Leading-Edge Motorsport Technology Since 1990

Racecar engineering™

F1 2012 • www.racecar-engineering.com • Special Edition

Formula 1 2012

A technical review of this year's contenders


20
Red Bull
RENAULT
TOTAL
INFINITI


40
LOTUS


32
NEC


66
MARUSSIA
QNET

SOLUTIONS MADE OF PASSION

At Kaiser we manufacture the Racecarchassis, -engine and -gearbox components our customers require within the shortest possible and agreed production time. We manufacture prototypes and small batches for the top end of motorsport, aerospace and the automotive industry.

F1 RACE PARTS

- suspensionwishbones and rods (incl. carbon)
- torsion bars incl. scragging and antiroll bars
- rockers, hubs, spacers, nuts
- shockabsorbers (incl. rotary-dampers)
- steeringhousings
- steeringracks and pinions
- steeringcolumns, quick releases and paddles
- hydraulics
- brakecalipers and -cylinders
- chassis parts in metal and carbon
- engine valvetrain
- conrods
- crankcases
- cylinderheads
- pumpbodies, gears and shafts
- clutch components
- gearbox-cases
- gearbox-internals
- gearbox-hydraulics
- turbo components
- energy recovery system and e-motor components
- and many more ...

Kaiser Werkzeugbau GmbH
Gewerbegebiet Helferskirchen
56244 Helferskirchen · Germany
Tel. +49 2626 9243-0 · Fax +49 2626 9243-20
www.kaiser-wzb.de · kontakt@kaiser-wzb.de

KAISER®
WERKZEUGBAU
TEAM

Total recall

The Formula 1 season in 2012 was captivating from start to finish

For the first time, *Racecar Engineering* has charted the development process of each Formula 1 car in a single season, and what a year we chose. From the start, there were the doubters about Ferrari, and they were right. The car struggled to get traction, and the drivers were unhappy. By year's end, however, the car was a title contender and finished ahead of McLaren in the constructors' standings, second only to Red Bull.

Following the debate regarding blown diffusers, the Formula 1 designers found a workaround to the new regulations that stipulated the height and position of the exhaust in an attempt to prevent the gases being used to generate downforce. They were partially successful. McLaren was the first to produce the 'Coanda' exhaust, a design that was copied by others to generate a similar effect to 2011. Sure, downforce was reduced, but there was still imact.

Then there was the sensitivity of the cars to the Pirelli tyres. He who could make them last best would be competitive, and that was no mean feat. Teams struggled throughout the year to understand how to reach the sweet spot, and then stay there for the different compounds. It was a question of design as much as set-up, and so some teams were able to cope better than others. That, in part, contributed to the fact that eight different drivers won races this year.

The battle for middle ground was tightly contested between Mercedes, Lotus, Sauber, Williams and Force India. Lotus scored its first win in 25 years with Kimi Raikkonen at Abu Dhabi, and the Finn remained in the title hunt, albeit as an outside chance, until the dying embers of the season. And, the battle to catch these middle teams was no less hard fought. Marussia had Caterham in its sights, and both produced update kits throughout the season in a bid to remain competitive.

Nico Rosberg brought Mercedes to the front of the grid in China as technical changes shuffled the established order in the first half of the year

All of that led to an incredible season, one that will be lauded as one of the closest ever, with no driver managing more than one win until the eighth round in June, when Fernando Alonso added the European Grand Prix to his victory in Malaysia in March. That was a short-term blessing, and a long-term curse.

For those who have a passing interest in the sport, that the outcome was so unpredictable each weekend made it extremely exciting. There were first wins for Nico Rosberg and Pastor Maldonado, while Sauber, Mercedes and Williams managed to break the monopoly of Red Bull, Ferrari and McLaren and make it on to the front of the grid.

For those within the sport, it created a problem. With a freeze on engine regulations since 2007, the 2.4 litre V8s have reached a parity of sorts in terms of power. That led to close racing which turned on the audience, but it cannot go on forever, and the fear is what will happen when change is introduced in 2014.

Money is tight throughout the grid – witness HRT having to serve redundancy notices on its staff before the end of the season – and the expenditure on new engines, and large hybrid systems, has led to concern. So much so, in fact, that Bernie Ecclestone is trying to delay the introduction of the 1.6 litre V6 engines. He wants sound and fury when the cars pass, and the ground to shake.

However, engine manufacturers are already at the advanced planning stages, and Renault, keen to drive home the point, released images of its engine on the dyno and allowed *Racecar Engineering* to feature their development process so far. There should be little doubt that Mercedes and Ferrari will be progressing at a similar level, while Cosworth, currently up for sale, also has an engine on the drawing board.

"The spotlight shines brightly on Formula 1, and failure therefore becomes even more expensive"

If the new engine regulations do arrive as planned, the manufacturers will be ready for them. But there is another problem. If one manufacturer has got the formula even slightly wrong, they will be left behind, and the close racing that has drawn in so many will be gone. The spotlight shines brightly on Formula 1, and failure therefore becomes even more expensive.

In these pages following, we take a look at how the Formula 1 teams were able to overcome the enormous technical challenges that have been faced and overcome in 2012. We chart the development of each car, including the Ferrari, which, for *Racecar Engineering*, is exclusive to these pages. I hope that you enjoy the coverage that we have given to this extraordinary season, and look forward alongside us to a fascinating future for Formula 1.

Open season

Aerodynamically-positive exhausts, nose jobs and tyre compounds are the talk of the first test at Jerez

BY SAM COLLINS

Formula 1 has undergone a major change over the winter, which could upset the established order on the starting grid. Unless you are looking at a McLaren, it is easy to spot a 2012-spec Formula 1 car from its 2011 cousin. A small change in the technical regulations made to improve safety in car-to-car impacts has altered the face of grand prix racing, and not for the better. The maximum nose height has been reduced by just 75mm, but the height of the front of the monocoque remains unchanged. The change was implemented to reduce the risk of the nose hitting the driver in a 'T-bone' situation. But inadvertently, it has led to almost all of the cars featuring an ugly step in the nose.

Whilst this inevitably catches the eye, the aerodynamic significance of it is small. 'It is an aerodynamic fact that the underside of the nose is what does all of the work,' explains James Allison, technical director at Lotus F1 Team. 'They are quite insensitive to top surface shape so you can have a fairly abrupt shape on the top surface of the car, as long as you are focussing on the underside. Indeed, there are lots of other abrupt shapes - just behind it you have the windscreen and cockpit.'

Allison, according to another team's technical director, actually suggested the rules should be changed as the cars look so ugly!

Other teams, however, may have found a gain in that area. When Red Bull released pictures of its RB8, immediate attention was drawn to a large duct on the nose 'hump'. Suggestions have been made that it serves some kind of aerodynamic function to do with the front wing, but the team deny this. 'The step on the nose is really just a product of the regulations where they restrict the height of the nose but not the height of the front of the chassis,' explains Adrian Newey. 'Most of the teams have gone one route to try to satisfy the regulation with a higher chassis and ended up with an awkward looking step. For styling, we have moved the driver cooling duct from where it is traditionally at the front of the nose. We did it purely for aesthetic reasons to break up the ramp on the nose.'

Perhaps, but the duct is far larger than the tiny driver cooling ducts found on the cars at hot races. It is also larger than the apertures used on the now outlawed f-ducts, so its real purpose is not clear, though driver, Mark Webber, did claim to be suffering numb feet as a result of the large duct.

Sauber does not offer any such explanation for the duct featured on the nose of its C31. It will not be drawn on the purpose of the duct and, with it facing away from the nose of the car, it is not likely to be for driver cooling...


TOTAL

1. Red Bull's 'driver cooling duct' has attracted much discussion 2. McLaren's exhaust exits sit a long way outboard of the chassis and on the limit of the regulatory box. Some have already questioned the legality of the design 3. Ferrari has experimented with many variations of its exhaust in an attempt to re-capture some of the lost downforce 4. Sauber's nose duct faces the opposite direction to the one on the Red Bull

McLaren has approached the nose height reduction problem from a different angle. It already had a relatively low nose and, as a result, has avoided the ugly step. Some in the paddock believe this approach could limit the scope for aerodynamic development on the lower part of the front of the car, especially on areas like barge boards, but the Woking-based team do not seem too worried about that, or what other teams think.

With the changes to the regulation on the nose having a fairly minimal impact on the actual performance of the car, it is likely to be a topic of discussion throughout the season on forums and in the mass media. Where there is a more substantial change in the design of the cars, however, is at the rear.

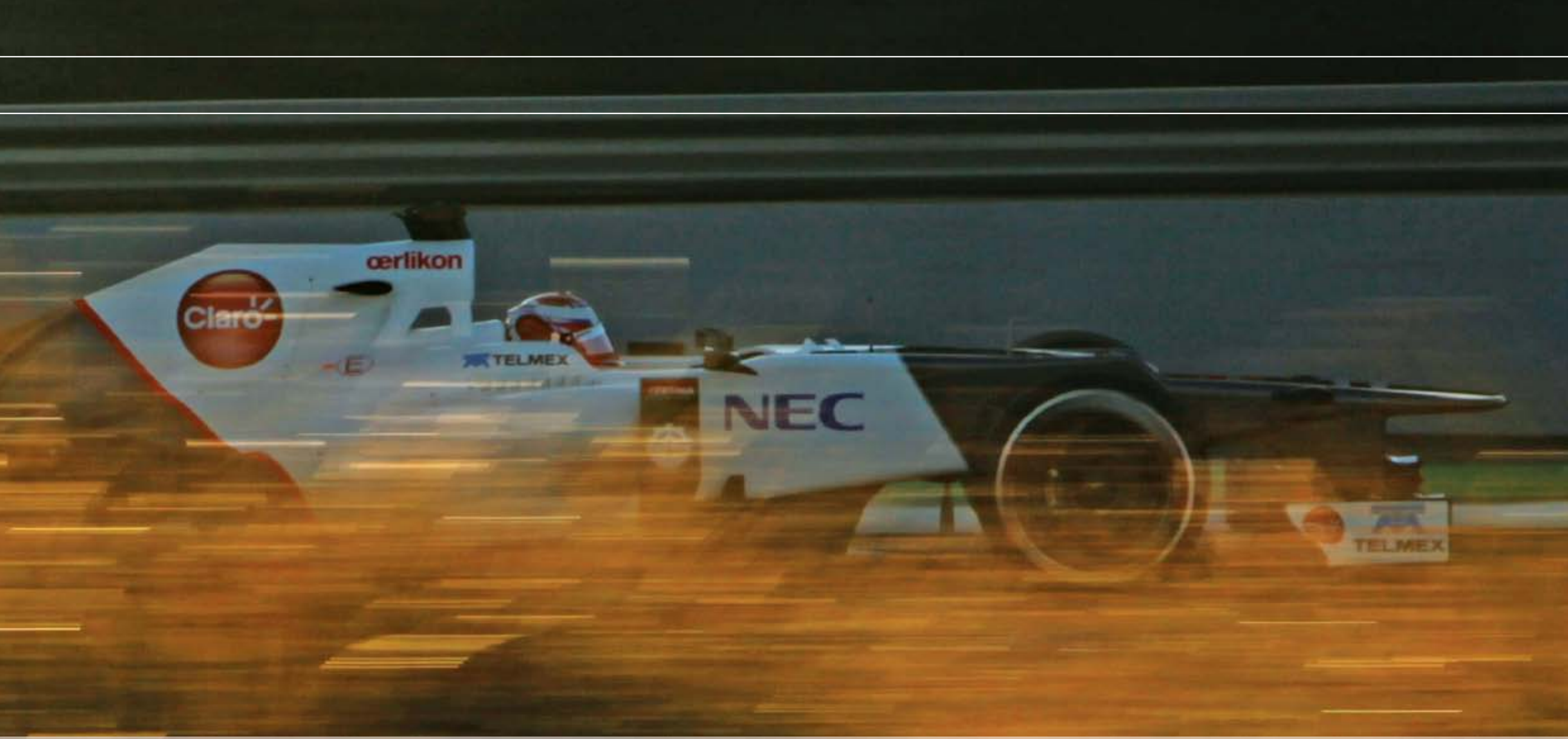
THE EXHAUST ISSUE

In 2010, and especially in 2011, many teams took advantage of a loophole in the regulations that allowed engine exhaust gasses to be used to drive the car's floor, essentially increasing downforce. Notably Red Bull and Renault built their cars around the concept. Special engine maps were created which, in very broad terms, turned the driver's accelerator pedal into a torque demand switch whilst the engine ran at 100 per cent throttle 100 per cent of the time. The downforce gain from the concept was significant, but it was clear that the situation could not continue. A mid-season ban was mooted, enforced and then dropped, but blown floors were definitely on the way out.

'The teams decided around Silverstone in 2011 that we were going to get rid of exhaust blown rear diffusers, and that point alone requires a very different design concept,' explains Allison. 'Recent car designs have been heavily influenced by their rear exhaust configurations, and the intent of the rule is to stop that happening. The rules on the exhaust geometries themselves have been reinforced by some engine operation rules which don't sit in the technical regulations, but which arrived by Technical Directive quite late last year. The exhaust issue, although agreed in principle at Silverstone, continued to unfold as late as mid-November, so the challenge has been to roll with the punches as the detail emerged over a fairly extended period – trying to make the best of each version of the rules as they've come out, whilst trying to anticipate where the end position is going to be.'

For 2012, the new regulations dictated that the exhaust must exit in a prescribed box that is in a similar location to the top exit exhausts of 2008 and 2009. The designs are also subjected to particular exit angles and diameters as a means of providing further restriction. Finally, a raft of technical regulation changes were introduced to limit software, especially on the engine and transmission maps.

'For us in the world of engines, 2012 involves dealing



with the backlash of the exhaust regulation changes,' explains Rob White, Renault Sport's F1 engine boss. 'The easy option would be to go back to what we did in 2010, but we can't. We can't because things move on and we cannot unlearn what we've learnt. More particularly, we are not permitted to do some of the things that we were doing then. Some of the engine set up things we found quite useful for reliability and performance reasons have subsequently been forbidden. So now our job is to work out new solutions to those problems and deal with specific installation challenges of the cars we have.'

RE-CAPTURING LOSSES

Despite the rule makers' best efforts, it seems the teams have already started to find ways to re-capture some of the losses, or at least are actively trying to do so. One team's chief designer claimed that gaining points of downforce from exhaust blowing was 'addictive'. The way the rules are written, too, could leave some areas open for interpretation, and this has already sparked debate.

'The overall intention of the rule change was to make the exhaust as aerodynamically neutral as possible. The written rules allow lots of solutions that are aerodynamically neutral, but they also allow lots of others which are very aerodynamically positive,' explains Allison. 'The FIA has indicated in technical directives that the intention of the rule had to be respected as well as what is written. So there are solutions that are legal by the regulations, but are not legal in the intention of the regulations. So the real challenge is to judge where to exit the exhaust and whether that is acceptable in the intention of the regulations, and what acceptable means!'

Force India's technical director, Andrew Green, openly admits that his teams of engineers at Silverstone and Brackley are actively trying to circumvent the ban and find ways of using the exhaust to generate downforce. 'We have quite a few developments in this area, but it is a very, very fine balancing act between trying to get the exhaust to deliver in the area where we had it last year without fundamentally bringing down the overall performance of the car.'

'The exhaust position and direction is pretty well tied up, but you can do a little bit with it and you'll see teams tweaking it in testing and early races, but I think the main source of development is going to be the way the bodywork reacts with the plume around the exit of the exhaust, and that is where the development will be trying to get the exhaust to attach to the bodywork and drag it down to the rear. It's about adding energy to the rear of the car. It's a huge source of energy you want to do something with and it's about trying to get it down to that suction point on the car. There are areas that have shown promise and it comes down to the amount of development resource you can apply to it. We are actively pursuing it and we see it as an important area to exploit.'

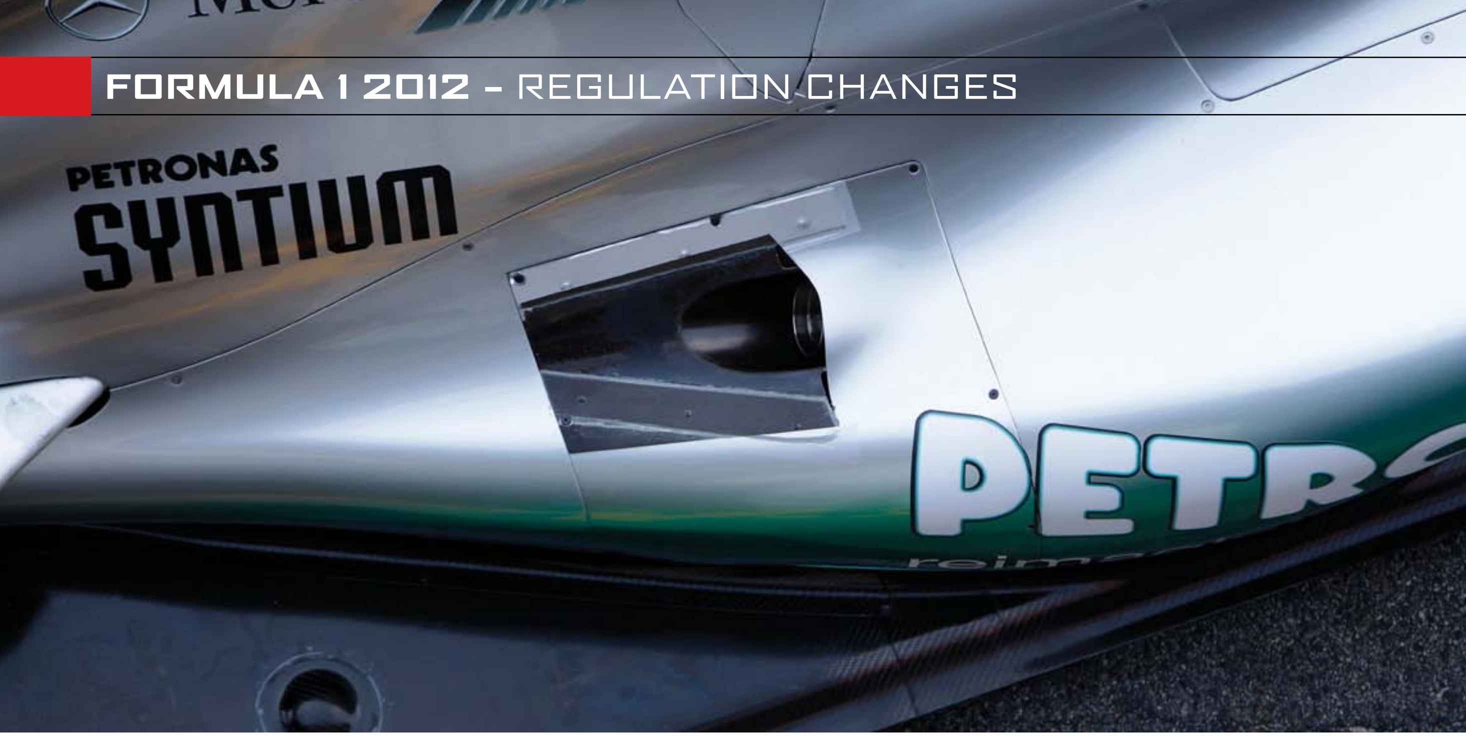
But with software restricted more heavily than in 2011, the teams are now faced with a new challenge – not only are the exhausts critical in terms of engine performance and downforce, they are also critical in the driveability of the car. In 2011, the complex maps used by the teams meant exhausts created downforce when the driver was off the pedal. In 2012, that is not possible, creating another complex problem: 'You really do have to get the balance right though, on and off the throttle,' Green continues. 'You can start to exploit the exhausts but it suddenly gets harder and harder to drive, and it's a balance between the car being driveable and aerodynamic performance. That's all being developed in the simulator.'

Even if the FIA suspect that a design is not complying with the intention of the rules, it seems hard to comprehend how the scrutineers will check the direction of the exhaust gasses in practice.

Developing a workable blown floor was not easy in 2011, and not all teams were able to reach fully working solutions, so it seems likely that in 2012 there will also be teams that are not able to develop optimum layouts. 'I do not mind displaying my ignorance in this area,' explains the candid technical director of the Toro Rosso team, Georgio Ascanelli. 'We cannot be the best because our simulation capacity is limited in this respect. We cannot simulate this in our wind tunnel, yet. It depends on the pulse, the speed of exhaust gasses compared to the speed of the airflow, the expansion rate, the temperature, ride height and cornering speed. We cannot simulate all of these things with sufficient certainty. Ferrari supply us data on what they expect the exhaust plume to be, so what we can do is try to apply theory.'

But not everyone places such importance on the exhaust position, including the technical boss of the team that gleaned the most benefit from blown floors in 2011. 'There is not a lot to come out of them,' contests Red Bull's Adrian Newey. 'As often happens when there is not a lot to be gained, you get a real variety of different positions.

"For us in the world of engines, 2012 involves dealing with the backlash of exhaust regulation changes"



Working within tight bodywork regulations, the teams are having to find a way to ensure exhaust gasses flow down toward the rear of the car

NEW TYRES = NEW PRODUCTS

Whilst the Pirelli tyre compounds for 2012 have been revised, they are still from the same family, and this could see a continuation of a phenomenon seen since the introduction of the Italian rubber at the start of 2011. English firm Zircotec, best known for its thermal barrier coatings, came up with a solution, dubbed ThermoSlik, in 2011 and has opened the product up to the wider market in 2012.

'Ensuring clean surfaces is essential,' explains the firm's managing director, Terry Graham. 'A development from our smooth thermal barrier coating – itself conceived to minimise disruption in and around the diffuser – adds a repellent property to the formulation.'

With tyre degradation, aerodynamicists have been troubled by the build up of debris, notably rubber 'marbles' on aerodynamic surfaces. 'The repellent element is an intrinsic part of our thermal barrier coating,' adds Graham. 'It offers a lightweight, subtle solution that not only prevents delamination, but also adds a little aero performance.' Developed over the past eight months and proven in the second half of 2011 on track, the ThermoSlik coating is applied at Zircotec's UK facility where all preparation, coating and finishing takes place. Due to the application process and materials used, ThermoSlik is only validated as a combined heat and repellent offering, but Graham leaves the door open for further derivatives. 'We are always keen to work with the teams on specific issues,' continues Graham. 'We have a number of other projects in the powertrain and aero where a coating is solving issues or unlocking performance.'

Understanding the tyres is also critical, and another English firm has re-worked its products to meet the demand of the teams. bf1systems has introduced a new ECU for its tyre monitoring systems. It is 50 per cent smaller than the company's previous motorsport digital ECU, whilst retaining all the same functionality. Later in the year, the firm will introduce a combined ECU / antenna unit, which will be introduced to teams using its systems, replacing the existing antennas and ECU on the car with a single box. 'We are able to offer a 140g (down from 250g to 110g) saving over the current on-car parts,' says bf1systems' electronics manager, James Shingleton. 'Together with a much simplified wiring loom, this is a notable weight and complexity saving. Testing of the combined system is expected during the season and direct pin-out compatibility means users will be able to make the smooth transition without concerns over loom connectivity when it is released.'

With testing so restricted and teams craving ever more data, bf1systems is offering an eight-channel version of its tyre pressure and temperature monitoring system. 'For the first time, we are enabling engineers to accurately and reliably measure the inner tyre carcass temperature at two different places on the tyre,' claims Shingleton. 'The opportunity to acquire temperature data from two parts of the same tyre concurrently, on all four tyres, is especially important with the new tyres and running time being so limited.'

I doubt there is really a lot to be had though and the FIA do not want to see flow-catching ducts. In other words, scooping the exhaust flow up and then using that flow somewhere on the car. When double diffusers were banned at the end of 2010 we were largely able to replace the fact they had gone with the exhaust pipe location. With this rule change it is very difficult to replace the exhaust effect and there is no big grand idea that will replace the diffusers of last year.'

INCREASED POWER

All of this has more than just an impact on aerodynamic performance and engine tuning. The change to the exhaust exit location and, more significantly, the changes to what is allowable in terms of engine maps, has effectively increased the amount of power produced by the 2.4-litre V8 engines, and also has had an impact on the cars' fuel tanks. To power a blown floor effectively and generate additional downforce, an engine must produce significant amounts of exhaust gas. Simply put, the more fuel burned, the more exhaust is produced, and potentially more downforce. According to Renault, the teams using its RS27 engine at the 2011 Australian GP were able to burn 10 per cent more fuel than normal without running out, giving more exhaust flow to its partners using the blown diffuser.

But whilst pretty much every

car on the grid features a smaller fuel cell, the effect on weight distribution is not that great, at least according to Newey. 'There is a small reduction in fuel consumption due to the exhaust regulation change but it is not 10 per cent. The fuel is carried centrally in the car so it has a small effect on start line weight, but its effect on weight distribution is negligible.'

Anyone watching the free practice sessions at the 2011 Abu Dhabi GP could not have failed to notice the front wing of the Ferrari fluttering badly. This wing could pass all of the load tests designed to stop wing flex at high speed, yet still clearly flexed a large amount. So a technical directive was issued by the FIA in November, increasing the amount of load the front wings have to take without flexing during the scrutineering tests. This small regulation change was aimed at stopping teams using clever composite design to circumnavigate the intention of the regulations, but it had unintended consequences. 'It was a bit of a shock to have the front wing change so late in November,' admits Newey. 'The main consequence is that the front wing becomes heavier, which is particularly difficult for drivers like Mark Webber, who is naturally heavy in the first place, and that puts a bit of the challenge on the weight distribution.'

Further increasing the technical directors' headaches at that late stage was that the fixed weight distribution window introduced in 2011 to help Pirelli join the series as a new tyre supplier was carried over for 2012 and 2013. This limits teams to a maximum front axle weight of 291kg and a rear of 342kg in qualifying (and subsequently the race) and only gives designers a 7kg window to operate in.

SOFTLY, SOFTLY

One of the factors all teams' engineers will have to deal with is the Pirelli tyres. The Italian firm has adjusted some key characteristics of its tyres in response to the 2012 aerodynamic regulations, specifically the loss of blown floors. The results of on-track tests with the teams and Pirelli's own Toyota TF109 test car have been integrated with the data from simulation, which is able to recreate and predict tyre behaviour and performance at the circuits and weather conditions of the 20 tracks that make up the Formula 1 calendar.

Pirelli found that without the blown floors there would be a reduction in downforce acting on each tyre, requiring a wider and more even contact patch. This objective has been met by having a less rounded shoulder on each tyre and using softer compounds, which the firm claims will produce better grip and more extreme performance.

Three of the four slick tyre compounds have also been changed. The soft, medium and hards will all be somewhat softer, as Pirelli attempts to reduce the performance gap between them. During the 2011 season, there was a difference of between 1.2 and 1.8 seconds per lap among the different compounds. For 2012, however, the firm's engineers have targeted a difference of between six and eight tenths of a second, though not all in the paddock expect to see that happen.

'We get basic Pajeka book data and the profile data from Pirelli, along with a compound working range stiffness chart, which lets us compare where the compounds sit compared to last year, and we have our own thoughts on that and they are different to where Pirelli think they sit,' reveals Green.

The season, it seems, is likely to be dictated not by which team has the best (or ugliest) nose, but rather who manages to best exploit the exhaust gasses and the regulations covering them, and also the one that succeeds in working the tyres in the best possible window.

One thing at least seems certain – Red Bull will not have such an easy ride as it did in 2011. The RB7 was entirely built around a now-outlawed concept, so the RB8 does not have that in its favour, and its rivals are certain to take full advantage of that fact.

FERRARI FRONT SUSPENSION by Nicholas Tombazis

'The reason we went for pull rod front suspension was primarily aerodynamic. We feel it handles in a better way the flow structures that come from the front wing, so that is the main driving force. We were obviously very concerned about the loadings to the suspension and so did quite a lot of work making sure we have done our homework correctly. In quite a few areas we found that the front suspension had to be made more robust, which we have done to overcome those loads. if you look at the front view of the car, you will notice the pull rod and the wishbone form fairly regular triangles in relation to each other. So, in the end, we found a solution that was probably a bit more loaded, but was quite acceptable from both a mechanical and an aerodynamic standpoint.'

Ferrari has taken a very different approach to its front suspension on the F2012, uniquely for the 2012 season going for a pull-rod layout

OTHER RULE CHANGES

Car floor
The floor under an F1 car (the so called step and reference planes) has to be designed flat. Because things cannot be made perfectly flat, a manufacturing tolerance of +/-5mm was permitted. It was felt latterly that this 5mm tolerance allowed opportunities to design [illegally] some mild contours into the floor. To clamp down on this possibility, the tolerance has been reduced to +/-3mm.

FOM cameras
Recent seasons have seen the FOM nose cameras located in a manner clearly aimed at promoting the performance of the front wing, rather than to deliver effective TV pictures. A new article (20.3.4) has been introduced to ensure a minimum standard for the field of view of any nose-mounted camera. A similar minor change is made to the roll hoop camera location to ensure that a clear picture is not sacrificed on the altar of downforce.

Suspension
Suspension members (wishbones / track rods etc) are bound by strict aerodynamic limitations on such as chord, symmetrical section, maximum incidence angle etc. This is not true of the uprights, which hold the wheel on to the suspension. Their design has always been free and there existed a possibility (albeit never yet exploited) that someone would make a giant, aerodynamic upright to make use of this hypothetical freedom. Pre-empting this, a change to article 10.5.3 has been introduced to ensure that the uprights cannot protrude beyond the volume currently allowed for brake ducts, effectively preventing the giant upright problem from ever occurring.

Red arrow

A controversial design and a problematic start to the season raised eyebrows, but tweaks behind the scenes helped put the Maranello marque back on a competitive track

BY SAM COLLINS

"We decided that the only way to make a step forward was to be much more aggressive in our approach to the design of the car"

Ferrari's 2012 season did not get off to a good start. The official launch and shakedown runs of its 58th Formula 1 car had to be cancelled at the last minute due to heavy snowfall in Italy, and indeed at one point it looked as though the team's transporters would struggle to make it to the first pre-season test at Jerez in Spain. When the car was shown off on a snowy Fiorano circuit, the reception was not positive. The Italian press dubbed the F2012 'the ugliest Ferrari in history', and certainly its angular nose was far from pretty.

Ferrari's chief designer Nicholas Tombazis defended its design. 'This car represents a clear break with the one that preceded it,' he said. 'It features concepts that are very different for us, that require much more fine tuning. We decided that the only way to make a step forward was to be much more aggressive in our approach to the design of the car. It's true that the arrival of Pat (Fry) in the role of technical director made a significant contribution to this change, but it was a direction our group had already initiated. No one will be able to accuse us of having been timid in the design of this car.'

FUNDAMENTAL CHANGES

The car, which was known internally as the 663, was a major change from the 2011 design. Practically every area of the car was fundamentally revised. 'The nose has a step in it that is not aesthetically pleasing,' explained the manufacturer's official literature. 'With the requirement from the regulations to lower the front part, this was a way of raising the bottom part of the chassis as much as possible for aerodynamic reasons.

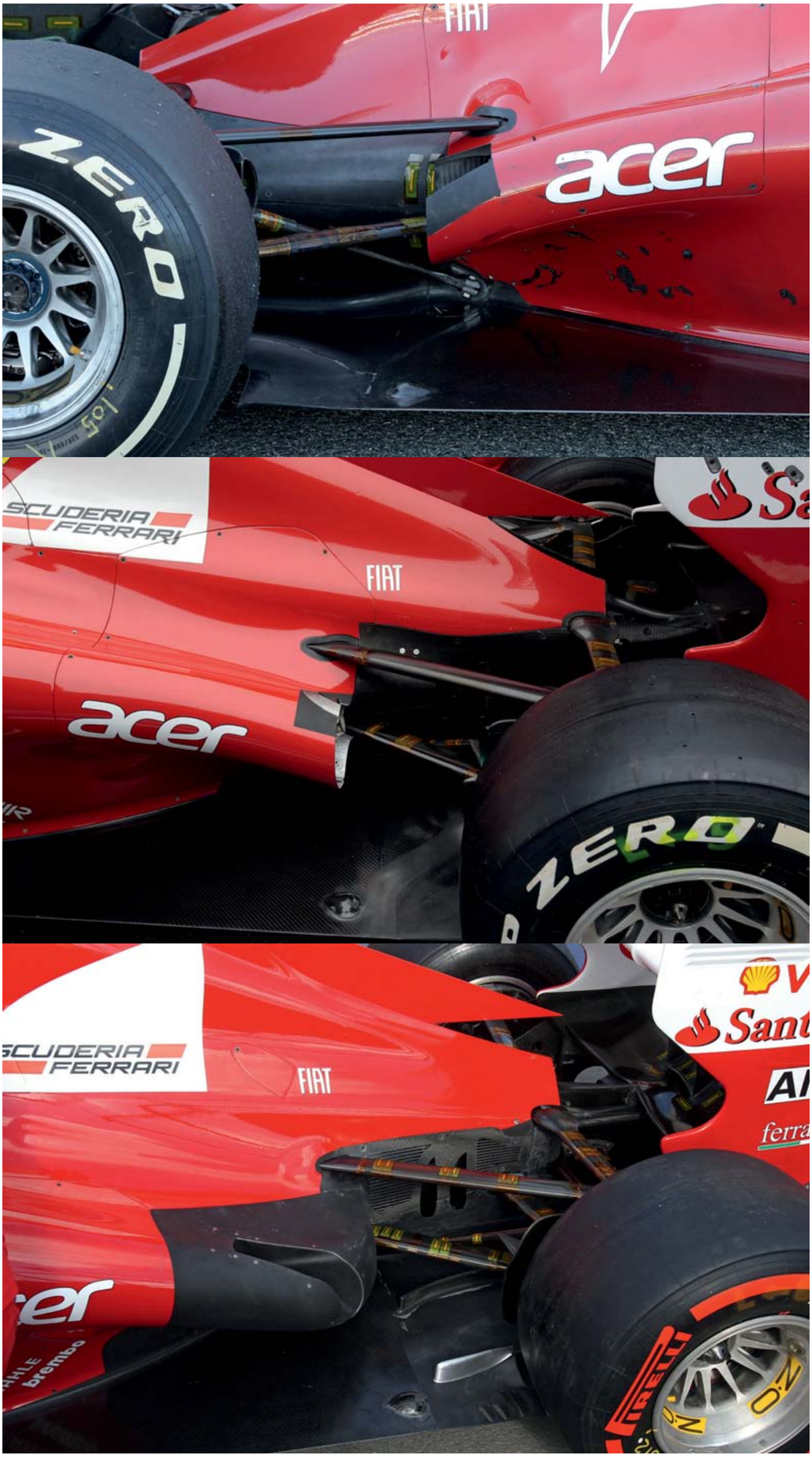
'The sides have been redesigned, through modifications to the side impact structures, the repositioning of the radiators and revisions to all aerodynamic elements. The lower part of the rear of the car is much narrower and more tapered, a feature achieved partly through a new gearbox casing, and a relocation of some mechanical components. The front and rear air intakes for the brakes have been redesigned and work was carried out in collaboration with Brembo to optimise the braking system.'

The engine in the car was a mild evolution of the Ferrari 056 2.4 litre normally aspirated V8. Development of internal components has been forbidden for some time, leaving the Maranello engine department to concentrate on other areas, such as making the installation much neater so as not to negatively impact the cars aerodynamic package too severely. On top of that, ways of improving the engine's life became critical as the calendar extended to 20 races. Several decades of technical collaboration with Shell has seen further progress on the fuel and lubricants front, aimed at improving performance in absolute terms and on durability over the life cycle of the engines, as well as reducing consumption.

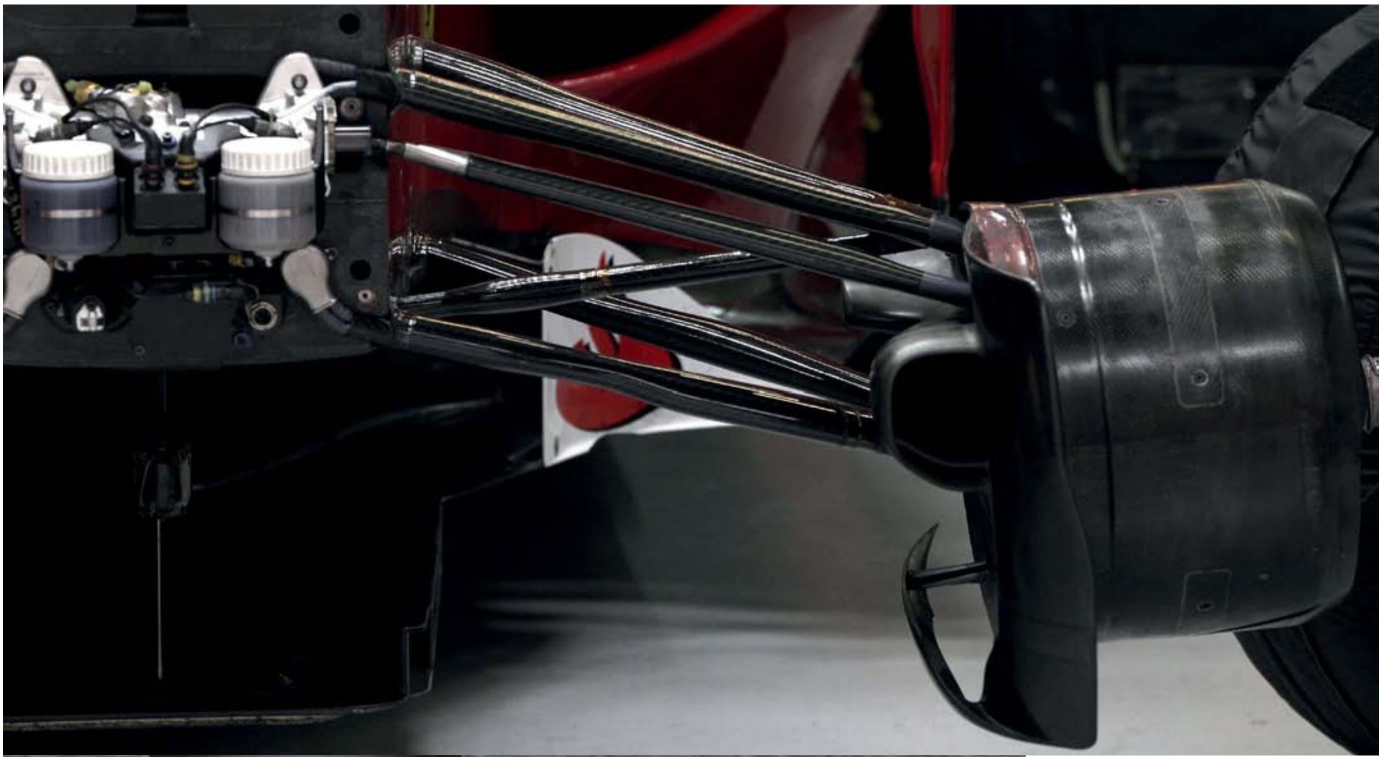
The electronic management of the engine had to be revised due to the substantial rule changes aimed at outlawing 'hot blown' diffusers. Finally, the KERS was revised. While the battery pack remained under the fuel cell, an update directed mainly at reducing system weight, while improving the efficiency of some of its components, was carried out. After the car took to the track in testing, things did not look much better – it was off the pace and appeared to lack stability. Coming out of slow corners, it appeared to struggle to get the power down, and in fast corners it appeared to understeer.

SUSPENSION ISSUES?

Observers immediately questioned one of the obvious design features of the car, the front suspension. Uniquely, it had pull rod actuated dampers instead of the more commonly used push rod layout. 'The reason we went



Ferrari struggled with its exhaust design throughout the year. In early versions (top and middle) the aim of effectively generating a blown diffuser was not really achieved. The team did not fully understand why its designs were not working until later in the year when it found issues with its wind tunnel. Sessions in the TMG wind tunnel resulted in a more effective layout used in the final races (bottom)



The F2012, unusually, featured pull rod suspension all round, principally for aerodynamic reasons. Whilst the layout is not as good from a suspension design perspective as a push rod layout at the front, the beneficial impact on the air flow outweighs that.

"A team has the right to question his chief designer, and if they're not winning, wonder if he is the right person for the job"

for pull rod front suspension was primarily aerodynamic,' Tombazis explains. 'We feel it better handles the flow structures that come from the front wing, so that is the main driving force. We were obviously very concerned about the loadings to the suspension and so we did quite a lot of work making sure we have done our homework correctly.

'In quite a few areas, we found that the front suspension had to be made more robust, which we have done to overcome those loads. If you look at the front view of the car, you will notice the pull rod and the wishbone form fairly regular triangles in relation to each other. So in the end we found a solution that was probably a bit more loaded but it was quite acceptable from both mechanical and an aerodynamic standpoint.'

The problems in testing, however, did not relate to the suspension, but more the exhaust layout on the car. With off-throttle blowing of the diffuser essentially outlawed and the exhaust exit position fixed into a very limited wind, the aim was to get some benefit from a passive or 'cold blown' diffuser. To do this requires some sophisticated tools, and it was clear from the number of iterations of exhaust design fitted to the F2012 that Ferrari had lost its

Subscribe & SAVE OVER 30%

UK readers **SAVE £20** *PER YEAR*

US readers **SAVE $45** *PER YEAR*

OFF THE RETAIL PRICE!

Receive 12 issues of *Racecar Engineering* for just **£46 in the UK** or **$105 in the US**, that's a saving of **more than a 30% off** the newstand rate!

PLUS FREE POSTAGE to your home or workplace

SPECIAL OFFER PRICES ON *RACECAR ENGINEERING*

Subscribe for 2 or 3 years and SAVE EVEN MORE!

UK	USA	REST OF THE WORLD
• Direct Debit 1 year just **£46**	• 1 year just $105 (usually $150)	• 1 year just £69 (usually £90)
• 1 year just £52 (usually £75)	• 2 years just $198 (usually $300)	• 2 years just £130 (usually £180)
• 2 years just £96 (usually £150)	• 3 years just $290 (usually $450)	• 3 years just £190 (usually £270)
• 3 years just £140 (usually £225)		

DON'T MISS OUT! ORDER NOW

Online www.subscription.co.uk/racecar/P206

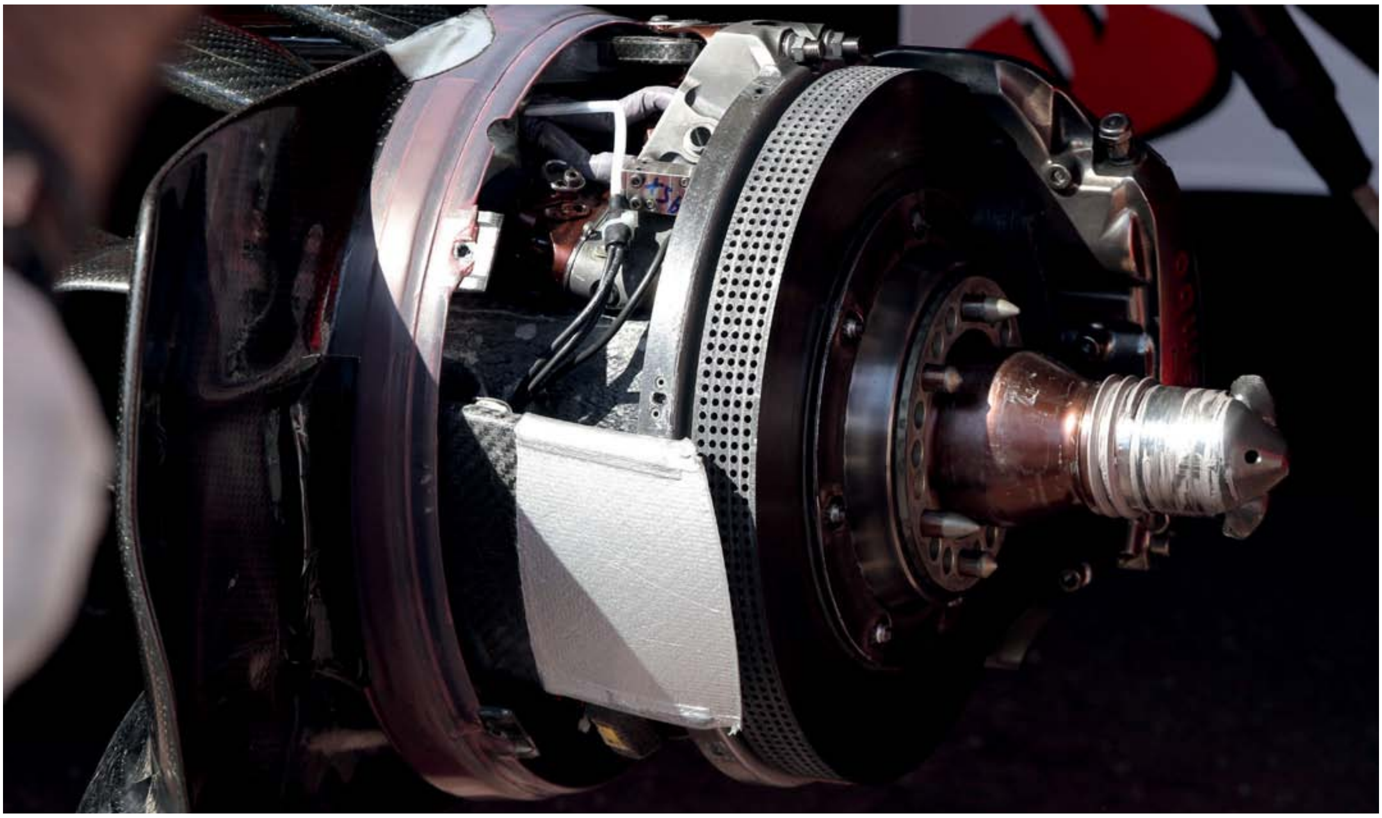
Phone +44 (0) 1858 438443 quote code P206

DIGITAL SUBSCRIPTION

Racecar Engineering is also available to read on your iPad, computer or smartphone - giving you instant delivery and easy access to the magazine wherever you are in the world.

NEW!

For more information visit www.racecar-engineering.com/subscribe



Ferrari lacked the clever temperature adjusters on the brakes used by Red Bull and McLaren, as the technical team was focussed on understanding why its updates did not work

way. Indeed one of the critical tools was not functioning as it should. 'I think we had a reasonable understanding of the problems with the car,' Tombazis admitted. 'There were a number of different issues that we had early on, the most obvious being the exhaust system, where we were struggling with what that was doing to the rear tyres. The biggest performance differentiator in Formula 1 is aerodynamics. We had some issues there.'

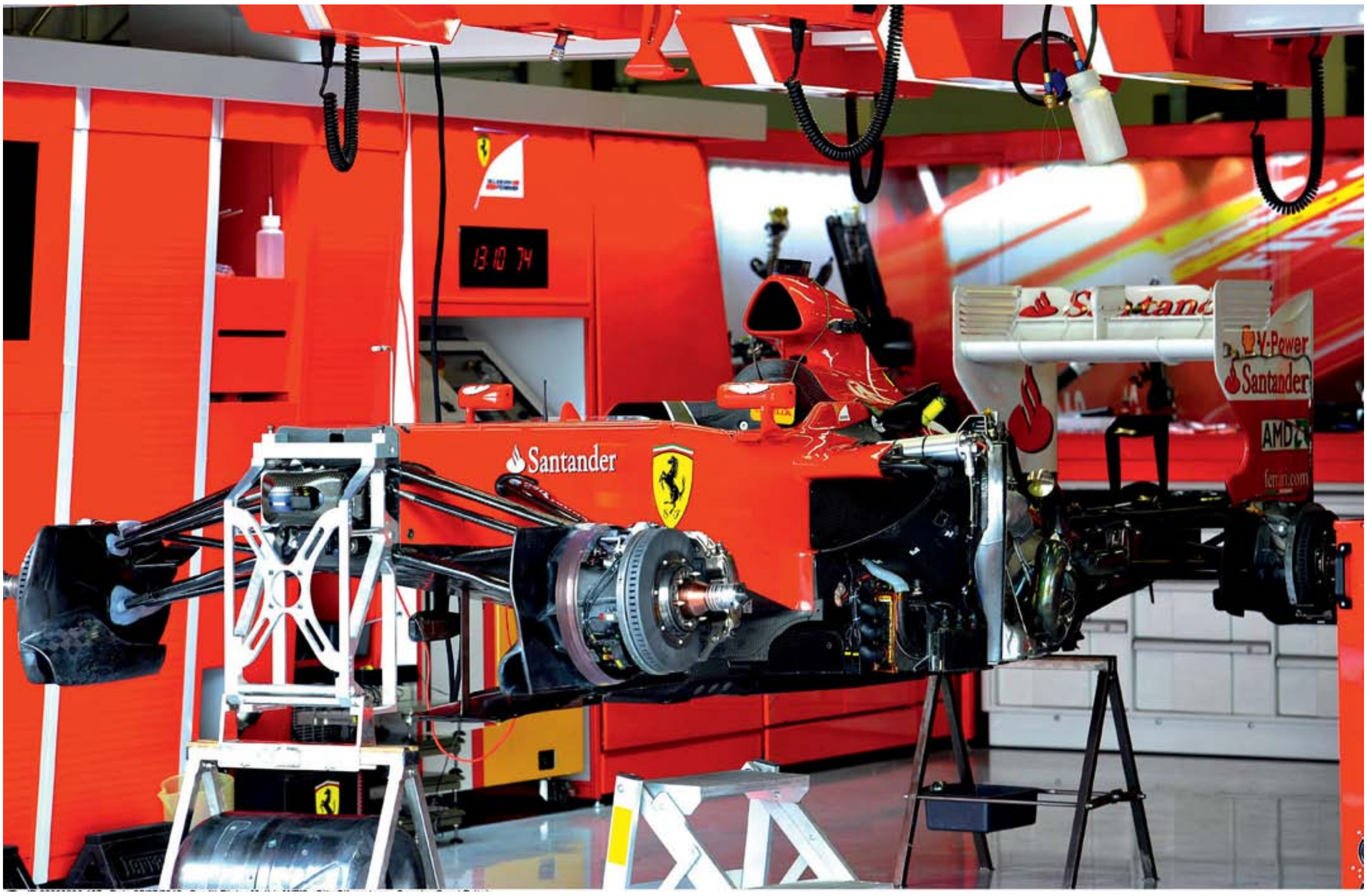
BAD WIND

The issues made it look like Ferrari was in for one of its worst seasons ever, and Tombazis later admitted that he feared for his job. 'A team has the right to question his chief designer,' he says, 'and if they're not winning, they wonder if he is the right person for the job. We have recovered from one of the worst beginnings of my whole career. For now we are alright, but we needed to keep developing if we were to win the world championship. The first step was to recognise where we were wrong. And as is the case with an alcoholic, one starts from admitting you have a problem.

Ferrari circumvented regulations, only allowing a single opening in the bodywork by linking many additional slots and ducts together with tiny cracks. The collection of holes are a single hole in the eyes of the regulations

One thing that Ferrari had to admit was that there was a problem with its wind tunnel. Built in 1997, the 50 per cent scale rolling road wind facility was not producing the expected results. Team principal Stefano Domenicali admitted this to the press during an FIA Conference. 'Our tunnel is not the best one,' he said. 'It is quite old, so we had to try to improve the quality of the tools that we had. We had to resolve a correlation issue. I saw the impact of this in the second part of the season, when we were trying to bring new updates on the car. Not all the of them were working on the track.

'So, we started to investigate a little bit better and we've found this issue, going into the deep analysis of the reason, we understood, we considered and realised it was coming from the tool. It is not obsolete, but not really up to the speed of the new technologies that are available on the market. So, that was the reason why we are trying to



TECH SPEC

Ferrari F2012 (663)

Class: Formula 1, 2012

Chassis: Carbon-fibre and honeycomb composite structure

Transmission: Ferrari longitudinal gearbox, 7-speed, plus reverse, quick shift, limited-slip differential.

Brakes: Brembo ventilated carbon-fibre discs.

Suspension: Independent, with pull-rod activated torsion springs front and rear.

Wheels: OZ Wheels, 13".

Weight: 640kg (with water, lubricant and driver).

Engine: Type 056, 8 cylinder. Cylinder block in sand-cast aluminium V8 90°.
32 valves, pneumatic distribution, total displacement 2398cc.
98mm piston bore, weight >95kg.
Electronic injection and ignition.

Fuel: Shell V-Power

Lubricant: Shell Helix Ultra

make sure that the percentage of the things that we bring to the track is higher than before.'

To counter these issues, Ferrari used liberal amounts of flow visualisation paint in free practice sessions to find out what was going on. 'We brought some new components for the car that should have made it faster, and it had the opposite effect,' explains Tombazis. 'When you find things working in the wind tunnel but not at the track you have to be very careful about what is happening. Wind tunnel correlation is not black and white. There can be poor correlation for a number of reasons, whether it is the quality of the flow, the scale of the model, or the size of the tunnel. There can be a huge number of causes. What's clear with our tunnel is that there are some areas where we have failed in bringing performance to the car. What we have decided to do is to take some big steps to upgrade our wind tunnel.'

While the upgrade process was taking place, Ferrari started to use the TMG wind tunnel in Cologne. 'In an ideal world, to have one good tunnel is much simpler than having two. Then you don't have to constantly compare them,' Tomabis continues. 'When you have correlation issues, though, it's useful to have the second tunnel. We organised an aero test to evaluate all the components ahead of the Indian Grand Prix, and we found some clear directions then.'

By mid-season, Fernando Alonso scored three wins and six podium finishes despite the deficiencies of the car. Then, Sebastian Vettel recorded four wins in succession, signalling a return to form for Red Bull, and they were joined at the front by McLaren. Both had overtaken the Italian team in the development race. Ferrari never managed to regain its points advantage, although Alonso was able to take the fight to the last race. 'If you look at it as a whole, you could be reasonably pleased that we were one of the two championship contenders compared to where we were at the start of the season, when we were in a very bad shape,' rues Domenicali. 'That said, we had hoped to be a bit further ahead in the last few races. We had brought quite a few upgrades to the car that we hoped would close the gap to Red Bull, but that did not happen for various reasons. That has been frustrating for us.'

Ferrari expects to bounce back next year, and fight for the title once again, this time on even terms with Red Bull, Lotus and McLaren. 'We need to work very hard to make sure that the problems that we had this year, mainly at the beginning of the season, will not happen again,' concludes Domenicali.

'So, it's quite long work that we are doing at home to make sure that we will improve that situation.'

"The biggest performance differentiator in Formula 1 is aerodynamics. We had some issues there"

Development of a champion

The heritage of the Red Bull RB8 stretches back further than you might think. Adrian Newey takes us right back to the start

BY SAM COLLINS

'I think the result today or the result last week or whenever, the results in the last two years are not just thanks to me, or thanks to any particular person in the team, I think it's thanks to all of us. Everyone is pushing hard, there are lots of bright guys with good ideas. Obviously some guys are really important but all in all, that's the spirit we share and it's just nice to be a big part of it.' These the words of an elated Sebastian Vettel following yet another dominant win. His team Red Bull Racing has essentially dominated Formula 1 ever since it adopted a new design concept at the start of the 2009 season.

The man heading up the team behind that concept is used to life at the front of the grid. Indeed, in the last two decades Adrian Newey-designed cars have won eight World Constructors Championships and nine drivers titles. His philosophy is not one of aggressive revolutions in design, but instead gradual steps in a particular direction.

'The way I have always tried to work is that if you can get the concept right in the first place then, within stable regulations, I think it is good to evolve a car from there,' says Newey. 'That's what I did at Williams with the FW14 through to the FW16. That concept stopped when at the end of 1994 when there was a big regulation change. The Williams FW17 as a result was a brand new car that had nothing to do with the FW16 due to the rule changes. From then the FW17 to FW19 were very much evolutions of each other. It was the same during my time at McLaren, the MP4/13, MP4/14 and MP4/15 were all very similar.' Newey admits however that this approach has not always worked as it should. 'At the end of the MP4/15 I felt that while there was no big regulation change, the concept we were using had reached its limits,' he says. 'So we went a new way with the MP4/16 and MP4/17, but I didn't get the DNA quite right with those.'

In 2006 Newey joined Red Bull Technology, the company that develops the cars raced by Red Bull Racing, and which in the past has looked after designs for Toro Rosso as well.

LEARNING CURVE

'Continuity is hugely important,' Newey explains. 'Really, Red Bull Racing is a team that first raced in 2005, and in truth that was a Jaguar painted blue. Then it had a steep learning curve of developing the culture – there were quite a lot of new people joining, and some people from the Jaguar days choosing to leave. So it was a period of quite rapid change and that took time to settle down, and to develop a way of working – a culture, an ethos – to develop some of the bigger tools, be it developing the wind tunnel, developing simulation, things that you can't just go to Argos and buy. It takes some time to develop those from scratch which is what we were doing and to learn how to use them and how to work with them. Once you got to that stage, continuity becomes very important. People have learned to work with each other and it's

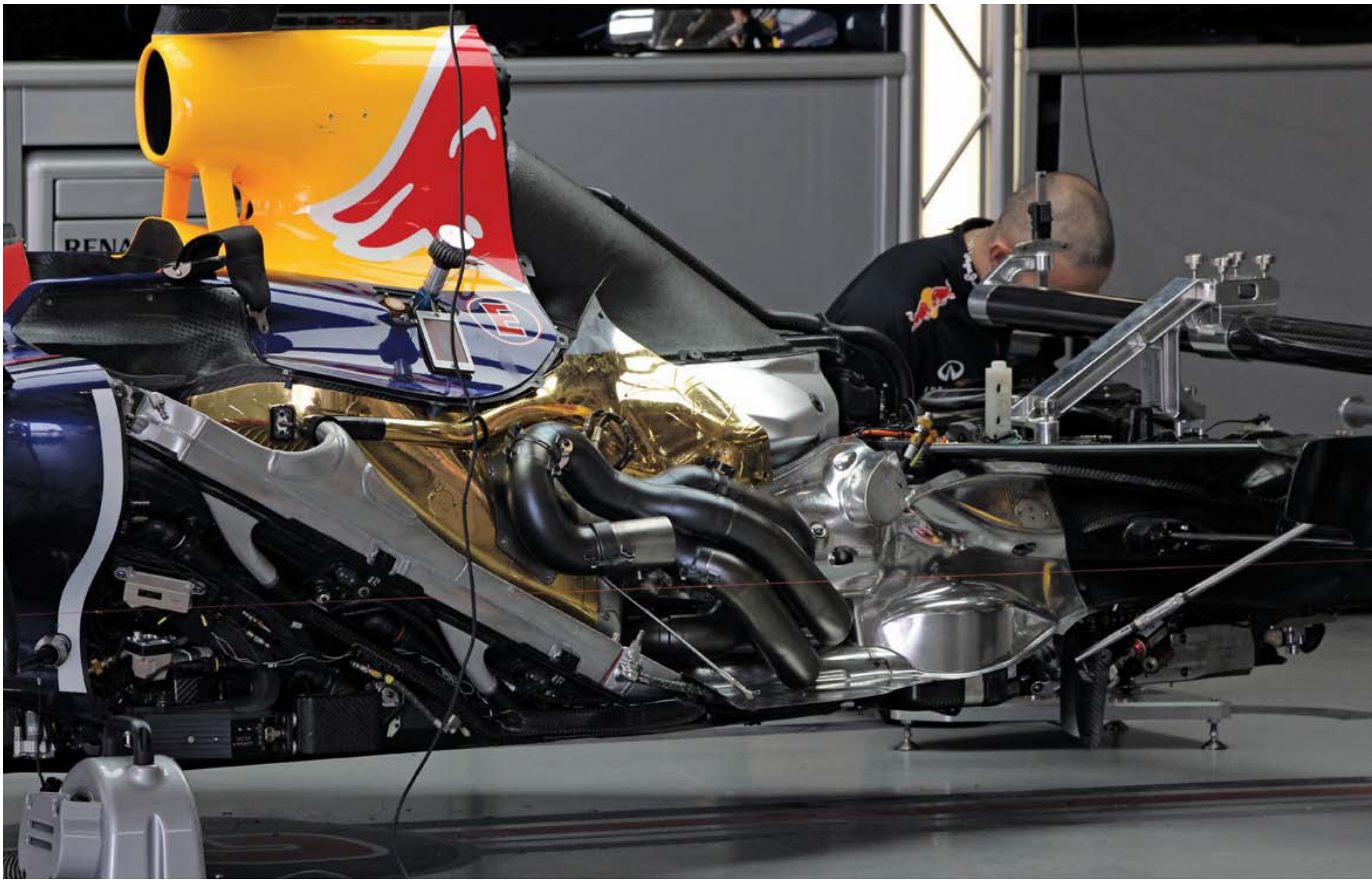
then making that an ever tighter-knit group and trying to maintain it as the team continues to grow. It's been flat for the last couple of years in numbers as a result of the RRA, which I think is very good. But it's an evolutionary thing which took us three or four years to settle down into. The big regulation change in 2009 was good timing for us, because that coincided with the point where we had started to gel together.'

This is one of the reasons for the strong form of Red Bull's cars. When the new rulebook was introduced, Newey's new concept hit the sweet spot almost straight away. If it had not been for the Brawn team's innovative double diffuser, the new Red Bull concept would have won every championship since the rule change.

Mating a Renault RS27 engine, an in-house seven speed transmission, and pull rod rear suspension with Newey's trademark, very tight aerodynamic packaging, the overall car concept introduced in 2009 still remains one of the strongest on the grid, and much of the DNA remains the same.

'The concept started with RB5 in 2009 so I guess this makes the RB8 the great-great-grandson of that design, the RB5, RB6, RB7 and this year's car are all

"The regulation change in 2009 was good timing for us, because it coincided with the point where we had started to gel together"



Exhaust layout was a strength of the Red Bulls until the regulation change for the 2012 season, which hurt the team more than most

evolutions of each other. If you sat an RB5 next to an RB8 there would be a clear and obvious resemblance,' says Newey. 'Generally speaking if a car is an evolution, which the RB8 was, its kind of a gradual process. The knowledge from the development of the RB7 was constantly fed into RB8. You have to get the big bits out of the way, though, to hit the time scales, and the longest lead items on the RB8 were the chassis and gear case as well as the internals. The initial research will centre on what is needed for those long-lead time items and it will progress on from there.'

Red Bull supplies one of those long-lead time items, its transmission, to a customer team, Caterham. On the RB8 the layout is little changed from the RB7 and the unit found in the CT-01. 'With the gearbox everybody now has instant shift, which means that you're engaging the new gear before you come out of the old gear, and you're using the backlash to get out of the original gear before you have the two gears fighting against each other. After that it is just reliability and packaging. On the RB8 the gearbox internals are the same as on the RB7, and quite a few of the assemblies carried over too. Wheel bearings, pedals and that sort of thing are the same, so we have only changed parts where there was a reason to do so,' he continues.

"With the RB8 It was about damage limitation from losing the exhaust technology"

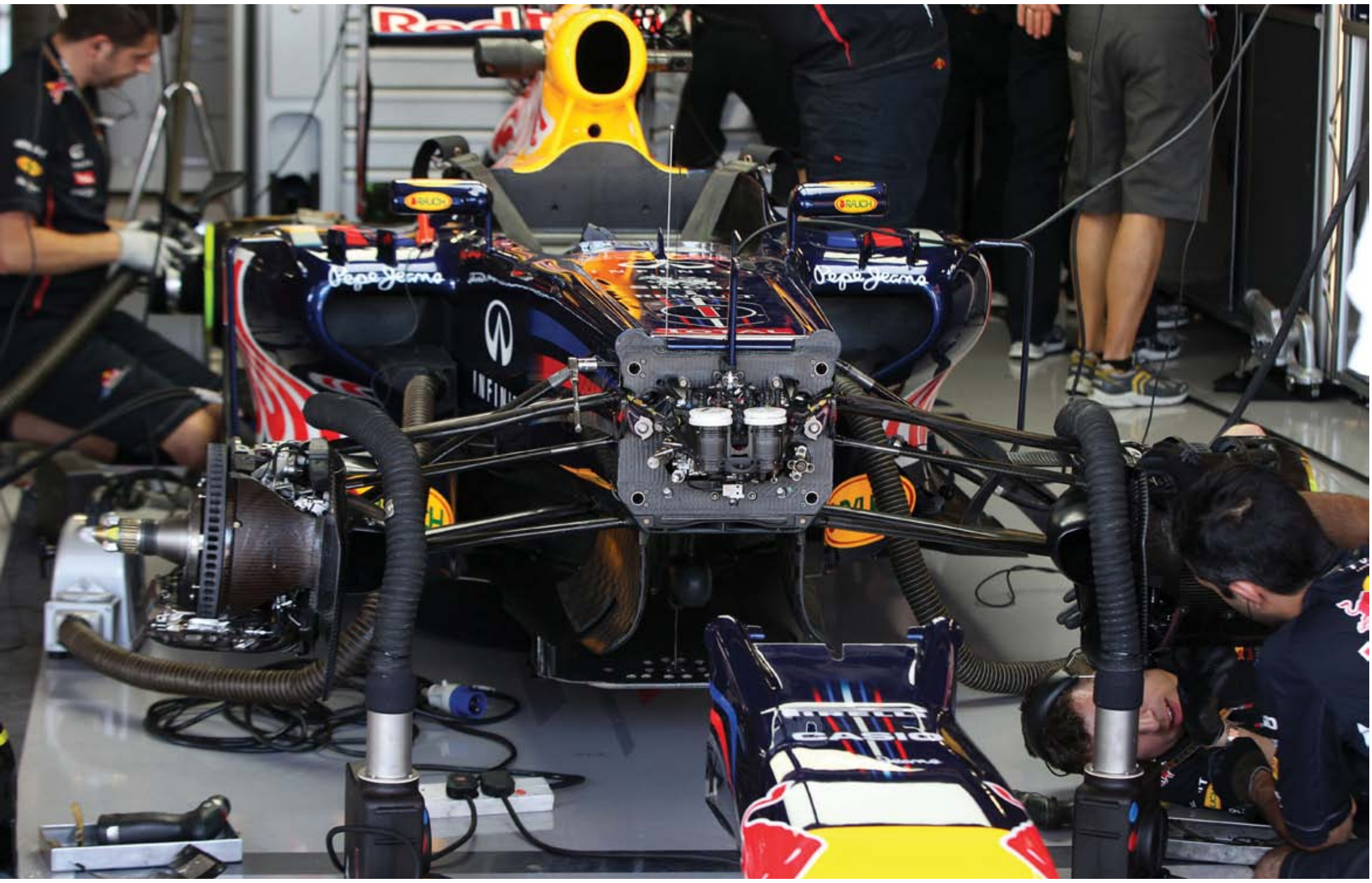
The car's monocoque is another of the long-lead time items and as was the case with all of the Red Bulls since 2009 it had to accommodate the 64kg of Sebastian Vettel who is 174cm tall and the larger 75kg frame of Mark Webber, who stands at 184cm. A regulation limits all cars on the grid to a very small window for weight distribution and this is certainly a challenge where the latter is concerned.

'That regulation puts an emphasis on light drivers, as long as we're in a situation where we don't have ballasted seats,' says Newey. 'For instance, with Mark Webber we have a driver who's on the heavier end, compared to Sebastian. That means he has less freedom on weight distribution. The obvious solution to that would be that drivers have to carry ballast on the side of their seat, but that's something that has been discussed and it hasn't happened so far. It really means that if you make the wrong move, you're locked into it for a while. It's one less variable, but one that's the same for everyone.'

While the gearbox itself is little changed, the area around it is key to understanding not only the RB8's design but also that of the RB7 and earlier cars. 'The RB5 was designed as a single diffuser car,' says Newey, 'but when double diffusers were deemed legal we put one on RB5 as best we could, but it had not been designed for it and was not as effective as it could have been. So the main focus of the RB6 was to redesign the back end of the car to maximise the double diffuser effect – that dominated the packaging of the rear suspension and so forth.

'The RB7 was different. With the double diffuser gone again it was about maximising the exhaust technology which we started to do with the RB6. It was really taken a step further with RB7, the way to recover much of the downforce lost with double diffusers was with the exhaust. It was a remarkably effective system to the point where RB7 was very close in terms of downforce to where the double diffuser car had been.'

The major change for the 2012 season was the outlawing of that exhaust technology, the so called 'hot blown' diffusers, which again meant that Red



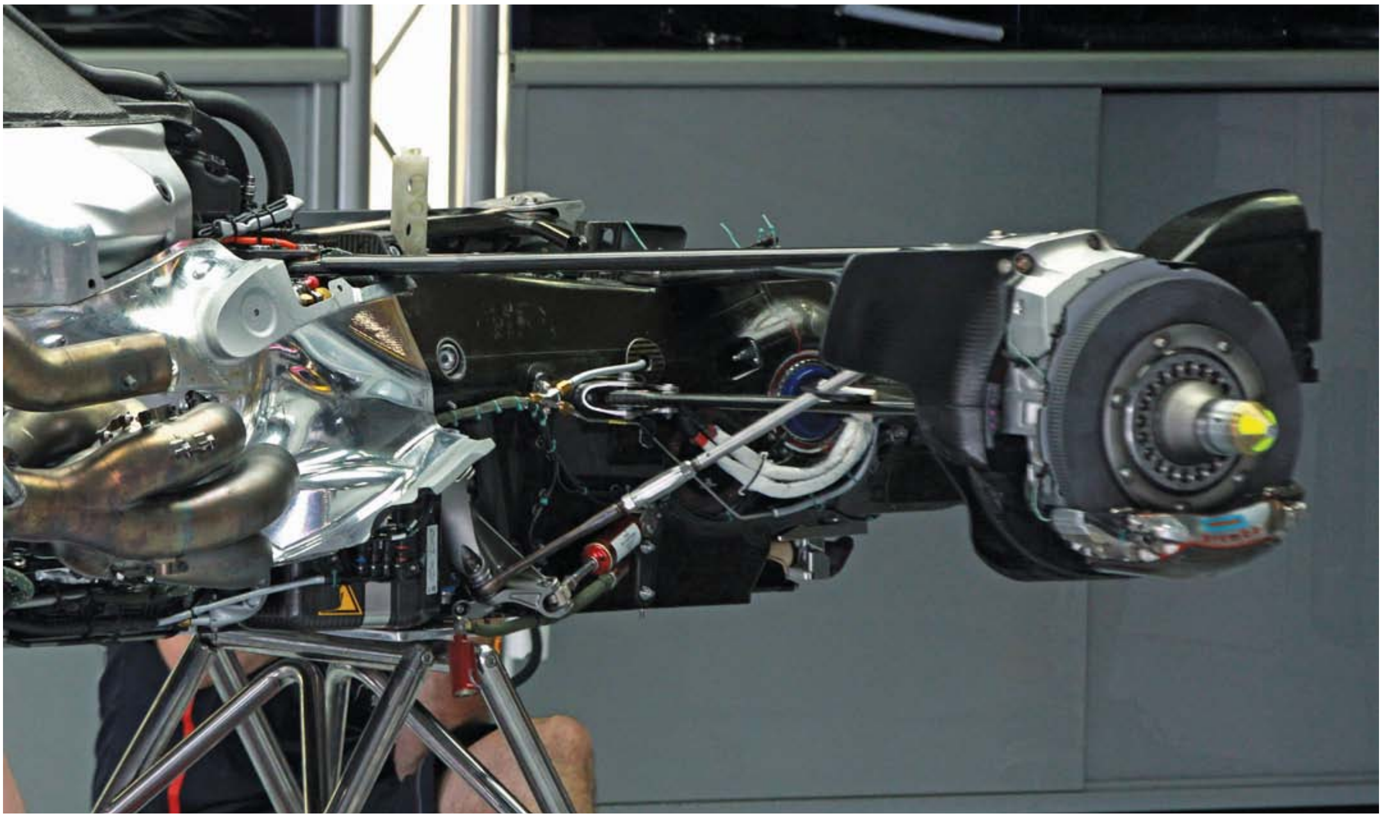
The RB8 is a clear evolution of the RB5 to the RB7 as Newey concerns himself with evolution, rather than revolution each season

Bull had to rework its rear-end concept. 'With the RB8 it was about damage limitation from the cut in downforce from losing that exhaust technology. We have suffered more than our competitors in terms of the exhausts. We were the first to do it in 2010, so we have been on that track for two years and had probably taken it further than other people. It's been difficult to get the car to work properly again with that missing – we've had to re-learn the baseline,' Newey admits. 'The RB7 was designed around the exhaust. This year, knowing that the exhaust position from last year would be taken away we've had to go back and look at how we developed the car through the two years with the side exit exhaust. The routes we'd taken that were only suitable for that exhaust position now had to be re-evaluated. Probably one of the key things there is the rear ride height. The exhaust allowed us to run a high rear ride height – it's much more difficult without that, so we have to go back down and redevelop the car around that lower ride height.'

While television commentators are very keen to tell audiences that blown diffusers were banned at the end of 2011, a quick look at the development of the exhausts this season shows how clear it is still a benefit.

The RB8 was launched with a fairly conventional solution, but after initial testing, it was fitted with a Sauber-style solution, which differs from the Coanda layout, but achieves the same goal, reducing the disruption to air flow in the diffuser caused by the rear wheels.

'It is a combination of two things that hit at one time,' says Newey. 'One was the restriction on where we could physically put the exhaust exits and the other was the restriction on the



Aerodynamic packaging is famously tight on Newey designs. A new chassis was introduced to accommodate the new exhaust layout

mapping of the engine. Those combined have hugely reduced the exhaust effect, but you will never reduce it to zero. Compared to the other teams, there are obviously two ways of skinning the cat in terms of getting the most out of the exhaust given the limitations in the regulations. The concepts are different in the philosophy and the way they achieve the effect.'

The ever-tightening rulebook is something that clearly concerns Newey, who feels that things are starting to get too restrictive. 'Regulation changes I enjoy,' he says. 'Regulation restrictions I rather lament. All of those changes of the concept from RB5 to RB8 about are always due to regulation restrictions. Ultimately if the regulations become tighter and tighter then you end up with Formula 1 becoming GP1. All the cars will converge to become more or less the same and I think that would be a great shame for the sport. For me, what differentiates F1 from tennis or golf is the fact that it is a combination of man and machine, and to win either the drivers or constructors titles you need a combination of good driver and good car. If the regulations mean that the cars are all more of less the same it would to me reduce the attraction of the sport.'

It is worth noting the RB8 has pushed the current restrictions hard in a couple of areas, resulting in two high-profile regulatory issues. First the team was forced to change the design of the rear floor of the car. A new floor used at the Spanish Grand Prix and the Monaco Grand Prix featured a small cutout ahead of the rear wheel, but this was questioned by rival teams who argued that it did not conform with the technical regulations. These state: 'All parts lying on the reference and step planes, in addition to the transition between the two planes, must produce uniform, solid, hard, continuous, rigid (no degree of freedom in relation to the body/ chassis unit), impervious surfaces under all circumstances. Forward of a line 450mm forward of the rear face of the cockpit entry template, fully enclosed holes are permitted in the surfaces lying on the reference and step planes provided no part of the car is visible through them when viewed from directly below.'

To circumvent this, other teams, such as Ferrari, fit a tiny slit between the hole and the outer edge of the floor meaning that the hole is not 'fully enclosed'. The FIA technical department said that in its opinion the floor did not meet the rules as it interpreted them, and for the next race in Canada Red Bull changed the design.

MAP WRAP

Another run in with the FIA Technical department took place at the German Grand Prix. This time it centred on the torque map loaded on to the car's McLaren ECU. The FIA's technical delegate, Jo Bauer, discovered the code ahead of the German Grand Prix and issued the following statement: 'Having examined the engine base torque map, it became apparent that the maximum torque output of both engines is significantly less in the mid RPM range than previously

THE CURSE OF KERS

With seven race wins (at press time), Red Bull's RB8 has rivalled McLaren's MP4-27 as the strongest car of the season. The Silver car missed out on certain wins due to accidents and gearbox failures, while some minor reliability glitches have hampered the blue machine. An alternator failure cost a certain victory in Valencia, and resurfaced at Monza.

Other minor issues have also hampered progress in some sessions, notably one that has carried over from the RB7, which suffered with frequent KERS failures.

'The layout and packaging and indeed many of the components of the KERS are identical to RB7,' reveals Newey. 'I think one of the problems we had with RB7 as far as the KERS was concerned was not so much how we packaged it or what we were doing with it – we are as a team not KERS specialists and we were teaching ourselves about something we knew nothing about. As in all such things when you're doing that it's a rapid learning curve and mistakes were made. I think that the main difference hasn't been design features or layout – rather it has been us getting to grips with the technology.'

Red Bull has twice been before the beak to explain parts of its car. It lost on the rear floor slot and was forced to change.

seen at other events. In my opinion this is therefore in breach of the technical regulations as the engines...Furthermore this new torque map will artificially alter the aerodynamic characteristics of both cars which is also in contravention of technical directives.' The mid-range torque map is critical in optimising the car's exhaust gas flow to get a blown diffuser effect, though it was not clear that this was what Red Bull was doing. Nonetheless, Bauer referred the matter to the event stewards.

Three hours after Bauer's report was released, the FIA stewards of the meeting announced that no further action would be taken. Their statement read: 'The stewards received a report from the FIA Technical Delegate, along with specific ECU data from Red Bull Racing Cars 1 and 2. The stewards met with the team representatives and the representative of the engine supplier Renault. While the stewards do not accept all the arguments of the team, they however conclude that as the regulation is written, the map presented does not breach the text of the Formula 1 technical regulations and therefore decided to take no action.'

Drivers of rival teams feel that the RB8 has more downforce at their disposal, but transmitting that downforce to the track is just as important.

TYRE MATTERS

Indeed, one of the biggest talking points of the 2012 season has been the tyres, the impact of which Newey feels has been somewhat overplayed. 'Everybody talks like the tyres have become so much more critical this year compared to last year,' he says. 'I think they are trickier to use generally, but equally the grid has closed up again and that's partly due to regulations being restrictive and this being the fourth season since those regulations were introduced. The cars are converging and the grid is getting tighter. Now if you are a tenth or two tenths a second slower, it might be a few grid places dropped whereas last year it might have made no difference at all. It puts tyres into a bigger focus and quite often when you get these big swings between grid results between the teams, tyres are singled out as being the reason. But that's a bit too simplified in truth. Some cars will be better in high speed corners and not so good in low speed corners; some cars may be better on bumpy circuits, but tyres are the visible feature that people just latch on to.'

Despite this, Newey admits that the 2012 Pirelli tyres are more challenging than expected. 'The tyres are very difficult to understand,' he says. 'Sometimes we think we've got a handle on them, then something happens that makes us realise that we've not properly understood them. Effectively we are trying to reverse engineer someone else's product so it is tricky, and for all of the teams. Inside our own team we have not highlighted anyone purely as a tyre specialist. But it's fair to say we have dedicated more time among our engineers than we would have done previously, or we would have done with a Bridgestone or a Michelin. If you compare them to - say - the height of the tyre war between Michelin and Bridgestone, then you got to the point where the race was really a series of qualifying laps and the drivers would therefore push very hard throughout without worrying too much about degradation, be it thermal or wear. That's different now. I think that brings a different set of skills to the floor, almost like Prost in the 80s, when he got the reputation for being The Professor, thinking about how he did the race. I think that's coming back, which gives some variety and change in the field both race-to-race, during the race and qualifying to race. I think that's all good for the sport, good for spectating.'

As Racecar closed for press Red Bull had an 82-point lead, and the RB8 was clear favourite for another title. And to compound things for the rest of the grid, the RB9 is to be another evolution of the family line. But for 2014 a major rule change will bring the RB5-RB9 family line to its end.

"Effectively we are trying to reverse engineer someone else's product, so it is tricky"

TECH SPEC

Red Bull RB8

Class: F1 2012

Chassis: Composite monocoque structure, designed and built in-house,carrying the Renault V8 engine as fully stressed member

Suspension: Wishbone and pushrod (front)/pullrod (rear) activated torsion springs and anti roll bar

Wheels: OZ Racing, front: 12.0in x 13in diam., rear: 13.7in x 13in diam.

Tyres: Pirelli

Brakes: Brembo calipers Carbon/Carbon

Electronics: McLaren Electronics Systems standard ECU and FIA homologated electronic and electrical system

Transmission: In house seven-speed gearbox, longitudinally mounted with hydraulic system for power shift and clutch operation.

Clutch: AP Racing carbon plate

Engine: Renault RS27, 2.4 litre N/A V8

Max rpm: 18,000 rpm (limited)

Bore angle: 90deg

Bore: 98mm

Valves: 32, pneumatic

Block: Cast Aluminium

Lubricants: Total

Engine weight: 95kg

It's all in the detail

The trend-setting McLaren MP4-27 has been a race winner in 2012

BY SAM COLLINS

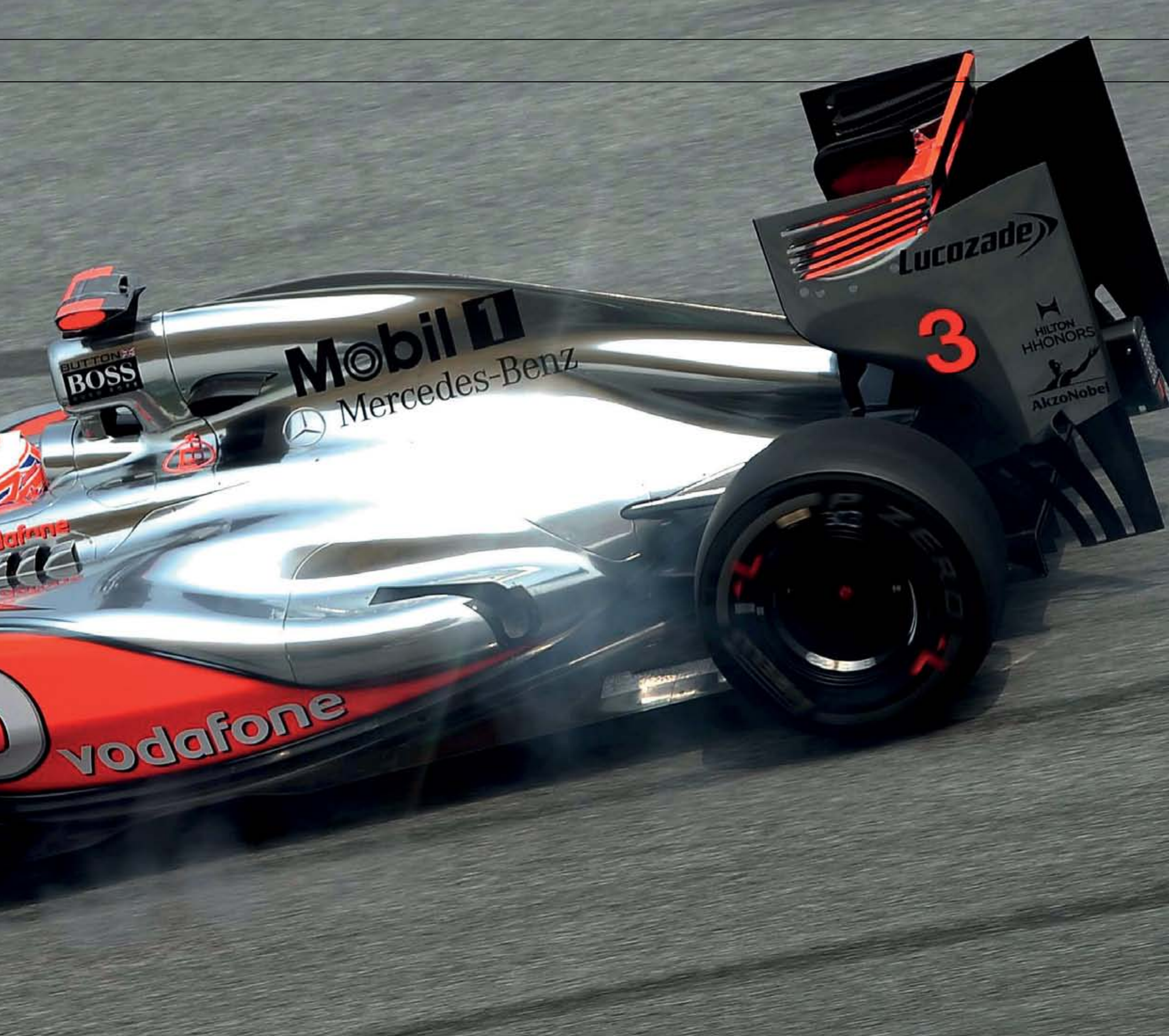
McLaren's MP4-27 is a good racecar. That much is obvious. By the end of the European racing season it had won more Grands Prix than any other car, yet the unpredictable nature of the 2012 season meant that it headed into the championship showdown not topping either of the World Championships.

The car has been consistently competitive throughout the year, although according to Paddy Lowe, McLaren's technical director, 'it doesn't always feel like we have been at the front. It has been quite a tough year just trying to get that consistency, but everyone has struggled in the same way. You tend to focus on the challenges you have faced yourself, rather than how others have fared. We have learned a lot along the road, but it is all driven by trying to keep the tyres in the right window.'

Indeed the characteristics of the revised Pirelli tyres are something that surprised many teams in the paddock, including McLaren. When the MP4-27 was launched, much of the focus was on recapturing some of the downforce lost due to rule changes related to exhaust position and usage.

'Every year, we sit down and want to design a race-winning car,' says McLaren's director of engineering, Tim Goss. 'We didn't have the quickest car at the start of last season, but we did everything possible to build the quickest car possible this season. We set ourselves very tough and ambitious targets and the car was a complete re-work from nose to tail. Everything on the car was changed.

'I think there's very little that we've carried over. There's a few pieces of the fuel system, but otherwise I think just about everything on the car has changed. We've worked extremely hard at producing a very integrated aerodynamic and design package. Our main objectives for the 2012 season were to optimise downforce



despite the changes to the blown floor, and to improve our understanding and utilisation of the Pirelli tyres, which were new to us last year.'

While almost the entire car was new, the concept was still evolutionary as the 2012 car carried over components from its predecessor, the MP4-26, including the in-house carbon fibre gearbox (built by McLaren and supplied to Force India), the 2.4-litre Mercedes-Benz HPE engine, and many of the smaller components.

McLaren's 2011 car, the MP4-26, was also a race winner and had some very distinctive design features including a sidepod shape. For the 2012 season, this concept was dropped, but not because it did not work.

'Last year's U-shaped sidepod worked very well indeed with what we were trying to achieve with the exhaust layout,' explains Goss. 'It was all intended to create more down wash to the rear end, and it performed particularly well. This year, at a fairly early stage, we set about a different approach to both the external and the internal aerodynamics of the car. Once the exhaust regulations had started to become clearer, it was quite obvious to us that the U-shaped sidepod no longer fitted in with

The 2011 MP4-26 featured a distinctive U-shaped sidepod concept, but late changes to the exhaust regulations saw McLaren abandon it. Overall the MP4-26 was a strong basis for the MP4-27

both the internal aerodynamics and some of the external aerodynamics that we pursued early on. So it works, it worked very well last year, but it's actually just not suited to what we're trying to achieve this year.'

Indeed the whole U-shaped sidepod was defined by the blown diffuser concept, something that was not widely reported at the time. It was all about channelling the air flow, and in turn the exhaust plume, down into the space between the inner edge of the rear tyre and the outer edge of the diffuser.

But the FIA outlawed the low exhaust exits used on the 2011 cars and the engine maps crucial to the off-throttle blowing (see V22N7). 'The regulations around the exhausts became very prescriptive: the exhausts must now exit within a very tight space at the rear of the car in order to minimise their aerodynamic influence,' Goss explains.

'The final 100mm of the exhausts must be cylindrical – so they can no longer be oval, or flattened – and must be sited at a particular vertical and horizontal angle – between 10 and 30 degrees upwards. That's to direct the exhaust exit away from the floor. They have the inevitable impact on the flow-fields around the rear of the car, yes. In previous years, the exhausts exited directly into the rear corner of the floor. We can't do that anymore so, as you'd expect, that changes the flow characteristics at the rear of the car. The knock-on effect is that all of the aerodynamic devices at the rear of the car have had to be re-designed.'

The MP4-27 features fairly conventional rectangular sidepods, at least when viewed from the front. 'The rule changes put the exhaust position right in the middle of the U-channel,' explains Lowe. 'Having to have the exhausts in the middle of that channel destroyed that approach, so this years sidepods are a lot more conventional.'

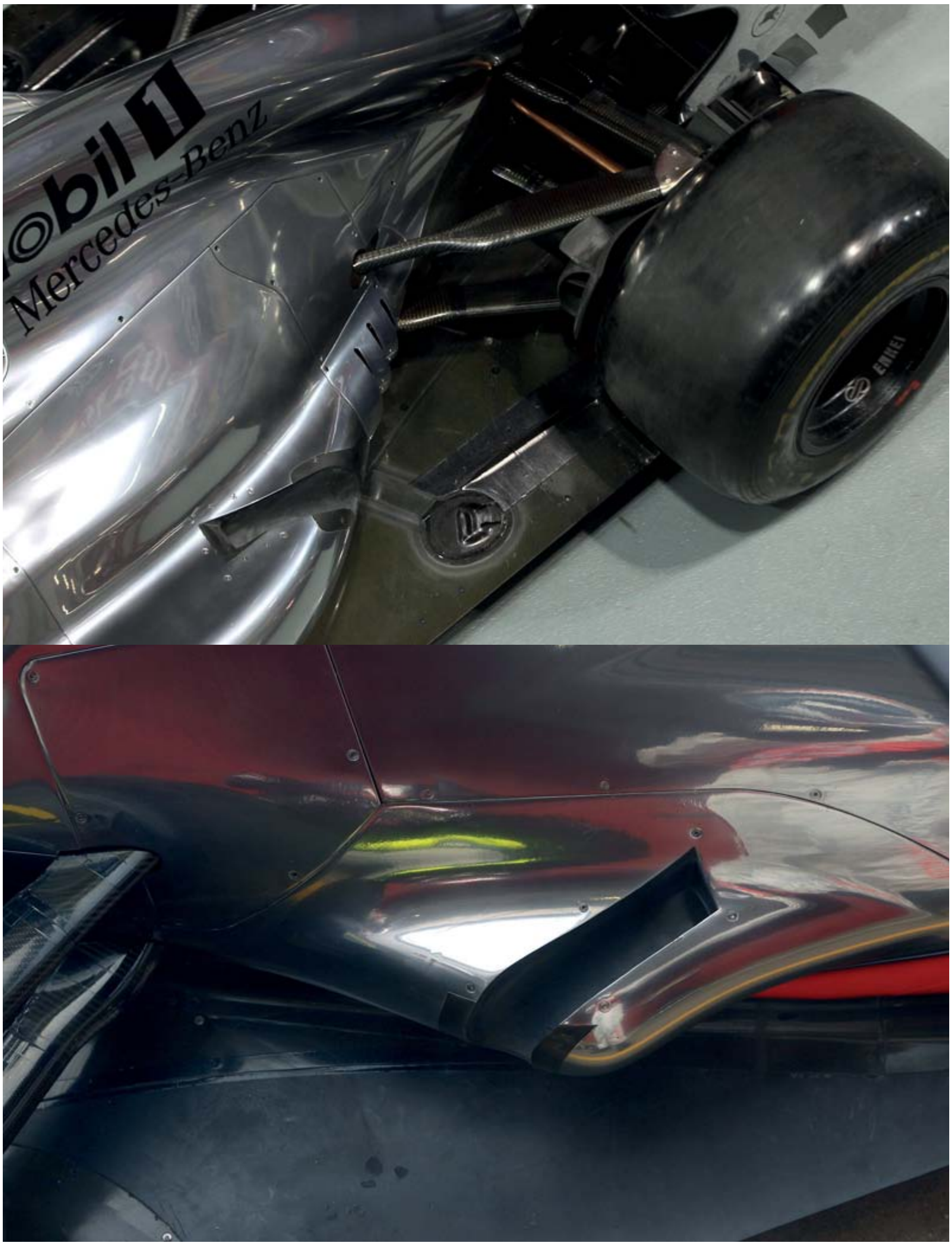
The rules also meant that McLaren had to come up with an entirely new exhaust concept. Whilst the rule changes saw off one approach to the blown diffuser, the concept itself was not outlawed. 'Blown diffusers in themselves have never been defined, and therefore were also never banned,' stresses Lowe.

'That's an important point to make. What we were doing last year was exploiting the exhaust to deliver a huge amount of aerodynamic performance and for this year, that performance has been severely reduced by changing the rules around exhaust exits and engine mapping.

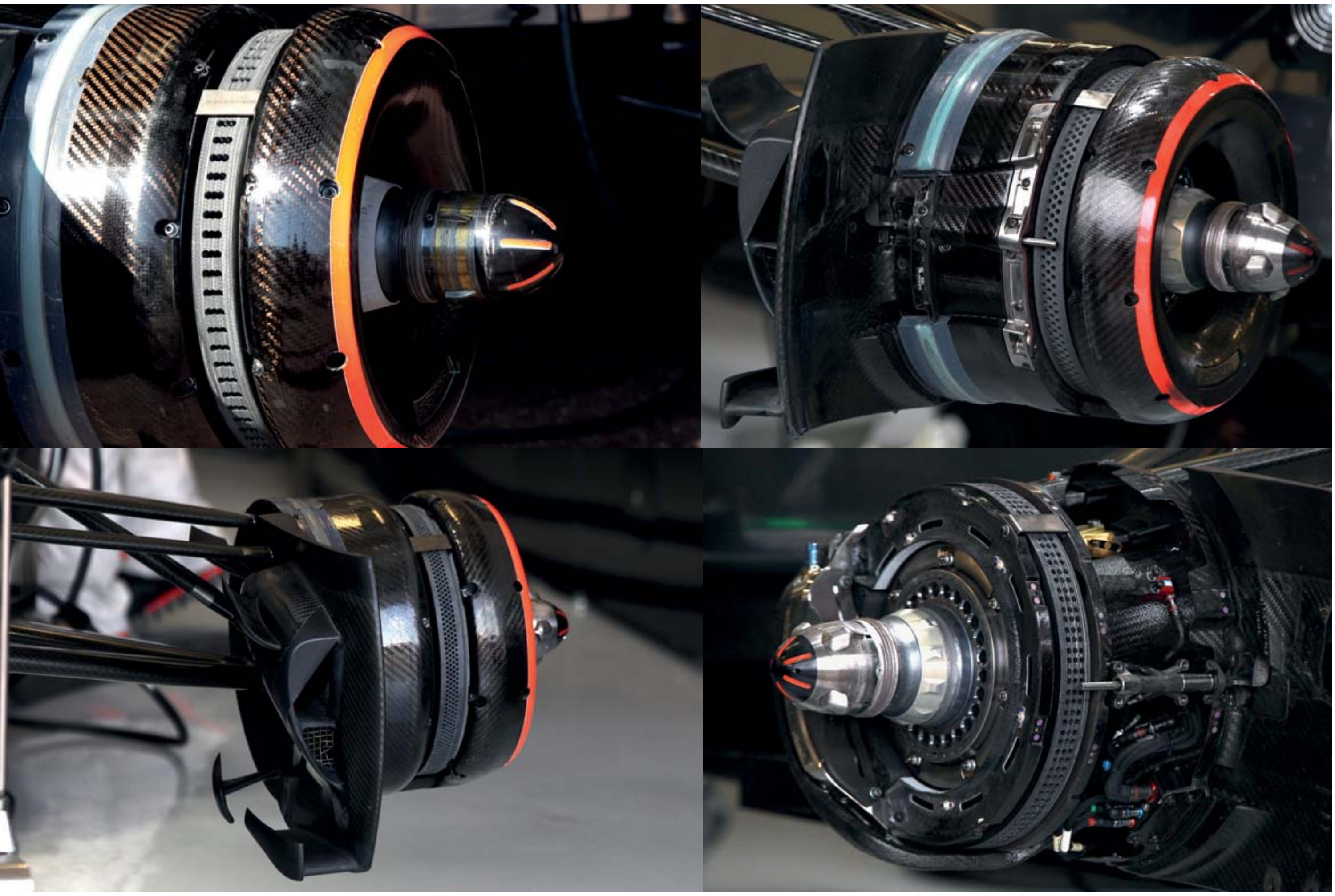
'Are people still generating performance from the floor, including some elements of exhaust-generated downforce? The answer is yes. We are doing that and I think most of the teams are to a greater or lesser extent. It's a direction where you can find some performance, but it's not anything like as extreme as it was in 2011.

'Whether it is in the spirit of the rules or not is unimportant. There's no such thing as the spirit of the rules. It's a term often used, but the rule book is text that has a meaning, and you decide what that meaning is and you work to it. There's no headline regulation that says 'above all else, you've got to remain within the spirit of what was intended'. I'd like to think that we were the pioneers of this blown-floor concept. We were first, along with Sauber this year, to come out with exhaust designs to do that, and most of the teams on the grid now have it.'

The MP4-27's exhausts exit the bodywork via a bulge in the rear portion of the sidepod. A small channel behind the exit itself, and the overall shape of the sidepods themselves, channel the flow to that crucial area at the rear of the car's floor. In fact, the main focus of the car's aerodynamic design since it was launched at the start of



Key to the design and development of the MP4-27 is the 'Coanda' exhaust. It has been copied by most of the teams on the grid, and channels the exhaust plume to give the effect of a 'cold blown' diffuser



Brake cooling and disc design has been a key area of development on the MP4-27, as McLaren struggles to control the temperatures of the Pirelli tyres. Here we see four different patterns of drillings on the discs. The image on the bottom left also shows the complex devices in the brake duct areas

Failures in McLaren's in-house carbon fibre gearbox (also supplied to Force India) have cost the team some points

the season has been about the four corners, and in particular the tyres. Pirelli revised its compounds for the start of the 2012 season and the result has been some of the best racing in Formula 1 for a long time.

'I think the effort to get on top of the tyres has increased during the season, as they have proven far more critical than expected,' admits Lowe. 'I doubt Pirelli predicted how critical the tyres would be this year. The changes to the tyres over the winter seemed to be reasonably small, but the impact has been dramatic. Indeed I'm not sure Pirelli understand it themselves.

'A great example of the races being dominated by tyre conditions, and in particular tyre temperatures, was Malaysia. Jenson [Button], came out into clear air on a new set of tyres from near the back and had some extraordinary pace, as his tyres were in the correct temperature window.

'As soon as he came up on some traffic, and didn't get past immediately, you lose that temperature and you spiral into much lower performance – to the extent that the drivers you catch up can start to leave you behind again.'

Aerodynamic elements have been developed or redeveloped to improve how the car works its rubber, notably the brake ducts (see sidebar), as Lowe explains. 'You may call them brake ducts, but in reality they are air ducts as you no longer need them to just cool the brakes.

'It was something F1 went away from in the regulations as it was too difficult to police, so we use those devices to generate aerodynamic downforce, as well

IN-RACE BRAKE COOLING ADJUSTMENT

After the switch to Pirelli tyres, a lot of care has been required in managing degradation in rear tyre construction. This drop in tyre performance happens when the tyres fall out of their operating temperature window because they are running too hot, or too cold. McLaren has been active in understanding this problem and, over the past year, has developed an innovative method of controlling tyre temperature via its relationship with brake temperatures. it has an adjustable brake duct set up and this can have an impact on tyre temperature.

Formula 1 carbon brake disc temperatures can peak at over 1000 degrees centigrade. The discs being 278mm diameter inside a 305mm wheel means that there is little space between the two, so heat inevitably passes from the disc into the magnesium alloy wheel. By altering the flow of heated air coming from the periphery of the brake disc, the amount of heat passed into the wheel and tyre and can be altered.

Teams already tune brake cooling with different inlet scoops, but these tend to stay fixed from the qualifying laps of a race onwards (wet races excepted). If the team wants to alter brake, and thus tyre, temperatures, during the race they're usually prevented from doing so by *parc fermé* conditions. However, McLaren has fitted an adjustable window in the rear brake ducts. A mechanic can adjust this in the pits to tune the brake and tyre temperature to suit conditions via a control near the fuel filler.

To do this, McLaren have altered their brake cooling design from most other teams. More typically, the round brake drum cooling ducts exit the airflow from the brakes through the rounded outer face of the duct. This then passes out through the wheel spokes. McLaren's brake discs vent through openings in the outside of the brake drum, with its outer face closed off from the disc. So, all the hot air flows between the duct and the wheel before exiting through the wheel itself.

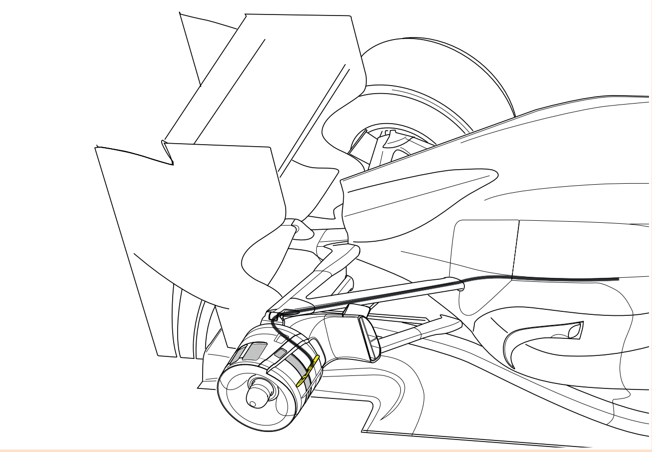
To accommodate this flow, McLaren's wheel spoke arrangement has been altered. The Enkei wheel features 29 drillings around the face of the rim, with the more conventional spokes positioned inside them. The air flow from the brakes is also directed through these drillings. With this set-up, the heated airflow has far more contact with the wheel, both as it passes towards the spokes, and from the spokes themselves, which have more surface area to absorb heat.

Changing the brake ducting will alter the amount of brake cooling: opening the duct will allow more heat to escape and reduce brake disc temperatures and vice versa with closing the ducts. Adjusting the rear brake temperature may not be the sole reason this season. With changing tyre balance and KERS usage, the rear brakes have been prone to overheating. But the more likely benefit is the effect of the brake heat altering tyre temperature. As the brake heat passes through the smaller set of drillings in the wheel, which has a greater surface area than the more usual 8-10 spoke wheel, allowing more heat to transfer into the wheel.

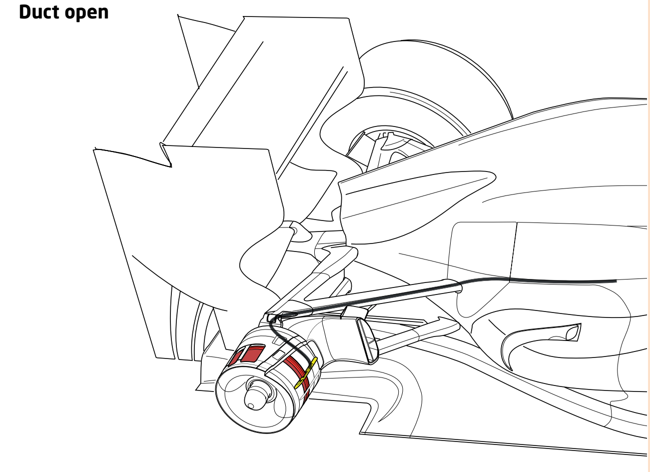
Heating the wheel will transfer heat into the tyre; this will be useful when the driver is struggling for tyre temperature. The contrary is reducing the heat transfer into the wheel to reduce tyre temperature when the driver is struggling with heat-related degradation.

Craig Scarborough

Duct closed



Duct open



as cooling the brakes and calliper, and a big thing is controlling the rear tyre temperature. We are certainly measuring a lot more and putting a lot of work into that corner, especially looking at the air ducts. Whilst we develop all of the car all of the time, we have put extra effort into the air ducts and the area around it.'

This optimisation goes to a great level of detail, even to the drillings on the brake discs themselves – something McLaren has worked on extensively in 2012 with the designs frequently changing.

'It can be simply down to driver preference which brake they want, but its all part of this optimisation of the corner cooling packaging,' explains Lowe. 'We have different styles of disc drillings which impact the cooling, but also the behaviour of the brake, and drivers have different preferences for brake fluid and brake feel. One disc may be more controllable and the other more aggressive in initial attack, but with a different consistency.

'With different types of material and geometry of cooling holes you can get different characteristics.'

NO BIG DEAL

Of course the most distinctive thing about the McLaren MP4-27 is the look of the car. It is one of only two on the grid (see p22 for the other one) that does not feature a 'hump' in the nose. This is because for some years McLaren has used a comparatively low nose on its cars and continued this concept into 2012.

The rules on nose height and chassis height led to the stepped noses of rival cars, which overall have a higher chassis. Whilst the difference is obvious to they eye, it does not seem to have much impact on the time sheet.

'We don't regret doing the low nose,' explains Lowe, 'but we are an outlier in this respect. It is one of these things that looks very dramatic, but it's just one thing of thousands on the car – there others that are not as obvious with a much higher influence than the nose.

The chassis and nose height are something you decide on very early, as they are fundamental to the rest of the design.

'We are not unhappy at the route we took. Is it the best? I don't know. It is the route we have gone, so it's like asking

Sidepod wings first trialed by Sauber and then Red Bull appeared on the McLaren after the summer break, taking the place of small turning vanes

The core mechanical components of the MP4-27 were carried over in modified form from the MP4-26

TECH SPEC

MCLAREN MP4-27

Chassis: McLaren-moulded carbon fibre composite, incorporating front and side impact structures

Suspension: Inboard torsion bar/ damper system operated by pushrod and bell crank with a double wishbone arrangement

Brakes: Akebono six-piston calipers, carbon fibre pads and discs

Transmission: In-house longitudinally-mounted carbon fibre, seven-speed quick-shift; carbon fibre clutch

Electronics: McLaren Electronic Systems. Including chassis control, engine control, data acquisition, dashboard, alternator, sensors, data analysis and telemetry

KERS: Mercedes HPE

Tyres: Pirelli

Radio: Kenwood

Batteries: GS Yuasa Corporation

Steering: In house PAS

Wheels: Enkei

Weight: 640kg (inc driver, tank empty)

ENGINE SPEC

Mercedes FO 108Z

Type: Naturally aspirated V8; 90-degree cylinder angle; electronic injection and ignition, NGK plugs

Valves / valvetrain: 32 / pneumatic

Fuel: ExxonMobil (5.75% biofuel)

Lubricants: Mobil 1

Bore: 98mm

Weight: 95kg

is my front wing the best? I don't know if it makes as much downforce as the Ferrari front wing, but it's the wing we have. The nose gets a level of attention it does not deserve because everyone can see it, but it's just not a big deal.'

The MP4-27 won on its debut in Melbourne and has since taken wins at Montreal, the Hungaroring, Spa and Monza [correct at time of going to press], alongside a good number of podium and points finishes. Heading into the closing stages, a McLaren driver is fourth in the championship and the team is second in the constructor's table. And it would certainly be topping the latter, had it not been for a small fuel system issue in Italy, and two unwanted interactions with other cars (those of Maldonado and Grosjean in Valencia and Spa respectively) and a gearbox failure for Lewis Hamilton in Singapore having set pole position time and led the race comfortably.

'The biggest thing we are proud of on this car is the exhaust design'

Despite this, McLaren is broadly upbeat about the season to date, with the car on balance the best all-rounder this year. 'The thing we are most proud of on this car is the exhaust design,' concludes Lowe. 'We put a lot of effort into that. It's always nice to see the other teams, with all of their engineers working on the same problem, come back and conclude that your concept is the best and copy it. That's a great compliment.

'But the opposite applies if there is something on another car that you have to pick up and the other team gets there first. It's not good and there have been a few of those too, but nothing substantial.

'In general, though, I am really proud of this car,' concludes Lowe. 'It's done well, came out of the box and got two front rows in the first two races.'

“we don’t have a lot of people or a lot of money, so everything we develop has to work”

Efficiency drive

Lacking the budget of the big teams, Sauber has performed beyond expectations, and remains the only team on the Formula 1 grid to fully understand the Pirelli tyres

BY SAM COLLINS

Formula 1 has seen a record number of winners in the opening races of the 2012 season. Some of that has been down to gained or lost performance through rule changes regarding blown floors and diffusers. However, as detailed in ***Racecar Engineering*** V22N8, it is understanding the Pirelli tyres, and making them work, that is key to success. Some teams find the sweet spot by accident, others, like Sauber, claim its car works perfectly with the Italian tyre compounds.

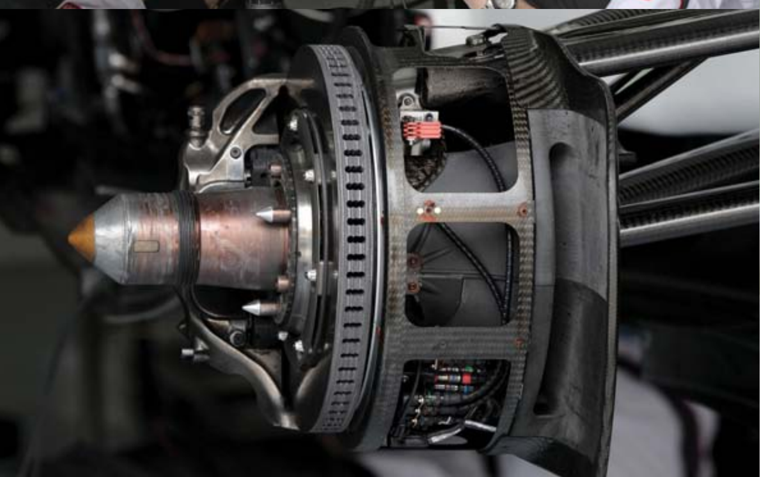
Efficiency, in all of its forms, was high on the list of design criteria for the C31. Ever since the Sauber team parted company with BMW, it has lacked in sponsorship and, as a result, perhaps lacks the budget of the bigger teams it is often racing with.

'One of the things with this team is that we don't have a lot of people or a lot of money, so everything we develop has to work,' explains Matt Morris, the Swiss team's chief designer. 'So we can't really develop two solutions and choose which one works best. As a result, we spend a lot of time doing up-front simulation, CFD and tunnel work and, to be honest, one of the reasons we can make a competitive car and have a efficient way of working is because we have got very good correlation between CFD, the wind tunnel and on track. If the guys working in CFD find something, it carries over to the wind tunnel and then, of course, onto the track.'

The result is, at first glance, a very conventional 2012 Formula 1 car, which borrows heavily from the 2011 C30. Its rollover structure, for example, is simply a lighter version of last year's design, but the overall design of the C31 is tidier, and a lot of time has been spent on the attention to detail. 'The wheelbase has changed very little,' Morris reveals. 'The amount we have changed it would have zero effect on the car performance. It's not a first order effect, it tends to be as a result of other things you want to do on the car in terms of packaging. It sort of comes out in the wash whether it goes longer or shorter, at least within a window. Outside of that, you could find or lose some performance, but we are only talking a few millimetres.'

NEW DAMPING

The front suspension has been optimised for integration with the chassis and the upright. Otherwise, it's a traditional layout with a pushrod and a high level wishbone. The dampers and springs are packaged quite differently compared to the C30, in order to support a new philosophy for the front suspension set up.



Top: central 'vent' is not a vent at all, but smooths airflow around the nose. Middle: packaging in the sidepods is a 'nightmare', and airflow through the radiators is controlled by blocking the system (see right), depending on track temperature. Bottom: continual development work goes into the cooling ducts on the C31's brakes, optimising them for different tracks

One of the key things for the car was to retain the way it worked with the tyres, as the C30 was well known for being easy on the rubber. 'At the end of last year, we sat down and looked at everything and made a list of things we needed to have available. One of those was the way we use the tyres, and we designed that into the car's architecture,' Morris continues.

Sauber, it seems, is the only team on the grid that feels it has a good understanding of the 2012 tyres, as head of track engineering, Giampaolo Dall'Ara, explains: 'I don't want to sound like someone who knows everything, and sound arrogant, but when I read in the press that the teams are struggling to understand the tyres and interaction with the car, and look at the outcome of the races, it supports that, but we do not have an issue with that, we understand it well. We have, of course, had some bad races because of others factors in the car's design, and some bad races because of incidents. But looking at the tyres alone, comparing them to one year ago they are a lot easier to work with for us.'

"I think our balance is something that just works quite well on the tyres"

Contrary to the belief of some in the paddock, the Sauber is not equipped with a special tyre saving solution. Indeed, Morris believes the engineering tools the team used to crack the Pirelli code are already available to most of the grid. 'There is no black magic or golden bullet. Perhaps we've developed a better understanding of how it works. Most of the work understanding it is done purely on simulation. In terms of testing, it's very difficult. The only way to test the tyre is on the track, and we don't have too much time on the track!'

LONGER STINTS

Sauber does not use its understanding of the Pirelli tyres to improve outright lap time, or to get the tyre into its working range faster. Indeed, the opposite is often true. The C30 baffled many of its rivals with its ability to run much longer on a stint without the tyres going off, which means the team make fewer pit stops and gradually move up the field as faster cars lose time on in and out laps. It can also mean that the softer – and theoretically faster – tyre can be used for a larger portion of the race. 'I think there's a lot of things you can do to make tyres last longer, but there's always that compromise between qualifying performance and race pace,' explains Morris. 'We spend a lot of time and effort understanding what the tyres actually want, in terms of making them last longer and trying to extract the most out of them. It is about having the tools available in terms of the mechanical car set up, and allowing us to do all the different circuits and still get the most out of the tyres. Like most things in F1, you usually have to compromise something else to achieve what you want, be it weight, or aero, or something else. But I think our balance is something that just works quite well on the tyres. That really is one of our key philosophies. We've got a really good group of guys back in Hinwil that really understand [the tyres] and know what to do with them. I guess they are one of the golden bullets, especially Pierre Wache. He is an ex-Michelin engineer and is in charge of our vehicle dynamics group. He knows what the tyre needs.'

NEATLY PACKAGED

One of the major differences between the Sauber C30 and the 2012-specification C31 is at the rear end, and it has the potential to have a major impact on the car's usage of the tyres. Mounted to the now-familiar Ferrari 056 V8 engine is an all-new carbon fibre transmission, identical to the one used in the works F2012. The 'box is, according to the team, a 'very tidy and neat unit.' The entire rear of the car is much more tightly packaged as a result.

Crucially, the rear suspension is now a pull-rod design, featuring a long pull rod towards the front of the gearbox and wide angled wishbones. This allows improved packaging of the rear spring and damper elements. Despite the change from push rod to pull rod, in terms of kinematics, the engineers maintained a similar direction to the C30, and that was all to do with the tyres.

'With the Ferrari gearbox casing, we are limited on the inboard pick ups, but we are pretty much free on the other inboard suspension elements, dampers, springs and geometries, and of course totally free outboard,' reveals Morris. 'What is not ideal is choosing the rear suspension geometry, but even with those restrictions, it's still pretty open for us. As a result, we have not really struggled with the tyres this year, apart from in Bahrain, and that's because it was really hot and there are a few things that were not available to us there.'

But, as Morris mentions, getting the maximum life out of the current breed of tyres is a compromise, which often comes at the expense of single lap performance.

'We realised last year we had done a good job on the tyre management. We found that with the Pirelli it was very easy to get them to perform and get them to work, but it was not very easy to make them last,' adds Dall'Ara. 'That is one thing we found in our car that we could do, and the car was designed around making those tyres last. But on some tracks – indeed I would say the majority of tracks with the C30 – we've had a lot of trouble trying to get the tyres up to temperature in qualifying, and that's resulted in poor qualifying performances. Quite often that meant that in the races it was impossible for us to run at the pace we could, because someone slower would sneak through in front of us at the start or in qualifying, and it is very difficult to overtake, even with DRS.

'This season began with the big target of improving the qualifying performance, as last year our race performance wasn't necessarily down to car performance, rather that we were able to preserve the tyres throughout the race.'

HOT AIR

Making that job even harder for Dall'Ara and Morris is the fact that Sauber has adopted a very innovative exhaust layout, which appears to have inspired many others in the pit lane.

'Last season, we were not able to keep up with the development of the car, and it's no secret that we missed out on one major element of car development, which was the blown diffuser,' admits Dall'Ara. 'We introduced our version at the Spanish Grand Prix last year, but somehow we were not good enough to make it work. After a few attempts, we decided not to pursue it any more, and the management decided to develop the car around more conventional technologies. In my view, that limited us a lot in mid-season. In 2012, we tried to use the experience with the exhausts from 2011 to learn, because the regulations this year are so much more restrictive on exhaust position. That simply re-set that area of development with all the teams back together in performance terms.'

With its focus on efficiency, developing the C31's exhausts was a major risk. 'It was a big step forward for us. But we realised that it was important to get it to work and we started the early development over the winter. It was more about understanding how it worked though, rather than designing it, which is something we didn't manage to do last year. So we took the gamble in developing it, which took a lot of effort, especially when Charlie Whiting of the FIA could have just turned to us and said actually that is not permitted. Even then we were

Hot track set up has a large cooling aperture at the rear (above), while that aperture is made significantly smaller when running at cold tracks

Innovative exhaust design essentially acts like a blown diffuser, and has since been copied by a number of other teams on the grid

not sure we could get it to work. We did though, and Charlie saw no problem with it. Now it's very nice when other teams perhaps take a lot of inspiration from what we're doing. Of course, there is no aerodynamic advantage from the exhaust because that would be illegal!'

The exhaust outlets, whilst restricted in position, are still placed in such a way that the effect of the exhaust gasses simulate a blown diffuser, as detailed in *RE*V22N7. 'Once you know what it's capable of, like any device on the car, you can tune it with the other things. Getting balance on and off throttle with all aero components on the car is critical. If you have a huge difference the drivers don't tend to like it, and that is especially true here. It's not like we designed the car around the exhaust, but it does have an effect – that's one of the big things I think we have done a good job on,' Morris enthuses.

AERODYNAMIC DETAILS

Beyond the exhausts, the aerodynamic details of the C31 have drawn many admiring glances, and not a few quizzical ones, too. Especially on the car's nose, which features a mysterious duct, similar to the ones employed on the 2008 Ferrari, just behind the 'hump'. 'I could say that it is something like driver cooling, but that's clearly not the case! Everybody is interested in it, but it is something that is not actually worth much performance. When you look it is clearly not the best dynamic device on the planet, so we just use it to improve the flow in that area.'

The cooling package on the car is also of interest. Based on the C30, the shape of the sidepods play a crucial role in the car's aerodynamics. Internal packaging was optimised so the area under the sidepods is opened up for more aerodynamic development. The cooling layout itself is based around a similar philosophy to the 2011 car because, according to the team, that proved effective.

'With the engine design being pretty much frozen, you know how much heat you have to reject. It all comes down to packaging, and each year we seem to design sidepods that are more tightly packed. It's a nightmare for the electronics guys and the pipework guys.

'We are pushing the radiator manufacturers to optimise their designs so they have to get a smaller radiator. It is something you have to work on early because it's integral to the rest of the car's design. You make sure you can put the radiators in and then put everything else in around them,' explains Morris. 'Whilst you do not necessarily fix the radiators for the season, it becomes difficult to change from a cost point of view. With no testing, if we found we did need to change them because it didn't work we would be screwed.'

The Formula 1 season comprises a wide range of circuits around the globe, including predictably hot venues such as Sakhir in Bahrain, as well as unpredictable locations like Silverstone in the UK, where the track temperature can fluctuate by as much as 25degC in a single afternoon. On paper, this provides a significant challenge to the teams. 'We use the same cooler size all year round, but the engine has quite a wide operating range so the engine suppliers are not too bothered if you run a little cooler,' reveals Morris. 'What we do in order to get the most aero potential out of the car is try to have as little air flowing through the radiator as possible. So, without doing new ducts or coolers, we have to restrict that flow somehow, and we do it by restricting the air coming out of the rear of the car, essentially blocking the system all the way through. At the rear of the engine cover area, we have different options for aperture size. If you compare the car we

"the aerodynamic details of the C31 have drawn many admiring glances"

CHELSEA TIE

It started with Superleague, an ill-fated attempt to link football and motorsport, but Sauber and Chelsea have taken the concept to the next level, announcing a reciprocal link between the two teams.

At the time of writing, there was no flesh on the bones, and Monisha Kaltenborn admits Sauber jumped the gun and made the announcement early, but promises results will be seen this season.

'Chelsea approached us with the idea, and it has two areas of co-operation,' says Kaltenborn. 'On the sport side, both teams focus on developing young athletes, so have a lot of accumulated data. By exchanging that information, we can learn from each other.

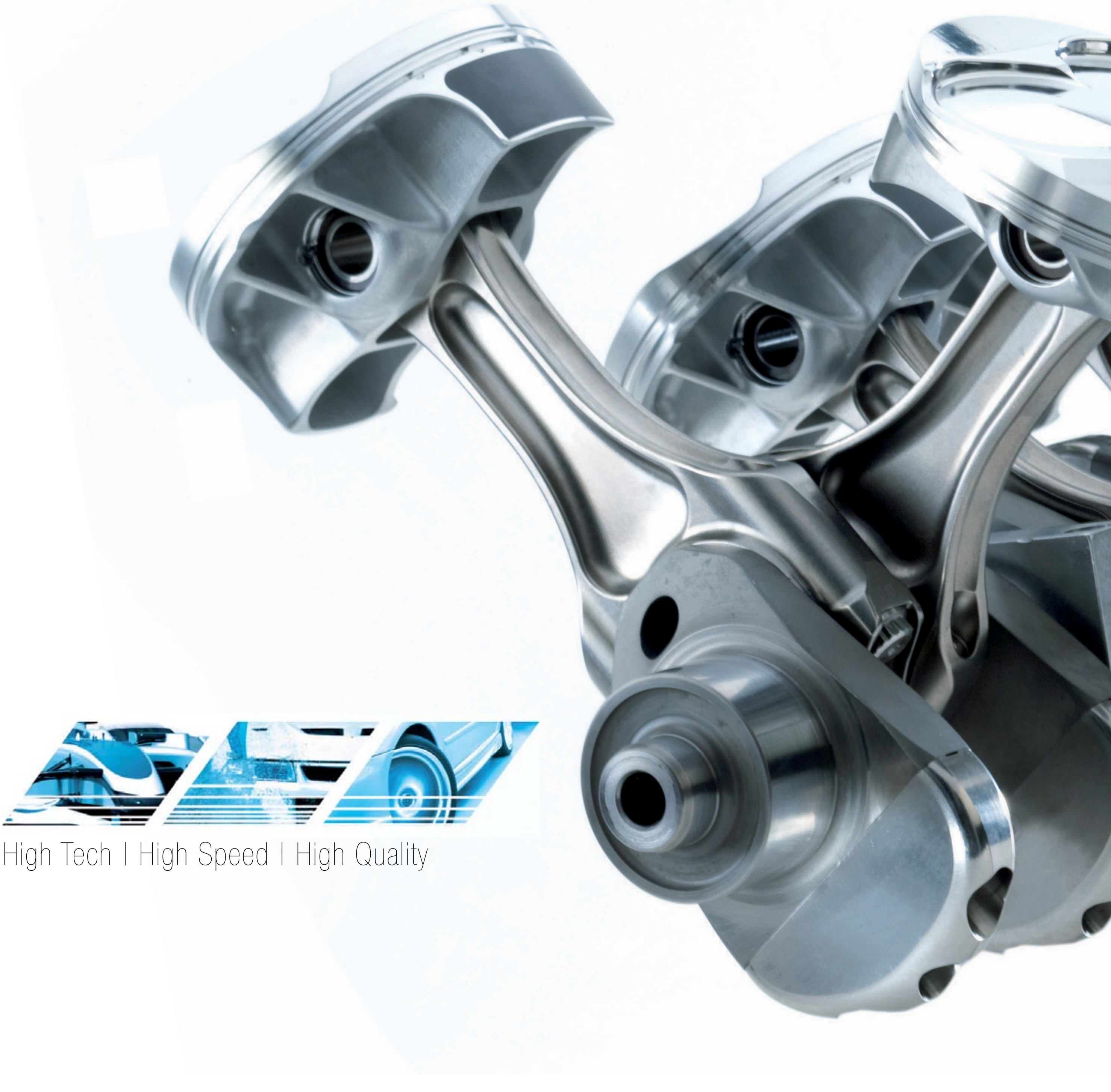
'The other side is the commercial side, and together we can reach out to a huge fan community because they are the two most watched sports around the world. Now, if you want to become a partner of either team, you can make savings by putting both platforms together.'

A look through Chelsea FC's partners makes interesting reading. Audi is the official global automotive partner, Gazprom the global energy partner, together with Singha beer and now Sauber. It's interesting because Audi is already linked with Toro Rosso, Russian oil company, Gazprom, would make more sense with Marussia, or Caterham with Vitaly Petrov, and Singha is already a partner of Red Bull.

If Audi does seek to enter Formula 1, would it consider buying former BMW partner team, Sauber, I wonder?

Andrew Cotton

PANKL RACING SYSTEMS



High Tech | High Speed | High Quality

Pankl Engine Systems GmbH & Co KG
A member of Pankl Racing Systems

A-8600 Bruck/Mur, Kaltschmidstrasse 2-6
Phone: +43(0)3862 51 250-0
FAX: +43(0)3862 51 250-290
e-mail: engine@pankl.com

www.pankl.com

Front suspension was re-designed from the 2011 car but retains the enviable characteristic of being kind on tyres

TECH SPEC

SAUBER C31

Chassis: carbon fibre monocoque

Suspension: upper and lower wishbones front and rear; inboard springs and dampers (Sachs Race Engineering) actuated by push rods

Brakes: Brembo six-piston calipers, carbon fibre pads and discs

Transmission: longitudinally-mounted carbon fibre Ferrari seven-speed quick-shift; carbon fibre clutch

Chassis electronics: MES

KERS: Ferrari

Steering wheel: Sauber F1 Team

Tyres: Pirelli

Wheels: OZ

Dimensions:
Length: 5195mm
Width: 1800mm
Height: 1000mm
Track width, front: 1495mm
Track width, rear: 1410mm

Weight: 640kg (inc driver, tank empty)

ENGINE SPEC

Ferrari 056

Type: naturally aspirated V8; 90-degree cylinder angle; electronic injection and ignition

Engine block: sand-cast aluminium

Valves / valvetrain: 32 / pneumatic

Displacement: 2398cc

Bore: 98mm

Weight: 95kg

ran in Valencia to the car we ran at Silverstone, you'll see a big difference. We design the car to [run at] 46degC. If it hits that temperature, we need to use an option. Some people think that's a waste of time, but it hit 47degC at Valencia.'

AERO SWEEP

The C31 has been optimised aerodynamically for a particular type of track, and it seems to have an advantage at them, as was apparent early in the season. 'I think this car, like quite a few of the most recent others from Sauber, likes flowing tracks with sweeping corners.

'We saw that in Barcelona and Shanghai and we were really looking forward to Silverstone, until the red flag ruined qualifying,' explained Dall'ara. 'We are looking forward to Suzuka and this kind of circuit.

'I don't really want to make out that we are necessarily slow everywhere else, but those are the circuits we are particularly strong on. The sweeping tracks make it easier for us to find the ultimate performance from the car. We have a performance advantage compared to the competition in corners around the speed of 200km/h.'

One of the weaker points of the C31, however, is the braking system. It is a problem that has carried over from the C30. The issue appears to lie with the overall vehicle dynamics, as Dall'Ara explains: 'Braking performance is a bit of a limiting factor, braking stability in particular. It has improved though. Shanghai showed us that it was very satisfactory starting on the second row and making places by braking into a corner after a very long straight. In the past, this was a bit of a problem for us. These kind of corners call for a car that is stable under braking and stable in the entry. We are now okay at that, but we're not the best around. For example, when Perez had a struggle with the balance at Valencia, it was to do with the brake balance as the tyre temperature built up over a run.

'it is very difficult to allow for that as the track temperature is always evolving, and he lost confidence in the braking. When that happens to a driver he loses a lot of lap time. We still have some issues with the brake balance, when braking from 320km/h down to 80km/h.'

AREA FOR DEVELOPMENT

Whilst the brakes themselves are not solely to blame for the instability, they are a key area for development for the team, especially in terms of aerodynamics. 'Once you start working closely with a brake supplier, you tend to stay with them, as all the products on offer are essentially very similar. You need to get to know the guys, and they need to understand your needs, and get to know what you want. In terms of the actual design work, a lot of it is in material development, and we don't get involved in that. We tell them what we want, and they go away for six months and come back and tell us they have a new material,' Morris explains. 'What we spend time on at Sauber is the cooling. As soon as you stick big brake ducts on the inside of the wheel, you get a big drag penalty. We invest a lot of time and money into that. Kim Stevens lives and breathes brake cooling, and spends all her time understanding how the air flows around the disc, pad and caliper. She is forever optimising it to make the cooling ducts smaller and smaller, and she is good at it.'

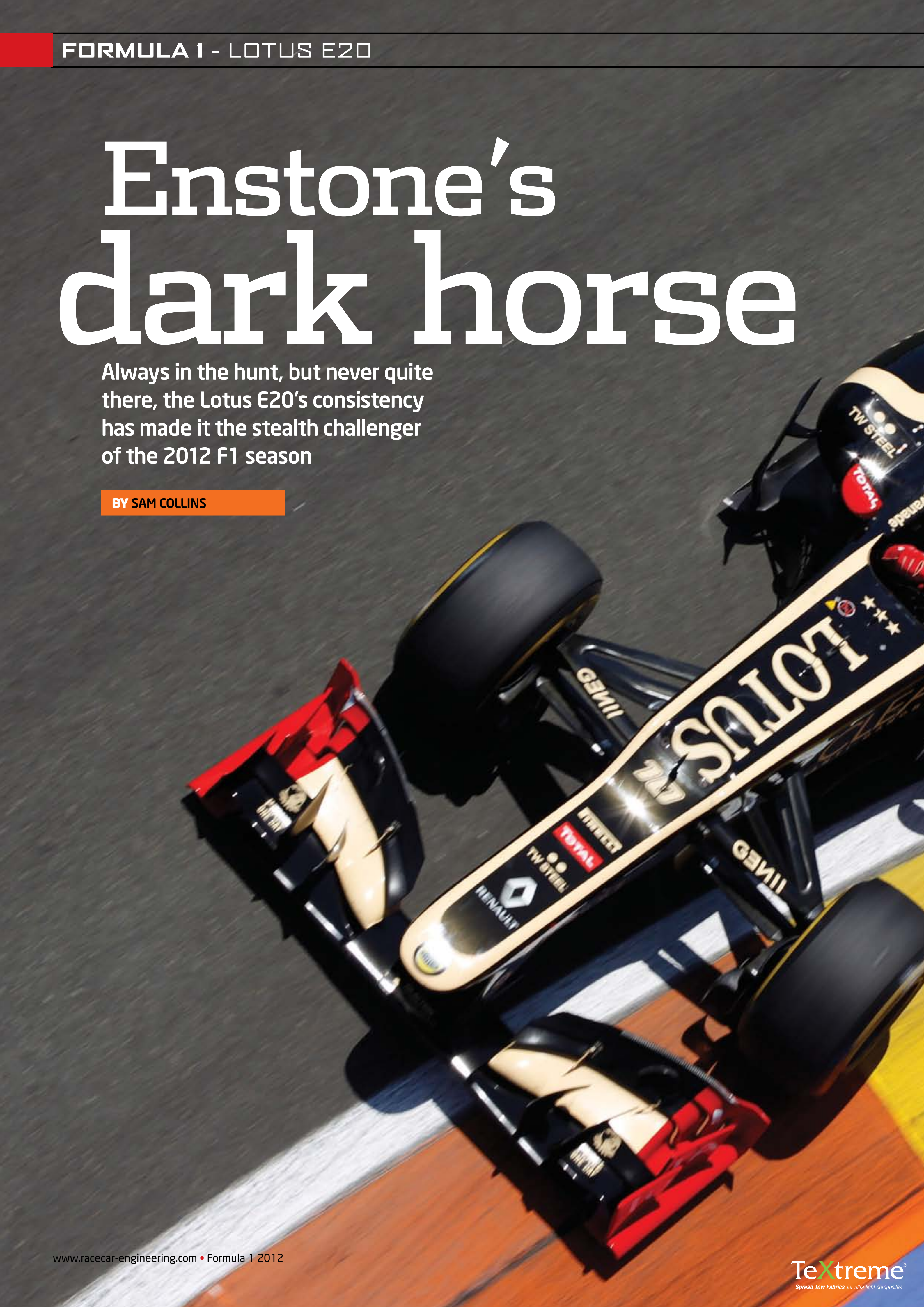
"We have a performance advantage compared to the competition in corners around the speed of 200km/h"

At the time of writing, the C31 had yet to win a race, but has twice threatened to do so, both times obtaining a podium position. At the half-way point this season, Sauber was the best of the midfield teams and, with tracks like Suzuka that should really suit the car still to come, that elusive victory could soon arrive. If it does, it is almost certain to be a race won by calculated efficiency.

Enstone's dark horse

Always in the hunt, but never quite there, the Lotus E20's consistency has made it the stealth challenger of the 2012 F1 season

BY SAM COLLINS



Despite its iconic black and gold John Player tobacco-inspired paint job and famous name, many have overlooked the Lotus E20. With three-quarters of the 2012 season completed, the car had not won a race and the only headlines it had grabbed were for driver-induced mishaps.

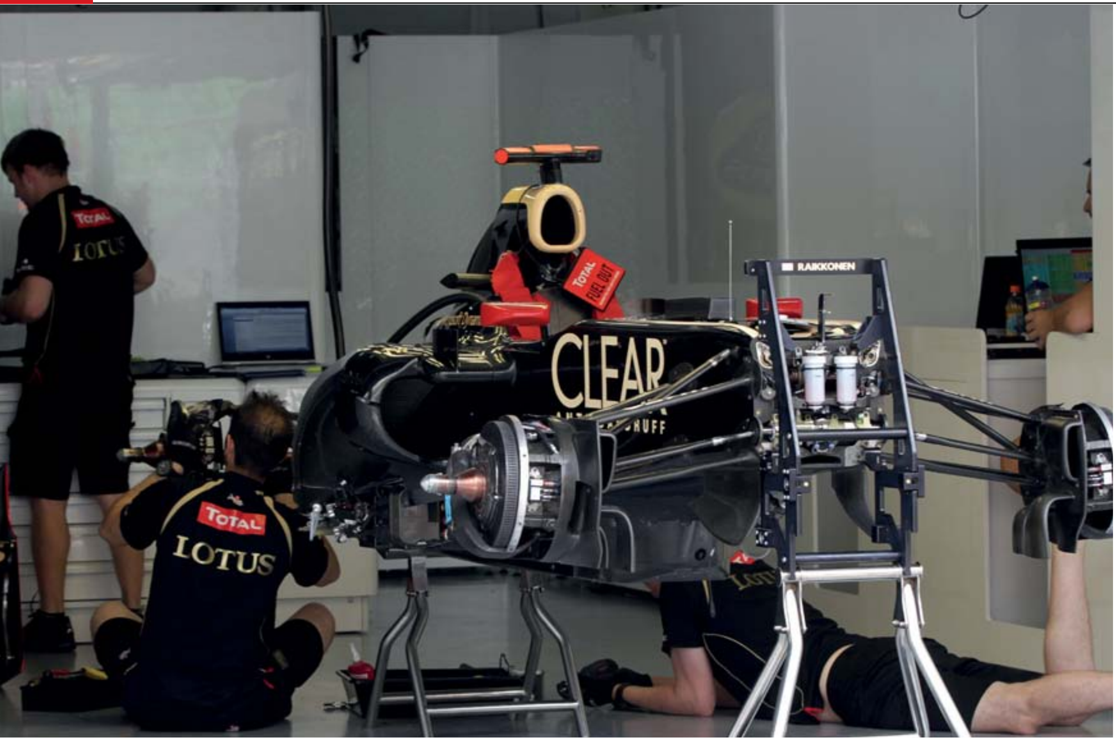
But that is not the whole story. The Lotus E20 has consistently run towards the front of the pack, and going into the final races of the year, finished on the podium and, at time of writing, had Kimi Raikkonen third in the drivers' World Championship standings.

'The car has not been that consistent in the last few races,' James Allison, technical director at the Enstone, England-based Lotus F1 Team complains, 'but in the first 10 or 11 races we were very strong.' Strong seems to be something of an understatement. While every other team on the grid has seen variable performances, there always seems to be a Lotus in the points. Of 30 possible finishes in the first 15 races, 21 have been in the points. Of the nine that were not, four were due to driver errors forcing the car into retirement, and another one due to a failed alternator, making the E20 the most consistent points finisher of 2012.

"The traditional way of going racing is you make a car, and that car is either good or bad, and it tends to remain that way all year"

'This is just quite a good car all round,' Allison continues. 'The traditional way of going racing is that you make a car, and that car is either good or bad, and it tends to remain that way all year. What is strange this year is that the other teams have not been like that. We have not been there every race, though there have been a couple of races where we haven't been able to get the tyres warm enough to do well either in qualifying in the race.'

Despite wearing a different name on its nose, the Lotus



The E20 is a fairly conventional 2012 F1 design, with pullrod rear suspension and pushrod front suspension. Note the side impact structures sitting just forward of the sidepod duct

E20 followed on from the radical Renault R31, which was designed to fully take advantage of the off-throttle exhaust blown diffuser concept by having its exhaust exits at the front of the sidepods. Allison feels that lessons were learnt with that car and that the E20 is a major improvement.

'When I think of this car, I think of it just as a neat car. There is no bit of it that I think is embarrassing – it is a well-conceived neat workable good car. That is what I'm proud of. Last year's car was a bold old thing but it was ugly in many ways; this one is a step forward on almost every single item. It is proper tribute to Martin Tolliday, our chief designer, whose first car this is. He took all of the strength and goodness that Tim Densham had engineered into previous generations of our car, and took us on to another level.

'Depending on where you look, some parts are a ground-up redesign, and in other areas we have further optimised the best bits of the design philosophy we've adopted for several seasons. The front and rear suspension layouts are substantially revised to try and give us better aerodynamic opportunities. The front wing is a continuation of the concepts we have worked on since the 2009 rules were published. With the rear wing system we've continued to try to work on having a satisfactory level of rear downforce stability, while having a maximum DRS switching potential.'

While the team's 2011 car was radical in its application of the exhaust gases, the E20 could not be more different - its exhaust ports are found in a conventional location on the rear of the engine cover. 'As far as the exhausts are concerned, our forward exhausts would now be illegal under the new rules, and didn't live up to our expectations in any case,' Allison explains. 'So that part of the car we say goodbye to and welcome in a complete redesign. We had a very plain jane exhaust system for most of the season; indeed it was the same one that we ran at the start of the year virtually right up until Korea. It served us OK and it is a very easy system to make work. You just make the exhausts the length and shape that gives the engine the best chance of producing as much power as it can, and then put the exits in a place where you get a mild advantage, but nothing special.

'In that respect we were ploughing something of a lonely furrow on the circuit with our exhaust, but since well before the launch of the E20 we were carrying out parallel developments in our wind tunnel programme based around a Coanda-effect exhaust. Once we saw the potential gain of the Coanda system surpass that of

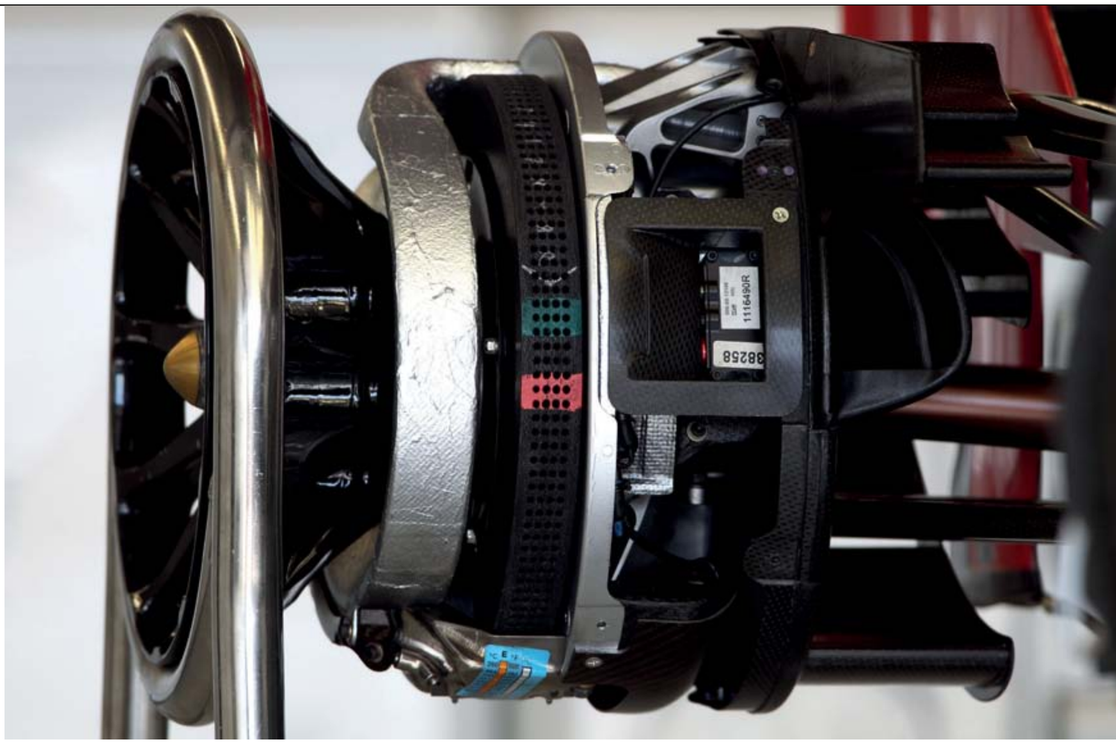
"Our forward exhausts would now be illegal under the new rules and didn't live up to our expectations in any case – so we welcome in a complete redesign"

'THE DEVICE', by Craig Scarborough

'The device' as it is known, came about from the Lotus request for clarification on the Mercedes DDRS, which is linked to the rear wing's DRS to stall the front wing. This system was controversial as switchable drag reduction systems were effectively banned after the F-Ducts of 2010. However the rules to counter this were largely worded to reduce the stalling slots in the rear wing and the driver interaction in turning the system on or off. The Mercedes system sidestepped these rules by having the stalling slot in the front wing and the system switch by the DRS opening (an allowable moveable aero device). When in Bahrain, the FIA gave clearance for other drag reduction systems, whether linked to DRS or not, Lotus announced they would take advantage of the clarification and develop their own device.

Unlike Mercedes, whose system stalls the front wing to balance the aero when the DRS rear wing is used, the Lotus system is passive and not linked to an external switch. Instead the system uses increasing airspeed to send more flow to slots under the wing to stall the airflow and reduce drag (and downforce). Having the passive system means that the Lotus device can be used to stall the wing above a certain speed on every lap, meaning the small 5-8km/h speed advantage is available on every straight and fast corners. With the system being tuned to airspeed, the wing can be designed to stall at speeds high enough to allow fast corners to be taken with the rear wing stalled. At these speeds the diffuser provides enough downforce for cornering and the rear wing is not required for aero load. Typically teams will want this stalling to occur at speeds of over 250km/h.

The system is formed of two roll hoop inlets feeding a central duct, and then an L-shaped duct tees off the central duct to blow the rear wing. The inlets are clearly visible either side of, and slightly behind, the roll hoop inlet, reminiscent of the 2010 Renault F-Duct, although they are permanently bonded to the roll hoop structure, so even when the car is running without the device, they are still in place. These inlets form ducts that pass up and over the airbox snorkel to merge into a single duct that then passes down our current design it was clear that we needed to implement it, both for the benefit we could get in the last quarter of this season and also for the learning experience it presents us for next year. Installing this style of exhaust is not as big a deal as the 2011 style blown exhausts. Last year – for all teams, but especially for our forward exhausts – it was quite challenging to ensure that the exhausts did not set fire to the car. The Coanda system is a little more indirect, and the jet has cooled a little before it impinges on the floor, which makes things a little easier to manage. There's still a fair amount of rearrangement, including new Coke panels, new exhausts, new exhaust exit panels, some fireproofing of the floor and so on.'



As has been the case for several teams this year, the area surrounding the brake ducts has been approached as a key development region for the engineers at Lotus F1 Team

the back of the airbox. Part of this duct is bonded to the airbox before a tail section of duct is bolted to it. This is where the complexity of the central duct is hidden; the duct splits again into two above the airbox, with one exit above the other. The outlets are formed by machined metal flanges, to ensure that the connection to the subsequent ductwork is air tight. One further curiosity ahead of these two outlets is a stepped feature in the ducts profile. This may be crucial to the airflow towards these two flanged outlets at different airspeeds. How the two outlets are then linked to the final duct that exits over the beam wing and the duct leading up to the rear wing are yet to be seen, so we can only speculate how the diversion of flow works.

The tail of the central duct exits over the centre of the beam wing. Here a small winglet is formed around the exit to rescue pressure at its trailing edge. Visible inside the exit of this duct is a smaller duct exiting within, so the apparently large cross-section central duct may be a double walled structure housing two exit ducts.

"The passive system means the Lotus speed advantage is available on every straight"

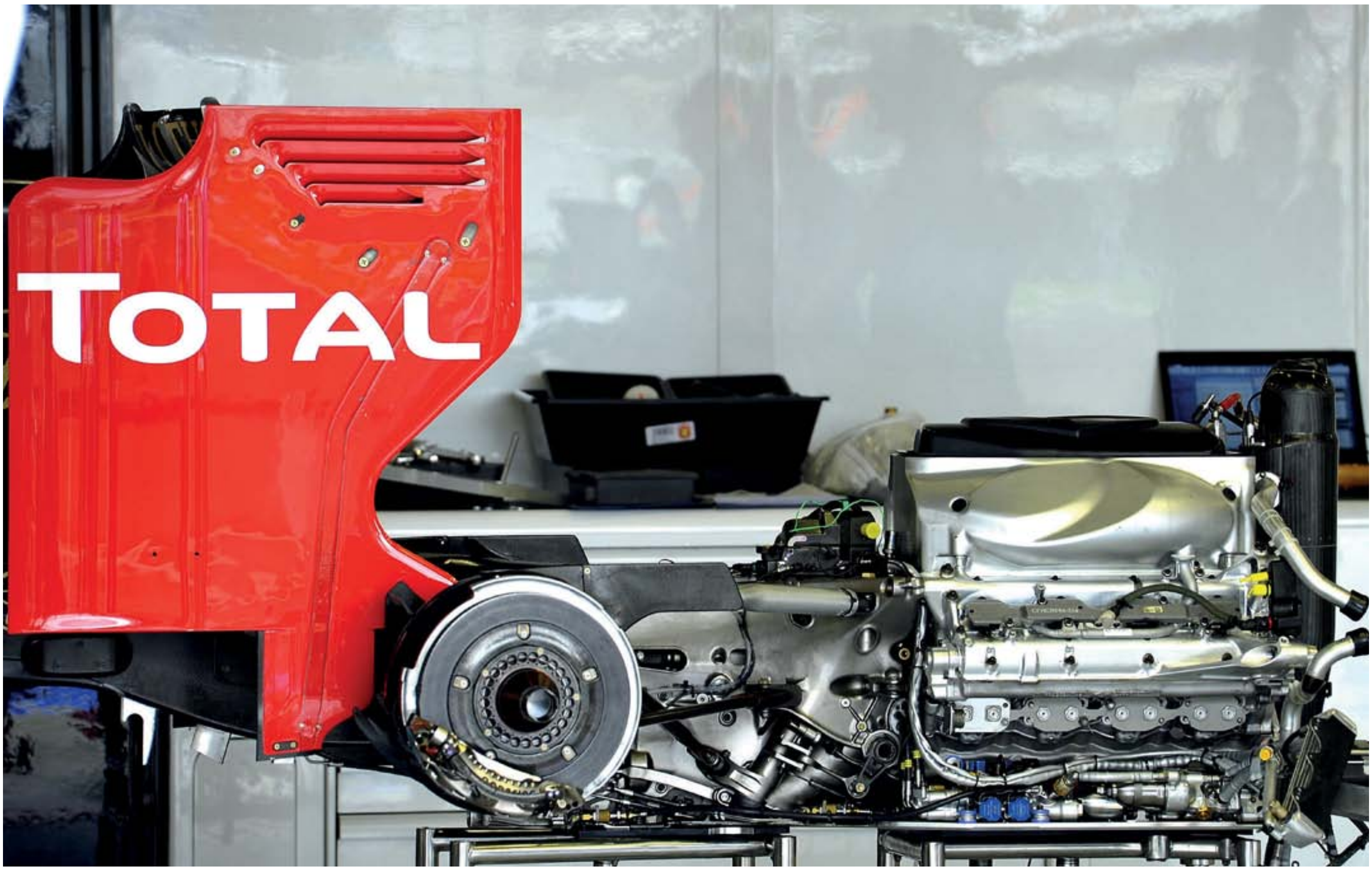
With the central ducts outlet blowing over a revised beam wing, it's possible that the effect of the device when not stalling the rear wing is to aid the upwashed airflow coming up under the centre of the car, to create downforce. Although this would be an inefficient way to create downforce, it is probably a way for the system to contribute to lap time when the upper rear wing is not stalled.

Teed off from the central duct is the upper duct. This is far smaller in cross-section than the central duct, and would offer a lot of resistance to airflow, most likely to encourage airflow at lower speeds to pass into the central ducts exit, rather than up to the rear wing. This duct has a 90-degree bend, not for aero reasons, but as a workaround to the zone ahead of the rear wing not being allowed to have bodywork. This was part of the 2010 F-Duct ban on bodywork (shark fins and F-Ducts) reaching the rear wing.

Other than the join of the duct to the underside of rear wing's main plane, the top rear wing and endplates appear to be the same as the non-device set up. The duct meets the wing, but does not blow into it. Unlike the 2010 F-Ducts, the stalling slot is not a lateral slot across the wings span, but instead four small vertical slots in the duct. These blow sideways where the duct meets the wing's underside. Being part of the duct and in the middle 15cm of wing, they are exempt from the minimum radius rule that was introduced to ban F-Ducts.

It's clear the system has had to be compromised to fit into the post F-Duct rules, but in every sense it meets the regulations and would be hard to declare illegal without a new clarification of the rules being issued by the FIA.

One issue facing the FIA is that the Mercedes DDRS solution will be banned in 2013, via wording to prevent secondary use of the DRS opening. But as it stands, being passive, the Lotus system does not employ this solution, and will be legal.



The E20 is powered by the Renault RS27 2.4-litre V8 engine seen here mated to the in-house titanium transmission. Note the rear suspension arrangement mounted on the side of the transmission

Another key to the new exhaust working adequately is the flexibility offered by the transmission, but unlike some other top cars the Lotus does not use a carbon fibre maincase. 'The transmission has a titanium case. Like everyone, the main development path of the transmission has not been the internals for some time,' Allison reveals. 'Everyone has had seamless shifting for a good while now. The development that has been done is all about making the case as teeny weeny as you can, so you can waist the car in as tightly as possible. That is to do with getting as much high energy air to the back of the car as possible, and have the transmission provide the minimum blockage. All of our efforts have been on that.

'The only advantage to a composite casing is weight. You can make a casing in either material small. You can expect the carbon casing to be slightly less stiff but a kilo or two lighter, and that's a lot. I think that carbon boxes are a better ultimate solution, but there is a lot of time, money and effort in making that, and the amount of benefit it gives you is relatively slender. The way that the rules are at the moment, especially the tyres, in order to get the car into the permitted weight distribution and still have a high performance car, you tend to be struggling hugely to get weight off the front of the car and really not in any real stress at the back. That's the reason that the Red Bull has its KERS batteries at the back of the car. We don't need to use the Red Bull solution because we can get the weight distribution where we want it without putting the batteries back there, and it is an awful lot easier to have all of the parts in one place than have a distributed system around the car.'

Despite its strong run of results, it could be argued that the E20 lacks slightly in pace over a single lap, something Allison hopes the new exhausts will go some way to improving – but not at the expense of changing the car's tyre usage characteristics. 'We've often been devastatingly fast on the harder of the tyres in qualifying but then come up a bit short on the softer option,' Allison admits. 'You can point to cars on the grid that are very quick in qualifying but not so competitive in the race and vice-versa. We seem to have a car that is not among the very quickest in qualifying at the moment, but has very good race pace. It's not a bad combination, and we'd rather have it this way round than the other, but if we want to win races we are going to have to improve our qualifying performances. It's not going to take much, we just need that little bit extra if we want to challenge for higher honours.'

TRICKY TYRES

The way the E20 uses the famously tricky Pirelli rubber seems to be one of the keys to understanding just why it has been so consistent during the season, and the giveaway is how the car tends to perform in hot temperatures. 'Tyres have a certain window in which they work – get them too cold and they don't grip, get them too hot and they don't grip. There's a reasonably wide band in the middle where they work well. It seems like the E20 generates a little less heat in the tyres than some of our opponents' cars, meaning we can live with a hotter track when some of our competitors are starting to move out of the tyre window. The downside of this comes when we have a cold track – or after a safety car. Fortunately, most of the races are contested in summer conditions where you are trying to keep temperatures down rather than having to worry about generating heat, so we've probably got it the better way around – even if it can be a bit frustrating at times.

'Our knowledge of the tyres is no deeper this year than in other years. We just try to use that to keep them in the window where they behave well. It's not very sophisticated. I'd be surprised if it was very sophisticated in any team. After each session Pirelli give you wear information showing whether you are wearing the inner shoulder or the outer shoulder, they tell you if you are wearing your front axle rather than your rear axle, and you work with the set-up

Lotus ran 'plain jane' exhausts on the E20 for most of the year, but finally fitted the more effective Coanda exhausts at the Korean Grand Prix in October

of the car to compensate. If you are wearing the inner shoulders you take a bit of camber out, if you are wearing the front more than the back you try to move the weight back a bit, but that's just standard car set-up. The only thing about the tyres that is unusual is that they punish you heavily for being too hot or too cold and the plateau where they are good is narrower than at other times.'

WIND TUNNEL BLISS

Allison had a significant new tool to use in the development of the E20 with a significantly upgraded wind tunnel at its base in Enstone. 'The 60% wind tunnel has allowed us to expand dramatically the realism of the tests that we perform, so we get the car to more realistic steer and yaw values,' he enthuses. 'Those are pretty fundamental things. That means that the car can be more tolerant of a wider range of cornering conditions. The simulation methods in the factory are good, allowing around 70%-80% of the upgrades that we put on the car to work straight away with no problem.

'Of those that suffer birth pangs, a fair proportion are eventually found to perform as expected when given a second hearing. When you're not running dedicated track testing, there's a whole raft of variables you're not in control of. The drivers might not get clear laps, and with the track constantly evolving plus tyres not always being a new set for each run – you do not have a stable baseline to compare against. These factors can cloud the assessment of a new part, so if you are struggling then you very often remove them from the car out of an abundance of caution and look for a suitable opportunity in the future to have a second go with them.'

STALLED AIR

One update to the car that has suffered from significant birthing pains is the team's version of the rear wing stalling device (see boxout, p10), similar in concept to the one debuted by Mercedes. While Lotus has tested their version on a number of occasions, it has yet to function as the team would like. 'I rather like calling it "the device"; it has a kind of Dr Strangelove appeal,' Allison jokes. 'It has been really tricky to get working, though. We have not had anything from it as yet, because with no real testing opportunities we have not managed to make it deliver the anticipated benefit. We know it is all there for us, but we have not got it to work: it is a difficult birth and it is not out of the birth canal yet. We will work on it until the end of the year, but we need to be careful not to get too distracted. It punishes you by taking one session out of the weekend each time you play with it.'

Overall Allison simply puts the E20's consistency down to its neat design. 'The car has a reasonable amount of downforce,' Allison assesses. 'It's quite driveable – the drivers are not fighting oversteer one minute, understeer the next. It is consistent and predictable; it does not suffer from front locking at one corner and rear locking at another, so the drivers can wring a fair amount out of it. On the large majority of circuits it has had better tyre degradation and lower tyre wear than the competition, which has meant we have tended to race strongly. I hope we can stay in the driver title hunt. If our plans unfold as I hope they will, then we have some performance upgrades coming that will serve us well. Hopefully we will grace the top step of the podium at some point!'

TECH SPEC

Lotus F1 Team E20

Chassis: Moulded carbon fibre and aluminium honeycomb composite monocoque, manufactured by Lotus F1 Team and designed for maximum strength with minimum weight. RS27-2012 V8 engine installed as a fully-stressed member.

Front suspension: Carbon fibre top and bottom wishbones operate an inboard rocker via a pushrod system. This is connected to a torsion bar and damper units which are mounted inside the front of the monocoque. Aluminium uprights and OZ machined magnesium wheels.

Rear suspension: Carbon fibre top and bottom wishbones with pull rod-operated torsion springs and transverse-mounted damper units mounted in the top of the gearbox casing. Aluminium uprights and OZ machined magnesium wheels.

Transmission: Seven-speed semi-automatic titanium gearbox with reverse gear. Quickshift system in operation to maximise speed of gearshifts.

Fuel system: Kevlar-reinforced rubber fuel cell by ATL.

Cooling system: Separate oil and water radiators located in the car's sidepods and cooled using airflow from the car's forward motion.

Electrical: MES – Microsoft Standard Electronic Control Unit.

Braking system: Carbon discs and pads. Calipers by AP Racing. Master cylinders by AP racing and Brembo.

Cockpit: Removable driver's seat made of anatomically formed carbon composite, with six-point or eight-point harness seat belt by OMP Racing. Steering wheel integrates gear change, clutch paddles, and rear wing adjuster.

KERS: Motor generator unit driving into front of engine with batteries as an energy store. Motor Generatorsupplied by Renault Sport F1. Electronic control unit by Magneti-Marelli.

DIMENSIONS AND WEIGHT
Front track: 1450mm
Rear track: 1400mm
Overall length: 5038mm
Overall height: 950mm
Overall width: 1800mm
Overall weight: 640kg, with driver, cameras and ballast

Making up lost ground

Mercedes, as Brawn GP, got off to a blistering start with a Championship title in 2009, but innovation at the design stage has been hampered by frustration on and off-track

BY SAM COLLINS

Mercedes has found itself needing to move forward in Formula 1 in the last few seasons. As Brawn GP, the team finished fourth in the world championship in 2010 and 2011, after winning both the drivers' and constructors' titles in 2009. It was, as team principal Ross Brawn commented, simply not good enough. Brawn told the press at the roll out of their 2012 car: 'My dream would be for Michael Schumacher to win again and for Nico Rosberg to win for the first time - that's our ambition.'

Rosberg did win at the Chinese Grand Prix in the Mercedes F1 W03, and came close to repeating that victory at Monaco, but the second half of the year was a struggle for the team and Mercedes found itself fighting to keep fifth position in the constructors championship ahead of Sauber.

In terms of concept, the W03 is largely an evolution of the 2011 W02, a car that also disappointed. 'I don't think that there was anything revolutionary about the car in terms of concept,' explains Bob Bell, Mercedes AMG F1's technical director. 'The 2011 car was not the most successful, and one of the biggest problems was that it was hampered by a number of design issues which meant that it did not cool particularly well. This made it difficult to manage the cooling in some conditions, and that compromised aero performance.'

The aerodynamic shortcomings of the 2011 car were compounded by a number of other factors, including the major technological development of the season. 'We were late off the mark with the final version of the exhaust blown diffuser,' he says. 'There were several other issues like that across the car, that as much as being design issues, said something about the way we were organised and the way we were running the business.'

This gave the Mercedes engineers some clear objectives for the W03. Although the whole concept was not dropped, major changes were clearly required. 'The 2012 car was a lot about accepting that we needed to do things differently in terms of how we design the car,' Bell continues. 'We put a lot of work into the organisation and the structure, to make sure that we did not carry those issues from 2011 over into 2012 as a result of not doing a good enough job in the design office.

'It was also clear that we had to more than anything else find a big step forward in aero. You could do the sums and see that there was quite a deficit in aero performance, so we set very aggressive targets on that. With the car we got most of the way there, which was more than you would normally expect a team to make from one year to the next. The other features on the car - the suspension layout and concept - were refinements of what we had in 2011. We also did all of the usual things, we had a hard push on making things lighter and lowering the centre of gravity. Overall the car got a bit longer, we found aero benefit from that and it allowed us to have a longer and narrower fuel tank, which made packaging the radiators easier.'

One significant carry over from the 2011 concept was the car's suspension, which features hydraulically-interlinked Penske dampers. This is becoming the state-of-the-art for grand prix cars and all of the major teams are thought to run a similar system. 'Interlinked front and rear suspension systems are not

new – they've been on and off cars for many years,' says Bell. 'You can arrange them so that the car is very stiff in heave and very soft in pitch if that is what you want for the handling of the car, and depending on how you plumb the thing up. Dependant upon what you are trying to achieve with the suspension characteristics of the car, you can change it.

'But there is very little you can do with an interlinked suspension system because of the way the regulations are written. You are restricted to doing things that only function as a result of the vertical load on the wheels, which is basically what a traditional suspension system reacts to. You are not allowed to do anything beyond that, but even within that limited scope of control parameters you can hydraulically connect the front and rear suspension and you can therefore affect how the car handles in a different way to having a completely independent suspension front and rear. Connecting it hydraulically is the only thing to do because to connect the front and back of the car with a mechanical linkage would be impractical. And, if you do it electronically, you would fall foul of the regulations as it would be a powered device.'

DIGITAL ADVANCES

Bell says that the re-emergence of interlinked suspension in grand prix cars is due to the advances made in the digital tools available to the teams, and the resulting change in development methodology.

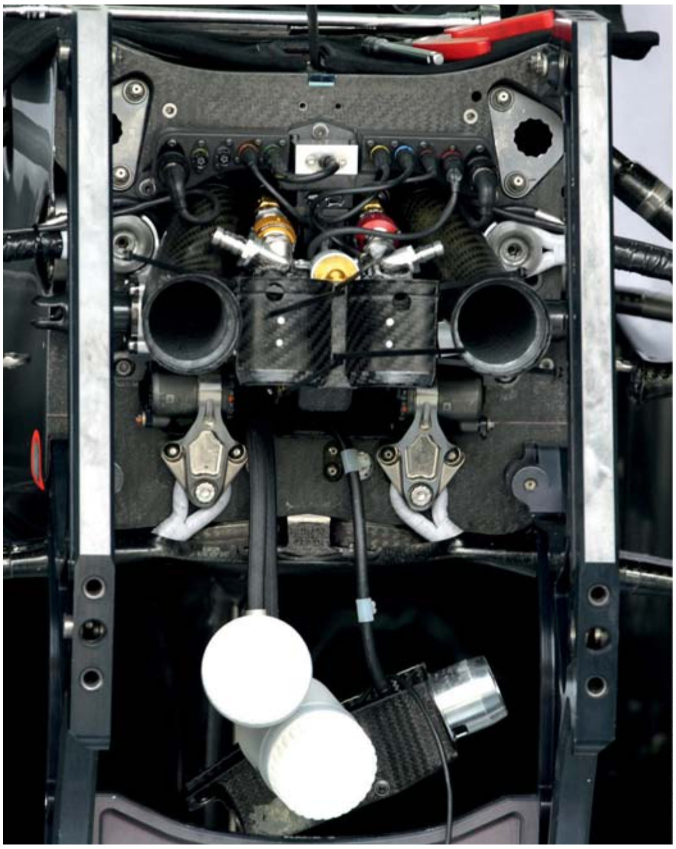
'Various teams in the past have tried it, and its never really, until now, become a standard feature on the cars,' he says. 'I think nowadays we are much more sophisticated in our analysis and prediction of what these systems can do. We can model their behaviour properly, whereas before you sort of plucked an idea out of the air, did a little bit of thinking, a little bit of scheming work, a little bit of analysis and if you then thought that it might offer something you would put it on the car to test. If it didn't work, you'd put it in the bin and start on something else. These days, when you see something that clearly offers you a performance benefit, you can absolutely exercise the concept in the theoretical domain and it's almost more of a formality to see if it works at the track.

'These systems are quite delicately balanced, and if you get them slightly wrong you don't get the performance advantage. In the old days it would have been lost in the noise. These days we are prepared to work much harder to dig right down into the detail and get the most out of it. As a result, the interlinked suspension is here to stay, unless the FIA decides otherwise.'

It is not only the suspension on the W03 that is linked front-to-rear. The car also features a controversial aerodynamic linkage between the rear wing and front wing, the so-called 'double-DRS' front wing stalling device. Its operation is essentially fairly simple: when the drag reduction system opens, a pair of ducts on the inside of the rear wing end plates is exposed. These ducts are linked by a pair of tubes that run the length of the car through the front wing pylons down to a pair of slits on the underside of the front wing.

'The aero concept was fairly straightforward to implement,' Bell explains. 'When you activate the DRS you can feed some high pressure air from the rear of the car to the front, and that is enough to interrupt the

With the DRS open, a small duct is exposed on the rear wing endplate which draws air into two tubes running forward through the car



The tubes run the entire length of the car and through the front bulkhead and on down to small slits on the underside of the front wing

flow at the front wing and stall it. It sheds load and drag, and that means you can go a bit quicker in a straight line.

'Coming up with it wasn't too difficult. Thankfully we came up with it early enough to be able to integrate the pipework into the chassis, which was one of the most difficult bits. To get the pipes from the front of the car to the rear retrospectively is very difficult. There are some challenges, though it was easier than dealing with the F-Duct development because there you were dealing with a fluidic switch and a carefully balanced aerodynamic device. It required quite a lot of detailed analysis to be able to design each one to make it work. This thing was a lot simpler in concept, but slightly trickier in practical terms, such as actually making the bits and plumbing it all. But if you do it as a retrofit it will probably end up heavier and that will reduce its benefit. So it's not something you would take on lightly – I think that is why nobody else has got it to work.'

Once the word of the innovative stalling device got out, there was great debate in the paddock about its legality, and at the Chinese Grand Prix the Lotus team lodged a formal protest which was overturned and the system deemed legal.

'The FIA were very supportive the whole way through and we did not try to pull the wool over their eyes,' says Bell. 'We explained it to them before we did it and they interpreted it as legal. But there are a lot of very clever people in F1 and they were bright enough to find a myriad of reasons why the system would not be legal. I dread to think how many things were thrown at us as potential infringements, but we methodically worked through all of them and demonstrated counter-arguments to show that we complied with the regulations. It was a reasonably close run thing – our interpretation versus other people's. The FIA were judge and jury in this and came down on our side. Perhaps the presentation of the system from some people outside of the technical part of the sport made out that it was some revolutionary device on the level of the F-duct which made a big difference.'

While the double-DRS was deemed legal for 2012, it has been outlawed for 2013, to the understandable chagrin of the team. 'It is frustrating that it has been banned, but frustrating in the context of other things,' says Bell. 'It was largely got rid of for next year as it was deemed to fall foul of Article 2.5 of the Technical Regulations, which refers to technologies that "add no value to Formula One in general". That's fair enough, but at the time its banning was being discussed, we tried to draw an analogy with the Coanda exhaust systems which can be viewed the same way. 'Coanda exhausts are very expensive to develop...' To do a good job on one you can eat up a lot of dyno time. We felt that it was somewhat inconsistent

GEARBOX DEVELOPMENT

The Mercedes AMG started the season with a fairly conventional aluminium gearbox casing, but mid-season development saw a new rear-end, complete with a carbon fibre gearbox casing introduced. Bob Bell explains the logic behind this update.

'This company was at the forefront of carbon fibre gearboxes back in its early days, but that work was stopped for a number of reasons,' says Bell. 'Aluminium gearboxes are less of an overhead in both a financial and resource sense, but they are not as efficient as a carbon case so by using one the team finishes up with a heavier design.

'We had an aluminium casing in 2011, but we decided that we wanted to do what we deemed to be a best in class carbon fibre design for the 2013 car. By the time we chose to do that we were already committed to starting 2012 with an aluminium case, but we didn't want to jump straight into the 2013 car with our first attempt to get back into carbon gearboxes.

'We knew that if we did it reasonably well there was a good weight saving to be had and an improvement to be made in specific stiffness. So we decided to do a carbon version on the aluminium case used on this car as a lead-in programme for a much more refined version next year. This allowed us to adjust the suspension characteristics as a result of what we were seeing with the tyres.'

Fitting a much lighter casing at the rear of the car also had benefits for the car's weight distribution, helping with tyre usage. Says Bell: 'Part of the reason was to save a bit of weight at the extremity of the car just to give us more freedom on where we want to put the weight distribution, even though it's in a fairly narrow window by regulation. Apart from a few at the back of the grid and one at the front, there is a huge gaggle of teams running at similar speeds and all these small things make a big difference.'

The rear end of the Mercedes W03 has been heavily updated with a switch from an aluminium gearbox case to a lighter carbon fibre design

to have the DDRS outlawed and no firmer stance taken on the Coanda exhausts.'

Indeed, Bell was to find out first-hand how costly the Coanda-effect exhaust exits, which have appeared on most of the 2012 F1 cars, really are, and not just in financial terms. In an echo of Mercedes' slow adoption of the exhaust blown diffuser in 2011, the team was also slow on the uptake when it came to Coanda exhausts, first running such a system at a test in September, as it believed that the system would be banned. 'Where I think we dropped off, in terms of the concept of the car, was missing the opportunity to have it from the start of the year,' admits Bell. 'We mistakenly believed that the FIA would regulate them out, but clearly they were not able to do that. We felt that, because of experiences we'd had in 2011, where we had a lot of tyre-related problems due to exhaust blowing effects overheating the rubber, we were a bit reluctant to dive straight into a Coanda system.

'We were all looking at the Lotus E20, thinking that it seems to be the most consistent of the bunch. It had good performance and it did not have a blown exhaust, so if you wanted to pick a car to follow in terms of a trendsetter, it's probably that one. You have to bear in mind at that stage Red Bull, who you may see as the obvious target to follow now, were taking their exhaust on and off at different races, while Ferrari were chopping and changing configuration every five minutes. We should have bitten the bullet right at the start, said clearly that a Coanda system is the way to go, and then had a year to develop it rather than the couple of months that we ended up with.'

EXHAUSTING ALL AVENUES

Although tight restrictions on engine and transmission maps were introduced by the FIA at the start of the 2012 season in an attempt to outlaw blown diffusers, teams are still working hard to increase the exhaust flow to work with the Coanda layouts. 'You could get a huge amount more out of the exhaust if there were no restrictions on mapping, so there is a big incentive to find ways where you can legally exploit the maps to generate more exhaust thrust,' Bell explains. 'All teams are working hard to get what they can within the regulations, but sometimes teams overstep the mark. Not necessarily by deliberately breaching what is written, but by opening up a new avenue that the FIA had not considered. Several teams have done that this year and the FIA have told them to stop it as it is in their opinion aimed solely at increasing exhaust flow which they have said that they do not want to see. They sometimes stop it by issuing a technical directive limiting set up parameters for the mapping.

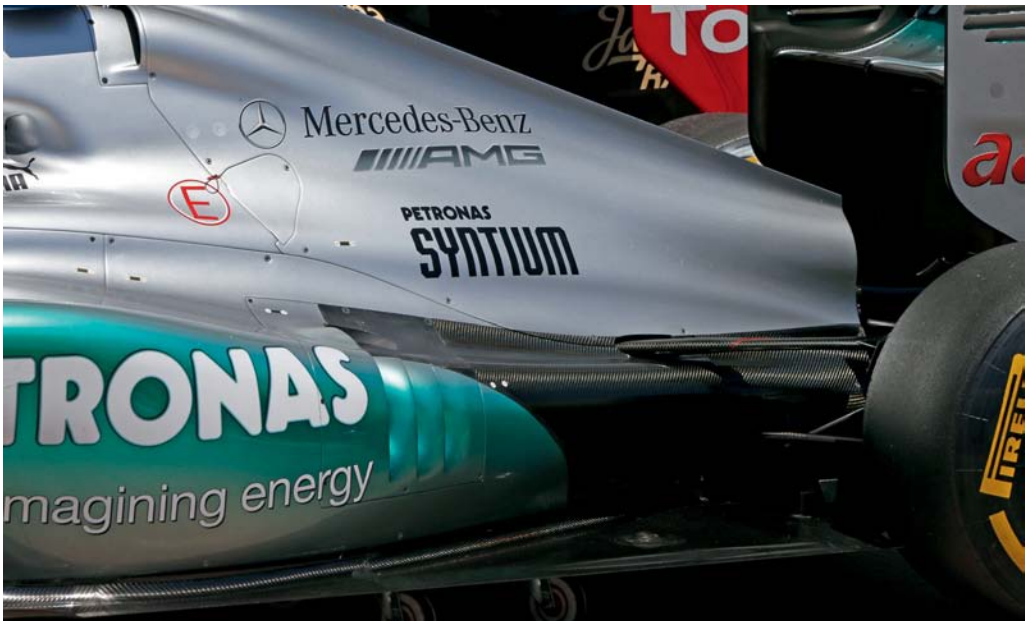
'So it's a bit of a cat and mouse game: they cut off development in one route, and we find another, which they then sometimes cut off too. The reason is that it can give you such an advantage if you find a way to do it, it is very powerful.'

While the Mercedes did not lack innovation for the second half of the season, it has certainly lacked in pace and has struggled to accumulate many points. Indeed, at time of writing, it has failed to score any at the Japanese, Korean, Indian and Abu Dhabi Grands Prix.

'I think there is no great surprise that we are weakest at circuits with lot of high-speed content,' Bell concedes. 'We are weak in high-speed corners. We lack high-speed grip. We also do not get as much out of the tyres as other teams – we have struggled to heat the fronts and cool the rears. The balance of the car on these tyres is not great either. The things that you have to do to protect the tyres give us a difficult balance. We tend to get a lot of understeer and that's been a common complaint from the drivers. I don't think any of us, going into the season, anticipated the problems with the tyres.'

"We are weak in high-speed corners because we lack high-speed grip. We don't get as much out of the tyres as other teams"

The installation of a Coanda exhaust (above) is something the team admits that it should have done earlier in the season, but it believed the concept would be outlawed. As a result for much of the season the W03 was fitted with a more conventional layout (below)



TECH SPEC

Mercedes AMG F1 W03

Class: F1 2012

Chassis: Moulded carbon fibre and honeycomb composite structure

Suspension: Wishbone and pushrod (front)/pullrod (rear) activated torsion springs and rockers

Dampers: Interlinked Penske

Wheels: BBS forged magnesium

Tyres: Pirelli

Brakes: Brembo calipers. Carbon/Carbon

Steering: Power-assisted rack and pinion. Carbon-fibre construction wheel

Electronics: McLaren Electronics Systems standard ECU and FIA homologated electronic and electrical system

Transmission: Seven-speed unit with cast aluminium maincase, later replaced with carbon case. Sequential, semi-automatic, hydraulic activation

Clutch: Carbon plate

Engine: Mercedes-Benz HPE FO108Z, 2.4 litre N/A V8

Max rpm: 18,000 rpm (limited)

Bore angle: 90deg

Bore: 98mm

Valves: 32, pneumatic

Engine weight: 95kg

Number of cars built: 9

Length: 4800mm

Height: 950mm

Width: 1800mm

But, despite the team delivering a competitive car early in the year, it has fallen off the pace with development of the W03. 'I think that we made a good step in terms of aero performance, but it simply wasn't big enough,' admits Bell. 'During the season we've had a number of things which hampered the aero development. The net result is that towards the end of the season we are not in great shape. Each thing is not too much on its own, but when you put them all together it leads to a pretty torrid end of the year. One of the things was making the transition from 50-60 per cent wind tunnel models. All the front running teams have done it previously and it's no small undertaking. I was very impressed with the team here and how they took it on and delivered it. It went remarkably smoothly, but it took a large degree of capital investment. Now all our development is at 60%, but it was pain we had to go through to keep up with the front of the grid in terms of facilities.'

"We made a good step in terms of aero performance but it simply wasn't big enough"

Bell and the staff at the team's factory in Brackley, England, are not disheartened by this. Indeed, there is a sense of hopefulness among the staff. 'We are through that development now, through the difficult things we had to do and that gives us great optimism for next year,' says Bell. 'It's not something you see physically on the car, but we have very much raised our game in terms of doing our homework; the analysis used to design the systems on the car, be they cooling or suspension systems or whatever, and properly understanding them before we get to the track. Although this year's car is lacking basic performance in terms of what it does and the way it does it, we understand it, and we know what it does.

'We have genuinely taken a step forward in understanding the car and its strengths and weaknesses, and that's what you need to know what to improve for next year.'

Same, same, but better

After a disastrous 2011 season, and major personnel changes, Williams looks to be back on form with its 2012 challenger

BY SAM COLLINS

"We ensured the bad bits didn't carry over and the good bits did"

It was the worst season the Williams Formula 1 team had ever endured in terms of point scoring. A finish of ninth in the 2011 World Championship had many questioning the English team's long-term viability. The prospects for 2012 did not look much better, with two reputed 'rent-a-drivers' signed for the season, but all that appeared to change at the Spanish Grand Prix when one of those drivers, Pastor Maldonado, was victorious. It was the first win for the team in eight seasons.

Throughout the 2012 season, the Williams FW34 has run near the front of the field,

sometimes aggressively so.

Surprisingly, despite the poor performance of the FW33 in 2011, it forms the basis of its more competitive successor, perhaps because those poor performances sparked a major re-shuffle of the Williams technical team.

'When I joined the team, I felt it had everything it needed in terms of equipment and resource to be successful,' explains Mike Coughlan, who took the role of technical director in the summer of 2011. 'I felt that the engineering side lacked general focus and direction, but that it wouldn't take much to make the team competitive again. We started by instigating regular meetings across each area of the car to make everybody understand the overall vehicle is what is important, rather than just one particular faculty. We had to make sure everyone realised it wasn't just their area that was going to make the car faster, it was the overall package.'

It was a view shared by both Jason Somerville and Mark Gillan, who both joined over the following months as head of aerodynamics and chief operations engineer respectively. With the 2011 season still in progress, it was decided to use the remaining events to work on the FW33's positive traits, and to find improvements for its weaknesses.

'The championship position wasn't very good, so we used the last number of races almost as an extended test session to try to understand the shortcomings of the FW33,' explains Gillan. 'We simply concentrated on the weak points we found. Aerodynamically, it wasn't bad. it had a few areas needing a tweak. Mechanically, it was good too, though it was very hard on the tyres and we had to understand that. There were a few other problems, which we can't go into, but we fixed those, too. We ensured the bad bits didn't carry over and the good bits did, like the rear end with the very clean airflow to the rear wing and diffuser.'

'We couldn't afford to take our eye off the ball,' adds Somerville. 'The FW34 was the future, so we had one round of aero updates on the FW33 and worked a little bit on the exhaust-blown diffuser, which was a big performance benefit last year. Unfortunately, it became quickly apparent that we weren't going to be able to easily tap into the sort of advantage that other teams were exploiting.'

CHANGE OF HEART

Attention was then firmly on the 2012 car and, at its heart, one of the biggest changes of all – the engine. Williams switched from the Cosworth CA to the more popular Renault RS27 and instantly the team found it a very different piece of equipment, as Gillan explains: 'The initial feedback on the engine from Pastor Maldonado was very much positive, even on the installation lap, which is very unusual. Indeed, it is incredibly unusual for the driver to get out of the car and comment on the improvement he felt straight away.' The installation of the engine into the car also opened up some design scope, according to Gillan: 'The Renault engine differs in a number of ways to the Cosworth. It has opened up a lot more flexibility in terms of mapping and it allows us to run a lot hotter with the water and oil, which from an aerodynamic point of view is much better. Now we can close up the bodywork a bit. It also has less degradation with mileage and, at the end of the season, that makes a big difference.'

One part of the car that seems little changed is the rear end, which retains the very low transmission which drew admiring glances in 2011. 'If you look at the rear end of the car, we have a lot of free space as a result of the gearbox design. It's a nice thing to have from an aero perspective and we carried it over after tidying up a few bits and pieces along the way. That whole area is really an evolution of last year's car. We have tried to ensure that what we gave up mechanically for the aerodynamic benefits we get back,' explains Gillan.

Aside from the regulation-driven nose hump, and the lack of an exhaust-blown diffuser, the FW34 is clearly a continuation of the FW33 concept but, according to Gillan, it has much better detailing. 'The car is a lot tidier in every aspect, especially under the bodywork. But I can't show you that. Otherwise the design is similar to 2011, but it's all those details that make the

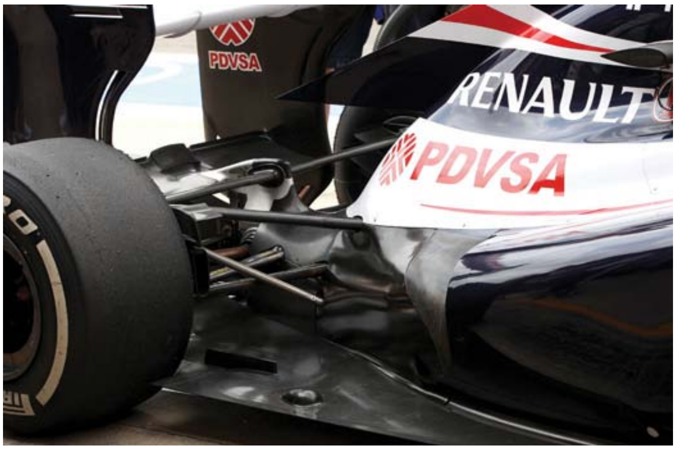
Driver errors have seen the Williams team lose many points in the 2012 season, such as here at Monaco, but they have helped reveal some of the car's underbody and technical details…

long way in that respect, from the design idea to how we test a component, and that whole process has been dramatically improved. We are not where I want to be yet, but it's a dramatic improvement,' he explains. 'I think the big difference is that when you make changes, the car reacts well, so the driver has a platform they can work on. Last year, when we made changes, it was very difficult to push anything forward as the car didn't react as expected. This year the correlation with the wind tunnel is very good, we also have a high hit rate in terms of performance items we put on the car and generally the car is kinder on its tyres, easier to driver and better overall.'

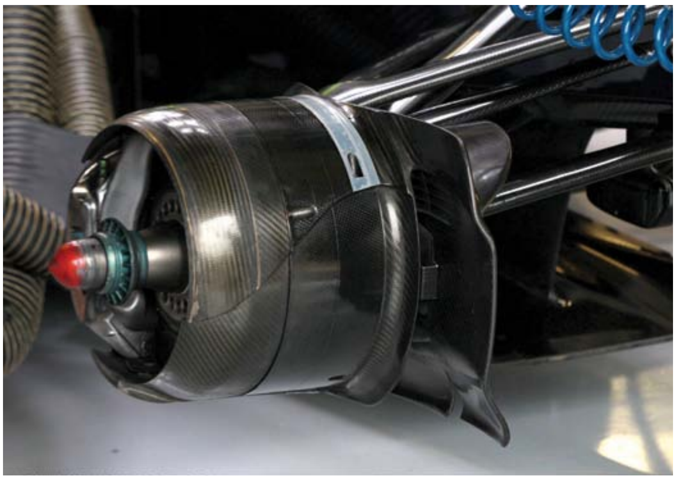
RATE OF DEVELOPMENT

Whilst the base car was clearly a step forward, there was a lot of work still to do, not least in understanding how the car interacted with the notoriously fickle Pirelli tyres. 'The rate of development this season has been tremendous,' says Gillan. 'To be in the mix, you have to keep that up, as a couple of tenths makes a difference very quickly now. A lot of pieces are being tested on Friday and, looking down the grid, all the aerodynamic areas are being developed, so there is no single item and you have to improve the whole cars. In the past, you could focus on a single area like the diffuser, but now base performance and tyre management are key.'

Getting a handle on those tyres has been the biggest challenge for engineers up and down the F1 paddock this season, and it is no different for Williams. So far no team has consistently proven they are able to exploit the rubber's potential. 'Like all teams, our understanding of the tyres has been improving. They have a very small operating window, so you have to manage them carefully, and the drivers have had to learn that. It also has a lot of set up implications. I don't think any team has a definitive handle on it, the integration of the car, the drivers, the aerodynamic loadings, the mechanical balance… it's a complicated puzzle,' Gillan continues. 'The drivers are especially important, and that feedback is crucial. We are lucky with our three. They



The very low gearbox height is carried over from the 2011 car, as is the clean air flows to the rear end



Mark Gillan: 'Brake duct improvement has been significant… We have very good aero data and correlation in this area. Sometimes brake cooling can be a problem, but not for us!'

TECH SPEC

Williams FW34

Chassis: monocoque construction laminated from carbon epoxy and honeycomb composite structure

Front suspension: carbon fibre double wishbone arrangement, with composite toe link and pushrod-activated springs and anti-roll bar

Rear suspension: double wishbone and pullrod-activated springs and anti-roll bar

Overall height: 950mm

Overall length: 5000mm

Overall weight: 640kg (with driver)

Wheels : RAYS forged magnesium

Engine supplier: Renault 2.4-litre 90-degree V8; pneumatic valvetrain; fuel and lubricants by Total; high energy inductive ignition system; engine materials include block and pistons in aluminium alloy; nitrided alloy steel crankshaft with tungsten alloy counterweights; titanium alloy con rods

Transmission: Williams F1 seven-speed seamless sequential semi-automatic shift, plus reverse gear; gear selection electro-hydraulically actuated

Cockpit: six-point safety harness with 75mm shoulder straps and HANS system; removable, anatomically formed carbon fibre seat covered in Alcantara

Cooling system: aluminium oil, water, KERS and gearbox radiators

Tyres: fronts – 325mm wide; rears – 375mm wide, Pirelli

Brake system: AP Racing six-piston calipers all round; carbon discs and pads

Brake material: Brembo

Dampers: Williams F1

Following the Spanish GP, the Williams garage was destroyed by a freak fire, though this did enable us to see the front suspension and bulkhead

are all quite different, but all of them understand the tyres and what we want from them. They understand the problem in different ways and they have subtly different requirements, so we get three sets of feedback, which is interesting to dissect in terms of tyre understanding.

'A good tyre model helps, but it is still a whole car championship and the driver is an important part of that. Even with all of the best models and simulations, the driver is the most highly tuned sensor in the car. They are incredibly sensitive and I don't remember them contradicting one another, but they do have different cues and it's a case of translating that into useful data and feeding it back to the other drivers in the right way.'

One of the main tools the engineers would like to use to be able to get the best out of the tyres has been removed from the box, as the weight distribution of the cars is restricted to a very small window and, says Gillan, it is not an ideal one.

'Using a car's weight distribution is a key driver in tyre management. If it was open, you would be looking to move it a bit from where it is now, but we work within the limits and it's the same for everyone.'

Despite its win, Williams was only in seventh position in the World Championship going into the mid-season break. But this is not really representative of the car, as driver errors have cost the team a significant number of points. It could be argued the real performance potential of this car has yet to be realised.

WILLIAMS ADVANCED ENGINEERING

Williams is unique in that it designs, builds and runs its own Kinetic Energy Recovery System, something the organisation is very keen to promote: 'Our KERS is very good,' enthuses Mark Gillan, Williams' chief operations engineer. 'Hybrid power is part of our business model and we are confident in our capabilities, though packaging is the main constraint, so many of the systems have similar set ups. But our system is continually evolving in terms of packaging and, looking at it, you realise it is very state of the art and we do a good job. Our system never appears on my radar for reliability or performance issues, and the integration with the RS27 is great, too. It's first class.' Whilst only Williams uses the system currently, it has made it clear it is available to customers, too. Indeed, a new company has been formed as part of the Williams Group, tasked with getting the best out of the technologies and IP's created by the F1 team.

'Rule changes often drive our innovation. Why did we never race the flywheel KERS on the F1 car? Rule changes. A ban on refuelling meant a bigger fuel tank was required, and that in turn meant there was insufficient space on the car for a flywheel,' explains Kirsty Andrew, business development manager at Williams Advanced Engineering. 'So we developed our own battery electric KERS. That's created a whole new skill set – the battery management system, cooling, MGU, KCU and inverter are all designed and built in house. That's a very obvious technology for use in cars, and that's the basis of some of the work we are doing with Jaguar on the new C-X75.

'We take the IP and know how we have developed in Formula 1 into other areas and we have a very clear direction from Frank Williams and the board that is something we should do if it benefits a wider society. Of course, it is also an alternative revenue stream.'

"Hybrid power is part of our business model and we are confident in our abilities"

Williams Advanced Engineering started initially as a department within Williams Grand Prix Engineering, but has now grown to a 150-person company. 'We started with what we know. We did the gearboxes for Toyota in their final seasons in F1 and designed the F2 car,' reveals Andrew. 'So some of our work is still in Formula 1. We make the gearboxes for the HRT team and we lease one of our wind tunnels to Caterham F1. They are a customer type we understand. It's our market, our operating environment, with people we know and understand, with similar aims to ourselves.

'It's not just motorsport though. We see the hybrid offering as a great opportunity going forward. If you look at our flywheel, for example, we created a flywheel for F1 in 2009 and it has won Le Mans, raced at the Nürburgring and, later this year, it will be on a London bus. It's a great example of the rapid flow of our technology to other applications. Anything which has a stop-start duty cycle, it can be made to work on. It can be a mobile system or an off-board system with the flywheel beside the track in the station – for example in a railway application.'

Williams Advanced Engineering is also handling the development and construction of the Jaguar C-X75 supercar, and will be constructing a dedicated factory next door to the F1 team to build the new hybrid. 'The head of the C-X75 programme works for Williams Advanced Engineering. It's a blended team, with staff seconded from Jaguar, as well as some other people from third party suppliers, and the majority from Williams,' reveals Andrew. 'Some of those from Williams come from the F1 team, and there are some new recruits experienced in low volume, high performance car production. The production line will be blended. We have no knowledge of interior and trim, for example, and the styling is all Jaguar, too. We have done the aerodynamcics, the composites, the battery and hybrid technology and the vehicle control module. The composite chassis production is sub-contracted, but the assembly is here. We are doing 200+ vehicles here, building them up from parts made both in and out of house.'

For Williams, while racing is always going to be its core business, it seems there are some interesting times ahead.

The battle for middle ground

Battles are raging from the front of the grid to the back, and Caterham is looking over its shoulder at new challengers after taking a bold new path with the CT01 Renault

BY ANDREW COTTON

It is easy to look at Caterham and think 'that's an underperforming team' as Marussia closes in from behind and starts to challenge their position as a mid-field runner, but the team has taken some brave steps this year and from Abu Dhabi onwards expects to reap the rewards.

As if contesting the full World Championship schedule wasn't challenging enough, Caterham decided to move, mid-season, from the Hingham facility in Norfolk to the former TWR factory in Leafield, Oxfordshire. It also ran KERS for the first time, and switched from the Aerolab wind tunnel in Italy to the Williams tunnel in the UK, which led to their first major headache of the season.

'Fundamentally the intention was to have one set of bodywork for the first four races,' said Caterham technical director, Mark Smith. 'As you would expect, moving the model from one tunnel to another produced big differences. One of them was a cooling offset. We were faced with the dilemma: either to trust the numbers from Aerolab, or when we switched, we completely switched, and we just go with the new numbers from the Williams tunnel.

'We felt it was too big a risk to go with the previous numbers from the Aerolab, and we found that we had to revise our cooling which prompted the bodywork change with the big hole in the engine cover. It was fairly apparent fairly quickly that we didn't need to worry as much as we did. We didn't have the cooling issues that we thought we had at Williams. Had that [issue arisen] mid-season, it wouldn't have been an issue because we would have had track data, but this was a brand new car – there was no track data and so caused a little bit of a dilemma.'

The CT01 featured shorter sidepods as part of the overall aerodynamic package and improved underfloor airflow, but a lack of resources meant that the development of the most fundamental part of the aero package, the exhaust plume, had to wait until the British Grand in July before it was introduced, and represented a significant risk to the performance of the team.

With Marussia closing the gap and Toro Rosso and Williams pulling away, Caterham has undeniably lost ground.

'Essentially the first challenge is to accurately model what you do, whatever that is,' says Smith. 'That requires all sorts of things to replicate the car, and one of them is to create as close an approximation of exhaust gas flow as you can get.

'We don't have reciprocating engines or hot gas on the model, but we can govern the mass flow rate of the cold air that we are feeding. When we introduced the system, we weren't able to accurately model the exhaust gas flow rate, so there was some limitation in the ability to model the system. That means that we had very little choice other than to model it as best we could. We were trying to understand what the exhaust plume is doing on the full scale car, which people have been doing with thermal cameras. We are now using them too, so are better able to represent the car in the wind tunnel.

'Once you have got a reasonable match between model and car, you can start to model the areas that the plume is feeding, but essentially it has been about trying to identify what we have on the real car compared to what we have on the model, and have the two as close as possible. This means working on the model to get what we have on the car, bizarrely, because you want it the other way around!'

With a model that's not as accurate as the team hoped for, everything has to be validated on the track. That means that much of Friday's running on race weekends involves a lot more validation work than the team would have liked. 'If you have as near total confidence in the model environment, then you go from model to track. We have to validate quite a few components that are directly related to the exhaust plume aerodynamically,' says Smith. The new package in these circumstances was risky, but the team felt that it was worthwhile as the regulations will remain the same for next year. With the validation work completed mid-season, the results are starting to come through on the track, with a further upgrade introduced at the Abu Dhabi Grand Prix.

RED BULL LINK

While Marussia is undoubtedly benefitting from its tie-up with McLaren, Caterham opted to go with the Red Bull mechanical package at the rear, including engine, gearbox and alternator. Significantly, it also runs the Red Bull developed KERS for the first time and has found that to be the least troublesome part of the car.

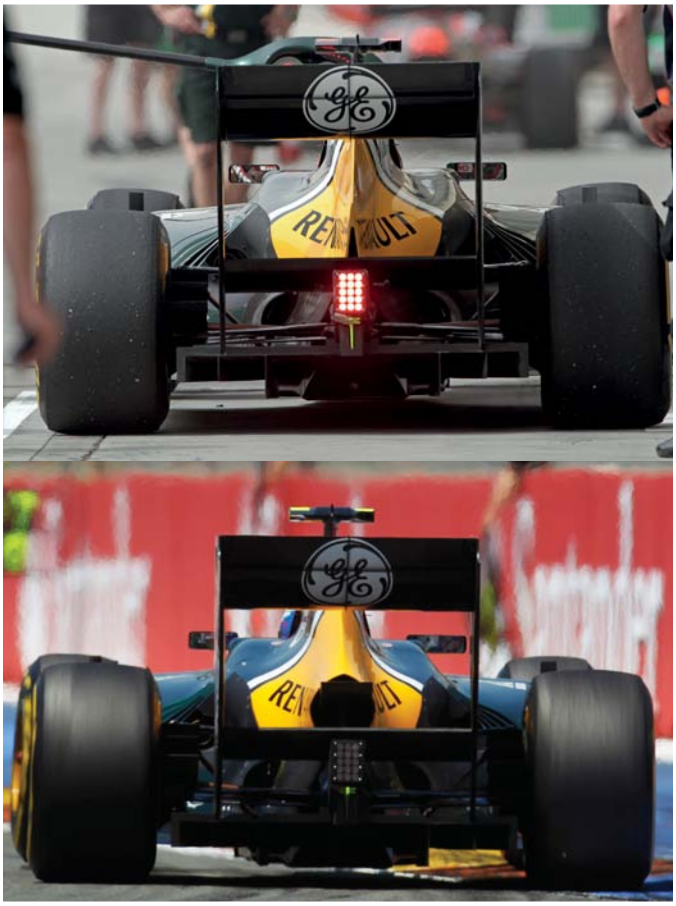
With batteries sitting in front of the gearbox, and one either side, weight distribution and reliability have not been an issue. 'We were aware from the outset that there were concerns about the alternator,' says Smith. 'We revised the way in which we loaded the electrical system at low rpm, managed the system ourselves reasonably well, and by and large we have been fairly trouble-free. There will be developments [for next year] led by Renault that we will integrate as required.'

"We're developing at the same rate as other mid-field teams – but that doesn't close the gap"

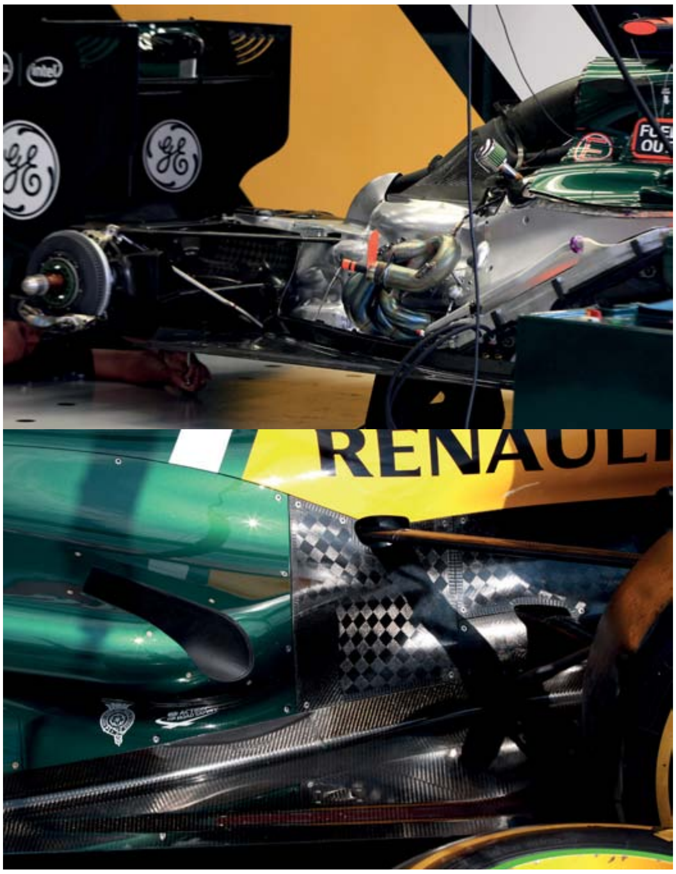
DEVELOPMENT CURVE

With the team having introduced the new aero package without simulated data, it has now lost its ability to be able to open out track space to the Marussia during the races to enable it to make a pit stop and not lose position. This, says Smith, is a more realistic situation than at the start of the year when the luxury was there, but means that the team has to adapt its race strategies accordingly. However, the gap to the front of the grid is static as all teams follow their development curve in the first 15 races of the year.

'To the front of the grid it is close, but the problem is that we all have our performance development gradient, which is predominantly an aero development gradient,' says Smith. 'As every team we do competitor analysis, and we have been developing at the same rate as the other mid-field teams, but that doesn't close the gap, and that is the problem. On the one hand, given our resources and the relative immaturity of the team, why would we expect to close the the gap at a faster rate than the guys who are more established? On the other hand, the further back you are, the steeper the development gains, so you should be able to close the gap. We have struggled



A potential cooling problem was highlighted following a switch from Aerolab to Williams' wind tunnel and led to new bodywork introduced earlier than planned, diverting the team's resources



The team's understanding of the exhaust plume has relied on track testing rather than the wind tunnel model, and has led to the team losing ground to its rivals. At least the introduction of KERS has been relatively painless

"We have seen the benefits, but we haven't yet felt them"

to close that gap simply because to get a steeper gradient to the others is tricky. One of the ways to do that is to bring in people from other teams who are at the front of the grid and benefit from what they are doing. The other is to give ourselves more resources, like ramping up the number of hours in the wind tunnel.

'You do that from one week to the next and you don't see the benefit overnight, and so we are only now starting to see the benefit, but to be honest we haven't felt it yet this season. That should come with the introduction of the 2013 car.'

Tyre management has been a significance in 2012, and Caterham has found a particular issue with generating the necessary heat in the front tyres. It has been a general pattern that the CT01 performs better at the hotter races than the cold. A lack of outright downforce means that the car is more prone to sliding, and so degredation has been an issue, too, as has the fact that the car has had to run flat out to maintain its position on the grid. As front-running teams may be able to back off on overall pace slightly in order to maintain their tyre performance, Caterham has had no such luxury.

PEOPLE MOVES

The move from Hingham to the motorsport valley, close to Brackley, has opened the door to the team being able to recruit more experienced staff as the team grows, and the increased experience should, in theory, translate into speed on the track.

The team opened up the design office to be an open plan room, with all the engineers and designers in the same place, including the race engineers, aerodynamicists and CFD operatives, leading to better communication within the team. The workshops were operational almost immediately following the compulsory two-week summer shutdown, when Caterham completed its move, and while there were reservations, and logistical problems due in part to some of the production remaining in Hingham, it looks to have been a positive step for the team.

'There is no secret that we did it for the recruitment perspective,' says Smith. 'Obviously for the first 12 months there are some retention problems, but by and large most people have moved here. Now we are here, we have more interest from guys who are living here, which is what we wanted. That will be advantageous for us.'

TECH SPEC

Chassis material: Carbon fibre

Bodywork material: Carbon fibre

Front Suspension: Push-rod actuated, arms made of carbon fibre

Rear Suspension: Pull-rod actuated, arms made of carbon fibre

Dampers: Penske & Multimatic

Steering: Caterham F1 Team

Gearbox: Red Bull Technology

KERS: Red Bull Technology

Clutch: AP

Discs: Carbone Industrie or Hitco

Calipers: AP

Pads: Carbone Industrie or Hitco

Cooling system (radiators, heat exchangers): Caterham F1 Team

Cockpit instrumentation: MES

Seat belts: Schroth

Steering wheel: Caterham F1 Team

Extinguisher system: FEV

Wheels: BBS to Caterham F1 Team specification

Engine: Renault V8 RS27-2012

Capacity: 2400 cc

Architecture: 90° V8

Weight: 95 kg

Max rpm: 18,000 rpm

ECU: MES SECU

Fuel: TOTAL

Fuel cell: ATL

Lubricants provider: Various

HYDRAFLOW

the right connection

for perfect fluid control

the connector taken to the next stage

The Hydraflow 14J21 Clamshell is a threadless flexible coupling with a unique safety feature for fluid transfer in motorsport applications and used with industry standard flanges.

SPECIALTY FASTENERS & COMPONENTS

Cert No. 1259QM8001
ISO9001

Tel: +44 (0) 1803 868677
www.specialty-fasteners.co.uk

(Im)proving ground

Far too late for 2012, and quite late for 2013, will the appointment of James Key to the role of technical director help Scuderia Toro Rosso become more than the Red Bull nursery?

BY SAM COLLINS

Red Bull has two teams in Formula 1. One is tasked with winning championships, the other is primarily used to prepare the next generation of drivers to win championships for Red Bull. Scuderia Toro Rosso may have been around for seven years, but the team has only built three Grand Prix cars in that time. Prior to 2010, STR used identical cars to its sister team, albeit with Ferrari engines and an in-house transmission. It took a major step forward at the start of the 2012 season with a significantly upgraded facility in Faenza, Italy, and numerous new hires. The first fruits of this expansion were seen in the STR7, as it was rolled out in the pitlane of Spain's Jerez Circuit.

The design was immediately notable for its raised sidepods and roll hoop-mounted cooling duct. 'Looking at the design of STR7 in general terms, we could start from the fact that 2011's STR6 was a good concept,' explains former technical director Giorgio Ascanelli, who headed up the car's development. 'But it didn't lend itself well to running a low exhaust and was better with a high one. Therefore it was logical that as the rules have changed in this direction, we should stick with a similar concept for 2012, expanding on the idea and its characteristics. Cooling - as always - plays a major part in the design of the car, and we've done something which should allow even more of an undercut on the sidepods, aimed at getting a better

"I would say we have been consistently slow, apart from the qualifying in Bahrain, which was really a flower"

streamlining of the rear of the car. In simple terms, we've made a shorter chassis, with a larger distance between the engine and the gearbox, so that the car can be thinner and more streamlined. We've also tried to improve the behaviour of our DRS and have a new generation of wings aimed at this, hopefully in time for the debut of the car. We've also worked on the braking system, because we wanted to improve its efficiency, both front and rear.'

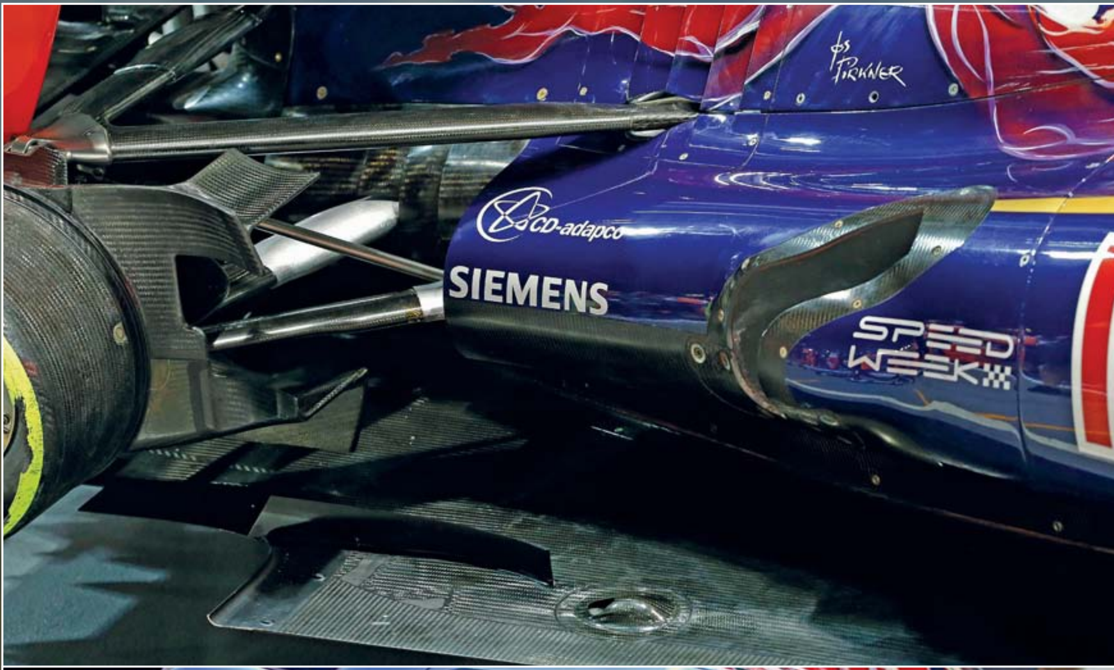
It looked good on paper, but the results were not what the team had hoped for. The first half of the season saw only two low-level points finishes, and it was clear that the car was underperforming. Following the open test in Mugello before the European leg of the season, Ascanelli was clearly not happy with the progress of development. 'With the new people and capabilities do we get more bits? Yes, we do. Are they good bits? Sometimes. Half the things we brought to Mugello worked, half didn't. We have to keep looking at it. I would say we have been consistently slow, apart from in Bahrain [where Daniel Ricciardo qualified 6th on the grid], which was really a flower.'

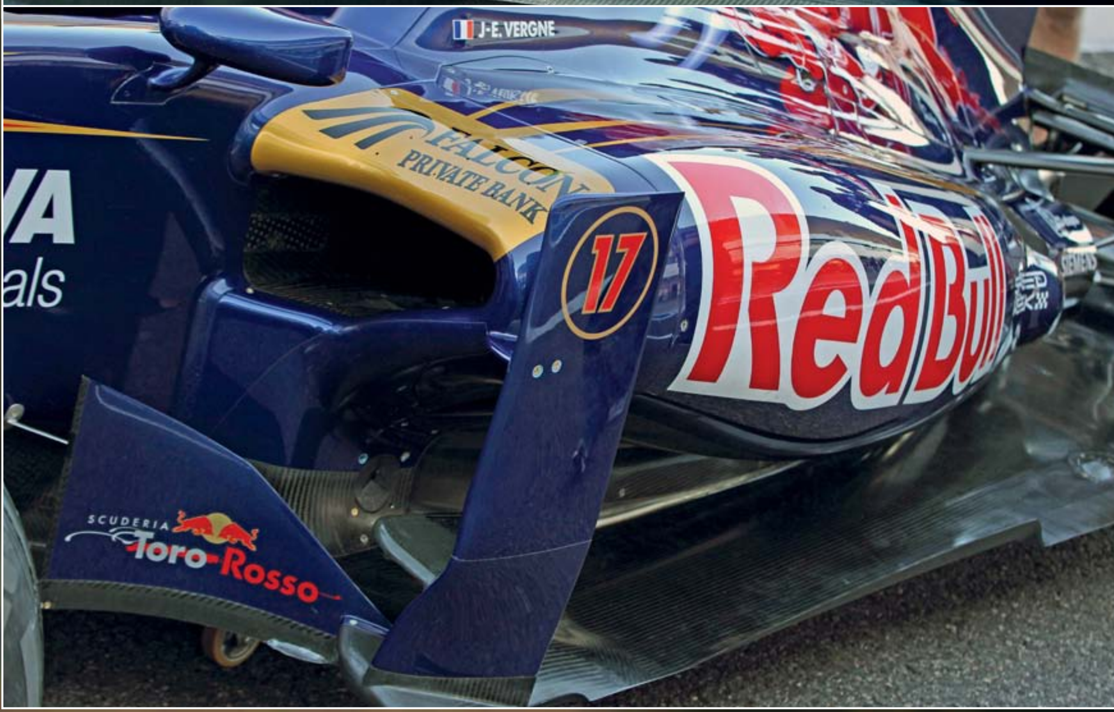
Things did not improve, and by mid-summer Ascanelli had resigned from his post and left the team. Former Sauber and Force India technical director James Key was eventually named as his replacement. 'You could not pick a worse time for a TD to start at a team than September,' smiles the Englishman. 'You're just in time to catch the new car if you're quick, but too late to catch the overall architecture of it. You're just on the edge of being able to do something, so it would have been nice to start earlier, but it's certainly not too late to have an influence.

'My chance to look over the car has been quite brief as that time has been split between races, the factory in Italy, and the tunnel in the UK,' Key explains. 'Divide that by four weeks and it doesn't leave you with too much time. My feelings looking over the 2012 car are mixed, to be honest. I think that there are some very nice bits on it. It's really a nicely put together car. The quality of the parts is generally very high, the gearbox – for example – is very, very tidy and very compact, a long step from where cars were 10 years ago. Those sort of details are very nice on it.

'I think where it's suffering, though, is on the aero side. The car is efficient, but the total downforce is not enough, and if you look at qualifying performances it has been a bit variable. It's a little bit too aerodynamically sensitive, so there's work to do there. I think mechanically there are a few areas that are a little bit strange, in ways that don't allow you to balance the car in lots of different ways that you would perhaps want to. There are a few restraints mechanically, but a lot of those things have been tackled for 2013 anyway. The team had recognised those problems, so next year the track engineers will have a far bigger toolset to play with.'

While it's pretty clear that not everything on the car is ideal, Key has still to make up his mind about some of the concepts featured on the STR7, including its most striking features. 'From what I've seen of the sidepod concept so far it clearly has its advantages, but potentially there are some disadvantages there as well, so it is difficult to





Top: The STR7 started the season with very basic exhaust exits as the team had struggled to simulate the plume in the wind trunnel. New facilities lead to a better understanding and the installation of a Coanda style exhaust. Above: The heavily undercut sidepods on the Toro Rosso are one of its defining features, this raises the centre of gravity of the cooling system but has a number of aerodynamic gains

know how to proceed,' he admits. 'The team has developed around the concept for a couple of years, so it's quite well established and the moment you step away from something like that you step backwards.

'You have to be sure that the step backwards leads to a higher rate of development. It's one of a number of areas of the car we're looking at right now. The problem is that it's all of the areas aerodynamically are interlinked – you change one thing and it means two other things need changing. That carries on and it gets quite complicated, so you need a history to the car before you make too many big decisions. While the radiators sit higher, your cooling layout is not particularly ideal because you've squashed the box it has to sit in. It is one of those factors we need to assess for next year to see if it's worth taking those hits for the aero gain.'

When the STR7 was first rolled out, it featured a very conventional exhaust exit blowing onto the underside of the upper wishbones. The design caused early headaches for Ascanelli, with the suspension getting too hot. The Italian was also open about his ignorance of how to control the exhaust flow, but as the season progressed, his ignorance appeared to fade and the original exhaust layout was replaced with a more effective solution, not dissimilar to the one found on the McLaren.

'There is obviously a strong interaction there between the sidepod shape and the exhaust,' details Key. 'If you look at a more traditional sidepod design where you have the Coke bottle shape, there is a lot of inwash, and that is acting at an angle that isn't ideal for your exhaust trajectory. With ours you have less of that inwash due to the shape of the back of the car. So I'm not sure the sidepod concept of the STR7 is that detrimental to the exhaust; while there is more we can get out of the current system it doesn't dictate things one way or the other.'

TRANSMISSION

One area of the car Key highlights as a strong suit is its transmission. Toro Rosso has continued the Minardi tradition of designing and building its own transmissions, whereas most of the team's immediate rivals buy their gearboxes in. 'The current gearbox as a packaging exercise is really tidy,' enthuses Key. 'It is an aluminium casting with a carbon front end / bellhousing which contains the suspension components; it is a fairly conventional layout in terms of a pull rod suspension, but it is all our design. We have the rigs at the factory to build and test it. It is very much an in-house part, but there are pros and cons to that, because there are teams considered to be our rivals that source their gearbox elsewhere, and that's fine.

'To produce a gearbox takes a lot of resources: there are a lot of people involved and it is a reliability critical thing – you don't have that hassle if you do not do your own gearbox. However, what you do have is complete flexibility over the design of the rear end of the car; your wheelbase, diffuser design, rear suspension, bodywork, [and] cooling philosophy are all areas that are affected by the gearbox and they are completely open. That's good, because rather than finding out what you will have, which is what happens when you buy in your gearbox, you get to define what it is going to be. It is a trade off, but it is nice to have the freedom.'

Despite the mid-season misgivings and the departure of Ascanelli, Key is impressed by the Toro Rosso facilities in Italy.

'When I arrived I was pleasantly surprised,' he admitted. 'It's a lot bigger than I thought, though it is quite spread out. The resource and manpower is slightly bigger, if anything, than Sauber and Force India. In terms of facilities it is OK. There are a lot of performance-related rigs, for example, but it suffers slightly as it has grown from little more than a race team to what it is now in three years, so in many respects it is a new team. It has kind of exploded in F1 terms, going from 80 people to more than 340 in such a short space of time, but you have to make sure that what you end up with is the shape you want, and there is work to do to make all of that stuff fit together. The different departments are all fairly separate and dispersed – the buildings are all near each other but they are not next door to each other. But for its size it is really quite good. The new facilities that are being built will solve a lot of the issues and people will all be in the same place.'

"STR have done a good job in the last three years in getting something from nothing"

One of the departments that Key has set out to change is the simulation group. 'To date, STR have done a good job in the last three years in getting something from nothing. Having said that, and having come from teams with more time and budget, there are some clear steps we need to make to improve. We're reforming the department that does all of the simulation work. We are calling it vehicle performance and it covers vehicle dynamics and the bits attached to that. We are looking at stepping up our simulation capability quite a bit.'

Where the car, and the results, are concerned, Toro Rosso's 2012 season was not one to remember. Key hopes that he has turned the team's fortunes around in time for the 2013 season.

TECH SPEC

Official car name: STR7

Engine: Ferrari V8 Type 056

Chassis material: Composite monocoque structure

Bodywork material: Carbon fibre composite

Front suspension: Upper and lower carbon wishbones, torsion bar springs and anti roll bars, Sachs dampers

Rear suspension: Upper and lower carbon wishbones, torsion bar springs and anti roll bars, Sachs dampers

Steering: Scuderia Toro Rosso

Gearbox: Seven-speed hydraulic

Clutch: Sachs Triple-plate pull-type

Calipers: Brembo

Pads and discs: Brembo

Cooling system (radiators, heat exchangers): Scuderia Toro Rosso

Cockpit instrumentation: Scuderia Toro Rosso

Seat belts: OMP

Steering wheel: Scuderia Toro Rosso

Driver's seat: Carbon fibre construction, moulded to driver's shape

Extinguisher system: Scuderia Toro Rosso/FEV

Wheels: Advanti

Racing fuel cell: ATL

Overall weight : 640kg (including driver and camera)

Target locked

Marussia's MR01 missed pre-season testing and only began wind tunnel testing one week before the start of the season. The team now believes that it has the beating of Caterham

BY ANDREW COTTON

The start of the 2012 season saw a change in the Formula 1 regulations that introduced new crash tests and an insistence that teams pass each of the 18 tests before being allowed to take part in pre-season testing.

In the Marussia camp, the year didn't start well. The MR01 failed one of the tests and didn't pass the final one until a week before the first race in Australia, where Timo Glock and new driver Charles Pic became embroiled in a competition with HRT to see who could prop up the grid in qualifying. As it happened, it was Marussia that had the honour, but only because HRT failed to qualify either of its cars at all.

Pic in particular went into the season completely unprepared - his only sight of the 2012 car was a single day at Silverstone on Pirelli's demonstration tyre and his pre-season testing was undertaken in one of the team's old MVR-02s from 2011.

In previous years, the car was designed solely in CFD without correlation in the wind tunnel. Former Renault technical director Pat Symonds joined Marussia at the start of 2011, and in July effectively took over the same role at the team, and immediately started to change the methodology behind the design of the car. Now, with the tail-end of the season approaching, Symonds reckons that the Caterham team is beatable.

The team moved to the Marussia Technical Centre in Banbury, bringing the entire team under one roof for the first time. Last year they secured an agreement with McLaren Applied Technologies

"It was heavy – the big thing was to get weight off the car"

to help it progress, and with an aerodynamic team of just 28 personnel – led by Richard Taylor and that number including model makers, designers and aerodynamicists – efficiency in the personnel was going to be the only way forward.

The decision was taken to stick with the Cosworth engine as it was proven, and the team was only two years into a three-year contract. As a financially mindful team, they didn't want to spend the money buying its way out of the agreement. A link with Xtrac provided a new gearbox and, most importantly, the team set about improving the aerodynamics to produce a worthy mid-field competitor in year one of the MR01.

Mid-season, the team was rocked by an accident at Duxford airfield in which its new test driver, Maria de Villota, crashed into a support vehicle, an incident which resulted in her losing the use of her right eye. The team satisfied itself that there were no car-related issues that led to the accident, and cleared its chassis to continue to race in 2012.

AERODYNAMICS

From the start, the aero maps for the Marussia MR01 were as expected, and downforce was therefore not the primary concern of the team. At Monza in September, with a new aero package on the car and at a track where the Cosworth customer engine was not expected to be the strongest in the field, the two Marussias nevertheless qualified within a 10th of a second of each other, comfortably inside the 107 per cent time, signifying a huge leap in performance compared to the start of the year.

The team has brought new elements of the aero package to every race this season, and is starting to advance up the grid, offering a real challenge to the Caterhams. In Monza, Pic finished the race 10.9s behind Vitaly Petrov and 11s behind Heikki Kovolainen.

'Mechanically the car was fundamentally OK,' said Symonds. 'It was a little heavy, and old-fashioned, it was not state-of-the-art, but if it had aero on it, the rest was more or less acceptable. The big thing was to get weight off the car, and to get some minor detail design.'

That minor detail design included switching from a pull rod to a push rod rear suspension, tidying up the rear of the car, and concluded from an investigation into the frontal aerodynamics that the much-maligned platypus nose on the majority of cars offered little, if any, advantage.

'It was obvious that this was going to be the norm, but we couldn't get better performance from it,' said Symonds. 'We pushed things to the limit to see if it would open up an area for us, but we couldn't find it. In Silverstone we lowered the nose even further, and got a gain from it, but there was very little in it.

'I think a lot of people did it hoping to open some areas.'

With that decision taken, the switch to a dry sump, and a joint development programme with Xtrac for the gearbox casing on which the rear suspension was mounted, Marussia began to turn their attention towards its methodology.

The Manor Motorsport team knew how to engineer a car, and there was clearly nothing wrong with the ability of the squad, but the results were not being achieved.

The problem, said Symonds, was the lack of wind tunnel

The MR01 started the season with a conventional exhaust exit but was later fitted with a Red Bull style soultion

testing time, and ahead of the season set about rectifying what he saw as the car's biggest flaw – the aero package.

The first time that the car saw a wind tunnel, it was just one week before the Australian Grand Prix. The 2011 car was used to provide a baseline against the 2012 car, which, since March, has added an estimated 15 per cent more downforce, worth between 1.5s to 2s per lap.

'That is 15 per cent delivered to the car,' says Symonds. 'What has been delivered in the wind tunnel is a lot more, but that will go on to the 2013 car.'

The advantage of more downforce was that the car worked the tyres better, although there is still a long way to go to achieve the same performance as even the midfield runners. 'We think that we're understanding the tyres better now, getting the car to the sweet spot,' said team principal John Booth.

'We're starting to understand it. The cars that have higher downforce, at tracks where it's difficult to get the temperatures where you want them – those with higher downforce get there easier than we do.'

Weight distribution was critical. The 2011 car simply had the weight that it was born with, but the team has worked hard on reducing that in order to be able to place ballast.

A relaxation of the strict weight balance regulations might have helped, as was rumoured over the winter, but this didn't happen, leaving the teams without the resources to run KERS at a disadvantage. 'Without KERS we would've had the chance to use the weight distribution better, but the FIA have been quite clever in tightening up the weight distribution band when KERS was introduced,' said Booth. 'With the Pirelli tyres, 65 per cent front bias was the way to go, but we could never get anywhere near that.'

'We had to shift a bit of weight rearwards to regulation requirements, but it wasn't a big deal,' said Symonds.

'We're carrying a lot of ballast compared to last year but we're sitting on the same weight as everyone else, there is only a margin of one per cent by regulation.'

KERS

At the start of the year, the team sat down and worked out that a KERS system would cost in the region of £4m-£6m (US$6.5m-9.7m) and instead decided to spend that money in the wind tunnel. That saved on the complexity and weight of the car, and allowed them to tidy up the rear end. 'To spend [that money] in the wind tunnel would have led to a greater gain than four tenths of a second, so that was the maths that we did,' said Booth.

"I know the Renault figures from 2009, and we weren't even achieving those"

For Symonds, the calculation was even more stark. 'When we looked at the aero figures, they were years behind where we should be,' he said. 'The FIA changed the regulations in 2009, and I know the Renault figures from 2009. We weren't even achieving those. I didn't want to add complication and there was no cost benefit [to KERS].'

ENGINE

With both Williams and Marussia using the Cosworth engine, Caterham having bought their way out of the contract at the start of the year, there were some differences of opinion.

While Williams pushed for top-end power from the British engine manufacturer, Symonds preferred torque. The problem was that the team was second in the wish-list queue, rightfully so given the results. Instead, it was able to play with exhaust exits and inlets, and improved the delivery of power.

'There were subtle changes, but Cosworth have provided bloody good value for money,' said Symonds.

The team has announced that it will stick with the Cosworth engine in 2013 – extending its contract for a further year – and says that it will run with KERS next season, bought from Williams and which is already configured to run with the unit.

Before then, Marussia expects that – at some point this season – it will be in a position to challenge Caterham.

TECH SPEC

Marussia MR01

Class: F1 2012

Chassis: Carbon fibre monocoque

Dampers: Penske

Suspension: Carbon fibre double wishbone with flexure joints, push rod actuated Penske dampers front, pullrod rear

Steering: In house designed hydraulic PAS

Transmission: Xtrac Aluminium seven-speed, mounted longitudinally

Engine: Cosworth CA N/A 2.4 V8

Dampers: Penske

Clutch: AP Racing

Brake discs: Hitco Carbon - carbon

Wheels: BBS

Fuel cell: ATL

Electronics: Braille battery, MES ECU and Dash

Weight: 640kg (including driver)

Dimensions:
Front track: 1800mm,
Rear track: 1800mm
Wheelbase: 3300mm

Cost-capped Formula 1

With a budget dwarfed by the front-running teams, is HRT an example of Formula 1 – how fast can you afford to go?

BY SAM COLLINS

Late in 2009, a new Formula 1 team was born, designed to run to a budget of just £40m, as designated by the FIA. Campos Grand Prix had partnered with Dallara to develop a new car, the F111, but changes in the team's ownership and management led to that car never being fully completed. Since that false start, the team has morphed into Hispania, and eventually HRT (Hispania Racing Team). Since its race debut, it has done little more than prop up the Formula 1 grid, but a recent re-structure is aimed at changing that.

The Hispania-Dallara F110 of 2010 wasn't ready for the first race of the season and raced for a season without any notable developments, beyond some new wing mirrors and a different make of fuel cell. The 2011 car, the F111, was late too, and the trend continued into 2012, although the F112 did manage a brief shakedown run at Barcelona ahead of the opening race meeting.

Toni Cuquerella was appointed technical director of the team in early 2012 – a position that had been vacant for some time – and what he inherited was a team in a state of disarray. 'The car was very late. The drawings only started in September of 2011, just after Geoff Willis had left the team,' he explains. 'The car was done with the people who were just remaining in the team, and Jacky Eeckelaert, who was leading it. There were different clusters of people all around Europe because we did not have a central facility. We did not have a drawing office or stress analysis or any of that stuff. So the design of the F112 was done by a number different companies – one did the monocoque, another the front wing and another the rear wing. Even when the groups are in the same country, they are nowhere near each other.

'It's fair to say the main cluster of these companies has been in Augsberg, Germany, around the Holzer Performance company, who were the suppliers of the design of the car. The chassis is manufactured by Carbo Tech of Austria, but it is not designed by them. That was done in England. The situation is really a big mess and it's difficult to understand as many people and companies were involved. I think we were lucky it was all assembled in a reasonable way... You'd expect things not to fit together but actually that wasn't really a problem.'

PROJECT TARGETS

The complex nature of the car's development left the car without any real direction on the face of it, but there were still project targets. 'The target was to be on time because everybody knew it was very tight to get a car done to be at the first race, as well as meet the regulations, but a big one was to be quicker in comparison to the rest of the field than the last car. Some of these things have clearly been achieved, but others we are still working on.'

The result is the HRT F112. It made it to the first race in Australia, but was clearly

"Our biggest lack of performance is really aerodynamics"

less developed than most of its competitors and lacking in performance, so much so that both cars failed to qualify for the race. It is has since improved and both cars have made the cut at every race since, with a highest finish of 15th at Monaco. However, the team is still the least competitive in Formula 1.

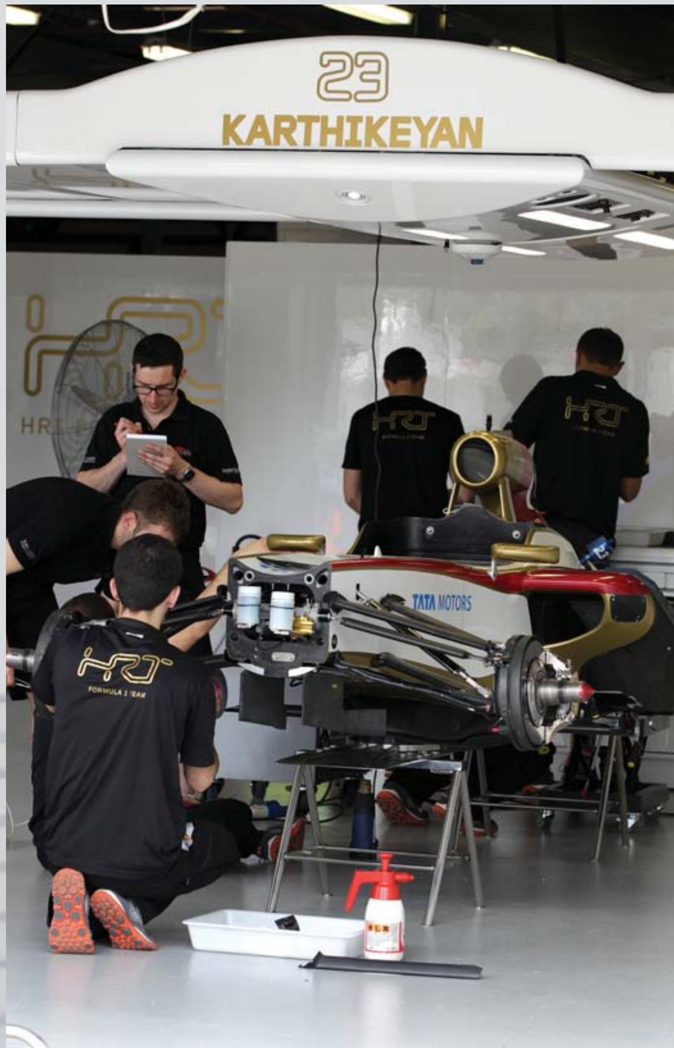
'Our biggest lack of performance is simply aerodynamics,' says Cuquerella. 'There are other things we may be missing compared to the top teams, but 90 per cent of the difference is on the aero side. Really that's the main task of development, because the car was built in such a short time. We have a group of aerodynamic engineers in Munich, Germany, and we use the second Mercedes wind tunnel at Brackley to test.

'You can see from looking at all of the cars on the grid, they are beginning to become very sophisticated aerodynamically. When these rules started, the cars were very simple, but now that has changed. This is the result of the stability of the regulations and the effort the teams have been putting into exploiting them. If you look at the front wing in 2009, for example, they were all very simple. Now they're very complicated again. We are in the process of getting there too, but we are so far behind. At the moment, in every session in the wind tunnel our car is very good and very productive because we've had so far to go forward. With the other teams, sometimes you can come back after a week in the tunnel without having found anything really useful. We were always finding something, but it is still not enough.'

ROLL OVER

The short gestation period of the car means that it carries over many concepts from the F111 and the Dallara F110. But it is actually quite a different car. 'When the aero people started in September, they did not have enough time to properly evaluate the car concept and come up with a new one, so they started with the baseline of something they knew from the 2011 car. That's why it looks very similar to the old car but, if we had started earlier, it would have been a lot different.'

One of the major aerodynamic developments of the F112 was to optimise the cooling, compared to the inefficient F111. 'That has changed completely. The radiator cores are much smaller, because the car last year was a bit too



After being behind schedule in 2010 and 2011, the principal aim of the re-vamped HRT was to be ready for the 2012 Australian GP

"a big [target] was to be quicker in comparison to the rest of the field than the last car"

The real cost of running a competitive F1 team is in development, and HRT has to choose very carefully which areas of the cars to develop, balancing potential gain against cost at every point

safe on cooling. We are leaning them at 20-25 degrees and they are very long. You can see the influence of this from outside the car. The undercut is massive compared to last year and the intakes are much smaller as well.'

A pair of curious NACA ducts also appeared on the car next to the driver's headrest, though it turns out these are simply to cool some onboard electronics, as the team feel that at some of the hotter races they were too marginal on cooling.

QUICK SHIFTS

Mechanically, the car retains the Cosworth CA engine, and uses the same Williams gearbox found in the race-winning FW34. 'When you get to that certain level, the gearbox is not a performance differentiator between the cars. Everybody's got quick shifts so, from the best to the worst, is probably only a couple of tenths a lap. Williams give us a good product and it is reliable.'

One of the most notable things about the Williams 'box is its very low upper surface, which opens up a range of aerodynamic possibilities. 'In terms of volume, it is no smaller than a normal gearbox, but the top is much lower, though we are not yet taking advantage of that performance potential.

'With the engines there are simply not many options out there, but we don't have anything signed for next year.'

Using a bought-in gearbox gives some design restrictions at the rear of the car, notably around the rear wing mounting and suspension pick-ups, so the rear of the F112 is likely to be similar to the rear of the Williams.

'We don't use the Williams suspension geometry because that is not allowed according to the Concorde Agreement,' says Cuquerella. 'All of the components are our own, like the torsion bars, pullrods, wishbones and Penske dampers. We are limited by the inboard mounting points on the casing, but everything else is ours. We are probably not very far from what they have at the rear but, in reality, we don't know.'

Notably, the F112 is longer than the F111, for a number of reasons, but it's likely the HRT engineers found that a longer car gave more stability and gave the aero team bigger surfaces to work with. 'This car was designed to be able to accept KERS, the previous two cars were not. And that requires more space inside the car. But the car does not actually have KERS. When I started to make decisions in this project it was very late, but one of the decisions I made almost right away was to drop KERS. In our case, we can spend more effectively in other areas, like aerodynamics. If you're in the midfield, you need KERS to give you that extra bit but, in our position, we simply need more aero budget. We are so under developed that putting that money in other areas just makes more impact.'

"One of the decisions I made almost right away was to drop KERS"

That is, of course, the real reason HRT finds itself at the back of the grid – it is very restricted on its budget. 'That's an understatement, it is a huge restriction!' exclaims Cuquerella. 'We are counterbalancing R and D against the benefit of what comes out. As engineers, we like tables, coefficients and factors like that. So we put on the table how much it costs to do a particular area of development and what we predict the lap time gain to be. Then the one at the top of the list gets done. We cannot do everything we want to do because we don't have the money for it. Sometimes we have to wait to manufacture the new parts until the differences are big enough to make it worthwhile. When you bring something new in, you have to scrap everything you had before, and that is expensive. It is not a problem for top teams to throw away brand new front wings, but it is for us.'

Despite what appears to be an incredibly tight budget – in F1 terms at least (HRT would not be drawn on numbers) – the team is still able to qualify for races and, with Formula 1 moving back towards some kind of budget restriction, in future HRT could start to move forward.

TECH SPEC

Engine: Cosworth CA2012 2.4-litre V8
Max rpm: 18,000
Engine weight: 95kg (minimum FIA regulation weight)

Chassis: carbon fibre and honeycomb composite monocoque

Suspension: carbon fibre double wishbone with pushrod operating torsion springs and anti-roll bar via rocker (front) and pullrod operating torsion springs and anti-roll bar via rocker (rear)

Dampers: Penske lineal hydraulic

Fuel tank: Kevlar reinforced rubber

Wheel: carbon fibre with integrated electronics and instrumentation

Steering system: HRT hydraulic, servo-assisted system

Gearbox: Williams seven speed with 'Quick-Shift' sequential semi-automatic shift

Clutch: carbon multi-plate

Brake material: carbon discs and pads

Brake calipers: six-piston all round

Cooling system: aluminium oil, water and gearbox cooler

Seat belt: six-point OMP

Cockpit: removable seat made of anatomically-formed carbon composite and HANS system

ECU and logging system: FIA standard ECU and FIA homologated electronic and electrical system

Battery: 12V

Wheels: magnesium alloy

Tyres: Pirelli P Zero

Dimensions:
Width: 1800mm
Height: 950mm
Front track: 1445mm
Rear track: 1420mm

Weight: 640kg (FIA minimum)

A question of balance

Part 1

With more emphasis placed on track data than wind tunnel data, the VJM05's development is based on a new way of thinking

BY SAM COLLINS

The Force India VJM05 was the first 2012-specification Formula 1 car to run on track, albeit at a frozen Silverstone circuit. As the team members rolled up to see that first chassis turn its first laps, it was clear from their attitude that this was something of a new era for the team.

'The biggest change for us was the aerodynamic philosophy of the car,' reveals Andrew Green, the team's technical director. 'It took us quite a long time to wean ourselves off the old philosophy. We did some testing during the season last year, trying to move away from it, and then we used that knowledge over the winter to come up with the new concept at the front. It's delivered on the fronts we had hoped, and it continues to do so, though it has been harder to find the on-track optimum than we expected.'

Force India's approach to the car has been primarily aerodynamic. Its engine is direct from Mercedes HPE and the transmission is identical to that used in the McLaren MP4-27. 'We are using the same internals and composite casing as McLaren,' explains Green. 'We put all of our own suspension system inside and outside of that though. The mounting pads on the casing are the same as on the McLaren, but the brackets are our design. I have no idea what they use. As a result, we are driven to a certain degree on their geometry, but it's not exactly the same, and outboard of that it is, of course, all our own. That said, aerodynamics is the the primary source of performance for us. You have to do a lot to the suspension to get a little lap time out of it.'

Sidepod, exhaust and engine bay layout shows how the aerodynamic concept carries through inside the vehicle as well as outside

COMPLETE CHANGE

The new concept used in the VJM05's aerodynamic package was not so much a set of designs, rather it was a new way of thinking. 'It was a complete change in flow around the car, and it was no longer about beating the air into submission,' explains Green, 'it was about making it do the least work possible. That was the main focus as we worked on the car over the winter. This is not a wind tunnel model championship, it is a whole car championship.'

That is one of the key elements of the new Force India philosophy – to not be overly

reliant on the data produced in the wind tunnel using the team's scale model – something the team had apparently struggled with in the past.

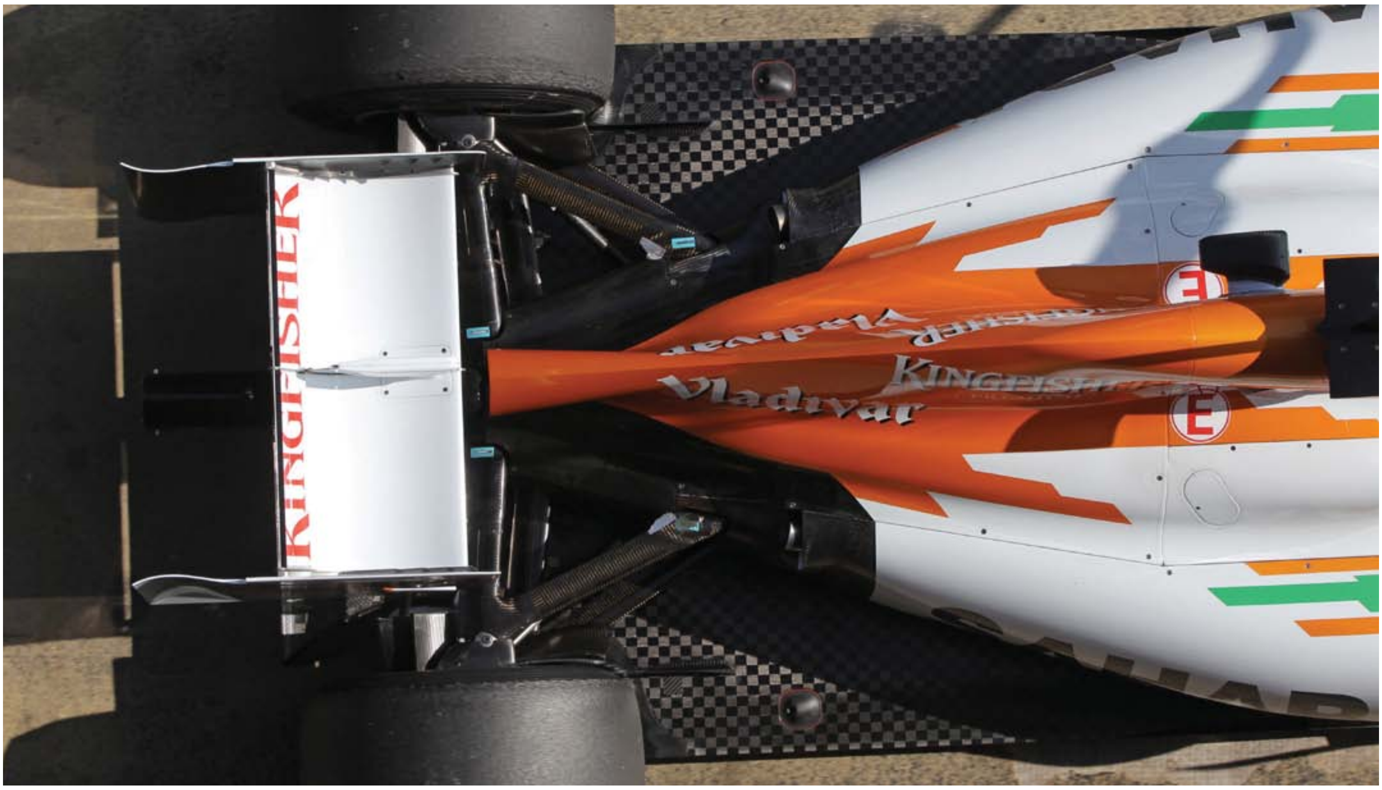
'We stopped chasing ultimate load all of the time and started feeding information from the car back into the tunnel,' says Green. 'When the tunnel says a part is good, and the car says it is bad, you probably should listen to the car, not the tunnel. It is true the other way round too – if the tunnel says it is bad and the car says it good, keep it on the car. That means sometimes the numbers on the wind tunnel go down, whilst the numbers on the car actually go up, which has never happened before.'

It might sound like a problem with the team's wind tunnel in Brackley, England, but Green insists that is not the case. 'It's not a calibration issue, it's just areas of the car that are not modelled correctly. There are lots of areas you simply cannot model correctly. It can even be the whole car that is at fault. The attitudes of the car in the tunnel cannot replicate the attitudes of the car on the track. There is no tunnel that has been designed that can do that. As the car goes round a corner, the airflow that the car sees on the track is not the same as the car sees in the wind tunnel. It's impossible to mimic that, so there is always a doubt that you can pull the result from the wind tunnel model directly onto the real car. You have to take the results with that in mind.'

Whilst clearly the team no longer place overriding importance on the scale tunnel, Green and his aerodynamicists in England are still actively striving to improve the figures from the wind tunnel and work with them, even using another facility to tune their own. 'We only have one scale model. We use it in our own tunnel in Brackley all of the time, and we also use the TMG tunnels in Cologne, [Germany]. We have used TMG a lot to correlate back to our tunnel. We use the data to modify our tunnel and use the numbers ours gives to match the TMG one. We believe TMG matches the real car more closely. We don't have some things that they do, such as continuous motion, but we are looking at it and are hoping to bring it online in the next 12 months.'

Many were surprised at

"The attitudes of the car in the tunnel cannot replicate the attitudes of the car on the track"



Exhaust detail was deliberately conservative on the launch-spec car, the team waiting until the FIA clarified what was legal before bringing out…

…this 'blown diffuser' version at Barcelona. It works, but has caused some balance problems for the drivers

the launch of the VJM05 how conservative the car's exhaust exits were, but the rule changes and technical directives brought in over the winter had left many teams wondering what was actually legal. All of them were still trying to find a way of 'blowing' the diffuser.

'We had the launch spec exhaust on the car for the opening races,' explains Green. 'The strategy was that we had various concepts working in the tunnel over Christmas, but we would wait to see what the FIA's view would be about blowing the diffuser area. We just waited for everyone to test the water, and then went for the solution we thought best and fitted the new system at Barcelona. It has taken some time to get to grips with it, as there are some balance implications that are proving tricky to get around.'

The regulation changes limited the teams in not only where they could place the exhausts, but also how they can use the car's exhaust gases to drive the car's floor. In 2011, some very complex software maps were used, in very basic terms, to allow the drivers' right pedal to essentially act as a torque demand switch and the engine to run at full throttle all of the time, keeping the exhaust blowing through the diffuser.

'The mandated exhaust position is causing the balance issue. Last year we had the engine maps to smooth it out from entry to mid-corner, and that was the big thread of development last year. When we went away from that, it became a lot harder. It is still essentially blowing the diffuser and stopping the vortex from the rear tyre from entering the diffuser area, but now we are doing it from a distance. Last year, the exit was right there, creating a vortex off a nice clean edge. This year, we have to curve it into that zone and then keep it in that zone.'

DRIVER-DRIVEN DOWNFORCE

This change in exhaust location, allied to the ongoing attempts to blow the floor, mean the car has become very different from behind the steering wheel. 'The driver now has a lot of downforce connected to his right foot. As a result, they need to understand where they lift the throttle and what it does to the car. They need to know about gear selection, as the shorter the ratio, the higher the engine rpm, and the more downforce you get. So picking a gear is crucial. Normally, you would expect a shorter ratio would give you more of a rearward loss in grip, but now it does the opposite, so you can gain rear grip simply by running shorter ratios. So that's an area we need to keep on top of,' explains Green. 'It certainly makes for interesting set ups and interesting driving styles. It's not just the set-up conundrum either, it's combining it with a driving style, and you do have to drive differently to get the most out of this. You also then have the factor of driving the car in sympathy with the tyres, which, as we have seen, is crucial in the races. So to combine it all together to find an optimum is a multi-dimensional puzzle, which takes a long time to solve.'

long one I think now. Lotus are too strong, so realistically we have to beat Williams and Sauber. We will push until mathematically it is impossible to beat them or be beaten by them.'

As well as his clear fighting spirit for this season, Green is already actively working on the team's 2013 car, the VJM06. 'I think the car will naturally carry over to 2013, too. With no major regulation changes, you could carry over the chassis, but there are enough changes we want to make to this car that we will do a new chassis anyway. Because it is going to be so tight next year – tighter than this year – a tenth of a second is going to be a huge amount of lap time to find. So we will need a new chassis to be able to optimise it fully, otherwise we will be running around with a handicap. The powertrain will carry over and the car will be an iteration of we have now, but it will be a new car.'

Green is planning even further ahead of that though. With major changes expected in 2014, he believes his team can create cars that are capable of fighting at the front of the pack, but is currently waiting to find out if he will have the chance to prove it: 'We need an indication from the shareholders on the future direction for the team. We have an effective ceiling on our relative performance, and there are some big teams with big budgets and very good facilities out there. If they get it right, we cannot compete with them. What I need from the shareholders is to know where they want to be. Are they happy with where they are now? Or do they want to be on the podium a bit more often? The proposed cost cap would bring it back to us a little bit, but right now the cost cap is something we aspire to. It won't reduce our costs, but we would love to be able to spend up to that. It's more about facilities though. We need the best and most up-to-date tools, and we don't have that at the moment. Lots of other teams have some really good tools. We have great soldiers, we just need better guns.'

"you can gain rear grip simply by running shorter ratios"

At the season's half-distance point, Force India sits in eighth position in the constructors' championship, and that is not a position Green is happy with, despite being upbeat about the car's performance. 'It's mostly gone to plan, but what has not gone to plan is others have done better than we thought they would. We are happy with where we are with the car, but not with the championship points, so we have to claw back some of those points, which is going to be a fight. But then it always is.

'The initial target of finishing fifth in the championship is a

TECH SPEC

VJM05

- **Chassis:** carbon fibre composite monocoque with Zylon legality side anti-intrusion panels
- **Front suspension:** aluminium uprights with carbon fibre composite wishbones, track rods and push rods; inboard chassis-mounted torsion springs, dampers and anti-roll bar
- **Rear suspension:** aluminium uprights with carbon fibre composite wishbones, track rods and pull rods; inboard gearbox-mounted torsion springs, dampers and anti-roll bar
- **Wheelbase:** 3500mm
- **Front track:** 1480mm
- **Rear track:** 1440mm
- **Overall height:** 950mm
- **Overall length:** 5100mm
- **Overall weight:** 640kg (with driver)
- **Wheels :** BBS forged wheels to Sahara Force India specification
- **Engine supplier:** Mercedes AMG High Performance Powertrain 2.4-litre V8
- **KERS:** Mercedes AMG High Performance Powertrain
- **Transmission:** McLaren Racing seven-speed, semi-automatic, 'e-shift'
- **Lubricants:** Mobil 1 products
- **Spark plugs:** NGK
- **Clutch:** AP Racing carbon clutch
- **Tyres:** Pirelli
- **Brake system:** AP Racing
- **Brake material:** Brembo
- **Dampers:** Penske

A question of balance Part 2

How Force India and Cranfield University are using a simple rig to assess the effects of aerodynamic changes on the stability of the VJM05

Behind a rather uninspiring set of wooden doors on the campus at Cranfield University lies one of the secrets of the Force India vehicle dynamics programme. The moment of inertia rig at the Cranfield Impact Centre is a remarkably simple looking device, yet its data is crucial to many aspects of the Silverstone-based team's operations.

'Measuring the moment of inertia of an object is a case of measuring the resistance to motion in a rotary fashion,' explains the man behind the rig, Dr James Watson. 'So we oscillate the vehicle in a rotary fashion to find that moment. We have tested road cars, F1 cars and even missiles – anything where an object is rotating and where you need to know the inertial properties.'

The rig itself looks deceptively simple, like a scaled-down version of a child's see-saw. Mounted on an air bed, which supports the vehicle, there is an arrangement of steel arms with two long ones running the length (or width) of the vehicle. 'The red arms have a blue arm attached with a spring,' explains Watson. 'What we are trying to do is to move the car in pitch, and oscillate it. Once it dips on one side, it moves the spring on the other. That spring then goes into tension whilst the other is in compression. That gives you the oscillation motion. What we are trying to get hold of is the time period of that oscillation. If we did not have the springs, the car would just flop onto one side. It is very difficult to take a vehicle of this size and balance it.'

The rig is capable of being aligned for testing in pitch, roll and yaw and all three are used by Force India for its calculations. 'We can also calculate the principal moment of inertia and find out which axis the object would like to rotate about,' Watson points out. 'The c of g is not always on the car's centreline, in either x or y planes, but we assume a symmetry through the car. Certain vehicles, like Formula 1 cars, are very evenly balanced, so with them it is usually within 2mm of the centreline, but on road cars it can be up to 10mm off.'

"The c of g is not always on the car's centreline, in either x or y planes"

SHOVE OFF

Simple in appearance and seemingly simple in operation the car is levelled using a standard spirit level and the rocking motion is started by a shove of the technician's finger on one end of the car. But, as Watson explains, how hard that operative pushes is irrelevant to the results. 'What we look at is the time period from top to bottom. After a few of those have been logged, you get the oscillation time, which we average over 50 cycles. The attitude does not effect that time period, it's just like a pendulum in a clock. The arm length, spring stiffness and similar factors are all crucial to the calculations though.'

The rig is linked to a computer that logs only three channels of data, including the timing pattern and force via a load cell. But the results are just what is required by racing teams' vehicle dynamicists.

'There is no point in just measuring the moment of inertia on its own though.' Watson adds, 'that would be meaningless. We have to reference it back to the c of g. You can get that in the x and y planes very easily on a flat patch with corner weights, but by using the rig for a supplementary test you can measure the height of the c of g by simply measuring the reaction force in a pitch orientation and a roll orientation. That is simply a case of tilting the vehicle to a set number of degrees and measuring the reaction force at one end. You then get two values – the c of g height and also any offset from the x or y direction.'

Certain factors need to be added to the calculations to give a realistic result. The mass and effect of the components of the rig itself need to removed from the figures, so even the blocks of wood used to chock the car have to be precisely measured and weighed so they can be subtracted from the data. 'We can't have things on the object moving, it has to be a rigid body, so if there are things like fuel and oil sloshing around, you can't get a proper result. We either need the fuel tank full up right to the top or empty. The suspension can also be an issue. If it moves too much during the test, again that causes problems, so it has to be set rigidly, too,' explains Watson.

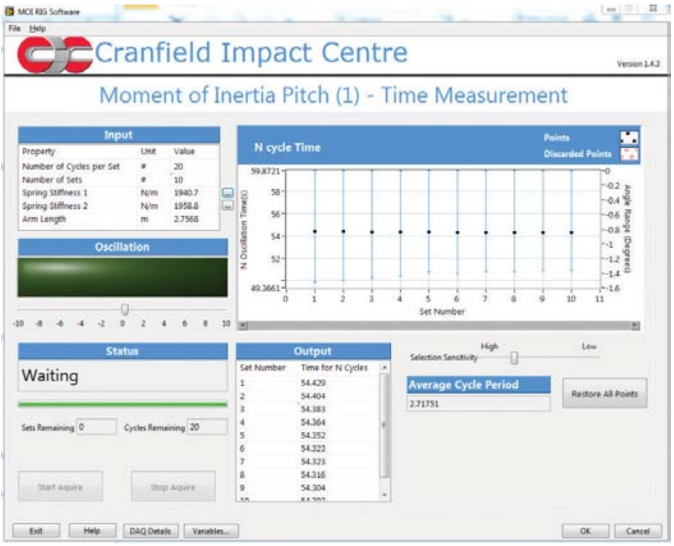
MASSIVELY IMPORTANT

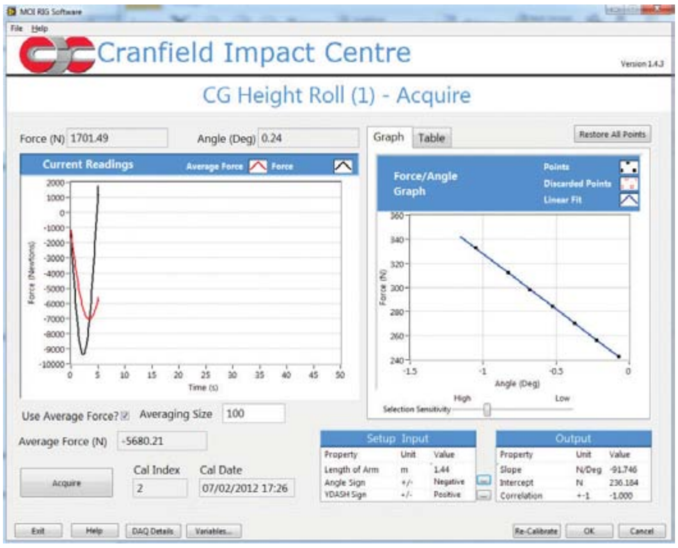
Force India's head of vehicle science, James Knapton, is in charge of the team's usage of the Cranfield rig, and for him one of the results it puts out is clearly the most important when developing a new model, such as the VJM05. 'We go there once a year to carry out a c of g test and an inertia test. We primarily look at the c of g height as that is massively important in F1 – change it by 10mm and

The Force India VJM05 on the Cranfield moment of inertia rig, which the team are using to test alignment in pitch, roll and yaw, as well as to measure c of g height and numerous other factors being used to develop the team's current F1 chassis

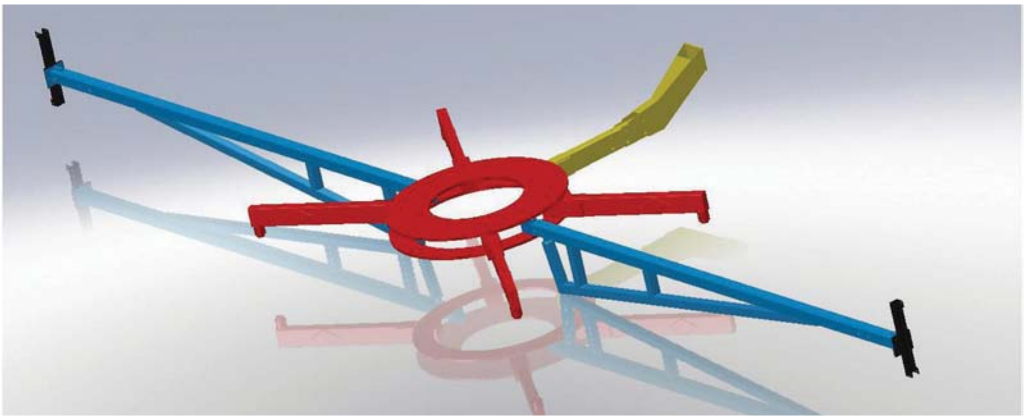
you can go about two tenths of a second faster,' he explains. 'Over time you may expect the c of g to go down as each new model is completed, but actually it has often gone up, which can scare the management. It can be heavily influenced by regulation changes, too. When car safety was improved with side panels for driver protection and bigger headrests, for example, the [c of g] height raised.

'The aerodynamicists always want to put things higher, too. The chassis has raised at the front over the years as they want to get air under the nose. In the past, there also tended to be a lot of winglets on the top of the bodywork, and we had to assess whether the gain outweighed the losses from raising the c of g height. But, if the rules don't change, you target it to





A screen grab of the rig's ouptut when pitch measurement is being taken (left) and with the rig set up to find the c of g height and the car being oscillated in roll (right)



CAD model of the rig. The blue arms are attached to the red body with springs, which produce the oscillation movement

be reduced, and for us it has between 2010 and 2012. It is usually between 200-250mm above the bottom of the car, which is fairly low. We could make it lower still, but we would have to compromise the aerodynamics, by lowering the radiators and sidepods, things like that.'

PRIMARY FUNCTION

Beyond understanding the car's c of g height, knowing the inertia of the car is also very important to the team. 'The inertia, or how much it resists turning round a corner, is of course the primary function of this rig,' Knapton continues. 'Over the years it stayed roughly the same with our cars, but in 2009 we started to make the car longer, for stability and aerodynamic reasons. And in 2010, the refueling ban made them longer still, and that changed it a lot. There is not a lot we can do about yaw inertia because the parts of the car pretty much have to be where they are, and we have regulatory limits on weight distribution, which further limits where we can place things. The yaw inertia is usually dominated by things like the front wings and front tyres, which are right out at the corners. Our yaw inertia has gone up quite a bit recently, but strangely the drivers don't notice it. You'd imagine they would get out and say it feels very sluggish and unresponsive, but they don't really pick it up.'

In the age of digital simulation, it seems strange that such a simple looking tool is so critical, but what CAD packages output is no comparison to the real world. The data gained here is crucial to improving the team's digital version of reality. 'We use a lot of the data from this rig in our simulation models. It's very important that we have the correct c of g height and inertial properties in our vehicle model,' reveals Knapton. 'It must behave like the real thing. We use that data in dynamic models like our driver-in-the-loop simulator. Getting the data right means it feels like the real car for the driver. We had an incident recently where we got the roll inertia wrong and the drivers were complaining that the car was very strange to drive. We didn't believe them, but later realised it was out by a factor of 100, due to user error. The car was oscillating and the drivers picked it up.'

REAL WORLD DEVELOPMENT

The data also can be used in real world car development, something technical director, Andrew Green, has placed particular emphasis on with the 2012 VJM05 (see p20).

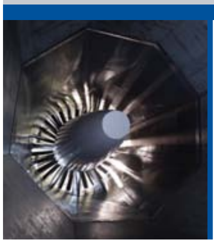
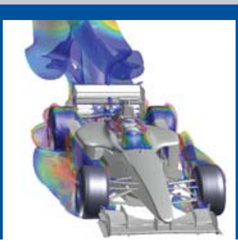
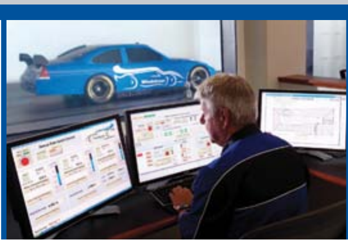
'We work out the aerodynamic loading on the car via load cells on the pushrods. If we change an aero component, we look at those outings to see if there is any change, but when the car brakes you get a huge weight transfer forward putting load on the front. If you look at the data it then looks like there is a massive load on the front, so we need to compensate that out, and to do that we need to know the rate of deceleration and the c of g height.

'Another way we use the data is if we do stability calculations on the car, and try to work out the yaw moment making the car turn. The front tyres will try to make the car go round the corner, whilst the rear tyres try to stop the car going round the corner. Looking at the yaw rate sensor of the car, and differentiating that from yaw acceleration, we can then divide that by the yaw inertia and get the moment acting on the car. We can then use that yaw moment to asses the stability of a change we make to the car.

'Finally, the data from the VJM05 and the forthcoming VJM06 will be fed back to the design team to allow them to optimise other parts of the car.

'We then use this when we are designing the suspension elements. The data from the c of g height helps us accurately predict the car's contact patch loads, and that feeds into other models, which give us the maximum loads for the suspension. It's especially critical as we don't use very high safety factors, perhaps 25-50 per cent.'

Force India believe in the value of the Cranfield rig, and they're almost certainly not the only F1 team using it. But with relatively affordable costs, perhaps more race teams will start to utilise it in order to develop their own models.


THERMA
MOTORSPORT
Temperature is our Business.
The sophisticated Specialist in Thermo Sensor Technology for Motorsports.
Sensor especially for Karting
Sensor for Applications with Fluids
Plug-in Temperature Thermocouple
Screw-in Thermocouple
PT100 Resistance Thermometers
F1/LMP1 Exhaust Gas Temperature Sensor
Therma Thermofühler GmbH . Schreinerweg 8 . 51789 Lindlar . Germany . Phone: +49 2266 8026 . www.therma-motorsport.com


CLAYTEX
SOLUTIONS FOR SYSTEMS ENGINEERING
Specialists in Systems Engineering across multiple industries
• Dymola - Modelling and Simulation Software
• Open and intuitive modelling environment
• Multi-domain modelling and simulation tool with comprehensive range of library solutions
• Real-time simulation for HILs on dSPACE, xPC and McLaren Electronics vTag systems
• Compatible with the FMI standard supporting model import and export
Edmund House | Rugby Road | Leamington Spa | CV32 6EL
T +44 (0)1926 885900 E sales@claytex.com W www.claytex.com

A load of hot air?

Formula 1's blown diffuser theory was topical in 2011. While designers are still trying to master it in 2012, one student applied the theory to a Pilbeam Sportscar

BY SAM COLLINS

In 2010 and 2011 there was one major area of discussion surrounding Formula 1 aerodynamics. With the banning of the multi-level diffusers pioneered by Brawn, Toyota and Williams, Red Bull had found a new way to boost the performance of its car's underbody – it had placed its exhaust exits lower than was then conventional, so the gas from the pipes blew into an area around the rear wheels.

Using exhaust gases for aerodynamic gain was not new. Various Formula 1 cars over the years have featured 'exhaust-driven diffusers', many of them designed by Adrian Newey, notable as the designer of the current breed of Red Bulls. Key to this is using the gases expelled by the exhausts to energise the flow around critical components such as wing elements or, more importantly, the diffuser.

The concept is not only limited to open wheelers and has also made an appearance in Sportscar racing, with the Allard J2X of 1992. While that car is largely forgotten, it housed its exhaust tailpipes in a through-car tunnel, in theory increasing downforce. The concept had dropped out of fashion of late, possibly because the tools required to fully understand what is going on with the airflow were not well developed. Even then, it was the preserve of high-end cars such as the highly advanced Allard.

> **"Using exhaust gases for aerodynamic gain was not new"**

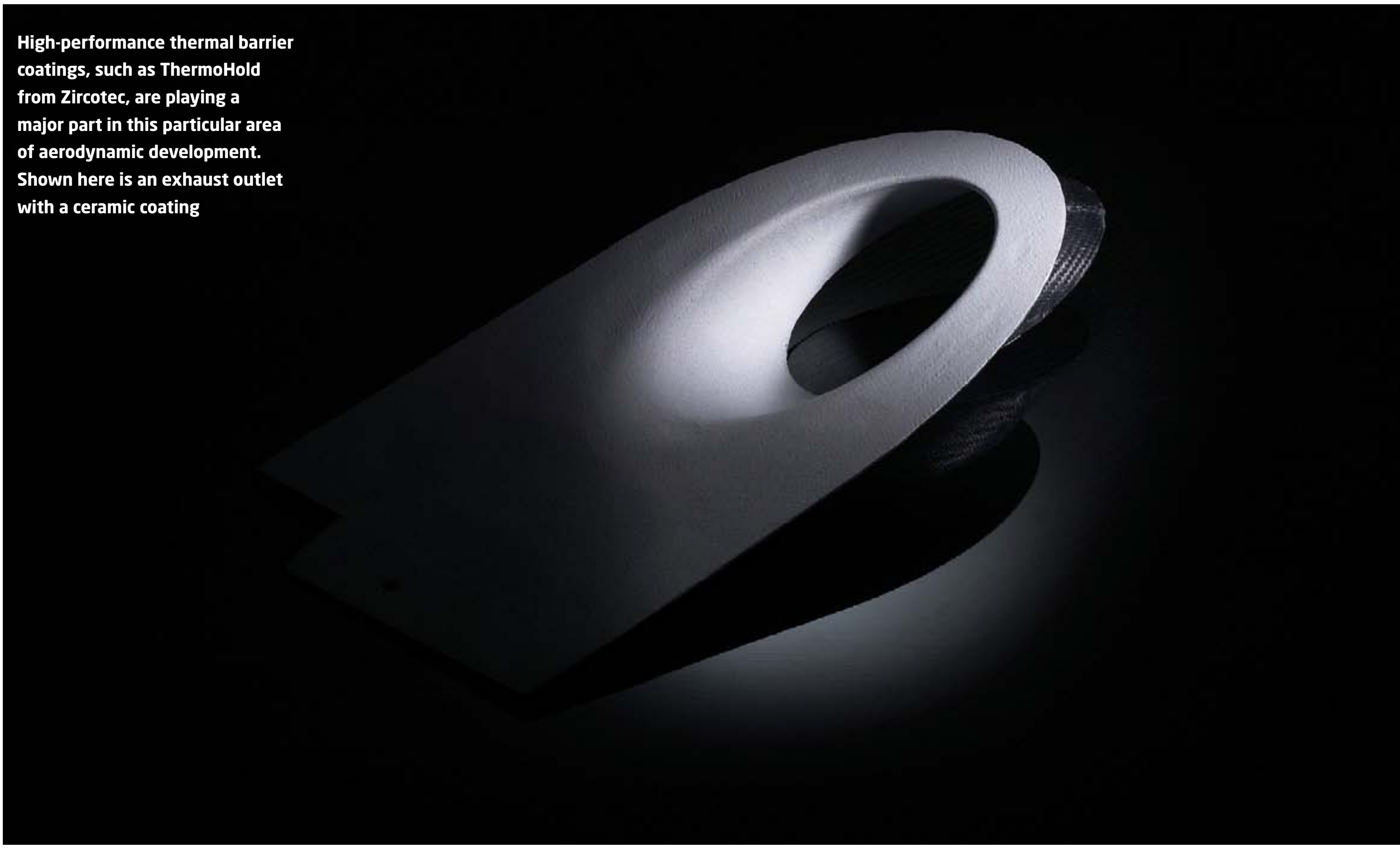
HOLLAND CALLING

It was a subject that fascinated Dutch graduate, Thijs van Rees, who was working on a Phd at Cranfield University. He decided to make the concept the subject of his thesis, but not on the traditional top-end open wheeler. Instead, he picked out a mid-range, full-bodied car as the model for his study.

'I used the Pilbeam MP98 CN regulations Sportscar [shown in lead pic, above]. It was developed purely in CFD and later tested on track, which is fairly unique in that category,' explains the Dutchman, who now works in Formula 1 with Williams. 'The regulations for that class of car stipulate that exhausts must be mounted in a specific area and must point either rearward or sideways, which gave me an interesting challenge. But they do not prevent you locating them in an area that can bring aerodynamic gains.'

To study the implementation of such a layout on a mid-range car (turnkey CN machines retail for around £80,000-£100,000 ($125,575-$157,000) makes this an unusual piece of work, and the results of the research are substantial. Van Rees was heavily influenced by Red Bull's recent designs, which appear to be all about the flow structure around the rear wheel.

'Their concept was to manage the wheel wake at the rear of the car, and that was to improve the flow through the diffuser,' he explains. 'Tyres are



High-performance thermal barrier coatings, such as ThermoHold from Zircotec, are playing a major part in this particular area of aerodynamic development. Shown here is an exhaust outlet with a ceramic coating

very strange things. The radius and the contact patch changes continuously, and this is a very important aspect in terms of aerodynamics, especially in open-wheel cars. At the base of the tyre there is a vortex created and, if this gets into the diffuser, it reduces its effectiveness. Using the mass flow from the exhaust to drive this vortex away from the diffuser and other critical areas effectively makes the diffuser larger and more efficient.'

COMPUTER SAYS 'NO'

But to fully understand these flows is a complex challenge, only really made possible by recent technological advances. Indeed, when van Rees attempted to run his first simulations he discovered it required more computing power than the clusters at Cranfield could supply, so he was forced to simplify his model.

'One of the important things to remember is that the exhaust is a very high temperature gas flow, and you have to manage that in the simulation,' explains van Rees. 'To do it fully, you have to understand the changes of the properties of the gases. The velocity, density and the thermal conductivity are all influenced so, for me, CFD was really the only way to survey all these factors.'

Van Rees' simulation was basic by current F1 standards, but nonetheless highly revealing, and he found substantial gains to the aerodynamic performance of the Pilbeam. 'Just using a very rudimentary design, the MP98's downforce increased by 11 per cent, and more detailed studies could almost certainly bring greater gains. The drag level also increased but, even so, there was an overall gain.'

With the widely reported change in Formula 1's exhaust regulations often called a ban on blown diffusers, many of the innovative layouts, such as those used by Red Bull, were outlawed. However, blown diffusers are not banned *per se*, and the teams are still actively trying to optimise their exhaust plumes. 'It is still important, but when you have changes in performance of the order of magnitude that we are seeing with the tyres and getting the tyres to work, it's not our higher priority,' explains Ross Brawn of Mercedes. 'Last year it was one of the predominant performance factors, but this year it is nothing like as significant as it was. I think the cars that came first and second at the Spanish Grand Prix had very conventional exhausts so, unlike last year, the cars with innovative positions are not pulling away from those who are conservative. The range of performance between the solutions is much smaller now. But we still do a lot of work on it, both in CFD and tunnel testing. You can't do everything in a wind tunnel and, obviously, you cannot generate hot gas. It's a combination of both that gives the best results.'

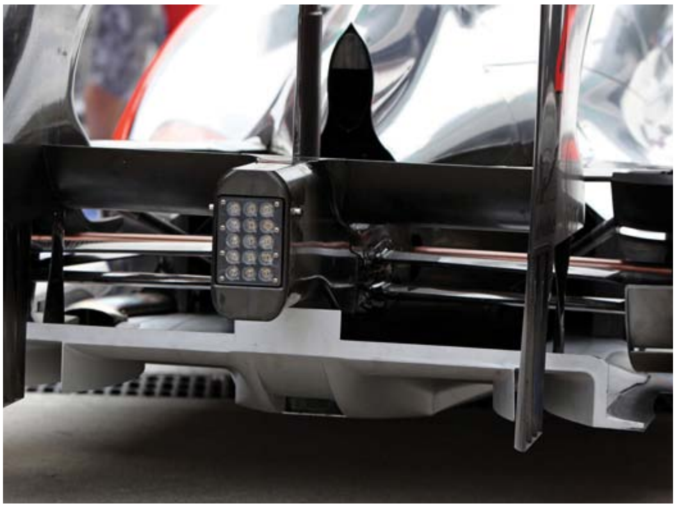
Indeed, most modern F1 teams are now working on simulating exhaust flows in the wind tunnel, but it is notoriously difficult to do, as Giorgio Ascanelli, technical director at Toro Rosso, admitted in pre-season testing: 'Our simulation capacity is limited in this respect. It depends on the pulse, the speed of exhaust flow compared to the speed of the airflow, the expansion rate, the temperature, ride height, cornering speed and we cannot simulate all of these things with sufficient certainty.'

THE TMG CONNECTION

However, some wind tunnels are more advanced in this respect, and Toyota Motorsport GmbH (TMG) in Cologne is a popular destination for Formula 1 teams chasing aerodynamic gains, partly because both of its wind tunnels are capable of simulating exhaust gases, as engineer, Chris Herbert, explains. 'We have two systems at TMG. In wind tunnel one, we use an air amplifier inside the model connected to a compressed air line. In wind tunnel two, as part of the wind tunnel assembly,

"exhaust is a very high temperature gas flow, and you have to manage that in the simulation"

This close-up of the Red Bull exhaust outlet shows how the floor is being blown directly ahead of the rear wheel with the exhaust pointing to the inside edge of the rear tyre to stop the vortex interfering with the flow through the diffuser. Note the cut out just ahead of the wheel where the flow will go down



Shown in white at the bottom of the picture, the McLaren diffuser covered with a ceramic thermal barrier coating

A further iteration of the exhaust blown floor, as seen on the Mercedes, showing the attachments to channel airflow through the diffuser

we have a large accumulator for the storage of compressed air and this is fed directly into the strut, then into the model.

In both wind tunnels, the compressed air lines are fed down the main strut and into the model via the cockpit. In wind tunnel one, the air lines terminate at the air amplifiers, which are located in the engine region. The air amplifiers use the compressed air to entrain additional flow, which is drawn from the roll hoop and then fed into the tailpipes. In wind tunnel two, the supply is simpler, with the compressed air lines being directly connected to the tailpipes.'

However, it is not really possible to replicate the gas temperatures in the wind tunnel. 'Doing the temperatures is very difficult,' admits Lola's Julian Sole. 'We have a cooler in our tunnel but, once you start pumping hot gases in, you are working it overtime. I'm not sure anyone in F1 is doing that.'

Herbert elaborates: 'It is not possible to heat the model scale tailpipe flow. We cannot simultaneously replicate a scale equivalent of both the speed and mass flow of the full-size car in the wind tunnels. Therefore, based on our experience, as well as a lot of testing and configuring, we know the appropriate level to set the wind tunnel tailpipe velocity to replicate actual exhaust gas behaviour.'

"We cannot replicate a scale equivalent of both the speed and mass flow of the full-size car in the wind tunnels"

It would seem, then, that van Rees was right in that the only real way to get a full simulation of the heated gases is to either run the car on a track and see what happens – which is not simulation at all – or to use CFD.

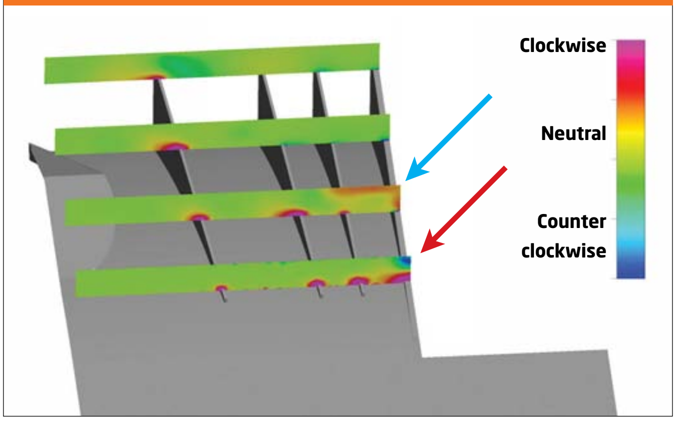
'We use CFD to visualise the flows,' continues Herbert, 'and we use our PIV (Particle Image Velocimetry) technology to ensure a good correlation between tunnel results and CFD modelling, in the same way we use PIV to enhance the accuracy of our CFD for other aerodynamic work. CFD can also be used to assess whether the plume impinges on the tyre surface and, if necessary, to simulate the thermal effects on the air around the tyre.'

THERMAL MANAGEMENT

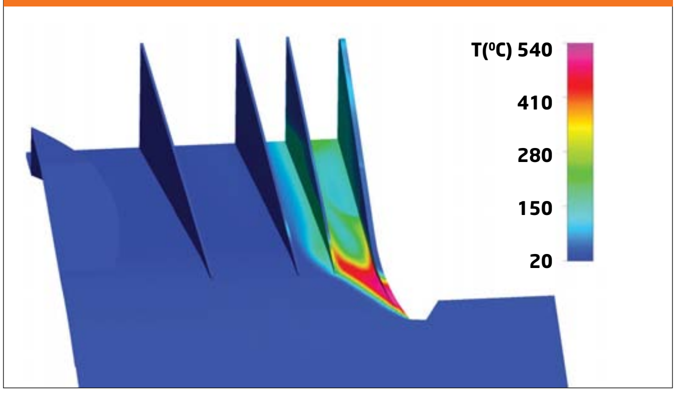
As Herbert hints, the temperature of the gas has more than an influence on the dynamic properties of the exhaust plume. It also has significant implications for the materials and structures of the car itself. Exhaust temperatures of 650-1000degC are commonplace and any team contemplating a blown diffuser has to take this into account.

There are several different solutions available to help cope with this, including gold foil wrapping or thickening of carbon fibre structures, but ceramic coatings such as those offered by the Oxfordshire-based firm, Zircotec, are now an essential

DIFFUSER VORTICITY



DIFFUSER TEMPERATURE



Top: the vortex from the rear wheel of the Pilbeam with an unblown floor can be seen to reduce the overall efficiency of the diffuser
Bottom: the blown version of the floor, showing the temperature of the exhaust gases into the diffuser (both images from Thijs van Rees' thesis)

ingredient. Its zirconia-based product, ThermoHold, has a thermal conductivity of less than 1.7W/mK, compared with 4W/mK for alumina. Its origins are in the nuclear industry and Zircotec was previously part of the UK's Atomic Energy Authority. The firm uses gas plasma spraying to load molten ceramic powder onto composite parts, building up layers until a thickness of somewhere between 250-400microns is achieved.

'Our coating reduces surface temperatures by 125degC and enables hot exhaust gases to pass over delicate carbon parts like diffuser strakes, protecting them from delamination. Not having to do complete re-designs helped teams reduce the introduction time for the blown floors,' says Peter Whyman, Zircotec's sales director. The influence of CFD-generated simulations of the heat distribution are clearly crucial.

'We are now seeing engineers incorporating the coating into the design, rather than merely solving heat issues after they find them. Our first coating applications provided a safe solution. With reliability proven, teams are now seeking performance gains by maintaining high gas speeds. Our ability to finely adjust the surface finish means we can offer a smooth finish with no impact on thermal protection.'

"teams are now seeking performance gains by maintaining high gas speeds"

So, with the simulation of the gases on the MP98 modelled and understood by van Rees, why has the Lincolnshire-based constructor not yet implemented the concept on its car? Well, as always seems to be the case in engineering, the reality is more complex than the theory. 'There is a slight problem in that the regulations in that category state we must use in-line, four-cylinder engines, and so we would need to have split the exhaust system somehow without losing performance, or only have it blowing on one side, giving an imbalance,' explains Pilbeam.

THROTTLE DEPENDENT

John Iley, now Caterham F1 performance director, was instrumental in the design of the Allard J2X, but says he was not a fan of the system: 'As a rule, I am not a supporter of such a system as it makes the car's performance too throttle dependent, which does not provide the basis for a stable platform,' he told Mike Fuller of mulsannescorner.com. 'However, the location on the J2X Allard was far enough rearward that its effect was greatly reduced. The main drive to route the exhausts this way on J2X was to achieve an incredibly low and tidy rear deck for the lower rear wing, not to utilise a blown diffuser principle.'

Van Rees elaborates on the instability Iley mentions: 'Obviously, these designs rely on exhaust mass flow, and that relies, of course, on the driver's foot being on the throttle. It means a driver can get on the throttle earlier because the mass flow massively increases downforce, and therefore traction.'

But in a section of corners where the driver is balancing the throttle, the mass flow from the exhaust is constantly changing, as is the downforce level. This makes cars with a so-called 'cold-blown' diffuser (where the exhaust mass flow is purely dependent on the driver's right foot) somewhat unpredictable, as Iley mentions, though van Rees suggests there are ways of making it a bit easier: 'You could do things like keeping the brake pedal on the car as you go through the corner and drive through on the throttle, all the time keeping the mass flow rate going through the system,' he suggests.

In 2010 and, particularly, in 2011, Formula 1 teams used a more advanced solution to this problem. A 'hot-blown' diffuser is used to maintain a constant stream of gas through the diffuser to keep downforce levels consistent. When a driver goes off throttle with a hot-blown diffuser, the engine throttles are kept open, fuel keeps being injected (and is ignited through careful mapping), maintaining the necessary gas flow. Naturally, this approach has a detrimental impact on fuel consumption but, put simply, the more fuel burned, the more exhaust gas is produced, and potentially the more downforce created.

The Renault RS27 Formula 1 engines fitted to the two cars that took the greatest advantage of hot-blown diffusers – the Renault R31 and Red Bull RB7 – burned 10 per cent more fuel than normal during the Australian Grand Prix that year, simply because the throttle stayed open when the driver was off the accelerator pedal.

'In general, our goal is to optimise the overall performance of the car [for that read: race results]. For many purposes, this can be simplified to optimising the lap time,' explains Rob White, deputy managing director (technical) at Renault Sport F1. 'One of the performance trade-offs within this optimisation is the extent to which exhaust gas energy is deployed to gain aerodynamic performance vs engine performance degradation (eg power loss, fuel consumption penalty, driveability penalty, durability or reliability risk).

'With off-throttle blowing, this is typically achieved by some combination of exhaust design to increase gas velocity, such as smaller tailpipe diameter, or nozzle, exhaust design to deliver exhaust gas to where it can influence aero (longer tailpipe), and throttle position – more open equals more air. Also things like cylinder cutting with no fuel or spark reduces torque to compensate for open throttles. Ignition retardation by later

The aerodynamically efficient Dome S102. Current ACO regulations state the floor must be continuous but it does leave scope for exhausts to be exited into the wheelarch, which could increase downforce, even in a cold-blown situation

spark timing increases exhaust temperature, and reducing torque compensates for open throttles. Finally, you also need to look at post-combustion – fuel burning in the exhaust after the combustion chamber.'

"increased fuel consumption is not the only downside of running a hot-blown diffuser"

But, as White is keen to stress, increased fuel consumption is not the only downside of running a hot-blown diffuser: 'There are things to consider, like engine power being compromised by increased back pressure and acoustic compromise. Driveability, too. Cylinder cutting is a blunt tool, so managing torque transitions is challenging, and can cost lap time, and there may be second-order effects from vibrations associated with cylinder cuts, though this is typically marginal. Increased temperatures are also more difficult for engine and car components – notably, exhaust valves and exhaust components.'

So, despite the effective ban on hot-blown floors in Formula 1, they are not banned in many other categories and F1 teams are instead finding ways of using cold-blown diffusers inside the current regulations, engineering the cars' bodywork to have a similar influence.

Hot blown floors are outlawed in F1 but attempts to utilise cold blowing continue, as seen here on the Red Bull RB8

WIDER APPLICATION

Why are blown floors not being used more widely elsewhere? According to Audi Sport, a turbocharged engine does not produce enough mass flow to be able to take advantage of the concept, ruling out the current generation of diesel-engined Sports Prototypes, Indy cars and the forthcoming new generation of Formula 1 cars from 2014 onwards. But what about normally aspirated racecars, such as the Dome S102.5 or Toyota TS030?

It is clear to White that the concept has applications across many areas of motorsport, at least where regulations allow, and hints that those who say that blowing a floor with a turbocharged engine does not really work may be incorrect: 'All of the above is generic and equally true of any high-end race engine with electronic engine control, fly-by-wire throttle and unrestricted control of individual cylinder ignition and fuel injection. Note that a turbocharged engine would have additional scope, relative to a normally aspirated engine.'

Sole, of Lola, feels the reason the concept has not yet been taken further is not so much technical as commercial: 'We had blown floors in F3000, so we have some experience of that. Doing it on a Le Mans Prototype is difficult, but not impossible as the regulations say you must have continuous surfaces. Also you can hit budget limitations, not least through burnt bodywork as you develop. Moving the exhaust position around is expensive, with the cost of new pipes and bodywork, as well as the R and D.' However, his conclusion is enigmatic: 'There are other ways to take advantage of the aerodynamic impact of the exhaust, other than working the diffuser...'

The price of success

Formula 1 delivered close racing, but the regulations need to be relaxed

The 2012 season was dominated by engineers in Formula 1. Thats what made it exciting. The technical staff at each team first had to deal with a major rule change, then had to learn to understand a tyre with very awkward characteristics. Later, many teams had to develop a blown diffuser from scratch, using cleverly sculpted bodywork around the exhaust exit. This development race led to on-track overtaking and a whole load of new names unexpectedly running in the top three. Innovation was rewarded, but that is the exception not the rule.

'New regulations are a part of Formula One, it is just a shame that regulation changes are always restrictions,' said Adrian Newey. 'The danger is that if the restrictions become too restrictive, then we all end up racing GP1, cars though we haven't quite got there yet.'

He is right to be concerned though. As I loitered in the pitlane at Jerez at the start of the season, I realised that all the cars look incredibly similar. They all have the ugly step in the nose, the high chassis and the same basic overall shape. Yes, I know the McLaren was a bit different, but everything else on the grid looked like the Force India, or is it the Mercedes?

Mechanically, too, the cars are near identical. So much so that one technical specification could cover them all, even down to the ECU software version and crankshaft centerline height.

The devil is in the details, but those details are fiercely guarded secrets, and they are usually just refinements anyway. If those details are already defined then there may be no evil at all!

"The real solution to overly restrictive regulations and rising costs, is a cost cap"

It's not just in Formula 1 either. The whole of motor racing has descended into nightmarish identikit world of spec racing from which there appears to be no escape. The once great racing classes have all become the technical equivalent of a bowl of plan boiled rice. Formula 2 is a mere parody of the name, Indycar is a North American version of GP2 in a plus size outfit, and even Formula 3 has become a Dallara-only zone, unless you travel to Latin America. All of these series, bar Indycar (which has its own bizarre idea of aesthetics), strive to make their cars look more like Formula 1 cars, despite the fact that nobody really likes the look of Formula 1 cars.

It all makes the racing very tedious too. If every car works in the same way and they set off in order of speed, with the fastest at the front, is it any wonder that there is barely any over taking? Even if there was it would simply be a different paint job in the lead.

The argument for going over to spec cars is simply to cut costs (much as they are trying to do in Formula 1), but I find that argument very odd. If you only have a single supplier for everything then surely that supplier controls the cost? I think an economist would argue that competition creates lower costs as long as a certain standard of product is kept up. He would likely roll out a set of formulae that would essentially show cost vs level of quality over sales. I can't find out because that same economist is rather more interested in telling me about the Euro shaped elephant in the room, but I'm not interested in that as it is not covered in the regulations.

The real solution to overly restrictive regulations and rising costs, is a cost cap. This would allow the FIA to open up the technical regulations and reward innovation, as car performance would be severely limited by the budgetary restrictions on the R&D department. Instead of simulating and trialling every conceivable iteration of a design, the rules would end up rewarding the mental agility of a team. This would suit teams like Red Bull down to the ground, with Adrian Newey taking to his drawing board with glee.

So, with all of that said, two other measures that Formula 1 is contemplating in the same breath as reducing costs are introducing new engine regulations, and increasing the number of races. Increasing the number of races will increase the TV revenues, but will also mean that the teams will have to build more cars and recruit more staff. Meanwhile the change in engine rules in 2014 will wipe out any savings made by teams, and actually lead to them spending more money, not less.

A cost cap would still be a very good thing. If it was properly enforced, it would keep the budgets down. Imagine a grid full of HRTs, Marussias and Caterhams. The racing would be fantastic. This is what was different about 2012; different cars did different things, the engineers dominated, not the drivers, and as a result it will be a season that goes down in history as a classic. The only thing I can see bringing that back any time soon is a cost cap.