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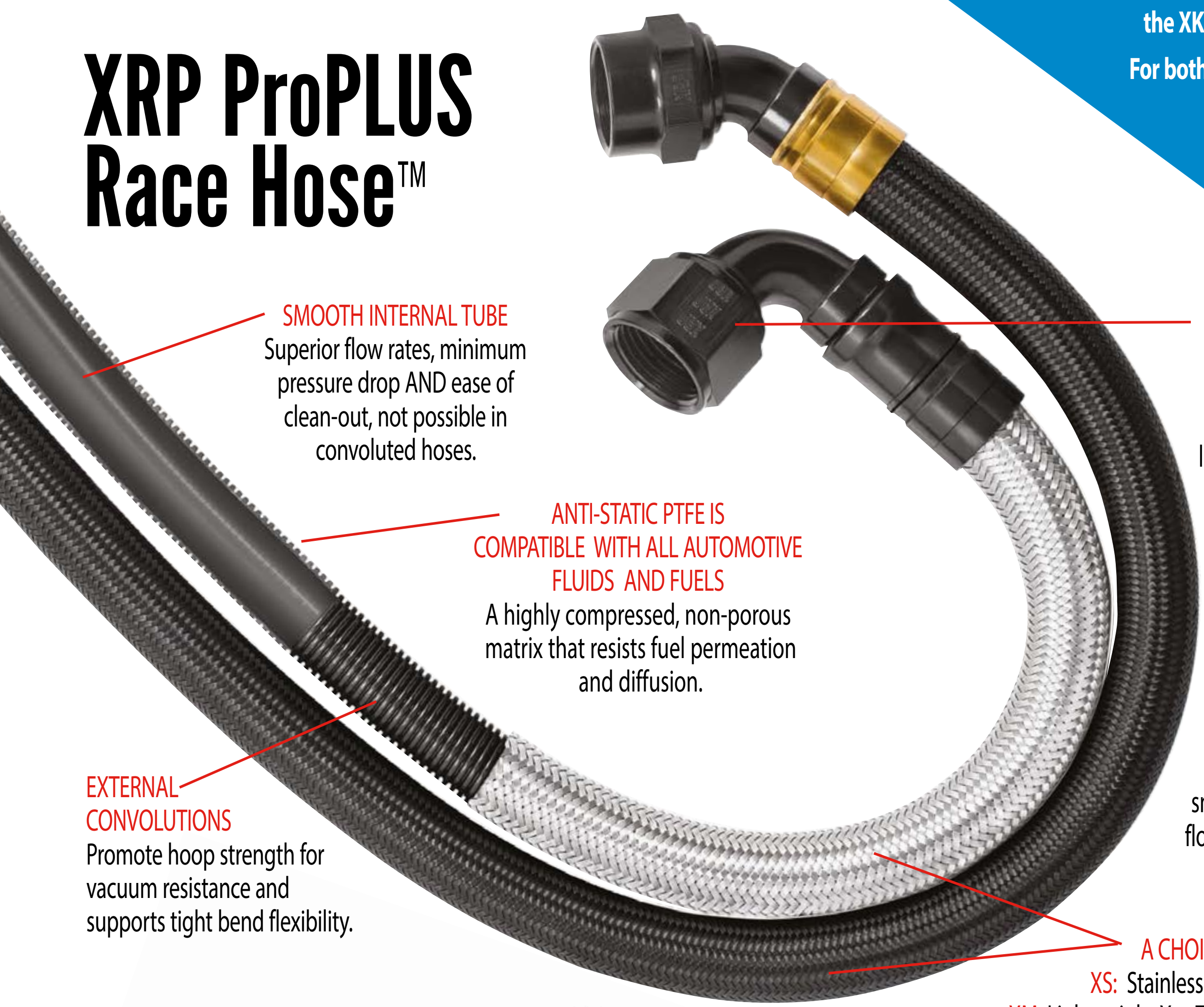

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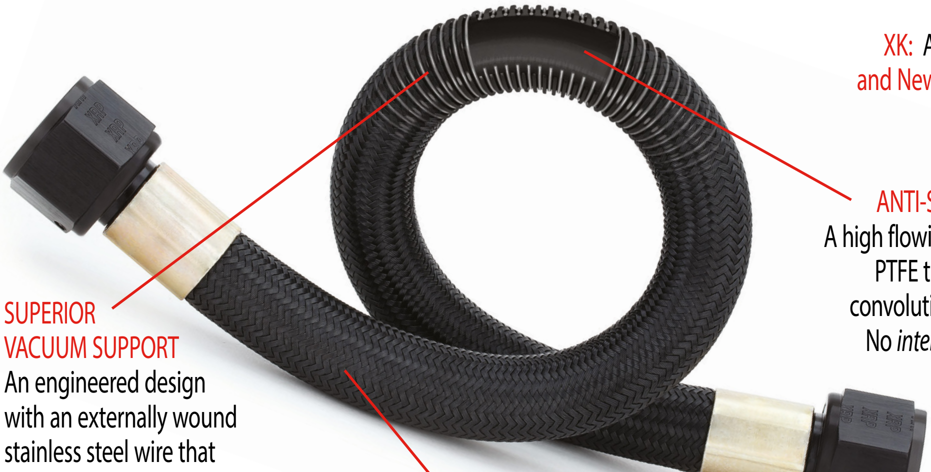

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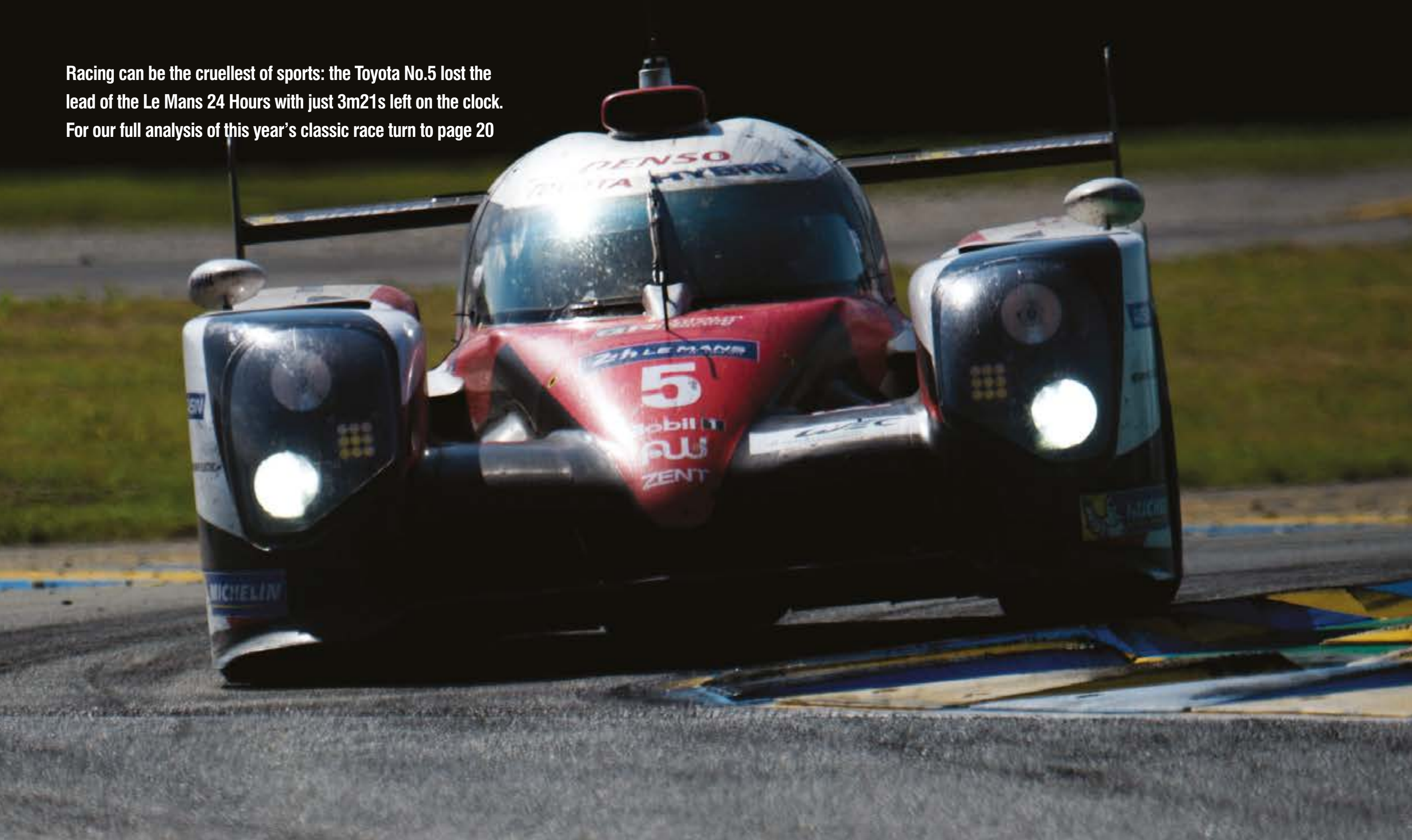


Racing can be the cruellest of sports: the Toyota No.5 lost the lead of the Le Mans 24 Hours with just 3m21s left on the clock. For our full analysis of this year's classic race turn to page 20

COVER STORY

COLUMNS

FEATURES

TECHNICAL

BUSINESS NEWS & PEOPLE

Bopping the night away

Why levelling the playing field can be one of the toughest jobs in motor racing

In the early 1940s Jazz saw the birth of a new wave, characterised by dissonant triadic and chromatic chords, fast tempos and eccentric rhythms, intricate melodic lines punctuated by pop-tune phrases, and emphasising the inventions of soloists. This was called bop, also bebop.

If we look up bop in the dictionary we also have the noun being defined as 'a blow'. But there is another definition of bop for the racing fraternity: 'Balance of Performance', which is an extension of the tradition of handicapping used in horse racing.

Wiki defines handicapping in sports as 'the practice of assigning advantage through scoring compensation, or other advantage given to different contestants to equalise the chances of winning. The word also applies to the various methods by which the advantage is calculated. In principle, a more experienced player is disadvantaged in order to make it possible for a less experienced player to participate in the game or sport whilst maintaining fairness'.

Horse power

In a handicap horse race each mount must carry a specified weight called the impost, assigned by the racing secretary based on factors such as past performances, age and form, so as to equalise the chances of the competitors. To supplement the combined weight of jockey and saddle, up to the assigned impost, lead weights are carried in pockets in the saddles.

So far, so good, then. But now to car racing. The existence of successful series such as Blancpain GT3 also depend on the concept, and it is also intrinsic to the concept of class, such as in endurance racing, where the mix of LMP1s, LMP2s and GTs brings big grids of disparate cars with different rules. It also takes account of different experience and driving capabilities, with Pro and Pro-Am classes, plus in some cases the requirement of different graded drivers in Platinum, Gold, Silver and Bronze grades.

As rules they work, despite my instinctive bridling at the thought that it is all artificial. But then, all rules are artificial. An honest, objective approach would make team principals and engineers go to the best combination of fastest car and driver, which would rapidly devolve to a single make and drive out the amateur that all too often is the financial backbone of racing.

The involvement of manufacturers touting their wares implicitly demands wins, but the different regulations and market demands make for a different level of performance at the track, due to the production requirements of the road car in different countries and market niches. The scene being set, and racing being what it is, as soon as the regs are published we find engineers and team principals being driven to game the system.

It starts when the rules committee, which also includes representatives of all interested parties, discusses proposed future rules, all pulling their chestnuts out of the fire; the rule makers trying to adhere to a concept, such as limiting speeds to the accepted limits of tracks, the safety of drivers and the spectators, cost, and the direction of which technology is deemed to be a wanted one. It can be Byzantine, with all the horse-trading catering to individual vested interests and, incidentally, it can also give the other members an insight into what the opposition considers to be their ace cards and their advances in technology.

We soon find engineers and team principals driven to game the system

XPB

The Balance of Performance in GTE caused a major headache for the ACO at this year's Le Mans with the limits not set until the Friday before the big race

Handy caps

The politicking behind the scenes and engineering decisions will be driven by marketing demands. This is well known and accepted, and countermeasures by rule makers have now escalated to the point that their monitoring of car performance includes dedicated data logging to avoid 'cooking the books' by team sensor calibration, watching out for throttle position, engine mapping and low boost when the case applies. It's a tricky game, demanding foresight from the governing body, and a modicum of skew, to help out those cars that have either less competitive drivers or teams, or to give new manufacturers a running start when entering a championship, but also to forestall the inevitable sandbagging that will happen. It implies thinking through what will spring out of the woodwork, and also the unintended consequences of human nature. As William Dunbar stated: 'A lawyer who does not know men is handicapped.'

We have all played this game, but lately it can imperil the whole concept; as seen in the 2016 Le Mans fracas in the GTE class, where the evolution of handicaps went all the way to the Friday rest day, when new limits were imposed pre-race, and still rumbled along in the universal protesting of everyone by everyone. The acceptance of an out and out racecar like the Ford GT was a perfect example of political pressures: the production of a car designed for the rules, but also indicative of the need to bring major manufacturers into the fray. A difficult tightrope to walk. And Porsche probably understood *bop* in its second sense, 'a blow', here.

In the example of endurance racing we also have the weight of the 24 hours of Le Mans, the golden prize for any manufacturer, with the marketing return enhanced by the halo effect and also double points for the World Endurance Championship. This has traditionally made the other races only a proving ground for what the team intends to run at Le Mans.

Cycle of strife

Racing has been through this cycle several times before (and probably is at a crossroads now). To avoid the mid '90s crash cars were built to fit the spirit of the rules, but then true road cars like the Ferrari F40, McLaren F1, Bugatti EB110 and Jaguar XJ220, were blown away by the flat-out racers built by Nissan, Porsche, Mercedes and, more egregiously, Toyota with the notorious 'luggage space' in the fuel tank. When road-based cars were encouraged in '93, Porsche and Dauer built a sportscar based on the Porsche 962, and duly went on to win Le Mans '94 through the use of regulation loopholes.

One does feel sorry for the rule makers. The limited number of people that can produce and police laws are no match for the massed onslaught of engineers. Quoting Albert Einstein: 'Never bet against an engineer. If you give enough time and money to an engineer, he will find a solution.'

The human race

F1 could learn much from Le Mans when it comes to expressions of humanity

Thank you, Bernie, for making me swivel-eyed from simultaneously trying to follow both the grand prix from Baku and Le Mans, especially with the start of the former coinciding exactly with the finish of the latter. There is no way that these events should ever have been allowed to clash. Perhaps it didn't cross Mr E's mind that many of the F1 TV fans on which his business is so dependent may also follow that other motor racing discipline, which he treats with such disdain? Not the best way to boost F1's waning TV audience.

Of the two, the 24 Hours was by far the most exciting, the dramatic finish being almost unbelievable and exposing just about every emotion possible. To all the Toyota team, grief would probably not have been too strong a word. After a year of dedicated work and a faultless performance, to lose after 23 hours and 57 minutes while comfortably leading and with just one lap remaining must have seemed unbearable.

Real life superhero

In contrast, and contrary to expectation, the GP was a fairly tame affair, despite the – welcome – hairy nature of the circuit. Nevertheless, emotions no doubt ran high for winner and losers. No emotions at either event, however, can surely surpass those of Frenchman Frederic Sausset. This magnificent person, this incredibly determined man, completed the world's toughest endurance race driving an LMP2 car, despite being a quadruple amputee. To say that he is an inspiration is not even close to adequate.

The Paralympics and other similarly-aimed sporting challenges for those with disabilities have shown what miraculous feats can be achieved, but none as far as I know at nearly 200mph. When I wrote in a previous article that physical fitness should not necessarily be a primary factor in race-driving, I had in mind something of the nature of Sausset's endeavour. I did not expect that such a successful demonstration of my point would occur so soon, and despite the presence of such a seemingly devastating level of injury, the nature of which might have mentally destroyed even the most resilient of individuals.

For those of us who in various forms are a part of motor racing, surely this puts into perspective many of the gripes and groans that, in F1 in particular, appear to increasingly dominate much of the news. Lewis Hamilton has criticised a number of his fellow drivers for always moaning; many would support his comments, and not just about those in the cockpits. Lewis has actually done his own fair share of complaining, although in his favour never about the risks of racing on the edge at tracks such as Baku (I'll swear that he would relish the challenge of the Nurburgring Nordschleife were it still viable as a GP circuit!).

A racing driver's competitive nature – and the need to impress if not already in a top team – naturally stirs anger over perceived injustices, whether due to inferior equipment, poor strategy calls, other competitors' misdemeanours or whatever. This resentment is inevitably shared by many who are party to the same perception and frequently leads to comments that would be best kept behind closed doors. Food for the media, but seldom helpful to the image of the sport.

XPB

One of many human interest stories at this year's 24 Hours was quadruple amputee Frederic Sausset's inspirational drive in the SRT41 Morgan-Nissan

So sometimes perhaps we should all step back and reflect on the very positive side of what most of us have just by being involved, because for most of us it's a result of our original passion. Full marks to Jenson Button for stressing that just racing an F1 car remains a privilege and an enjoyment, despite his and Alonso's current frustrations with their car and engine combination. With so much money, media exposure and personal egos fuelling the pressure-cooker environment at the highest levels of motorsport it is easy to overlook the humanity. Without it, that which most of us prize would never have been created. People, not machines, provide the motivation and means for going racing – the rest follows. So thank you Monsieur Sausset for so bravely demonstrating what barriers human beings can overcome, and reminding us, in whatever role we occupy, and at whatever degree of success, that there is so much that we take for granted.

Race relations

The introspective and, let's face it, *superior* environment of F1 is highlighted by the difference to be found in the world of Le Mans and the WEC. In this community there is little of the constant sniping, complaining, character-assassination and sarcasm present in what is generally billed as the premier form of motor racing. I cannot envisage the president of the ACO telling drivers and teams that they can go home if they have track safety concerns. Instead I guarantee that they would be listened to and action taken if the complaint was valid. While politicking over regulations and their implementation obviously does happen, it is done in a much more professional and pragmatic manner. It seems that the majority of the participants realise that, over eight decades, the ACO has done an amazing job of building the 24 Hour race into such a hugely prestigious event, famous even outside of motor racing, protecting it from the many economic and political dangers that have occurred at various times and retaining its constant allure for global automotive manufacturers. It is also acknowledged that, with the FIA, it has created the clever regulatory framework for encompassing different types of energy that has resulted in a remarkable equality of performance which also showcases the technologies employed, a model for encouraging the aforementioned car-makers.

Thus there is a desire to co-operate, to accept that there must be give-and-take for the good of all and the continuation of the event itself, along with the World Endurance Championship which has been created around it. F1 people, in particular, if not exclusively, would do well to note this approach and improve their act accordingly.

To lose at Le Mans after 23 hours and 57 minutes while comfortably leading and with just one lap remaining must have seemed unbearable

Yellow fever

Renault's return to F1 as a full works effort meant far more than just a bright colour scheme for its RS16 – there were also some mighty engineering challenges, including a change of power unit, for the Enstone team to overcome

By SAM COLLINS

‘It was quite different between the two units, the heat rejection figures are totally different, the way each unit cools the ERS is different, there was a lot to adapt’

Making a splash: while Renault has brightened up the grid with its bold colour scheme this year it’s failed to shine on track, after its late decision to return as a works team in 2015

Renault has been something of a constant in Formula 1 for almost 30 years, winning world championships as an engine supplier and as a works team. Only Ferrari as a manufacturer has a longer continuity. Even at times when the brand officially stepped back from the sport, such as in the late 1990s, it was still on the grid with its Mecachrome, Supertec and Playlife branded V10 engines. Indeed, the marque has been involved in the sport from the very birth of grand prix racing, winning the first ever official grand prix, the French GP, back in 1906.

Yet part way through 2015 it looked as though its long run of participation was about to come to an end. Senior figures in its management team were openly saying that Renault was on the verge of walking away from the sport, as a result of negative publicity and a widely reported spat with its most prominent power unit customer, Red Bull Racing. ‘We are looking at a lot of options, including getting out of Formula 1 if it’s bad for Renault’s reputation,’ Renault F1 managing director Cyril Abiteboul said at the Malaysian Grand Prix in 2015.

Meanwhile, its former works team, based in Enstone, England, then re-branded as Lotus and running Mercedes power units, was on the verge of financial collapse. Suppliers had gone unpaid for a long time, and at one race the team arrived to find itself locked out of its hospitality unit, and had to rely on the goodwill of other teams to keep its staff fed and watered during the race weekend.

In the latter half of the season things really got quite serious when a group of the unpaid creditors, including transmission supplier Xtrac, lodged a petition for a winding up order in the UK Companies Court. Later HMRC, the British Tax and Revenue office, applied to the High Court for the company to be placed into administration over unpaid taxes on staff salaries.

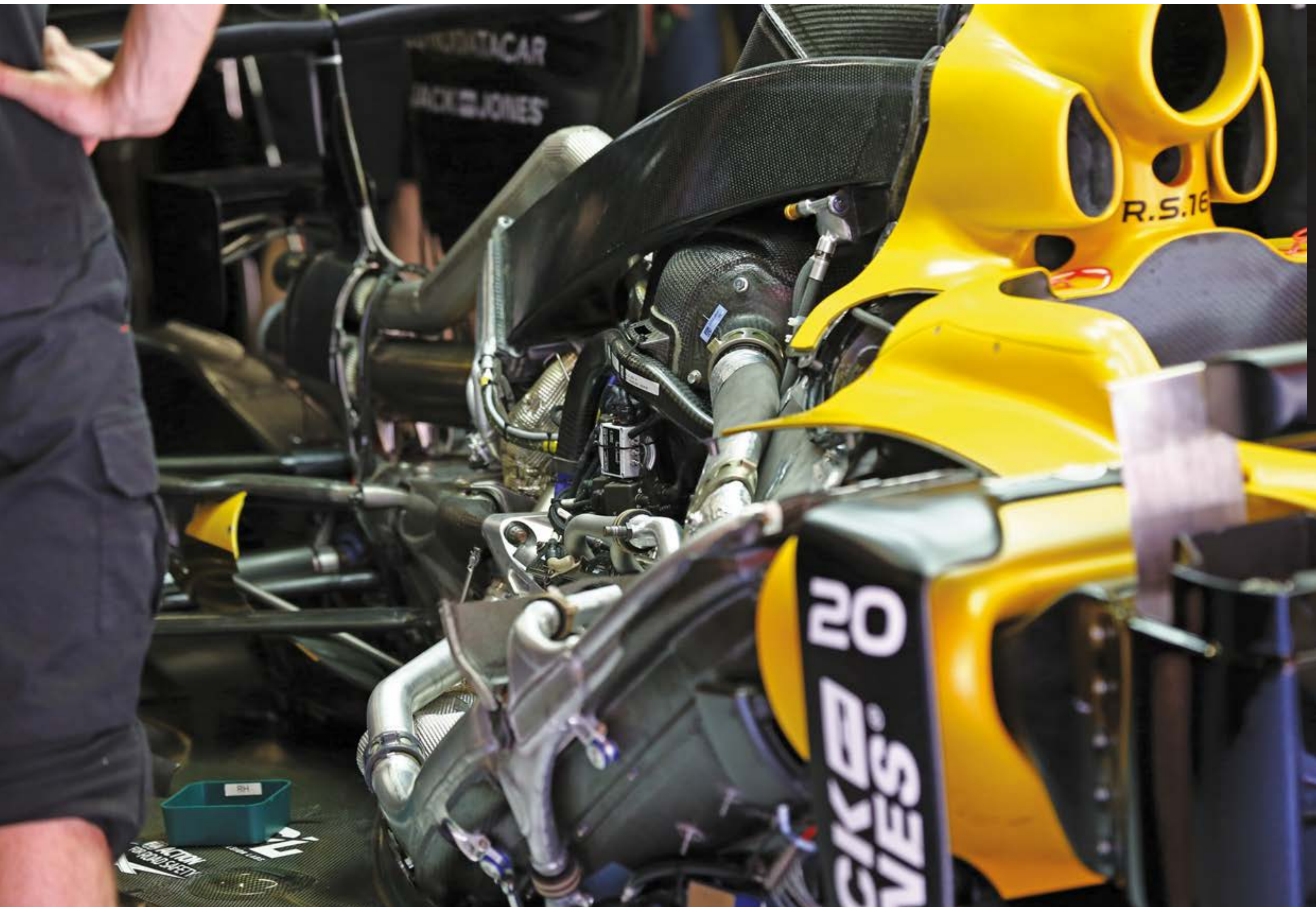
Waved yellows

It looked to all that unless something drastic happened that the team would suffer the same embarrassing fate of the Caterham F1 team in late 2014. Indeed, an auction house had already been appointed to sell off the team’s assets. It also looked like Renault was likely to leave F1 in favour of a mooted LMP1 programme, to replace the troubled Nissan GT-R LM project in 2017.

Eventually the Renault management decided to remain in Formula 1, but as a works effort rather than just a supplier of power units, and to this end it re-acquired the Lotus F1 team, which it had sold off in 2009, for the princely sum of £1. The purchase of the team saw off the legal action and satisfied the creditors, who were all keen to see the team stay in the sport. However, the deal had come together very late, so late in fact that the court had to twice set aside the final winding up order of the Lotus team in order to allow the deal to go through.

Lotus was immediately re-branded Renault and the Mercedes power unit supply deal terminated. But this left the engineers at Enstone with a problem – they needed a car for the 2016 season. While Lotus had designed a car for 2016, the E24, this was entirely designed around the Mercedes power unit, and some of the longer lead time items had already been manufactured.

‘It was a super tricky time as we designed the car for a Mercedes unit, I think we had less than eight weeks,’ Renault Sport F1 chassis technical director Nick Chester says. ‘We made the decision about which way we were



The switch from the Mercedes power unit the Lotus team used last season to the Renault caused some problems for the Enstone operation. Note the up and over wastegate pipe

Tail pipe layout with wing pylon support above. The RS16 has just the single wastegate exit pipe, which is largely a packaging solution, while all the other cars in the F1 field use a twin exit

designing in terms of power unit in October then we had a massive amount of work to change the chassis patterns, cooling system, the rear end of the tub. We had to get the pattern out for the chassis very quickly; we only had about three weeks. We'd tooled the chassis in a way where we could just change the back section, and had to change that a fair bit.'

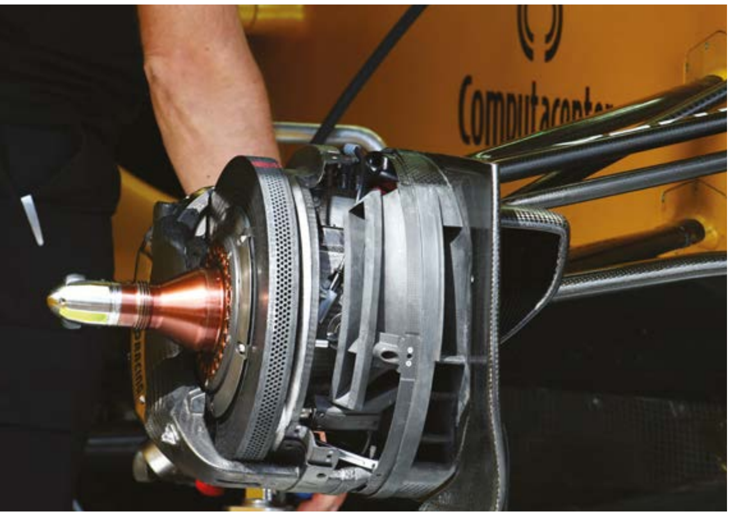
The biggest problem in reworking the E24 into the RS16 was the very different shape of the power unit it was designed to accommodate, and the one it was to be fitted with. The German-branded, British-built Mercedes V6 engine mounts its compressor at the front of the block and its turbine at the rear; the Renault unit mounts the entire turbo assembly at the rear. Additionally the two differ in many other ways. 'It was a big job changing the tub for the battery. For example, we had to change the opening, the whole back of the tub, to cope with the ERS cable layouts and different cooling pipes,' Chester says. 'The designers did a superb job and got it out at 9am on the first day of winter testing. There were no problems with homologation, all the structural tests went well, if anything had gone wrong we would not have made it to the first test.'

When the RS16 was initially launched in Paris, the covers were off to reveal a repainted Lotus E23, but few were fooled. The team was later forced to admit that the car was indeed just a 2015 Lotus and that the new car was not yet complete. Yet when the real RS16 was shown off for the first time in Barcelona just ahead of winter testing it became clear why Renault had taken this approach, the two cars were visually almost identical. 'Switching power units did not have a huge impact on the aero side of things, [although] obviously the coolers and the rear coke bottle area [changed] to an extent,' Chester says. 'Overall the aero package is fairly close to the E23, the car was an evolution of that, which we then had to adapt for the Renault. The wind tunnel numbers are a bit up, I'd like them to be a lot up, so while we have made some progress we have work to do'

Under yellow

Once the bodywork was removed from the car it became even more clear that the RS16 was indeed an updated version of the E23, not just in aerodynamic terms, but also mechanically. Notably the E23 itself was a close development of the 2014 Lotus E22. But this approach had some advantages, as it meant that Chester and his engineers could call on past experience, as the E22 had run with the Renault RS34 power unit on which the current RE16 unit is based.

'I think with the time we had available one of the reasons we got it done was down to the fact that we had good relationships with the Renault power unit guys we had worked with before at Viry-Chatillon, and of course experience with the overall architecture and



Front brake with AP Racing caliper at the rear of the assembly. AP Racing also supplies the carbon discs and pads, plus the master cylinders, for the RS16

The Renault's launch spec nose is shown here above the RS16's new nose. The first of the two noses was very similar to that used on the Enstone team's 2015 racecar, the Lotus E23

Rear brake and aluminium upright. Like all F1 cars the RS16 uses pull rods at the rear. Enstone was hit hard by the banning of interconnected technology in 2014

The roll hoop with cooling inlet 'ears'. Renault has leaned on many of the cooling lessons learnt in 2014, when the Lotus run the then new Renault turbo engine. It now uses air-to-air coolers

demand from 2014, that let us get things done in time. We knew where to look for the relevant data, how the CAD models worked, and we just got on with it,' Chester says.

One of the main differences between the Renault and Mercedes power units is the cooling layout (not least because of the compressor location). But again this is an area where experience with the first generation Renault unit came in handy.

'It was quite different between the two units, the heat rejection figures are totally different, the way each unit cools the ERS is different, there was a lot to adapt,' Chester says. 'We had quite a lot of experience, though, with the Renault, having gone through 2014 with it, and we knew how it needed to be cooled, so when we knew we were switching back we had a fair idea of what we had to do. At the roll-out of the car we had a cooling package which worked pretty well, but we are still refining it. There are still some gains to be found in it and we are chasing those. There is a lot of work on the cooler design itself. Most teams are playing around trying to get the most efficient system, and there are some different solutions out there. It's still an area to develop. You can save drag and weight in this area, get the coolers as small as you can and close up the bodywork, but you have a lot of conflicting targets to manage. You have to trade them all off to get the best layout. We knew our solution would work; it's pretty safe, so once we got the switch confirmed we then just had to optimise it as best we could, and that is ongoing.'

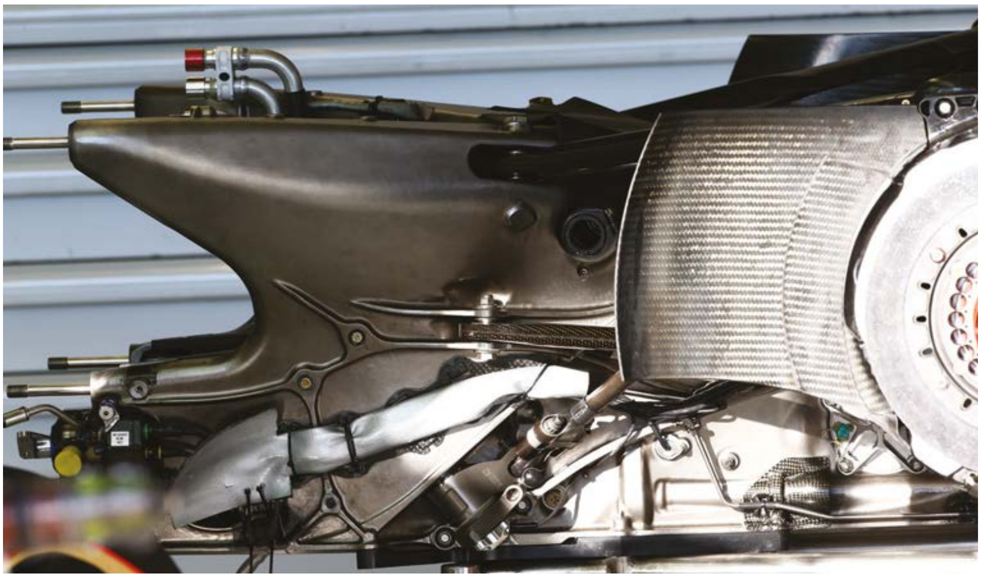
The RS16 does not have a simple facsimile of the E22 cooling layout, however, as the engineers at Enstone recalled some of the lessons they learned the hard way in 2014, especially in terms of charge air cooling. 'It was not too tricky to design compared to 2014 when it was all new, that was really tricky,' Chester says. 'We learned a lot in the last two years. Back then we ran a water-to-air cooler and I have to say it was problematic. This time round we are now using air-to-air coolers. They worked well for us last year and it seems to be the case for this year's car, too.'

Twin charge air coolers are a feature of the RS16, mounted in the side pods under the main water and oil heat radiators for the V6 engine and some ERS components. Cooling ducts

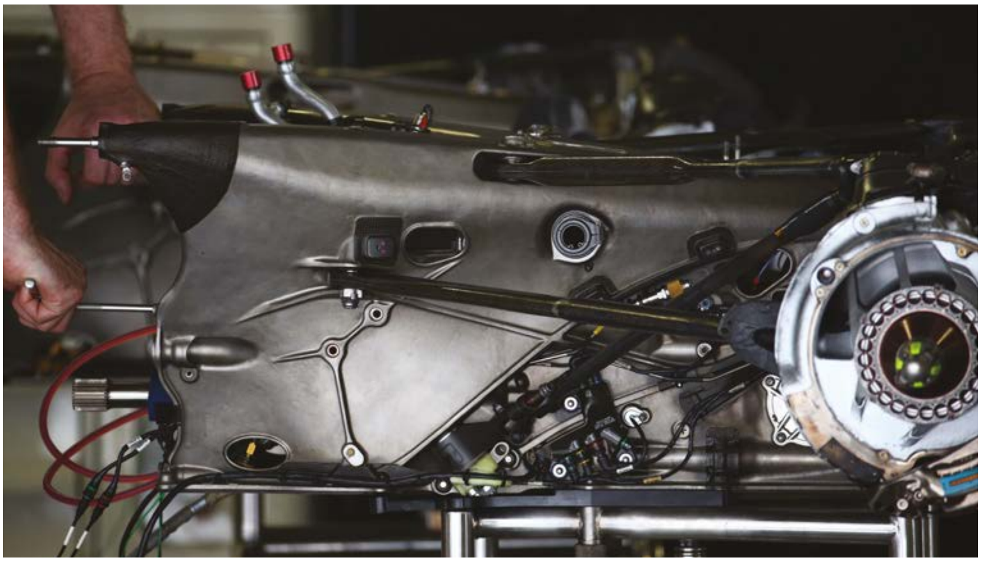
The biggest problem in reworking the E24 into the RS16 was the very different shape of the power units

remain, however, feeding a cooler mounted on the top of the bellhousing thought to cool both the transmission and some ERS parts. 'It would have been very painful to have to change the roll-hoop, but that is one advantage of having the ears; you can use them for cooling if we need to' Chester says.

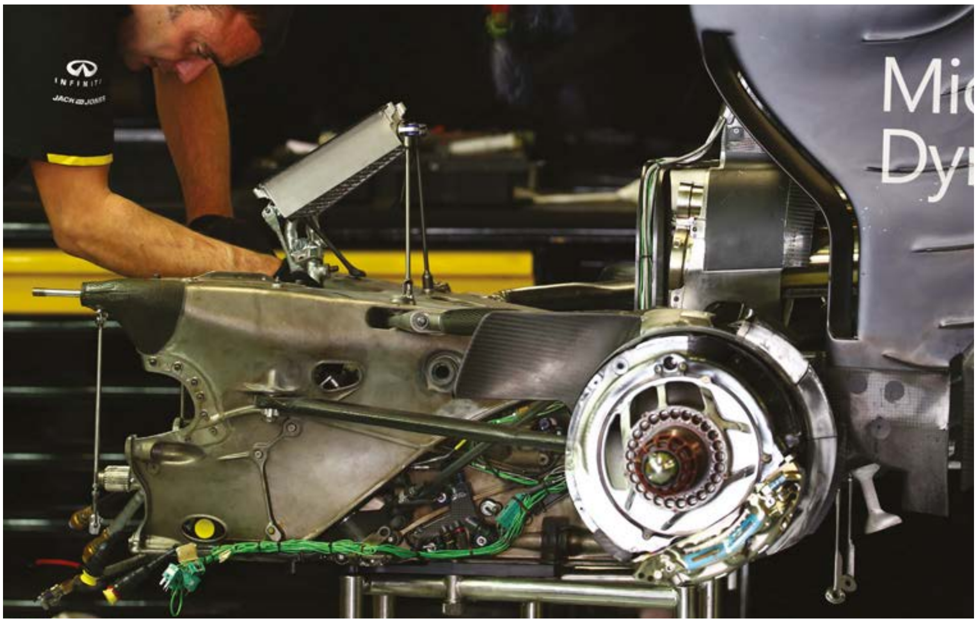
The location of the coolers did create some headaches in terms of the layout of other components, though, notably the mandatory wastegate exit, intended to increase the sound level of the power units when running on track. The Renault is unique in that it only has a single wastegate exit pipe, where all other cars in the field have a twin exit. Leaving the wastegate



This image, and the two below, show the evolution of the transmission casing from 2014 to 2016. The 2014 casing features an all-titanium construction with an integral bellhousing. Renault says it's considering a switch to a carbon casing next year



The 2015 design featured revised suspension pick up points and a different leading edge, with small composite sections on the upper mounting points – these were added for Lotus' switched from Renault to Mercedes power for the 2015 season



The 2016 transmission. The casing is exactly the same with the same pick up points but a chunk of the leading edge has been machined away in order to accommodate the Renault's exhaust layout, while the input shaft is also slightly different

upwards, the pipe then takes an up-and-over route to the rear of the car, in an arrangement that is clearly a compromise.

'We did it that way partly for weight,' Chester says. 'The single pipe is lighter even with the additional length we have to have. I think it's something we may move away from, as there are some bodywork and aero advantages to the three-pipe layout that others use. It's just a packaging solution, things you have to clear. It's not a particularly brilliant layout, but we had other things in the way, mainly coolers, which we couldn't just move. We could not take it directly out as it would have to pass through the middle of those coolers, we were hemmed in, and I would be in trouble if I asked for doughnut coolers.'

The weight of the RS16 caused a few sleepless nights for the Renault team, who simply did not know what its weight actually was. They had an idea through simulation, but time had prevented them from checking it ahead of the car's first run. Formula 1 has a fixed weight distribution at the request of the tyre supplier, Pirelli. All cars must have at least 319kg on the front axle and 376kg on the rear with a minimum weight of 702kg, giving a very small window for the weight distribution.

'We were very worried about the weight of the car, even into testing, we were so late with the car that we had not actually weighed it properly before the first day of testing was over, we didn't get it on the scales until after that. We knew we could be compromised in that respect,' Chester says,

But these worries were unfounded, it seems. 'We found that we are in the middle of the range, right where we predicted,' Chester says. 'With such a short time to design the car it was a worry, as we did not have all the information we needed, but it worked out pretty well and we can actually run with a little bit more ballast than we expected. We could easily have ended up in trouble, especially with the changes to the gearbox, and we had considered that if it had been a problem we would have had to move the front axle. That would have been a big job, and we didn't want to do it, but in the end it was not an issue anyway.'

Boxing clever

The transmission casing was one of the longest lead time items on the 2016 car and by the time that the switch to Renault power was confirmed it was too late, the titanium casings had already been made, and quite simply they did not fit the Renault power unit.

'Changing back to a casing that suited the Renault layout was not particularly easy,' Chester says. 'For 2016 we had made some changes to the 2015 casing but that did not fit the different exhaust layout of the Renault, so we had to come up with a few solutions in a short time. We knew we could not cast a new casing in time so we had to use what we

'Switching power units did not have a huge impact on the aero side of things'

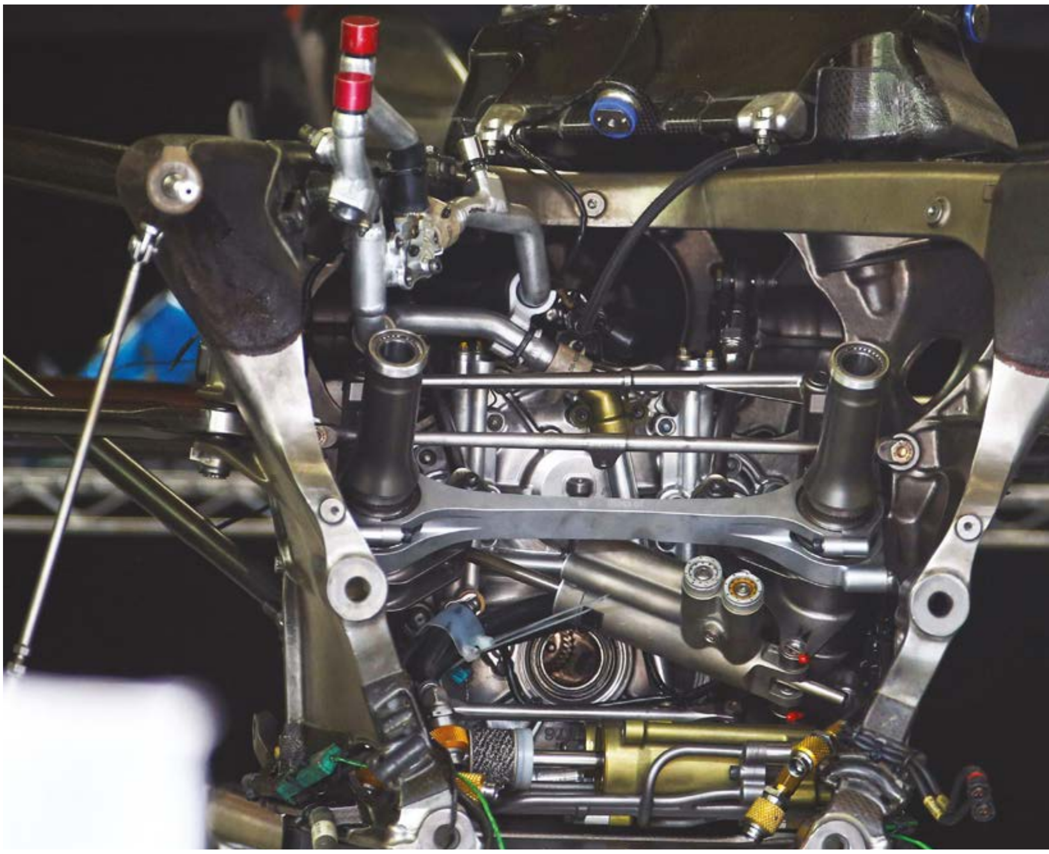
had. There were some castings which had not been machined for financial reasons, and we also had some casings used in 2015 which were still good and could be modified, too. Between those un-machined castings and the recycled 2015 casings we will have enough to last the year.

'I wouldn't call this gearbox a cut and shut, but we have done what we could in the available time and you can see that clearly. But the rigidity has not changed that much, the mounts are the same and overall the 'box is still relatively stiff, so we don't have a problem there. There is no doubt that the 'box is a compromise compared to what we would like to have. Next year you will see us change that concept,' Chester says.

The three images on the facing page reveal the evolution of the transmission casing from 2014 to 2016. The 2014 casing features an all-titanium construction with an integral bell housing. The 2015 design featured revised suspension pick up points and different leading edge with small composite sections on the upper mounting points – these are thought to have been added after the switch from Renault to Mercedes power ahead of the 2015 season. Looking at the 2016 transmission the late adaptations are clear to see in the picture. The casing is exactly the same, with the same pick up points, but a chunk of the leading edge has been machined away in order to accommodate the Renault exhaust layout. The input shaft is also slightly different.

Casing point

Enstone has used a titanium casing for many years, along with Xtrac internals, but looking to the future it is clear that Chester and his team are contemplating adopting a composite casing in 2017, though they have yet to fully commit to it. 'I think there are pros and cons to using a cast titanium 'box,' Chester says. 'The structure works quite well, but then some people have done very nice carbon fibre cases which could give a bit more freedom on suspension pickups, for example. But if you have a relationship with a good casting firm and a good machining firm then its straightforward – you design it and it gets made. With a carbon gearbox you have to develop all the processes to laminate it, manufacture it, work out the bulkheads – it is quite a big engineering exercise. While it works well for some teams this is not a trivial process. For 2017 it will be a totally new gearbox, a new concept, but it is a bit early to reveal much more than that now.'



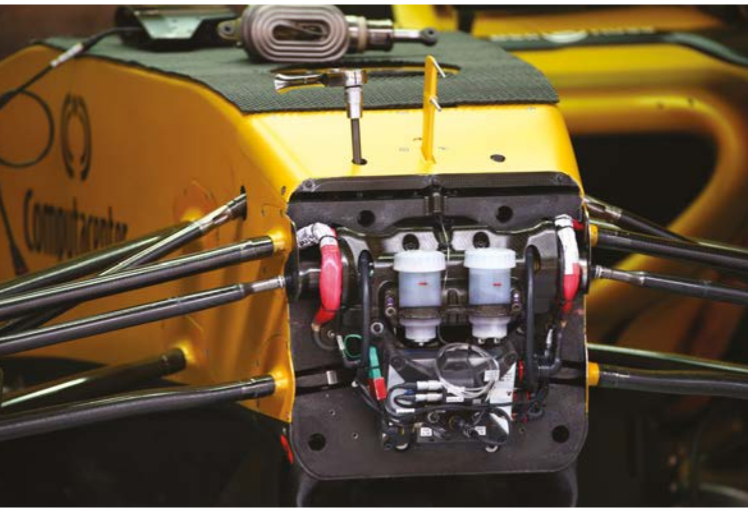
The rear suspension on the 2015 Lotus E23; note the dampers and torsion bars mounted inside the bellhousing. Because the RS16 transmission casing was carried over from the E23 it made sense for Renault to stick with this well-proven layout

The RS16 does not have a blended lower wishbone on the front of the car, while the team has so far resisted the temptation to go with a narrow span wishbone, which some cars are running this season, though this approach is now being considered

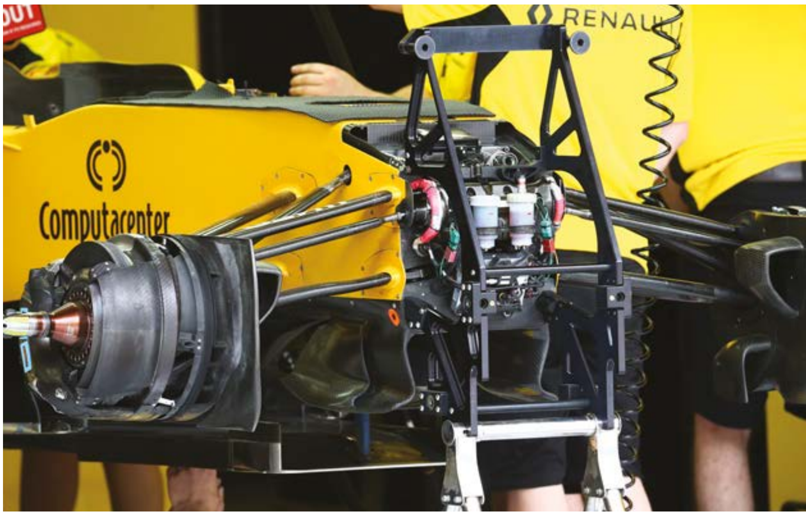
With the retention of the E23's transmission casing, albeit in modified form, the overall rear suspension layout has largely carried over in its entirety. Like every car on the grid it has a pull rod layout with the dampers and torsion bar mounted inside the bellhousing.

'We were quite happy with the handling of the E23,' Chester says. 'We would always like some more grip but the characteristics of the car were nice and the drivers felt comfortable with it. It had no nasty vices so, overall, the suspension is pretty similar, with only a couple of things tidied up a bit.

'As you can see looking at the transmission, the inboard points are the same and the outboard is similar, though the uprights have not fully carried over, they just look similar. The front is also very similar, not quite the same but similar. A lot of teams have gone for the narrow span front wishbone. Its' an interesting area to look at. We are looking at the front and we know there is a gain to be had in terms of aero



Front bulkhead. One of the big worries for Renault at the first test this year was that it simply did not know the exact weight of the car or just how that weight was distributed



The scuttle has been removed here, revealing the torsion bars. The front suspension is almost an exact carry-over from the Lotus E23, though there are some small differences

TECH SPEC

Renault RS16

Chassis: Moulded carbon fibre and aluminium honeycomb composite monocoque, manufactured by Renault Sport Formula 1 team and designed for maximum strength with minimum weight. Renault power unit installed as a fully-stressed member.

Front suspension: Carbon fibre top and bottom wishbones operate an inboard rocker via a push rod 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 inside the gearbox casing. Aluminium uprights and OZ machined magnesium wheels.

Transmission: 8-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.

Electrical: MES-Microsoft Standard Electronic Control Unit.

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

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

Dimensions and weight
Front track: 1450mm
Rear track: 1400mm
Overall height: 950mm
Overall width: 1800mm
Overall weight: 702kg, with driver, cameras and ballast

profiles. At the rear there are always things we can do to make the car ride better, too. Overall the wheelbase is very similar to the E23.'

One area where the Enstone engineers have been trying to make up lost ground in the last two seasons is dealing with the banning of interconnected suspension part way through the 2014 season. Renault, and later as Lotus, had pioneered the technology and all of its cars were built with it in mind.

'Losing the interconnected suspension hurt us a lot in 2014, it hurt us a lot from losing the ride height control we had with it, but also we developed our aero package around it for a lot of years and that meant we took a double hit,' says Chester. 'So, we had to change our aerodynamic development to make up for it and through last year that took some intense work. We [gained] some of it back, and now it perhaps isn't an effect on us any more. For us the whole advantage of it was the rear pushing the front up, and that is what it was all about. Once you have taken that away it just leaves a lot of people running quite a stiff front end and a fairly soft rear end. You could do a remote springing unit, but it does not gain much over having it just sat between the rockers.'

It is clear that the Renault RS16 is something of a transitional car for the team, as it adjusts to life as a works operation once again, and all that that entails. A heavy recruitment programme is ongoing with the staffing level at Enstone expected to hit 650 by the end of the next season. While at the time of writing the team had only scored points once in the 2016 season (a seventh in Russia), that is perhaps understandable, considering this racecar's difficult birth.

'The weaknesses of the car are pretty clear, we need more downforce and more power, those are the two biggest things. It's a general development thing, we need more time on bodywork development, we lost a lot of time with that last year with the issues we had, and you just need to work on it and work on that development curve,' Chester says. 'If you look up and down the grid you can see it; you look at the Mercedes car, it has very intricate bodywork with lots of little developments coming to it. The more you look to the other end of the grid the more you find that the cars are much more simple. It's just the time required for developments and refining them, and we didn't have a lot of time.'

Future focus

Renault knew from the outset that it was in for a tough season in 2016, and it did not expect to be able to take the fight to one of its old rivals from the early days of grand prix motor racing, Mercedes. So perhaps criticism of the team at this stage is unfair, as it clearly has its eye on the 2017 season, and the new chassis regulations that are coming in next year.

'We have accepted this year that we have had to make compromises just to get the car running,' Chester says. 'We will do what we can within a sensible scope to improve the aero and improve the handling, but we won't do something like a new monocoque, as it's too much work while we are doing the 2017 car at the same time. There is a limit to how much we want to throw at it. We do have quite a few developments coming, so we think with those and the new spec engine we will be able to haul ourselves up the grid by a decent chunk and be a regular top 10 finisher. But now we are putting quite a lot of work into the '17 car.'

As a works team based out of Enstone, Renault won two world championships in the not too distant past. With a rebuilt team and new rules it could be that the yellow cars will once again be a major contender in grand prix motor racing.

Renault re-acquired Lotus, which it had sold in 2009, for the sum of £1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French revolutions

After a poor season for its power unit in 2015 Renault seems to have turned things around with its much improved RE16. Here's how

By SAM COLLINS

Renault introduced turbocharging into F1 in the late 1970s and after initial struggles used the technology to win world championships. With that in mind it should perhaps come as no surprise that the French manufacturer was one of the main driving forces behind the introduction of the current Formula 1 power unit regulations.

Renault was the first to show off its new 1.6-litre V6 engine (in this very publication) in late 2012, and was the first to show off a full power unit in 2013, but when Formula 1 pre-season testing began at the start of 2014 pretty much everything went wrong. It was almost an echo of the 1977 to 1979 F1 seasons, where that first turbo engine blew up so often that the cars from Paris earned the nickname 'Yellow Teapot'.

The RS34 power unit developed a substantial amount of problems from the moment it first ran on track in Jerez, Spain. Component after component failed in a period which one senior Renaultsport engineer described as being like playing 'whack-a-mole', where when one problem was solved two more popped up. There were issues with the data from the dynos in Paris, production glitches and frequent failures.

Despite all of this, it was quickly clear that this was not a repeat of the 1970s. The first competitive outing for the unit at the Australian Grand Prix saw it complete a race distance for the first time and cross the line in second position in the back of a Red Bull. That car was later disqualified when a failed fuel flow sensor left uncertainty over the legality of the rate used in the race (nobody could prove it was illegal, but also nobody could say if it was legal). The Red Bull-Renault partnership went on to take three race wins and second in the constructors' championship in 2014, but the following year was much tougher. In 2015 there were no victories and the Red Bull team was only fourth in the constructors' championship.

Under pressure

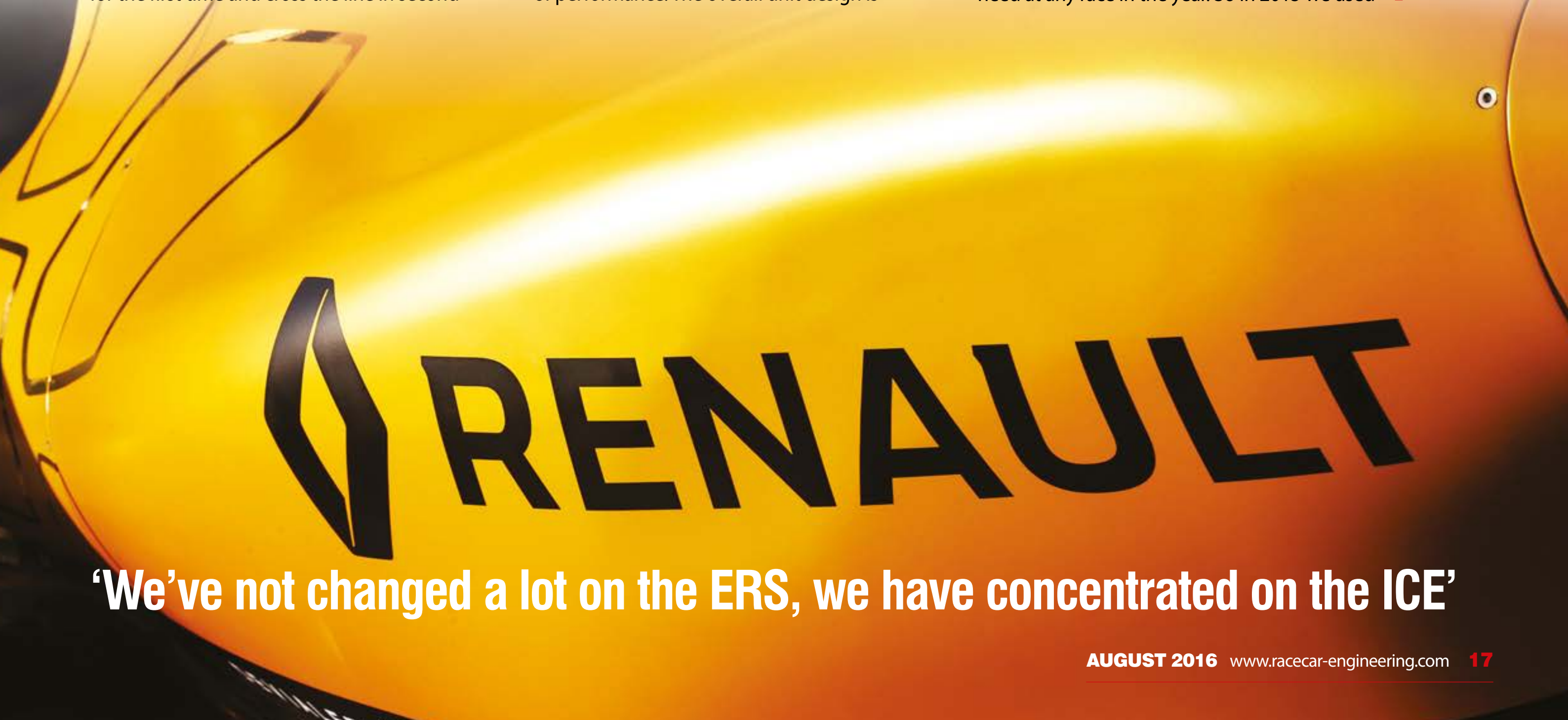
Development progressed through 2015, though obviously not at a rate fast enough for Red Bull's senior management, who expressed their ire in the media at regular intervals, especially in the early part of the '15 season.

But Renault's engineers in Viry-Chatillon, on the outskirts of Paris, had a plan to improve the situation, and they stuck to it despite the huge pressure from Red Bull. Working through 2015 they made substantial performance gains in the workshop and prepared to bring the upgraded design to the grid in 2016.

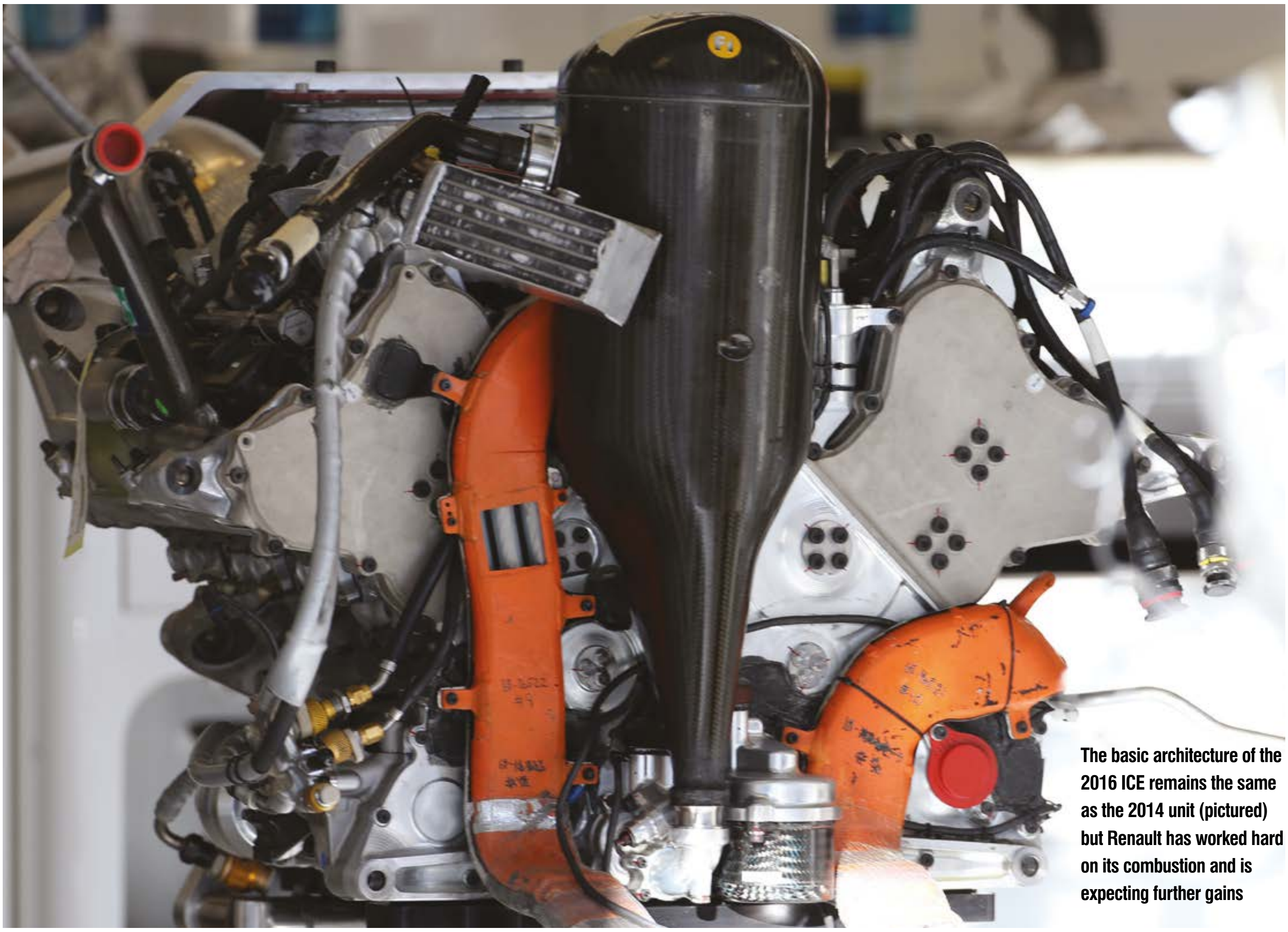
The result of that work was the Renault RE16, a power unit largely based on the RS34 but with a number of modifications to the PU seen in Jerez two years earlier, many made for reliability reasons, but some made for reasons of performance. The overall unit design is essentially the same as that of the RS34. By regulation it remains a 1.6 -litre V6, with a 90-degree bank angle. The MGU-K (made by Marelli) is mounted on the left side of the block, just under the exhaust headers. Both turbine and compressor are mounted at the rear of the engine, with the MGU-H sitting just inside the V.

'Basically what we did for the RE16 was continue with the late 2015 RS34 concept, Remi Taffin, Renault's engine technical director, says. 'The thing is that we have not changed a lot on the ERS, we have fully concentrated on the ICE. We have kept the same V6 but we have plugged in a new turbo and we have a new concept plenum on it. We still have a lot more energy to come from the fuel than the ERS, so the best thing to focus on is that, the combustion. For now I think we have found the limit of what is possible with the MGUs. It is the ICE which is where the gains come. In terms of efficiency, two years ago if you had said we could get 40 per cent it would have been fantastic. Now we are up to 45 per cent. The thing with this technology is you can push a long way.'

Although Taffin says that there is little gain to be had now from the energy recovery system (ERS) he does admit that there has been significant development in terms of the energy store. 'In 2014 we played it a bit safe, using a battery with a bigger capacity than you would need at any race in the year. So in 2015 we used



'We've not changed a lot on the ERS, we have concentrated on the ICE'



The basic architecture of the 2016 ICE remains the same as the 2014 unit (pictured) but Renault has worked hard on its combustion and is expecting further gains

The 2016 engine with the MGU-K visible in its position on the left side of the block. This revised power unit has proved a great improvement over last year's largely disappointing offering

a slightly different technology and resized it a bit, but it's not just pure gains now, it's all about trade offs', he says. 'We are on the tail of what is being done on road cars – there is a massive amount of work in that area. Nissan and Renault put a lot of resources into that and we share a lot with them on that. Where we are going to find the improvement for Formula 1 is making lighter cells with a higher specific capacity, but I don't think this is the big focus for the coming years in F1; it's in the future.'

With the works team having switched from a Mercedes power unit back to Renault for 2016, some comparisons between PUs are now possible, though in general the engineers are keeping tight-lipped on this subject. But they do claim that the driveability of the Renault unit is equal to that of the Mercedes.

'Basically we are following the plan we set out ages ago,' Taffin says. 'Now the ERS is sorted out, and the reliability is sorted out, we have a big programme around the ICE, especially the combustion chamber. We had a first step with the new spec this year, we tried some steps last year but we could not fit the right turbocharger, so we could not extract the full performance that we knew we could achieve.

'So that first 2016 unit was a big step over the 2015 unit, but the new unit we ran in testing in Barcelona after the race was another step in terms of technology on the ICE. It's all looking good, we now have every little bit we need to gain after proper study and proper testing,' Taffin says.

Winning again

The upgrade tested in Barcelona was felt to be worth around 0.5 seconds a lap in the right conditions, according to Taffin. With its improved driveability the updated unit was put to good use in the Red Bull chassis which for the first time beat the Mercedes on outright pace on the twisting streets of Monte Carlo, scoring pole position and almost a race win. Only a botched pit stop cost the Renault power unit its second successive victory. However, Renault's first victory had come a fortnight earlier in Barcelona, where one Red Bull driver managed to beat the Ferraris after the Mercedes drivers eliminated each other on the opening lap in a coming together.

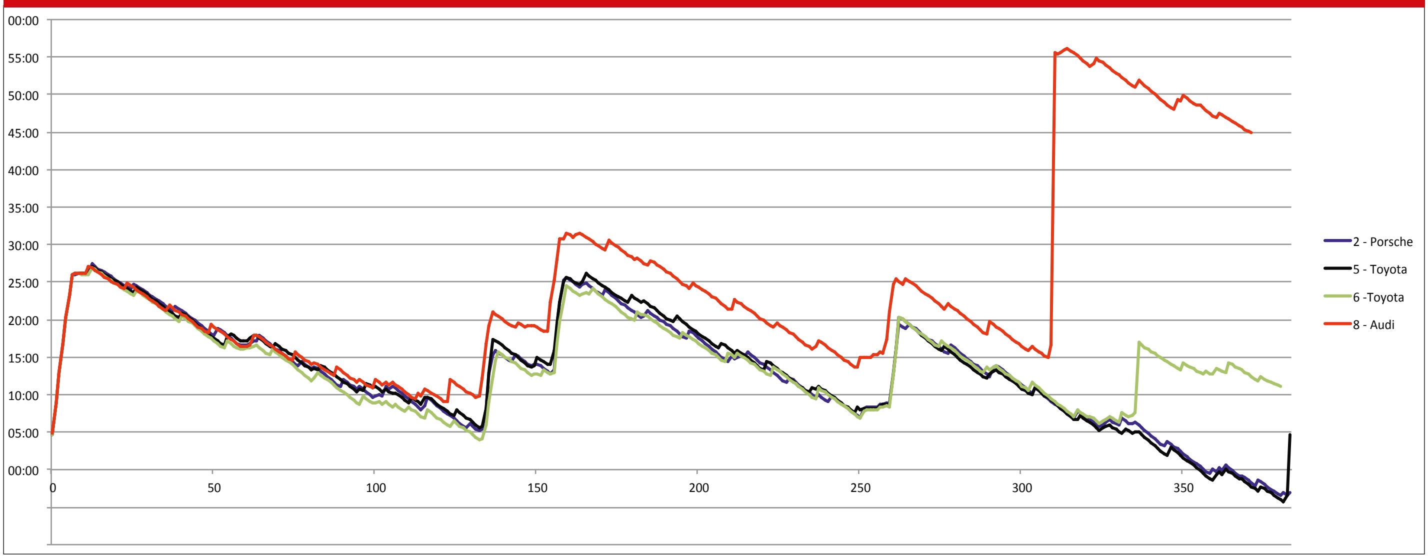
The performance increase and the now seemingly solid reliability was enough for Renault and Red Bull to bury the hatchet and agree a continued partnership. For the 2017 and the 2018 seasons both the Red Bull Racing team and its sister outfit Toro Rosso will use the Renault power unit. And they are both happy to do so, which is a sign of just how much progress has been made at Viry-Chatillon.

Heartbreaker

Toyota's TS050 was the class of the field at Le Mans but a penultimate lap failure meant the No.5 car was not even classified, leaving Porsche to take the spoils

By ANDREW COTTON and PAUL TRUSWELL

Race summary chart



This chart shows the gaps between the leading cars plotted against a notional average lap time. It shows how the No.6 Toyota (represented by the green line) leads early on and how the No.5 Toyota, the car which so very nearly won it, joins in the battle for the lead in the second part of the race. The y-axis units show the time (in minutes) behind the race leader

The Toyota team persevered with an aggressive strategy, one that was almost perfectly executed

The record books show that Porsche won the 84th edition of the Le Mans 24 hours, returning a back-to-back victory for the 919 Hybrid and a first win for Marc Lieb and Neel Jani, a second for Romain Dumas. However, the real story was the showing from Toyota's TS050, with its all-new chassis, engine and hybrid concept.

The Toyota team persevered with an aggressive strategy, one that was almost perfectly executed and good for beating the competition, but for a loose pipe between the turbocharger and the intercooler that caused a loss of power. The data shows that the car was slower crossing the line at the start of lap 383, with eight minutes of the race remaining; then Kazuki Nakajima reported a complete power loss out of the first chicane on the Mulsanne Straight further round the same lap. The car then suffered the ignominy of grinding to a halt for an agonising minute and a half in front of the pits – and the packed grandstands – as the No.2 Porsche swept past to take victory.

The build-up to the race was fraught with doubt from all sides. Audi had struggled with its front MGU, suffering a failure in qualifying as Lucas di Grassi hit a kerb and flew for approximately 10m. 'It was an unlucky accident because two protection mechanisms were not activated in the form they should have been,' said Jorg Zander, head of engineering at Audi Sport. 'He had a problem braking for the first chicane, the car got unstable, hit the kerb, the car lifted off the ground for 10m, and because he was braking and recuperating, the front wheels were decelerating, and when he hit the ground there was strong acceleration against the inertia of the MGU and that is inducing high torque. It could happen any time, but we had done the pre-test with no issues.'

Porsche had sent both of its cars back to Weissach post test day in order to complete preparations for the race, although the team denied that it had anything to do with a technical failure. A batch issue meant that Porsche will run the rest of the 2016 season with the 2015-specification battery, rather than the more powerful, lighter, 2016 unit, but it was clear that the 919 Hybrids were not so much quicker than their opposition as last year.

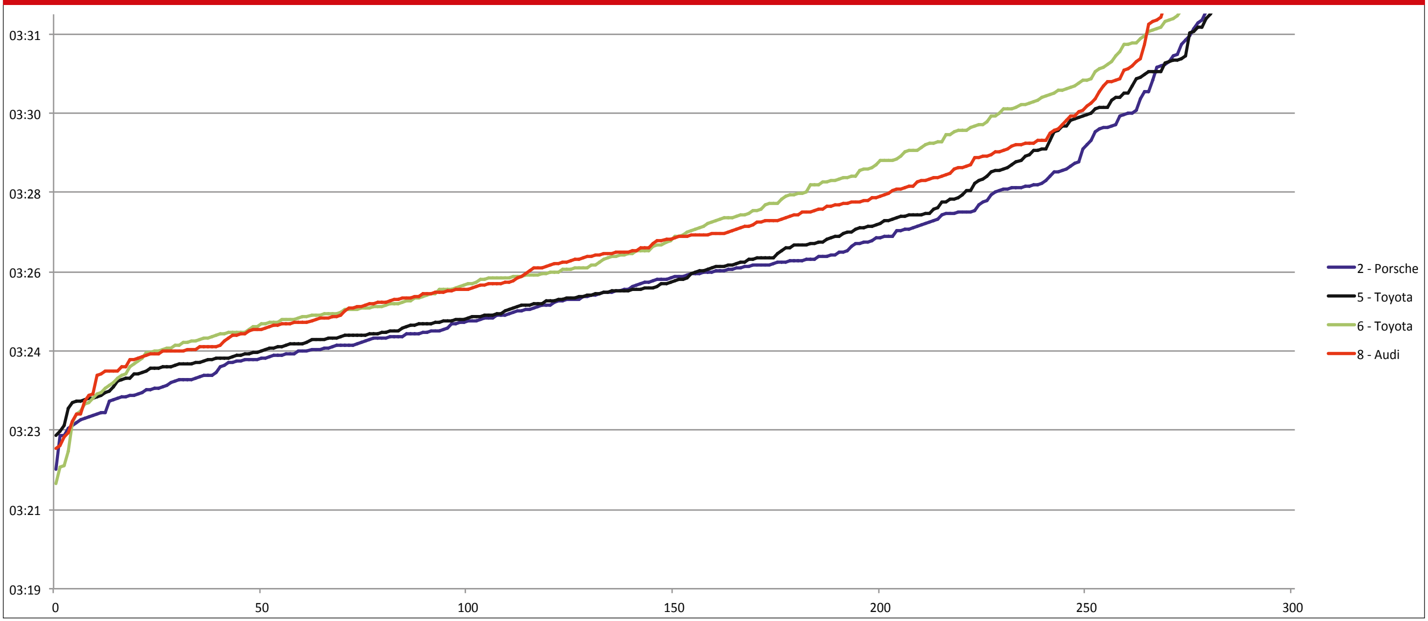
The reduction of fuel by 10MJ for hybrids was estimated to be worth around 4.5s at Le Mans, but at other circuits on which they raced this year, they have matched the pace of 2015. Yet, at Le Mans, despite intense competition, the fastest lap was slower than expected; Toyota's Kamui Kobayashi setting a 3m21.445s as early as lap 81. This was partly due to the limitation of 300kW energy allowed to be deployed from the hybrid systems of the LMP1-H cars, imposed only at Le Mans because it is classified as a Grade 2 circuit. But with bad weather in practice and qualifying, and temperatures dropping to 12degC overnight, optimum tyre choice was both near-impossible and crucial.

False start

A heavy downpour before the start meant that the race started behind the Safety Car. By the time the decision was made to withdraw it and allow racing to commence, track conditions were much drier, and the decision was whether to switch to intermediates or a full slick. As the Safety Cars pulled off, the race proper started, but it was not a good start for the No.5 car, with Buemi suffering from a failed sensor that saw him falling behind both the Audis in the quickly drying conditions. Davidson took over the car and found that the slick tyres he had taken had such vibration that he felt it would shake the car apart, so he had no option but to stop at the end of his out lap. The team had rustled up a set of high temperature tyres that were fitted to the car in low temperatures.

Now on a fully dry track, Davidson re-passed both the Audis and was using the longer stint lengths achieved by the Toyotas (14 laps per tank of fuel) to good advantage. His pace was not a match for either of the Porsches, though, nor was it as quick as Kobayashi in the sister

LMP1 rising average



This chart shows each lap time of the top four LMP1 cars sorted in order of fastest lap, with the fastest lap on the left and the slowest to the right. It shows that the No.6 Toyota set the outright fastest time but it was not consistently quick. The No 2 Porsche (the blue line) was the most consistent, but it was closely matched by the No.5 Toyota for much of the race

How does it feel to be within a lap-and-a-bit of winning Le Mans only to break down? Ask Toyota. The No.5 was the class act at this year's race but was beaten in the closing stages thanks to a loose pipe between the turbocharger and the intercooler

Toyota. The leading Porsche, driven by Mark Webber, Brendon Hartley and Timo Bernhard, was alternating in the lead, while Mike Conway had a great drive in the No.6 Toyota TS050.

With the pit stop sequence the Toyota was ahead at the hour mark, able to run 14 laps on a tank of fuel while Porsche stuck to its pre-race plan of running 13 laps, as it had in 2015. As a consequence, Porsche's re-fuelling stops were quicker, but the Toyota would theoretically be able to save itself two stops over the 24 hours. Each stop would need to be around three seconds longer, though, to account for the extra fuel being added. With a fully dry race and minimal running behind the Safety Car or in slow zones, it could mean an advantage to Toyota of about a minute at the end of 24 hours clean running. Any bad weather, Safety Car periods or slow zones could reduce that advantage, however, and Porsche was no doubt banking on its reliability being superior to that of the Japanese manufacturer.

In the event it was the No.1 Porsche that stopped, at 11:12pm, to have its water pump repaired. The stop took an hour and a quarter, and was followed by a further stop of an hour and twenty minutes, putting the car out of contention and leaving the No.2 car to take up the cudgels for Weissach.

Five alive

The Race Gap Chart showing the gap between the two Toyotas shows how, just before the 200-lap mark, at about 3am, with Davidson back at the wheel, the No.5 car came back into the race. Davidson would describe after the race how the car just came alive in his hands. Not only did 5 catch 6 – in the hands of Kobayashi – but it was catching the leading Porsche, being driven by Lieb. By the end of Davidson's stint, just after 4am, he was trading the lead with the No.2 Porsche at each pit stop. 'That stint flipped our fortunes,' said Davidson. 'That inspired everyone. We had this new energy and we were on fire. We were flying. [Buemi] got back in and set the fastest lap of our car, gained 30s on Mike [Conway], then I jumped in against Lieb, and carried on pulling away from Kamui, and then Kazushi just had to bring it home.'

Indeed, Conway, Kobayashi and Sarrazin fell away in the final third of the race, having led more laps than any other car (173 out of 384).

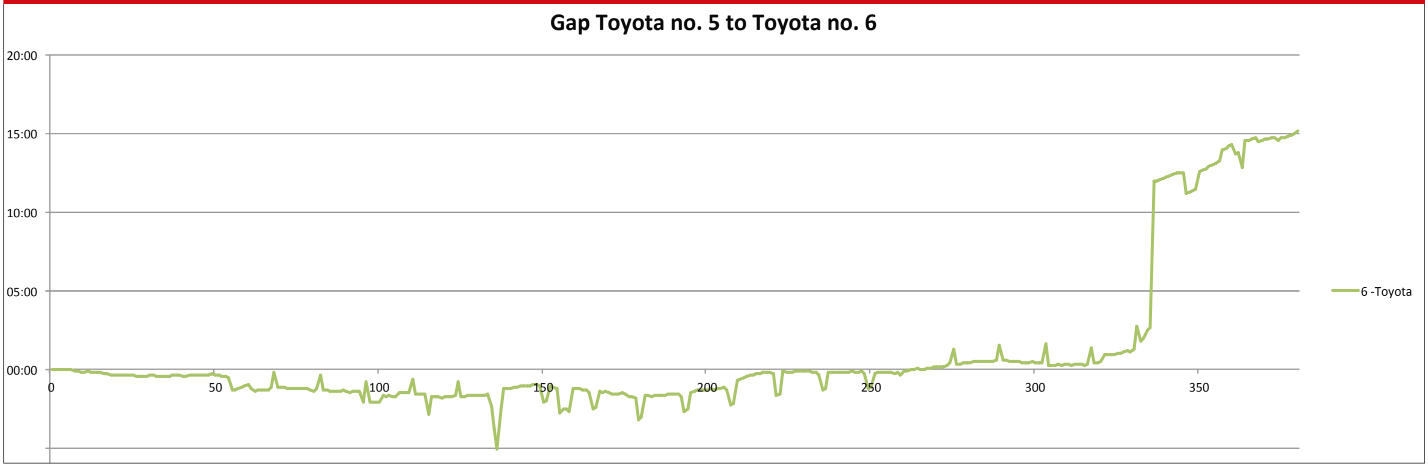
Close examination of the data indicates that, in the early stages of the race, the pace of the Toyotas improved during a triple stint, whereas in the latter part, they were quicker at the beginning of the stint than its end. This could have been due to the track temperature, which rose as the race wore on. It's certainly noticeable from the Gap Chart showing the gap to the No.2 Porsche, that the stints driven by Davidson and Buemi put it in its strong position.

Toyota's cause was helped by the fact that Lieb suffered a puncture just five laps into a stint, at 4:40am, requiring him to stop and take on tyres. The team then spoiled the driver rotation, by putting Dumas in the car when Lieb came to the end of his stint, even though he had an hour-and-a-half of driving time remaining. Dumas got back in the car for a 10-lap stint to complete the wear cycle of the tyres, and then handed the car to Jani, who handed it back to Lieb after completing only a double stint.

With four hours remaining, Lieb in the Porsche was only 17.6s behind Davidson in

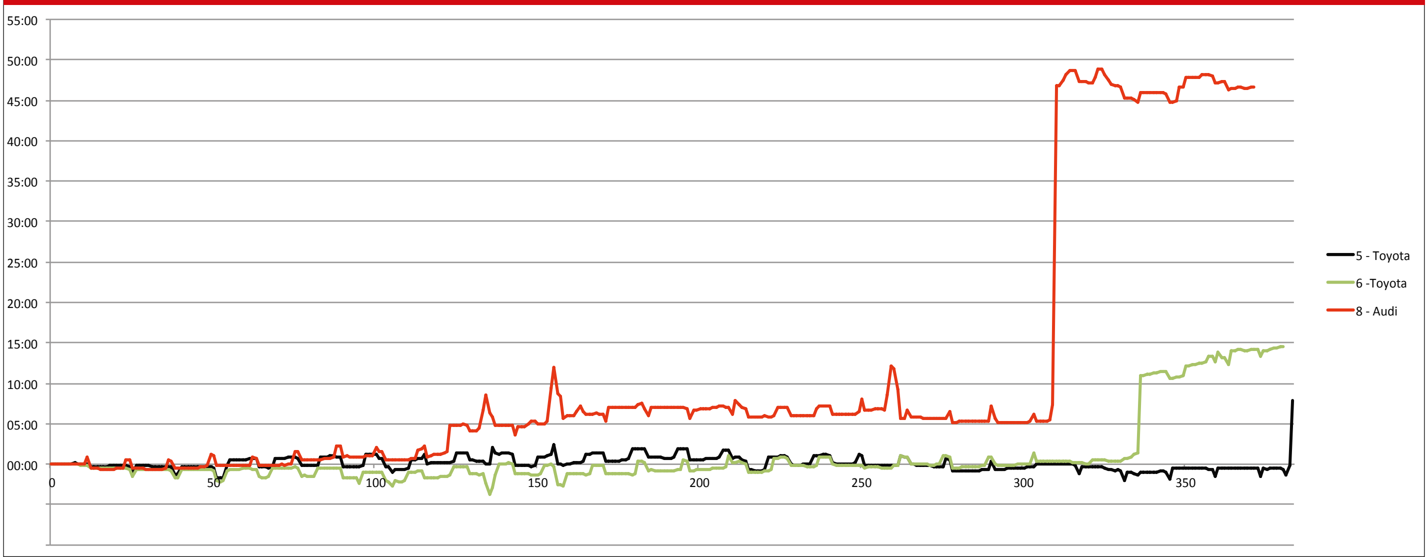
Porsche was banking on its reliability being superior to that of Toyota

Race gap chart



This chart shows the evolution of the gap between the two leading Toyota TS050s. In the first half of the race – up to lap 250 – it shows that the No.6 Toyota is ahead, but in the second half of the race it is losing ground (note the increasing y-axis values). The y-axis units show the time it is losing, in minutes, behind the No.5 Toyota

Race gap chart



This chart shows the evolution of gaps between the leading LMP1 cars. It is plotted against the car which was ultimately the winner, the No.2 Porsche. Notice that, despite being quite far behind, the No.8 Audi actually holds its ground and even gains a bit, before later falling even further back. The y-axis units show the time (in minutes) it is behind the race leader

the Toyota, but the team realised that it could not win unless there was a Safety Car or Toyota unreliability. Not only that, but it would need a splash of fuel before the end of the race if the car would continue with 13-lap stints. There was no option but to roll the dice and switch to 14-lap stints for the remainder of the race.

Back in third place, the No.6 Toyota spun on Sunday morning, Kobayashi losing precious seconds in the gravel trap although the 4wd option was enough to get the car out of trouble and back into the race without losing a position.

Porsche left Jani in the car for a final quadruple stint, but he was 30 seconds behind, and although he would gain seconds on some laps, Nakajima would gain them back on others. Then, with just over 10 minutes remaining, Jani suffered a puncture and had to pit for four new tyres, putting him 1m24s, behind the Toyota.

Overall, there was little to separate the Jani/Lieb/Dumas Porsche from the Buemi/Davidson/Nakajima Toyota. They were on the same lap throughout the race. Both were reliable, both were fast, but ultimately Toyota's day ended in tears after the air line connector worked loose on the penultimate lap, leaving Porsche to take its 18th win. Toyota was even denied a podium by the rule requiring cars to complete their final lap in under six minutes. The irony is that if Nakajima had stopped a hundred metres earlier – before the finish line and therefore before beginning his final lap – it would have been the penultimate lap that was longer, not his final one. The car would have been classified second.

The Audi R18 e-tron quattros had a shocking race by the standards we have come to expect. At times (as can be seen from the tables and graphs) the cars had the pace of the leaders, but the drivers struggled with tyre pick up throughout the race, experiencing vibration that affected the drivers' vision, particularly in the third stint. The grip and balance were there for the car, but the vibrations were too much.

The car of Andre Lotterer, Benoit Treluyer and Marcel Fassler was the first to falter, with a broken turbo that needed 20 minutes to be repaired before the race was 90 minutes old. Both cars had to have the lights around the

Race lap times

No.	Car	Best Lap	Average Best 20%	Best Stint Average	Top Speed
1	Porsche	3m 21.816s	3m 23.595s	3m 23.9s	334km/h
2	Porsche	3m 21.756s	3m 23.783s	3m 24.3s	331km/h
5	Toyota	3m 22.495s	3m 24.056s	3m 24.3s	331km/h
6	Toyota	3m 21.445s	3m 24.368s	3m 24.4s	333km/h
7	Audi	3m 23.043s	3m 25.078s	3m 25.3s	323km/h
8	Audi	3m 22.206s	3m 24.347s	3m 23.8s	331km/h

The build-up to the race had been full of rumours of sandbagging

number on the side of the car repaired, costing time, both had front suspension changes in a bid to get over the high brake temperatures that were being experienced, and both had some silly delays – the No.8 car had a door that needed to be replaced on Saturday afternoon. When it was running properly, on Sunday morning, Oliver Jarvis, di Grassi and Duval were quicker than anyone on the track. By that time, though, the car was 10 laps behind.

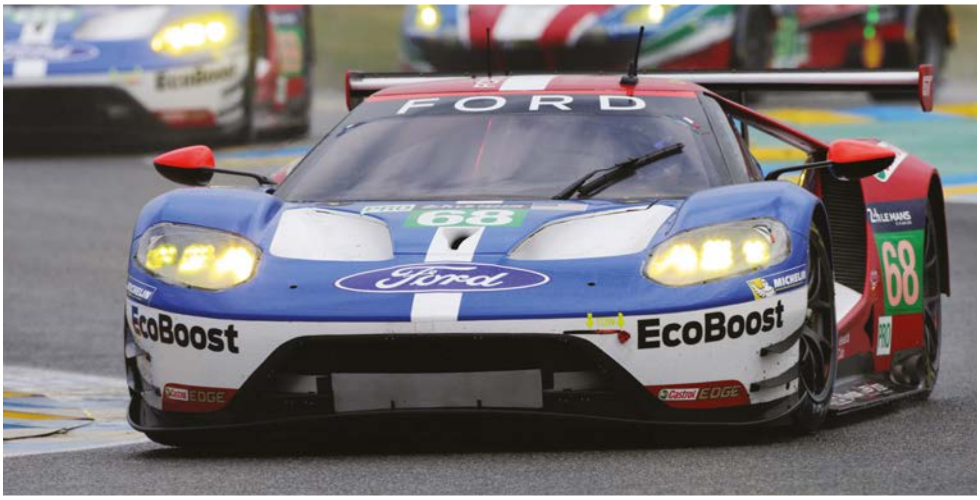
In the LMP1 privateers category, the Rebellion team won the class, finishing 54 laps behind the winners after numerous problems. Nick Heidfeld, Nicolas Prost and Nelson Piquet Jnr stopped to have a malfunctioning air intake temperature sensor changed early in the race, stopped twice to change the clutch and had the fuel injectors replaced as a precaution, as these had failed on the sister car.

GTE

The build-up to the race had been full of rumours and tales of sandbagging, and the FIA admitted that it had learned a lot regarding how to identify and manage this. Ford and Ferrari brought new cars, built to the new aero regs and likely to be faster than the adapted 2015 cars from Aston Martin, Porsche and Corvette.

The jungle drums started to beat harder following qualifying. Dirk Muller's pole position lap was a 3m51.185s, three tenths quicker than Ryan Briscoe in the sister Ford, with the AF Corse Ferrari also dipping into the 3m51s. The slowest of the Ferraris was the Risi car, with a 3m53.176s, but the jump to the adapted cars was huge; Fred Makowiecki setting a 3m54.261s lap in his Porsche, a full 3.7s off pole.

'Obviously, we discovered some things a bit late,' said Bernard Niclot, technical director of the FIA after the first qualifying session on Wednesday night. 'We can look at the BoP, and that is something that we are looking at very attentively, the performance in each sector, how the cars change between practice sessions, and we have good tools to do it. We have questions for the manufacturers, and then we will define the final BoP. Then you have the final concept. If somebody has really masked his real performance we have also the possibility to have a penalty during the race, and this is something to discuss with them tomorrow [Friday]. We can apply a big penalty if we realise that a car has completely hidden the performance from the FIA. What we want is that the GT manufacturers face their responsibilities, if there are problems, why?'



The Ford GT of Dirk Muller, Joey Hand and Sebastien Bourdais came out on top in GTE, marking an impressive return to Le Sarthe for Ford. It was not altogether satisfied with the result, though, and protests and counter-protests flew after the race

The Risi Ferrari driven by Giancarlo Fisichella, Toni Vilander and Matteo Malucelli, spoilt the Ford dream of a one-two-three – which would have echoed its success with the GT40 in the '60s – by splitting the Fords on the podium with second in GTE

Friday balancing

Prior to the race, on Friday, Ford had its turbo boost pressure pegged back, and 10kg weight added, while Ferrari also had weight added, its 15kg estimated to be around 0.5s/lap. Porsche was given more fuel to enable the 991 to complete 14 laps on a tank of fuel, and the refuelling rate was also restricted to be the same for all competitors. At the same time, both Aston Martin and Corvette were allowed a 0.2mm increase in the diameter of the air restrictor, to boost their performance.

GTE pro analysis

No.	Car	Average Lap Time - Race	Average lap time - hours 1-4	Average lap time - hours 5-8	Average lap time - hours 9-12	Average lap time - hours 13-16	Average lap time - hours 17-20	Average lap time - hours 21-24
51	Ferrari	3m 53.7s	3m 54.9s	3m 53.2s	3m 53.2s	3m 53.9s		
71	Ferrari	3m 55.6s	3m 55.7s	3m 54.8s	3m 55.2s			
82	Ferrari	3m 53.9s	3m 54.6s	3m 54.0s	3m 54.5s	3m 53.0s	3m 53.5s	3m 53.1s
66	Ford	3m 53.2s	3m 53.9s	3m 53.8s	3m 53.4s	3m 53.6s	3m 53.0s	3m 52.2s
68	Ford	3m 53.1s	3m 53.5s	3m 53.4s	3m 53.1s	3m 53.0s	3m 52.7s	3m 52.5s
69	Ford	3m 53.2s	3m 54.6s	3m 53.6s	3m 54.1s	3m 53.7s	3m 52.8s	3m 52.2s
63	Corvette	3m 56.2s	3m 56.8s	3m 56.0s	3m 56.8s	3m 55.2s	3m 54.8s	3m 55.3s
64	Corvette	3m 56.9s	3m 56.4s	3m 56.0s	3m 56.3s	3m 55.3s		
91	Porsche	3m 55.0s	3m 55.9s	3m 54.3s	3m 54.9s			
92	Porsche	3m 54.8s	3m 56.7s	3m 54.6s	3m 54.5s			
95	Aston Martin	3m 54.8s	3m 55.2s	3m 54.8s	3m 54.7s	3m 54.0s	3m 54.2s	3m 54.1s
97	Aston Martin	3m 55.6s	3m 56.8s	3m 55.4s	3m 56.4s	3m 55.5s	3m 55.1s	3m 54.7s

Aston Martin, along with Porsche and Corvette, fielded cars that were adapted to the new GTE aero rules, whereas the Ford GT and the Ferrari 488 were both designed and built around the new regulations, and had a performance advantage

The FIA was reluctant to make too much of a change until it had analysed all the race data. However, at a special meeting held on Friday between the GTE manufacturers, teams were reminded of the regulation 7.4.3 that: 'Any competitor or manufacturer who deliberately gives false information, attempts to influence the BoP process, or displays a level of performance beyond the expected result may be issued a penalty prior to, during or, after a race. Minimum penalty stop-and-go five minutes at the steward's discretion'.

'For me it is clear that it is easier to do it when the cars have raced for some time, and for sure after this race we know them better,' said Niclot. 'The Porsche and the Aston are not new 2016 regulation cars; they are old cars modified. When they bring new cars [in 2017/18], we have a period where we don't completely know the cars. It is difficult. When we know the evolution, it is easier to do a better BoP for the future.

'Even with the Ladoux testing [see page 34], you test the cars with set-ups, we check different ride heights, but the facility itself has its own uncertainties. At the end we don't know how the guys will use the potential of the car. We can put the cars in the performance windows but to know what the race engineers do in testing, with race set-ups, and how that will react on the car it is difficult. But we can say that we consider your best performance from Ladoux should be at a level, then we balance this, and then they can do their job. This needs to be discussed with them. The way we do it at the moment has its limits. If we get the good information, we can do some good adjustments, but with the sandbagging we don't get the good information. I think we have analysed a lot of sandbagging, and understood many things, so the result at the end is not so bad and it is perfect between the two leaders, so the race is great.'

Corvette adapted the C7.R to the new aero regulations but claimed that the reduction in air restrictor hurt its lap times. The cars were uncompetitive at Le Mans and the FIA wants to see more data

Post race protests

After the race, Ford and Ferrari lodged protests against each other (see Bump Stop, P98). Aston Martin provided Ferrari with data that it claimed showed that the Ford had breached the 107 per cent rule (lapping within 107 per cent of the average of the four fastest LMP2 cars on track at the time). With Ford and Ferrari racing at similar pace, it seems likely that Ferrari also breached the rule. Rumour has it that Ford was looking for more power and less weight before the race, a move that Aston Martin's David Richards considered to be akin to a 'professional foul'.

Aston Martin said that Ford exceeded the 107 per cent rule 57 times. However, taking 107 per cent of the average of the fastest four LMP2s at the end of the race gives a minimum target lap time for the GTE cars of 3m 50.016s. Ford drivers exceeded this eight times. 'We got this reference, but we worked on some other ones because we know by how much people in this game, if we tell them the parameters, they play it!' explained the FIA's technical delegate Denis Chevrier. 'Some others may have [breached the 107 per cent rule] as well because there was good temperature for their tyres, there were some cars that were very competitive in the middle of the night and they struggled when it was getting hotter, was it a good choice of tyre? It is not as easy as [an outright limit]. We try to enter a more structured process, but we know more structure means people try to close it. It is too early to [judge this]' Chevrier adds.

The **stage** is set

A new breed of quicker and more spectacular World Rally Cars will be unleashed next season. But where do the manufacturer teams currently stand in the 2017 development race? *Racecar* investigates

By MARTIN SHARP

The extended body width of the next generation 2017 WRCs provides increased space to enhance side impact protection for crews

Here are the headline figures concerning next year's new WRC regulations. Close to 50bhp more power than this year (to 380bhp), from a turbo inlet restrictor diameter increase from 33mm to 36mm for the 1.6-litre 4-cylinder engines. Minimum car weight goes down by 25kg, and handling and traction improvements come from a central differential with active slip-limiting. The cars will also be 55mm wider. Meanwhile, aero changes include increased dimensions for the fixed rear wing, with an extra 30mm overhang allowed. A 60mm front overhang is also permitted, and the rear diffuser design is free, within maximum dimensions.

These new rules were approved by the FIA WMSC on July 12 last year and Volkswagen Motorsport was the first top team to test designs and development components for its 2017 World Rally Car. Its first test was in Finland last August, just one month after the new rules were approved. Given the time scale it is impressive that the test car appeared with wider versions of the 2015/16 wheel-arch extensions, development wider track suspension, and an intermediate, active centre diff-equipped transmission solution. By this year's Rally Portugal the team had completed 'more than 5000km, less than 10,000km,' of testing, says VW Motorsport's chief chassis engineer Francois-Xavier 'FX' Demaison, rather enigmatically.

'Because of the more open rules for the suspension and geometry we tested different options,' Demaison says. 'The best compromises; the best way to increase the track width and the maximum potential we could get out of the more freedom we have for suspension pick-up points. That was the purpose of most of the tests we did last year with so many different specs, but last year it was not really a 2017 car.'

VW's early start

Such continuously honed specifications enabled Demaison to consider it prudent to sign off the final car spec by mid-2016. 'In October we have to give a final document, but we want to start in January with three cars at Monte Carlo. So, if we have three cars then we have [to have] the spares, and we have also Rally Sweden three weeks later. If we have bad luck in Monte Carlo and we crash three cars, we need also spare chassis' ready for Sweden.

'We are in the validation phase for the transmission, for the suspension, for the

Citroen has taken a sabbatical from the WRC this year to concentrate on the development of its 2017 car. The aero on the new C3 rally car has benefited from the company's WTCC experience

Because the Yaris WRC will be freshly homologated as a World Rally Car for 2017, the rules allow Toyota to have an unlimited testing programme in the run-up to its top level rallying comeback

The current spec Fiesta WRC. M-Sport is testing many of the components for the 2017 Ford on a 2016 car, which it says has a very similar chassis and suspension geometry to the new Fiesta

bodyshell, the cooling, everything. The only thing which is not tested yet on the car is all of the bodywork,' Demaison adds.

This is because, at the time of writing, the manufacturer teams and the FIA were discussing the side impact protection of the new cars. The tragic death of co-driver Michael 'Beef' Park after Markko Martin's Peugeot 307 WRC hit a tree sideways in the Margam Park stage on the 2005 Wales Rally GB convinced the FIA to mandate specific deformable impact-absorbing foam in driver and co-driver side doors. But at the time the doors remained standard thickness, so there was limited space for the foam.

The extended body width of the next generation 2017 WRCs provides increased space to enhance side impact protection for crews. It is a manufacturer team-driven campaign, and meetings between the FIA and teams have made some progress, but before a final ruling the requirements of each car model need to be taken into account.

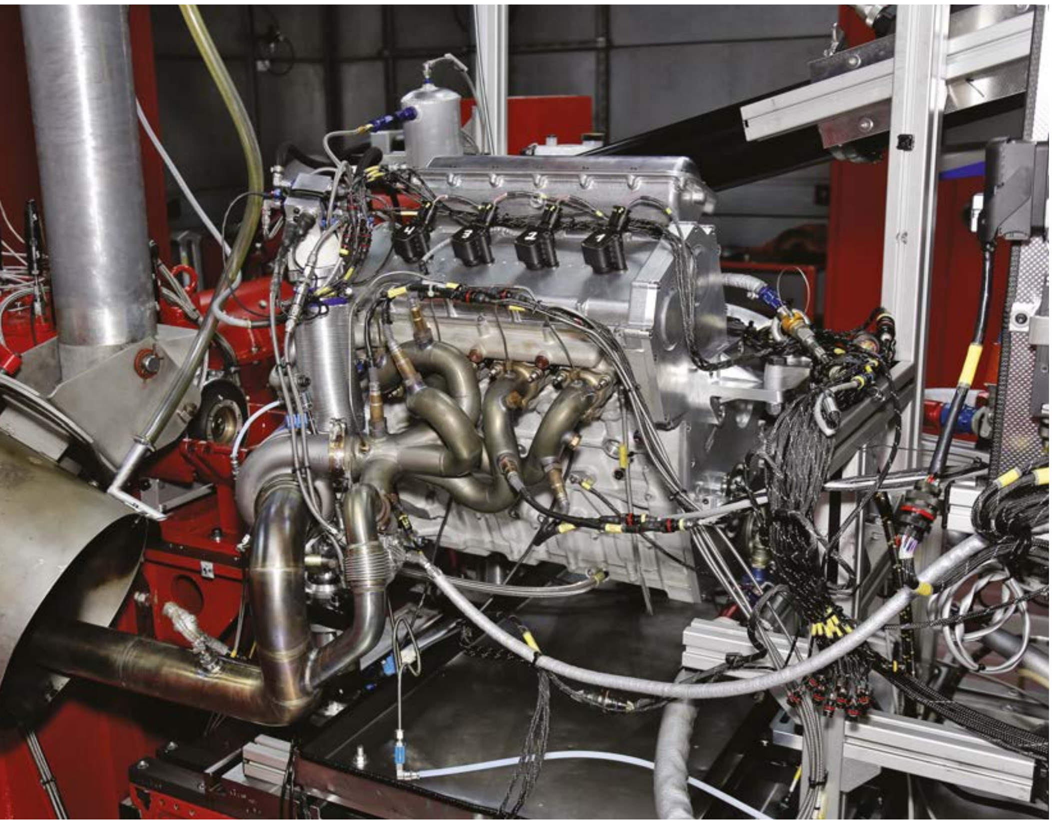
Foam call

Demaison says: 'For sure, we increase the car by 55mm compared to today, so it's 27.5mm per side, so yes there is room. It's always a fight with designers in the road car department; they do not want us to change the shape too much, but for safety reasons we will do it.

'We're talking with the FIA, just to find a solution which – because all the cars are different – gives all cars the same level of safety and protection. That's the most difficult thing. So that's why we do it together; all the manufacturers. We can check on our car and say yes or no; this we can't do, this we can do, and have a final decision,' Demaison adds.

Currently the FIA has suggested mandating a further 30 litres of deformable foam in each front side door to the existing 60 litres. This is still yet to be ratified by the FIA WMSC, but will likely include the possibility to increase door thickness for those cars which cannot accommodate 90 litres of foam in each side door. It is, however, possible that further side impact protection provisions will also ensue.

Active differentials were part of the old 2-litre turbo World Rally Car designs. Then the 1600cc turbo regulations demanded passive front and rear axle diffs and no centre differential. Under the 2017 rules the passive axle units remain, but an active centre differential is again allowed. Demaison explains why: 'We mainly pushed



Citroen has experience with the Global Race Engine (pictured) it will use in the WRC from its programme in the WTCC, where it also runs with a 36mm inlet restrictor as per 2017 WRC regulations. Power goes up by 50bhp to 380bhp next year

for this because it's for us like having a proper damper in the drivetrain, which causes much less technical issues with driveshafts, with the propshaft, with the internal parts of the diffs. That's the main thing, and we all agreed to have a very simple and basic active strategy.'

This will likely contribute to making the more powerful and lighter 2017 cars somewhat more controllable in corners. But will the cars then look more as if they are cornering on rails? There is internet video footage of some 2017 WRCs on test already, and this is Demaison's expert opinion: 'The movies we have seen of the '17 cars on gravel, and even on tarmac, for me they look a bit more spectacular.'

But he also makes the point that early tests are development exercises; not demonstrations of ultimate pace. Volkswagen Motorsport's three WRC drivers have already tested the 2017 car specification, but the bulk of the test driving tasks are undertaken by twice World Rally Champion Marcus Gronholm: 'When we have Marcus testing, he is not driving at the same speed as [Sebastien] Ogier, Jari [-Matti Latvala] or Andreas [Mikkelsen]; it's not what we're asking. He doesn't need to push 100 per cent,

Volkswagen's first test was in Finland last August, just one month after the new rules were approved

it's not his job; we need really good technical feedback from him,' explains Demaison. He says the same of early footage of Toyota's 2017 WRC testing in Finland and Spain, with four-time WRC Champion Tommi Makinen behind the wheel.

Toyota's advantage

Because the 2017 Toyota Yaris WRC will be freshly homologated as a World Rally Car the rules allow works team, Tommi Makinen/Gazoo Racing to have no limit on the amount of pre-season testing allowed, and it is the same for Citroen Racing with its C3 WRC, which will also be a new car to WRC homologation. This freedom is not available to VW Motorsport, which will be homologating the same, victorious, three-door base Polo, as campaigned in previous seasons, as its 2017 WRC.

Which is partly why the team started testing early, Demaison says: 'We were limited in the number of days testing, so it's quite a disadvantage. We are were limited because it says in the rules that if you keep the same model you have limited testing. We had 30 days for both 2015 and 2016, so 15 and 15 for each year.'

But how far ahead of his rivals does Demaison consider VW to be? 'This is really difficult to say: are we ahead? We don't know. We are doing the work we think is necessary to be ready for Monte Carlo and we will judge in Monte Carlo. But before that it's really difficult to know [how we compare] with the red ones, Citroen, with the experience they have.'

Meanwhile, Hyundai Motorsport took delivery of its 2017 specification Sadev transmission during the week after Rally Portugal, and planned to test this a week later, after rig testing had proven gearbox and differential components. Its 2017 tests began in April, using a 2016 five-door i20 WRC, as Hyundai Motorsport team principal Michel Nandan explains: 'We have dedicated one car to do all this; a 'mule' car in order to test some components and not wait until the 2017 bodyshell; not to lose too much time.'

Hyundai's progress

Engine components, a bigger restrictor, and new coolers have already been tested in this way by Hyundai. The 2017 wider track suspension is designed but yet to be tested, but it plans to build a full 2017 specification car ready for testing around July time, 2016.

That 2017 specification Hyundai WRC will be the three-door coupe version which the team originally planned to be its 2016 challenger. It started testing with it, then realised production figures for the 25,000 minimum required for the model would be marginal for 2016. So Hyundai Motorsport opted for the five-door i20 as the base for is 2016 WRC challenger.

But the manufacturer has now hit the three-door coupe production targets for the 2017 WRC homologation and Nandan is happy that the lower drag characteristics deriving from the smaller frontal area of this model will have significant advantages.

Nandan does have some reservations about the new rules, though. 'Yes, the cars will look a little bit more fancy, but for me the worst thing is the increase of power – I would not have done it. The cars are quick enough now. I would have given them more torque [Maximum boost pressure is retained at 2.5bar absolute; therefore torque output will be affected minimally] to have a bit more of a spectacular impression, but the power I would not have touched. I think it's too much – especially now that the rallies are much faster than before, because all the stages, if you have a look, are a lot faster.'

Maximum allowed WRC hydraulic pressure is now 120bar, and providing the required pressure to operate the active centre differential in the Hyundai's 2017 transmission when fitted to the 2016 'mule' i20 WRC has not been difficult, Nandan says. '[The hydraulic system] is quite similar to what we have here [in the 2016 car]. We have already a hydraulic block with two electro-valves for the gear change and one for the rear [disengage] clutch; so now [in 2017 spec] there is no rear clutch, but there is a centre diff. It will be modified [to cater for greater hydraulic pressure], but it's nothing. It's something we have already tested.'

Before Rally Portugal the 2017 i20 WRC mule had already covered some 1000 test kilometres, adequate when considered simply as a vehicle to test components. But has Nandan formed any opinion on rival 2017 WRCs? 'I've had a look at the videos. Yeah, okay, you can see things, but

'The potential of our new World Rally Car is quite incredible'

The aggressive stance of the 2017 WRC cars is clear in this pic of the VW Polo development car, but the bodies of the new cars might yet look a little different as new safety regs have yet to be finalised

Hyundai Motorsport head Michel Nandan says that enough three-door new Hyundai i20s have now been built for the road for it to be homologated, and the team will use it for its 2017 WRC base car

M-Sport boss Malcolm Wilson says he is not worried that the new Fiesta on which its 2017 WRC car is to be based has not yet been launched and he is confident the new car will make Monte Carlo

for sure it is not the final specification; especially in bodywork, because the regulation is not final, there's still the side impact devices to be defined. It could change a lots of things, but yes it gives some ideas. It's always interesting to have a look at what the others are doing. But I think that for everybody that is now running the [2017] car, for sure it is not the same as their final spec will be,' Nandan says.

Citroen's sabbatical

Another varied approach to the 2017 WRC is the considered tactics of Citroen Racing, which is taking a sabbatical from the WRC this year, while PH Sport runs DS3 WRCs under the Abu Dhabi Total World Rally Team banner. This year is also the last time Citroen will contest the World Touring Car Championship, which leaves 2017 free for an all-out WRC onslaught.

Based on a yet to be launched new C3 road car, the WRC version had its first shakedown test in early April, driven by Alexandre Bengue on the small tarmac track next to Citroen Racing's Satory, Versailles site. The car was then tested on rocky gravel by Chris Meeke, and then by Craig Breen, without major problems. After the tests, and with a broad grin, Meeke said: 'The potential of our new World Rally Car is incredible.'

Meeke then put more testing miles into the C3 WRC in Portugal. Conditions were very mixed, with some rain, hail and fog joining the occasional sunshine. Component lifing was part of these tests, together with performance and crew comfort development. Citroen Racing technical director Laurent Fregosi said: 'We were actually quite pleased to have these variable conditions because they meant we could test different set-ups and assess how the bodywork stood up to being loaded with mud.'

The team has worked on the 2017 WRC project for over a year now, from first design stroke to built components, assemblies and car. A current priority is to improve access to components likely to be replaced in service.

One advantage for Citroen Racing is that the Global engine in its C-Elisee WTCC racers is similar to that chosen for its 2017 WRC, and it has run with a 36mm diameter inlet restrictor from the beginning. So the team has a good working knowledge of the similarly restricted engine in the 2017 World Rally Car. 'The car immediately possessed the same power level as we'll see next year. We have also tested the latest suspension systems,' Fregosi said.

A further bonus of the WTCC racing programme is the team's increased knowledge and experience in aerodynamics, team director Yves Matton explains: 'Before we had virtually no real experience in aerodynamics. It is now a field in which we have genuine expertise.'

Adopting a just-in-time approach to account for long lead-time items, assembly of the first prototype was completed in under a month. Data analysis from the tests is under way to hone the specification and a second, tarmac, test car was under build at the time of writing. Chassis, engine, transmission and aerodynamic developments will continue apace until homologation for the 2017 Monte Carlo Rally: 'We've only just begun the journey,' Fregosi says, adding: 'That point [homologation] seems so far away, and yet it'll be here before we know it.'

It's a serious approach, then, from the French team, running the test 2017 C3 WRCs before the new C3 road cars hit showrooms, which is expected in August. And it's an approach that the M-Sport team would love to share. But currently this seems unlikely.

Ford's tight deadline

The Cumbria, UK-based M-Sport squad is determined to be at the 2017 Monte Carlo Rally with a new World Rally Car, although team insiders rate the timing as tight. Some work on the new car has begun, with the main developments due to commence in early June, and M-Sport is expected to have the new mechanical components ready for testing in a current Ford Fiesta WRC bodyshell in July.

A potential difficulty for the M-Sport team is that a totally different new Fiesta road car is imminent. The team does not have a physical example of the new road car yet, and there are two possible launch dates mooted, but none decided. 'It's not a facelift; it's a completely new car,' says M-Sport managing director Malcolm Wilson. 'The wheelbase is about the same and we have the old [current] base to work on; that's how we can do it. Some of the things associated with the new bodyshell will be different, but the actual geometry – all the CAD data of the chassis – is the same, which means we can basically modify the current car to the new car. I'm not concerned; the main thing is running the [new] mechanical components, which we will be doing from July onwards.'

There will be changes to the engine, too: a different cylinder head, a different turbo, perhaps slightly different pistons, a modified oil pump, and much of the ancillary items, but the cylinder block and crankshaft will remain the same as in M-Sport's 2016 engine. The team's Focus RS WRC had a Ricardo transmission and the same specialist is supplying the gearbox and centre differential assembly, and front and rear diffs, for the 2017 Fiesta WRC.

While Wilson confirms the arrival of the all-new Fiesta road car will restrict when his team can launch the 2017 WRC version, he is still adamant that the car will be ready in time: 'The plan is to be in Monte Carlo. I'm not that worried; we've enough experience in M-Sport. We've just done a [Focus] rallycross car in six months from start to finish, that's as quick as anything going straight out of the box, so I'm not that concerned,' Wilson says.

We will have to wait until Monte Carlo to find out whether his confidence is justified. A great many other questions about WRC 2017 will be answered there, too.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On balance

For over a decade balance of performance has played a major role in international motorsport – but just how do you go about implementing an effective BoP and how do they differ from series to series?

By ANDREW COTTON

Development programmes are rife and the whole topic of BoP has become a political debate, rather than a sporting one

Back in 2005 the FIA GT Championship was very much a victim of its own success. GT promoter Stephane Ratel had a series with his 'dream cars', including the Ferrari 550 Maranello, the Dodge Viper and the Lister Storm. But then along came Maserati with its MC12, which essentially used the same running gear as the Ferrari Enzo.

The car, mid-engined and fabulously expensive, matched Ratel's desire for exotica, but he also knew that it would blow the Corvette C5R, and others that had supported his series through the thin times, out of the water. Enter stage left Max Mosley, who promised to balance the car through aero restrictions, while Peter Wright developed a system that would accurately map a car's characteristics. To the chagrin of Claudio Berro, sporting director at Maserati, the front and rear bodywork of the MC12 had to be chopped, reducing aerodynamic efficiency and cutting the speed of the car. The fact that it was able to perform on almost every type of circuit meant that the car was phenomenally successful anyway. But the balancing concept has since evolved.

Delicate balance

The BoP system has now become integral to racing, with many claiming that it is taking away the purity of the sport. Originally, a secondary function of balance of performance was that it discouraged manufacturers or teams from undertaking costly development programmes. Yet now development programmes are rife, and the whole topic of BoP has become a political debate, rather than a sporting one.

In the races leading up to big events, accusations of sand-bagging are common. Ahead of the Daytona 24 hours in January the cars run at the pre-season test, labelled as the catchy 'Roar before the 24' where the organisers get their first track data for the cars. Le Mans 24 hours in June is preceded by the test at Paul Ricard in March, Silverstone in April and Spa in May, before the BoP is decided ahead of the test

Ford versus Ferrari at Le Mans might bring to mind epic battles from the 1960s but these days much of the dicing is over Balance of Performance numbers

The FIA checks that GTE cars from the manufacturers fit within the performance boxes for power, drag and downforce – the latter is tested on this clever downforce plate at Ladoux

Michelin's Ladoux test facility in France is where the nitty-gritty of the FIA's GT Balance of Performance work takes place. The manufacturer submits its figures and then they are checked here

and the race in June, while there are numerous Blancpain Sprint and Endurance races ahead of the Spa 24 hours in July.

Organisers have taken steps to address this problem. In LMP1, the Equivalence of Technology is set after Le Mans, and held for 12 months, allowing for development. In IMSA and the WEC, new data loggers have been introduced that monitor key parameters, to details such as the angle of the throttle body, to ensure that maximum acceleration is being carried out. The SRO takes an altogether more pragmatic approach, using a spec data logger and having professional drivers test the cars at Paul Ricard. Of them all, the SRO's system, having been around for longest, is not only the cheapest for the competitors, but also the one that produces the fewest complaints.

Ladoux

The first stage of the BoP process is that the GT cars are required to fit into a performance box of power, drag and downforce. The manufacturer declares its figures, and brings its car to Michelin's test facility at Ladoux, France. There, it is tested to ensure that it does, indeed, fit into the stated performance window, with the downforce tested on a special plate. 'It is different to the past when the manufacturers didn't know what to extract from a road car to produce a racecar,' says the FIA's technical delegate, Denis Chevrier. 'Now, from the road car, the manufacturer knows that to be eligible they need to bring the racecar to this level of performance. 'I have a technical regulation that allows me to make some modifications from a road car to a racecar, is it worth doing it or not?'

'Before any kind of BoP, we need to make sure that all the cars, to be eligible, have to show that they are playing inside the performance windows. That is to be done under some manufacturers declaration from the dyno, such as the influence of different restrictors and boost pressure, so there is a declaration for the car. We all know that we can't trust them and just believe that everything is perfectly true, so there enters the process of checks of the technical characteristics, that are subject to the eligibility of the car through different means. This is where the aero calibration of the cars enters, at the Ladoux facility which is used for GT3 and GTE.'

Incidentally, as part of its mission to better understand the GTE and GT3 cars, representatives from IMSA went to Ladoux to observe the tests for the 2016 cars. Weather conditions meant that two tests were not completed to the satisfaction of the FIA, and so a deal was struck to put cars, with both low- and high-downforce configurations of the GTE cars, in the wind tunnel at Windshear in the US.

> **'What we find out in our test is that the manufacturers don't always tell the truth'**

'We make a complete merge of every single information that we can get on the eligibility of the car, including 3D scanning, which is one of things that we did in Ladoux,' Chevrier continues. 'We entered the homologation process with a deposit of bodywork CAN, and on the basis of this, we check that the car in front of us in Ladoux is really a car that will be a duplicate of what the racecars will be, and that we didn't have in front of us a car that was specifically adapted to show some bad performance [instead of] what the car should be.' Or to put it another way, sandbagging.

Bespoke BoPs

'We wanted to compare the true bodywork of the cars with their homologated bodywork,' Chevrier continues. 'We did not, at this stage find any changes. Over the years the manufacturers have become more or less ready. Some have cars that are not mature yet, but are close to being so. Some others do the first car, and do this test, and it's right. We didn't catch anyone with a car presented to us that had a problem.'

Once the data has been collected and the cars validated, the series are then free to set their own balance of performance according to their needs. In the United Sportscar Championship, for example, uniquely the GTE and GT3 compete on track in the same race. The pace must be measured to allow for LMP2 and LMPC cars, and keep GTE sufficiently ahead of the GT3 cars. In the WEC, there is no such restriction as it is LMP1, LMP2 and GTE cars only on track at the same time, while Ratel only runs GT3 cars in his Blancpain series.

'What we find out in our test is that the manufacturers don't always tell the truth,' says

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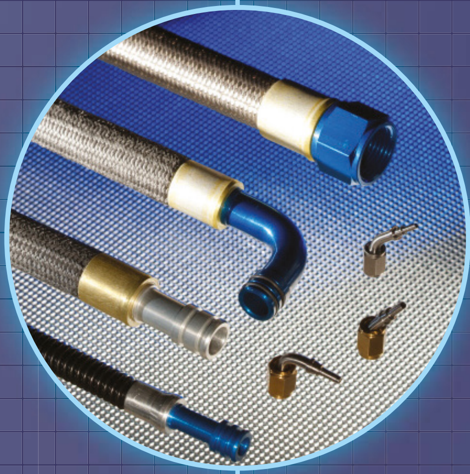

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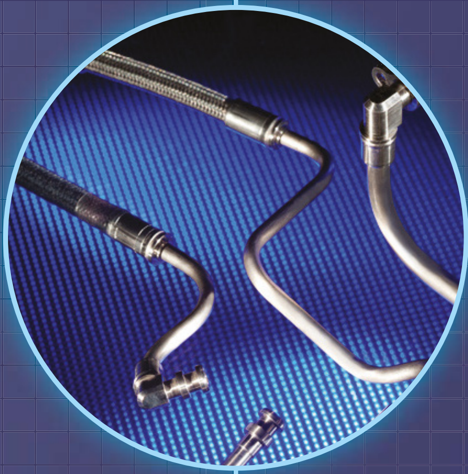

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'The same tyre can work better on one car than another. It will never be possible to separate a tyre from the rest of the car'

Ratel. 'Of course they don't. Our second step of validation [after Ladoux] is the test that we do at Paul Ricard. This has been conducted by Jean-Marc Gounon since 2005, and he did it at first with Christophe Bouchut, and now we have Eric Comas. You don't need guys going for the extreme, but you do need the same guys in the same cars. The Paul Ricard test gives you the same drivers in the same cars, on two circuit configurations, a fast and slow one. Also we have added more days to set up the cars, because the manufacturers have a tendency to give cars that are not optimised. It is why the BoP test is now four days.'

Data logging

Sector and overall lap times are measured, and driver feedback is also a critical part of the process. The cars run a standard data logger, developed by Belgian Claude Surmont, that costs around €2800 and runs on all the SRO's series GT3 cars. The software belongs to Surmont, the hardware is from Race Technology.

Ratel's series all run on Pirelli tyres, which makes life a little easier for his manufacturers, and for Surmont. Ratel says: 'A well done BoP is to balance cars, not to balance a team or drivers. The problem with many series is that a team will never admit that it is not a good team, and a so-called professional driver will also never admit that he is not the best professional driver. They are always going to blame the BoP rather than themselves. As a promoter, you will have a tendency to keep your clients happy and balance not the car, but everything; the level of the drivers, the level of the team, and that creates politics and everything.'

The SRO BoP is the only one in which different types of circuits are graded. There are four categories: one for high speed such as Monza, Macau and Bathurst; one for a combination of high speed and downforce, essentially Spa; one that is a more traditional circuit, which encompasses most Grade 1 and 2 circuits; and one is for street circuits.

'[At the start] you have data acquisition, which produces data,' says Ratel, whose BoP was monitored by the FIA. 'That data went to a referee, who was Claude [Surmont], and after that it was going to the FIA where you had Peter Wright, Gabriele Cadringher and Jacques Berger, who was the technical director of the FIA. Now we have put it more into the hands of Claude, because in my experience the decisions that were made were more than linked to a [political] environment, and other parameters when the only parameter should be that this was the data, and it should be scientific.

'When we moved it to SRO, it was still an amateur category. Peter [Wright] used to say that if we were [within] eight tenths of a second [per lap] we were okay. The system used to have cars having BoP done for a full season. You take the data and put it into the simulation system, which you have for racing engineers, and you were in-putting the various configurations of your circuit and take an average. This worked as long as the first generation of the cars were all the same in terms of downforce.'

Downforce dilemma

The new generation of cars, particularly from Audi and Lamborghini in the first instance, matched by Ferrari with its 488GTE this year, are more downforce-driven. As manufacturers have been attracted to the Nurburgring and Spa 24 hour races, the concept of GT3 has subtly changed. 'Over a long distance race, downforce is a lot better in the rain,' says Ratel. 'Before we would say that the cars had a different weight, different engine, but we didn't have different downforce. Then we had different downforce, and that led to Spa three years ago, where we said, one unified BoP between Blancpain and the FIA, and the FIA said that if you have an advantage with your BoP on all the short circuits when you arrive at Spa, it is the same BoP. BoP is a very simple equation between downforce and power. I remember, I went for dinner with Bernard Niclot [the FIA technical director] and he was clear; they can't have everything.

'Manufacturers now are all going for downforce so of course on fast circuits, where they need speed, they lose,' Ratel continues. 'So then they cry for power, but then they would have everything. If they go for downforce, too bad, they will have less power. That was easy from a principle, and I completely agree with the FIA, but the reality is that I have clients, and one of them had Audis and was going bankrupt! The clients would leave, and the whole thing would be a catastrophe and you realise that you are going to put your clients into major trouble, so we created the variable BoP.

'We made it clear to the manufacturers, Audi in particular, that we would introduce the system, but that we won't change restrictors on the different circuits, because then it is too easy,' says Ratel. 'We didn't want you and us to lose your client, but for the new car, there will be one restrictor and you will have to deal with this restrictor. If you go with too much

JOHN BROOKS

Top: The car that in many ways kicked off performance balancing in GT racing was the Maserati MC12. This is the 'long tail' version of the mid-engined and hugely expensive car which arrived in FIA GT in the mid-2000s and threatened to dominate **Above:** Faced with the prospect of losing many of its manufacturers the FIA clipped the wings of the MC12. The front and rear bodywork was chopped, reducing the car's aerodynamic efficiency. But it still went on to become a GT racing legend

Adjustment of performance: Le Mans 2016

Decision N°: 16-D0026-LMGTE – 17/06/2016 – With Refueling Restrictor diameter

LMGTE PRO		CHASSIS			ENGINE					FUEL						Additional Comments
		MINIMUM CAR WEIGHT (kg)			2 x MAXIMUM RESTRICTOR DIAMETER (mm)			MAXIMUM BOOST RATIO	DECLARED MINIMUM LAMBDA	MAXIMUM ONBOARD FUEL VOLUME (liter)			MAXIMUM FUEL RIG RESTRICTOR DIAM. (mm)			
MANUFACTURER	MODEL NAME	base (1)	adjust.	final (1)	base	adjust.	final			base	adjust.	final (2)	base	adjust.	final (3)	
PORSCHE	911 RSR (2016)	+1243 kg	+5 kg	+1248 kg	30,0 mm	-	30,0 mm		0,89	90 l.	+8 l.	98 l.		-	Car #77: 28.8mm Car #91 & 92: 28.7mm	
FERRARI	488 GTE	+1243 kg	+25 kg	+1268 kg		-		See table	1,10	86 l.	+4 l.	90 l.		-	25,9 mm	
FORD	GT	+1243 kg	+5 kg	+1248 kg		-		See table	0,90	90 l.	+8 l.	98 l.		-	28,85 mm	
ASTON MARTIN	VANTAGE	+1243 kg	-60 kg	+1183 kg	29,8 mm	-0,4 mm	29,4 mm		0,88	95 l.	+7 l.	102 l.		-	28,9 mm	Aero kit "B" mandatory
CHEVROLET	CORVETTE C7.R	+1243 kg	-	+1243 kg	29,3 mm	-0,3 mm	29,0 mm		0,91	88 l.	+7 l.	95 l.		-	26,7 mm	

Ferrari 488 GTE

Engine speed (rpm)	Pboost ratio Max (-)
4000	1,67
4500	1,65
5000	1,67
5500	1,64
6000	1,58
6500	1,49
7000	1,37
7100	1,10

Ford GT

Engine speed (rpm)	Pboost ratio Max (-)
4200	1,46
4500	1,46
5000	1,46
5500	1,46
6000	1,41
6500	1,36
7000	1,24
7100	1,00

LMGTE AM		CHASSIS			ENGINE			FUEL						AERODYNAMIC					
		MINIMUM CAR WEIGHT (kg)			2 x MAXIMUM RESTRICTOR DIAMETER (mm)			MAXIMUM ONBOARD FUEL VOLUME (liter)			MAXIMUM FUEL RIG RESTRICTOR DIAM. (mm)			HEIGHT OF REAR WING (mm)			GURNEY HEIGHT (mm)		
MANUFACTURER	MODEL NAME	base (1)	adjust.	final (1)	base	adjust.	final	base	adjust.	final	base	adjust.	final	base	adjust.	final	base	adjust.	final
PORSCHE	911 RSR (991)	+1248 kg	-20 kg	+1228 kg	28,6 mm	+0,7 mm	29,3 mm	90 l.	+5 l.	95 l.	28,0 mm	+2,5 mm	30,5 mm	-100 mm	-	-100 mm	25 mm	-	25 mm
FERRARI	458 ITALIA - model 2015	+1248 kg	-10 kg	+1238 kg	28,3 mm	-	28,3 mm	90 l.	-	90 l.	28,0 mm	-	28,0 mm	-100 mm	-	-100 mm	25 mm	-	25 mm
ASTON MARTIN	V8 VANTAGE	+1248 kg	-20 kg	+1228 kg	28,3 mm	+1,1 mm	29,4 mm	90 l.	+10 l.	100 l.	28,0 mm	-	28,0 mm	-100 mm	+100 mm	0 mm	25 mm	-25 mm	0
CHEVROLET	CORVETTE C7-Z06	+1248 kg	-	+1248 kg	27,9 mm	+1,2 mm	29,1 mm	90 l.	-	90 l.	28,0 mm	-	28,0 mm	-100 mm	+75 mm	-25 mm	25 mm	-25 mm	0

Note: Adjustments below are made with the waivers required, with the data and information provided by the manufacturers until now, with the data of Ladoux test and with analysis made by FIA/ACO

(1): weight including camera equipment or dummy camera equipment

(2): Onboard fuel volume allocated to restrict stint length to 14 laps without "slow zone" or "safety car" at race pace (minimum lambda)

(3): Refuelling restrictor declared by manufacturer to permit a complete refuelling in conditions of note (2) in at least 31 seconds

To be used with minimum length of fuel hose of 480 cm

IMSA Technical Bulletin IWSC #16-26

GTLM Vehicles		Mass		Engine				Rear Wing		Fuel							Notes
Manufacturer		No Fuel/Driver (kg)		Restrictor (mm)			Boost Ratio	Min Angle (deg)	Gurney Minimum Height (mm)	Type	Declared Minimum Lambda	Tank Capacity (L)		Refueling Restrictor (mm)			
		adj	current	qty.	adj.	base			current		λ	adj	current	Type	adj	current	
Event: 20160703 IWSC Watkins Glen				Bulletin: TB 16-26			Date: 5/18/2016										
BMW	M6 GTLM	0	1240				See Table	N/A	15.0	E20	0.96	0.0	103.0	Dan Jones	0.0	36.0	
Corvette	C7R GTE	0	1250	2	0.0	29.5		N/A	10.0	E20	0.87	0.0	87.0	ATL	0.0	31.0	
Ferrari	488 GTE	0	1240				See Table	N/A	10.0	E20	1.10	0.0	79.0	Dan Jones	0.0	28.0	
Ford	GT GTE	0	1250				See Table	N/A	15.0	E20	0.90	0.0	90.0	ATL	0.0	35.0	
Porsche	911 RSR GTE	0	1230	2	0.0	30.9		N/A	10.0	E20	0.89	0.0	92.0	Dan Jones	0.0	32.0	

* All engine restrictor geometry must comply with the FIA homologated design and be registered and approved by IMSA prior to competition.

BMW M6 GTLM

Engine Speed	Boost Ratio
[rpm]	
2000	1.510
2500	1.684
3000	1.841
3500	1.921
4000	1.941
4500	1.969
5000	1.969
5250	1.947
5500	1.901
5750	1.851
6000	1.800
6250	1.740
6500	1.678
6750	1.623
7250	1.506
7350	1.000

Ferrari 488 GTE

Engine Speed	Boost Ratio
[rpm]	
2000	1.709
4000	1.709
4250	1.695
4500	1.680
4750	1.648
5000	1.634
5250	1.657
5500	1.666
5750	1.642
6000	1.605
6250	1.561
6500	1.508
6750	1.434
7000	1.386
7500	1.263
7600	1.000

Ford GT GTE

Engine Speed	Boost Ratio
[rpm]	
2000	1.562
4200	1.562
4450	1.539
4700	1.547
4950	1.552
5200	1.546
5450	1.549
5700	1.536
5950	1.479
6200	1.448
6450	1.445
6700	1.420
6950	1.369
7200	1.318
7700	1.215
7800	1.000

Top: Bop details for Le Mans were settled on the Friday before the race **Middle:** IMSA BoP **Above:** IMSA says its rpm specific boost tables are an extremely effective way of policing turbo engines

downforce at Spa, don't come and cry that you don't have the power. With less downforce, your car would be quicker. It is very simple. They are going now, all of them if they want to win long distance events, they all go for downforce, but it is clear that some of the amateurs had an easier time in the 458 than the 488, because the power is easy to use, the downforce is difficult to use.'

SRO also does BoP for the Japanese GT300 and Australian GT, as well as the Pirelli World Challenge and the FIA GT World Cup at Macau, all for GT3 cars and does not get involved in GTE.

WEC

Meanwhile, the WEC launched its own data logger system for its GT cars, based on the same Magnetti Marelli system used in the LMP1 hybrid racecars and so is over-specced for the job. That made it expensive, but the FIA has a lot of data to study and it chooses to do this post race, which is partly what led to the drama at Le Mans in 2016. 'We chose the data logger, telemetry and equipment for the global championship, with some LMP1 hybrid racecars requesting some capacity of data acquisition, and everything that is far bigger than what a GT car is requesting, but they have the same data logger, so the equipment is powerful,' says Chevrier. 'If we dedicate all its resources to GTE it is very powerful because it has been chosen to follow the LMP1-H, which in the IMSA field is not the same. They don't have an LMP-H to look at.'

The WEC logger also helps with the marshalling system and it sends information to the TV companies for on-screen graphics. With so much live data, teams are able to use the information to help to set up the car during the session. In the US there is no such capability.

JOHN BROOKS

The Audi R8 was one of the first of a new generation of GT3s which embraced downforce. This caused complications for a BoP that had previously been based on weight and power

The rise of data loggers and more accurate measurement is key to killing off the on-going political arguments, but even then, there are places to hide. Rumours of sandbagging prior to Le Mans were rife in the World Endurance Championship, but establishing that is harder than might be expected.

But as Chevrier points out, even two cars from the same team see a performance difference, and that is down to set-up, driver ability, or simply the amount of mileage a car may complete in the practice sessions, or the ability of the team's data and race engineers.

'We can't see everything,' confirms Chevrier. 'The only thing that we can see is compared to what we expect. We don't know if the shock absorbers and dampers have been set up properly, or if they have been individually calibrated, and then there are many things that we don't know with the braking.

'We have more sensors, which just gives us the possibility to help to have the kind of degree of confidence in the way the car has been operated regarding its maximum potential. If the range is reasonable, we don't know if that's because from one car to another, depending on the settings, one guy one will be four tenths faster than another one.

'From everything that we knew and were able to collect from the aero and engine we try to manage the top speeds in the same range. If from some cars it makes us outside the range we expect, what to do? The explanation will have 200 hours of discussions, but we will know more. At one stage we say we will do something, and if we can't understand we say, okay, and we wait for the people to run the cars in the proper way, to extract the performance of the car.'

One of the key differentiators is the amount of running that a car does in the practice sessions. That leads to a set-up that works, or it may not. 'You have FP1 and FP2, if people make more miles in testing, they are able to accommodate a better race than one which had a lack of running,' says Chevrier. 'They have a good end of meeting because they had this knowledge. If their weekend is lost because they didn't run the proper miles in the first session, is the BoP good or not? What we don't want is to over react, because we know that it is not reasonable to over react.'

'The further step that was a challenge, and is still a challenge, is the turbo cars'

Tyre selection

One of the key topics for the WEC is the tyre selection. In the GTE-Pro class, tyre makers Michelin and Dunlop both supply confidential tyres to their teams. Tyres, therefore, that are developed by a manufacturer specifically for an individual car, which leads to a performance gain if the job is done correctly.

The solution, says the FIA, is to introduce another technical working group, this time for the tyre manufacturers. 'What is impossible to do for FIA, or simulation guys, is to model the tyres and to know their performance on a dedicated car,' says Chevrier. 'It is impossible to do. Even in Formula 1 Pirelli has 200 engineers and they don't know how a tyre will behave on the car. The same tyre can work better on one car than another. It will never be possible to separate a tyre from the rest of the car.'

At least in the IMSA series the cars all run on Michelin tyres, but even there, there was a problem. The cars started the season on tyres that were better suited to sprint rubber, as teams can change tyres at the same time as refuelling, so there is no time advantage to double stinting, unlike the WEC. With the cars balanced, Michelin then brought its endurance tyre to the last round prior to Le Mans, at Laguna Seca, essentially to allow Corvette to race on it before Le Mans. Ford's drivers said that the tyre particularly suited the GT, partly explaining the performance gap at Le Mans. However, that tyre will now be used for the remainder of the season, potentially requiring another BoP change. That happened mid-2015 when Michelin introduced a 'low-energy' tyre that particularly suited Porsche and Ferrari, but which was swiftly withdrawn.

'We saw a change of tyre mid-season last year, and it was an interesting circumstance where we had some challenges to deal with,' says Geoff Carter, series manager at IMSA. 'We had that class to within 0.2 to 0.4 per cent across all the brands. The solution that was introduced on a bolt-on configuration was 1.3s per lap. It created some challenges, but it was an opportunity. We grew closer to Michelin, we understand better the elements of that in the BoP analysis process. We don't see that with our spec tyres. We are here for Michelin to achieve their goals, and we want to achieve our goals and we want to work together.'

IMSA

IMSA monitored what the FIA was introducing in terms of data logging this year, but could not introduce the same system. Apart from the rumoured cost of the kit – in excess of €30,000 – the volume required could not be introduced before the start of the 2016 season.

The IMSA series then got together with Bosch to create its own system and trialled it for the first time at Daytona. Essentially, the data logger is similar to that of the SRO, in that it measures more than 20 parameters and feeds

IMSA has teamed up with Bosch to create its own data logging system to monitor performance. One of the US body's biggest challenges is to keep the GTEs such as this Corvette ahead of the GT3s while not getting in the way of the sports prototypes

back to a computer system that flags up any anomalies through a series of warning lights.

A sector time, for example, that may be faster than expected will be flagged up on the screen, and the cause can then be examined. 'Since we put out our new IMSA scrutineering logger that is quite comprehensive,' says Carter. 'It has been a little difficult to implement with the teams because there are a lot of sensors for the teams, and the looms, and so it has been a bit front-loaded, but the message that we sent by how thorough it is, it says that we get it, or that we are trying harder.'

Daytona test

Carter continues: 'At Daytona [the test in January] for the first time in my career I was dealing with BoP racing, and setting the BoP and chairing the committee. [And] we have had manufacturers saying that they have gone to the teams saying not to hold back. Traditionally people come to the Roar, they manage the pace, come to a level and the first day you ran a GTLM, they ran a 44.4 and you think that you don't need a BoP change because everyone is right. Everyone is within a tenth, but then they come back and you realise that they are sitting on 1.3s. We see all that in the data.

'We have gone to the manufacturers and told them to get with it. Not that I see a change in the tide, but for the first time that night [at the test], I had teams come to me and said the manufacturers have said to push. They realise that it is going to me more difficult to hold back and not be exposed. With the new system, with the Lambda controls and timing, it is becoming more difficult. If they are running to a lean map, we see that now. If they are short shifting, if they are rolling in the brake zone, if they are managing the performance, we absolutely have a chance to see it,' Carter says.

'The problem with many series is that a team will never admit that it is not a good team'

'In the past we did timing and scoring analysis from A to B, but the new logger tells us how they got from A to B and, with our new partnership with DEKRA, and new app for the inspection process, we can tell the configuration of the car, we can see how the car got from A to B and also what A to B was.

We have three layers pretty quickly and then on that Daytona weekend, we instituted something that they do at Le Mans, with random inspections during the sessions. Now we have a reference point of what the car was when it made that lap time. They realise, not that the game is up – they still have some tools – but that their toolbox is getting a bit smaller, and ours is getting a bit bigger.'

Turbochargers

As the road car market moves towards small capacity, turbocharged cars, it was inevitable that turbo cars would be introduced into GT racing. Ratel produced a system for GT3 where the turbo boost pressures across a rev range was introduced, designed to make a turbo engine resemble the characteristics of a naturally aspirated engine. It is a system that has also been adopted by the FIA in balancing the turbocharged engines from Ferrari and Ford, but it has introduced a further layer of complication for those charged with balancing the performance of the racecars.

'The further step that was a challenge, and is still a challenge, is the turbo cars,' confirms Ratel. 'You have other parameters, and all we hear about now is atmospheric pressure. You have heat; some cars have their performance more related to heat than others. You see a clear difference of performance when it is cold or hot. The turbo cars had a drama in Utah [at the Miller Motorsports Park], because you have a high-altitude circuit, so for the turbos that makes a big difference, and you have the atmospheric pressure, which also makes a big difference. It is an on-going process, it is a learning curve but the result is there. At Monza, we had 31 cars within a second. It is working! But, by definition it cannot be perfect.

'We started GT3 with one BoP, for one calendar, and we are now on four BoPs with four calendars. We have one clear rule, which allows us to change the BoP once per type of circuit. For the moment we can't do anything, and won't unless there is a clear increase of power which you see in the data, and if a car shows suddenly 30bhp more because they made an engine step, the car would be disqualified.'

Monitoring boost

In IMSA, Carter says: 'The rpm specific boost tables are a very good way of shaping the power curve, and are way more effective than a constant boost, max boost pressure with a restrictor. They are much more tunable to shape the curve. The power output of a turbocharger is very different to a normally aspirated (NA) car, so you can shape the curve to match the torque and horsepower curve of an NA engine. It is much more accurate, much more tunable. It is difficult to get them to play together, but there is another tool in the box to balance them.'

One thing seems to be clear with balance of performance; the longer the cars run in the same specification, the closer they will come together in overall performance. However, this is the same in any kind of racing – look at the performance differential in Formula 1 in the V8 era from the beginning to the end, and then look at the gap once the technical regulations changed to the current specification.

However, new cars are being introduced all the time. 'You have a car that comes, which is new and let's say the manufacturer is the most correct and wouldn't fool you,' explains Ratel of the headache a new car can bring. 'You come with a car to the BoP test, and race it, and then the car progresses. They get to know the car, the set-up of the car gets better, and then you have a progress curve of the car from the first event, and then you need correction.'

Balancing performance is far more complicated than just measuring a racecar and then applying a correctional factor. There are trip hazards and arguments aplenty to be had over the issue, and they will rage on, until someone comes up with a better idea.


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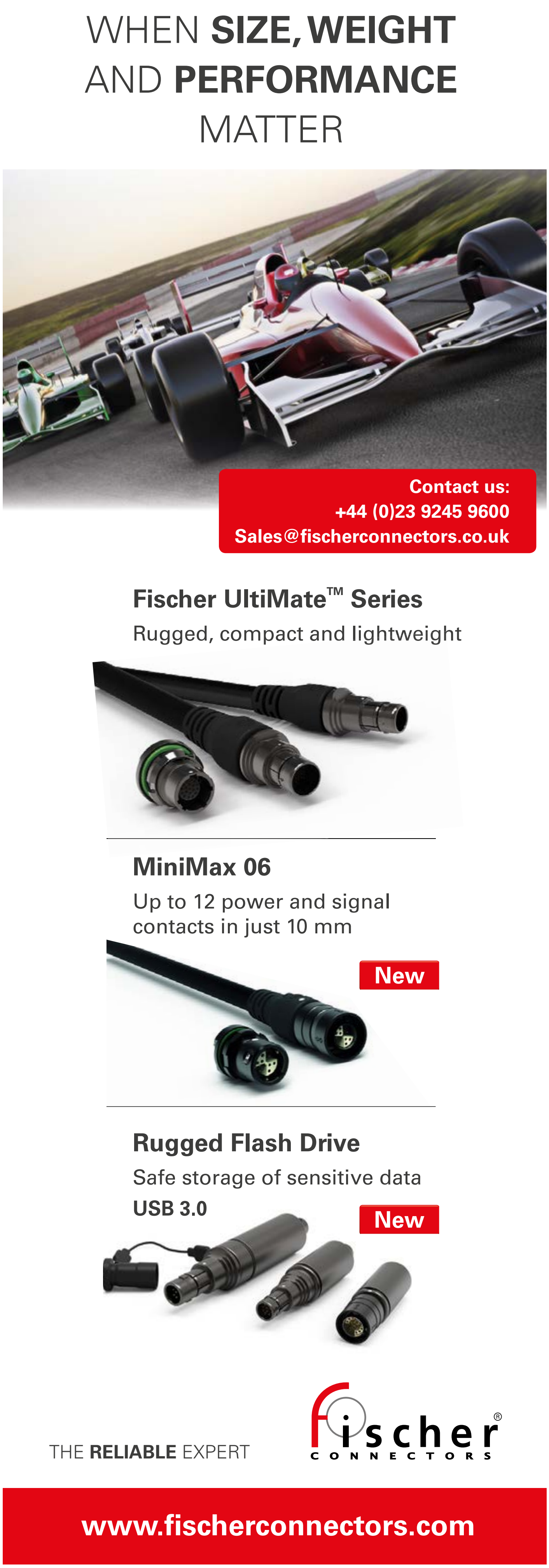
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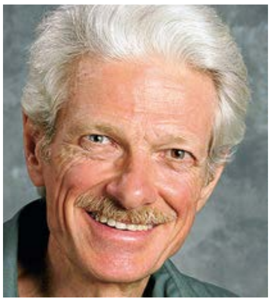

Squatters rights: axle positions for off-road

Can the drive axle inclination really affect squat and anti-squat?

QUESTION

I have a question about drive axle inclination in plan view. A friend who does off-road racing pointed out that if the wheels are in front of the driven inner axle, the tendency will be anti-squat, and if the wheels are behind, the tendency will be to squat on acceleration. I am embarrassed that I never thought about it, but it does seem very obvious. Is this correct? Assuming it is correct, will the anti-squat action be the same as that resulting from anti-squat A-arm geometry?

How does anti-squat affect corner exit traction? On the one hand I would expect the greater load on the tyres to cause oversteer, while at the same time it seems that a pro-squat rear would also increase oversteer, by jerking the tyres up.

Or would both be a short-lived dynamic, lasting only as long as the effect took to equilibrate (move the springs)? To experiment would mean a change in wheelbase; plus F/R weight balance, plus polar moment, or a change in F/R weight balance and polar moment, giving unwanted variables.

As a kid, I experimented with a dirt bike and varied the rear geometry so that I could have the wheel lift or push down with power. The lifting rear tyre made the bike easy to control, and to slide, but wheelspin slowed it down. So, interesting, but slow.

THE CONSULTANT

Plan view driveshaft angularity (in independent or DeDion suspension) does not create anti-squat or pro-squat. What your friend is probably thinking is that the system is subject to a torque about the ring gear axis, and that tries to force the diff down if the wheel axis is behind the diff axis, or force the diff up if the wheel axis is ahead of the diff axis. That would only be true if the shaft were not jointed – but of course in that case the car couldn't go anywhere; any movement at all would only be the result of compliances and clearances in the components.

When a shaft has universal joints in it, and has some provision to accommodate plunge, each segment can only transmit torque, and only about its own axis, since the assembly moves freely in bending and in tension and compression. The stub axle at the differential transmits torque about its axis, the shaft transmits torque about its own axis, and the stub axle at the upright transmits torque about its axis. The shaft cannot act as a lever or crank since it is flexible in bending.

As with any suspension, jacking force induced by longitudinal force at the contact patch depends on the instantaneous rate of *x* (longitudinal) displacement at the contact patch with respect to *z* (vertical) displacement at the contact patch. For drive with a sprung differential, and also for braking with inboard brakes, this is the same as the instantaneous rate of *x* displacement with respect to *z* displacement at the wheel centre, unless there is gearing at the upright.

In the case of a car under steady forward acceleration, anti-squat only increases rear tyre loading slightly. The increase results from the cg being slightly higher under power. The same applies to a motorcycle, except that motorcycles have a lot more longitudinal load transfer than cars, because the cg is so high and the wheelbase is so short. I'm not sure just how the rear geometry was adjusted on the bike mentioned. Generally we can't move the swing arm pick-up very much with respect to the frame unless we add some form of chain tensioner. If we can't do that, then we would be adjusting the ride height of the whole bike to change the anti-squat, and that would have a bigger effect on rearward load transfer than the change in anti-squat would.

Things get a bit more complex when we consider abrupt application of power, as opposed to steady forward acceleration. In such situations, both the suspension and the sprung mass have velocities and accelerations, in heave and in pitch. These are affected by suspension geometry, springing, and damping. In general, however, the rear wheels will have more load momentarily with anti-squat than without it, but this may then be

Things get a bit more complicated when we consider an abrupt application of power

Off-road cars are subject to all sorts of suspension demands. But is it true that if the wheels are in front of the driven inner axle the tendency will be anti-squat, and if the wheels are behind the tendency will be to squat on acceleration?

A commonly accepted rule of thumb is to make the overall width at the outside of the tyres about four inches narrower at the rear than at the front

Making the track narrower at the rear than at the front is a common design feature of Formula Student cars, mainly because this helps the driver to negotiate the often tight courses without knocking over too many plastic bollards

followed by the rear wheels having less load as the car reaches dynamic equilibrium. In some cases this can create wheel hop.

Adding weight (adding mass) at the rear also adds oversteer. Adding tyre loading at the rear through dynamic load transfer (colloquially misleadingly called weight transfer), without adding mass at the rear, adds understeer. Adding normal force to a tyre increases its friction force capability, but at a decreasing rate. Adding mass increases inertia linearly, and also increases normal force linearly, which increases frictional force capability less than linearly. Thus the increase in frictional force capability does not keep pace with the increase in inertia, and decreased acceleration capability results.

QUESTION

I am still fabricating away on my Exoskeleton racecar: about 120kW, rear-wheel-drive with engine and gearbox at the back. The rear end is now complete with about two degrees of camber gain at full roll of 50mm of wheel travel from normal ride height.

I need now to start on the front suspension. Double wishbones, top two thirds the length of the bottom and scrub radius about 20mm, based on some rims I already have.

I have read that it is beneficial to have the front track wider than the rear for a car that is going to be used purely on track, and a very small and twisty track at that.

First question: Is this statement correct? Second question: how do I determine how much wider the front track should be compared to the back? Third question: what can I design into the chassis to help the understeer prone design of this type of car? Fourth question: do I have to get the same camber gain in the front for the same amount of wheel travel, planning on a 50/50 weight distribution front to back?

THE CONSULTANT

Making the rear track narrower than the front is popular for cars that are purpose-built for American autocross and Formula SAE/Formula Student, where the courses are extremely tight and are laid out with traffic cones in a parking lot. The idea is primarily to place the wide end of the car in the driver's view and make it easier to avoid collecting cones with the inside rear wheel. There is no magic correct number or formula for how much narrower to make the rear, but a commonly accepted rule of thumb is to make the overall width at the outside of the tyres about four inches (100mm) narrower at the rear than at the front.

Making the rear track narrower also reduces the tendency of a locked axle or limited-slip diff to add understeer.

Actually, a car with 50/50 weight distribution is not inherently prone to understeer, at least if the tyres are equal size. However, all cars tend to understeer more in tight turns than in larger-radius ones, mainly because the rear tyres tend to track on a smaller radius than the fronts in tight turns. This is called off-tracking.

In this situation, the combination of drag force from the front tyres and thrust force from the rears tends to create a situation that adds understeer. Making the car more tail-heavy, while keeping front and rear tyre sizes identical, helps. However, that may not be an option if the car is at a stage where the locations of most of the components have already been defined. Making the wheelbase shorter reduces off-tracking.

Giving the rear more roll resistance than the front reduces understeer. This can be done by giving the front less geometric roll resistance (lower roll centre), and/or less elastic roll resistance (softer springs and a/r bar) relative to the rear. It is not uncommon in FSAE cars for the car to corner with the inside rear tyre almost completely unloaded, and even then teams often run toe-out at the rear to try to kill understeer in the very tight turns.

The choice of the differential matters. Probably the best type available is a worm-gear limited-slip, with viscous fluid in it and little or no preload. This produces little torque transfer or locking torque when power application is modest and the wheels are turning close to the same RPM, yet can still transfer enough torque even with the inside rear very light if wheel speeds start to differ by a lot, such as when the inside rear starts to spin. Note that some wheelspin has to occur for this to happen, so having traction control can actually prevent this strategy from working. The aggressiveness of the viscous locking effect can be tuned by changing the viscosity of the fluid.

Having similar camber change properties front and rear is generally a good idea. For tight turns, it is generally advisable to have considerable Ackermann geometry (toe-out with steer) in the front end.

If the car will have to negotiate high-speed sweepers as well as tight turns, it will often have excessive oversteer in the higher-speed turns when it's happy in the tight turns. Rules permitting, this can be addressed with aerodynamics: adding a preponderance of downforce at the rear of the car.

CONTACT

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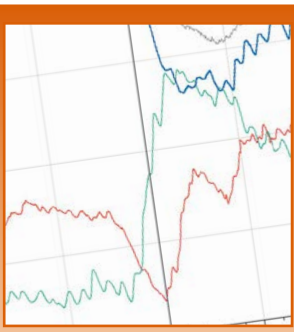


Databytes gives you essential insights to help you to improve your data analysis skills each month, as Cosworth's electronics engineers share tips and tweaks learned from years of experience with data systems

Trace engineering for race engineers

Data logging is now commonplace at all levels of motorsport but to get the most out of it you need to know exactly how to read those traces

In the wake of the Le Mans 24 hour race, where reliability is the key, we thought that this month's instalment would be a good opportunity to look into the various ways in which data can be viewed, and what to look out for in that data.

Gone are the days when data logging functionality was reserved for the top level teams and race series; nowadays even club level racing and karting championships feature some quite comprehensive data logging systems. Yet even though data logging functionality is now fairly mainstream, many still struggle to interpret the endless squiggly lines and dots in order to analyse what is actually going on with the car. It's this ability to understand the information gathered and how it corresponds with the physics and mechanics of the car that makes a good data engineer.

There is no exact right or wrong way in how to actually lay out your combination of time-distance charts, X-Y plots, bit field indicators, etc. Pretty much every engineer has their own personal preference in how the data is presented. This could simply be down to the different colours of the traces, or could extend further to completely different layouts, or to what information is displayed on what chart.

But the key question you must ask yourself is: what is this data actually telling me? **Figure 1** is an

Gone are the days when data logging functionality was reserved for the top teams, nowadays even club racers and karters use it

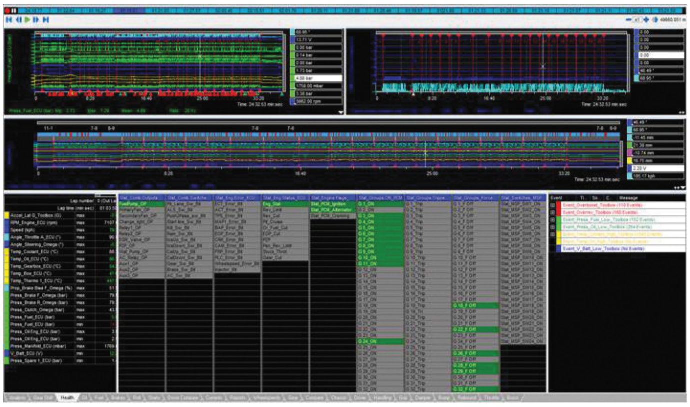


Figure 1: A typical data display page used to check the health of a racecar

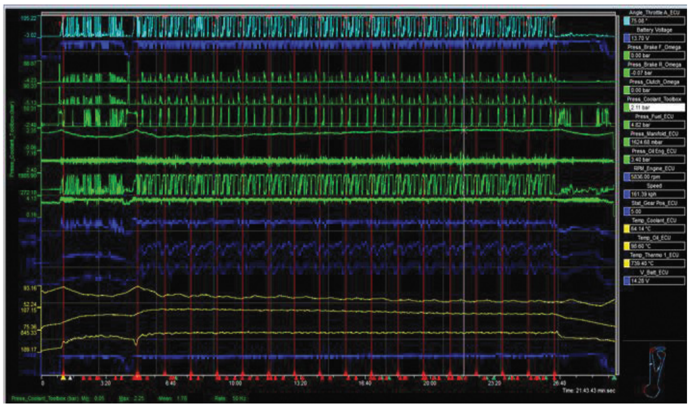


Figure 2: This shows the temperature, pressure and other key parameters

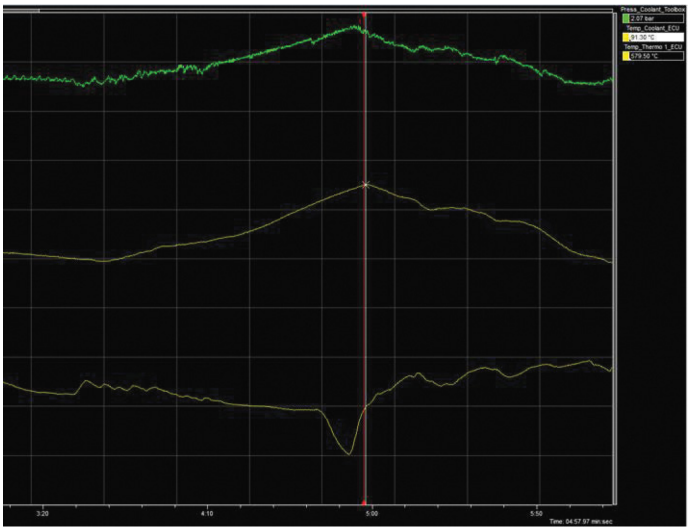


Figure 3: Car health data should always be measured in the time domain first

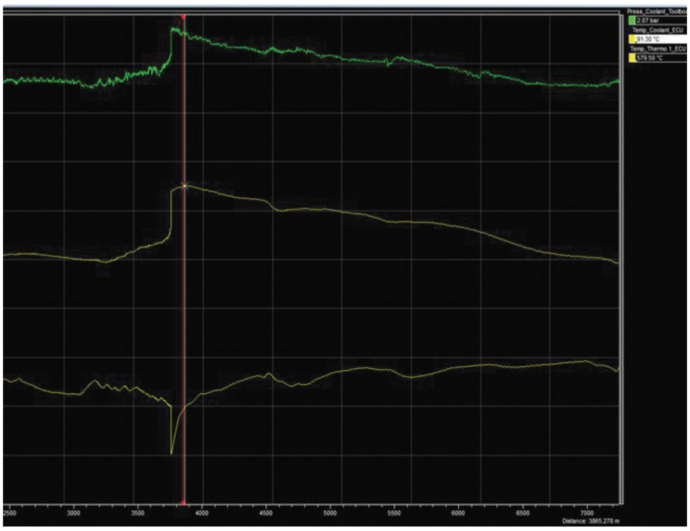


Figure 4: Sometimes the racecar might be running but not actually moving

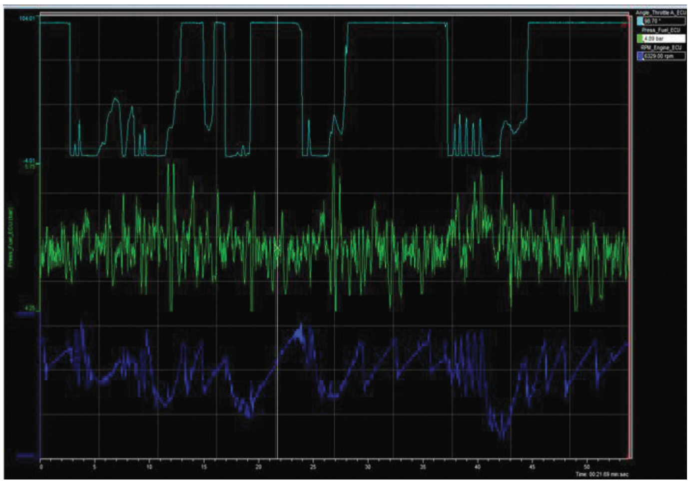


Figure 5: The fuel pressure is sealed for the normal operating range of 4.5 to 5.5bar

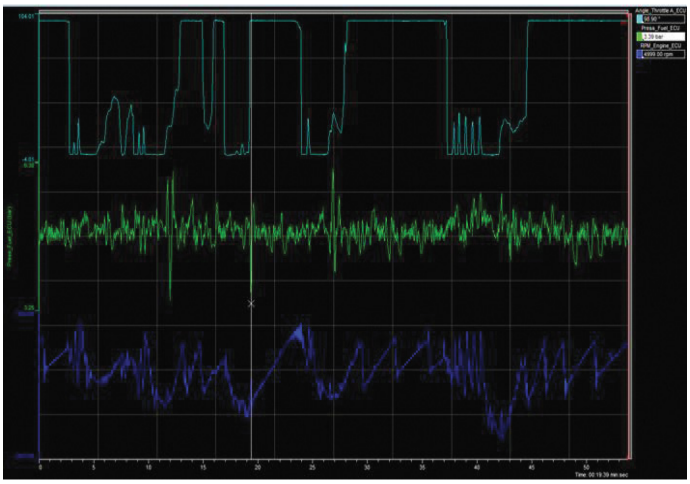
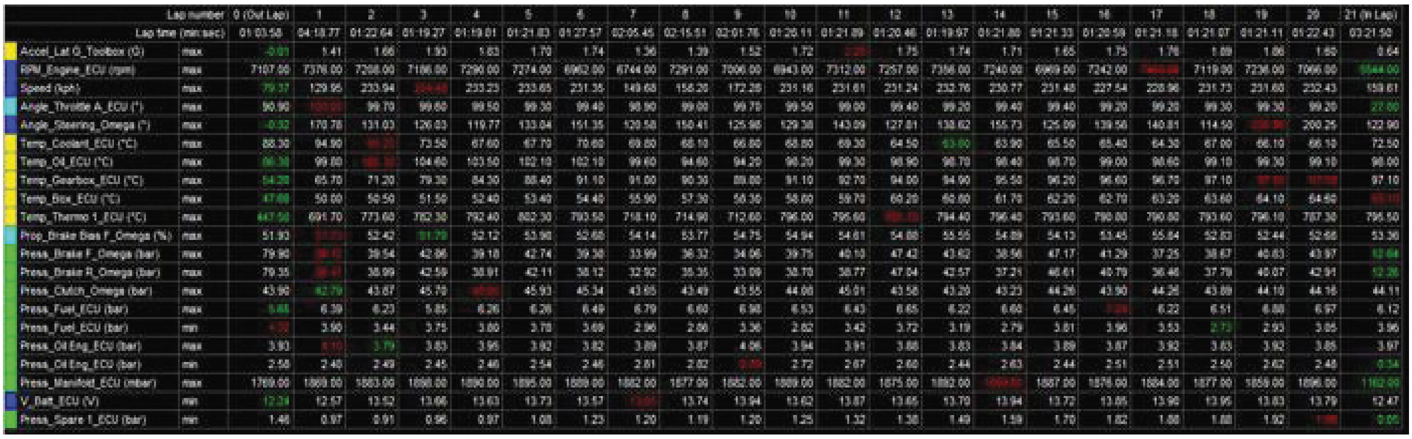


Figure 6: The autoscaled trace clearly shows the true extent of pressure spikes



Lap number		0 (Out Lap)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21 (In Lap)
Lap time (min:sec)		01:03.58	04:18.77	01:22.64	01:19.27	01:19.01	01:21.83	01:27.57	02:05.45	02:15.51	02:01.76	01:26.11	01:21.89	01:20.46	01:19.97	01:21.80	01:21.33	01:20.59	01:21.18	01:21.07	01:21.11	01:22.43	03:21.50
Accel_Lat G_Toolbox (G)	max	-0.01	1.41	1.66	1.93	1.83	1.70	1.74	1.36	1.39	1.52	1.72	[illegible]	1.75	1.74	1.71	1.65	1.75	1.76	1.09	1.86	1.60	0.64
RPM_Engine_ECU (rpm)	max	7107.00	7376.00	7208.00	7186.00	7290.00	7274.00	6962.00	6744.00	7291.00	7006.00	6943.00	7312.00	7257.00	7356.00	7240.00	6969.00	7242.00	[illegible]	7119.00	7236.00	7066.00	5544.00
Speed (kph)	max	79.37	129.95	233.94	[illegible]	233.23	233.65	231.35	149.68	156.20	172.28	231.16	231.61	231.24	232.76	230.77	231.48	227.54	228.96	231.73	231.60	232.43	159.61
Angle_Throttle A_ECU (°)	max	90.90	[illegible]	99.70	99.60	99.50	99.30	99.40	98.90	99.00	99.70	99.50	99.00	99.40	99.20	99.40	99.40	99.20	99.20	99.30	99.30	99.20	27.00
Angle_Steering_Omega (°)	max	-0.32	170.78	131.03	126.03	119.77	133.04	151.35	120.58	150.41	125.98	129.38	143.09	127.81	138.62	155.73	125.09	139.56	140.81	114.50	[illegible]	200.25	122.90
Temp_Coolant_ECU (°C)	max	88.30	94.90	[illegible]	73.50	67.60	67.70	70.60	69.60	68.10	66.80	68.80	69.30	64.50	63.60	63.90	65.50	65.40	64.30	67.00	66.10	66.10	72.50
Temp_Oil_ECU (°C)	max	86.30	99.80	[illegible]	104.60	103.50	102.10	102.10	99.60	94.60	94.20	98.20	99.30	98.90	98.70	98.40	98.70	99.00	98.60	99.10	99.30	99.10	98.00
Temp_Gearbox_ECU (°C)	max	54.20	65.70	71.20	79.30	84.30	88.40	91.10	91.00	90.30	89.80	91.10	92.70	94.00	94.90	95.50	96.20	96.60	96.70	97.10	[illegible]	[illegible]	97.10
Temp_Box_ECU (°C)	max	47.60	50.00	50.50	51.50	52.40	53.40	54.40	55.90	57.30	58.30	58.60	59.70	60.20	60.60	61.70	62.20	62.70	63.20	63.60	64.10	64.60	[illegible]
Temp_Thermo 1_ECU (°C)	max	447.50	691.70	773.60	782.30	792.40	802.30	793.50	718.10	714.90	712.60	796.00	795.60	[illegible]	794.40	796.40	793.60	790.00	790.60	793.60	796.10	787.30	795.50
Prop_Brake Bias F_Omega (%)	max	51.93	[illegible]	52.42	[illegible]	52.12	53.98	52.68	54.14	53.77	54.75	54.94	54.61	54.08	55.55	54.89	54.13	53.45	55.84	52.83	52.44	52.68	53.36
Press_Brake F_Omega (bar)	max	79.90	[illegible]	39.54	42.86	39.18	42.74	39.38	33.99	36.32	34.06	39.75	40.10	47.42	43.62	38.56	47.17	41.29	37.25	38.67	40.63	43.97	[illegible]
Press_Brake R_Omega (bar)	max	79.35	[illegible]	38.99	42.59	38.91	42.11	38.12	32.92	35.35	33.09	38.70	38.77	47.04	42.57	37.21	46.61	40.79	38.46	37.79	40.07	42.91	[illegible]
Press_Clutch_Omega (bar)	max	43.90	[illegible]	43.67	45.70	[illegible]	45.93	45.34	43.65	43.49	43.55	44.08	45.01	43.58	43.29	43.23	44.26	43.90	44.26	43.89	44.10	44.16	44.11
Press_Fuel_ECU (bar)	max	[illegible]	6.39	6.23	5.85	6.26	6.26	6.49	6.79	6.60	6.90	6.53	6.43	6.65	6.22	6.60	6.45	[illegible]	6.22	6.51	6.88	6.97	6.12
Press_Fuel_ECU (bar)	min	[illegible]	3.90	3.44	3.75	3.80	3.70	3.69	2.96	2.06	3.36	2.62	3.42	3.72	3.19	2.79	3.81	3.96	3.53	[illegible]	2.93	3.05	3.96
Press_Oil Eng_ECU (bar)	max	3.93	[illegible]	[illegible]	3.83	3.95	3.92	3.82	3.89	3.87	4.06	3.94	3.91	3.88	3.83	3.84	3.89	3.87	3.92	3.83	3.92	3.85	3.97
Press_Oil Eng_ECU (bar)	min	2.58	2.40	2.49	2.45	2.46	2.54	2.46	2.81	2.82	[illegible]	2.72	2.67	2.60	2.44	2.63	2.44	2.51	2.51	2.50	2.62	2.48	[illegible]
Press_Manifold_ECU (mbar)	max	1769.00	1869.00	1883.00	1898.00	1890.00	1895.00	1889.00	1882.00	1877.00	1882.00	1889.00	1882.00	1875.00	1882.00	[illegible]	1887.00	1876.00	1884.00	1877.00	1859.00	1896.00	[illegible]
V_Batt_ECU (V)	min	12.34	12.57	13.52	13.66	13.63	13.73	13.57	[illegible]	13.74	13.94	13.62	13.87	13.85	13.70	13.94	13.72	13.85	13.90	13.95	13.83	13.79	12.47
Press_Spare 1_ECU (bar)	min	1.46	0.97	0.91	0.96	0.97	1.08	1.23	1.20	1.19	1.20	1.25	1.32	1.38	1.49	1.59	1.70	1.82	1.88	1.88	1.92	[illegible]	0.05

Figure 7: Outing reports can provide a quick snapshot of the maximum and minimums to identify any particular laps of concern which can then be analysed more thoroughly

example of a display page used to check the health of a car. This is the first thing to check in the data. This engineer uses a black background as opposed to a traditional white with contrasting colours, to easily see the traces. It mostly consists of a series of time-distance charts and bit field displays, coupled with an event report and lap report. It is quite data intensive, with a lot displayed, but this allows the engineer who uses this chart to obtain a detailed overview of the key parameters that can cause problems with the racecar.

Bottom line

Expanding the main time-distance across the top, then **Figure 2** shows the temperatures, pressures and other key parameters of the car: coolant, oil, battery voltage, etc. The colours have been configured so the pressure's in green and the temperature's in yellow.

For car health, data should always be analysed initially in the time domain across the bottom as opposed to distance (**Figure 3**). The reason for this is that there may be times where the car is running but not actually moving and therefore you can often miss important information, such as during a race start. This can be seen in **Figure 4**. In the distance domain it appears that the temperatures all of a sudden increase, which could be mistaken for a problem, whereas actually in the time domain it is clear that they increase steadily as the vehicle is stationary on the starting grid.

Similarly, when checking car health, you should always set traces to autoscale rather than fixed limits. Although having fixed limits provides increased resolution during normal operating conditions, if you are not careful if can be easy to miss important information.

Autoscaled traces

Figure 5 has the fuel pressure scaled for the normal operating range of 4.5 to 5.5bar, but in **Figure 6** it is set to autoscale. The autoscaled trace shows clearly the true extent of the fuel pressure spikes with a dropout down to 3.39bar.

On top of all this outing reports (**Figure 7**) can also be useful to provide a quick snapshot of the maximum and minimums over the outing to identify any particular laps of concern which can then be analysed more thoroughly.

Car health data should always be analysed initially in the time domain across the bottom as opposed to distance, as there may be times when the car is running but not actually moving

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Spire Sports Cars aero examination

How will a high wing and dive planes affect the Bikesports car?

This month we conclude our studies on the Spire Sports Cars RGB and Bikesports racecars, both very successful representatives of the bike-engined sports racing genre in the UK, built to run to the 750MC's technical regulations, but competitive in other sports racing and open categories too.

To briefly recap on what we have seen in the past two issues, **Table 1** shows the basic aerodynamic numbers for the best balanced set-ups we found on the two cars during our all too brief half-day session in the MIRA full-scale wind tunnel. Last month we concentrated on the balancing act on the RGB car, which saw reasonably well-balanced set-ups at two levels of downforce achieved. This month we are going to focus principally on the higher downforce Bikesports car.

Bikesports regulations are refreshingly free on aerodynamics, only limiting rear wing span (to full car width) and ground clearance to the UK Motor Sport Association's catch-all 40mm minimum. Hence, the Spire Bikesports car achieved very respectable aerodynamic performance, as shown in **Table 1**, with results on a par with the lower end of the balanced downforce levels found on the highly developed Ligier JS49 CN car we tested in 2008.

The Spire Bikesports featured the low rear wing location favoured by a number of successful sports racing cars around the world (a topic studied in some depth in our December 2014 issue, V24N12). The car also had a good balance and decent downforce (at the same drag level as the RGB car). However, the first modification was to mount the rear wing 200mm higher to gauge response and explore potential higher downforce options. **Table 2** summarises the results, with 'Δ' or delta values showing the changes in counts, 1 count = a coefficient change of 0.001. The results fitted the expected pattern; rear downforce increased quite significantly as the rear wing was moved into more energetic air, but front downforce decreased, the result no doubt of the extra mechanical leverage from a better performing overhung rear wing, but also the reduced interaction of the wing on the underbody's downforce contribution. Interestingly, drag decreased very slightly, leading to a sizeable efficiency increase. However, balance shifted off the front, so the next modification was at the front end to try to recover a balance.

Dive planes

We have seen on several occasions in our wind tunnel studies that large, steep dive planes can be potent balance adjusters, but they are not usually very efficient. This was the case with the dive planes that Spire brought along, as the results in **Table 3** show. There was a fairly significant increase in front end downforce, but a loss at the rear end. And the drag increment was significant too, with 47 counts of drag for 76 counts of overall downforce gain, not an efficient ratio. Nevertheless, overall efficiency level was higher than the baseline configuration, and the balance was quite reasonable at just under 43 per cent front. So

Table 1 – Balanced aerodynamic configurations on the Spire RGB and Spire Bikesports cars

	CD	-CL	%front	-L/D
Spire RGB	0.568	0.886	44.24%	1.560
Spire Bikesports	0.565	1.399	43.85%	2.476

Rear downforce increased quite significantly as the rear wing was moved into more energetic air

Table 2 – The effects of raising the rear wing 200mm

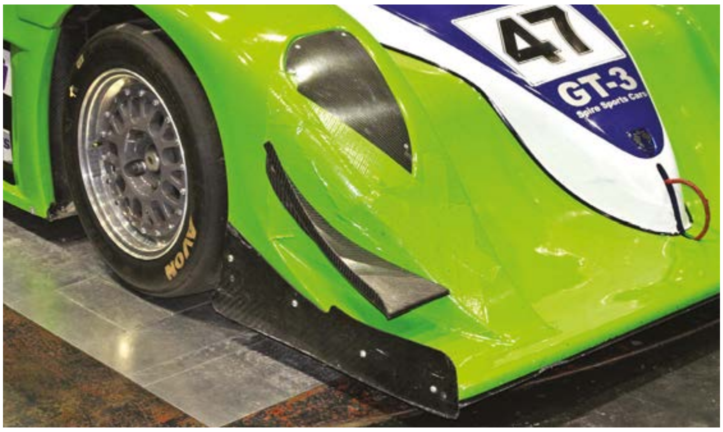
	CD	-CL	-CLfront	-CLrear	%front	-L/D
Baseline	0.565	1.339	0.613	0.786	43.8%	2.476
Rear wing raised 200mm	0.558	1.481	0.550	0.931	37.1%	2.654
Δ values	-7	+82	-63	+145	-6.7%	+178

Table 3 – The effect of dive planes

	CD	-CL	-CLfront	-CLrear	%front	-L/D
With high rear wing	0.558	1.481	0.550	0.931	37.1%	2.654
Plus dive planes	0.605	1.557	0.663	0.894	42.6%	2.574
Δ values	+47	+76	+113	-37	+5.5%	-80

The Spire Bikesports car was balanced and effective as delivered to the wind tunnel

To begin with the rear wing was raised by 200mm to explore higher downforce potential



These dive planes produced an increase in downforce at the front and a loss at the rear

The rear infill panels produced a surprising drag reduction on the Bikesports racecar

The more aerodynamically basic RGB car had a longer tail than its sister Bikesports racer

RGB infill panels produced a larger downforce change compared to the Bikesports car

Table 4 – The effects of rear infill panels on the Bikesports car

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Δ values with side panels	-4	+19	-9	+27	-1.1%	+48

Table 5 – The effects of rear infill panels on the RGB car

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Δ values with side panels	+6	+37	-9	+45	-2.7%	+48

this higher drag configuration of high-mounted rear wing plus front dive planes might be worth considering as a wet weather option, or for those race tracks that demand maximum downforce and are less drag-critical.

Rear infill panels

The sides of the rear wheel arches behind the rear wheels of both the Bikesports and RGB Spires were tapered when viewed from above, as is often the case on sports racers, the intent being to reduce the size of the wake and, hence, reduce drag. What, then, would be the effect of affixing flat panels over these areas to mask off the tapered section? The results on the Bikesports car are shown as Δ values in **Table 4**. In this instance drag reduced when the side panels were installed, the opposite result to that which was expected. There was also a small increase in rear downforce and what was probably a 'mechanical' loss of downforce on the front wheels arising from the cantilever effect of the increase in rear downforce.

Before attempting to explain these results, let's look at the results of the same modification on the RGB car, as shown in **Table 5**. In this case drag did increase when the side panels were installed, albeit very slightly, but at least this met expectations. Interestingly, in other respects the results fitted the same pattern as they did on the Bikesports car, although the increment of additional rear downforce was somewhat greater on the RGB car.

The drag increase on the RGB car arising from fitting the rear infill panels is relatively straightforward to explain, assuming the initial premise for the top-view taper at the rear is correct, of course. That is, the base area of the car was slightly bigger with the panels installed, so the wake was slightly bigger, and hence drag was slightly higher. In other words, tapering the rear of the rear arches in top view did indeed result in slightly lower drag.

In the case of the Bikesports car, the drag decrease arising from fitting the infill panels would perhaps have come from the effective vertical extension to the rear wing end plate, which would have delayed the formation of the lower wing tip vortex and lessened the overall vortex drag created by the wing.

The reason for the gains in rear downforce on both cars is also probably tied to the base area increase, in that if base area pressure decreased in both cases, then this would have reduced the pressure under the rear floor of both cars, causing a rear downforce increase. The Bikesports car's rear overhang was shorter than the RGB car's, which might explain the smaller increment of extra rear downforce .

It's also interesting to note that despite the intrinsic drag increase that the infill panels brought (notwithstanding the rear end plate interaction that we saw on the Bikesports racecar) the car's overall efficiency was better with them in place rather than with the designed tapered rear end.

Racecar's thanks to Paul Nightingale, Tim Gray, Sam Johnson and James Kmieciak

CONTACT

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

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Ace in the pack

NASCAR's quest to improve its racing through aero development continues – here one of its R&D boffins explains how it's now working on apex speeds in the Cup and bump drafting in Xfinity

By ERIC JACUZZI

In our last article we looked at how the X-3 test programme was investigating the effects of downforce and side force on a NASCAR Sprint Cup (NSCS) car (see *RE* V26N1). Over the off season the NASCAR R&D Team in North Carolina then got busy on working on two major developments impacting both the Sprint Cup and the lower tier NASCAR Xfinity Series (NXS). Both explore what makes the cars race together well in two very different conditions – one in the max handling conditions of an intermediate oval, the other in the unique slipstream conditions at the superspeedways of Daytona and Talladega.

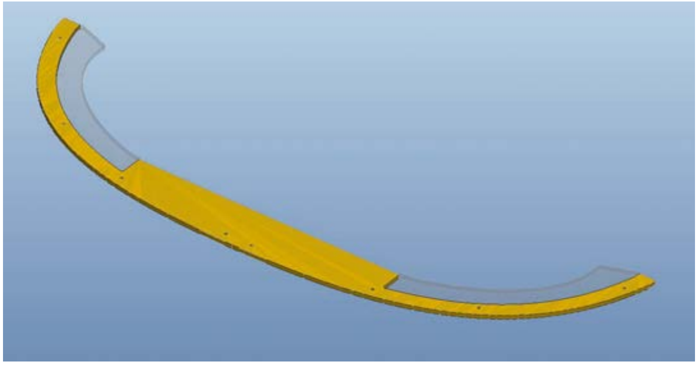
For 2016, NASCAR embarked on a path to lower aerodynamic reliance in the series and place greater emphasis on tyre and mechanical grip. A 25 per cent reduction in downforce for the 2016 season along with revised Goodyear tyres has led to a great start to the season, with closer finishes and increased passing throughout the field. But, in the spirit of continued innovation, NASCAR has been investigating furthering the reduction in aero forces in an effort to improve the racing even further. All this based on feedback from the drivers, teams and NASCAR.

With the newer, higher grip, tyres developed by Goodyear, tyre degradation has been increased at the vast majority of tracks. However, the increased grip of the new tyres has led to corner entry and apex speeds remaining mostly similar to last season. Based on input from the NASCAR Drivers' Council, it was suggested that drivers would like to see a slower speed at apex to facilitate more side by side racing and opportunities for mistakes under braking and corner entry. A target emerged of a 10mph reduction in apex speeds. Prior to implementing for the 2017 season, NASCAR again decided to use the approach of testing during race events in the current season to get the best possible indication on the package in a race environment. Michigan and Kentucky were selected as tracks to test the new aero package on.

The story so far

Before all this, NASCAR had previously explored the fundamental aero forces that impact the cars using CFD and track testing. We learned that the cars are very sensitive and reliant upon rear side force, which is the rear lateral force pushing the tail of the car toward the centre of the track due to the body design and offset of the spoiler. This creates a large, stabilising yaw moment on the car that drivers rely on. We established that aerodynamic side force had six times the effect, pound for pound, when compared to downforce. The CFD studies indicated that both forces were highly variable in traffic situations. With the success of the reduced downforce package so far this season, it seemed natural to explore whether even an further reduction in these parameters would improve racing in a measurable way.

Development of the new rules package was achieved through a NASCAR/team aerodynamics technical group, consisting of three team aerodynamicists and NASCAR's



Experimental splitter's been reduced to 2in at outer edges. Outline shows 2016 version

The Michigan/Kentucky development spoiler has been reduced in both width and height

aerodynamics team. Rather than setting an initial aero target, the group used the 10mph apex speed reduction based on feedback from the Drivers' Council and then worked through the aero force reduction required to achieve this. The results indicated that for a 500lb/f reduction in downforce approximately 125lb/f reduction in side force would be required. From our testing experience, the downforce reduction accounts for around a half second, while the side force reduction is 0.3 seconds. So on tracks greater than 1.5 miles, the expected lap time increase is anywhere from 0.5 to 0.8 seconds *vs* the current 2016 aerodynamics package. Around 100 CFD runs were performed in a week by NASCAR R&D to achieve these targets.

The Michigan/Kentucky aero packages consist of a splitter that has been reduced to 2in at the outer edges, mimicking the shape of the X-3 splitter, shown in comparison to the 2016 splitter in the picture top right. The radiator pan was kept the same width, at 33in, to avoid teams needing to modify their front chassis structures to accommodate a narrower pan. The spoiler is the most obvious of the changes visually, reduced in both width and height to 53in wide (the same as Daytona and Talladega) and standing at a modest 2.5in tall.

Aero balance was not impacted by the new package, and after validating the downforce and side force deltas at the Windshear wind tunnel, the package was tested on track by four NASCAR teams at Michigan International Speedway.

An interesting side effect of the small spoiler is the enormous reduction in drag. One car achieved a top speed of 217mph in the cool conditions, while seeing an 11mph reduction in apex speed compared to the current 2016 package. But speeds at the race should be more reasonable, as the warmer temperatures will reduce tyre grip.

All-star test

The annual Charlotte Motor Speedway All-Star Race is a non-points paying race with a grand prize of $1m to the winner. It features interesting format changes and pit stop requirements outside of the norm for the Sprint Cup Series. It also presented a great opportunity to tip toe into the theories on downforce and side force reduction. It was decided to eliminate extraneous electric cooling fans from the cars and mandate neutral rear toe on the cars for this event.

Since the under-hood region is a continuous volume open to the ground below, minor differences in pressure can result in a sizable increase in downforce. As brake cooling fans evolved and became more powerful, they began to be used by clever team aerodynamicists to manipulate airflow around the wheel openings to lower under-hood pressure. This was obviously the intent of the many fans, as they were often disconnected completely from an incoming air source, or were clearly being used to develop circulation under the hood outside of any cooling requirement. Needless to say, the fans were becoming a big expense for teams, and an easy target for reducing downforce. Estimates put the fans contribution to total downforce at something around three to five per cent. This rule was instituted at the All-Star Race, but continues for the remainder of the 2016 season.

Surprisingly, the elimination of rear toe is also an aero related regulation change. Since we turn left on ovals, teams were permitted a certain amount of toe on the left and right rear wheels, leading to an asymmetric set-up (one of many asymmetric parameters). This means the left rear would be toed inward, with the right rear toed outward. This in effect steers the rear axle, allowing the body of the car to attain a higher yaw angle when cornering. This presents the

We learnt that the cars are sensitive, and reliant upon rear side force

Gen 6 NASCAR Sprint Cup Cars at Talladega where superspeedway rules can lead to pack racing. The aerodynamically optimal 0.75 to one car length separation is apparent

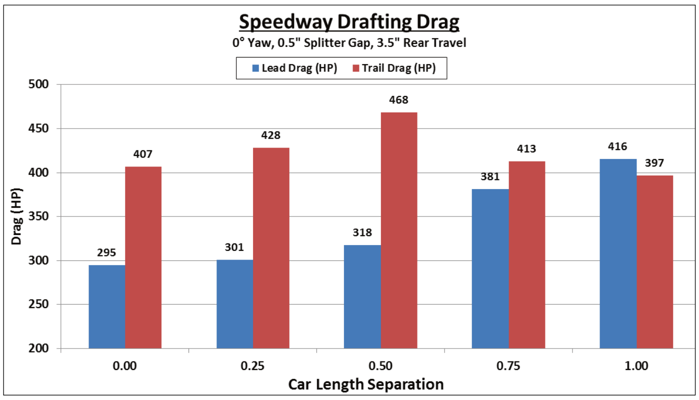


Figure 1: NSCS Superspeedway drag on each car from zero to one length of separation

The current breed of NASCAR Xfinity Series racecars in classic tandem or 'bump' drafts

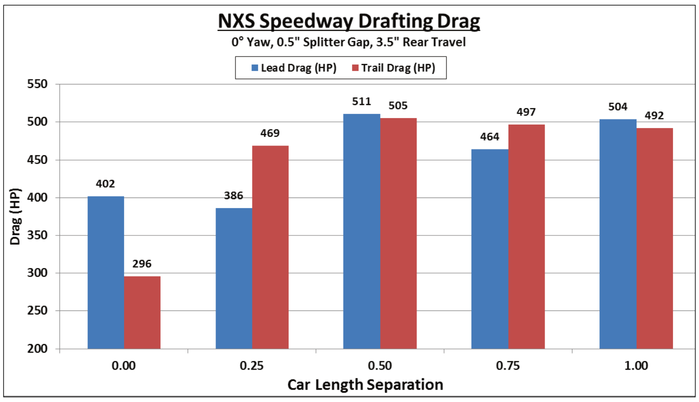


Figure 2: NXS Superspeedway drag on each racecar from zero to one car length of separation. The drag inversion in the nose to tail configuration is simply staggering

substantial side area of the body to the incoming flow, generating a large amount of front and rear side force.

Increasing the yaw angle of the body allows the car to develop more lateral force, leading to much higher corner and apex speeds, since the driver can run a much larger arc into the corner. This makes the car faster alone, but as we have learned from CFD and testing with the X-3 test car, side force is highly variable in traffic conditions. The sensitivity of rear side force was learned to be six times as great as that of downforce, so a 17lb loss in rear side force has the same effect as losing 100lbs of rear downforce! Simulations indicate side force swings that are in the hundreds of pounds in traffic.

The loss of rear toe was estimated to reduce body yaw by a half of a degree, resulting in a side force reduction of approximately 55 pounds. The additional loss of side force for the new rules package was achieved via the smaller and narrower spoiler, contributing another 30 to 40lbs of rear side force reduction.

The All-Star Race ran on May 21 and featured great side by side racing action, including the first pass for the lead in the final laps in many years. A week later, the Coca Cola 600 ran on the same track, in roughly the same environmental conditions. The only difference was the restoration of normal toe rules. The race saw the winner lead the most laps in NASCAR history, with 388 of 400 laps led. It is too soon to know how much of an impact the regulation differences had on the race outcome, or whether it was due to the varied race format, but it appears that less reliance on downforce and side force is correct.

Superspeedways

Changing gear from the limit-grip handling conditions of intermediate tracks, we turn to the superspeedways of Daytona and Talladega. Daytona International Speedway and Talladega Superspeedway are two iconic and unique NASCAR tracks, both requiring a special superspeedway rules package. At 2.5 miles in length and with banking in excess of 30 degrees, the speeds would be simply too high for stock cars to race safely using the normal regulations. The crucial component of the package is limiting the horsepower to something just north of 400bhp. The limited horsepower leads to large packs of cars traveling near 200mph for lap after lap, mere feet from each other. Teams do everything in their power to build cars with as low drag as possible, since the cars are at terminal velocity for the entire lap.

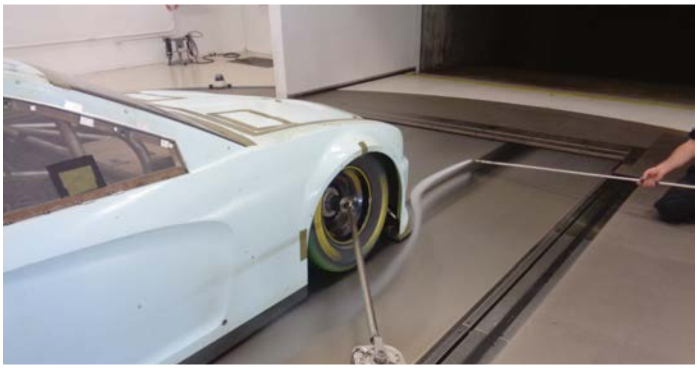
A 17lb loss in rear side force has the same effect as losing 100lbs of rear downforce!

The slipstream effect means a group of cars is certainly faster than a single car, which can be observed in lap speed differences between qualifying and the race. Typically, NSCS cars are approximately 3-4mph faster in the pack than they are in single car qualifying. However, the Xfinity Series and Truck Series are both in the order of 10 to 15mph faster in a pack than they are alone.

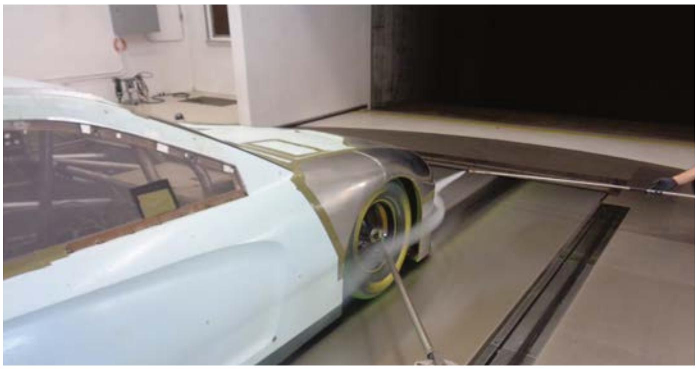
There is an even more intriguing phenomenon in the Xfinity Series and also in the Sprint Cup series prior to the Generation 6 car (introduced in 2013); bump, or tandem drafting. According to lunch room discussions at the R&D Centre, the first time tandem drafting was observed on track was at the 2009 Talladega Aaron's 499. In the final laps, a two-car tandem of Carl Edwards was pushed by Brad Keselowski in a tandem draft configuration to pass Ryan Newman for the lead of the race. The difference in speed between the tandem cars and the other cars is striking to observe in the old footage – they pass the other cars like they're standing still. Then the more sinister side of the bump draft occurred near the finish line, with the massive airborne crash of Edwards as he was spun by his pushing partner Keselowski. Luckily, Edwards was unhurt in the incident, but the dangers created by tandem drafting were becoming evident.

However, tandem drafting was here to stay until NASCAR introduced the updated body style of the Gen 6 car, which seemed to prefer a three-quarter car length spacing when in a slipstream. Contrast the photos on the top left of this page showing this spacing arrangement, and two tandems in the Xfinity Series. The former Sprint Cup Gen 5 body style was very similar to the current Xfinity Series body, and both exhibited the same behaviour in this situation. NASCAR has attempted to curtail the


Windshear
Windshear
180 MPH WITHOUT MOVING AN INCH



Xfinity cars have highly flared wheel openings. Note the flow of the smoke over the flare



Compare the top pic with the flow visualisation over a smoother wheel opening (above)

A 42 probe door-mounted Kiel testing array was fashioned for each side of the racecar

tandem drafting practice in the Xfinity Series by policing it from race control. The issue is of course that it is an impossible task to deal with policing the entire field of 40 cars when the race is drawing to a close, as Xfinity Series director Wayne Auton has informed us on many occasions.

Several explanations for the tandem draft were offered in the media and among the industry, with several popular misconceptions remaining today. One common misconception is that when the cars touch each other, the drag of the combined cars precipitously drops. By this logic, we should see that two NXS cars together have lower drag than two NSCS cars nose to tail, since the Sprint Cup cars cannot tandem draft. This is untrue, as we'll explore later from our CFD results. In fact, between the NXS cars which can bump draft and the NSCS cars that cannot, there is no appreciable difference in the total drag between either two-car train. Drag for the two-car unit is around 700 drag HP at 200mph.

While it is true that the nose to tail arrangement is the lowest drag arrangement for the two cars, the hallmark of a tandem draft is that the trailing car is actually pushing the lead car – not that they simply maintain a nose to tail position and are faster. If it was mutually beneficial to be in this arrangement, you would expect that the two drivers would

Surprisingly, the elimination of rear toe is also an aerodynamics related regulation change

have to work to maintain the spacing, but that is not the case. Once the trailing car is engaged and pushing, the lead car is simply along for the ride. Unfortunately, this is the fastest arrangement for any car on the track to be in, necessitating its continued use by drivers in spite of the dangers.

We've thus outlined the behaviour and established the trailing car is definitely pushing the lead car, and together both cars are faster than a car alone or in any other drafting configuration. The only remaining answer is that the aerodynamic drag on the trailing car is so low in this position, that pushing a 3400lb stock car around in front of it is favourable to drafting alone. Thanks to CFD, we are able to investigate this idea and compare between the two racing series and see what's revealed.

A series of CFD runs were performed in the superspeedway rules configuration for each series. Five runs were performed, with the spacing between the lead and trail car ranging from nose to tail to one car length for the fifth run. The Sprint Cup series results are shown in **Figure 1**, corresponding well with what we observe during races. At one car length of separation, the trailing car has a slight drag advantage, and thus would move closer to the car in front since the cars are essentially traveling at terminal velocity on a superspeedway. However, as the trail car approached three-quarter car lengths, it begins to reduce the drag on the lead car. From a half car length onwards, the drag on the trail car remains high while the leading car's drag continues to drop. The trail car is pushing the lead car away from it.

The Xfinity results in **Figure 2** show a similar trend from a half to one car length of spacing, but the anomaly of tandem drafting is apparent in the nose to tail configuration. Drivers have described that they require the lead driver to drag his brake until they can make contact – the lead driver has to slow his car to overcome the quarter car length drag difference between the two. However, once they have done this and are in the nose to tail configuration, the trailing car sees a drag reduction of over 170 drag horsepower (318lb/f)! The trail car is effectively driving *through* the car in front, and both see a major increase in speed because of this.

So we have great news – the CFD correlates to what we see out on the race track. The next step is determining what the aerodynamic flow structures are that are enabling this phenomenon. Finally, we must identify the design features of the car that are contributing to the problem and attempt to remedy them in the simplest, most cost-effective way.

Start at the front

I travelled to IMSA's Roar Before the 24 test in early January of this year. The purpose of the trip was twofold: the first was to check out the fantastic hardware on display in the prototype and GT classes, and the second was to meet with *Racecar Engineering* editor Andrew Cotton for the first time. One of the things I enjoy doing is trying to discern the aero philosophy of a car by observing the detailed bits visible to the public, without having any advance knowledge.

A striking thing I noticed about nearly every car in the paddock was how smooth the corners of the front fascia were in comparison to what I'm used to seeing in NASCAR, and how much rear bodywork detail they all featured. It was perplexing that so many fins and turning vanes at the tail were getting enough air to be effective, particularly in comparison to the muddled flow field of a stock car at that same point.

This thought stuck with me over the next few weeks, until I finally decided to investigate the effects of a smoother fascia on one of our cars. At the very least, it would be an informative exercise and give some basic insight into this effect. But before we dive into that, it might be helpful to explain how we ended up with the fascia shape that we have.

The homologation process for all three NASCAR series has been established to allow manufacturers to have brand identity in the front fascia, sides and rear of the car. There are certain areas that are common for all cars – the greenhouse and wheel openings being two examples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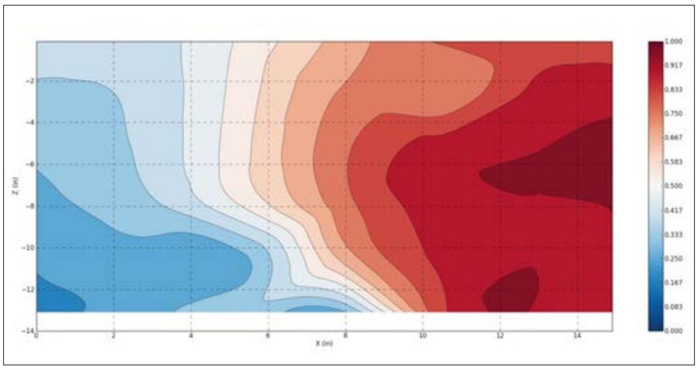


Figure 3: Pressure coefficient plots (Cp) indicate a substantial increase in flow alongside the car. Flared wheel opening is on the right side. The left side is the door of the racecar.

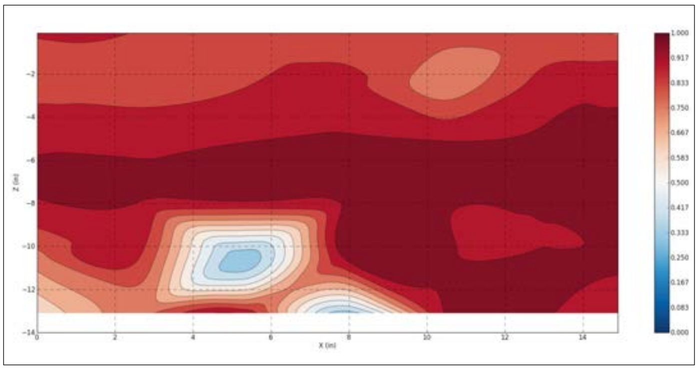
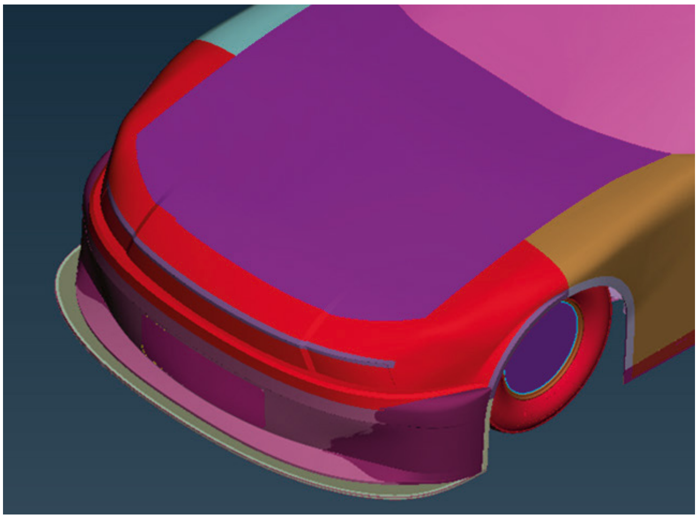


Figure 4: Cp plot of smooth fender flare; again with the left side being the door of the car

Figure 5: A CFD comparison of a flared fender opening with a smooth fender opening



NASCAR's final NXS fascia insert solution is shown in this CAD image in dark purple

of this in the Sprint Cup Series. In order to ensure parity, wind tunnel testing is performed using a test car that has removable fibre-glass body panels at Aerodyn Wind Tunnel. The test car is the benchmark and is used to calculate the targets for the new submission on the day of the test, since results measurements are done in a wind tunnel months or years apart at varying conditions etc.

So, on a particular day, the test car would be loaded into the wind tunnel and run through the submission ride height map. Average values are calculated for the downforce, drag and side force generated by the racecar, and those are used to establish the target thresholds. There is a lower limit on drag, and an upper limit on downforce and side force. The manufacturer installs its new body panels on to our car and the car is run through the ride height sequence several times. A passing test is based on the submitted body falling acceptably within the range for all three forces.

When the Generation 6 NASCAR Sprint Cup Series car was introduced, it was targeted at a downforce level of approximately 2500lb/f at 200mph, with a target aero balance near 50 per cent. Thus, the front width and wheel openings are based on achieving this downforce level. Drag was a secondary consideration and more of a consequence of the chosen design path. Wheel openings feature a pronounced wheel band and aggressive outward flare that adds substantial front downforce. These are even more dramatic with the Xfinity Series racecars.

The flaring of the wheel opening works intuitively – it essentially throws air outward from the car, creating a substantial low pressure region near the wheel opening. Since the wheel opening and under-hood region are connected, a small change in pressure under the hood can make a substantial change in total downforce due the surface area involved. In essence, the car's aerodynamic footprint is much larger than it actually is because of the front fascia shape. This is especially true of the NASCAR Xfinity Series and the Camping World Truck Series, where the front wheel openings protrude dramatically and they feature extremely blunt front fascia.

This effect is shown via a smoke wand with a highly flared wheel opening compared to a smooth front fender flare in the pictures on page 59. But while smoke wands offer good visuals at low speed, the real business of measuring the wake along the body sides was left to the Kiel probes. We fashioned a 42 probe array for each side, based on the region that showed the greatest change in CFD from the nose modifications. The pressure coefficient plots (Cp) indicate a substantial increase in flow alongside the car, exactly what we had hoped to see (note the results in **Figure 3** and **Figure 4**).

Draft dodging

But getting back to the issue at hand – why does one fascia shape lead to tandem drafting and one not? The answer is the downstream effects of this outward push of air and how it shields the trailing car. In essence, the nose of the car is ploughing a large trough of air for the trailing car, keeping its fascia hidden from the drag it would normally experience by having to move that same air mass. CFD illustrates the downstream effects quite dramatically, as can be seen in **Figure 5**. The white and red regions are higher energy air in the order of 40 to 50 per cent higher downstream with the smooth fascia compared to the flared fender opening.

The above is what needs to be addressed if we are to solve the problem. With this in mind, NASCAR R&D embarked on an extensive CFD programme to address the issue by designing fascia inserts that would rest on top of the current common areas of the Xfinity front fascia, while still maintaining the manufacturer's identity in areas they have designed character into. The lower half of the fascia is tightly mandated by NASCAR in the Xfinity Series, thus making this process much simpler. The finished product is shown above.

Accompanying this idea is a corresponding narrowing and reshaping of the rear spoiler, which also contributed to air not reaching the trailing car as effectively.

The NASCAR R&D team heads back to sunny Florida to visit Daytona International Speedway as our next test venue in July. The Xfinity series will race on a Friday night, with the Sprint Cup series on Saturday. The plan is to test these new developments on Sunday after both events and see if the bump draft behaviour can be eliminated as CFD has predicted. Three cars from the Friday night race will test the fascia inserts and various spoiler arrangements to see if this work correlates on track. The results in July will allow plenty of time to consider modifications to the Xfinity cars for next season.

In a tandem draft the trailing car is actually pushing the leading car

Automotive application, combination of Windform Additive Manufacturing and high-performing CNC Machining.
Courtesy of Ilmor Engineering

‘Two or three years ago we would not have expected to reach these levels, it was unthinkable, impossible, but now we are here’

Fire and ICE

Now that energy recovery systems have been largely optimised Formula 1 PU research has refocussed its efforts on the good old internal combustion engine. *Racecar* investigates

By SAM COLLINS

When Formula 1 announced it would adopt a new efficiency based engine rulebook, the idea was for the sport to become more relevant in terms of production car technology, especially hybridisation. But in the third season of the current rules things have panned out rather differently.

'At the early stages of the development of these power units all you would hear about was the energy recovery systems (ERS). That is because it was new, but now that has changed,' Remi Taffin, technical director (engines) at Renaultsport F1 says. 'With ERS we have kind of reached a maximum level and our focus is now on the ICE and we are talking about combustion a lot. There is now a pure physics challenge. We are fighting against mechanical limits rather than looking for the ideas.'

This re-focussing of attention can be seen across all four of the Formula 1 power unit manufacturers and has resulted in a series of technological breakthroughs in terms of engine development. In the quest for efficiency compression ratios have risen dramatically. 'What is amazing with Formula 1, you take the technologies and move them on faster than expected and in directions that you do not expect and that is the nature of Formula 1. It is the ability to put hundreds of engineers on one technology and develop it. This is true for the efficiency level. Two or three years ago we would not have expected to reach these levels, it was unthinkable, impossible, but now we are here, and we are entering a new cycle where we have to develop new technologies to cope with the ICE,' Taffin says.

While none of the manufacturers are willing to give exact numbers in terms of efficiency levels it is clear that all of them are between 45 per cent and 50 per cent. To achieve this the compression ratios have risen significantly to a level approaching 18:1, and in order to slow development the FIA has temporarily set a limit at that level in the hope of evening the field a bit. Fabrice Lom, the FIA's head of powertrain, said this limit was set at the level of the best in class currently, so it can probably be assumed that Mercedes at least has a compression ratio somewhere just below that level.

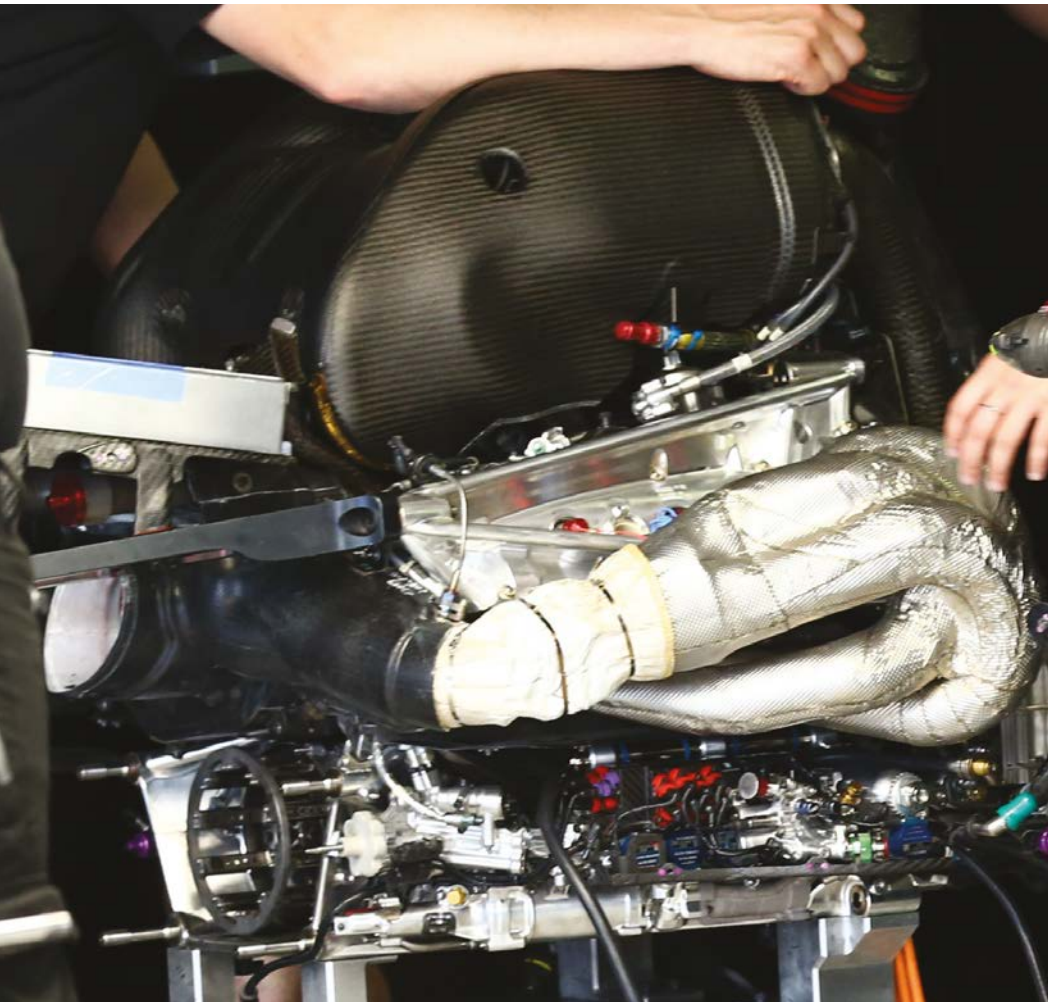
'In theory the higher the compression, the higher the potential efficiency but it also brings a risk of knock with it,' Yusuke Hasegawa of Honda R&D says. 'So the level set at 18:1 is high enough for us not to care about it for now.'

Taffin adds: 'If you look at 18:1 and look at the maximum cylinder pressure it's frightening, but that limit is not a restriction on us, we don't think we will reach that any time soon. I know what the constraints are, I look at the materials technologies I have around me and I don't think there is anything to cope with this for the next five or six years, but things are moving faster than I could ever have imagined.'

Fuel's paradise

Formula 1 clearly leads the world in this type of technological development, ahead of LMP1 despite the fact that the WEC technical regulations have far more freedom in terms of engine design and configuration. The reason for this is that the fuel used in WEC is common across all cars in all classes including GT (apart from diesel which is currently unique to Audi). As a result the intensity of research seen in F1, restricted to a single type of 1.6-litre V6 engine but allowing bespoke fuel development, is far greater. With that in mind it must be wondered what the potential for the current Porsche and Toyota engines used in LMP1 would be given bespoke fuel as used in Formula 1.

'There is still so much to look into in this area; looking at the fuel mixture, its ignition, that is all at the first order, but maybe there are second and third order things we have still to explore,' Taffin says. 'Fuels is such a complex study, it's about how you want your ICE working. We started by looking to reduce the knock sensitivity, then as we developed the combustion chamber we got a bit more freedom



The Mercedes Formula 1 power unit. It's believed that the British-based F1 engine maker is leading the way in combustion technology. There has been much more development in this area in F1 than in the WEC because the latter uses control fuels

to develop the fuel as we found you could be a bit less knock sensitive but get a bit more energy from the fuel; but it's a loop and you go round and round. Three years ago we did not develop the fuel in the same ways that we do now, I guess it's going to evolve or change more in the next two or three years.'

Friendly fire

Homogeneous Charge Compression Ignition (HCCI) was reported as being in use in F1 already by other publications earlier in the 2016 season, with great enthusiasm, but in reality none of the manufacturers have reached this level yet, and indeed they may not. 'We are heading to something in between SI and CI and that means the fuel we develop is different,' Shell's Jorg Landschoff says. 'I think HCCI is really a road car technology. I know some research is happening on this area but we have not been asked for a HCCI specific fuel for racing.'

That is not to say, however, that some techniques and some degree of compression ignition is not already happening, and some technologies such as Mahle's TJI (see *RE* V26N7) which are very similar to those used on diesel engines are already in use and have been for some time. 'It's clear to see that some of the tricks from a diesel engine we are trying to make work on a gasoline engine,' Taffin says. 'I guess it's going to evolve or change more in the next two or three years and if then we think the best thing to have is some level of compression ignition, then we will have to look there. We know already we could make it work, but it's working out what is the best compromise. We are on a learning curve, and it's about where you spend your effort and resource. But of course we have some people looking into these areas, but in general terms with these engines it is early days, especially when you consider it could end up working as a diesel engine.'

The most outspoken exponent of diesel engines in motor racing is Ulrich Baretzky of Audi Sport. His compression ignition engines have won Le Mans a number of times in the Audi R10, R15 and R18. 'It is interesting to see that Formula 1 has started to use pre-chamber ignition. This is very well known for diesel engines which have been working like that for decades, almost centuries,' he says. 'Now they have made it work for gasoline engines and this has allowed them, with a lot of ignition energy to manage, a very lean burn. This is combustion that you could not get with a spark plug as the energy is not enough and you would get knock. To avoid that you have the pre-chamber. Mercedes started that, and now the others are following, it may seem new but this is actually old technology; old does not mean bad though. It is going to be interesting to see how it will be applied now, going forward.'

Fire on the whole

When asked what is the next step in terms of the development of the current power units very few of the manufacturers really knew. But they all openly wonder just how far they can go in terms of efficiency and performance. 'We have not reached the end of the understanding with these engines,' Taffin says. 'With the V10 or the V8 we could write a book on it, but on the V6 we are not even halfway through. Each day you spend on these engines you are amazed, you are surprised by the numbers, and often you find yourself saying, "wow". That is where we are, there is still so much more to come. You have a certain type of combustion chamber, a compression ratio and a level of power which is being delivered from the maximum cylinder pressure. To go forward you develop your combustion, you get away from the knock, then you go back to physics and thermodynamics and you increase the compression ratio again, and you go back round that loop. But you have to think that all of those components: piston, crank, rods, block, head; they are all something that fights against it, and that is the whole thing, you have to develop them all.'

With rules stability confirmed in F1 until at least 2020 (aside from the lifting of the compression limit and component weight limits) the path of current power unit development will continue in the same direction for some time to come. 'If you look at the compression ratio, yes it's getting much closer to diesel,' Baretzky says. 'Because if you look at the diesel engine over the years it has always been the most efficient combustion process because the pressure is high, the fuel by its nature is totally knock resistant, regardless of the how high the compression is it will not knock. Maybe you lose efficiency because you have over-compressed it, but generally it allows you to go very much in advance with injection which means equal to ignition.

'And yes,' Baretzky adds, 'the gasoline guys are following, because the laws are the same for everybody. Temperature and pressure means efficiency – the higher the better.'

Combustion is very much the focus for now in Formula 1. But with the regulations now finally fixed for the coming years attention is now turning to the future.

In the quest for efficiency compression ratios have risen dramatically

Opportunity NOx

As motor racing searches for relevance in a green-tinged world the ACO has announced it's to introduce emissions limitations in LMP1. But does this really mark the start of a new era for the sport?

By SAM COLLINS

Shortly before the Le Mans 24 Hours the Automobile Club de l'Ouest (ACO) announced that in 2018 it would introduce some form of emissions limitation in the LMP1 category. In doing so the French organisation has taken the first steps down a road that many in the industry feel motorsport needs to take.

It should perhaps come as no surprise that emissions are now in the spotlight following the VW affair of 2015. With both F1 and LMP1 considering new power unit regs for 2020 or 2021, it seems highly likely that these rules will shift from the efficiency based formulas we have now, and emissions will play a major role, too.

The current efficiency gains made in the ongoing quest for ultimate performance are being made with little, if any, attention being paid to anything beyond how the car performs on track. As compression levels get higher and the air fuel mix gets leaner special fuels are being developed to cope with that, but all the while the emissions are overlooked.

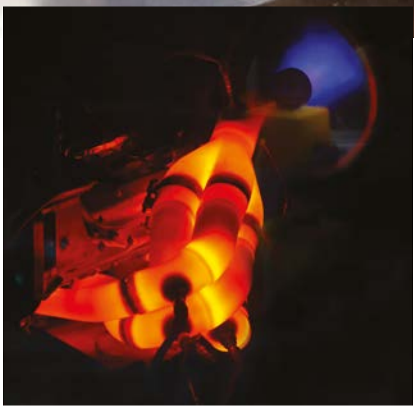
As Audi Sport's Ulrich Baretzky says: 'You have to ask the question first, what is efficiency? Well, at first it's the reduction of consumption compared to the power we are creating, but you also have to take care of the environmental things because this is what the world asks of us now. There are new laws in Europe that means that the fleet average must be below 95g/km CO2, I think motorsport could contribute a lot to that. With Formula 1 at the moment the gasoline used is not something that you could ever get at the petrol station. I think that is one of the negative things about Formula 1, because they are so far away from a normal pump fuel, so that brings into doubt whether this is a reasonable technological way to go.

'I don't know what the impact on emissions is, I'm not sure anyone knows,' Baretzky adds. 'But what we all know is that the higher the efficiency, the pressures and the boost and the temperature, the more you are producing nitrogen and other things which are now in the focus for being bad for our health.

'The question is, how big is the quantity we are producing? This is something we must be careful about in motorsport. We cannot just close our eyes and say let's have fun going in circles; instead we have to be the fastest,

'Motorsport cannot close its eyes and just have fun going in circles'

The Garage 56 experimental entry at Le Mans is just one of the ways the ACO encourages fresh approaches. WR's bio-methane car (above) will occupy the garage in 2017. It's powered by fuel made from human waste



Exhaust emissions might be the red hot issue at the moment, but some say that we need to take a more holistic approach when it comes to future rules

the most efficient, yes, but also we have to be the cleanest, too,' Baretzky says.

The ACO has also suggested that in future it envisions CO2 neutral motor racing, but there are some in the industry who voice caution about this focus and suggest perhaps a wider view needs to be taken. 'The thing about the word emissions is that there is very little understanding of what people are talking about,' says Wolfgang Warnecke, chief scientist for Mobility at Shell. 'I think, for sure, reducing CO2 must be a good thing. But emissions does not just mean CO2, it also means local air quality and this is often not taken into account fully, because quite often you end up with a conflict, a kind of balloon squeezing, where by reducing one you increase the other.'

This difference in definitions may not seem like something to really influence motorsport power unit development, but rather a subject you would find in the mainstream automotive industry press, but according to Warnecke its impact on racing could be profound. 'I well remember when in the USA they introduced three-way catalysts combined with unleaded fuel, but to get that catalyst fully working you need a stoichiometric air/fuel ratio all the time. On an engine without the catalyst you would run rich on part load and lean at full load. I moved from one Volkswagen Golf with no catalyst to one which had a three way catalyst and the air fuel ratio went immediately from 1.1 to 1, and that reduced my fuel economy by about 10 per cent, just for the benefit of clean tailpipe emissions. That is a very good example of how if you push one area of emissions you can have a detrimental effect on another area, like efficiency,' Warnecke says.

Racing green

While the ACO announced that the first emissions controls would begin in 2018 with an evolution toward carbon neutral or even carbon negative racing in the future – indications suggests it means by 2021 – Warnecke and others are calling for local emissions to also be included in the new regulations.

'The over-arching challenge is sustainability, and in short that is emissions, emissions, emissions,' Warnecke says. 'That mainly means greenhouse gas emissions (CO2 primarily), local emissions and noise. I think motorsport should follow that route and understand what we can do as an entire sport; the vehicle manufacturer, the tyre manufacturer, the fuel manufacturer, everything. We should all jointly deliver these improvements while still having good racing. Already there is a heavy focus on CO2 emission reduction and efficiency improvement but frankly speaking we need to look at local emission reduction, too. It is a problem motorsport will have to consider and be a leader in. It is not only Shanghai and Beijing with these air quality problems, there have been major issues in Paris and in London in the last six months, too. At the moment there is very little being done in that direction in motorsport.'

Pipe dreams

But, as the Volkswagen affair shows, emissions measurement is very tricky, and with the development of 'defeat devices' by major production car engineering teams one wonders about just how creative the rather less constrained motorsport engineering world could be in this respect. Indeed, it seems that currently there is no reliable way for motorsport emissions testing to be conducted.

'I don't know what the emissions from our LMP1 engines are like, because we are not equipped to measure that,' Baretzky admits. 'I'm always surprised when I read about how bad or good a car is in terms of emissions because while the emissions tests have a certain relevance, you need to do the testing under laboratory conditions to really measure them properly. The conditions must be really controlled so that you don't end up with incorrect results. I can't imagine that this is really possible at a race track. So now we have to find a way to calculate it, or to measure it, under laboratory conditions, and then to make an estimation, or a very good calculation, toward the situation you have on the race track. You need to see how it changes when the humidity

'With the way Formula 1 is at the moment the gasoline used is not something that you could ever get at the petrol station'

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‘Emissions does not just mean CO2, it also means local air quality, and this is very often not taken into account fully’

or temperature changes. It’s a big bit of work and it will take a lot of effort but we have to start one day with that. We cannot just say “no we won’t do that because it’s complicated or expensive”, we just have to do it.’

This focus on emissions highlights the perceived need for motorsport to be road relevant, and follow – or maybe even lead – the technical directions taken by the mainstream automotive industry.

‘I truly believe that we do motorsport for the track to road technology transfer,’ Warnecke says. ‘We believe that all of the industry together

In the World Endurance Championship both petrol and diesel is used, the latter by Audi alone. LMP1 will be the first major category to run with emissions limits from the 2018 season

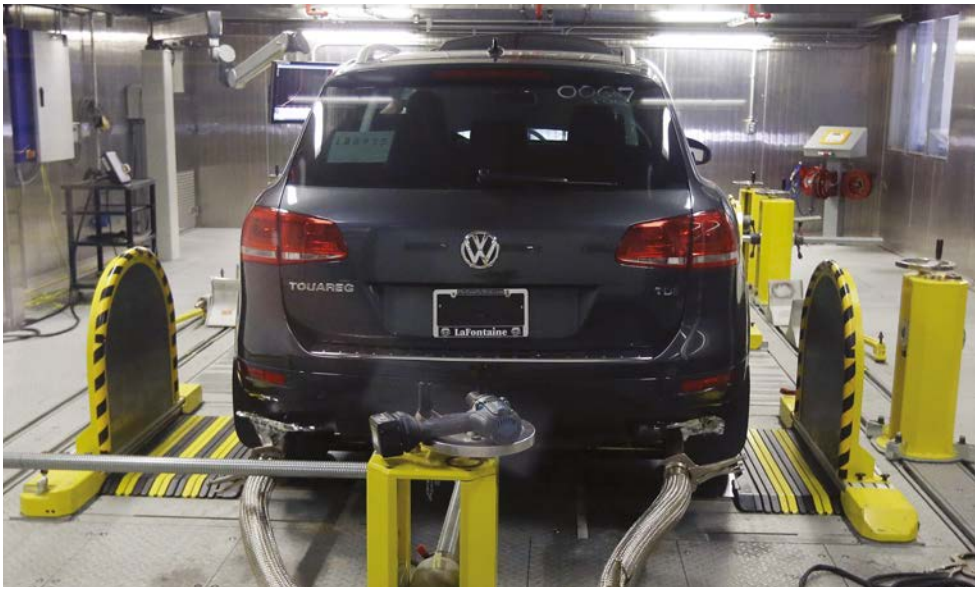
needs to have an innovative environment where we can test and prove things which, if they are successful, will eventually enter the market. Whatever we do in motorsport should reach the road if it works. So, what should the starting point be when thinking about what is the future of motorsport? You should think of what is on the road in 10 years time. We need to look at the challenges of mobility and use motorsport as a testing ground for that.

‘If you look at today’s race series I think there are two extremes. One is the perfect show and the perfect business, it has exciting races, that is NASCAR,’ Warnecke continues. ‘But that is not a proving ground for future innovation in mobility, but it is a very nice thing in terms of what they do for vehicle optimisation. The other extreme is a series that is very open-minded and technology driven, and that is WEC; ideas like Garage 56, it is great. If you look at DTM or Formula 1 regulations they are very restrictive and that reduces the relevance.’

Transfer window

‘Race to road’ is one of the phrases often raised in motorsport engineering conferences and in the odd mainstream magazine article, which will almost certainly mention rear view mirrors and the Marmon Wasp. The idea is a simple one; technology transfer from racing to road. But some senior engineers warn against expecting too much from the idea that you can take a technology developed on the race circuit and apply it directly to a production car.

Renaultsport F1 technical director Remi Taffin says: ‘We are using engines that are not all that close to what you see in production. We are revving to 11,000rpm and we spend a lot of time at full throttle. If you work out how much time you spend at full throttle in your car on the road you understand that the duty cycle is not in the same area at all.



Emissions came to the forefront of the public’s attention in the aftermath of the Volkswagen ‘diesel-gate’ scandal last year. Motorsport might now be forced to clean up its act, but it’s not yet clear just how emissions will be measured at a race track

‘We still don’t pay a lot of attention to the emissions,’ Taffin adds. ‘But on road cars there are a lot of technologies used to deal with the emissions constraint. It’s not the specific technologies, but how you use and develop them, which can transfer.’

To enable and increase this potential transfer of skills and technologies, the LMP1 rule makers have deliberately created a mechanism that allows a wide range of different solutions to be employed on track. The equivalence of technology (EoT) regulations used since 2014 in LMP1 are generally seen as a balance of performance between the different cars in the class, but the intention of it is really to allow a wider range of technologies to be used while also delivering some level of cost reduction.

‘If you got rid of EoT then everybody would be forced to make a diesel engine, because it is the most efficient powertrain, but we don’t want that, even as a diesel manufacturer,’ says Baretzky. ‘EoT means that every technology has a fair chance. It is difficult because everyone has a lot of arguments in one direction or the other. But it is clear to me that allowing different technologies is not more expensive than a uniform technology.

‘I don’t have anything against diesels in F1,’ Baretzky adds. ‘I think it would be a very important move for Formula 1, like they have made in the past to be more open for different technologies than what is prescribed now. What they are doing now, looking to make things cost efficient; at the end of the day they actually increase the costs because they force everybody to invest an awful lot of money to make a very little difference. If the rules were more open to different technology you would get a lot more efficiency and a lot more effect for the same amount of money. If the money is there it will get spent anyway.’

Fillosophy

So now, with CO2 and possibly other emissions regulations becoming an ever-growing factor in the regulations, along with wider road relevance, attention is not only on what comes out of the tailpipe of a racecar, but also what goes in to its tank.

Warnecke says: ‘I can tell you that WEC is very open minded about new fuels and engine concepts as long as the idea is that the technology will at some point enter the market. Hybridisation is the first step in that, now the discussion is about different fuels and manufacturers coming with new concepts. I

It's not just what comes out of the tailpipe that needs to be looked at, the experts argue, but also what goes in to the petrol tank. In F1 that is presently just gasoline, albeit highly optimised gasoline

think we are making small steps in the right direction, but I think we need to be careful and take care of the types of emissions I mentioned. We need to find the balance between innovation and exciting racing.'

Currently the WEC is a single specification fuel class with every car in the field using identical Shell-supplied gasoline. The sole exception is Audi, which uses a diesel fuel from the same manufacturer. But, perhaps surprisingly considering that the company sells a lot of its product to the WEC teams, Shell is suggesting that the time has come for the spec fuel era to end. 'We have a vision of multiple fuels in racing, you will see that in mobility around the world anyway,' Warnecke says. 'If you think about it, 200 years ago you had horses fed by grass pulling a coach, then we had steam engines fed by coal, then thanks to German engineers we had the Otto [internal combustion] engine and the diesel engine, and from that point we have basically had two fuels and two engine types. Now we have this beautiful and exciting challenge where we have 10 or more different engine concepts ranging from clean diesel engines, direct injection turbo gasoline, mixed combustion processes like HCCI, different levels of hybridisation, fuel cells and many others.'

Fuel spectrum

'On the fuels side we have gasoline, diesel, hydrogen, natural gas, ethanols, synthetic fuels, and electricity,' Warnecke continues. 'It gives us all of a sudden multiple options, and it means the R&D effort must be split, and eventually the solutions will reach the market. There will be no single solution, things will vary on application and location. For example, LNG is not a solution for passenger cars but it is a good solution for marine, locomotives and long haul trucks. We are moving out of [just two] solutions to perhaps a solution that involves 10.

'So, then you apply that to motorsport and treat motorsport as a laboratory for passenger car development. You can exclude some technologies that are only really suitable for larger applications, and you are still left with a wide range of options. Right now WEC has the two solutions, F1 only one, but moving forward they will have five or six. From a regulatory point of view the challenge is now to find a way of creating a fair and equitable competition between them. We need to find a way to have all these different options racing together.'

The ACO is clearly keen on this as an option and it was no coincidence that the Green GT H2 made its track debut at Le Mans ahead of the race, and that Welter Racing's new Bio-Methane project is set to take part in Le Mans next year.

'The dream fuel is carbon free hydrogen, if you can produce it using a renewable energy,' Warnecke says. 'Then you have a zero CO2 fuel. But there are stepping stones to negotiate; for example, the more you move to a gaseous fuel the more you lose energy density, and that means you have to find ways to store it onboard and also to refuel the car. But if you can achieve it you have a more sustainable fuel.'

It is now becoming a little more clear what direction top level motorsport is going to take in the years to come, with LMP1 looking like it will be the leading class in terms of power unit relevance and innovation, though it is also fairly clear that the need for change has not been lost on F1. The new rules present major challenges and it remains to be seen how they are met. But it will be very interesting to watch.

Shock tactics

Racecar's king of sim shows how by using lap time simulation and the shaker rig toolbox in ChassisSim – and a little bit of maths – a near perfect damper curve spec can be arrived at

By DANNY NOWLAN

XPB

The mystery single seater that's the subject of this month's damper simulation analysis runs Formula 3 (pictured) levels of downforce

Recently I've been working on a customer racecar that has allowed me to put into practice some simulation techniques with regards to damping. Not only was I satisfied with the result, but I was also satisfied with how it was achieved. It used a combination of the shaker rig toolbox and the lap time simulation features of ChassisSim. Some good lessons were learned so it makes for a worthwhile discussion.

Before we begin I have to say that I can't give you specific numbers with regards to the dampers. Since this is a customer car, for me to do so would be professional suicide. That being said I don't see this is a setback because the crux of this technique revolves around understanding damping ratios, so we can still have an informed discussion. What I can tell you is that this particular car was running F3 levels of downforce, but is heavier than an F3 car.

The first step is, not surprisingly, to look at data and understand the damping ratios. To get a simple picture of the car we used a dual rate approximation of the dampers. That is breaking the damping up into a low and high speed visualisation. This is illustrated in **Figure 1**. What this means in plain speaking is we are breaking the damper up into a single rate in the low and high speed sections of the damper. Also, given that we will be speaking about damping ratios, it would be wise to give you a quick summary of what these are and where they come from. We will be using the quarter car approximation, which is a very powerful tool to estimate what our damping rates should be and also the spring rates we should be considering. To refresh your memory our quarter car approximation looks like **Figure 2**.

The trick here is to visualise the spring/damper unit at each corner of the car. While it isn't obviously the full story of what's going on with the car it's a valuable building block to quantify the spring and damping characteristics of the racecar. Mathematically the crux of the quarter car method is shown in **Equation 1**

The trick is to visualise the spring/damper unit at each corner of the car

and **Equation 2**. The power of the quarter car is that given a damping ratio we want we can readily calculate the damping rate we want. Once we know the damping rates we want we can then turn around to a damper builder and say this is the damping curve we want. This is why this technique is so effective.

For this particular car the damping ratios are shown in **Table 1**. The one thing that instantly caught my attention was the low values of the damping ratios particularly in the high speed. As a rough rule of thumb, once you are talking CLA's north of two with car weights around the 700kg mark your damping ratios for the low speed should be about 1.5, and in the high speed it needs to be in the order of 0.3 to 0.4. These are just some rough rules of thumb I have gathered over the years. My suspicions were then confirmed once I overlaid a smooth simulated data run to actual data. This comparison is shown in **Figure 3**.

As always actual data is coloured, simulated is in black. Take a look at the damper traces. Note the high frequency oscillations compared to the smooth simulated data traces. This confirmed that there was a problem that needed to be dealt with.

Damper specs

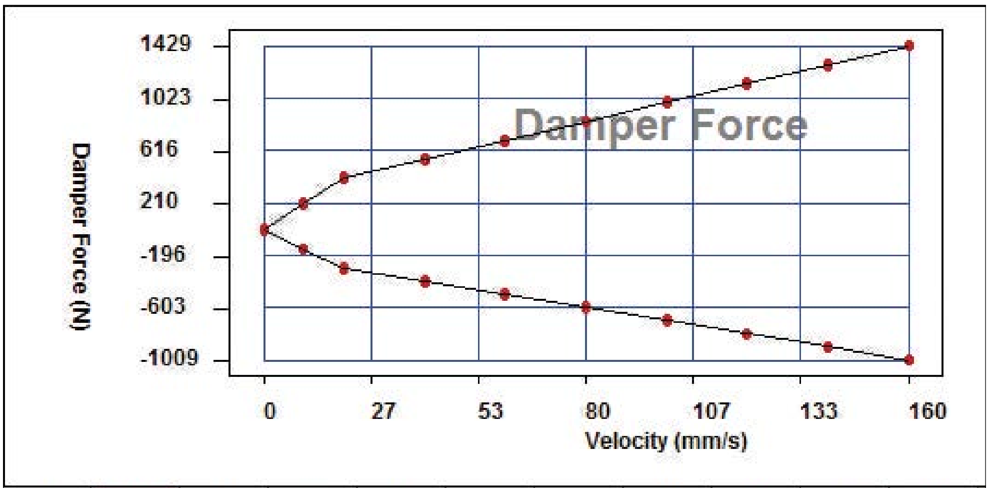
The first step we took when looking at this was to spec the new dampers at damper ratios I've seen in my experience. That is low speed with damping ratios at 1.5 and high speed at 0.3 to 0.4. The results where a mixed bag. The good news was the dampers where definitely better controlled. This is presented in the damper plots that are shown in **Figure 4** and the histogram in **Figure 5**.

The baseline simulated dampers were coloured and the changes where black. As can be seen from the damper plots there was a significant improvement in body control as shown by the reduction of oscillations in the dampers. This was also confirmed in the increased peak seen in the Histogram plots. There was just one small problem. The lap time was 0.2 seconds slower than the baseline.

To get to the bottom of this the ChassisSim shaker rig toolbox was employed to have a closer look. I used a test speed of 150km/h and a peak input velocity of 100mm/s. The results that are shown in **Figure 6** showed the reason behind the loss of lap time.

Black is the baseline and red is the modified dampers. As per the lap time simulation the modified dampers exhibit considerably improved body response. The peak heave response has reduced from 3.64 to 2.92 and the cross body response, as indicated by the cross pitch mode, has also improved.

However, where things are worse is with the contact patch load variation, which has gone up both front and rear. Contact patch load variation is a measure of mechanical grip. The lower the number is the more grip you have.



vel	0	10	20	40	60	80	100	120	140	160
Bump	0	200	400	547	694	841	988	1135	1282	1429
Rebound	0	-150	-300	-401	-503	-604	-705	-806	-908	-1009

Figure 1: Dual rate damper model. This breaks the damper up into single rates for its low and high speed sections

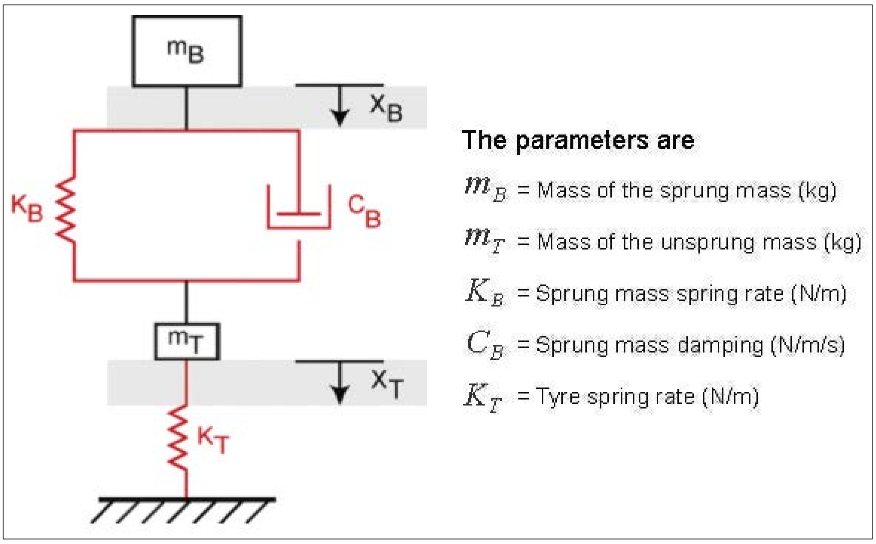


Figure 2: The quarter car approximation is a powerful tool for estimating what the damping rates should be

EQUATIONS

EQUATION 1

$$\omega_0 = \sqrt{\frac{K_B}{m_B}}$$

EQUATION 2

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

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

Here the terms of the equations are:

- K_b = wheel rate of the spring (N/m)
- C_b = wheel damping rate of the spring (N/m/s)
- m_b = mass of the quarter car.
- ω_0 = natural frequency (rad/s)
- ζ = damping ratio

Table 1 - Baseline damping ratios

	Front	Rear
Low speed bump	1.07	0.93
High speed bump	0.24	0.24
Low speed rebound	1	1
High speed rebound	0.24	0.24

Where things are worse is with the contact patch load variation, which has gone up both front and rear

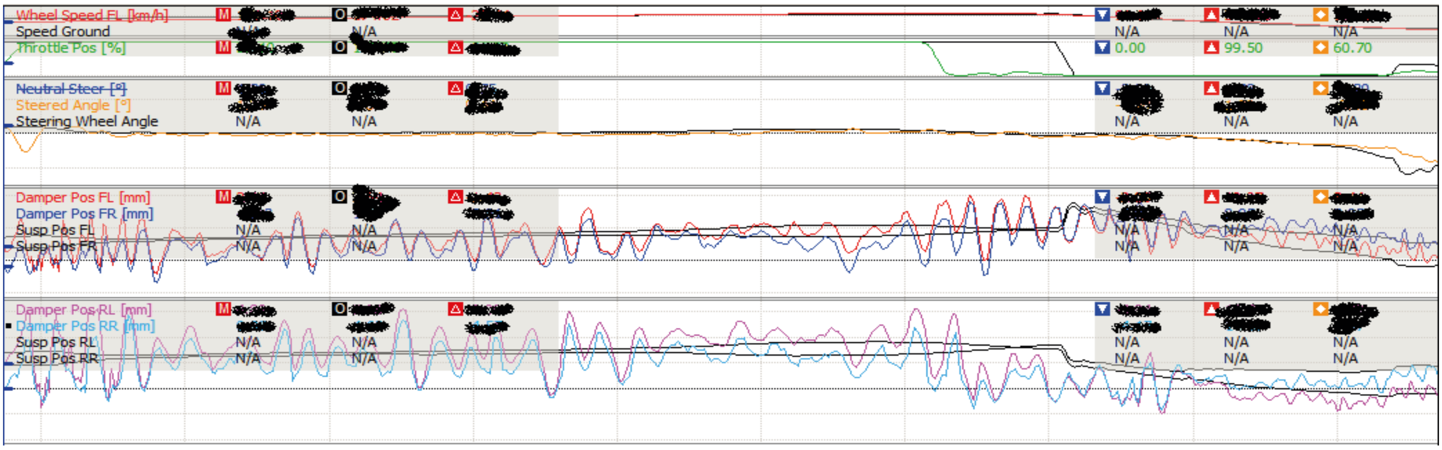


Figure 3: This is a comparison of actual (the coloured traces) to simulated (black) data. Note the high frequency actual oscillations compared to the smooth simulated data traces

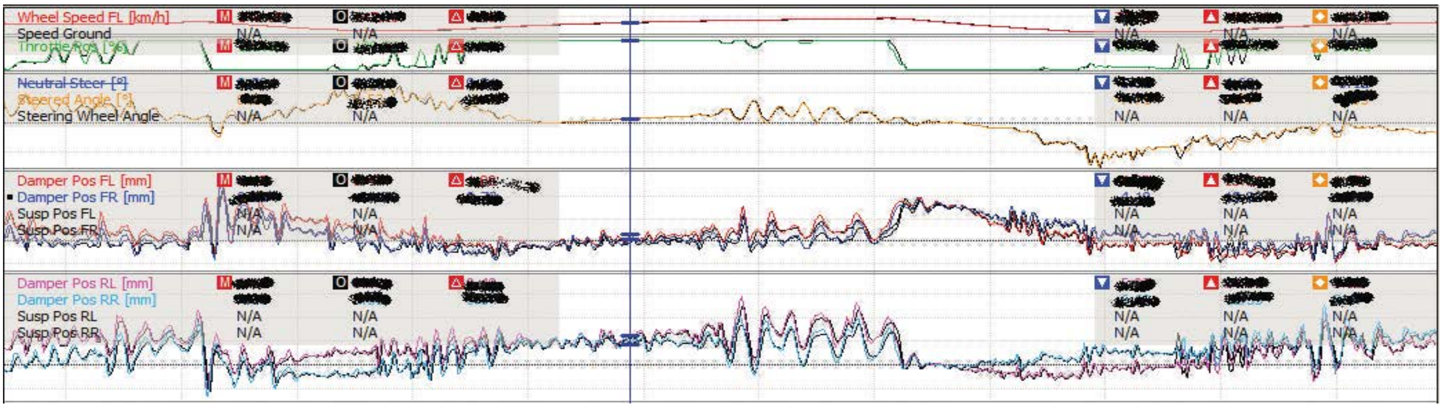


Figure 4: Damper plots of baseline dampers *vs* modified dampers. There was a significant improvement in body control as seen by the reduction of the oscillations in the dampers

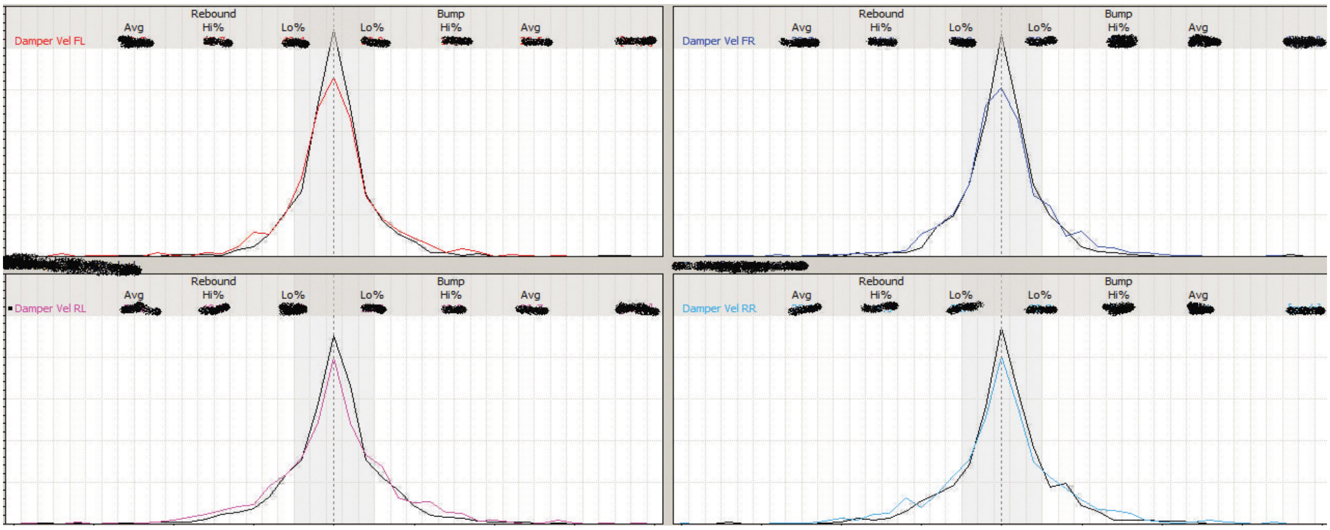


Figure 5: The findings in Figure 4 (above) were also confirmed in the increased peak seen in the histogram plots. But now the problem was a 0.2 second slower lap time

This has increased from the baseline of 153.9kg at the front and 201.2kg at the rear to 155kg at the front and 202kg at the rear. This would explain the increased lap time that was seen from the lap time simulation.

So the challenge here is to reduce the contact patch load variation while not compromising the body control. To that end the damper specification in **Table 2** was implemented. The thinking here was to control the front to allow better aero control while using a softer spec damper at the rear to get back the contact patch load variation. However, the big difference to the original spec was that the high speed damping was kept in the order of 0.3 to 0.4. This was in place to improve body control over the bumps.

The shaker rig analysis of this new damper specification proved to be a positive step. The results from the ChassisSim shaker rig toolbox are shown in **Figure 7**. The original dampers are black, the first modification is red, and the specification outlined in **Table 2** is green.

Firstly, it can be seen that the contact patch load variation has improved. The front has gone down from 155kg to 154.5kg. However, the rear has been reduced from 202kg to 200.4kg. We have also not lost that much in the heave control. This is seen from the favourable comparison of the heave control between the red and green traces.

However, where we have seen significant improvements is the cross pitch mode. Looking

Table 2 - Damper specification arrived at by shaker rig analysis

	Front	Rear
Low speed bump	1.4	0.9
High speed bump	0.35	0.4
Low speed rebound	1.4	0.9
High speed rebound	0.35	0.3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The simulator is much more consistent than an actual driver, and it has no concept of fear

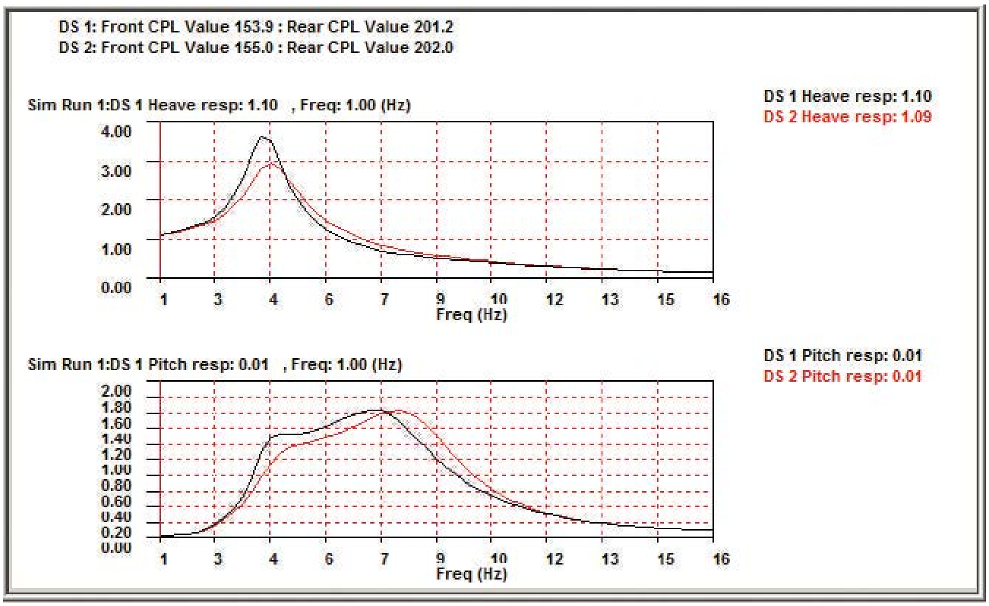

Figure 6: Comparison of baseline to modified dampers in the shaker rig toolbox. Contact patch load variation has gone up

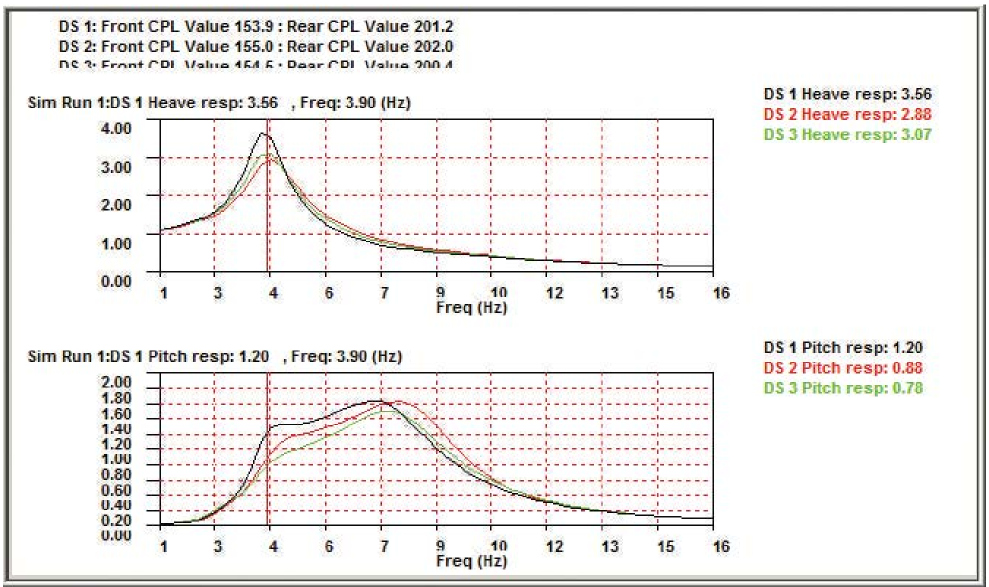

Figure 7: Shaker rig toolbox with new spec dampers. Original is black, the first mod is red, and the spec in Table 2 is green

at the second trace the cross pitch response is significantly better because it has been substantially reduced. All of these indicate that we have achieved our desired goals.

This improvement was also reflected in the lap time simulation as well. The simulated lap time gain was 0.1 of a second from the baseline specification. The damper response is illustrated in **Figure 8.**

As can be seen from the damper plots the oscillations over the bumps have definitely decreased from the baseline configuration. However, the effects of the reduction of the contact patch load variation have made their presence felt with increases in the mid-corner grip and with being able to brake slightly later.

Studying data

This might also be a good place to discuss the differences between looking at simulated and actual data. Simulated changes will always be smaller in magnitude and more subtle than their actual counterparts. This is primarily due to the fact by its very nature the simulator is much more consistent than an actual driver, and it has no concept of fear. Consequently the big changes you'll see is differences in corner speeds and subtle changes in the damper movements as you hit the same bumps. You need to bear this in mind when comparing the two different types of data.

This has been a very succinct but effective example of applying simulation techniques to help specify your damper curves. The first step is to break down your damper into a dual rate model and understand your damping ratios. Then you look at the actual dampers *vs* smooth simulated dampers to see where you are at. Then, using damping ratios in reverse, you specify the damper curve you need and refine it in the shaker rig toolbox, as was illustrated in **Figures 6** and **Figure 7.** You then run a final sanity check using the lap time simulation.

If all the above checks out you put it on the racecar and enjoy the fruits of your labour in the form of better results on the track.

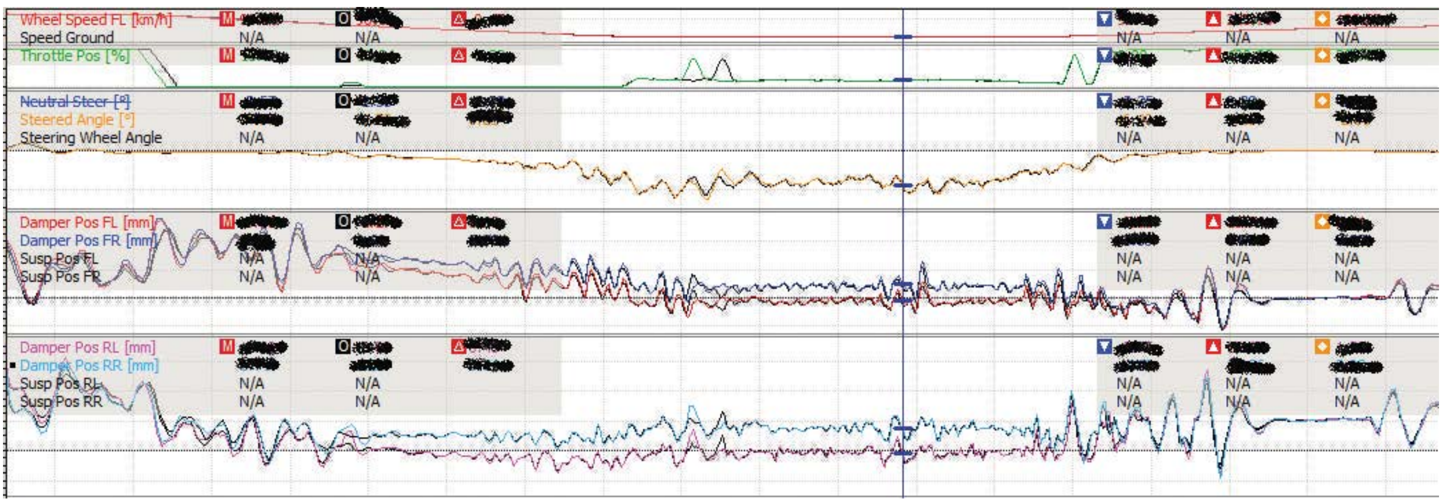

Figure 8: Baseline dampers *vs* the Table 2 specification of the modified dampers. As can be seen here the oscillations over the bumps have decreased from the baseline configuration


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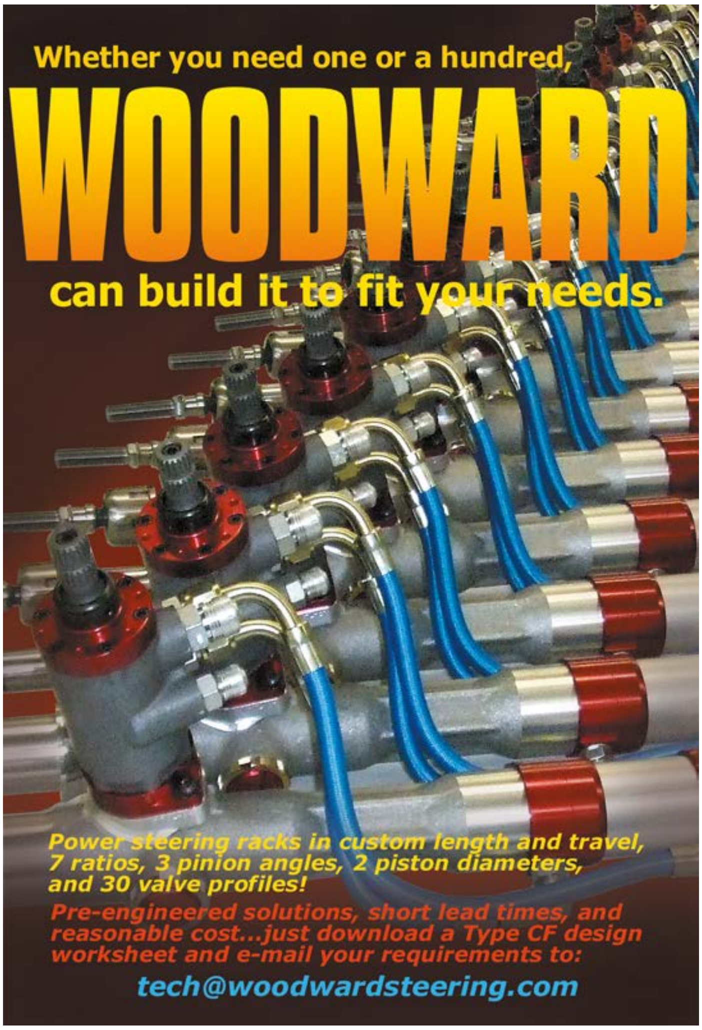
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The future of LMP1

To close the performance gap between LMP1-H and LMP1-L the ACO has issued regulation changes which include aero changes for both, plus unlimited engines and DRS for privateer teams

By SAM COLLINS

The future of the LMP1 category has been laid out by the FIA and ACO, and it will result in some visually quite different looking cars in 2017, and particularly from 2018. Much focus has been placed on bridging the gap between the privateers in LMP1 and the works teams.

Currently only two teams run privateer cars in LMP1, though others such as Strakka Racing and the works Alpine team have looked at stepping up to the sub-category, depending on the direction of the regulations.

One key area in all this was a desire for both a performance increase, to bring LMP1-L closer to the works cars with their hybrid power units, and also a reduction in costs. To achieve this the aerodynamics of the cars have been adjusted by the rule makers, who have decided on an overall reduction in downforce levels for the works LMP1-H cars. This will be achieved primarily through the use of a 15mm higher front splitter and a 50mm smaller rear diffuser. Meanwhile, the privately entered LMP1-L (lightweight) cars will get an overall increase in downforce, which will be achieved through using wider and larger rear wings, and wider front bodywork.

Along with the aerodynamic changes the weight of the privateer cars will be reduced down to 830kg, and the teams will be able to use an unlimited amount of engines during the season, while the upper limit for powerplants of 5.5 litres has also been removed. In order to reduce costs somewhat only a single fuel flow sensor will be required and the torque sensors will be removed altogether.

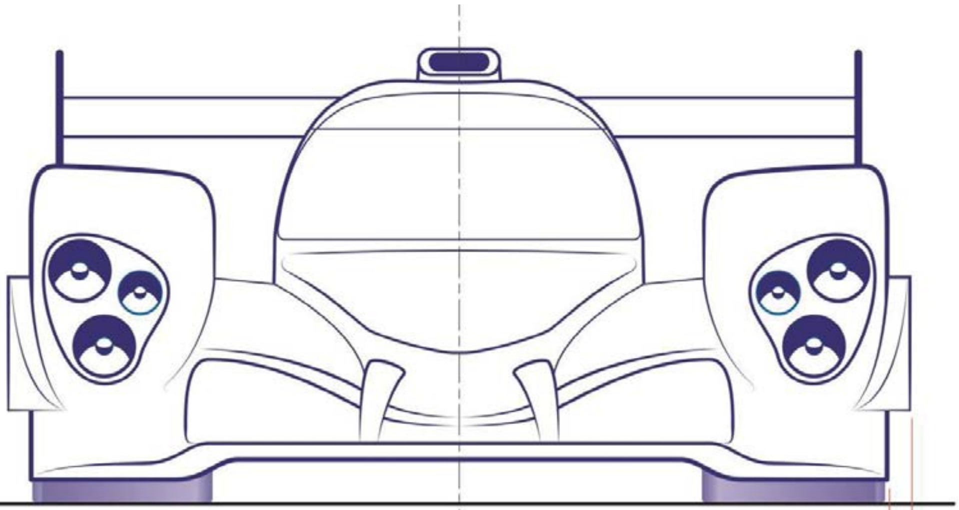
Bigger change will come in 2018 to both versions of the LMP1 class as new chassis regulations come into force. These are mainly based on new driver safety requirements expected to be rolled out across all top level motorsport in the next few years. The aim of the changes is to avoid the lower back injuries suffered by a number of drivers recently, and to achieve this the driver seating position is changing so that they now sit more upright

Currently Rebellion is one of only two teams in the LMP1-L class for non-hybrid racecars. The ACO is hoping regulation changes will attract more privateers

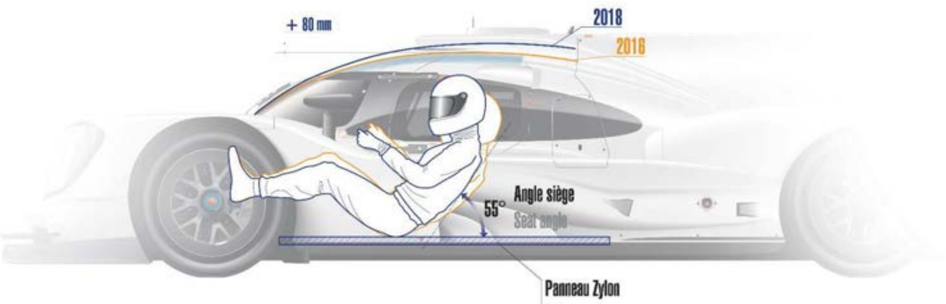
The LMP1-L cars will get an overall increase in downforce

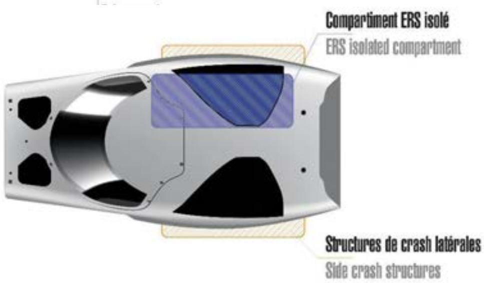
The height of the front splitter will be increased by 15mm on LMP1-H cars while the rear diffuser will be reduced by 50mm

Downforce will be increased for LMP1-L with wider and larger rear wings, while there will also be DRS



For next year the front of the LMP1-L cars will be wider, which should help bridge the performance gap to P1-H





Among many safety changes to the cockpit area is a more upright seating position for the driver, while energy stores will need to be kept in an isolated compartment (right)

in the cockpit. Additionally, a Zylon panel is to be added to the floor of the cars and the result of this is that the roof-lines of the racecars will now be around 80mm higher than at present, increasing the frontal area of the car overall slightly, with the visibility further improved, too.

There will also be a requirement for a larger free space around the driver's head, an overall larger cockpit area, and a slightly different space around the legs, to help with driver changes. More protective foam will also be used.

A number of other changes to the cockpit area and monocoque will be imposed. Any energy store mounted in the car will have to be in a separate isolated compartment located in the passenger seat area, and the crash test requirements for the chassis will be increased, as will the front and rear impact test requirements.

Major changes are also being introduced to the power units employed in the LMP1-H category, with the maximum ERS energy allowed increasing from 8MJ to 10MJ, and three energy recovery systems being introduced (two was the previous maximum). Partially offsetting the increased potency of the hybrid systems an eight per cent reduction in the fuel allocation will also be imposed. All running in the pit lane must be on hybrid power only – something the ACO attempted to introduce back in 2009 when the first hybrids ran at Le Mans.

DRS code

In a further bid to close the gap between LMP1-H and LMP1-L, a drag reduction system (DRS) is under consideration for 2018, but the implementation of this is widely believed to be both expensive and tricky.

The introduction of the new chassis regulations might cause some headaches for privateer teams. Many of the current LMP2 chassis were designed to be upgradable to LMP1-L cars, as is the case with the ORECA 05 and Rebellion R-ONE. Indeed the Ligier JS P2, Dome S103, BR-01 were all designed specifically with LMP1 in mind, but the 2017 LMP2 regulations outlaw all three of these chassis, as do the 2018 LMP1 chassis rules, leaving teams uncertain over their future direction. It has also been suggested that the new LMP1-L regulations would be extremely attractive to a manufacturer team such as Peugeot or Nissan willing to enter the class but not spend the budget required for a full hybrid effort. Works teams are not allowed to do this currently but it seems likely that if such a project was put together then it would be granted some kind of special dispensation, especially if they opted to use a fuel other than petrol or diesel.

It seems international prototype racing is entering something of a transitional period, and what shape it will be in by the time it all shakes out in 2018 is unclear.

The chassis regulations might cause some headaches for privateers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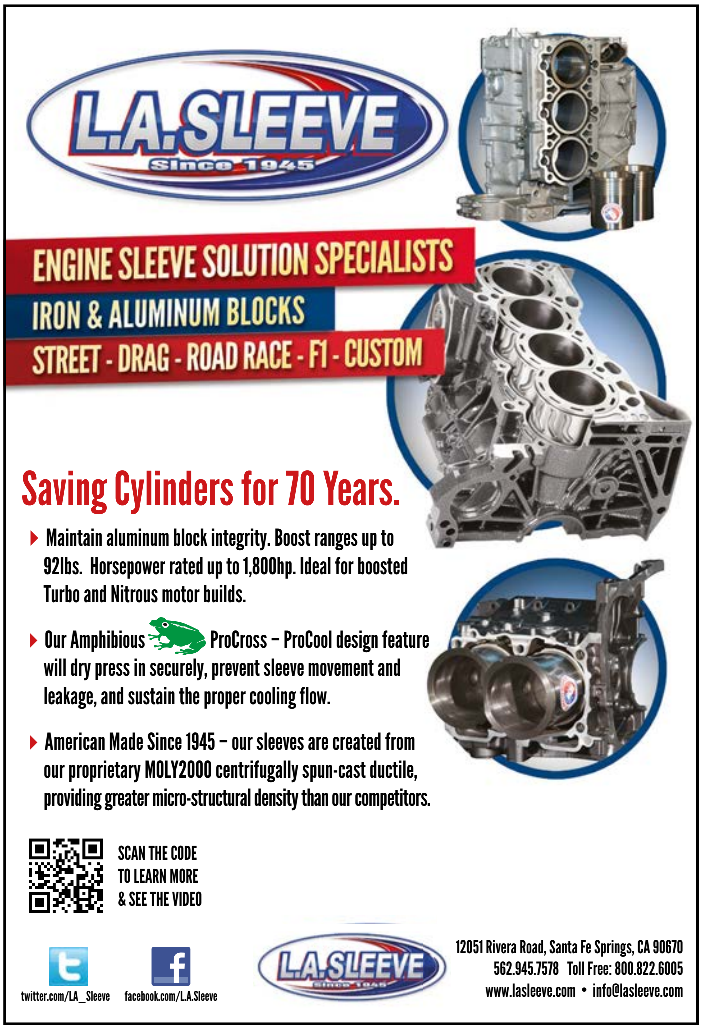
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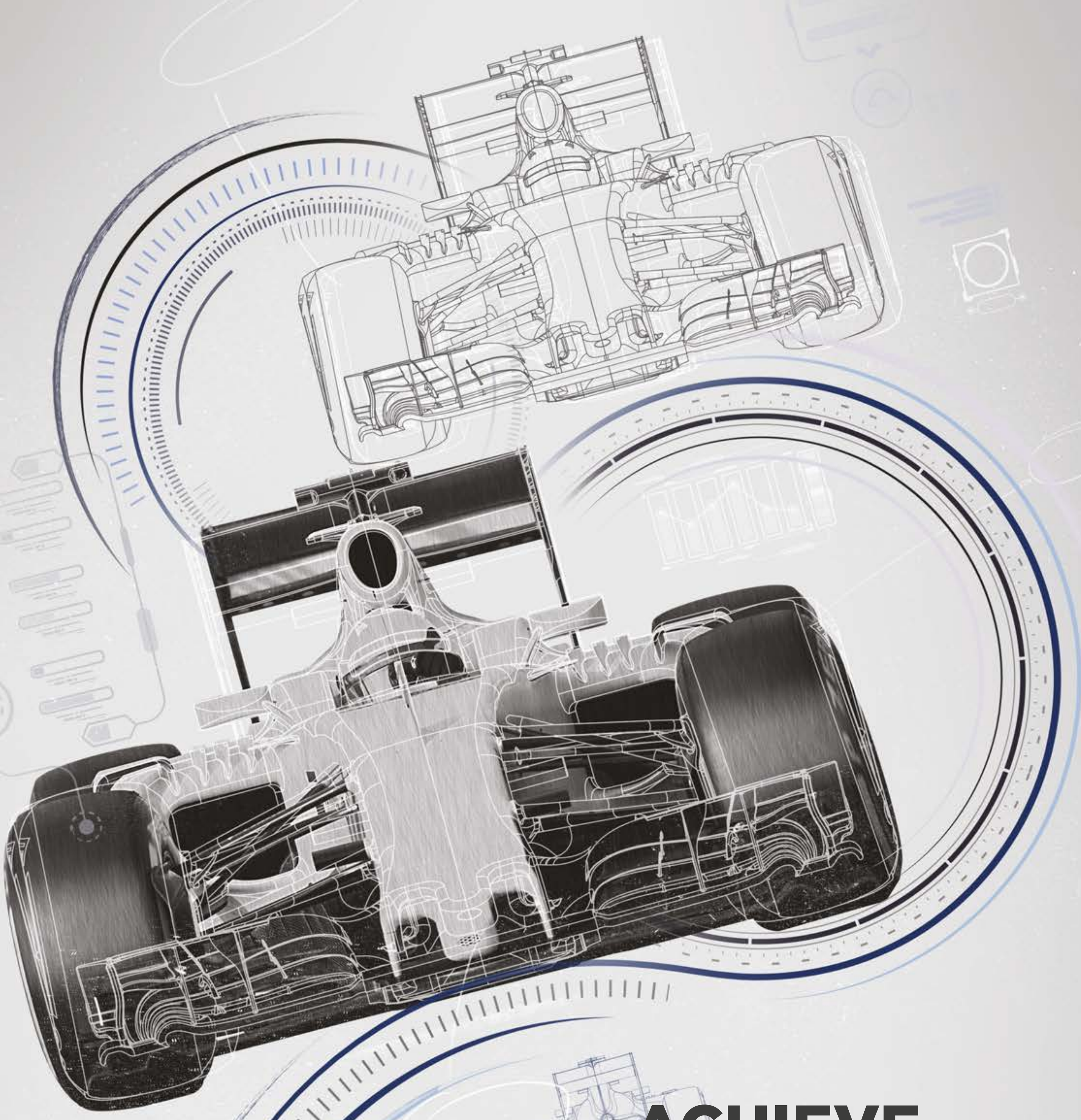


Racing in to 2017

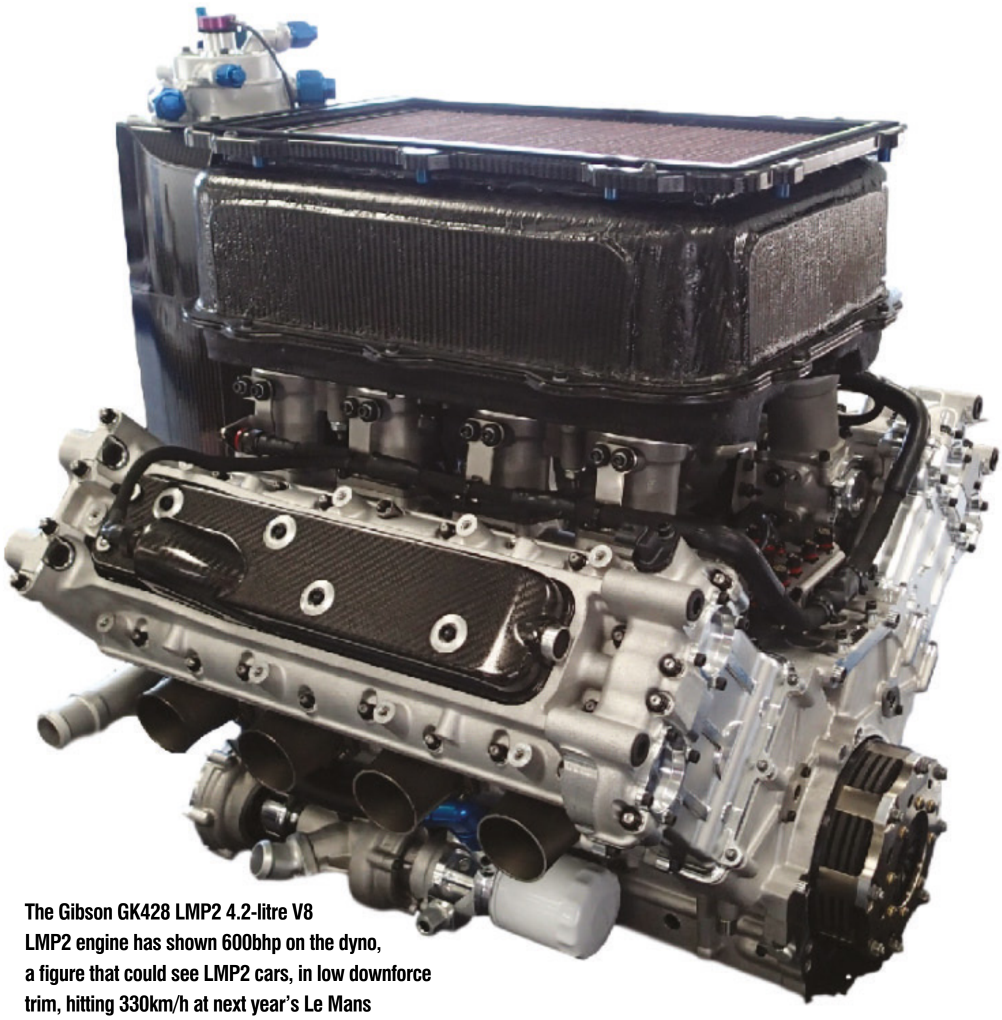
Gibson's recently unveiled LMP2 engine is typical of the high end race technology that will be on display at next year's ASI show

By ANDREW COTTON

The pieces of the LMP2 2017 jigsaw are falling into place with the first of the chassis set to run this summer fitted with the new Gibson GK428, 4.2-litre V8 naturally aspirated engine. The engine has been tested to 600bhp, and with an efficient aero package, top speeds at Le Mans are expected to top 330km/h in low downforce trim, challenging the mid-order LMP1 cars.

The British manufacturer won the tender to supply the reference engine against which all DPI power units will also be balanced against, based on its previous experience supplying the likes of F3000 and A1GP.

The terms of the tender were strict; the price was limited to €1300 per running hour, the servicing of the engine was included in the price, as was the time between rebuilds, which put more pressure on the engine supplier chosen. Gibson was awarded the contract mid-2015, and immediately started endurance testing before a final specification was set. It planned initially to build 20 engines, but has had to revise that to 40 in the first season.



The Gibson GK428 LMP2 4.2-litre V8 LMP2 engine has shown 600bhp on the dyno, a figure that could see LMP2 cars, in low downforce trim, hitting 330km/h at next year's Le Mans

Spec expert

'Having done single make racing for a number of years, we felt that we were in a pretty good position and had a good understanding of what needed to be done,' says Gibson's operations manager John Manchester. 'It is difficult because you have a sophisticated expensive race engine that is strictly controlled by cost. There are ways around things. We worked out that we could do it, and to keep the costs down, the general architecture of the engine is based on the 2009 [Zytek] LMP2 engine.'

That engine was a 3.4-litre V8, and so work had to start on the pistons, crankshaft, conrods and liners to increase the bore to 4.2 litres, as required by the tender regulations. 'We started with something that we think is durable, although you never know until you get the engine into the car, but we have four different chassis manufacturers,' explains Manchester. 'That is the only thing that is different for us; single make racing in terms of the engine is the same, but it is four different chassis manufacturers, so we could have four different sets of installation issues which we will have to overcome. Hopefully not.'

The first engine ran on the dyno in December and since then the company has undertaken 57 hours of testing, simulating qualifying laps around Le Mans in order to get to the minimum 50 hour rebuild time, equivalent to around 10,000km of running between rebuilds. 'This engine has to be extremely durable, so an enormous amount of work went into durability of the parts, piston design, con rod, crankshaft, cooling in terms of the engine, and making the engine as bullet proof as you can,' says Manchester.

'Support has to be included in the hourly rate, and that's not easy. It is not something that we have ever had to do before. We have made the engine as serviceable as we can in the car, so if there is a problem then we can react to that problem relatively quickly and remove a part without having to remove the engine.'

The electronics package was developed with long-term partner Cosworth, which the

'Having done single make racing for a number of years we were in a good position and had an understanding of what needed to be done'

Zytek 09S at Le Mans in 2009. The 3.4-litre engine in this car is the lump on which the new LMP2 unit is based. It is now bored out to 4.2 litres and will be fitted in the four new P2s next year

company hopes will avoid many of the initial teething troubles normally associated with installing a new powerplant.

'We have a database, so after each session, we can download the data from each car and very quickly see if there is an area of concern, see if the Lambda is not reading right, or the sensor is going down,' explains Manchester. 'We are using the Cosworth system on our Nissan engines, and on the FR3.5 engines, so we have a good understanding of the Cosworth electronics. The electronics package is a very important part of engine performance. There are a lot of problems to overcome as they don't always work in harmony with each other to start off with. The engine won't run with anything other than that ECU. If a team tried to get into the ECU or change the ECU and do some running outside of what they are allowed, it stops the engine running. We have total control.'

The take up for the engine has been higher than expected, and Gibson has had to double up on its initial manufacturing order to meet demand. The four chassis manufacturers will each receive an engine in August to begin testing, but each has an extensive test plan already. 'We have had forecasts from two chassis manufacturers and, if they turn into orders, then clearly 20 engines won't be enough,' says Manchester. 'We are in the process of starting another production of 20, so we are going to be making 40, which is something that we never thought we would do. It's difficult because there is a big investment level to make these engines.

'The first delivery is scheduled for August and we are on target for that. One engine will go to each chassis manufacturer – there is no preferential treatment for anyone. Once that happens, they will start the testing programmes and we will support that test. There are a certain number of days that we have to support, that we have to include, and if a chassis manufacturer goes beyond that, and it looks as though they will do a lot of running we certainly didn't envisage that they would do to start with, then that support has to be paid for.'

The US market

The four chassis manufacturers and the FIA have been kept fully up to date with the latest design and development of the powerplant, as well as the installation requirements for the chassis. A monthly report has been sent to the FIA on the latest developments, and one manufacturer in particular had an installation issue, but that is now fixed, we're told.

However, the burning question remains, what will happen when the turbo engines are developed for the US market? As previously detailed in *Racecar Engineering*, the European-spec Gibson is the reference engine against which the DPI cars will be balanced. However, they will have very different characteristics, probably producing more torque, although the bodywork will likely not be as efficient because of the need for more cooling.

'The turbo engines will be restricted to produce the same level of horsepower as this engine,' confirms Manchester. 'It is difficult to control torque because this is a 4.2 litre engine and it will generate *x* amount of torque. If you race a 5-litre engine, you can control the power, but the torque is clearly going to be more. You are always basically working on horsepower levels. A 4.2-litre engine would meet the targets and we exceeded the 600bhp and were pleased with that. Because of all the work we have done over the years on the single make engines you have to make sure you have a consistent level across all the engines, and we are working on plus or minus one per cent of the overall horsepower, and we know what we need to control between rebuilds to maintain that through the life of the engine. We were relatively comfortable with the performance level.'

Gibson's support package will include one engineer and one technician for six cars, as well as a spares truck at the European races, and a spares container at the fly away events. With the rules fixed for at least four seasons, expanding from the WEC and IMSA series to the Asian Le Mans Series, Gibson can expect a large amount of custom in the coming years.

The take up for the engine has been higher than expected and Gibson has had to double up on its initial manufacturing order to meet demand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Heineken signs $200m deal to become one of Formula 1's biggest backers

XPB

Heineken's Gianluca di Tondo will be hoping Formula 1 reaches consumers other sports cannot reach

Leading global beer brand Heineken has signed one of the biggest sponsorship deals in Formula 1 history, which will see it become the title partner for three grands prix, as well as having a large presence at all the other races.

The deal, which has initially been agreed to run until the end of 2020, is said to be worth $200m, and includes sponsorship of this year's Italian Grand Prix – in effect saving the historic event, which has been under threat over recent months.

This marks an extension of an already large sponsorship portfolio for the Dutch beer brand, which is also involved in the Rugby World Cup, Champions' League football and the James Bond movie franchise.

While Heineken would not confirm the widely quoted $200m figure, it can be extrapolated from the fact that the company says it will be one of its biggest ever deals. Its Champions' League sponsorship costs Heineken over $70m a year, and a figure of $200m over five years would mean $40m a year, which is actually much less.

However, a sponsorship expert has told us that the company will spend 'much, much more' on actuating the partnership, and total spend could be as much as a billion dollars. Heineken can certainly afford the outlay, last year it posted revenues of over €20bn.

Heineken will now be the official beer of Formula 1, with Heineken bars set up at all the grands prix, while there will also be trackside advertising at some events. Heineken will also promote itself and F1 through a wide range of platforms, including TV commercials, digital activations and live fan experiences and events.

Gianluca di Tondo, global head of brand for Heineken, said: 'F1 delivers in three specific areas; strong commercial opportunities; expansion of our responsible drinking platform in new and innovative ways; and enabling skill transfers between F1 and our employees. This partnership complements our existing global platforms, enabling us to reach F1's huge spectator numbers and 400 million unique television viewers every year.'

Not all have welcomed the deal, though, and despite Heineken's promise to push its 'If you drive never drink' message. Eurocare, a public health body, wrote to FIA president Jean Todt to say: 'We would like to remind you that drink driving is one of the key killers on the road.'

Teams split on how future Formula 1 revenues should be paid

Formula 1 teams have shown that there is a wide variance in how each believes revenue from the sport should be distributed in the future, but most agree change is needed.

Currently, and at least up until 2020, the top teams are given the lion's share of revenues, largely because of contracts signed to keep them in the sport when CVC, F1's majority shareholder, was planning to float it on the Singapore Stock Exchange and was working to lock in value by getting the teams to sign long term contracts, with the big teams offered the best returns.

However, there is a growing feeling that this process has led to an unfair situation, as the teams with the most resources also get the most money. With the negotiations for new contracts for post-2020 now about to begin, team bosses have suggested a number of alternatives, and of six asked recently which system they would prefer, it was interesting that each had its own answer; ranging from keeping the current model, to splitting the F1 money 11 ways.

Robert Fernley, deputy team principal at Force India, said: 'The idea of privileged teams going away, negotiating with CVC and deciding how much to skim off the top before distribution to other teams, for me is not acceptable. I would like to think the Commercial Rights Holder this time does it in a more transparent way. The Premier League is a perfect example of where you've got a performance-related programme that's very fair and transparent. There's no need for negotiations: we've got a pot of money; split it in a proper manner; make it transparent.'

Franz Tost, team principal at Toro Rosso agreed: 'I hope that the private teams get more money because the manufacturer teams anyway have a lot of money, and [then] we can close the gap from the performance side. Because [that] is simply a question of the financial situation.'

Dave Ryan, racing director at Manor GP, said: 'It would be nice to think it could be made more equitable. The difference between the front teams and the back teams is too big. I do believe the leading teams should get more money but I think the gap is just massive at the moment and it needs to be looked at in a slightly different manner.'

XPB

Force India is one of the teams that believes the current F1 revenue distribution model needs to change

Top Swedish touring car series to switch to TCR regulations

The TCR category is to be embraced by the Swedish-based Scandinavian Touring Car Championship from next year on – the STCC the first major series to opt to race under the customer sport driven regulations.

TCR, which is overtly based on a GT3 business philosophy and allows manufacturer sports departments to build touring cars to sell, already has its own International Series, plus numerous regional and national series around the globe. The STCC, though, is thus far the highest-profile championship to adopt TCR rules.

Jonas Ludin, CEO of series promoter STCC AB, said: 'We were looking for a set of regulations that could bring [our] touring car competition back to its place as one of the premier motorsport series in northern Europe. TCR is the perfect opportunity to build a long-term programme for the years to come.'

STCC was created through a merger of the Swedish and Danish series in 2011, and it currently uses Solution F silhouette cars. However, recent grids have been thin, with only 10 cars turning up for the first two rounds of the championship this season.

Marcello Lotti, the former World Touring Car Championship boss who created the TCR concept, said of the new deal: 'We are delighted to add this extra jewel to the TCR crown, and it is one of the brightest. The Scandinavian countries have always had a solid tradition of strong touring car championships. I am sure that a lot of fans fondly remember the Super Touring years in the 1990s and, more recently, the seasons that featured the Super 2000 cars.

'We will be working together to build a series that is at least as successful as those championships were,' Lotti added.

Since 2013 STCC has raced in Sweden only, and that will still be the case in 2017, although Ludin is hoping that it can become a regional series in the future. 'There is a lot of interest from the Danish, Norwegian and Finnish teams,' he said. 'As the promoter of Nordic Rallycross, we have built excellent relationships with the national sporting authorities of our neighbouring countries, which will make it easy to expand.'

There are currently Asian, European and Benelux TCR series, plus national series in Germany, Italy, Portugal, Russia, Spain and Thailand. There are also TCR classes in other championships across the world.

XPB

The Scandinavian Touring Car Championship is to run with TCR machinery (pictured here at Imola earlier this year) from 2017

Silverstone Park breaks ground on new speculative development

MEPC, the commercial property company that owns the Silverstone Park business development – which is on land next to the Formula 1 circuit – has started work on new premises at the site.

The new build is a 'speculative development', which is basically building premises in the expectation that they will be filled, something that is generally considered a huge vote of confidence in a market or location in the commercial property world.

The project will see 14 new speculative industrial units for hi-tech engineering companies built. These will total 125,000sq/ft in area, and the units are arranged as two self-contained buildings and two terraces, and range in size from 5000sq/ft to 25,000sq/ft. The units, built to shell and core specification, offer flexible accommodation, MEPC tells us. They will provide a blank canvas ready for a company's bespoke fit-out, and they can be amalgamated to create a wide range of unit sizes. All of the units can be used as B1 (light industrial use and R&D), B2 (general industrial use) or B8 (distribution use). MEPC expects the units to be highly desirable, given the location, which is opposite the main entrance to the Silverstone circuit.

Each property will sit in newly landscaped grounds adjacent to the already successful Buckingham Road units, which have proved popular with many engineering firms and racing teams. The development is set to be finished by the end of the year.

James Dipple, MEPC chief executive, said: 'Our market research shows that there is a shortage of industrial units in this size range. Since taking over management of Silverstone Park in September 2013, MEPC has increased the number of hi-tech businesses on site from 50 to more than 70, and built two new 8000sq/ft units on land already within the existing Silverstone Park footprint.

'This project is therefore terrifically exciting for MEPC – it really marks the next steps in reinforcing the global significance of the hi-tech cluster here,' Dipple said.

'These units are of a high specification, and are designed to meet the requirements of a broad range of occupiers and include high eves of up to eight metres plus five-metre high loading doors,' Dipple added.

IN BRIEF

Millions in R&D cash up for grabs

Innovate UK, a British government organisation that gives grants to businesses, has up to £15m to invest in innovative research and development projects, offered in an open competition targeted at a whole range of technology, engineering and industrial areas, including motorsport. Proposals can be drawn from any area, says the organisation, particularly the key sectors of manufacturing and materials: emerging and enabling technologies; health and life sciences, and infrastructure systems. The registration deadline is the end of August. For more go to: www.gov.uk/government/organisations/innovate-uk

F1 owner plans phone swoop

CVC Capital Partners, the owner of F1, has teamed up with Apex Partners (best known for its involvement in the Karl Lagerfield fashion label) to make a bid for mobile phone provider O2, according to City sources in London. The move comes after an attempt by O2's owner Telefonica to sell it to rival telecoms firm Hutchison Whampoa for £10bn was blocked by EU competition watchdogs. CVC, which has held a majority shareholding in F1 for over 10 years, is currently trying to sell its stake in the sport, it's widely believed.

Adelaide race rakes in dollars

The Clipsal 500 Supercars race in Australia has continued to prove itself the most economically successful event in the premier Aussie race series, formerly known as V8 Supercars, with this year's race recording its highest economic impact of A$65.6m (£34.2m). The 2016 attendance figure was 263,500, with more than 13,500 people travelling from outside South Australia. The event was broadcast to an audience of nearly 300m people, with an estimated media value of more than A$179.5m (£93.5m) internationally, up A$12.5m (£6.5m) on the 2015 media value of A$167 (£87m).

INTERVIEW – Frits van Amersfoort

Going Dutch

The boss of crack F3 operation VAR talks openly about 'super-teams', Formula 3 technical development, and the state of sub-F1's last nominally free formula

By MIKE BRESLIN

XPB

'We know now, looking through the eyes of Adrian Newey, that it's not easy to make the Dallara a better car'

Rightly or wrongly, there seems to be a perception among some drivers right now – or more precisely those that control their budgets – that if you're not with one of the three 'super-teams' then Formula 3 is simply not worth doing. It explains, in part, why the grid numbers have fallen from 35 last year to 22 in 2016. The argument goes that if a hotshot can't land a berth at either Van Amersfoort Racing (VAR), Prema Powerteam or Hitech GP then he might as well go and race GTs.

There might be something in it, too, as a number of stalwart F3 teams have turned their back on the category, saying they can't compete with these billionaire-backed outfits and their development programmes, and ultimately their ability to lure drivers. But talk to the men behind the super-teams, the owners not the backers, and a different story emerges.

One of these men is Frits van Amersfoort, a Dutchman who 'loves' F3, and has been involved in it since the '80s. His team, VAR, ran Max Verstappen in his single non-F1 car racing season in 2014, and now has four cars in the European series. He also has backing from Cirque du Soleil founder Guy Laliberte, whose son Kami races in VAR's F4 operation. Some say this gives VAR a big advantage, but van Amersfoort believes they are making too much of it. 'Honestly, I'm a little bit disappointed by this,' he says. 'Despite the fact that we have a good financial background now, that's only changed over the past two years, and we're lucky to have somebody taking care of that. But it doesn't mean that we give away drives, and it doesn't mean that we don't have to make our business profitable, and that's the challenge. When you have some finance behind you, you can invest in things; better transporters and a little bit more on the workshop, that sort of thing. But we don't throw money out of the window. And I'm a bit disappointed that some have used that argument to throw at us. We also have the son of Adrian Newey [VAR F3 driver Harrison], and I heard stories that our car was in the Red Bull factory. Basically it's a lot of rubbish.'

Arrested development

The same has been said of Prema, too, that Lance Stroll's Dallara has been seen at the Williams factory, but van Amersfoort is sceptical. 'I tend to doubt it. There is only one company in the world in F3 that knows everything about that car, and it is Dallara. So I don't see any point in our car going to Red Bull, or the Prema car going to Williams. The Dallara is a very good design. And we know now, looking through the eyes of Adrian [Newey], that it's not easy to make the Dallara a better car.'

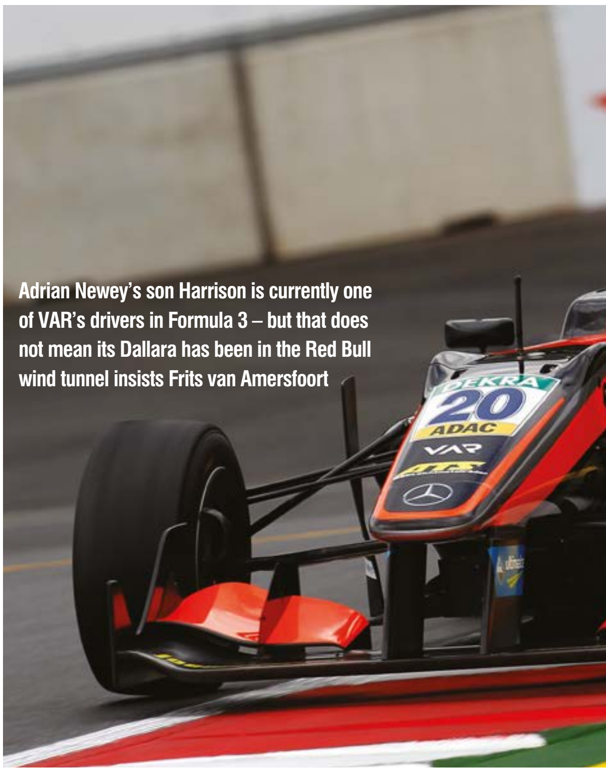
In fact, van Amersfoort maintains that there's actually not much that can be done to develop the F312 these days, and that the already four-year-old chassis has seemingly reached the end of its development potential. 'You can maybe develop a few tenths, but that's it; and that's within the possibilities of the car anyway. You try to make the car as efficient as possible, yes. But on the aerodynamics there's nothing you can do. Oh, you can cut the floor a bit, but that's all. Everybody is doing the same thing. But, for sure, we never had a car in the wind tunnel. It's just not true. I think even a small Formula 3 team can work on the racecar just as much as we do.

'But we shouldn't forget, in F3 you need a proper driver,' van Amersfoort adds. 'That is the key, and of course that's always the big thing in the winter, to get hold of the best drivers, and that game is maybe harder to play for the smaller teams. But, you know, we got hold of Max Verstappen as a small team, in those days we were a small team. So it's also down to the wheeling and dealing of the team owner.'

Young blood

That's not to say engineering is redundant in F3, though, far from it. 'As a team, you need good engineers; guys that work hard and are smart. And that does not need to cost a fortune. We don't spend a fortune on engineering, really. We have a couple of good guys, who we recruit from university, and I especially want to underline this; young guys; young guys that have drive; they really want to win. They work as hard as the drivers, they work as hard as me.'

Indeed, VAR will go out if its way to recruit an engineer at the start of his or her career, even over one who has years of experience in F3. 'I love young engineers. Engineering is down to hard work and trying to be smart. And, of course, somebody with a mathematical mind has an advantage there. But I'm not really in favour of an engineer with a lot of experience, because



Adrian Newey's son Harrison is currently one of VAR's drivers in Formula 3 – but that does not mean its Dallara has been in the Red Bull wind tunnel insists Frits van Amersfoort they tend to lean on their experience. I engineered F3, for 25 years, but I know now, my time's up, because you tend to work from the past. Racing has changed, although racecars are nearly the same, racing has changed over the last decade.'

Part of that change is the way the engineers now work with that key component in F3, the driver, van Amersfoort says. 'Engineers play an important role in showing the driver where he can gain time, and that's an item you shouldn't forget. Basically, I would say the time spent by an engineer to work with his driver, to make his driver better, is 70 per cent, and the other 30 is maybe trying to make the car better.'

Despite the drop in numbers this year van Amersfoort says Formula 3 is in a good place, and he is also happy with the way the FIA has addressed the single seater ladder. Though he is certainly not happy with one recent development; the change of title of BRDC F4 to British Formula 3, which he thinks could devalue proper F3. 'I really don't like the fact that the BRDC F4 calls itself F3 now, because I think that it is not F3, and the name doesn't belong to it. I don't think it is right when a series that is not an F3 series calls itself F3, because in the end we have to admit that some people might think it is an F3 car, and some will tell their sponsors, tell their financiers, that they are to drive in British F3. And I think that is basically wrong, I don't like it.'

Cost control

European F3 budgets are anywhere between €550,000 and €750,000, yet the latter amount is actually a big increase on 2012, when the new car was introduced with the intention of cutting budgets that were then widely reported to be around €600,000. A new engine formula came in 2014 with the same intention. There has also been a restriction in the amount of testing, just 12 days now. So, has this drive to cut costs been a failure? 'In racing, a lot of things are invented to keep costs under control, but getting costs down is nearly impossible. But we should be very careful not to let the costs rise too much.'

While VAR will always be an F3 outfit at heart, van Amersfoort says he is seriously eyeing GP2, or the new Formula 2 it seems set to become. He is also looking at touring cars, specifically TCR. But that's for the future, and for the time being he has his sights firmly set on another F3 super-team: 'We want to beat Prema!' he says.

RACE MOVES

XPB

Jost Capito has said that he may not now move in to his new role as Formula 1 CEO at McLaren until the World Rally Championship is settled. It was announced that Capito was to join McLaren in January, but only when a successor for him as head of VW Motorsport was found. He has now made it known that he intends to wait until VW has a firm grip on the World Rally Championship before he finally jumps ship.

The Manor F1 team has taken on **Simon Pavitt** as its new marketing director. Pavitt has 15 years of experience in sports marketing and has spent the past six years at Fuse Sport + Entertainment, where he advised 10 of the top 30 global brands on partnership strategy, and was involved in a number of major sponsorship deals. He will oversee all commercial and marketing activities at Manor GP.

Chris Meek, the racer and property developer who saved the Mallory Park circuit in the 1980s, has died at the age of 73. Meek was a successful race driver in a wide variety of machinery, including Formula Atlantic and sportscars, and was also instrumental in helping **Tom Pryce** as he rose through the ranks and in to Formula 1 in the 1970s.

Ade Barwick has joined UK sports and racecar builder Ginetta as its commercial director. He will work with technical director **Ewan Baldry** and production manager **Simon Laughlin**, and Ginetta says his role will partly involve him 'building upon a successful introduction of the Ginetta Prototype and the resulting interest from overseas'.

Malcolm Swetnam took **Hugh Chamberlain's** place as team manager of the Murphy Prototypes LMP2 team at Le Mans, after the former stepped down from the post before the Imola round of the ELMS. Swetnam was previously team manager at the Anglo-Irish squad back in 2013.

Former single seater and GT ace **Neil Cunningham**, a well-known figure on the domestic motorsport scene in the UK, has died at the age of 53. The New Zealander, who was a star in FF1600 at the start of his career but went on to excel in a wide variety of categories, was diagnosed with motor neurone disease when he was 47, and spent the latter years of his life raising money to help fund research into the condition.

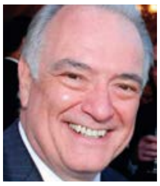
Supercars stalwart **Campbell Little** has left the Erebus Motorsport outfit, with team boss **Barry Ryan** now taking over as engineer for **David Reynolds** while the team looks for a permanent replacement. Meanwhile, **Dennis Huijser** has moved into the role of crew chief on the Holden Commodore. Italian race engineer **Mirko DeRosa** has also recently joined Erebus.

Campbell Little (see above) has joined Australian Supercars outfit Lucas Dumbrell Motorsport to engineer the car of New Zealand racer **Andre Heimgartner**. So far this season team boss **Barry Hay** has worked as the race engineer on the Heimgartner car, in tandem with his management duties. Little has had a long career in Supercars and has worked with many of its top teams, including Prodrive Racing Australia, Triple Eight and Dick Johnson Racing.

Australian Supercars outfit Erebus Motorsport now has an all-female number one and two mechanic line-up working on **Aaaren Russell**'s Holden Commodore. Former Blancpain Endurance and Toyota Racing Series engineer **Frances Buckley** is now number one mechanic on the car, while **Bonnie Beard** has stepped up from the organisation's Ute (pickup) squad to the number two mechanic position.

KW Special Projects, a UK-based engineering consultancy specialising in technology transfer across industries, has taken on former IndyCar vice president of technology **Will Phillips** as its technical director.

Step change



Within six hours of the referendum result we asked the MIA's CEO Chris Aylett for his take on the UK's decision to leave the European Union

In the short term, it is important to remember that legally we are still in the European Union, and will continue to be for the next two years at a minimum. And this could be extended from both sides. Clearly, we are dealing with instant volatility in the markets, but that could have applied whatever the result.

The freedom of movement of employees means that they come and go, and when you walk through Motorsport Valley you hear so many languages from inside and outside the EU. If you want to be in the best place, in the best industry, you go where the best employers are. And the best employers will always employ the best people, somehow. It might be more awkward administratively, but the best people will find the best employers and the best jobs, and motorsport relies on those people whether they are from China, South America or the USA.

Will this invigorate UK engineering companies? It is too early to tell. We have always traded with the world. Although America is as equally important and valuable as Europe, we will continue to trade with all those markets, as long as we as a group deliver the winning result. The business we are in is about delivering winning solutions, and to do that we would buy them from Argentina, China or Japan, or wherever else in the world.

If the EU was to restrict the movement of people in the UK, and I can't think why they would want to, it would have an effect on racing in Europe. We are travellers, we are connected, we move around freely. If the future of the European Union is coming up with ways to restrict people doing business, travelling and finding work, there is no future for the EU. And that is the reason so many people voted to leave.

Dramatic change

There is a strong feeling that this is the beginning of a dramatic change within the EU, because we will not be the only major partner who has been told to leave by its electorate. The value of this result, which is strange to some people, is that it may waken Europe to change some of the practices that has clearly made it unpopular. You can harp on about the negatives, because we have had three months of being beaten up by the negatives, but you look at the positives, and think that this is the beginning at long last of a sensible new European approach to business, labour, employment, and immigration. If you are in the doom camp, you can dream up a lot of negatives. Or, you can say that markets have opened up all over the world to trade with us.

Positive thinking

I have this positive view that although I have read that there will be a vindictive response, I cannot see the value to the European governments to penalise trade with one of their major partners. Otherwise it goes straight back to protectionism, which is not what the future is about.

You can dream up a lot of negatives, or you can say that markets have opened up all over the world

Let's hope that sanity comes out of this very strong message that the European Union could have done things differently, and this might have persuaded a relatively tiny number of people in the UK, a million or more, to stay in. Maybe this will make them look at this, and change.

They have played the game incorrectly, and encouraged intelligent people to vote not to stay in. Out of that could come a sensible relationship with the United Kingdom. And I cannot imagine why they would want another 40 years of penalising the UK, because it plumped for change.

In motorsport terms? Well, as long as the solutions win, we buy from anybody. We cannot afford not to.

But are we self-sustaining? You know, in the long discussion on this it was said that we send money to Europe to receive some of it back. If we stop sending it to Europe, we can resend it to wherever we wish, and that could be to R&D. As a government we use a lot of public money on R&D from our own resources. The mix will probably change, but it is up to the UK government where it puts the money.

RACE MOVES – continued

XPB

Claire Williams, the deputy team principal of the Williams F1 team, has been awarded with an OBE in the Queen's Birthday Honours List. She joined the team her father Frank founded in 2002, working in the PR department, before taking the position of director of marketing and communications. She has been deputy team principal since 2013. The award was given 'for services to Formula 1'.

Dr Phil Raynor, the chief medical officer for the MSA, has died at the age of 66. Raynor was also chairman of the MSA Medical Advisory Panel, and a long serving member of the FIA Medical Commission, as well as a member of the FIA Anti-Doping Disciplinary Committee since its formation.

MSA steward **Roger Reed** has died at the age of 74. Reed was chairman of the Scottish Association of Car Clubs for the past six years and, before that, chairman of the Eastern Association of Car Clubs for 20 years. He also served for 21 years on MSA Regional Committees.

Former Formula 1 driver and now director of Racing Operations at the Confederation of Australian Motor Sport, **Tim Schenken**, has been awarded the Medal of the Order of Australia in the Queen's Birthday Honours List.

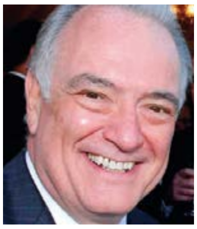
Past and present team owners are among the newly elected members of the 2017 NASCAR Hall of Fame Class. **Rick Hendrick**, who has won a record 11 NASCAR Sprint Cup Series titles; **Raymond Parks**, who won NASCAR's first premier series title in 1949; and **Richard Childress**, whose pairing with **Dale Earnhardt** produced six championships in NASCAR's top division, all make the list. Meanwhile, Martinsville Speedway founder **H Clay Earles** is this year's recipient of the Landmark Award for Outstanding Contributions to NASCAR.

John Thornburn, who was a well-known race team manager in Britain, has died at the age of 78 after a long illness. He managed the Team Elite Lotus outfit in sportscars in the 1960s, and the Alan McKechnie Formula 5000 squad in the 1970s. Thornburn was also a very successful driver manager and played a part in the early career of **Nigel Mansell**.

Three members of the PFL Motorsport British GT operation were injured in a freak accident while loading the team's Aston Martin Vantage GT3 after the Silverstone 500 round of the championship. Two suffered minor injuries, the third a broken foot, after the transporter's tail-lift failed, dropping the Aston to the floor. The racecar was also badly damaged in the incident

Holden Racing Team (HRT) has changed the engineering structure of its Australian Supercars outfit, with both its drivers, **James Courtney** and **Garth Tander**, now working with new engineers. **Rob Starr** is now on the Courtney car, while the team's research and development manager **Alex Somerset** is engineering Tander's mount. Starr replaces **Alistair McVean** while Somerset replaces **Blake Smith**.

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



Trading in futures

If the industry desires continued growth then it must not be complacent

For the past 12 years, the UK motorsport industry has seen revenues growing steadily at a rate of 4.7 per cent each year through a period of significant economic instability and an unprecedented global financial crisis. On this basis, by 2020, it is estimated that annual revenues will exceed £12bn. These revenues continue to be split evenly between motorsport engineering and the provision of services such as commercial rights, sponsorship, circuit operations and the like. Clearly, far more employees are engaged in producing the engineering solutions than in the area of servicing the entertainment of the sport. Just think of the low number of employees working for FOM and the huge sales income it declares each year.

By 2020 it is estimated that the annual revenues will exceed £12bn

XPB

The MIA's Motorsport Growth Plan has stressed the need for the UK racing industry to embrace new forms of motorsport technology such as that which is used in Formula E

Growth plan

The figures above come from a recently published Motorsport Growth Plan from the MIA, after months of interviews, research and discussion. The Plan aims to help those in this business consider their future investments and growth strategy.

It is clear that this is currently a robust industry sector which has survived the recent economic difficulties in good health and can look forward to a secure future over the next few years. However, there is danger in complacency. Changes are certainly coming and will require top-class management skills and careful planning to overcome. It is possible to see an accelerated growth by 2025 if some actions are taken. The MIA estimates the industry could exceed £18bn in revenues by that date, depending on actions taken in the near future.

On tracking the industry's revenues for the past 15 years, it is clear that whilst the service side of motorsport is entirely reliant on its popularity, this is not true of the engineering companies who have steadily increased their revenues from adjacent sectors such as automotive, aerospace and defence. Currently, it would appear that approximately half of all revenues in engineering come from outside motorsport and the report sees this trend increasing to becoming 60 per cent of all revenues by 2025.

The Plan considers growth opportunities both within motorsport and outside. But the core, essential capability of the engineering companies relies on the 'halo' of motorsport activity, so continuing growth is essential to the service sector. But the world of sport entertainment is changing rapidly, as is the way the sport reaches individuals. In the next decade, the traditional pay-per-view TV model will come under increasing attack from the myriad of alternative online access points enjoyed by fans, and yet the major motorsport series are committed to selling the sport to subscription channels and have little engagement in these new media. Throughout the world there is also a steady decline in paying spectators attending motorsport events. The MIA's Plan underlines the essential economic value of increasing our fan engagement at all levels. The lifeline of the sport is attracting paying spectators, to then attract sponsor and media interest. In the light of the changing broadcast world, it will be ever harder to calculate the popularity of a live sport, so full grandstands will count in sports of the future. The recent Indy 500 record crowd exceeding 300,000 is a good omen, but is increasingly looking like an oasis in the desert.

The MIA Plan also recognises that there is not one single organisation that is tasked with increasing the fan engagement, but we should create a community-wide discussion bringing in promoters, governing bodies, and the industry, all of whom depend upon revenues from fans.

It seems that within motorsport there are good opportunities for growth in international markets, which have yet to develop. China and India are communities where wealth is increasing, bringing car ownership, and history shows that motorsport will shortly follow. The MIA recommends five years of continual engagement with both China and India, encouraging motorsport to become popular by working with governing bodies and promoters, and also the government of these countries who wish to see engineering growth at the heart of their communities, and so will support the growth of motorsport when they realise this will brings hi-tech jobs to their community.

Growth outside motorsport will come from increasing collaboration with other sectors as most of them require the unique capabilities of motorsport engineering companies. The value of speed in resolving a period of enormous disruption is an important asset to motorsport. The agility and flexibility of the motorsport supply chain to meet and resolve technical challenges as they arise, is now being recognised by automotive companies. The MIA is working closely with the Automotive Council in the UK, on a new collaborative programme which will help these companies engage with automotive OEMs and Tier Ones – a programme which could easily be replicated in areas of the defence industry, which are seeking the same capabilities. When compared to the enormous size of these two multi-billion pound industries, it may be seen that these are relatively small programmes, but to our motorsport community, they offer the chance of many billions of pounds of new revenues by 2025.

Global scope

In recent years, Motorsport Valley has had great success at attracting new investment into the community from around the world and it seems that this will continue. As long as our community embraces new technologies, just as it has with Formula E, then it will be seen as the motorsport business community most well equipped to handle the future challenges coming our way.

The increased number of Formula 1 teams that now have their operations in the UK is a sure sign that this is the place to be. The MIA Plan recognised, however, that the international growth in volume will probably come from sportscars in GTs and touring cars over the next decade, as these are the cars that are most likely to sell well in the under-developed motorsport markets and elsewhere in the world. So it makes a strong case that on a global basis the business for motorsport engineering companies is going be in these series and, as Formula 1 becomes more restrictive, the supply chain will rely less on its influence.

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The protest movement

The issue of GTE's Balance of Performance at Le Mans started months ago, with arguments raging over sandbagging, over who was hiding what, and over who was trying to pull the wool over everyone else's eyes. It inspired the feature that we have run this month (p34) which proves that it is almost impossible for a governing body to get it completely correct, and so it was with some circumspection that we viewed the run up to Le Mans. As Paul Truswell shows in his Le Mans analysis (p20), the true picture was not quite the same as that shown in qualifying on Wednesday night. However, the real GTE story has nothing to do with balance of performance at all; the real GTE story is one of sportsmanship, and that went out of the window in the final hour of the race this year.

The Risi Ferrari ran the race with 12 team members, and three engineers. They were the last of the Ferraris still in with a chance of winning, although to be fair, Ford had the legs on them after Ferrari's Toni Vilander spun in the Porsche Curves. Having wandered down to the team to see what was happening, I spotted Multimatic's Larry Holt emerging from the Ferrari pit and wondered what that was all about. Ford was set to lodge a protest against the Ferrari as its leader lights, supplied by the ACO, had failed – one light was not working. But Ferrari argued that it was neither a safety issue nor a performance issue.

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Outside the Ferrari pit, Aston Martin's David Richards was set to weigh in, on the record, claiming that Ford had committed a 'professional foul' on the balance of performance arguments pre-race. In response to the very public outcry, the FIA had called in the manufacturers on Friday afternoon and, as well as slightly adjusting the BoP for the race, had given them all a warning. If, at any time during the race, a GTE car was to run within 107 per cent of the average of four fastest LMP2 times, they would receive a five minute stop and go penalty in the final half hour of the race. Aston Martin claimed that Ford had breached this rule 57 times during the 24 hours. Ford's drivers wondered how many times Ferrari had done the same, as the two were pretty much perfectly balanced in terms of performance. This could explain Aston Martin's desire to lodge this appeal; should Ford and Ferrari get thrown out, they would be declared as winners!

According to the FIA stewards' decisions, Ford did, indeed, bring the matter to the attention of the stewards, who showed the 488 the black and orange flag for not having the leader lights working. These leader lights, incidentally, are not the same as the lights that illuminate the number on the doors, which 11 cars, including Ford and Audi, had to stop to repair during the race. Ferrari ignored the flag, took second on the road and stood on the podium, although they knew the chance of keeping the position was slim.

Then, rather than lodge a protest against the outright pace of the Ford, instead they protested them for speeding through a slow zone. This had all the makings of a disaster – Ford had a formal challenge to the Ferrari lodged too. However, the teams sent up their more diplomatic members and, according to one insider, neither wanted to change the results; saying they should all be allowed to stand as they been well-earned by both. 'Following the hearing with both competitors and a review of timing and telemetry data, the stewards upheld the protest of the Entrant of car 82,' said Stewards' Decision number 58. An extra 50 seconds were added to the winning Ford's time. Ferrari got its money back. Decision number 59 read: 'Having heard from the competitor's representative, the Stewards accepted the explanation that as he did not have time to reach his garage after the flag was given, [and] before the end of the race, and his deputy was not fully informed, that his deputy then told the driver to stay out.' Ferrari was fined €5000. Decision 60 was to do with the Ford's wheel speed sensor not functioning properly, and added a further 20 seconds to the 68 car. Ford's protest against the Ferrari was also upheld, and the Ferrari had a further 20 seconds added to its race time. Ford got its protest fee back.

Was all of this really necessary? Both manufacturers introduced new cars this year, both had run 24 hours pretty much reliably and were in a position to fight for victory. The political manoeuvres rather soiled the efforts of the mechanics and the drivers who had performed their usual heroics during the longest week of the year. It was a shame that the race finished in the stewards' room, but at least common sense prevailed in the end. Ford kept its win, Ferrari was second.

What happens in the WEC, and in the US in the IMSA Sportscar Championship, I hope will be infinitely more gentlemanly than what happened at Le Mans.

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