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Aston Martin

The all-new Vantage GTE that's set to shake up Le Mans

Gilles Simon

Exclusive interview with FIA's new technical chief

Bloodhound SSC

Aero secrets behind the 1000mph record car

Formula 1 PUs

New engine regulations under the microscope

Shock tactics

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The WTCC races into history at Macau. Next season the FIA will run a World TCR Cup in its place; turn to p86 for an in-depth interview with TCR founder Marcello Lotti


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Can Formula 1 truly be the pinnacle of technology when it's ultimately a business?

The banner of 'red hot tip of technology' is often waved about in any discussion about F1 and what it should be; it's over-arching ethos. Well, it has been true in some departments, but not because of motorsport's ingrained belief in it. Motor racing in this era is really a business, which incidentally ends up attracting new technology, but does not in itself generate any by its very nature, except in some very specialised areas.

Aerospace does, but only because it is inextricably entwined with defence, for which spending is often not to be questioned and budgets for it tend to be of the blank-cheque variety, going directly against Lord Kelvin's observation: 'Large increases in cost with questionable increases in performance can be tolerated only for race horses and fancy women.'

One could add racecars to that, but only in lower classes which are bankrolled by individuals trying to make up for lack of talent by acquiring an advantage. Not the flagship category, for that is a business, and innovation, even if it reduces costs in the longer view, tends to be expensive in the short term.

Down to business

In contrast, racing, as we know it is driven by other considerations. Keeping the manufacturer paying for it happy, and the sponsors that pay the workers happy, too.

When it comes to where the money comes from it falls squarely on the marketing budget, with some part of it coming from R&D budgets, being siphoned off to use technology you theoretically master and would like to sell. There is no lack of finance, being a small percentage of what is available given the size of the car industry.

I have mentioned before that if we look at the business of making and selling cars we can have several thrusts in the manner it can be conducted. Publishing ads that will have a rosy glowing lifestyle you can achieve by owning this particular car; supplying motoring magazines with a souped-up model of the car with extra performance not found in the plain-vanilla production version (which is why you should buy ex-press cars if you have the opportunity, bearing in mind, of course, that it has been pre-thrashed for you); or working on the aura of the car indirectly by going racing to show it can beat the opposition – despite the fact that customers very seldom use said car in these specialised conditions. But we are not talking about logic here, we're talking about emotion. In several categories of racing this ploy stumbles on the notorious Balance of Performance, which again takes away all the logic behind this avenue.

If you have been in any technical working group you will know it's so nakedly political that someone should charge them with indecent exposure.

The crux of the matter is that you can have CEOs that love racing (we are lucky to have them) and can understand the appeal to that demographic, but applying it to the company, then it has many other priorities that can overwrite it.

Sales drive

I would go as far as saying that tobacco, energy drinks or banks have understood and promoted racing better, in the sense of tying in their involvement and binding the link between their product and the aura of racing. Most manufacturers dabble in racing, coming in and leaving once a particular group of persons achieve their personal goals, the board then reverting to default mode and going for the easy lift; publishing or airing advertisements the old fashioned way.

For Ferrari racing is in its DNA, but other car manufacturers may need regulatory incentives to lure them into the Formula 1 arena

But a few manufacturers do have it in their very DNA, easy to spot as they are conspicuously there for the long term. Ferrari has no advertising for its road cars, but it has an advertising budget nonetheless, re-badged 'Racing team running costs'. Ah, the joys of creative accounting.

My experience with a slew of manufacturers tells me that all racing programmes are pushed by the petrolheads in the company, but the possibilities are not necessarily exploited and the requirements not necessarily satisfied, the bias being wearing the 'racer' hat but then forgetting the reason that would be of most important to the company, whose core competence is producing transport.

Both Formula 1 and LMP1 have now taken engine technology to new heights, in terms of efficiency. This is something that should be trumpeted far and wide, yet seems to have sunk into the quicksand of general indifference, despite the importance of its consequences.

Having won championships with companies that spent a considerable amount of money to finance their racing, finding out nobody knows about it through lack of capitalising on the results is not at all unusual. Marlboro spent the same amount proclaiming its racing results as on the race team, but it is an exception.

Charles Jarrott said in 1906: 'The curse of commercialisation is the ruin of every sport, and the degeneracy of motor racing as a sport is due to the financial issues now involved in each race – the immense value of victory and the commercial disaster of defeat.' So we are aware this is not a new phenomenon, it is woven into the very fabric of the sport and is not going away, so we might as well accept it.

The evolutionary dead end in F1 development and technology is therefore rule-driven, and these rules, in their formulating, are derived from the need to keep and bring manufacturers into the fold by offering them some advantages.

Regulation issues

Max Mosley's taking away of driver aids is understandable in the light of what ESP, traction control, ABS or active suspensions and aerodynamics can do even at current levels of knowledge – see any road car – in the interest of keeping it a sport for humans, not engineers (I accept the previous phrase can be perilous, let us state engineers are quasi-human). Until we have self-driving racing cars, that is, thus eliminating the problem.

Once again, I have ranted on about the problems without bringing any solutions, because being an engineer my horizon is tied to my profession, solving technical problems. The solutions will have to come from the FIA (but its depends on the money flow), the marketing departments of manufacturers (who seldom do their work thoroughly enough) and the public, the ultimate arbiter, as it will ultimately pay for it (and it seems to be drifting away from racing).

Then maybe F1 cars will be technologically more advanced than production cars, but the prospect does seem bleak.

The evolutionary dead end in F1 development and technology is rule-driven

Power brokers

Is it impossible for independent engine builders to make a business case for F1?

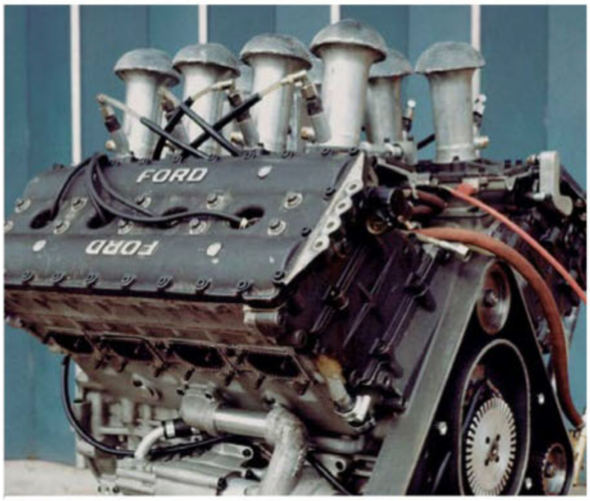
The seemingly endless debate regarding reduction in F1 power unit costs feels to have been going on as long as Britain's political strife concerning the EU. With about as much progress. Money, ambition and ego will always form the background agenda, and the real objective mainly depends on from what end of the spectrum any change is being viewed.

However, taking the view that something along the lines of the latest proposed 2021 regulations (basically higher-revving 1.6-litre V6 single-turbo KERS hybrids without MG-H and with peripheral expenditure contained, see page 36) is finally settled upon, what chances really exist for a truly independent power unit supplier to offer a competitive product to non-manufacturer F1 teams in future, this being one of the supposed main targets for the changes?

Investor beware

Assume that interested parties would be of the calibre of Ilmor and Cosworth, to name two companies with anything like the capability to take on such a project. If I were to put myself in the seat of the CEO concerned, with shareholders and workforce and the well-being of the company to consider, there would be some key factors needing to be addressed before putting a recommendation to the board of directors. My bullet list would look something like this:

- What is the business case for undertaking a Formula 1 customer engine supply project? Is it solely as a profit stream, or are there additional returns such as technology acquisition and beneficial transfer to other company activities? Maybe the potential for attracting a major manufacturer or another substantial sponsor to pay to badge the power unit?
- How real is the customer base and what is the size of the customer base being targeted?
- Is Formula 1 a good fit for the company and can the shareholders be persuaded; return on investment (ROI) generally being the key decider here?
- How much are these power units going to cost to design, manufacture, assemble and prepare?
- Factor in the inventory requirements, this includes planning, control and – very importantly – parts obsolescence.
- What is the investment required and the source of initial funding (maybe borrowing will be needed?) until inward cash flows commence?
- How stable are the regulations and therefore the minimum longevity of the project, in order to obtain that eventual ROI?
- What are the lead times involved *v* the F1-relevant resources in R&D, design and manufacturing already existing in-house; and how much top-quality interim outsourcing and poaching of key personnel can be realised?



The legendary Cosworth DFV once dominated F1. Even in simpler times manufacturer support, in this case from Ford, was needed

- Will at least one of the prospective customer teams be sufficiently budgeted, competitive and competent to test with beneficially, and from which initial and ongoing power unit performance can be judged and showcased?
- Does a contingency plan exist for avoiding/handling payment defaults by customers and the reduction in income should one drop out?
- Are support costs fully allowed for the customer service and liaison that will be required – technical, engineering and commercial?
- Risk factor – does the business case still realistically reflect all the above?

The list is lengthy, but by no means exhaustive. Most people without the necessary insight cannot fully appreciate the scale of the task in producing and supplying a competitive – and reliable – contemporary F1 power unit. Mercedes worked relentlessly on the design and development of its formidable product seemingly from the time that the 2014 regulations were confirmed, and went through many iterations before reaching its target. This target keeps moving higher and higher almost with every race. Even with a simplified power unit, which will still, however, retain a complex-to-manage KERS, and restrictions on development and ultra-sophisticated digital technology, competing against the sheer depth and breadth of resource within Mercedes and the other manufacturers is going to be a tall order.

Making a marque

Without the luxury of the manufacturers' marketing budgets that support most of the costs from the bullet list above it is very difficult to see a commercial business case based solely on F1 engine supply at a fixed cost that stacks up on its own merits. Realistically, a relatively small number of three or four teams is likely to form the actual market, probably fewer. On top of this, there's the stated intention of the FIA to reduce the engine cost to all teams. Given the number of under-financed F1 outfits that have departed the scene over just the last few years, the risk factor in terms of potential ROI must be looked upon as very high.

Therefore, the only 'real world' basis on which an independent engine supplier could responsibly go ahead remains with badging of the power unit – meaning financial support from a manufacturer or sponsor keen to enter attracted by the move away from sky-high power unit costs and the opportunity to compete on a more equal footing. Looking back, this is really little different from the way it's been since the late 1960s; in order to compete with Ferrari and then Honda, Cosworth needed Ford backing to create the DFV and its derivatives, BRM and Matra were both backed by major industrial concerns whose owners saw F1 racing as a means of developing and publicising their automotive products and who were determinedly patriotic. The marketing connections here are obvious, and remain so to this day, albeit in a much more nuanced and sophisticated way. This perhaps could resonate again with major car and hi-tech industrial manufacturers; it will be for the independents to make those pitches and realise the less closed-shop situation for F1 teams that is supposedly being sought.

Most people cannot fully appreciate the scale of the task of producing and supplying a competitive, and reliable, contemporary Formula 1 power unit

AdVantage Aston

It's been a long time coming – and there's quite a while before it will actually race – but early signs are that Aston Martin's all-new Vantage GTE car has been well worth the wait

By ANDREW COTTON

The new Aston Martin GTE is both longer and wider than the previous version but, despite appearances, it has a similar frontal area. Though the car is very nearly race ready it won't see action until May

This might seem strange for a car that is not due to make its race debut for more than seven months, but Aston Martin was right up against it when it launched its new Vantage, which will contest the FIA WEC 'Super Season' in 2018/19.

The timing of the road car launch on which it is based, and the development of the GTE Vantage, meant that the team could not attend the Ladoux test in France in September, and was developing the racecar right up until it completed its homologation process at the Windshear facility in North Carolina in November – all the new cars and evo kits had to be tested at either Ladoux by the FIA, or at Windshear by IMSA with FIA observers.

That's now done, but there's now a long wait until the car can race, as for Aston Martin there is no IMSA programme yet, Daytona is off the schedule for now, and so is Sebring in March due to the fee that the manufacturer would have to pay to IMSA's entry fee to compete. That puts the race debut for the car back to the Spa six hours in May, just over a month before the Le Mans 24 hours, at which the manufacturer hopes it can repeat its class victory of 2017.

Since 2012, Aston Martin has relied on its V8 Vantage to carry its banner in GT racing, and with some fairly major upgrades – mechanical in 2013 and aero in 2016 to meet new regulations – the car has remained competitive, thanks in no small part to the FIA's Balance of Performance system. But many have criticised Aston Martin's ability to remain competitive on pure pace with such an old car against models that are designed specifically to the new regulations. But now the British team has finally launched its newest model.

The 2018 Vantage is almost completely new. The team says that there are just five carry-over parts from the old model, and a list of major changes in supply companies goes along with a complete change in philosophy for Aston Martin Racing. Michelin replaces Dunlop as the tyre supplier, Ohlins takes on the suspension manufacture, Alcon the brakes, along with a completely different AMG twin turbo engine and all-new aero, not to mention a new body and bespoke components.

Stiffer chassis

The out-going Vantage featured the old VH architecture for its chassis. That meant that, in road car guise, the chassis could be stretched to DB9 or even four-door Rapide length, but for racing it lacked a certain rigidity. The old chassis was also a modular design, and while that has helped the team to complete repairs following accidents, it also meant a chassis that was not stiff enough to match the current competition.

Aston Martin Racing (AMR), believes that the all-new lightweight aluminium chassis, based on the latest Vantage road car, is twice as stiff

The 2018 Vantage is almost completely new – Aston Martin Racing says that there are just five carry-over parts from the old model

The Vantage cocks a wheel during Sebring testing. Prior to launch it amassed more than 10,000 kilometres, including a 30-hour test. AMR has switched from Dunlop to Michelin tyres

as the outgoing model, thanks in part to closer links with the production line. 'The stiffness of the chassis has improved vastly, and we have also done more with the roll cage,' says AMR technical director Dan Sayers. 'Being involved with Aston at an earlier point means they have done the first three shells on the prototype line, and we have been able to get parts in there and modify them before they go in, such as floor brackets, exhaust brackets, lightening and things like that. In terms of stiffness, the chassis is close to double what it was.

'The old car was modular, which had its benefits, because we had some heavy prangs in the old car and you can then unbolt part of it and bolt a new part on,' Sayers adds. 'But a bolted part is inherently weak.'

The new car is both longer and wider than the previous version, leaving it with a similar frontal area than the outgoing car (despite appearances to the contrary), and Aston Martin Racing hopes that this will help to improve the handling of the racecar, particularly on the tight and twisty high downforce sections of track that was a real weakness with the previous Aston Martin GTE racer.

AMR is experimenting with torque sensors that may in future become part of the balance of performance process

There are also major changes that will help improve the handling that have been made under the skin. AMR has worked hard on the detail, lowering the centre of gravity through dropping the engine and fitting a bespoke Xtrac gearbox to the point that they are touching the all-new five-piece floor. The carbon fibre and steel floor features a splitter, three mid-car sections, and a diffuser.

Conventional layout

The team did not consider an extreme concept, such as Porsche's mid-engine, in the latest GTE and forthcoming GT3 car, saying that it could achieve its targets with a conventional layout, but there have been some major changes.

'We have stretched the wheelbase to allow us to package everything nicely, and that was a regulation change part way through the design,' says Sayers. 'The GT3 regulations say that you could move [the wheelbase] 60mm and GTE was 50mm, and [following the convergence talks] now they have consolidated them to say both are 60mm, so we eked it out. It is a lot wider than the current racecar, hence the similar frontal area, and it is longer, so it is by no means BMW M8 style, but it is a big car.'

AMR goes AMG

The biggest component change, however, is the engine. Gone is the V8 naturally aspirated powerplant, replaced by a 4-litre twin turbo engine from AMG. AMR has made modifications to the base unit, including fitting new, smaller Borg Warner turbos than the road car due to the boost pressure regulations that mean the turbos don't have to work as hard as in the production car, plus new pistons and valves to increase the compression ratio and improve efficiency. However, the 'hot-side inside' turbos, nestled within the V-angle of the engine, have led to an extensive re-packaging exercise within the car.

Under the bonnet the car is tightly packaged, although the team says that cooling is not an issue following some careful planning. Large ducts channel air through the radiators and out ahead of the engine. One major design target was to keep the charge air temperature as low as possible, and the team believes that it has achieved that goal. 'We have insulated the exhaust, the turbines in the turbos, and so we have taken as many precautions as we can, and with so low boost it helps because they

The Vantage GTE alongside its road car cousin. AMR benefited from access to the standard car on the prototype line and was able to specify some race components very early on

Gone is the V8 naturally aspirated powerplant, replaced by a 4-litre twin turbo engine from AMG

are not working massively hard, so they are surviving reasonably,' says Sayers.

'The engine is not ideal from an installation point of view [with] the turbos and the intercoolers, it is a huge packaging exercise in the front. The guys here have done a great job on the engine, and already in testing we have more mileage on the engine than we had on the current one. The two turbos are quite small, and although they are slightly higher than you want them due to the V-angle, AMG have been excellent. They gave us the base engine and told us to get on with it. I thought that they would try to control it and define what we could and could not do, but they let us get on with it.'

Boost control

With the Balance of Performance boost tables, the FIA is able to marry the behaviour of a turbo engine closely to that of a non-turbo. However, Aston Martin has had to do a lot of work to improve driveability from its new engine. While IMSA measures the boost pressure from 2000rpm, the FIA goes from 4000rpm, leaving a little room at the bottom of the rev range to exploit. AMR says that is less of a problem than over-boosting, and avoiding the penalties that could arise from that phenomenon. 'There is a huge amount to learn – we have never been policed on over-boosting and you don't want to be pinged,' says Sayers. 'At the exit from corners you have enough boost anyway, so you have to control how the boost comes in.'

All-new lightweight aluminium chassis is twice as stiff as outgoing model while roll cage has been beefed up

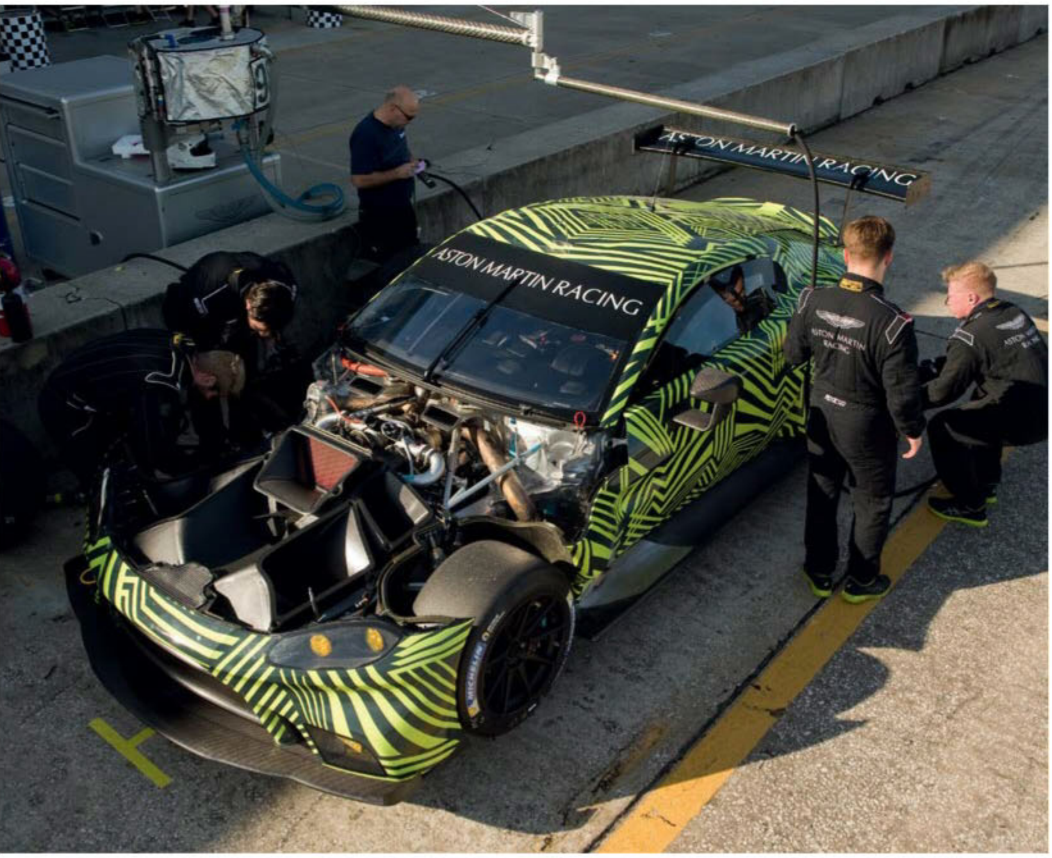
Prior to the launch AMR had amassed more than 10,000kms, including a 30-hour test, something that's all the more important given the amount of change the team has to adapt to. One of the biggest of these is the switch from Dunlop to Michelin rubber for the new car. The French manufacturer is the supplier for the Valkyrie hypercar and Aston Martin wanted the racecar to reflect this. The decision was taken relatively late in the programme, after the suspension geometry had been fixed for the racecar, but the team already has experience running with Michelin with its previous car – Dunlop had come on board in 2016 with an aggressive development strategy that the team felt would help it remain competitive against the Michelin runners with its aged car.

New tyre regulations introduced this year saw the development process slow dramatically, and with the 'joker' tyre banned in 2018, the mid-season development cycle has effectively stopped. 'We are doing the testing anyway, so arguably we just add to the mileage,' says Sayers. '[Michelin] know what they are doing, and we have the WEC ranges so can go through the normal development process over the year. If we had sat with Dunlop [at the start of the relationship], and said we would win a championship and Le Mans, we would have been sceptical, but it worked. Now, we have a new car, it should be competitive.'

Gone also, then, is the link up with OptimumG, which was involved in tuning the car to the tyres at the race track and provided dedicated support to the team.

Filling up

A change in the tyre regulations will have a major impact on another area of the car; the refuelling coupling. Regulations have yet to be announced at time of writing, but the GT cars will be allowed to refuel and change tyres at the same time in 2018, which means that the importance of all the work that has gone



New AMG 4-litre twin turbo powerplant sits far back in the engine bay. The packaging of this unit was a challenge for AMR

AMR has switched to Alcon brakes, which has produced bespoke kit. Car will still need a pad change at Le Mans 24 hours

Lowering the centre of gravity on the car was a major design target for the team

into speeding up the wheel change time has been reduced dramatically, and the refuelling coupling, which was switched from Staubli to Krontec to avoid the time wasted latching the probe to the car, is also now a concern.

'We spent a lot of time perfecting wheel changes, and it won't be wasted effort because if it rains, or you are short filling, you will need to change the tyres quickly, but it does change it,' Sayers says. 'It changes it for the team; it is the one bit of competition that they have in the pit lane, and they thrive on that, and so we put a lot of effort into making it as slick as we can, so we have the captive wheel nut, same threads.

'The refuelling point is a single point and we have changed to the Krontec valve. Primarily it is for the pit stop but ironically, because now you can refuel at the same time as change the tyres, you have to get the car into the air as quickly as possible. The Staubli system had the latching on, and the latching wasted three quarters of a second each time, so we got rid of it, and now we have to see how easy it is to hold it on there while the car is moved into the air. It sounds like not a big change, but there are a lot of decisions which are driven by the pit stop procedure, because that is where you can gain time.'

Centre of gravity

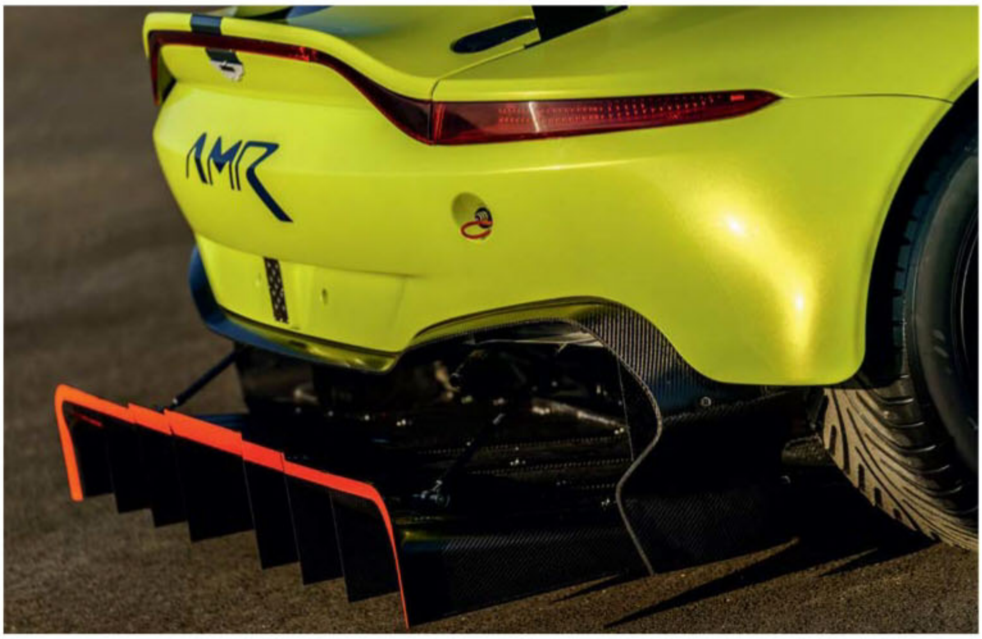
Lowering the centre of gravity was a major design target for the team, and it went to extreme lengths to achieve this. That included an all-new fuel tank that lies low in the car, and stretches into the cockpit, replacing the upright tall tank in the previous car. AMR estimates that the new magnesium case Xtrac gearbox is up to 15kg lighter than the previous 'box, having got rid of the drop gears that were run before, and it sits lower in the chassis. The team has also switched to an electronic gear change mechanism, replacing the pneumatic system which was in the older racecar, and has an electro-hydraulic power steering system.

'We have moved the engine as far back and down as we can,' says Sayers. 'Basically it is now not quite touching the bulkhead but it is close. We use the standard road car crank so you have a natural throw on that, while the dry sump is as low as possible, and that literally touches the floor.

'Serviceability is unquestionably slightly compromised, but if you have a problem with the car, and you have to go to the garage, [with the level of competition] you are out anyway,' Sayers adds. 'If it takes a few more minutes [to repair a fault], it is not the end of the world. Suspension is not too bad in that respect, and the coolers are on the front end, so that won't take much longer than the current car. The steering rack is slightly more hidden by the intercoolers but you can whip it out of the side. You can either make it very serviceable, but your aero will be worse, or not.'

The team has switched to Ohlins for the dampers, but the major change in that



Carbon fibre and steel five-piece floor features splitter, three mid-car sections, and runs into a whopping diffuser at the rear

TECH SPEC
Aston Martin Vantage GTE
Chassis: Lightweight aluminium chassis; steel roll cage to FIA safety numbers.
Engine: 4-litre V8 twin turbo, Borg Warner turbos with integrated electric wastegates. Dry sump. Power 400kW (variable by boost). Torque 700Nm.
Driveline/Transmission: Rear-wheel-drive with traction control; Xtrac 6-speed sequential transmission; Alcon motorsport multi-plate clutch; mechanical limited slip differential; semi-automatic paddleshift; direct acting electric gear shift actuator.
Suspension: Double wishbone front and rear; Ohlins 5-way adjustable dampers.
Steering: Electro-hydraulic power assisted steering.
Brakes: Alcon monobloc 6-pot (front), 4-pot (rear); integrated caliper temperature and pad wear sensors front and rear.
Fuel system: 100-litre fuel cell to FIA standards; single point Krontec fuel coupling.
Wheels: TWS forged magnesium 12.5in x 18 front, 13in x 18 rear; captive wheel nut design.
Tyres: Michelin 30/68-18 front, 31/71-18 rear.
Weight: 1245kg (regulated base weight).

area is with the brake supplier, which is now Alcon. 'That's a highlight for me,' says Sayers. 'Everything on the car from them has been designed specifically for us, so front and rear calipers, clutch, everything, has been optimised and designed around our geometry. They have been brilliant and the braking performance is a step forward, not just because of the brakes, but also because of the geometry and the aero.

'[We have] bigger discs on the front, which means a bit more heat, but you have more pad volume and hopefully you can get away with minimal changes. We are still far away from not having to change pads at Le Mans. This car, with the centre of gravity now lower, and with the geometry we are using, it means the rear brakes [are used] more, so that should even up the wear. It is a promising start.'

The rear suspension is also easier to work with as the production car has a trailing link suspension, which translates into a freer double wishbone design at the rear of the race version.

The team has also designed in some 'contact cases' which are designed to protect the vital components, such as the steering arms and driveshafts, in the event of a side-impact.

Torque sensors

Driveshafts are lightweight, and Aston Martin Racing is experimenting with torque sensors that may in the future actually become part of the balance of performance process as they measure output to the wheels, rather than inputs into the engine. This, believes Aston Martin, is far more accurate than the current system and it says that it may race with the torque sensors, if only to provide the FIA with some real data in advance of such a change.

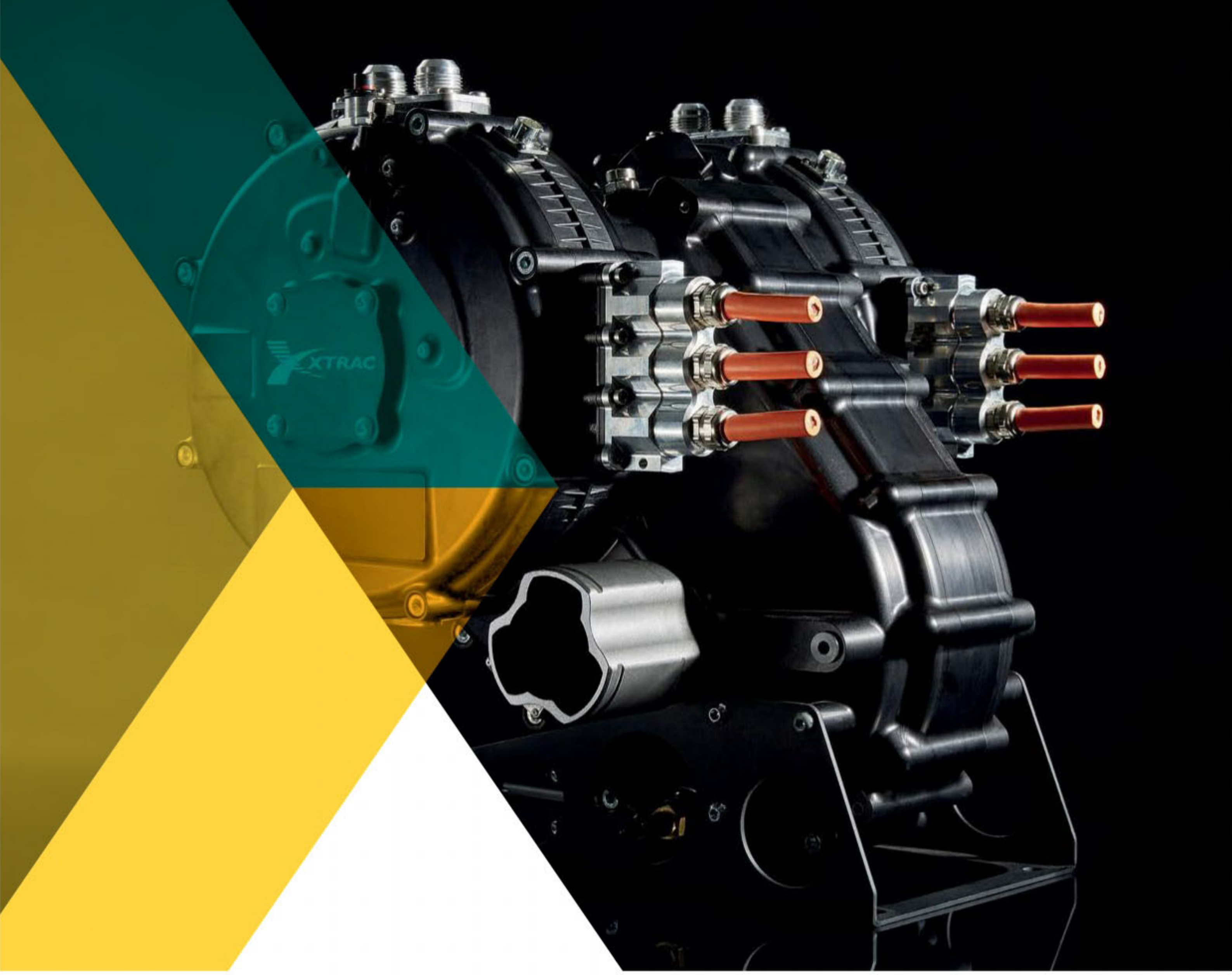
Cosworth provides the electronics for the car, including the power steering and gearshift mechanisms, as well as new injector drive boxes. The new car will also feature the GM-developed side impact protection for the driver, which is a mesh designed to stop objects from penetrating the cockpit and damaging the driver's legs. Also featured is the rear view camera with collision avoidance, developed by Bosch.

At time of writing, the car had yet to be homologated and the team was working on rear brake cooling before running in final trim in December. But is still seems a bit strange that the racecar will actually be finalised some months ahead of its first race in May.

'We have moved the engine as far back and down as we can, it is now not quite touching the bulkhead, but it is close'

'Because the car is fixed so early, it would be lovely to have a race before May,' admits Sayers. 'You saw Ford at Daytona, with the amount of testing that they did and 20 minutes into the race and they were in trouble. There is nothing like getting it into a race, and waiting until May is not ideal from my point of view, but we will do more testing. Sebring would be a good test for the car, but the manufacturers' fee is deterrent enough, so the WEC it is.'

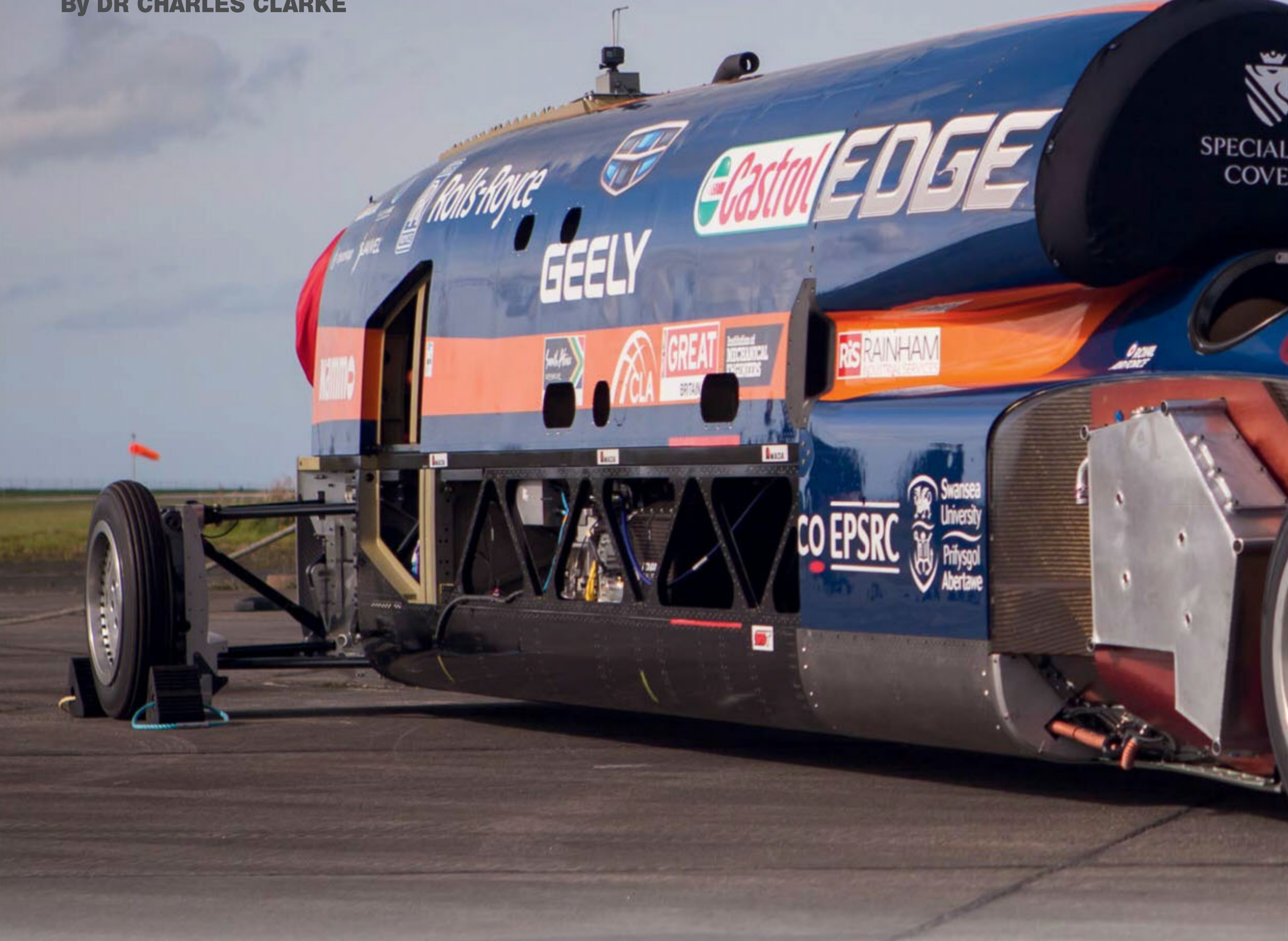
Aston Martin will hope that testing goes well in the interim seven months, as its biggest test is sure to come at the Le Mans 24 hours in June against new cars that have been racing since January at the latest. So might Aston Martin Racing consider a change in its schedule for 2018? It wouldn't be a surprise.


XTRAC

For the record

The Bloodhound SSC Land Speed Record car has passed an important milestone with its first public shakedown – *Racecar* was on hand to check out recent technical breakthroughs on this 1000mph projectile

By DR CHARLES CLARKE



Bloodhound SSC wowed LSR (Land Speed Record) fans and international media as the car completed its first public shakedown runs at Newquay Airport in the UK at the end of October. Everything went pretty much according to plan for the Bloodhound team, with a very minor brake fire the only drama of the day.

But while that might not sound so dramatic, the emotions from within the team were palpable. It was one of those witnessing grown men cry moments as the car did its first public high-speed runway runs. The team has been together for about 10 years and many before that were involved in the previous Thrust SSC record. So few teams are this close knit, and it seems for most that building the car and the record attempt is more of a passion than a job.

That's understandable, too. For the goal of the project is to break the 1000mph barrier, and the numbers involved in taking a land based, wheeled vehicle to 1000mph are as big as the ambition itself. One interesting indication of enormity of the task is this: at 1000mph the wheels will be spinning at 10,200rpm (170 times per second) four times faster than those on a Formula 1 car, and generating 50,000 radial *g*.

Bloodhound SSC will be the first – and probably for a long time, the only – land-based vehicle in history to travel for a sustained period of time well above the speed of sound. One of the crucial aspects of the aerodynamics of this vehicle is unique, then, in that the airflow is supersonic for a sustained period, and in particular there are multiple shock waves, which interact with the ground.

Grand designed

Much of the early aero work was concerned with coming up with a shape for the car that was, as far as possible, Mach number insensitive. That is, it was stable and exhibited neutral lift and downforce, whatever the speed, and perhaps more importantly at 1000mph or Mach 1.3 it was in its most stable configuration.

This first shakedown really signals the end of the design phase and the start of the development phases

PICTURE BY STEFAN MARJORAM

'The last thing we want is to make the world's fastest plough,' joked Dr Ben Evans of Swansea University, one of Bloodhound's CFD engineers.

Things tend to happen in unpredictable ways as the car goes from subsonic, transonic to supersonic. And even with some of the best CFD code and hardware in the world available, courtesy of the Zienkiewicz Centre for Computational Engineering in Swansea – the renowned birthplace of the Finite Element Method – each CFD analysis of even very minor configuration changes takes about 30 hours. Consequently,this meant that homing in on an acceptable shape configuration took nearly three years.

It is difficult to summarise where the project is, given the complexity of the engineering and logistical challenges, but the first shakedown really signals the end of the design phase and the start of the development phases.

Blast chance

At Newquay Bloodhound only reached 210mph, but this was constrained by the length of the runway, the fact that it was on tarmac, and that the car was on 'runway' wheels borrowed from an old Lightning jet fighter. Coming up over the next two years are tests to 600mph, 800mph and finally 1000mph, assuming all goes well during the previous increments. 'We are intending to go faster in 2018,' says Richard Nobel, Bloodhound's project director and former LSR holder. 'The tricky bit is to validate the CFD and to run to supersonic and collect data, plus you have to make sure it's stable.' The CFD used special code developed by the University of Swansea, which used over a hundred million finite elements for the CFD simulation.

'You can't use a wind tunnel to verify the CFD as there is no tunnel available that goes to 1000mph with a moving ground plane even with scale effects,' Nobel adds. 'Instead we used the reciprocal and used a rocket sled as we needed to validate the analysis before starting to build.' The reciprocal of the wind tunnel

Bloodhound is prepared for first public showing. It's hoped it will be ready for Land Speed Record attempt in South Africa in 2019

Bloodhound hit 210mph at the shakedown. The 600, 800 and then 1000mph barriers are still to come

moves the object through the air, not the air over the object. There are several rocket sled test tracks for testing armaments and jet fighter cockpits around the UK. 'We found one that wanted to use up some rockets that were close to their expiry date,' says Nobel. 'We used 200 rockets for 13 runs of the sled and thankfully the data correlation to the CFD was a straight line.'

Each of the high-speed tests needs a different configuration of power/propulsion units as the thrust requirements are different. It's well known that drag increases with the square of the speed in turbulent flow, but the power required increases with the cube of the speed. So double the speed, the drag increases fourfold and the power required increases eightfold.

Jet set

The Eurojet EJ200 jet engine produces nine tonnes of thrust and it should be sufficient alone for the 600mph tests. The 800mph tests will require the jet and a single mono-propellant rocket, but 1000mph will need the jet and three rockets. Unfortunately, the three rockets require more space than the single rocket, so significant rear suspension changes need to be made to repackage for them. But lessons learned from the previous testing need to be incorporated into the ultimate speed configuration.

The total thrust required to 1000mph is 20 tonnes with a thrust to weight ratio of about two and half times. The car in 1000mph trim is about 7.75 tonnes in weight.

As said, the first rocket for the 800mph tests is a mono-propellant rocket. 'We basically decompose peroxide to steam plus oxygen – there is no combustion for the thrust,' says Mark Chapman, Bloodhound engineering director.

Minor brake fire was the only problem. Braking will involve air brakes, wheel brakes and two parachutes

'This is a three-stage, multiple chamber rocket with three stages feeding a single nozzle producing four tonnes of thrust. For 1000mph instead of decomposing to steam and oxygen there is a fuel element in the hybrid rocket that is burning to produce 10 to 12 tonnes of thrust. Both rockets need the same amount of peroxide – one tonne peroxide in 17 seconds.'

One of the most significant challenges in the development phase is perfecting the Bloodhound pit stop. The FIA rules stipulate that for a valid record the vehicle has to go through a measured mile in two directions within an hour. Simple enough, but that hour starts as the car trips the start of the first measured mile. So after eight seconds (the first mile) the car needs to decelerate and stop (usually taking in excess of five and a half miles), get turned round and refuelled with jet and rocket fuel and be on its way to trip the start of the second measured mile within the hour. Unlike an F1 pitstop, where there is a simple five metre box to hit at 80kph, figuring out where that box is after a run of up to 1000mph, on a desert bed, with potentially

The airflow will be supersonic for a sustained period and there will be multiple shock waves which will interact with the ground

PICTURE BY STEPHEN HUNT OF SPITFIRE PRODUCTIONS

The wheels used for the Newquay shakedown came off a Cold War-era English Electric Lightning jet fighter

variable weather and wind conditions, is no simple task – having the support crew in exactly the right place at the right moment is critical to making the second run in the time required.

Stopping a 7.75-tonne jet car is not as simple as it sounds either – there are air brakes, two parachutes and wheel brakes to be deployed. Again, these things have to happen at exactly the right time in a particular sequence. Deploying the supersonic parachute too early could rip it to shreds and negate its effect, which means that the other braking mechanisms have to provide all the deceleration, increasing the stopping distance to six maybe seven miles. This extra distance could mean the car could run off the end of the desert at worst, but it would also affect where the pits top is performed and crucially it places the car further from the measured mile, which could mean the car runs out of fuel before completing the second run.

The other tricky bit is that the jet has to be shut down manually, before the end of the measured mile, to achieve the optimum deceleration. A jet doesn't work like a mechanically coupled internal combustion engine that starts to decelerate as soon as you lift off. The EJ200 is a digitally controlled jet engine, which was designed to be used in a fighter plane, not a car. This means that certain functions aren't ideal for use in Bloodhound without some modifications. If the EJ200 loses its connection to its control unit, it is designed to continue operating so that the aircraft doesn't stop flying. However, in Bloodhound the opposite is required, so that the car doesn't career off into the desert. To prevent this there is a mechanical fuel cut off lever in the cockpit. With a jet there is constant acceleration to terminal velocity, so knowing the optimum split second where to lift off needs the superhuman reactions of an RAF jet pilot like Bloodhound driver Andy Green. And yes, you can practice these procedures, but even with a programme as well organised as Bloodhound SSC, the opportunities to do multiple high-speed practice runs are relatively limited.

Pumped up

Another significant technical challenge is to deliver enough fuel to the rocket to make optimum use of its power. The auxiliary power unit (APU) for Bloodhound drives the rocket oxidiser pump, which supplies 800 litres of high test peroxide (HTP) to the rocket at 76bar (1000psi) in just 20 seconds, which is why the design of the pump is so vital. This is equivalent to 40 litres (over nine gallons) every second.


At 1000mph the Bloodhound's wheels will be spinning at 10,200rpm (170 times per second) and generating 50,000 radial *g*


Rear wheel track width needed to be minimised to help counter aerodynamic lift problems caused by the rear shock wave


The 800mph tests will require the EJ200 jet engine and a single rocket, but for 1000mph it will need the jet and three rockets

'The last thing we wanted to do is to make the world's fastest plough'

Currently the auxiliary power unit is a 550bhp Jaguar supercharged V8 engine. As mentioned, the rocket will be a single mono-propellant unit for the initial high-speed runs (up to 800mph) and then a cluster of three hybrid rockets for the 1000mph runs, both developed by Norwegian rocket specialist Nammo. The Jaguar engine has to sit next to the HTP tank, but it is vital that the heat from the engine doesn't transfer to the HTP itself, to prevent it exploding. The engine's exhaust is therefore covered with a ceramic coating which reduces its surface temperature by at least 30 per cent.

Electric switch

In an effort to make this situation safer, more compact and to improve weight distribution the team is investigating using electrical power for the HTP pump. An electric motor would be significantly smaller than the current APU and provide greater flexibility in the location of other components within the car. It would also offer a great opportunity to showcase the potential of an electrical automotive powertrain.

'Bloodhound has always sought to push the boundaries of technology,' says Chapman. 'However, when the team last looked at an all-electric solution for the APU, suitable motors did exist, but the battery technology was simply not mature enough to provide a realistic packaging solution. Since those early discussions, two things have happened: the team has developed the pump, improving its efficiency dramatically, and battery technology has moved on immeasurably, to a point where a packaged solution can be developed. When we first examined this option we thought we needed about a half-tonne of batteries. Now solid-state batteries and super capacitors are much lighter. This is where road cars are going, so we need to evaluate it.

'The Bloodhound SSC project never stops developing and we are always looking at emerging technologies,' Chapman adds. 'An investigation into an electric APU powertrain will allow the project to maintain currency with the direction of automotive technology and in addition allow us to showcase the potential that exists today.'

The switch to using an electric unit within the car's powertrain has been made possible by the increase in power and reliability of batteries over recent years, alongside a reduction in cost. For Bloodhound, one of the greatest challenges is accommodating all

PICTURE BY STEFAN MARJORAM

CFD analysis of even the smallest configuration changes takes about 30 hours and so homing in on an acceptable aerodynamic package has required close to three years of work

the components, including multiple braking systems and engines, and its fuel/power supplies. A petrol engine APU is not only larger than the equivalent electrical unit would now be, but also requires the relationship between the engine, clutch, gearbox and pump to be fixed as a single entity, along with the need for a closely positioned air intake, fuel and oil system.

Conversely, although the position of an electric motor still has to be fixed relative to the pump, the remainder of the system – including the motor controller, battery packs and so on – can be more flexibly positioned within the car, and even separated if necessary. This gives far more packaging opportunities for the engineers within the car. 'So we can move the centre of gravity if we need to as the speeds increase,' says Chapman. 'Flexibility in packaging is the biggest benefit of the electric solution.'

Trimmed out

One of the early aero problems was caused by the rear suspension shock wave producing huge rear supersonic lift. The ability to re-trim the vehicle by moving the batteries could prove beneficial in this regard, too.

'It soon became apparent that understanding the complex interactions between the positions and sizing of all of the components comprising the rear wheel suspension system and how they affected the strength and position of the rear wheel shock waves was not going to be an easy task,' says Evans. 'We therefore set about trying to simplify and parametrise the geometry at the rear of the car focussing on the variations that we felt were the critical ones: rear wheel track and the position of the delta leading edge. With help from MathWorks [providers of the MATLAB software package] we implemented a technique which we call "Design of Experiments" (DoE). This allows us to vary known parameters within the design space to find the optimum solutions – things like what combination of the parameters we were varying would give us the minimum rear car lift and drag.'

Ultimately, the output from this DoE study prescribed the way that the rear of Bloodhound SSC looks today. 'More importantly, it told us that we needed to minimise the rear wheel track width as far as possible – in our case, as far as we deemed it safe from a roll stability point of view,' says Evans. 'It also gave us the precise shape of the rear body of the car and the size and position of the crucial delta strut.'

One thing both APU systems will require is cooling, using the water tanks on either side of the monocoque. However, as there is no need for a cooled air intake for the electric option, the system for the electric alternative could therefore be much simpler.

Plugging in

Incorporating an electric motor in the car still presents challenges, but ones which the team see as an exciting opportunity to explore the boundaries of what an electric motor can achieve. Not only will it have to perform in very extreme physical conditions, including high temperatures, intense vibrations and desert dust, but it will also have to deliver its power in around 20 seconds, which is in marked contrast to how it would be expected to perform in a road car. The one hour turn around time will require either very rapid battery recharging or a highly efficient way to swap out the battery units. Experience with changing battery packs in F1 would indicate that considerable special design investigation is critical. 'We're convinced that the technology is now at a stage that will allow us to use an electric solution and we are keen to work with companies in this field to explore what's available and how it can be integrated into Bloodhound SSC,' says Chapman.

Pan handlers

There are other factors, not so much under its control, that the team has to plan for, too. Land Speed Records involve complex engineering solutions, but often the vagaries of the weather and the ability to produce a viable lake bed running surface by hand can scupper even the best laid plans. The high-speed runs at Hakskeen Pan in South Africa are very weather dependent, for instance. 'We need the lake bed to flood every year,' says Chapman. 'But not in their winter – this can happen as early as November or as late as January [South African Southern Hemisphere summer] and the lake then dries off by April or May, and sometimes a few showers can then mess things up.

'We also need to clear the track by hand as just under the surface is a light layer of shale and beds of rock underneath that,' Chapmam adds. 'If we used earth-moving equipment we would simply churn up the underlying shale and then bring more stones to the surface. When we clear the top level by hand this gives us a great smooth running surface.'

All that hard graft is to come, though, and for now the Bloodhound team is just pleased to have completed its first 210mph public shakedown without mishap – now it only has another 790mph to find.

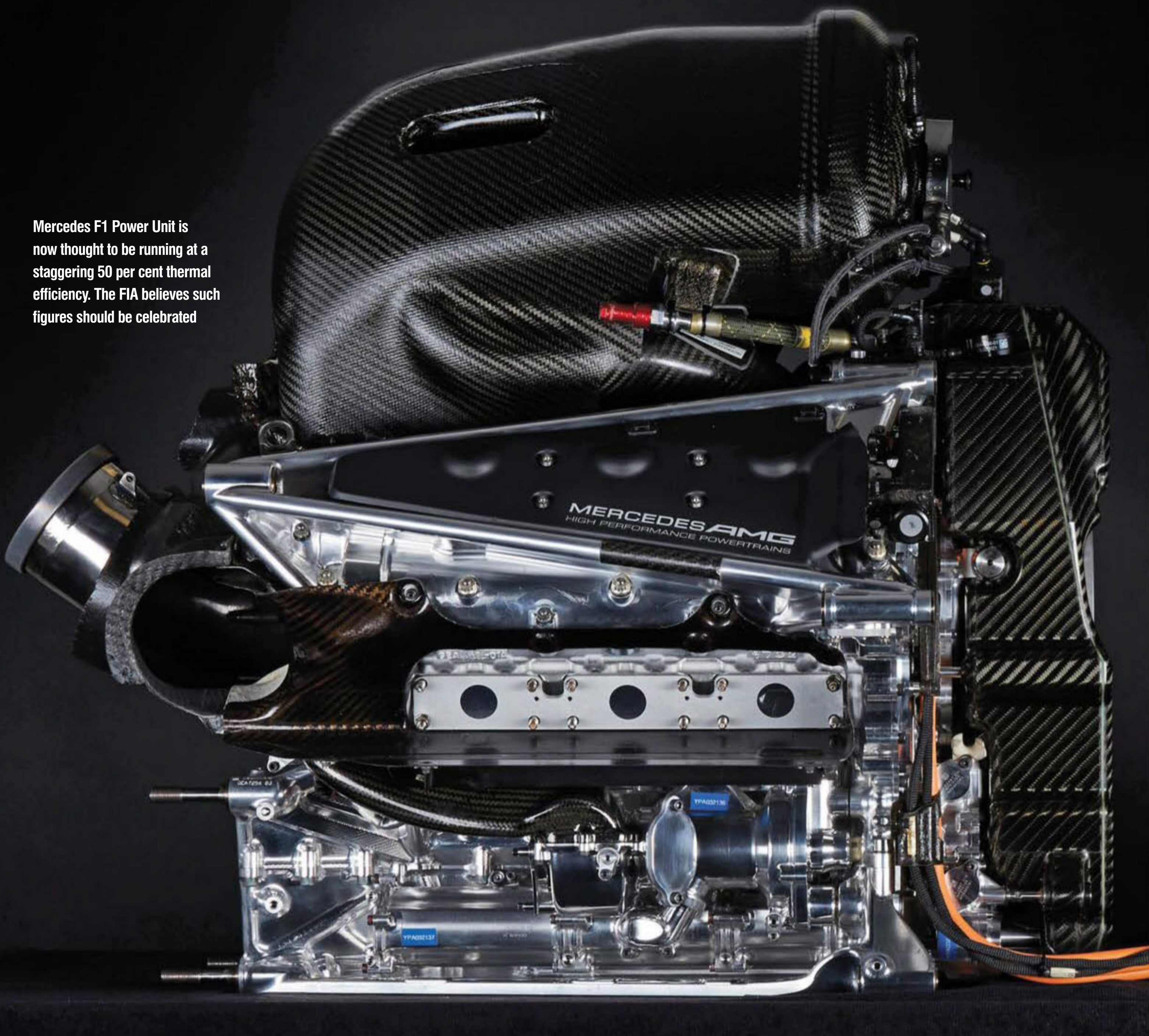
'You can't use a wind tunnel to verify the CFD as there is no tunnel available that goes to 1000mph with a moving ground plane'

EXCLUSIVE

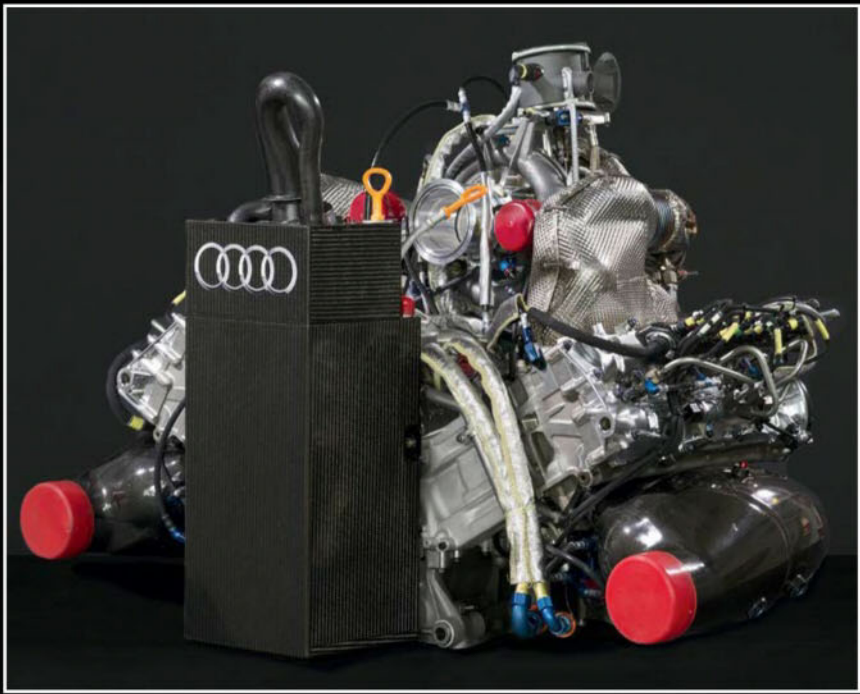
Simon says

The technical future of high-end motorsport has never been as uncertain as it seems right now. So we went to the very top – the FIA's new head of Technical, Gilles Simon – to get a clearer view

By ANDREW COTTON



Mercedes F1 Power Unit is now thought to be running at a staggering 50 per cent thermal efficiency. The FIA believes such figures should be celebrated



LMP1 gave Audi an opportunity to both develop and promote cutting-edge technology (2015 engine pictured) but its very successful programme was axed within a year of the emissions scandal that shook the VW Group

There was no fanfare, just a statement put out in September by the FIA that Gilles Simon would take on the responsibility of head of Technical at the organisation. The Frenchman is a long-time associate of FIA President Jean Todt, and has previously worked at the FIA as technical and powertrain director, until he moved to stillborn engine manufacturer PURE. He was then, until recently, working with Honda in Formula 1 as a consultant.

It's fair to say that Simon has stepped into the position at a very difficult time. Formula 1 is currently looking to finalise its 2021 engine regulations and there are disputes over how these might finally look (see page 36). The WEC has lost Porsche and Audi, Peugeot has decided not to return and Toyota has yet to commit to the 2018 season. The regulations that were announced at Le Mans are now rescinded, and there are no new manufacturers on the horizon.

Meanwhile, the World Touring Car Championship has failed, and its TC1 formula won't continue into 2018 (see news, p90), while Formula E appears to be an electro-magnet for motor manufacturers.

At the heart of it all sits the conflict between technical development and entertainment. Formula E offers the manufacturers what they need in terms of showcasing their electric capability, but cannot be described as exciting racing, while back of the grid Formula 1 teams, and the WEC manufacturers, are drowning under the cost of hybrid development. Poor organisation, along with the high cost of machinery, has led to manufacturers walking away from the WTCC in favour of the customer-focussed TCR formula. And it is now Simon's responsibility to bring order to all this chaos.

His job is to chart a clear path for top-level series – as well as the feeder formulae – that keeps racing road relevant with innovative technology, while maintaining some level of cost control that allows private teams to compete. He also has to keep up fan engagement at a time when the car industry is itself having to adapt to a changing world following the 2015 dieselgate scandal, and the rise of electric mobility.

Hybrid technology was introduced into Formula 1 as a means to give manufacturers corporate responsibility within their racing

'I don't feel that entertainment and technology are against each other'

While all Formula E cars look the same there are plenty of different manufacturers involved in the championship. The FIA is content with the progress of its all-electric race series

Emissions are an issue everywhere and some cities could ban ICE cars in the future. Little wonder EVs are gaining ground

'We have to explain it properly so that anybody sensible can understand good performance from a technical point of view'

programmes and the gains made, since 2014, in engine efficiency have been truly extraordinary. Thermal efficiency has risen from an estimated sub 30 per cent to almost 50 per cent in F1 as development continues.

School of hard NOx

However, the costs associated with running these power units has put customer teams in particular in a difficult financial position. For the manufacturers, life is similarly complicated, but for other reasons. One of the main issues facing the motor industry today is the shifting sand beneath the feet of the manufacturers that has left them uncertain of the ground on which they are standing. Previous governments have targeted CO2 emissions as the Holy Grail of engine efficiency, until they noticed that low CO2 producing diesel was in fact emitting high NOx levels. With the dieselgate scandal, in which Volkswagen was found to have installed a 'cheat' device to pass emissions tests, the world decided that diesel is effectively poison.

Arguably, it was this case that has started the debate on our future mobility, as trust in the manufacturers has suffered. In the UK, new tax regulations coupled with the above has seen a drop in the number of new cars sold, although electric cars are clearly on the rise. They still form a small part of the market, but the trend is clear; the consumers are after electric. Advertisements have changed from promoting lifestyle to air quality, particularly in towns, which is where electric mobility is so strong and where governments are looking to ban combustion cars. It seems that Formula E was ahead of the curve in predicting this rise in electric.

Plugging in to E

'Formula E had been thought of well before [dieselgate], in 2010 when the FIA was trying to put together what could be an electric racing car, and that led to a championship that is successful today,' says Simon, speaking to us in the vast meeting room on the fourth floor of the FIA building in Geneva. '[We were] trying to look a little forward. The FIA has put in place regulations of the championship that at the beginning people were asking "why? What is the scope of the formula?" Today many manufacturers are interested in this championship and it is a good showcase for the electric technology that they need to sell.'

Show business

With governments jumping onto the bandwagon and targeting an end to the sale of new ICE cars, the FIA has to write technical regulations that keep the sport relevant and lead the development of technology while also driving up fan engagement.

'I don't feel that entertainment and technology are against each other,' says Simon. 'As a promoter in any of our championships, they want the championship to be interesting to the last minute, to be spectacular and provide a good show. This is the best way to catch fans and keep them interested, and is generally the case for all sport and all entertainment. What is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Formula E has attracted good crowds at many of its city-centre events but there are some who question whether the level of spectacle is quite on a par with the level of technology

specific to motorsport is that there is a motor, so you have already technology there. Part of the fan interest is about the cars. It is about the fight, but it is also the beauty of these cars. It is about having spectacular and fast cars, and also anyone of us looking at any kind of race, it is about the engineering of these cars. Why is this one faster, and behaving like this? Part of the show is due to the technology.'

Racing's essence

While the sport has always been about the drivers who can extract the maximum from a car, it is the technology and, Simon argues, the efficiency of the racecar that leads to championship victories. 'The fact that someone reaches 50 per cent efficiency and someone else is not at that figure, let's say 49, one will be in front of the other,' he says. 'The only way, with the fuel flow control, to have more power is you have higher efficiency and this has always been the case. When you are engineering a racecar, you always care about fuel consumption. In an endurance race you want to have a longer stint, and in a shorter race you want to start with the least amount of fuel. If you could start a race with 10kg of fuel less than your competitors, you have an advantage. This is part of the engineering of a racecar, in any formula. I believe this was already the case when Bugatti was fighting the Bentleys. One had a small displacement high efficiency, another raw power, and that is the basis of motorsport.'

'When you are engineering a racecar you always care about fuel consumption'

Road relevance

The burning question is; who decides what is road relevant? Is it the FIA taking a lead in its rule writing, or is it the manufacturers who have a vested interest in their own technologies? For Simon, it is a negotiation that reaches a common agreement, although outlining the framework and then distributing it is not always the best policy. Releasing its roadmap for the 2021 F1 engine regulations was met with criticism from teams and manufacturers, but he would not be drawn into a discussion on the public statements that have been made.

However, Simon is pleased with the way that hybrid technology has been integrated into Formula 1 and the WEC, and says that it has allowed companies to start the development of such technology that, if not transferable immediately, will be in the future.

'Turbocharger manufacturers had some experience with energy recovery with a turbocharger, but it was limited, and a one-off project to see if it could work,' explains Simon. 'They concluded that it could work in the right conditions, and they were keen to work on the F1 project because this helped them with the resources that they needed to develop the idea to the point that they can say that they can do it, produce it, and they know the limits. They have invested some resource and now they have the technology actually on the shelf. When it will be applied I don't know, but this is part of their catalogue on the shelf. They have no fear to push it into production if the need comes and this is what I expect from motor racing.

'In June, I was at a congress on gasoline engines, discussing this with other people, and I understood that at least two big OEMs started a programme on energy recovery on the exhaust, because they knew this was a potential solution. They never had the ability to get the

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Toyota leads Porsche and Audi in the WEC. Manufacturers like the hi-tech, but they can also walk away. Toyota is the last remaining car maker in LMP1-H after Porsche and Audi left

budget to research it. As soon as they said "it's the system that they use in F1", they got the budget. This effect of leading has always been so, and I believe that it remains important for our industry and for our sport.'

Development costs

The issue, of course, is the cost of developing such experimental systems, particularly for the privateer teams. Their criticism is that the power unit supply costs have risen by a factor of four, but there has certainly not been four times the return on their investment. It has led to disquiet at the back of the grid, and the FIA is by no means ignorant of their plight.

'The tricky question for us from a technical regulations side is to find a balance between the cost and the maximum technology that you can fit into [the racecar] for that price,' says Simon. 'We are facing some difficulties but we have to find a compromise. The question is simple; we have to find the right balance. It is tricky [to do so] and you have different opinions, but we have to discuss it at length to find what is reasonable and the right direction. So our approach is to sit down with interested parties rather than to simply say "this is the regulation".'

Ulrich Baretzky, head of powertrain at Audi Motorsport and a man who is known to be an advocate of future technologies (and diesel), has said that motor racing could consider publishing its consumption figures. Although these would be frightening at first, it could be a way forwards for the FIA and the ACO to promote efficient motorsport, but Simon was not in favour. The Frenchman prefers that the communication of the technology improves, and that the fans have the engineering explained to them in a way that gets them excited, and more importantly, they understand what racing is trying to achieve.

Selling technology

'The best engine in Formula 1 is at 50 per cent efficiency, say, but what does this mean?' he asks. 'If you had this efficiency on your road car, your consumption would be around two litres per 100km, or something in this range, and that's spectacular. But how do you translate this to a car that is above 800bhp and 70 per cent of the time under full load? If you try to do this with your car, the fuel consumption will be up, but the efficiency, the fuel you burn for the horsepower you need, is very high. I think some figures can be difficult to explain, while others can be translated. If you speak about fuel consumption in a race, in a lap, or per 100km, it is high because it is very fast, but if you try to go that fast with any other car, it will be at least twice that, and maybe you are as fast. We have to explain it properly so that anybody sensible can understand good performance from a technical point of view.'

Hi-tech highway

So, it seems that the FIA is going to stay on its high-technology route, and be a leader in the development of road relevant components. It will, with negotiation, decide how the regulations should work in top-level motorsport within a cost framework.

'There is no antagonism between technology and entertainment, there is just balance for each championship,' Simon concludes. 'The costs have to remain in a window that is acceptable. The issue is probably more to have a sustainable model in each formula of motorsport, so to understand what kind of budget makes sense in Formula 1, endurance, GT or touring cars. Once you define this, then you have to identify the technology within this window.'

'Motor racing is about the fight, but it is also about the engineering of the racecars; why is one faster, and behaving like it is?'

Road to Le Mans

FIA tech boss Gilles Simon gives us a glimpse into LMP1's future – which could include clever new aero rules and road car styling

One of the big tasks facing the FIA WEC is to attract new manufacturers to the series. Audi left in 2016 and Porsche announced its withdrawal a year later. This left Toyota as the last to show its hand. Porsche's handling of its withdrawal clearly rankles with the FIA. 'I think that the problem that we may face in many championships, and we face in the endurance championship, is that you discuss the regulation with a small group of manufacturers, and then they go off,' says Gilles Simon. 'Obviously, motor racing means being submitted to the possibilities that an OEM can withdraw from one date to another, some are committing to a long term, and that gives an image of consistency, but each manufacturer has to deal with its own image. When you discuss very hard with the manufacturers about how things should go and then a week later one sends a communique that it will not be present the following year it is not a good situation for anybody and not giving a good message, but that is how it is.'

The FIA says it has six manufacturers interested in its 2020 regulations

Interested parties

There are no new manufacturers on the horizon looking to join under the existing regulations, yet the FIA has come up with a new plan for the 2020 season, and says that it has six manufacturers interested and sitting around a table to help formulate these new rules. Converting these into actual entries will be the next stage of the process.

The core of the new regulations currently under discussion is that by 2020 all cars, including the privateers, will be hybrid, and the FIA will take control of setting aerodynamic targets. This will be based on the current system used to balance the GTE cars, which are tested and measured in the Windshear wind tunnel facility in North Carolina. They are then performance balanced, but the FIA is not looking to carry over a BoP system. What it is looking to do is to set drag and downforce figures, giving a clear point in the graph for a manufacturer to hit in whichever way it feels that it wants to go. Once that package is homologated, there will be a single aero kit that will have to cope with Le Mans, and other WEC tracks.

'Endurance racing, we have two issues,' says Simon. 'The first is short term. We have two categories able to race in LMP1, hybrid and non-hybrid. By the way the regulations were designed with two in parallel, there was not a huge consistency between them. For instance, some aero is forbidden for hybrid and accepted for non-hybrid, which is unfair on hybrid; but on fuel consumption, hybrid is favoured, due to combustion plus hybrid.

'What we have done first, discussing with the ACO but we are taking the lead, is to analyse the fuel efficiency of the different engines, and set a power unit balance. We set it such that cars should have similar performance. I cannot say "the same" because of the precision of the calculation, but the target was a fair calculation. This is what we have done from September onwards, with a clear view that this is fair and honest with everyone.'

On the level

The FIA calculates that the hybrid will have an advantage in fuel consumption of a lap over the non-hybrid cars, but that the lap time capability will be the same. This is done by reducing the capability of the hybrid cars rather than increasing the performance of non-hybrid cars. It hope that the non-hybrid car manufacturers can possibly win races, particularly Le Mans. 'What was limiting LMP1 non-hybrid? It was very difficult to imagine an LMP1 privateer winning Le Mans,' says Simon.

Recent LMP1 cars have not been visually similar to their road car cousins. This could change for the 2020 WEC season

For the longer term, hybrid is clearly at the heart of the regulations, though. 'Hybrid is our target, with a much simpler system, and just one system, typically a powerful KERS,' Simon says. 'For now, it is too early to know how far it will be standard or non-standard. We need to discuss this with our manufacturers.

'We will then extend discussions not only with the manufacturers and the ACO but also with IMSA. The concept is to go to higher identification of the brand. Our proposal is to take our responsibility as a governing body to measure the cars. Let's imagine that we define it as GT Prototype, so it can come from a road car, developed for a race version, or a racecar that can have a road car version … What will define the car is the dimensions for the windscreen, length and so on. One configuration of bodywork, and we will define an aero efficiency figure that gives the drag figure and load, downforce, that you have. Everyone will have the same frontal area and aero efficiency in a given condition. We already test the GT cars in the wind tunnel to define their aero efficiency. We can be more precise and define one point. To homologate your car you need to be at this point. Once we have done this, we can define such that it will not compromise your design, your efficiency, with a car that looks like your brand car.'

Long term investment

The plan is to make the cars capable of current LMP1 speeds although the running costs have to come down. The cost of the cars is not currently at the heart of the regulations as the FIA is keener that the cars are campaigned for longer periods of time, which suggests an homologation period.

'What we believe is that the fact that aero target and efficiency target will be defined and controlled by us, will allow a reasonable running cost because you will not have to invest much in development once the car is homologated,' says Simon. 'If you look at the cost of the GT3 car, for example, it is quite high but that is not an issue because you have professional organisations that are racing this car every weekend, so it is an investment. It is like a machine tool; you use it to make components, that is not a problem, it is good amortisation. We should think like that, and what is important is that you don't need to change the machine every race. What is important is that once you have homologated it and the targets of aero and weight and performance of the power unit is set, this is it. Then you open it to the market of the serious privateers.'

Engine mapping

The FIA's recently released 'roadmap' outlining the key aspects of the 2021 Formula 1 power unit rules has not been well-received by all in the F1 paddock – but what exactly does the plan entail and what are the key objections? *Racecar* investigates the on-going story

From the first publication of the 2014 Formula 1 power unit regulations it was made clear that a new set of rules would be introduced in 2021. What those rules would be was, until very recently, entirely unclear. A large number of different and often conflicting ideas and opinions were being discussed by different parties with different motivations, everything from a 3.4-litre V6 twin turbo engine to some kind of large capacity V12 were suggested at different times. But what was clear was that many in the sport felt that the current generation of power units were simply not right for Formula 1.

'For me, these engines have done nothing but damage F1. They've done nothing to contribute to the sport,' Red Bull Racing team principal Christian Horner says. 'They have taken away the sound, the passion and they have added too much complexity; they have become far removed from road car technology and they are effectively turning into diesel engines in some cases. I can't see anything that they have contributed that's been positive. So the sooner it goes, the better.'

Although Horner's sentiments are not universally held, some of the issues he raises are of concern to the sport's governing body, the FIA, and also its new promoter, Liberty Media. So, after seemingly endless discussions, the FIA came up with a set of key goals for the new generation of power units to achieve, aiming to address the criticism, these are: '*A desire to maintain F1 as the pinnacle of motorsport technology, and as a laboratory for developing technology that is relevant to road cars. Striving for future power units to be powerful, while becoming simpler and less costly to develop and produce. Improving the sound of the power units. A desire to allow drivers to drive harder at all times.*'

Those objectives were issued part way through the 2017 Formula 1 season, and were then used as a basis for debate and discussion among the manufacturers, teams and a number of suppliers. Then, following the Mexican Grand Prix in late October, a more detailed plan was revealed for 2021. This 'roadmap' laid out the core elements of the new power unit formula.

At a superficial level what was presented is very similar to what is in use today, with a turbocharged 1.6-litre V6 engine at the core of a hybrid power unit. But within the six bullet points that make up the roadmap there is also substantial scope for change.

Volume control

Perhaps the most criticised element of the current 2014-2020 generation of power units is the sound they produce, or rather the lack of it, while what sound there is, is clearly not to the taste of many fans. As a result there have been various efforts to improve it and increase its volume, notably giving the wastegates a separate exit pipe, though this has had only a minor impact. A project to add a sound generator to the exhaust system was also under

Perhaps the part of the roadmap that will have the biggest impact of all is the plan to no longer use an MGU-H

development at one point but to date has not been seen out on the race track.

A new attempt to improve the sound is included in the 2021 roadmap, namely increasing the maximum revs of the V6 engine. Currently the maximum speed is set at 15,000rpm but this will be raised to 18,000rpm in 2021. However, there is some debate about whether this will have any effect. These days the cars almost never hit the peak RPM, as in an efficiency based formula it is simply not the optimum way of operating the engine.

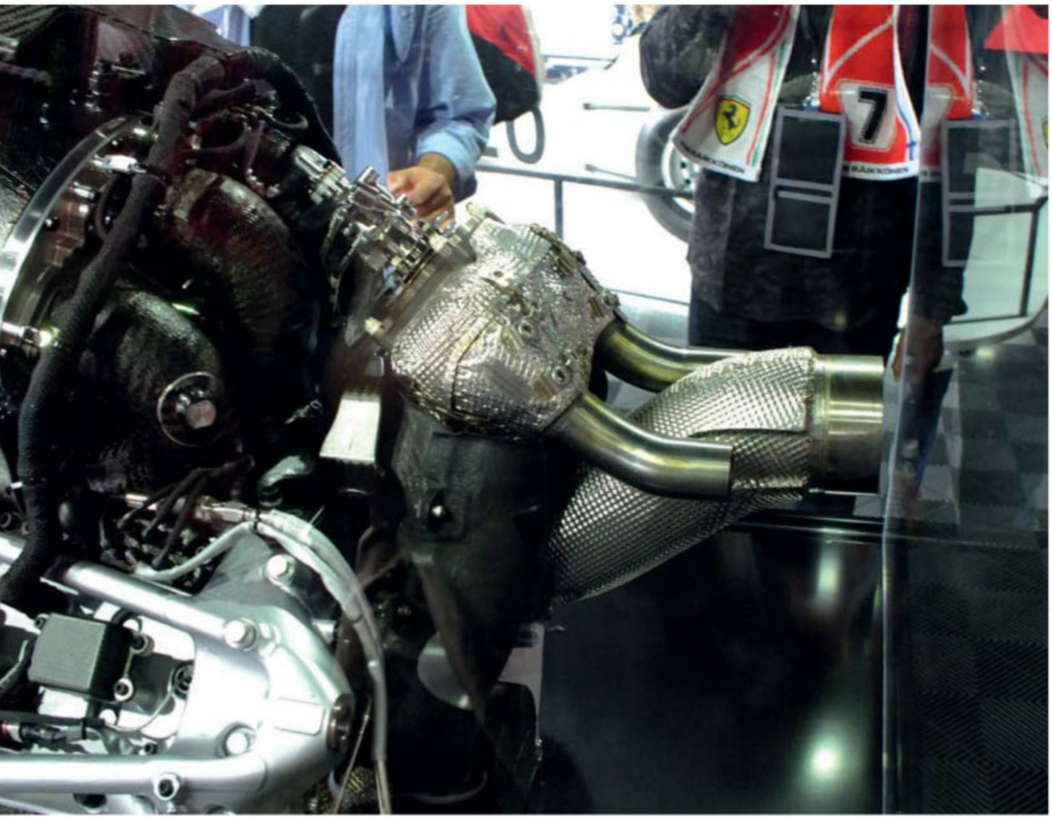
But FIA engine boss Gilles Simon says this will be addressed: 'I think that the first natural idea to discuss in detail is that we will just follow the fuel flow curve 3000rpm higher, so you will have higher fuel flow,' he says, which leads to the thought that bigger fuel tanks might then need to be fitted. 'Not necessarily. What I believe can be agreed is that the race fuel allocation is seen as a limit to race fighting, so while we continue to impose a fuel flow maximum [we could] also have an agreement to allow for free race [fuel] allocation, but someone will have a bigger tank than others, maybe. But it will be a choice, and fuel efficiency [will still be] important to manage the race properly,' Simon says.

The H bomb

Perhaps the part of the roadmap which will have the biggest impact of all, though, on not only the sound of the power unit but also the overall layout and design of the engine, is the plan to no longer use an MGU-H. The use of the MGU-H under the current rules means that the V6 engines are designed partly to have recoverable energy in the exhaust, something which means that the best power unit is not always the best combustion engine, but the best compromise between ICE and ERS. 'What counts at the end is the overall efficiency of the system. If you take off the MGU-H you reduce the efficiency, so we will not be at 50 per cent.' Simon says. 'We are discussing that. It is a proposal, but today we are trying to find a good balance between the cost, complexity, show and technology and it is not easy. In this compromise we thought it necessary to make a step with the MGU-H, and I think that it is an important point. It gives good efficiency, but it is a complex system and to have it with quite a wide freedom in F1, it leads to serious cost issues, so we had to address that.'

Special K

Removing the MGU-H will obviously have a performance implication for the whole power unit. So in order to restore any loss in overall car performance that will come as a result, a new more potent MGU-K will be employed. Its exact performance level is not clear, but it will certainly produce more than the current maximum of 120kW. Additionally, according to the roadmap, there will be a 'focus on manual driver deployment in race together with option to save up energy over several laps to give a driver controlled tactical element to racing'.



Attempts to improve the sound of the current F1 power units has seen separate wastegate exit solutions tried, but with little effect. Upping the maximum revs by 3000rpm to 18,000rpm is the approach being looked at for the 2021 PU regulations

This could place more emphasis on drivers to manage the operation of the ERS. From a driving standpoint this could also add to the complexity in the cockpit. Then again it may well be as simple as the addition of some kind of 'e-boost' button on the steering wheel to allow the Formula 1 drivers to activate the MGU-K.

While a twin turbo layout was clearly considered for 2021, a single turbocharger will be employed, according to the roadmap. But much of the design freedom on the turbo itself will be removed and much stricter dimensional and weight constraints will be applied.

KERS and effect

Turbo lag could also become an issue with the loss of the MGU-H, but Simon is not too worried about that. 'If you have a powerful enough KERS you can compensate,' he says. 'Also, I believe that you have to find the right compromise on the design of the turbine wheel by itself … I am not so worried about the turbo lag effect. There are ways to design the turbine to limit this, that would be a technology challenge, but that is motor racing. I think that if you have a new project where you change fundamentally the input then Formula 1 is spending a lot. If you have a new project where you tune the current input that you know, then it is much more reasonable. My understanding is that some people believe they are now in a phase of fine tuning the solution they have in hand and they are frightened by the fact that going to a new regulation, even if it is simpler. [They think] you have to re-engineer everything or have enough money in the project that you could re-engineer everything, [and] that is why they are saying that this will be expensive.

'I think I designed eight or nine 10-cylinder engines [as an F1 engine designer], but it was not that expensive because it is a yearly exercise and you take what you know and tune it, and that is where Formula 1 is comfortable,' Simon adds. 'When you change the rules of the game, this is where the expense may be, because this is over-cost that they cannot plan. That is the reality, so we have to be careful on that.'

Split decision

The removal of the MGU-H and the tightening up of the rules on turbocharger design will make a substantial difference to the overall layout of the power unit, and it is almost certainly the end for the innovative split turbo concepts used by both Honda and Mercedes, which see the compressor and turbine placed at different ends of the engine block, linked by a common shaft, with the MGU-H mounted in the V of the engine. It now seems certain that the 2021 regulations will restrict power unit suppliers to mounting a conventional turbocharger at the rear of the engine block, in the bellhousing area of the car.

Standardising this area of the power unit helps fulfil another one of the aims of the 2021 road map, namely a 'high Level of external prescriptive design to give "plug-and-play" engine/chassis/transmission swap capability.' A number of teams have, since 2014, been forced to make a short notice switch of power unit and this has created problems in terms of the design of the rear face of the monocoque and the front face of the transmission, two of the longest lead time items on any new Formula 1 car. For instance, Sauber was unable to switch to a supply of Honda power units for 2018 as it could not secure a suitable gearbox.

Currently all power units have common mounting points for chassis and transmission but they have very different installation requirements. A lot of this is down to the design of the turbocharger and accommodating the pipework relating to it. This can see the rear of the chassis made in fundamentally different ways to suit each power unit, something which is costly and time consuming for the teams.

Partly for the same reasons the road map also seeks to standardise the battery pack (energy store) along with the control electronics, as this will also make it easier for teams to design the chassis. And while it reduces some scope for technical development it also seems likely to cut costs. Some manufacturers might be unhappy with this, though, as the power unit companies have invested heavily in staff and facilities in order to develop both battery packs and the related electronic systems.

Tuner fishing

One standout feature on the road map is that it is specifically directed at making it more feasible for private engine tuners like Cosworth, Gibson, Mecachrome and Judd to enter Formula 1, meaning the sport is less reliant on manufacturers who are felt to be somewhat fickle and capable of quitting the sport with little notice. The high cylinder pressure levels of the current V6 engines are known to deter some of the small tuners from getting involved in F1 right now, but the road map promises 'prescriptive internal design parameters to restrict development costs and discourage extreme designs and running conditions'.

Simon says: 'It is part of the discussion. What we propose is to set some targets to limit the development costs. If you look to the current regulation, it is already quite detailed. You have a lot of parameters that are fixed. The dimensions are fixed, materials are defined; you have not a lot of choice: weight, weight distribution, [but] in the engine you have many dimensions that are

Everything from a 3.4-litre V6 twin turbo engine to some kind of large capacity V12 has been suggested at different times

'I am not really so worried about the turbo lag effect, there are ways the teams can design the turbine to limit this'

fixed. You can design [an engine] for an LMP1 car with any displacement, with any number of cylinders. This is not the case in Formula 1. The engine in Formula 1 is quite controlled, but controlling the dimensions does not have a lot of cost implication. [But] this is the output that has the cost implication – the balance between high cost and high efficiency, because the higher the efficiency, then the higher the cost, and we have to balance this.'

Indeed, there are already quite a few regulations limiting the internal design of the V6 engine, including the bore, crankshaft centreline position and height – which are all tightly defined – while other components have size and weight limitations, including the valve stem, main bearings, crank pin, piston and conrod. The overall centre of gravity of the power unit is also defined in the current regulations.

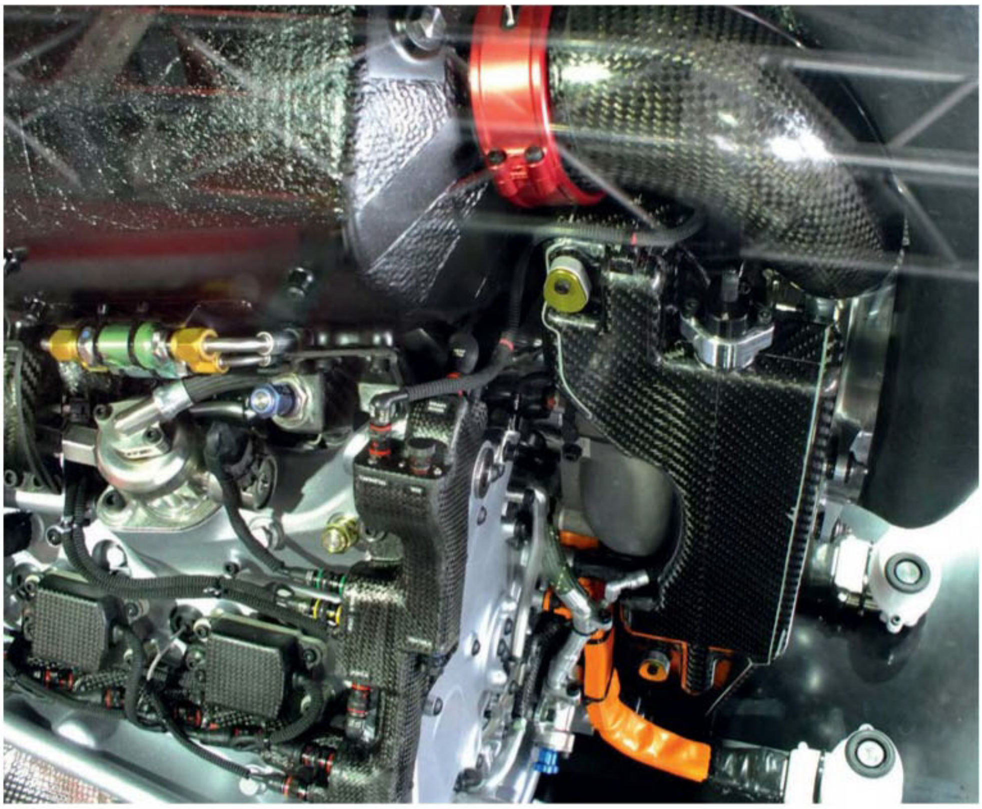
In 2014 and 2015 Mercedes and Honda (pictured) used exhaust layouts designed to allow the MGU-H to recover maximum energy. The new regulations should switch focus on to maximising the ICE

Fuel's paradise

Another barrier for private tuners coming into Formula 1 is fuel. All of the current power unit manufacturers work closely with fuel partners who will develop bespoke fuel for each update to the ICE, something generally beyond the reach of private tuners. To address this the road map promises an 'intention to investigate tighter fuel regulations and limits on the number of fuels used'. But could this mean a single fuel spec, as is the case in the WEC?

'This has to be discussed,' Simon says. 'The fact is that to develop a bespoke fuel for each engine is not realistic … [but] it is a very good tool for the development of technology because by doing specific fuels, and mixture of chemicals, you can understand exactly the effect of combustion. It is very useful.

'I have worked with different fuel companies and they have all the understanding and it is interesting knowledge for their fuel and combustion experts,' Simon adds. 'I have had good experiences developing the engine and the fuel, and understanding it together with the fuel specialists. This is the best way to progress in understanding combustion, and this is useful for the industry. The fuel specialists in Formula 1, they are involved in other projects, so for them to understand the specifics of combustion is of interest. By this way, you justify it. It is not just about finance [sponsorship] – that is important – but it is also a good technology enhancement. I believe that we have to be cautious on that, and you have to do something with more accurate definition of what should the fuel be, with less possibility of variability, to define better, or have less difference in performance due to the fuels.'



Removing the MGU-H could reduce the complexity of power units and spell the end of the split turbo concepts used on some designs such as this 2017 Honda. To make up the power deficit from losing the MGU-H a more potent MGU-K will be used

Cry Wolff

Perhaps not surprisingly, on the publication of the road map not everyone in Formula 1 was delighted with what it contained. 'This is the FIA's vision and proposal and we haven't accepted it,' Mercedes team boss Toto Wolff said following the meeting where it was presented. 'The flaw of the concept is that it's a completely new engine and new investment. It portrays it in a way of this is how we're going forward and none of the current manufacturers was particularly impressed.'

Renault managing director Cyril Abiteboul had similar reservations, claiming that rather than a simple re-work of the current 1.6-litre V6 engines what is being proposed in the road map constitutes 'a new engine on which we would have to make substantial development and substantial financial commitment without an understanding of the broader picture of what Formula 1 would look like past 2020.'

Abiteboul went on to claim that the roadmap does little for private tuners wanting to enter the sport. 'I don't see how what has been presented would be offering a model for an independent engine manufacturer. It lowers the cost of access for a car maker, but you would still need a substantial amount of dollars to spend into research and development to make any business plan work for the new engine. That is actually our problem, that we need to spend again, just like a new entrant would have to spend. But I don't think an Ilmor or a Cosworth will be able to go for it independently without the [backing] of another car company.'

Horse play

Ferrari, too, was unhappy with the proposals, to the point where its chairman and CEO Sergio Marchionne make a thinly veiled threat to quit Formula 1 if the roadmap was not amended. 'There are things we don't necessarily agree with in the roadmap. One of which is the fact that somehow powertrain uniqueness is not

Fuel flow meters are set to still play an important part in F1 power units beyond 2021

'We should be able to have a good understanding of where we are going in the first quarter of next year'

going to be one of the drivers of distinctiveness of the participants line-up,' Marchionne said. 'I would not countenance this going forward. But if we change the sandbox to the point where it becomes an unrecognisable sandbox, I don't want to play any more. I don't want to play NASCAR globally, I just don't.'

Positive feedback

But not everyone thinks the roadmap is flawed. Both Cosworth and Ilmor have stated that they feel that it puts them in a position where they could consider returning to the sport, and Aston Martin has said it is willing to consider developing its own power unit, while some already working in the Formula 1 paddock certainly see it as a useful starting point.

'I think they've thrown out a good concept to start off with. Now the details can be worked out by the technical people. The concept is out there and I don't think the concept will be changed,' Guenther Steiner of the Haas F1 team says. 'Now they need to work on the detail of the concept to achieve the goals they've set themselves with more noise, more equality, and lower costs for the customer teams. Hopefully, they can achieve it.'

False premise

Some, including Williams technical director Paddy Lowe, feel that the route to improving Formula 1 has nothing to do with power units anyway. 'The more you leave things alone the closer the racing becomes. You see that with the engines today, as they are a lot closer than they were three years ago. I think the new regulation change has to be done with great care. I find it curious that people place emphasis on new regulations needed to create convergence when it does the opposite.'

Crucially, the road map has been left deliberately vague in some areas, so that well funded manufacturers cannot get a head start on smaller concerns. 'Work will continue over the next 12 months to define certain elements of the power unit, but the design and development of the complete power unit will not be possible until all the information is released at the end of 2018. This aims to ensure that manufacturers continue to work on the current specification power unit,' an official FIA statement read. 'During the remaining part of 2017 and 2018, the FIA and F1 will also work with the teams to establish power unit test and development restrictions as well as other cost containment measures.'

But is that time-scale realistic? 'I think that if we have a reasonable discussion we should be able to have a good understanding of where we are going in the first quarter of next year, and then refining it towards the end of the year, but the target of having the regulation set next year is really possible,' Simon insists.

Toto Wolff
'The flaw of the concept is that it's a completely new engine and new investment … None of the current manufacturers was particularly impressed'

Cyril Abiteboul
'I don't see how what has been presented would be offering a model for an independent engine manufacturer'

Guenther Steiner
'They need to work on the detail of the concept to achieve the goals they've set themselves; with more noise, more equality, and lower costs'

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Crate expectations

TRD has brought a GT500-inspired race engine to market and will now offer its off-the-shelf BIZ 001 powerplant to tuners and race series across the world. *Racecar* jumped to the front of the queue

By SAM COLLINS

The RI4AG NRE that powers this Lexus LC500 GT500 Super GT is described as the 'mother of the BIZ 001'

Before the start of the 2014 racing season both of Japan's top racing categories, namely the GT500 class of Super GT and the open wheel Super Formula championship, adopted a brand new engine formula. Dubbed NRE (Nippon Race Engine) the new regulations mandated a 2-litre turbocharged in-line 4-cylinder design featuring direct injection. As was the case with Formula 1 and LMP1, the rules also saw the introduction of a fuel flow limit, although in this case governed by a physical restrictor rather than a sensor.

The result of the introduction of these new rules was the creation of three very small, light, powerful and extremely efficient engines, one each from Honda, Nissan and Toyota. In bench testing Honda's NRE reportedly has offered better performance than its Formula 1 V6, when running on the same specification fuel.

It did not take long for the wider motor racing industry to take note of this new generation of race engine, and many began to wonder if the NREs could be used in other applications. Some even speculated that with its small size and low weight the NRE could be the perfect power unit for a non-hybrid LMP1 car. But none of the manufacturers seemed willing to offer customer engines.

BIZness plan

That all changed at the 2017 Tokyo Auto Salon, where with almost no fanfare whatsoever and no information released in English at all, Toyota's performance and special vehicles arm TRD showed off what looked to all like a customer version of the RI4AG (Toyota's NRE) used in the Lexus LC500 GT500 and the Dallara Super Formula cars. Called the BIZ 001 the engine on display was an all aluminium 2-litre turbocharged unit, featuring direct injection, but beyond that little information was released at the show. Now more details on the engine can be revealed for the first time.

'We started working on it in 2016,' Yoji Nagai director and general manager of the motorsport development department at TRD reveals. 'It is a motorsport engine purely for customer use. When we started the project we didn't have a plan for any particular category, team or championship. The reason for that is that we as TRD do not support any particular project directly, we will just make the engine available to tuners. After that it is up to the tuners to supply teams and support it.'

While the BIZ 001 looks a lot like a variant of the RI4AG Nagai insists that it is a completely new design, albeit one heavily inspired by the

TRD's 2-litre turbocharged BIZ 001 powerplant was unveiled with very tittle fanfare at the Tokyo Auto Salon

While the BIZ 001 is based on the RI4AG (above) it does not include its secret tech and it's cheaper to produce

'With a customer engine cost, reliability and performance have to have equal weighting'

GT500 unit. 'You could say that the NRE is like the mother of this engine, but it could not be the same,' Nagai says. 'Because the NRE is designed by Toyota it is also the intellectual property of Toyota and there are many secret things on it. That makes it impossible to sell this engine to customers, there are just far too many technologies in it that can't be shared. Even the alloy used in the block and heads is proprietary to Toyota. So the BIZ 001 had to be an engine like the NRE, but without any of the confidential things. So this engine is 100 per cent designed by TRD, and that means that it is possible to sell it to customers.'

Customer focus

When Toyota created the RI4AG it was designed specifically for use in GT500 and Super Formula, both of which have substantial backing from the manufacturer and allow continual technical development. No real consideration was given to the needs of customer teams, and along with the confidential elements of the design, this was also felt to be something that made it unsuitable for general customer use.

'Of course, our starting point was indeed the NRE but we had to redesign everything,' Nagai says. 'With the NRE the first priority was performance, then reliability and finally cost, and really that was a much smaller concern. With a customer engine cost, reliability and performance really all have to have equal weighting. That changes the whole way you design it. On the cylinder head, for example, the RI4AG has an extremely complex internal structure using special materials, as I said, but the BIZ 001 head is made of a commercial alloy and has an internal design which is easier to cast; that cuts cost but also performance. The casting process itself is different, too, Toyota itself casts the NRE block and head using proprietary technologies, but the BIZ 001 casting is outsourced commercially.'

Some areas of the RI4AG have carried over to the prototype BIZ 001, mainly for reasons of cost and availability. The electronic throttle control system on the Super GT engine, for example, is itself carried over from the Lexus NX SUV and that can also be seen on the BIZ 001.

Cost control

Keeping the costs down has proven to be a major challenge for the TRD engineers. 'The big thing for us was the cost of the engine. It has been very difficult. Motorsport is very cost conscious at the moment and a lot of manufacturers are looking away from traditional motorsports. They are abandoning [ICE] in favour of fully electric vehicles, but we wanted to offer a racing engine.'

While the BIZ 001 was not designed for a specific category of racing it is clear from its design that certain types of vehicle have been considered. 'The block is designed to be a fully stressed component, we calculated the

At around 90kg the BIZ 001 is a light unit. It has been designed to be easily adapted for use in many categories

load requirement based on the current Super Formula car and the NRE engine. We know that the stiffness of the NRE is equal to that of the RV8K 3.4-litre V8 engine used in the [Toyota] TS030 and Rebellion R1. As that engine has already been used in LMP1 it follows that this engine should be fine for LMP1 as well, based on those numbers. We have designed the mounting points with stressed installation in mind, so that it would be suitable for single seaters or sports prototypes,' Nagai says.

The BIZ 001 is thought to weigh around 85 to 90kg, notably lighter than many other engines on the market such as the AER P60 (115kg) and the Judd-AIM (130 to 140kg). While TRD has yet to release official figures the BIZ 0001 is believed to be around 500mm in length.

Flexible approach

But with applications for the engine uncertain the internals have also been designed for maximum flexibility and tune-ability. 'This engine has the option to be direct injection or port injection, it's an easy change,' Nagai says. 'It's a customer engine so it's up to the tuner to decide which way to go, but as standard it is direct injection and the system we use is very similar to that found on the NRE. In terms of the combustion chamber, of course we started with looking at the NRE, but this being a customer engine the demands could differ. So we worked a lot on simulation and came up with two combustion concepts and right now we are deciding which is better for this engine. We also had to consider the difference between a fuel flow restricted series and an air flow restricted series, and the final combustion chamber design will be able to work with either.'

The engine's target power output is 600bhp and it has already achieved that on the dyno. While Nagai understands that this figure is not high enough for LMP1 and some other series, he also makes it clear that there is more potential in the engine. 'LMP1 needs more than 600bhp but this engine could be pushed by increasing the cylinder pressure. That might shorten its life, but it should still work for 6000km,' he claims.

GT300 spec

With varying levels of tune likely to be offered when the BIZ 001 comes on the market some lower specification versions could produce 400 to 450bhp, making it very suitable for classes like Super GT GT300. 'Running it in a lower horsepower range extends the reliability by two or three times, but also perhaps we can use some lower cost components in that trim too, so it does not get too expensive. But the target is really 600bhp. In terms of reliability the minimum level is 6000km but many

BIZ 001 is said to be capable of carrying the same loads as the Toyota RV8K (pictured), which has been used in LMP1

'We have designed the mounting points with stressed installation in mind so it would be suitable for single seaters or sports prototypes'

BIZ 001 engines will be sold to tuners or series who will then be able to brand them; it's also believed it might become the standard GTA unit used in GT300 Mother Chassis (above)

components are good for over 10,000km and we are looking toward 20,000km.' Nagai says.

One thing that really sets aside the BIZ 001 from most other commercially available competition engines is the way TRD plans to sell it, as it will not be available directly to teams. Instead TRD intends to sell the engine to tuners who will then work with the teams. 'My dream is to have an engine that many engine tuners can take and work with. If you look at Ken Matsuura Race Engines back in the Formula Nippon days, they would buy BMW engines and tune them and do the support to teams. We don't mind if a tuner buys this engine and changes the camshaft, crankshaft or turbo or whatever, it's fine, it allows them to have the perfect engine for the application' Nagai explains. 'Tuners don't have to buy the complete engine, they could buy just the block or any of the parts or combination of parts. They will have the freedom to choose. The export market is very interesting and if there was some tuner overseas that wanted to use it it would be good.'

When the BIZ 001 was launched in Tokyo the aim was for it to be available in 2019. However the project has fallen behind schedule somewhat. 'Unfortunately we are a little behind schedule with the project. We had planned to have it fully available for customers in 2019, but now the target is to be on the market in 2020,' Nagai says. 'In 2020 it will be available to any customer, but we are still trying to ensure that it is ready for some races in 2019.'

'An LMP1 engine would need more than 600bhp, but the BIZ 001 could achieve this, by increasing the cylinder pressure'

Unfinished project

The BIZ 001 may have looked complete when it was launched in Tokyo but Nagai stresses that there is still significant work to do before the engine is ready for market. 'We need to improve reliability and reduce the cost,' he says. 'I'm a little reluctant to disclose the cost target, but right now we are not competitive with the price of European engines, perhaps by 50 per cent more. But that is the price now and the engine is still in development, and we are working hard to get the price down. The price level is a mix of things such as exchange rates, import duties, but also machining costs are very high in Japan. But when the engine is with all the tuners in 2020 that could see the cost reduce further, not just the economies of scale but also they might choose to use lower cost crankshaft, conrods, pistons or other parts.'

The delayed schedule might still allow the engine to make its LMP1 debut in the 2018/2019 season, and rumours already link long-time Toyota collaborator TOM'S to being an early customer, possibly with the intention of fitting the BIZ 001 into the back of a new Dome chassis, although the FIA is targeting all LMP1 cars to be hybrid in 2020. Another rumoured application for the engine is perhaps rather more far-fetched, with a GT500 team said to be planning to acquire a Mercedes C63 DTM chassis to race in Japan, the racecar being surplus to requirements as the German marque is quitting DTM at the end of the 2018 season. Rather than using the 4-litre normally-aspirated V8 DTM engine the team in question is said to be planning to use the BIZ 001 in its place.

Perhaps more likely is for the apr team to rework its two Toyota Prius GT300s to accept the 4-cylinder in place of the aged RV8K V8s they are currently fitted with. Meanwhile, in the very same class the Mother Chassis package requires a new engine to replace the GTA-branded 4.5-litre V8 currently used by the Toyota GT 86, Toyota Mk X and Lotus Evora GT300 cars.

Naming rights

'We recognise there is already interest in this engine, customers are asking us about it already,' Nagai says. 'The engine is a TRD engine, but if some tuner takes it and modifies it then it could have their name on it. Actually it would be no problem to brand the engine with a series organiser name, too. Maybe in future this could be used in the Mother Chassis cars, but probably not for the 2018 season. GT300 is certainly a business area we are looking at.'

According to Nagai the BIZ 001 is only the first step for TRD, with a new range of engines for tuners coming onto the market in the next few years. 'I don't want to stop at BIZ 001,' he tells us. 'I am already thinking of the BIZ 002, perhaps that will be a normally-aspirated V8 using a similar approach, making everything available to tuners. So if this 4-cylinder engine is a success we will look to make that V8. That's my dream.'


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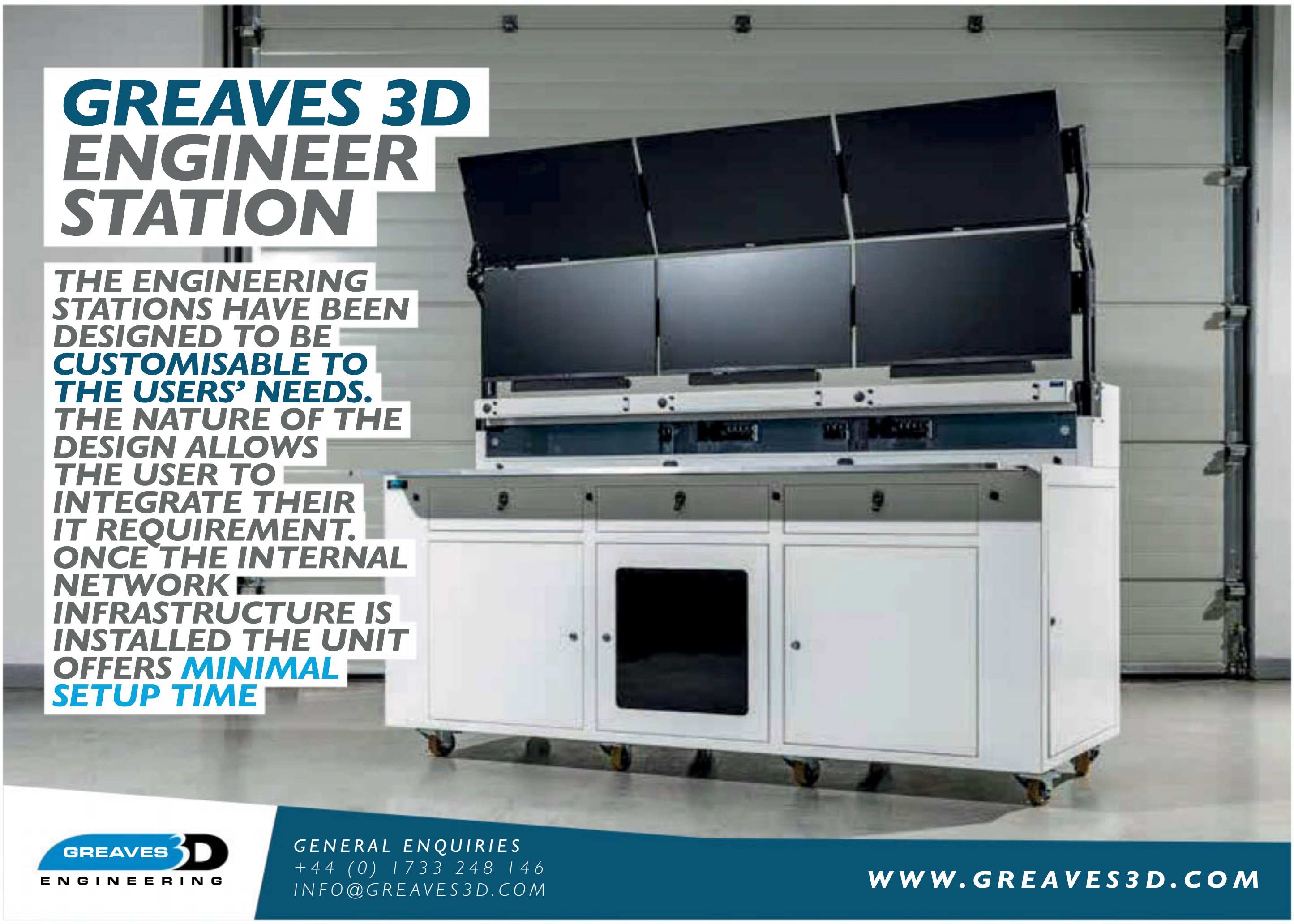
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Get a Griiip

Israel is hardly well-known for racecar design, but with its clever little G1 bike-engined single seater new manufacturer Griiip aims to put that right

By LEIGH O'GORMAN

There is nothing new in a company creating an all-new single seater from scratch. But it's not often that you will hear of a new racecar coming out of a country with very little singe seater heritage. That is just one of the reasons the Griiip G1 is so very interesting.

Based in Petah Tikva, in the Central District of Israel, Griiip has created an entry-level single-seater to the Sports Car Club of America's Formula 1000 regulations. Called the G1 and launched earlier this year, the machine is paired with an Aprilia RSV4 Superbike engine and developed in association with Internet of Things (IoT) and augmented reality specialist Parametric Technology Corporation (PTC). But while the concept and design is all-Israeli, the Griiip G1 is built in Italy by Dallara, and it also started racing in the Formula X Italia Series.

'We did a market analysis back in 2013 before Formula 4 was introduced,' says Griiip's co-founder and CEO Tamir Plachinsky. 'You had karting and you had Formula 3 and many, many types of racing series in the middle like Formula Renault. A year later the FIA introduced F4, but before that we found a regulation from the US called Formula 1000, which uses a motorcycle engine at 1000cc and is a very simple package.'

Promised land

While there is some off-road competition in Israel, Plachinsky admits that the country's lack of motorsport industry made the in-house construction of the G1 a tricky proposition, acknowledging that the Griiip team had to focus on the design, in the face of limited knowledge of building cars. Its existing relationship with Italian constructor Dallara helped here, as Plachinsky explains. 'I had worked with Dallara in 2012 and kept a warm and very close connection with Gian Paolo Dallara, the owner, president and founder. He helped us lot with this.'

Despite its headquarters being situated some 3500km away from Dallara's base, Plachinsky sees some advantages to Griiip's location. 'Because there is no motorsport industry here it means we are not confined by any kind of dogma or certain ways of thinking that tells you a racecar should look like this, or should be operated like that. We have no culture behind us; and so we can think outside of the box very easily.'

He adds that while Israel may not have a motorsport industry, it does contain a significant hi-tech sector. 'Being part of this industry gives access to many new and interesting technologies that we always look at and think of adapting for our racecars.'

Power to Griiip

Griiip does have a facility in Italy now, though, as well as another high-profile Italian partner: Aprilia. 'We met Aprilia and asked them if they would be willing to allow us to use their engine in our racecar, which is the best engine we could ask for,' says Plachinsky.

With an output of 201bhp, the Aprilia RSV4 engine is rotated longitudinally to 90 degrees,

TECH SPEC

Griiip G1

Chassis: Tubular 4130 chrome-moly steel spaceframe. Front, rear and side crash structures.

Engine: Aprilia RSV4 1000cc Superbike powerplant; power, 201bhp. Griiip intake and exhaust systems.

Transmission: 6-speed sequential gearbox; ECU contains built-in cut-offs for clutch-less quick up- and down-shifts. Limited slip differential. No chain drive.

Suspension: Double wishbone made from aerofoil section; pushrod-actuated coilover dampers; front and rear anti-roll bars.

Aerodynamics: Front and rear twin element wings; front splitter; rear diffuser.

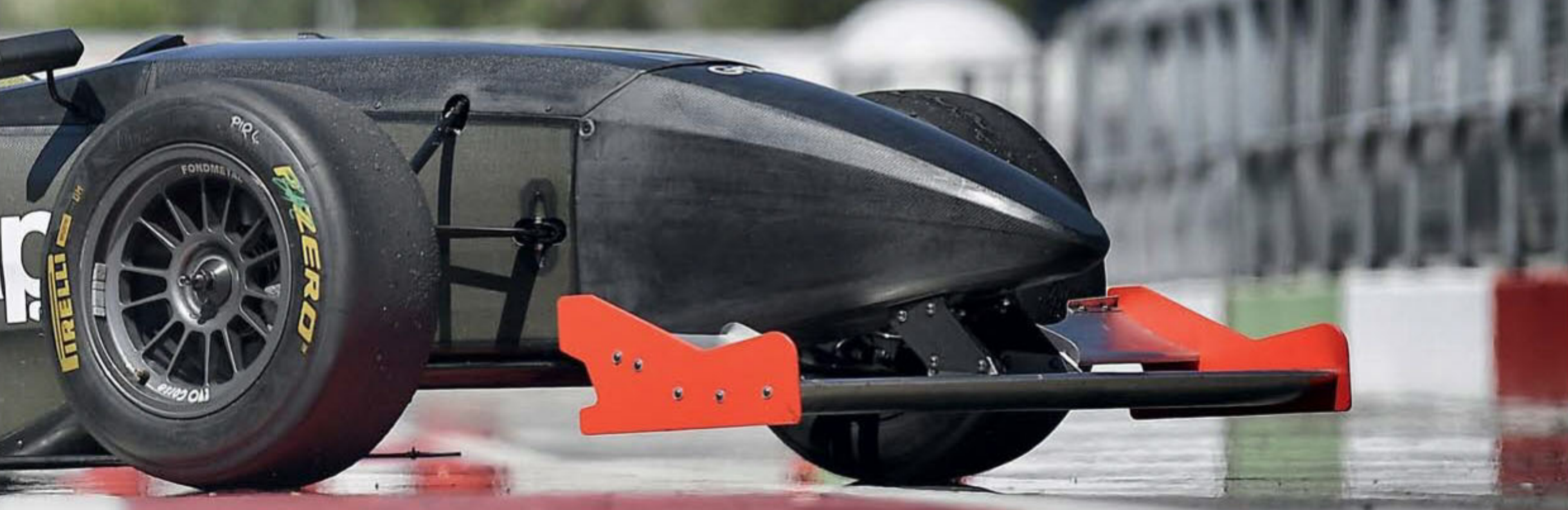
Brakes: Double circuit, 2-pot calipers acting on 256mm diameter ventilated discs.

Fuel tank: 28-litre FT3 FIA fuel tank.

Dimensions: Wheelbase 2.5m; front-track 1.6m; rear track 1.55m.

Weight: 390kg including fuel.

'Because there is no motorsport industry here it means we are not confined by any kind of dogma'



with the crankshaft mounted along the car and the power output shaft pointing to the rear of the car, which attaches to the driveshaft. 'The engine and the driveshaft runs a crown pinion system; and the crown wheel is now attached to the differential in our custom differential housing, which is also a stressed member. All of the rear suspension is attached to that case,' Plachinsky says.

That suspension is a double wishbone pushrod, front and rear, actuating coilover dampers, with front and rear anti-roll bars.

The engine and a 6-speed sequential gearbox are installed as a single unit, which reduces weight and ensures the unit is compact. 'In the Aprilia motor, you have a feature where you can take out the gearbox without having to take out the engine,' says Plachinsky. 'It's like a cassette, so it's very comfortable. It's something they adapted from their Superbike engine.'

Plachinsky and his team also decided to opt for a driveshaft system with a limited-slip differential, rather than a chain drive. 'It is a system we have a patent pending on, and it looks like a really good system, mainly because of the performance, but also the zero maintenance. We think that this system makes the car completely better.'

The Israel-lights

Considering the level at which Formula 1000 sits, keeping the costs in check was a must. 'It looks like the perfect car to fit into that gap between karting and F4, with the right performance, the right sound,right look, right cost and performance,' Plachinsky says. 'It's a very simple package and the thing we loved is that it's very light; when finishing the race, it's around 450kg with driver, which is nothing.'

Griiip's ambition stretches beyond the supply of entry-level machines for club races and Plachinsky sees an opportunity to create a G1 series in its own right and there are moves to have something running in 2018. 'We saw a gap and we said we want to change this situation and we want to offer some kind of solution for drivers, which would be much more cost effective than anything that is currently on the market,' Plachinsky says. 'You see that [with] Formula 4, the car itself is not that expensive – it goes up to around €50,000. Then if you want to enter a series, you need to add at least €200,000 plus and it's a lot of money and not a lot of people can afford it, and we asked ourselves if this was a just cost and if the drivers are getting back what they are paying for.'

Shared data

Plachinsky adds that he wants Griiip to change the perception of how the racecar is used, primarily by involving the driver in the engineering and data correlation process, with the help of a lead software engineer. Rather than each team collecting information and using this to drive their individual needs, logged data will be processed to a cloud server and shared amongst all competitors. 'This is essentially what I want the G1 series to be – a place where drivers can learn and

The car's been built to Formula 1000 regulations but its creator is planning a spec G1 series. It packs an Aprilia Superbike engine

grow together. That this can broadcast data to one server means that everybody learns from everybody, so you have to accept that others drivers will have access to your data and learn from it. All the technology that we are developing means that you will be able to run the car and learn and improve without the need to have a full racing team helping you.' The server is currently in development, Plachinsky says. The G1 racecar uses a data logger from Evo4 and an AiM Formula steering wheel.

Sump action

Griiip has also designed a unique dry sump system, says Plachinsky, but it cannot divulge details at this time. 'We are checking also the possibility of a patent on that. Being a dry sump system, you need to monitor all the time the oil pressure, so we have sensors on that.' An upgraded car package allows for additional sensors to monitor other areas.

The company's collaboration with augmented reality specialist PTC began after the gestation of the G1 had already started, but it is a relationship that is beginning to bear fruit. Plachinsky met representatives of PTC, which opened a development centre in Israel back in 1991, at various tech events and eventually switched development of the G1 to the Creo software programme, with a particular focus on PTC's augmented reality and Internet of Things platform. 'They see a lot of value for them using our racecar as a development platform for their technologies, so now we are one of the partners in PTC,' Plachinsky says. 'ThingWorx is the system that we are using to collect the data and analyse it and everything.'

'We want to have a G1 series running in every country in the world that has racecars'

As would be expected for this level, the aerodynamic profile of the G1 is relatively straightforward, partially due to regulatory constraints but also because of a desire to maintain simplicity. It features twin-element front and rear wings, a front splitter and rear diffuser, but Plachinsky deliberately avoided adding numerous extra aero devices such as bargeboards, deflectors and dive planes and has reduced the complexity without overly harming the drag coefficient.

Limited resources ensured effectively no CFD work on the design, but with the aid of PTC Plachinsky now plans to re-examine this aspect for the racecar's next generation upgrades. 'Now we are switching back to focus on those parts, because it is very easy to change them on the car. You can change the front wing by itself and not change [the car concept] and I think it will improve even more the performance of the racecar once we introduce them.'

Space race

The chassis is constructed from a tubular 4130 chrome-moly steel spaceframe. As Formula 1000 is not an FIA regulation, a crash test was not necessary, while the diameter and width of the tube in the spaceframe exceeded the minimum requirements for an F1000 car – an element that further reduced costs. Griiip, however, *did* complete a simulated crash test.

'We decided that, for us, the regulation is not strict enough, so we made an interpretation from the Formula 3 crash test to our car, remembering that our car weighs around 100 kilos less,' Plachinsky says. 'We made some interpretations of the speed and weight of a Formula 3 compared to us and made simulations on our frame and made it strong enough to hold that kind of test and we are currently exceeding that. We have doubled [the strength of] the main hoop and have a rear crash box, which is not mandatory in the regulations. The fuel tank is F3 standard, the safety harness is six-point, all the normal things.' Plachinsky adds that bulking the car up to full F3 standard would add too much weight, negating any power delivered from the engine.

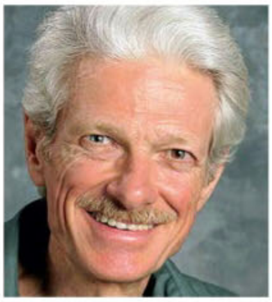
The G1 uses Formula 4 specification brake calipers and discs, as supplied by AP Racing. Plachinsky considers these items to be quite cost-effective and less prone to excessive wear when considering the relatively lower weight and speed of the car. The wheels are lightweight aluminium single-nut rims supplied by Evo Corse and the G1 has, to date at least, run on Formula 4 Pirelli tyres.

Sales drive

The base price for a G1 car is €52,900, which includes the chassis, the new engine, the dry sump, the data acquisition system and an additional set of wings – but Plachinsky is keen to emphasise that early buyers could be in line for a reasonable discount.

Griiip have sold seven cars – all to Israeli clients – and with Israel's' first permanent circuit set to open at the turn of the year, it is hoped these machines will be running in anger in their homeland soon. For now, though, the focus is shifting towards selling cars in Italy, so that a series can begin in earnest next year. 'We have started manufacturing 12 cars that will be used next year in the first G1 series that we are establishing in Italy,' Plachinsky says.

Plachinsky ultimately sees the G1 series and racecar project growing, and he leaves you in no doubt he has lofty ambitions. 'We want to have a G1 series running in every country in the world that has racecars; not only because it will be the most cost effective series, but also because it will be the most exciting series,' he insists, adding: 'Eventually, if one or more of our drivers that started his career in the G1 series get to the top classes, like Formula 1, I think it will be a success story.'



May the jacking force be with you

An old edition of *Racecar* sparks a debate on tyre loading

QUESTION

I was going to ask you a question about Panhard bar rake, but found you did a piece on it back in August 2006 [below]. What I am wondering is what the change in tyre loadings are from the jacking force? I see you mention it's not significant? Also, regarding spring split you say if the RR spring is stiffer than the left and you have the Panhard bar sloped down to the frame attachment that the LR will gain load and diagonal cross weight per cent. This confuses me. I would think the stiffer spring would carry more of the load than the softer?

THE CONSULTANT (2006)

'In a NASCAR oval track chassis, a Panhard bar that slopes down from its attachment on the left axle tube to its frame attachment on the right does create a force trying to lift the rear of the car. This force is present through the entire turn, not just during entry. This force does not just load the left rear tyre. It does pull down on the axle on the left, but it also lifts up on the frame on the right. Its effect is most commonly modelled as a force spreading the axle and frame apart, acting at the midpoint of the bar's span, approximately in the middle of the car.

'If the car has little or no rear spring split, a force in the middle, lifting the frame away from the axle, gets the rear spoiler up in the air but does not significantly change wheel loads, except by aero effects. But NASCAR set-ups use considerably stiffer springs at the right rear than at the left rear, so there is some increase in left rear load, and diagonal percentage, because of that. If the car has a left-stiff rear spring combination, the effect reverses, and the jacking force actually increases right rear tyre loading and reduces diagonal percentage.

'Again, these effects persist through the entire turn, and only go away when the rear tyres cease making lateral force.'

THE CONSULTANT

Does a jacking force change wheel loadings? Disregarding secondary effects from aerodynamics and small effects due to cg movement, jacking forces can significantly change diagonal percentages but not front, rear, left, or right percentages.

The suspension linkage and springs can't press down on the axle harder than the rest of the car presses down on them. When the linkage generates a force trying to lift the frame with respect to the axle, that takes some load off the springs. The linkage is then partially supporting the frame. Since the springs have less load on them, they extend.

Use the force

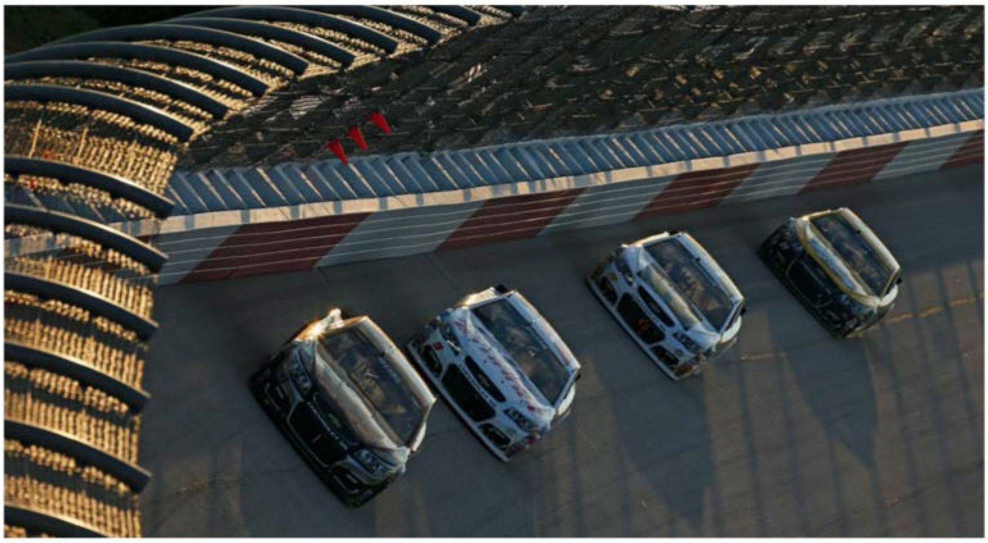
Remember that rate is not force. It's the amount of force *change* per unit of displacement. A stiffer spring exhibits a greater force increase per unit of compression, and also a greater force decrease per unit of extension. When a jacking effect adds load to both rear springs similarly, the stiff one gains more load. When a jacking effect unloads both springs, the stiff one loses more load. Actually, it's a bit more complicated than that. The front suspension affects things, too.

Some extreme cases may serve to illustrate. Suppose we have a beam axle rear suspension with a 200lb/in spring on the left and a 300 on the right. Suppose we take the front wheels off the car and support the front end on a jack stand with a piece of angle iron on the top of it, under the middle of the front cross-member, so that the front end is held up but can't resist roll, and we have the rear sitting on the tyres as usual, on wheel scales. Suppose there is a cross-member above the axle and we can put a bottle jack on the axle and lift the frame, midway between the springs. Then suppose we exert a 500lb force with the jack, spreading the axle and frame apart.

The springs will each unload by 250lbs. The left will extend an inch and a quarter (250/200). The right will extend 5/6 of an inch (250/300). The car will rise and roll to the right. There will be no significant change in the scale readings.

Infinitely stiff

Now suppose we do the same thing, except now we have the front end on its wheels as well, on wheel scales. Suppose the front end has an infinitely stiff anti-roll bar, and the tyres and the frame and all other parts are perfectly rigid, so that the front end prevents the car from rolling at all and the frame can't twist. The rear springs will want to extend unequally as before, but they can't. They will have to extend equal amounts, since the car can't roll.



Jacking forces on NASCAR racers can significantly change diagonal percentages and they certainly affect wheel loading

When a jacking effect adds load to both rear springs, the stiff one gains more load. When a jacking effect unloads both, the stiff one loses more load

The springs have a combined rate of 500lb/in, so they will both extend an inch. The left one will then unload by 200lbs and the right one will unload by 300lbs. The right rear wheel will show a load decrease. The left rear wheel will show an equal load increase. The front wheels will show approximately equal load changes, the opposite way. The diagonal percentage will increase. The left and rear percentages will not change significantly.

Real world situations fall somewhere in between these extremes. We can definitely say that any time anything in the rear suspension creates a roll moment, the resulting change in diagonal percentage becomes greater as we increase the relative elastic roll resistance at the front and becomes less as we increase the relative elastic roll resistance at the rear. This applies even to torque roll from driveshaft torque. This explains why we can improve the drag strip times of a powerful live axle sedan by disconnecting the front anti-roll bar.

We can generalise this a bit further. Anything that produces a roll moment at only one end of the car changes diagonal percentage. The magnitude of that change increases as we add relative elastic roll resistance at the opposite end of the car and decreases as we add relative elastic roll resistance at the same end of the car.

Thinking big with a GP Midget

A short oval racecar designer plans to copy Formula 1 tech. But is this a mistake?

QUESTION

I have really enjoyed your articles in *Racecar Engineering* and I hope you would be able to help with the suspension design of our new GP Midget chassis for the 2018 season. We are designing the car from the ground up and given that the rule book for UK GP Midget oval racing is very open in regard to the suspension we really could do with a hand with what direction we should go in. Our current car uses conventional double wishbone suspension with large coilover dampers at each corner.

My plan for the new car is to make much better use of aero, which will be a first in the class. Most of the current competitors' cars run little bodywork and fit a large F1 stock car style wings to the upper roll cage. But I am thinking along the lines of a Formula 1 car or an IndyCar style body, front and rear adjustable wings, sidepods, flat floor and diffuser, with inboard dampers front and back to improve aero/packaging. The ovals we race on tend to be rather small with around 15 to 17s laps with a varying degree of banking on tarmac.

The car will be packing a 180bhp 1.4-litre Vauxhall Ecotec in a rear engine and rear-wheel-driver configuration. Tyre wise, we run Avon crossply 10/20/13 on the back and 9/20/13 on the front, but the sizes could vary from this if we needed them to.

If I was doing this I wouldn't build a mini formula car, I'd build a mini Super Modified

It makes little sense to copy Formula 1 thinking when designing a short oval racer. F1 is restricted by its rules while the requirements are vastly different

THE CONSULTANT

This is a completely new class to me. I had never heard of these cars. But I've now read the rules. A few initial thoughts, then.

Remember that the bodywork and wings and undersides of current Formula 1 and LMP cars are the result of their rules, not what works best. They use flat floors and diffusers because they are no longer allowed to use tunnels. They don't use big overhead wings because they aren't allowed to. They need relatively low drag because they have long straights.

But you are running your car on short ovals and have none of those rules. You need high downforce, almost at any price in drag.

If I were doing this, I wouldn't build a miniature Indy or formula car. I would build more of a miniature Super Modified – with the engine way to the left, between the left wheels, alongside the driver.

IndyCars have to run on road courses. You run only short ovals. You need to maximise left percentage. If you do put the engine behind the driver, you still want to offset as much mass to the left as you can. The only constraint I see in the rules is that you can only offset the driver 10 inches. Most of the legal engines are from front-drive sedans with transverse engine mounting and have integral transaxles. One exception is the old BMC A Series engine, which was used in that sort of layout and also in conventional rear-drive cars like the Spridget and Morris Minor.

These racecars are required to have starters and reverse gear, unlike US-style Midgets. It might be possible to mount a front-drive powertrain far to the left, rotated 90 degrees, substitute a spool for the diff, and run a driveshaft back to an open tube quick change rear axle, if the gear ratios could be made to work. The car would have to run in high gear at the transmission, and the rear axle would have to be toward the tall (numerically low) end of the available ratio range. But quite possibly the gearing would be too short even then.

I also don't know how much stagger can be obtained with the legal tyres. That's important with any kind of locked axle.

With the driver and the engine offset to the left, it might be possible to have a single tunnel to the driver's right. I would also have a rear wing to help drive that, whatever wing would fit at the front, and I would have an overhead wing on the roll cage.

Small cars like this on short tracks can go really fast and be a lot of fun, without costing an arm and a leg.

CONTACT

Mark Ortiz Automotive is a chassis consultancy service primarily serving oval track and road racers. Here Mark answers your chassis set-up and handling queries. If you have a question for him, please don't hesitate to get in touch:

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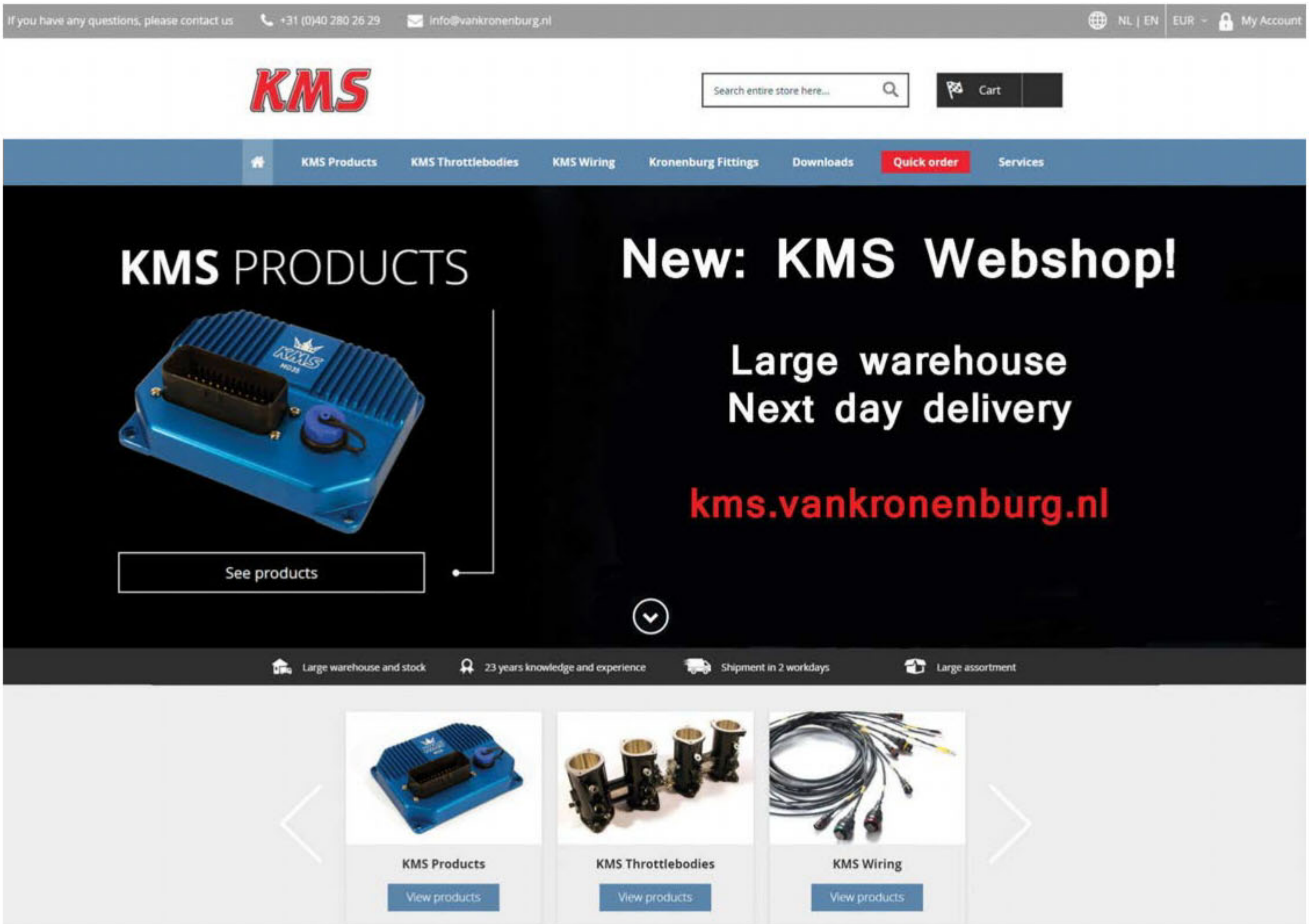
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Testing the cutting edge of the Sabre

Evaluating the front-end aero on the Aries Bikesports racecar

The Aries Sabre two-seater sports racer is one of the latest entries in the UK's 750 MC Bikesports category. Running with a 1000cc Honda it fits into Class C of that series, for up to 1100cc engines, and is also eligible for the BRSCC's Open Sports Series (OSS) class E, for up to 1000cc engines. Compared to its category competitors running with larger capacity Suzuki Hayabusa engines in Bikesports classes A and B, such as the Spire GT3 we evaluated in our June to August 2016 issues, the Sabre has up to 40 per cent less power and this places different requirements on the aerodynamics package.

As delivered to the wind tunnel the Sabre was in a specification never previously evaluated or raced, with many of the test parts already in place; it being quicker to remove parts than to attach them. A new low, well-aft positioned rear wing was complemented by wide front diffusers (where previously a simple flat splitter had been used), a longer rear diffuser with extended tail section above, and various other parts were also in place. The baseline run produced data shown in **Table 1**, revealing quite low drag, modest downforce, and a balance that was slightly too far forwards for a racecar that has a static weight distribution of between 45 per cent and 50 per cent with the driver on-board.

Front diffusers

We saw in our CFD feature in December 2017's issue (V27N12) that diffusers set into a splitter's underside added significant extra downforce. This principle has been used for a long time on sports racing cars and others that utilise front splitters, but we have not previously had an opportunity to evaluate the effects in the wind tunnel. Pre-session discussions led to the Aries Motorsport team integrating wide, ingeniously and simply adjustable diffusers into the previously flat splitter so that we and they could evaluate them.

As ever with ground-proximity devices, we should state the usual caveat that MIRA's fixed floor, despite the boundary layer control fence being installed, may produce under-estimates of the effects. Nevertheless, some very useful trends were observed, and a clear-cut answer to the question 'do front diffusers work better than a flat splitter?' was obtained. The data are shown in **Table 2** as Δ or 'delta' values, that is, changes relative to the flat splitter, or zero degrees diffuser if you prefer. Changes are given in 'counts' where one count is a coefficient change of 0.001.

The car arrived with front diffusers which were set at 18 degrees, which we can see from **Table 2** was actually too steep; the diffusers had stalled. Nevertheless, the baseline data in **Table 1** showed that even with stalled front diffusers the front downforce had gone up by 49 counts, equivalent to 21 per cent more front downforce relative to the flat splitter. At 12 degrees that increase was more than 27 per cent. Front diffusers are considerably better than a flat splitter on the underside.

Looking at **Table 2** in more detail, the gains in total downforce, front downforce and %front peaked at 12 degrees front diffuser angle, but –L/D peaked at six degrees. And examining **Figures 1** and **2** in conjunction with the above statements, it would seem reasonable to think that the best front diffuser angle at this ride

Front diffusers are much better than a flat splitter on the underside

Aries Sabre runs in Class C of the 750 MC's popular Bikeports category in the UK

Table 1: Baseline aerodynamic data on the Aries Sabre

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Baseline	0.460	0.613	0.307	0.306	50.0%	1.333

The Aries team fabricated these adjustable diffusers. Lock-nut arrangement (centre) allowed the front diffuser ramps, hinged below with tape at the transition, to be adjusted for angle

Table 2: The effects of changing front diffuser angle

	Δ CD	Δ -CL	Δ -CLfront	Δ-CLrear	Δ %front*	Δ -L/D
+6deg	+4	+13	+57	-44	+7.0%	+13
+12deg	+10	+17	+65	-47	+7.8%	+4
+18deg	+16	+6	+49	-43	+6.3%	-37

Absolute rather than relative difference in percentage front.

Figure 1: Aero balance *vs* front diffuser angle

Figure 1: This shows that %front appeared to peak at the 12-degree front diffuser angle

Figure 2: -L/D *vs* front diffuser angle

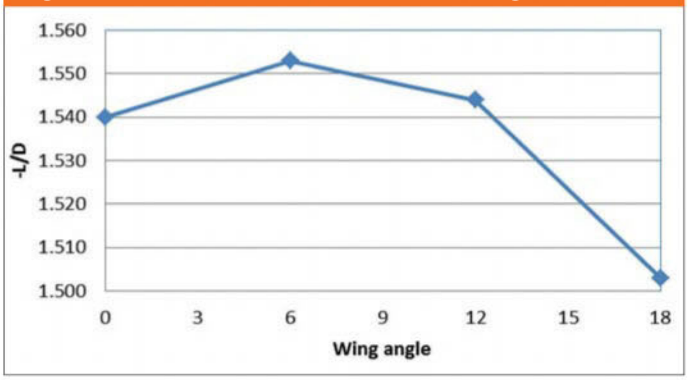
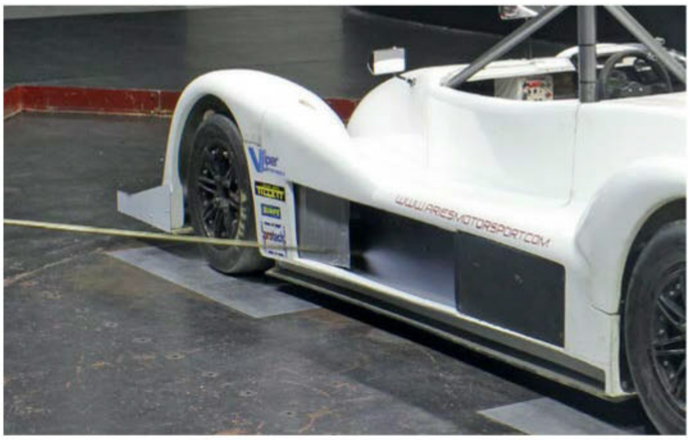


Figure 2: The aero efficiency appeared to peak at the 6-degree front diffuser angle

Front wheel fairings on the Ligier JS49. These inspired the examples tested on the Sabre



Silver-taped wheel fairings can be seen behind the front wheels; the results were better without these in place. Sidepod undercuts are just above the running boards

Table 3: The effects of removing the front wheel fairings at two different wing locations

	Δ CD	Δ -CL	Δ -CLfront	Δ -CLrear	Δ %front*	Δ -L/D
High, forward wing	-6	+31	+7	+23	-1.1%	+78
Low, aft wing	-1	+49	-6	+55	-3.8%	+107

**Absolute rather than relative difference in percentage front.*

Table 4: The effect of the sidepod undercuts being exposed

	Δ CD	Δ -CL	Δ -CLfront	Δ -CLrear	Δ %front*	Δ -L/D
Undercuts exposed	-1	+16	+6	+10	-0.2%	+36

**Absolute rather than relative difference in percentage front.*

height, and in this test facility, would be in the six to nine degrees range. It would be remiss to ignore the drag penalty, but it was relatively minor in relation to the front downforce gains. The losses in downforce at the rear wheels may just have been the mechanical result of increased downforce and, hence, leverage ahead of the front wheels, but it is also possible that downwind flows were altered in a way that aerodynamically reduced rear downforce, especially where the front diffusers were stalled. The front diffusers were set at six degrees for the remainder of our session.

Front wheel fairings

Another test item fitted prior to the session was a pair of tapered polyurethane foam and race tape-covered fairings behind the front wheels. The idea was to provide a defined path for front diffuser exit air to follow down the car's sides, and to minimise the front wheel wake's presumed adverse effects on this. The Ligier JS49 that we featured in April to June 2009 provided the inspiration for this test.

As the data in **Table 3** show, the fairings and their removal were evaluated with two different wing locations, and the detailed response was different each time, but essentially the car was better without the fairings in place; proving the worth of testing!

In both cases there was an improvement in rear downforce, more pronounced in the case of the low, aft wing mounting position. However, drag was either no different or slightly lower, suggesting that rather than the rear wing being the source of the extra (rear-biased) downforce, which would have been accompanied by an increment of induced drag, it might have been that the flow to the aft underbody was improved. Certainly it seems reasonable to assume that the fairings' removal improved the downstream flow. It was perhaps curious that front downforce did not also improve (more, in the case with the high, forwards wing), which suggests that mass flow from the front diffusers wasn't significantly altered by the removal of the fairings, but that downstream flows were improved by removing the fairings to the extent that the rear gains masked any gains at the front.

Finally this month, a quick look at the effects of the sidepod undercuts, included at the request of the Sabre's design consultant Enrique Scalabroni. **Table 4** shows the effect of the undercuts relative to them being taped over. There were modest downforce gains front and rear for no drag change, implying that the underbody's performance was enhanced. Gains on track may be bigger than this.

Next month we will be doing a rear wing location trial on the Sabre.

Big thanks to all at Aries Motorsport.

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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Shock developments

Optimising dampers for different motorsport disciplines is a key facet of shock absorber technology. *Racecar* spoke to those at the forefront of suspension system development to find out more

By GEMMA HATTON

Coilover damper. The damper's task is to control the behaviour of the spring which ensures the tyres are in contact with the track surface as much as possible

Quite often, the only time we hear F1 teams talk about suspension is when they are arguing the legality of their clever designs with the FIA and the rest of the paddock in the latest regulation row. So why can't teams leave their suspensions alone? Well, that's simply because suspension is arguably the most important tool for gaining track performance.

The main purpose of the suspension is to absorb the oscillations between the vehicle body and the wheel, generated by undulations in the track surface. Also, maximum contact between the tyres and the track also needs to be achieved for optimum grip. Suspension also plays a role in maximising cornering stability, braking distances and acceleration. So you can see why motorsport engineers invest so much time, resources and money into manipulating suspension characteristics in their continued quest for that optimum set-up. And much of the work is centred on dampers.

'The main damping concept of flow architecture and how the pressure is built up in the damper, is the same for all our dampers in high level motorsport,' says Claes Hesling, project manager, Racing, at Ohlins. 'Our damping technology ensures that the damper responds properly under all conditions without experiencing cavitation. This helps minimise the variation in contact patch load, which in turn optimises grip and control. Another aspect is the versatility which is achieved

'The main challenge is to fit all the required features of a high performance motorsport damper into a very limited space'

Each motorsport discipline experiences different loads at the wheels and they require completely contrasting damping characteristics. This leads to a wide array of damper designs, as shown here. **Top:** ZF Formula 1 damper. **Above left:** Ohlins Formula E damper. **Above right:** ZF rally damper (not to scale)

with flexible valving systems to ensure powerful and precise adjusters.

'Of course, the main differences between the dampers for different motorsport categories is the size and weight demands,' Hesling adds. 'In all forms of motorsport you want to achieve the lightest and most efficient packaging possible but it cannot be at the expense of durability. A damper failure would be catastrophic so you try to be as close to the limit as possible without going over it.'

Formula 1 dampers

In Formula 1, suspension design is extremely aero driven because the main source of grip comes from the downforce generated by the aerodynamic package, as opposed to pure mechanical grip. Therefore, Formula 1 engineers are continuously hunting for ways to use suspension behaviour to influence the ride height and other parameters to increase downforce. Of course, these types of active systems have been banned since the 1990s, with the current regulations dictating that the only method in which suspension design can result in an aerodynamic gain is when it is 'wholly incidental' to the primary purpose of the suspension itself. Not that this stops teams trying, as the past has proven; collapsible heave systems have been used at the rear to reduce ride height, with teams optimising the front suspension to increase ride height at the end of straights, as well as altering the pushrods and uprights to lower front ride height at the corner apex.

Geometry set

It is not only the behaviour of the suspension that is aero driven, but also the geometry. For example, in Formula 1 the lower front wishbones are in line with the axle, because this ensures they do not disrupt the airflow coming off the front wing, minimising any potential turbulence and consequent drag. This may not be the most mechanically effective design, however the desires of the mechanical engineers are some way down the pecking order.

'The main target of the dampers or shock absorbers in Formula 1 is to control the aerodynamic platform of the car because this is where you get the most gain in grip,' says Olivier Lardon, manager of Motorsport Dampers at ZF Race Engineering. 'However, the suspension is also linked to the tyres, so you can also use dampers to adjust tyre temperature and therefore bring the tyres into the best working range to achieve optimum grip. For example, if you have larger or stiffer tyres, you may need to increase your damping coefficient to get more energy into the tyre.'

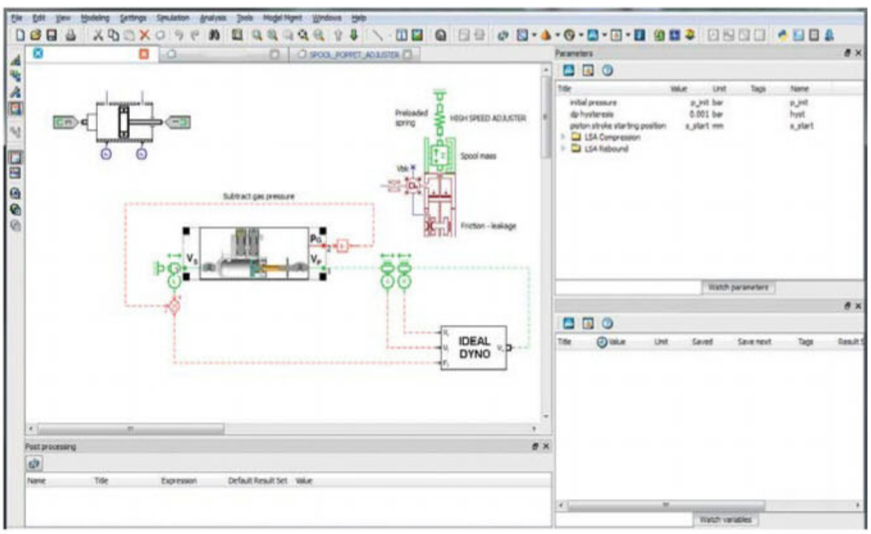
Tyre role

The characteristics of rubber ensure that tyres naturally contribute to the damping of the unsprung mass and must not be forgotten. This behaviour can be utilised by the suspension set-up to try and control bulk tyre temperatures and therefore grip. At high speed, the high frequency inputs of the track consequently help to generate bulk tyre temperature. Therefore, modifying the high-speed damper settings will have minimal effect on tyre temperature and may compromise other areas of handling.

However, at low speeds, particularly for stiffer tyres such as those running in colder ambient temperatures, the compression or bump of the damper is increased. This higher damping generates more resistance which consequently transfers additional energy into the tyre as the 'damping' part of the tyre is being utilised rather than the 'spring' part of the tyre. On the other hand, if you are using softer compounds that are more susceptible to overheating, low speed compression should be reduced to achieve a more benign behaviour. Interestingly, in the motorbike world, a stiffer suspension actually decreases tyre temperatures.

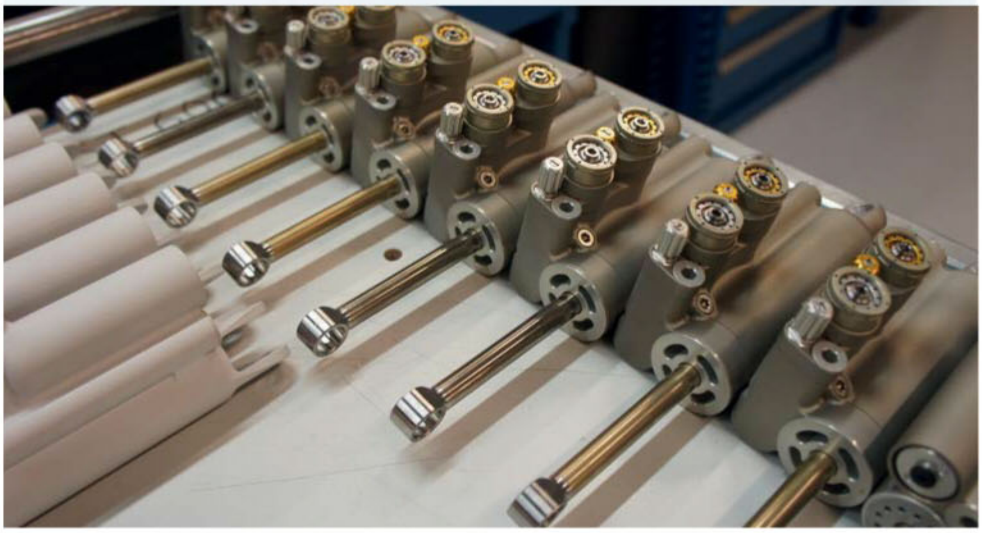
'In Formula 1, weight and packaging are crucial, which pushes us to use extreme

The characteristics of rubber ensure that tyres naturally contribute to the damping of the unsprung mass



Models are built to help engineers simulate and therefore define the optimum characteristics of their design

The 5 way-damper from KW Automotive



F1 dampers. Formula 1 teams use the dampers to influence the aero performance and also to control the tyre temperatures

Race engineers adjust the dampers by clicks, altering the valving within the shocks to increase or decrease the resistance

materials such as composites, magnesium and titanium to achieve the weight targets,' says Hesling, 'The main challenge is to fit all the required features of a high performance damper into a very limited space.'

Things are a bit different in Formula E. The word 'Formula' may lead you to think that these electric racecars face the same suspension challenges as Formula 1. However, due to the very nature of the inner city circuits and the strict regulations, there is much less emphasis on aerodynamic grip. The tracks are, however, bumpy with many kerbs and the tyres have less damping due to their thinner profiles, therefore improving mechanical grip is most important for Formula E cars.

'Every category presents different challenges and our job is to optimise our suspension products around these issues,' says Heinz-Joachim Gilsdorf, senior manager Motorsports Chassis at ZF Race Engineering. 'For example, Formula E is not as fast as Formula 1, therefore you don't have such complex aerodynamic packages which result in lower levels of downforce and reduces the consequent loads on the suspension. On the other hand, Formula 1 cars drive on race tracks whereas Formula E cars race in cities and so there are more inputs from the bumpy track.'

Dampers for rallying

The extreme of 'bumpy' is, of course, rallying, where maintaining mechanical grip, regardless of whether it's on a mud, snow, ice or gravel stage, is the number one priority.

'On gravel and tarmac rallies, the initial damping is relatively soft on both the bump and rebound side to try and get the car to float along the track,' explains Lutz Passon, head of the motorsport department at KW Automotive. 'However, during the high peak loads seen in rally, you have to increase high-speed bump and rebound forces to control the body motion of the car.' In circuit racing, low-speed-bump and rebound forces are usually much higher.

These bigger loads require much larger dampers, with some measuring strokes of 300mm in WRC, compared to 40mm strokes in Formula E. With the FIA regulations dictating that rally cars feature MacPherson strut suspension both front and rear, the side forces are much higher than a Formula car. This demands an overall stiffer damper with larger piston rods (or cartridge), measuring up to 45mm in diameter. Whereas Formula E has double wishbone suspension which results in minimal side forces and therefore smaller piston rod diameters at only 8mm.

'A rally damper is exposed to extreme conditions and load cases, and therefore

Inner city Formula E street circuits are bumpy with many kerbs and the tyres have less damping due to their thinner profiles

the challenge is to design a damper that has superior end stop protection,' explains Hesling. 'Of course, this has to be achieved in combination with a subtle ride performance to avoid affecting the level of mechanical grip that is so crucial in rallying.'

Race engineers will often adjust the dampers by 'clicks' in low speed and high speed bump and rebound. These clicks essentially alter the valving within the damper, to increase or decrease the resistance and therefore the force in relation to the velocity of the piston rod. Some motorsport dampers can have up to 5-way adjustments, so both bump and rebound can be adjusted at low speed and high speed, with the fifth way being the control of the high-speed blow-off valve.

GT3 special

KW Automotive has developed its new version of an adjustable 4-way damper specifically for GT3 cars. The possible adjustments are in low-speed bump and high-speed bump and rebound. 'Our design allows a higher flow-rate through the valves and also our valving is all located in the same place at the bottom of the damper, both of which ensure a good response, and this is the highlight of this design,' explains Tim Schroder, race suspension engineer at KW Automotive. 'We use a completely closed piston which is a new concept for us; we really started the design with a blank sheet of paper. The closed piston allows larger flows through the valves, which lowers the pressure within the damper and ensures better hysteresis, all of which greatly improves the damping response.'

Future iterations of this design could include an optional blow-off valve. This would be located on the piston, so that when the racecar hits a kerb on the track, these high peak loads are absorbed quickly, without affecting the vertical movement of the vehicle body. 'We are also developing another type of valve that we call IDC, Intelligent Damping Control, because it will be able to define whether the input into the damper has come from the wheels or the vehicle body, and so will be able to react accordingly.'

Electric shock

As for the future of damping technology, electronically controlled damping remains out of reach for motorsport. Although the technology already exists, the regulations simply do not allow it. These systems would allow full optimisation of the suspension and therefore damping to improve the handling of the car through the entire spectrum of experienced loads. However, the complexity of these systems suddenly opens the doors for endless possibilities for both the engineers and drivers to try and define. Therefore, it is just much simpler to control mechanical shock absorbers with adjusters.

Spring time

High performance springs are another crucial element of a suspension system. These have to be designed to ensure a consistent and accurate rate with every increment of deflection. This is achieved in two parts, says Mark Campbell, engineering manager at Hyperco: 'To design these precision springs, you have to understand the 'bowing and buckling' that results from four critical physical parameters and their relationship to each other. These include: total deflection to free length ratio, mean diameter of body coils to wire diameter, free length to end coil ID [inner diameter] and corrected stress level of the spring at solid height.'

Precise work

'You also have to be able to manufacture the springs accurately, which requires precision equipment with skilled operators,' Campbell adds. 'Production processes that additionally affect linearity of rate are the squareness and degree of the end coil grinds, centring the position of the end coils with respect to the centreline of the spring, end coil tip thickness with respect to wire diameter, and end coil positioning from one end of the spring to the other.'

Forming process

Springs are manufactured using a forming operation, which is significantly different from traditional machining operations.

Initially the springs are coiled longer than the finished free length

'I relate forming operations to a quarterback throwing a football to where the receiver isn't, when he releases the ball and hoping that they both arrive at the same place at the same time,' says Campbell.

Initially, the springs are coiled longer than the finished free length. For example, a 14in, 250lb/in spring with an ID of 2.5 inches, is often coiled to approximately 18in to 19in long when it comes off the coiler. It is then stress relieved and pressed, with the initial pressing operation proving critical as it puts the 'memory' into the spring.

'Pressing the spring brings the free length down to around 14.75in to 15in, the spring is then ground on the ends,' Campbell says. 'After that it goes to shot-peening with a follow up low-temperature stress-relief operation to seal-in the residual compressive stresses imparted during the shot-peening. Both the shot-peening and low-temp stress relief operations change the physical parameters of the spring slightly. The final pressing stage then locks in the final free length. All our coils must pass a final inspection to ensure they are in complete compliance will all tolerances and dynamic performance criteria.'

Spring perches

You may think that the spring perches on a coilover shock absorber are parallel, but they are not, as the perch on the body sits at a slight angle determined by the thread pitch used. This thread fitment between the spring perch and the shock body can have a huge impact on the bowing of the spring during deflection, as well as adversely affecting the rate linearity. 'The number of threads per inch can also affect this,' explains Campbell. 'If a coarse pitch thread is used and the fitment of the threads is relatively loose, the shock body perch can tilt considerably and induce bowing into the spring. This is particularly problematic in classes where coilover adapter kits are used on a non-threaded shock to allow coilover operation. Many of these kits are very sloppy and create perceived spring bowing issues when the spring is not the problem. The problem is the shock body perch is tilted a few degrees because of the thread pitch. From our point of view, shocks using fine pitches with a tight class of tooth/groove engagement provide the best mounting to assure accurate linearity of rate and best shock/spring assembly performance.'

Boing! Springs may look like relatively simple components but the manufacturing process is complex and involves highly skilled engineering

Spring perches on a coilover shock are not parallel; they sit at a slight angle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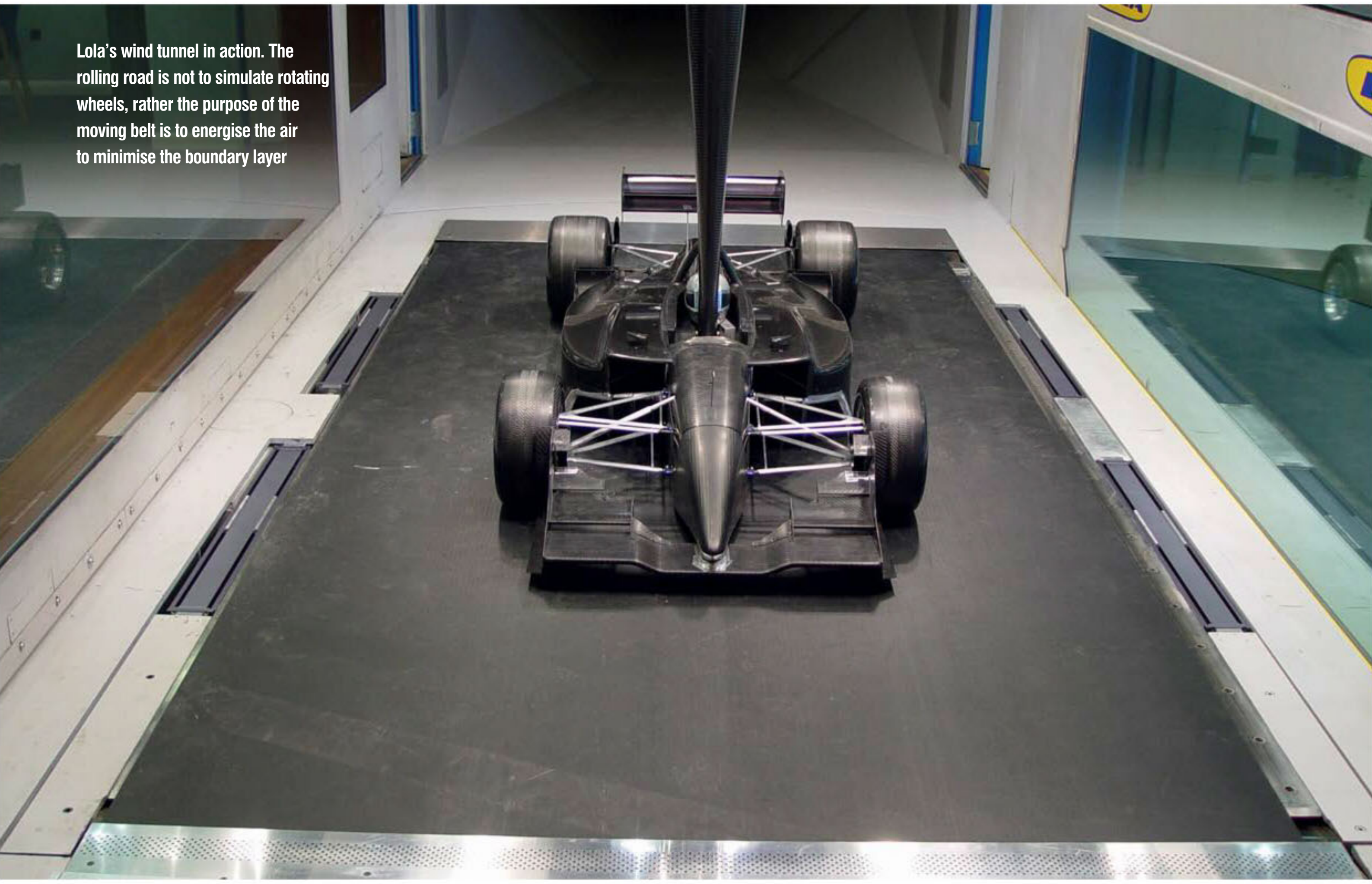
Pushing the boundary

Despite the demise of Lola in 2012 its wind tunnel continues to operate at the cutting edge of motorsport aerodynamics – we paid it a visit to gain a unique insight into the workings of a high-end aero facility

By GEMMA HATTON



Lola's wind tunnel in action. The rolling road is not to simulate rotating wheels, rather the purpose of the moving belt is to energise the air to minimise the boundary layer

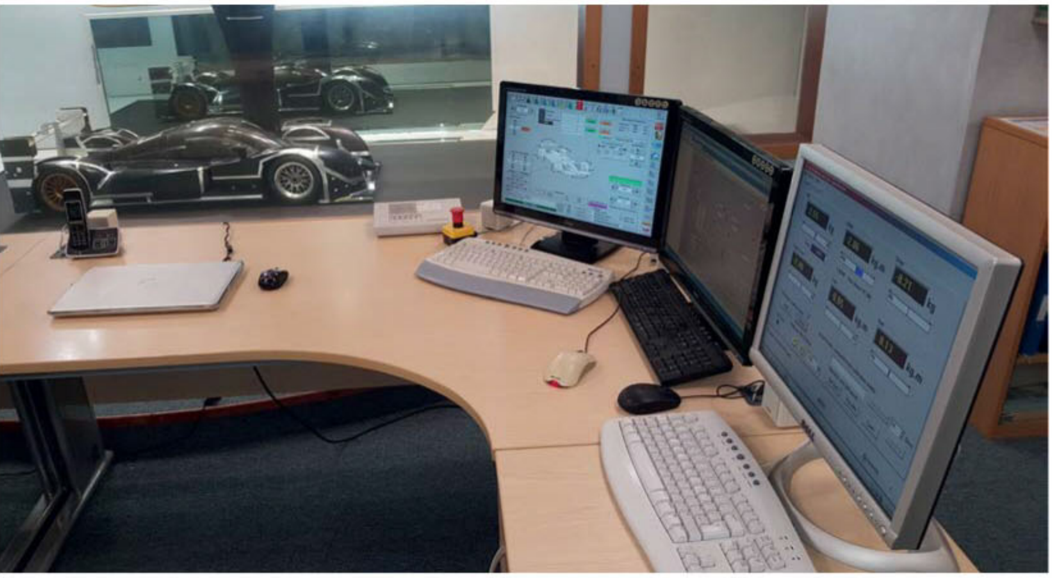
Since its downfall in 2012, you might have thought Lola joined the growing community of extinct motorsport concerns, who had their factories stripped of their racecars, personnel and assets, never to race again. Well you would be mostly right. However, one of Lola's businesses survived: the Lola wind tunnel.

When Martin Birrane took over the company in 1998, he made one thing clear; he wanted to build the best wind tunnel possible. 'I knew before I even bought Lola that a wind tunnel was needed and, because I wanted to make sure that we had the best, I listened to our engineers. Of course, that meant every day we were adding more toys to the tunnel, so there really was no expense spared,' Birrane says.

This philosophy ensured that the wind tunnel was built properly, from the 10-metre deep concrete foundations to the £750,000 Load cell. 'We had great success on track, and sold our sportscars to the likes of Chip Ganassi Racing and Penske Racing to name just two,' Birrane says. 'There was a time when everything was going great, and the wind tunnel was the essence of that, because built properly and used properly, it is a fantastic tool.'

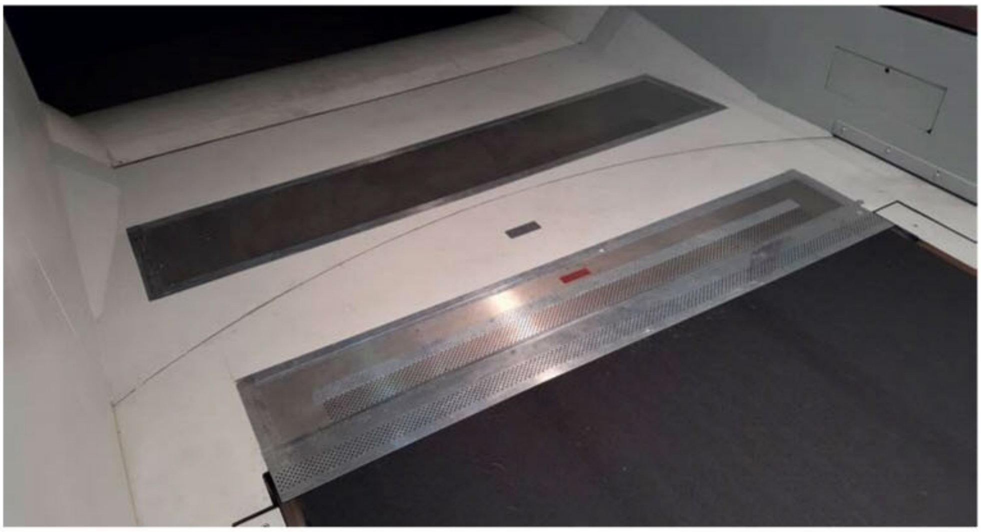
The Lola wind tunnel was actually born 200 miles away from where it now stands, in Warton, Lancashire, in 1954, and it was originally designed as a 7ft low-speed tunnel for British Aerospace (BAE). This was then de-constructed and transported to the Lola site in Huntingdon,

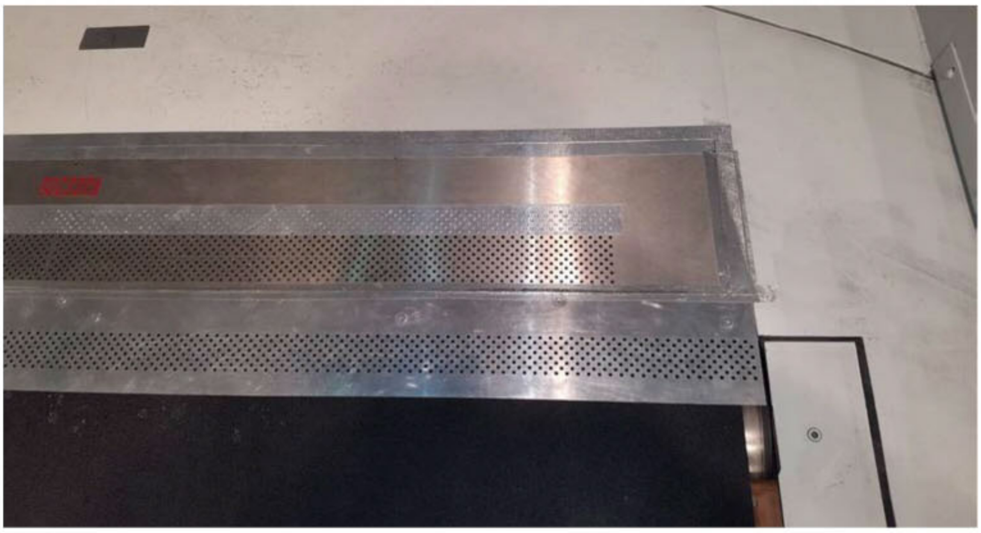
When Martin Birrane took over at Lola in 1998 he made one thing quite clear; he wanted to build the best wind tunnel possible



Lola's tunnel has high correlation with track data. It's been used for Formula 1, LMP2 and GT racecars, and Scania trucks

The honeycomb is arguably the most efficient method of removing any swirl or lateral velocity variations





Middle and above: The Boundary Layer Removal System (BLRS) is made up of a primary and then secondary perforated suction plate. The secondary plate sits on the moving belt and is of high-grade aerospace aluminium to prevent it buckling

Cambridgeshire, where it was rebuilt and then upgraded for motorsport. These modifications included a new test section, cooling system, wide-angle diffuser, a Rolling Road System (RRS), Boundary Layer Removal System (BLRS) and an overhead balance. The efficiency of the original BAE fan was also improved through redesigned blades, along with a new more powerful motor and variable speed drive.

Wind power

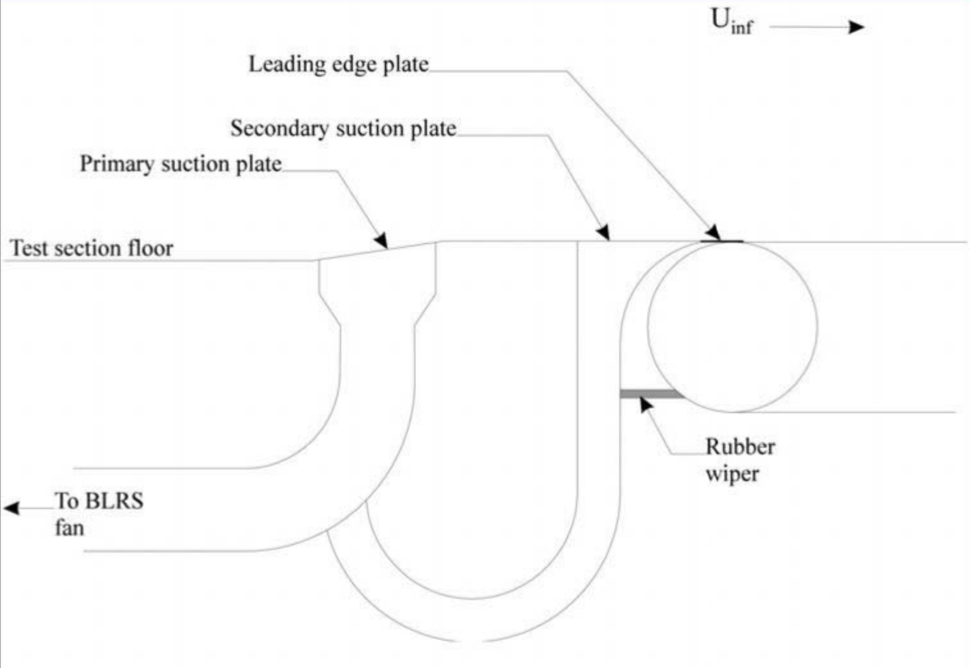
The tunnel is a classic closed loop design. An externally mounted DC motor, powered by a 678kW variable speed drive, spins the fan which then blows air through to a settling chamber. Here irregularities of the flow are minimised through a long cell stainless steel honeycomb and a series of three screens. The honeycomb is arguably the most efficient method of removing any swirl or lateral velocity variations, whereas the screens help to break up large eddies, encouraging quicker decay. Both devices significantly reduce the turbulence intensity to an impressive 0.08 per cent and help to pre-condition the flow before it enters the contraction area. This next section not only achieves uniform flow quality, but the contraction ratio of 7:1 accelerates the flow into the test section, achieving speeds of up to 65m/s. Immediately downstream of the test section is the diffuser area, which is used for pressure recovery, before the air is then flowed back around to the fan.

To ensure consistent data during running, the temperature of the airflow also needs to be carefully controlled at a nominal 20degC. Therefore, a single row air-to-water heat exchanger is located upstream in the settling chamber and uses chilled water to remove 350kW of heat, generated from the fan and BLRS. 'If you were to run a wind tunnel without a chiller, within 10 minutes you might see the air temperature increase by 8degC and that would simply keep rising,' explains Chris Saunders, who used to be head of aerodynamics and is now a consultant at Lola. 'Air temperature changes the air density, and can affect the wind tunnel data, so we like to keep it as constant as possible.'

Winds of change

Wind tunnel testing for motorsport applications started to become engineering practice in the 1970s, when quarter-scale car models were used at low wind speeds of around 50mph. Throughout the 1980s, teams moved towards third-scale, with 40 per cent and then 50 per cent scale becoming more popular in the 1990s. 'In 1991 I was involved with the Number One wind tunnel at Williams which was built for 50 per cent scale models and it was no coincidence that we were beating everybody, as we had the best wind tunnel – it's a war between the best tools,' says Saunders. Subsequent regulations then limited model size to 60 per cent with a maximum wind speed of 50m/s.

Lola's Boundary Layer Removal System



The wind tunnel model is attached to a carbon support strut that is connected to a six-component pyramidal virtual centre balance

Larger tunnels, such as those at Toyota, Mercedes, Williams and Sauber were also used for full size testing. But to reduce costs, full scale wind tunnel testing is now mostly banned in motorsport, and has been for a long time. Therefore, Formula 1 teams have had to stick with testing 60 per cent scale models.

To replicate the same 'state' of the fluid in the wind tunnel as the air out on track, a high-enough Reynolds number has to be achieved. The Reynolds number is the ratio between the inertial and viscous forces within the fluid and is governed by Equation shown below:

$$R = \rho VL / \mu$$

where

R = Reynolds number (dimensionless)
ρ = Density (kg/m^3)
V = Velocity (m/s)
L = Characteristic length (m)

Naturally, as the size of the model decreases, the characteristic length decreases. Therefore, to maintain the same Reynolds number either the velocity or density needs to increase or the viscosity needs to decrease.

'There is an unwritten rule about wind tunnel testing and it's all to do with the Reynolds number,' Saunders says. 'Let's say you have just designed the Airbus A380 and it has an 80-metre wing span. You can't put that in a wind tunnel, but you can make the biggest model possible and test it at high wind speeds or high pressures. Testing at 5bar gives you approximately five times the Reynolds number. There are other aircraft wind tunnels where liquid nitrogen is injected to cool the airflow and increase the density – so you can play around with the parameters in the Reynolds equation.

'Typically, you need to test at a minimum of 40 to 45 per cent scale at speeds above 45m/s to get to a Reynolds number where tunnel data starts to correlate to track data,' Saunders adds. 'It's therefore natural to run a model scale that's as large as the tunnel and rules will allow (due to blockage considerations) and at wind speed sometimes governed by the rules (depending on the formula tested). This then gives the most accurate data you can acquire for the given scale and windspeed, although there will always be some parts on the models which are too small to work 100 per cent as they would full size.'

Boundary layer

The aim of any wind tunnel is to accurately simulate the flow of air over a racecar, as if it were on track. However, on track, the racecar is moving, with the air and ground remaining stationary. To try and replicate these conditions within a wind tunnel where the car is stationary, the air has to move and, crucially, so does the ground to minimise the effect of the boundary layer. 'Essentially, the boundary layer is a lazy section of air, due to the effects of viscosity,' says Saunders. 'If you imagine the flow in a wind tunnel when the floor is stationary; the molecules of air sitting on the ground would remain stationary. However, as you move away from the floor, the velocity gradually increases until at some point, it matches the velocity in the mainstream of the flow – this is your boundary layer.'

This distance from the floor to where the free stream velocity is reached is defined as the boundary layer thickness and is dependent on the roughness of the surface. 'In motorsport, if your boundary layer thickness was around 20mm, and your front wing is only 15mm off the ground, then your car is sitting directly in this 'lazy' air and not seeing the true velocity. This error needs to be removed, which is why we have our Boundary Layer Removal System (BLRS),' Saunders says. 'Most people aim to have a boundary layer thickness of approximately 1mm, so that the wind tunnel can be typically quoted as having a free-stream velocity of nominally 99 per cent at this height, this is extremely difficult to achieve in practice; a lot of time is spent during the commissioning phase of the tunnel to fine-tune the boundary layer.'

Layer slayer

Lola's BLRS is one of the main reasons the tunnel achieves such accurate correlations. It consists of a primary and a secondary suction plate located upstream of the test section. A fan is used to draw approximately 5.82m^3/s of air from the boundary layer through a series of holes in these aluminium plates. To avoid

'The boundary layer is a lazy section of air, due to the effects of viscosity'

Figure 1: 60mm upstream of the first suction plate

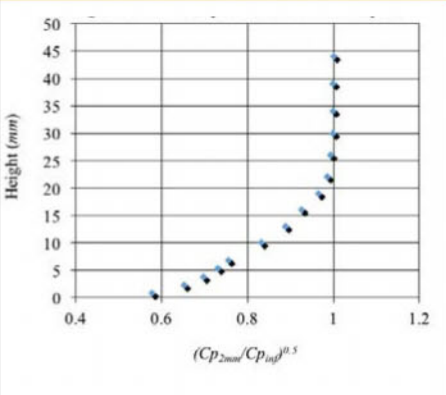


Figure 2: Directly downstream of the first suction plate

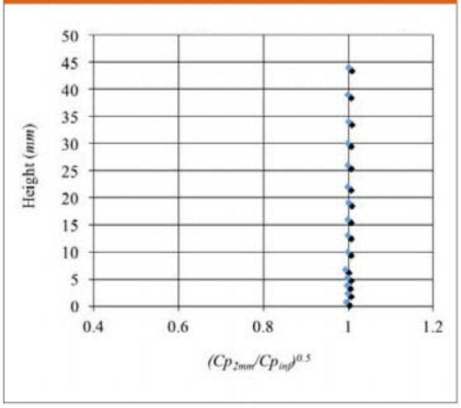


Figure 3: Immediately upstream of the second suction plate

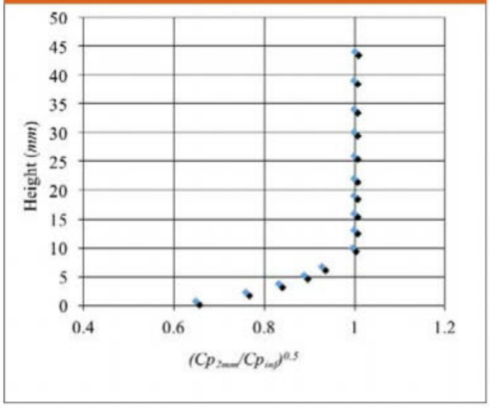


Figure 4: Directly downstream of the second suction plate

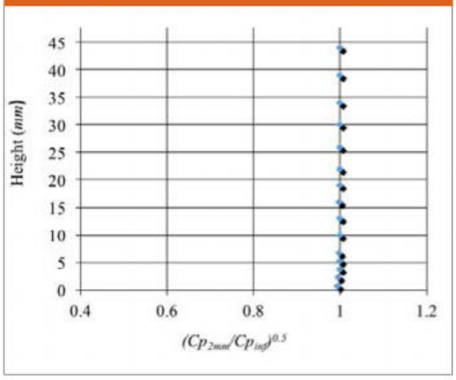
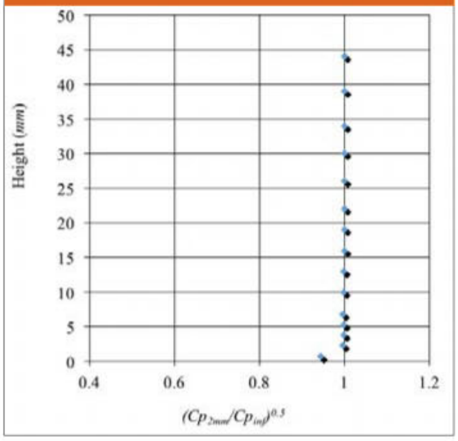


Figure 5: 5mm downstream of the leading edge plate (on the stationary belt)



'It's natural to run a model scale that's as large as the wind tunnel and the rules will allow'

potential re-growth of the boundary layer, the secondary plate actually sits on the moving belt or rolling road and is made of high-grade aerospace aluminium to prevent buckling. This is a relatively traditional method of reducing the boundary layer thickness. 'If you were to have only one suction system, it would drag the boundary layer down, inducing a steeper angle into the flow, resulting in the flow approaching the model at the wrong angle,' explains Saunders. 'The whole idea is to gradually suck out the boundary layer air bit by bit, so you end up with the flow normal to the car.'

The effect of this is shown in **Figures 1** to **5** at the top of the page, where the height of the boundary layer was measured at five points along the wind tunnel by a rake consisting of 15 pitot tubes. **Figure 1** shows the boundary layer thickness is initially around 25mm, 60mm upstream of the primary suction plate. This is completely removed with minimal induced angularity directly downstream of the plate as illustrated in **Figure 2**. However, it does not take long for the boundary layer to re-grow as shown in **Figure3**, where the thickness has increased to around 10mm and is removed again by the secondary suction plate **(Figure4)**. When the flow reaches the moving belt, the flow is energised, again, reducing boundary layer growth, achieving a thickness of approximately 0.5mm **(Figure 5)** before the air reaches, and interacts with, the car.

Balancing act

Another area that's important for high accuracy is the load cell or 'balance'. The model is hung above the rolling road via a carbon support strut that is connected to an externally mounted six-component pyramidal virtual centre balance made by Aerotech. This system is then mounted to an independent balance support structure which is mechanically isolated from the wind tunnel and the rest of the building.

'Essentially the load cell, in layman's terms, is a set of upside down bathroom scales,' Saunders says. 'So, when you blow air over the model, the model reacts and all those forces are measured. You also need an accurate and repeatable motion system to control the attitude of the car for ride height, yaw, roll and steer sweeps. Isolating the balance system is crucial, otherwise any external vibration can transfer through to the load cell, compromising your data which is then impossible to filter out.' Lola's overhead load cell avoids having to instrument each individual wind tunnel model (with an internal balance) and is so reliable that it has only been switched off twice throughout the last 18 years (this helps keep it at a constant temperature).

Gone with the wind?

Over the last decade, we have been constantly told that as computing power and the capabilities of CFD improve, wind tunnels will become redundant. And yet every motorsport team that is able to, from Formula Student to Formula 1, does continue to validate its designs through wind tunnel testing.

'When the new regulations are released, usually an initial and rudimentary CFD and wind tunnel model is made and you start the development process. CFD is a fantastic tool, but you need good engineers who know what they're doing,' says Saunders. 'You also need a high-quality wind tunnel, but to validate both you have to use data from the track as much as you can. Our tunnel achieves such high correlation with reality because not only have we invested in the most accurate technology, but we have also used it for testing a wide range of models including Formula 1, LMP2, GT and Scania trucks, which has helped us fine tune our design.'

Lola's wind tunnel has by no means remained dormant since the racecar manufacturer went into administration, then. As Saunders says; wind tunnels are like 'classic cars that need to be run.' Therefore, the tunnel has been continuously used for customers testing a wide array of automotive and motorsport models and projects.

'Our wind tunnel is truly multi-purpose. A new model can be installed on the strut and be ready to run within 45 minutes, rather than half a day, because it was always designed to be a customer tunnel,' explains Birrane. 'The tunnel itself is so reliable that the only thing we could update is the software to suit specific aerodynamicist's needs.'

Since our visit the Lola Technical Centre and the wind tunnel has been put for sale.

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Tread carefully

How you intend to work a set of tyres on a racecar is a key aspect of chassis design. Our numbers man explores the mathematics behind it

By DANNY NOWLAN

Equation

EQUATION 1

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

where
TC_{RAD} = Traction Circle radius (N)
k_a = initial coefficient of friction
k_b = drop off of coefficient with load
F_z = load on the tyre (N)

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

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

This quote from Mark Donohue goes to the core of what our business is about: 'The four footprints of your tyres are the only thing that lie between you and St Peter'. We can talk about aero loading, engine power, inerters etc. until we run out of breath. But if we don't have a clue about what the tyres are doing we're lost. Having been around the business for a while, I can tell you that when you design a racecar there's a lot of empirical knowledge of what to do to work a set of tyres. What I have not seen is a clear mathematical methodology to achieve this. This is what we'll be discussing here. Also, given that we are now in a racing world where we have the same chassis running on multiple types of tyres, this article is not just timely, it is necessary.

The core of our methodology will revolve around using a 2D tyre model. That is the traction circle radius *vs* load characteristic. Mathematically this looks like **Equation 1** and some typical values for this are presented in **Table 1**. When you plot this out you'll have something that looks like **Figure 1**.

The reason we are using this to get started is twofold. Firstly, it is simple. This readily lends itself to hand calculations. Consequently it gives you a sixth sense of where the numbers go. However, more importantly it gives us the basis for correlation, as shown in **Figure 2**. As always in these examples the coloured is actual data and simulated is black. As you can see, we are already in the ball park. What this means is we are not designing in a vacuum.

There are two components we need to quantify; these are grip and balance, because this is what you live and die by at the race track.

To quantify grip we need to take into account lateral load transfer and then use **Equation 1** to quantify what will happen to the lateral forces on the tyres. For a given load transfer couple we have **Equation 2**.

Here Lo is the static load on the tyre, ΔL is the load transfer and Fy is lateral force. A lot of you might look at Lo and simply say 'so what?' Remember, this incorporates both static and aero loads. Let's park this for the time being because we'll get back to it later. Given a lateral load transfer factor of pr the front and rear load deltas will be given by **Equation 3**.

Maximum grip

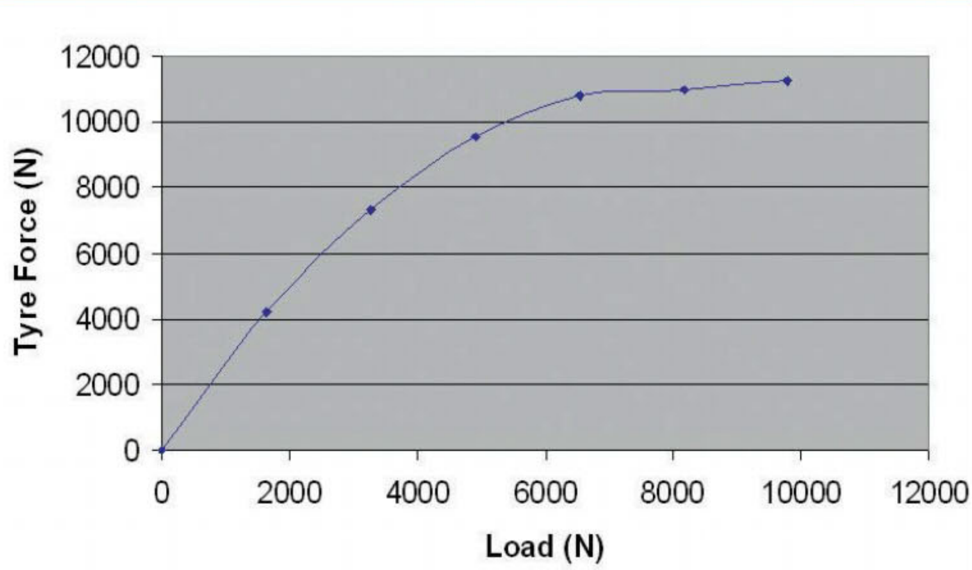
At this point in the discussion you may once again be asking yourself the question 'so what?' Well, what all this mathematical gobbledegook actually means is that for a given lateral load transfer distribution, a given lateral acceleration and a given tyre model, we can then calculate the maximum possible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

So, remember that thing we mentioned about Lo being the combination of the static and aero load? Well to quote the Joker from *The Dark Knight*, I'm about to show you a magic trick – or at least **Equation 5** is.

What this all means is that when you substitute **Equation 5** into **Equation 4** you have all the mathematical tools needed to quantify car grip or force as a function of both speed and lateral grip. When you plot this out you get a function like the one shown in **Figure 3**.

An important question to be asked is what do we do about lateral acceleration? You get

Figure 1: Second order plot of the traction circle *vs* load characteristic



There are two components we need to quantify, grip and balance. This is what you live and die by at the race track

that from logged data. The power of this is you now have the tools in your possession to see where your combination of bars and roll centres need to be in order to get the maximum possible performance out of the tyre.

Now that we know how to quantify the grip we now need to think about how we quantify the handling. To nail this down the stability index is about to become our best friend. To refresh everyone's memory, the stability index is calculated by **Equation 6**.

The great news is that *Fm*(L_1) through to *Fm*(L_4) is given by **Equation 1** and the *ka* and *kb* terms for all of these equations are given to you by using ChassisSim and the process we have discussed many times in the past on tyre load modelling from scratch. The tyre loads L_1 to L_4 are given by **Equation 7**.

Slip angles

The final part of this process is the calculating of the slip angle derivatives. Fortunately, there are some techniques available that can help us along the way here. The first thing we need to quantify is what the slopes of the normalised tyre force curve are. There are a couple of approaches you can use here, but let me get you started by suggesting the normalised ChassisSim slip angle curve, which has worked very well. This is shown in **Table 2**.

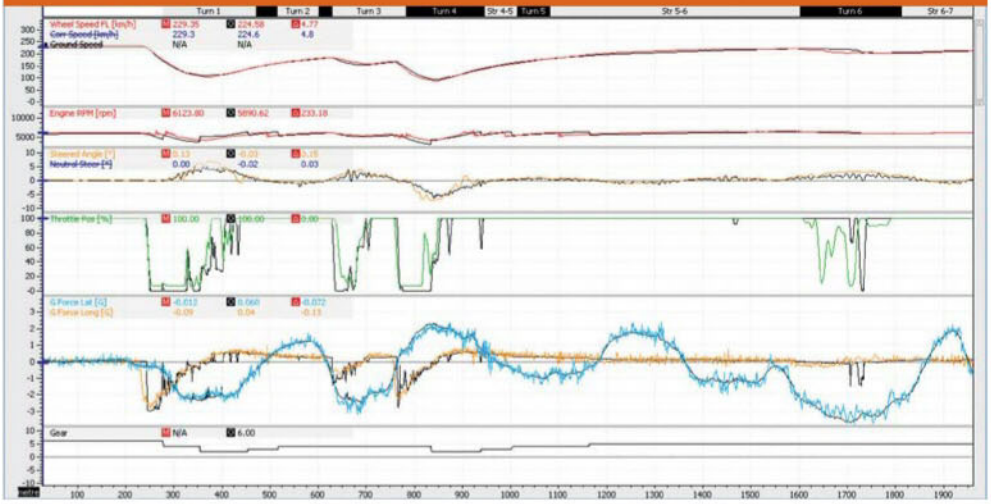
The last bit in the process is choosing what slip angles to take these calculations from. Looking at **Table 1** you'd be nuts to choose six degrees. The slopes are zero and it makes no sense. In light of this, the procedure will be to set the rear slip angle at five degrees. Then the front slip angle will be given by **Equation 8.**

Bear in mind **Equation 8** isn't something that is set in stone. It is an approximation to help you get an expectation of the relationship between the front and rear slip angles so you can calculate the stability index.

At this point in the game it would be worth giving everyone a reminder about how to calculate the stability index.

So we can put some figures to this let's illustrate via some Formula 3 numbers. This is summarised in **Table 3**. Let's say the front

Figure 2: Sample correlation using a 2D tyre model



The second order plot in Figure 1 gives us the basis for this correlation. Coloured trace is actual data and simulated is black

Equations

EQUATION 2

$$L_1 = L_0 + \Delta L$$

$$L_2 = L_0 - \Delta L$$

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

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

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

EQUATION 3

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

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

Here we have
ΔL_F = Delta load at the front (N)
ΔL_R = Delta load at the rear (N)
m_t = Total mass (kg)
pr = lateral load transfer (scaled from 0 - 1)
a_y = Lateral acceleration (m/s2)
h = centre of gravity height (m)
tm = Mean track (m)

EQUATION 4

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

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

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

Here we have,
F_{yt} = Total lateral force in N
L_{SF} = Front corner weight in N
L_{SR} = Rear corner weight in N
k_{af} = Front tyre initial coefficient of friction
k_{bf} = Front tyre drop off of coefficient with load
k_{ar} = Rear tyre initial coefficient of friction
k_{br} = Rear tyre drop off of coefficient with load

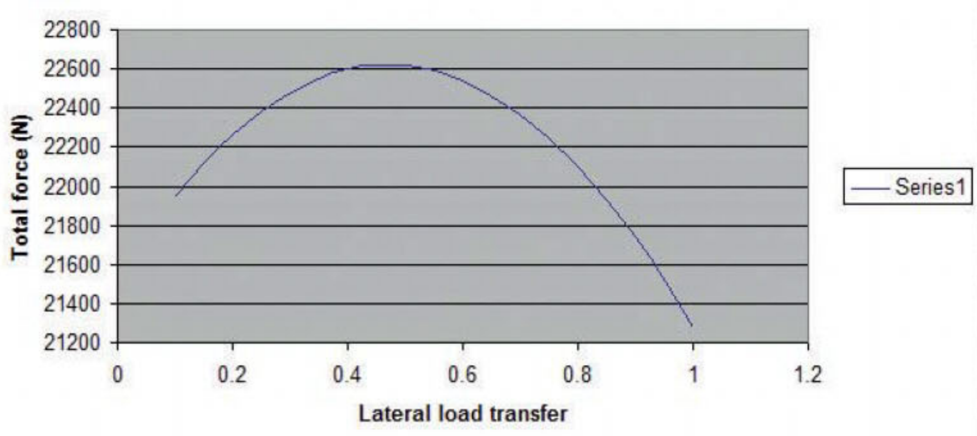
EQUATION 5

$$L_{SF} = \frac{wdf \cdot mt \cdot g + awf \cdot 0.5 \cdot \rho \cdot V^2 \cdot C_L A}{2}$$

$$L_{SR} = \frac{(1 - wdf) \cdot mt \cdot g + (1 - awf) \cdot 0.5 \cdot \rho \cdot V^2 \cdot C_L A}{2}$$

Here we have
wdf = Front weight distribution (%/100)
awf = Front aero distribution (%/100)
$C_L A$ = Lift coefficient time area
ρ = Density of air (kg/m3)
V = Velocity of air (m/s)

Figure 3: Total lateral force *vs* lateral load transfer distribution



In order for this technique to work properly the tyre models you use really need to be reverse engineered from race data

Equations

EQUATION 6

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

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

$$C_T = C_f + C_r$$

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

Here we have

$dC_F/da(\alpha_f)$ = Slope of Normalised slip angle function for the front tyre

$dC_R/da(\alpha_f)$ = Slope of Normalised slip angle function for the rear tyre

$Fm(L_1)$ = Traction circle radius for the left front (N)

$Fm(L_2)$ = Traction circle radius for the right front (N)

$Fm(L_3)$ = Traction circle radius for the left rear (N)

$Fm(L_4)$ = Traction circle radius for the right rear (N)

C_f = Slope of total front tyre force vs slip angle

C_r = slope of total rear tyre force vs slip angle

C_T = slope of total tyre force front and rear vs slip angle

EQUATION7

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

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

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

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

The terms here are:

L1 = Vertical load on the Front left tyre (N)

L2 = Vertical load on the Front right tyre (N)

L3 = Vertical load on the Rear left tyre (N)

L4 = Vertical load on the Rear right tyre (N)

pr = Total front Lateral load transfer factor on the front axle

mt = Total vehicle mass (kg)

h = centre of gravity height

tm = Mean track (m)

EQUATION 8

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

Here we have

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

b = Moment arm of rear axle to centre of gravity

a_f = Front slip angle

a_r = Rear slip angle

Table 2: Plot of normalised ChassisSim slip angle derivatives

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

slip angle is 5-degree and the rear slip angle is 4-degree. Using **Equation 6** and the derivatives from **Table 2** the stability index is **Equation 9**.

Oversteer case

Let's now reverse the case and consider oversteer, where the front slip angle is 4-degree and the rear slip angle is 5-degree. Again, evaluating **Equation 6** we see **Equation 10.**

Let's now tie all this together into a process to see how the stability index varies with the lateral load transfer distribution at the front. The process is summarised below:

- **Using Equations 4 to 5 plot lateral force *vs* lateral load transfer.**
- **The maximum value of this is your start value for lateral load transfer.**
- **You set the rear slip angle at 5-degree and then use Equation 8 to calculate front slip angle as you sweep front lateral load transfer distribution.**
- **Using Equations 6 and 7 you then calculate the stability index.**

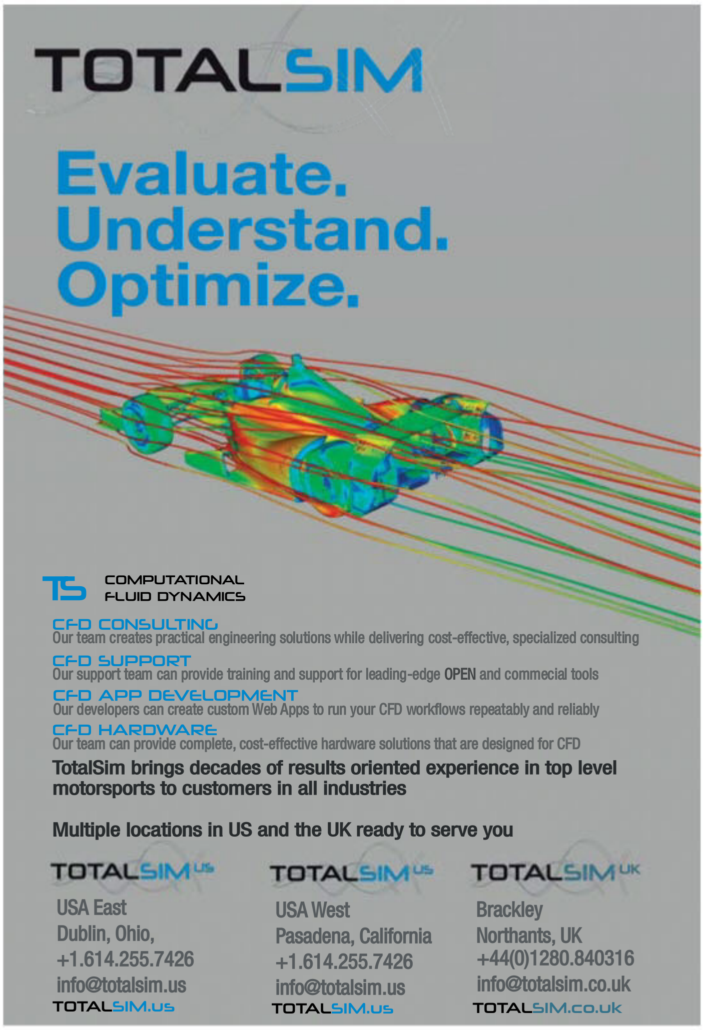
The great thing about all this is it readily lends itself to an Excel sheet. As with the lateral force case, you take the lateral acceleration from logged data. And while this will not be exact it will certainly get you in the ball park.

F3 example

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

To say these figures are fascinating is an understatement. As we can see the peak lateral force occurs at a front lateral load transfer of 0.5. Not surprisingly, the stability index is very marginal at -0.00291. What is interesting is when we go to a lateral load transfer factor of 0.6 we drop only 80N of force but the stability index drops to -0.072.

This is a big change in handling. What is even more interesting, though, is the spread of forces is only about 1000N, or about four per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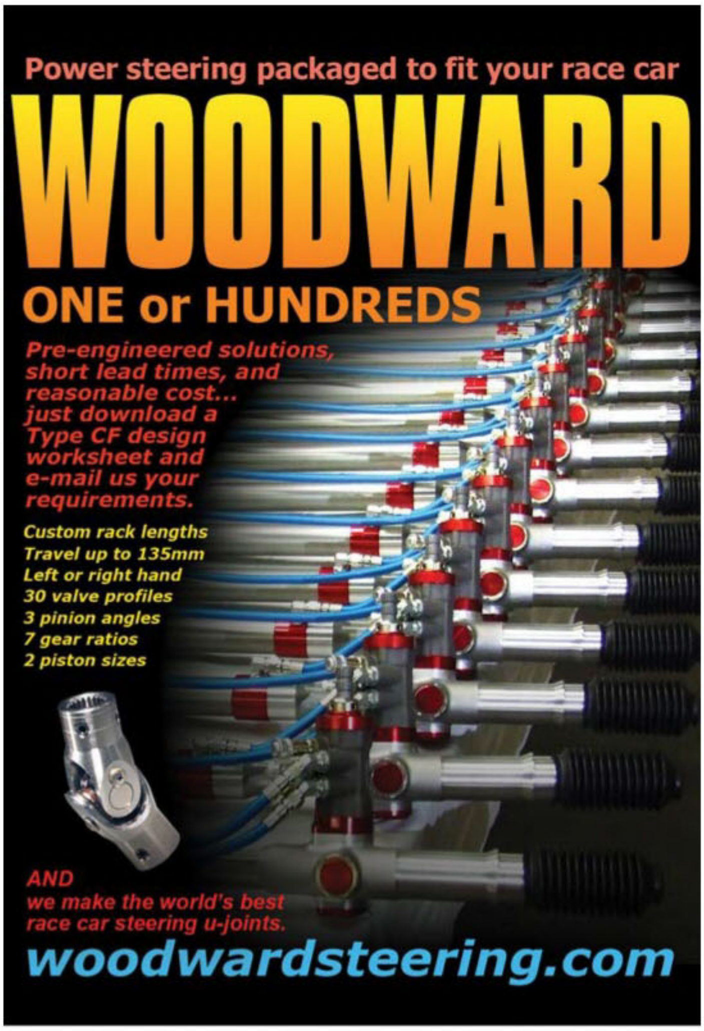
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Table 3: Typical values for stability index based around a Formula 3 car

Item	Description	Value
$F_{m1}+F_{m2}$	Sum of traction circle radius for the front	5000N
$F_{m1}+F_{m2}$	Sum of traction circle radius for the rear	7000N
a	Distance of front axle to the c.g	1.6m
b	Distance of rear axle to the c.g	1.1m
wb	Wheelbase	2.7m

Table 4: Results of lateral load transfer *vs* the stability index

Lateral load transfer	Total lateral force (N)	Projected front slip angle (deg)	Stability index
0.1	21952.64	4.24	0.162
0.2	22264.4	4.42	0.13
0.3	22479.4	4.6	0.09
0.4	22597.6	4.80	0.05
0.5	22619.05	5.01	-0.00291
0.6	22543	5.24	-0.072
0.7	22371	5.51	-0.166
0.8	22102.6	5.8	-0.303
0.9	21736.9	6.14	-0.524

Equations

EQUATION 9

$$C_f = \frac{\partial C_f}{\partial \alpha_f}\bigg|_{\alpha=\alpha_f} \cdot (F_{m1} + F_{m2}) = 4.375 \times 5000 = 21875$$

$$C_r = \frac{\partial C_r}{\partial \alpha_r}\bigg|_{\alpha=\alpha_r} \cdot (F_{m3} + F_{m4}) = 7.9567 \times 7000 = 55760$$

$$C_T = C_f + C_r = 77634$$

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

$$= \frac{1.6 \times 21875 - 1.1 \times 55760}{77634 \times 2.7}$$

$$= -0.125$$

EQUATION 10

$$C_f = \frac{\partial C_f}{\partial \alpha_f}\bigg|_{\alpha=\alpha_f} \cdot (F_{m1} + F_{m2}) = 7.9567 \times 5000 = 39783.5$$

$$C_r = \frac{\partial C_r}{\partial \alpha_r}\bigg|_{\alpha=\alpha_r} \cdot (F_{m3} + F_{m4}) = 4.375 \times 7000 = 30625$$

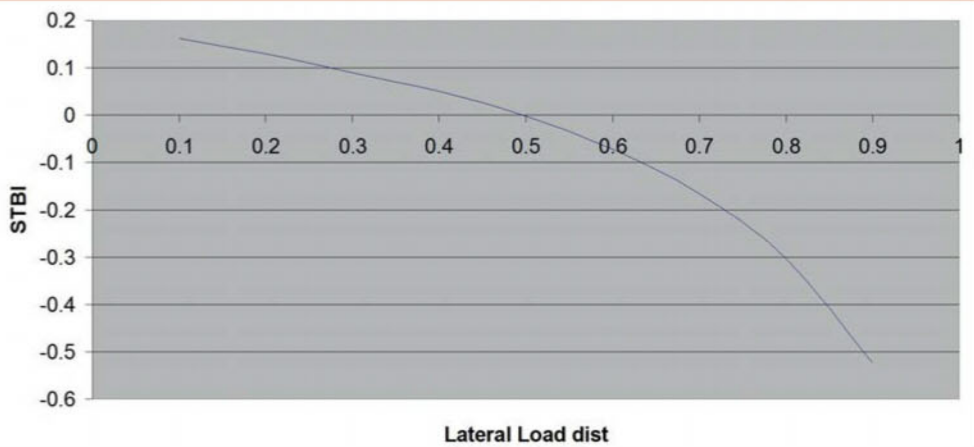
$$C_T = C_f + C_r = 70408.5$$

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

$$= \frac{1.6 \times 39783.5 - 1.1 \times 30625}{70408.5 \times 2.7}$$

$$= 0.157$$

Figure 4: Plot of stability index *vs* lateral load transfer



cent. However, we do see large fluctuations of the stability index. I have graphically illustrated this for you in **Figure 4**.

The fantastic news is that you can now combine tyre performance data with what you get in **Figure 3** and **Figure 4** to start nailing down some key attributes about where you need the racecar to be. This is a very powerful tool and you would need to have rocks in your head to ignore it. The reason for this is at a glance you can see instantly what the grip is and where you need to be on balance. Also, you can do this on an Excel sheet. While this is not going to be spot on it gives you the tools to nail down what the car will do.

Changing tyre sets

It's now time to put all this into practice. What I'm about to present to you is the parameters for a VdeV car (this sports prototype is the Formula 3 equivalent of an LMP1/P2 car, in a way). What I am going to do is keep the set-up constant but I will change the tyre set. I will illustrate the tyre parameters in **Table 5**.

The difference here is that in Tyre Set 2 we have increased the peak load of the front tyre from 600kg to 700kg. The effect this had on both the total lateral force and the stability index is profound. This is shown in **Figure 5** and **Figure 6** respectively.

This, ladies and gentlemen, is why we have gone to all this trouble. The blue trace is Tyre Set 1 and the purple trace is Tyre Set 2. As we can see Set 2 has more grip, but to get the most out of them you need to change the Lateral Load transfer distribution at the front (LLTDf).

The reason for this is that **Figure 5** and **Figure 6** show these tyres are two fundamentally different animals. For the total lateral force, you will see the peak has shifted slightly to requiring more lateral load transfer. However, the stability index has had the neutral point shift from a LLTDf from 0.5 for Tyre Set 1 to 0.65 for Tyre Set 2. Consequently, the set-up that would work on Tyre Set 1 would be undrivable for Tyre Set 2.

If you don't have the ability to adjust this in the chassis you will be struggling. While this is an extreme example it also showcases very well the importance of everything we have discussed, and why you should be thinking about this in the design phase of the racecar.


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Table 5: Different tyre parameters for a VdeV sports prototype

	Tyre Set 1		Tyre Set 2	
	Front	Rear	Front	Rear
ka	2.3	2.4	2.3	2.4
Lp	600	700	700	700
kb	8.5034e-5	7.2886e-5	7.286e-5	7.2886e-5

Figure 5: Total lateral force *vs* lateral load transfer distribution at the front

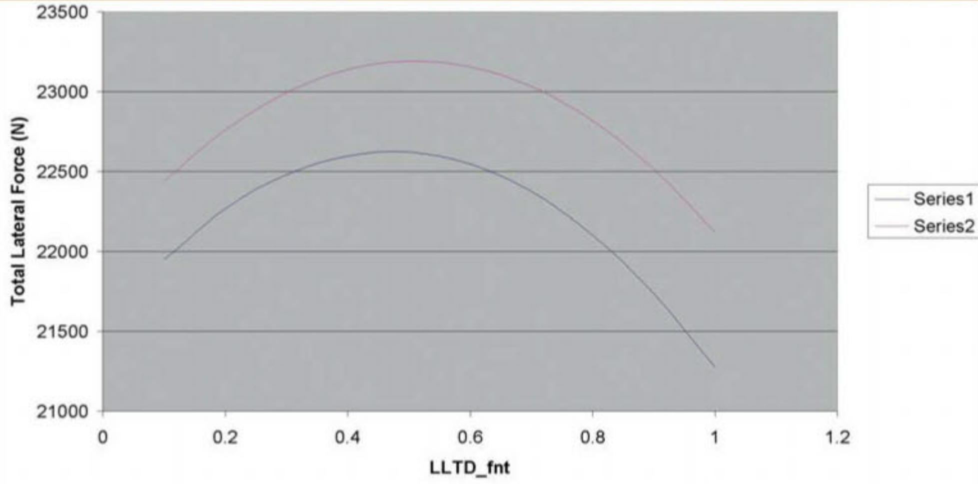


Figure 6: Stability index *vs* load transfer distribution at the front

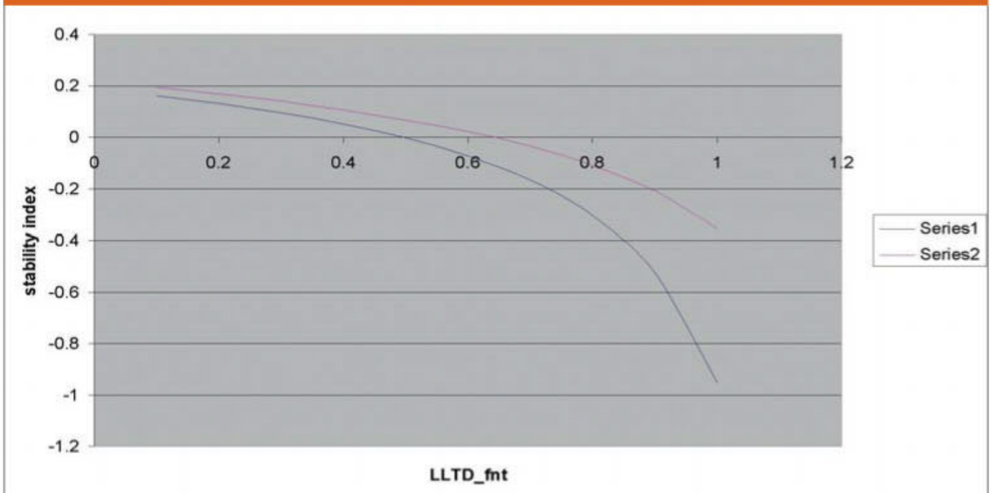
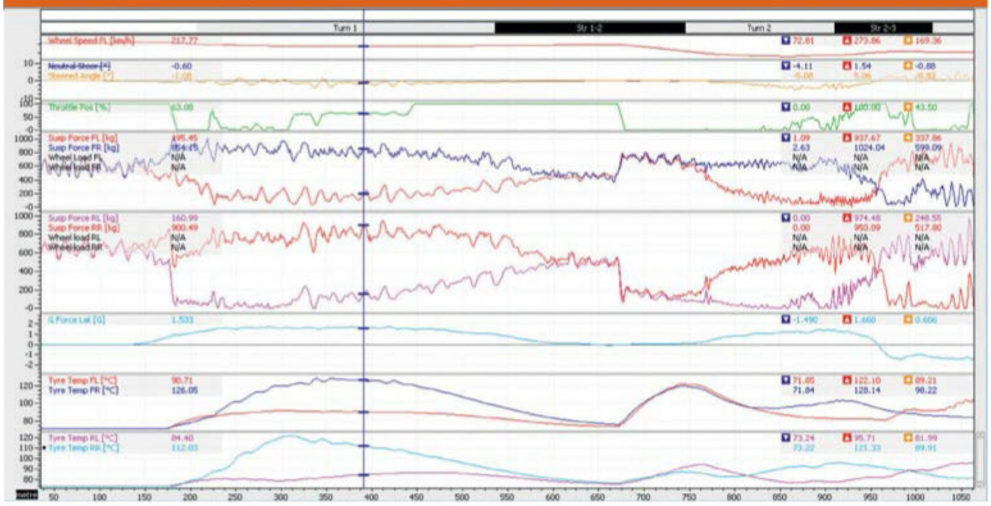


Figure 7: Plot of tyre temperature in a corner



The tyre temperature model in ChassisSim can help to show how the tyre gets up to its working temperature in the first place

Using a simple 2D tyre model we can see where we need to be in order to work the tyre appropriately and achieve the desired handling

To wrap up this discussion we need to discuss two matters. The first is the role of tyre temperature and working it appropriately. The 2D tyre model, while a very good approximation of the performance for a given thermal condition, does miss how we get it up to temperature in the first place. To help resolve this question you need experience, but also the tyre temperature models in ChassisSim are about to become your new best friend. This is illustrated in **Figure 7**.

Also, it's worth your while remembering some rough rules of thumb, such as: the stiffer the spring/damper and the higher the roll centre and anti-dive and anti-squat, the more it will drive temperature into the tyre. Consequently, keep this in mind.

In order for this technique to work properly the tyre models you use need to be reverse engineered from race data. With a few noted exceptions steer away from manufacturer supplied tyre data/models like the plague. They certainly have a role to play in tyre design and manufacturer but for race engineering they fall well short of the required standard.

I realise this will put a few noses out of joint but I say this from bitter experience. I have lost count of the number of dodgy tyre models that have seen tyre rigs that have led myself and ChassisSim customers up the garden path. If you're reading this and have a problem with what I'm saying, then I suggest you consult **Figure 2** , which was generated from the ChassisSim tyre force modelling toolbox.

Summary

In closing we have just presented some very powerful tools and techniques for classifying racecar performance and ultimately using this to specify what we want out of the racecar as opposed to guessing. Using a simple 2D tyre model we can answer very quickly where we need to be in order to work the tyre appropriately and achieve the desired handling.

While this isn't the full story, it allows the racecar designer to answer some critical question of where they need to be on springs/bars and geometries well before the car turns a wheel. This is a very powerful tool that you would be foolish to ignore.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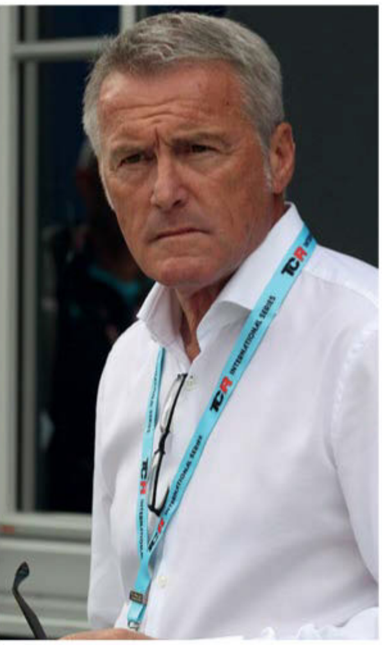
Interview – Marcello Lotti

Tour de force

The TCR founder tells us why his category – which is set to become an FIA World Cup in 2018 – is one of motorsport's great success stories

By MIKE BRESLIN

XPB



'Now a second hand market is open everywhere. So if a team wants to sell their TCR car, they spend one week and it is sold'

What sort of team set-up would you need to race in touring cars pretty much anywhere in the world? 'I have here in TCR Italia, this one guy. He presents to me the spirit of TCR; he goes to the races with his car, with his wife, and the dog. This for me is TCR.' Those are the words of TCR founder Marcello Lotti. But while the racer turning up with a car on a trailer harks back to the romantic image of motorsport of yesteryear, it's worth remembering that what's at the very core of TCR is a cold business-driven concept that is winning the commercially savvy hearts of manufacturer motorsport departments, while making good economic sense to many teams, too.

TCR was founded just three years ago, at the end of 2014, and it hit the tracks in 2015. It now has 16 series around the world, and is set to start up a new championship in the UK in 2018, while the category is also run as a class in seven other series. On the car front, manufacturers have been quick to see the potential with – at the time of writing – 10 makes receiving the TCR treatment. These are Audi, Alfa Romeo, Honda, Peugeot, Volkswagen, SEAT, Opel, Kia, Hyundai and Subaru – the latter two awaiting final homologation – while cars from Renault and Ford are also in the pipeline.

But perhaps the most impressive figure is 552, the number of TCR cars that have been sold to date, surely the soundest measure that this concept is working. But what exactly is this concept? 'First of all we had to look at the world today. The crisis of 2008, 2009, it is not finished,' Lotti says. 'So this is the situation, and so we have to make it an easily affordable market; and provide a very good customer business [Lotti has admitted that the inspiration for TCR was GT3]. They don't really make money [with TCR] – the manufacturers – but they don't lose money. It's a product that's designed for the customer, but it's also very nice in terms of sporting and performance, and it's very good for the owner of the car.'

Market forces

Good for the owner as due to the success of the category, and the stability of the regulations, there is now a ready market for TCR machinery. 'Now a second hand market is open everywhere,' Lotti says. 'So if a team wants to sell the car, they spend one week and it is sold. Because there are people looking for TCR cars all over the world.'

Including, soon, in the UK. But in these pages recently (November 2017 issue, V27N11) BTCC boss Alan Gow poured cold water on suggestions that TCR would be successful in Britain, going as far as to suggest that the category only thrives in countries where there is no well-established touring car series. Not surprisingly, Lotti disagrees: 'He has to [talk] to me, say, in six months, and I will tell him then how good British TCR is,' Lotti says. 'I think that where there is touring car racing, anywhere there has been touring car racing, contemporary or in the past, all these areas for me are perfect for TCR. Because TCR represents what touring car racing is, I think.'

TCR is also some way cheaper than some other touring cars categories. While a budget for a season depends on a number of variables (the amount of testing, for instance) it is generally reckoned to cost between €100,000 and €200,000 to run in a domestic series, and the initial start-up spend is also attractive as the cars themselves are cost-capped at €130,000. This cost-cap should also help keep development spending down as more and more manufacturers enter, because customer sport departments need to keep an eye on the bottom line.

But far more fundamental in policing over-spending by car makers is, of course, the Balance of Performance. This works over three parameters; weight, ride height and engine restrictor. But because with the latter it's difficult, as the 2-litre turbo units (giving 350bhp) are all different, they are adjusted from the production restrictor as a baseline. 'We start on 100 per cent of the production restrictor, and then adjust it to 95 per cent and then 90 per cent,' says Lotti.

The BoP has proved controversial, but as Lotti says: 'It's not so bad now. And if all the manufacturers complain, it means that it's [working]. If they stop complaining, we can have a problem, but today we have no problem.'

Hectic start

In fact, the only real problem TCR has had since its inception has actually been its success, especially in the early days. 'It's difficult, when something is growing so fast and you're not quite ready, but you have only one chance if you want to stay in the loop with all the projects,' Lotti says. 'There are only four

of us [in the TCR team], to form everything, and we [were] speaking with TCR China, we then receive a phone call from TCR Russia, then TCR Portugal, meeting with this person then the other one, and it was a little bit stressful, but then you cannot do this type of job if you have no passion; but also we start to have a lot of white hair!'

TCR has actually had an International Series from the start, but with the problems besetting the World Touring Car Championship (which Lotti re-established himself in 2005) it has now emerged that Lotti has franchised TCR to the FIA and that the series, formerly called WTCC, will now run TCR cars in 2018 and will be known as the FIA World TCR Cup, with both WTCC and TCR International being consigned to history.

But could TCR ever actually become a pukka world championship in its own right?. 'We spoke a little with our stakeholders, and with the FIA, because of the new evolution [of TCR] coming in 2020. And we were looking to see if there was an opportunity to make TCR labelled by the FIA. There are enough manufacturers that it [could be a world] championship, but the point of TCR is that it is customer orientated. So if in two or three years the top of the [FIA touring car] pyramid is TCR , then of course it must also remain customer oriented. But it is on the table, for discussion.'

Racing ahead

That's all for the future. But what does Lotti think that future will look like? 'I want to say that for me customer racing is coming more strong than before, because it is very difficult today to find budgets for manufacturer championships without €10m or €50m. For manufacturers, they will now do super hi-tech like Formula 1, or new technology like electric [Formula E]. But for the traditional championships, day by day, it will be more difficult – and this will be customer racing.'

And TCR? 'I am very happy with the way it has gone,' says Lotti. 'What do I have to tell you, I was always sure it was a fantastic idea for this kind of thing, but I think that at the end we have exceeded our expectations; and it is not finished.

'We are working with a different country. We are discussing a request, that they want to establish a series, and there are another two manufacturers, I can't tell you who, currently working with our technical department. And so, we are continuing to grow.' But however big it gets, the regulations means there will always be room for the small teams.

SEAT, Honda and Volkswagen TCR cars battle it out at Monza. The customer sport category has proved to be very attractive to manufacturers

RACE MOVES

Dave Pericak in no longer director of Ford Performance. Pericak was partly responsible for Ford's successful return to Le Mans in 2016 with its GT. His duties are now to be split between motorsports engineering manager **Mark Rushbrook**, who will oversee Ford's racing arm, and Special Vehicle Team director **Hermann Salenbauch**. Pericak has moved to another role within Ford.

Doug Fritz, the chief marketing officer for NASCAR Cup Series outfit BK Racing, has now left the organisation. Fritz was previously president of Richmond International Raceway, executive officer of Iowa Speedway and senior director of Marketing and Business Development for NASCAR itself. He joined BK Racing at the start of 2016.

Johnny Stevenson, a championship-winning team owner in IMSA competition in the US, has passed away at the age of 60. Stevenson Motorsports called time on its IMSA activities recently after Stevenson and his wife Susan announced their retirement from motor racing.

Alex Somerset has left Australian Supercars outfit HSV Racing. Somerset, the team's chief designer, had been with the organisation since 2014 – he joined it after two years with Nissan Motorsport in Australia. Somerset, who has had a 30-year career in racing, mostly in the BTCC, now intends to take up an R&D position outside motorsport.

Todd Malloy is to be the new technical director at IndyCar outfit Schmidt Peterson Motorsports. Malloy comes to SPM from Chip Ganassi Racing, where he was a race engineer. Before that he was at Penske, while he also worked at Bryan Herta Autosport, before it merged with Andretti Autosport.

Veteran NASCAR crew chief **Darian Grubb** will tend the No.24 Hendrick Motorsports Chevrolet of Xfinity Series graduate William Bryon in the Cup Series in 2018. Grubb is currently crew chief on the Kasey Kahne-driven No.5 car at the Hendrick operation. Grubb won the 2011 NASCAR Cup Series with Tony Stewart and has chalked up 23 wins in the top NASCAR division.

Tom Dooley, a president of the British Racing and Sports Car Club (BRSCC), and also the chairman of the BRSCC's North Western Centre for a time, has died. A minute's silence was held on the grid for the Formula Ford Festival final in honour of Dooley, who devoted 60 years of his life to the BRSCC.

Jim Watson, a fabricator for Furniture Row Racing's NASCAR Cup Series team, has died at the age of 55 after a heart attack. Watson had been a member of Furniture Row Racing since February 2017. He worked for Roush Fenway Racing from 2006 until 2015 and spent 2016 with HScott Motorsports. He was also a driver, competing in dirt Late Models and in asphalt Super Late Models in his home state of Wisconsin.

Rod Nash, the co-owner of the Prodrive Racing Australia Supercars operation, has been voted on to the Supercars Board, where he replaces **Roland Dane**, owner of the Triple Eight team – a long-time board member who chose not to stand for re-election. The other board members are **Brad Jones, Peter Wiggs**, and until late December outgoing CEO **James Warburton** (see separate story on page 88).

Glen Cromwell is now the president of the National Hot Rod Association, the US drag racing governing body. Cromwell was previously senior vice president, Media and Marketing, and prior to that a division director. Cromwell, who has been at the NHRA since 1997, succeeds **Peter Clifford** in the post, the latter now taking on the newly created position of chief executive officer.

UK motorsport PR and sponsorship agency MPA has signed up two-time IndyCar champion and Indy 500 winner **Gil de Ferran** as a board director. **Darryl Eales**, formerly the CEO of private equity company LDC, has also become a director of the company.

Aston Martin hires former Ferrari F1 engine chief

Former Ferrari F1 engine boss Luca Marmorini is now working with Aston Martin, as it evaluates the possibility of becoming involved in Formula 1 power unit production from 2021.

Aston Martin, which will be Red Bull's title sponsor from next season, has said Marmorini is employed on a consultancy basis. It's known that the famed British sportscar maker, which had an unsuccessful stab at Formula 1 in 1959 and 1960 with its DBR4, is interested in the new engine rules. Andy Palmer, CEO at Aston Martin, has said: 'We are enjoying the global brand awareness that a revitalised F1 provides. The power unit discussions are of interest to us, but only if the circumstances are right.'

The manufacturer has confirmed that Marmorini is now involved in its F1 engine evaluation, although that it is as a consultant rather than a full-time member of the company. In a statement a spokesperson said: 'Luca Marmorini is helping us on a consultancy basis as we continue to evaluate options for the 2021 power unit. We have not hired anyone to work full time on this and the power unit remains an area of study for the company, consistent with previous comments and our attendance at the Formula 1 Power Unit Working Group meetings.'

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Luca Marmorini is helping Aston Martin to evaluate a possible Formula 1 future

Aston Martin and Red Bull first joined forces in 2016, launching an 'innovation partnership' which helped create the Valkyrie hypercar. The 1130bhp hybrid road car, which has been partly designed by Red Bull's chief technical officer Adrian Newey, is expected to go into production next year, before being released in 2019 at a rumoured cost of around $3m.

Warburton to quit CEO role at top Australian race series

James Warburton is to step down from his role as CEO of Australia's premier motorsport category, Supercars, at the end of this season.

Warburton, who has been in charge at Supercars for the past five years, is to now take on the CEO position at Australian advertising firm APN Outdoor.

A former executive at the Seven and Ten television networks in Australia, Warburton's time at the helm at Supercars was notable for a landmark six-year media rights deal with Ten and Fox Sports that began two years ago – a deal that was part of a drive to boost the finances of the Supercars teams. The teams have owned 35 per cent of the business since 2011, when Archer Capital bought the majority share in the series.

Warburton said: 'I am proud to have led a management team which has executed a very strong growth strategy, with the administration finalising a record number of agreements for the sport in the past four and a half years.

James Warburton is to leave Supercars at end of season

'Equally, the staff at Supercars are some of the most committed and dedicated people I have ever worked with,' Warburton added. 'We are very lucky to have them and I know they will continue to punch above their weight and create the perfect canvass for the teams and drivers to entertain our fans.

'I thank the shareholders for letting the management team execute and deliver on the plan,' he said. 'As I have said many times, I would not and could not do the role without the absolute support of the Supercars teams.'

Warburton will leave Supercars on December 22 and start in his new role towards the end of January.

RACE MOVES – continued

XPB

Former F1 driver **Derek Warwick** (63) has stepped down as president of the British Racing Drivers' Club, which owns British Grand Prix venue Silverstone. He has held the position since 2011, when he succeeded **Damon Hill**. Monte Carlo Rally winner **Paddy Hopkirk** (84) has been elected as his replacement. Hopkirk has been a BRDC member since 1965.

Nico Rosberg is to take on an advisory role in his father's Team Rosberg organisation as it moves into GT racing with a brace of Lamborghini Huracan GT3s, which it will campaign in the German ADAC GT Masters series.

Peter W Schutz, the former president and CEO of Porsche, has died at the age of 87. Just weeks after assuming the top role at the company Schutz reversed its earlier decision to stop production of the rear-engined 911, while his time at the helm also coincided with a period of great success on the race track for the marque. He retired in 1987.

Andy Petree is to help out top NASCAR outfit Richard Childress Racing in an advisory role. Petree has been working in NASCAR for over 30 years and has experience as a championship-winning crew chief, race driver, team owner and more recently as a television analyst.

The Motorsport Industry Association (MIA) has appointed **Iain Wight** as chairman of its board while **James Grainger** is its new vice chairman. Wight recently joined Williams Advanced Engineering and prior to that worked at Ricardo. Grainger is from hi-tech casting concern Grainger & Worrall. **Brian Gush**, director of motorsport at Bentley, has also joined the MIA's executive committee.

Bernard Cottrell, the chairman of the British Racing and Sports Car Club (BRSCC) for the past 13 years, has stepped down from the position due to ongoing health issues. He has been replaced by **Peter Daly**, formerly vice-chairman at the organisation.

Todd Parrot is no longer the crew chief on the No.95 Leavine Family Racing Chevrolet in the NASCAR Cup Series. At the time of writing **Jon Leonard** was interim crew chief on the car, but next season it will be overseen by **Travis Mack**, who is currently car chief for Dale Earnhardt Jr at Hendrick Motorsports. The No.95 car will be driven by Kasey Kahne in 2018.

Former US single seater team owner **Rolla Vollstedt** has died at the age of 99. Vollstedt was a member of the board of directors for the United States Auto Club (USAC), serving as car entrant representative from the late 1960s until the 1980s. A WW2 veteran who was wounded in Europe, Vollstedt will perhaps be best remembered for providing a car for the first female Indy 500 driver, Janet Guthrie, in 1976, while he also ran Jim Clark at Riverside in 1967.

IndyCar race engineer **Allen McDonald** has signed up with Ed Carpenter Racing for the 2018 season. The experienced Brit comes to the team from Schmidt Peterson Motorsports.

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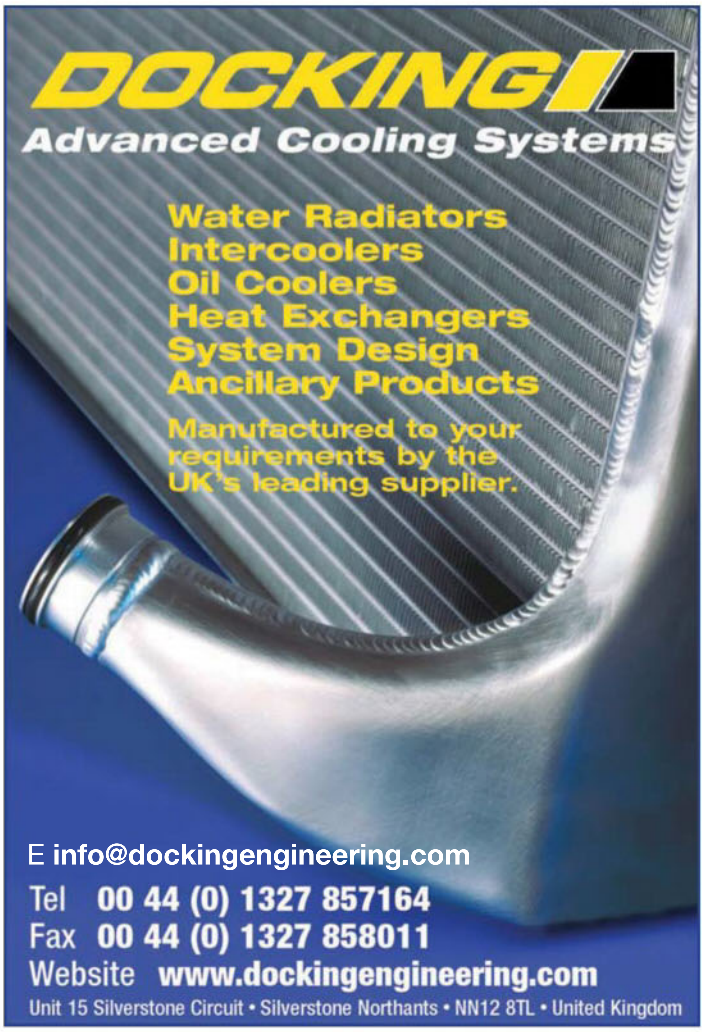

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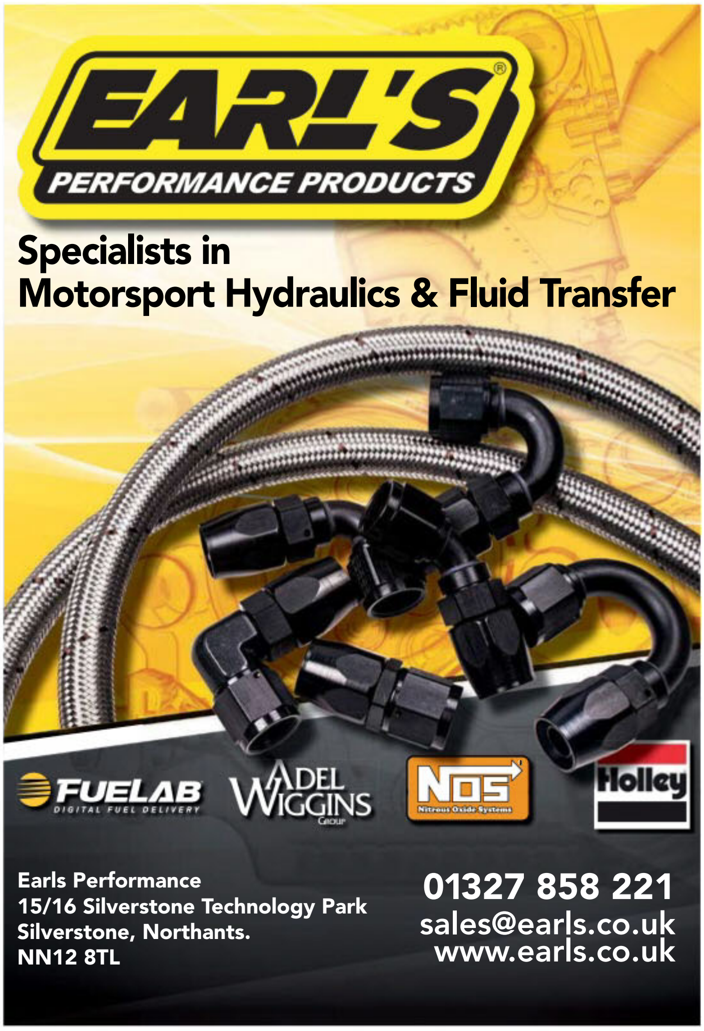

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Formula V8 3.5 series cancelled due to lack of entries

At its Renault-backed height Formula V8 3.5 was very popular with teams

The organiser of World Series Formula V8 3.5 has said the championship will not run in 2018 as it has been unable to attract enough entries to justify it continuing.

Formula V8 3.5, which has been known by a number of names since its debut as World Series by Nissan in 1998, has been in decline since Renault pulled the plug on its sponsorship at the end of the 2015 – it was then known as Formula Renault 3.5.

It has struggled for numbers since Renault pulled out and the final race of the 2017 season – during which it supported the WEC – saw a paltry 10 cars take the start. The WEC's 'Super Season' has added to the series' woes, due to uncertainties over its 2018 calendar.

The series said in a statement: 'Neither World Series Formula V8 3.5 nor any other top single seater series in the world have reached the ideal number of participating drivers in 2017. The continuous and alarming drop in the number of driver entries in the main European single seater series has now forced Formula V8 3.5 to withdraw from the 2018 season racing calendar.'

This does not mean the series is completely finished, however, and the statement goes on to say that it could be relaunched at some time in the future if there is enough interest from teams and drivers.

Run by Jaime Alguersuari Sr, the championship attracted huge crowds at its peak thanks to a free ticket promotion by Renault, and under its many guises it has been the launching pad for some illustrious Formula 1 careers. It can count world champions Fernando Alonso and Sebastian Vettel among its graduates, as well as Robert Kubica, Kevin Magnussen, Carlos Sainz Jr and Daniel Ricciardo.

Electric GT to make use of new 'smart' composite body panels

Electric GT, the all-electric series for Teslas, is to use a new type of body panel that's said to make a considerable weight saving over traditional carbon fibre, while it also has the capability to electronically display information.

The new series, which hopes to start sometime in 2018, will use Bcomp's new high-performance lightweight material for the automotive industry, which should cut up to 40 per cent weight with maintained performance.

Bcomp's PowerRibs and ampliTex reinforcement fabrics have previously been used within the sports and leisure markets, while the company has also collaborated with the European Space Agency on the development of lightweight space applications for several years.

Bcomp has also tested a revolutionary LED system within the natural fibres which can create a display for live data and telemetry on the body of the car.

Electric GT (EGT) CEO Mark Gemmell said: 'Not only do Bcomp's revolutionary natural fibre panels give us increased performance in terms of damping and stiffness, it's also helped us achieve a 20 per cent weight saving compared to the road-going version of this car.'

EGT has also announced its first team, SPV Racing, a merger of two operations from Sweden and Spain.

The panels can be used to display information on the car body during the race

Bentley Continental GT3 breaks cover

New Continental GT3 will initially be run by M-Sport

The new Bentley Continental GT3 racecar has been unveiled and is now ready to hit the tracks in 2018.

The GT3's been developed by M-Sport – which was responsible for the earlier Continental GT3 that was raced from the end of 2013 – in collaboration with Bentley Motorsport. It has used the all-new Continental GT road car as its base, which shares its structure with the latest Porsche Panamera, utilising it's mostly aluminium structure as the foundation to deliver a race-ready weight of significantly less than 1300kg, and helping to deliver an ideal weight distribution for racing, we're told.

The engine is a development of the race-proven 4.0-litre Bentley twin-turbo V8, with a totally redesigned dry sump system and all-new intake and exhaust systems. Unrestricted power is in excess of 550bhp.

Exterior aerodynamic surfaces have been crafted in the wind tunnel and Bentley says they are 'based on the shape of the road car, enhancing the muscular exterior panels with aerodynamic devices for additional downforce.'

Suspension and braking systems are new and bespoke to the Continental GT3.

Bentley's director of motorsport, Brian Gush, said: 'After four years of success with our Continental GT3, we're excited to reveal our second-generation car. The new car leaves no area or system untouched in the search for even better performance, and the early test results are promising.

'The new Continental GT road car has proved to be a great starting point for the development of the racer, and the engineering work is true to Bentley's impeccable standards,' Gush added.

The car has already started a six-month test programme in the UK, France and Portugal. Upcoming development work includes full 24-hour endurance race simulations. The Continental GT3 will initially be raced by the factory M-Sport team before deliveries to customer operations will begin in June of 2018.

AUTOSPORT INTERNATIONAL
THE RACING CAR SHOW

Engineer heaven

While the punters are excited by the racecars in ASI, the pros get their kicks in the Autosport Engineering halls

Whether you are a fan, a student or a professional engineer, the 2018 Autosport Show showcases plenty of the latest racing machinery for you to enjoy. However, if it's the latest motorsport technologies you want to discover, you really will need to attend the Autosport Engineering Show on 11 and 12 January.

Energy billed

The show unofficially starts on the Wednesday with the MIA's Energy Efficiency Motorsport Conference, that will take place just outside the main show. As the world's leading conference for high performance energy efficiency, this key event presents a unique opportunity to learn, discuss and experience the future of vehicle-based energy efficiency in the company of prominent business leaders and high performance engineering organisations, and engineers including *Racecar Engineering's* own technical consultant, Peter Wright.

With the world of motorsport needing to react to the challenges facing the production car industry, this has become a key event in the motorsport diary. Contact the MIA (www.the-mia.com) for further information.

As mentioned above, Thursday sees the opening of the Autosport Engineering Show. Here the very best of cutting edge motorsport technologies for the forthcoming season are on display, and you will also find good opportunities to link up with key suppliers throughout the two-day event.

A fascinating example of technology that you rarely get a good look at at the race track is the brake caliper. Formula 1 calipers can take around 40 hours to machine, due to the complexities of the intricate designs; aimed to minimise weight, dissipate heat and provide huge pressures. AP Racing will be showcasing its entire range of brake and clutch systems on **Stand E380**, including it Radi-CAL 2. This is a new forged 6-piston caliper which incorporates AP's patented technology, designed to not only increase rigidity and cooling capability, but also reduce weight.

You may think suspension springs are relatively simple, but as is explained on page 63 of this issue, there is a lot of science behind ensuring that a spring exerts a constant and linear force for every increment in deflection. Eibach is renowned for its reliable race spring systems and it has developed designs to deal with the extreme off-road conditions seen in the WRC, as well as the specialised characteristic curves demanded by F1 teams. To find out more about its technology, visit Eibach at **Stand E1260**.

Stand and deliver

Finally, don't forget to come and visit the *Racecar Engineering* editorial, advertising and marketing teams on our stand in the Engineering Show. We will have the latest edition of the mag to give away, and a subscription offer unique to visitors to ASI. Don't miss this opportunity to pick up the best in motor racing technology reporting.

The best technology for the coming season will be on display and you will have the chance to link up with key suppliers

Featured at ASI

MIA Business Excellence Awards Dinner in association with WMG

Held immediately following the first trade day of the show (Thursday 11 January), the MIA Business Excellence Awards Dinner, in association with WMG, attracts over 500 guests from across the globe, making it an ideal place to network at Autosport International. Winners of these prestigious awards are decided by the industry, and MIA members are invited to vote in each of the seven categories, including:

- The Business of the Year Award with annual sales over £5m
- The Business of the Year Award with annual sales under £5m
- The Teamwork Award
- The Technology and Innovation Award
- The Service to the Industry Award
- The Export Achievement Award
- The New Markets Award

Lifeline moves driver safety forward with new range of fire safety systems

Following the introduction of its class-leading Zero 3620 fire suppression system, Lifeline Fire and Safety Systems has consolidated its range of onboard extinguishers and re-homologated its range of FIA Technical List 16 approved systems for 2018. This is in light of knowledge gained from conducting the higher-level Technical List 52 homologation, to which the Zero 3620 range conforms.

Innovations in nozzle design and deployment rate of the suppressant which the company had employed with the Zero 3620 range were found to be suited to other systems in the range and the decision was taken to extend the technology across the board. In addition to making the resulting three ranges of systems possibly now the most advanced and safest available, the consolidated range means they also cover an even greater number of applications.

Visit Lifeline on **Stand E185** or head to www.lifeline-fire.co.uk to find out more.

Introducing the Mini 5-speed sequential and H-Pattern rod change gearboxes

The huge following for classic Minis has led Quaife, a global leader in the performance automotive drivetrain industry, to design and develop QBE18A and QBE19A, two products that are expected to be very popular within the historic and classic motorsport scene.

QBE18A is a 5-speed sequential rod change gearbox, while QBE19A is a 5-speed H-pattern rod change transmission. Both are compatible with the Mini's A-Series engine. They have been developed alongside Swiftune, the leading S-Series race engine builder and the company which exclusively sells all of Quaife's classic Mini products.

Head to www.quaife.co.uk for more and make sure to visit it at **Stand 8500**.

New top-of-the-line chip tuning product from RaceChip

RaceChip, the market leader in electronic performance upgrades, has expanded its range upwards, adding a new top product called the GTS Black.

With high-quality hardware, improved software and a comprehensive warranty package, the GTS Black is aimed squarely at drivers of high-performance petrol or diesel-engined cars with 200bhp or more.

The GTS Black can increase power and torque by up to 30 per cent in some engines, but what really differentiates RaceChip's latest offering from other products, the company tells us, is the precision of the calibration between chip tuning and engine.

The German company's engineers have calibrated version 2.0 of their optimisation software for specific engines and have also included seven fine-tuning mappings, raising their high-end product a step above the rest.

Find RaceChip on **Stand 19120** and for more info please visit www.racechip.com

ARP can be found in most racing series – and now at Autosport Engineering

ARP develops and produces engine and driveline fasteners, in addition to providing quality OEM replacement parts for speciality hardware, and it come to Autosport Engineering with more than 49 years of experience. Its equipment is used in Formula 1, IndyCar, NASCAR and NHRA drag racing, as well as marine applications.

The company has developed many patented processes for manufacturing its high-strength threaded fasteners and works closely with many teams using its products in global motorsports series, aerospace and the oil and gas industries.

ARP also manufactures a range of bolts, studs and nuts in high-strength materials that vary in strength from 170Ksi (1200MPa) to 300Ksi (2000MPa).

Find ARP on **Stand E670**.

Ferrari at ASI: 488 GTE

As part of a celebration of all things Ferrari at Autosport International a number of the marque's racecars will be on display in a special Ferrari feature. Among them will be this AF Corse Ferrari 488 GT, which sealed the GT manufacturers' crown at the last WEC race in Shanghai, Ferrari's fifth WEC constructors' title (2012, 2013, 2014, 2016, 2017). The 488 GTE packs a 4-litre, twin turbocharged V8 engine capable of 500bhp plus advanced aerodynamics, including a double splitter and under-body vortex generator, making it one of the most powerful and aero-efficient GT cars there is. For more on this car check out *Racecar Engineering* from March 2016 (V26N3)

Technology transfer in the spotlight at ASI show

Autosport International is known for its extensive representation of the motorsport and automotive industries, however, the exhibitors' influence is much wider than these sectors alone.

From defence and marine to film production and agricultural applications, the £9bn motorsport industry transfers technology born through competition to a range of sectors worldwide and this cross-industry benefit will be showcased by a range of exhibitors at the NEC, Birmingham, in January.

ProFormance Metals (**Stand 6515**) supplies metals and plastics to the motorsport industry, with its main line of products being steel tubes used in the construction of roll cages and chassis.

The company developed its own grade of tube, ROPT510, a cold drawn seamless tube manufactured to meet MSA and FIA regulations for roll cages. It has a high level of strength but retains its formability, both of which are crucial not only in the construction process of a roll cage or a chassis but also upon completion when involved in impacts and roll overs.

The ROPT510 tube was at first used within just the motorsport sector, but in recent years has found its way into many different industries. This is often within an application where higher strength than a 'mild steel' is required but without the costs of aerospace standard steels. These include: motion picture production (stunt vehicles, camera rigs, occupant safety cells), defence (modular seating, roll over protection cells) and performing arts (circus equipment rings, stage props).

Intercomp (**Stand E964**), which designs and manufactures weighing and measurement solutions, is celebrating its 40th anniversary in 2018. The company boasts a worldwide footprint with offices in the United States, United Kingdom, Chile and Singapore and customers in many other countries around the globe. It originally served the agricultural and industrial wheel load sector, but now serves many other industries including motorsport, aviation, military, government, law enforcement, heavy industry, transportation, automotive, material handling and crane and rigging sectors.

One product used across a multitude of industries is Intercomp's thermal imager, which the company will be displaying at Autosport International. Although primarily aimed at the motorsport and automotive industries, this tool can also be beneficial in any environment where a clear, saveable image of heat signatures given off by a particular item is required. This could be useful in a range of applications, including military, aviation automotive and materials handling.

Show Director for Autosport International, Kate Woodley, said: 'It's all too easy to take a somewhat blinkered view of the motorsport industry and not see the impact and benefits it has on so many other sectors around the world. We're pleased to welcome so many exhibitors to the show that highlight this crossover and reinforce the wider importance of technological development and advances in motorsport.'

Rallying call at ASI

The launch of the 2018 World Rally Championship is to be at Birmingham's NEC in January where teams, drivers and cars will take centre stage at the Autosport show

Above: Two weeks after they star at the NEC the World Rally Cars will be strutting their stuff on the sometimes snowy stages of the Monte Carlo Rally Below: Welsh rally ace Elfyn Evans, shown here during his winning drive on Wales Rally GB, says he is excited that the WRC is to be celebrated at the Autosport show in January

The 2018 World Rally Championship is to launch at Autosport International ahead of the season-opener in Monte Carlo just a fortnight later – marking the first time a top-tier FIA World Championship has launched at the show in its 27-year history.

All the leading WRC drivers, co-drivers and team principals will be in one place and on hand to talk about the 2018 championship, sharing their opinions on what the new season will bring across all four days of Europe's biggest pre-season motorsport show at the NEC Birmingham, from 11 to 14 January 2018.

WRC takeover

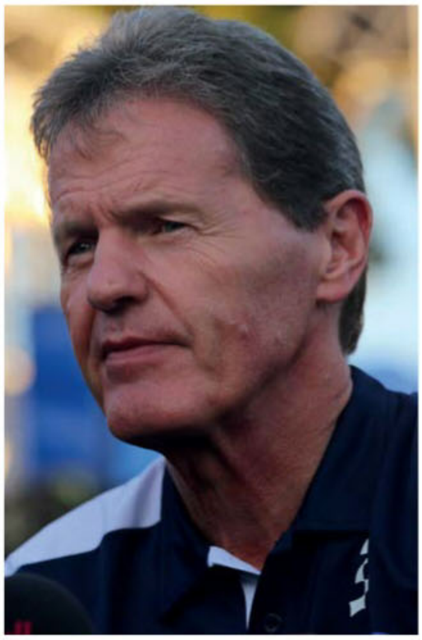
Each manufacturer team contesting the 13-round 2018 season, M-Sport (Ford), Hyundai, Toyota and Citroen will parade their 2018 rally cars on the Autosport main stage across the Thursday of Autosport International – in what ASI organisers are calling a WRC takeover day. All of the rally cars will then remain on display at the show throughout the weekend.

Recent Wales Rally GB winner Elfyn Evans was quick to lend his support of the launch at ASI, outlining the benefits to fans as well as those who are working inside the industry.

'The Autosport show is something that, certainly the likes of myself, Kris [Meeke], Craig [Breen] and all of our co-drivers, have grown up with and it's a good show in its own right. There's a bit of everything from across all aspects of motorsport, and for the World Rally

'For the WRC to be right at the heart of the ASI show is very good news'

The Autosport show has long been a venue for WRC car launches – this is M-Sport's then new Ford Fiesta in 2013


Malcolm Wilson welcomes ASI 2018 WRC focus

Visitors will be able to get up close to the rally cars, drivers and team personnel at this year's Autosport International

AUTOSPORT INTERNATIONAL
11 to 14 JANUARY 2018

TRADE DAY PRICES:
Trade visitor: Advance £28, on the door £30
MSA licence holders: Advance £23, on the door £30
BRSCC member: Advance Free, on the door £30
Advance booking conditions apply, see show website for information

Main show pricing:
Standard: Adult £35pp, Child (6-15yrs) £17
Ticket includes entry into Autosport International, the Live Action Arena and Performance Car Show (children under five years of age go for free). Ticket price includes the £2 booking fee per ticket.

Paddock Pass: Adult £46pp, Child (6-15yrs) £27.50pp
Ticket includes entry into Autosport International, the Live Action Arena and Performance Car Show (children under five years of age go for free). Access to backstage Paddock area in the Live Action Arena, Paddock Guide and access to driver autograph sessions.

Family Pass: £87 (2x Adult and 2x Child of 6-15yrs).
Ticket includes entry into Autosport International, the Live Action Arena and Performance Car Show. Valid for standard tickets only. The price includes booking fee charges.

VIP Club: £127 (no VIP Child ticket available).
Ticket includes entry into Autosport International, the Live Action Arena and Performance Car Show. In addition VIP Club includes free parking, seat at VIP enclosure in the Live Action Arena, complimentary drinks and canapes, VIP gift bag and much more.

For more, visit **www.autosportinternational.com**

Championship to be right at the heart of that is very good news,' the Welshman said.

'I'm looking forward to it. It'll be good to do something a bit different and it's a great chance for the fans to come over and have a look,' Evans added. 'It's good for Britain to have a second major event in the WRC season.'

M-Sport team principal Malcolm Wilson said he was delighted to see the series being given a high-profile boost ahead of the opening round. 'I've been going to Autosport International since it began and it really is seen – industry-wide – as the start of the season, so to have an event with this sort of global reach is fantastic for the World Rally Championship. Coming at it from the other side, I've always championed more rally content at Autosport International and next year we're going to have more than ever.'

Heaven '17

Sebastien Ogier and co-driver Julien Ingrassia successfully defended their World Rally Championship title, in an M-Sport run Ford Fiesta WRC, at the penultimate event in the championship – Wales Rally GB.

The 2017 WRC season included substantial revisions to the technical regulations aimed at improving the look and the performance of the cars, while allowing a greater degree of technical and design freedom for teams.

The series is supported by the WRC 2 and WRC 3 championships with the Junior World Rally Championship at selected rounds.

Visitors will be able to get up close to the rally cars, drivers and team personnel who will be at the show and interviewed on the Autosport stage across the four-day event.

Meanwhile, a dedicated WRC stand will be the perfect place for rally fans to get up to speed ahead of the 2018 WRC season, which begins in Monaco's Casino Square two weeks after Autosport International. The Dayinsure Wales Rally GB stand will also form a significant part of the rally celebrations, with rally cars and drivers from both the WRC and the British Rally Championships present.

Oliver Ciesla, the WRC promoter's managing director, said: 'What better occasion to kick-off next year's FIA World Rally Championship than at the fantastic Autosport International, which is rightly regarded as the start of the new motorsport season.

'It provides a wonderful opportunity to showcase the 2018 WRC, featuring the impressive World Rally Cars which have proved such a massive attraction to fans this year, and all the leading drivers from our manufacturer teams

'Thursday at the show will truly be a WRC takeover, but fans attending later in the weekend will still have the opportunity to whet their appetite for the season ahead as the cars will remain on display and there will be plenty of driver appearances,' Ciesla added.

Special stage

ASI show director Kate Woodley said: 'We really are writing history for Autosport International and the World Rally Championship in January. What an honour and a privilege to have arguably motorsport's most exciting series in the world launched under our roof.

'All of the best rally drivers, co-drivers and cars in the world will be in one place and that place is Autosport International at the NEC,' Woodley added. 'This really is a brilliant opportunity for all of us here at ASI, the World Rally Championship and fans of rallying around the world.

'For a big part of the WRC's history, Britain had the final say in the championship, first with the RAC Rally, and then with Rally GB, but this is the first time we've ever had the opportunity to open proceedings.'

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The heart of the matter

There were two stand-out moments at the Macau Grand Prix that will have grabbed the attention of its global audience. One was the multi-car pile up in the GT qualification race that eliminated five cars from Sunday's World Cup event, and the second was the epic last lap Formula 3 battle between Ferdinand Habsburg and Sergio Sette Camara. The GT crash was an 'it's Macau' moment, usually a large track-blocking exercise normally reserved for touring cars but not exclusively, and the second was simply racing in its purest form.

Both highlighted the joy of the Macau Grand Prix, although that was tempered by the sadness of losing one of the racing community. Motorcyclist Daniel Hegarty had an accident on Saturday afternoon and lost his life, an incident that cast a shadow over the event and also briefly made the world news. It was an accident which, I am sure, the safety-conscious FIA will look into and will then insist on changes to the circuit to ensure that it doesn't happen again.

To do so would, I think, be a mistake. Racing at Macau is an old-school experience. There are no issues with track limits – if you go wide, you hit the wall . The circuit is narrow, challenging, and precision and confidence is key to success. Making a mistake, or suffering a mechanical fault, is hazardous. When there are no injuries, it is a pleasure to go to the circuit every year and see racing from a different era.

There are changes afoot, though, not least in Formula 3 and touring cars. The F3 grid was smaller than in previous seasons, with multiple possible reasons for this. One of those is the upgrade kit for the cars that costs pretty much double what it should per car, estimated at €40,000 by one team owner who also complained that the constant meddling with the regulations was putting people off. On the plane home, one driver wondered what would happen to his car at the end of the Macau Grand Prix next year; would it be obsolete as the FIA pursues its strategy of having maximum performance within a cost window and a new formula?

The other change was to the World Touring Car Championship. The teams were convinced of only one thing; that this would be the last year of their TC1 cars and that they were facing a future either with TCR cars, or no championship in which to race. As the weekend progressed it seemed more likely that the TCR regulations would be franchised by Eurosport Events, that the WTCC calendar would continue as this year while the International TCR series stops, that the 2018 schedule will include the Nurburgring date alongside the 24 hours, and that the title to the series would include the words 'FIA World Cup'. But with just a two-year window for the TCR cars, what's the longer-term future?

FIA tech boss Gilles Simon has indicated that they would look for another solution, and that must be the DTM, or Class 1 as it will be called if the German and Japanese get together. According to BMW, these talks are progressing well, the engine formula is agreed, and they're looking at how they can improve the cars and the show without raising the cost. It too, wants a World Cup, likely to be a round in Germany, and a round in Japan, while pursuing their domestic series.

With the FIA focussed on the maximum technology, what will happen with the domestic series? With the termination of some national Formula 3 series, so long the bedrock of events such as Macau as well as a proving ground for future talent, will they use the new machinery, and if so will the European calendar really provide enough cars that events such as Macau can thrive? Or, will Macau see the end of the Formula 3 World Cup?

Racing at Macau is an old-school experience. There are no issues with track limits – if you go wide you hit the wall

It would be a shame to lose a race with such heritage, and I am sure that the crowd would be devastated. Standing in the pit lane after the GT crash, each car that came back (especially Darryl O'Young's Porsche) received a rousing cheer and applause from the appreciative crowd that had watched the accident on the big screen.

As for the reaction to Habsburg and Camara, well, there was a slight fear that the grandstand would fall down – and that was only from the reaction in the press room!

It really was a spectacular race, and this event is one that must at all costs be preserved. The track is not of the highest safety standards, and the racing is never perfect, but if you want perfection, you are in the wrong sport. The Macau Grand Prix is one of the last bastions of old-style racing. The bikers will go back, the teams will go back, and GT impresario Stephane Ratel hopes that the manufacturers will also return for the GT World Cup. I'll go back too, and revel in the madness that is the Macau Grand Prix.

ANDREW COTTON Editor

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