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The new 2016 Aston Martin GTE. For detailed analysis of 2016 GTE regulations turn to page 10

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So it would not be illogical to conclude that work environments will *ipso facto* have some defining characteristics created by the thought processes and culture of the participants. Diversity in a work environment breeds ideas by the interchange of different cultures or ways of life, but one thing that stands out is that we are all theoretically working to the same rules.

And when anyone says `theoretically,' they really mean `not really', for different departments are working to different agendas. The design department is trying to get the different inter-related systems working harmoniously to produce a quick car, and motor racing's always glorified the ethos of the unfair advantage.

Slippery slope

I subscribe to this, by having development breakouts in new concepts and interpretation, which is close to gaming the system…but it is a slippery slope. Engineering can be exempt from cheating by adhering to the rules, but it does not mean the companies that pursue the sport, by their undue influence on how they are framed, do not manipulate the rules.

The board that decides if they will invest in racing will defer to marketing more than engineering despite the mantra of 'showing the technological prowess of the company'.

The repercussions in the business world of bad corporate behaviour; such as the major manipulation of the emissions in EPA tests, will be with us for a long time. The general public is awakening to the fact that the whole manipulation of government and justice by corporations buying government through financing campaigns and the subsequent nomination of Supreme Court justices does have consequences; need one mention the effects of 'Citizens United' in US politics?

And of the special interest groups that are gaming the government, business stands out first and foremost. Who can forget the mantra GM president and chief executive Charles E Wilson was misquoted on: 'What's good for General Motors is good for the country', justifying its procedures.

The sharing of the cake slices for those who have an F1 racing franchise is definitely a zero sum game and the fighting can get more savage as the pot is not growing, unless the owners allow more of the profits to trickle down to teams. This is currently the battleground between teams, governing body and the franchise holder. Standing back from the environment lest the pixels obscure the picture, it all seems reminiscent of the libertarian ethos in Silicon Valley, 'get mine', walled off from reality due to hermetic environment – much as in racing, but also playing for big stakes.

'Caesar's wife must be above suspicion,' said Julius Caesar. In this vein one could bring in the whole structure of the FIA under scrutiny for the way the commercial rights were sold off, but this is now compounded by the FIA also owning part of Formula 1, supposedly in the interest of financing its safety push. That seems to me to fail the most elementary check for objectivity and impartiality, not to mention principles. Motor manufacturers being embedded in this matrix of behaviour and mores are beginning to reflect this, with the corollary of it seeping into motorsport. Who pays the piper is always relevant.

Ethics does not inform you about the stresses in a wishbone

XPB

In motorsport the temptation to bend the rules can be hard to resist; but engineers should base their decisions on ethics as well as maths

The Competition Directorate of the European Commission is now looking at the operating principles of F1 at the behest of two of the smaller teams to ascertain the legality of methods in light of EC rules on competition. It is not the first time; there was a similar review of FOM and the FIA in 1999.

This brought forced changes in the way things were done then. At the same time, there was the hurried setting up of the FIA headquarters in Switzerland, long known as the base for any endeavour that likes transparency and oversight … surely this had nothing to do with the fact that if you are based in any of the EC countries you can be subjected to some legal constraints and could be pursued for any transgressions, but rather on its cuisine and excellent weather.

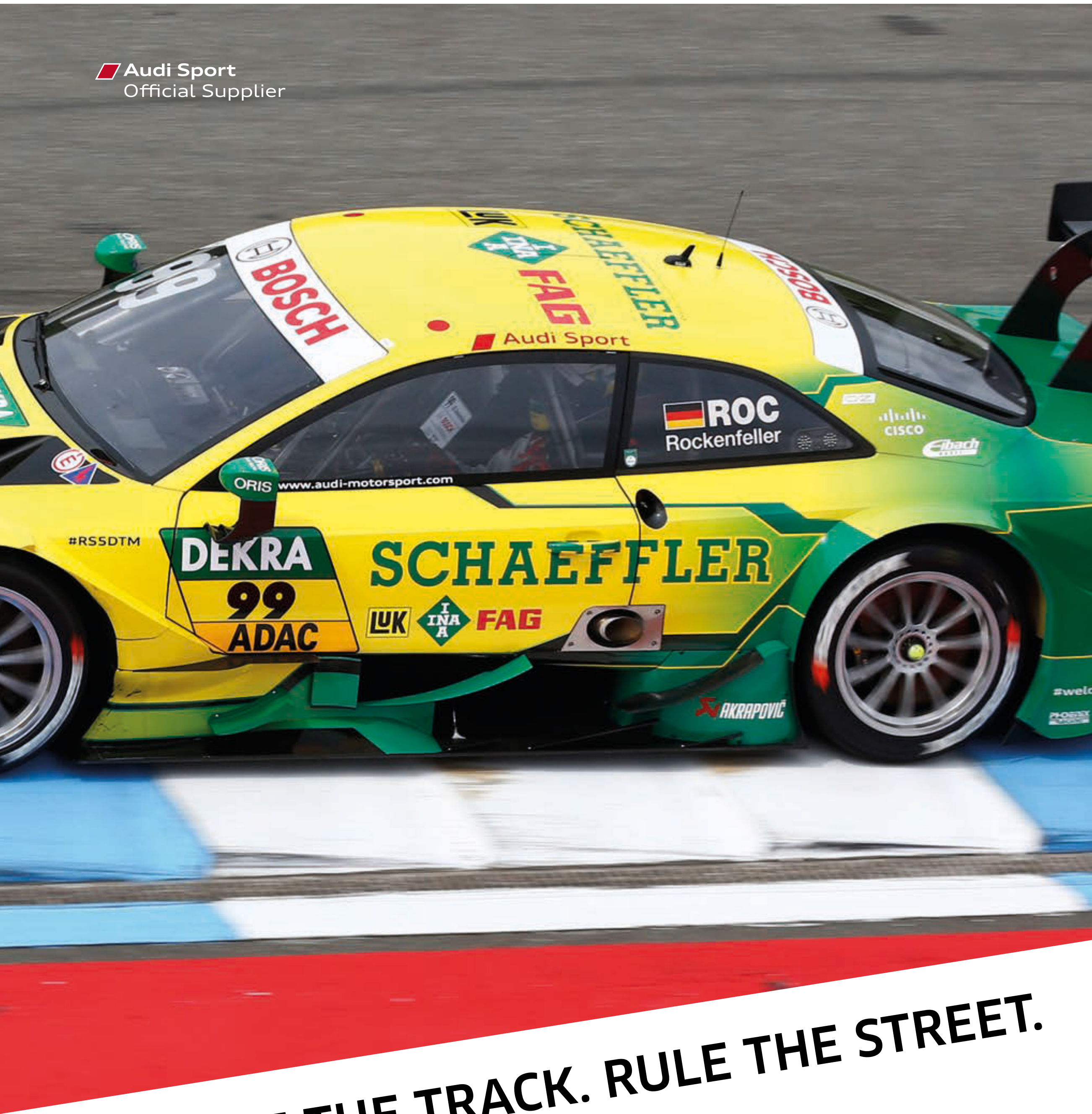
As far as engineers are concerned all this happens in the swirl above them. They are more concerned about solving the day-to-day problems. But I should not anaesthetise your ethical judgment on how you play the rules, never mind blatant cheating of bigger capacity engines or being underweight. The ultimate behaviour of the team principal and management tends to give the flavour of the team, so it behoves on them to be ethical in all parameters of their activities. As I have stated before, in racing (as in life) there is no condition as being half a virgin. You either are or you aren't. Likewise, even if uncaught for cheating, you're a cheat.

Ethics has not always governed engineering, one will just mention lead additives to petrol, CFCs and nuclear weapons. Engineering students would seem to be imbued by work ethic rather than ethics, it not being part of the curriculum, and the sheer quantity of skills to be learned to use in today's high technology domain, in constant change; as Noam Chomsky stated: If you're teaching today what you were teaching five years ago, either the field is dead or you are. It conspires to create characters versed in hi-tech but with low culture. Contrary to the humanities students, those who are active in causes and feeling for people at universities, valuable skills for their future jobs as waiters, baristas or civil servants, say advertising or marketing at best, McDonald's at worst, not to mention the absolute pit of the amoral press (*Racecar* not included, of course, *Ed*).

Machine-centric

Being less interested in people and more in machines does not mean you have Asperger's, but it helps. Ethics as a way of life does not inform you what stresses are in a wishbone or what is the mass flow through a radiator, and is not functionally more useful than calculus or programming, and as far as one can see does not impinge on behaviour; witness the current pickle of a major manufacturer, where expediency and corporate culture led to some rather unpleasant consequences.

Aristotle, the great Greek philosopher of antiquity, stated in *The Nicomachean Ethics*: 'Freedom is obedience to self-formulated rules.' So you self-govern, guided by your in-built virtue, not fallible ones formulated by the society you live in, variable from culture to culture.

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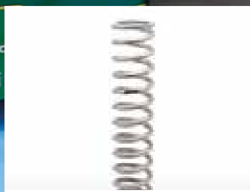
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Switching to auto pilot

The news that there's to be a series for driverless cars has created quite a buzz

John Lasseter directed a Pixar film about autonomous motor racing in 2006, called: *Cars*. No humans were involved in the races, with the cars being transported by autonomous trucks, and serviced by Luigi, the tyre-changing forklift. Okay, the vehicles all had human personalities, but they did not have two arms or two legs. The film brought in $10bn over the five years after its release. If one is picky, there were not any actual cars or tracks involved, but who really needs them with an autonomous racing contest? Just a screen and a computer will do.

Yet according to a recent announcement by Formula E and Kinetik, from the start of the 2016-2017 Formula E season, each event in the championship will include a one-hour race for identical, driverless, electric cars, called Roborace. There is no word about the type of car, though rumours include predictions that the performance will be greater than an F1 car! Nor is it known whether there will be car changes during the one hour race – if they perform better than an F1 car, there will have to be. Nor whether the cars will have standard sensor packages and control systems, with just the software varying between teams, or whether all control technology will be free.

Drop the pilot

Whatever your thoughts about motorsport without human drivers involved, that is a pretty technically intriguing prospect. Whether it is entertaining or not will depend on how good they are in terms of speed, overtaking and accidents – all the things fans watch motorsport for, in fact, except for engagement with their favourite drivers.

The first car design issue to be considered is how much of a normal racing car can be left off: cockpit/cabin, seats, windows, controls, information display, roll cage, harness, crash structures, and just about every safety system except fire extinguishers. Does it need to look like a car as we now know it? But then what is the purpose of the car if not to carry and protect people?

These cars will be lighter than a conventional equivalent racing car as a result, and they will also have a smaller cross-section, and so be more aerodynamically efficient. Thus the speed for a given power and range (weight) could be pretty impressive. If they are all identical in these respects, the contest, which is as ever about average speed around a circuit, will be a function of the speed of sensing and decision-making.

Some years ago, I was tasked by Max Mosley to investigate the potential for the Automated Highway. I was fortunate to meet Dr John Hansman during a workshop at MIT. He is a Professor in the Department of Aeronautics and Astronautics at MIT, where he is head of the Humans and Automation Division; he is also Director of the International Center for Air Transportation and is among the first people to be consulted during an air accident investigation that may involve man-machine interface issues. Through a common love of flying gliders, we hit it off immediately. The FIA engaged John to advise on the man-machine issues of autonomous driving and he made the following essential point about the differences between computer-controlled aircraft and computer-controlled cars.

Traffic control

Air traffic controllers, whose job it is to stop aircraft hitting each other, monitor the separation between conflicting aircraft. They work to a complex set of rules, involving combinations of vertical, longitudinal and lateral separation, and speed. In general they try and keep aircraft under radar control at least five nautical miles apart in *en-route* airspace and three nautical miles in terminal airspace. This equates to about 40 seconds at 500 knots *en-route* and about 60 seconds at 200 knots in the terminal area. The aircraft systems, that is the pilots and/or autopilot, have to achieve this.

Cars operate in a totally different environment. Audi has already shown that a driverless A7 can lap Hockenheim and climb Pikes Peak at speeds that would not be totally shamed by a racing driver. But there were no other cars on track at the time. To race against 19 other driverless cars on a street circuit means that the car will always be a second or two from a concrete wall and often a few thousandths of a second from a conflict with another car. All this without the supervision of a traffic controller.

To manoeuvre in this environment requires precise position information; data about track limits, which can of course be learned; radar, lidar or laser 3D scanner data about the whereabouts of conflicting cars; and ideally information about the other cars' intentions. Processing all this input data and computing the optimum control inputs will be algorithms to keep the car on the circuit at the greatest possible speed for the given track and tyre conditions, plus avoiding other cars, whatever they do; overtaking slower cars, and executing the optimum, but continuously-changing race strategy. The on-board computer will process all this at a

Whatever your thoughts about a motorsport series without human drivers involved, this is a technically intriguing prospect

Can autonomous vehicles deal with racing in tight packs of cars on street circuits; the latter part of the DNA of the Formula E series that the Roborace initiative is to support? Pictured is Formula 3 at Macau; 'a drivers' circuit'

In terms of safety autonomous racing offers a great deal, with no humans on track to be injured

Technology for autonomous vehicles on the road is well advanced and is now very much focussed on safety issues

rate greater than 1000 times per second. In order to compensate for the slow response of the car, it must have a measure of prediction built-in, in just the same way a human driver performs.

On the road, the priority for autonomous driving is safety, with performance always limited by traffic rules. Videos of Google's driverless cars on the road show caution in the decisions made by the cars when manoeuvring in traffic, and a strong tendency to maintain adequate separation, depending on speed.

The quest for autonomous vehicles goes back to the late 1970s, but the first challenge for them was organised in 2004 by DARPA. No vehicles completed the off-road, 240km Grand Challenge, the best managing only 11.8km before becoming stranded on a rock. The challenge was repeated in 2005, and the winner completed the course in just under seven hours, at an average speed of 34kph. In 2007, the contest was changed to the Urban Challenge, with a 96km urban-area course laid out at the George Air Force Base. Vehicles had to stick to traffic regulations, merge with other traffic, and avoid obstacles. Major automobile manufacturers teamed up with universities, for example GM-Carnegie Mellon University, and VW-Stamford University. GM won at an average speed of 22.5kph.

Speed is key

The 100 prototype Google driverless cars, launched in 2014, have a top speed of 40kph. It's going to be a big leap to racing cars. I know the Audi lapped Hockenheim at an average of around 140kph, and it reached speeds of up to 220kph, but this was on a known route, which was learned, and without other cars on track.

Formula E's plan to include Roborace in its events is a brave proposal. Whether it entertains the spectators remains to be seen, but anyone who has watched a contest between robots will know this can be highly entertaining, mainly thanks to the way these human-like devices fail in their tasks.

Development potential

Its value to the development of autonomous vehicles for use of the public road is mixed. It will stimulate the speed and precision of software decision-making, but it will not do much to develop the autonomous vehicle's ability to mix with unpredictable cyclists and pedestrians – the most vulnerable road users. This last aspect may prove to be the most critical issue to be solved before driverless cars are generally accepted.
In terms of safety in motorsport, autonomous racing offers a great deal: no humans on track to be injured. Also, if autonomous trucks bring and unload the cars, no crews should be necessary, and no catering/offices/travel/accommodation will be needed. Think of the cost savings!

Perhaps, like so many things nowadays, driving a car really is too complex a task to be left to a human. We are no longer trusted to start a car, nor change gear if optimum efficiency is required. It will even park itself if we lack the skill or are too lazy. Skill and bravery are no longer needed or desired to conduct a car on the road, so why develop racing cars that need these human qualities, and display them on an artificial track? Social media has shown that to become famous you do not need to be able to actually do anything useful. Motorsport personalities don't offer much. So maybe *Cars* was right; made up personalities are much more entertaining.

Thinking inside the box

A new performance box-based set of GTE technical regulations has attracted a host of exotica to the Le Mans Grand Touring class

By SAM COLLINS

This season will be a transitional year in the world of sportscar racing, with new rules on the horizon for the prototype classes, and a completely new rulebook in the GTE category.

For a long time organisations including the FIA, ACO and SRO all worked to try to unify the high profile LM GTE (aka GTLM) rule book with that of the FIA Group GT3 rules; a deal was close but ultimately the negotiations failed. The big difference between the two classes was that in GTE there was a set of technical regulations defining all the usual factors, such as engine size, minimum weight, aerodynamics, as well as a balance of performance process. Added to that various cars were given waivers, and this sometimes led to some manufacturers being unhappy with the performance breaks that their rivals were given.

In GT3 there were, in essence, no technical regulations, just a balance of performance and performance boxes in which aspects of the car had to fit. This was an easier rule set for checking the compliance of cars; basically anything goes as long as it meets with the homologation forms.

The problems facing the ACO, who jointly with the FIA had to create new rules for the GTE, were that the GT3 cars were much cheaper yet about as fast as the GTE cars, and that the manufacturers which run works teams in the World Endurance Championship preferred proper technical regulations rather than being reliant on a balance of performance process which they could not fully influence.

Once serious work on the new rules was started it was found that the work carried out on the chassis regulations at the GT convergence working group was transferable and this new approach allows a 'simpler and less expensive implementation of technical regulations.' In addition the rules were designed to meet the demands of the manufacturers who wanted rigidly enforced technical regulations a 'drastic reduction in waivers from homologation procedures; less restrictive regulations but more strictly enforced'; which in practice seems to have resulted in a more complex version of the GT3 rulebook. This announced by the ACO at Le Mans in 2015.

What in reality this meant was a simplification of the technical regulations, with the deletion of many details. Meanwhile the GT3 style performance boxes were implemented which also meant the manufacturers had a lot more technical freedom, especially in terms of the engines.

Freed up engines

Under the old GTE rules engines were tightly regulated in terms of design and construction with a 5.5-litre maximum for normally aspirated engines and a 4-litre maximum for turbocharged units. Obviously, with cars such as the Viper, waivers had to be granted. Under the new rules almost anything goes in terms of the engines as long as it fits within the performance box, although hybrids are expressly outlawed – despite there being clear interest in using such systems from some manufacturers.

The performance boxes have also enforced an increase in power of approximately 10bhp (according to the June presentation but in reality probably more). This increase is largely to ensure that the GTE cars are faster than GT3 machines. It also allows for better differentiation in performance between all classes, including the 2017 LMP2. Air restrictors will still be used by all cars but the sizes will now be entirely defined by a balance of performance, whereas under the old rules the restrictor sizes were largely defined by engine capacity.

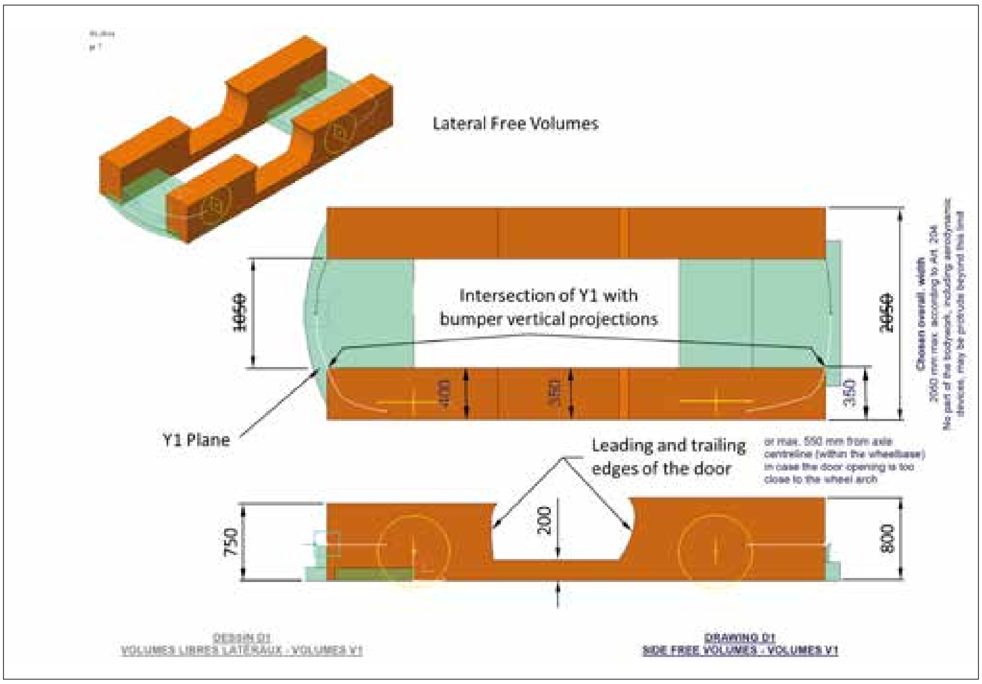
On the chassis side the rules are similarly free, with seemingly very little restriction on chassis modifications. The rule makers again

Under the new rules almost anything goes in terms of the engines

These changes have seen the chassis move very close to GT3

are reliant on the performance boxes. Even the engine location seems to be free. Wheelbase, track and overall length are undefined though a maximum vehicle width is part of the regulations. These changes have seen the chassis move very close indeed to GT3 to the point where at least some GT3 cars can be upgraded to GTE specs with new engines and transmissions among other adaptations. The BMW M6 GTE was built using the GT3 version as a basis, while the Ferrari 488 GTE is visually extremely similar to its stable mate and designed to be upgradable, though the GT3 seems to have more complex aerodynamics.

There have also been changes and relaxations to the materials restrictions placed on the cars in the past. Magnesium alloy sheet is now allowed if it is over 3mm thick (unless a thinner sheet is used on the production car), and chemical and heat treatments of components is now permitted as long as the relevant weights and dimensions are maintained – in 2015 this was a grey area. Finally, composite components can now be used on engine components, but if fitted directly to the engine must be made from fire-retardant material. Screws must be steel or aluminium alloys.



The new GTE regulations gives manufacturers a degree of design freedom when it comes to certain areas of the racecar

Ford's focus

From the first look at the Ford GT, launched before the regulations had been finalised, it was clear that the 2016 cars would be more aggressive looking and have a lot more freedom in terms of bodywork design. The aerodynamic packages of the new cars are defined less by the performance boxes and more by traditional rules, though perhaps more like the rules of DTM or GT500 than of GTE in the past. The maximum width of the car is set at 2050mm, the same as it was in 2015, but the rules requiring limited modification to areas such as the fenders to retain as much of the original appearance as possible have been deleted. Instead there is now a free development area on the side of the cars 400mm around the front wheels and 350mm rearward of the front of the door. This area is 800mm high at the rear of the car and 750mm high at the front; below the door it is only 200mm high.

These shapes can be quite clearly seen on the designs of the 2016 Corvette C7, the BMW M6 and the Ferrari F488, which have wide floor extensions, but it is not common to all cars – the Aston Martin, for example, has a very different side concept which is similar to what it used on its 2015 design.

Frontal attack

There are similar free volumes at the front of the car, for development around the bumper and also a 125mm volume for a front aerodynamic device. Dive planes and turning vanes are permitted, but once the car is homologated that is the specification which it must retain for all races bar Le Mans, where a low drag kit may be used, the details of which are still to be revealed.

These new front ends have become noticeably more complex, with much larger front splitters, winglets and turning vanes present on all cars, with perhaps the Ferrari adopting the most extreme solution. It features a large front splitter with raised centre section and a prototype style cut-out and turning vane.

GT3: the customer is always right

Ferrari 488 GT3 is sure to be a star of customer-focussed GT3 racing this year

Stephane Ratel has outlined his vision for the future of GT3, a class he originally created as a catch-all category for former one-make cup cars.

'Our objectives are to preserve the essence of GT3 which is a category reserved for true sports and GT cars from the premium segment,' he said during a presentation in the UK. 'GT3 is essentially shaped around customer racing programmes and has different needs from manufacturers competing at Le Mans,' he added.

Ratel went on to say that GT3 needs to maintain its current cost level and not to increase in cost. At the same time it needs to attract the last few prestigious manufacturers to join the class, a comment primarily aimed at Jaguar. Additionally, Ratel has made it clear that hybrid power-trains would be accepted if a manufacturer wished to build a car using one, a comment thought to be aimed squarely at Honda with its rumoured NSX GT project.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Ferrari's 488 GTE. The defining feature of the 2016 rules is the huge rear diffuser. The design of the diffusers is free but they must sit within the measurement area defined in the regulations

Ferrari has perhaps adopted the most extreme solution up front with a large splitter featuring a raised centre section and a Le Mans Prototype style cut-out and turning vane

New cockpit rules see the drivers sitting in seats of a higher safety standard while nets must be fitted to windows. Steering column position is free and cabin temp must not exceed 32degC

The BMW M6 GTE car was built using the company's Z4-replacing GT3 version as a basis, and it makes good use of the aerodynamic freedoms offered in the new GTE regulations

At the rear of the car is the one thing that has been described as the defining feature of the 2016 GTE racecars, the very large diffuser. Design of the diffusers is free as long as it fits inside a box defined in the rules, and has a maximum width of 1400mm and a maximum height of 260mm. The flat bottom of the cars is retained, other than on the diffuser, and the ride height remains unaltered.

Cooling ducts are rather more tightly regulated, with Audi R15 style through-car air flows explicitly outlawed, and ducting only allowed to feed defined sub systems, namely the engine, gearbox and diff, heat exchangers, exhaust (and turbo), clutch, driveshafts, brakes, power steering and on-board electronics.

With base models as varied as the BMW M6, Corvette C7 and Ford GT, it was felt that even with the aerodynamics of the cars having full technical regulations, rather than the freedom of the engines and chassis, there was still the need for a performance box to be used. 'The frontal area of the cars is basically the same,' Dan Sayers, technical director of Aston Martin Racing, says. 'All manufacturers now target the FIA performance box values for aero, and depending on your starting point depends where you then focus your attention, and that starting point is quite different for the different manufacturers.'

Boxing clever

To check where the different cars sit within the box all cars were subjected to straight-line testing during the mandatory track test session at the Ladoux proving grounds. Straight-line testing outdoors though is notoriously fickle due to climatic variations and there are some who would prefer the testing to be done either in a wind tunnel such as Windshear in the USA or in a dedicated coast-down facility such as Laurel Hill in the US, or the yet to be competed Catesby Tunnel near Silverstone in England.

In the cockpit the new rules have had a notable impact, too. The drivers will be sitting in higher standard seats and the windows will be protected by racing nets. It could be argued that both of these thing might reduce visibility to an extent, but it is clear that the rule makers were concerned with some aspects of visibility. While some cars like the Corvette feature rear view cameras with computer game style, but effective, following-car indicators, the ACO is still insisting on the use of traditional wing mirrors and indeed has forced car designers to take them a bit more seriously. The mirrors must allow the driver, when sat in his normal seating position, to be able to read numbers on a board 15cm high x 10cm wide arranged on boards positioned 10 metres behind the car. The numbers could be positioned between 40cm and 100cm from the ground and up to 2m away from the car centre-line. The mirrors must be

All the GTE cars were subjected to mandatory straight-line testing

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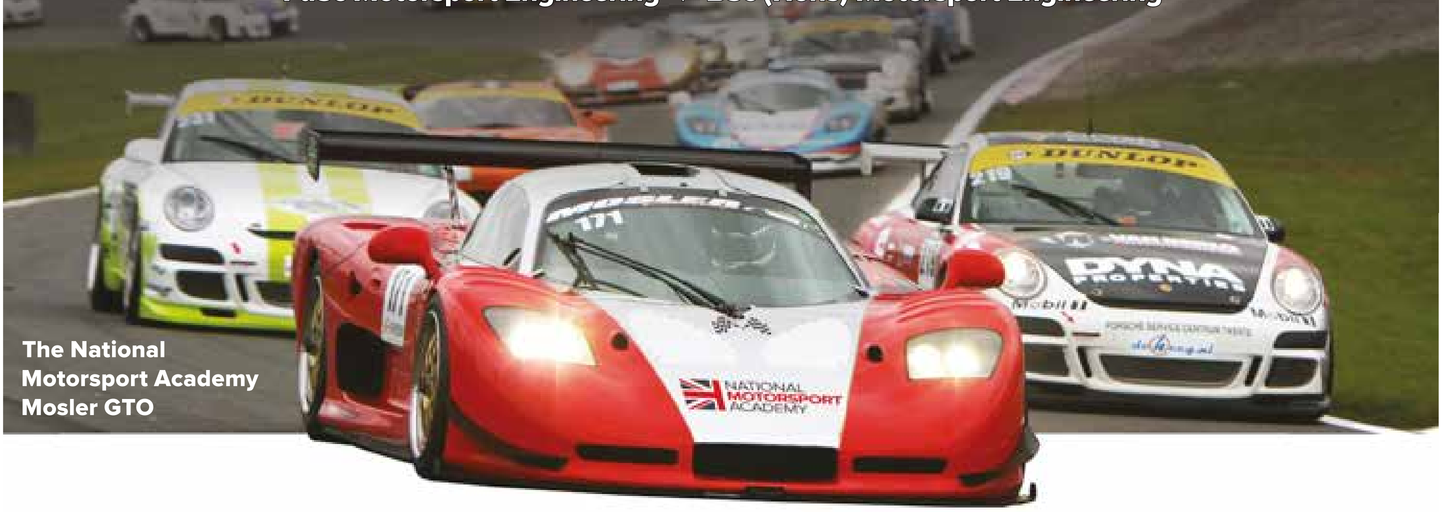

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Despite the greater scope allowed in the design of the flanks of the car the Vantage looks similar to its predecessor from the side view. Aston Martin has had to work hard to make sure its wing mirrors comply to stringent new ACO regulations

One of the most exciting aspects of GTE in 2016 is the return of the Ford GT. The announcement of this new Le Mans assault by the Blue Oval back in June of last year gave the world its first glimpse of the shape that GTE was to take from this season

The Corvette C7 GTE. Variety is the spice of life in GTE this year which means that even with the boxes an element of balance of performance will need to be applied and the FIA and ACO will be policing this throughout the 2016 season

driver adjustable and also feature a 'day/night' mode, which will be tested in scrutineering.

For some such as Ferrari and Corvette this change has been of little consequence, but for others including Aston Martin it has lead to a noticeable amount of work. The Vantage has an entirely new wing mirror design and Ford has used a number of different iterations in testing.

The cockpit may also be a slightly more comfortable place to be now, as the steering column position is totally free, and the temperature inside the car must never exceed 32degC if it is cooler than that outside. If it is hotter than that outside the car, then the temperature inside the cockpit must not exceed the ambient temperature. After a stop the car must cool itself to the 32degC, or higher ambient temperature, within eight minutes. In reality at most circuits this means the cars must all use air conditioning.

Driver aids

Arguably the driver will not have to work as hard in the cockpit now, as the rules on traction control systems have been eased. In 2015 the systems had top operate 'solely though the Engine ECU'; now traction control is simply 'allowed.' Restrictions on gearshift aids have also been eased, simply replaced with the wording: 'assisted shifting is allowed'.

With some very different cars and open rules even with the performance boxes BoP is still required. This was actually conducted some months ago at the Ladoux test track. That initial BoP will be supplemented through an ongoing process with the ACO and FIA looking at the fastest average lap time of the fastest car for each model and for each model year. Taking those averages, the handicappers will apply adjustments to any or all of the following areas: minimum weight of the car, restrictor size, boost pressure, fuel capacity, rear wing height or indeed anything else it can think of.

Ticking the boxes

The GTE technical regulations do not contain some of the elements you may expect to find in normal technical regulations such as minimum weight or maximum engine size. This is due to the performance box rules. So, while in 2015 the minimum weight (before BoP) of all cars was 1245kg, in 2016 there is no blanket minimum weight. The lowest weight allowed by the initial performance boxes shown in June last year was 1225kg and the maximum allowed weight was 1245kg. The lowest power level was 475bhp and the maximum power level was around 490bhp. The official performance boxes cover many areas including aerodynamic characteristics, engine performance and overall car performance.

Governing bodies

In the face of escalating speeds at Le Mans, the ACO has moved to slow P1 cars and new bodywork rules will be implemented

By SAM COLLINS

In 2015, LMP1 cars reached performance levels never seen before in sportscar racing. The cornering speeds had risen to a point where they were close to being deemed unsafe for Le Mans, and if nothing was changed, they were set to go even faster in 2016.

Moves have now been made to slow the cars at the famous French track next year with the output of hybrid systems limited to a maximum of 300kW, a limit which might be rolled out to all of the circuits in the WEC in 2017.

Another major bone of contention in the WEC in 2014 and 2015 was bodywork, which pushed the limit of what was allowed in the regulations. The rules were tightened up in 2015 with new flexibility tests introduced, but even then there was widespread speculation that the top cars were still on the limit of legality and at times over it. So, for 2016, the rules have been tightened up even further.

In an attempt to further reduce the influence of the exhaust plume over the rear of the car (blown diffusers are explicitly outlawed) bodywork licked by the gasses must be positioned more than 50mm above the upper edge of the diffuser, suggesting some teams were still optimising the rules in this area.

At the 2015 Nurburgring 6 Hours race Porsche ran a new version of the mandatory rear wheel cut outs on its 919 Hybrids which, rather than being a single large opening on the inner face of the wheel arch, consisted of two separate openings linked by a crudely cut out slot. This approach was thought to improve the aerodynamic efficiency over the rear of the car but the officials and rival manufacturers took a dim view on this and for 2016 the rules have been amended to stop this. Meanwhile, the openings on the front wheels have been enlarged from 335mm x 300mm to 435mm x 335mm and must now be located on the top of the wheel arches rather than on the inner face (an approach no team used in 2015).

Flexible bodywork was a big issue in LMP1 in 2014 with every works team found to be flouting the rules at some point in the year. It was again the subject of some speculation in 2015 and once again the ACO has tightened up the rules in this area by revising the bodywork deflection, particularly on the rear wing. A rule on general bodywork deflection has been tightened, stating that no part of the bodywork should deflect by more that 5mm in any direction with a 100N load applied in any direction (apart from upward deflection, that is, which will not be tested).

With Audi picked up for having illegal rear wing end plates in 2015 (it made no difference to the car's performance so was allowed to remain) the rules have again tightened up on the definition of what constitutes a wing section. The practice of using angle brackets as Gurneys has also been outlawed.

Because it was unclear whether the regulations permitted exactly what Porsche was doing, the regulation has been reviewed, outlawing anything in the system which has a function not linked directly to gravity (previously it stated that; 'Any device, system or procedure the purpose and/or effect of which is to increase the flow rate after the measurement point is prohibited).

Most of the changes in LMP1 have been made to close loopholes exploited during the 2015 season, or for safety reasons, but more drastic changes are expected in 2018, including new aerodynamic regulations and

It's tightened up rules by revising bodywork deflection, particularly on the rear wing

Wheel design has been an area of development for teams in both P1 and P2 for some years with low drag designs adopted for some races, such as Le Mans. This practice has now been outlawed, with only a single spec of front and rear wheel allowed per season.

The new rules also address the operation of the cars. During the latter part of the WEC season the refuelling speed of the Porsche 919 raised speculation regarding its refuelling system and Audi had to play catch-up to challenge for the title. While no information on

new chassis. Vincent Beaumesnil, technical director of the ACO says. 'You will have to make a new monocoque to accommodate the safety devices, and you cannot decide to make a new monocoque six months before the start of the season. It is a work in progress now, but there is a big step this year, and another big step when the new monocoque is introduced.'

Those safety devices include a new headrest which will be introduced for the 2016 season (this can be added to an existing tub) and a new driver position in the car.

Audi's new R18 has been built in line with a number of new regulations, some of which tighten up on aero interpretations

The power and the glory

Formula 1 2015 was once again all about the powertrains, yet while Mercedes dominated on track there was still plenty to spark interest at a technical level

By PETER WRIGHT

The front of the F1 field had a familiar look in 2015 with the Mercedes cars to the fore. The W06 won 16 of the 19 grands prix with only Ferrari spoiling the party, at Malaysia, Hungary and Singapore. Pictured is the Mexican GP, which returned to F1 in 2015

F1 is now a powertrain formula dominated by engine manufacturers, or at least the two who have mastered the quest for efficiency

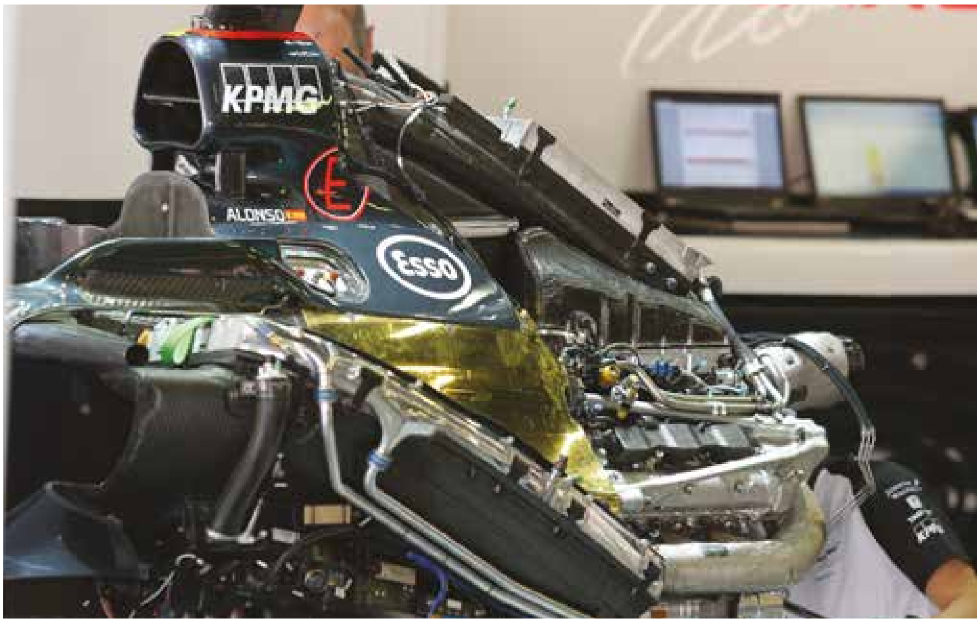
Two years after the introduction of the fuel-efficiency formula in F1, a distinct pattern has emerged, and some people don't like it. Inevitably, it is now a powertrain formula, dominated by engine manufacturers, or at least the two who in 2015 mastered the quest for efficiency – gaining as much useful work and as little waste as possible from a limited supply of energy.

These two manufacturers, Mercedes and Ferrari, supplied powertrains to five of the remaining eight teams and thus enabled some close midfield racing. Renault's engine stabilised at a level just below Mercedes and Ferrari, but the Red Bull and Toro Rosso chassis it powered enabled it to be reasonably competitive. Honda, meanwhile, did not appear to make much performance or reliability progress, which is somewhat baffling. I will try to analyse the reasons for this below.

Meanwhile, chassis development, or aerodynamic development, converged, with even Red Bull incorporating certain features from the front wing of the dominant Mercedes. But Red Bull did appear to possess the best chassis overall, although whether it was a lack of Renault power, or the sacrifice of drag reduction for downforce, that prevented it competing with Mercedes and Ferrari, and even Williams at many circuits, was not clear.

The Mercedes chassis worked everywhere, except Singapore! Why it should not be able to work its tyres at this street circuit is strange, but maybe Mercedes knows why. In the absence of facts, conspiracy theories abound to keep everyone amused. The Force India, Toro Rosso, and Lotus chassis were pretty good too, but it would have needed everyone to have a Cosworth engine in the back to really find out what was what. Williams continued to make its own path, sometimes brilliant, sometimes mysteriously off the pace. When it figures all this out, as Pat Symonds and Rob Smedley surely will, it will start winning races once again.

Mercedes was so dominant in 2014 that it was able to start developing its 2015 powertrain during the racing season, and did its homework well. Apart from some niggling reliability issues, the powertrain was pretty well bulletproof, with no grid penalties



Top: Honda power unit proved to be a major disappointment in 2015 despite the company's previous experience with turbocharged race engines **Above:** Honda RA615H fitted in the McLaren MP4-30. The tight packaging of the powertrain might have compromised cooling **Right:** One feature of the Honda unit is a small compressor mounted within the V of the engine and driven via the ERS-H by the rear-mounted turbine

taken by either of its cars. Some may grumble about the dominance of Mercedes, but it simply got it right, or at least more right, than anyone else. Why would one expect otherwise? Mercedes has re-entered F1 to establish its credentials as the world's best car maker in an era of new objectives and new technical solutions for the automobile industry. While it would have been difficult to do so under the previous F1 era of high-revving engines and aerodynamics-dominated overall performance, the new for 2014 powertrain regulations provided the perfect stage, where ample, resource-backed technical excellence would win out. Mercedes had to win, and a strategy of domination is the easiest way to ensure this. In its second year it was far enough ahead to be able to use some of its powertrain development tokens to prepare for 2016, running a potential specification as early as Monza. While others lobbied to be able to develop powertrains all season, Mercedes gained the most from the freeing up of the token regulations.

Compress to impress

One of Mercedes' most visible 'secrets' was the large diameter compressor, mounted at the front of the engine, and driven by the exhaust turbine at the rear. The shaft between the two includes the rotating part of the ERS-H. The RPM limit for the ERS-H, and hence the whole rotating assembly, is 125,000rpm. By using a large diameter compressor the desired tip speed of the compressor blades can be achieved at around 100,000rpm – well below the limit. This also allowed some room to increase RPM at the high altitude tracks such as Mexico, to maintain air mass flow and hence be able to utilise the maximum permitted fuel flow.

Ferrari worked hard on the combustion in its engine, and it was much improved in 2015. The gain in powertrain performance, allied with a James Alison chassis, gave Sebastian Vettel what he needed to win three grands prix – Maurizio Arrivabene allegedly undertook to walk barefoot in the Maranello hills if Ferrari won more than two grands prix; so there's something to look forward to, then …

Renault, however, all but admitted it got left behind in the critical combustion technology, possibly due to simulation software that was not adequately validated. It was lashed by Red Bull's tongue, and had the further indignity of having the team insist on Mario Illien and AVL getting involved. It is not clear how the latter two contributed, but Renault stabilised somewhat towards the end of the year and no longer appeared to suffer catastrophic engine blow-ups, an inevitable consequence of not having knock under control. Renault further suffered

Honda's racers have retired and been replaced by managers who appear to believe that Formula 1 can be run just like any other R&D programme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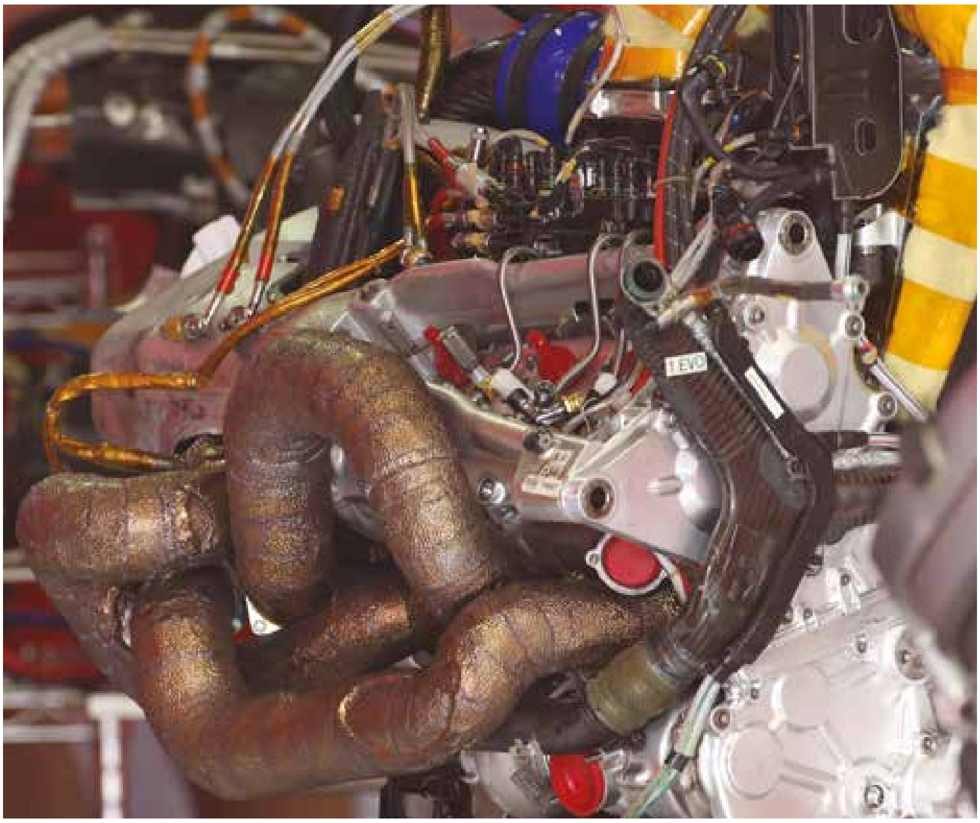


The Ferrari 059/4 power unit helped the Scuderia to take the fight to Mercedes on a number of occasions in 2015 – most noticeable changes over 2014 included a new exhaust layout while on the inside Ferrari worked hard to improve combustion

from not being the developer of Red Bull's KERS system in previous years, and so it had to learn from scratch how to integrate the electrical power systems into the overall powertrain.

Around 2008, when the FIA under Max Mosley first started to explore powertrain regulations relevant to the automobile industry in an attempt to keep it interested in Formula 1, meetings were held with all the manufacturers then involved or likely to be involved. Predictions for future automotive gasoline powertrains were surprisingly varied. Mercedes, BMW, Audi, Renault all said: 'small, four or fewer-cylinders, T/C, GDI and hybrid'. Ferrari said: 'larger, six-plus cylinders, T/C, GDI and hybrid, if we must!' Toyota and Honda: 'small, four-plus cylinders, NA, GDI, high-revving, variable everything, plus hybrid'.

Perhaps it is not surprising that of those that are currently participating, Mercedes has shown itself to have the most commitment to the current powertrain, while Honda appears somewhat at sea. Yet Honda has only just launched a turbocharged road car engine. It had a very successful experience with the 1.5-litre turbocharged F1 formula, and with IndyCar powertrains. The difference between these two formulae and current F1 is that their objective was, or is, ultimate performance, unconstrained by efficiency requirements, while now F1's performance basis is efficiency.

One feature of the Honda powertrain was a small diameter compressor, mounted within the V of the IC engine, and driven via the ERS-H by the rear-mounted turbine. To achieve the mass flow, the maximum 125,000rpm was needed, and this appeared to have compromised the performance of the ERS-H, possibly due to the full output of the turbine being required to drive the compressor. It also appeared that the much-vaunted tight packaging of the powertrain had compromised the cooling of key components.

Different approach

The Honda organisation today is very different from the one that dominated F1 with Williams and McLaren in the late 1980s and early 1990s. Mechanical ingenuity allied to high RPM, developed by a well-resourced, dedicated racing R&D department, with support from the highest levels in the company were the foundations of its earlier successes. The experienced racers have retired and been replaced by managers who appear to believe that F1 can be run just like any other R&D programme. To have two cars on the back row of the grid for the 17th race of 2015 is really unacceptable progress for a partnership with the history of McLaren-Honda. Something is terribly wrong and whether it can be rectified in 2016, as all and sundry within the two organisations keep telling us is about to happen, I'm not sure. I do not yet see the scale of change that is necessary. Once again, I hope I am proved wrong.

As to why Ron Dennis vetoed Honda supplying Red Bull, I do not understand. Surely he believed this would stop Red Bull beating McLaren by such a mammoth margin. Maybe he just wanted them to depart from F1? But quite how Red Bull got itself into its predicament is the other baffling event of 2015. Christian Horner and Helmut Marko must have been convinced Audi would provide them with a Red Bull-subsidised powertrain, and can be forgiven for not spotting the Volkswagen runaway steamroller heading for them. After all the drama things remained the same come the end of the season; a Renault engine for 2016, even if it is named after a watch (TAG Heuer).

Counting the cost

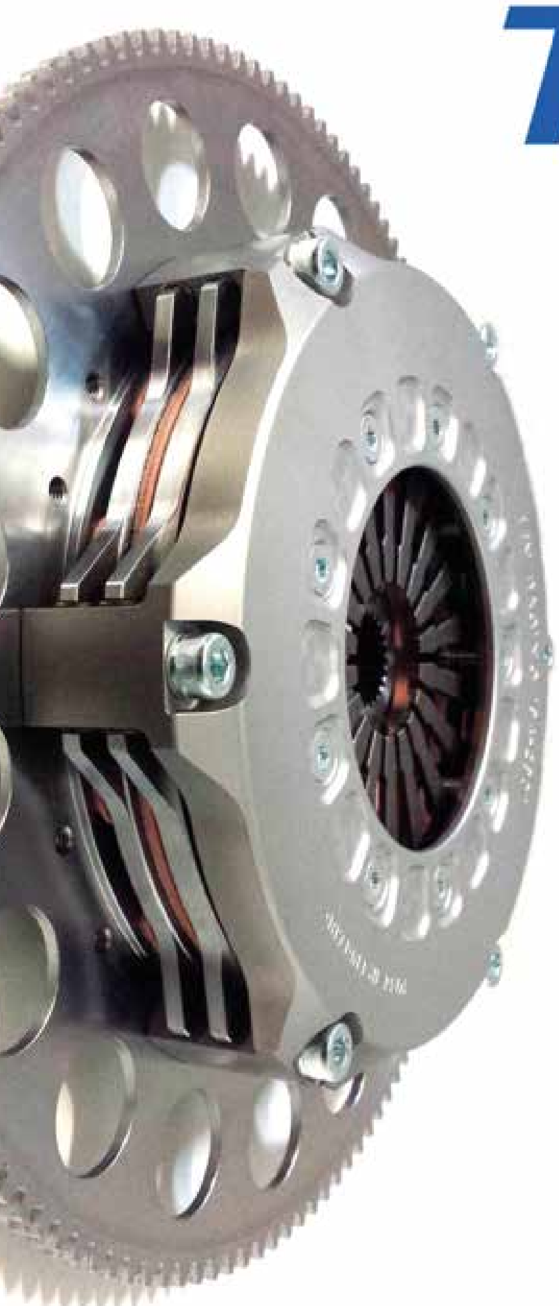
Maybe Mercedes, Ferrari, McLaren *et al* saw advantages in three car teams, with the likes of Daniel Ricciardo, Daniil Kvyat, and Max Verstappen driving, and so a few collateral casualties would not be such a bad thing, should some smaller teams go to the wall. But I'm not so sure.

The cost of entry into F1 as a powertrain manufacturer is very high, due to the R&D required to even compete with Mercedes, let alone beat them. So asking the manufacturers who supply the powertrains for F1 to subsidise their customer supply prices from around \$22m to around \$12m was like asking Mercedes and Ferrari to subsidise F1 to the tune of around \$50m per year. No wonder they were not keen, and that others are still wary of joining in.

Once again Pirelli came in for a fair amount, I would even say an *unfair* amount, of criticism. The role of a sole tyre supplier is not a happy one as it appears to involve mainly being criticised, seldom being praised. Rosberg's and Vettel's tyre failures at Spa are a case in point. Quite a lot of the components on a racing car fail explosively when they are run at full performance in a damaged or worn out state, for example the engine, brakes, front and rear wings, and the results do put the driver at risk. Pirelli's tyres at Spa suffered an above average number of cuts and carcass damage, likely to have been due to excursions over kerbs defining the track limits, and in some cases were run to or beyond their wear life. Two of them failed and the drivers didn't like the consequences. When it is the engine or chassis, their thoughts are expressed to engineers behind closed doors; they really should afford Pirelli the same respect.

Pirelli also took lots of criticism for the way it designed its tyres to degrade: a characteristic it built into the tyres at the FIA's request for two

The highly optimised cars put an enormous emphasis on grid position and even more emphasis on the start and first few corners



At the moment there is no regulation that says the car cannot be intelligent enough to advise the driver how to get the best out of it

specifications of dry tyres at each event, neither of which was supposed to be able to complete a race. This set of sporting regulations succeeded in its objective of mixing up the races and generating the ability to overtake. The effect was rather the same as when it rains and drivers find themselves on different tyre specifications at different times in the race.

The race at Sochi highlighted, by exception, exactly which characteristics Pirelli built into its tyres that people did not like. At Sochi, the state of the tarmac was such that the tyres never exceeded their operating temperature window, and so the drivers did not have to drive to keep them within their limits. They could drive flat out until wear degraded the tyre performance, and then change them. This is what Michelin said it would accomplish with F1 tyres, if selected to supply tyres from 2017 – though now Pirelli is to be kept on until 2019, but the tyre rules in Formua 1 have been changed (see page 28).

Probably a bigger constraint to more interesting racing - that is close racing and more overtaking - was the inability of a slightly faster or equally fast car to follow one ahead without overheating its engine and brakes. The downforce deficit has been partially compensated for by DRS, but if you can't do the rest of the lap on the tail of the car ahead, it is often impossible to gain the benefit of DRS. This feature of the highly optimised current cars put an enormous emphasis on grid position and even more emphasis on the start and first few corners. This led to some desperate moves being attempted to gain a place, and the need for better definition of driving standards and the penalties for infringement. These decisions are inevitably subjective; and the world of Formula 1 doesn't much like having subjective decisions affect race results.

The same problem arose with the way drivers used track limits, and led to a call for technology to identify and report infringements objectively, instead of human inspection of video images. Safety would certainly be enhanced if kerbs were removed.

Outside assistance

Regulations are either sporting, technical or safety, and it is when they come into conflict that strict and enforceable regulations are actually needed. That the driver must drive an F1 car alone and unaided is a sporting regulation. Pushing this rule to the limit is done by providing technical information to the driver about how he, and maybe his teammate, are driving the car during a race, relative to some ideal. The engineers can also help the driver set up his car to an optimum, for example for the critical start of the race. During 2015, and 2014, severe limits were set on what a driver's engineer can tell him and on how much help they can give him while he is on track. In general these fall into three areas; first, the driver's driving technique, particularly racing line, throttle application, braking, gear selection, use of DRS, use of the overtake button; second, all of the above relative to another driver – usually the teammate, as this is the only detailed data available; third, setting up the clutch bite point for the start of the race.

All the data upon which this advice is based is telemetered from the team's two cars to the pit garage and is analysed by expert engineers, with selected feedback to their drivers. It is the last part that is now banned. However, the raw data is all in the car, and so the expert analysis and selection of advice could be performed by 'expert' software in the car, and the information for the first and second items above could be communicated to the driver, visually or even audibly. At the moment there is no regulation that the car cannot be intelligent enough to advise the driver how to get the best out of it. Already embodied is intelligence to carry out key tasks without involving the driver at all, such as executing gearchanges; optimising engine settings – fuel, spark, boost, etc.; rate of clutch take up; brake balance between ERS and hydraulics, all tasks that were originally

Relations between Red Bull and Renault were strained as the French power unit failed to deliver in terms of both reliability and performance. It looked like divorce was likely, but Red Bull is to stick with a TAG Heuer-branded Renault engine in 2016

On the whole Pirelli had a good year, supplying tyres that largely performed in the way the FIA had required. However, there were some high profile failures at the Belgian GP which – quite unfairly – cast F1's tyre supplier in an unfavourable light

Formula 1 had a scare at the Sochi event when the Toro Rosso of Carlos Sainz appeared to spear beneath the barrier system; though in reality F1 safety measures worked well here

performed by the driver at the very start of motor racing. However, with the relentless advances in technology towards autonomously driven road cars, how will the sport remain a true human contest?

F1 suffered its first fatal accident since 1994 in 2014 (Jules Bianchi succumbing to his injuries in 2015). Yet while 2015 saw some heavy accidents, there were no major injuries. Yet the issue of open cockpits was kept in the spotlight due to Justin Wilson's fatality at the Pocono IndyCar event. The FIA continues to investigate and test solutions for protecting drivers in open cockpits, with the focus being two possible approaches; fighter aircraft type bubble canopies, or protective bars, arranged in front of and around the sides of the cockpit.

The first provides protection against large (for example, wheel and major body components), and small (springs, small body parts, cameras) loose components, and might even help with another car landing on top of the cockpit. But it has optical, dirt, driver egress, and ventilation problems. The second can protect against large objects, but in order to deflect small ones it would need to be built with forward bars, which might impede the driver's line of sight too much.

Safety is both an experimental and statistical science; the interaction between hazardous, high energy objects and the human body is so complex that it is just about impossible to predict all the possible interactions, and so a number of (expensive) test impacts must be carried out. Simulations help, but only for what one can imagine. The number of possible scenarios is so large that in the end statistics from actual accidents are the only way to show whether a potential preventative measure has made a net gain in safety or not, and that takes time.

Barrier brief

Barriers are another case in point. Carlos Sainz's 153kph head-on impact at Sochi was arrested by a barrier system developed over the last 20 years. Neither he nor his car suffered sufficient damage to prevent either of them racing the next day. And yet people who should really know better rushed forward to criticise the FIA because they believed the car had gone under the barriers. If they had waited for the facts, as presented by the FIA to the drivers in Austin two weeks later, they would have discovered that the barrier worked remarkably well, and the part of it that ended up on top of the car was as a result of being lifted up, as the car and barrier rose up on the final layer of Armco as it was flattened, and rebounded. The low noses, at which much of the criticism was directed, were regulated in order to minimise the chance of a car being launched when it impacts the rear wheel of a car ahead; the under-running of barriers was of course taken into account.

With season 2015 over, F1 sits at the watershed of commercial, sporting, and technical changes. The issues are so complex and interrelated, and in many cases confidential, that it is nigh on impossible to predict changes that will occur before the 2016 season gets underway. This magazine is about technical issues, so I shall avoid any thoughts on the others. Technically there is a desire to significantly increase the performance of the car through more downforce, bigger tyres, and more power. Clouding this issue was the matter of engine supply, and there was even the possibility of low cost, alternative powertrains, which would of course require balancing of performance. Balance of Performance in F1?

While all this is being discussed, it should be borne in mind that if the technology is not relevant to the automobile industry, then it is *ir*relevant, with all that that may imply.

Williams continued to make its own path, sometimes brilliant, sometimes mysteriously off the pace

Regulation issues

Some of the sporting regulation changes for 2016 are likely to have a big impact on the F1 teams

By SAM COLLINS

While tunnel time limits remain much the same as in 2015 the F1 teams will be required to provide the FIA with date-stamped digital photography of wind tunnel testing this year

Formula 1's rulebook is a major topic of speculation, negotiation and uncertainty at the moment. But shortly before Christmas the FIA did release the latest set of sporting regulations, which contained a number of areas which impact the design and operation of the cars.

One major area which will be changed substantially for some teams is aerodynamic development operations. While the restrictions on tunnel occupancy remain much as they were in 2015, with a maximum model size of 60 per cent and a max wind speed of 50m/s, there have been clarifications on what counts toward the CFD. In 2015, restricted flow only counted if it was used on a full size F1 car, but in 2016 the wording has been tightened to count any 'representation of a F1 car or sub components' though engine simulation remains unrestricted.

In the wind tunnel, operations will change slightly too, with teams now required to take two digital photographs of the working section (including the model) before each run. The pictures have to have a date stamp and show the complete model clearly (hence two pictures, front and rear quarter views). These pictures must then be supplied along with the various other data to the FIA technical department.

Wind tunnel operations will also be changed for teams in 2016 by a rules clarification issued at the 2015 Abu Dhabi Grand Prix. During the season Mercedes had become rather concerned about the relationship between Haas and Ferrari. In the end Paddy Lowe wrote a long and detailed letter to Charlie Whiting about the legality of the situation. Whiting passed the responsibility of making a decision on the issue to the stewards at the Abu Dhabi race. The main points of Lowe's queries were as follows: could Haas F1, as a non-competitor, share data with Ferrari, and could it share design and development staff with Ferrari?

The answers from the Abu Dhabi stewards were clear. Under the rules as they are written, Haas could indeed share data with Ferrari, as at the time Haas was not a Formula 1 competitor and, as the testing could be deemed to be of benefit to both Haas and Ferrari, and not exclusively for Ferrari, then that too was permissible. Sharing staff was also permissible, though Haas could not simply use Ferrari's designs for its cars in 2016.

It will now be possible for older power units to be re-homologated and used by customer teams

Prancing Haas

For 2016 only, the rules have now been clarified and Haas can no longer share data with Ferrari, but at this point in the development of both the Haas and the Ferrari much of the work is already at an advanced stage. It also means that Haas and Ferrari can no longer share staff and this may include the head of the Haas aero programme, Ben Agethangelou, who still lists himself as a Ferrari employee on his Linkedin profile. Staff will now have to pick which team they are working for and if they want to switch from one team to another they must take a minimum of six months gardening leave. How this stewards' decision sits with employment law in the EU is not clear.

Power units is another area that was in the spotlight at the end of the 2015 season, not least due to the somewhat self inflicted situation that the Red Bull teams found themselves in. In the past, manufacturers could only homologate a single specification of power unit a year (Manor was allowed to use the 2014 Ferrari unit under a waiver agreed by all teams). That has now been formalised and it will now be possible for older power units to be re-homologated and used by customer teams. Toro Rosso will be the first team to do this and will use a 2015 Ferrari unit while Haas, Sauber and the Scuderia will use the proper 2016 version.

As *Racecar* closed for press discussions about using only three units per season from 2017 were ongoing, but in 2016 teams will be allowed five units per driver due to there being 21 races on the calendar. This is an increase from the four allowed in 2015, when there were only 19 grands prix, and it is also a notable decrease in the required life expectancy of each power unit, something which will come as a relief to some in Viry Chatillon and Sakura City. However, dropping below 21 races means teams will only have four units per driver, so if a single race gets cancelled (and the US GP in Austin remains to be confirmed) then the required life for each unit increases somewhat.

Homologation deadlines will also create something of a voyage into the unknown for the power unit manufacturers, the confusion caused by the omission of a power unit deadline in the 2015 rules, which led to in-season development being allowed, will not be repeated.

Modifications for safety, cost and reliability

One area which will be changed is aerodynamic development operations

Tyre rules

For 2016 new tyre usage regulations will be in force in Formula 1, along with a new 'ultrasoft' compound. The new rules are intended to give teams more freedom in strategy and allow for less predictable racing, at least in theory.

Before each race Pirelli will select which three tyre compounds to take to the track and let the teams know what is on offer. The Italian firm will then nominate two mandatory sets of tyres for each car for the race itself, obviously being the same for all, though only one set of the two has to be used in the race. One set of the softer compound tyres will be reserved for use in the final segment of qualifying.

Beyond that the tyre usage becomes free with teams able to select whatever compound they want within the three nominated by Pirelli for each weekend. However, the teams have to make this tyre selection eight weeks in advance for European races, so that they can be produced in time. If a team misses the deadline the FIA will make the tyre selection for it. That selection deadline is extended to 14 weeks in advance of a flyaway race, so teams needed to select tyres for the opening races before Christmas for Australia, something which could prove tricky considering no team had actually run a 2016 car, and one team, Haas, had never run an F1 car at all! Total amount of tyres used per weekend (13 sets per car) remains unchanged.

The tyre usage regulations have been changed for 2016 with the hope of spicing up the show with less predictable race strategies

F1 winter testing begins on 22 February, yet design dossiers for the power units must be submitted to the FIA by 14 February, which means the PU designs must be signed off before the engines have been run on a circuit

can still be made and in-season development within the token system will continue and is now officially part of the rules.

For 2016 the homologation deadline for power units comes on 28 February (one suspects the FIA did not remember that 2016 is a leap year), and design dossiers must be submitted two weeks prior to that (yep, on Valentine's day). Trouble is, winter testing does not begin until 22 February, meaning that the power units must be signed off before they have ever been run on track.

The loophole which in the past would have allowed a power unit supplier which was not also an entrant, Renaultsport, Honda or arguably even Mercedes HPP, to have used an old car to run on track outside of the usual restrictions has been closed. Now the testing ban applies to not only teams but also power unit suppliers and 'third parties'.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Alternative realities

Just how difficult would it be to equalise different engine types in Formula 1?

Since the FIA invited 'Expressions of Interest' from engine suppliers concerning a so-called 'Alternative Engine' for F1, commencing 2017, the concept has been voted down by the F1 Commission. Nonetheless, Formula 1 czar Bernie Ecclestone has declared that it is not dead. And with him having been given, along with Jean Todt, a subsequent mandate by the World Motor Sport Council to propose 'changes for the good of F1', it seems that the idea could be back on the table under this guise.

The last time an equivalency formula was part of the engine regulations in F1 was in the 1980s, (apart from 2006, when – with special dispensation – Toro Rosso ran a restricted 3-litre V10 instead of the then-new 2.4-litre V8s). Renault had led the previous move to 1.5-litre turbocharged engines, and for two years non-manufacturer teams had to use the normally-aspirated DFV. Thus for a brief period Formula 1 became effectively a two-class championship, because the theoretical balance between the two forms of induction was again shown not to work – as was the case post-WWII with supercharged versus atmospheric engines.

Equivalency formula

Now, one can argue that equivalency can be much more accurately predicted and monitored these days, bearing in mind the powerful simulation tools and accompanying data available. The ACO and FIA have done an excellent job with WEC LMP1, judging from the close battles between Porsche and Audi, with very different hybrid powertrain configurations, not least that one is gasoline-fuelled and the other diesel!

However, this is not a fair comparison with what might yet be mooted for Formula 1. Foremost, the LMP1 regulations basically set out the parameters of hybrid energy usage permitted and let each manufacturer decide how best to achieve these. Would that this was so in Formula 1! The Alternative Engine idea is to have a separate set of regulations for one type of power-unit to another, which is a very different thing, and introduces a number of factors difficult to calculate.

What is the Alternative Engine to be? 2.2-litre or 2.5-litre, V6 or V8? Single or twin turbo? Fuel flow meter or not? RPM limit? In a way, it doesn't matter. Clearly, to meet the suggested $12m annual team supply figure, the Alternative Engine will have to be much simpler than the current hybrids and with no ERS content, some of the resulting performance deficit being made up presumably via larger displacement. Sounds good, but there are a few problems.

To start with, the F1 car minimum weight now is a monstrous 702kg because of all the ERS kit – pre any kind of KERS, it used to be 600kg. Carrying the amount of ballast required to bring the car equipped with this powertrain up to 702kg would be impractical and dangerous. Therefore we must assume that a lower minimum weight limit would be imposed. Depending on the figure this could give the lighter cars a considerable advantage over the hybrids, especially if it still allowed weight to be moved around. Obviously, this would cause a revolt from the likes of Mercedes, Honda etc. They would almost certainly either take legal action or walk away. Conversely, if the Alternative Engine cars are too slow, which teams would want to run them? The value of gaining even one Constructors' Championship point, as highlighted recently by Manor Marussia, is such that it more than negates the saving in lower engine costs.

XPB

If an alternative engine was used it would not be the first time. The most recent occasion was 2006 when Toro Rosso was allowed to run an old V10

But let's assume that the data-crunchers at the FIA could get their sums about right and the two types of power/car weight result in similar overall performance (but how do you do that at circuits as disparate as Monaco and Monza?). Maybe the intent is to achieve equivalency by adjusting rpm limits, car weight, fuel allowance/fuel flow or whatever race-to-race – but, unless already at the back, who wants GT and touring car-style 'Balance of Performance' in F1? Such action would inevitably lead to claims of deliberate manipulation of results, real or perceived. F1 is divided enough without adding more fuel to fan the flames.

Then there's tyres. Given a significant difference in weight and torque as just postulated, without doubt different tyre compounds and constructions would be needed in order for them to work effectively for each type of car.

Would Pirelli be prepared to do this? How would the difference in race degradation and performance ever be estimated accurately, circuit to circuit, hot or cold, dry or wet conditions? Once more, a major headache.

Second class

Contrarily, as a consequence the potential could sometimes exist for a major race result shock, which is appealing. However, in reality the cons far outweigh the pros. Logically, the only practical solution is to forget equivalency and accept that F1 should be a two-class formula. This is anathema to me, as it probably is to most who believe that this is not what the premier category should be about.

Should, however, this be accepted as the only way to maintain healthy teams and grids, then there is no need for a new Alternative Engine, given some willingness all round. Simply allow a proven engine company to licence and develop one of the 2013 V8s and make this the much less expensive Class 2 powertrain. Benefits? It would be financially far more viable than designing a new engine from scratch for a very limited number of customers, plus who wants another dull-sounding turbo motor when you can have a satisfying screamer?

Hopefully, in reality, the master plan is rather to use the Alternative Engine threat as a means of getting the manufacturers, including Ferrari, to consider the bigger picture where the pricing of customer hybrid engine supply is concerned. Or to pave the way for a simpler and therefore less expensive engine formula for 2017, leaving the 'green' aspect to endurance racing, which is maybe where it sits more comfortably.

If nothing else, however, it illustrates the potential holes to fall in to when proposals purported to be for the good of the sport are not fully thought through.

If Alternative Engine cars are too slow which teams would want to run them?

Back from the brink

This time last year Manor had pretty much ceased to exist – now it goes into the 2016 season with Mercedes power and new-found confidence. We examine the car that saved a team

By LEIGH O'GORMAN

Come the second-half of the 2014 Formula 1 season, Marussia F1 was a team dead in the water. Crippled by a lack of finances and an owner who, having been burned by Formula 1, had now lost interest. The team was sinking fast.

The crash in Suzuka that would eventually lead to the death of young French star Jules Bianchi the following year was another brutal blow and at the following race in Russia, the team fielded just Max Chilton. It was to be its final appearance on the 2014 grid as attempts to resuscitate the effort for the double-points finale at Abu Dhabi failed. For all intents and purposes, it looked as though the Marussia name had been wiped out of Formula 1.

Yet, astonishingly, the team reappeared in 2015 as Manor Marussia Grand Prix. During mid-February it exited administration and set about

It looked as though the Marussia name had been wiped out of Formula 1

the 2015 season with a plan of running cars for a new driver pairing, Will Stevens and Roberto Merhi. But pulling everything back together for 2015 was no easy task. In January, huge chunks of the team's infrastructure was put up for auction and sold with precious little fanfare.

Of course, while the 2015 car was quite heavily developed, it was not ready in time for the start of the new season. This forced Manor to race with an already ageing car, and meant that with the MR03, Manor effectively became the first team to field a car for two consecutive full Formula 1 seasons since the controversial Honda RA106 in the middle of the last decade.

Salvage work

The team had managed to keep hold of some essential parts to run the cars at the end of 2014's final flyaway race, but of what was lost, the factory infrastructure was most significant, says chief designer John McQuilliam: 'Much of the equipment that we take to the track was all paid for and ready to go to the [Abu Dhabi] flyaway anyway, so that was retained by the company. What we lost was everything in the R&D labs, everything in the stores, everything that was in the factory that we don't take to a race was lost, and that's what we had to get back together for the new season. So we had to reproduce that very quickly.'

Rather than buy back all of the lost equipment, McQuilliam and his team were forced to innovate where they could. For instance, when it became necessary to produce new floors and bodywork for the racecar, the team designed upgraded elements. McQuilliam says: 'Basically all the tooling was lost. We did not have the possibility of recreating any of the parts, so some parts we had enough of, and everything else we had to reproduce.'

Manor had a reasonable amount of spares to get through the initial part of the season. And with two chassis, and a respectable amount of spares for aero parts and suspension, the team was at least able to produce a racecar.

Plan B

However, the MR03 did require some modifications to comply with new regulations introduced at the beginning of last year, giving the 2015 machine the designation of a 'B'-car. 'We had quite a lot of work to do on the 2014 car to make it 2015 compliant,' says McQuilliam. 'It had to have a brand new nose, be crash tested for the new nose structure, with various modifications to the monocoque to make it compliant to the 2015 regulations. That was

Manor aims to carry the metal bulkhead over into the 2016 racecar – this was actually a feature that was copied by the Red Bull team last season

Front suspension is decoupled roll and receive spring system, to enable the team to individually tune and adjust damping. It also features inboard torsion bars

The 'B' version of the Manor MR03 had to have a brand new nose and various modifications to the monocoque to help it comply with the 2015 regulations

Manor lost many parts and much equipment during the financial dramas that beset it but managed to keep hold of the kit that was ready for the Abu Dhabi GP

quite a body of work that we started only in the middle of February.'

Such was the tight deadline, McQuilliam and his colleagues put in extensive shifts in order to get the car ready and compliant for the 2015 season, which included the addition of anti-intrusion panels. It meant members were continuing work on laptops after work, although this is a factor that McQuilliam plays down, noting that: 'It is not unusual at that time of year for engineers to work basically every hour that they are awake, so the fact that myself and several others were doing work on laptops over weekends was not a surprise at all.'

'What we lost was everything in the R&D labs, everything in the stores, and everything that was in the factory'

However, he also says others continued to work for Manor, even if their official place of work had changed. 'Some of the team had found alternative employment, so some of the work had been carried out during what one might consider outside of normal office hours,' McQuilliam says.

Melbourne wipeout

Despite the delayed start, and having had no testing, the team arrived for the first race in Melbourne. However, it would prove to be something of a false dawn for the squad. The team discovered all too late that in the days leading up to the auction their computer systems had been wiped, ensuring the engine management system was unable to communicate with the power unit.

The cars barely left the garage all weekend. 'We built the parts that we needed to build and got them completed in time. It took a monumental effort from a lot of people, but we were ready and had two complete cars in Australia; unfortunately the communications to the engines were a little bit difficult, so it took us a while to successfully run the cars,' McQuilliam says.

There were additional problems in the second round in Malaysia, where both cars were allowed to start despite not reaching the 107 per cent mark in qualifying; although Stevens' machine did not even make it beyond the pitlane. But from there on the team stabilised – and difficult qualifying days at grands prix would soon be a thing of the past.

As far as aero development was concerned, Manor did secure some windtunnel testing during the year, but McQuilliam admits the focus of this was very much on future endeavours. 'We did manage to do some testing. But our wind tunnel testing time in 2015 has only been on the 2016 car and CFD work has been split between the new car and the 2015 car.' For while much precious data was lost in the auction, one thing the team did not lose was its CFD cluster – if only because it had been decommissioned after a factory fire a few years previously. It meant that this was one loss the team did not feel quite as heavily. 'We were in the position where we knew of a CFD cluster

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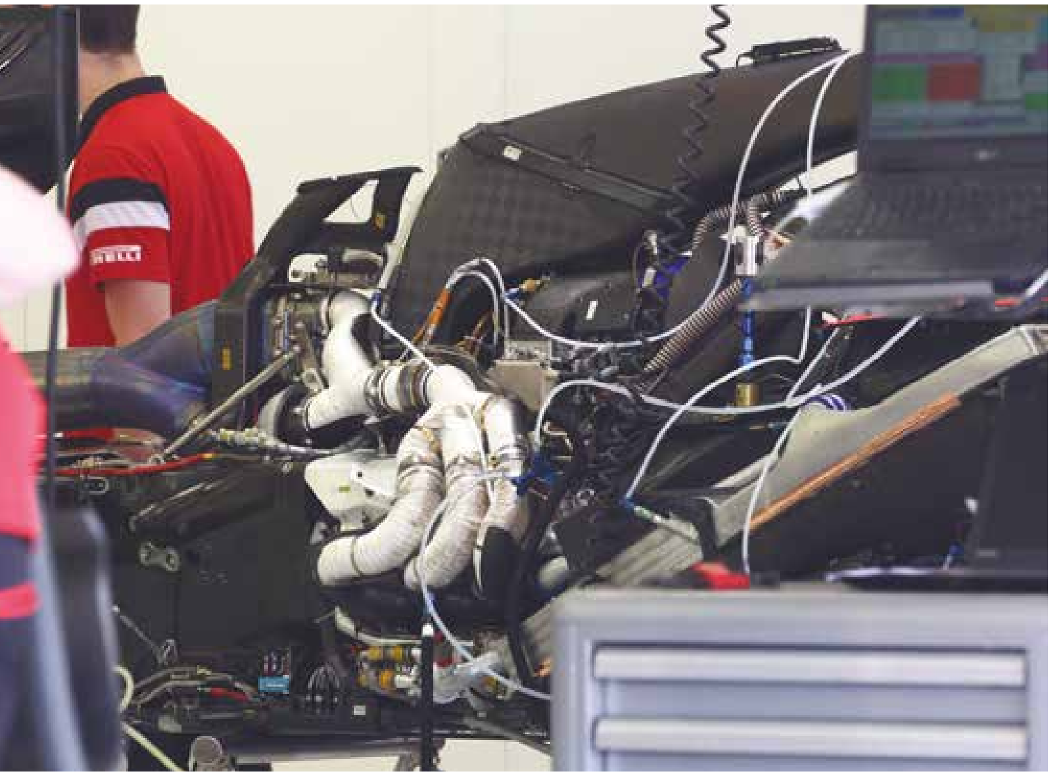
‘We did have an upgrade on the car – had we deferred that, we would not have been within the 107 per cent’

that would be available for hire, so we knew where we could get that CFD resource. And that's what we did,' McQuilliam says.

Throughout the 2015 season the Manor cars generally stayed quite well within the 107 per cent cut-off in qualifying – a notable feat considering the aggressive updates at the front of the field. But, as McQuilliam reveals, that was partly due to its own developments. 'We did have an upgrade on the car – had we deferred that, we would not have been within the 107 per cent. The Silverstone upgrade was quite literally a 'B' car behind the engine cover. It was quite a step in performance. After that, there were some parts that kept us on the pace.'

A mixture of in-season upgrades to bodywork, sidepods, front wing and brake ducts helped to keep the team ahead of the cut-off point for each grand prix, but McQuilliam adds that there was more to Manor's stability than just the occasional update. 'Some of it was about familiarity with the cars and the drivers getting up to speed and understanding the car,' he says.

Beyond the updates, there was some admiration for the front suspension concept the Manor team had been using throughout the 2015 season, although McQuilliam was actually keen to downplay its importance. 'The concept is fairly standard for modern Formula 1 cars. It's a decoupled roll and receive spring system, so that we can individually tune and adjust the damping system. It's got inboard torsion bars, and it is fairly standard.'



Manor was very much an underdog throughout the 2015 season even though it had access to Ferrari power and a Ferrari rear end. It showed a remarkable rate of reliability in races, though, something that's become a bit of a hallmark of the team

Another view of the Ferrari engine in the Manor. It's to be replaced with the all-conquering Mercedes power unit in 2016, but not a Mercedes gearbox as Williams is to supply that. Manor has worked with the Grove operation before, back in 2013

Nose confusion

A common misconception about the MR03B is the relationship between the nose spacer and the front wing. On first appearance, it was thought the front wing had moved forward due to the placement of the spacer, but McQuilliam is quick to dispel this theory: 'It didn't move the front wing forward – the front wing position and the wheelbase effectively stayed the same. The difficulty was that we have a much shorter nose to get through the crash test.'

Now, of course, it's all about 2016, and while the team has been understandably coy about its 2016 car going into the new season, a series of key changes promises to give Manor a healthy boost this year. From a useful Ferrari power unit and rear end last year, Manor is set to utilise a Mercedes engine and energy recovery unit package in 2016, while also taking on a technical partnership with Williams. This relationship will not only see Manor run a Williams gearbox and rear suspension, but will also see technical staff from the Grove-based team assist Manor with these bought-in elements during grand prix weekends.

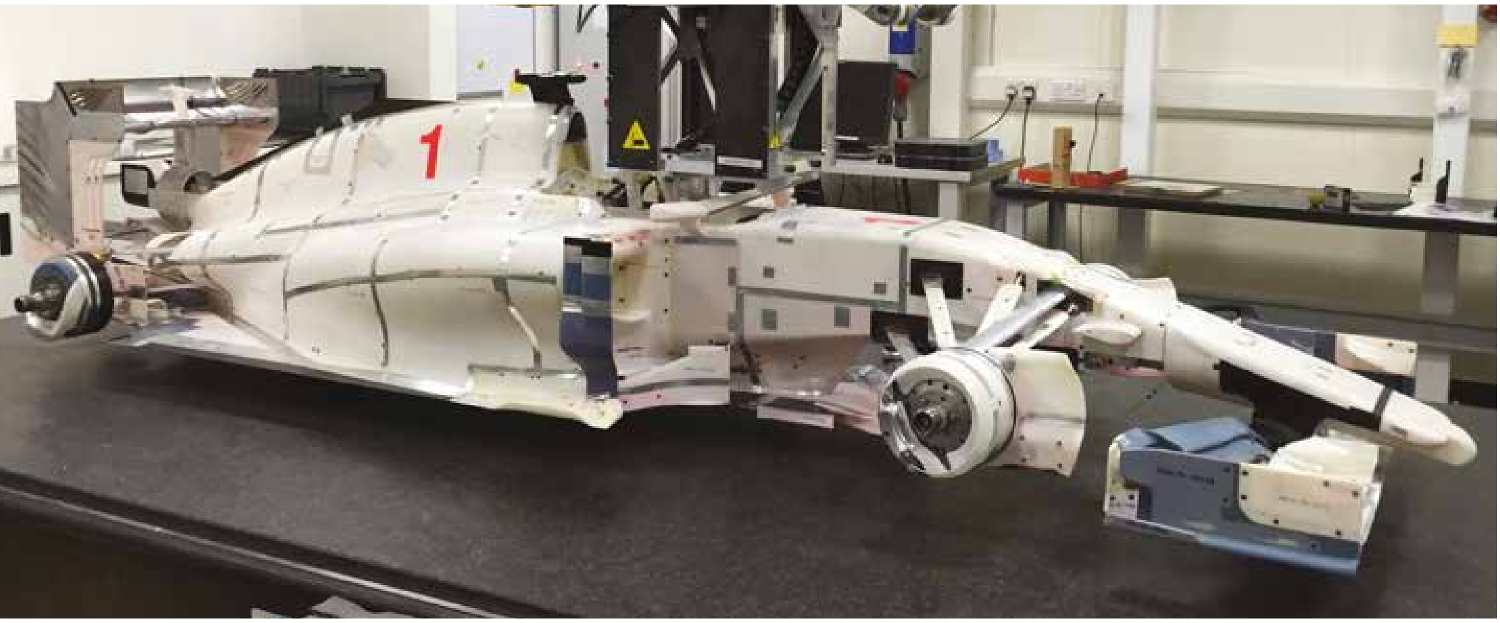
Key partnership

McQuilliam is pleased with this development and is clearly looking forward to reuniting with the Williams squad, with which Manor worked in 2013. 'We enjoyed a very good relationship with Williams in 2013,' he says. 'They offered to provide engineering support for the [2016] car and we thought that it would be an asset to be a customer team with the Williams Advanced Engineering division, so it is very simple and straight forward.' The close-quarters relationship with an independent entity such as Williams was also a selling point, says McQuilliam: 'They are the right people to deal with to get good response as a customer.'

Lining up with a Mercedes/Williams rear-end also brings its own challenges, as it necessitated a reworking of the back of the 2016 car, which –

The brake ducts received an upgrade during the 2015 season. Some of the MR03B's improved performance was down to the relatively inexperienced drivers getting up to speed with the car

An upgrade mid-season meant a host of changes at the rear of the car – without these mods Manor doubts it could have made the 107 per cent qualifying cut-off



Manor did do some wind tunnel testing in 2015 but this was mostly concentrated on developing modifications for the 2016 season. This is the wind tunnel model of the 2015 car

in its 2015 guise – had been designed for an all-Ferrari powertrain. McQuilliam explains: 'The general architecture of the engine is quite different, which has an impact on the shape and size of the monocoque and again the Williams gearbox is quite different to the Ferrari gearbox, and these things change the general architecture and weight distribution of the car. We have also adjusted the parts around them. Those are the reasons why the 2016 car has finished off very different than the one that we expected to build, had we stayed with Ferrari.'

One thing that Manor has become well-known for at in recent seasons is reliability, and even though the team is now focusing more on outright performance going forward, McQuilliam remains convinced the switch to a Mercedes and Williams rear – and the teething troubles that may come with this – will not actually dent Manor's impressive finishing record. 'It's important for us to have a good reliable car and the parts we are changing, with the engine and gearbox from Mercedes and Williams, are very reliable parts.'

'We don't want a back of the grid car anymore, we want to mix it with the midfield and have a chance to score points'

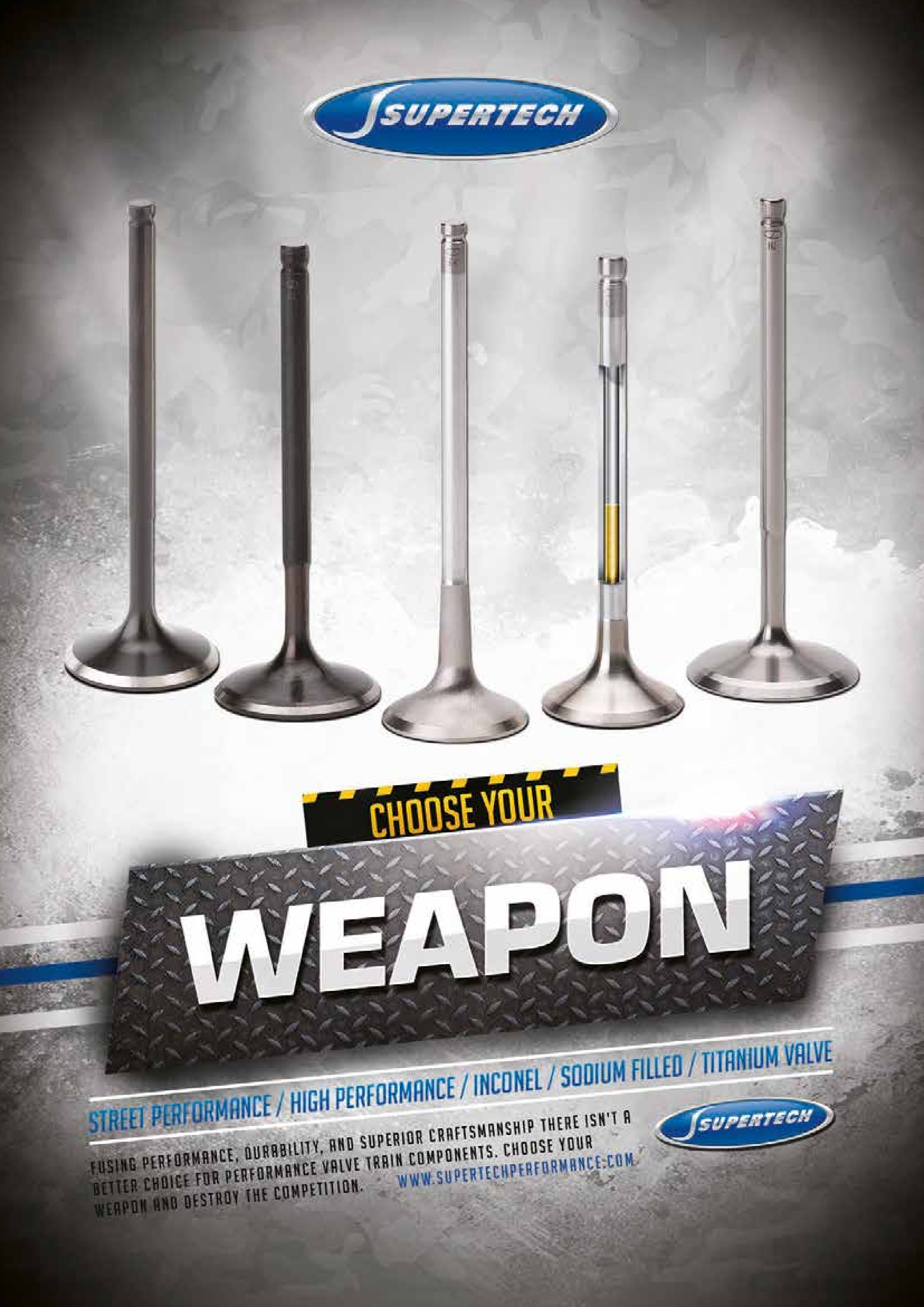
Quiet confidence

At the front, the new Manor will retain the metal bulkhead – an element copied by the Red Bull team last season – and while there was much talk about what would eventually become the 2016 car throughout 2015, what will arrive for the opening pre-season test in Barcelona in March is likely to be a heavily evolved design from what was originally imagined, as McQuilliam has said.

For the coming season there is a feeling that Manor may well be in the best shape it has been in for quite some time, and although questions remain about the long-term future of the operation, McQuilliam is excited by the challenges ahead and the possibilities that lay before him. 'The challenge is to deliver on the promise of the car. I think it's clear that we don't want a back of the grid car anymore, we want to mix it with the midfield and have a chance to score points,' he says.

Registering points would not be a first for the team, but there is a push to make this a regular feat, especially with the switch to Mercedes. Yet despite McQuilliam's positive outlook, the designer is keen to ensure the team doesn't get too ahead of itself. As he says: 'The danger is that we don't produce a car of that quality; the challenge is to produce a car that is capable of that and [to produce it] with what we have got, which is the most modest resource in Formula 1.'

It's still fighting talk, of course, but there's a lot more behind the talk this year as, for the first time, Manor may be in a position to land a few surprise punches.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Great call of China

An updated specification is set to reinvigorate the Chinese Touring Car Championship. *Racecar* contemplates this enlightened eastern philosophy

By ANDREW COTTON

Touring Car racing around the world is in a state of flux, with bright new ideas for low cost variants popping up every year. From the DTM and its jointly-developed car, shared with the Super GT series, to the Australian V8 Car of the Future; from the NGTC to the TCR and the World Touring Car Championship, the sheer number of tin-top concepts is bewildering.

From a solid base concept of the Super 2000 category, with an international World Championship feeding into national series, the touring car category is now splintering into as many pieces as the single-seater market before the arrival of Formula 4.

Joining these new ideas is the Chinese Touring Car Championship. But this at least has introduced a novel new approach. It employs Chinese company Gusto to produce a tube frame chassis that can be adapted to fit almost any body, opening up the market for smaller teams, and for manufacturers. The 2016 season is the third under these new regulations, but features updates to the cars which include a more aggressive body style, based on the World Touring Car Championship TC1 cars, but for around one tenth of the price.

The initial design for the chassis was undertaken by RML in the UK, which also produces the TC1 Chevrolet cars, and performance is targeted to fall squarely between the WTCC and the TCR. Bodywork and size is largely based on the WTCC's TC1 regulations, but weight is higher and power slightly down. The target, says Gusto's boss Alex Hui, is to create a strong Chinese racing base to improve the quality of racing in the country.

'We are trying to build a supply chain,' confirms Hui. 'When we started with this proposal in 2013, we proposed this to CTCC and they contracted us to do the job, and we contracted RML to do the base design. They designed the basic chassis kit, but we own the IP. Now we have got the update for the wings and wider car. The first car was a Polo, and RML did the installation design, but all the others that were built – Citroen, Mercedes, Audi A3 – all installation design, scanning and design is done by us. We try to learn as a company and do more and more, but there is one very important baseline for the company; if we think we cannot do it, we will pay the right person to do it. We don't want to mess it up.'

The concept

The more aggressive look of the WTCC, and DTM cars for that matter, has been largely copied under the new regulations. The chassis kit is similar in concept to the NGTC regulations, which is the same chassis fitted with a different bodyshell. However, the aero cues have been taken from the TC1, including the width of the car (1950mm) and rear wing, but while the TC1 cars have a flat floor, the CTCC cars will have a diffuser that starts at the rear axle line and rises at a maximum of 25 degrees.

While a TC1 chassis costs more than half a million pounds, the CTCC car is targeted at less

They are based on the World Touring Car Championship TC1 cars, but for around one tenth of the price


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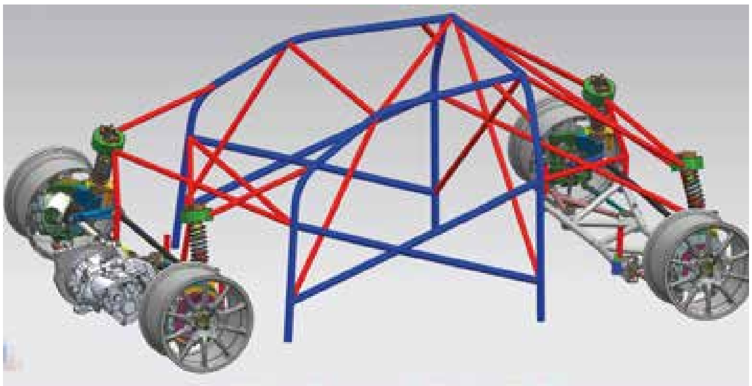
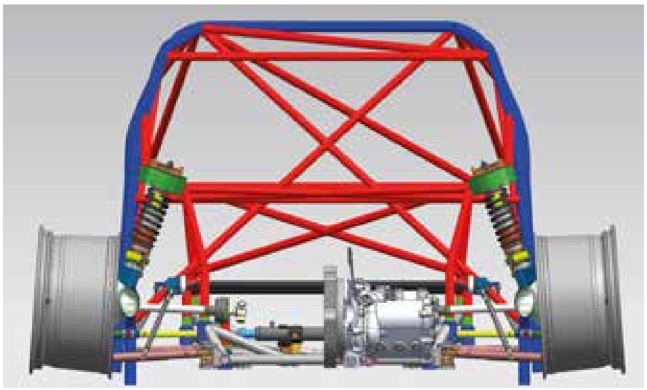
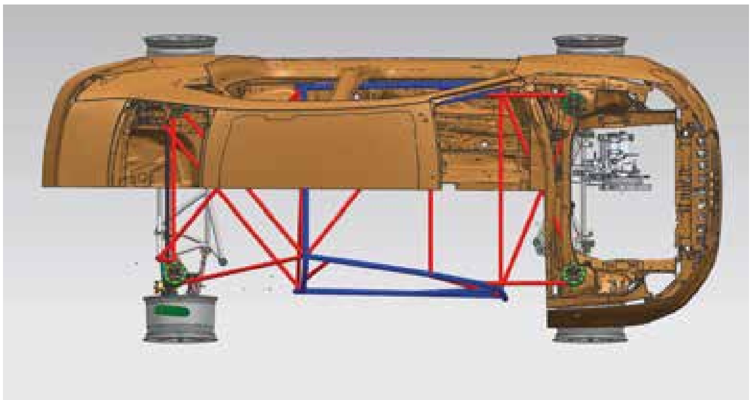


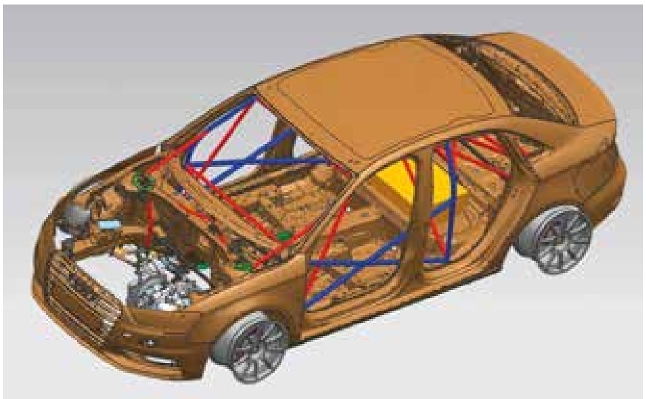
The suspension for the CTCC base car is MacPherson struts all round while there is also a standardised front and rear subframe, wishbones, uprights, dampers and brake package



At the time of writing there had been no decision on a gearbox for the new iteration of the CTCC car but Xtrac, Sadev and Hewland all have suitable 'boxes



Wheelbase is between 2.5 to 2.8 metres. It can be adjusted by 100mm compared to production car's spec depending on whether or not the manufacturer has a long or a short base model



It is expected that teams could find it difficult to hit the minimum weight of 1180kg but there is scope to save weight by using carbon bodywork parts

TECH SPEC

Engine: 2.0-litre turbocharged engine modified from production base with 36mm restrictor, approximate 380bhp/480Nm

Chassis: Front and rear McPherson generic chassis kit fitting in different body cell – designed by RML in the UK

Gearbox: 6-speed sequential

Clutch: Alcon twin-plate sintered clutch

Damper: Ohlins four-way adjustable TTX46 damper

Brakes: Alcon front 6-pot forged caliper with 380mm disc, rear 2-pot caliper with 300mm disc

Wheel: 18 x 10J

Ground clearance: 60mm

Track width: 1950mm

Min weight: 1180kg

Aerodynamics: based on TC1 regulation with rear diffuser of 1650mm max width

'CTCC wants to have regulations with lower costs, to allow more privateers and more small manufacturers to enter the championship'

than £100,000, and that difference will certainly show in the engineering. The minimum weight of the CTCC car will be 1180kg, 80kg heavier than the TC1 car, but Hui still expects teams to struggle to reach that base weight. Weight savings can be found in the engine and in the bodywork, where extensive use of carbon will be allowed, although that will not add dramatically to the cost, Hui insists.

'We expect the cars to have a lot of pressure to reach the minimum weight,' Hui says. 'The bumper in fibreglass, with the moulding and manufacturing costs, will perhaps be £250. But if we make it in carbon it will cost around £450. It is nearly double, but it is not £4000 compared to £2000.' The suspension in the base car is MacPherson struts all round, and there is a generic front and rear subframe, wishbones, uprights, dampers and brake package.

The wheelbase is between 2.5 and 2.8 metres, and can be adjusted by 100mm compared to the production car's specifications according to whether or not a team has a long or a short wheelbase model. The suspension mounting points, subframe and roll-bar hole have to be relative to each other regardless of the ride-height and wheelbase. A longer car may carry further tubes, but that comes with a weight penalty that will not be compensated by the regulations.

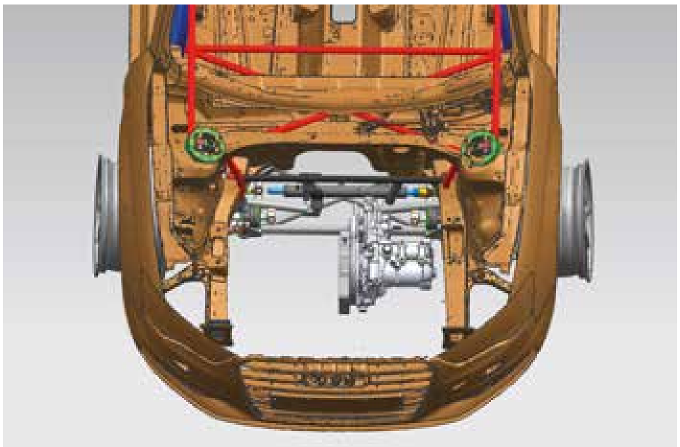
The target for the regulations is to make it possible for teams to engineer their cars, but for limited costs. 'Super 2000 became expensive to develop,' explains Hui. 'CTCC wants to have regulation with lower costs, and allow more privateers and more small manufacturers with less motorsport background to enter the championship easily. This is not F1, or WRC, or a platform for technology development, it is for marketing, and that is a good way.'

The engine

While the TCR cars are a clear inspiration for the CTCC cars, the engines are completely different. TCR relies on the 1.6-litre Global Race Engine concept, one that the CTCC considered to be too expensive to develop. Instead it has come up with an interesting take on the production-based engine.

The powerplants are based on 2-litre turbocharged engines, using the production block and head. Engine development is relatively free, including the pistons and con rods to help get down to the minimum weight, but the production parts must be able to be fitted back into the engine at any time.

There is a maximum compression ratio, a standard turbo and a standard air restrictor, at 36mm, but low performance differentiators such as the exhaust manifold are free to develop. The series expects that the engines will produce around 380bhp compared to the 400bhp of the WTCC engine, yet with dramatically different running costs. The



The regulations state that the suspension mounting points, subframe and roll-bar hole have to be relative to each other regardless of the ride-height and wheelbase

Citroen CTCC engine: the powerplants are based on 2-litre turbocharged units using the production block and head, but engine development is relatively free

The Chinese Touring Car Championship has been running its one-chassis-fits-all concept (similar to the NGTC rules in BTCC) since 2014. The Audi A3 was one of its first racecars

The Mercedes version of the CTCC car. The company behind the supply of the CTCC chassis hopes it will provide the catalyst for a new motorsport industry within China

Racing with Gusto

The Gusto business was started in 2005 in Beijing by Alex Hui, initially providing aftermarket road car parts before a love of racing took over. In 2008 Hui started to sell racing brakes and accessories from Ferodo to friends, and from there built up a company that in 2014 had a turnover of more than €8m.

'I question whether or not something is working or not. Or, if it is perfect, I want to find out why,' says Hui. 'I learned, and [provided] technical support for the customer teams. Then I started to build more relationship with European engineers, and now we can do a complete car.

'In 2010 we bought two [WTCC spec] Lacettis from RML and ran them in local championships with Teamwork [a team that is closely linked with Gusto and for which Hui drives].

'When we first saw the RML car it was very different from what we were used to running. We had a very good manual, and very clear information, and we learned how they work. If we didn't run the Lacetti, how could we know that we could build a new car like that?'

The team prepared cars for itself and for supply to customer teams, and so far has proven to be successful. In Macau it prepared not only the Citroen C-Elysees for the CTCC, but also a Peugeot RCZ.

'If you could hand over a well-developed product with a good manual, a good chassis, to a team that is eager to learn, it is a good starting point for them. Maybe in five years they become a small Gusto. That is more competition for me, but why is England the world number one in racing? It is because you have loads of small companies there. I want to be the best one, but more small companies is a good sign for the country.'

Gusto has formed partnerships for aftermarket performance supply with companies such as Alcon, Ohlins, HR Suspension, Ferodo and Cosworth. Its racing department has engine dynos, damper dynos, a chassis build rig and a gearbox spring rig, alongside a crack testing facility. It supplies parts and engineering services to one-make series, including the Chinese Racing Cup, the Nissan Tiida Cup and the Polo Cup. It also specialises in gearboxes, drivetrains, ECUs, data logging, suspension and brakes.

complete engines are leased, and are good for eight race weekends. Each engine within a two-car team is priced at £24,000 that includes two two-day tests, with 1000km mileage, with the engine married to the chassis, and with rebuilds during the season.

The target running costs for a team are – including the engine lease – between £85,000 for an entry-level team, to £150,000 for a more professionally-run outfit.

As for the gearbox, the plan was originally to have a French company supply a spec unit, but that has since changed and there is a possibility that this will be open to competition. Xtrac, Sadev and Hewland all have gearboxes that could do the job, but the final specification is still to be finalised at the time of writing.

The quest to find that Holy Grail of a touring car series continues, but the Chinese may have found the right formula, using a mix of different regulations and making them work for the burgeoning domestic market. The series is designed to build a racing industry in China, and Hui for one is convinced that this concept will work, providing low cost, high quality, attractive touring car racing.

The target running costs for a team are between £85,000 and £150,000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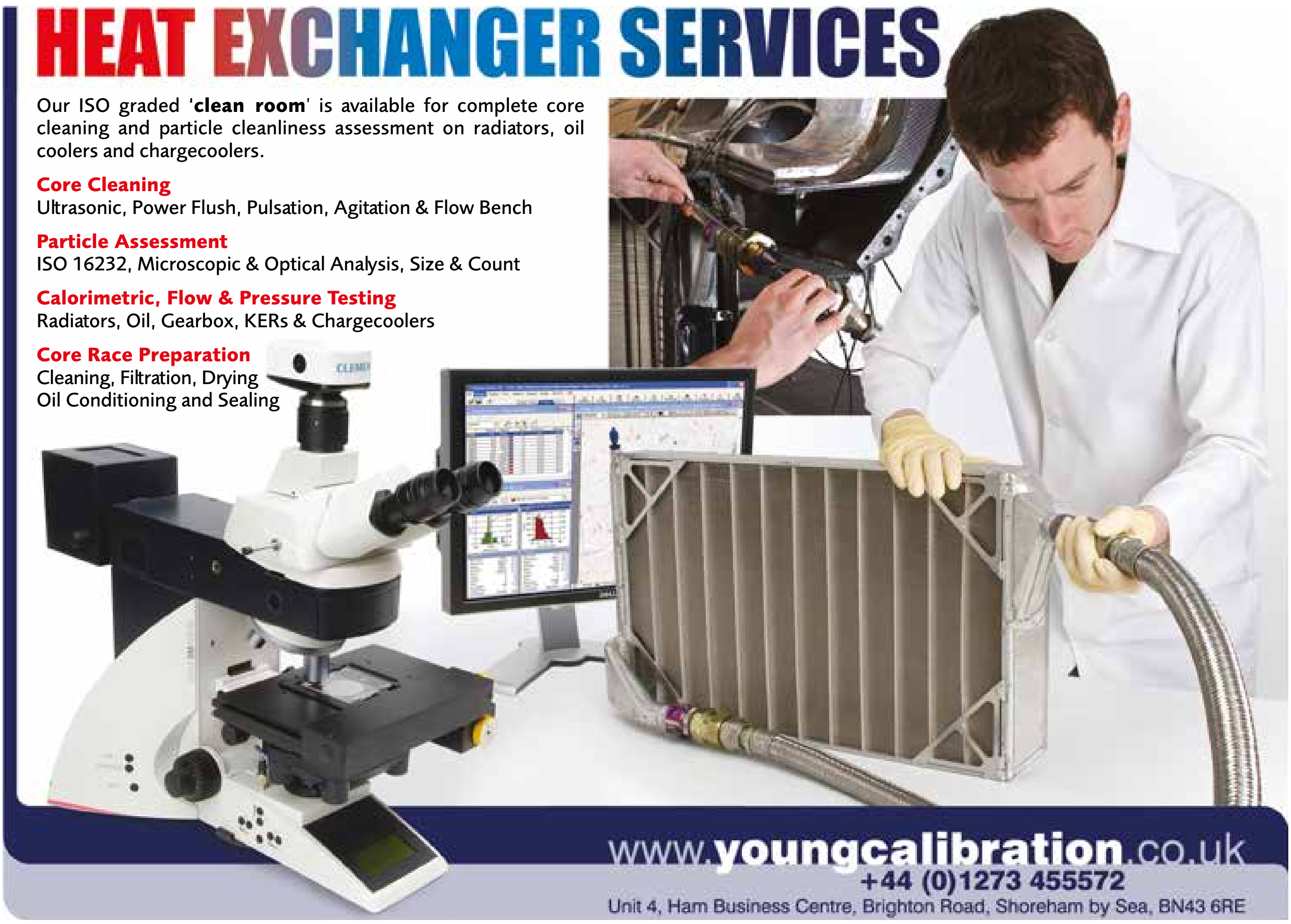
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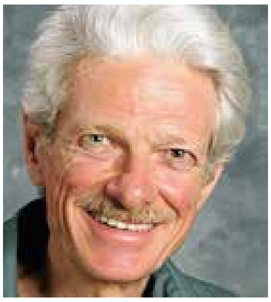

Buckle up and prepare for a crash landing

How do you prepare race seats to withstand pancake crashes?

Question

A fellow Locost [Caterham 7 type sportscar] driver had a relatively minor incident caused by chassis bracket failure on a road course where he ended up with a severe back injury.

I am hoping you might be able to shed some light into a safer way to mount seats, or to cushion the impact to the driver in an incident where the chassis impacts the ground first. Foam? Collapsible brackets? I've looked into a lot of information, but I've only really only come up with preventing compression injuries in front end impacts.

I've read an account of a crash at Texas Motor Speedway where, due to a suspension failure caused by hitting a pothole, the car left the track and went airborne due to an abrupt 3 to 4ft drop-off. It landed approximately flat, and bottomed against the ground. The resulting upward acceleration and jerk caused compression fractures to several of the driver's vertebrae. He writes: 'Not sure what I'm going to do here in the future, but I can tell you that I will not be sitting in an aluminium bucket that's bolted directly to the frame that's using a thin section of foam and my ass for padding. Seat mounts need to be able to absorb the initial shock of a vertical impact.'

The consultant

I should begin by mentioning that I do not claim to be a real expert on seat design, restraint design, impact attenuator design, or safety equipment design in general. Others have made careers specialising in these areas. However, I do know enough physics to have reasonably well informed opinions.

More or less coincidentally, I have encountered the same issue of spinal compression injury from bottoming impact in the course of mentoring a senior design project at UNC Charlotte. The students have been tasked with designing an improved frame/cage/cockpit for a midget (midget car, not driver). Concepts developed may then also be applied to sprint cars and Silver Crown cars, which are similar in construction. The idea is to do for sprint cars and related classes what NASCAR did for Cup car safety with the Car of Tomorrow (CoT): create a driver cell with more room between the driver and things that could injure the driver, and then hopefully get that design adopted as a required standard.

One issue identified by industry partner Brown and Miller Racing Solutions was that of spinal compression injury. This has been brought to the attention of the sprint car racing community by the recent paralysing injury to Kevin Swindell. His car got launched into the air, spun around, and landed flat while travelling backwards. Not only did he land hard, but the brake disc on the rear centre section reportedly came up into the seat and hit his pelvis. There's a video of the crash at www.802solutions.com.

His car got launched into the air, spun around, and landed flat while travelling backwards

The site is interesting. The company, 802 Solutions, that is marketing a product they call the Crash Pad. This is a pad intended primarily for sprint car seats, but also applicable to others, that is specifically intended to protect against spinal compression injury. According to the company, the material they use is the choice of the US military for this purpose, adopted after exhaustive testing.

This product is a new discovery to me, and I am not in a position to comment on it from personal experience or client experience, but it appears to be a good choice as a way to address the specific problem of spinal compression injury without major alterations to the rest of the car.

However, the whole question of whether to provide compliance of any kind within the seat structure, either with padding or by making the seat itself compliant, is highly controversial even among experts and it is by no means a simple matter.

If the structure is compliant but resilient (springs back), the resilience can actually intensify accelerations imposed upon the driver. If the structure is non-resilient (does not spring back), it absorbs impact well, but because it stays deformed, after impact the driver is a looser fit in the seat and harness. This is then a problem if there is a second impact – and racing crashes often involve multiple impacts. The more deformation we allow, or the thicker we make any non-resilient padding, the looser the fit of the seat and harness becomes after deformation.

One thing that helps in a bottoming impact is reclining the driver. As little as 15 degrees

When a chassis lands floor-first after an airborne accident the forces are unusual and they can lead to serious injuries

A good quality and well-mounted seat is a prerequisite in any racecar but how resilient should the seat material be?

can be a lot better than straight up, for a pure bottoming impact. This makes the cockpit area longer in a sprint or midget. This means the engine needs to move forward, or the front of the fuel tank has to move rearward. However, there is no guarantee that a bottoming impact will be purely that. Cars can take hits from any angle. There can be some impact that produces accelerations and jerks whose vector sum is aligned with the driver's spine, no matter how we seat the driver.

Another controversial issue is whether to mount the belts to the seat or to the frame. Probably the best answer to this question is that ideally it shouldn't even arise; the seat and frame shouldn't be separate parts. However, if we are not racing a monocoque car, the seat will inevitably be a separate part. Production cars are always made with separate seats because for street use the seats have to be readily adjustable. In these, the belts anchor to the bodyshell.

Heavy trucks often have suspension systems for the driver's seat, not so much for bottoming impact protection but rather for comfort in normal operation. In these, the belts have to anchor to the seat. Sometimes the belts have a secondary anchorage to the floor, but then there has to be slack between that and the seat anchor, so the seat suspension can work. The belts also would have to anchor to the seat if we use a seat suspension system or compliant mounting of some kind to absorb bottoming impacts.

If the seat cannot move with respect to the frame, theoretically it doesn't matter much whether the belts mount to the seat or the frame. We do want the belts to all be as short as possible, provided we can get enough length adjustment. That argues for mounting them to the seat. If we accept that there is probably going to be some situation in which the seat moves with respect to the frame, it's better to have the belt anchorages move with the seat than to have them stay with the frame while the seat moves.

On the other hand, anchoring the belts to the seat causes the belt forces to go through the seat mounts. The belts are trying to tear the driver and seat loose rather than hold them in place with respect to the frame. This requires the seat and its mounts to be stronger, and/or increases the likelihood that the seat will fail structurally or get torn loose.

Ideally, we want to place the driver inside a structure that guards against intrusion and holds him in place

Ideally, we want to place the driver inside a structure that guards against intrusion and holds him in place without injuring the him. This driver envelope or capsule should have continuous smooth surfaces, preferably with a bit of padding. The driver should be supported and restrained so that impact loads are fed into the driver's body in accordance with the body's ability to withstand them. Side loads, for example, should be borne primarily at the hip and shoulder, not the ribs. However, the ribs can absorb a bit of force, and that can allow the hip and shoulder to withstand a somewhat harder hit. Arguably, if the forces are perfectly distributed, you either don't break any bones, or you break a lot of them at once.

We then should add impact attenuation devices, but we want these to be mainly outside the driver protection envelope, not inside it or in the seat. Impact attenuators can be of various materials: foam, aluminium honeycomb, sheet steel or aluminium. New materials for this are probably being developed as I write this; impact absorption technology is still not really mature. But we can lay out some performance requirements for impact attenuating structures, no matter how they are made:

1. **They have to crumple, in something resembling a controlled manner.**
2. **They should crumple more easily in their outer regions and with greater resistance closer to the structure they are protecting. This is sometimes called graduated rigidity construction. This causes accelerations to build more gradually, i.e. it reduces jerk values.**
3. **They should be as thick as possible. The more thickness they have, the greater a distance they have over which to absorb an impact, and the better they can cushion the blow.**
4. **While they have to be weak enough to crumple, they have to stay attached in a variety of crash scenarios. If they dislodge they become hazards in their own right.**

In the case of an impact attenuation structure under the driver, this last criterion is particularly crucial. In many bottoming impacts, the car is still travelling horizontally at a good clip. An under-car impact attenuator has to withstand this without getting torn off. The vertical space constraints are also pretty severe in most cases. Generally we're trying to get the driver and car as low as possible.

It's particularly nasty if the driveline is under the driver, as in a midget. These components are unyielding, and they can be driven upward with respect to the frame even if the frame itself never hits the ground. To some degree this can be dealt with by raising the driver and providing shielding and padding, but to achieve big gains, it would be better to re-think the layout of the car. The driveline really should go alongside the driver, not underneath. The driver can then be in a protective envelope; legs alongside the engine, an impact attenuator underneath the protective envelope, and a reclined seat back.

For best results, this structure should be a composite monocoque with the belts attaching to it, and a thin poured-foam insert filling most of the space around the driver's sides and upper back, with thin 802 padding under the pelvis and lumbar region.

CONTACT

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Databytes gives you essential insights to help you to improve your data analysis skills each month, as Cosworth's electronics engineers share tips and tweaks learned from years of experience with data systems

Setting the data displays for drivers

It's vital that a driver is able to quickly take in and understand the dash data if he is to clearly communicate problems to an engineer

Communication with your driver is fundamental to understanding what is happening behind the steering wheel and under the bonnet, particularly if telemetry isn't available during an outing, as you are totally reliant upon the driver to relay any irregular performance with the vehicle. Visual aids such as displays and LEDs allow the driver to quickly understand what is happening in the car and make changes to his/her driving style to compensate for this while also allowing them to feedback any vital information to the pits.

Displays are now so advanced that it is very easy to over-complicate matters and get carried away with their features. Data from the vehicle can be displayed in a manner of different ways which we will now look over with a few examples to make sure you get the most from your display and your driver.

First there's channel value. The standard way to show any value on a display is as a number (**Figure1**). It's precise, easy to understand and communicate over the radio. However, without a label or unit it is rendered useless. The last thing a driver wants to do is decipher which number is which on a display while trying to concentrate on the race

Channel values can be very useful but must be used sparingly to avoid confusion and an untidy display. If several number values are required, try to break them up into sensible sections on the display with boxes or colours. Separating values by their units is usually a sensible policy to adopt.

Field indicators

A similar display method to a channel value is a bit field indicator. These allow you to display a specified text string for a given bit field value. This is often used for gear indicators (**Figure 2**) but can be particularly useful for displaying system statuses.

Bar indicators act as a quick indication of whether a value is within the range expected. Use of different colours across the value range is essential so that the drivers can see it in their peripherals or with a quick glance. For example, you may want to display coolant temperature here with blue for the lower temperatures and red for the high temperatures.

Another ideal application is a lap delta (**Figure 3**), using green for a faster delta and red for a slower delta. The driver can then quickly decide whether it is worth continuing to push on a qualifying lap or to save the tyres for the next lap. A bar indicator can also make a good replacement for LEDs when used for rpm as a gear change indicator (**Figure 4**). The key drawback with bar indicators is lack of precision. It is very difficult to identify the exact value when it is shown on a bar.

Cosworth dash fitted in a Porsche GT racer. It's important the driver is able to read off data quickly and accurately

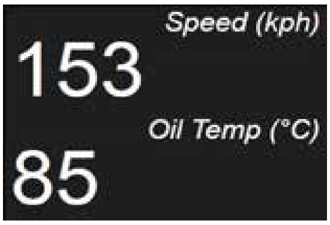


Figure 1: The standard way to show any value on a display is as a number

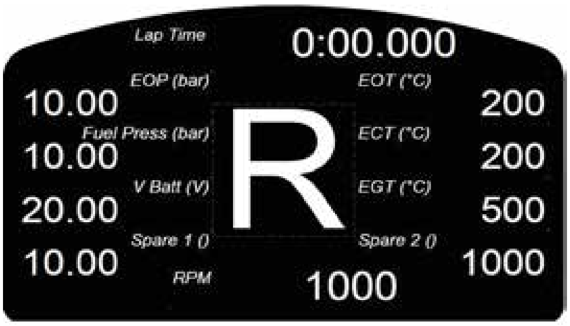


Figure 2: A bit field indicator allows you to display a specified text string for a given bit field value. This is often used for gear indication

Figure 3: Bar indicators can be used for clearly showing lap time deltas

Figure 4: A bar indicator can make a good replacement for LEDs when used as a gear change prompter

Figure 5: The set-up screen for the dash LED display – LEDs are especially useful for emergency situations

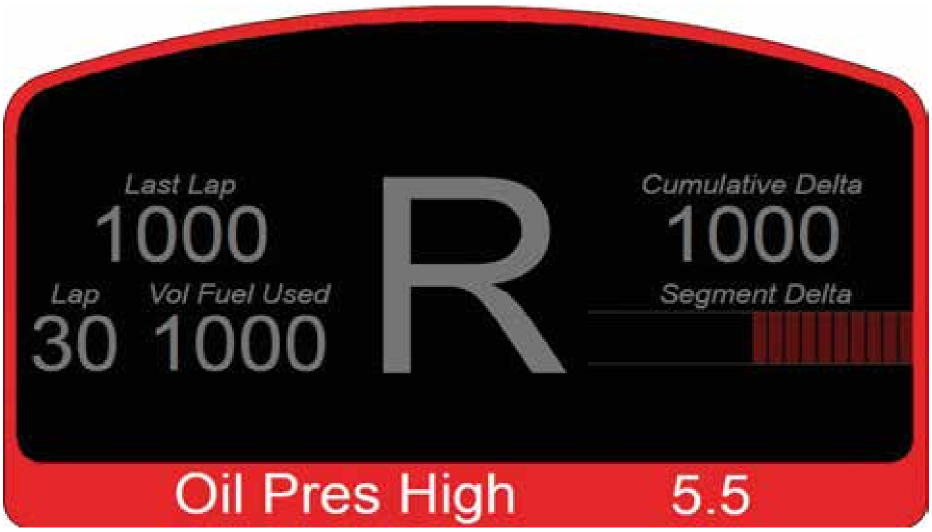


Figure 6: A display overlay is used to display info under certain circumstances, such as when an alarm is triggered

Many displays also include built-in LEDs with the primary use expected to be a gear change indicator. Any auxiliary LEDs, however, may be particularly useful as alarms or warnings for the driver, with different colours giving a different message or severity of warning.

The LED position may also be used to your advantage for applications such as brake and tyre temperatures, allowing the driver to distinguish which LED corresponds to which wheel. In general, LEDs are more noticeable than a display, particularly when driven so that they flash. This makes them particularly useful for severe warnings that may require the car to be stopped on track. In this case, the driver doesn't necessarily need to know what is happening. Just that they need to stop the racecar if all the LEDs are flashing. **Figure 5** shows a set-up screen for this. This could save vital seconds that would normally be spent communicating with the driver, potentially preventing engine failure.

Display Overlays

A display overlay is usually used to display information that is only required under certain circumstances, such as when an alarm has been triggered (**Figure 6**). The sudden change in the display is also quite visible to the driver, which prevents it from going unnoticed. Overlays conditions can be defined so that they only appear when it is necessary. This means you can set alarm overlays to be triggered at the same values and conditions as you have defined in your data analysis software.

It is often sensible to add a channel value to any alarm overlay as the numbers are easier to distinguish when isolated from the rest of the display in the background. In circumstances where more than one alarm has been triggered it may only be possible to see one of them. At this point you must consider the priorities of each alarm. Setting a hierarchy ensures that vital alarms are displayed ahead of minor warnings.

Another option is to allow only certain overlays to be dismissed so that they are removed from the display on a button press. This can then allow the driver to keep check on the main display screen and other alarms when one alarm is frequently triggered.

When creating your display configuration make sure to keep it simple and intuitive. Don't try to add too much but if necessary, provide the driver with the option to change between display pages. More importantly however, you must make sure that your driver understands what the display is showing so that you can get the information that you need from him.

The aerodynamics of the GT racecar

Our man raids the archives for an overview on GT aero trends

As a prelude to an upcoming new mini-series on a current GT car, we've been rummaging through the Aerobytes archives, comparing GT cars we have tested previously in the MIRA full-scale wind tunnel. International and national GT category names and numbers have fluctuated over the years, and the technical regulations never stand entirely still for long. Nevertheless, it's interesting to look back at the responses to devices, and to adjustments that we have made, to see what makes these cars tick, aerodynamically speaking.

Nissan 350Z

Our first foray into GT aerodynamics was almost a decade ago when we examined the RJN Motorsport Nissan 350Z that was being developed for what was then called GT2. Our feature in the June 2006 (V17N6) issue looked at the fundamental challenge that arose with this car from its short front (especially) and rear overhangs, limiting the plan area for downforce generation and the leverage it could exert on the respective axles. RJN's own testing at MIRA had demonstrated that getting actual front end downforce at all was not easy. This in part explained why the car used a low rear wing height, for although this limited rear end downforce generation, there was little point in making a lot of rear downforce when it could not be balanced at the front.

Much of RJN's effort therefore focussed on trying to tease downforce increments from the front of the car. This included airdam and splitter shaping within the permitted and very restrictive plan periphery of the vehicle and, importantly, cooling system ducting and front compartment extraction through the bonnet and front wheel arches. The effects of chassis rake and diffuser roof angle were also looked at and these featured in our Aerobytes column in February 2007 (V17N2). Some fairly extreme chassis rake changes were assessed but interpolating the results indicated that an increase of 0.3deg (equivalent to about 14mm between the axles) produced an increase of around 13 per cent in total downforce and, usefully, a significant forwards balance shift of almost 10 per cent. Mapping a set of diffuser roof angles also revealed some valuable trends, reproduced here in **Figure 1**. With the usual reminder that the MIRA wind tunnel's fixed floor would have its influence on the outcome, the conclusion was that a diffuser roof angle of 12deg was optimal here, given that the gains in downforce, efficiency (–L/D) and balance (%front) peaked at this angle.

Ferrari F430 Scuderia

Moving on four years to 2010 we tested the Ferrari F430 Scuderia of MTECH Racing, which ran to GT3 regulations in the British GT Championship. The regulations were somewhat less restrictive at this point, allowing a decent sized splitter (with front

The RJN Motorsport Nissan 350Z GT2 we tested almost a decade ago (Pic: Horiba MIRA)

This Ferrari F430 Scuderia GT3 racer performed well when we tested it back in 2010

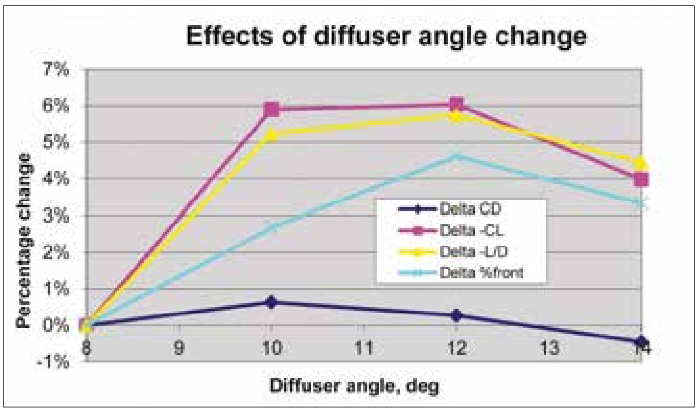


Figure 1: The Nissan 350Z GT2 car's responses to diffuser angle changes; 'delta' values represent the change to each parameter relative to an 8-degree diffuser angle

Table 1: Baseline aerodynamic coefficients on the MTECH Racing Ferrari F430 Scuderia GT3

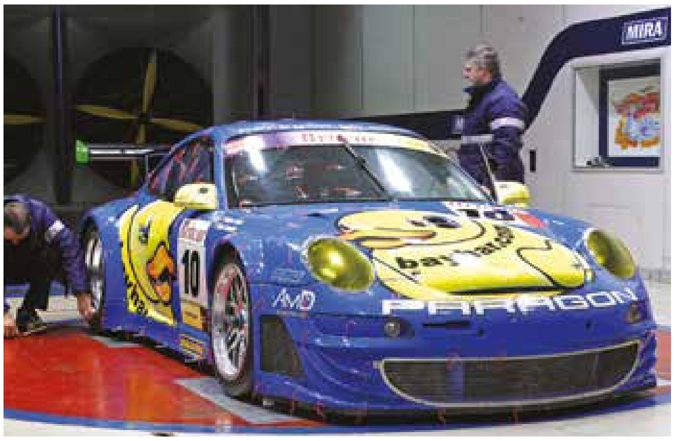
	CD	-CL	-CLfront	-CLrear	% front	-L/D
Baseline configuration	0.521	0.821	0.348	0.473	42.4	1.58

Table 2: The changes to the aerodynamic coefficients from fitting small dive planes on the Ferrari F430 GT3

	CD	-CL	-CLfront	-CLrear	% front	-L/D
Delta % 'with'	+1.0%	+0.5%	+6.4%	-4.2%	+2.62 abs	No change

'Abs' = absolute

Flow from F430's central diffuser was orderly – but not so from the outer diffuser (below)



The Porsche 997 GT3RSR in restrictive ALMS GT2 format lacked total downforce and balance. The car was campaigned by British race team Paragon Porsche

The rear wing on the F430 was actually originally developed for the Ferrari F550 racecar

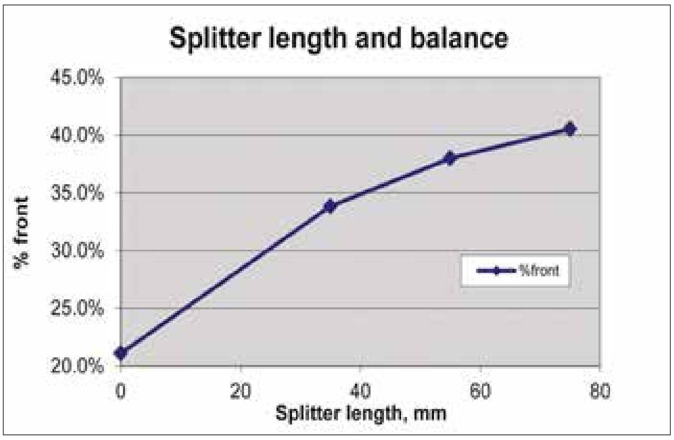


Figure 2: The trusty front splitter came to the rescue of the Porsche 997 GT2

diffusers) and a wide span 400mm chord rear wing originally developed for the F550 racer but subsequently homologated on the F430. A relatively shallow rear diffuser completed the underbody. Not surprisingly the baseline aerodynamic numbers had moved on a bit too, and in fact were very respectable as **Table 1** shows.

The –L/D and %front values demonstrated a decent amount of fairly well-balanced downforce. Note that the car featured nicely ducted cooling systems at the front as well as that medium sized splitter, which incorporated diffusers feeding into the area between the front wheels and the chassis. The car was sensitive to small ride height increases, just 2mm causing tangible changes to total downforce and aerodynamic balance.

A rear wing angle sweep illustrated that the angles used by the team to provide a balance on track correlated with the balanced settings found in the wind tunnel, and that this balance was at a relatively low overall downforce level, which the team thought had been developed for fast circuits such as Monza.

The car had not been homologated with the dive planes seen in our photo but, as the team also ran in other less restricted categories, they were evaluated and found to be quite effective at adjusting balance, as **Table 2** shows.

The smoke plume proved its value in highlighting the disturbed nature of the airflow emerging from the outer sections of the diffuser compared to the smooth, organised flow emerging from the centre – this is a trait common to many racecars.

Porsche 997

Late in 2010 and into 2011 we featured the ALMS GT2 Porsche 997 GT3RSR of UK race team Paragon Porsche, and although the car was under development to run outside ALMS/FIA sanctioned series it is included here because of the relevance of some of the information we obtained.

Once again the rules pertaining meant that aerodynamic devices had to fit within homologated overhangs and within the perimeter of the original bodywork. This precluded a useful splitter and the car came into the tunnel with a small airdam protruding downwards slightly below the plane of the floor. The detailing and packaging of the front cooling ducts, however, was very clever, and would have minimised if not eradicated the lift that can come with poorly or non-ducted cooling systems. Nevertheless, although the car did generate front downforce, the balance was just 21 per cent front, this on a car with 39 per cent static weight on the front.

Total downforce on the 997 was some 36 per cent lower than the F430, but plan area was smaller. There was no splitter at this stage, the rear wing was smaller and the rules limited the rear diffuser to an inclined panel with no vertical fences.

The development aim was to increase total downforce and improve balance so a set of front splitters was evaluated, with the results in **Figure 2**. Clearly a modest splitter would be able to achieve a %front value comparable to the front static weight percentage, although with a more potent rear wing to be fitted further aft than the standard wing, yet more front end downforce was going to be needed. A useful and efficient increment was found with small front dive plane extensions.

We will see soon how our 2015 GT car stacks up against these earlier models ...

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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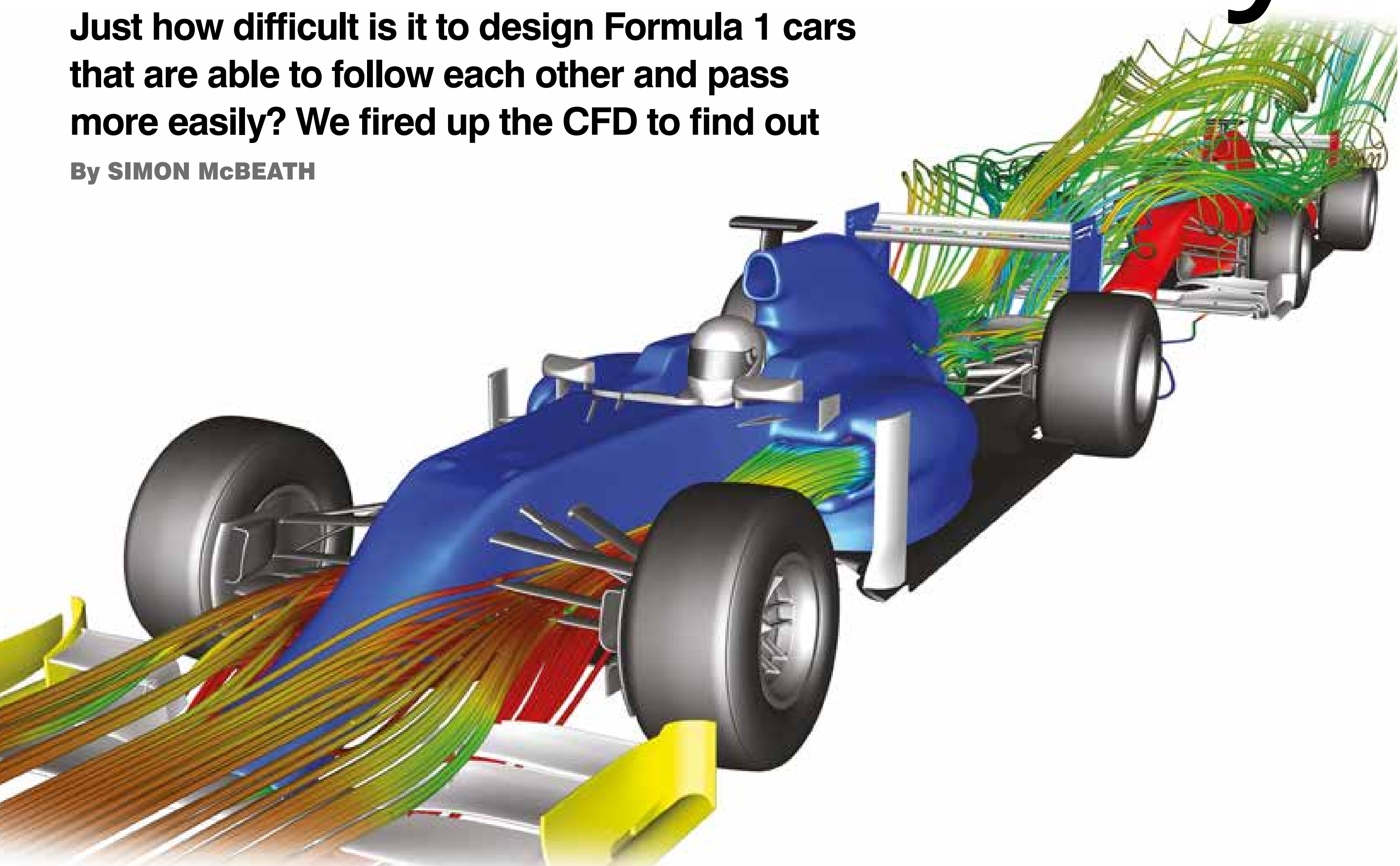
Follow closely

Just how difficult is it to design Formula 1 cars that are able to follow each other and pass more easily? We fired up the CFD to find out

By SIMON McBEATH



Nothing makes a mess of air quite like an F1 car at full chat – as CFD spaghetti image of '2017' cars shows. This is why it's difficult for a car to chase another through fast turns

Overtaking in F1 is not as common as many would like. But there seems to be widespread agreement that to increase the frequency of passing it is necessary to make it easier for following cars to be able to close up on the car in front.

Artificial aids such as DRS and differential tyre degradation aside, which have little to do with the execution of skilful overtakes, the issue relates particularly to higher speed corners where the aerodynamics play a large role in grip generation, since following closely on the straights (even without DRS) or in slow corners isn't a problem.

To get in position to execute an overtaking manoeuvre, by definition the following car must be close enough to the car in front in the first place, so the small extra advantage needed to draw alongside can then be implemented. The not unreasonable precept that follows is that if the cars could follow more closely on all, or at least, more sections of a track then more overtaking would result. Assuming the precept is valid, what needs to be done to achieve the aim?

The problem is clearly a complex one if, after numerous attempts at solving or at least reducing it, artificial means such as DRS and tyres with limited durability were required to facilitate changes of track position to supplement overtaking events *per se*. Discussion in the sidebar (p61) highlights the various aerodynamic factors at which fingers are pointed, but loss of downforce and loss of aerodynamic balance on a following car are clearly uppermost. F1 seems understandably intent on maintaining high downforce, so mitigating the effects of its loss and its shifting balance on following cars is and has been the obvious focus of attention. This feature looks at the first iteration of a potential solution that would entail, in Formula 1 terms, very modest costs, and which, as promised in our last study, also sees greater emphasis on ground effects.

First response

With such a complex problem the resources of an F1 team's aerodynamics department to study as wide a range of potential solutions as possible would be useful. Such is not the case at *Racecar Engineering*, but we are very fortunate to have the

To get in to a position to execute an overtaking manoeuvre, then the following car must be close enough to the car in front in the first place

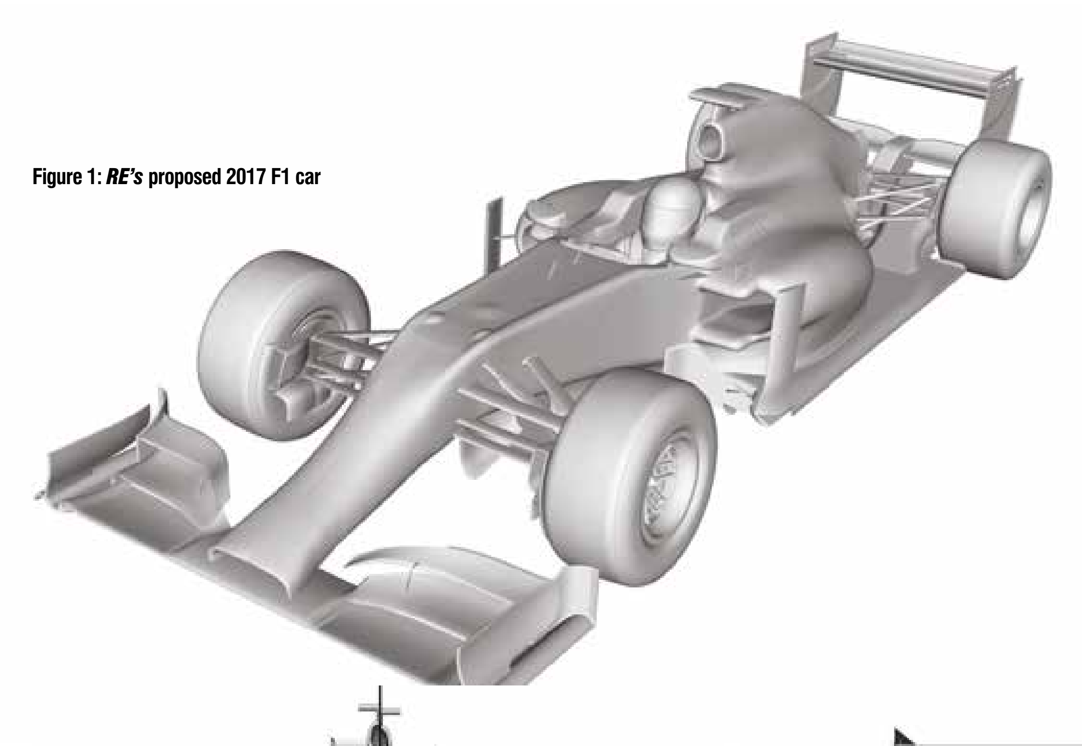


Figure 1: ***RE's*** proposed 2017 F1 car

The main aims were to increase the underbody's contribution to overall downforce and to reduce upwash in the wake

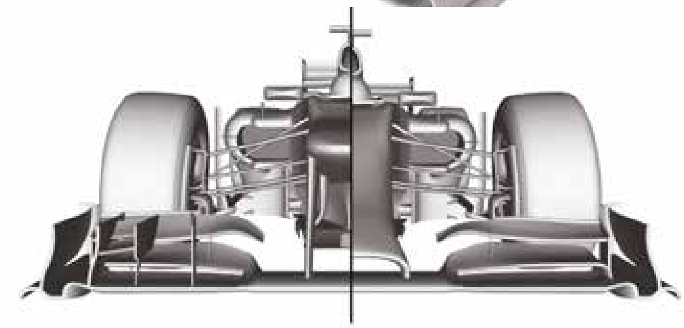


Figure 2: Differences between 2013 and 2017 car – the latter is right half of racecar

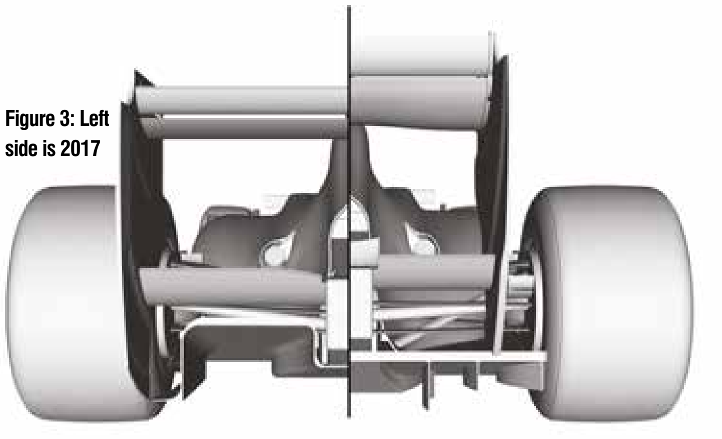


Figure 3: Left side is 2017

Table 1: The aerodynamic data on the 2013 and 2017 F1 racecars at the same rake and ride heights

	CD	-CL	%front	-L/D
2013 model	1.173	3.89	45.0	3.32
2017 model	0.96	3.95	45.0	4.11

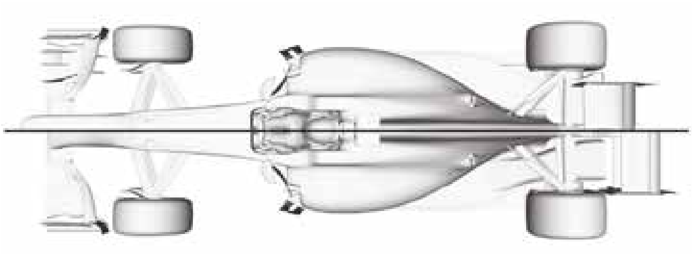


Figure 4: Bottom half of image is 2017 racecar

resources and skills of Dynamic Flow Solutions and its director Miqdad Ali ('MA') to make some carefully thought through, selective studies on aspects that would seem to be likely contributors to the problem.

Regular readers will have seen the illuminating CFD studies that MA has carried out on a 2013 rules F1 car model using OpenFOAM CFD software in our July and October 2015 issues (V25N7 and V25N10). While working on these studies the idea occurred to MA that by using two of these 2013 models in line astern the current problem could be examined (2015 F1 cars are obviously slightly different to 2013 cars, but the basic problem appears to be ongoing), akin to the study in our October 2004 issue (V14N10) by Advantage CFD on a BAR Honda 002 F1 car. Furthermore, adaptations to the model would also enable alternative aerodynamic concepts to be studied and compared to the current situation.

For the study in this feature, MA's initial approach to creating an improved F1 car for 2017 was, he says: 'To make minimal changes to existing cars and get positive results. In our case it was a lowered nose (in line with 2015 safety thinking); a simplified front wing; a smaller rear wing moved rearwards and downwards; the floor step plane was lowered from 50mm to 25mm above the reference plane; the diffuser outlet area was doubled and the length increased; the beam wing was moved backwards; and 25mm side skirts were fitted on the underbody side edges.'

In greater detail the key changes involved are as follows:

- **Front wing was simplified, number of elements kept to three and central neutral section retained. Span kept the same (as 2013) and height above the ground was the same as before; however, its height was different relative to the step plane by 25mm.**
- **Rear wing span increased to 1000mm with a less aggressive profile and camber to fit a (smaller) 290mm x 110mm side elevation box, and it was 170mm lower than before and 250mm rearwards, measured at the flap's trailing edge.**
- **The underfloor had a 25mm step compared to 50mm before, hence the sidepods were 25mm lower, lowering the CofG. The diffuser outlet was twice the size of the current diffuser and was 980mm long with a 12-degree roof angle. There were 25mm deep side skirts to assist the underbody; these were simple extensions of the underbody side edges protruding towards the ground with a thickness of 3mm.**

The CAD renderings shown as **Figures 1** to **4** show the 2017 car compared to the 2013. The main aims then were: to increase the underbody's contribution to overall downforce, and to simultaneously reduce upwash in the wake. The first CFD runs enabled refinement of these basic modifications until the downforce and balance levels were

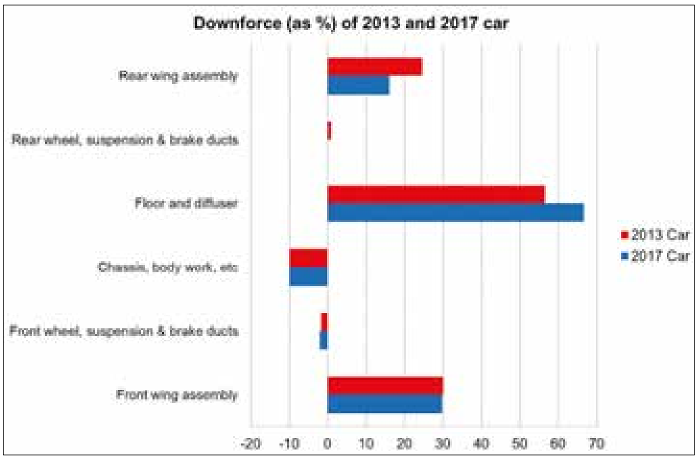


Figure 5: Downforce contributions on the two cars showing differences between them

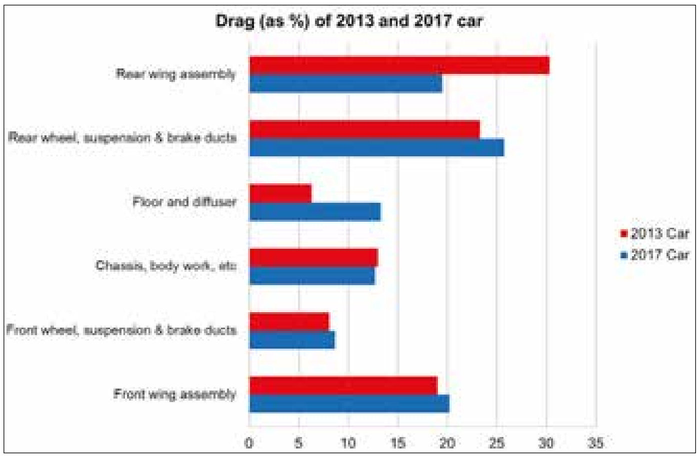


Figure 6: Drag for both – note 2017 floor contribution in both drag and downforce (Fig 5)

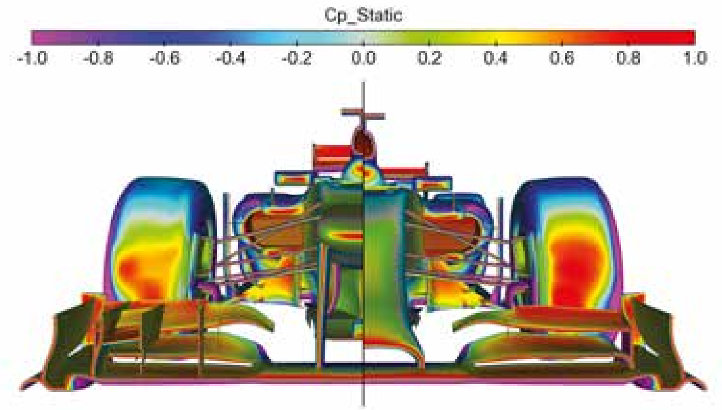


Figure 7: Front view surface pressure coefficient comparison; 2017 on right of image

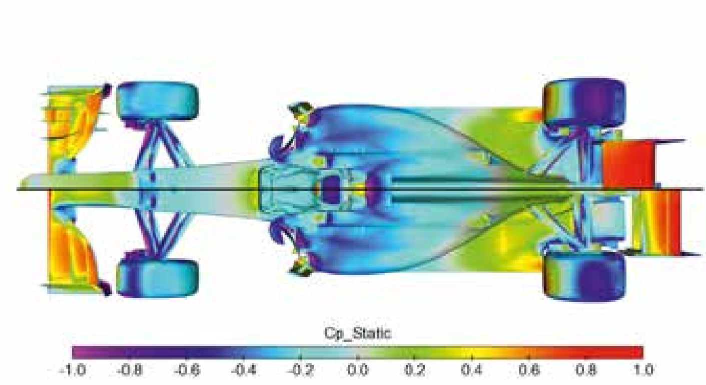


Figure 8: Top view surface pressure coefficient comparison, 2017 bottom of the image

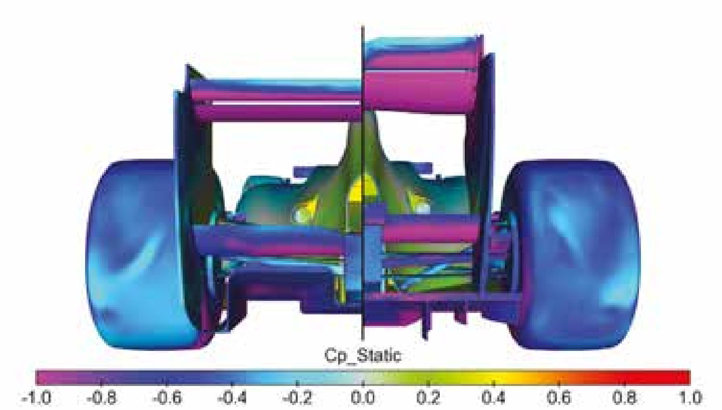


Figure 9: Rear view surface pressure coefficient comparison; 2017 on the left here

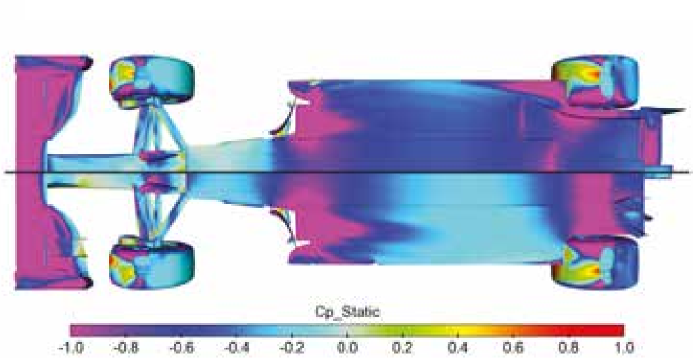


Figure 10: Surface pressure coefficient comparison; 2017 at the top of image

comparable to the previous 2013 model so that direct comparisons could be made in two-car scenarios. This produced a 2017 car with an -L/D better than the 2013 car, approximately 45 per cent front aerodynamic balance and very similar -CL to the 2013 car. **Table 1** shows the basic aerodynamic numbers.

Figures 5 and **6** give comparisons between the sources of downforce and drag on the 2013 and the 2017 cars. The proportion of total downforce generated by the rear wing was smaller on the 2017 car but the underbody contribution was bigger; front wing downforce was roughly comparable. The main changes in drag contributions were in line with rear wing downforce decreasing and underbody downforce increasing, but total drag was lower, hence the -L/D value increased. **Figures 7** to **10** show comparisons of surface pressure coefficients on the two cars simulated in CFD. But how would this first 'F1 2017' concept fare in two-car line astern simulations? First we needed comparative data from the 2013 car…

2013 cars line astern

Figure 11 shows the changes to each of the main aerodynamic metrics at a range of longitudinal car separations from half a car's length to eight car lengths, and **Figure 12** is from our 2004 article on the BAR Honda 002 showing similar but not quite identical information. Nevertheless, at first glance the plots show basic similarities; drag and downforce reduced on the following car, and the reductions were greater at smaller separations. One difference in the curve shapes shows that the reductions steepened at two car length separation on the 2013 car but this steepening did not occur until one car length on the earlier car, so in that sense things were slightly worse on the more recent car.

One key aspect is that balance (%front) shifted significantly off the front of the car in both cases from right out at eight car lengths, and in both cases this became greater at the closest separations. The reason for the balance shift is equally clear; the front end lost more downforce than the rear end with both cars. Irrespective of the losses in total downforce, if the %front reduces then aerodynamic understeer would be bound to occur as soon as a following car got close to another, making it more difficult to exploit the remaining grip to try and stay close, let alone close up on the car in front through an 'aero' corner.

Steady balance

Next, a pair of 2017 cars were put through their paces at the same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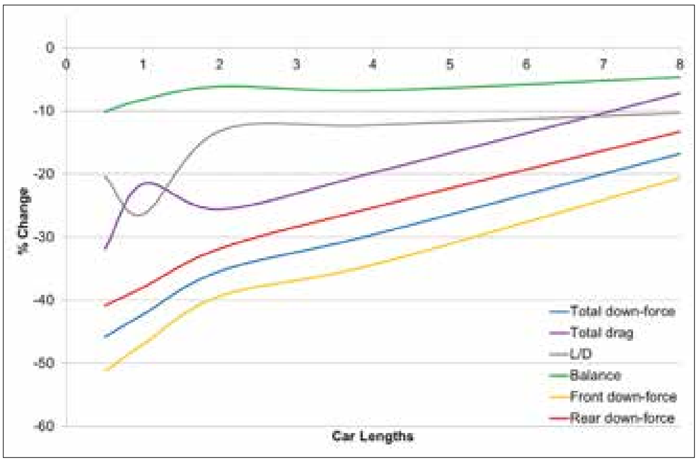


Figure 11: The changes to the aerodynamic numbers on our 2013 following car. At first glance the results seem broadly similar to our BAR 002 study (see Figure 12, right)

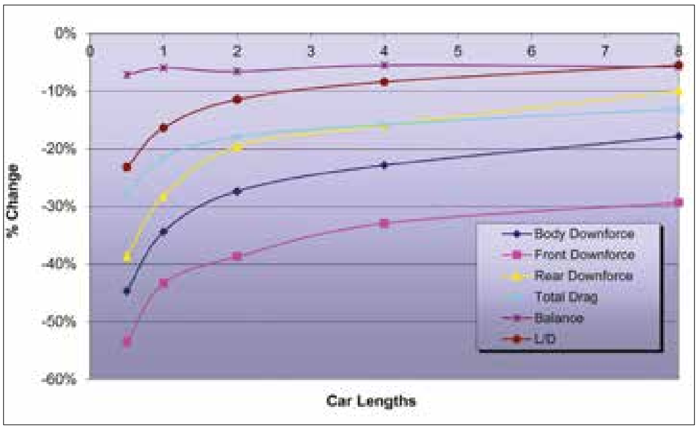


Figure 12: The changes to the aerodynamic numbers on the BAR Honda 002 (as featured in *Racecar* in 2004) following the car at a range of fore-aft separations

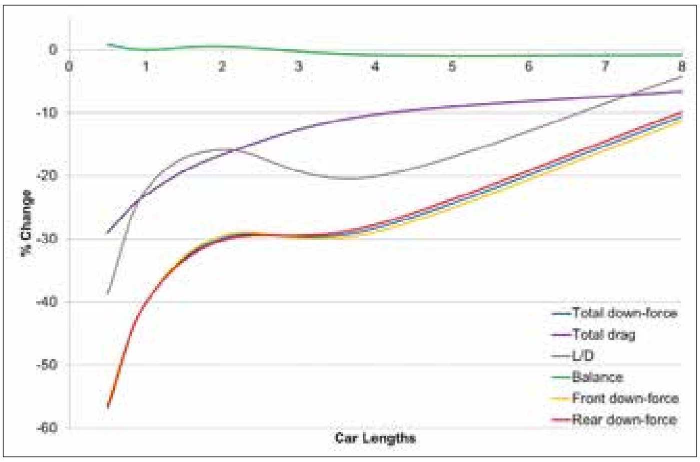


Figure 13: The changes to the aero numbers on our 2017 following car at a range of fore-aft separations. It seems that the 2017 car punches a smaller hole in the air

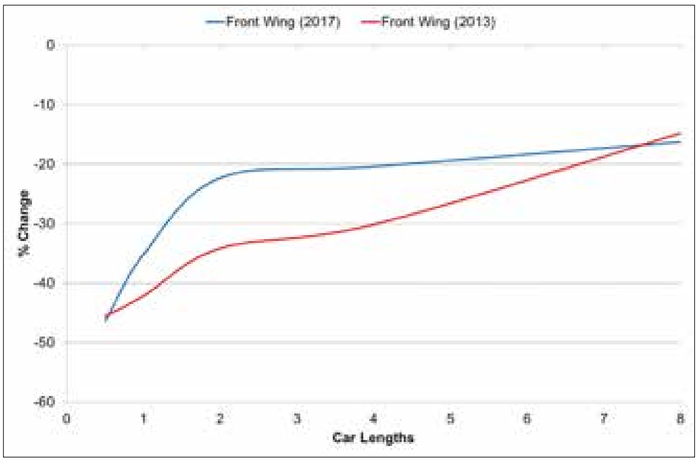


Figure 14: Changes to front wing comparison. The following 2017 car lost a lot less downforce at all the intermediate separations, which should make it easier for the driver

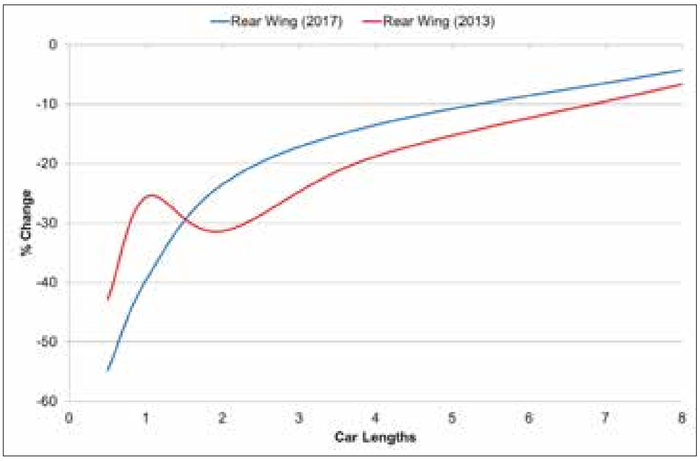


Figure 15: Comparison of changes to rear wing downforce on the racecar following another. Rear wing losses were generally less on the 2017 car than the 2013 car

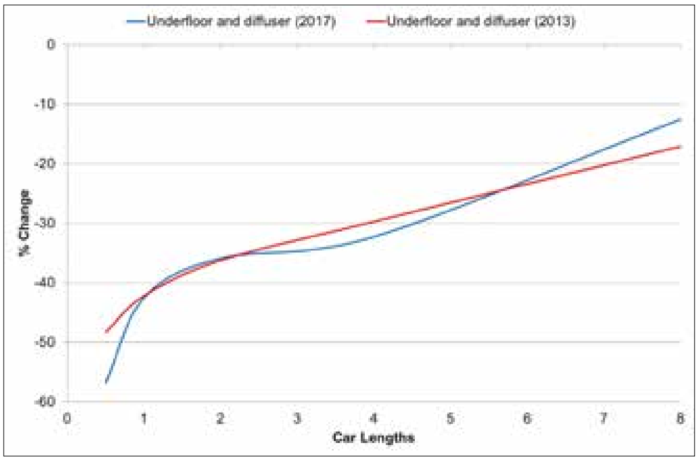


Figure 16: Comparison of changes to underbody downforce. This shows that the cars lost roughly comparable proportions of downforce across the range of separations

longitudinal separations and the plot in **Figure 13** was generated. The first and most obvious conclusion is that the 2017 car also lost downforce when following an identical car and, like the 2013 and the earlier car, it lost more downforce when closer to the car in front. Those are the least surprising of the findings, given that the leading car still punches a hole in the air. However, on closer examination it appears that the 2017 car punched a smaller hole because the total downforce reductions were, on average, smaller; at eight car lengths the 2017 car had only lost around 10 per cent of its total downforce compared to almost 27 per cent for the 2013 car; at four car lengths the figures were similar at roughly 28 per cent and 30 per cent respectively; and at two car lengths the figures were roughly 30 per cent and 36 per cent. At a half a car length the 2017 car lost slightly more downforce than the 2013 car.

Perhaps of greater significance though was the almost complete absence of balance shift with the 2017 car right across the range of separations, and this was mainly because the front and rear wing downforce decline rates were almost identical across the separation range. So although a following car to this 2017 design would still experience a loss of downforce when behind another car, that loss would be smaller and, because there would be no change in aerodynamic balance, there would not be the 'aero understeer' from which the 2013 and earlier design concepts would have suffered. The combination of these two factors – less downforce loss and no balance change – ought to make it significantly less difficult to run close behind another racecar, and hence, when the race circumstances and the driver skill allow, easier to get closer to that leading car.

The differences in how drag changed on these two cars when following another were also interesting. At eight car lengths the 2013 and 2017 cars saw roughly equal drag reductions of around 7 per cent; at four car lengths the 2017 car saw a drag reduction of about 10 per cent but the 2013 car saw about 20 per cent; at two car lengths the reductions were about 16.5 per cent and 25.5 per cent respectively, and at one and a half car separations the reductions were very similar. Would these smaller drag reductions at the bigger separations make it more difficult to 'slipstream' the 2017 car on a straight? The drag reductions were still quite significant, though, so while the rate of (unassisted) closing might be slower, hopefully the gap would be smaller in the first place.

In more detail

Let's examine the changes and their causes in more detail. The plots in **Figures 14** to **16** show direct comparisons between downforce reductions on the 2013 and 2017 cars' main downforce-inducing components. In **Figure 14** we see that the front wing of the following 2017 car lost a lot less downforce at all the intermediate separations, which would surely make life less difficult for the driver of a following car. **Figure 15** shows that rear wing losses were generally less on the 2017 car too, although there was an interesting 'reduced loss spike' at one car length on the 2013 car, perhaps related to that car's high rear wing location. And **Figure 16** shows that the underbodies lost roughly comparable proportions of their downforce across the range of separations, except when half a car length apart, when the 2017 car actually saw a somewhat greater loss.

Using delta-Cp plots, which show the differences in surface pressure coefficients as the result of changes, we can see how the two cars responded when following. **Figures 17** and **18** illustrate the lower and upper surface delta-Cps at four car lengths separation, at which the 2013 and 2017 showed roughly similar reductions in total downforce. Looking at the underside in **Figure 17** it is apparent that the front wing on the 2017 following car saw smaller pressure increases (meaning lesser reductions in suction and

Governing documents

The latest FIA ideas on the way forwards for F1 aerodynamics, some outlined by Charlie Whiting in summer 2015, include proposals to make 2017 F1 cars five to six seconds per lap faster. This would apparently be achieved by using wider cars; wider front and rear tyres; wider front and rear wing; and one reference suggested a reduction in height of the stepped underside plane by 25mm, to put it 25mm above the reference plane beneath the central chassis, rather than the 50mm it has been since 1995.

However, Whiting was quoted as saying that he doubted these changes would result in more overtaking and saw no reason for changes on that front anyway. 'Most of the technical guys feel the work done by the Overtaking Working Group [OWG] back in 2008, in preparation for 2009, was very small by comparison to the two major factors now, which are tyre degradation and DRS. Those two things will probably outweigh anything the OWG did, so we will still have those,' he told *Autosport.com*. 'If, as some people think, it may be a little more difficult to follow a car closely then we can increase the authority of the DRS. I don't see a big issue there.'

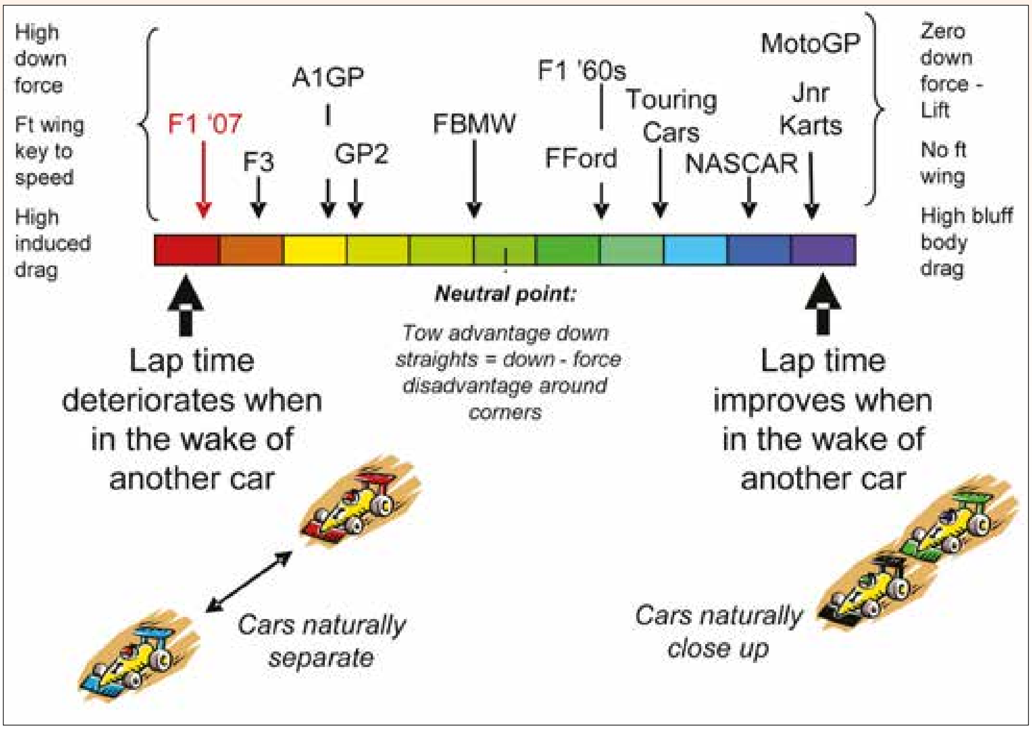
So this proposal does not address the issue of cars being able to follow one another closely and places continued reliance on tyre degradation and DRS to facilitate position changes.

Seemingly another recent proposal from Red Bull was based on utilising large underbody tunnels, an idea that the FIA's (and *Racecar Engineering's*) technical consultant Peter Wright reported on in this magazine in our April 2000 issue (V10N3). In reference to expected rule changes at the time he said: 'On the table for 2001 is less pitch-sensitive and reduced downforce aerodynamics using venturi sidepods but no diffuser, a raised front wing and limits on the number of elements making up the rear wing. The rules are somewhat similar to those used in CART [IndyCar predecessor] where it has been found that not only do venturi sidepods encourage longer side impact structures but also help to maintain aerodynamic balance in the wake of another car on high speed ovals.'

Clearly that particular concept never materialised but the notion re-appeared in modified form in an FIA document Wright jointly authored with Tony Purnell in 2007 entitled 'Formula One 2011: Chassis Regulation Framework'. We reported on this in our September 2007 issue (V17N9) and, in a nutshell, the proposed aerodynamic changes incorporated a standardised underbody with a forward-biased centre of pressure that, it was hoped, would reduce an F1 car's reliance on its front wing, making the aerodynamic balance less sensitive to running in another car's wake. Front and rear wings would be constrained on dimensions and number of elements, and would also be 'active' to enable high downforce in corners but low drag on straights. Interestingly, 'aerodynamic balance' appeared in both these earlier references as a significant contributor to the difficulty in following closely.

The same paper also suggested in a graphic (below) that the factors involved were; high downforce; high dependence on the front wing; and high induced drag (drag generated by downforce-generating devices, especially the rear wing). Given that there is no apparent ambition to make reductions in downforce, which would threaten F1's position at the pinnacle of motorsport performance, the other parameters identified don't seem to tally with current FIA proposals …

There is no apparent ambition to make reductions in downforce



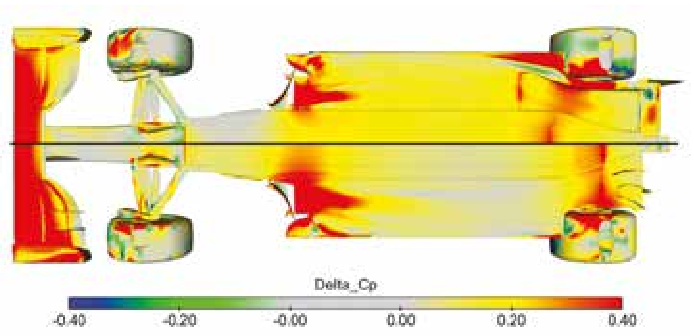


Figure 17: Comparison of changes to surface pressure coefficients on the two cars' undersides at four car lengths separation – the 2017 car is at the top in this image

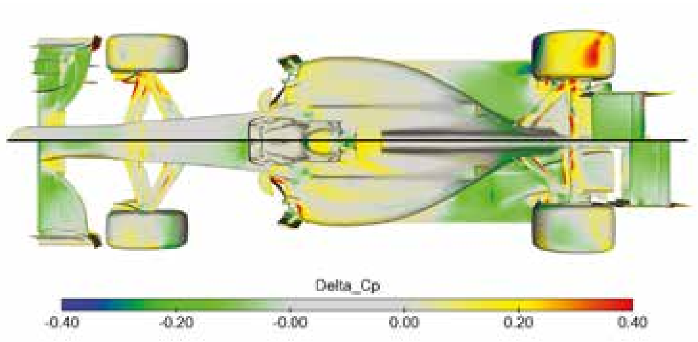


Figure 18: Comparison of changes to surface pressure coefficients on the two cars' top surfaces at four car lengths separation – 2017 is again at top of image

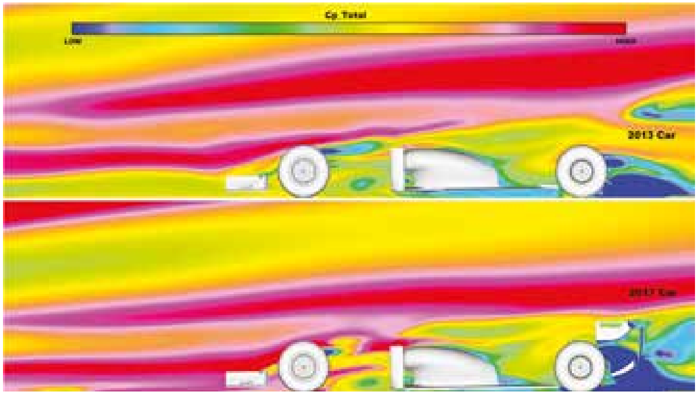


Figure 19: A slice 500mm from the racecar centreline of total pressure on the following car at two car lengths of separation – the 2017 racecar is at the bottom of this image

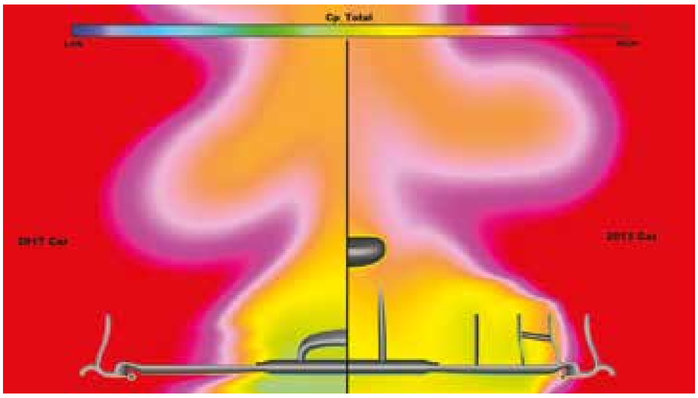


Figure 20: Transverse slice at the front wing leading edge of total pressure – the energy of the airflow reaching outer portion of the 2017 (left) front wing was generally higher

hence smaller losses of downforce). Interestingly though, these smaller losses were on the outer portions of the 2017 car's wing and flaps and under the end plate's footplate, when we might have expected the reduced upwash to have reduced the losses at the centre of the wing. Nevertheless, we can now see why and where the front end of the 2017 following car lost less downforce at these intermediate separations.

Moving aft to the floor and diffuser, the 2013 following car saw greater increases of pressure under its forward underbody, from the leading edge of the splitter to the front quarter of the wider flat floor under the sidepods. The 2017 car's underbody pressure increases were more evenly spread along its length. These two differences would have further contributed to the greater proportionate loss of front downforce on the 2013 car. **Figure 18** shows the delta-Cps on the upper surfaces and once more there are differences on the front wing, the 2013 car showing greater reductions of positive pressure, again translating into greater losses of front end downforce. Elsewhere there are relatively minor local differences between the two cars except perhaps on the top of the rear tyre of the 2013 car, which saw an increase in pressure (which would translate as a reduction in lift).

As mentioned above, the reduced downforce losses of the front wing of the 2017 car when following another car seemed from the delta-Cp plots in **Figures 17** and **18** to be the result of better performance from the outer parts of the wing. **Figure 19**, a vertical slice 500mm from the following car centrelines at two car lengths separation, shows total pressure (total energy) and gives more insight into why this was the case. It is clear that the air that encounters the front wing in the 2017 following car case at this distance from the centreline had greater energy than in the 2013 car. **Figure 20**, a transverse slice of total pressure near the front wing leading edges of the two following cars at two car lengths separation, shows the energy of the airflow reaching most of the outer portion of the 2017 car's front wing was generally higher. In other words, the 2017 design is giving the front wing of the following car an easier time.

MA is confident further modifications to the rear of the 2017 car would enable reductions in the amount of 'dirty' air reaching the front wing of the following car.

Summary

We have clearly seen with these CFD insights why current and recent F1 aero packages make life difficult for a following car. We have also demonstrated how a straightforward re-design producing more downforce from ground effects and less from wings – that could be very cheaply incorporated onto existing cars – overcame a key part of the problem.

Thanks to Dynamic Flow Solutions for its help with this piece.

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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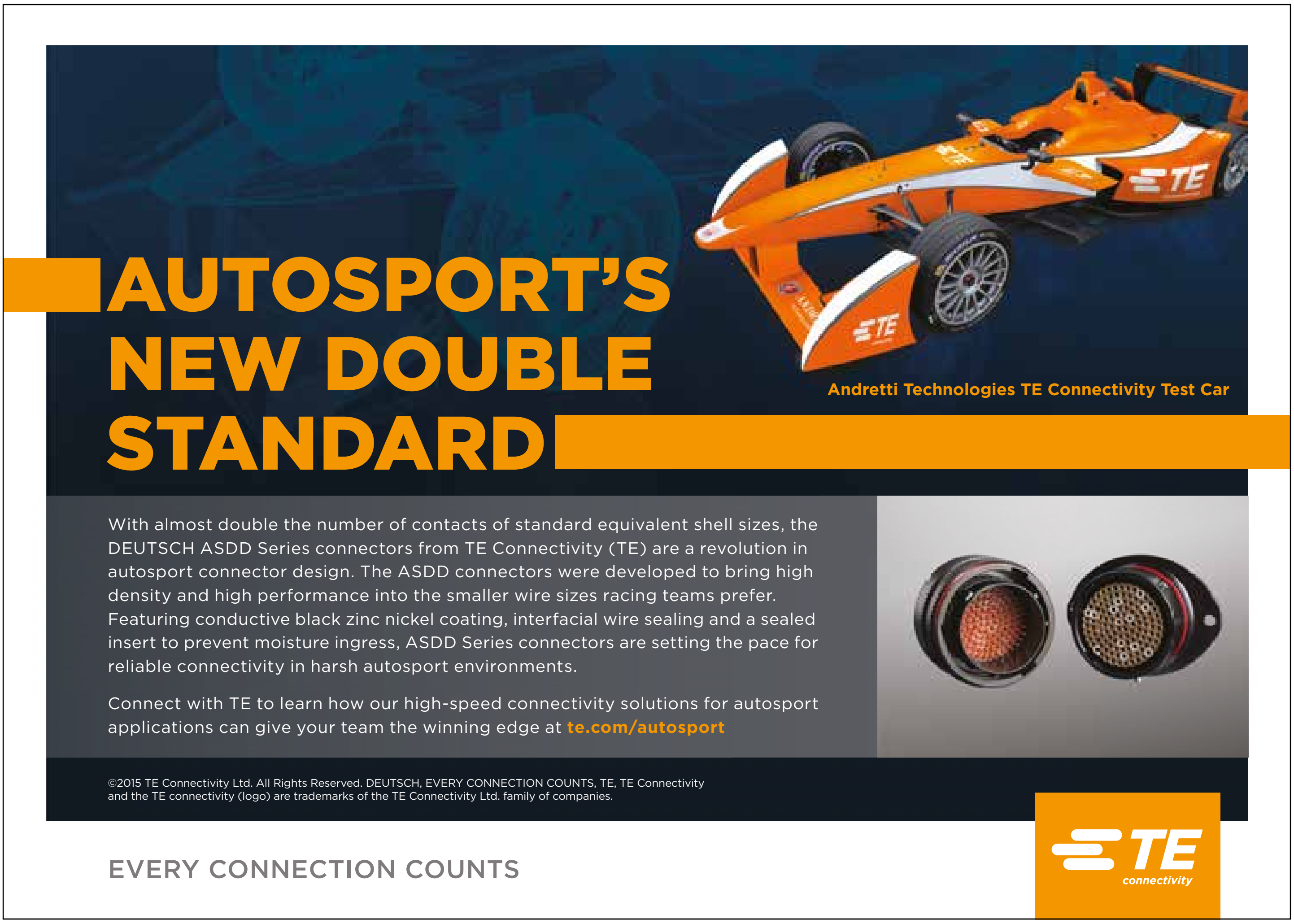
The 2017 car's underbody pressure increases were more evenly spread along its length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Sensor sensibility

Could an ultrasonic fuel flow sensor that's proved itself at the very pinnacle of motorsport become the perfect balance of performance tool further down the racing ladder?

By ANDREW COTTON

The Sentronics ultrasonic fuel flow meter has worked well in Formula 1 and in the World Endurance Championship and is now being marketed to lower formulae

Having proved itself on the world stage through extensive testing, development and racing in both Formula 1 and the World Endurance Championship, the Sentronics ultrasonic fuel flow meter is now about to be introduced to the wider racing community.

These sensors, which are designed by the British company to measure both instantaneous and average fuel consumption, were introduced into the two global series, F1 and WEC, midway through the 2015 season, a year after the initial introduction of the technology by another manufacturer. It's no secret that when the original sensor was introduced there were the sort of problems commonly associated with new technology to begin with, and these led to high-profile cases – including Red Bull taking its argument to court following its first grand prix with the sensors. But today the technology has matured and with the Sentronics variant maximum errors of +/- 0.25 per cent of reading can now easily be achieved – as is required by the regulations.

The company is now looking for further markets for the technology in series other than the high-profile world championships, and its targets include championships that run spec engines, where the sensors could ensure parity across the board, and also those with multiple engine configurations that need to be performance balanced. Indeed, Sentronics firmly believes that by using its scientific approach to monitoring fuel flow and consumption, a more cost-effective and accurate balance can be carried out than is the case using the current tools, such as air restrictors, ballast, and added drag. It's also interesting to note that fuel flow control achieves Balance of Performance (BoP) by promoting efficiency, while traditional approaches actually decreases efficiency.

Cost control

Of course, before the fuel flow sensors will be accepted within the wider racing world any new customers need to be convinced about the product, especially when it comes to costs and reliability. Sentronics managing director Neville Meech is confident these objectives are being met and says; 'We spent a full season talking, listening and reacting to feedback we received from end users in WEC and F1. This enabled us to develop a market leading technology and prove its reliability in a real application environment. Having established reliability and confidence in the technology, reducing the manufacturing cost and increasing output, it should now be cost-effective to introduce the technology elsewhere.

'It is a complex product, but the data from the sensor should be simple to use,' says Meech. 'If we can roll that down through various intermediate series it could finish up in F3 and be able to replace air restrictors.

'As the technology advances, we should be able to make the product smaller and lighter, potentially have it treated like a fuel filter. As with many other sensors, once installed it should perform its function without any special

Sentronics is currently offering three different types of fuel flow meter and they can be bought for about the same price as an air restrictor, which means they could be a cost-effective BoP device

support but rather just be another logged data input,' Meech adds.

Costs are clearly one of the major issues surrounding this technology; even in the big-spending world of Formula 1 the costs have been capped in a tender process. The FIA put out to tender the contract to exclusively supply the Formula 1 World Championship in 2016 and 2017. The price of the fuel flow meter is capped for the first time, to €7500 with a warranty of 100 hours functionality. The cost of functionality of 100 extra hours is not allowed to exceed €2500 and the lifetime of a sensor may not be less than 400 hours.

But for use in the more junior series Sentronics believes that its lower cost base model is of comparable cost to air restrictors and offers more flexibility than the current range of BoP options. 'The feedback is that people want the high-end accuracy regardless of the series,' says Meech. 'The base model retails at £2500, running up to £9000 for a bespoke specification device.

'We currently have three different models already available, for the entry level model we achieve a lower cost option by only verifying the unit's performance across temperature but not specifically calibrating the device. By adopting this technique we can achieve accuracies of +/- 0.75 per cent of reading. For more advanced models each sensor is individually calibrated across temperature and flow rates allowing us to achieve accuracies of +/- 0.25 per cent of reading. The calibration requirements clearly represents a significant portion of the costs.

'In Formula 1 and WEC, the sensor manufacturers are not permitted to provide the calibration, but in other series, there is no reason, if we were supplying the whole series, why we could not offer the whole package of the sensor and calibration,' Meech says.

Breathe easy

From the start, the fuel flow sensor was designed to replace the air restrictor, allowing the engines to perform better by reducing the amount of fuel consumed rather than air inducted. In Formula 1 and the WEC banks of engineers analyse the data to ensure that a penalty is not unfairly imposed but, should the sensor replace air restrictors, there is the opportunity to leave analysis until after the race. Even then, says the FIA, analysing the data is a difficult job that would replace what is now a relatively simple process of choking the engine by covering the air restrictors.

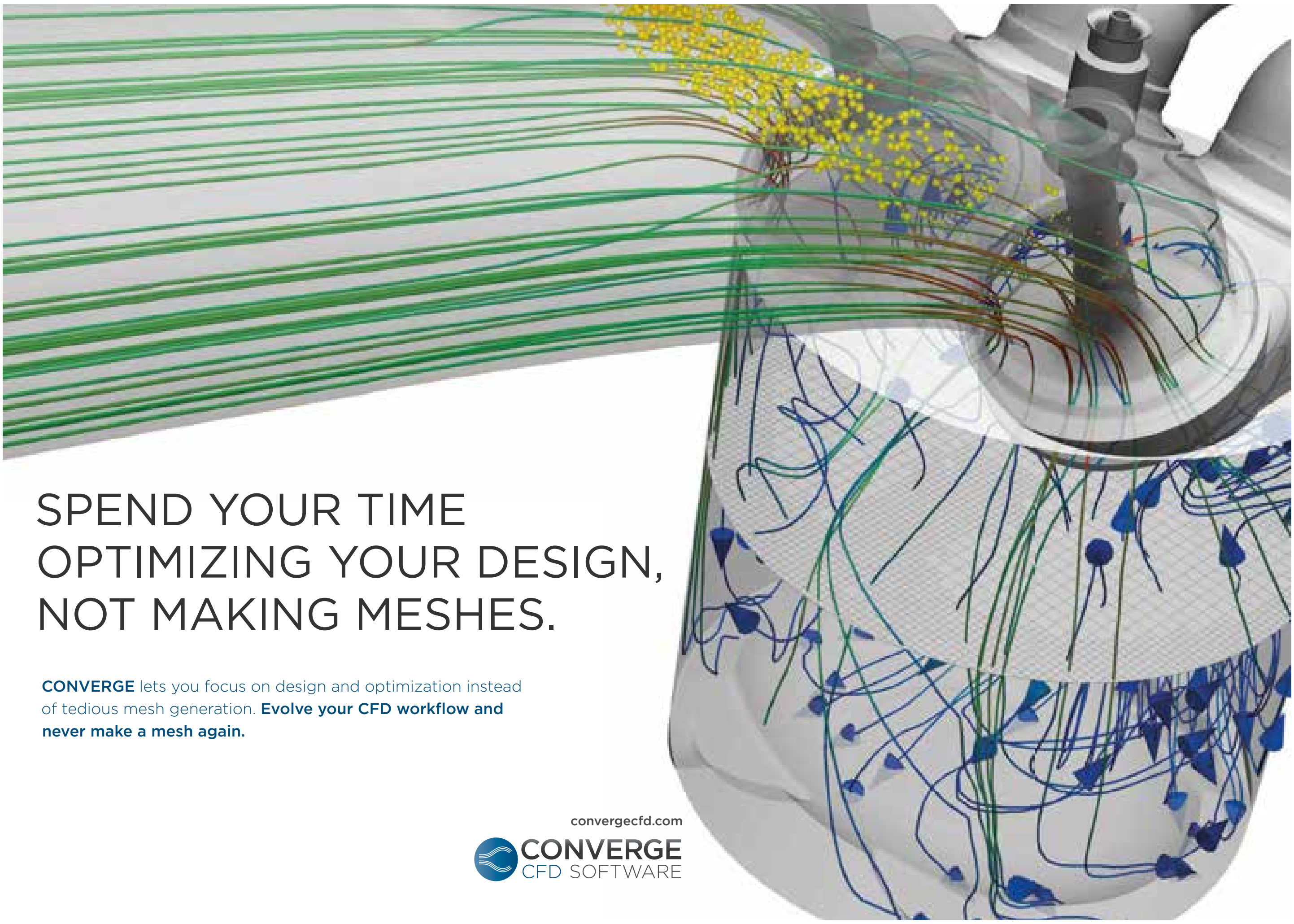
But Meech points to other benefits with the Sentronics system: 'If it is going into a series where it would replace a device like an air restrictor, the benefits are that now an engine manufacturer has the ability to maximise the engine performance rather than be restricted on the amount of air it can take in,' he says. 'You not only free up the engine manufacturer to perform a better job, you can balance the performance across the competitors. The FIA, or governing body, can adjust the balance of performance across all the competitors, or monitor and apply restrictions if they need to, and that potentially makes more exciting racing.'

Similar to the way in which the WEC balances its engines, limiting the amount of fuel consumed by each powerplant and measuring it using the fuel flow meter would solve the performance balance problem with a cost-effective solution. The DTM, Japanese Super GT and Australian V8 Supercar series, where cost-effective methods of balancing different engine configurations need to be adopted, might be ideal markets for this sort of technology.

Wider horizons

The FIA agrees that sensors should become more widely used, but has its reservations regarding their development to date. Its technical director, Bernard Niclot – though it's important to note he is speaking about sensors

Limiting the amount of fuel consumed and measuring it using the fuel flow meter would solve the performance balance problem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The accurate monitoring of fuel usage is vitally important at Le Mans and improved sensor technology has made it possible for LMP1 cars to run closer to the maximum fuel flow limit

in general as opposed to Sentronics' products in particular – said; 'If we go to a more reliable sensor, more user-friendly sensors that are plug-and-play, then we can begin to think of other applications. The first thing is to get such a sensor. The problem in the championships that we manage is that you cannot replicate what you do in one championship in others. You have championships where you have people who pay money, and they want to be rewarded in the technology that they can demonstrate and show that they have the best technology.

'With the other championships, like GT3, which are much more oriented to customers, people want to show their product, they don't want to show the highest level of technology inside. They can do that in Formula E, WEC or F1. You cannot apply the same solution in each championship. Typically the fuel flow sensor, if it becomes more standard, can be used in other championships, but we have to be careful in which ones. If, in the future, fuel flow becomes easier than measuring restrictor size, then there is no problem, but we are not at that stage yet.

'We trust completely what the sensors do and what they deliver, but you need engineers to monitor this, in the teams and in the FIA, because when you see the data, each signal has spikes, things that go wrong, and you have to understand them. Can I consider a spike that is not representative, or is it telling me something representing reality? For the moment, you need engineers for this,' Niclot says.

To counter this Sentronics points out that spikes in the data can be created by aliasing and this is precisely what it has now addressed.

Aliasing problems

While Formula 1 has gone for a sole supplier, the WEC continues with an open market. Sentronics has developed its sensor to be more accurate than ever before, and is working with several engine manufacturers to address the challenging problems surrounding flow measurement aliasing. Having a sensor that operates in excess of a genuine 2kHz has addressed this issue of aliasing that has been a problem in the past. That has led to a more accurate sensor that allows for strategy changes mid-race. Meech says: 'Some of the issues that we see in F1, with the aliasing problems, are where sensors don't measure fast enough to capture the higher frequency flow components. In summary, if you are not sampling quickly enough, you miss real changes in flow that equate to error. This could be as much as several per cent of reading or more.'

With a rolling three-lap average for the LMP1 cars, accurate monitoring of fuel usage is paramount. Where that crucial extra lap at Le Mans is marginal, any inaccuracy is magnified and could potentially lead to a penalty or retirement of the car. More accurate sensors mean that the range of error is smaller, making it possible to run consistently closer to the maximum fuel flow limit.

Indeed, this could be something that helped Mercedes in F1 last year as it worked closely with Sentronics to develop its 2kHz technology ahead of its homologation mid-season. 'Mercedes in particular have been smarter than most in identifying these problems in F1 and came to us early in the year,' said Meech. 'Your laboratory industry standard meter that everyone uses in the dyno test cell updates at 100Hz. The FIA said they required a minimum sample rate of 1000hz, 1000 times a second, but we are now measuring at over 2000hz, 20 times faster than the accepted industry laboratory flow meter – and we have to put it on a car with extreme vibration and heat.'

Sentronics says that it has now developed its sensor to a level in motorsport that it can be relied upon, and that now is the time for other series to think about embracing the technology. So, has the future of ultrasonic fuel flow sensors finally arrived?

'Can I consider it a spike that is not representative, or is it telling me something representing reality? You need engineers for this'

Getting to grips

Racecar's number cruncher explains how mathematics can help engineers create a very effective tyre model from scratch

By DANNY NOWLAN

One of the most common questions that I get regarding simulation is this: 'What happens when I don't have tyre data or I have serious doubts about the tyre data I have been given?' It's an important question, too, because if your base model is way off it can take a lot of time to get yourself back on track.

Fortunately the fix for this is actually pretty simple and its basis comes as a spin off of using a second order curve fit of the traction circle radius *vs* load characteristic. If you can combine this with some baseline simulated or actual data, not only can you get a really good start point but you'll also get a good idea of set-up sensitivities. This technique is something I've been using in the ChassisSim community recently to good effect. It's a great example of hand calculations meeting computer aided engineering, which makes this discussion even more relevant.

To kick of this explanation it's worth revisiting the second order fit of the traction circle radius *vs* load characteristic. There are many forms this can take, but the most instructive way of looking at this is presented in **Equation 1,** while some typical values for this are presented in **Table 1.** When you plot it all out you'll have something that looks like **Figure 1**.

Where things get real interesting is the relationship between the initial coefficient of friction and the peak tyre load that produces the most force. If we take the derivative of **Equation 1** with respect to load and set it to zero we can show **Equation 2** – where Lp is the load where the maximum value of the traction circle radius will occur. Doing a little bit more manipulation of **Equation 1** and **2** the maximum possible value of the traction circle radius is shown in **Equation 3**. This is best illustrated graphically, see **Figure 2**.

What this shows is that the maximum force of a tyre can be described by its peak load and initial coefficient of friction. A spin of this curve is that as the peak load decreases the shape of **Figure 2** becomes more compressed.

What this means is you have more set-up sensitivity. The downside is, if you exceed this load the tyre model will go over the curve and the grip will drop off. The inverse of this is where the peak load is very large. In this situation when you make a change it will do very little.

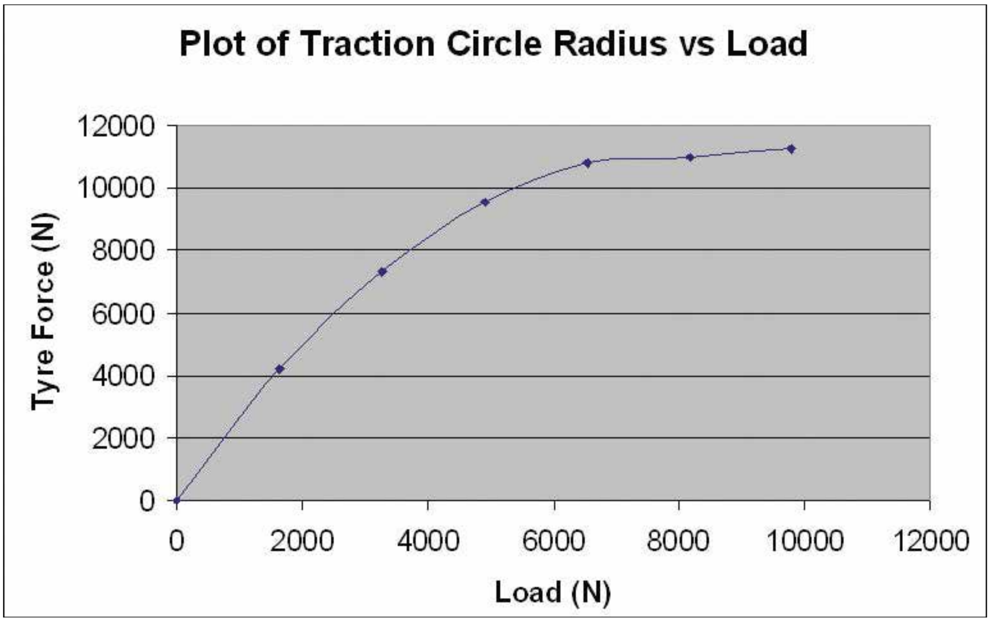

Figure 1: Plotting out Equation 1 will give you this second order plot of the traction circle versus the load characteristic

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)

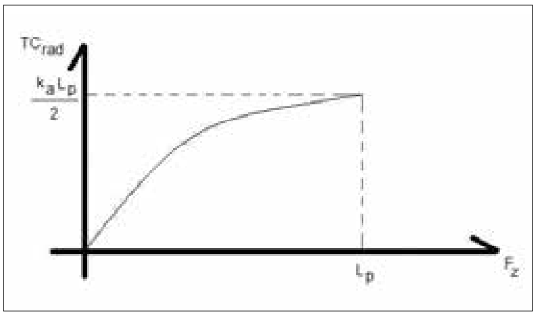

Figure 2: This shows that the maximum force of a tyre can be described by its peak load and initial coefficient of friction

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

$$L_p = \frac{1}{2 \cdot k_b}$$

EQUATION 3

$$TC_{RAD\_MAX} = \frac{k_a \cdot L_P}{2}$$

This is a great example of hand calculations meeting computer aided engineering

EQUATIONS

EQUATION 4

$$F_{yf} = wdf \cdot m_t \cdot iR \cdot V_x^{\ 2}$$

$$F_{yr} = (1 - wdf) \cdot m_t \cdot iR \cdot V_x^{\ 2}$$

Here we have

F_{yf} = Front lateral force deduced by plugging the front loads into eq (1)
F_{yr} = Rear lateral force deduced by plugging the rear loads into eq (1)
wdf = Front weight distribution (%/100)
m_t = Total car mass in kg
i_R = Peak corner curvature in 1/m
V_x = Cornering speed (m/s)

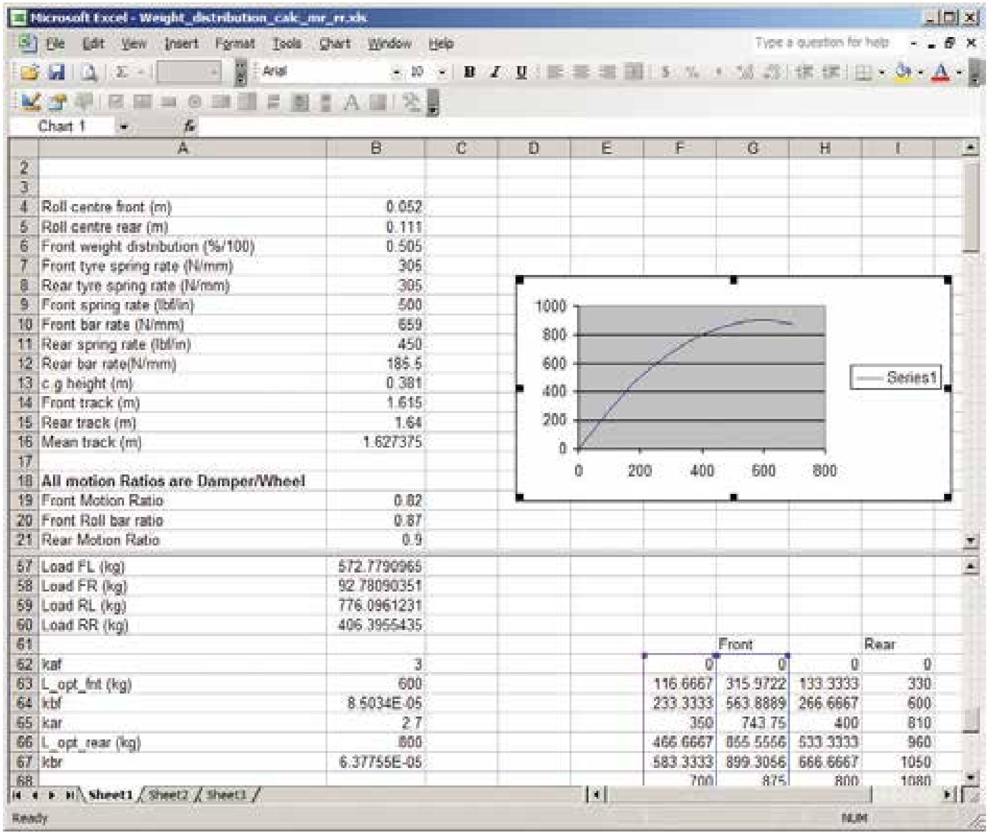

Figure 3: Load transfer distribution worksheet that's been expanded to include tyre force and cornering speed predictions

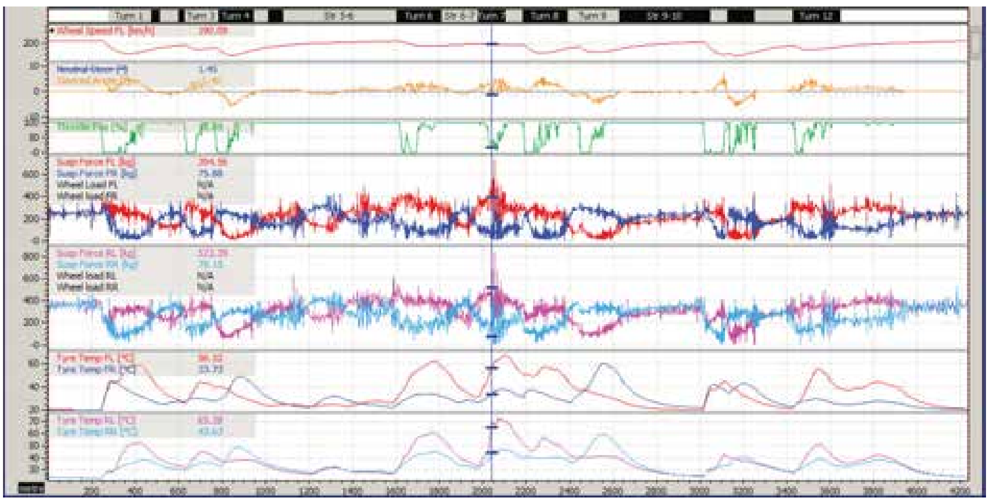

Figure 4: A plot of tyre loads for a given lap; it's important to determine the peak value of the loads for both the front and rear

We'll quantify this mathematically in a moment, but where this comes out to play is when you use **Equations 1** and **3** for a simple static load balance. All that you are doing is taking your roll centres, springs, bars and front and rear track and aero information to determine your tyre loads for a given lateral acceleration and speed. Your front and rear cornering speeds can be determined by what's shown in **Equation 4**, which, believe it or not, is the basis of pseudo-static simulation.

The payoff of all this is that you can combine it into a simple set-up sheet and start to use it to predict cornering speeds. A screen shot of this is shown in **Figure 3**. This is the worksheet that I use for calculating load transfer distribution and I've expanded it to include tyre forces and cornering speed predictions.

While **Figure 3** is not going to win any beauty awards it is actually very powerful because in an instant you can adjust your initial coefficient of friction and peak tyre load to estimate what your cornering speed should be for a given speed and peak curvature (this you can pull off logged data). Then, what you can do is change the set-up parameters to see how sensitive either end is to set-up changes. This actually started its life as a sanity check for what ChassisSim would output, and it has proven to be very useful.

Peak performance

The next step in this process is to estimate the peak tyre loads. You can use this with either simulated or actual data. The key is to look at the peak tyre loads as illustrated in **Figure 4.**

The important thing here is to look at the data and determine the peak value of the tyre loads front and rear. The peak load in this case was about 400kgf at the front and 500kgf at the rear. As a rough rule of thumb you add about 100kgf to get the peak tyre load and this is what you plug into the Excel sheet we illustrated in **Figure 3.**

Once you have this you will play with the initial coefficient of friction to dial in your corner speeds and which end you want to slide; oversteer or understeer. You do this by taking some values from the data from low speed, medium speed and high speed corners. You will then play primarily with the initial coefficient of friction and then you will tweak the peak load to dial in the results.

When this is completed you then enter the numbers into ChassisSim, or whatever simulation package you are using. In ChassisSim speak you reset the tyre load axis to correspond with the peak load you determined in **Figure 4** and **Figure 3**. You then use the tyre model quick start to enter the tyre curve you determined in the Excel sheet in **Figure 3**. An example of this functionality is shown on the next page in **Figure 5.** You then run the simulation and tweak the global grip factors.


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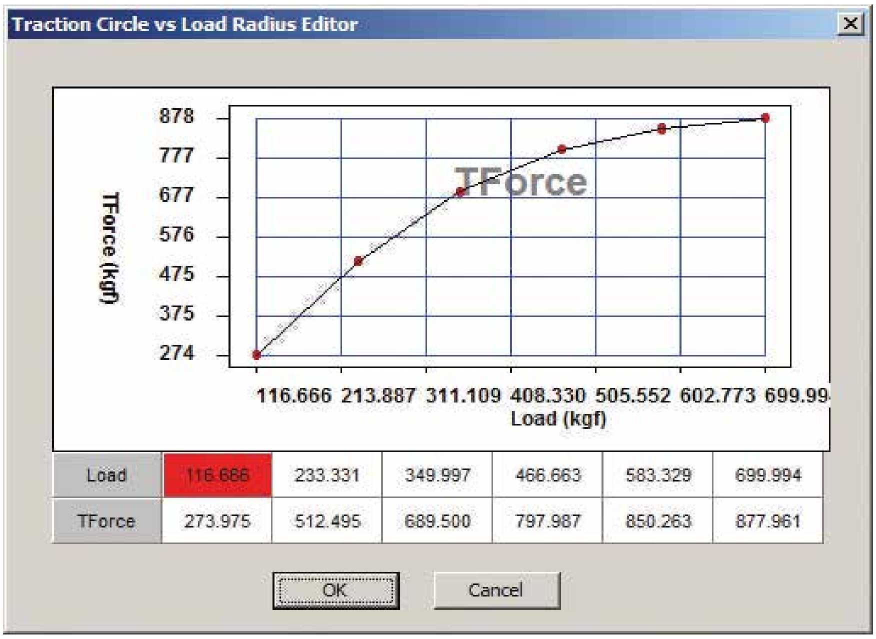


Figure 5: An example of the tyre force 'quick start' in ChassisSim – with the tyre curve from Figure 3 entered

EQUATIONS

EQUATION 5

$$F_{yT} = k_a(1-k_b\cdot(L_S+\Delta L))\cdot(L_S+\Delta L)+k_a(1-k_b\cdot(L_S-\Delta L))\cdot(L_S-\Delta L)$$
$$\therefore F_{yT} = 2\cdot k_a\cdot(1-k_b\cdot L_S)\cdot L_S - 2\cdot k_a\cdot k_b\cdot \Delta L^2$$

EQUATION 6

$$F_{yT} = k_a(1-k_b\cdot(L_S+\Delta L))\cdot(L_S+\Delta L)+k_a(1-k_b\cdot(L_S+\Delta L))\cdot(L_S+\Delta L)$$
$$\therefore F_{yT} = 2\cdot k_a\cdot(1-k_b\cdot L_S)\cdot L_S + 2\cdot k_a\cdot \Delta L\cdot(1-k_b\cdot(2\cdot L_s+\Delta L))$$

EQUATION 7

$$\Delta F_{yT} = 2\cdot k_a\cdot k_b\cdot \Delta L^2$$

EQUATION 8

$$\Delta F_{yT} = 2\cdot k_a\cdot \Delta L\cdot(1-k_b\cdot(2\cdot L_s+\Delta L))$$

EQUATION 9

$$\Delta L = \frac{LLTF\cdot m_t\cdot a_y\cdot h}{tm} = \frac{(51.6/100)\cdot 700\cdot 1.8\cdot 9.8\cdot 0.3}{1.57} = 1217.5N$$

EQUATION 10

$$\Delta F_{yT} = 2\cdot k_a\cdot k_b\cdot \Delta L^2 = 2\cdot 2.7\cdot(7.3\times 10^{-5})\cdot(1217.5)^2 = 584.3N$$

EQUATION 11

$$\Delta L = \frac{LLTF\cdot m_t\cdot a_y\cdot h}{tm} = \frac{(44.7/100)\cdot 700\cdot 1.8\cdot 9.8\cdot 0.3}{1.57} = 1054.7N$$

Table 2: Open-wheeler parameters

Quantity	Value
Car mass	700kg
Weight distribution at the front	0.43
CLA	3
Rear bar range	0-70N/mm
c.g height	0.3m
Corner speed	120km/h
Corner acceleration	1.8*g*
Mean track	1.57m
Lateral load transfer range at the front	51.6 - 44.7%

Table 3: Tyre model numbers for a high downforce open-wheeler

Quantity	Value
Ka (Initial coefficient of friction)	2.7
Lp (Peak load)	700kg
Kb (Load drop off / N)	7.3x10-5 /N

I can't speak for other simulation packages, but the final step in this process is to use the ChassisSim tyre force modelling toolbox to fill in the details. Usually this is the cherry on top but it's actually needed because, tyres being tyres, they can exhibit some non linearities and the tyre force modelling will help you fill in the details. The tyre force modelling toolbox works by doing a whole bunch of track replays and comparing simulated to actual lateral *g* and changing the tyre model to minimise the difference between the two.

Quantifying data

To complete this discussion we can use what we discussed to quantify set-up sensitivities. Laterally, let's say we have a delta load of +/- ΔL N and a static load of Ls N. From **Equation 1** it is seen in **Equation 5.** The kb term comes from **Equation 2**. Longitudinally, for a uniform change of load of ΔL N per tyre we see **Equation 6.**

What all this means in plain English is that we can calculate the lateral forces as function of static load and differential load. In terms of the differentials laterally we have **Equation 7.** Longitudinally we have **Equation 8.**

To quantify this discussion let's consider an open-wheeler running moderate to high downforce. The parameters for this vehicle are shown in **Table 2**, while the tyre values are to be found in **Table 3.**

For clarity we'll focus our discussion at the front of the car, using the parameters from **Table 2.** So let's consider when the front bar is disconnected. The change in load will be given by **Equation 9.** The change in lateral force for this change will be **Equation 10**.

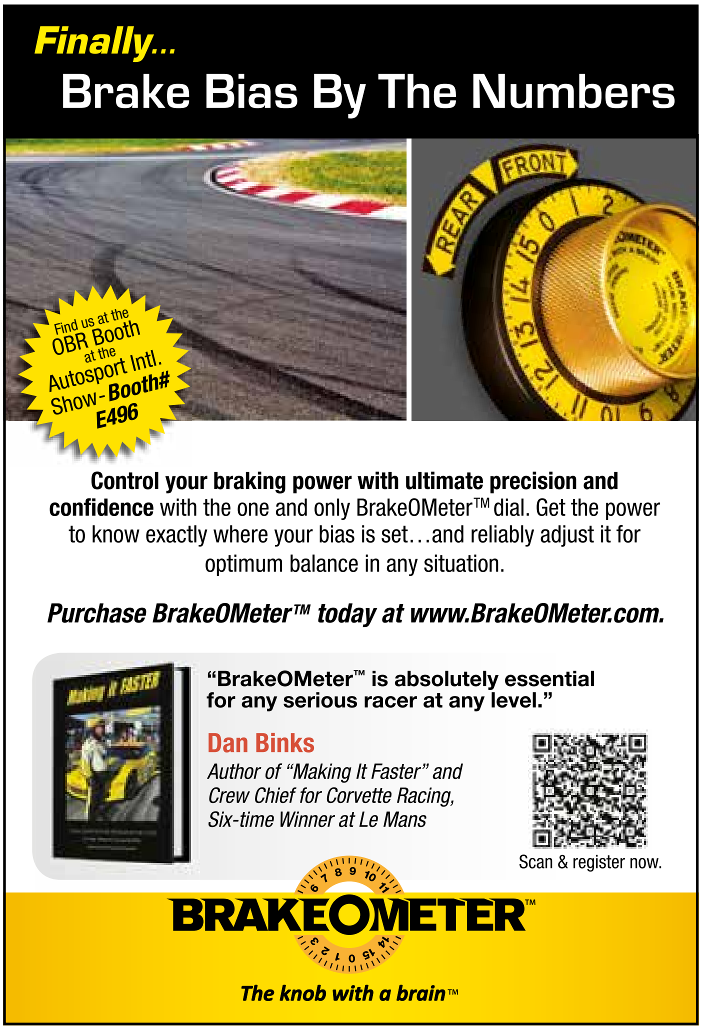
Let's now consider the case where the rear bar is at 70N/mm. The load transfer in this case will be given by **Equation 11**. So the change in lateral force for this case will be **Equation 12** (see equations box on next page).

Here is where the rubber meets the road. From **Equation 6** all we need do to figure out the differential force and hence differential corner speed is to subtract the two differentials in lateral force, and we have **Equation 13**. Since the cornering speed is given by **Equation 14** It surmises that the differences in speed will be the square root of these changes. So in this case we have **Equation 15.**

So what this is telling us is that disconnecting the rear bar will lead to a 1.2 km/h change in front cornering speed.

Long weight

To complete this section of this discussion let's evaluate a longitudinal load change. Let's say we make a ride height change and it leads to a CLA change of 0.1. So at our quoted speed of 120km/h, assuming this is distributed with weight distribution, we have a change in load as represented in **Equation 16**. So the static load is given by **Equation 17,** while the differential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EQUATIONS

EQUATION 12

$$\Delta F_{yT} = 2 \cdot k_a \cdot k_b \cdot \Delta L^2 = 2 \cdot 2.7 \cdot \left(7.3 \times 10^{-5}\right) \cdot \left(1054.7\right)^2 = 438.5N$$

EQUATION 13

$$\Delta F_y = 584.3 - 438.5 = 145.8N$$

$$\therefore \Delta F_y = 145.8N / \left(m_t \cdot g\right) = 145.8 / \left(720 \cdot 9.8\right) = 0.02g$$

EQUATION 14

$$F_{yt} = \frac{m_t \cdot V_x^2}{R}$$

EQUATION 15

$$V_{x\_new} = V_x \sqrt{0.98} = 120 \cdot 0.989 = 118.8km/h$$

EQUATION 16

$$\Delta L = wdf \cdot 0.1 \cdot 0.5 \cdot \rho \cdot V^2 = 0.43 \times 0.1 \times 0.5 \times 1.225 \times \left(120/3.6\right)^2 = 29.26N$$

EQUATION 17

$$L_S = L_{CW} + L_{AERO}$$

$$= 0.43 \times \left(700 \times 9.8 + 3 \times 0.5 \times 1.225 \times \left(120/3.6\right)^2\right)/2$$

$$= 1913.86N$$

EQUATION 18

$$\Delta F_{yT} = 2 \cdot k_a \cdot \Delta L \cdot \left(1 - k_b \cdot \left(2 \cdot L_s + \Delta L\right)\right)$$

$$= 2 \times 2.7 \times 29.26 \times \left(1 - \left(7.3 \times 10^{-5}\right) \times \left(2 \times 1913 + 29.26\right)\right)$$

$$= 113.5N$$

EQUATION 19

$$V_{x\_new} = 120 \times \sqrt{\left(1 + 0.0165\right)} = 120.98km/h$$

change in lateral force can be evaluated using **Equation 5**. Working the numbers we now see **Equation 18**. So this will be a change of 0.0165*g*. This will lead to a cornering speed change as shown in **Equation 19**. In order to produce a CLA change of 0.1 you are looking at a 2mm to 4mm change in front/rear ride height, or two degrees of front/rear wing.

The key thing about this discussion is that at least we have some gauge on set-up sensitivity. It won't be perfect because these discussions rarely are. However, by using **Equations 1** to **3**, incorporating our Excel sheet and using a bit of simulation, we have filled in some very big blanks about what the car is capable off. Also **Equations 5** to **9** can be readily incorporated into an Excel set-up sheet.

Power tool

The second order fit of the traction circle radius *vs* load curve of the tyre is a powerful tool in creating a tyre model. We can quickly visualise a tyre in terms of its initial coefficient of friction and peak load. We can then use a static force balance to see what these values need to be. By using simulation and comparing it to actual data we can fill in the details and get something we can use. Once we're aware of the numbers we can get an initial read on the set-up sensitivity of the car. All of these tools will give you an innate feel of the numbers, so you know what to change when the car hits the track.

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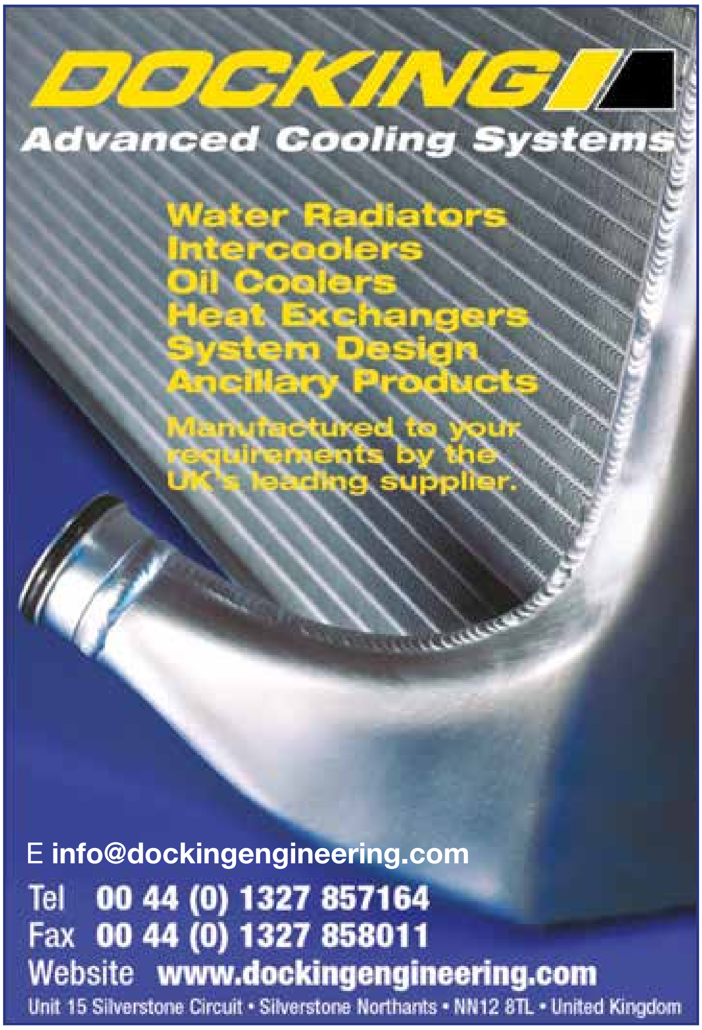
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Another fine mesh

Engine builder Ilmor has boosted its IndyCar operation thanks to the adoption of a radical CFD program which helps it to reduce development time and costs

By NICK BAILEY

Ilmor-built engines powered Chevrolet to every pole position during the 2015 IndyCar season

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, whilst reducing development time by around 50 per cent and providing a 75 per cent reduction in the prototype build cost for its IndyCar project.

Ilmor's achieved this by using Converge, a novel program specifically created to assist engine designers to optimise design, performance and efficiency through CFD simulation. The ease at which Ilmor's engineers have got to grips with the new software means that it is now already able to offer Converge as part of its engine design and optimisation service to its burgeoning customer base in automotive applications.

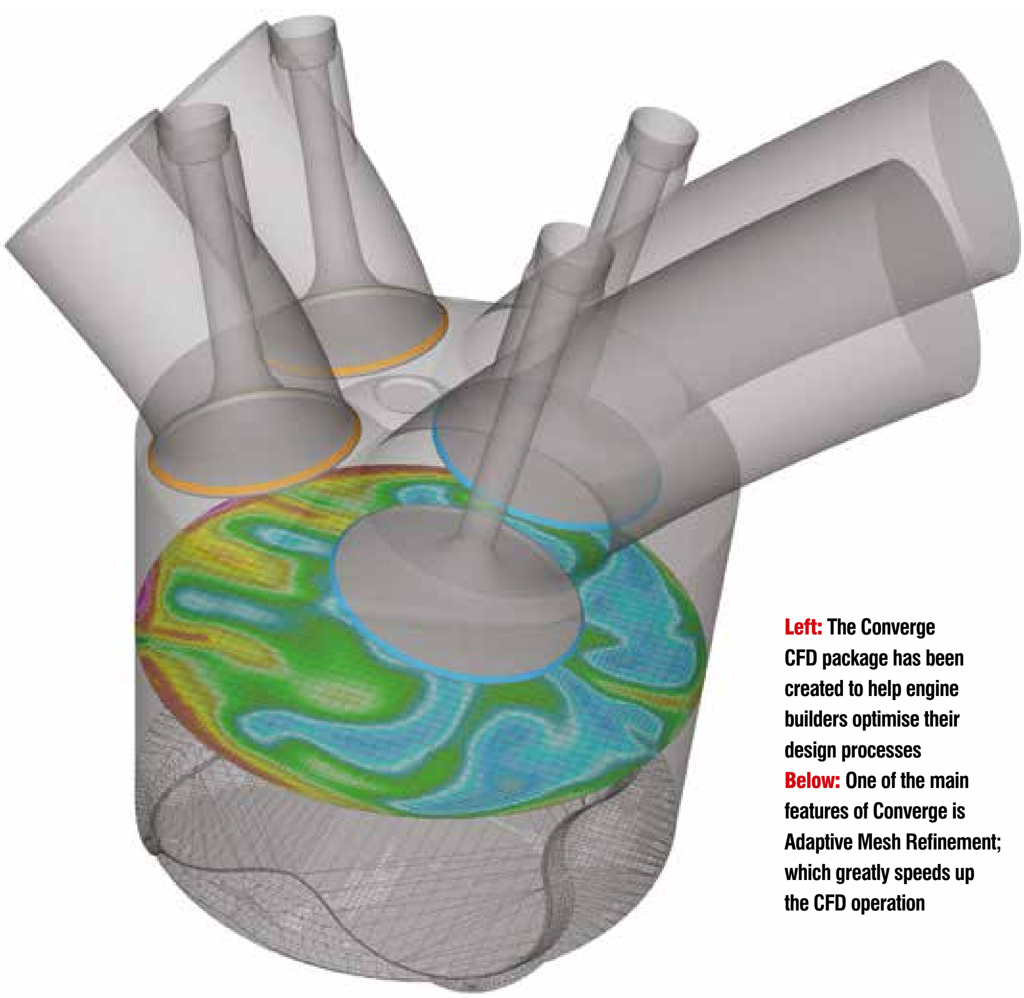
Convergent Science's Converge software differs from legacy CFD programmes, as it fully couples and automates the mesh at run-time, saving Ilmor eight weeks in development time on its 2016 IndyCar Chevrolet engine update. Generating the mesh also crucially eliminates user-to-user variation inherent in traditional CFD programmes that can lead to correlation errors.

Steve O'Connor, chief engineer, Ilmor Racing, says: 'With over 30 years of experience, our engineers are incredibly adept at creating ideas to extract performance from road or race engines. This is demonstrated by having won 17 IndyCar championships including the 2015 title, as well as securing every pole position in 2015.

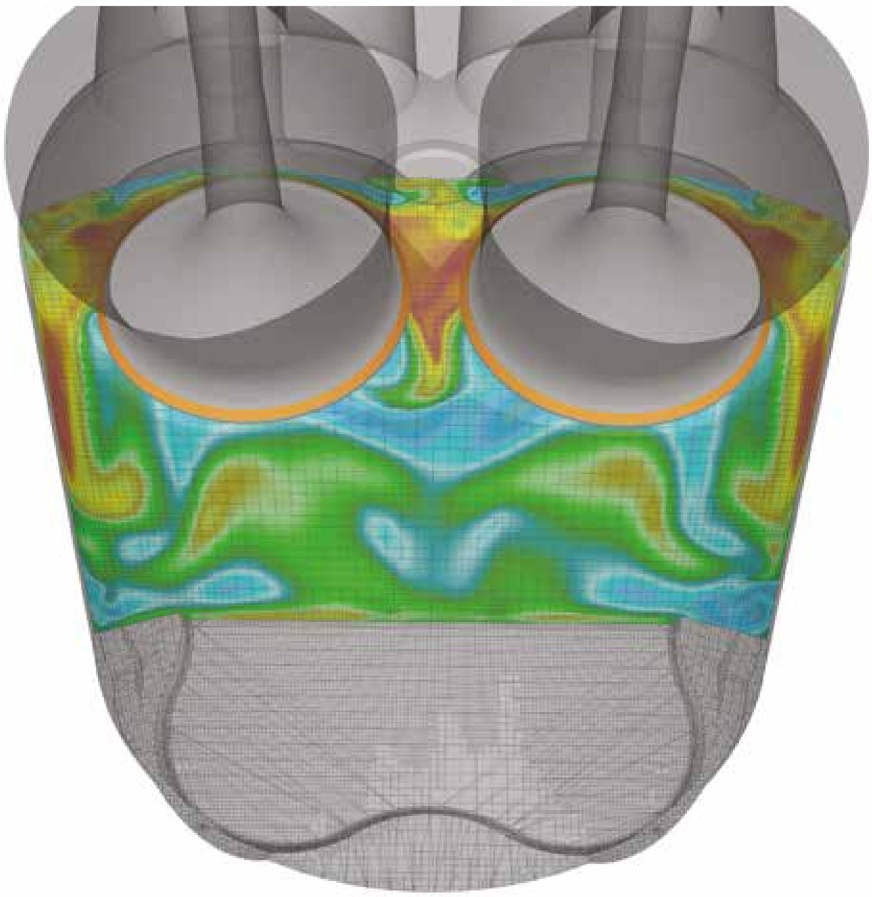
'We have always used simulation but to date it has supported our traditional approach of us actually producing a part or concept and then trying it on the dyno. This development method obviously provided accurate, real world data but was more costly and time consuming. Our engineers heard about Converge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

O'Connor added: 'At the moment, we are using Converge intensively to further optimise the combustion system of the Chevrolet IndyCar engine. The work is 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. The use of Converge has improved our understanding of the complex mechanisms that occur within the combustion chamber and has guided us along new avenues of development.'

Converge CFD fully couples and automates the mesh at run-time



Left: The Converge CFD package has been created to help engine builders optimise their design processes
Below: One of the main features of Converge is Adaptive Mesh Refinement; which greatly speeds up the CFD operation



A more virtual development approach has brought benefits to the testing side, too. A fully instrumented engine test stand is expensive and switching to Converge CFD has helped Ilmor to reduce dyno usage for checking only the developments that pass the CFD stage. 'In just six months we discovered Converge was a cost-effective and viable alternative to real world testing,' says O'Connor. '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 CFD but also how we manage our entire development process.'

Rob Kaczmarek, director of global marketing at Convergent Science, says: 'Ilmor often leads on the track and now it is really leading the field in embracing CFD for engine development and optimisation. Converge was created by engine specialists to address the deficiencies of other CFD codes in their field and to focus on the areas that really mattered to them. Factors such as flame propagation and knocking can be a real problem. You can create larger mesh cells to save time but your accuracy diminishes or, you can have too small mesh cells and find your run-times extended. Converge, thanks to its coupled and automated meshing, offers a run-time grid generation and refinement resulting in grid-convergent results.

'This means Ilmor's engineers can use their time to come up with more creative ideas instead of building meshes. Providing grid-convergent results is a real benefit to its consultancy business as well, because it offers the ability to study design optimisations accurately,' Kaczmarek added.

Converging technology

Ian Whiteside, chief engineer at Ilmor Advanced Projects, says: 'Converge also links seamlessly with GT-Power, the 1D Simulation package that we use here at Ilmor. By coupling the two software packages we have been able to optimise the design of complex multi-cylinder inlet and exhaust systems within a reasonable model size that runs quickly even with modest computing power.'

With opportunities to use Converge in areas such as optimising flame propagation, and the use of the highly advanced models for understanding sprays and even exhaust after-treatment, Ilmor is now keen to blend its knowledge with Converge tools to acquire more OE contracts. 'We are known for our motorsport success, but we are doing an increasing amount of Automotive and research and development work,' Whiteside says, before adding. '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.'

'The use of Converge has guided us along new avenues of development'

Formula 1 engine suppliers defend the high price of their hybrid power units

F1 engine builders have said that it would be difficult to justify supplying cut price power units to smaller teams, and they have insisted that they too are operating under their own budget constraints.

Current hybrid power unit supply deals are said to be worth around €20m a year, which makes up a large part of the budget for a small F1 operation, and this has led to a move to bring in an alternative low cost, performance balanced engine – although at the time of writing the likelihood of this being introduced looks slim.

The engine manufacturers have also been repeatedly asked to cut the price of their units, but they insist that they simply cannot do this without a good business case, and add that in the final analysis all F1 business needs to be justified.

Cyril Abiteboul, managing director of Renault Sport F1, said: 'We need to demonstrate [to the wider Renault business] that investing in F1, or spending – because it's not an investment – is more cost-efficient than spending, for instance, in regular advertising.

'We need to be extremely careful about whatever can, I would say, threaten or destabilise our business case in Formula 1, and obviously subsidising the cost of engines to independent teams – even though we appreciate it might be a necessity to be in the sport and to have a healthy sport – it is something that is endangering the business case,' Abiteboul said.

Mercedes executive director Toto Wolff (left) and Renault Sport F1 managing director Cyril Abiteboul agree that their first duty is to justify their F1 business to their parent companies rather than offering cheaper power units to cash strapped teams

Toto Wolff, executive director at Mercedes, agreed: 'It is a situation where all those big OEMs are trimmed on efficiency and particularly the car industry, [they] are in a constant loop of margins, recalibrating margins, of trimming down costs and Formula 1…needs to have the right price for what you do and this is why you can't just apply easy-going mentality and say it doesn't matter if you spend a little bit more or a little bit less. It does because somebody will look at the numbers and somebody will make a decision whether it makes sense or not.'

Maurizio Arrivabene, team principal at Ferrari, said: 'We need to be careful. Mr Marchionne [Sergio Marchionne, head of Ferrari-owning Fiat Chrysler Automobiles] is not joking about that, to respect the budget that is assigned to us. We are not the kind of company that is throwing money out of the window.'

Renault believes engine supply role was poor value for money

Renault has said that the reason it is returning to Formula 1 as a fully-fledged constructor, having now completed its long awaited takeover of the Lotus team, is because the marketing return on its engine supply deal was not effective.

The French car giant signed a letter of intent with Lotus – which grew out of Renault's last works effort ending in 2009 – in September, with the deal finally sealed in December.

It's understood that the buyout has cost Renault somewhere in the region of €100m, and it has pledged to stay in the sport for at least nine years. The deal was held up for months as Renault negotiated its share of constructors' championship bonus money and 'historical' payments – arguing it was due the latter because of its previous spells in the sport as a constructor in the late 1970s and the 1980s, and in the 2000s.

Renault Sport president Jerome Stoll met with Bernie Ecclestone at the Abu Dhabi GP to discuss the above, and a compromise was reached allowing the deal to go ahead.

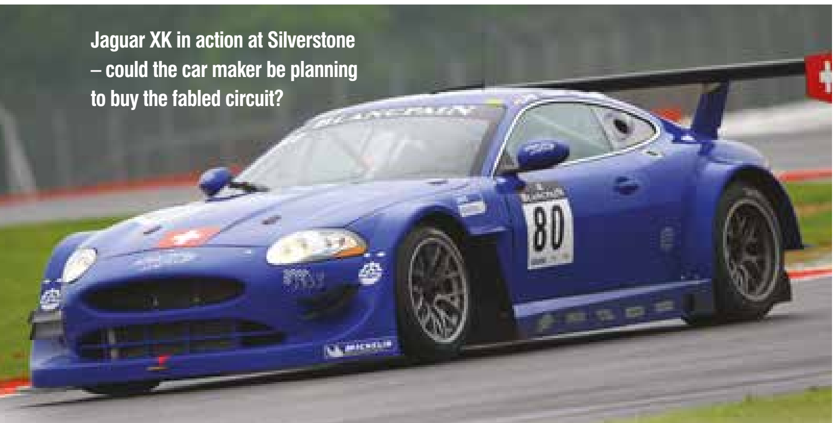
Explaining the reasoning behind its return to F1 as a constructor, a Renault statement claimed that it failed to gain much credit for its success with Red Bull between 2010 and 2014. 'As a full team, Renault will take maximum benefit from its victories,' it said. 'The payback as an engine supplier proved to be limited.

'The return on the investment necessitated by the new engine regulations and the return in terms of image were low.'

Meanwhile, the Renault engine that will continue to motivate the Red Bull F1 cars is to be rebranded as a TAG Heuer. The news came shortly after the F1 team poached the watchmaker's sponsorship from long term partner McLaren – TAG was actually the branding used for McLaren's Porsche engines in the mid-1980s.

Red Bull has also split with Infiniti, the luxury arm of Nissan, and there will in fact be no marketing activities undertaken by Red Bull for the Renault-Nissan alliance in 2016. It is widely believed that Red Bull pocketed $70m a year from its deal with Infiniti.

Renault will return to Formula 1 as a constructor for the first time since 2009 (pictured) having completed its deal to take over Lotus



Jaguar XK in action at Silverstone – could the car maker be planning to buy the fabled circuit?

Jaguar shows interest in purchasing Silverstone

According to reports in the UK financial media, Jaguar Land Rover (JLR) could be shaping up to buy Silverstone.

JLR, which is a part of the mighty Tata business empire, is said to have approached property consultant Cushman & Wakefield in order to obtain a valuation of the British GP hosting venue, which it's thought to be planning to use as a headquarters for up to 1000 staff.

It's also been said that JLR is planning on building a hotel and a heritage centre – which is very much in line with the circuit's current plans – should the deal go ahead, while the historic venue would carry on operating as a race circuit.

Cushman & Wakefield valued the Northamptonshire facility at £22.7m, but for any deal to go ahead Silverstone's owner, the British Racing Drivers' Club (BRDC), would need to ask its 850 members to approve the sale.

The BRDC has said it has as yet received no formal offer from JLR but in a statement issued to its members it added: 'The British Racing Drivers' Club receives confidential approaches from a number of different parties attracted to Silverstone circuit and considers these on their merits. Should an attractive offer be received from any party, the BRDC board would seek a mandate from club members before progressing it. We have no further comments to make on the recent press reports.'

In the summer of 2015 there had been doubts about Silverstone keeping the British Grand Prix after it asked for a deferment on the payment of its race hosting fee to Formula One Management (FOM), due to a lack of funds. However, since then Patrick Allen, the circuit's managing director, has confirmed that the British GP contract would in fact be honoured through to 2026.

SEEN: Hyundai i20 WRC

Hyundai has taken the wraps of its new generation i20 WRC, the car the Korean company will campaign in the 2016 World Rally Championship. The new five-door i20 will see just one season of action, however, as the regulations for the WRC are changing in 2017.

Hyundai has conducted around 8000km of testing with the new car, which it had originally planned on introducing during the 2015 season.

Hyundai team principal Michel Nandan said: 'We are entering an exciting phase in our young team's journey, which I think will reinforce our commitment and ambition in the competitive WRC community. We have come a long way since our inaugural foundation year, and our performance in last season's championship gave us renewed optimism for the future.

'The new generation i20 WRC is the product of a full year of development and with a more experienced team of staff, we should now raise our objectives to be more confident to fight at the front. The competition remains strong and we know our manufacturer rivals will not ease in their pursuit for victory but we want to take the fight to them in 2016.'

Hyundai failed to win in the WRC in 2015, but it did chalk up a victory in its first season in 2014, its cars finishing one-two on Rally Deutschland. In 2015 it finished third in the manufacturers' standings, trailing Volkswagen and Citroen.

Robot racecars to hit the track by the autumn of 2016

Hands up all those who think races for robots is a great idea (Robot cars will support FIA Formula E)

Races for cars without drivers, or autonomous vehicles, are to be included on the support race package from the start of Formula E's season three – which runs from the autumn of 2016 and in to 2017.

Kinetik, which describes itself as an investment company specialising in emerging technologies, has gone into partnership with FE to run the series, races for which will be held on the same tracks used by the Formula E electric racecars. The series is to be called Roborace.

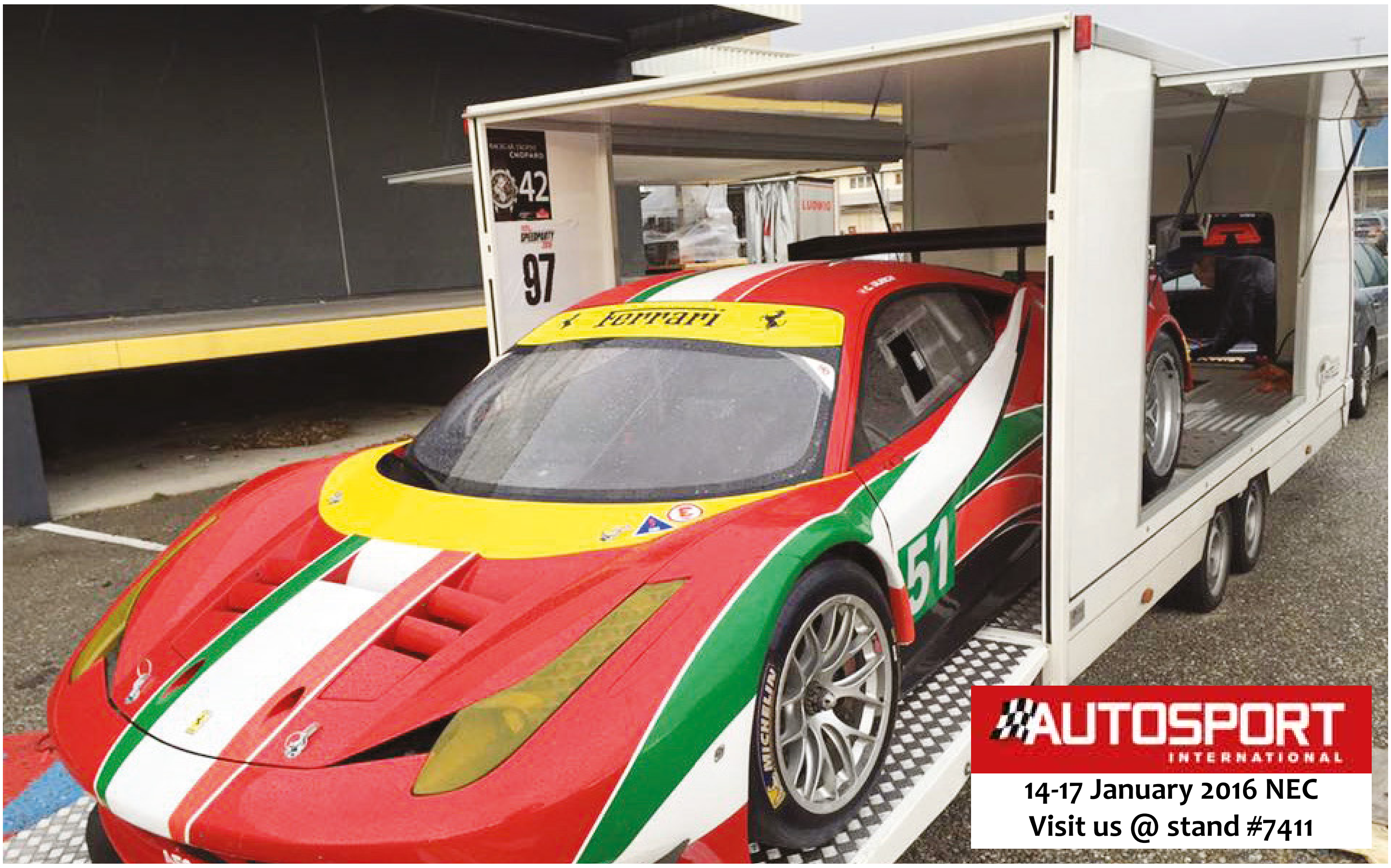
The races are to last an hour, and in common with Formula E each team will use two cars per race – there are to be 10 teams in all. The cars themselves will be identical, but there is to be some scope for engineering creativity as each team will be free to develop the Artificial Intelligence (AI) technology, and the computer programmes, that will operate the cars.

Kinetik founder Denis Sverdlov said: 'We passionately believe that, in the future, all of the world's vehicles will be assisted by AI and will be powered by electricity, thus improving the environment and road safety.

'Roborace is a celebration of revolutionary technology and innovation that humanity has achieved in that area so far,' Syderlov added. 'It's a global platform to show that robotic technologies and AI can co-exist with us in real life. Anyone who is at the edge of this transformation now has a platform to show the advantages of their driverless solutions and this shall push the development of the technology.'

Formula E CEO Alejandro Agag said: 'We are very excited to be partnering with Kinetik on what is surely one of the most cutting-edge sporting events in history. Roborace is an open challenge to the most innovative scientific and technology-focused companies in the world.'

Further details on the technology to be used, and the teams which will fill the grid, are set to be revealed early in 2016.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Xtrac bags another prestigious manufacturing award

Famed automotive and motorsport transmission maker Xtrac has added yet another manufacturing award to its glittering collection.

Xtrac directors with an example of the company's hardware. (L to R): operations director Martin Halley, development director Cliff Hawkins, executive chairman Peter Digby, finance director Stephen Lane, and managing director Adrian Moore

Xtrac won the People and Skills award at the TMMX 2015 Awards (previously known as the Manufacturer of the Year Award), which was held in association with the Institution of Mechanical Engineers for the first time towards the end of last year.

The Berkshire-based company (which also has facilities in Indiana and North Carolina in the US) has become a regular recipient of UK manufacturing industry awards. In 2014 it was crowned the overall winner having secured the 'Leadership and Strategy' and 'Medium Sized Enterprise of the Year' awards.

Peter Digby, who has recently stepped into a new role as Xtrac's executive chairman, said of the award: 'The TMMX Awards showcase the best manufacturing companies and people in the UK. It was the opinion of the judges that Xtrac best demonstrated how skills and workforce development can help optimise productivity and quality, which has always been one of our key priorities. The judges commended us for our focus on talent and on performance, and for the motivation among the members of our staff to strive for improvement.'

Xtrac managing director Adrian Moore said: 'During their rigorous assessment, the judges toured our facilities and interviewed numerous staff throughout the organisation. This was followed by equally demanding formal interviews with key personnel. In particular, they liked our fortnightly team briefings, quarterly meetings for the whole factory, apprentice and undergraduate schemes, and applauded the ownership of our company by its employees.'

The company is a world-leader in the design and manufacture of transmission products and components, which are used throughout international motorsport and in particular within F1, IndyCar, touring car, rallying, and many forms of sportscar and GT racing, including a major involvement in the WEC and at Le Mans.

SEEN: Tatuus USF-17

Andersen Promotions, the company behind the Road to Indy single seater ladder in the United States, has released renderings of the Tatuus chassis which will serve as the replacement racecar for the USF2000 Championship and the Pro Mazda Championship – as detailed in Business News in the last issue of *Racecar* (V21N1).

Lifeline sets up shop in the US

Well-known motorsport fire suppression system manufacturer Lifeline has set up an arm in the United States to market its products in North America.

The new operation is to be called Lifeline USA and it has been initiated as a result of a partnership with James Clay, a race team owner and driver and also the founder of BimmerWorld, the motorsport parts company specialising in BMW.

Lifeline USA will be based in Dublin, Virginia, from where it will service and refill the entire range of Lifeline fire suppression systems. While initially the company will focus on selling to the road racing market, there are plans to develop dedicated oval track and drag race systems.

Clay said: 'I am very much looking forward to bringing the existing Lifeline products to the market, as well as developing brand new, US racing series focussed, ranges.'

Jim Morris, managing director at Lifeline, said: 'James not only has a very good understanding of the needs of the racer, he also has great expertise in distribution, so we are delighted to have him on board'

Sunoco fuels scoops top NASCAR marketing award

US fuel company and iconic motorsport sponsor Sunoco has won the prestigious 2015 NASCAR Marketing Achievement Award for its efforts in using the US stockcar platform to publicise its brand.

Sunoco, which is the official fuel of NASCAR, has been involved in the sport since 2004. It impressed NASCAR with its efforts off the circuit as much as its fuel supply at the track: 'Sunoco utilised an integrated marketing approach to engage fans, customers and employees through promotions, B2B, digital, broadcast, event marketing and social media,' NASCAR said.

Steve Phelps, NASCAR chief marketing officer, said: 'For the past 12 years Sunoco has been synonymous with high performance both on and off the track. Delivering a creative multi-channel marketing campaign that produced engaging content and drove positive business results made Sunoco a highly worthy recipient of the Marketing Achievement Award.'

Cynthia Archer, executive vice president and chief marketing officer, Sunoco, said: 'Since 2004 Sunoco has been proud to fuel over 12 million miles of spectacular NASCAR racing. We are thrilled to partner with the entire NASCAR racing community and look forward to fuelling great victories for many years to come.'

Previous winners of the NASCAR Marketing Achievement Award include Coca-Cola; Mars; Nationwide Insurance; Sprint; and Toyota.

IN BRIEF

Extra Audi GT3s

Audi has made a commitment to ramp up production of its new R8 GT3 in order to meet demand, and is now planning on delivering over 50 of the V10 cars to customers by the beginning of the 2016 season. Audi will not put an exact figure on the amount of GT3s it will now produce, but the original plan was for 45. The first two customer R8 LMS GT3s competed in the GT World Cup in Macau, entered by Audi Hong Kong and the Absolute Racing teams. The official Audi entries for the World Cup in Macau, from Phoenix and WRT, were factory development cars. The new R8 retails at €359,000, plus taxes.

INTERVIEW – Jost Capito

The gate keeper

VW's motorsport director has his own answer to the scandal that's rocked the German car manufacturer – keep a three-car team, and continue to win rallies

By MIKE BRESLIN

XPB

We are in the public eye very much with the motorsport programmes and we can deliver obvious success and good news

In motorsport you need to expect the unexpected. In rallying even more so – from kangaroos in the road to snow storms. But you might have forgiven VW Motorsport director Jost Capito for relaxing just a little in September as his Polo equipped team closed in on its third world title.

Then the storm hit, and VW's rosy world changed forever in what even Capito refers to as 'Diesel Gate', the scandal in which Volkswagen was found to have fiddled its road car emissions tests in the US. It's no secret that it's hit the VW Group very hard indeed, and motorsport has not escaped, with both the Porsche and Audi WEC teams cutting back their commitment from three-car to two-car operations at Le Mans.

But what of VW's WRC effort? 'It is affecting everybody in the company,' says Capito, who has had a long career in the motorsport and automotive world, coming to VW in 2012 after a spell at Ford. 'It's affecting the motorsport as well, and of course we had to look at our budget, and we also had to reduce our budget. But it's not affecting the number of cars, because we believe that to be competitive and to be in the position to win the championship you need in the WRC to have three cars. We have other areas where we could try to do some savings, but not on the most important issue; to be competitive.'

In WRC only two cars per team per event are allowed to score manufacturer points, so this is an interesting decision, but as Capito explained: 'You need an additional car that you can place in between you and the other teams to take championship points away from the other teams.'

Positive PR

Of course, at the time the scandal erupted Capito's worries were far wider than just losing a car, but deep down he always believed that the WRC programme was safe, largely because it's worked so well for VW. 'I think when Diesel Gate happened everybody was worried about everything! But on the other hand we were not so much worried because we are successful and we deliver. WRC really fits the Volkswagen brand and I think that Volkswagen at the moment is also quite happy to have some positive news. I think we are in the public eye very much with the motorsport programmes and we can deliver obvious success and good news.'

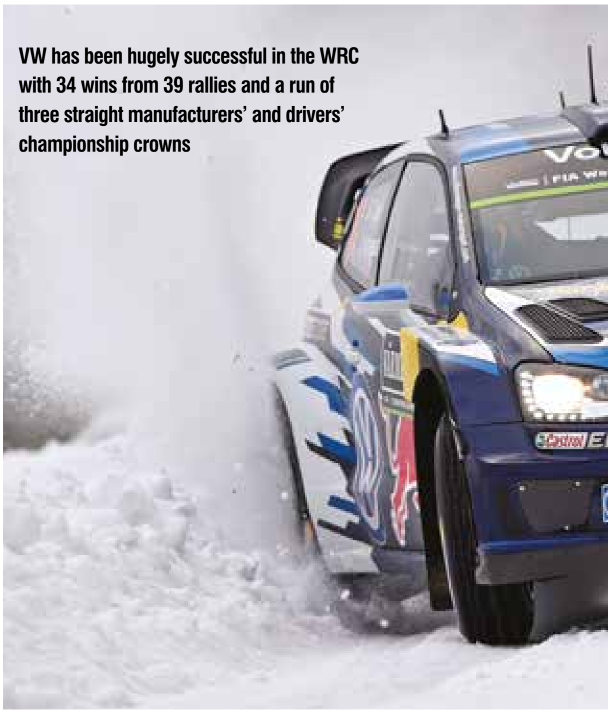
That success has been somewhat remarkable – since joining the WRC in 2013 VW's chalked up a staggering 34 wins from 39 events. Which is why the company approved the programme until 2019 back in 2014, although as Capito says: 'We still have to go every year to the board with a new budget and get it approved.'

New for WRC 2016 is an expanded championship, to 14 rounds, one of which is in China – to the delight of all the manufacturers including VW – but for 2017 things are even more exciting. That year seems to be a big one for motorsport in general (there are new formulae just about everywhere in '17), but for the WRC it represents something really special, because for perhaps the first time in history the world's top four car manufacturers (a returning Toyota, VW, Ford and Hyundai) will compete head to head in a major international championship (add Citroen to the mix, too), and on top of that there's a sexy new rules package to look forward to.

VW has already started testing its 2017 development 'mule' for the new formula, which is a low cost upgrade based around bigger cars, more power (380bhp over 300bhp now) and the return of electronically controlled centre diffs. 'We have maybe 60 to 70 per cent of the new parts in now,' Capito says. 'It's mainly upgrading, it's an evolution. To make the cars a bit wider, to make it 25 kilos lighter, it's not like we've changed the philosophy of the car; and having the centre diff, that has been there in the past already, so it's nothing new, really. This is what the manufacturers all proposed and wanted; to keep the cost down, to have more attractive looking, more aggressive looking, cars, but still with reasonable development costs.'

Deceptive domination

With evolution rather than revolution for 2017 it would be hard to look past VW cleaning up in WRC for the next few years, although Toyota will surely have something to say about that. But Capito actually plays down the dominance to a certain extent, saying that while Volkswagen has won more than its fair share of rallies, they are seldom easy wins. 'When you look at the results, it looks more dominant than it actually is. The cars are still very close, because we have very good technical regulations, which allow a certain freedom for the engineers – it has been enjoyable for the engineers. But it is also only small



VW has been hugely successful in the WRC with 34 wins from 39 rallies and a run of three straight manufacturers' and drivers' championship crowns differences, the cars are all very similar, very close. I think our drivers made less mistakes than the others, and that makes it look very dominant.'

Beyond the WRC VW's motorsport presence – one-make competition aside – is largely as an engine supplier in F3 and the Global Rallycross Championship with the Beetle in the US. Capito actually says it can be difficult to find a fit for VW in US motorsport, as there is no WRC round there, and he admits the company has looked at NASCAR, although a word of caution is needed here. For, while VW has looked at NASCAR, it is pretty much in the same way that it has looked at F1. More keeping an eye on, than making plans. And anyway, any decision to do either would be made at a VW Group board level, not at VW Motorsport. 'I think NASCAR is the same as with F1. If you are a manufacturer you have to look at all kinds of motorsport activities, and see how they are going, what is the future,' Capito says. 'I think that is the responsibility of a motorsport director, to analyse and to always have a full view of what is happening on the scene; always checking that the strategy that we have is in line [with VW marketing], or whether it should be changed.'

Electric avenue?

With this, and its recent problems, in mind it's fair to assume that all at VW will be keen to – somehow – bolster its green credentials, and Capito admits that Formula E is interesting. 'We will carefully watch it and see where it goes. It depends very much on where the regulations go – if car manufacturers are to get interested and have a bigger commitment and a bigger involvement. For the moment with VW it is just a sticker on the Abt car, because VW has a close relationship with Abt. But we will have to see where the regulations go: what kind of parts are free in the future; where is there the possibility to learn something for the production of electric cars. Here Formula E could offer some opportunities. Because nowadays, with the budget constraints that are around, it's very important that the production development benefits from the motorsport activities. It's not just the marketing side and the media side now, it's also the technical side.'

Right now Formula E might seem an obvious fit long term, but as we've said, in motorsport you never know what's around the corner, although you can bet that Jost Capito would be far happier facing kangaroos in the road and snow storms than another corporate scandal.

RACE MOVES

XPB

Citroen Racing deputy director **Xavier Mestelan Pinon** is to take charge at the French company's DS Performance division, where his primary motorsport role will be with the Virgin DS Formula E team. Pinon, who has worked at Citroen for 20 years, masterminded the Citroen C4 and DS3 during his time as the WRC team's chassis manager and head of its technical department. He was also at the forefront of the development of the dominant C-Elysee WTCC car.

Wolfgang Ulrich, the boss of Audi Sport, is to remain in his post for a further two seasons. Ulrich hit retirement age (65) this summer but thanks to a special contract extension – it's VW Group policy that all employees should retire at 65 – he will now stay with the company until at least the end of the 2017 season. Ulrich has been in charge of Audi's motorsport effort since 1993.

Michael Bugarewicz is to be the new crew chief for **Tony Stewart** as the Stewart-Haas Racing co-owner takes part in his last season as a driver in the NASCAR Sprint Cup. Bugarewicz moves up from his previous role with SHR as race engineer on the No.4 Chevrolet of **Kevin Harvick**. He previously spent time with Roush Fenway Racing in an engineering role.

Chris Lencheski has been appointed vice chairman of the board of managers and chief executive officer at IRG Sports and Entertainment. IRGSE promotes more than 1150 motorsport, live entertainment and corporate events annually at its venues and within its series, which are chiefly concerned with US drag racing. Its properties include Palm Beach International Raceway, Memphis International Raceway and Maryland International Raceway.

Billy Scott is to be the crew chief on the NASCAR Sprint Cup Stewart-Haas Chevrolet of **Danica Patrick** for the 2016 season. Scott joins Stewart-Haas after eight year as an engineer, and later a crew chief, with Michael Waltrip Racing – which shut up shop at season's end. Scott replaces **Daniel Knost**, who has been promoted to the senior leadership role of manager of vehicle dynamics within the Stewart-Haas organisation.

Chad Johnston has moved from Stewart-Haas Racing's NASCAR Sprint Cup operation, where he was crew chief on Tony Stewart's car, to take up the same post for Kyle Larson at Chip Ganassi Racing. Johnston replaces **Chris Heroy** as Larson's crew chief.

Tim Gibson, a track engineer for Dunlop, has died suddenly at the age of 30. Gibson, who had a heart transplant when he was just 15, played a key part in the Jota Sport LMP2 win at Le Mans in 2014, while he was also a keen club racer, competing in Formula Ford, BMW Compact Cup and Legends.

Australian V8 Supercars team owner **Charlie Schwerkolt** has split with Walkinshaw Racing, which ran his car as part of a four-car operation in 2015. Schwerkolt intends to run his entry independently in 2016.

Martin Whitaker, the former CEO of Bahrain International Circuit and V8 Supercars, has been named as CEO at the Circuit of Wales – the future venue for the UK's MotoGP round, which has recently cleared its final planning hurdle. The £315m project is to include an automotive and motorsport business park within the 830 acre Ebbw Vale development.

Former DTM performance engineer **Romy Mayer** has joined the Red Bull Racing Australia team, which competes in the V8 Supercars championship. Mayer, 30, is data and performance engineer on **Jamie Whincup's** car, working alongside **David Cauchi**. She spent five years in the DTM with HWA Mercedes.

Sebastien Metz has joined Onroak Automotive, where he will manage the company's Ligier LMP2 manufacturing facility at Le Mans. Metz has worked for Audi Sport in LMP1, VW Motorsport in Rally Raids, and since 2010 he has been at Marc VDS Racing.

More power handed to Todt and Ecclestone in F1

Formula 1 boss Bernie Ecclestone and FIA president Jean Todt have been handed the power to make final decisions on many of the key issues to do with Formula 1's future.

The move, which was decided at the World Motor Sport Council (WMSC) in December, comes in the wake of mounting criticism over the effectiveness of the F1 Strategy Group. The Strategy Group is made up of six of the 10 teams – Red Bull, Mercedes, Ferrari, McLaren, Williams and Force India – plus Ecclestone and Todt.

With little progress on some of the problems facing Formula 1 throughout 2015 the WMSC has now tasked Todt and Ecclestone with taking the lead on several key decisions.

In a statement the WMSC said the mandate was approved 'by a near unanimous number' with 'just one vote against.'

The issues Todt and Ecclestone will primarily focus on regard F1's governance, cost reduction and – related to costs – its engine regulations. The statement said the pair intend to 'establish conclusions on these matters' by the end of January 2016.

While team bosses and members of the Strategy Group have not commented on the announcement there had been growing talk about the inability of the group to actually change things before the WMSC meeting, and Cyril Abiteboul, managing director of Renault Sport F1, had said: 'I think on balance, if you look at Formula 1, I would prefer it to be more progressive than it is. So if that involves a little bit of dictatorship maybe that would be better.'

Miller replaces Pemberton as boss of competition department

NASCAR's senior vice president of competition, Robin Pemberton, has left the organisation and former team boss Scott Miller has stepped in to fill the high profile position.

Pemberton joined NASCAR in August of 2004. Since then he has overseen all areas of NASCAR competition and been credited as a key figure when it comes to bridging the gap between the sanctioning body and the racing community.

Miller will now take on Pemberton's role and will be responsible for managing all competition efforts related to technology, inspection, rule development and officiating. He will report directly to executive vice president and chief racing development officer Steve O'Donnell, and work closely with senior vice president of Innovation and Racing Development, Gene Stefanyshyn. All three are based at NASCAR's Research & Development Centre in Concord, North Carolina.

Miller most recently served as executive vice president of competition at Michael Waltrip Racing (MWR), and prior to this he was employed in management roles at Richard Childress Racing.

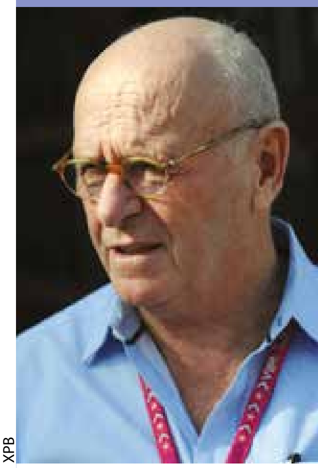
NASCAR has seen a great number of technical and safety advancements during Pemberton's time with the organisation. His team overhauled the inspection and rules process and procedures for all vehicles racing in the national series, while he also oversaw the transitions of NASCAR to electronic fuel injection and to greener race fuels. Among his larger projects was the launch of the Gen 6 car in the NASCAR Sprint Cup Series in 2013, which has just completed its third season of racing.

Miller said of his new post: 'I'm looking forward to using the experience I've gained working within teams in an entirely new way at NASCAR.

'Our sport has evolved quickly over the last several seasons through advanced technology and its creative application in the garage area. We will strive to continue this forward momentum while assuring a level playing field and competitive racing. It's a challenging opportunity and a logical next step for me. I can't wait to get started.'

Robin Pemberton is no longer the senior vice president of competition at NASCAR

RACE MOVES – continued



XPB

Derrick Walker, the former IndyCar president of operations and competitions, is now the president of SCCA Pro Racing, replacing **Robert Clarke**, who will now serve as chairman of the board. Walker has spent more than 40 years in racing, during which time he has worked as a mechanic, engineer and team owner.

Piers Phillips is now the general manager at IndyCar squad Schmidt Peterson Motorsports. Phillips comes to the team from Brabham Racing, where he was team manager and technical director, and before that he held a number of management and engineering roles, including spells at Strakka Racing and SEAT Sport UK.

Lesa France Kennedy, CEO of US race track operating giant International Speedway Corporation, has been named as the Most Powerful Woman in Sports for 2015 by Forbes. Kennedy, who is also vice chairperson at NASCAR, received the most votes from an eight-member panel assembled by the New York business magazine.

New Zealand's Taupo circuit has been renamed in honour of **Bruce McLaren**. It will now be known as Bruce McLaren Motorsport Park.

The No.41 Stewart-Haas Racing NASCAR Sprint Cup pit crew has won Mechanix Wear's prestigious Most Valuable Pit Crew award, and a cheque for $100,000, for their work during the 2015 season. The crew comprises: **Shayne Pipala, Jon Bernal, Sean Cotton, Coleman Dollarhide, Dwayne Moore, Rick Pigeon** and **Joe Piette**. It is led by its crew chief. **Tony Gibson**.

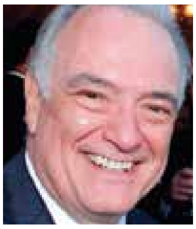
WC Vision, the company behind US sportscar series the Pirelli World Challenge (PWC), has signed up **David Caldwell** as its director of operations within its Competition Department. Caldwell was previously the PWC technical programme manager for General Motors.

Tom Kristensen has been named as the new president of the FIA Drivers' Commission. The Le Mans legend was previously the commission's vice president and will now take over the helm from three-time Formula 1 world champion **Emerson Fittipaldi**.

Former racecar designer and constructor **Adrian Reynard** is putting his personal collection of eight of his erstwhile company's cars up for sale. Among the racecars on offer include a brace of Reynard-built BAR-Honda F1 cars (from 2002 and 2003), plus the breakthrough Reynard 873 Formula 3 car which took **Johnny Herbert** to British championship success in 1987.

Prema Powerteam has recruited technical director **Guillaume Capietto** from championship-winning GP2 squad ART Grand Prix as it prepares for its step up into GP2. **Jonathan Moury** will take up the team-manager position at the Prema GP2 operation. Prema is well-known for the great success it's enjoyed in the European Formula 3 Championship, in which it will continue to race.

◆ 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**



Looking to the future

It's up to the industry to embrace new forms of motorsport entertainment

It was interesting, while visiting the PRI show in December, to see the diversity of motorsport, and the willingness to accept new motorsport in the US marketplace is really refreshing. Take the off-road scene, where you can either go point to point and destroy your car over 1000 miles driving flat out with unlimited technology, and that is entertainment. Or, you can do 'Best in the Desert' and go round in circles and 58,000 people will watch you doing it. That's *entertaining*.

And new motorsport brings new fans. We have clearly found another group of people who love motorsport, have suddenly found that Formula E, delivered to a street in front of Starbucks, is what they want. It is quiet enough that they can talk to their friends, fast enough to be entertaining, and again we might have judged that that wasn't necessarily a good motorsport series. Now, we have heard of an autonomous championship and what we have to do as an industry is to recognise that we are in the entertainment business. New entertainment ideas will just flood the future. I think that if we look forward, because of the speed of change brought about by connectivity, there is every chance that new entertainment ideas are going to come thick and fast and be really quite hard for an industry to embrace. The sooner we wake up to the business opportunities in entertainment, the better the motorsport industry is going to be.

That's entertainment

Formula E brought in new money, from sponsors, from audiences, from media and manufacturers. It has discreet partnerships with manufacturers that are clearly motivated, and this could be true with off-road, why wouldn't off-road run in North Africa and Spain? Why couldn't there be a Baja event in Europe? That wouldn't limit the money, that would bring new money and new entertainment.

The sooner we wake up to the business opportunities in entertainment, the better the motorsport industry is going to be

Spectacular and popular forms of motorsport such as drifting should not be ignored by the racing industry

I guess my point is; is it firstly entertainment, or are we going to continue for ever more to discuss the role of technology, and entertainment is secondary to that? I am more and more convinced that, in our future, money will come from entertaining more people with some form of motorsport or powered entertainment, and we should get on with supplying the technology to support it. It is wrong to think that OEMs are the only people to gain from motorsport. There are legions of companies, including Apple, Google and Uber, who we haven't yet captured to bring money into our entertainment business.

If we were more honest and open about building entertainment, growing an audience and fans, they would come in their droves.

We should be more openly welcoming of new ideas and give them a chance – look at other entertainment industries, not every film is a blockbuster. Not every app sells. Not every idea is going to be a winner. That's fine. That's for us to judge.

We were talking at the PRI Show to the man behind Formula Drift. What a ridiculous kind of motorsport that would have seemed 15 years ago! Many people have said, what would people find interesting about going sideways? Yet now millions of people love this form of motorsport and to them it *is* motorsport; a minute of sideways motion. There's drag racing, too. If you look at the support for drag racing around the world; dead straight, very fast, and millions love it.

So we have got to be careful not to be so closeted in our thinking. Bring on the entertainment, capture the fans, get them to attract sponsors and media, and we should focus on whatever technology is needed or expected in the entertainment category. But somehow we seem to get muddled.

Business focus

There are two aspects of motorsport. There is the sport as seen through the eyes of the competitor, which is the fun of driving, and then there is the business of motorsport, which is about entertainment. We can't really say that this commercial side of the thing we call motorsport can be seen as a pure sport. That is like saying that the Premier League is the same as what the guys in the park play on a Sunday morning. It isn't. It moves into a professional entertainment business. It happens to be called football. The American football scene has recognised that this is entertainment with a sporting connotation, just as a film is connected to real life or a documentary, but they have been honest enough to say that their aim is to entertain fans. I would love to have a decade of working hard, using the best brains in the industry, to focus on bringing entertainment of all kinds.

As far as my argument about the new fans coming to Formula E goes, though, I am not actually sure they are all new. They are a group of young people who love motorsport and have found something that they enjoy, and the same with the people who follow Formula Drift, and now we have a business. So, be much more embracing of new entertainment ideas in motorsport and then bring the best technology and engineering to make sure the entertainment is at the highest peak.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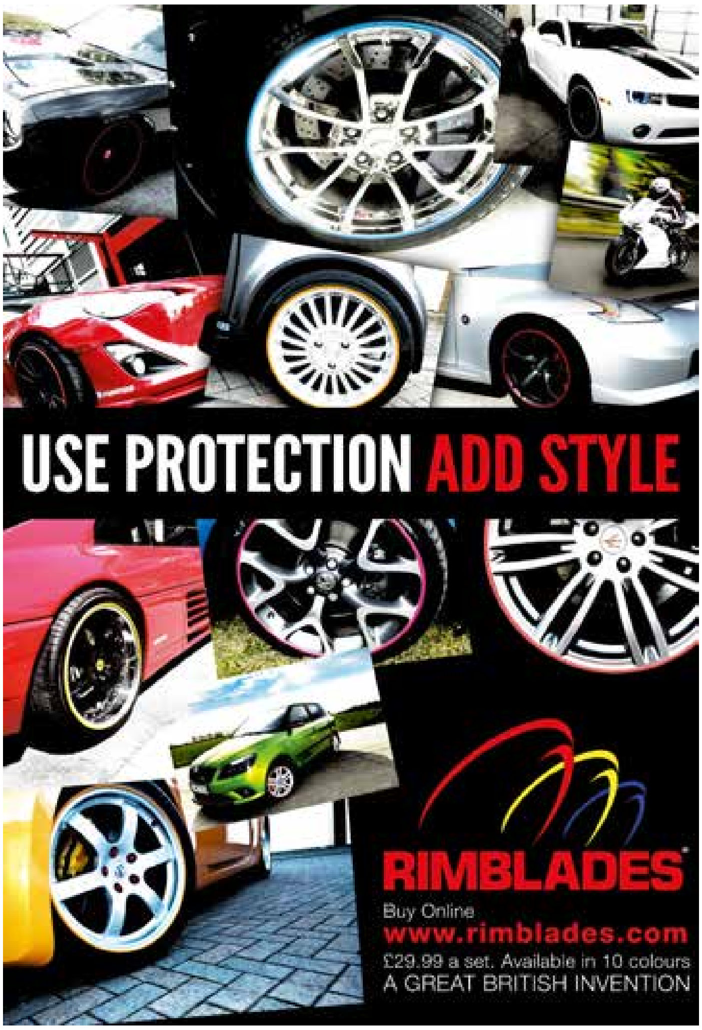
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Race bred tech

Williams Advanced Engineering will be showing off its F1-derived commercial technology at this year's ASI

Williams is a name synonymous with F1 success. The team secured nine constructors' titles and seven drivers' championships between 1980 and 1997. In the past decade, however, another arm of the Williams group has also been making headlines: Williams Advanced Engineering (WAE).

Throughout its history, Williams has been involved in projects outside of F1, but it is only in recent years that a dedicated company has specifically handled bespoke commercial projects. Craig Wilson, managing director of WAE explains. 'It commenced with the development of the flywheel energy storage device, which was named under Williams Hybrid Power. That device was not able to be used in F1, but we continued to develop it, because we saw potential in it for other applications, so that was probably the start of what then became Williams Advanced Engineering.'

In 2010 Jaguar approached Williams to jointly develop the C-X75 supercar and that project was confirmed and ratified, becoming a full-blown project in 2011. In that time frame, WAE was created and a number of these projects were brought under one umbrella. Although work on the C-X75 ceased prior to production, the Williams board saw the potential in the advanced engineering business and continued to support it.

It is only recently that a dedicated company has specifically handled commercial projects

Hi-tech base

The WAE factory at Williams' Grove HQ was opened by British Prime Minister David Cameron in July 2014. It houses comprehensive prototyping build facilities, assembly facilities, and a specific dedicated battery assembly area. Wilson says: 'We completely outgrew the previous facilities. This has given Advanced Engineering its own identity and its own home.'

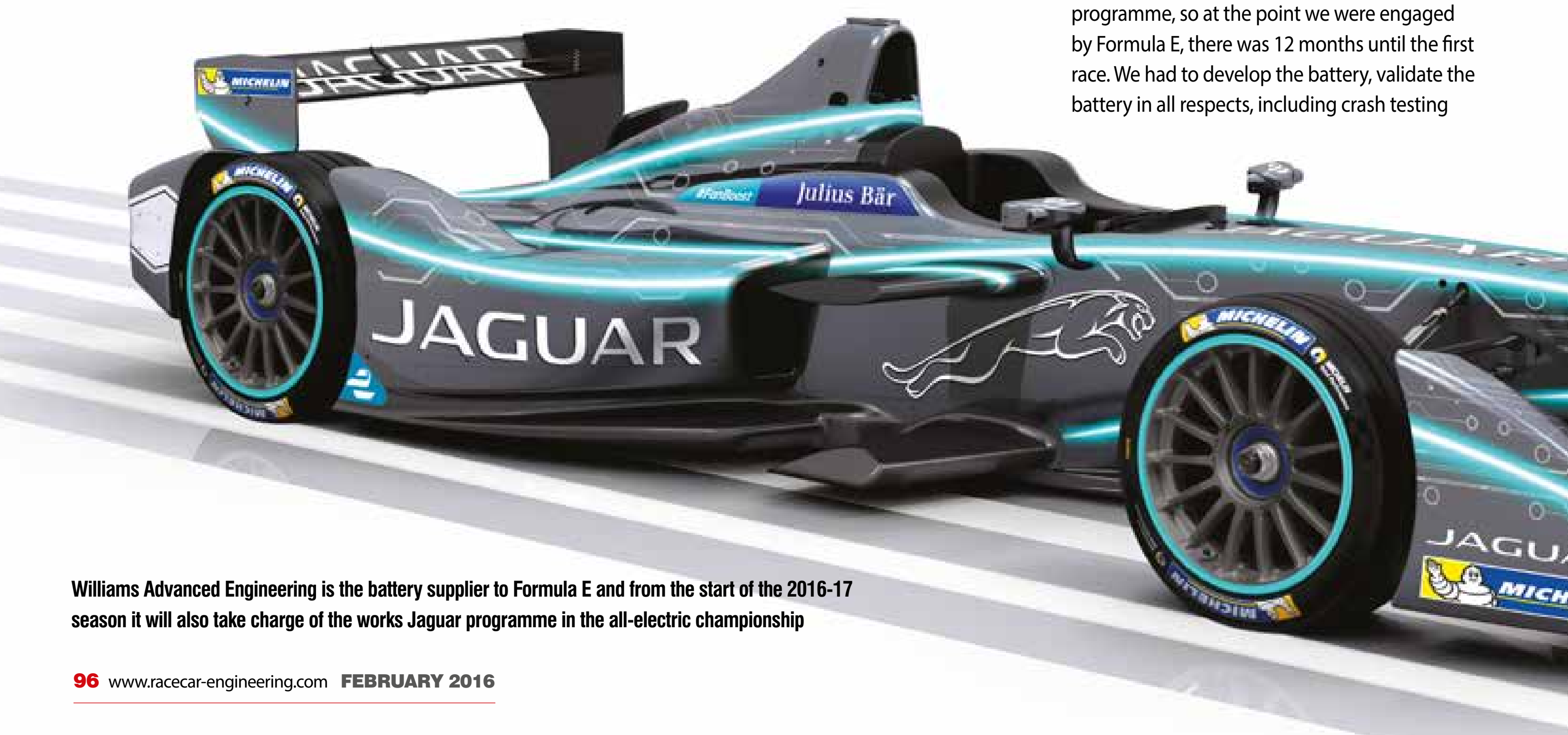
As the scope of WAE has grown, so has the skills base of those on site. Projects such as developing and producing the Formula E battery unit, automotive and defence projects, as well as renewable energy projects, have necessitated a refocus on the talents of those sought by the company. For example, to cope with these programmes, WAE has employed a number of staff experienced in battery design and assembly and has also brought in engineers with specific defence experience to complement the company's existing mechanical and electrical capabilities.

Wilson is keen to acknowledge that some crossover with the company's eponymous Formula 1 team is in place, particularly with regards to engineering know-how and capability. 'Williams is a very, very capable engineering organisation. Williams throughout its history has developed the majority of what it races, has developed and manufactured everything itself, apart from the engines. Williams was the first to develop KERS, for example,' Wilson says.

'We increasingly share resources and facilities in wind tunnels, mechanical test laboratories and electrical test laboratories, so we are increasingly using joint assets for both the Formula 1 business needs and the Williams Advanced Engineering business needs,'

Wilson admits that Formula 1's stringent regulations regarding the use of wind tunnels has played somewhat into Advanced Engineering's hands, here. 'It has given Advanced Engineering an opportunity to provide those services to commercial customers and other projects. We use the available capacity that we have to our best advantage.'

Williams has ties with Formula E as a battery supplier, but the advanced engineering division faced an uphill battle to complete the battery project in time. 'The battery was an aggressive programme, so at the point we were engaged by Formula E, there was 12 months until the first race. We had to develop the battery, validate the battery in all respects, including crash testing



Williams Advanced Engineering is the battery supplier to Formula E and from the start of the 2016-17 season it will also take charge of the works Jaguar programme in the all-electric championship

Williams Advanced Engineering grew out of the Jaguar C-X75 Hybrid supercar project and Williams' commercialisation of its Formula 1-bred hybrid technology. Sadly the Jaguar never went in to production

and then build 40 batteries plus some spares.'

Initially developed for 133kW of power, the regulations demanded an output of 150kW, which increased further still to 170kW for this season. It is another challenge that the Williams Advanced Engineering team has met head on.

'The first season was hugely successful from a battery perspective,' says Wilson. 'We only had one issue which prevented a car on track from finishing the race in the whole season.'

Ties with Formula E deepened last month, when it was announced that Williams Advanced Engineering would become a technical partner with Jaguar when it launches its FE campaign at the start of the 2016-17 season.

Spreading the risk

Yet despite its successes, Wilson and his team have also been burned by an economy still recovering from the crash of the late 2000s – the Jaguar C-X75 programme was lost as a result of the downturn. This did, in a sense, force Williams to rethink its approach to the programme, though, allowing the group to introduce a level of project diversity not previously utilised. 'We are not immune to those economic changes, which is one of the reasons why we strategically moved into other sectors, so we are spreading the risk,' says Wilson.

This means diversifying into areas outside of the motorsport and automotive spectrum but Wilson says there can still be no complacency when it comes to global business. 'We've got enough of a unique offering at the moment that is of interest to other companies and sectors, so we are quite busy, which we are grateful for, but we're certainly not immune from the pressures that are out there from a general global economic situation.'

According to Wilson, the advanced engineering team has 35 projects on its books, split approximately 40 per cent motorsport related and 42 per cent automotive, while the balance is made up of 12 per cent in the defence sector followed by a mixture of projects based in energy and other sectors.

However, while that's a fair chunk or work, there are certainly no plans for Williams to slow down just yet: 'There's more room to expand,' says Wilson. 'For the last 18 months we have been constantly at capacity because we're continuing to grow – how much longer that goes on for remains to be seen.'

In motorsport Williams may still be getting plenty of headlines for its Formula 1 efforts – and for its links with Formula E – but Wilson is not content to rest upon the company's laurels and he sees plenty of opportunity to further develop new technology in both the motorsport and automotive arenas.

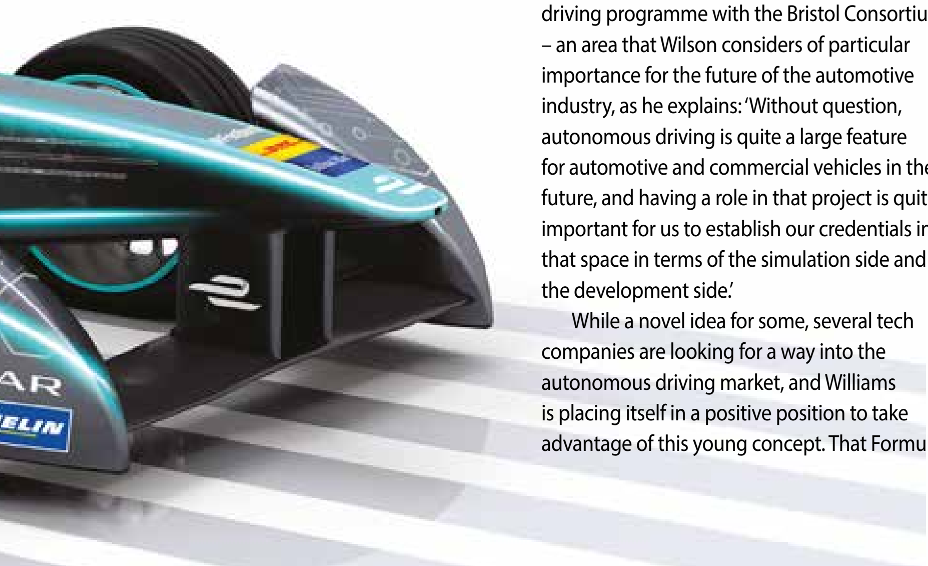
The advanced engineering team is also developing the simulators for an autonomous driving programme with the Bristol Consortium – an area that Wilson considers of particular importance for the future of the automotive industry, as he explains: 'Without question, autonomous driving is quite a large feature for automotive and commercial vehicles in the future, and having a role in that project is quite important for us to establish our credentials in that space in terms of the simulation side and the development side.'

While a novel idea for some, several tech companies are looking for a way into the autonomous driving market, and Williams is placing itself in a positive position to take advantage of this young concept. That Formula E recently announced that an autonomous racecar series to supports its races is not something that has escaped many in the industry who are looking to the next great step.

Wilson is clearly anticipating a busy future for Williams Advanced Engineering, but some of that future he is not quite ready to reveal. 'Motorsport is always very competitive and we're very please that we are a supportive partner in a couple of quite substantial projects in the next 12 to 24 months.'

Of its currently active programmes, Wilson is positive and is enjoying the challenge. 'We are a silent partner in a number of motorsport projects that we can't talk about, but we are involved in a few and they continue to be challenging, which is good. And they continue to be quite successful, which is also good.'

There is little doubt that Williams Advanced Engineering will always have ties of some nature with the Formula 1 team, whether they be business, engineering or emotionally related. But Wilson and his team are keen to make sure the advanced engineering side becomes a recognised force in its own right. 'A racing environment is very much about a 'can do' attitude, speed and precision,' he says. 'And those aspects are ingrained in the *modus operandi* at Williams Advanced Engineering.'



Show briefs

BILSTEIN

Bilstein will be demonstrating its motorsport and tuning proficiency to the public and the industry in Hall 20, where it will be showing products and spectacular show cars.

OHLINS

Ohlins' updated motorsport range for both racing and rally will be on display, complete with an updated TTX46 racing shock absorber. An upgraded shock absorber kit for the Polaris RZR will also be launched. This new kit comes with the Ohlins ORQ 16/46 shock at the front and the large ORQ 18/50 shock for the rear.

TRELLEBORG

An innovative seal material designed to accelerate performance in motorsport is to be showcased at Autosport International. The material is Turcon M12, from Trelleborg Sealing Solutions, a polytetrafluoroethylene (PTFE) based sealing material. 'It is medium-filled with a complex mix of non-abrasive mineral fibres combined with additives and has been vigorously tested, comparing it to best-in-class compounds against important sealing parameters,' the company tells us.

YOUNG CALIBRATION

ASI exhibitor Young Calibration will be opening its new 100kW aerodynamic wind tunnel at its facility located in Shoreham in mid-January. The tunnel is for the calibration of flow grids, yaw probes, kiel probes, pitots, Wilson Flow Grids, Annubars, Emprise Anemometers and thermal anemometers.

Pursuit of imperfection

The launch of the 'Roborace' series in support of Formula E set the alarm bells ringing, and it was hard to stop them. Autonomous vehicles driving around for an hour is not my idea of a fun race to watch, unless there are imperfections deliberately built in. With no driver on board the safety margins are so different that perhaps it could be the modern day banger racing with the only safety concern being the spectators. The cars could be made out of tin foil. Or they could have cannons on them, with three shots per race to blow up the car in front. This idea suddenly could make sense – it's entertainment rather than racing. Perhaps the spectators could fire the cannons by app?

One of the major problems that I have with the concept of autonomous cars is that they will have to be perfect. I have written before about the responsibility should something go wrong, and there are entertaining philosophical arguments concerning an autonomous car's decision-making process in the event of a certain accident. If there was a certainty that there will be a fatality as someone steps off a kerb, for example, should it be the person who steps off the kerb who gets hit, or a car approaching in the other direction? If it is the car, how many people are in it? Does that make a difference to your car's decision-making, and anyway, why should the occupant of the car die due to the mistake of a pedestrian?

This pursuit of perfection has led to problems that are affecting our current racing series. Grass roots racing is as popular as it ever was, and it is not perfect. At the other end of the scale, Formula 1 is as close to perfect as any racing series in car preparation terms, and yet it seems it is apparently losing spectators. How about, instead of this pursuit, we start to introduce imperfections into Formula 1 and turn around its fortunes?

We talk about banning wind tunnels, or at least reducing the amount of wind tunnel time in the interests of costs. What happens if we introduced imperfections into the whole system that would mean wind tunnel testing is useless? How about we don't have billiard-smooth circuits, and allow them to be bumpy? The aero platform is no longer stable, the suspension must be able to soak up the abuse from the track. This idea, incidentally, came from a conversation with Roger Norman of SCORE International Off Road Racing. His key event, the Baja 1000, has wide-open technical regulations and he works on the basis that the rough terrain will break pretty much anything that isn't robust. There is no point introducing anything that is supremely expensive and delicate; agricultural is more reliable, and it is cheaper.

So, rough terrain in Formula 1? On the Motorsport Industry Association stand at the PRI Show, FIA race director Charlie Whiting was appalled at the idea. Mind you, they complain that the speeds are rising too high and look for ways to slow the cars. A lower grade track surface would offer less grip, and the speeds would drop. We want the drivers to be challenged, to see the cars sliding a bit and them having to control them. A less grippy surface would do that.

Of course, this leads to problems setting up the cars, but it works in endurance racing when the cars go to the Sebring circuit in March. Teams preparing for Le Mans go there to test over 24 hours to see what falls off. If everything stays where it is supposed to be, the car is reliable enough to send to France where, incidentally, much of the circuit is public road, which leads to its own challenges during the race week.

We want the drivers to be challenged, to see the cars sliding a bit and have them control them. A less grippy surface would do that

There are problems with leaving the circuits to slowly degrade; tram lines would lead to puddles in the event of heavy rain, but when it gets too wet the safety car is sent out anyway. This safety initiative has extended into endurance racing. In the German round of the WEC, rather unbelievably, the safety car was sent out so that the marshals could sweep the track clean of gravel mid-race. In the wet, drivers usually find more grip off-line. And, I think if a circuit had to spend less on its actual track, it could then spend more on the spectator facilities and improve their experience of attending an event.

It is, after all, the spectators that bring in the gate revenue for the circuits, and that needs to be as high as possible or we will lose more great tracks. Television is the big driver for advertising, but that wouldn't be affected by the track conditions (unless the track started to fall apart, as happened in extremely hot temperatures at Sebring a few years ago). The cars, and their drivers, would have to cope with more challenging conditions, but that's their job.

We wait until the end of February for the new Formula 1 technical regulations that will govern the sport from 2017, but I do wonder about the sense of changing the cars to make them more appealing when there are other, far cheaper, *imperfect* alternatives for improving the racing.

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