fuel system: dual-stage injection

Max power/max torque 62kW at 9500rpm, 67.5Nm at 7500rpm

Transmission 4-speed gearbox

Differential Drexler limited-slip differential

Final drive 29/11, chain drive

The total weight of the Zurich car comes in at 172kg and it can produce 216hp. It features swan neck rear wing supports and raised-nose front aero

Gotthard's pass

ETH Zurich scooped Design honours for the third time with a car featuring self-built electric motors and a good dose of aero and packaging nous

By JOSH KRUSE

The AMZ Racing team from ETH Zurich had grabbed all the headlines ahead of the 2016 Formula Student event at Silverstone, after setting a world record for electric vehicle acceleration. That record, however, was taken using the team's old car and the car at Silverstone was a new model dubbed 'Gotthard'. This was deemed by the judges to be the best designed in the competition, and thus Zurich won the Carroll Smith Shield for the third time.

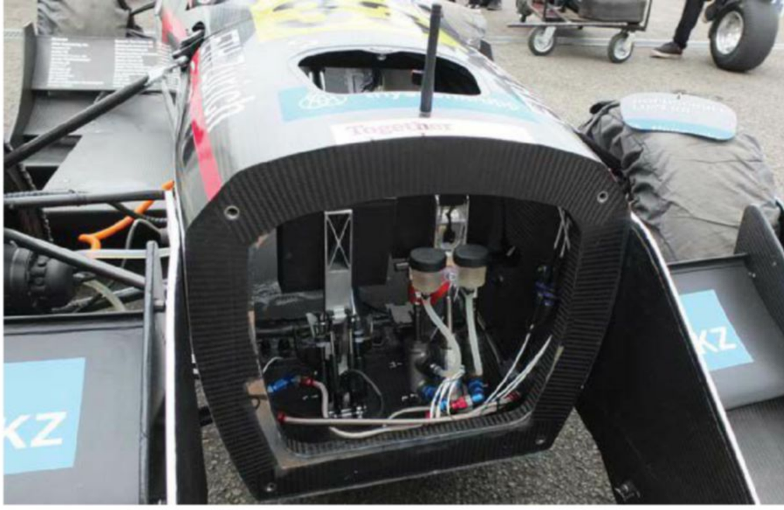
Gotthard is ETH Zurich's 10th Formula Student car and the seventh driven by electric motors, and here lies one of the secrets of the Swiss team's success. The motors on the car are not off-the-shelf units as is generally the case with other cars; instead they have been developed by the students themselves.

The four hub-mounted units deliver 54 horsepower each, at a weight of just 3.4kg, and they are based on those used in 2014 and 2015, but now in modified form, as team leader Daniel Hentzen explains: 'We made [the motor] a lot shorter and gained some power. We changed the voltages of the motor by changing the geometry of our winding, so we always have the freedom that's tailored to the main concept of the car. We can set the target torque and set the target RPM and so on, we're very free in the design of the motor, which distinguishes us from other teams. When we did the world record at the end of June with the car from 2014 we gained some valuable insights. We did a lot of work on the interplay between the inverters, motors and the whole traction control system which we could implement in the new vehicle.'

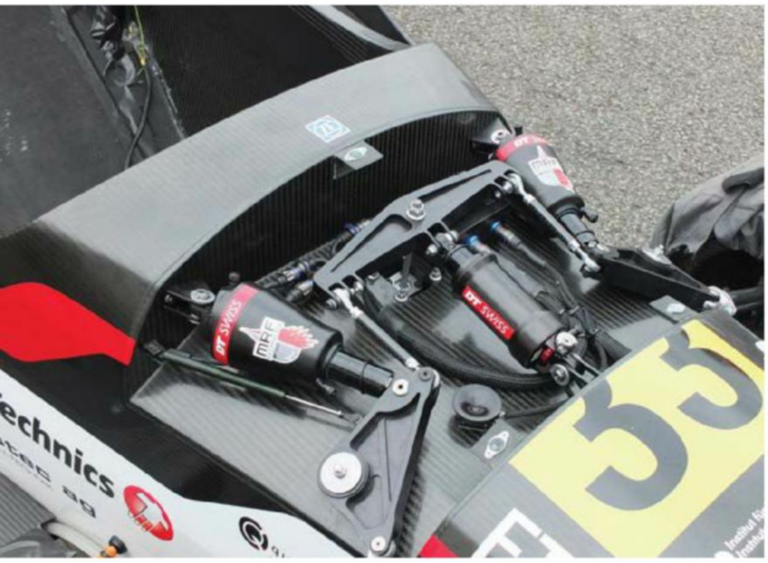
A notable change in the 2016 car is that it features a split battery pack with one group of cells under the driver's legs and another just behind the driver. One of the benefits of this is that it enables the team to construct a completely new undertray design, so the

The motors are not off-the-shelf units as is generally the case with other FS cars, instead they have been developed by the students themselves

Gotthard's four hub-mounted electric motors deliver 54 horsepower and they weigh a paltry 3.4kg. The motors were redesigned for this year and now produce more power



The front bulkhead and the pedal box. Driver aids include traction control for optimal wheel slip plus a torque vectoring system to improve the car's agility on tight FS courses



The car features a three-element suspension with a heave spring for the aero loads. Single-wheel springs feature magnetorhelogical technology for adjustment on track

Half of the split battery pack; the other half goes under the driver's legs, which has enabled the team to construct a completely new undertray while also lowering C of G

diffuser starts further forward than it did on the older models, resulting in an increase of downforce of 40 per cent without adding any extra weight to the car.

The split accumulator also lowers the centre of gravity by having it flat and close to the ground towards the front of the car, decreasing the centre of gravity by 2 to 3mm. The battery packs are, like the motors, a student design, as is the management system. There are many small modules inside the accumulator box so each cell is monitored for voltage and temperature, all of the modules communicate with one another via an infra-red signal, which the team believes to be an industry first. This helps reduce the vulnerability of the system to electromagnetic interference and reduces the vibrations in the accumulator, making it a more reliable unit overall.

'Through the split packaging we are able to achieve our target centre of gravity which is 50.5 rear and 49.5 front,' Hentzen says. 'In the last years we had some trouble to achieve this with the accumulator package at the back of the car, so we were able to solve this problem.

'A lot of work was focussed on aerodynamics, we have the new undertray, we packaged our cooling at the back of the car, so there's no more radiators on the side of the car to increase our drag and decrease the performance of the rear wing,' Hentzen adds.

The electronic control system on the car integrates a traction control for optimal wheel slip, a torque vectoring system for high agility, as well as a sophisticated energy management system for use in the endurance competition.

Continental drift

Another modified element from last year's car is the suspension concept. For the past two years, Zurich has run magnetorhelogical dampers, but on the '16 car a heave element has been added front and rear, so that they can set single-wheel springs a lot softer while the heave springs carry the aerodynamic loads. The single-wheel springs still feature the magnetorhelogical technology, allowing the team to adapt the damping ratios when the car is driving.

The tyres used are bespoke, built specifically for this car and developed in cooperation with Continental AG. The new tyres are claimed to provide more grip, an improved temperature behaviour and increased driveability. The total weight of the vehicle comes in at 172kg. At 216 horsepower, a ratio of 1.26 HP/kg results when it's set to the most powerful mode. The team's already contemplating another tilt at the world record for EV acceleration.

TECH SPEC

ETH Zurich 'Gotthard'

Length: 2943mm

Width: 1159mm

Height: 1425mm

wheelbase: 1530mm

Track (front/rear):1220mm/1220mm

Weight of car (no driver): 170kg

Weight distribution including 68kg driver (front/rear): 118/120

Suspension (front/rear): Double A-Arm pushrod actuated by adaptive spring-damper, plus heave spring

Tyres: 205/470 R13 custom Continental

Wheels: 13in ETH Zurich-developed carbon rims

Brakes: Aluminium brake calipers with ETH Zurich-developed 190mm brake discs

Chassis construction: CFRP single-piece monocoque

Engine (electric motors): ETH Zurich-developed wheel-hub-mounted brushless in-runner motor with 39.4kW, 26.1Nm, 19,200rpm

Type of energy storage: Lithium polymer cells with high energy and power density

Accumulator: Split to help with weight distribution and C of G

Max power/max torque: 157.6kW, 1500Nm

Transmission: no transmission

Differential: Not needed due to wheel hub motors and control systems

Final drive 14.37:1

The Amberg-Weiden entry used a quite simple and certainly cost-effective suspension design made from steel, the team's calculations showing that the weight and stiffness ratio was good

Edith Cowan University's car ran a De Dion rear beam suspension with satchell links so it didn't have to have a subframe on the rear. This allowed it to use a full-length monocoque

Renstall Esslingen used a triple damper layout at the rear, the third to support aero, in common with a number of 2016 cars – but it used a different concept with the pitch and roll separated

Hub motors and small wheels made the suspension mounting tricky for defending champ team Delft. Its other main focus was stiffening the car's suspension with carbon fibre rods

Shock and yaw

There were a wide range of suspension systems on show at this year's FS UK event – here's our run-down on some of the more ingenious solutions

By JOSH KRUSE

There was an array of new and innovative design solutions on display up and down the pit lane this year as, partly as a result of the growing trend toward the use of large wings, suspension was a major area of focus for many of the teams.

Almost as soon as the cars arrived at the track there was talk spreading through the Formula Student paddock about the suspension configuration on the Monash University car. The Australians had opted for a hydraulic suspension which worked by interconnecting the front and rear of the car, the team dubbed it 'the hydro' and says its a hydraulically actuated mode separated suspension system which has only ever been attempted by one other team in the past. The aim is to separate and isolate each mode of movement (roll, pitch, heave, bump and warp) so that they may be independently tuned for a fully optimised set-up. 'Regular shocks and springs do not allow such separation,' says team member Simone Briggs. 'If the springs on a conventional damper are changed for roll, they may also change pitch, heave and warp stiffnesses, even if these are not required to change. The challenge then was to design a system that achieved these aims. The first hydro system was designed by our 2013 chief engineer Andrew Trathen in 2014, to be compatible with our M14 car so it could be validated on track. Even though there were many issues to fix with the initial iteration, the feedback from the drivers on its maiden run was encouraging, one describing it as being "like driving a hover-car."'

This initial testing gave the team the confidence to move ahead with the concept and redesign it for 2015, with previous suspension leader Alan McNaughton leading the design. As the new Hydro system was being designed alongside the rest of M15, instead of having to be retro-fitted to an existing car, it

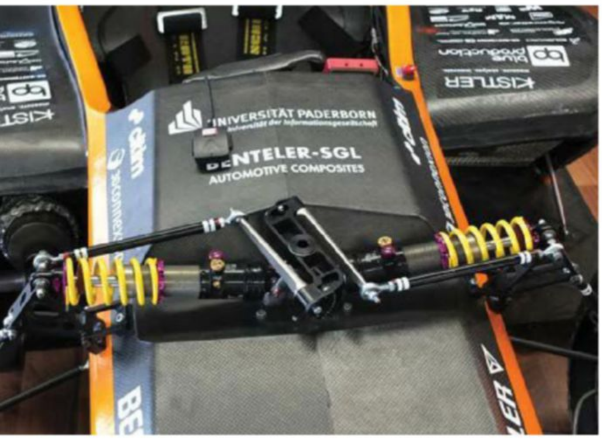
Suspension was a major area of focus for many of the teams this year

allowed the team to develop a better optimised system. The final design isolated roll to be tuned through Hydro, with heave and pitch controlled by the use of monoshocks, and so (theoretically) completely eliminating warp stiffness.

'The configuration of the lines allows fluid to merely transfer between four actuators when the car is experiencing pitch, heave, bump or warp, but hydraulically compresses the springs in the accumulators during roll,' Briggs says. 'By changing these accumulator springs and tuning the damping settings on the integrated damping unit, called the 'snowflake', we are able to tune the roll independently of the other modes. Two monoshocks (front and rear), which are simply extended Ohlins dampers, provide heave and pitch stiffness which can be tuned by conventional means. As neither the Hydro system or the monoshocks provide warp stiffness, the system has theoretically zero warp stiffness. This is highly advantageous as it allows maximum contact with the ground over the bumps and road irregularities.'

The Australian Monash entry caused quite a stir in the Formula Student paddock. Its suspension set-up has been described by the team as a hydraulically actuated mode separated system

The rear of the Monash car. The aim of this ingenious system is to separate and isolate each type of chassis movement (roll, pitch, heave, bump and warp) so they can then be independently tuned



Paderborn used purpose-made Formula Student dampers from KW Suspension. The pair of dampers are mounted horizontally on the top of the chassis – note the neat linkage between them

Down-under steer

Another Australian team, Edith Cowan University, ran a De Dion rear beam suspension with satchell links, so it didn't have to run a subframe on the rear. This allows it to run the monocoque all the way back and use it to support all of the suspension. 'The suspension and steering is a big thing for the car, the rear beam is actually slightly inferior to having an independent suspension, but our implementation I think is quite successful, we've only gained 1kg in unsprung mass through the whole rear section,' technical director Eric Curwood says. 'Overall through the custom engine and the beam we've lost over 20kg from the car, so you eliminate the whole rear structure and with the four satchell links coming forward and the engine bolting straight into the chassis, you've basically got a whole rear system that drops straight out. That was massive with the design of the custom engine, designing a rear suspension system that worked well with it and met the primary goals of the car, which are fairly simple: low weight, low centre of gravity.'

Edith Cowan's car runs very low to the ground, which is made possible by the steering using a planetary geared pitman arm system, lowering the front end of the chassis by 40mm. From the pitman arm, two rockers come out that work with it, so the change from linear movement to circular movement helps the team develop a system that goes Ackerman from parallel steer up to 160 per cent. These can also be tuned and can me made linear if the situation calls for it, or it can be made quadratic so it moves faster towards the end. Edith Cowan reduced its running costs by using non-adjustable Penske dampers, which gives it the ability to do the direct-acting simple suspension without added weight due to the non-adjustable nature of the monoshocks.

The TU Graz team from Austria brought upgrades for the 2016 car. A lot of its parts are manufactured in the workshop, including 8in wide carbon fibre rims and carbon fibre uprights which are self-developed for the front and rear. The team also changed the kinematics design slightly on the suspension to make the car more stable and give it a flatter ride, in order to give the driver a better feeling for the car.

Reigning champion Delft focussed on placing its motors in such a way in each wheel that they could fix their suspension pick up points at the right place, and also on stiffening the suspension by running a system of carbon fibre rods to meet their targets of compliance. 'If you would analyse or make a simulation of the system without any of the stiffening elements it would be deflecting more than a millimetre between the upper and the lower pick up points of the suspension system,' its chief of powertrain, Thomas van der Hout says. 'Now, using the stiffening elements, we can reduce it to only 0.1 or even less which was our desired deflection target. So in that way you can still have the desired stiffness without having all the extra mass which makes the system even more stiff than you wanted.'

Fjord focus

The design of the Norwegian University of Science and Technology car was interesting. As with the Delft car the team had to deal with the electric hub motors sitting in areas where they would otherwise place suspension parts. The end result was a double wishbone with pull rod actuated dampers on both the front and rear of the car to clear the motors. To reduce the stress in the monocoque it mounted dampers on top facing towards each other, and installed a compact anti rollbar system which allows the team to adjust for understeer and oversteer.

Competition runners-up Karlsruhe designed its suspension to get a low centre of gravity. All the dampers are located under the monocoque and the suspension is pull rod rather than push rod, so there are no dampers over the monocoque, which improves C of G and aero as well as keeping the design clear and clean.

'We have a really lightweight suspension,' technical chief Sebastian Buchwald says. 'For example, we have a hollow steel design upright. It's made of steel but also with lightweight aluminium, but it is stiffer so even better. Also our integrated wheel hub, it's a five-axis milled single piece, so that is also pretty tight. So you don't have much space between the rim and the suspension packaging. From last year, where we really improved was in decreasing the weight by 15kg, which is quite a lot.'

Amberg-Weiden ran a simple and cost effective design made from steel. The team made calculations and believe that the weight and stiffness ratio is better using this material. It opted not to use a third damper for the car because it implemented a well-functioning anti-dive and anti-squat set-up, and felt that the car simply didn't need a third element.

4 the love of it

Amateur racing does not necessarily mean uninspired engineering as Canada's club level Formula 4 surely proves. We take a close look at some of the clever home-built cars this class has produced

By FORBES AIRD

DEVIN HANES

Jim Morton's Gamma II F4 with its new CFRP bodywork. This 750cc machine regularly mixes it with 2-litre cars

CHRIS HALEY

Bob Long in his Triumph 650cc engined Walker F4 at Mosport back in 1970. Walker was an early supplier of F4 cars to Canada

KATE AIRD

The late Gord Green (left) and Bob Long pictured in the 1980s. Green was a graduate engineer who built exceptional racecars

The appeal of F4 is as old as the sport itself: comparatively affordable little racecars running circles around big expensive racecars

The word *amateur* has taken on a rather offensive shading over the last century or so. It originally simply meant someone who does something for the love of it, but to many it now connotes a dabbler, a dilettante, not-ready-for-prime-time. Well, Jim Morton is an amateur, and his 'prime time' at Mosport in Canada is 1:25.4. In a mixed field that included 1600cc and 2-litre open wheelers, that puts him ahead of all the 1600cc cars, and mixing in with the 2-litre stuff. The thing is, Morton's Formula Four car has just 750cc. Oh … and he made the car himself.

In fact, this is Morton's third home-built F4. The first two, he readily acknowledges, were direct copies of Bob Long's Gamma I and II cars, respectively, but at six feet-plus – a good five inches taller than Long – Morton found himself seriously cramped. So he built a third car, almost identical to the Gamma II, but this time with the cockpit stretched by one inch.

Thus, while the conception was not Morton's, the execution was entirely his. Anyone who dismisses this as the dabbling of a dilettante should try it themselves, three times, and initially without drawings. To accomplish this he acquired (through an improbably complex series of deals over the course of several years) a lathe, a TIG welder and a mill, which is odd, because Morton had no real

RICHARD WALKER

THE AUTHOR

Above: Richard Walker's Phoenix is a resurrection of Gord Green's 1972 Mk 6 and is still racing. Wings are relatively recent additions
Left: It is possible that no racecar in history has sported the same specification as Green's Mk 8, which had beam axles at both ends, front rubber springing, friction dampers and hydraulic steering

The liberal rules are a major factor in F4's success. They invite more creativity and offer owners more opportunity to tinker and experiment

idea how to operate any of these most useful tools. So he taught himself. All that said, we are using Morton's car as the exemplar, as it is the newest, the fastest and in Long's own words, 'the prettiest' – in short, the alpha Gamma.

But Morton's is just the most recent chapter in the long story of F4 home-building here in Canada, and to start this tale we have to go back to June 1967. Sergeant Pepper was first striking up the band that very month when Long, then a garage proprietor in London, Ontario, imported the first two Formula Four cars into Canada. Built in the UK by Johnny Walker Racing, they were initially intended to pack 250cc engines – a bare step up from karts. Acceleration was anaemic, and the owners underwhelmed, and so many of them began fitting 650 engines. Back in the UK Walker helped them out here with a general beefing-up of its Formula 4 chassis.

Fab 4

Long saw potential in the larger engined cars, and all but the first to reach Canada were to 650cc specification. Over the next two or three years about a dozen Walkers arrived in Canada, nine of them imported by Long, plus four of another, similar English brand, the Vixen. Meanwhile, the category in the UK was splintering further into three displacement classes: 250, 650, and 875cc, that last intended for Hillman Imp engines, a productionised version of the Coventry Climax FWM. Alas, this fragmentation crippled the class there, Walker folded up his tent, and by the early 1970s the English chassis pipeline had dried up (although the formula continued in the UK for some decades). For a time, then, if you wanted to run a Formula 4 in Canada, you had to build your own.

By the end of 1970, the number of cars appearing at events was sufficient that the Canadian Auto Sport Club granted F4 status as a separate class, the Three Quarter Litre Association was formed, and the first set of rules established. Seeking to avoid the scenario that had caused problems in the UK, it was firmly

The rules were refreshingly and deliberately brief, partly on the grounds that the cost of a racecar is proportional to the size of the rule book


THE AUTHOR

Luchinger F4, seen here after the installation of a Honda 750, was run with a turbocharger fitted when in was in 500cc guise

SIEGRIST ENTERPRISES & HEATHER MacARTHUR BELL

The first Xpit with original bodywork. It used a simple chassis frame made up mostly of square-section mild steel tubing

THE AUTHOR

Another early Xpit F4 with modified bodywork. These tough little racecars were 'built like tanks' and some are still racing

established that engine displacement must not exceed 750cc, and the minimum empty weight was set at 225kg (496lb). Otherwise, the rules were refreshingly and deliberately brief, partly on the grounds that the cost of a racecar is proportional to the size of the rule book, and partly to inspire home-builders and encourage innovation. These uncommonly liberal rules are surely a major factor in the formula's success – F4 invites more creativity and more variety, and offers owners more opportunity to tinker and experiment, than any other class in road racing.

Racing Green

The opportunity was first seized by Gord Green, who constructed six F4s of three different designs over the next dozen or so years. A veteran home-builder with five previous sports and formula cars to his credit, Green was also a graduate engineer, and his cars showed that. On his first F4, for example, the detachable engine bay was secured by four bolts, two of which also acted as engine mounting points, while the same junctions provided trailing link attachments. Similarly, a transverse chassis tube served as the steering rack housing.

Overall, a combination of sound intuition and confirming calculation meant that, although Green's cars were always very light (barely over 500lb), they were demonstrably durable. The first F4 he built still competes, resurrected from the metaphoric ashes as the Phoenix by Richard Walker of Ajax, Ontario. Indeed, Walker won the class championship from 1981 through 1983 with this car and, by sheer persistence, won again in 2015. Adding wings front and rear, a fuel cell, on-board extinguisher and various other oddments has brought Walker's Phoenix up to about 570lb. Notably, the class minimum weight was subsequently raised, initially over concern that others, less competent than Green, might push things too far; later to avoid discouraging drivers of substantial heft. Walker's car and a couple of other ancients are 'grandfathered' from the latest weight rule.

Gord almighty

Green's cars to this point had all been conventional designs, artfully executed. But with his last, the Mk 8, he went off the deep end. It is probable that no racecar in history has sported the same specification: beam axles at both ends, front springing by rubber, friction dampers, and hydraulic steering. The steering was so hopelessly numb, and the handling so diabolical, that Green chopped the thing up for fear someone might buy it and get hurt.

Other home-builts of that era were one-offs, including a very light but desperately

CHRIS HALEY

The Gamma I was based on another home-built car, the RM1. The modifications made by Long and Morton justified a name change

DEVIN HANES

Morton in his Gamma II (left), with which he took a run of F4 class championships from 2011 to 2014

ERIC MacARTHUR

The Gamma II Formula 4 came about after Long decided to return to racing. It's pictured with him at the wheel at Mosport

DEVIN HAYNES

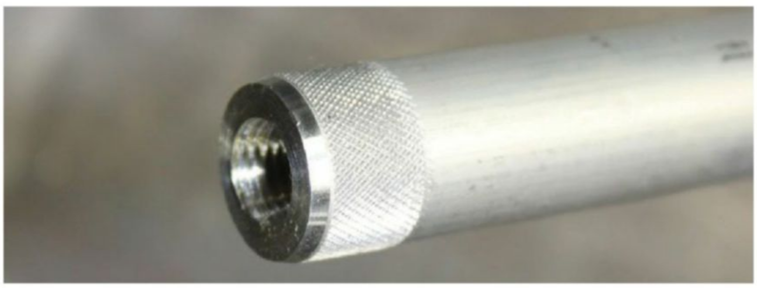
Morton's stretched Gamma II near completion. The car's wheelbase is now at 92in and front and rear tracks are 54.5in and 50in respectively. The plywood training wheels on the front are an essential addition in order to fit the racecar into the trailer

DEVIN HAYNES

Stretched Gamma II frame after powder coating. The modification was made because Morton needs more space in the car

All of the suspension links on the Gamma are thick-wall aluminium tubes tapped for rod-ends

DEVIN HAYNES



underpowered BMW 600-engined car of stressed-skin construction by Doug Bartels and Alex Purdy. Another one-off, built by Ferdi Luchinger, was distinguished as the only F4 ever to take advantage of the provision in the rules permitting supercharged engines up to 500cc. Unfortunately, turbos small enough were not yet available and the one he employed was far too big for his 500cc Honda twin, so that engine was swapped for a Honda CB750 four. Matt Crossley, stimulated no doubt by his involvement in the Formula SAE contest while at the University of Waterloo, built yet another. More recently, Toronto's Tom Owen offered copies of his RM-1; two were sold. We shall return to this later.

Northern Xposure

By 1973, the Beatles had broken up, Pink Floyd was topping the charts, and Eric Siegrist had turned his hand to F4 building in his shop in the rural outskirts of Wiarton, Ontario. A good three hour drive north from Toronto, Wiarton endures bitterly cold and snowy winters. He named the cars he produced Xpit (pronounced 'Speet'), of which 14 were built over as many years, followed by two more of a newer design.

A simple chassis frame, made up mostly of square-section mild steel tubing, initially accommodated essential corner bits, half-shafts, u-joints, differential internals etc. from the then-ubiquitous Mini. 'They were built like tanks,' says Siegrist, some years later, 'and that worked out – they're still racing'. But the angular bodywork that initially cloaked the whole perhaps carried the theme of simplicity a little too far – almost all owners eventually changed it.

The other anticipated flaw was brakes. As the class minimum weight and the power of available production engines increased over the years, there was concern that 8in Mini drum brakes, as fitted to the Walkers, would be inadequate. Siegrist dealt with this on the earliest Xpits by fitting a disc brake inboard of the upright, *a la* the 1966 Brabham Formula 1 car, but the close spacing between the Mini-sourced hub bearings allowed excessive 'knock-back' of the pads, yielding a low pedal.

Previously, similar concerns about brakes for a Formula Ford car using 10in wheels had led Siegrist to the idea of the Drisk brake (see box-out), and all but the first few Xpits were equipped with this novel design: 'It was the only way to get decent brakes in a 10in wheel,' he says. Convinced of the Drisk's potential, Siegrist eventually abandoned racecar construction to develop and market Drisks for faster, heavier cars. Eric still supplies suspension uprights and Drisk assemblies for Formula 4 cars, having now built his own foundry – which is one way keep the workshop warm in winter!

Gamma-time

The Gamma saga began in about 1992. For the previous five years, Jim Morton had campaigned one of the two Mk 7s built by

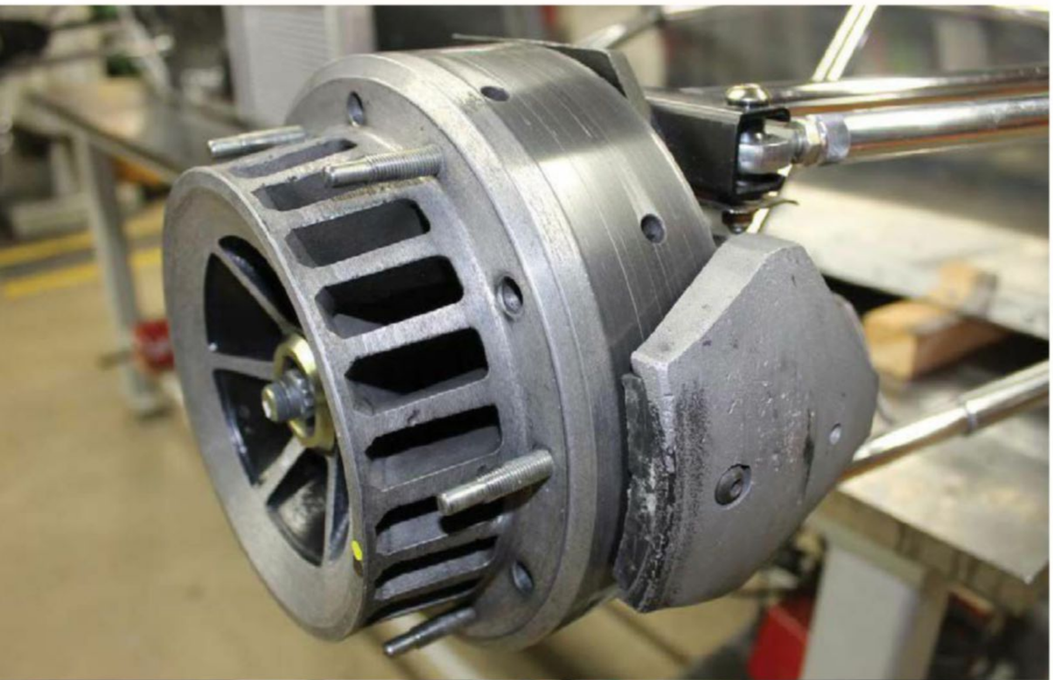
The Drisk brake

Drisk brakes employ a rotor shaped like a brake drum, but with both inner and outer surfaces finished. Both surfaces are clasped by a caliper like that on a disc brake, but having pads curved to mate with the rotor. The idea dates back to the Star car of the 1920s, and was revived in the 1970s by the European component supplier Valeo, whose Crown brake was looked at by several manufacturers.

The arguments for it are: for a given wheel diameter, a larger working radius can be achieved; the surface area is increased, potentially improving cooling, and the packaging is likely eased. However, there are some problems, too. The inner and outer surfaces cool at different rates; the braking ring cannot be allowed to 'float' on the hub portion, since the ring could then orbit around its nominal centre. However, if one edge of the brake band is restrained by the hub but the free edge is not, a certain amount of 'bell-mouthing' can be expected, demanding more pad travel.

Siegrist addresses the first problem with a centrifugal fan, formed integrally with the single Al-Si-C Metal Matrix Composite casting comprising hub and rotor – the rotor is 8in od x 2.5in wide. The pad/pedal-travel issue is dealt with by a combination of positive pad retraction by springs, and a dual-stage master cylinder that takes up the initial clearance with large first stage cylinders, and then switches to smaller ones to provide the hydraulic multiplication needed.

It seems the selection of pad material is tricky. Anecdotally, there is a rather narrow 'Goldilocks zone' of temperature between inadequate friction when cold and rapid rotor surface deterioration when excessively hot. But when the heat of the porridge is 'just right,' the rotor surface shows no measurable wear after literally years of operation.



Green, winning the 1990 class championship with it. That car was ageing, and a tight fit anyway, so he sold it and ordered an RM1 replica from Owen, who had by then completed the prototype; Long followed suit. Morton's car arrived first, Long's months later. But in both cases they were not satisfied with the car, and began their own programme of development.

Starting with little more than a bare chassis frame the pair fabricated suspension links, commissioned Drisks and rear uprights from Siegrist, and completed two running cars, sufficiently removed from Owen's original to justify the new name, Gamma. Long completed his car first, but Morton won the 1995 championship in his own Gamma, and campaigned it until 1999. Frustrated that a minimum-weight rule change that now included the driver still left him with a 40lb handicap, and facing other commitments, he then withdrew from racing for a time.

Long shot

Long won the championship the following three seasons, but then, facing some medical problems, he retired from racing and sold his Gamma. By 2004 Long was restored to health so he 'unretired' and began building the Gamma II, winning the championship with that car from 2008 to 2010. To Morton's relief, the minimum weight had by then been increased to 825lb with driver, so now, having some spare time available, he once more set about following Long's lead. He finished his own Gamma II in late 2008, and promptly turned it into a two-wheeler by wiping off the entire left side suspension against a guard rail! A feverish winter rebuild then ensued, followed by four championship wins, from 2011 to 2014.

And so we return to the 'stretched' version, begun by Morton in late 2012 and first raced in 2015. The wheelbase is now 92in; front and rear tracks are 54.5in and 50in, respectively; empty weight is 595lb, start-line weight 840lb, distributed 50:50; wheels and tyres are 8x10in front, 10x10in rear. The inboard, sprung portions are largely orthodox, featuring a multi-tubular frame of mild steel, mostly 1in x 0.062. The rack (modified) and many drive train bits are from a Suzuki Swift/Cultus. Apart from conversion to dry-sump lubrication, the Suzuki GSX R750 engine is essentially stock; it delivers 114bhp to the rear wheels, a few bhp more than Long's older version of the same model.

Detail touches

The novelties of the unsprung bits are dealt with in the accompanying box-outs, but the elements joining the two are also worthy of note. All steering and suspension links, including the pushrods, are formed from thick-walled (5/8in od, 5/16in id) 6061-T6 aluminium tubing, directly tapped for LH and RH 3/8-24 thread. Thus, no machining of end fittings, no welding, no heat-treatment, no plating. Notably, parallel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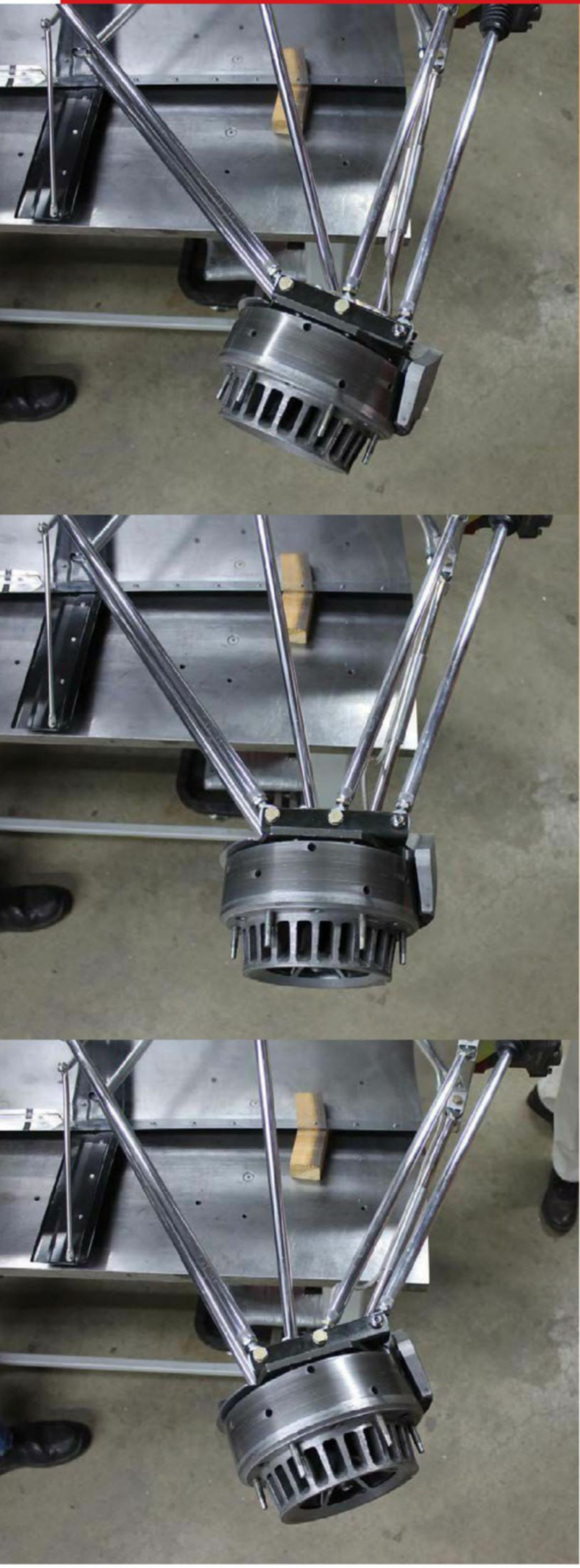
The 'invisible pivot' steer axis



Centre-point steering has many theoretical advantages, but also many practical drawbacks. With the scrub radius reduced to zero, the driver is spared all the 'noise' that arises in the steering feedback from even minor road surface irregularities, allowing a better feel of what the tyres are trying to tell him. It also permits the elimination of kingpin inclination, which only exists as a compromise solution, reducing the scrub radius at the expense of the adverse camber introduced with any steer angle.

Using conventional suspension linkage, this merit in principle demands, when its rendered in metal, a deeply dished wheel, yet still leaves little or no room for brakes. One solution is to use inboard brakes (such as Citroen DS/ID).

Another way is to transform the wishbones from a triangular structure to a mechanism – a four-bar linkage – that provides a virtual ('invisible') pivot point. BMW did this on their larger cars, starting in the '90s. Eric Siegrist did it first on a Formula Ford, and then on his Xpit Mk II. The Gamma IIs followed suit.

Lock and load

Done in this way, adequate room is provided for brakes within the wheel but, as the adjacent photos show, the steering axis – located at the intersection of the extended axes of the two individual suspension links – moves around rather a lot with substantial steer angles. In racing applications, however, steer angles are small; full-lock, or anything close to it, is encountered only during paddock manoeuvring.

A side benefit of this arrangement is that the pushrods connect directly to the upright via a linear ball-joint, rather than to any suspension link. The rod-ends that terminate the links are thus freed of any axial loading, and the links themselves are spared from the bending loads, however slight, imposed by the more usual arrangement.

DEVIN HAYNES

Jim Morton (left) and Bob Long with the latter's Gamma II. Long is still racing in F4 at the age of 78

transverse lower links are used at the rear, which virtually eliminates bump/roll steer there, and provides outstanding rear toe-stiffness.

Morton has also added an underbody diffuser, with much stiffer springs to cope with the added downforce, and saved a few pounds with startlingly thin CFRP bodywork. This combination usually enables him to stay (just) ahead of Long. Now committed to a programme of instrumented testing and modification of the car's aerodynamics, Morton's car will inevitably depart ever further from the prototype.

Canadian club

The appeal of self-building for this particular type of Formula 4 is as old as the sport itself: it's all about comparatively affordable, tiny, little racecars running circles around big expensive racecars: 'The bang for the buck is just phenomenal,' says Siegrist.

We might also talk also about these cars' appeal to the senses. Most F4 owners pay attention to cosmetics, so the cars tend to look good. The production 750cc motorcycle engines, replete with intricate die-castings and plenty of shiny aluminium and chrome, contribute to the visual aesthetic. They also provide the acoustics – they rev like dentist drills and at 14,000-plus rpm the noise also makes your teeth hurt. 'These cars sound like what everyone really thinks a racecar should sound like. All the rest of them are cement mixers!' Long said, some years ago. And then there is the chance to 'roll your own', as it were, something that's lacking in most modern motorsport: 'It's been a hell of a pile of work, but I wouldn't have missed it for all the world,' says Siegrist.

With each year, the renewal of Long's medical for his competition licence becomes increasingly improbable, for the same reason that Long is an improbable race driver – he is 78-years-old! Which says more about the appeal of these cars than anything else.

The future of Formula 3

With budgets soaring and grids dwindling Formula 3 seems to be at a crossroads – so just where does this much-loved single seater category go from here?

By LEIGH O'GORMAN

To run a car to a reasonable level in F3 for a season would require a budget around the €700,000 mark

Stefano Domenicali, president of the FIA Single Seater Commission, has no doubt about just where Formula 3 should stand on the driver development ladder. 'Formula 3 should be the first international category in which youngsters can compete in high performance single seaters in a professional environment, while still being accessible in terms of the current financial landscape. At the Federation, we are working on ensuring the smooth running of a championship run at a professionally high level.'

But there are those in the motorsport industry who might question the FIA's success with this, especially when it comes to the words 'financial' and 'accessible,' for as Fortec Motorsport team principal Richard Dutton points out, to run a car and driver to a reasonable level in the Formula 3 European Championship for a season requires a budget of around the €700,000 mark. 'At the moment in FIA F3, we have got three billionaires fighting and that is very unhealthy,' says Dutton, referring here to the wealthy backers behind three of the more successful teams, who some believe are driving costs up in the championship.

Dutton also believes that many of the cost issues lie with the current engine regulations, now based on full race engines rather than the traditional production-based units of F3's past. 'I think they've got the engines quite wrong. They are as expensive as they have ever been; they tried to bring costs down, but it didn't work'

From a grid that generally ran around 34 cars in 2015, the field shrank to just 21 to 22 entries for this year. But what can the FIA do to stop the rot, and what do the potential solutions mean for the future of this much-loved category?

In the context of modern motor racing, Formula 3 is an anomaly. As it stands, the category is the only single-seater class outside of Formula 1 that still runs an open technical

The success and numerical dominance of the Dallara F312 chassis means that despite its open regulations these days Formula 3 is actually very close to being a spec category

A Formula 3 car on the limit at the Monument Foch in Pau is still one of the great sights in motorsport. Here Joel Eriksson in a Motopark Dallara gets airborne in qualifying for this year's race

Formula 3 is still a great challenge for young drivers. It requires a smooth style and a good technical understanding and is seen as the perfect training ground for Formula 1 by many in the sport

rulebook allowing manufacturers and teams the opportunity to develop areas of the car. Yet this is facing severe restrictions in light of rising costs and Dallara chassis domination. 'In order to control costs, it's important to restrict the amount of room to manoeuvre within the technical regulations and in fact that is the direction in which we are working,' says Domenicali. 'Let's not forget that the aim is to bring on the most talented people, be they drivers or teams, and the most direct route to achieve this is by having very strict rules.'

Dutton says: 'It's an old story. It's nice to have the freedom and it is good for young engineers and drivers to have that freedom to learn, but you also need to be careful that it doesn't make it too expensive. The more open they make it, the more you can change things and spend money on development.'

Three-conomics

As spec championships proliferate, it is not beyond the realms of thinking that the days of the open technical regulations and multiple manufacturers in junior single seater racing have passed for good, and there are indeed those who believe that the concept of open technical regulations at Formula 3 level is no longer relevant to the upper echelons of single seater motorsport. Christian Horner, team principal at F1 team Red Bull Racing, is among them. He says the GP3 Series is now closer to his heart than F3: 'There are less variables [in GP3], so there you see the real talent of the driver,' says Horner. 'If you look at FIA Formula 3 at the moment, the budgets that are required, the development, the testing, and the programmes these guys are running to is too much. There is more you can play with on a Formula 3 car, but all the sensitivities [for drivers] are the same.'

But what about training engineers? Despite the limitations now placed on technical

While Formula 3 is justly famous for the part it plays in educating drivers it is also an important step in the development of race engineers and mechanics and very many have used the category as a springboard to successful careers in Formula 1

The elegant Dallara chassis has proved itself to be robust in a number of high profile shunts in recent seasons yet there is still a real possibility that in the future F3 cars might be required to run with Halo or some other form of cockpit protection

Macau remains one of the jewels in the Formula 3 crown and is a fine showcase for the formula, while also a challenge for both drivers and engineers with its mix of tight streets and fast straights

With more variables than most sub-F1 formulae the communication between the racecar driver and the race engineer is a crucial aspect of Formula 3

freedom in Formula 3, there are still those who believe there is more than enough room to allow young engineers and mechanics to develop race engineering skills. For engineers at Van Amersfoort Racing (VAR), general manager Rob Niessink sees Formula 3 as the second step on the team's ladder, with a portion of the engineering team having entered at the Formula 4 level. 'Very often [new staff] already have some experience as an intern and then they come in to F4 and they get used to the racing atmosphere, the time schedules and pressures, and the performance pressure, and then they make some steps up,' he says.

'In F3,' Niessink continues, 'they are more fine-tuning their skills and learning and developing their skills and very often you see the guys making steps up in to Formula 1, often via GP2 or [Formula V8] 3.5, although more and more are going from Formula 3 into F1.'

Three thinking

Niessink also says that the youngsters entering the VAR fold believe F3 is a must-do category, which he understads: 'In the past, a couple of our guys climbed up to F1 after they worked with us in F3. It is still good on your CV, because it is a challenging class, it is a challenging championship, and in F1 they still rank F3 very high and it is a benefit if you did that series.'

Domenicali is also keen to promote the value of working in Formula 3 to those hoping to make a career in Formula 1. 'To put yourself in the spotlight in such a competitive and professional series is definitely an important item on the CV of anyone aiming for a career in Formula 1. And let me say that this is equally applicable in other areas of expertise, on the sporting, commercial and communications side.'

At Fortec, however, Dutton notes that while Formula 3 remains a category that is important for burgeoning engineers and designers, Dallara's dominance has had the impact of reducing that relevance. 'Twenty years ago, it was definitely for young engineers, because you could do a lot more in those days and there was a lot more opportunity,' he says.

Indeed, one must look back as far as the mid-1990s to find a consistent race-winning challenger to Dallara. 'It was more of an engineers and designers formula then, because there were different chassis, but now Dallara are so far ahead, I can't see any manufacturer catching up with Dallara,' Dutton adds.

In recent years, there has been a sea change in F1 regarding the power units. Gone are the 2.4-litre normally aspirated V8s, to be replaced by 1.6-litre V6 turbo engines, fuel flow restrictions and multiple energy recovery systems. But when asked whether Formula 3's

'In order to control the costs in Formula 3 it's important to restrict the amount of room to manoeuvre within the technical regulations'

technical engine future should follow that of Formula 1, Domenicali was not convinced this was necessary for the more junior formula. 'If I can draw an analogy with football, I don't think we should have an approach similar to Barcelona's in the sense that all the junior teams have to play in the same formation as Messi and company. Having said that, we should not lose sight of reality and, as of today, I don't think a direct link is vital from a technical point of view.'

While Niessink and Dutton broadly agree with Domenicali's sentiments, their viewpoint is understandably dominated by costs. Niessink believes that the FIA should not move too far from the formula that currently regulates Formula 3 and says that he thinks that adding complex electronics and power recovery technology would prove unaffordable, while the introduction of turbocharging would make the category difficult to control.

'I think we shouldn't go too far,' says Niessink. 'It doesn't make sense to copy and paste it from Formula 1, because it is a different category and what we feel about [Formula 3] is that it is still an open wheel category, which is highly competitive and prepares the drivers for the next step in their future career.'

Dutton, meanwhile, admits that while complex powertrain technology may not be the right direction for a class at the level of Formula 3, it may have a place further along the junior single-seater ladder. 'I don't think [Formula 3] should be a formula where manufacturers are developing engines. I think we need to keep an eye on that; I could see Formula 2 [the new F2, the direction of which is still to be decided] going that way. Formula 3 was to show off young drivers originally, so that is more for Formula 2 and not Formula 3.'

One area in which Formula 3 might follow Formula 1 is, of course, with safety. Earlier this year Carlin driver 'Peter' Li Zhi Cong suffered and astonishing accident at the FIA F3 meeting at the Red Bull Ring, during which he suffered multiple broken bones in his heel and fractured vertebrae, yet in terms of the size of the impact, he was relatively unscathed.

Dutton says this is one area in which Formula 3 is actually doing very well: 'The most effective aspect of Formula 3 is the safety. They are really strong cars as we witnessed recently. The FIA brought out new modifications, which were all pretty sensible.'

Yet while it is truly incredible that drivers are still in one piece after shunts such as Zhi Cong's, due to the safety advances, Domenicali continues to believe that F3 should follow a safety package that runs somewhat parallel to Formula 1, which could mean the use of a Halo type head protection device in the future. 'While I said earlier that it's not vital for Formula 3 and other junior series to follow the same technical path as Formula 1, the opposite is true when it comes to safety. There should be no compromise in this area and that credo has been observed for some time now, as with the wheel retaining cables, for example. So, too, the same should apply when it comes to driver head protection,' Domenicali says.

Three delivery

There is no doubt that the FIA's European Formula 3 championship is facing problems, but these are issues that are reflected across the spectrum of junior categories in Europe. With the next set of Formula 3 technical regulations delayed until 2020 (see the March issue of *RE* V26N3), there appears to be no clear picture as to what shape the rulebook will take in years to come. However, cost management may very well be the feature that dominates the immediate future of this category.

When taking the chair as the Single Seater Commission president in 2012, Gerhard Berger was adamant Formula 3 should be the pivotal step on the road to Formula 1. It is a belief that Domenicali has taken through to 2016. 'For the FIA, the European Formula 3 Championship is one of the most important steps on the ladder for young drivers aiming for the highest level in single seaters, namely F1. There is no better preparation than that provided by this series, aimed at youngsters,' he says.

'To put yourself in the spotlight in such a competitive and professional series is definitely an important item on the CV'

F3 or not F3? That is the question

The FIA got a little precious about the Formula 3 name a couple of years ago and stopped its use elsewhere. Because of this the European F3 Open Championship (previously Spanish F3) had to change its name to Euroformula Open, although it is basically a low-cost F3, running with a spec Toyota engine. It's popular, too: 'Euroformula Open is a European F3 championship, it uses exactly the same car, but because of the different rules packages the budget is just €350,000,' says Gavin Wills of Team West-Tec, which runs cars in both Open and Euro. 'That is really good value. It just goes to show what can be done when you have a rules package that is based completely around trying to deliver value.'

The FIA has now recognised there's a huge gap between the many F4 series across the world and European F3, particularly in terms of budget. With this in mind it's been looking at allowing regional or national versions of F3 once more. The first of these is the BRDC British Formula 3 Championship, which despite its name is actually the former BRDC F4 Championship – a series which uses cars which boast better performance than FIA F4, but not quite Formula 3 lap times.

The BRDC fills the gap left by the once-mighty pukka British Formula 3 Championship, which folded due to lack of entrants at the end of 2014. However, not all are sure it's such a great addition to the F3 world, with Frits van Amersfoort, the boss of Euro F3 front-running outfit VAR, telling this magazine last month that he thinks it might devalue 'proper' F3. 'I really don't like the fact that the BRDC F4 calls itself F3 now, and because I think that it's not F3, and the name doesn't belong to it. I don't think it is right when a series that's not F3 calls itself F3, because in the end we have to admit that some people might think it is an F3 car, and some will tell their sponsors, tell their financiers, that they are to drive in British F3.'

At the start of this season MSV's F4 changed its name to BRDC F3

FIA Single Seater Commission president Stefano Domenicali. The former Ferrari F1 boss believes Formula 3 is a vital part of the motor racing scene

Haul of fame

With 1200bhp, 13 litres, and a minimum weight of 5300kg, there's nothing average about race trucks. Which is why we just had to find out more …

By SAM COLLINS

It is perhaps one of the oddest forms of motorsport there is, and at first glance truck racing does not seem like a particularly sensible activity. But, on closer inspection, it is one of the most entertaining forms of racing in the world, both from the standpoint of spectators and engineers.

Truck racing exists all over the world, but its real heartland is Europe and in 2016 the FIA European Truck Racing Championship was relaunched by a new promoter, the forward-looking and ambitious ETRA organisation. The new management has set itself the brief of growing truck racing and increasing its visibility across Europe, while also keeping what is at the core of the sport's success – entertaining racing and a degree of technical freedom.

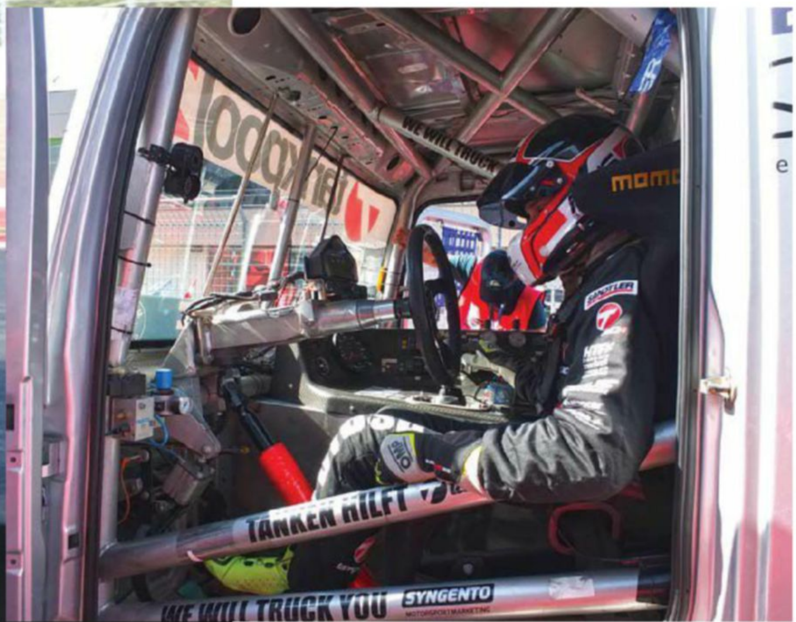
At a glance the FIA technical regulations for race trucks are full of impressively enormous numbers; a 5300kg minimum weight and a 1500bhp maximum power output jump out immediately. But when looked at in detail they are actually a good example of how well placed restrictions can control costs and still leave plenty of engineering freedoms.

Race trucks must be based on mass production road going trucks with two axles, and as Stefan Honens, the technical director of the Tankpool 24 racing team explains, that in itself creates some interesting technical challenges. 'The regulations state that the minimum weight is 5.3 tonnes and then there are regulations on weight distribution, 3150kg must be on the front axle. Traction is always the problem as a result, we are always looking to get more traction, and that is the big problem. The trucks also understeer, because there are four rear tyres and only two fronts.'

Most of the trucks in the European Championship are the typical layout commonly seen in Europe, with the bluff-fronted cab mounted right at the front of the chassis, mostly

The Tankpool 24 team's Mercedes truck showing signs of contact out on track. When it comes to racing thrills these big machines always deliver

The Buggyra 'cab rear' style Freightliner truck with its bodywork removed. The bump bar at the front of the chassis gives an indication of just how physical FIA European Truck Racing gets

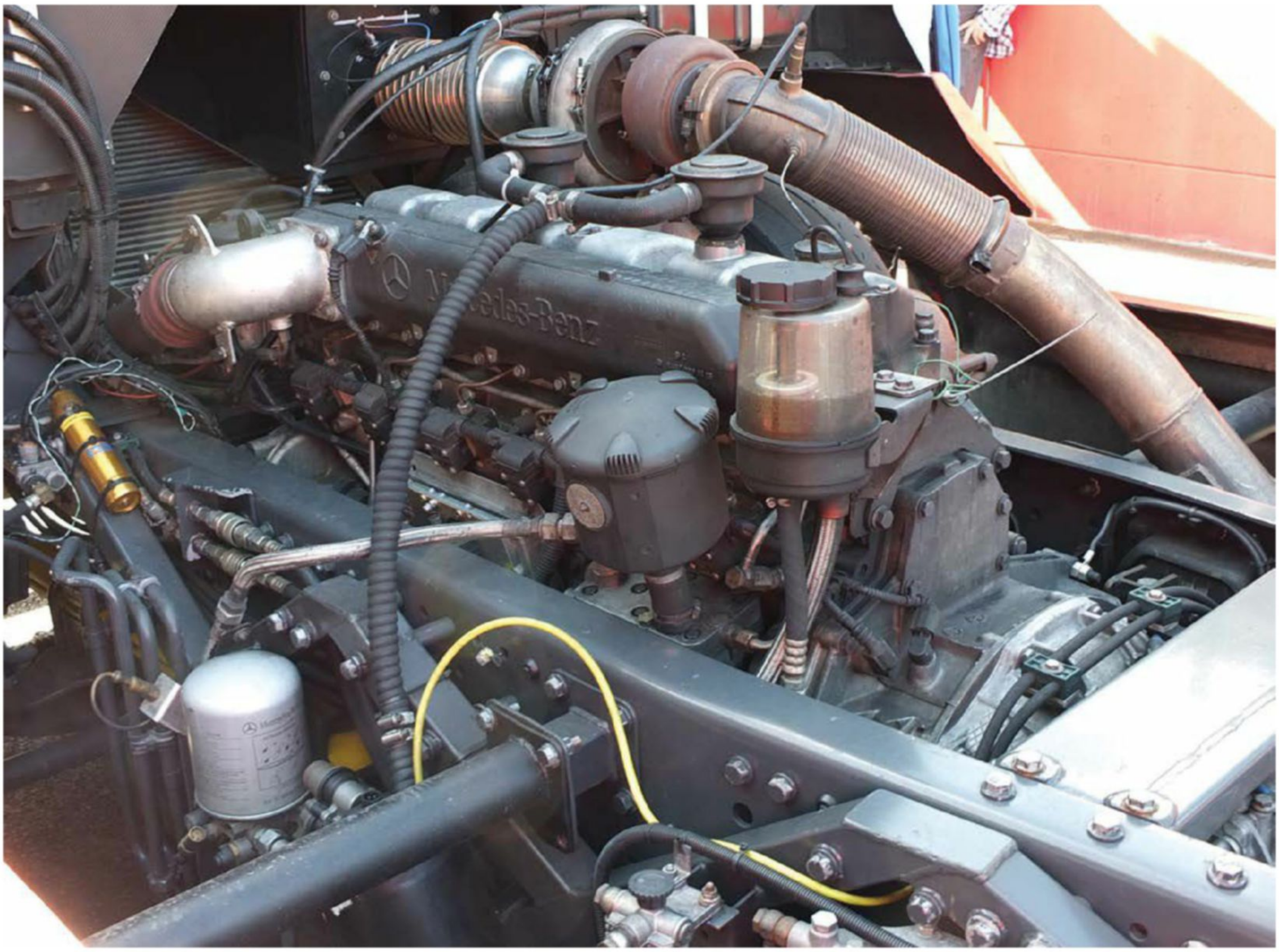


The cab is a very busy place. The driver has to deal with monitoring the temperature of the brakes and cooling them, a constantly shifting balance, and a 5-tonne machine that handles like a kart

ahead of the front wheels, while the engine and transmission are mounted to the rear of that between two large steel chassis rails. The rear wheels, of which there are four on a single axle, are driven. The exceptions to this layout are the less common American style trucks which are often called 'cab-rear'; the engine mounted at the front of the truck and the cab behind it. Currently only the Czech Buggyra team uses this layout with its Freightliner based racers.

Getting such a large vehicle to handle correctly with the major weights generally in the wrong place on the car (oddly, the truck engineers refer to their vehicles as cars) requires something of a mental reset. As the trucks roll out of their tents in the paddock (as they are too big to fit in most pit garages) ahead of a session the front wheels show a huge amount of caster as the steering is turned to full lock. 'In a straight line the track cannot run with any camber, that is one of the restrictions in the rules,' Honens says. 'But they have a lot of caster, so we run 35 degrees of caster in order in increase the cornering speeds, when we turn in, the wheels have massive angles. We don't have any rigs to calculate this at the moment so it has been learning by doing over the years. Back in the Super Truck [a previous formula] times we

Getting such a large vehicle to handle correctly with all the weights generally in the wrong place requires something of a mental reset



The engines in racing trucks make use of standard parts in the main, up to 90 per cent in fact, although they also use special pistons and injector pumps and optimised turbochargers

started with just eight degrees, but found more and more benefit with bigger angles.'

All the trucks use hydraulic steering systems largely derived from production vehicles, and steering such a huge vehicle at high speed requires some mechanical solutions not seen elsewhere in motorsport. 'To run the angles we are at now is a real challenge, we have to run 400bar oil pressure in the steering system as when it turns it lifts the whole truck,' Hohens says. 'The hardware is pretty much standard componentry from the production trucks but we have selected the ones with the biggest pistons. For the last couple of years it's been this way. We have a locked rear axle like a kart, and four tyres at the back and just two at the front, so when you want to turn in the truck just wants to go straight on. When you have that much caster the truck is basically a three wheeler when you turn in. But you have to be quite careful as if you don't get it right you lose traction coming out of the corner.'

'A few years ago we rented out a track and tested all the dampers back to back in a single day'

This description will sound fairly similar to another much smaller, but far more common form of racing vehicle, as Honens points out: 'This is where our driver, Norbert Kiss is good. He likes to drift the truck into the corner and this helps with traction on the exit. I also drive the trucks from time to time in testing and it is really like driving a go kart. They are really fun!'

Heavy metal

There is a large amount of variance in suspension design (leaf springs are in evidence here), with damper type, position and operation, all differing from team to team. Honens is very familiar with the layouts used by both the Tankpool 24 Mercedes trucks and also the more common MAN trucks, the development of which he was deeply involved with before he switched teams at the start of 2016.

'Everyone has their own ideas on suspension,' Honens says. 'The springs we run are quite soft because of the nature of the vehicle, but some of the components we use have to come from strange places. The linear pot on the damper, for example, is not a motorsport part, it is from some kind of industrial application. We are not Formula 1, we cannot make everything bespoke so we are always looking around for what parts are available. In general, though, the dampers are quite an area of research at the moment, they are motorsport parts and there is a variety on offer. Penske, for example, offers a design which has the advantage of being a bit like a kit damper and it comes with lots of information on how to build it up and get the best out of it.

'We build that up how we like, then get a damper dyno and have a play,' Honens adds. 'A few years ago we rented out a track and tested all of the dampers back to back in a single day, three days of testing just on dampers. From that we knew what the curve needed to look like. We have these very big tyres, it's [like] another spring to consider; we get some data from Goodyear, but we prefer to use our own.'

Penske is not the only supplier to the top truck teams. Dampers from KW and perhaps the biggest Ohlins TTX dampers in existence are also in use in the 2016 European championship. 'There is still so much more to do in that area, I would like to get one of these laser ride height sensors on the truck, use it on the rear axle, then I will be able to get some better data on

The trucks run up to 35 degrees of caster to increase the cornering speeds. They use hydraulic steering systems largely derived from production vehicles, using 400bar of pressure with these big caster angles

Race trucks are limited to just 99mph. If they were to go any faster then barriers would probably not be able to cope with the impacts

A whopping Ohlins TTX damper on a MAN race truck. Damper development is a vital part of race truck engineering as the spring rates run by the trucks are generally quite soft. Motorsport shocks are used

'You would blow the whole head off the engine if you did not reduce the compression'

the spring rate of the tyres. But the problem we have is lack of time,' Honens says.

Powering the race trucks are a range of different diesel engines which by regulation have a maximum displacement of 13,000cc and typically produce a little over 1200bhp and 5500Nm torque with a red-line usually around 3000rpm. The performance is impressive, too: the 0-100kph time is five seconds and the 30-160kph time is around seven.

Freight expectations

The engines used are pretty similar to their production counterparts though tuning and bigger turbos more than doubles output. 'We use about 90 per cent standard parts. We have special pistons, injector pumps, turbo, con-rods, but the camshaft, lifters, all of that is standard,' Honens says. 'We have to change the piston because we have about double the amount of boost pressure and run a lower compression ratio compared to the production engines, otherwise the cylinder pressure would be far too high. You would blow the whole head off if you didn't reduce the compression!

'The pistons themselves are not specially made, though, and typically a standard piston would be taken and machined to meet our design and requirements, so we use Mahle pistons. But they don't come from Mahle motorsport, just Mahle production. There is no motorsport piston in this size,' Honens says.

Getting the best out of these engines, which were originally designed to run for hundreds of thousands of miles hauling heavy loads across Europe at low speeds, requires further tuning beyond the reworked components, and here the regulations also come into play.

'The injection timing is a really important factor for us,' Honens says. 'With this set-up you only have a certain amount of crank angle where there is enough pressure in the chamber to inject the fuel in the right way. If you miss that and the pressure is dropping then you have to make a longer injection pulse for the same amount of fuel and that ends up creating smoke out of the exhaust which is forbidden in the regulations...well mostly forbidden.' Some trucks in the series do puff out small amounts of smoke from time to time. 'We have tried using particulate filters in the past to get around that but it had a very bad effect on response so we felt it was better to just get the timing right and the chamber right.'

Home to boost

The turbochargers used on race trucks are unsurprisingly some of the biggest found in motorsport, though it's worth noting that the compressor on the Mercedes F1 power unit was sized in part by the Daimler truck development team in Germany. 'As there is an air restrictor which is the same on all the trucks, most of the teams have pretty similar turbo sizing, just a

The drivers tend to use two or three gears, relying on the huge torque

few small differences here and there,' Honens says. 'Because the turbo, like all turbos, has a window of its best operation you have to go and find where it is and how to get the best out of it. You can calculate that to a point but to really find out you have to test it. It's to do with the dynamic acceleration of the turbine and things like that, plus the relationship between the injection system and turbocharger is where you get the power. We spend hours and hours on the dyno, but also we do a lot of testing in straight lines driving up and down airfields. Because of the high exhaust pressures and temperatures of the race specification engines compared to production the bearing is always an issue. The Schwitzer one we are using is maybe 20 years old in terms of its design, but it works well and has the best bearing housing.'

Trucker torque

The big engines drive the rear wheels via what is basically a standard off-the-shelf transmission. While these can have a vast number of gears, typically 16, the drivers only tend to use two or three during a race, relying on the huge torque of the engine instead of making lots of gearshifts. 'In general the transmission is slightly modified from production specification but it has to be mostly the same as a road going unit,' says Honens. 'You do not have to use the 'box used on the model of truck you are racing but it must be a commercially available production truck unit. It also must have the correct number of gears, if it was designed as a 16-speed 'box for the production truck then you have to run 16 gears in it on the race truck. The gears have to be proper size too; super thin cogs you never use, as this is carefully checked by the officials.'

Once the trucks have got up to speed they are electronically limited to 160kph (99mph). This is mainly for safety reasons as if they were to go any faster circuit barriers would probably not be able to cope with the impacts. The FIA monitors the speed of the trucks via a 10Hz GPS system, so most of the teams set electronic limiters at just below 160kph limit, though they all have overrides which can be used for up to 2.7 seconds in some places.

'We use a Stack data system,' Honens says. 'Beyond that we only have the ECU in terms of electronics, that is a standard unit but with modified software. The shifting, throttle, brakes all of that is mechanical. Everything is quite basic, we have no telemetry and we just download the data after each run. We have about 64 channels of data on the engine, brake disc temperatures, and wheel speed sensors in all four corners, steer angle, front and rear brake pressure, damper pots, and various temperatures as you would expect.'

The brakes are water cooled in order to get them through a race of 20 to 25 minutes. There are two nozzles on the front brakes spraying water into the disc's air vents. Trucks use steel discs rather than carbon, for reasons of durability and price

Racing trucks must use a production gearbox with the standard amount of available ratios. This means that there can be as many as 16 gears, but because of the huge amounts of torque (some 5500Nm) drivers tend to use just two or three in a race

Truck stop

Stopping a 5300kg race truck is not a simple task, and it is one made more tricky by the imposition of a production-based braking system. It is actuated by compressed air with a maximum of 12bar, while anti-lock systems of any type are outlawed. Drivers such as Kiss (the 2015 European Champion) who have come from other forms of racing immediately comment on the braking being the hardest thing about driving race trucks.

'The driver has no real brake pedal feel,' Honens says. 'There is just a return spring but there is no back pressure like you would get on a hydraulic system. You want the pedal as long as possible, as when you hit the brakes air goes into the pipes and when you release it changes it. So you have to adjust the pedal movement to the locking of the wheels, then you adjust the rear to the front. As a driver you hammer the pedal to the floor and get the air to the brakes as quickly as you can then lift off entirely, then have a moment! With new drivers we need to find the exact right return spring for them.'

The brakes themselves are water cooled in order to keep them functioning for the duration of a race, typically 20 to 25 minutes, with three races per day in the European Championship. 'We have two nozzles on the front brakes

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A cab rear truck. Most other European trucks are flat-fronted, as is the case on the roads, which brings its own challenges in terms of weight distribution and getting the power down coming out of turns

Turbochargers in truck racing tend to be on the large side. The teams spend a great deal of time in finding the sweet spot on their turbos, both by running the engine on the dyno and in straightline tests at airfields

Watt the truck?

Road haulage is facing a new era in Europe as manufacturers and governments look to cut emissions. This means new technologies and hybrid systems are being introduced on production vehicles and there are those in the paddock who feel that the sport should play a role in this transition, Stefan Honens chief among them. 'We have an air restrictor so top end power and speed is basically restricted on the race trucks. On the end of the main straight we use about 400bhp to maintain the maximum speed, leaving us a spare 1000bhp basically for quite a long time,' he says.

We could do something with that excess power, but the FIA don't really want to know about using hybrids in truck racing at the moment,' Honens adds. 'I have already worked out a system in my head based on the systems used on city buses which these days are all hybrids. They all run capacitors which are high power and quick release in terms of energy. We have a minimum weight in this class and to meet that we run 300 to 500kg of ballast, why not use that excess weight? You can do a lot with that.'

'For now the FIA is not so interested. I sit on the technical working group and it's important that we keep costs under control with this class and not have some idiot like me suggesting crazy things like hybrids and other new technologies. But, if in the next few months and years the promoter continues to do a good job then I think maybe I will look at it again,' Honens says.

'In terms of discs we have found that in this application there is nothing better than steel. We tried carbon, but steel was better'

spraying water into the air vents on the disc [not the disc face],' Honens says. 'In terms of discs we have found that in this application there is nothing better than steel. In Super Trucks we tried carbon but steel was overall a better choice. The carbon discs cost €6000 each, and they failed after two laps, but the steel discs are only about €70 each. We use standard production brake pads. We have tried Performance Friction ones with the ceramic in them and it was quicker, but it was too aggressive on the disc, so overall we have found that the road going stuff gives the best performance for the range of temperature.'

Daze of thunder

Managing the brake temperatures is down to the driver, who not only has to race in a series (which has been compared to both NASCAR and the BTCC in terms of racing style) but also keep a close eye on the many various read outs in the cockpit. 'The temperature sensors feed information to the driver in the cab,' Honens says. 'There he has two regulators, one front, one rear where he can control the water flow. In three tanks mounted on the side of the trucks we carry 220kg of water, and that is enough for about 30 minutes in race conditions. That is pressurised at about 10bar. When the driver sees the brake temperatures rise he can adjust the flow, he should be on a range between 250degC and 450degC. Because the truck is losing weight each lap, as the water is used up, the driver also has to adjust the brake pressure every two or three laps by about 0.3bar. The speed limit actually helps here as when you are flat out down the main straight at just 160kph you have lots of time to adjust things.'

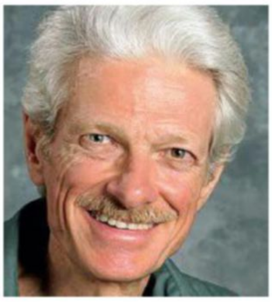
The speed limit and the fact that a race truck is by its nature one of the draggiest shapes possible means that aerodynamic development in truck racing is at a minimum with just some small panels at the front and sides of the vehicles fitted, which the drivers tend to smash off during typically fraught races anyway.

There is some aero on the trucks, but officially wings and aerodynamic devices are banned in the sport. But look closely at the trucks and you can see that there is some benefit to be had from the panels used. 'We have done wind tunnel testing in the past, but to be honest with the speed limit the real limit on acceleration is not drag but traction, so up to that speed if there is any air left to play with you want to direct it to the intercooler or radiators, more power and more cooling. The racing can be quite close and the shape of the trucks means that sometimes in a pack it can be hard to keep things cool. You can lose power in that situation, too,' Honens says.

Keep on trucking

Every engineer involved in truck racing seems to love their work. Perhaps it's because of the technical freedom, or perhaps the involvement forced on them by limited budgets. 'We don't have a big team, perhaps just four of us involved, our regulations give us so much room to play,' Honens says. 'It's so much nicer than other series where you are so restricted these days and you can only do a bit of set up. Here we do everything ourselves, we don't really buy much at all, the chassis rails, some engine things and the cab, it's great. I love it.'

Under its new management and with the rules and racing the way they are it seems certain that the popularity of truck racing in Europe will grow. But then it will have to deal with the problem currently being faced by Rallycross, the return of manufacturers and with them big budgets. How that develops will be interesting to watch.



Steer-way to heaven: the basics explained

All you need to know to get the most out of your car's steering

QUESTION

I would like to know more about the interaction and effects of spindle offset versus caster on steering effort, steering angle-induced camber gain, and weight transfer. An auxiliary topic would be discussing the trend to, and effects of, attaching the front spring mount to the upright rather than the lower control arm (LCA), in a manner that allows it to be offset fore and aft from the king pin axis, thus variably loading and unloading the spring and damper as the wheel is steered.

THE CONSULTANT

I have addressed at least the first part of this question before, but not for a while. At the risk of belabouring points many readers already know, I'll start at the beginning.

When we steer a car's front wheels, each one steers about an axis, not surprisingly called the steering axis. In a beam axle front end, the steering axis is the centreline of the kingpin. In an independent suspension with an upper and lower ball joint, the steering axis is a line passing through the two ball joint centres of rotation. Some older independent suspensions have kingpins like a beam axle. In a MacPherson strut suspension, the steering axis is a line through the centre of rotation of the upper strut mount and the ball joint.

It is possible to have a sort of virtual ball joint by substituting two links for an upper or lower control arm. When these links lie in a common plane, they form a linkage that has an instant centre where their centrelines intersect. This instant centre will migrate as the wheel steers, and it will generally lie closer to the wheel centreplane and further from the car centreplane than a ball joint can.

The steering axis usually does not pass exactly through the tyre contact patch centre, and it usually is not entirely vertical. It generally intersects the ground plane somewhat ahead of the contact patch centre, and somewhat inboard. It generally is inclined rearward at the top and inboard at the top.

The side-view inclination angle of the steering axis is called caster. This is conventionally positive when the steering axis is inclined rearward at the top.

The front-view inclination angle of the steering axis is called steering axis inclination (SAI) or sometimes kingpin inclination (KPI). It is positive when the steering axis tilts inboard at the top. The side-view distance between the contact patch centre and the point where the steering axis meets the ground is called trail. It is positive when the contact patch centre is behind the point where the steering axis meets the ground. The front-view distance between the contact patch centre and the point where the steering axis meets the ground is called steering offset, per ISO terminology, or scrub radius, per older SAE terminology. ISO uses scrub radius to mean the radial distance between the two points, which makes more sense. With either SAE or ISO, the quantity is positive when the contact patch centre is outboard.

The wheel axis or spindle pin centreline can also lie ahead of or behind the steering axis. I call this pin lead or pin trail. 'Spindle offset' is another term that is not an ISO or SAE standard term. I'm not sure what the questioner means by it, but I guess it would logically be the front view distance from wheel centreplane to steering axis at pin height.

It will be apparent that the contact patch centre's instantaneous motion path is along a circle concentric with, and perpendicular to, the steering axis. That circle then lies at a compound angle to the ground plane, since the steering axis is at a compound angle to ground vertical. When the wheel steers, the contact patch moves up and down with respect to the car. This causes that corner to rise or fall, and the wheel to load or unload.

The effects are similar to what we'd get if we raised or lowered a given corner by adjusting the springs. The corner we raise gains load, and so does the diagonally opposite one. The other two lose load. The diagonal totals and percentages change. The front, rear, left, and right totals and percentages don't change.

To understand the effects of these different variables on tyre loads and forces in the steering, let's look at some hypothetical cases, where most of the parameters have a value of zero but one does not. For simplicity,

The effects are similar to what we'd get if we raised or lowered a given corner by adjusting the springs

A fully unloaded inner wheel on a hard-pressed Ford Escort Mexico rally car – just one of the effects you can expect when an older-style steering system is put through its paces. The steering axis will move as each variable is changed

Bump creates little or no moment about the steering axis, and the steering feels like the helm of a motor boat, with no feel or self-centring

The steering axis does not usually pass through the tyre contact patch centre. Hillclimb cars have specially adapted steering systems to help them precisely navigate the narrow courses that are a feature of the sport at very high speed

let's imagine that the tyre has no width or compliance, and let's look at how things are changing instantaneously in the condition considered, because once things move we'll no longer have only one non-zero parameter.

First, let's consider the case where everything's zero. The steering axis is straight up in both front and side view, and smack in the middle of the tyre. In this case, when the wheel steers, there is no jacking and no camber change. Lateral force at the contact patch creates no moment about the steering axis. Bumps create little or no moment about the steering axis. The steering feels like the helm of a motor boat: no feel; no self-centring. Actually, such a geometry will have a little self-centring due to tyre self-aligning torque, but the steering will be very numb. Wheel loads will not change with steer.

Adding trail

Now let's add just some trail, but no caster: geometry like a furniture caster. This means we will also have some pin trail. There will still be no jacking or camber change when we steer. If the car is sitting still, the front will move laterally a little when we steer. Tyre drag will tend to create a centring force. Lateral ground plane force will create a moment about the steering axis. We will be able to feel cornering force through the steering. Also, the car will tend to follow a lateral slope of the road surface and we'll have to apply force at the wheel to counter that when running straight.

Next, let's consider a case where there's positive caster but no trail: the steering axis passes through the contact patch centre but tilts rearward in side view. This implies pin lead. Now there is camber change with steer. The wheels tilt in the direction we steer. However, since there is no trail or steering offset, cornering force and bumps do not create a moment about the steering axis, and there is still no jacking or wheel load change.

Trail with caster

Next, let's combine trail and caster. Now we have a steering axis that tilts, at least in side view, and also passes in front of the contact patch centre. Now we get some ride height change with steer. The car drops when the wheel steers either direction. Both front corners drop identically when we steer either direction. This creates a gravitational de-centring force in the steering.

There will be a centring force due to tyre drag, since we have trail. There will be no change in tyre load when we steer, because both front corners jack down together. Note that we don't get any jacking with steer unless the steering axis is tilted and offset at the ground plane. Also, we don't get wheel load changes if both front corners jack identically.

Let's now try non-zero front-view parameters, with no caster or trail. Suppose we have some positive steering offset but no SAI. The axis is inboard of the contact patch centre, and vertical. Now we have bumps and braking forces creating a moment about the steering axis, but not lateral forces. There's still no jacking and no load transfer with steer.

Next, SAI but no steering offset. Now, the camber goes toward positive on both wheels when we steer. The inside wheel leans into the turn and the outside one leans out of the turn. There is still no jacking, and no wheel load change. Now, we can try both SAI and steering offset. Now we get some jacking. As before, the steering axis has to be both tilted and offset at the ground plane to produce jacking. Now, instead of both front corners dropping identically as we steer, they both lift identically. Again, we get no load change with steer. We do get a gravitational force in the steering. This time it's a centring force. The steering seeks centre with respect to the car centreline, but there is no drag centring or transmission of lateral force through the steering.

Load transfer

Finally, let's combine SAI, steering offset, caster, and trail. Now we get some load transfer. The ride height change due to caster and due to SAI are additive on the inside wheel and subtractive on the outside wheel.

The inside front corner jacks up more than the outside front corner. The inside front and outside rear gain load and the other two corners then unload. The front end of the car as a whole rises, at least for small steering angles, so there is a gravitational centring force. Quite often this effect will reverse at large steer angles and we will get a gravitational de-centring force.

To get maximum load change when we steer, we want a lot of steering offset and a lot of caster. To increase the gravitational self-centring, we need SAI and steering offset. To get more cornering force felt through the steering, we will increase the trail. To get the wheels to lean in the direction we steer, we will increase the caster.

Now, what about anchoring a coilover, a push rod or pull rod, or a drop link for a leaf spring directly to the upright? I actually think this is a very promising idea, because it will allow load transfer and jacking with steer to be controlled independently of camber change with steer and transmission of contact patch forces through the steering.

However, things to watch out for when attempting such a layout include the possibility of running joints out of travel and having interferences as things move.

CONTACT

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Subaru touring car aerodynamic study

How will the BTCC's newest racecar fare in the wind tunnel?

We start a new mini-series this month with a close look at the new Subaru Levorg British Touring Car Championship racecar, constructed by Team BMR. We featured the design and build of this car in our July issue (V26N7). Because of the extremely short time between the project's go-ahead and the cars' first appearance (just 87 days) none of the four racecars had previously been aerodynamically tested. The only information available was that obtained when a standard road car that was put in the MIRA full-scale wind tunnel to obtain the mandatory rear wing location (based on a maximum permitted rear downforce figure), plus some slightly optimistic production car drag data.

So it was up to chief designer Carl Faux to use his extensive BTCC experience (gained previously at Triple Eight Racing and RML before heading to BMR) to design the aero package with which the car started the 2016 season. And it was in this guise that the Levorg came to the wind tunnel between the Oulton Park race, where it scored its first win, and Croft, where it scored a second win, in mid-June. Given that one of the reasons for running the Subaru Levorg in rear-wheel-drive configuration in the BTCC was a small rule amendment in mid-2013 that permitted an improvement in aerodynamic balance and an overall load increase for rwd cars, it was going to be fascinating to see what the sports tourer's aerodynamic numbers actually were.

Baseline data

Refreshingly, BMR has allowed us to illustrate the baseline data measured on the Levorg in coefficient form, although the notional frontal area used to convert the measured forces into coefficients will remain under wraps to conceal the precise numbers. Nevertheless, these numbers form a basis on which to gauge subsequent changes. The starting configuration saw the maximum permitted rear wing angle (one degree nose up), fully open radiator ducts, and zero chassis rake; data shown in **Table 1**.

Although BMR was of the opinion that the Levorg had slightly higher drag than was hoped, the measured drag level in this starting configuration was, without giving away specific data on any cars, quite similar to other BTCC cars we have evaluated in the past (2010 Honda Civic and 2015 Mercedes A Class). Downforce in starting trim was also competitive with the most recent BTCC car we have tested that was built to the same NGTC technical regulations, the Ciceley Racing Mercedes A Class, in its starting trim, although of course both cars progressed to higher levels of downforce during their respective sessions.

The aerodynamic balance is worth commenting on too, for during our interview with Faux for our feature in the July issue he did speculate at that time that he might need to reduce rear downforce in order to attain a balance. That comment was, no doubt, based on driver feedback that the cars had some aero-induced understeer. Given the static front weight percentage is around 52 per cent on the Levorg, an aero split of 42 per cent front would indeed be commensurate with aerodynamic understeer. We should keep in mind that the MIRA wind tunnel's fixed floor and stationary wheel configuration might have seen an underestimate of front downforce.

But with 80mm ground clearance under the lowest part of the car (the front splitter's leading edge) and the tunnel's boundary layer control fence in place as always in our sessions, that underestimate would be of smaller

The only information available was that obtained when a standard road car was put in the tunnel for mandatory wing location

Table 1 – Baseline aerodynamic coefficients of the BTCC Subaru Levorg

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Baseline	0.441	0.200	0.084	0.116	42.0	0.454

The first aero test for the BTCC Subaru Levorg GT. Team BMR driver Jason Plato wields the smoke wand while chief designer Carl Faux looks on. The car has had success in its first season, with victories at both Oulton Park and Croft

The baseline airdam was designed purely from previous experience. It featured an undercut across the whole of the splitter and an inset scallop in front of the wheel

Filling the outboard scallop on the Levorg achieved nearly half of the drag benefit found by smoothing out the bumper – as well as all of the modest downforce loss

A further small drag gain was achieved by filling in most of the transverse undercut

Further smoothing of infill below the lower inlet achieved another small drag benefit

Table 2 – The effects of airdam smoothing

	ΔCD	Δ-CL	Δ-CLfront	Δ-CLrear	Δ%front	Δ-L/D
Smoothed airdam	-7	-3	-3	0	-0.8	+2

‘The drag is far and away the key parameter for lap time’

magnitude than it would be with a racecar with a lower ground clearance.

How significant are the aero numbers on the performance of a BTCC racecar? Faux’s response was illuminating: ‘Drag is far and away the key parameter for lap time, and if we are looking for downforce then a change doesn’t go on the car unless it offers better than a 3.5:1 lift to drag benefit.’ With this in mind we will come back to how Faux quantifies the benefits of improvements to the aerodynamic parameters shortly. First, let’s move on to the first set of configuration changes.

Airdam modifications

The initial design of the Levorg’s airdam above the splitter was based on previous experience of how to produce the maximum downforce possible, and thus featured undercuts and an ‘inset scallop’ at the outer end. A set of three infill blocks was brought along that successively smoothed out the front airdam, and the overall changes to the aero numbers are shown in **Table 2** as ‘counts’, where one count is a coefficient change of 0.001. The Greek letter Δ (delta) refers to the change to the coefficient.

In short, the airdam infills produced a seven count or 1.6 per cent reduction in drag and a three count or 1.5 per cent reduction in front downforce, which produced a slight rearward shift in downforce balance. The reductions in drag and downforce didn’t seem overly significant to your writer until Faux declared that this was worth ‘a gain of approximately half a tenth on lap time.’

How was this conclusion reached? It emerged from a lap time delta calculator spreadsheet that Faux uses to quantify the theoretical worth of changes to drag and lift coefficients. In essence this boils down to a lap time simulation program that enables different overall drag and downforce numbers to be entered, and which then calculates a theoretical lap time difference over the average BTCC circuit lap time relative to either a baseline configuration test, as in this case, or to historical data. It does not take aero balance into account, but it does enable the relative effect of changes to drag and total downforce to be quantified in a meaningful way. Interestingly, the changes to the airdam had already been scheduled for the forthcoming race weekend at Snetterton in late July, and the wind tunnel test has clearly vindicated that decision.

Next month we will look at the responses to chassis rake and wing angle changes.

CONTACT

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

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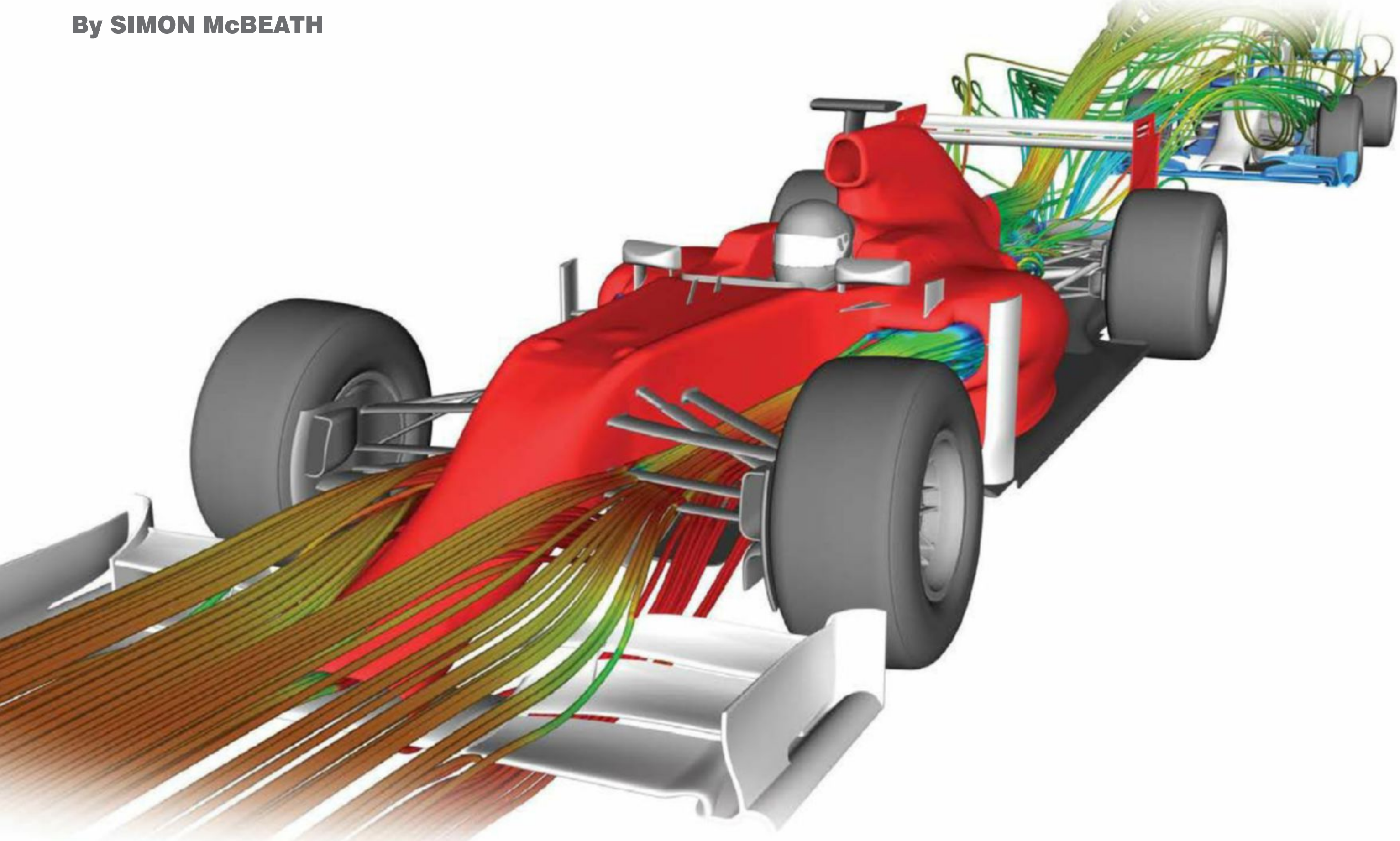
Pass masters

Continuing our quest for an overtaking-friendly Formula 1 aerodynamic configuration we examine another ground effects package and ask 'is there light at the end of the tunnels?'

By SIMON McBEATH



Over the past year or so we have been reporting on CFD studies on digital Formula 1 concept models carried out by Dynamic Flow Solutions and its director Miqdad Ali ('MA'). Essentially the dual aims of the project are (a) to enable visualisation and greater understanding of the complexities of the aerodynamics of a Formula 1 car, and (b) to specifically study what happens in two car line-astern configurations to better understand the aerodynamic interactions in overtaking scenarios.

By generating actual data on a range of different aerodynamic design concepts we have witnessed a number of extremely interesting effects along the way. This month we take our studies of a full ground effect package a step further, to see if it really could provide benefits over the current concepts in Formula1, to enable cars to run close, and hence overtake more easily.

Project review

To recap, in the July and October 2015 issues (V25N7 and V25N10) we examined a model created to the 2013 Formula 1 regulations **(Figure 1)** and saw that a following car not only lost downforce but also had a significant balance change that would create increasing aerodynamic understeer as it closed on the car in front from eight car lengths to half a car's length. This fitted well with what we know about cars of that period, and is something that seems to still afflict 2016 cars.

Then in our February 2016 issue (V26N2) we studied the data generated on a car we named RE 2017 V1, which featured greater emphasis on underbody-generated downforce, still with a flat underside but with a significantly larger rear diffuser, and with a modified and repositioned rear wing that produced less upwash **(Figure 2)**. The aims were to produce more downforce with the underbody and also to improve the airflow on to a following car. The car in isolation produced comparable total downforce and balance (as %front) to the 2013 car but generated less drag and a higher efficiency (-L/D or downforce to drag ratio). Excitingly, when in the two car line-astern configurations the following car lost somewhat less downforce than the 2013 car at all separations, and there was negligible balance change at any separation tested. Thus, a car to this design would lose slightly less total grip

Our full ground effect concept car worked well except when very close to the car in front, when it was worse than the previous two concepts

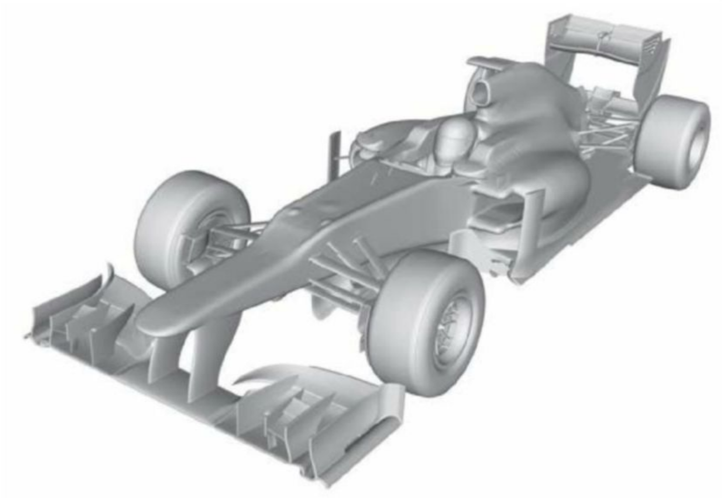


Figure 1: ***Racecar Engineering's*** 2013 rules F1 CAD model

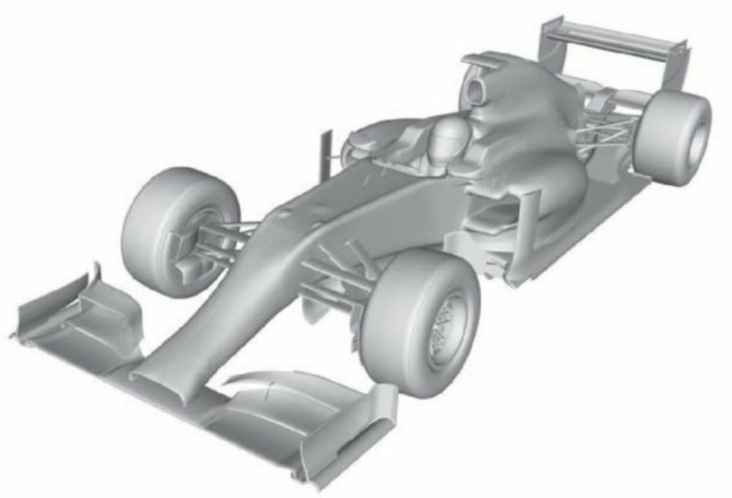


Figure 2: RE's 2017 F1 car with bigger diffuser plus modified and repositioned rear wing

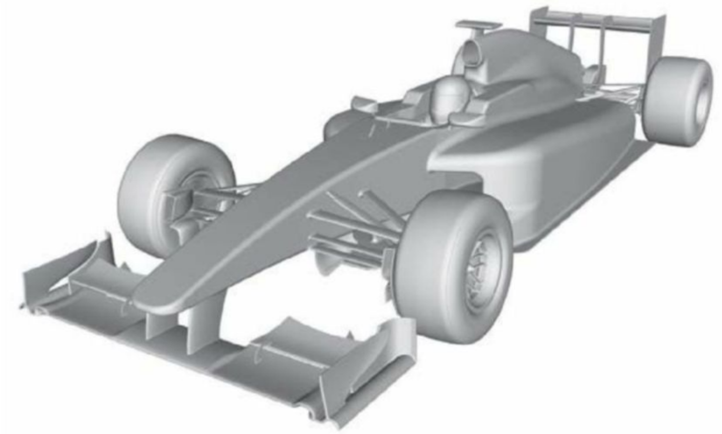


Figure 3: RE 2017 V2 with full underbody tunnels and detuned wings

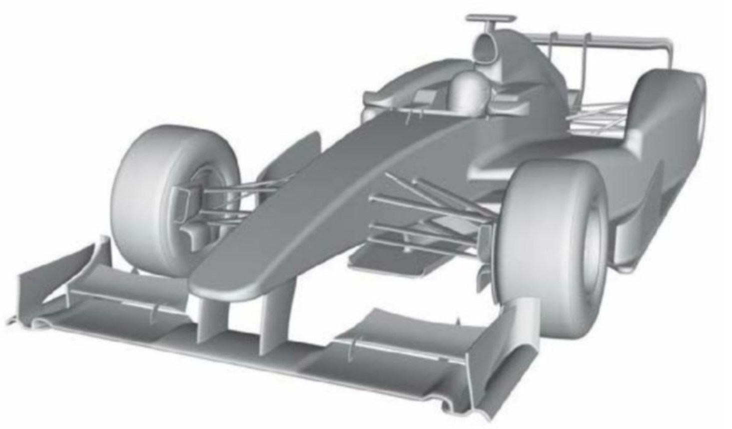


Figure 4: V3 with detuned tunnels, wider body, further detuned wing and wheel fairings

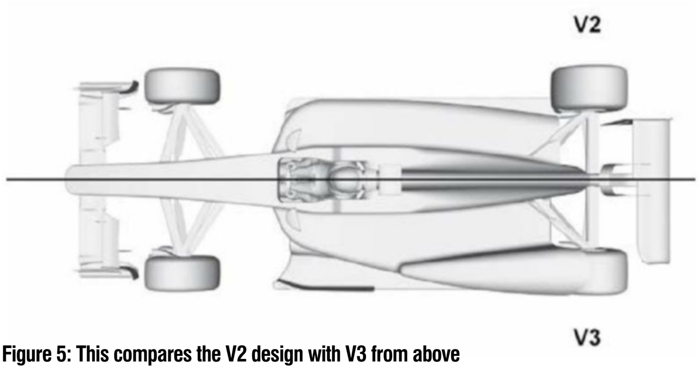


Figure 5: This compares the V2 design with V3 from above

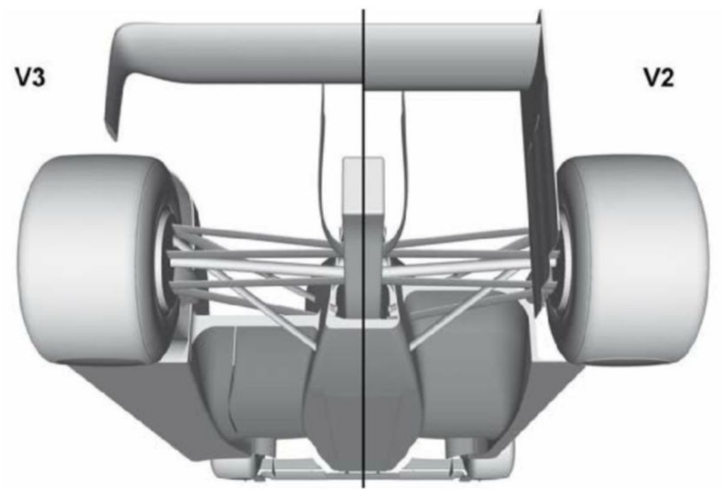


Figure 6: Comparing V2 and V3 from behind and below. The strake in V3's tunnels created a vortex that reduced pressure and increased mass flow for more downforce

when close behind another, and the balance of that grip would not alter as it does on current cars; it seemed reasonable to expect that this would make closing up on and following another car closely, both needed for overtaking, much easier.

The logical next step was to examine a full ground effects concept to see if generating a much greater proportion of the total downforce with the underbody further improved the situation, as had been widely postulated and as RE 2017 V1, by extension, implied might be the case. So, in our May 2016 issue (V26N5) we reported on the same CFD evaluations of 'RE 2017 V2', this now a full ground effect car with de-tuned wings **(Figure 3)**. Again the design was established so that total downforce and balance were similar to the previous models to enable direct comparisons. Drag reduced still further, and –L/D increased again as a result. Around 90 per cent of the total downforce came from the underbody on this design, compared to about 55 per cent on the 2013 car and about 65 per cent on RE 2017 V1.

In the line-astern scenarios RE 2017 V2 saw less total downforce loss at four car lengths separation but greater loss at the closest separations. As for the key issue of balance, for the most part V2 behaved very similarly to V1 with no balance shift across the range of separations, except at the closest separation of half a car length, when it exhibited much greater balance shift than either V1 or the 2013 car.

Perhaps frustratingly then, our first full ground effect concept car seemed to work well except when very close to the car in front, when it was worse than the previous two concepts. Why was this? Because, at the closest separation, the flow which emerged from the leading car's tunnels featured large vortices that drew in the rear wheel wakes and led to reduced energy flow encountering the front wing, and also ensured that the onset flow directionality was very uneven across the front wing's span, rising steeply upwards in the centre for example. Thus, the front wing and the forward underbody lost downforce at this close distance, leading to the marked balance shift. One could perhaps argue that a

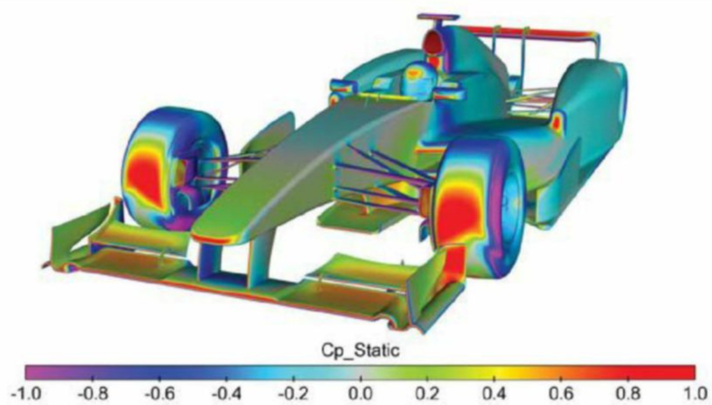


Figure 7: Surface pressure distributions

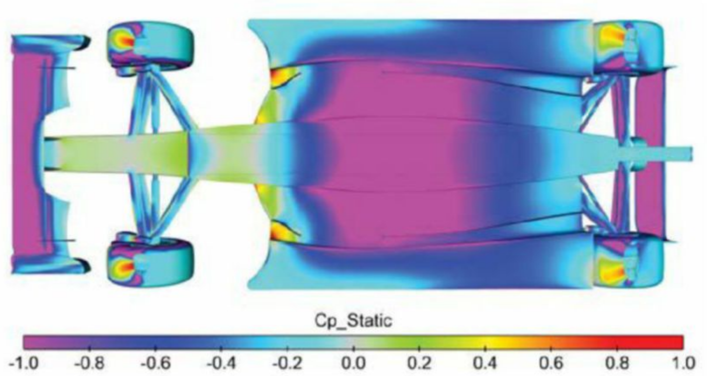


Figure 8: The underbody developed over 80 per cent of the new V3 model's total downforce, which is slightly less than the V2 car model's underbody contribution

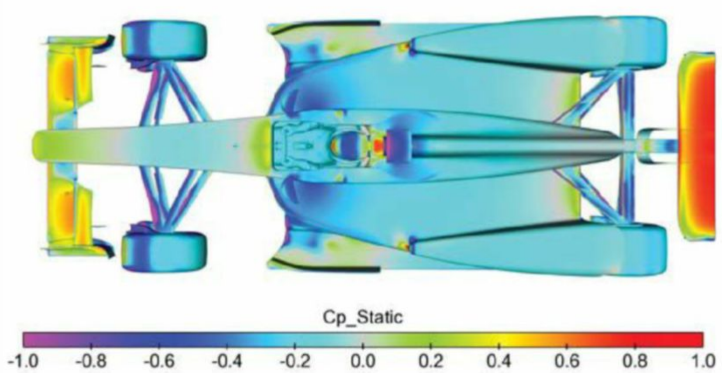


Figure 9: Lift from the upper body surfaces was less than on the V2 model, which helped the total downforce to compare well with our previous designs

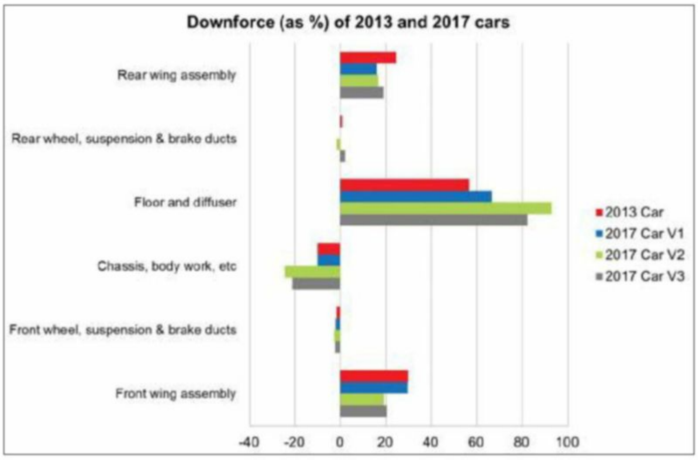


Figure 10: Downforce contributions from the major component groups on our four cars

Table 1 – The aerodynamic data on the RE 2017 V3 compared to the previous models we have tested

	CD	-CL	%front	-L/D
2017 V3	0.61	3.75	44.0%	6.15
2017 V2	0.77	3.87	44.4%	5.04
2017 V1	0.96	3.95	45.0%	4.11
2013	1.173	3.89	45.0%	3.32

racecar that has closed to just half a car's length behind the one in front would probably be just about to jink sideways in order to draw alongside, in which event it would find itself in a more energetic airflow. But the racecars might be in a corner at this moment, making that move less likely, and for the purpose of this exercise the aim was to improve things in the line astern formation.

Version 3

This, then, brings us to the latest design concept, RE 2017 V3, and the main focus of this feature. This was once more a full ground effect design but in order to try and tackle the issues of RE 2017 V2, MA decided to reduce the cross-sectional area of the tunnel outlets by halving their height at the exits, and obviously re-shaping the whole tunnel accordingly with a gentler profile. The tunnel inlets and overall tunnel widths were the same as V2. Overall body width was taken out to the car's maximum width of 2000mm, permitting wider footplates outboard of the tunnels (V2's body width aft of the front wheels was 1500mm). And rear wheel fairings were also incorporated to hopefully mitigate some of the rear wheel wake issues that afflicted V2 in the close following situation. The same front wing as V2 was utilised but the rear wing was detuned slightly further and featured a smaller, integrated end plate. **(Figures 4** to **6)**

The basic aerodynamic numbers are given in **Table 1** along with the same data on the previous designs for comparison. Surface pressure distributions are shown in **Figures 7** to **9**. The data in **Table 1** show that V3 produced slightly less total downforce than the previous models although in much the same ballpark, but balance was the same. Drag was significantly reduced, and –L/D was well up as a direct result.

Figure 10 shows the downforce contributions of the major component groups on all four of our concept models. The main difference between V2 and V3 was that V3's underbody contribution, shown as 'floor and diffuser', was proportionately slightly less than V2's, although still over 80 per cent of the racecar's total.

Figure 11 shows the drag contributions of the major components on all four cars, although we must keep in mind that total drag reduced on each new design so the proportions are not directly comparable. Nevertheless, the changes in drag contributions correspond to the changes in downforce contributions.

But the big question is, of course: how did V3 fare in the line astern scenarios? Looking first at the usual aero parameters, **Figure 12** illustrates the changes across the range of separations. Comparing with the other cars, the total downforce losses are shown in **Figure 13**, and V3 performed better than all but V1 at eight car lengths separation and much better than all other variants across the rest of the range of separations, with significantly reduced downforce losses on the following car. In this respect then, V3 was the best concept yet, and this finding corresponded with the widely held perception that ground effect cars lose less downforce when following another racecar.

What about the balance changes? Curiously, as **Figure 14** illustrates, V3 was a backward step in this respect, with negligible balance change at eight and four car lengths separation, but at two and one car lengths separation it showed the largest balance shift of any variation thus far tested. It could perhaps be suggested that this shift was less significant in a sense because the

With the new V3 design concept we decided to reduce the cross-sectional area of the tunnel outlets by halving their height at the exits

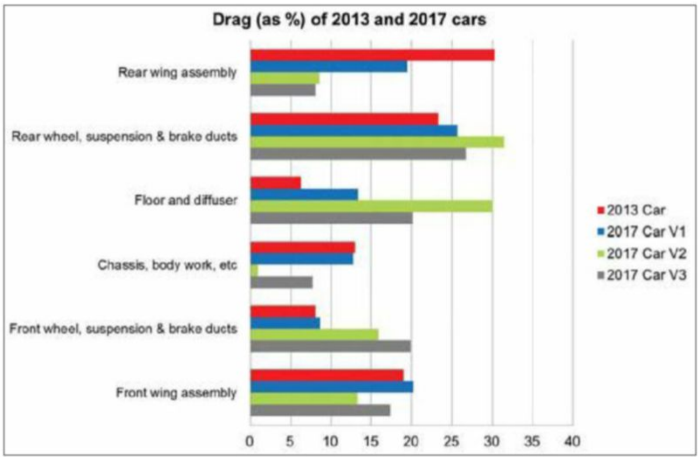


Figure 11: This shows the drag contributions from the major component groups on our cars. Note that the overall drag reduced incrementally from the 2013 car to 2017 V3

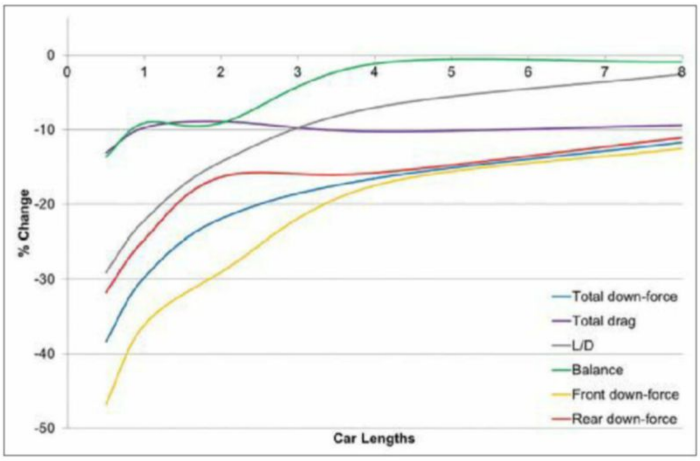


Figure 12: This shows the changes to the principal aerodynamic numbers on the 2017 V3 racecar model when it is following another racecar in a line astern formation

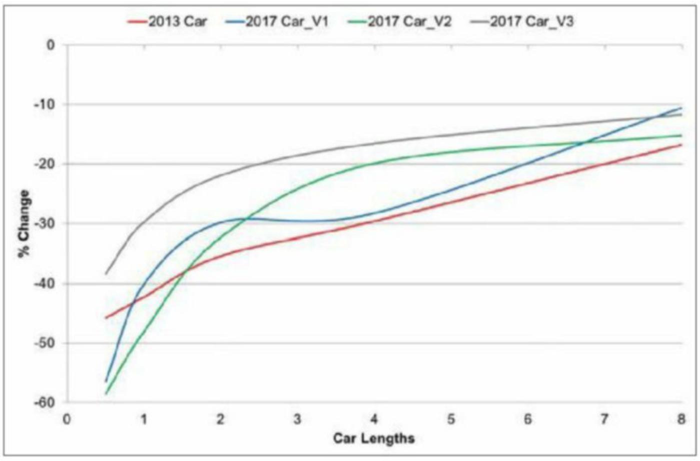


Figure 13: V3 lost much less total downforce when following than the previous designs

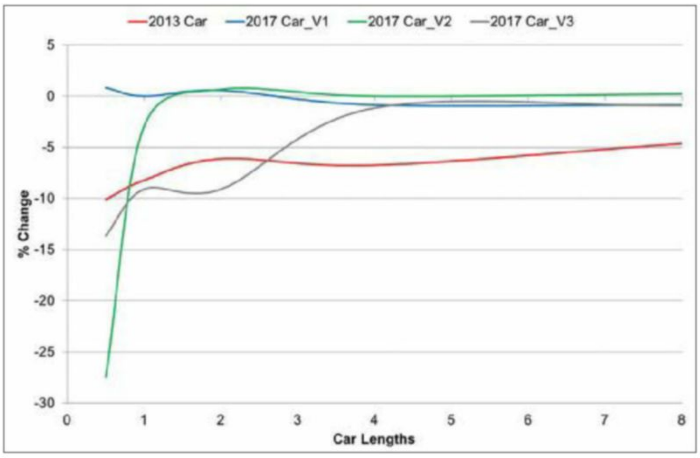


Figure 14: The V3 balance shift was not quite so good at two and one lengths separation

loss of overall downforce was much less with V3, but ideally we should be looking for less downforce loss and minimal balance change. So, why did this balance shift happen and what were the mechanisms?

We can identify the cause of the problem by looking at the plot of front wing downforce versus car separation for the four variants we have tested, **Figure 15**. V3's front wing contribution almost matched the 2013 car's front wing at eight and four car lengths separation, but at two and one lengths V3's front wing lost proportionately more downforce than all the other variants, while at half a length it was the second worst performer. Contrast that with how the underbody performed **(Figure 16)** and we see that V3's underfloor lost proportionately much less downforce than all the other variants. Nevertheless, although the front wing's overall downforce contribution was smaller on V3 (and V2 of course), the proportionate loss in front wing performance on the following car was enough to cause significant balance shifts with this concept. This perhaps served to demonstrate that even though the ground effect underbody of V3 appeared to work very well at all car separations, it doesn't appear to be possible to generalise and say that ground effect will solve all the aerodynamic problems that a following car encounters.

Perhaps this finding begs the question: 'what if there was no front wing at all?' Well, clearly there needs to be some means of generating adequate downforce on the front axle, and this might also suffer from whatever it is the front wing was suffering from on V3. It's not that the front wing is at fault *per se*; rather it is the airflow from the car in front that impinges on the following racecar's front wing that is the culprit. So let's try and figure out why the V3 car's front wing showed greater losses when following.

Energy losses

Figure 17 is a 'delta Cp-static' view comparing the static pressures on the underside surfaces of V2 (top) and V3 on the following car at four lengths separation with the static pressures on the cars in isolation. Red to yellow colours show where surface pressures increased, which on the underside of wings and the underbody means less suction or, simply put, less downforce.

Looking at the front wing, we can see that V2 lost downforce from the centre of the wing whereas V3 lost downforce right across the front wing. Conversely, V2 lost more downforce from its underbody than did V3, although this would have had less effect on balance. So even at four car lengths, where V3 saw just a few per cent shift in balance, the changes to the pressure distributions were markedly different.

The problem that afflicted V2 was a combination of reduced energy and adverse directionality in the airflow that encountered the front of the following car, which conspired to selectively reduce the front wing's downforce at closer separations. In the case of V3 there appeared to be even greater energy losses, as the total pressure slice that's shown in **Figure 18** demonstrates.

Total pressure is a measure of the energy in the airflow, and here we are looking at the transverse plane in line with the leading edge of the front wing in the four car length separation case. The red colouration shows where the airflow has free-stream ('full') energy; other colours show where losses of energy have occurred. And it is very evident that

At both two and one car lengths separation the V3 model showed the largest balance shift of any variation we have thus far tested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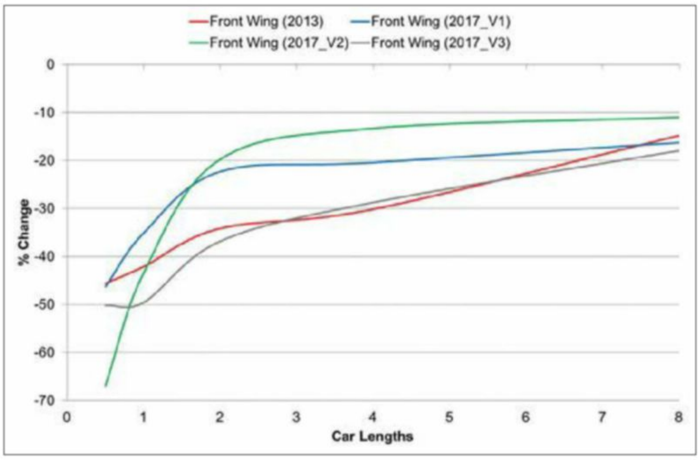


Figure 15: The loss of a larger proportion of the front wing downforce was V3's pitfall

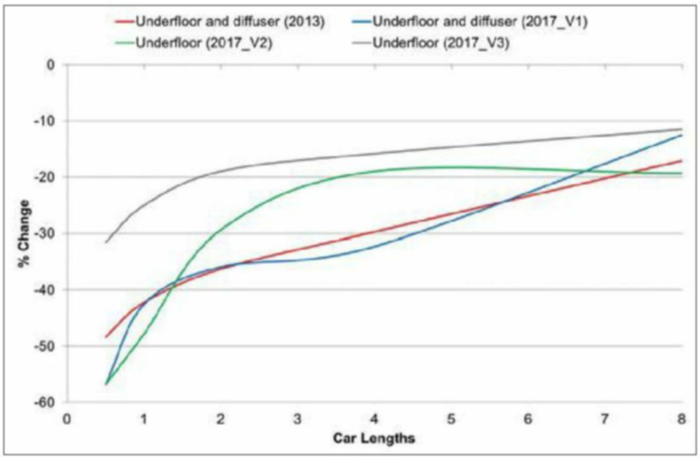


Figure 16: The V3 model's underbody lost far less downforce than the previous designs

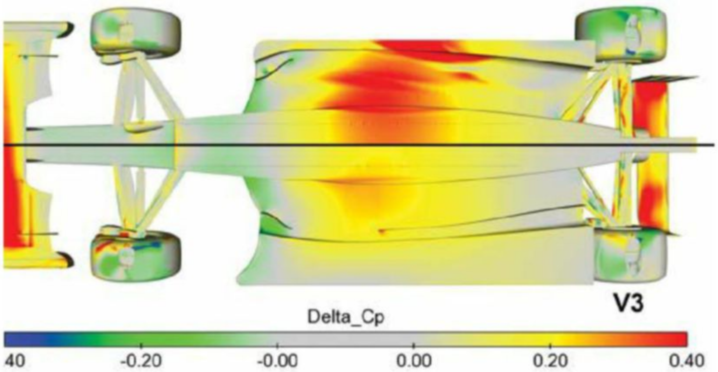


Figure 17: Underside surface pressure changes on the following car at four lengths separation on V2 and V3; note big differences in front wing and underbody responses

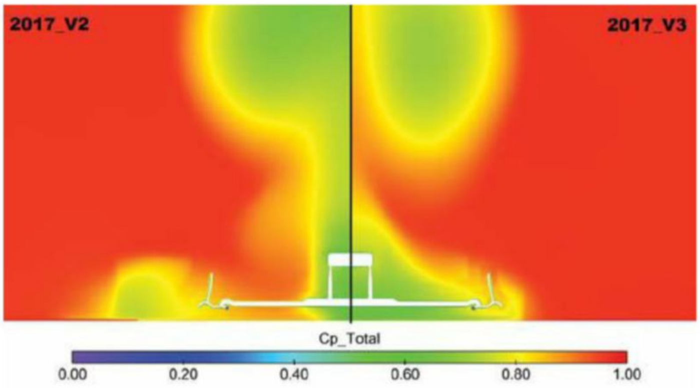


Figure 18: A transverse total pressure slice at the front wing leading edge at four car lengths separation shows that the V3's front wing received less energetic airflow

V3's front wing saw reduced energy over much of its span where V2 saw losses principally in the centre of the wing at this separation, explaining the static pressure changes described in the preceding paragraph.

Looking back at **Figure 19** from the previous article on this project, this provided two views of streamlines projected upwind and downwind from the following car's front wing at four lengths separation. The overhead view in the upper part of the image shows that the airflow encountering the front wing in the V2 concept case was drawn in from around the outside of the leading car, and this ensured that the onset airflow was reasonably energetic at four lengths (and less) separation, although not at very close separations. The lower part of the image reinforced that the energy in the flow reaching the centre of the wing was reduced. Now looking at a comparable image for the V3 concept **(Figure 20)**, the picture is quite different. The overhead view shows less energetic streamlines in the leading car's wake right out to four car lengths and clearly the air that encounters V3's front wing is at reduced total pressure (energy) almost right across the wing's span compared to the V2 case.

This corresponds with the transverse total pressure slice we examined above. It is also apparent that at further reduced separations this problem would worsen.

Underbody airflow

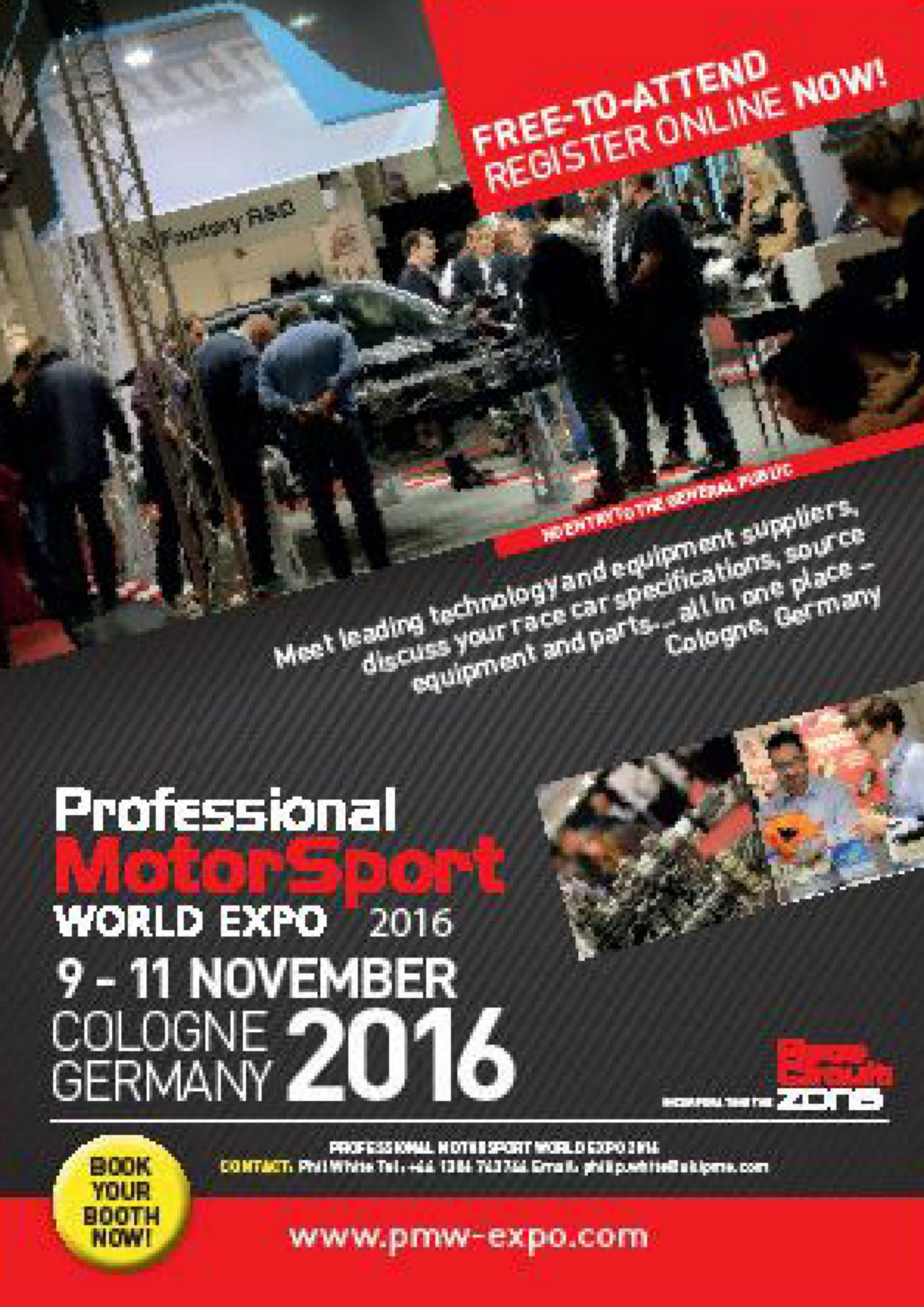
So although the design modifications on V3 were intended to improve the conditions in the wake, what seems to have happened is that although total downforce reductions on the following car were much reduced, the flows to the front wing and the ensuing balance shifts were actually made somewhat worse at intermediate to closer separations because of reductions in 'inwash' behind the leading car. However, while the front wing may have been more adversely affected on V3 when following, the underbody was much *less* affected than on any of our other variants, V2 included, as **Figure 15** demonstrated, and this is really worth a pause for thought.

We saw in **Figure 16** above that total pressure at the front wing's leading edge was reduced more on V3 at four car lengths separation than on V2. If we look at a similar slice further downwind, in line with the front axle line **(Figure 21)** we see that in the region between the chassis and the front wheel the total pressure is generally lower on V3, meaning that the total pressure in the airflow reaching the underbody inlet would be less on V3.

Yet we have seen in various ways that the performance of the underbody is less affected on V3, despite this greater reduction in the energy of the airflow reaching the underbody when following. How could this be? MA commented on two possible and not necessarily mutually exclusive influences. 'Firstly, on V3 the tunnel width was similar to V2 but V3 had extended flat sides [footplates] which kept the free-stream air away from the tunnels where all the forces are generated. In V2, the footplates were smaller and thus, less effective, so low pressure generated inside the tunnel would have sucked in air from the sides and the tunnels would have lost effectiveness as a result. In V3, however, the tunnels could work the air closer to its maximum potential.

'Secondly, the ratios of the tunnel inlets to outlets were different. On V3 the inlet was bigger than the outlet so the outlet worked less hard than on V2 because of the lesser angle in the diffuser section and the gentler profile that allowed more underbody surface closer to the ground. Although the underbody downforce contribution was less as a result, the conditions it produced as a whole probably contributed to

While the front wing may have been more adversely affected on V3, the underbody was much less affected than on any of our other variants



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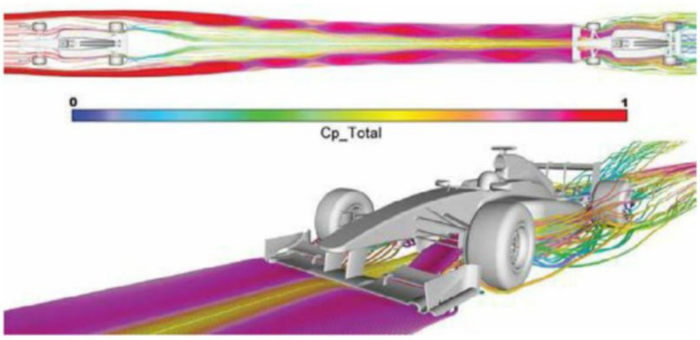

Figure 19: Streamlines coloured by total pressure show how inwash transported energetic tidy air to the following V2 car's front wing at four car lengths separation

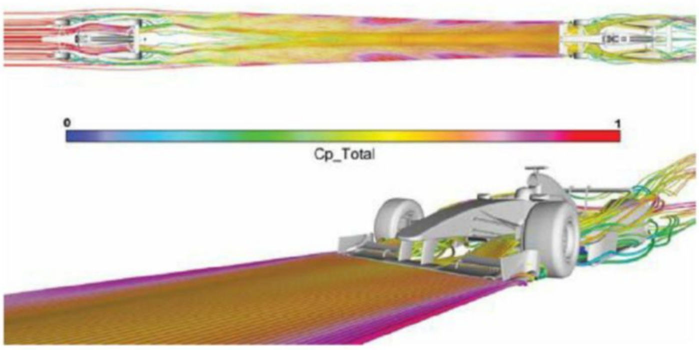

Figure 20: There are less energetic streamlines in the leading car's wake right out to four car lengths, and clearly the air that hits V3's front wing is at reduced total pressure

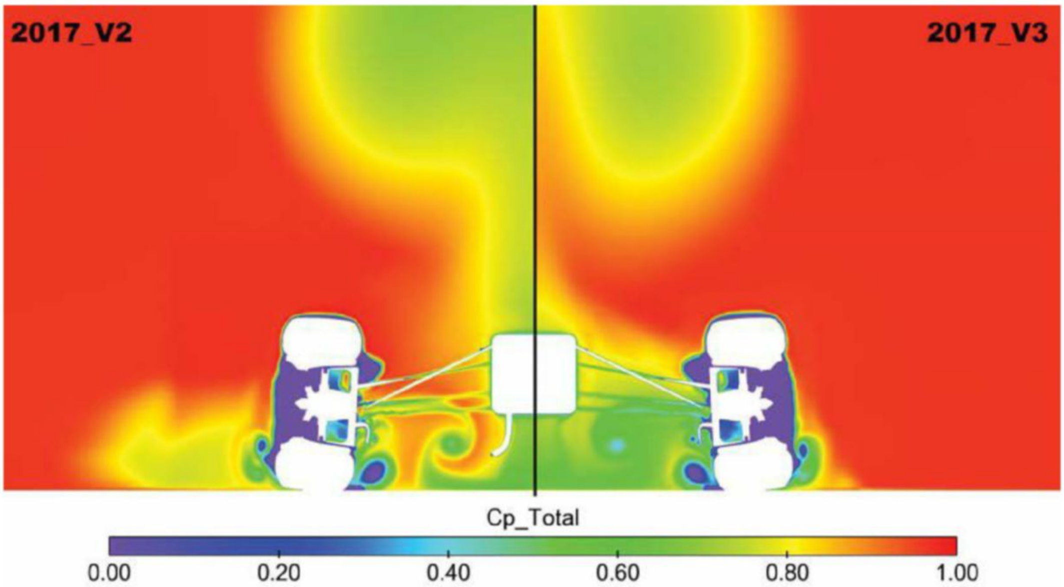

Figure 21: A total pressure slice at the front axle line at four car lengths separation shows that our V3 model's underbody also received less energetic airflow, and yet the underbody performed well and was less adversely affected than any of the other cars we have tested

the improvements we saw for V3.' So ground effect tunnels may offer advantages in terms of reduced downforce losses for a following car, but clearly there are factors here that need some further study.

Conclusions

We can summarise a number of interesting and varied lessons learned so far from MA's simulations.

- **The 2013 model lost downforce and balance when following.**
- **The RE 2017 V1 car, with enlarged diffuser and detuned, repositioned rear wing, saw smaller downforce losses except at the closest separation, but importantly saw no balance shift at any separation.**
- **The RE 2017 V2 car with full ground effect tunnels and further detuned wings front and rear produced mixed downforce loss results, but saw no balance shift except at the closest separation when it produced the biggest balance change of all.**
- **The RE 2017 V3 car with detuned tunnels, wider body with side footplates and a further detuned rear wing saw the smallest downforce reductions of all the concepts examined, but at two and one car's length separations saw the worst balance shifts of all.**
- **Balance shifts were primarily down to how the wake of the leading car, which varied from model to model, affected the front wing of the following car; energy losses and flow directionality including upwash and inwash as well as vortex formation and general wake turbulence were all involved.**
- **Ground effect tunnels that generated over 80 per cent of the car's downforce were far less affected than front wings when following another car.**
- **Wide footplate 'skirts' may have helped maintain tunnel effectiveness when following.**

If there is one certainty to have arisen from this project it's that there really isn't a simple solution to creating a more benign aerodynamic environment for a following F1-type car while simultaneously retaining current high levels of downforce. MA successfully created a configuration that eliminated aerodynamic balance shift when following line-astern at all separations tested, and also one that greatly reduced downforce losses when following at all separations tested. The aim must be to combine the two different aspects, or at least find the best possible compromise.

Meanwhile, with the FIA having now confirmed the bodywork and aerodynamic regulations for F1 in 2017, we shall next attempt to create a model that incorporates the regulatory requirements of those regulations and subject it to the same scrutiny in CFD. It will be interesting to see how the FIA's concept compares in these overtaking situations.

There really isn't just one simple solution to creating a more benign environment for a following F1 car

Dynamic Flow Solutions

Dynamic Flow Solutions Ltd is an aerodynamics consultancy led by director Miqdad Ali, an ex-MIRA aerodynamicist who has performed design, development, simulation and test work at all levels of professional motorsport, from junior formula cars to World and British Touring Cars, Le Mans prototypes, up through to F1 and Land Speed Record cars.

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

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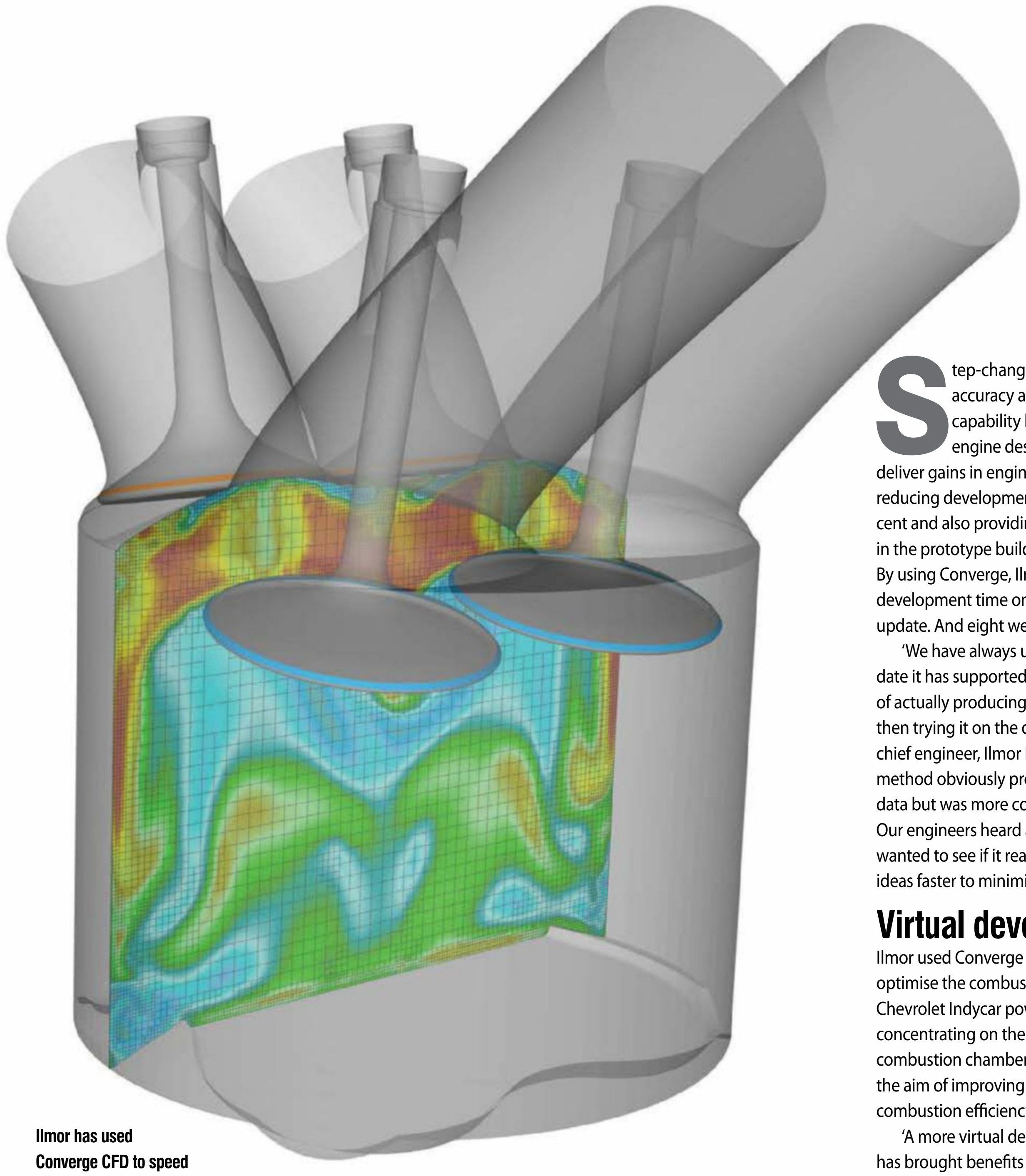
Computing power

How famed race engine builder Ilmor is using highly advanced CFD packages to optimise its powerplant design process



Ilmor has used Converge CFD to speed up its design process and minimise its prototyping costs

Step-change developments in the accuracy and resolution of its CFD capability have enabled renowned engine design company Ilmor to deliver gains in engine performance, while reducing development time by around 50 per cent and also providing a 75 per cent reduction in the prototype build cost for its Indycar project. By using Converge, Ilmor saved eight weeks in development time on its 2016 IndyCar engine update. And eight weeks is a long time in racing.

'We have always used simulation but to date it has supported our traditional approach of actually producing a part or concept and then trying it on the dyno,' says Steve O'Connor, chief engineer, Ilmor Racing. 'This development method obviously provided accurate, real world data but was more costly and time consuming. Our engineers heard about Converge and wanted to see if it really could be used to refine ideas faster to minimise our prototyping costs.'

Virtual development

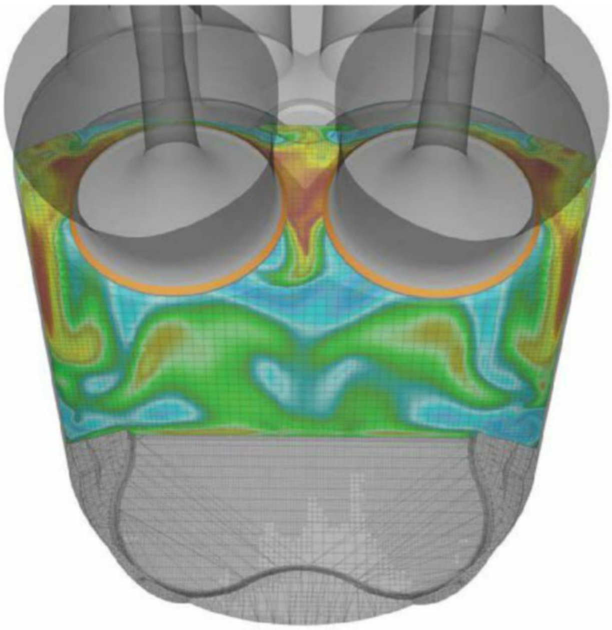
Ilmor used Converge intensively to further optimise the combustion system of the Chevrolet Indycar power plant, mainly concentrating on the design of the inlet port, combustion chamber and piston crown with the aim of improving both the volumetric and combustion efficiency of the engine.

'A more virtual development approach has brought benefits to the testing side too,' O'Connor says. 'A fully instrumented engine test stand is expensive and switching to Converge CFD has helped Ilmor to reduce dyno usage

It's reduced development time by around 50 per cent and also provided a 75 per cent reduction in the prototype build cost for the IndyCar project

Working with F1 has led to a wealth of knowledge of fuel flow restricted engines and Ilmor says that it is well placed to develop a WEC engine

The CFD operation is hugely speeded up with Converge's program thanks to the use of what it calls 'Adaptive Mesh Refinement', which is one of the suite's stand-out features



for checking only the developments that pass the CFD stage. With complex issues such as combustion system development, CFD avoids the need to manufacture and test every case and marks a step-change in not only how we use the CFD, but also in how we manage our entire development process.'

With opportunities to use Converge in areas such as optimising flame propagation, understanding sprays and even exhaust after-treatment, Ilmor is now keen to acquire more OE contracts. 'We are known for our motorsport success but we are doing an increasing amount of Automotive and R&D work,' says O' Connor. 'Combining our knowledge with the use of Converge to prove our concepts is attracting OEMs looking for novel ideas at the speed that only motorsport knows how to deliver.'

And Ilmor certainly has a great deal of experience in motorsport, at the very highest levels. It started out in 1984 with an Indycar programme with Chevrolet and progressed to F1 with Mercedes. Mercedes took a greater share in the company and then full control after one of its founders, Paul Morgan, was killed in a light aircraft accident in 2005.

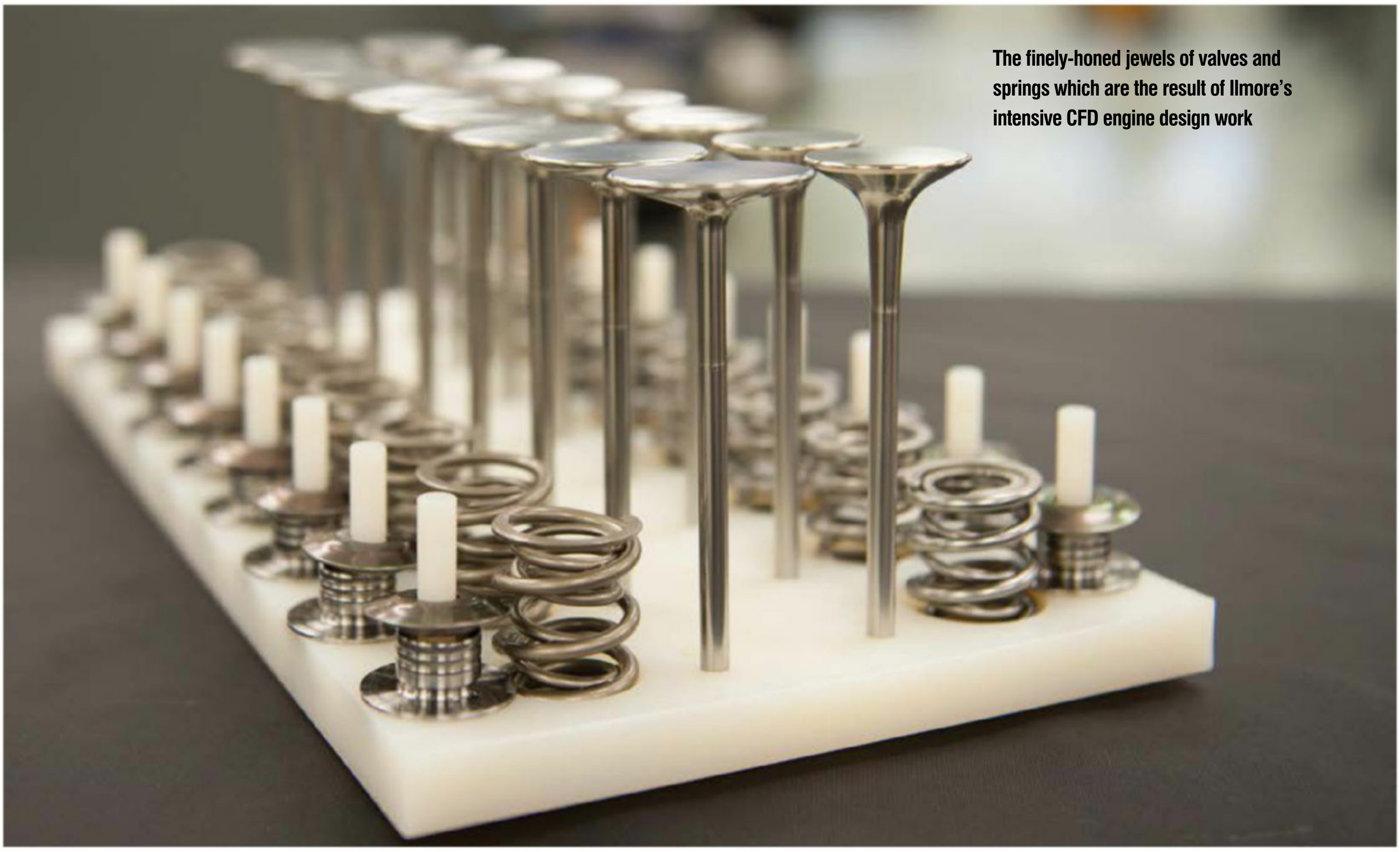
'There was a little area of the business known as Special Projects which did non-Formula 1 business, such as the Honda Indy V8 engine which was of no interest to Mercedes,' explains chief engineer, Advanced Projects, Ian Whiteside. 'That was sold back to the original owners along with the Ilmor name.'

The company has developed a racing business both inside and outside of F1, which includes Renault, manufacturing work with JLR, and with Roush Yates on the Ford NASCAR engine. It also developed Emil Frey's Jaguar GT3 engine, funded by EFR with some assistance from JLR. All aspects of the engine are developed in Brixworth, while the North American centre in Plymouth services Indycar engines and the Moorseville facility develops GM V8 engines for marine applications.

Advanced Projects

'Our other Group is Advanced Projects,' says Whiteside. 'This is where we now are trying to diversify the business; so mainstream automotive, aerospace and marine, research engines, but it turns out that probably half of my work is still in racing, including Renault F1 and Emil Frey's Jaguar engine. We also make quite a lot of WRC parts for several teams.'

Working with Formula 1 has led to a wealth of knowledge of fuel flow restricted power units and Ilmor says that it is well placed to develop a WEC engine. 'We have learned a lot in F1 that is directly applicable to the WEC engine with the fuel flow engines,' confirms Whiteside. 'In terms of how you configure the engine, it is completely different. You basically have to tear



The finely-honed jewels of valves and springs which are the result of Ilmore's intensive CFD engine design work

Ilmor's main motorsport programme is with the Chevrolet IndyCar engine but it also has an involvement with Renault in Formula 1 and with Roush Yates and Ford in NASCAR. The company was set up by Mario Illien and Paul Morgan in 1984

up everything that you have learned. Effectively you have an unlimited amount of air. In a normal engine you get as much air into it as you can because the more air you can get into it the more power you can make, but with this thing, you effectively have an infinite amount of air, and you have to make the most of it. There are some interesting things that you do that you wouldn't do on an engine normally. There are also some compromises that are for efficiency.'

Converging technology

As far as the design process is concerned, Whiteside says: 'We work on sub systems or up to the full design. CATIA V5, a standard industry software CAD, ANSYS for more complex Finite Element, and Converge CFD, and OpenFoam for simpler tasks. Converge is used for in-cylinder type work. We have one licence that allows us to run an unlimited number of cores, so we can only run one project at a time. We could, for instance, have two licences but we would have to limit ourselves to half the number of cores. We don't do sufficient work that we need to run multiple projects at the same times, so it is better for us to have the higher speed. The other package that we use is GT Suite. In addition to the performance simulation side, the Suite package is good for valvetrain design, crank design and tribology.'

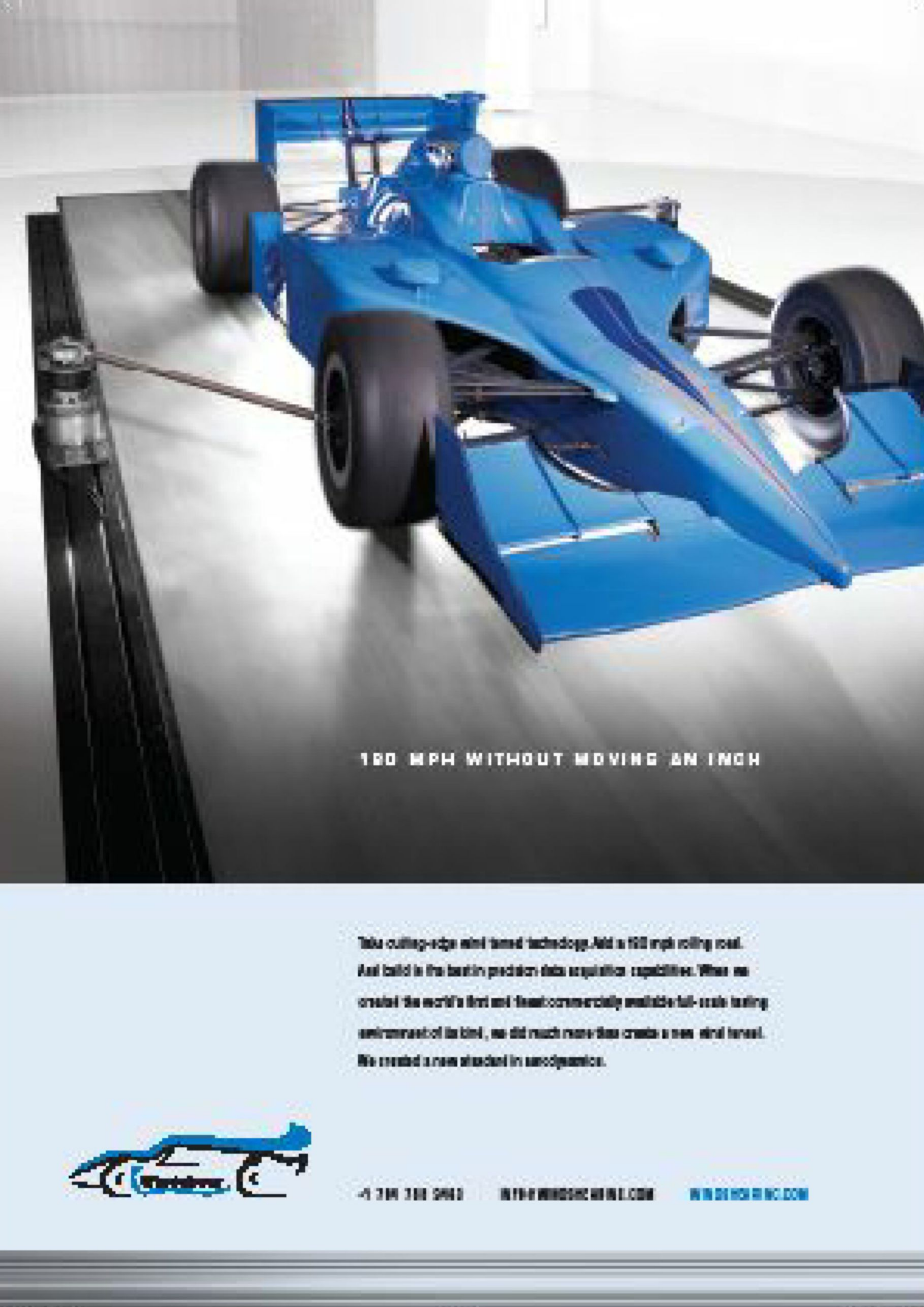
Ilmor retains a more traditional air flow test rig so that it is able to get into the right area before working in Converge to further develop the in-cylinder dynamics. 'We have a flow rig that is largely superseded by CFD, but we occasionally us it for correlation,' says Whiteside.

'There are quite a lot of knobs in CFD and you have to have them in the right place before you set off. The advantage of CFD is that it allows you to visualise what is happening in the cylinder and look at this in fine detail. We have found a number of things that work well in CFD, and in the engine, but often do not see the same effects on the air flow rig. Converge has been developed for in-cylinder engine modelling and they understand all the issues and requirements for this application. One of the plus points of Converge is how easy it is to use, in particular how the meshing works. It is an automated system so you don't need to do that manually. That saves a lot of time.

'We do a lot of testing on the fuel injectors, ensuring that they are all balanced between cylinders,' Whiteside adds. 'Every injector is flow tested and has its own characteristic. We have a rate tube, which means that instead of just being able to say that a pulse produces *x* milligrammes of fuel, the tube allows us to see how it flows against crank angle, and how the injectors are affected by age. That affects how the mixture flows in the cylinder.'

With dynos that are capable of testing up to 20,000rpm and 1000Nm of torque, Ilmor is also set up well for F1 and WEC testing.

'The advantage of CFD is that it allows you to visualise what is happening inside the cylinder'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The magic number

Calculating the available grip at the front of a car is crucial, but as *Racecar's* numbers man illustrates, gaining performance on the track is about so much more than pushing a tyre's load to its upper limits

By DANNY NOWLAN

Front lateral load transfer is easily observed with hard-cornering historic racecars such as this Ferrari GTO

If you have been in this business long enough you will have heard the term 'the magic number'. The magic number refers to the percentage of front lateral load transfer distribution at which the car produces the most grip. As with many things in this business it tends to get thrown around like a bad football, with some people swearing by it and others thinking it is totally irrelevant.

The focus of the article will be on how we can use a tyre model derived from actual data to delve in to what the magic number actually means. What you are about to see here is a fascinating case study in to one of the by-products of racecar simulation.

One of my perpetual frustrations with this business is how many engineers truly have no idea of what they have in their hands when they use a racecar simulation package. I have said time and time again that the lap time and data you get is the full stop at the end of the process. As you're about to see, what you learn in the process is the pay off, and what we are about to discuss is a perfect case in point.

To kick off, let's return to the most basic tyre model you can have, which is the second order traction circle radius *vs* load curve fit for a tyre. This has been represented mathematically in **Equation 1** and some typical values for this is presented in **Table 1**. When you plot this out you'll have something that looks like **Figure 1**.

Gripping stuff

As we discussed in detail in one of my most recent articles on tyre modelling from scratch (V26N2), using a simulator such as ChassisSim you can fill in the blanks for this very quickly.

However, where things begin to get really interesting is when we take into account lateral load transfer and use **Equation 1** to quantify what will happen to the lateral forces on the tyres. For a given load transfer couple we have **Equation 2**. Given a lateral load transfer factor of *pr* the front and rear load deltas will be given by **Equation 3**.

At this point in the discussion you may be thinking, so what? Well, what all this mathematical gobbledegook actually means is that for a given lateral load transfer distribution, a given lateral acceleration, and a given tyre model, we can calculate the maximum possible grip for a given cornering situation. Mathematically this is expressed in **Equation 4**.

Where things get very interesting is when we expand **Equation 4**, because it becomes a function of the lateral load transfer distribution. So, expanding **Equation 4** we get **Equation 5**.

In this case the *Fy0* term is all the non lateral load transfer terms in N. Things get even more interesting when we derive **Equation 5** by the lateral load transfer term *pr*. Setting this to 0 the lateral load transfer distribution that will give us the most grip is given by **Equation 6**.

This is the origin of the magic number and if you have done the homework using your simulation software to reverse engineer the tyres from the race data you can plot this, as is illustrated in **Figure 2**.

What is even more exciting is that it will tell you the sensitivities of this, which in the above case was 1400N. What **Equation 6** tells us is the magic number is purely a function of

EQUATIONS

EQUATION 1

$$TC_{RAD} = k_a(1 - k_b \cdot F_z) \cdot F_z$$

Where:

TC_{rad} = Traction Circle radius (N)

k_a = initial coefficient of friction

k_b = drop off of coefficient with load

F_z = load on the tyre (N)

EQUATION 2

$$L_1 = L_0 + \Delta L$$

$$L_2 = L_0 - \Delta L$$

$$F_y = k_a \cdot ((1 - k_b L_1) \cdot L_1 + (1 - k_b L_2) \cdot L_2)$$

$$= 2 \cdot k_a \cdot (1 - k_b L_0) \cdot L_0 - 2 \cdot k_a \cdot k_b \cdot \Delta L^2$$

$$= 2 \cdot TC_{RAD}(L_0) - 2 \cdot k_a \cdot k_b \cdot \Delta L^2$$

EQUATION 3

$$\Delta L_F = \frac{pr \cdot m_t \cdot a_y \cdot h}{tm}$$

$$\Delta L_R = \frac{(1 - pr) \cdot m_t \cdot a_y \cdot h}{tm}$$

Where:

ΔL_F = Delta load at the front (N)

ΔL_R = Delta load at the rear (N)

m_t = Total mass (kg)

p_r = lateral load transfer (scaled from 0 - 1)

a_y = Lateral acceleration (m/s²)

h = centre of gravity height (m)

tm = Mean track (m)

EQUATION 4

$$F_{yt} = 2 \cdot TC_{RAD}(L_{SF}) + 2 \cdot TC_{RAD}(L_{SR})$$

$$- 2 \cdot k_{af} \cdot k_{bf} \cdot \left(\frac{pr \cdot m_t \cdot a_y \cdot h}{tm}\right)^2$$

$$- 2 \cdot k_{ar} \cdot k_{br} \cdot \left(\frac{(1 - pr) \cdot m_t \cdot a_y \cdot h}{tm}\right)^2$$

Where:

F_{yt} = Total lateral force in N

L_{SF} = Front corner weight in N

L_{SR} = Rear corner weight in N

k_{af} = Front tyre initial coefficient of friction

k_{bf} = Front tyre drop off of coefficient with load

k_{ar} = Rear tyre initial coefficient of friction

k_{br} = Rear tyre drop off of coefficient with load

EQUATION 5

$$F_{yt} = F_{y0} - pr^2 \cdot (2 \cdot k_{af} \cdot k_{bg} + 2 \cdot k_{ar} \cdot k_{br}) \cdot \left(\frac{m_t \cdot a_y \cdot h}{tm}\right)^2$$

$$+ 4 \cdot pr \cdot k_{ar} \cdot k_{br} \cdot \left(\frac{m_t \cdot a_y \cdot h}{tm}\right)^2$$

EQUATION 6

$$pr = \frac{k_{ar} \cdot k_{br}}{k_{af} \cdot k_{bf} + k_{ar} \cdot k_{br}}$$

Table 1 – Typical open wheeler numbers for maximum tyre force with the coefficient of friction dropping off linearly with load

Parameter	Value
ka	2
kb	5.0 e-5 (1/N)

the tyres and what they want. However, there is much more to this story than meets the eye. In **Equation 6** we have considered the tyres purely in cornering. Let's now consider the case where we have identical tyres front and rear, but the car is rear-wheel-drive. Let's say we multiply the available force from the rear tyres by a factor of *eTE* which is scaled between 0 and 1. In the case of 1 we have all of the available traction circle radius for cornering, while 0 is when it is all used for accelerating. **Equation 6** will now become **Equation 7**.

Let's put some numbers to this. Let's set *eTE* to 0.9 and assume the tyres are the same front to rear. Since all the *ka* and *kb* terms are identical we then have **Equation 7a**. What this is saying is that for this rear-wheel-drive case

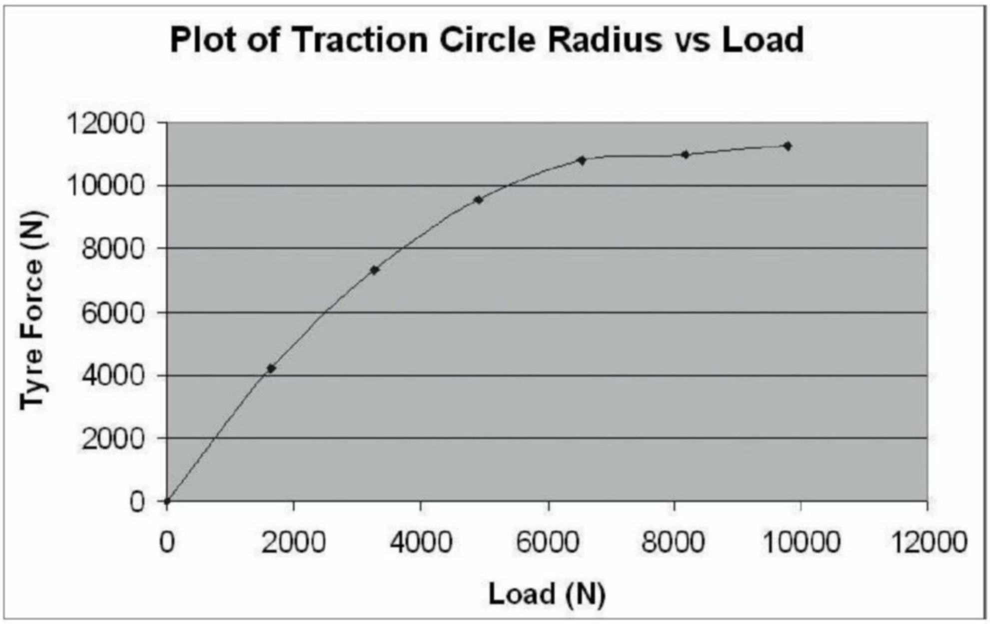

Figure 1: This is a basic second order plot of the traction circle *vs* load characteristic, showing how load works on the tyres

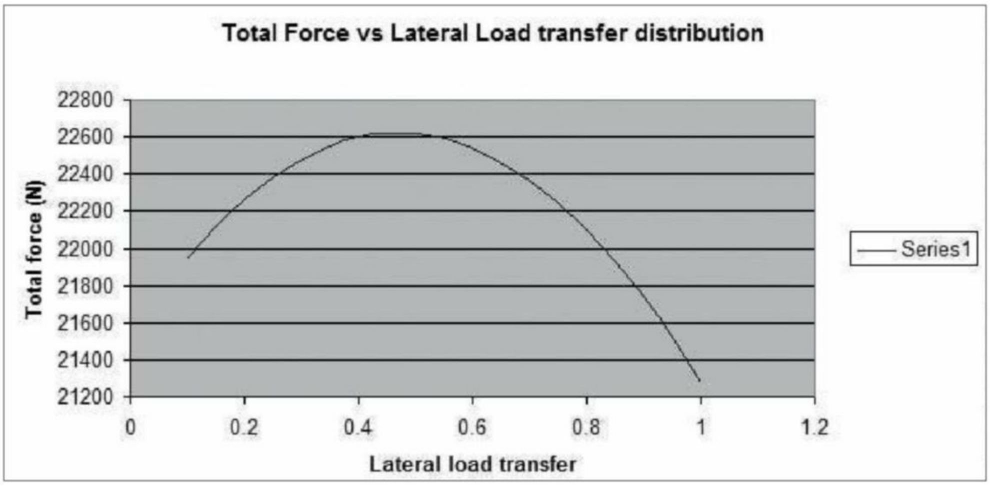

Figure 2: Using sim to reverse-engineer tyres from race data you can plot max lateral grip *vs* lateral load transfer distribution

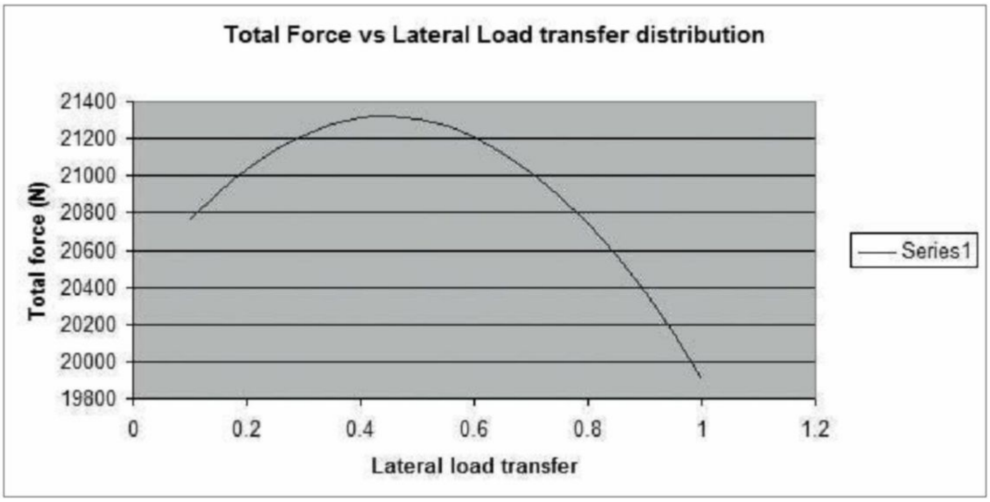

Figure 3: This shows the total force *vs* lateral load transfer with the rear-wheel-drive racecar model now taken into account

EQUATIONS

EQUATION 7

$$pr = \frac{e_{TE} \cdot k_{ar} \cdot k_{br}}{k_{af} \cdot k_{bf} + e_{TE} \cdot k_{ar} \cdot k_{br}}$$

EQUATION 7a

$$pr = \frac{0.9}{1 + 0.9} = 0.473$$

EQUATION 8

$$C_f = \frac{\partial C_f}{\partial \alpha_f}\bigg|_{\alpha=\alpha_f} \cdot (F_{m1} + F_{m2})$$

$$C_r = \frac{\partial C_r}{\partial \alpha_r}\bigg|_{\alpha=\alpha_r} \cdot (F_{m3} + F_{m4})$$

$$C_T = C_f + C_r$$

$$stbi \approx \frac{a \cdot C_f - b \cdot C_r}{C_T \cdot wb}$$

EQUATION 9

$$L_1 = L_{SF} + \frac{pr \cdot m_t \cdot a_y \cdot h}{tm}$$

$$L_2 = L_{SF} + \frac{pr \cdot m_t \cdot a_y \cdot h}{tm}$$

$$L_3 = L_{SR} + \frac{(1 - pr) \cdot m_t \cdot a_y \cdot h}{tm}$$

$$L_4 = L_{SR} + \frac{(1 - pr) \cdot m_t \cdot a_y \cdot h}{tm}$$

Where:
$dCF/da(\alpha_f)$ = Slope of normalised slip angle function for the front tyre
$dCR/da(\alpha_f)$ = Slope of normalised slip angle function for the rear tyre
$Fm(L_1)$ = Traction circle radius for the left front (N)
$Fm(L_2)$ = Traction circle radius for the right front (N)
$Fm(L_3)$ = Traction circle radius for the left rear (N)
$Fm(L_4)$ = Traction circle radius for the right rear (N)

we want 47.3 per cent of the load transfer at the front. So for maximum lateral grip we want the car to have its weight transfer biased to the rear. But each and every one of us who has ever run a rear-wheel-drive racecar know that this is a sure-fire recipe for disaster.

What this case study illustrates is that the maximum lateral grip will have the potential to push us into unstable territory. But before you all start hitting the brakes here, just remember, one of the biggest advances in fighter aircraft design was when aircraft designers recognised the performance potential in making their aircraft unstable. This trend was kicked off by the F-16 and has come to full maturity in the extreme-plus agility designs you see with the Russian Sukhoi Su-35S and the Su-50 PAK-FA. They are unstable because that is where the performance is, and it is no different than what we have seen with the magic number.

Slip angles

But what we need to do before we finally select the magic number is to choose a value that not only gives us good grip, but also satisfies car stability. As a case in point let's revisit our rear-wheel-drive scenario, but let's now plot out the lateral grip with an ellipse factor of 0.9. This is illustrated in **Figure 3.**

Take a look in the neighbourhood of lateral grip between 0.4 and 0.5. The lateral grip hardly drops off here. What this means is that we have plenty of room to tune for the racecar's stability, to ensure that we not only have the grip, but that it is usable grip.

To quantify this we will use the stability index. To refresh everyone's memory the stability index is calculated using **Equation 8**.

The great news is that *Fm(L1)* through to *Fm(L4)* is given by **Equation 1** and the *ka* and *kb* terms for all of these equations are given to you by using ChassisSim and the process we have discussed before with calculating tyre load modelling from scratch. The tyre loads *L1* to *L4* are given by **Equation 9**.

The last bit in this process involves calculating the slip angle derivatives. Fortunately there are some techniques that can help us along the way. The first thing to get a handle on is what the slopes of the normalised tyre force curve look like. There are a couple of approaches you can use to get you going, but let me use the normalised ChassisSim slip angle curve that has always worked very well as an example. This is shown in **Table 2**.

The next step here is to choose what slip angles to take these calculations from. Looking at **Table 2** you would be nuts to choose 6-degree. The slopes are zero and it makes no sense. In light of this the procedure will be to set the rear slip angle at 5-degree. Then the front slip angle will be given by **Equation 10**.

Bear in mind **Equation 10** isn't something that is set in stone. It is an approximation to help you get an expectation of the relationship


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Table 2 – Plot of normalised ChassisSim slip angle derivatives

Slip angle (deg)	Slip angle (rad)	δC/dα
0	0	14.323
1	0.0175	13.925
2	0.0349	12.731
3	0.0524	10.742
4	0.0698	7.9567
5	0.0872	4.375
6	0.1047	0

Table 3 – Typical values for Stability index based around a Formula 3 racecar

Item	Description	Value
Fm_1+Fm_2	Sum of traction circle radius for the front	5000N
Fm_1+Fm_2	Sum of traction circle radius for the rear	7000N
a	Distance of front axle to the c.g	1.6m
b	Distance of rear axle to the c.g	1.1m
wb	Wheel base	2.7

EQUATIONS

EQUATION 10

$$\alpha_F = \frac{b\cdot(Fm(L_3)+Fm(L_4))}{a\cdot(Fm(L_1)+Fm(L_2))}\cdot\alpha_R$$

Where:

a = Moment arm of front axle to centre of gravity (m)

b = Moment arm of rear axle to centre of gravity

af = Front slip angle

ar = Rear slip angle

EQUATION 11

$$C_f = \frac{\partial C_f}{\partial\alpha_f}\Big|_{\alpha=\alpha_f}\cdot(F_{m1}+F_{m2}) = 4.375\times5000 = 21875$$

$$C_r = \frac{\partial C_r}{\partial\alpha_r}\Big|_{\alpha=\alpha_r}\cdot(F_{m3}+F_{m4}) = 7.9567\times7000 = 55760$$

$$C_T = C_f + C_r = 77634$$

$$stbi = SM/wb \approx \frac{a\cdot C_f - b\cdot C_r}{C_T\cdot wb}$$

$$= \frac{1.6\times21875 - 1.1\times55760}{77634\times2.7}$$

$$= -0.125$$

EQUATION 12

$$C_f = \frac{\partial C_f}{\partial\alpha_f}\Big|_{\alpha=\alpha_f}\cdot(F_{m1}+F_{m2}) = 7.9567\times5000 = 39783.5$$

$$C_r = \frac{\partial C_r}{\partial\alpha_r}\Big|_{\alpha=\alpha_r}\cdot(F_{m3}+F_{m4}) = 4.375\times7000 = 30625$$

$$C_T = C_f + C_r = 70408.5$$

$$stbi = SM/wb \approx \frac{a\cdot C_f - b\cdot C_r}{C_T\cdot wb}$$

$$= \frac{1.6\times39783.5 - 1.1\times30625}{70408.5\times2.7}$$

$$= 0.157$$

between the front and rear slip angles so you can calculate the stability index.

At this point in the game it would be worth giving everyone a reminder about how to calculate the stability index. So we can put some numbers to this, let's illustrate via some F3 figures. This is summarised in **Table 3**.

Let's say the front slip angle is 5-degree and the rear slip angle is 4-degree. Then using **Equation 8** and the derivatives from **Table 2,** the stability index is **Equation 11**.

Let's now reverse the case and consider the oversteer situation, where the front slip angle is 4-degree and the rear slip angle is 5-degree. Again, evaluating **Equation 4** we see now **Equation 12**. Let's now tie all this together into a process of how you find the magic number. This process is summarised below:

- **Using equations 5 to 7 plot the lateral force vs lateral load transfer.**
- **The maximum value of this is your start value for lateral load transfer.**
- **Then, using the stability index increase the lateral load transfer to then get the desired stability index.**
- **Just as a rough rule of thumb go for about -0.025**

Stability index

The great thing about all this is this readily lends itself to an excel sheet. You simply take the lateral acceleration and the speed you are interested in. You calculate the front and rear lateral forces and then curve fit the slip angle derivatives. Then using **Equation 10** and keeping the rear slip angle fixed you can see where the front slip angles are and calculate the stability index accordingly. While this won't be exact it will get you in the ball park.

As a case in point I did this for a Formula 3 type racecar at a cornering speed of 200km/h and a lateral acceleration of 1.8*g*. The results for this are summarised in **Table 4.**

To say these figures are fascinating is an understatement. As we can see the peak lateral force occurs at a front lateral load transfer of 0.5. Not surprisingly the stability index is very marginal at -0.00291. What is interesting is that when we go to a lateral load transfer factor of 0.6 we drop only 80N of force but the stability index drops to -0.072. This is a big change in handling. What is even more interesting, though, is the spread of forces is only about 1000N or about four per cent. However, we see large fluctuations of the stability index. What this shows is the magic number isn't just about maximum grip, but it's about dialling in the handling of the car that you require.

To finish off this discussion it would be worth discussing the effect of total lateral acceleration on the lateral load transfer number we want. For absolute grip it won't

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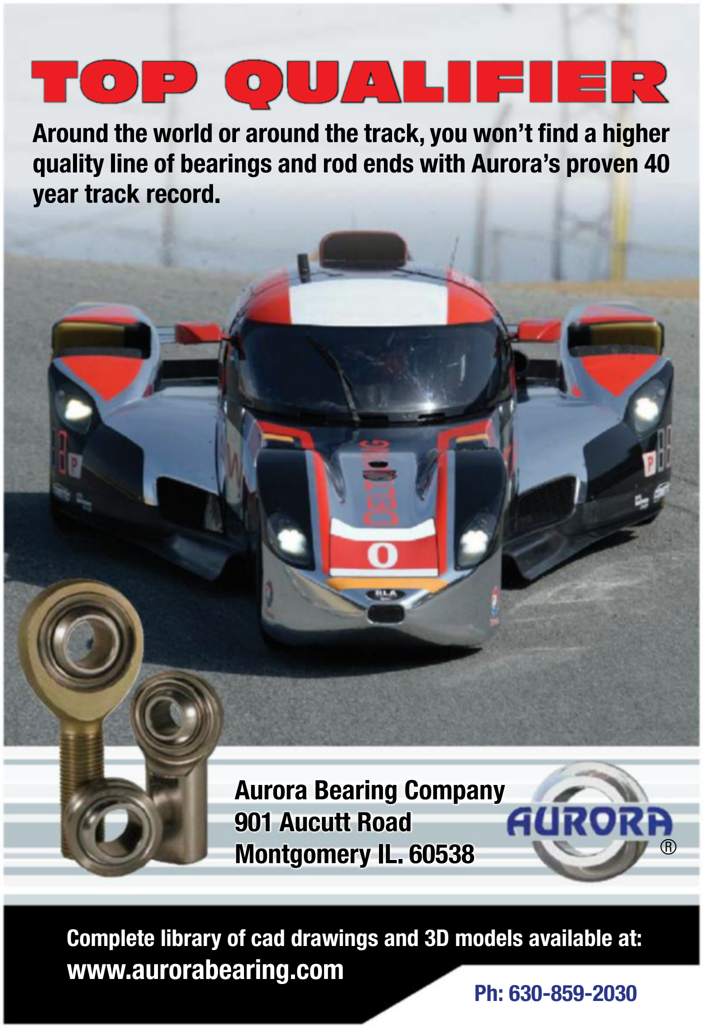

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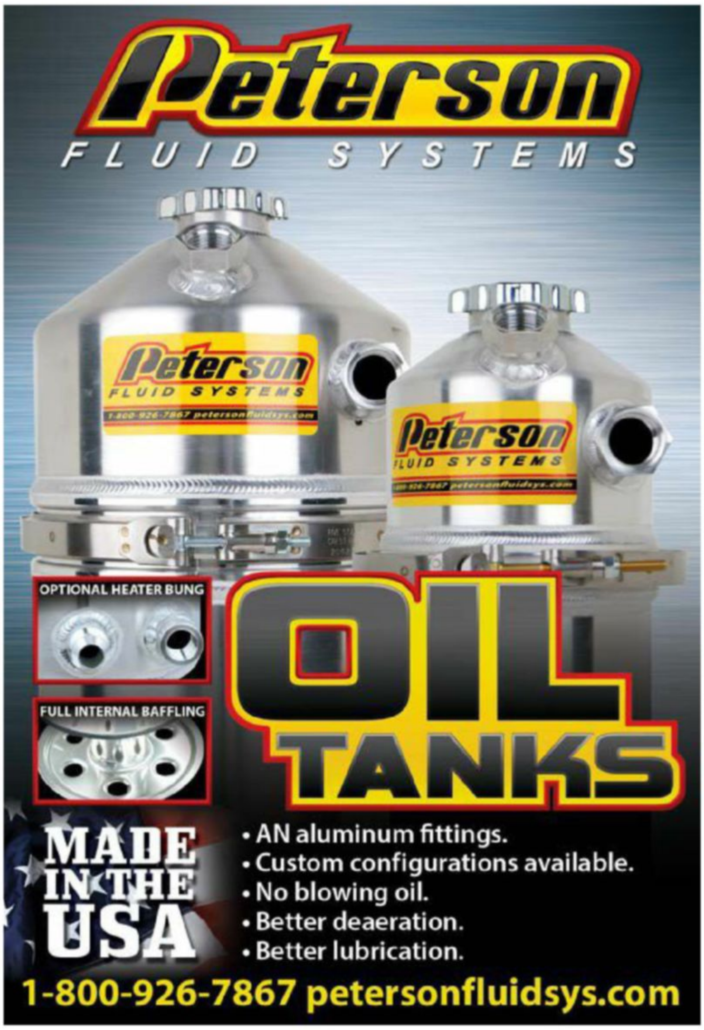

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The magic number is not just about the racecar's maximum grip

have an impact, but for stability it will. This can be quantified by **Equation 13**. This in turn impacts on the stability index we discussed. So when incorporating this in an excel sheet you need to be entering the lateral acceleration and corner speeds you are interested in.

However, everything we have discussed here will be all for nothing if you have not done your simulation modelling. This is where ChassisSim and its tyre modelling utilities are worth their weight in gold. The reason they are so useful is that you can use these tools to find out the *ka* and *kb* for the front and rear tyres from race data. Without these you are just guessing. Once you have this, filling in the details of all of the above becomes a *fait accompli*, which is one of the key reasons any race engineer worth their salt would be crazy not too have a simulation tool such as ChassisSim in their back pocket.

In closing, we have discussed in detail the origin of the magic number but more importantly how to calculate it. You start from the maximum grip number and then you add front roll distribution till you satisfy your stability requirements. But you need to remember, the final number will always be a trade off between maximum grip and driveability, as we have shown in **Table 3.** While this won't give you the perfect set-up straight out of the box it will get you to a very good start point. However, without the appropriate simulation package such as ChassisSim to fill in these numbers this will all be for nothing. But if you combine these analytical tools it gives you a very powerful way to help you understand what your racecar is truly doing.

Table 4 - Results of Lateral load transfer *vs* the stability index

Lateral Load transfer	Total lateral force (N)	Projected front slip angle (deg)	Stability index
0.1	21952.64	4.24	0.162
0.2	22264.4	4.42	0.13
0.3	22479.4	4.6	s
0.4	22597.6	4.80	0.05
0.5	22619.05	5.01	-0.00291
0.6	22543	5.24	-0.072
0.7	22371	5.51	-0.166
0.8	22102.6	5.8	-0.303
0.9	21736.9	6.14	-0.524

EQUATIONS

EQUATION 13

$$F_{yf} = 2 \cdot TC_{RAD}(L_{SF}) - 2 \cdot k_{af} \cdot k_{bf} \cdot \left(\frac{pr \cdot m_t \cdot a_y \cdot h}{tm} \right)^2$$

$$F_{yr} = 2 \cdot TC_{RAD}(L_{SR}) - 2 \cdot k_{ar} \cdot k_{br} \cdot \left(\frac{(1 - pr) \cdot m_t \cdot a_y \cdot h}{tm} \right)$$


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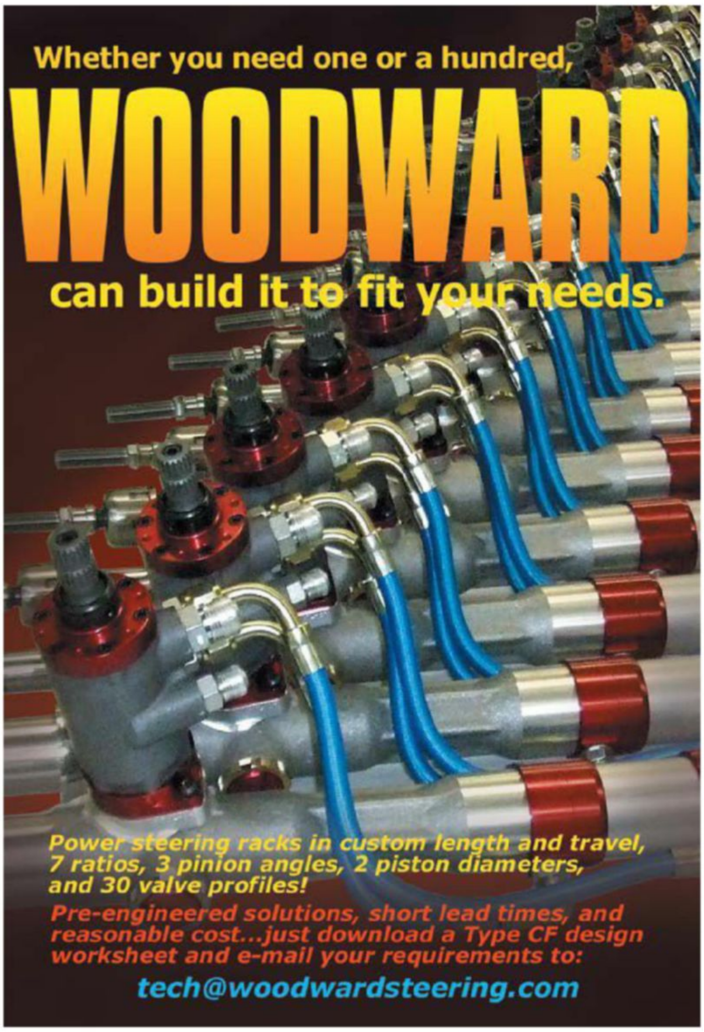
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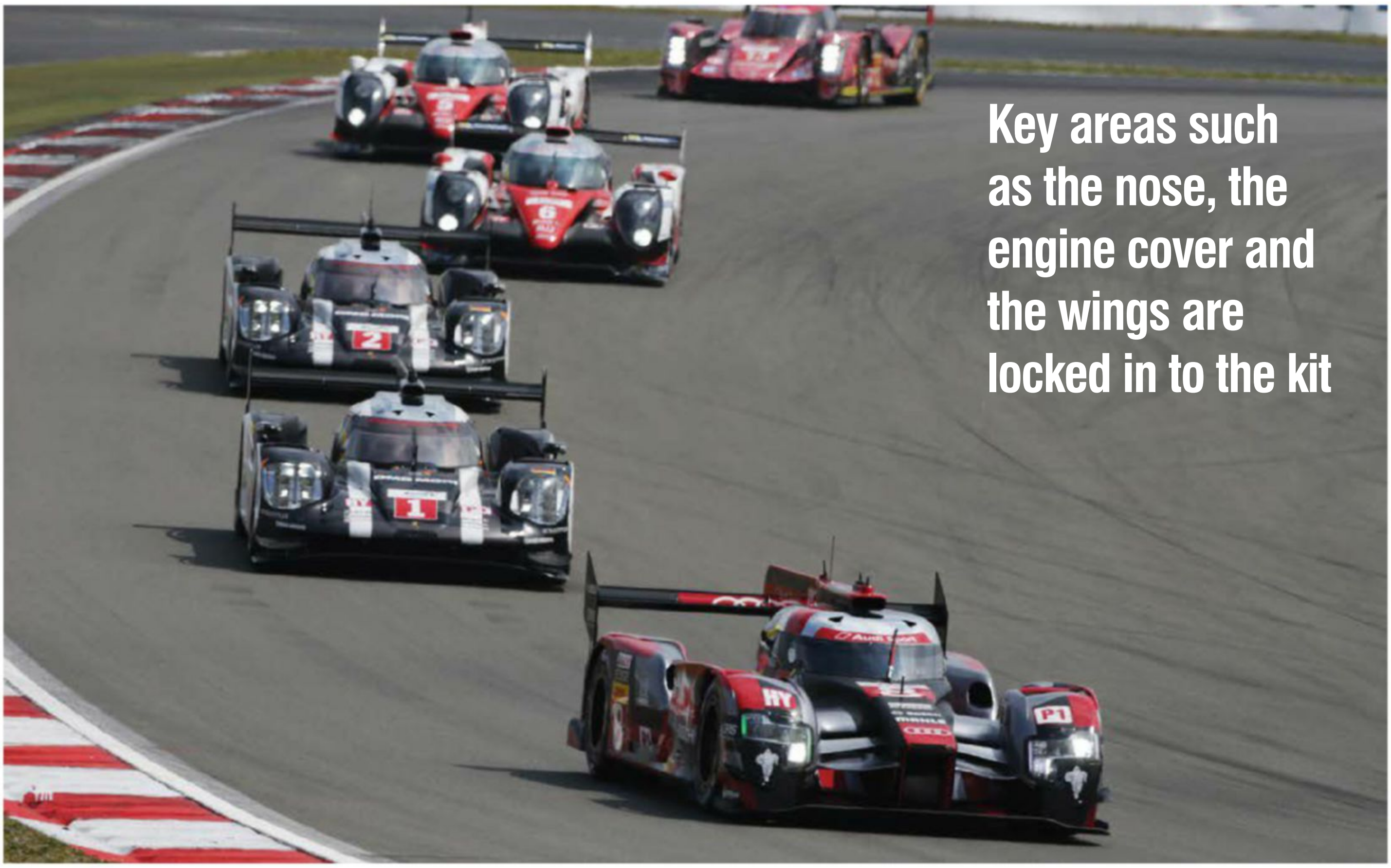
Change of kit

The LMP1 manufacturers are allowed just three aero kits this season – so there was great interest when the Spec C versions were unveiled at the Nurburgring round of the WEC

By ANDREW COTTON



Key areas such as the nose, the engine cover and the wings are locked in to the kit

The 2016 season of the World Endurance Championship sees the LMP1 regulations permit three bodykits, broadly broken down into Spec A for the first two races at Silverstone (and for some cars, Spa); Spec B for Spa and for Le Mans; and Spec C for the remaining races of the season, including the heat and altitude of Mexico City for the first time, in September.

The race in Mexico was added only in September last year, and so this year the teams have been allowed 'jokers' to accommodate the extra cooling that they have predicted for this race. The kits cannot be mixed either; so a team is not allowed to run the front end of Spec A and the rear of Spec C, for example, and they are not absolutely homologated.

Key areas such as the nose, the engine cover and the wings are locked in to the kit, but the smaller areas, such as the diveplanes and other cheap-to-produce components on the car can be changed.

For Audi, which is the only manufacturer to run a diesel engine, the focus was on cooling, particularly for the Nurburgring, which was expected to be hot at the end of July, and then Mexico and Austin, both in September. 'We will run the bodywork to the end of the season,' said Jan Monchaux, chief aerodynamicist at Audi Sport. 'The number one focus was the engine cooling and the relatively high demands that we have in Nurburgring, Mexico, Austin. We would not have been able to do these with the bodywork from Silverstone and Le Mans.

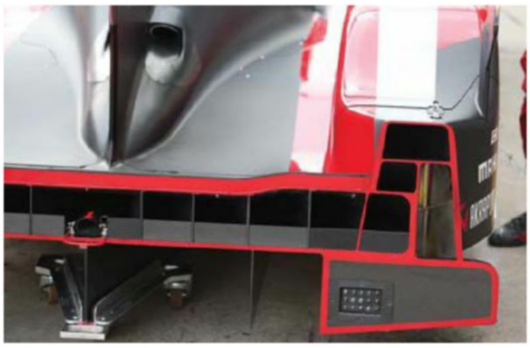
'We have done a new cooler installation and package to achieve the cooling target, but that means drag, which we don't want. Other parts [changed] are not cooling related, [they are] to get back our drag penalty. There are many parts that have been optimised. If you have *x* per cent more drag because of the cooling demand, you pay to get *x* per cent back, and we have been able to do this. Compared to Silverstone we can put more downforce on the car that the drivers like. Typically, in the WEC you have a drag to downforce ratio that is quite low. Putting downforce on the car, which you always pay against drag, you improve your lap time. At the Nurburgring you have a ratio of between 2.5 and 3.5, so if I find three per cent of downforce, you pay with one per cent of drag and that is okay, you are still quick. At Le Mans it is 10-11 and that is extremely difficult,' Monchaux says.

Specs-Mex'

One of the key elements of Le Mans in June was managing the R18's narrow operating window, but the team is hoping that, with more downforce, the tyres will be able to work harder and therefore the car will operate better in a

The new Spec C aero kits were aired at the Nurburgring for the first time this season. Toyota revised the front end of the TS050 for the latter part of the WEC, using the Spec A version (above left) of the body seen at Silverstone and Spa as a basis. The Spec C version (above right) features new, longer, flatter front dive planes in place of the bat-wing style of Spec A

Audi revised its cooling layout for the second half of the WEC. The rear exit of the bodywork was modified with a number of segments added to the Spec C (below right) used at the 'Ring. Spec A (above left) was used at Silverstone only, the similar but lower drag Spec B (above right) car was used at Spa and Le Mans



wider range of conditions. 'Tyre temperature is a major criteria, but downforce helps the car, particularly when you go to Shanghai and Fuji where you do not necessarily have 40-degree track temperature and you might need decent downforce to get the tyres to work, or to keep them up to temperature,' says Monchaux. We tried to reach the target that we were given for the engine and hybrid department for the tracks, and it was massive. The rear was changed to reach the level and the cooling that we only run in Mexico. We needed to have variability in the package, for getting rid of the drag when you increase cooling, and then increasing downforce.

'At the WEC tracks, all the manufacturers are front balance limited,' Monchaux adds. 'Adding downforce is quite simple; you run a higher wing angle, run a Gurney, increase the rear. Where it gets tricky is to balance that on the front without disturbing the flow that is going to the diffuser at the rear. With the WEC tracks the more downforce you can run the better, and the limiting factor is the front. Once we reached the cooling target the next was to find front balance, front downforce on the front tyres, efficiently, so that we easily increase the global level of the car by running a higher Gurney. [At the] front, all the teams are fighting hard to find the best concept, to get front downforce without sending poor flow to the rear.'

Body of evidence

Toyota and Porsche also introduced new packages targeting more downforce for the remaining races. 'One of the main driving factors behind the aero kit is that we have to look at Mexico and, as well, it was clear that at Silverstone we were lacking downforce,' says Toyota's John Litjens. The TMG team did not have the time to test the bodywork on the car before the Nurburgring but was encouraged by the relatively accurate correlation between CFD and reality. 'For sure, you cannot change everything again, but you can change mainly the front end, the splitter, wheel arches and the small details below,' says Litjens. 'The top part, the wheel arches, the engine cover is all changed, but it makes no sense to just chuck a lot of downforce on. It also has to be efficient, because you have [the long straight of] Fuji. We have done a little bit on the cooling; we have a little bit just for Mexico. The race came so late [but] you can do some modifications.'

Porsche dialled in more downforce with its new kit, but the question for all three manufacturers is; what happens for the 2017 season? The teams are allowed to produce just two kits, probably to include a high and low downforce kit, and will not have the luxury of producing a third kit mid season. All three have to make the assumption that they will go back to Mexico and have to include that possibility in

‘The number one focus was the engine cooling, with the relatively high demands that we have in Nurburgring, Mexico and Austin’

their planning. ‘You have to assume that Mexico is in the series for next year, but if we are lucky we will get the calendar by the end of October,’ says Litjens. ‘That brings forward the whole build process. You cannot do the first race and then do an update. We have started on the ’17 car, but you need final confirmation of what Mexico really needs, because we have to experience it.’

Monchaux agrees: ‘We are working on the new car because time is running and the lead times and delivery times are different to sprint racing in Formula 1. You do the simulation of Le Mans and this is time consuming and happens early,’ he says. ‘If this happens early and you run your final configuration in January and February, you need the car with finished surfaces in December, and time is running, so we are working hard on next year’s car.

‘We follow the strategy of an efficient car in terms of aero, and the more efficient that we make the Le Mans car, the better the high downforce package will be,’ Monchaux adds. ‘For the 2016 car, we had to develop the Le Mans package, and at some stage we had to define the high downforce package from that. We then continued to develop the Le Mans car up to the last minute that we were allowed to, and once this was done, we resumed activity for the high downforce car.’

Forward planning

While Toyota and Audi have both introduced new chassis for 2016, Porsche did not replace last year’s car, and so will run the same car for three years including the 2017 season. However, it is now working on the 2018 car and has to split its limited number of test days cleverly.

‘You work in parallel for 2017 and 2018,’ says Porsche’s team principal, Andreas Seidl. ‘The number of test days goes down from 43 to 40 next year [as part of the cost-saving measures], which is not a big change but you have to weigh up how many days you spend on the ’17 car, because most of the days you have to spend in the run up to Le Mans, and the 2018 car is a big step. You want to do some more testing in the second half of the season for the 2018 car. We had three kits for this year, but the first kit was a 2015 kit, which was slightly modified. We then put the focus on the 2016 kit and it is all about when you make the call, to bring them and use them.

‘The nose is quite different and obviously there is some stuff under the bodywork with the underbody flow. When you have a restriction with a given monocoque [it’s not easy]. Audi have more freedom, but we are pretty happy with how the car performs,’ Seidl says.

Porsche made notable changes to the nose of the 919. The new version has a slightly more pronounced and curved leading edge. Three variants of nose and front splitter have been used this year. Spec A (top left) appeared at Silverstone and Spa, Spec B (above left) at Le Mans only, and featured a flatter front dive plane and a slightly re-shaped front wheel pod, while the Spec C version (above right) featured the revised nose and a third front dive plane iteration – this one has twin supports, perhaps suggesting that it generates more load

Porsche opened up the rear of the 919 at the Nurburgring with its Spec C body (right). This is probably to help with cooling at the tracks to come which all have lower average speeds than Le Mans, where the tighter Spec B (left) bodywork was used. Mexico has the added challenge of being at altitude. Next year the P1s will have just two specs of kit for the season

Brexit has already hit Formula 1 business says Williams

The sharp fall in the value of the pound has had an impact on the Williams F1 team says Claire Williams

XPB

Williams Formula 1 deputy team principal Claire Williams has said the recent vote for the UK to leave the European Union has already hit its business, due to the sharp fall of the pound against the euro and the uncertainty in the sponsorship market the decision has precipitated.

Williams, who is now very much the public face of the team her father founded since her elevation to the deputy team principal role in 2013, explained that as her team purchases its power units from Mercedes in euros, recent moves by the FIA to slash engine bills by €4m for 2018 have now effectively been nullified.

'There have been short-term impacts around costs,' Williams said. 'We unfortunately pay for our engine in euros. All the hard work we have done to bring the costs down by four million [euros] for 2018 has been counterbalanced.'

She also says the team is worried about the impact Brexit is having on the sponsorship market: 'We don't have a mothership [road car manufacturer parent company] like many other teams, and sponsorship is one of our key incomes. The political instability that Brexit has caused has meant there are going to be a lot of businesses out there who will have to wait and see what they are going to do with their marketing spend. That could have implications for us.

'We were having great conversations prior to the referendum and those conversations are slowing down now and people are waiting to see what is going to happen. It is a real concern for us,' Williams added.

Meanwhile, Mercedes F1 boss Toto Wolff said it was worried over future staffing in the wake of the Brexit decision, as both the chassis and engine operations are based in the United Kingdom. '[Brexit] has a big impact because on a personnel level we don't know where it is going to go. There are many experts working in Brackley. I'm not sure how that will be handled in the future. And Mercedes in Germany, there are many Brits working on DTM. It looks like everybody can be impacted by the situation.'

However, Wolff added that the financial impact is not so much of a concern for Mercedes: 'The weak pound is not so bad for us because we get the income in dollars and mothership subsidises in euros, so it's actually quite a good ratio,' he said.

GP2 to keep the current Dallara racecars for an extra season

The second-tier GP2 series it to stick with its current incarnation of spec racecar until the end of 2017, postponing the chassis change that was set to come in to place for the start of next season.

The decision to keep the Dallara GP2/11, which has now seen five years of service, has partly been put down to the current economic situation, but the move might also allow extra time for a convergence with the all-new FIA Formula 2.

GP2 boss Bruno Michel would not comment on the tie-up with Formula 2, but he did confirm that the postponement of the new chassis was down to 'the economic situation', and that this had been agreed with the teams in the series, who said they were willing to wait another year.

The current spec GP2 Dallara racecar has had a stay of execution and it will not now be replaced with a new car next season

It was announced in December that negotiations were ongoing between the FIA and GP2 to rebrand the latter as Formula 2, but since then there has been very little word on how these talks were progressing.

GP2 is part of Bernie Ecclestone's F1 group of companies, and it is believed that Ecclestone is not keen to see it renamed as Formula 2, and that this is the main reason for the lack of progress with the talks at the present time.

The extra year will also give GP2 the time to consider whether it will follow Formula 1 with mooted safety changes, specifically Halo, which could have implications for the design philosophy of the new GP2 chassis.

GP3, run by the same company, changed its chassis this year as planned. Its new GP3/16 is the first completely new car introduced since the series began in 2010. It features a Dallara-built chassis and new Mecachrome engine.

US manufacturer to enter Formula E with Dragon Racing

Formula E has enticed another manufacturer to its fold with the news that emerging US EV maker Faraday Future is to tie-up with Dragon Racing for FE's third season.

Faraday was founded as recently as 2014, but the Californian-based company has huge financial backing from China and is seen as something of a shooting star in the emerging performance EV market. It showed off its own single-seater concept car, the FFZERO1, at the beginning of this year.

Dragon, which finished second in the inaugural FE teams' championship, will be renamed Faraday Future Dragon Racing as part of the deal, which has been described as a technical partnership, and its powertrain will be badged the Penske 701-EV – Jay Penske owns Dragon Racing.

This is not Faraday Future's first involvement in FE, it also sponsored April's race in Long Beach, which is close to the company's headquarters.

Faraday Future is backed by China-based mogul Jia Yueting. His Leshi Internet Information and Technology concern has a market value of around $12bn, and it's believed that Yueting has already invested around $300m in Faraday.

Meanwhile, following the sale of its entry to Shanghai-based China Media Capital, Team Aguri will be replaced by the Techeetah entry in season three. Other changes include NEXTEV TCR changing its name to NextEV NIO, in line with the now-completed takeover of the original Team China Racing entry.

The full entry and powertrain list for season 2016/17 is: ABT Schaeffler Audi Sport (ABT Schaeffler FE02); Andretti Formula E (Andretti Technologies ATEC-02); Faraday Future Dragon Racing (Penske 701-EV); DS Virgin Racing (DS-Virgin DSV-02); Jaguar Racing (Jaguar I-Type 1); Mahindra Racing (Mahindra M3 ELECTRO); NextEV NIO (NextEV TCR Formula 002); Renault eDams (Renault ZE 16); Venturi Formula E (Venturi VM200-FE-02); and Techeetah (TBC).

Faraday Future's first involvement with Formula E was as the sponsor of this year's Long Beach round (pictured). Now it will have a technical tie-up with a race team in the championship

Boston race files for bankruptcy but IndyCar pledges to help fans

Boston Grand Prix LLC, the company behind the Massachusetts city's stillborn IndyCar race, has filed for bankruptcy in the US.

The company owes almost $9m to creditors, court documents show. Among the organisations listed are IndyCar (owed $4.2m), Firestone ($233,500), Howard/Stein-Hudson Associates LLC ($435,186), and Delta Airlines ($45,000).

Ticket holders are owed $1,677,894, and IndyCar has now stepped into the breach left by Boston Grand Prix's failure to fully refund ticket purchasers after the cancellation of its planned race, The series has committed to contributing $925,000 to help reimburse fans.

IndyCar boss Mark Miles says the series will help to reimburse disappointed race fans in the wake of BGP's bankruptcy

Massachusetts Attorney General Maura Healey said: 'I appreciate IndyCar's willingness to step up for their fans and help resolve this problem. They've gone above and beyond to be a productive part of this solution, and their fans will reap the benefits.'

Healey also said that her office has filed suits against Boston Grand Prix and its CEO John Casey to pursue the remainder of refunds owed to ticket purchasers.

In May of 2015 IndyCar entered into an agreement with race organiser Boston Grand Prix (BGP) for races to be run in Boston each year from 2016 through to 2020. But on April 29 BGP cancelled the race, scheduled for Labor Day weekend this year, as well dropping its plans to stage races in Boston in the future.

Mark Miles, CEO of Hulman & Co, the company behind IndyCar, said: 'We enjoy some of the most loyal and devoted fans in all of sports, and so we are pleased to work with the Attorney General and contribute in her efforts to protect ticket buyers.

'We want our fans to know that we share their disappointment that the race won't take place. And we also want to join them in expressing our appreciation for Attorney General Healey's work on their behalf,' Miles added.

Sauber's future secured as finance firm buys company

The ownership of the Sauber Formula 1 team has changed hands in a deal which the Swiss company's founder, Peter Sauber, says should 'secure its future'.

Sauber has had a troubled time with its finances this year, and was not able to pay its salaries on some occasions due to problems with cashflow. However, it has now emerged that Longbow Finance SA has bought the team's parent company, Sauber Holding AG.

Longbow is itself a Swiss company, but is also said to have close links to Tetra Laval, the global packaging giant – of Tetra Pack fame – which is a long-term backer of Sauber driver Marcus Ericsson

The change in ownership will not result in a name change for the team, which has been in F1 since 1993 – although between 2006 and 2009 it operated as BMW.

Peter Sauber will now retire and will give up his position as president of the board of directors. Monisha Kaltenborn will remain on the board and continue to lead the company as CEO and as Sauber's Formula 1 team principal.

Pascal Picci, the president and CEO of Longbow Finance, will now be chairman of Sauber Holding AG.

Peter Sauber said: 'I am very happy that my courageous investment to buy the team back, which I made six years ago, with the intention to secure the base in Hinwil and the place in Formula 1 has proved to be correct.'

Kaltenborn said: 'We are convinced that Longbow Finance SA is the perfect partner to again make the team competitive and successful in Formula 1.'

The Sauber team has a new owner in the shape of Swiss finance firm Longbow

JLR says the design of its new SVO facility has been inspired by the motorsport industry

JLR opens £20m Special Vehicle Operations facility

Jaguar Land Rover Special Vehicle Operations (SVO) has opened its brand new Formula 1-inspired Technical Centre in the heart of the British Midlands.

The £20m facility, near Coventry, will be the headquarters of SVO with manufacturing, paint, technical and customer commissioning and presentation zones housed within the 20,000sq.m building.

Jaguar Land Rover Special Operations is the specialist division of JLR, created in June 2014 to build a business responsible for halo car products, vehicle personalisation, and heritage car programmes – including motorsport – by Jaguar Land Rover Classic.

John Edwards, managing director of Jaguar Land Rover Special Operations, said: 'The new Special Vehicle Operations Technical Centre is a major step forward in meeting the desires of our most discerning customers. There are more than 200 skilled employees here that are committed to outstanding quality and craftsmanship in everything they do.

'The SVO Technical Centre is a very modern facility, inspired by a Formula 1 engineering centre. It covers 20,000sq.m including a manufacturing area, one of the world's most eco-friendly and advanced paint shops, custom-built commissioning suite, technical suite, presentation suite and offices.'

The attention to detail throughout the Technical Centre has been inspired by the exacting standards expected in top level motorsport, JLR tells us.

Pro Mazda offers financial incentives to boost car sales

Andersen Promotions, the company behind the Road to Indy single seater ladder in the United States, has announced a series of cost-cutting initiatives and financial incentives for its Pro Mazda Championship.

Pro Mazda, which is the second step on the IndyCar driver ladder – under Indy lights and above USF2000 – is to get a new chassis in 2018, the Tatuus PM-18.

The PM-18 will now be made available to teams as early as June next year, providing an opportunity for a summer testing programme with the new chassis in preparation for 2018.

Andersen Promotions will also now offer teams a $5000 discount on the PM-18, or to each driver who commits to running the entire 2017 season, this is in addition to its almost 20 per cent full-season entry fee discount.

The Pro Mazda champion's scholarship prize will also be increased from $590,300 to $790,300 next year, bringing the total event and year end prizes to over $1.1m.

Next season, the series will also see a reduction in the number of events from eight to six, and the number of races from 16 to 14. This is to reduce budgets, but it will still provide a mix of circuits, for driver training reasons, with one oval, one street circuit and four road course events.

'[We] are fully committed to the Pro Mazda class and to securing the healthy grids we have seen the past few years,' said Dan Andersen, CEO of Andersen Promotions. 'With the PM-18 making its competition debut in 2018, we felt the need for a fresh and strong commitment now. We believe the opportunity to reduce budgets with a shortened season next year combined with a summer testing programme of the new car and an increased prize package and programme incentives will open the door for more drivers to join the series.'

The 2018 Pro Mazda will be based on the same Tatuus chassis as its USF2000 cousin (pictured)

Race school signs new deal with IMSA Properties

Skip Barber Racing School, one of the world's top race driver training providers, has announced that it has signed a new multi-year agreement with track operating company IMSA Properties.

As a result of the deal Skip Barber Racing School will continue to be headquartered at Road Atlanta until at least 2020, while it will also establish 'Central Learning Centres' at both Road Atlanta and Sebring International Raceway.

Rick Humphrey, vice president of IMSA Properties, said of the deal: 'We are proud to continue a long-standing partnership with Skip Barber Racing School at both Sebring International Raceway and Road Atlanta. Skip Barber Racing School has represented excellence in training aspiring racers for decades, and through this renewed partnership, the opportunity exists for a new generation to experience our world-class facilities.'

The Skip Barber Racing School is one of the largest race driver school operations in the world. As well as racing schools, it also runs defensive and high performance driving courses, amateur and professional racing championships, and corporate entertainment days.

Race driver Skip Barber started the school in 1975 with two borrowed Formula Fords. It now visits up to 30 race tracks across the United States and Canada and it owns 120 racecars.

IN BRIEF

Formula 3 World Cup proposed

The FIA and the teams competing in the Formula 3 European Championship are considering a World Cup consisting of three events, plus a cost cap of €500,000 for the main championship – budgets for which are currently around the €700,000 mark. The idea is to have eight events rather than 10 in the main championship, thereby cutting its costs, but three extra high-profile events for those teams and drivers who can afford it, which would then constitute the World Cup.

SEEN: AM-RB 001

If you've ever wondered what would happen if Red Bull F1 tech maestro Adrian Newey designed a car for the road, then here's your answer. The AM-RB 001 was actually co-designed by Newey, the project a collaboration between Red Bull and Aston Martin, Newey working alongside Aston Martin chief creative officer Marek Reichman and chief special operations officer David King to create the hypercar. The AM-RB's full spec has not been released, but we're told it will be powered by a naturally-aspirated V12 engine and its carbon fibre construction is expected to give it a power to weight ratio of 1:1. It's also said to boast unprecedented levels of downforce in a road-legal car, much of this generated through underfloor aerodynamics. Between 99 and 150 cars, including all the prototypes and 25 track-only versions, will be produced. First deliveries of the AM-RB 001 will commence in 2018.

Funding opportunities for UK-based low carbon technology companies

The UK's Niche Vehicle Network (NVN) has announced a new funding competition which is offering a total of £2.3m for low carbon automotive projects.

NVN tells us that 'the costs and risks associated with undertaking highly innovative R&D often inhibit smaller automotive manufacturers from developing new products and manufacturing processes'. It adds: 'The Niche Vehicle R&D Programme is designed to overcome these obstacles and help such companies to invest more intensively in emerging technologies and the development of new products'.

Sponsored by the Office for Low Emission Vehicles (OLEV), Innovate UK and the Advanced Propulsion Centre (APC), the competitions are focused on providing SMEs active in the low carbon vehicle technology sector with funding to undertake two specific stages of development. These are the early stage 'proof of concept' R&D; which is taking product ideas to the point where they are successfully demonstrated on a vehicle, and also the later stage R&D, which is moving forward from the demonstration stage to produce working prototypes and establish manufacturing routes which lead to production readiness.

The call for applications closes in late August. UK automotive SMEs, including vehicle manufacturers, technology companies and specialist suppliers who wish to collaborate to develop and productionise low carbon vehicle technologies are invited to apply for the funding. Projects for all types of powered on-road and off-highway vehicles are eligible.

For more visit the NVN website: www.nichevehiclenetwork.co.uk

New motorsport engineering training facility to open at Silverstone business park

The National College for Motorsport is to open a brand new purpose-built training establishment at Silverstone.

The £1.5m facility will be ready in September 2016 as part of the organisation's plans to increase its specialist skills training availability to an additional 240 students by 2021.

The National College for Motorsport is run by Tresham College of Further and Higher Education in Northamptonshire.

Tresham College's new facility will be located at Silverstone Park, the hi-tech engineering business estate situated next to the British Grand Prix venue, which is being developed by commercial property company MEPC.

The college already occupies other premises at the park.

The 7500sq.ft facility will consist of two fully-equipped workshops and classrooms and it has been designed by GSS Architecture to ensure that the space is suitable to combine the practical and theoretical training of the college's full-time students and apprentices.

David Higham, vice principal at Tresham, said: 'We are really pleased to be able to expand our motorsport training provision so we can welcome additional full-time students and apprentices from across the world to benefit from the specialist training that we provide at the National College for Motorsport. Our industry experienced staff work alongside race teams to design the curriculum for our students and apprentices to ensure that they are work ready and progress well with their future employers.'

The National College for Motorsport trains full time students and apprentices for careers in the motorsport and high performance engineering industry.

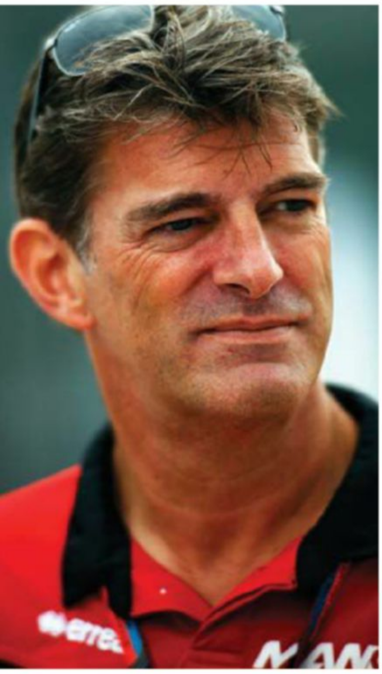
Past students have gone on to work in a wide range of motorsport companies, including Formula 1 operations such as Lotus, Red Bull, Force India, Manor and Mercedes, the College tells us.

INTERVIEW – Graeme Lowdon

In a Manor of speaking

The former F1 sporting director talks about life in the WEC, his views on Formula 1 from the outside looking in, and the importance of Bertha

By MIKE BRESLIN



XPB

'It's important to build a business around the racing, because if you don't you won't be racing for very long'

Bertha plays a vital role at Manor. It's no exaggeration to say Bertha is at the heart of the LMP2 operation, and has played a part in many of the company's other motorsport ventures over the past 27 years, too. Bertha is famous in paddocks the world over, but Bertha is not your average liveried team member. Bertha is a teapot.

'Kimi Raikkonen has made tea in this pot, Lewis Hamilton has, too,' says Manor's president and sporting director Graeme Lowdon, hinting at the illustrious history of this organisation, but also at the down to earth way in which it goes about its business. A single seater squad par excellence, Manor has hosted many of the greats as they've made their way up the racing ladder, while the name has also recently been a mainstay in Formula 1. But the current F1 outfit has absolutely no connection with the Manor which is in WEC now, which in many ways might be seen as the 'real' Manor, what with the continuation in personnel at all levels.

Manor founder John Booth and Lowdon left the F1 team at the end of last year. 'It was definitely a wrench to leave Formula 1, but it was absolutely the right thing to do,' says Lowdon, who was a successful businessman before he came in to racing in 2000. 'I worked very hard to save the [F1] team when I was a shareholder and director [when it was in administration]; that was an obligation that I had, and I have absolutely no regrets about all the effort and everything else; and the financial commitment, because we had to support the team when there was no ownership.'

Which begs the question, why leave after all that hard work? 'It's very straightforward, if you're an employee and you're not particularly happy where you are working, then you can just go and work somewhere else,' Lowdon says. 'The easiest thing in the world to do is to stay because you love the industry, you love Formula 1. But to be honest that's the worst thing you can possibly do, it's not fair on yourself and it's not fair on the people you work with.'

Pastures new

Very soon after quitting Formula 1 Lowdon, Booth and the Manor name arrived in the WEC, and the reason for this is both deliciously simple, and refreshing: 'To keep racing,' Lowdon says. 'We didn't want to have a year without racing. This will be the 27th year of Manor racing in something, whether it was Formula Ford, Formula Renault, Formula 3, Formula 1, or GP3. And WEC, and LMP2 in particular, ticked a lot of boxes. It was something in which we could establish a team quickly, because we only had about eight weeks to go from, well, not even a factory – just a screwdriver and an A4 entry form, if you like – through to having a team up and running, and it's possible to do that in a championship where you don't have to design and build the racecar.

'But it's a proper world championship,' Lowdon adds. 'And that's the level we're used to operating at. It goes to a lot of circuits that we're familiar with around the world and, of course, I think the clincher is, it's got Le Mans at the very heart of it, which is the world's greatest motor race.'

It's been a mixed year for Manor thus far, the highlights a fine third at Spa and qualifying fourth Le Mans, while the low point has to be crashing out of the 24 Hours with just four hours to go. But how does P2 compare with F1? 'The biggest observation so far is that the racing is intense,' Lowdon says. 'It is flat out from the moment the lights change. The playing field is pretty level in LMP2. Look at LMP2 at Le Mans, it's a grid of 24 cars, that's bigger than an F1 grid; and you can't design an advantage into your car. It's a test of both drivers and teams.'

Stepping up

This year Manor is fielding a brace of ORECAs in P2, but with the team's background it's no surprise to learn it's already eyeing the top category, and Lowdon has been observing recent moves to bring LMP1-H and the more privateer-orientated LMP1-L more into line with interest. 'The element that's not in the mix at the minute is we're not designing and building a car, and we've had six years of experience of doing that at the highest level, so we know what to do in that area, either in a manufacturer-backed environment or a privateer environment. So that's definitely something we're looking at.'

For the time being, the Manor WEC squad is based at a unit in Silverstone, rather than its traditional HQ in Dinnington, South Yorkshire, mainly because many of the skilled personnel needed for WEC live in the Motorsport Valley area. That said,

Manor has adapted well to the WEC but Le Mans was a disappointment – its single entry crashing out with four hours of the race remaining there are still a lot of familiar Manor faces in the team. 'We've got some guys who have been with Manor all the way through F3 and F1,' Lowdon says. 'Some who were with Manor through the F3 days and GP3, too. There are also a couple of key people in engineering who have done a few seasons of WEC and Le Mans. So I think we've got a good mix, and the main thing was that there were a lot of people who wanted to come and work with us on the project, and it's always nice when that happens, because these races are a proper challenge and the one thing we don't need to spend much time on is motivating our staff. They all want to be here, they all want to wear the Manor badge, and they all want to race, and that helps enormously; there's a lot of self-starting and self-motivation.'

Which is, of course, much the same as Formula 1. But what does Lowdon now think of F1, from the outside looking in? 'I still love Formula 1. I firmly believe that Formula 1 has got the ingredients to deliver a fantastic experience to the fans, and it delivers pretty well at the minute, but the opportunities are there for it to be so much more. I think the future for Formula 1 is very, very bright, though.'

However, he is not entirely convinced with the new 2017 regulations. 'My fear about the 2017 regulations is that as ever there's going to be a lot of unintended outcomes, because the process that we went through to actually get to those regulations wasn't ideal. It was done with a backdrop of wrangling about who should be involved, what the objectives should be, etc. What we do know is that F1 teams are fantastic at optimising a set of regulations, which means that those regulations have to be incredibly well set … But you have to worry about how well [these regulations] were formulated.'

Racing ahead

Lowdon says that there may still be a future for him in Formula 1, but as far as the future for Manor is concerned, it's the same mantra: 'To keep racing.' Though this racer is a businessman, too, and that is also important: I've established other businesses. If you want to make money, there's a million ways you can do it outside of racing, but the reason we race is because we love it. But it's important to build a business around it because if you don't then you won't be doing it for very long.' But whether it's big business or hard racing, at Manor there's always time for a cup of tea.

XPB

RACE MOVES

XPB

The Motorsport Industry Association (MIA) has recognised BTCC boss **Alan Gow** by awarding him with its award for Outstanding Contribution to the Motorsport Industry. Alongside his role as director of the BTCC Gow currently serves as president of the FIA World Touring Car Commission and chairman of the Motor Sports Association (MSA).

Stefan Dreyer, previously head of operations LMP Engines at Audi Sport, has now stepped up to the role of head of LMP with the company. Meanwhile, **Erik Schuivens** has started as new race engineer for **Marcel Fassler, Andre Lotterer** and **Benoit Treluyer** at the Audi WEC operation.

Kelly Tharp is now the president of Darlington Raceway. The former senior director of racing communications at NASCAR replaces **Chip Wile** in the position, the latter having moved on to take the lead role at Daytona. Tharp had been with NASCAR since 2005 .

With the departure of **Kelly Tharp** (see above) there has been a shakeup in the NASCAR Integrated Marketing Communications team, with **Matt Ciesluk** promoted to senior director; **Mike Forde** promoted to director, Racing Communications; and **Stephanie Harris** promoted to senior manager, Content Communications.

Michael Zoto, who was the technical director for the all-new Toyota World Rally programme, has now left Toyota Gazoo Racing, the team behind the operation. No reason was given for his departure by Toyota. The new WRC Toyota Yaris is set to make its debut at the start of next year.

Mathew Rumfield is now the race engineer on the **Todd Kelly**-driven Nissan in the Australian Supercars series (formerly known as V8 Supercars). Rumfield, who previously worked in NASCAR in the US, has replaced **Jesse Walker** in the position, the latter having moved on to take up a post with automotive technology company Faraday Future in the United States.

NASCAR journalist **Benny Phillips** has posthumously been awarded with the Squier-Hall Award for NASCAR Media Excellence. Phillips, who died in 2012 at the age of 74, spent 48 years with North Carolina newspaper the *High Point Enterprise*, and also wrote for *Stock Car Racing* magazine for 27 years.

Philip Surgen, the stand-in crew chief on the **Kyle Larson**-driven No.42 Chevrolet in the NASCAR Sprint Cup, has been fined $25,000 after the car he tends failed post-race inspection at the Michigan round of the series. Surgen was filling in for **Chad Johnston**, who was suspended after a lug-nut violation at the Pocono race earlier in the season.

As *Racecar* went to press Honda was considering working throughout the August F1 factory shutdown. It's believed it is allowed to do this as it is considered a supplier, to McLaren, rather than part of a team, as rival engine builders Renault, Mercedes and Ferrari are. But Honda's F1 chief **Yusuke Hasegawa** did say he would be double-checking the regulations before committing to working through August.

Force India boss **Vijay Mallya** attended his first F1 race of the year at Silverstone's British Grand Prix. The former billionaire has had his passport revoked by the Indian government in the wake of problems associated with the failure of his airline, Kingfisher, which means he has been unable to leave the UK to attend other races thus far this season.

Mexican motorsport promoter and former race driver **Alfonso Toledano** has died. He organised Mexican F3, Formula Renault and Pan American F3 races in his home country. As a driver he was third in one of the main Formula Ford 1600 series in the UK in 1981, behind championship-winning works Van Diemen teammate **Ayrton Senna**. Toledano also competed in European F3.

Blash calls time on F1 career after 51 years in the sport

XPB

Herbie Blash is to say goodbye to Formula 1 after over half a century working in the sport

Herbie Blash is to step down from his position as the FIA's deputy race director in Formula 1 at the end of this season.

The 67-year-old's departure will mark the end of a 51-year career in F1, Blash having come to the sport as a mechanic with privateer entrant Rob Walker back in 1965, before joining Lotus to engineer Jochen Rindt's car in 1968. Blash then joined Brabham as team manager in 1972. He later had a brief spell with the Yamaha Formula 1 engine programme, before joining the FIA as deputy race director in 1996.

Blash will still continue to work with the FIA in some capacity beyond F1, we're told.

Safety director Laurent Mekies, who joined the FIA in 2014, will take on Blash's duties from 2017, alongside his current role. Mekies began his F1 career with Arrows in 2001 and then moved to Minardi the following year. He stayed with the team when it became Toro Rosso, taking on the role of chief engineer and head of vehicle performance.

FIA president Jean Todt said of Blash: 'I would personally like to thank Herbie for all of his hard work for the FIA over the past 21 years, and especially for his contribution in maintaining F1's place at the pinnacle of motorsport. Along with Charlie [Whiting], he has been instrumental in the seamless running of grands prix for over two decades, and we are pleased that he will continue to work with the FIA in future.'

Whiting, FIA F1 race director, said: 'I would like to extend my sincerest thanks to Herbie for his years of tireless work for our sport. It has been a huge pleasure to be alongside him for almost two decades.

'Herbie will be hard to replace but, with Laurent's extensive experience in F1, I'm sure he will be a worthy replacement. He will also be able to bring a new dimension of experience to our team of F1 officials.'

OBITUARY - Carl Haas

Carl Haas, one of the most well-known personalities in the US motorsport industry, has died at the age of 86.

Haas started out as a driver in sportscars in the '50s before he set up the Carl Haas Automotive Imports business in 1960. By 1967 he was the exclusive importer for Lola Cars in North America.

XPB

The legendary Newman-Haas team last saw IndyCar action during the 2011 season

While Haas is chiefly known as a team boss in Indycar, he also fielded a team in Formula 1 back in the mid-1980s. But Haas, who was not related to current F1 boss Gene Haas, is far more famous for his tie-up with film star Paul Newman in CART, Champ Car, and IndyCar.

The Newman-Haas team claimed the CART title with Mario Andretti at the wheel in only its second year in the series in 1984. It went on to find more success with Mario's son Michael, and then F1 refugee Nigel Mansell in the early '90s.

Haas stayed loyal to CART during its rivalry with the Indy Racing League, keeping faith with the series when organisations such as Penske and Chip Ganassi Racing defected to IRL in the early 2000s, and winning the title with Cristiano da Matta in 2002. Newman-Haas then dominated the series, then known as Champ Car, with back to back titles with Sebastien Bourdais from 2004 to 2007. The team was never quite as successful when the two series merged to form IndyCar in 2008, and after Newman's death Haas joined forces with Bobby Rahal and others, before running his own team again in 2011, which then closed its doors that same year.

Haas also ran teams in Formula 5000, Can-Am sportscars, NASCAR and other formulae over the years.

J Douglas Boles, the president of the Indianapolis Motor Speedway, said of his passing: 'The IndyCar community was fortunate to have his personality as part of its family and Mr Haas' legacy of excellence and winning will long be remembered.'

Carl Haas 1930 - 2016

RACE MOVES – continued

XPB

Frederic Vasseur is now the team principal of the Renault Formula 1 team. Vasseur, who was initially appointed racing director following Renault's takeover of Lotus at the end of last year, will now be directly responsible for the performance of the F1 team. Cyril Abiteboul will continue as managing director, but will now focus on operations at Renault's Enstone base, rather than the engine facility at Viry-Chatillon.

Ex-Ferrari Formula 1 team principal **Marco Mattiacci** is now working with US electric vehicle producer Faraday Future, where he has taken on the post of global chief brand and commercial officer. Before Mattiacci took over the position of managing director and team principal at Ferrari's F1 team from **Stefano Domenicali** in 2014 he was CEO of Ferrari North America. He left Ferrari at the end of the 2014 season after just seven months with the Scuderia.

Elton Sawyer has been promoted to vice president, Officiating and Technical Inspection, within the NASCAR Competition Executive Team. Sawyer has spent the last two seasons as managing director of the NASCAR Camping World Truck Series. He joined NASCAR in 2015 following a spell as director of team operations for Action Express Racing in the IMSA Series. Before that he worked at NASCAR team Red Bull Racing.

John Probst has joined the NASCAR Competition Executive Team as managing director, Competition and Innovation. Probst joins NASCAR after serving as technical director for Chip Ganassi Racing with Felix Sabates. He also held the same role at the Red Bull Racing Sprint Cup operation, and spent more than 11 years as engineering supervisor at Ford.

Other promotions in the NASCAR Competition Executive Team (see above) include **Brad Moran's** appointment as managing director, NASCAR Camping World Truck Series; **Brandon Thompson,** who is to become the senior director, Touring Series; and **Jusan Hamilton,** who will become manager, Racing Operations and Event Management. Meanwhile, **George Grippo** will join the competition team as managing director, Competition Technology and Timing and Scoring. All of them will undergo a transition into their new assignments over the balance of the 2016 season.

Damien Smith, the editor of *Motor Sport*, is to leave the magazine he has headed for over 100 issues. Smith will take up a PR role with Influence Associates, where he will be an associate director, in September of this year. He is the second-longest serving editor in the history of *Motor Sport*, behind the late, great **Bill Boddy.**

Prince Harry is to be the Royal Patron of the project to create The Silverstone Heritage Experience (TSHE). TSHE is due to open in 2018, on the 70th anniversary of the first grand prix at the circuit. The project will bring the heritage of Silverstone and British motor racing to life for an estimated half a million visitors a year through 'the creation of a dynamic, interactive and educational visitor experience', Silverstone tells us.

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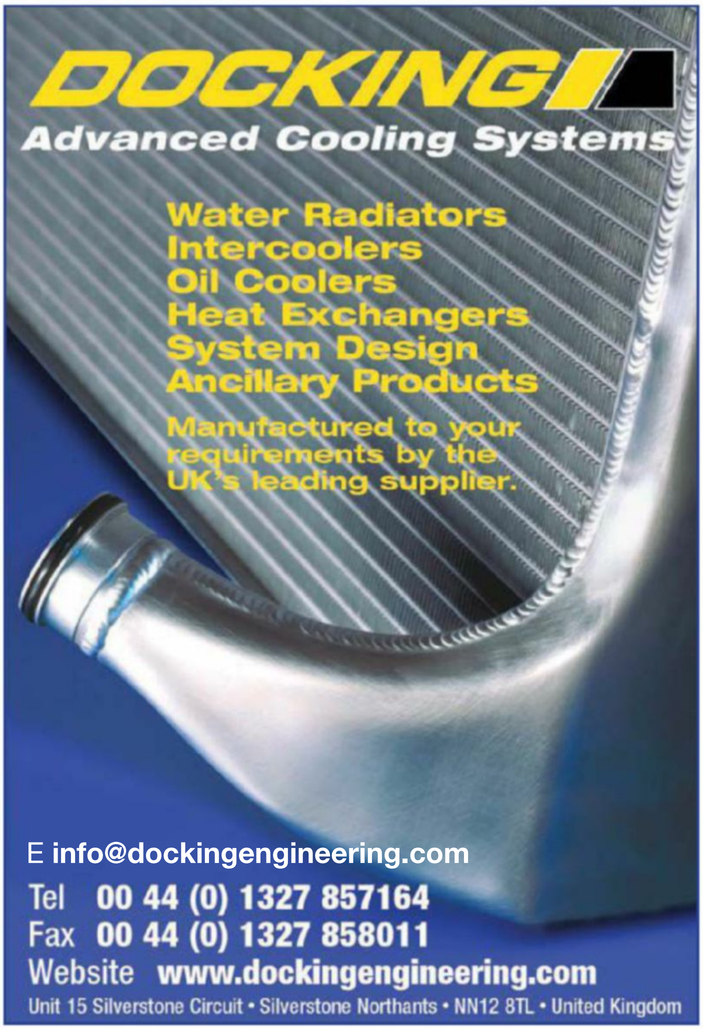
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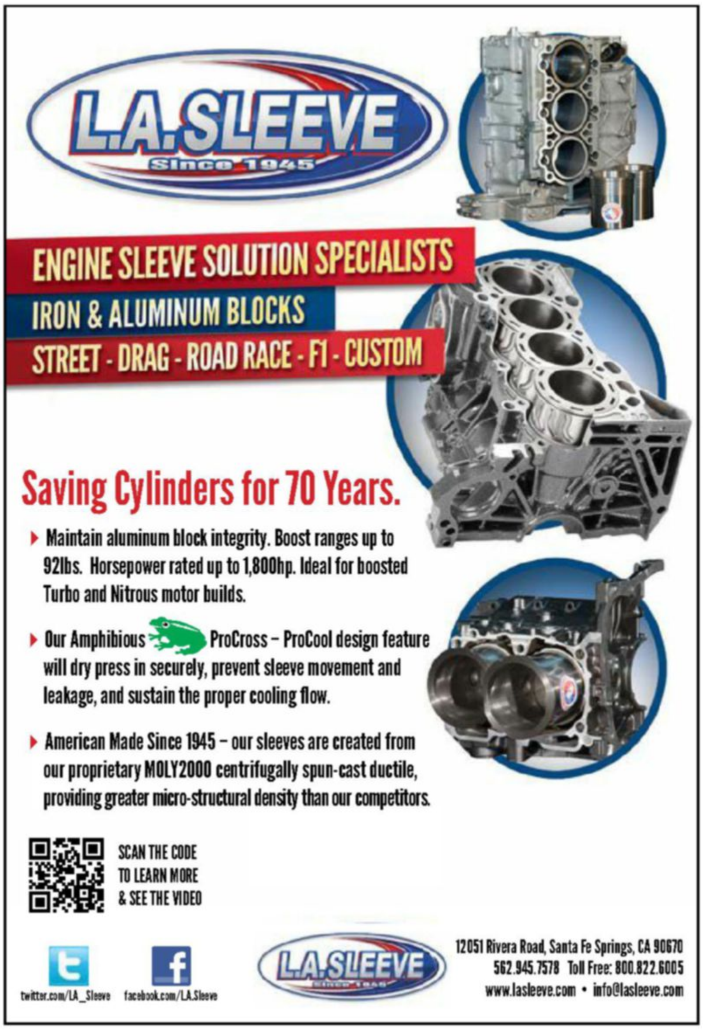
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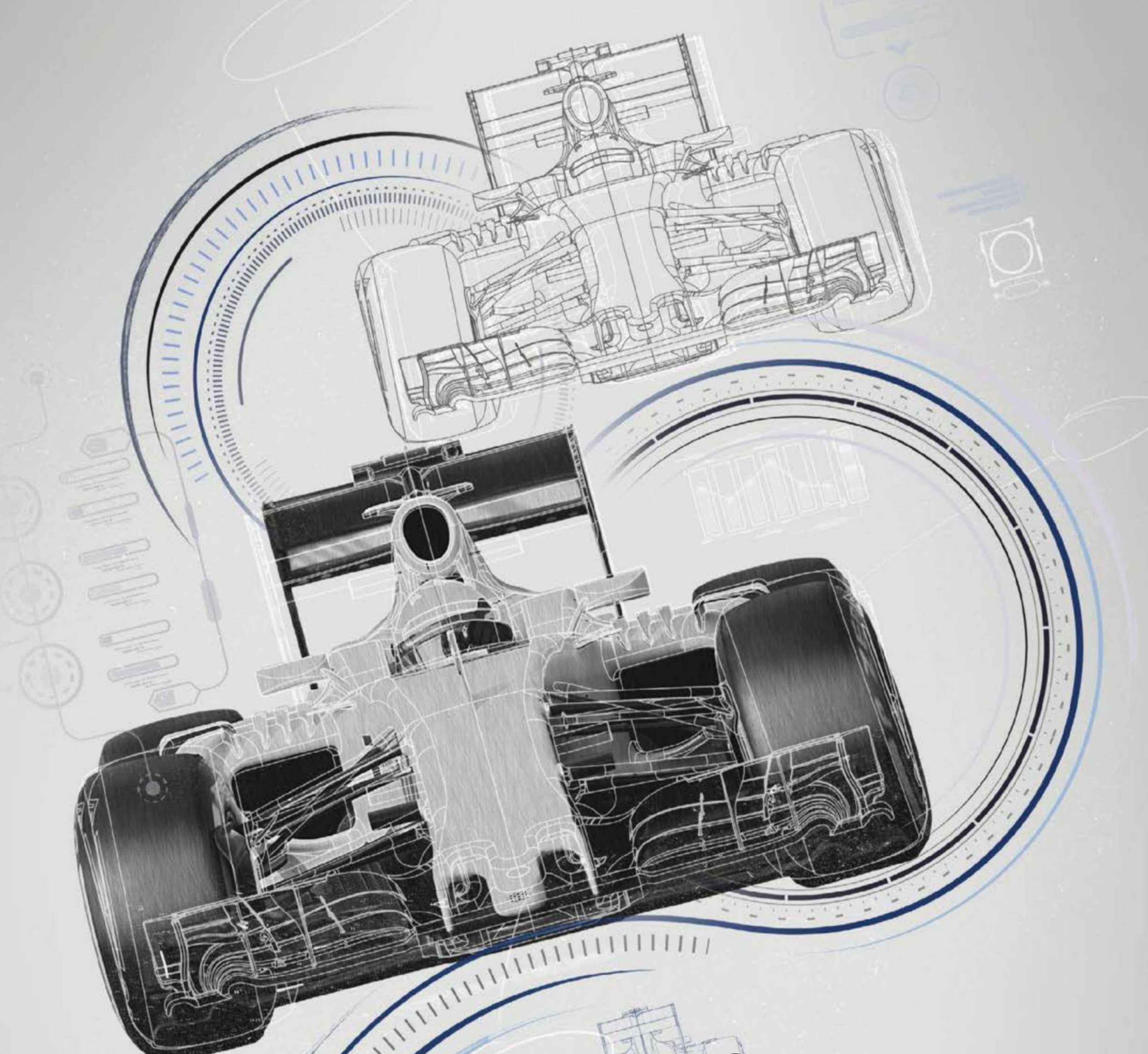

Spring time at ASI

As the excitement builds in the run-up to January's show we celebrate a milestone for one of the industry's best-known family businesses

Spring is here: Eibach forged its reputation with the manufacture of high quality coil springs for a number of applications

NASCAR is just one of the motorsport arenas in to which Eibach supplies its suspension components

The family-owned German manufacturer is marking its 65th year in business with the opening of this new hi-tech plant in Wiethfeld

This is a special year for Eibach. It's its 65th in business, and it has already celebrated in some style, with the completion of the largest investment in its history; the construction of an advanced new production plant in Wiethfeld, just seven kilometres from its main facility in Finnentrop, in North Rhine-Westphalia, Germany.

The new plant has expanded Eibach's capacity significantly, says the German spring maker, which has a huge involvement in motorsport across the world at all levels, including Formula 1, WRC and NASCAR.

Eibach tells us that with the new factory it now has one of the most modern production plants for suspension components in the world. The new plant will also allow Eibach to reorganise its General Industry and Engine Components departments to 'lean production', or 'just in time' as it is also sometimes known – a manufacturing system that tries to eliminate waste in the production process.

Another exciting development is its involvement as a manufacturing partner in the automotive industry with a new suspension system called 'active roll stabilisation'.

Personnel trainer

But it's not all about the products, the people are important at Eibach, too, and recently the firm was awarded the certificate for Outstanding Training Company in the Sauerland area for the third consecutive year.

Eibach employs 350 people and is a great believer in apprenticeships, with 35 young people currently working in 11 different trades. 'For decades, the training of young people has filled the owners and the management with pride,' the company tells us. 'There are 100 former trainees working in virtually all areas of the company bringing in their developed skills with enthusiasm and motivation.'

While the parent company celebrates its 65th anniversary this year, ENA (Eibach North America) will celebrate its 30-year anniversary next year, and is considered one of the most successful German family-owned businesses in the USA. In its own 16,000sq.m building in Corona, near Los Angeles in California, over 100 employees produce suspension springs, stabilisers and dampers.

Eibach has also now established itself in China, now the largest automotive market in the world. This is not because of lower costs, the firm tells us, but rather to service its current and additional customers in the entire Asia-Pacific Region. It has set up a production plant in Taicang near Shanghai during the past five years, which has allowed EST (Eibach Springs Taicang) to establish itself as a hub for all activities in the Asia-Pacific-Region.

In addition to the production sites mentioned above, there are also Eibach owned sales companies in the UK, Australia and South Africa. Currently Eibach has approximately 500 employees worldwide – complemented by independent sales partners in 80 countries around the globe. The company aims towards market leadership in all major business areas and intends to continue diversification into many smaller and interesting market niches.

Eibach was founded by Heinrich Eibach in 1951, and his son Wilfred now heads the company, one of the very few truly global family businesses in existence today. As a traditional family business, 'emotional intelligence' is part of Eibach's corporate culture, as well as loyalty, trust and mutual care. 'The daily contact of the shareholders and the management with employees and business partners mostly takes place on a trusting and often even a friendly level,' Eibach says. The third generation of the family are now shareholders, as well as being involved in the management of the Holding Company, Eibach Industries GmbH.

It's not all about the products, the people are important at Eibach too

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The shock of the new

The new 2017 Formula 1 regulations are out already, and before the summer break those who have tested the cars on the simulator have declared themselves to be decidedly underwhelmed. Yes, there is more power, but there is also more drag, and more grip, which means that although the cornering speeds and top speeds will be higher, the cars will actually be easier to drive, and that does not make for great racing.

One of the great aspects of the British GP in July was a puddle. It sat just where drivers would be turning through the apex of Abbey and caught out many of them. Happily, none crashed heavily, although they did lose time off the circuit and trying to rejoin. Although the 2016 cars don't look spectacular, they are a bit of a handful to drive, particularly in the wet.

The WEC boys have noticed this too. The lower speeds in the wet mean that the braking is not as severe, and that means that the batteries are not as well charged, which means that there is not the power on delivery. Which, in turn, affects the tyre temperatures, water temperatures and so on. This, then, further slows the car, and eventually you finish up with a problem on your hands.

The inverse is also true. If the battery is full, you can't rely on it to help with braking and, in slippery conditions, you cannot fully deploy the charge, or you will crash. This, then, leads to a whole different world of problems. Managing them is as difficult as the first example.

The world of racing these hybrid cars is very different to that in which the drivers grew up

The performance of the hybrids was clearly shown by Porsche at Spa, where its system failed early in the race, but the car continued at a reduced speed. Several seconds per lap slower than the sister car before it stopped, given the weight of the batteries and hybrid system this is a lot of money for a whole world of potential problems.

Yet, for the manufacturers, this is precisely what they want. Porsche lent me a hybrid Panamera for Le Mans, and while trying to charge the battery while driving (using much more fuel), or charging at the Porsche centre at Le Mans where a lovely breakfast was to be had, but which took an age, I wondered if this was the future. Without charge, the car is carrying around about 80kg of extra weight. In full electric mode, it would do a maximum of 21 miles. A combination of the two did improve economy, but was it worth it?

Actually, yes, it was. With cities looking to impose strict bans on diesels, I can see a world where electric cars only will be allowed in city centres. And, to make them attractive, we do need lighter batteries, lighter hybrid systems and better management of power, and racing is in the right place to deliver that. The WEC has said that it probably won't go above 10MJ of hybrid class as that makes it irrelevant for the road. (There is, by the way, pressure from manufacturers competing in the WEC to delay the 10MJ and third hybrid system until 2020 to allow Peugeot into the LMP1 fold in 2018). However, it is doing 800V cars, which is road relevant, and hybrids which must improve before anyone will take them seriously.

Having visited Mahle and Ilmor recently, they are pressing ahead with friction reduction systems to improve efficiency in the existing powertrain, and believe that there are plenty of gains to be had there. Mahle engineers were particularly amused at the ACO's plan to look at CO_2 emissions from its LMP1 cars in future. What's the criteria, they wondered? A one-lap average, race average, stand-still measurement? Will the LMP1 cars be fitted with PEMS machines (Portable Emissions Measurement System), which are a little weighty at 70kg, or will there have to be a development of these?

They liked the idea, but then applied some logic to the problem. On full throttle, the CO_2 emissions will be extraordinary and not representative of real world driving conditions. Mahle is working to introduce more real world driving condition testing rather than the lab testing that has proven to be so expensive for both the VW Group and Mitsubishi, so perhaps CO_2 in-car testing is the right way to go. Still, the CO_2 emission results will, initially at least, be incredible and probably extremely damaging to car companies.

The world of racing these hybrids is very different to that which the drivers grew up in. Managing brake and water temperatures is part and parcel, but when you have also to cope with fuel cut outs (which also come in when the battery is not fully deployed lap after lap) and managing your energy storage, it's a complicated affair. For the teams, what on the outside look to be elementary mistakes are still being made. At Le Mans, during qualifying, Audi lost one of its quick times as it exceeded its energy calculation. This was a simple mistake; the car was in race mode, not qualifying mode. In race mode, the car can use more energy over one lap, and then spend the next two with less energy to produce a three-lap average. In qualifying mode, this would not be possible.

There's still much to learn, and so much development to be had. Racing is on the right path to help. But my recent experiences have proven how far it, and motoring, has to go.

ANDREW COTTON Editor

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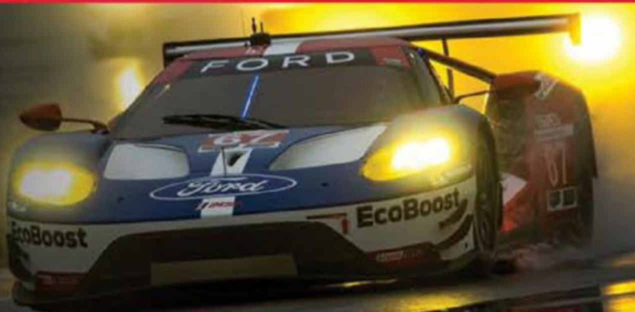

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